Mining Futures

Predictions and Uncertainty in Swedish

Mineral Exploration

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Abstract
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Any forward-oriented enterprise must somehow manage the challenges posed by uncertainty and with its distant temporal horizons, high stakes, and low probability of success, mineral exploration is a good illustration of this general rule. Based on a combination of interviews, observations, and archival research, this thesis investigates how explorationists use predictions to manage the material complexities and the uncertainties that contribute to determining the future minability of mineral deposits. Using data from industrial mineral exploration in Sweden, the thesis traces the production and use of predictions across the exploration process, from its early explorative phases to its development into a techno-economic hybrid in advanced stage exploration. With the aid of a detailed study of the valuation processes involved in measuring and predicting the future minability in exploration projects, the thesis demonstrates how risk management in mineral exploration relies both on a continuous addition of measurements and data on different dimensions of "risk" and the bracketing of any uncertainties unaccounted for in exploration practice and standards. Moreover, the thesis shows how industry standards provide explorationists with repertoires of values that are called upon in order to justify predictions as accurate and precise depictions of the future. However, the thesis also demonstrates how justifications of predictions in mineral exploration are not only about prediction correctness, but also about the merits of realizing the predicted future as explorationists are shown to actualize values expressed in contemporary debates to justify the benefits of a *mining future*. Lastly, the thesis also shows how predictions are used in explorationists' interactions with their publics. To accomplish this, the thesis outlines how investors, governmental agencies, and other actors upon whom explorationists depend on for resources such as capital and legal permits use second-order metapredictions to determine whether to invest in or grant permits to a project. Moreover, the thesis also highlights how these metapredictors are invited by explorationists to co-create the predicted mining future while other affected parties are left out. Together, the findings reported here demonstrates not only the way predictions are used in uncertainty management and the epistemic challenges involved in making predictions, but also the social and political implementations of how predictions are used not only to make claims about the future, but also how explorationists and their associates use predictions to claim the future for themselves.

Keywords: Uncertainty, Risk management, Sociology of the Future, Valuation, Justification, Mineral Exploration, Second Nature, Natural Resources

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For my grandmother, Eila Nilsson,
who had to forgo education
as her hands were needed
on the farm and not
in school.

And a river went out of Eden to water the garden; and from thence it was parted, and became into four heads. The name of the first *is* Pison: that *is* it which compasseth the whole land of Havilah, where *there is* gold; And the gold of that land *is* good: there *is* bdellium and the onyx stone.

The Holy Bible: King James Version – Genesis 2:10-12 (2012) edited by Marks

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Abbreviations

CAB	County Administrative Board (*Länsstyrelse*)
CIM	Canadian Institute of Mining, Metallurgy, and Petroleum
CRIRSCO	The Committee for Mineral Reserves International Reporting Standards, an international organization working for the harmonization of different industry standards worldwide
EIA	Environmental Impact Assessment (*Miljökonsekvensbeskrivning)*
JORC	Australasian Joint Ore Reserves Committee
MIS	The Mining Inspectorate of Sweden (*Bergsstaten*)
NI 43-101	National Instrument 43-101, a CIM standard
PERC	Pan-European Reserves and Resources Reporting Committee
SGU	Geological Survey of Sweden (*Sveriges Geologiska Undersökning)*
SveMin	The Association of Mines, Mineral and Metal Producers in Sweden (*Föreningen för gruvor, mineral- och metallproducenter i Sverige)*

Preface

Having negotiated the tricky boulder patches, the slopes, and cranes one finally reaches the summit and for the first time one is able to look out on the world ahead as well as back at the path that brought one to this place. But this is not *the* summit no matter how inclined one may be to grant it such a special place among the hills and peaks strewn across the geographies of a lifetime. Instead, it is but one of many different summits. And although you climbed it, it is not *your* summit as you have only negotiated a path trodden by many before you. Is it then, perhaps, *our* summit? If so, is this the point where one becomes we? Where the gates open to allow one to ascend that final threshold that separates one from the ones? Those who have completed the journey from those who have not yet and those who never will? I do not believe so. After all, this is but one of many peaks, neither more nor less. Nevertheless, while the journey to this particular summit is in itself not unique, the thrill of making it remains uniquely mine, yours, and ours.

Looking back at the experience of realizing this thesis, it emerges as something wholly unremarkable while at the same time truly remarkable; then you realize that nothing you do is unique in itself while at the same time everything you do is a unique experience to you. As a PhD candidate, you are but one among many and while the work may at times feel lonely and isolated, you can always look to your sides for comfort in shared experiences and ahead to find solace and inspiration in knowing that others have done this sort of journey before. This is the unremarkable part. The remarkable aspects of it all are the experiences you get while doing this unremarkable journey: the people you meet, the ideas you develop, the places you visit, the camaraderie you share, and the fact that at the very end of it, an unassuming little book published, and it has your name on the cover.

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This is a thesis about the uncertainties of the future, but before diving headfirst into the matter, I would like to take a moment to think about the past. This thesis would not be what it is without the support and contribution of all those who in some way supported, inspired, or in any other ways contributed to my writing of this thesis. Things do not grow in isolation, and any encounter, as Anna Lowenhaupt Tsing (2015) reminds us, leaves traces of contamination in the form of ideas, words, terms, feelings, and experiences, and they all change

us, to some degree, and transform us from what we were just before the encounter. The most important contaminations, or inspirations, for this thesis have been the informants who gave their time and experiences, without whom this thesis would not have been possible. Another crucial source of inspiration and support has been Patrik Aspers and Reza Azarian, whose thoughtful supervision has been vital for the completion of this thesis. I am also grateful to Tora Holmberg, Bertil Rolandsson, David Redmalm, María Langa, and Mai Lundemark, who read and commented on earlier versions of this manuscript, feedback that was invaluable in helping me structure and develop the story and argument presented here. I wish also to thank Bruce Carruthers for his kind generosity in commenting on my work, sharing his experience and thoughts on life in academia, and for hosting me at Northwestern University where I spent five months in a pre-doctoral fellowship in 2018. I am also thankful to Gary Alan Fine and Philip Jun Fang for inviting me to join the ethnography workshop at Northwestern and to Wendy Espeland for all her generous advice and encouragement.

The transformations that take place in encounters do not always happen in large events, however. In addition, small contributions over time can make an incredible difference. Such is the case with all friends and colleagues at the Department of Sociology at Uppsala University, and especially in the case of my office mates, Christoffer Berg and Richard Gäddman Johansson, whose support, friendship, and sarcastic commentary I have been able to count on over these five years. I also thank Jonas Bååth and Tom Chabosseau for granting me the pleasure of knowing them not only as colleagues but as roommates and *gastronomes* as well. Among the people I have been privileged to get to know while doing this PhD, I also wish to thank Ugo Corte for his kind encouragements and Hannah Bradby for all the support she has provided me and other PhD candidates in her work as head of graduate studies at the department. I too wish to thank all the administrative staff at the department for all the work they do to ensure that PhD candidates have the best possible conditions to grow and develop as researchers and teachers.

During my time as a PhD candidate, I have attended seminars and workshops at the Uppsala Laboratory of Economic Sociology, which has been a central source for comments, encouragement, and learning, and I wish to convey my thanks to all participants and a special thank you to its organizers over the years. Thank you Petter Bengtsson, Alexander Dobeson, Dominik Döllinger, Henrik Fürst, Alison Gerber, Greti-Iulia Ivania, Clara Iversen, Anna Khanukaeva, Sebastian Kohl, Sonia Köllner, Hannes Landén, Andreas Melldahl, Fredrik Movitz, Max Persson, Carl Sandberg, and Maya Schmidt! I am also thankful to the Cultural Matters Group at Uppsala University and The Center for Environment and Development Studies Research Forum that both offered an intellectual home away from home during my work with this thesis.

One encounter that has been incredibly important for this thesis was Elias le Grand's supervision of my bachelor's thesis at Stockholm University. Before meeting Elias, I cannot recall ever having considered pursuing graduate studies; I had a far more practical future in mind. However, at our final supervisory meeting, he asked me whether I had ever considered going for a master's degree; while I never had, I immediately began to. I am also very thankful to the mentorship provided by Peter Högström at Folkuniversitetet in Jämtland. After finishing my master's degree, I worked as an administrator and head of division with Folkuniversitetet's Östersund office where I enjoyed the support and encouragement to grow and develop that so characterizes Peter's leadership and management.

I also wish to thank my friends and family that in different way supported me during the work with this thesis. I have been extremely lucky to be able to count on your love and friendship during these eventful years. Thank you, mom, dad, Tim, Pontus, Anton, my grandmother Eila, Ernst, Manne, Jonas, Mohammed, Hannah, Nils, Elin, and Nina! Words cannot convey how grateful and happy I am.

1. Introduction

On December 8, 2014 Swedish iron miner, Northland Resources filed for bankruptcy. The mine that had once been hailed as a force that would pour new lifeblood into a struggling rural community had just defaulted on debts amounting to 14 billion Swedish kronor[1] and many asked how this could have happened. The press release announcing the bankruptcy cited the dramatic fall in the world market price for iron ore as the reason for the company's problems. However, although prices had dropped significantly in the months leading up to the bankruptcy, later investigations determined that flawed financial predictions used in forecasting the mine's profitability had played an important part in what eventually became the largest bankruptcy in Swedish history. The project, as the Swedish newspaper Svenska Dagbladet reported, had relied on overly optimistic forecast of the mine's future profitability. The consultants working with the company, who numbered in the hundreds, had "not understood how expensive operating a mine is" and had failed to keep relevant information such as predictions of future exchange rates and iron ore prices up-to-date (Sundqvist 2015). The events around Northland produced ripples across Sweden, and sections of Swedish academia got involved as a network was formed of scholars and researchers who called out for a temporary halt on mineral exploration and new mines in Sweden (Hjortfors et al. 2015).

Almost four years after the Northland bankruptcy, on October 26, 2018, Swedish mining once again made headlines when Loussavaara-Kirunavara AB (LKAB), a Swedish governmentally-owned mining corporation and the source of 90 percent% of the iron ore mined in Europe, made an unexpected announcement: the mineral resource beneath the Kiirunavaara Mountain in northmost Sweden was drying up. Until this point, the corporation had primarily described the future of the Kiirunavaara mine as a technological challenge, not a depleted resource challenge. The increasing depth of operations in the mine–which is already the world's deepest underground iron ore mine–posed problems as the deeper a mine goes, the costlier it becomes to extract and lift the ore. However, the announcement made on this day was something different. After two years of exploration work aimed at outlining the extension of the mineral deposit below the already explored levels, it turned out that the mineralization beneath Kiirunavaara was shallower than the corporation had

[1] Approximately $1.5 billion.

predicted. Instead of continuing towards the depth as expected, it was discovered that the deposit's geometry was more complex and a major section of it seemed to dry up just below the previously explored zone. Suddenly, questions arose about the life expectancy of the mine. The mine, which has been operating since 1898, was expected to last at least another 100 years, but now its future was uncertain as the reserves of iron ore appear to dry up some time by the mid 2030s. The people hit hardest by this news are, arguably, the inhabitants of the neighboring town Kiruna who are currently living through an intensive transformation of their city as parts of it are being moved or demolished to allow the mine to expand towards its 2030 boundaries (Perry 2015).

An uncertain business

While dramatic and highly publicized, the unexpected depletion of Kiirunavaara's iron ore and Northland Minerals' bankruptcy are not isolated or unique events. Instead, they are symptomatic of the exploration and mining industry as its members often face problems such as failed predictions and financial strain not only in Sweden but also around the world. For example, two years before LKAB's announcement, Rubicon Minerals, a Canadian exploration corporation, was forced to reduce its mineral resource estimates for their Phoenix Mine gold project by as much as 88 percent. This drop, which reduced the estimated volumes of minable gold from 3.3 million ounces to 413,000 ounces, came as a result of further exploration that showed the deposit's geometry and grade distributions to be far more complex than previous estimates had assumed (Koven 2016). While these three cases are unusual in how large the problems facing the exploration and mining companies involved were, there is nothing exceptional about them. Instead, they are illustrative examples of the uncertainty of mineral exploration.

The uncertainties that characterize mineral exploration are partly explained by the fact that minerals tend to be hidden and obscured by "material constraints" (Weszkalnys 2015:631) such as rock coverage and other overburden. Encapsulated and beyond reach, mineral deposits are not accessible for direct measurement and valuation, so they need to be sampled and assessed from a distance. Moreover, the exploration of deposits in the present must not only attempt to correctly estimate the amount of mineral in the ground, but also value the grades and volumes of mineralized material in the deposit in relation to the expected cost of its future exploitation, which will determine its future minability.[2] Therefore, the uncertainties facing mineral explorationists (i.e., the actors involved mineral exploration) are multifaceted and concern both the

[2] Estimated minability is here defined as the sum of assessments of economic, technological, environmental, and social feasibility in an exploration project.

actual existence of a mineral deposit and whether its qualities and location are such that the deposit can move from exploration to profitable and socio-environmentally acceptable mining operation. Unsurprisingly, the probability of success in mineral exploration is very low. Experienced geologist and author of handbooks on the topic, Roger Marjoribanks (2009:10) concludes that "[because] the overwhelming majority of programs are unsuccessful [. . .], most explorationists spend most of their time supervising failure" rather than enjoying success. Following from Marjoribanks's observation, mineral exploration in essence requires that explorationists be prepared to handle and manage non-success rather than trying to accomplish success despite not getting exactly the right results. At its core, exploration is as much about spotting a true negative before spending too many resources exploring and evaluating a project as it is about having success and making discoveries; and doing so involves managing a lot of uncertainty. [3]

While the challenges of mineral exploration may be interesting in their own right (like a business take on extreme sports), this thesis is not about these spectacular sides of the mining industry. Here, the focus is one of the more mundane but central aspects of the stories of Northland Resources and LKAB as well as with any success, failure, or hanging-on-by-the-skin-of-their-teeth project in the industry. The key dimension and question here is not the failure to anticipate the future, but the everyday struggle to seek profitable mineral resources and the challenges involved in producing predictions of such quality that they allow explorationists to manage successfully the uncertainties and risks that face a project.[4] This problem, the use of predictions as a way to make risks and uncertainties manageable, lies at the core of this thesis as it investigates how explorationists work to discover, estimate, value, and develop new mineral resources while facing significant uncertainties. The next section specifies how this study approaches the issue of prediction as a means to manage uncertainty in mineral exploration after which the current state of social science research on these topics is outlined in order to situate this thesis in the broader context of risk, uncertainty, and prediction research.

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[3] One thing to notice here is that while many industry representatives cite low probability of success and uncertainty as hallmarks of mineral exploration, it is hard to establish exactly how rare success really is. Nevertheless, estimates provided by informants interviewed for this thesis tend to quote numbers of success that range between one and two per thousand projects.

[4] While much can be learned from analyses of spectacular events such as the ones described here, this thesis follows William Foote Whyte's (1993) observation that extraordinary events can only be understood by first understanding the everyday patterns from which they arise. To understand spectacular events such as the Northland Resources bankruptcy, one needs to see it, to paraphrase Whyte (1993:xiv), "in relation to the everyday pattern of life" from which it arose.

1.1 Aim and research questions

Positioned at the crossroads of geological pasts, the present, and the uncertain future, mineral explorationists balance the complexity of very old and slow moving geological processes against the prospects for the future exploitation of the products of these processes, and they do so against a backdrop of the socio-environmental, economic, and technological conditions they presently face. The combination of complex presents and uncertain futures makes mineral exploration a rich source for asking questions about the role of prediction in uncertain economic life as well as about how predictions help make claims on the future by positioning certain futures as better, more valuable, or more desirable than other futures.

By analyzing how predictions are used to manage uncertainty in mineral exploration, this thesis addresses the practical processes mineral explorationists use to predict the future minability of deposits of mineralized material as well as the role these predictions play in mineral exploration. Moreover, this thesis asks how predictions are justified not only in terms of their qualities as depictions of the future but also in terms of their content (i.e., the futures they depict). Finally, this thesis asks what happens when predictions are put to use by explorationists in the continued exploration process and in their interactions with other actors. These different points of inquiry into the realities of mineral explorationists' work are specified in the form of the following three research questions:

1. How do predictions help explorationists manage uncertainty?
2. How do mineral explorationists justify their predictions in terms of their correspondence to present futures and the desirability of these developments?
3. What are the consequences of predictions in exploration work?

In relation to these three questions, two additional questions are asked in order to delimit and specify the focus of this thesis in terms of what practices and activities in the field are granted particular attention here:

4. How are predictions of the future minability of a deposit of mineralized material produced and what do these predictions look like?
5. How do explorationists use predictions in interactions with other actors and how do these actors assess the quality of these predictions?

To answer these questions, this study combines interviews, ethnographic observations, and archival research to map and analyze the exploration process in its entirety, from the initial search for locations in which to situate exploration projects to the decision to move ahead and construct a mine. Nevertheless, while the thesis accounts for each stage of the process, particular focus is granted to certain key stages of the exploration process where predictions comes to the fore, such as the application for exploitation concessions. An exploitation concession grants its holder the sole right to extract and exploit a mineral deposit. To secure a concession, mineral explorationists need to prove the future economic minability of extracting, concentrating, and selling the mineral as well as prove the socio-environmental viability of the project. In other words, the application for an exploitation concession is one of the stages in the exploration process where predictions and their credibility come to the fore as they play an important role in convincing the mining inspectorate to grant exploitation concessions; and because of this, concession applications will be a reoccurring theme in this thesis. However, before digging into the world of mineral exploration it is necessary to situate this thesis in the universe of research on predictions, risk, and uncertainty.

1.2 Managing uncertain futures: Predictions and risks in the social sciences

Although predictions and uncertainty play important roles in the cases presented above, few studies have explored how predictions and uncertainty influence explorationists and the industries that depend on mineral resources. Moreover, studies investigating the role of predictions in how actors manage uncertainty are also rare as the overwhelming majority of literatures discussing the topics do so separately, either as prediction or as risk and uncertainty. Therefore, the review that follows below will discuss the topics separately, highlighting the few studies bridging this divide, before eventually joining the threads at the end of this section. The section is based on a review of studies identified through systematic searches in social science databases as well as complementary searches based on examinations of lists of references to identify additional relevant studies.

Starting with the literature on predictions and prediction making, one initial thing to notice is that the use of prediction as a means to negotiate uncertainty is widespread among cultures (Alaszewski 2015) and has long connection with prophecy, astrology, and other means of divination (Armytage 1968; Asplund 1979; Curry 1987). However, despite being widespread and having a long history, prediction is a rare topic in sociology as well as in the general social science literature. Instead, there exists a small and disperse collection of works in different fields and disciplines. What unites these works is that they analyze how predictions are made, usually with a focus on particular cases of what Gary Alan Fine (2010) calls "futureworkers," that is, those professions who have the future as their professional domain. Together, these studies provide insight into how different professional cultures come into play in futurework. For example, the pioneering work by Robert Evans (1997) shows how macroeconomic forecasters combine their experience and judgment with the results of macroeconomic modelling as these models cannot produce plausible forecasts unaided. However, this is not only the case in macroeconomic forecasting. In a study of the professional culture among weather meteorologists in the Chicagoland area, Gary Alan Fine (2010) shows a similar balancing act in which theoretically-based computer models are combined with the meteorologists' experiences in order to produce weather forecasts that take local conditions into account (for more work on weather modelling and climate modelling, see Sundberg 2005). However, while the sociological work on prediction includes domains such as weather meteorology, the vast majority of research into prediction making focuses on financial markets and the economy. In these domains, forecasters produce models using judgment and experience through, for example, reflexive processes of "epistemic participation" where policy makers and business representatives participate in forecasting (Reichmann 2013). Swiss financial analysts (Leins 2018) and French economic forecasters (Pilmis 2018) have furthermore been shown to hold the creative production of narratives anticipating the future as central to their prediction making while tending to only bring in prediction models as a means to support their forecasted narratives. However, while forecasters and analysts appear to have much freedom in how they construct their narratives and use models to support them, others have shown financial markets tend to be less forgiving towards the blown forecasts made by inexperienced analysts than they are towards those made by experienced forecasters (Hong, Kubik, and Solomon 2000). In addition, Ekaterina Svetlova (2012) has shown that financial institutes adapt their forecasts to fit with front-stage conventions. Based on work on German and Swiss banking institutes before and during the 2007-2008 crisis, Svetlova demonstrates that when following their audiences' expectations, economic agents

> make the predictions that they present at the front stage rigid, formal, number-oriented and rather artificially precise. Because the frontstage convention is to present a scientifically justified and unambiguous definition of the situation, major uncertainties and lack of knowledge are downplayed and largely excluded; among many possible scenarios, only one is selected and presented. (Svetlova 2012:157)

The conventions of scientificity described by Svetlova are in turn supported by a "trust in numbers" (Porter 1996) that premiers quantitative and unambiguous presentations of predicted futures and tends towards obscuring the creative work put into forecasting as well as any qualitative inputs, which may be adopted to fit with expectations of calculative objectivity. Moreover, the adaptation of quantitative and unambiguous predictions have been shown to involve a decoupling and translation of any qualitative uncertainties away from unknowns and into lists of criteria to be met for the prediction to be realized (Reinertsen and Asdal 2019).

While studies of prediction makers illuminate how predictions are made in different domains, e.g., weather meteorology and finance, they tend to be limited to boundaries of their respective cases. In addition, studies of prediction makers tend to focus on the "backstage" (Goffman 1956) workings and professional culture in which these predictors operate, rarely providing an exhaustive insight into how predictions are made and weighted, the exception being the work by Svetlova discussed above. To address this gap in knowledge, this thesis proposes an expansion on this work by broadening the discussion of predictions' role in managing uncertainty to include a close attention to the details of prediction making as well as to the justification of predicted futures and the consequences predictions have when put to use.

With this broadened focus, it also becomes necessary to ask what predictions allow predictors to do. Discussing how the arctic nations use forecasting to stake claims on natural resources in the Arctic, Jenny Andersson points to the "urgent need to understand the socio-economic processes by which claims on the future are made, and by which expectations serve dominant or less dominant interests" (2018:98). Here, different methods of taming the future's uncertainty through prediction involves the production of expectations that make claims on and about the future and motivate actors to act in the present as they highlight certain futures while simultaneously close the door on others potential futures. One important role of understanding how this takes place is to understand the futurework that goes into producing futures as well as the work that takes place when a future has been produced. Stressing this point, Barbara Adam builds on the pioneering work by Wendell Bell, produced partly in collaboration with James A. Mau (1971, see also; Bell 1999), to propose that sociologists launch inquiries not only into "the knowledge practices associated with approaches to the future" but also into "how futures are lived and enacted" (Adam 2011:595). Following Andersson and Adam, there exists a present need for a better understanding of the practices associated with making claims about as well as on the future, and this need stretches beyond merely understanding the backstage world of prediction making. To accommodate a perspective that produces such understanding, this thesis furthermore proposes that a thorough study of predictions need to attend not only to the backstage activities involved futurework but also the frontstage application of predictions and their consequences when used to manage uncertainty, and to do so under the umbrella term "prediction work." This proposition concludes the present outline and discussion of the literature on predictions. The next section goes on to review and outline the larger body of work investigating uncertainty and risk.

1.2.1 A closer look at risks and uncertainties

The literature analyzing uncertainty and risk as well as their consequences in different social domains and phenomena is significantly larger than the literature analyzing predictions and encompasses a number of different literatures. These literatures include work on financial analysis, risk management, planning, and business management and have seen contributions from a broad spectrum of disciplines, including sociology, economic sociology, economics, economic anthropology, and history. Before adopting a finer grained perspective, this overview takes a broad perspective to tease out central aspects of these literatures and to establish a foundation for the coming discussion of prediction as uncertainty management in mineral exploration and other uncertain environments.

Notably, the diverse literatures on risk and uncertainty span different eras and different strands of social science. The list of classical works in these literatures includes, but is not limited to, Max Weber's (1978) discussion of rationality and Frank Knight's (2006) and John Maynard Keynes's (1937) work distinguishing uncertainty from calculable risks. In addition, Alfred Schütz's (1959) and Pierre Bourdieu's (1998) discussions of the roles of protention and projections as constitutive parts of action are additional classics in these literatures. Similarly, the risk society perspective launched by Ulrich Beck, Anthony Giddens, and others (Beck 1992; Beck, Lash, and Giddens 1994) as well as the bounded rationality perspectives provided by, for example, Amos Tversky and Daniel Kahneman (1974) and Herbert Simon (1991) have influenced how uncertainty and risk are understood.[5] Although each of these contributions is a classic in its own right, most works on risk and uncertainty are developed from Frank Knight's seminal distinction between the two phenomena wherefore Knight's contribution is given a more thorough introduction here.

Measurable uncertainty and true uncertainty: The contributions by Knight and Keynes

In his groundbreaking 1921 work *Risk, Uncertainty and Profit*, Frank H. Knight introduced a distinction between two types of uncertainty into economic theory. The first type was measurable uncertainties, or *risk,* for which

[5] As many sociological discussions of risk and uncertainty tend to challenge neo-classical economics and other literatures that make a case for instrumental rationality, the sociological literature on risk and uncertainty also feature a number of "negative classics." Notable works in this group are those of: Friedrich von Hayek (1944), Milton Friedman (e.g., 1994), and Eugene Fama (1970).

probabilities may be estimated, and the second was true, unmeasurable uncertainties. Because the world is characterized by uncertainty, Knight (2006) wrote, actors base their decisions on workable knowledge made from classifications of things into categories from which they may infer similarities and differences among objects and situations; and it is the accuracy of these classifications that make up the foundations for separating risks from uncertainties. Risks, Knight specified, are situations characterized by empirical specifications of instances where there are enough similarities between cases to render the potential distribution of outcomes calculable *within a group*. This calculability is not present in uncertain situations, as they are too unique to allow for the type of calculated estimation. In situations of uncertainty, Knight concluded, there is "*no valid basis of any kind* for classifying instances" (2006: 225 [emphasis in the original]).

This distinction between calculable risk and incalculable uncertainty places important limits on how far uncertainty can be reduced into risk in any given situation. However, it also opens up economic phenomena to the study of how actors seeking rational foundations for their choices can transform uncertainty into risk using devices that make uncertainty more or less measurable, e.g., by introducing systems for rating risks as in the case of credit ratings (Carruthers 2013). Although such devices are common (as will be discussed below), Knight appeared quite pessimistic about their usefulness in many everyday situations, writing that

> Business decisions, for example, deal with situations which are far too unique, generally speaking, for any sort of statistical tabulation to have any value for guidance. The conception of an objectively measurable probability or chance is simply in applicable. (2006: 231)

According to Knight, unmeasurable uncertainty is therefore hard to avoid, as measurability is not possible in unique situations. In addition to this, Knight also placed important restrictions on how much uncertainty can actually be translated into risks, stressing that the relationship between uncertainty and risk is far from linear even in situations where this translation is possible. Investments into reducing uncertainty by implementing some form of calculability comes with its own uncertain outcomes. However, there is a twist to this in Knight's thinking: Although uncertainty impedes on the type of rational foresight characteristic of theories of rational choice, the presence of uncertainty is a vital dimension of business, as it is known today. It is uncertainty that makes competition imperfect and therefore allows businesses to make profits, something that would not happen if all market actors had perfect foresight, which would work to equalize any divergences between production costs and selling prices (Knight 2006:198, 232). Following from this, uncertainty in Knight's definition is very much a double-edged sword as it both enables profit making and simultaneously impedes the ability of individual actors to use predictions to gain profits.

Fifteen years after Knight published his original work; John Maynard Keynes published his main contribution to the discussion of risk and uncertainty in *The General Theory of Employment,* a follow-up and development of his 1936 magnum opus *The General Theory of Employment, Interest, and Money*.[6] In this publication, Keynes discussed what he saw to be the difference between uncertainty and risk. Although Keynes's conceptualization of the phenomena in many respects differs from Knight's, there are enough similarities for them to be discussed together.[7]

Uncertainty, Keynes (1937:314) wrote, is present in cases where there is "no scientific basis on which to form any calculable probability whatever," whereas risk implies situations where probabilities can be calculated. According to this distinction, Keynes continued, the "prospect of a European war" or "the price of copper and the rate of interest twenty years hence" are uncertain, whereas a game of roulette, in contrast, is ruled by risk as its outcomes can only fall within a known distribution of probabilities. There are, after all, only so many numbers and colors that can emerge as the "winner" on a roulette table, and it is this distribution of possible outcomes that Keynes argues characterizes risk.

Therefore, the central distinction between risk and uncertainty, as defined by both Knight and Keynes, is that of the calculability of the potential outcomes of an act and the fact that estimation depends on the degree of similarity between cases and situations. In addition to this, one may note a further distinction that defines uncertainty as something different also from complexity. Providing an example of the differences between the two, Peter Katzenstein and Stephen Nelson noted that while chess is a very complex game, its outcomes are not uncertain (2013:1103, see also; Blyth 2002), and David Dequech emphasized this distinction further concluding that compared to uncertain situations games of chess change "only according to predetermined and possibly complex patterns" (2001:919). Based on these distinctions, one arrives at three different situations, one of uncertainty where no calculability is possible, one of calculable risks, and a third situation where the complexity of the situation makes risk difficult to estimate as the distribution of potential outcomes is hard to read.

Odd as it may seem given how straightforward Knight's and Keynes's discussions of risks and uncertainties are, no agreed upon definition exists for the two terms[8] in economics (their home disciple) or sociology. Instead, there are

[6] See Keynes (1936).

[7] For a discussion of the similarities and dissimilarities between Knight's and Keynes's work on uncertainty and risk, see Sakai (2016).

[8] An example of this lack of consensus is Sniazhana Sniazhko's (2019) finding that significant inconsistencies exist in how uncertainty has been conceptualized and measured only in the international business literature focusing on multinational corporations.

several takes on and approaches to risk and uncertainty. Mainstream economics (Lawson 1994; Poovey 2018) and economic sociologists (Azarian 2016), for example, have long neglected the relevance of uncertainty in economic action. Instead, economists and economic sociologists have tended to favor a focus on risk, both at the level of the individual actor and on levels of markets and societies. In the few cases that uncertainty has factored into these discussions, it has tended to be in the form the "animal spirits" (or intuition) that Keynes (1936) proposed entrepreneurs rely on in situations of uncertainty. Historically, also general sociologists have tended to overlook the contributions made by Knight and have instead produced a number of parallel risk perspectives, each with their particular definition of what constitutes risk and its consequences (Lupton 2013). One example of such a perspective are the risk sociologists and the literature on the "risk society" (Beck et al. 1994) that emerged in the 1990s. This literature featured a somewhat peculiar reading of Knight where risk somehow became uncertainty as a result of a conceptual definition akin almost to a mirror conflation of the two terms from that discussed above (see Power 2007). Nevertheless, a few economic sociologists, including Jens Beckert (1996) and Bruce Carruthers (2013), have picked up on Knight's writings about uncertainty and have begun to incorporate this view into their work. Moreover, following the 2007-2008 financial crisis, a growing number of economists had begun to discuss uncertainty and the role it plays in economic processes. Therefore, research has increasingly begun to focus on the relationship between risk and uncertainty, which the following section will outline and discuss in relation to the present study. In addition, the section discusses how the intersection between studies of prediction and risk and uncertainty studies opens up possibilities for investigations into how predictions are used to introduce calculability in the face of uncertain futures.

Approaches to risk and uncertainty in empirical research

While much of the work that has followed Knight and Keynes relies on some version of their distinction between uncertainty and risk, there are important differences in how these more recent works interpret and adapt the distinction in empirical research. These differences establish the central dividing line between different schools on risk and uncertainty as different approaches have different views on how far risk *viz.* calculable uncertainty can be used to reduce or manage un-calculable uncertainty. This section outlines five main approaches to the study of risk and uncertainty and builds on Deborah Lupton's (2013) influential review of risk research in its categorization of different approaches to risk and uncertainty scholarship. Lupton's original classification included techno-scientific approaches, critical realist (or weak constructionist) approaches, and constructivist approaches. To these categories, two more schools are added in the form of institutionalist and performativist approaches to risk and uncertainty. This section also discusses how each approach distinguishes unique and therefore uncertain situations from situations of calculable risk and the implications of this.

The first approach, the techno-scientific approach, views risk and uncertainty as hazards to be managed through calculation (Lupton 2013). Therefore, this approach tends to de-prioritize unmeasurable uncertainty in favor of calculable risks in a way that keeps with the positivist epistemology perhaps best summarized by the Marquis de Condorcet who wrote that

> all that is necessary, to reduce the whole of nature to laws similar to those which Newton discovered with the aid of the calculus, is to have a sufficient number of observations and a mathematics that is complex enough. (Marquis de Condorcet, quoted in Armytage (1968:29))

The techno-scientific approach is common in science, technology, and psychology, and social science work using this approach is often influenced by science and economics (Zinn 2009). Based on their focus on probability calculation, techno-scientific perspectives tend to view risks, or hazards, as something that exist as real "things" in the world. Furthermore, this literature often explores how actors can use objective measures to manage and reduce risks.[9] Therefore, techno-scientific approaches tend to view risk (and by extension uncertainty) as products of a deficiency in knowledge and therefore as an epistemic challenge that affects, e.g., organizational behavior (Jeong-han and Won 2010). Methods of overcoming such knowledge deficiencies have been studied in counter terrorism policy (Kessler and Daase 2008) and in first-order analyses of how risk can be managed in, for example, forest management (von Detten and Hanewinkel 2017). Additional approaches include the emerging field of neuro-economics, where risk is approached primarily as a cognitive process and where rationality is analyzed in reference to the cerebral processes involved in economic decision making (Bissonnette 2016).

While the techno-scientific perspective tends to favor risk over uncertainty and views risk as a consequence of imperfect knowledge, critical realists tend to perceive risk and uncertainty as reflecting not only actors' lack of understanding of the rules and regularities that shape events, but also as effects of disruptions. Uncertainty, in other words, remains a hazard, but one that is "mediated through social and cultural processes" as uncertainty and its hazards "can never be known in isolation from these processes" (Lupton 2013:50). In a critical realist perspective, the future is predictable to those knowledgeable of the rules that drive its realization. Nevertheless, the future in the critical realist definition is also a moving target as regular development is seen to be

[9] An example of works drawing the distinction between objective risks and subjective responses to these is the Royal Society (1992) report *Risk: Analysis, Perception and Management*.

disrupted and transformed through processes such as innovation (Beckert and Bronk 2018) and systemic changes. Based on these premises, critical realists conceptualize risk and uncertainty as real forces that are the products of systemic change where endogenous and exogenous shocks together with structural changes such as economic globalization render actors unable to rely on their knowledge of the past to foresee future events (Boyer 2018), a central tenet also of the techno-scientific view.

Unlike the techno-scientific view, which posits that actors may reach sufficient knowledge to reduce any uncertainty to risk, actors in the critical realist view are instead forced to find alternative ways to cope with and benefit from uncertainty. Ways to accomplish this navigation of uncertainty is by economizing it, as in insurance (Lehtonen and Hoyweghen 2014), by embracing uncertainty as in arbitrage investment (Mellor and Shilling 2016), or by using emotions such as trust or fear as means to stabilize uncertainty (Pixley 2012). One recent and prominent example of a critical realist proposition of how actors navigate uncertainty has been provided by Jens Beckert (2013, 2016), who invokes Knight's work on uncertainty and Benedict Anderson's "imagined communities" (1991) to argue that actors use imaginaries and fictions to navigate the uncertainty of the future.[10] According to Beckert, contemporary speculative financial capitalism has opened up the future in an unprecedented way, making present futures more uncertain than were those of previous societies. Because of this new openness, actors today need to find ways to manage uncertainty in order to find ways to benefit from the opportunities for speculation uncertainty provides while at the same time avoiding any detrimental uncertainties or risks and they do so by creating points of reference against which to orient themselves. These points of reference, what Beckert calls "fictional expectations" that function as "as-if statements," provide a degree of orientation in the face of uncertainty (Beckert 2016). Examples of such fictions include technical products such as financial models and analyses (Esposito 2018; Leins 2018) as well as the narrative logics (Lane and Maxfield 2005) that help actors orientate themselves in relation to uncertain futures–e.g., the narratives used by writers and artists to project career paths in highly uncertain labor markets (Fürst 2017; Menger 2014) and narratives that promote actors to engage with the financial sphere in order to manage risk and protect themselves from uncertainty (Maman and Rosenhek 2020), or drive people into artisanal diamond mining in the hope of future riches (Engwicht 2018).

Although fictional expectations and other imaginaries of the future help actors gain reference and coordinate their actions, imaginaries, narratives, and expectations may also lead actors astray. Heuristics and other narratives can become self-referential and the hype surrounding them can produce herd behavior and bubbles as actors flock to and act on a common imagined future. This tendency has been outlined by Lukas Linsi and Florian Schaffner (2019,

[10] For a discussion of Beckert's invocation of Anderson's work, see Carter (2019).

see also; Boyer 2018) in relation to the hype surrounding the emerging economies of Brazil, Russia, India, and China (BRIC) in the mid-2000s. Nevertheless, these heuristics still provide some point of orientation that is in turn made the object of analysis in critical realist inquiries. Whereas techno-scientific approaches tend to view uncertainty and risk as imperfect knowledge, critical realist approaches add additional layers of analysis in the form of uncertainty management strategies such as fictional expectations that pertain to managing the un-foreseeability of a future that is constantly being remade because of continuous innovation and change.

Related to the critical realist view are the institutionalist approaches that tend to operationalize risk and uncertainty along similar lines as the critical realists but with an emphasis on how institutions reduce uncertainty. For example, 1944 the Bretton Woods Agreement has been discussed by institutionalists as an uncertainty reducing institution that promoted stability in markets (Pryke and Allen 2000). Similarly, the differences in institutional environments has been used to explain the differences in the US and Russian credit card markets. For example, Alya Guseva and Akos Rona-Tas (2001) argue that the prevalence of institutions that allow for verification and accumulation of information enable US credit card issuers to reduce uncertainty into risk. As they do not have access to the same uncertainty reducing institutions, credit card issuers in Russia, Guseva and Rona-Tas continue, must instead rely on social networks and trust to manage credit uncertainties. Additionally, institutions such as industry standards have been theorized to reduce uncertainty by providing points of reference that in effect limit the scope of potential actions among a group of market participants (Aspers 2018). In this line of reasoning, institutions have been discussed as strategically implemented with a view to contribute to "the creation of a consistent structure of mutual expectations about the preferences, rationality and actions of agents" that helps facilitate stable patterns of cooperation over time (David 1994:209).[11] In this perspective, institutions such as standards and conventions can reduce uncertainty by providing points of reference around which action and interaction can be ordered. However, this ability of institutions soon becomes a double-edged sword as standards can malfunction, underestimate risk, or even produce new uncertainties. For example, Value-at-Risk (VaR) methods used in finance have been shown to underestimate the risks associated with property trading positions (Turner 2009). Moreover have boiler plate clauses in sovereign debt contracts been shown capable of producing significant uncertainty when disagreement arises around their interpretation (Choi, Gulati, and Scott 2017; Gelpern, Gulati, and Zettelmeyer 2018). Likewise, conventions and institu-

[11] A similar argument has also been made with respect to the function of networks (Azarian 2016) and organizations (Ahrne, Aspers, and Brunsson 2015) in reducing uncertainty among market participants.

tionalized narratives can–as the imaginaries discussed above–produce overconfidence in the face of uncertainty. Institutionalized "new era stories" that promote confidence on the basis of narratives of historical development have been argued to drive the formation of bubbles (Akerlof and Shiller 2010) as when the common belief that home prices would rise indefinitely helped produce the housing bubble that eventually led to the already mentioned 2007-2008 economic crisis (Nelson and Katzenstein 2014).

In contrast to techno-scientific, critical realist, and institutionalist inquiries into risk and uncertainty, constructivist approaches view risk as something that is not an inherent feature of the world, but something that needs to be constructed (Douglas 1992; Lupton 2013; Power 2007) and which is inherently intertwined with the practice that produces it (Besedovsky 2018). From a constructivist perspective, calculative uncertainties, or risks, "do not exist *suis generis* but must of necessity be organized, ordered, rendered thinkable, and made amendable to process and practices of intervention" (Power 2007:9).

Keeping with Keynes's metaphor of the roulette table, constructivist approaches to risk and uncertainty ask how roulette-like regularities are superimposed onto uncertain situations in order to re-construct uncertainty management into a management of risk objects. As a result, constructivists tend to emphasize uncertainty over risk and may be highly critical of disciplines such as neo-classical economics that approach the future as "an exhaustive list of possible events" and therefore overlook the radical uncertainty of (economic) time (Orléan 2010:14). Instead, constructivists such as Michael Power (2007:26) propose that much of what is presently called *risk management* is actually, from a Knightean perspective, *uncertainty management* as the probabilities and outcome data for the risks being managed "are, at a point in time, unavailable or defective" (2007:26). Examples of this have been provided in studies of cost-benefit analysis technologies (Porter 2008), credit rating and credit scoring (Carruthers 2017; Marron 2007), the work of financial securities analysts (Beunza and Garud 2007), governmental planning programs (Andersson and Keizer 2014), and risk management in finance (Lockwood 2015; Mikes 2011; Nelson and Katzenstein 2014) as well as in environmental policy (Wynne 1992). Based on a study of VaR methodologies and the failure of those wielding them to foresee the 2007-2008 financial crisis, Erin Lockwood proposes that the output of risk management methods such as VaR should be seen not as

> an approximately accurate measure of an objective reality, but rather as a conventional, contestable practice that is itself implicated in the workings of financial markets. (2015:720-21)

In a similar argument, Elena Esposito discusses how the statistics used in the stress tests put in place to monitor banks' abilities to withstand economic crises and to re-instate confidence in US banking institutions produces "second realities." Statistics, like fiction, Esposito writes

> neither describes nor "imitates" the real reality but builds a second reality, more structured and manageable than the uncertain world modern society has to face. This reality is used to eliminate arbitrariness and to govern contingency, to behave in a "reasonable" way when rationality becomes doubtful and unattainable. (2015:97)

According to constructivist approaches, in other words, risk management technologies create futures that *are made* predictable and manageable by the introduction of measurements and these futures will operate predictably as long as the uncertain reality they claim to describe does not take an unexpected turn and render the risk unruly.[12] The extrapolations from which these second realities are built, Helga Nowotny points out, do after all "meet their limits when surprises hold in store what has been unthinkable before" (2016:32). That is, although one may dress uncertainty as risk, true uncertainty, as Bruce Carruthers puts it, "nevertheless remains uncertainty" (2013:543). In other words, although any situation may be approached as if it were a roulette table, any underlying uncertainty would merely be absorbed (March and Simon 1958) and hidden from view. For example, the post-mortem performed on the 2007-2008 financial crisis has shown that the use of statistical models to manage risk created their own worlds that did not always align with the world proper. During the crisis, it has been reported, the banking institute Goldman-Sachs experienced losses estimated as rare as "a once-in-every-fourteen-universes" event on several consecutive days (Nelson and Katzenstein 2014:385), placing the bank in the peculiar position of experiencing extremely uncertain events with almost certain regularity.[13]

In addition to asking how risks are constructed and what the implications of this are, constructivists have also highlighted the highly political and ethical dimensions of risk and risk management. Using statistics and quantification, which on their own have political and ethical implications (Espeland and Yung 2019), to transform arbitrariness and contingencies into manageable risks means risk management does not describe the world in total; that is,

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[12] The use of "unruly" here is based on Brian Wynne's (1988) discussion of technology as open-ended technical-social systems whose functions become unruly due to unforeseen and uncontrolled uncertainties.

[13] A stunning example of such improbabilities can be found in how unlikely the financial crisis of the last decade was, according to those estimating it. Nelson and Katzenstein (2014:385) provides an example: while estimates of the probabilities of large scale deviations from the average such as a plus twenty-two sigma event (one sigma being one standard deviation's deviation from the average in a Gaussian distribution) is as low as one in a googol – or 1 in $1x10^{100}$), three such events occurred in the 20 years between 1987 and 2007.

quantified risk management merely describes a particular place and time, and it does so in the interest of certain actors. Therefore, studies of risk management, Liliana Doganova argues, should ask not only how risks are constructed, but also what any particular risk construct does and "when and for whom" these risks are taken to matter (2018:287).

Finally, performativist approaches stress the reflexive dimensions of risk assessments and the epistemological challenges involved in producing risks. Risks, performativists argue, are not only produced through risk management and analysis but are also *performed* through the same. For example, Horikazu Miyazaki (2003) describes how Japanese Sekai traders' theoretical understanding of arbitrage as a shrinking opportunity, resulting from more arbitrageurs entering the market, highly influenced their interpretation of the market, how it functioned, and the opportunities and risks it held. However, theory is not the only way objects and practices are performed; conventions and expectations play important roles in shaping practices too. This view is evident in Svetlova's aforementioned study of prediction making: economic forecasters tend to down play uncertainties and knowledge deficiencies to conform to conventions and audiences' expectations that forecasts are a "scientifically justified and unambiguous definition of the situation" (2012:157). This ability of forecasts and risk management technologies to obscure certain dimensions of the uncertainties they seek to manage has also been described in risk management technologies such as IT-based risk control systems. Analyzing the risk predictions produced in a certain risk management framework used in a large infrastructure project in Denmark, Tim Neerup Themsen and Peter Skærbæk demonstrate how the computer-based framework used to manage risk became an active mediator that in the end "distorted the process and led to unexpected effects" (2018:30). This view echoes Svetlova's findings of how conventions play into forecasting as Themsen and Skærbæk found that the risk management framework only admitted some uncertainties to be added to the program to be managed as risks while other uncertainties not granted significance by the management framework were left aside. Finally, conventions may even help actors navigate situations where the ability of theories and models to perform (e.g., a market) is disrupted due to contingencies affecting the actors, who are forced to rely on skillful coping and cooperation to negotiate the conflict between market and realm of production (Dobeson 2018).

In addition to the contributions outlined here, performativists also stress a second level of performance in how narratives of utopian or dystopian futures shape activities in the present. This argument follows the same lines as that put forth by the sociology of expectations (e.g., Borup et al. 2006). However, whereas the sociology of expectations focuses on science and technology, including studies of the ways in which technology influences how actors make sense of the future (Verschraegen and Vandermoere 2017), how forecasts influence the development of new artefacts (Pollock and Williams 2010) and how ideas about the future shape technology and knowledge in the present (Brown and Michael 2003), performativist approaches tend to focus on the economy and financial markets (e.g., MacKenzie, Muniesa, and Siu 2007). For example, studies of central bankers illustrate this as central banks public communications use language that intends to manage expectations and to promulgate and sustain ideas about the future as well as the desires of economic actors (Braun 2015; Holmes 2018). In addition, central bankers are not alone in relying on the ability of narratives to intervene in the present. Financial actors often use predictions not to manage risky futures, but as a means to intervene in financial markets (Esposito 2013). Moreover, although the futures depicted in these interventions may calm actors in the face of a crisis as in the case of the stress-tests of US banking institutes put in place by the US Federal Reserve during the 2007-2008 financial crisis (Langley 2013), narratives about the future may also limit the scope of imaginary futures. For example, the eschatological nature of narratives about techno-utopias tend to close down alternative futures by promoting a form of promissory inevitability in stories about future technological change (Geiger 2020). In addition, financial analysts' forecasting work has been argued to perform predictability in unpredictable financial markets (Leins 2018) and re-produce financial markets as orderly phenomena (Preda 2007).

Towards a sixth approach: Pragmatism and the paradox of futurity

Predictions and uncertainties are two dimensions of the future that are seldom joined together in sociological research. Instead, prediction research has tended to focus on the professional realities of futureworkers, whereas risk and uncertainty research has outlined different ways in which actors attempt to overcome uncertainty despite the inherent impossibility of their undertaking. The discussion here highlights not only how risk and uncertainty scholarship illuminates challenges involved in negotiating the uncertainty of the future but also how work to make these uncertainties manageable in order to allow actors to make claims, as Andersson (2018) points out, not only about the future, but also on the future. The paradoxical nature of the future does not only position actors in an uphill battle against uncertainty, but also open up the future to be colonized (Giddens 2003) by predictors making claims not only about what the future may look like but also what should be done to realize or avoid particular futures.

The five approaches to risk and uncertainty studies discussed here: the techno-scientific, critical realist, institutionalist, constructivist, and performativist, all highlight different prediction techniques that actors use to manage, or seek to manage, risk and uncertainty although with quite different ideas as to exactly how far uncertainty can be managed. Together, these five approaches to risk and uncertainty produce a multifaceted canopy of ways to understand these phenomena from different ontological and epistemological perspectives. Depending on which position one takes, risk and uncertainty can be viewed as intrinsically different things. In the highly realist techno-scientific approach, risks are objective hazards that need to be managed and tamed through probabilistic calculation. However, such a position becomes naïve from a critical realist position as it neglects to consider how hazards are mediated through social processes wherefore they still tend towards uncertainty. The techno-scientific approach becomes even more impossible still if a constructivist frame is adopted as risks, in this view, are ultimately the products of historically contingent cultural processes. These differences mean that any study of the use of predictions to manage risk and uncertainty needs first to determine whether to position itself solely within one of these approaches, thereby accepting any shortcomings of each particular position, or to reconcile these differences into some type of dialectic of risk. For example, Peter Katzenstein and Stephen Nelson (2013, 2014) combine the techno-scientific and constructivist optics to develop a more nuanced understanding of the 2007-2008 financial crisis.

A second way to reconcile the different positions in risk and uncertainty research is to bracket their immediate claims, and therefore their central differences, and focus instead on the practical implications of managing risks and uncertainties within a particular context. Such an approach is made possible through a pragmatist position that focuses on the "tangible and practical" roots of uncertainty management in a given context (Peirce 1878:293). This approach allows for a study of risk and uncertainty management through prediction that simultaneously focuses on the possible positionalities also within, so to say, "hard" calculative techniques such as statistics (see, e.g., Desrosières 2001) while focusing on how groups of actors seek to resolve the practical problems that stem from engaging in forward-oriented actions without being able to know the future. Focusing on this "futurity paradox" as Benjamin Braun (2015) has named this tension between action and uncertainty, opens the door to simultaneously acknowledging the context-dependent rationalities that guide actors' approaches to predicting the future and the inherent unknowability of the future. This approach may appear cynical as it could conceptualize risk management as a vain Sisyphean struggle rather than a rational approach to managing uncertainty; however, this is not the case. In his ferociously eloquent critique of techno-scientific approaches to risk, André Orléan (2010) outlines how radical uncertainty of (economic) time means that the past does not provide a sufficient basis for predicting the future. However, despite this actors still need to make predictions to accomplish some degree of rationality in their decisions and actions. Here it is may be useful to remember that what is rational is situationally determined, or as Max Weber (2002:38) put it:

> one may—this simple proposition, which is often forgotten should be placed at the beginning of every study which essays to deal with rationalism—rationalize life from fundamentally different basic points of view and in very different directions. Rationalism is an historical concept that covers a whole world of different things. It will be our task to find out whose intellectual child the particular concrete form of rational thought was [14]

Therefore, a pragmatic study of how groups of actors seek to manage the futurity paradox needs to consider not only the techniques of risk and uncertainty management, but also the context in which they make sense. Whether that which is being managed is truly risk–a point of considerable contention in the five literatures reviewed above–is only of secondary interest as it is the practices of using predictions to manage uncertainty and the context in which this is made sense of that is takes center stage here. Moreover, assuming such a pragmatist approach has two consequences for how uncertainty and its negotiation is to be studied. First, it requires an investigation that goes beyond black box concepts (Latour 1999) such as fictional expectation by accounting in detail for the practical processes involved in managing problems of uncertainty. Second, it means bringing the study of uncertainty and risk back to the Weberian and pragmatist underpinnings that characterize much of Knight's original discussion of the phenomena (see Hands 2006; Nash 2003). This shift means refocusing the inquiry into risks and uncertainties away from the approaches discussed above towards a more context-conscious approach that factors in not only particular risks or uncertainties, but also the problems with which they are associated and the social environment in which they make sense as rational means to manage the uncertainty of the future. In addition, a pragmatist approach to uncertainty ought to consider the way in which risk management such as predictions allow actors to make claims about the future and their right to said future. Regardless of whether actors work on the basis of fictional expectations based on imagination or careful calculation, the ways in which actors negotiate their paradoxical temporal positions is by anticipating and claims as their a future that they cannot know anything about.

[14] Weber is not alone among the classics to offer such as contextual definition of rationality as Karl Polanyi (2011:4) also defined rationality as contextually dependent, writing that rational action is any choice of means in relation to ends as long as these means are "appropriate to serve the end, whether by virtue of the laws of nature or by virtue of the laws of the game."

1.3 Uncertainty and predictions of the minability of mineral resources

This thesis aims to demonstrate how the paradoxical relation between future-oriented action and the uncertainty of the future is negotiated in mineral exploration by focusing on the role of predictions in how explorationists manage uncertainty while making claims about the future minability of a deposit. As the introduction to this chapter demonstrates, mineral exploration is a process characterized by a very low likelihood of success and a corresponding high risk that as poor failures–such as that of Northland Minerals–are costly. These characteristics coupled with the forward-looking nature of mineral exploration, its distant temporal horizons, and high level of uncertainty make mineral exploration a hot spot for prediction making and therefore an intriguing venue for studying processes of prediction in uncertain environments. That is, in mineral exploration, predictions matter, and they matter because the stakes are high.

Uncertain natural resources

Thematically, this thesis connects a focus on prediction with an inquiry into how uncertainty is managed as a practical problem in economic processes, particularly in mineral resource economies. The thesis investigates the processes through which pieces of "nature" are transformed into natural resource commodities and the work that goes into identifying and predicting which sections of "nature" can sustain this transformation into profitable "second natures" (Cronon 1991see also; Tsing 2015).[15]

The production of natural resource is primarily a matter of transformation and re-location of materials, but it is also a process that involves alienating

[15] William Cronon (1991, 1996) describes the process of turning nature into natural resources as a transformation of first natures into second natures. Writing about the natural resource economies that helped Chicago emerge as a metropolis in the American West, Cronon discusses how the Chicago markets laid under itself the natural riches of the western frontier and opened them up to the markets in the East. These natural riches, Cronon (1991:266) writes, "had once been members of ecosystems defined mainly by flows of energy and nutrients and by relations among neighboring organism. Rearrayed within the second nature of the market, they became commodities: things priced, bought, and sold within a system of human exchange." One clear-cut example of this transformation of systems of energy, nutrients, and organisms was the standardization of grains that developed around the Chicago Board of Trade and Chicago's grain elevators and resulted in the introduction of a grading system for wheat and other grains in 1857. This introduction of standards for grain meant that the heterogeneous realities of wheat and other grains were transformed into homogenized groupings that turned real grain into abstract categories of classes of wheat, oats, and other grains that could be traded at the Chicago Board of Trade.

materials (Tsing 2015) and of creating stable homogenous categories where there previously was only heterogeneity. This transformation may be cheap and straightforward as when a timber is categorized into different classes according to its quality and length, or open to human manipulation as in the use of fertilizers and pesticides that promote elements of control and help farmers manage uncertainties. However, some natural resources do not allow for such manipulation as they are situated in complex systems not open to such forms of manipulation such as small-scale fisheries who fish unpredictable fish stocks to be sold on a quota market. In his ethnographic study of fisheries in rural Iceland, Alexander Dobeson (2016a, 2018) demonstrates how the complex system of relations between fishers, "nature," and the quota market forces fishers to adopt different strategies to manage contingencies by adapting their work to suit the realities of both the fish and the market. Such uncertainty is also present in mineral exploration. Moreover, mineral resources are even further removed from human manipulation than most other natural resources. For example, while fish stocks are replenished by reproduction and may recover and grow were their exploitation to be halted for a period, the concentrations of mineralized material that explorationists seek have been deposited in the bedrock over billions or millions of years of geological process and are therefore non-renewable resources as they cannot be improved or replenished by human intervention. Furthermore, deposits of mineralized material are hidden underground, obscured, and transformed by geological shifts and thrusts, making them challenging to survey. Gaining access therefore depends on explorationists sampling the bedrock to learn their qualities while managing the complexity of the geological environments.

The transformation of a deposit of mineralized materials into marketable second nature mineral products such as concentrates and bullions requires that the deposit possess such quantities and qualities of mineralized material that it can sustain this transformation. Therefore, mineral exploration is about managing uncertainties about whether deposits can be transformed into second nature mineral products. At the heart of this process, explorationists explore and valuate first natures in order to identify those portions of it that can be turned into second natures to feed not only the market but also the portfolios of mining corporations presently depleting already discovered mineral riches. This latter dimension of mineral exploration is one of the hallmarks and peculiarities of mining and any natural resource economy that works faster than nature can replenish the resource. As a CEO of a Swedish mining company once said: "Any mining corporation that does not continually search for new discoveries has indirectly decided to someday shut down." In addition to searching for sustained supplies of minerals and metals, successful mineral exploration is about ensuring the survival of mining companies that depend on a continuous appropriation and transformation of new stretches of first nature. But which parts of "nature" can be turned into profitable mining operations? In order to navigate the uncertainties involved in such questions, explorationists turn to predictions.

1.3.1 A note on terminology: Resources and explorationists

Before turning the full attention to the work of developing answers to the questions listed earlier in this chapter, some clarification in terms and terminology is necessary. First, mineral exploration is a broad field that includes hard rock mineral exploration, exploration for hydrocarbons such as oil and gas, and alternative forms of exploration such as the methods used in artisanal mining. While the approaches and methods used in these different types of mineral exploration overlap, there exists important differences between them. Therefore, it is necessary to delimit the scope of this inquiry in these respects. The empirical materials gathered as part of the work leading to this dissertation concern industrial hard rock exploration for base, industrial, and precious minerals as well as iron ore and rare earth elements (REEs) wherefore any use of the term "mineral exploration" here refers to this limited set of resources and approaches to exploration. In addition, mineral exploration, as in most specialized fields, uses a specialized language that grants specific meanings to otherwise everyday words and terms.

One specialized term that has some relevance for this thesis is the term "mineral resource," which has different meanings when used by some social scientists and when used by mineral explorationists and miners. From the social science perspective, Ferry and Limbert's (2008) work on resource making in which they stress that natural resources do not exist in "nature" but are constructed through social and political processes. Following this, a mineral resource is a cultural entity just as much as it is a natural object. However, while most mineral explorationists would agree with this, they would find it problematic that social science scholars such as Ferry and Limbert locate the emergence of mineral resources at the very beginning of the exploration process and therefore ascribe a broader meaning to the term than industry actors do. Instead, the mineral exploration and mining industry is much more specific as to what constitutes a mineral resource. From the industry's point of view, a "mineral resource" is a technical term that denotes a body of mineralized material that has seen a certain amount of exploration work as defined in industry standards such as the Australasian code for reporting exploration results and mineral resources (JORC). The JORC code defines a mineral resource as a concentration of mineralized materials that holds "reasonable prospects" for "eventual economic extraction." The code also states that enough survey work should be done so the deposit's geological qualities "are known, estimated or interpreted from specific geological evidence and knowledge, including sampling." The *making of* a resource in this sense begins when there is enough geological data available to estimate the deposit's size and qualities. In order to reduce the risk of confusion, this thesis uses the term in accordance with its usage in the field; therefore, mineral resources are here understood as the potentially economically extractable parts of an explored mineral deposit.

Finally, mineral exploration sees contributions from actors of different professions and fields of expertise. In addition to geologist and geophysicists sampling the underground in search for concentrations of mineralized material, mining engineers, economists, biologists, lawyers, and others contribute to the process. Whenever applicable, these groups will be referred to individually. However, when discussing the generalized group of actors who contribute to the mineral exploration process, this dissertation will use the term mineral "explorationist" as a shorthand for the multiple groups of actors involved at the different stages of the process.

1.4 Outline and summary of the argument

This thesis is structured as follows. **Chapter 2** describes the contextual background to this study and builds an account of the empirical field by combining an outline of existing sociological and social science research into mineral exploration and the exploration and mining industries with an account of past and present developments of industrial mineral exploration in Sweden. In **Chapter 3**, some points of entry into a study of prediction making and justification are discussed to assess the relevant sociological literatures and to identify concepts that can capture and help unpack prediction making and justification in mineral exploration. The chapter complements the discussion in chapter 1 by adding perspectives from the sociology of the future and valuation studies to the conceptual toolkit through which mineral explorationists' work in predicting deposit minability can be dismantled and analyzed in its parts.

Having laid out the conceptual foundations, the thesis examines the methodological aspects of studying processes, such as mineral exploration, and the epistemic objects the process produces. **Chapter 4** outlines the approach through which the dataset, which combines interviews, ethnographic fieldnotes, and archival material, has been assembled to create a fine-grained description of how estimates and predictions of minability are produced and used in mineral exploration. In addition, the chapter outlines how these materials have been collected and analyzed. The chapter concludes with a review of the ethical dimensions and considerations involved in gathering the materials for this project. The chapter is complemented by four methodological appendices: the first discusses some first-hand experiences and challenges that arose in the work leading up to this thesis, the second and third list observational and archival data sources, and the final appendix provides an example of an interview guide.

The empirical section of this thesis begins with **Chapters 5 and 6**. The two chapters account for the mineral exploration process and the work explorationists engage in when *producing predictions* with which they work to "de-risk" exploration projects. Beginning with a general outline of the mineral exploration process and its different stages, the two chapters provide in-depth accounts of early, intermediate, and advanced stage exploration of the different types of prediction produced by explorationists at these stages and the work involved in making these predictions. **Chapter 7** examines how explorationists justify their predictions. Specifically, the chapter describes how explorationists engage in two different lines of justification: one consisting of claims regarding the prediction as a correct depiction of a realizable future and one consisting of claims about the desirability of realizing the futures depicted in these predictions. The chapter demonstrates that justifications in mineral exploration rely on values expressed in institutions, such as private and public regulation, as explorationists actualize these values to support claims of the prediction as an accurate and precise depiction of the future. Moreover, the chapter also shows how explorationists tie their justifications to narratives and current debates to claim the desirability of realizing the predicted mining futures. **Chapter 8**, the final empirical chapter, answers the "then what question" (Fourcade 2011). That is, what happens when a prediction has been made and is put to use by explorationists? In addition, the chapter analyzes the interactions between explorationists and their different publics over explorationists' access to resources such as equity, debt, or legal permits. The chapter pays particular attention to the assessments, or metapredictions, publics such as investors, financiers, and permit granting bodies make of explorationists predictions and the consequences these assessments have for explorationists' abilities to realize their mining futures.

Chapter 9 summarizes the empirical findings and discusses prediction making as a strategy to navigate uncertainty. Theorizing explorationists' use of predictions, the chapter develops an account of prediction making that highlights the practical role predictions serve in uncertain social and economic spheres while emphasizing the preliminary status of predictions as well as their political nature. As with the discussion on the dissertation's theoretical contributions, this chapter highlights dimensions and questions of potential interest in future research on mineral exploration and prediction work. The chapter also discusses some practical implications of the findings.

2. Contextualizing Mineral Exploration

Mineral exploration and the search for commercially viable deposits of metals and minerals in the earth's crust do not take place in a vacuum. That is, exploration follows logics prescribed in both standards and practice. This chapter gives context to the themes raised in the previous chapter and outlines the day-to-day realities of contemporary industrial mineral exploration. In doing so, the chapter combines existing social scientific research on mineral exploration and mining with primary sources such as industry publications, legal documents, and standards. A review of the existing literature shows that social scientific research in this domain is centered on a limited number of key perspectives and disciplines. One of the largest contributions to the literature on mineral exploration and mining has come from anthropology in the form of in-depth studies of artisanal small-scale mining in the global south that detail the conditions and conflicts surrounding artisan mining communities (see e.g., Frækaland Vangsnes 2018; Hilson 2010, 2011; Verbrugge 2015). In addition, the literature includes historical and economic historical case studies of mines or economic phenomena such as the rationalization of mining through double entry bookkeeping (see, e.g., Allen 2007; Libecap 1978; Vent and Milne 1989). Third, there is also the debate in economics as to whether mineral resource exploitation in developing economies tend to produce a "resource curse" by undermining inefficient state institutions while fueling corruption (see e.g., Alexeev and Conrad 2009; Boschini, Pettersson, and Roine 2007; Murshed and Altaf 2007). Finally, there exists a relatively large body of work, primarily sociological, that researches conflicts and contestation of mineral exploration and mining by local communities and indigenous groups (see below). Because of the concentration of the sociological and social scientific literatures around particular strands, this chapter relies on primary materials to fill-in the gaps that result from the present scarcity of research into mineral exploration. The primary data have been sourced from industry organizations, government archives, and services that review the mineral exploration industry in Sweden and internationally, including reports from mineral exploration and mining agencies such as the Mining Inspectorate of Sweden (MIS) and the Geological Survey of Sweden (SGU).

This chapter includes three sections that outline the context of the present study. The first section reviews historical and present trends in mineral exploration. The second section reviews the different categories of actors involved in contemporary mineral exploration. The third section outlines mineral exploration's legal context both in terms of public regulation and the private regulation in the form of standards that guide mineral exploration in Sweden and internationally.

2.1 Overview: Mineral exploration in history and in the present[16]

Ever since iron and coal laid the foundations for the emergence of capitalism (Weber 2003), modern society has depended on a steady supply of iron, steel, copper, aluminum, gold, silver, and, in recent years, rare earth elements, vanadium, cobalt, and nickel. Second perhaps only to the clock, as Mumford (1946) noted, metals and minerals have helped shape the world as we know it today, and it would be hard to imagine a world without them. In other words, the exploration for mineral resources is not only of interest to the members of the mineral industries but also to anyone who depends on its products.

The history of mineral exploration is deeply entwined with the history of mining and the use of minerals in human societies, a history that dates to the Paleolithic age when pre-historic people began extracting non-metallic materials, such as flint, for use in tools and weaponry (Kennedy 1990). Later came the extraction of metals as people started using native gold for decoration and meteoric iron for weaponry (Waldbaum and Muhly 1980) and metallurgic treatment of tin and other metals with melting points not requiring special furnaces. Finally came rudimentary hot metallurgical techniques for smelting of copper at the start of the Chalcolithic era around 5000 BCE (Radivojević et al. 2010). The history of mineral exploration is a very long and it is tied to humanity's, so to say, promethean transition.

[16] The historical overview here focuses on the developments and current state of industrial mineral exploration in Sweden and the Global North. However, not all exploration and mining has been part of these dramatic changes. While many actors in the industrialized mineral exploration and mining that characterizes the work done by mining companies and corporations in the Global North rely on state-of-the-art exploration equipment, the Global South hosts a range of actors involved in small scale artisan exploration and mining. That is, there is a variation within the larger field of mineral exploration and mining. This richness of variations on the same form means that mining and exploration involve anything from the techniques and methods discussed in this dissertation via small-scale mining using low-tech methods (Banchirigah and Hilson 2010) to examples of mining cultures where local chiefs distribute mining rights according to rotational systems based on local tradition (Lanzano 2018). The consequence of this diversity in exploration and mining is that this dissertation does not speak to all forms of mineral exploration but mainly to those employed in industrial mineral exploration.

The early forms of mineral exploration consisted of looking for visible outcrops of mineralized rock or using dowsing rods and mining compasses[17] to identify deposits of magnetic minerals. In modern history, mineral exploration has seen dramatic development as these historical methods have been replaced by geophysical survey methods, geochemical analyses, and, in recent years, machine-learning approaches through which algorithms scour through large sets of data to identify localities of exploration potential. However, these new technologies have not completely replaced old practices (perhaps with the exception of the dowsing rods) as prospectors still search rock outcrops for traces of minerals and geophysical magnetometry surveys are based on the same logic as the mining compass but on a much larger scale and through high tech applications (Nabighian et al. 2005). Therefore, mineral exploration remains a phenomenon in which attempts to read the geology are central to identifying places that promise hidden deposits of mineralized material in significant volumes and grades.

In addition to the introduction of new exploration methods, mineral exploration and mining has also seen significant changes arise from innovations that have rendered previously unminable deposits technologically and economically viable. One arena where significant developments have been made throughout the history of mining is furnace and smelter technology. The development of high temperature furnaces powered large changes in the mining world with the most important change coming with the introduction of the Bessemer converter, which made it possible to smelt phosphorous iron ores such as the massive deposits around Kiruna and Grängesberg, Sweden. This technology helped pave the way for mass-produced inexpensive steel (for an in depth account, see Heckscher 1954). Another important transition was the increase in productivity that enabled low-grade large-scale mining (Humphreys 2019) as lower grade deposits were opened up for mining using more productive extraction methods such as large-scale pit mining. In addition to these changes, technological developments in general society that have made most metals of the periodic table sought after resources to be used in a large range of high-tech applications have made mineral exploration and mining the industry it is today.

[17] Mining compasses consist of a dual gimbal compass that dips downwards when positioned above magnetic materials such as magnetite ores.

2.1.1 A small global industry

Today, mineral exploration is a global enterprise feeding new reserves to the international mining industry and exploration has become an important contributor to the mining industry and, by extension, to all down-stream producers that use mineral and metal raw materials to produce, for example, cars, wind turbines, steel, iPhones, and medical equipment. Although holding a central role as a supplier of raw materials, mineral exploration is at the same time a relatively small industry. In 2018, the combined budgets of exploration companies worldwide was 9.62 billion dollars across 1651 companies spending 80 percent of their budgets in only 25 countries[18] (Geological Survey of Sweden 2019b). As a small, globalized industry, mineral exploration is also relatively integrated with large parts of the world as it is covered by the same industrial standards and with international events such as conferences and trade shows providing venues that attract explorationists, miners, equipment manufacturers, consultants, investors, politicians, and governmental agencies from all around the world.

Furthermore, contemporary mineral exploration is part of an internationally integrated market where metal and mineral prices are set at central exchanges such as the London Metal Exchange (LME) and the London Bullion Market. Because of the relative integration of the minerals market and the relative standardization of mineral products such as concentrate, producers in the exploration and mining industry are “price takers” (Cairns and Lasserre 1986). That is, these miners and explorationists do not set the prices of their products as these depend on the spot prices in the global market.[19] Explorationists and miners working in ferrous minerals (i.e., iron ores) are an exception as ferrous contracts are negotiated with individual smelters, an arrangement that makes the market for ferrous mineral less integrated. However, the lack of a large central market does not render their situation much different from that of explorationists and miners working in non-ferrous minerals as ferrous contracts follow international prices too. The largest difference between the two instead depends on the relative price per ton of product as ferrous products fetch lower prices meaning that producers of iron ore products are more sensitive to transport costs than are producers of non-ferrous products, which fetch higher prices per ton (or even per ounce). Furthermore, the impact of the price taker role on mineral exploration relates to the fact that the access to finance capital tends to vary with the global market prices. Therefore, positive movements in

[18] The main exploration destinations in 2018 were Canada, Australia, the U.S., Peru, Mexico, Chile, China, Russia, Brazil, the Democratic Republic of the Congo, Argentina, Burkina Faso, Papua New Guinea, Ecuador, Ghana, Côte D’Ivoire, Mali, South Africa, Colombia, Sweden, Finland, Indonesia, India, and Senegal.

[19] Some variation, however, does occur in prices as smelters use systems of penalties for impurities and premiums for higher grades when they purchase concentrates.

prices tend to result in increased exploration efforts as incentives to explore and, by extension, the willingness to risk capital increase with rising metal prices (Borenstein and Farrell 2007).

Turning to the case at hand, despite having been a historical powerhouse with a near monopoly on iron exports on the early modern European metals market (Hildebrand 1987), present-day Sweden is one of the smaller members of the 25 largest exploration destinations. However, Sweden remains an important mining and exploration destination with more exploration dollars invested relative to country size than does exploration and mining giant Canada (Geological Survey of Sweden 2019b) and the Swedish mineral exploration sector has grown significantly since it was opened up in 1992. Before 1992, Swedish mineral exploration and mining was in the hands of a restricted group of actors with governmentally owned LKAB concentrating on ferrous minerals and Boliden Mineral concentrating on non-ferrous minerals. In addition, the Swedish governmental agency SGU and the publicly-owned exploration company SGAB made up the core of the exploration industry in the country. This concentration of mineral exploration into a limited set of hands led to Sweden being relatively underexplored compared to other destinations at the time. When Sweden was opened up for private and foreign exploration, it became an attractive exploration destination as investors recognized Sweden's underexplored nature as well as its geological similarities with large mining destinations such as Eastern Canada as well as Greenland, a realization that made the country stand out as a destination of significant exploration potential. Another important part of the quick success of Sweden as a new international exploration destination was the Geological Survey of Sweden's services that include one of the world's largest drill core archives, which, in addition to storing drill cores, includes other exploration data and material produced by government organizations as well as mining and exploration companies such as Boliden throughout the 20th century. Furthermore, Sweden is often ranked by industry organizations as a low risk jurisdiction (for an example of such a ranking, see, e.g., Cutifani 2017). Part of the reason for Sweden's low risk rating has been the country's relatively stable legislation and political situation; two factors that have helped the country emerge as an attractive destination for mineral exploration

Although a small member of the international exploration sector and mining industry, Sweden is one of the largest producers of metals and minerals in the European Union, producing 91 percent of EU productions of iron, 40 percent of lead, 33 percent of zinc, 11 percent copper, 21 percent silver, and 23 percent gold (Geological Survey of Sweden 2019b). These products come from the three mining regions: Norrbotten, Västerbotten, and Bergslagen. The map below shows the mines in Sweden as of January 2019 with the three mining regions visible as three clusters with Norrbotten in the far north, Västerbotten in the middle, and Bergslagen to the south.

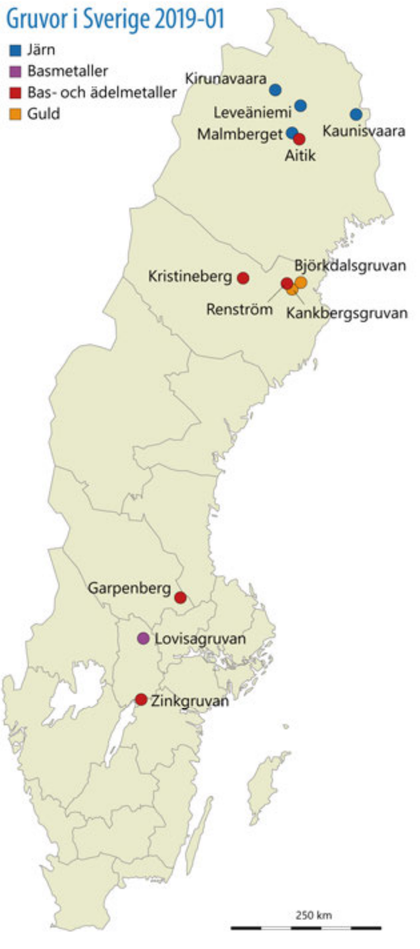

Figure 1. Mines in Sweden January 2019 (Geological Survey of Sweden 2019a)

2.2 Multi-national giants and small scale entrepreneurs

At the center of the mineral exploration and mining industry stand the mining and exploration organizations, companies, and corporations, which range in size from large multinational mining corporations such as Glencore, Rio Tinto, and BHP to individual entrepreneurs prospecting for deposits around which they could launch an exploration company. Between the multinationals and the entrepreneur, sit smaller mining companies such as the Swedish companies LKAB, Boliden, and Lundin Mining and even smaller junior exploration companies. These four categories of actors are often referred to in the industry as majors, mid-tiers, juniors, and entrepreneurs. These four categories of actors furthermore make up two distinct groups in the industry. The first group includes the major and mid-tier organizations who own and operate mines and therefore are able to finance their exploration using existing cash flow. The second group includes junior companies and entrepreneurs who do not operate mines and therefore depend on equity and other sources of capital to finance their exploration work. These differences in how explorationists finance their exploration efforts means that explorationists working within majors and mid-tiers first and foremost need to convince their own internal reviewers and decision makers to finance discovery and further exploration activities, whereas juniors and entrepreneurs depend on their ability to attract investors to fund their work. In addition to seeking new mines to replace their current operations, majors and mid-tier companies tend to be incentivized to explore around their existing mines in order to identify and develop resources that can be mined and processed using already existing infrastructure. Juniors, on the other hand, more often carry out exploration work in new regions, so called green field exploration, or near their established mines, so called brown field exploration. Because of their tendency to work in new regions or rework old mining sites, juniors are sometimes labeled, as was observed during field work for this dissertation, “the lifeblood of the industry” as they are more prone to make new discoveries.[20] Majors and mid-tier companies, in contrast, tend to carry out much of their exploration efforts closer to home and may even effectively outsource their exploration to juniors by investing in them or by acquiring juniors who have made substantial discoveries. The fourth category of explorationists, the entrepreneurs, are regularly small groups or individuals who rely on private equity and who carry out exploration work to discover deposits that may allow them to transition into becoming juniors themselves.

In addition to the explorationists themselves, the industry furthermore houses a large range of consultants, entrepreneurs, laboratories, and manufacturers that offer exploration equipment and services and some of these actors play important roles in making exploration possible. Specialized drilling companies, for example, often carry out drilling, and accredited laboratories are employed to analyze drill cores for metal or mineral content. Other important suppliers to the industry are geoengineering consultants, who use the geological information from laboratory analyses to produce models used to eventuate mineral discoveries, and environmental consultants, who undertake environmental impact assessments for exploration projects.

A third important group of actors in the industry are the governmental agencies and offices tasked with supporting, overseeing, and regulating exploration in Sweden. Among the different agencies working with the industry, the Geological Survey of Sweden (SGU) and The Mining Inspectorate of Sweden (MIS) are two central actors performing two distinctly different roles. The

[20] Field notes: International conference and trade-show.

current incarnation of the SGU is headquartered in Uppsala and works on all matters that relate to geology in Sweden. As part of their mission, the SGU are to market Sweden as an exploration destination internationally and provide support to explorationists in early stage exploration. One key resource in the SGU's work in mineral exploration is the agency's office in Malå, which houses Sweden's drill core archive and other geological information such as maps and records of historical exploration. These materials, available for a small fee, are useful resources for explorationists in the early stage of exploration. The Mining Inspectorate of Sweden (MIS) is the main regulatory agency in the exploration and mining sector. The MIS handles exploration permits and mining leases (or exploitation concessions as they are referred to in Sweden) and carries out annual inspections of active mines in Sweden. The head of the MIS is the Chief Mining Inspector or *Bergmästare*, an office established by Kristina I of Sweden and Axel Oxenstierna in 1637. Other offices and actors involved in overseeing and regulating mineral exploration in Sweden are the County Administrative Boards (CABs) in the 21 counties, the five regional Land and Environment Courts that rule on environmental permits, and the Swedish Environmental Protection Agency, which stands as a party in environmental permit cases with the Land and Environmental Courts.

2.2.3 Non-industry stakeholders

In addition to the exploration organizations, consultants, and governmental agencies, there is a fourth group: publics directly impacted by the mining and exploration industry's activities and the organizations and movements that oppose exploration and resource exploitation. The, at times hostile, relations between mineral explorationists and local communities has been approached in a significant number of sociological and social science studies that address community contestation of mining and mineral exploration (for a review of this literature, see Conde 2017). Although the majority of this research has examined opposition in, so called, developing countries, exploration and mining contestation have increased in the Global North and the Arctic (Zachrisson and Beland Lindahl 2019). The sources of contestation and conflict are many, ranging from community depletion (Askland 2018) and the creation of fly-in/fly-out economies (Perry and Rowe 2015; Storey 2001) to issues of ownership rights and underperforming property and resource regulation (Acuña 2015; Anshelm, Haikola, and Wallsten 2018b; Coxshall 2010; Engels 2018). Poised on the edge between value destruction and creation, mineral exploration and mining have been objects of opposition by local communities seeking to defend environmental or community values in the face of potential destruction or disruption from mining (Gallardo et al. 2017; Martinez-Alier 2001;

Persson, Harnesk, and Islar 2017; Walter and Martinez-Alier 2010). In addition, many conflicts between local communities and explorationists or miners have been shown to be catalyzed through social movements (Bebbington 2007; Bebbington et al. 2008). Following this, the contestation of mineral exploration and mining projects is done not by the local town hall alone but by networks of community members, NGOs, churches, student organizations, and other organizations (see, e.g., Holden and Jacobson 2008).

Besides conflicting values, struggles for recognition, and ownership rights, one central source of conflict in mineral exploration is time and the temporalities held by the different actors involved. Mineral exploration projects often work with distant time horizons and research has shown how the extractive industry's "timescapes" do not always coincide with the temporal perspectives held by the affected communities, a difference in expectations that may give rise to friction between the parties (Kesselring 2018; Lanzano 2018). One source of friction between explorationists' time and communities' time lies in how mineral exploration inspires expectations, which, if realized, may either not materialize in the time anticipated by community members or perhaps not at all (Weszkalnys 2008, 2015) and which are often tied up with discourses of development and anticipation of better futures conditioned on resource extraction (Wiegink 2018).

Turning once again to the case at hand, challenging relationships between explorationists, miners, local communities, and NGOs are also present in Sweden and have been outlined in a recent anthology investigating the relation between Swedish mining regulation and community contestation (Anshelm et al. 2018b). One of the most significant conflicts between local communities and exploration organizations in Sweden[21] is between the mineral industries and the reindeer herding Sámi communities in the country's northern half. The many unresolved conflicts over the rights of indigenous people and land use in Sweden's Arctic and Sub-Arctic regions leaves the geopolitical situation unresolved as Swedish governmental actors and Sámi districts and organizations grapple with each other in the Swedish courts over rights to land in the region.[22] Reindeer herding Sámi especially see their traditions and sustenance threatened by the continuous expansion of industrial and government interests in the region (Sörlin and Wormbs 2010).[23] While the conflicts today are related

[21]

[22] The conflict over fishing and hunting rights between the Girjas Sámi district and the Swedish government is a clear and important example of the conflicts in the region. In this case, the Sámi district went to court to seek the sole right to fishing and hunting on the district's traditional lands, thereby ending the government's management of fishing and hunting rights through the local County Administrative Board. Trials began in 2009 and the conflict received its final ruling in January 2020 when the Swedish Supreme Court ruled in favor of the Sámi district (The Supreme Court of Sweden 2020).

[23] For an account of the lived experiences of Sámi in relation to land use conflicts and the political treatment of Sámi rights in contemporary history, see Elin Anna Labba (2020).

to contemporary conflicts over land use, their roots can be traced to the repeated waves of Swedish colonization beginning in the 17th century (Bäärnhielm 1976). In relation to this it may furthermore be noted that Sweden, as in many other mining jurisdictions, has yet to ratify the ILO Convention no. 169 on the rights of indigenous peoples and that while the Sámi are an internationally recognized indigenous people, few in the mining and exploration industry recognize them as such (Lawrence and Moritz 2019).[24]

From the side of the industry, these conflicts are often incorporated under the umbrella of corporate social responsibility (CSR). CSR efforts have been shown to improve the conditions around mines in the Global South belonging to northern corporations (Dashwood 2007). However, CSR efforts are far from universally adapted and research in Sweden (Tarras-Wahlberg 2014) has shown that CSR spending in order to gain community license to operate is skewed towards juniors and foreign companies. The established Swedish mid-tiers, this research shows, tend to do no more than they are legally obliged to do as part of permitting procedures and that this trend is reflected in the affected communities. One reason for this appears to be that communities in Sweden tend to be more approving of local mid-tiers than they are of juniors despite the juniors doing more work to gain social licenses to operate. Finally it may be noted that CSR is but one among many strategies adopted by mining corporations to overcome local community resistance to new projects and that additional efforts include legislative efforts to escape local control and legal challenges to local zoning initiatives as well as media campaigns and attacks on aboriginal sovereignty (Gedicks 1998).

2.3 The regulation of mineral exploration

Mineral exploration in Sweden is regulated by national public regulation and local and international private regulation, and this regulatory environment structures the exploration process and provides targets that explorationists need to reach in exploration. Examples of such targets include proving the profitability of exploiting a particular deposit of mineralized material, demonstrating the socio-environmental feasibility of a future mine, and demonstrating sufficient understanding of the quantities and qualities of mineralized material in a deposit. The regulation of mineral exploration, in other words, plays

[24] A list of other countries that have not ratified the convention as of 2017 includes mining destinations Australia, Burkina Faso, Canada, China, the Democratic Republic of the Congo, Côte D'Ivoire, Ghana, Indonesia, India, Mali , Papua New Guinea, Saudi Arabia, Senegal, South Africa, and the USA as well as fellow Nordics Estonia, Iceland, and Finland (International Labour Organization 2017).

an important role as it defines the playing field within which explorationists work their projects and engage in prediction work. This section will outline the regulation under which mineral exploration takes place in Sweden and, as this matters are of material importance to how explorationists work to predict the future minability of deposits, it will do so in the form of an in-depth account of both national regulation and international private regulation in the form of code and standards.

2.3.1 Public regulation: The Minerals Act and The Environmental Code

From an international perspective, public regulation of mineral exploration tends to differ between jurisdictions, while much private regulation has gained international distribution. One example of how public regulation may differ between jurisdictions is how the tools for collecting rent or taxes from mineral exploration and mining operations differ between countries and territories with some jurisdictions aggressively taxing the mining sector while others, including Sweden, use relaxed tax and rent regimes (Wilson 2016). In Sweden, the present day mineral regulation dates back to the early 1990s when the industry was deregulated. This deregulation effectively dismantled the older system, which favored exploration and mining by public companies and organizations. In addition, this wave of deregulation also revoked legislation that granted the state ownership of half of all new mining concerns and that required foreign companies interested in exploring or mining in Sweden to apply for special wavers as foreigners, up to this point, had been prohibited from owning property.

Today, mineral exploration in Sweden is regulated under the Minerals Act of 1991 (*Minerallag 1991:45*), the Mineral Ordinance of 1992 (*Mineralförordning 1992:285*), the Environmental Code (*Miljöbalk 1998:808*), and the Ordinance on Land and Water Husbandry (*Förordning (1998:896) om hushållning med mark- och vattenområden*).[25] Together, these laws and ordinances set out a number of permits and conditions applicants need to satisfy at different stages of the exploration process in order to move a project forward from exploration to implementation. While there are many different permits and waivers explorationists need to acquire, there are four key permits: exploration permits, exploitation concessions, environmental permits, and building permits. The MIS manages the first two but relies on the local CAB

[25] These statutes are complemented by additional legislation concerning cultural heritage sites and monuments (*Kulturminneslagen*), construction and zoning (*Plan och bygglagen*), and the use of off-road vehicles (*Terrängköringslagen*).

for assistance in assessing the environmental impact of the proposed mine as part of the exploitation concession review. The environmental permits are awarded by the environmental courts, something that is relatively unique in a global perspective. Lastly, the local municipal authorities award building permits. These permits follow each other in succession.

The exploration permit is the first regulatory instance of the exploration process and permits are awarded by the MIS following five criteria: (i) the suitability of the applicant as defined by a review of the applicant's previous exploration records; (ii) whether the content of the application adheres to what is prescribed in the Minerals Act; (iii) the likelihood that exploration in the area applied for will result in a discovery of a mineral deposits, assessed on the basis of records from previous exploration, surveying or mining and in keeping with this criterion, the MIS does not, for example, generally grant exploration permits within already surveyed areas; (iv) whether the applicants have access to resources significant enough that they can be expected to successfully carry out an exploration of the area applied for; and (v) applications for exploration permits must adhere to the conditions necessary to protect the rights of the general public and of particular rights[26] of holders such as easements or reindeer herders. Therefore, applicants must explain why the area in question is a suitable site for exploration. If the applicant and the application meet these prescribed conditions, the explorationist will be granted a permit lasting three years with the chance of renewals of up to a total of 15 years if the explorationist can show that they have actively been carrying out explorations within the area. [27]

If awarded, an exploration permit grants its holder exclusive right to carry out exploration work within the area in question. However, the exploration permit does not award the holder any right to carry out exploration using invasive methods[28] such as collecting samples through exploratory drilling or geophysical measurements using airplanes, helicopters, tracked vehicles, snowmobiles, or other terrain vehicles. To carry out such surveys, the explorationist needs to formulate a work plan and get it approved by the MIS as well as apply for applicable wavers from environmental regulation such as prohibition of the use of off-road vehicles. In addition, the explorationist needs to share the proposed work plan with property owners and interested parties (e.g., people who have easements or reindeer herding rights) before the MIS

[26] Particular right (*särskild rätt*) is a legal term for groups owning some particular right of access or use to an area.

[27] A factor in extending exploration permits is that the permit is designed to grow increasingly expensive over time. This is argued to motivate explorationists to move forward toward exploitation concessions. The cost of an exploration permit consists of an application fee of 500 SEK ($53) per 2000 ha area and an exploration fee, which during the first three years amounts to 20 SEK ($2.1) per hectare but which increases with further extensions.

[28] Non-invasive surveys may, however, be used and may provide useful data. Examples of non-invasive exploration methods include analyses of historical data and field investigation of outcrops or other visible sources of geological information.

will approve a permit. These groups have the opportunity to comment on or object to the plan, and any objections are handled by the MIS with a view to negotiate a solution where exploration work is made possible.

While the exploration permit grants its holder the right to explore an area, it does not grant the permit holder the right to any discovered mineral. To acquire the right to exploit a discovered deposit, explorationists need to acquire an exploitation concession. Exploitation concessions are awarded by the Chief Mining Inspector at the MIS following consultations with MIS staff and the local CAB. Assessment of applications is done using two sets of regulatory criteria: (i) whether a mineral deposit of such dimensions and qualities have been discovered that it can be expected that future exploitation of the deposit will be economic over a 25 year period and (ii) whether the location or quality of the mineral deposit and the proposed mining operation is likely not to cause such impacts to private and public interests that future exploitation of the mineral deposit is rendered unsuitable.

To facilitate the review, applicants must provide the MIS with documents supporting their claim to an exploitation concession. These documents include descriptions of the results produced in their exploration work together with geological and geophysical maps and other surveys that can be of significance when assessing the economic recoverability of the deposit. Moreover, plans for the proposed operations are to be provided to the MIS as well as an outline, in the form of a preliminary Environmental Impact Assessment (EIA), of the proposed operation's impact on public and private interests as well as what measures the applicant believes need be taken to protect public interests and private rights.[29] The MIS and the chief mining inspector review the applications according to these criteria in collaboration with the local CAB, which reviews the application to provide their recommendation on the environmental impact of the proposed operation as part of the review according to the second criterion.[30]

The Environmental Code demands that explorationists demonstrate that the deposit and the proposed mining operation are not located in such a place or of such a nature that exploitation of the mineral deposit would violate the code and the principles outlined therein. The review of a project's environmental impacts and suitability is guided by the core principles of the Environmental Code, which must "promote sustainable development meaning that present and coming generations are ensured a healthy and sound environment" (The Swedish Riksdag 1998a, 1st chapter 1 §). Such sustainable development is later

[29] See the Mineral Ordinance, paragraphs 17 and 18 (The Swedish Riksdag 1992).

[30] As the assessments of the tolerability of the projected environmental impact from the proposed operation is carried out both by the MIS and by the local CAB, conflict at times arise between the two. In such instances, the case is transferred to the Swedish government, which either rules on the matter or refers it back to the MIS for re-processing.

connected to the promotion of long-term resource husbandry, which is defined in terms of the land and water areas being used:

> for that or those purposes for which said areas are best suited in respect of the nature and situation, and the present needs. Precedence shall be granted such usage that entails a, from a general point of view, good economic administration. (The Swedish Riksdag 1998a, 2nd chapter 1 §)[31]

In relation to this, the code furthermore lists qualities that may set land and waters apart as worthy of particular status protected from interventions that may hamper the use of this quality. One of these eight qualities concerns metals and minerals[32] and states that "Land and waters containing valuable substances or materials shall, to the extent possible, be protected from measures that may substantially obstruct the exploitation of these" (The Swedish Riksdag 1998a, 2nd chapter 7§).

As part of determining whether an exploitation concession and subsequent mineral extraction and exploitation can be deemed the most appropriate use of a section of land or water, the applicant of an exploitation concession must provide a study of the potential environmental consequences of future mineral exploitation in the form of an EIA. In such a study, the applicant is to do the following:

> account for and describe the immediate and indirect effects that the planned activity might cause persons, animals, plants, land, water, air, climate, landscape and socio-cultural environment, in part in relation to the administration of land, water and the general physical environment, in part in relation to the economies of materials, resources and energy. The aim is further to enable an overall assessment of these effects impact to persons' health and the environment. (The Swedish Riksdag 1998, 6th chapter 3 §)[33]

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[31] In the original Swedish: "Mark- och vattenområden skall användas för det eller de ändamål för vilka områdena är mest lämpade med hänsyn till beskaffenhet och läge samt föreliggande behov. Företräde skall ges sådan användning som medför en från allmän synpunkt god hushållning."

[32] The full scope of qualities according to which an area may be set apart and classified as protection worthy are as follows: (i) reindeer herding, (ii) fishing, (iii) environmental preservation and recreational use, (iv) cultural heritage preservation, (v) the national interest regarding valuable substances and materials (such as metals and minerals), (vi) industrial production, (vii) energy production and distribution, (viii) nuclear waste storage, (ix)Infrastructure and communications, (x) waste management, (xi) water distribution, and (xii) military defense (The Swedish Riksdag 1998b).

[33] Syftet med en miljökonsekvensbeskrivning för en verksamhet eller åtgärd är att identifiera och beskriva de direkta och indirekta effekter som den planerade verksamheten eller åtgärden kan medföra dels på människor, djur, växter, mark, vatten, luft, klimat, landskap och kulturmiljö, dels på hushållningen med mark, vatten och den fysiska miljön i övrigt, dels på annan hushållning med material, råvaror och energi. Vidare är syftet att möjliggöra en samlad bedömning av dessa effekter på människors hälsa och miljön.

The environmental impact assessment produced for the exploitation concession application process is later to be expanded in preparation for the application for an environmental permit. In Sweden, environmental permits are managed by the regional environmental courts. Before rendering a decision, these courts assess the testimony of the applicant and of the relevant governmental agencies, e.g., the Swedish Environmental Agency or the Swedish Agency for Marine and Water Management. As part of environmental permit procedures, applicants apply and argue for any additional permits such as water management permits and waivers from environmental protection designations such as species protections or Natura 2000 classifications. For the environmental permitting process, the applicant must provide, in addition to an expanded EIA, a waste management plan and a plan for how the area will be rehabilitated when the planned operation is eventually closed. Environmental permits are managed in two stages: the environmental permit and the eventual inclusion of terms and conditions with the permit. In addition to the environmental permit, explorationists must apply to the MIS to have land allocated to the mine as well as file applications for construction permits with the local municipality. Land allocation rulings are typically based on what has been agreed on by the explorationists and the landowners. However, if these parties fail to reach an agreement, the MIS may rule on the matter with support from the Swedish Expropriation Act.[34] In addition to the regulation discussed here, Sweden furthermore possesses a Mineral Strategy (Ministry of Enterprise and Innovation 2013), which lists a range of strategies meant to promote mineral exploration and mining to fuel economic growth and to develop Sweden as an attractive investment destination for foreign investors.

2.3.2 Private regulation: From fraud to framework

In addition to public regulation, mineral exploration is also regulated under a canopy of private regulation. These regulations are codes and industry standards for mineral resource classification and reports on mineral exploration results. Since their emergence in the 1990s and 2000s, these standards have seen international harmonization under the umbrella of The Committee for Mineral Reserves International Reporting Standards (CRIRSCO), an international body that organizes entities responsible for developing mineral reporting codes in most mining jurisdictions except China. While each individual standard applies primarily to companies and corporations listed and traded on the stock markets where the standards originate, the harmonization provided by

[34] Expropriationslag (1972:719).

CRIRSCO in effect renders the local standards as part of an international network regulating mineral resource classification and exploration results reporting in the majority of the world's mineral and metal producing jurisdictions. In addition, some cases, including Sweden, use some of these standards interchangeably.

Although commonly used in the exploration industry today, the standards under CRIRSCO have a peculiar history as they were initially put in place not with explorationists in mind but to protect investors by reducing uncertainty regarding the accuracy and quality of the information available regarding mineral resource estimates and exploration results. One of the standards, the Canadian Institute of Mining, Metallurgy and Petroleum's National Instrument 43-101 (henceforth NI 43-101), was even put in place as a direct consequence of one of the largest mineral exploration frauds in modern history. In 1993, the Canadian junior exploration company Bre-X Minerals Ltd. reported having discovered a huge gold deposit near the Busang River in Borneo, Indonesia. Reports of the discovery set the company's shares skyrocketing and this led in turn to aggressive competition among major mining companies seeking to gain shares in the deposit. In 1997, the mineral resource estimates for the project amounted to 70.95 million ounces of gold, making it one of the largest gold deposits in the world (Nicholls 1999). However, the entire project came crashing down later the same year when external actors carrying out confirmatory test drilling failed to reproduce Bre-X's assay results and investigations concluded that there was no significant deposit at the Busan site. Instead, it was concluded that Bre-X had been salting their samples with gold from other sources and that the Bre-X success story was nothing but a hoax (Ruffell, Majury, and Brooks 2012).

The codes and standards put in place at stock exchanges following Bre-X provide a system of categorizing and classifying mineral deposits according to the level of geological knowledge available for a deposits or sections of deposits. These systems of classification define geological knowledge as the confidence in estimating the quantity, quality, density, shape, and physical characteristics of the mineralized deposit and provide two different categories into which deposits may be categorized. The first of these categories is a mineral resource and depending on the level of geological knowledge and the degree of confidence in the estimate, mineral resources may be divided into subclasses of inferred, indicated, and measured resources. The second category is a mineral or ore reserve although which term is used differs between the standards. The Joint Ore Reserves Committee's Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (or JORC Code for short) uses ore reserves to denote this category, and the NI 43-101 and the Pan-European Standards for Reporting of Exploration Results, Mineral Resources, and Reserves (henceforth the PERC-Code) both use mineral reserves. As these two terms are essentially interchangeable and denote the same thing, this dissertation will use "mineral reserves" to denote both ore and mineral reserves. The more important difference is that which separates mineral reserves from mineral resources. While the definition of a mineral resource is that it is potentially minable, mineral reserves are estimated with extraction in mind and rely on what the standards refer to as "modifying factors" for their estimation. These factors include assumptions about mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social, and governmental factors, which are added to resource estimates to produce mineral reserves. In addition, the standards provide two subclasses of reserves in the form of probable reserves, which are based on indicated resources, and proved reserves, which are based on measured resources. Figure 2 below outlines this system of categories and the ways different categories relate to each other as it is stated in the CRIRSCO (2019) reporting template.

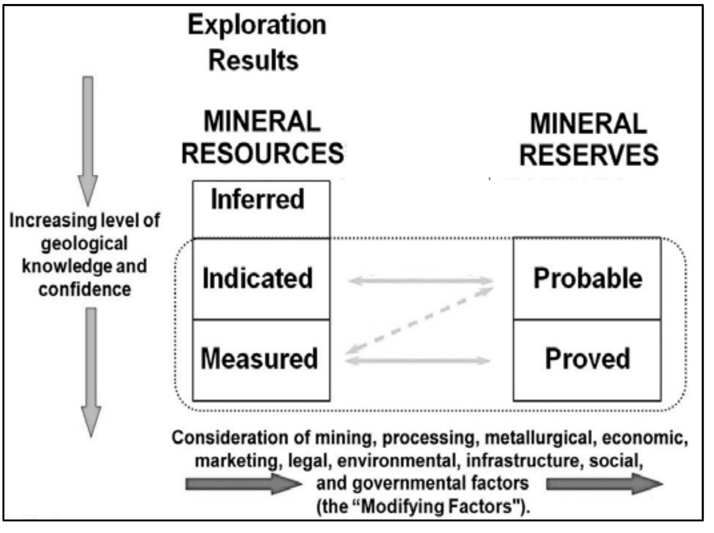

Figure 2. General relationship between Exploration Results, Mineral Resources and Mineral Reserves as outlined by CRIRSCO (2019)

The guiding principles behind the codes and standards discussed here state that exploration companies' reports to the public should be unambiguous, based on relevant information, and that reports should be produced or inspected by someone with the appropriate competence of the type of resource concerned and who is "subject to enforceable professional codes and rules."[35] Moreover, the codes and standards also provide systems of accreditation through which individual geoscientist and engineers (i.e., the experts with the appropriate competence) can receive the necessary accreditation to review

[35] Field notes: Class on Mining Economy and Risk Evaluation

mineral resource and reserve estimates. Such accredited persons are known as "qualified persons" or "competent persons" depending on which standard is used in accreditation. In order to become an accredited qualified person, one needs to show competences such as a university degree in engineering or geoscience, sufficient experience, often defined as having five years' experience in exploration, mine development, mine operation, or project assessment, and relevant experience in the specific subject matter on which he or she is writing the report. Competency, however, is not only measured in terms of experience but also in terms of social standing as an expert also needs to be "in good standing with a professional association" in order to receive the accreditation.[36] The role of the qualified person is a form of self-regulation put in place by members of the field. Qualified persons often work in teams and evaluate projects in line with what is stated in the standards in terms of estimates made, assumptions used, and modifying factors assessed. The role of accredited qualified or competent persons in exploration is discussed in detail in chapter 6.

This chapter has outlined the contextual and legal-juridical background of mineral exploration in Sweden. The public and private regulation discussed here demand that explorationists produce predictions for what future exploitation of a mineral deposit would entail in terms of profitability, design of operations, and environmental impact. By attending to regulation, explorationists gain legal resources such as exploitation concessions as well as legitimacy for their estimates provided to investors. In the domains of permitting and investment, mineral explorationists thereby gain different forms of resources from state and market actors.

[36] Field notes: Class on Mining Economy and Risk Evaluation

3. Theory: Prediction Work in Mineral Exploration

"Guitar groups are on their way out, Mr. Epstein."

Prediction is hard. The infamous words quoted above with which then Decca Records A&R man Dick Rowe is said to have turned down The Beatles is just one of many famed examples of how people historically have been painfully wrong in their predictions. As in the cases of the blown predictions by miners LKAB, Northland Minerals, and explorationists Rubicon Minerals, Decca Records and Dick Rowe were unable to make the connection between what they could see in the present and what would eventually emerge, so to say, around the next corner. However, while examples of flawed predictions are numerous (often making for good banter for those left unscathed by their consequences), prediction remains an important and prominent feature of human endeavor in an uncertain world. Despite this, there exists no sociology of prediction the way there are sociologies of, for example, art, culture, or organizations. Instead, a study of prediction is both free and forced to choose between many different sociological approaches that together can help unpack and analyze predictions and prediction work.

This chapter therefore reviews some theoretical and conceptual approaches to predictions to build a conceptual toolkit suitable for studying prediction making under uncertainty. In doing so, the chapter provides a more thorough introduction of the term *prediction work* as an umbrella for the different activities actors engage in when producing, justifying, and using predictions to manage uncertainty. To accomplish this, the chapter assesses the relevant sociological literatures in relation to their abilities to capture prediction making under uncertainty in mineral exploration and beyond. The result of this assessment is an outline of a conceptual toolkit through which prediction work can be dismantled and analyzed in its parts in order to build an understanding of how predictions are made in mineral exploration. This chapter first discusses the root of the problem facing predictors–i.e., the peculiar challenges involved in attempts at prediction. Following this discussion, the chapter discusses a conceptual definition of predictions based on a sociological reading of philosopher Nicolas Rescher's (1998) work on predictions in which predictions are conceptualized as epistemic challenges involving data collection and trend identification. Because of the importance of data collection and trends in Rescher's discussion of predictions, the subsequent section turns to valuation studies for an in-depth look at sociological perspectives on valuation, quantification, and commensuration as means of data production and pattern identification. The chapter ends with a section on justifications, lifting the perspective from making measurements for predictive projection to the justification of prediction correctness.

3.1 The status of the future

The uncertainty of the future has long beset those trying to predict its qualities. It is therefore not surprising that across history, different societies have developed different methods of divination through which to overcome the uncertainty of present day decisions and future events. Examples of divinatory devices range from the oracles to which Cicero saw kings and peoples turn in antiquity,[37] through astrology, which was once a premiere vehicle of prediction (Curry 1987), to present day cost-benefit analysis, market analysis, and forecasting (Rescher 1998, see also; Porter 1996). Mineral exploration is no exception to the use of contemporary forms of divination. Its distant temporal horizons, low probability of success, and regulation that demands proof of future minability and the permissibility of its environmental impacts make the industry a hotspot for prediction work; and explorationists need to ask themselves a series of questions about the big and small as well as long-term and short-term futures. Is it that the project they are presently working on will be one of the few to produce success and make the full journey from prospect to profitable mine? Will the costs of developing, constructing, and operating the projected mine be covered by future profitability? Will the project's impacts on environmental and social values be limited to such an extent that they are justifiable in relation to the benefits predicted to come from the project? The number of questions to answer in mineral exploration is great, and they all concern a future that needs to be made available to explorationists in the present. However, while mineral exploration work attempts to provide precise answers to such questions, there is little reason to expect that explorationists,

[37] Cicero asked what King or people there had been who did not make use of divination: "Quis rex umquam fuit, quis populus, qui non uteretur praedictione divina?" (Marcus Tullius Cicero 1730:43)

or anyone else for that matter, are capable of producing precise predictions because the future proper is not available to those trying to learn its qualities, making prediction an epistemological headscratcher.

The reason why the future is not available to predictors is because, ontologically speaking, the future does not yet exist (Rescher 1998). While ideas and expectations of what the future will hold are directly available in the present, the object to which they correspond is not. This problem lies at the heart of discussions of the uncertainty of the future, a discussion that emphasizes that the future cannot be *known.* Because of this, managing uncertainty in order to negotiate the futurity paradox discussed above cannot mean reducing uncertainty by making the future known, but rather finding ways to navigate unescapable uncertainties. One illustrative discussion of this is found in the writing of Saint Augustine of Hippo, who discussed the inaccessibility of the future and how this inaccessibility limits the foreseeability of future events to extrapolation from the present. According to Saint Augustine, the future's status of not yet having come into existence means that to those attempting to observe it in the present

> *Future* things therefore are not yet; and if yet they be not, at all they are not; and if so they bee not; possible to bee seene, they are not; yet foretold they may bee by somethings a *present*, which both are already, and are seene. (1631:770 [emphases in the original])

There is a corollary to Augustine's argument: as the future cannot be known, any attempt to predict it will need to be made on basis of the present. Moreover, in this line of reasoning, the present is a point that passes on and transforms the future into the past, existing only as an infinitely brief "now" in a sea of non-existing pasts and futures. Based in this view of time in which only the infinitely brief present truly exists, Saint Augustine concluded that the future does not have an extension in and of itself: "the long *future* time, is meerely a *long expectation of the time to come*" (1631:801 [emphases in the original]). Following Augustine, it is not possible to talk of the qualities of a future state but only of one's expectations of this future state.[38] This peculiar

[38] This proposition is as follows: While commonly not recognized as such, the future is essentially based on a philosophical presentist understanding of time and while it may appear strange, its practical consequence is merely that until the future has become present there can, ontologically speaking, not exist a "future" of which one can have knowledge. Alternatively, an eternalist conceptualization of time would mean that the future is conditioned in such a way upon the past, present, and perhaps even the future's future that it is already present, so to say, in the present. One example of such a position is that of the Marquis de Condorcet mentioned earlier. According to Condorcet, all things are calculable given a sufficient number of observations and a sufficiently complex mathematical model to capture the unfolding of the laws that guide natural and cultural events. A second eternalist position is that of dialectical historical materialism in which the historical present is dialectically contingent on the past and future in such a way that the historical object, Walter Benjamin (2002:475) wrote, "finds represented in its interior

nature of the future as expected but non-existing means that it is not possible to speak of truth in relation to predictions, forecasts, or other statements about what the future will look like. Statements about the future can, simply put, not be true or false as the object to which they correspond does not yet exist; they are merely more or less correct (Rescher 1998). Therefore, statements about the future cannot be based on knowledge about the future but must be based on knowledge of something else, as philosopher Lars Gustafsson (1971:120) put it in a discussion of the emergence and growth of futurology as a field of research in the latter half of the 20th century:

> Therefore, when futurology comes with claims of being a science of the future, these claims must either be empty since we cannot have any knowledge of the future; or its content must be a different type of knowledge than knowledge of the future.[39] [author's translation]

The consequences of the future's non-existence should not be over-emphasized, however. While the lack of a corresponding object makes foreknowledge proper impossible and prediction challenging as it voids any claim of absolute certainty, much of everyday life carries on with relative stability and regularity, which leaves plenty of room for anticipation and prediction, albeit with the qualification that they remain uncertain.[40] Instead, it is important to note the implications the future's ontological status has on its epistemic status. Given that there exists no way for an actor to engage directly with the future, the future must be approached through some other way. This is where predictions become uncertainty management. Through prediction, actors are able to produce measurable *present futures* that function as stand-ins for the uncertain *future present*. This distinction, introduced by Niklas Luhmann (1976), distinguishes between the future as it is perceived in the present (i.e., the present future) and the future as it is when it has become the present. Following this, there may be many (often competing) present futures, but only one realized future present to which the expectations contained in the present futures may or may not correspond. One of the key features of Luhmann's distinction between these two realms is that there is room for discrepancies between them. Therefore, the future may be defined as two separate

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its own fore-history and after-history." In this approach to time, the present caries within itself its past as well as its own future consequences–i.e., prediction, once again, becomes the struggle to unpack correctly the future from the present. However, considering how complex the present is, the scope of potential futures is still so great that foreknowledge, arguably, becomes an impossibility wherefore the entire discussion reverts back to its presentist beginning.

[39] In the original German: Wenn also Futurologie mit dem Anspruch einer Wissenschaft über Zukunft auftritt, muß ihr Inhalt entweder leer sein, denn wir keine als Kenntnis über die Zukunft haben; oder ihr Inhalt muß eine andere Art von Kenntnis sein als Kenntnis über die Zukunft.

[40] It is after all quite likely that even though one cannot claim it with absolute certainty, the sun will rise also tomorrow.

objects: the present futures projected from present expectations stand as a placeholder for the uncertain future present.

3.2 Patterns and projections: Sociologies of the future

The projection of present expectations onto the future depends on predictors performing what philosopher Nicholas Rescher (1998) calls an "epistemic leap." Such leaps from the present into the future are accomplished by rational evidentiation and this, Rescher continues, is the one and only window into the future. According to this reasoning, the quality of a prediction of future events is conditioned on the predictor providing rational evidence for why a trend observed in the present is likely to continue also in the future. However, what separates rational from irrational evidentiation is a question of what counts and what does not count as relevant information and data processing. That is, to a community that places equal faith in the stars and predictive econometrics, astrology and cost-benefit analysis would make up two equally rational modes of prediction. What makes up rational evidentiation and therefore the scope of available methods through which to attempt to create foresight is a socio-historical matter; therefore, the concrete system of what counts and what does not count as rational is more an empirical question than anything else. Evidentiation therefore becomes rational evidentiation when the information and tools used are *deemed appropriate* by those who attempt this epistemic leap into the future as well as by the publics positioned to assess the success or failure of these attempts.

3.2.1 Data and linkage in prediction work

The fundamentals of prediction work has already been hinted at in the discussion of the epistemic leap involved in prediction making above, but given the central role predictions play here, this note will be developed further in this section. Discussing a general theory of prediction, Rescher (1998:86) lists a series of characteristics that set predictions apart from other forms of foretelling. According to Rescher, one defining characteristic of predictions is that they attempt to answer questions and that they require predictors to commit to the prediction's answers (Rescher 1998:40); that is, prediction work goes beyond sketching potential futures such as is done in scenario making. In addition, Rescher continues, the work to answer these questions is characterized by its reliance on data describing the past and present as a means to foresee the future. Rescher thereby places great emphasis on the role of data collection in prediction by making the availability of data that can be obtained in a timely, accurate, and reliable way, as well as the exhibition of discernable patterns in this data, and the stability of these patterns over time three key conditions for the production of *rational* predictions. Predictions are therefore different from other forms of future-oriented statements, Rescher argues, as while other forms of foretelling may produce scenarios and imaginaries of what the future *might* be, predictions deal "in indicating what the future *will* be" (Rescher 1998:40 [emphasis in original]). In addition, there also needs to be some form of theoretical or experience-based justification provided in the aforementioned evidentiation. Such evidentiation, Rescher continues, is provided through linkage that rationalizes the connection created between the predictions made and the data used to produce the predictions:

> Rational prediction pivots on the existence of some sort of appropriate *linkage* that connects our predictive claims with the input data that provide for their justification. This linkage can be based either on explicitly articulated principles–explanatory regularities or presumed laws of nature–or on personal judgements that exploit a knowledgeable expert's tacit, unarticulated, and sometimes articulable background knowledge about the matter. (Rescher 1998:87 [emphasis in the original])

In Rescher's definition, rational predictions depend on the availability of adequate data as well as a *theoretical or experience based* link that can support the projection of patterns identified in present day data into the future. Together, these different components are the prerequisites for rational prediction as without them prediction becomes an impossibility. That is, there is not enough evidentiation and linkage necessary to sufficiently support the epistemic leap from present to future meaning that prediction instead becomes speculation. In this perspective, prediction making depends on the use of patterns identified in data through which questions about the future are answered by means of projecting these patterns into the future through linkage. Following this, any study of prediction work needs to consider how to best capture the processes through which predictors assemble data and how they then identify projectable patterns in this material. This dissertation therefore proposes that the work on data production and measurement provided in valuation studies and the literature on quantification and commensuration offer useful tools with which to unpack the work that goes into producing predictions to manage uncertainty.[41]

[41] The combination of perspectives from the sociologies of the future, the sociology of prediction, and valuation studies has been argued for previously by the author (see, Olofsson 2019).

3.3 Making numbers: Measurement and valuation in prediction work

> A mathematician, like a painter or a poet, is a maker of patterns. If his patterns are more permanent than theirs, it is because they are made with *ideas*. (Hardy 1967:84)

Valuation studies, or the sociological study of valuation and evaluation,[42] host a range of approaches to the study of how values are established (Lamont 2012) and ask questions about the processes and relations from which values–i.e., measurements of relative positions–are produced through valuation. Moreover, valuation studies tend to approach valuation practices with a view to unpack them so that the "establishment, assessment, and negotiation of values" is opened up as a topic for discussion and scrutiny (Doganova et al. 2014). In the eyes of pragmatist philosopher John Dewey (1939; see also Kornberger et al. 2015), valuation studies pertain to establishing understanding of the practices of valuation, making valuation studies effectively about studying how values are assigned to things and objects through processes such as ranking and comparison (i.e.,, to study what ideas went into producing the patterns). In this tradition, valuation is perceived as layers of classification through which things and people are sorted and distinguished from each other and which reflect the techniques, contexts, and motivations of those doing the valuing (Espeland and Lom 2015). However, while being unified in terms of subject matter and in viewing value as something ascribed to things and persons rather than being inherent to these things and persons in and of themselves, valuation studies are home to a pluralism of approaches to how valuation is to be studied.

Scholars maintaining John Dewey's (1939:5) original proposition tend to define valuation as an appraisal of objects and persons in which values are ascribed through the use of different means of comparison such as ratings and rankings. A second strand has instead chosen to focus on the structural aspects and on the status orders and standards that shape what values are assigned in valuation (Aspers 2011; Beckert and Aspers 2011). In this approach, the focus lies with the "collective process in which products become seen as possessing certain traits and occupying a specific position in relation to other products in

[42] While these terms are sometimes jointly referred to as (e)valuation, the present thesis will refer to the joint field of research as "valuation studies" while distinguishing between them when discussing instances of valuation or evaluation.

the product space" (Beckert and Musselin 2013:1) as well as with the role played by standards and status hierarchies in how objects are assigned to different categories in a market (Aspers 2009). Lastly, a third perspective is the more conflict-oriented situationalist perspective, which focuses on the situational dynamics and the dissonances that shape "moments of valuation" (Antal, Hutter, and Stark 2015). Together, these three approaches–the pragmatic, the structural, and the situationalist–provide different points of entry into the field of valuation studies. Although all three strands provide insights into how valuation takes place, there are important differences between them that need be considered in relation to this thesis. First, the general focus in this inquiry is with the production of data and patterns that support prediction making. As a result, this dissertation is more closely aligned to the more pragmatist approach and the definitions of valuation provided by Wendy N. Espeland and Stacy E. Lom (2015) and Trine Pallesen (2015), who write about valuation as collective actions that produce assemblages of heterogeneous values that are later translated and expressed in common singular metrics. Following this, this study uses valuation to denote the process through which values are ascribed to things and people. This positions this thesis in relative conflict with the situationalist perspective and its conceptualization of value as a verb and valuation as "contested processes" (Antal et al. 2015) as the pragmatist approach instead tends to favor an approach to value as a noun and valuation as the process through which different values (plural noun) are assigned to persons and objects. The reason for positioning this dissertation in such a way is both empirical and theoretical. Empirically speaking, mineral exploration produces values (noun) that enter a realm of already existing values and while valuations may rely on similar methods of valuation such as tonnages, emission estimates, and economic costs and incomes, and it is not certain that these values correspond to values already in place within this realm. Theoretically speaking, this opens up possibilities for asking questions about value heterogeneity and about the production of different values in reference to the same thing or person depending on how the valuation of the same has taken place, something that is less available in the situationalist approach.

In addition to the conceptual distinctions detailed above, this dissertation will furthermore employ the term *valuation device* (Dobeson 2016b) to denote methods used in valuation. Following this, valuation processes are here defined as the processes in which valuation devices are used to produce expressions of values based on a translation of often heterogeneous values into some common metric. Therefore, valuation processes constitute processes in which questions regarding the value of something or someone are answered by use of valuation devices that enable valuators to sort, rank, rate, or produce other systems of differences that answer such questions. The invention and development of cost-benefit analyses (Porter 1996), statistical methods such as the BMI, and other methods for determining the mean human person (Desrosières 1998), systems for ranking universities (Espeland and Sauder 2007) or credit ratings (Carruthers 2013, 2017) in this conceptual framework become introductions of new valuation devices that may be employed in valuation processes by actors seeking to answer old and new questions regarding the value of something or someone relative to the value of something or someone else.

Commensuration

Moreover, to provide practical answers, valuations rely on the resulting values being expressible as a homogenous system of values (Pallesen 2015). Homogenous systems of values allow things, people, or alternatives to be ranked and thereby place that which has been valued into a relation to other valued things where they are made to be more or less valuable than the other. One particular and powerful way of establishing such homogeneity in value relations and that hints at the negotiations that underlie the creation of these relationships is commensuration (Espeland and Stevens 2008:408, see also 1998). Commensuration is a process that

> creates a specific type of relationship among objects. It transforms all differences into quantity. In doing so it unites objects by encompassing them under a shared cognitive system.

While there exists other methods for establishing homogenous value relations to rank or rate objects and persons, commensuration's ability to absorb the underlying political nature and consequences of their use arguably makes them one of the more important ways of doing so (Espeland and Stevens 1998). Furthermore, while methods to commensurate are commonplace (e.g., in different systems of rating restaurants, educational performance through grading, or by expressing value in monetary terms), the positioning of objects in relation to other objects on the basis of commensuration has ethical and moral implications (Espeland and Yung 2019) and may produce resistance through contestation or suspicion. Examples of such resistance can be found in discussions on the commodification and commensuration of things perceived of as incommensurable such as public resources in the form of fish stocks (Dobeson 2016a; Helgason and Palsson 1997) or culturally sacred things such as human life (Zelizer 1978).

Valuation processes produce homogeneity from assemblages of heterogeneous values as it expresses potentially complex relations in a single common metric by means of commensuration. When predictors work to predict future events or developments by means of identifying patterns in the past and present in order to project these as present futures, they are reliant upon measurements that express and describe present and past occurrences of that phenomenon which future they are trying to predict. Sometimes such values are readily available as the result of others having already done the valuing as in the case of past and present prices; sometimes predictors need to produce these values themselves (e.g., by inventing systems for rating different alternatives when rating different dam and canal projects) (Espeland 1998; Porter 1996). What measurements are adequate for prediction work and what is the value of a prediction? The next section adds justifications as a third dimension to the present discussion.

3.4 Justification of uncertain futures and the trust in numbers

As with statements about some future time or the value of someone or something, the products of prediction and valuation seldom stand alone. That is, they are supported by some vehicle of legitimacy and justification through which their worth can be claimed. Therefore, justification is an important dimension of valuation as it grants legitimacy in the form of worth to any value ascribed to a thing or person. This connection between values, justification, and worth has been outlined in the “sociology of critical capacities” launched in the work of Luc Boltanski and Laurent Thévenot. Together, Boltanski and Thévenot (2006) investigated the relationship between different “orders of worth” and the justifications for why a thing or a person was assigned a specific worth. One example of this relation is how, according to Boltanski and Thévenot, industry operates with an order of worth that promotes values such as efficiency, productivity, and performance. According to this order, ensuring successful normal operations and the going concern of the industrial entity are indicators of positive worth. Likewise, the same order associates waste of capital as well as of human capabilities, unproductivity, and failure to adapt to present or future demands or problems with negative signs of worth. Based on these sets of values, the worth of an industrialist or any other thing or person from the eyes of someone operating within the industrial order of worth can be justified through references to these values. For example, someone becomes a good manager because of one’s ability to ensure stable production and high productivity.

The industrial order of worth is just one of a series of different orders. In their original work, Boltanski and Thévenot (2006) listed six self-enclosed orders of worth that gather different grammars through which worth is referred to actors and objects: civic, inspired, domestic, fame, market, and industrial.

While these six orders have been institutionalized through subsequent research leaning on the work of Boltanski and Thévenot, the six particular orders of worth are not set in stone. In later work, Boltanski discusses how new orders may emerge (Boltanski and Chiapello 2007), and some scholars have sought to develop the theory further by leaving aside the orders of worth in favor of an approach that focuses on the *grammars of worth* positioned within orders of worth, which are actualized in claims about the worth of something or someone. An example of the latter is the work of Laura Centemeri (2015). Arguing from the empirical observation that justifications of the worth of the environment mobilize competing and incommensurable *orders* of worth to define the value of the environment, Centemeri proposes that while retaining orders of worth as an analytical dimension, studies of justification ought to emphasize engagement with that which is being valued as a foundation for justifications over focusing on which order of worth a justification belongs to.

The orders of worth approach to justification and its subsequent developments open up a path to analyze how justificatory claims mobilize values to support claims about the worth of someone or something. However, as the present inquiry has less to do with which orders of worth are involved in justifying predictions in mineral exploration and more to do with the values actualized in valuation, this thesis proposes to move one step further and separate the underlying mechanism of justification from the larger orders of worth perspective discussed by Boltanski, Thévenot, and others. The reasons for this are threefold. The first reason is that reducing justifications to their basic mechanisms and therefore leaving aside the orders of worth means keeping in line with the overall conceptual framework and its pragmatist orientation towards empirical analysis of how prediction work takes place in the field. The second reason is that there are epistemic reasons to forego frontloading predefined orders of worth into the conceptual framework of this study as its problem is not one of predefined values but one of how explorationists mobilize values in their work. The third reason is based on the empirical observations undertaken for this dissertation where conflicting orders of worth frequently co-occur in justifications of explorationists' predictions. Therefore, this dissertation will maintain the link between values, justifications, and worth outlined by Boltanski and Thévenot (2006) but with a broader focus on what values are actualized as *signifiers of worth* in justifications of predictions in mineral exploration rather than on what the correct taxonomy of these values are in terms of what order of worth they belong to.

3.5 Concluding remarks: A toolkit with which to unpack prediction work

This chapter has discussed different sociological and philosophical perspectives on prediction. Based on these discussions, it is now time to weave the different threads together to form a tapestry consisting of different concepts that together contribute to unpacking and analyzing prediction making while considering the dimensions of valuation in prediction work and the ontological and epistemological challenges involved in predicting the future. These concepts hang together like the different layers in a Russian doll with Knight's conceptualization of risk as measured uncertainty and a sociological reading of Rescher's "philosophical anthropology" of prediction as pattern projection forming the outer shell. Beneath this shell, which helps explain why predictions matter (i.e., they help manage uncertainty as they provide rational and evidentiated accounts of what may come), is a shell that more closely analyzes how measurements describing the past and present are produced and how patterns are identified in these measurements. Finally, comes a third and final shell: the tools for an analysis of the justification of predictions and how actors ascribe worth to predictions and predicted futures.

Following this review, a stylized conceptualization can be added to the general outline of prediction work sketched earlier in this thesis (see chapter 1). In this conceptualization, prediction work is an umbrella term that captures efforts to navigate uncertainty through predictions; therefore, the term covers the entire process from the practical production of a prediction to its justification and use. Prediction work therefore starts, as Rescher (1998) stresses, with a question about the future that is to be answered in the form of a prediction. To provide answers, prediction workers need to identify data that describe the past and present and in which stable and projectable patterns can be identified. These patterns are then projected onto the future using some method of linkage through which past and present trends are carried onwards to form a present future. Having made the projection prediction, workers need to commit to the prediction and doing so means justifying the prediction and its parts as being a viable answer to the question it set out to answer. This concludes this discussion on the conceptual toolkit used in this inquiry. The next chapter completes the first section of the thesis by outlining the methodological approach through which this conceptual toolkit has been deployed in this study.

4. Methodology: Tracing Prediction Processes

Arthur Stinchcombe (1978) once remarked that the formulation of social theory should be founded in the detailed study of facts. This thesis adheres to this imperative as it aims to combine a detailed description of the prediction work undertaken by mineral explorationists while seeking to make a theoretical contribution to the study of predictions as a way to manage uncertainty in particular as well as to the study of future as a social domain in general. However, to establish facts one needs first to identify, codify, and understand them. One needs, in short, a methodological approach that allows one to accomplish this. Methodologically speaking, this dissertation traces its DNA to two sources: the first is the ethnographic approaches that developed out of the Chicago School and the second is the American and French pragmatist traditions (see, e.g., Barthe et al. 2013; Frère and Jaster 2019; James 1907; Peirce 1905)[43] and Alfred Schütz's (1962) combination of pragmatism, phenomenology, and Weberian sociology. Among the ethnographic traditions to which this dissertation has turned for guidance and inspiration are the participant observational approach pioneered by William Foote Whyte (1993) and Straussian grounded theory (Glaser and Strauss 2005, 2009; Strauss and Corbin 1998, see also; Howard-Payne 2016). Additional sources of inspiration have been the ethnographic work by Howard S. Becker (1977, 1991) and Gary Alan Fine (1993, 2003). The pragmatist influence joins the ethnographic approach and focuses the attention of the sampling and data collection on the establishment of practical truths and knowledge, particularly in the form of predictions and justifications of predictions, in the field. Adhering to these two lines of influence, the work leading to this dissertation has focused on tracing explorationists' understandings as well as the conventions, ideas, and know-how that goes into their prediction work. In addition, the thesis has furthermore sought to avoid drawing on extraordinary cases. Mining and mineral exploration is home to a series of larger-than-life stories about great successes and bleak failures. Although such cases may be inspirational and educational, they seldom reflect the day-to-day realities of mineral exploration. While extraordinary events may help illuminate the challenges of mineral exploration (see introduction

[43] Although questions have been raised regarding to what extent French pragmatism is a pragmatist approach, this dissertation views French pragmatism as a development of its American forerunner. The reason for doing so is based on Tanja Bogusz's (2014) treaties on the relation between American pragmatism and the works of French pragmatist forerunner Luc Boltanski (see also Frère and Jaster 2019).

above), this dissertation follows William Foote Whyte's (1993) observation that extraordinary events can only truly be understood if one first understands the everyday patterns from which they arise. Therefore, the focus of this study lies with the mundane day-to-day work of mineral exploration.

4.1 Methodological approach

Although based in an ethnographic approach, this study combines traditional ethnographic data such as observations with interviews and archival research. This combination of an ethnographic orientation coupled with interviews and archival research under a pragmatist umbrella was chosen because it allowed for adjusting the sampling strategy to accommodate some of the particularities of the field. Mineral exploration is a multi-sited and multi-temporal endeavor in which different actors become involved in the process at different times and where old predictions are remade and revised as projects mature. In order to accommodate these realities of the field, the methodology needed to consider the different domains in which the prediction work takes place in mineral exploration and how this work is expressed both in explorationists' personal experiences and in written communications such as the reports produced as part of mineral exploration. One of the challenges of studying mineral exploration is, in short, that although it is possible, to paraphrase Clifford Geertz (1988), to gather information about the people living "there" and later make this information available to one's scientific community, it is not obvious where "there" is located in this particular case. As the field consists of different actors working in different fields of expertise and much of the work explorationists do takes place in documents such as exploration reports, permit applications, and models, a variety of data needs to be combined for a thorough analysis of prediction work to be possible in this case.

These challenges mean that the strategy for this study needs to consider several factors. First, although interview data and ethnographic observation capture the subjective experiences and actions of actors involved, modelling is notoriously hard to study ethnographically as it is difficult to follow what the actor or actors producing the model are doing (see Sundberg 2005). This appears to be especially true for mineral exploration as the majority of prediction work undertaken by explorationists takes place in models, documents, and reports. Second, although the predictions tend to be situated in these documents, the documents cannot be fully understood without understanding the processes behind their creation nor without insights into the overall field in which they are produced. Based on these considerations, this study combines interviews, archival materials, and ethnographic observation to produce a dataset that describes prediction work in mineral exploration from different sides and in its different dimensions. Interviews were conducted with informants in key positions along the exploration process in order to capture explorationists' subjective experiences and understanding of prediction work at different stages in mineral exploration. At the same time, documents in which predictions are made and publicized have been analyzed for how explorationists produce and present predictions. Moreover, participant observation has been carried out on classes and courses that address the skills necessary in prediction making in mineral exploration. In addition to this, observations of events where industry members met and discussed present trends and debates in mineral exploration are used to build an understanding of the field in general and of the context in which explorationists' prediction work takes place.

In addition to questions regarding what types of data best depict the day-to-day realities of the field, there was also a question of whether to focus this inquiry on a select number of cases or whether to look more broadly. Would it, for example, be possible to follow a few cases of mineral exploration in detail? The answer to these questions grew increasingly clear as work began. First, it became apparent that there existed potentially important differences between exploration organizations of different sizes (i.e., between majors, mid-tiers, and juniors) and that any sampling strategy would have to accommodate these differences. Second, as exploration projects take about ten years to finalize and the low likelihood of success means that only a few projects make it through the entire process, the challenges of identifying and following a specific project as explorationists work them appeared less than feasible as there was nothing to guarantee that the projects would not be terminated during the observation and data collection. To navigate these challenges it was decided that the approach that best could manage the idiosyncrasies of studying mineral exploration would have to include looking broadly and sample across the exploration process rather than on a case study basis. Therefore, the methodology and ultimately the analysis focused on the exploration process as it is expressed in several cases rather than on specific actors or projects. As a result, this dissertation follows and maps the processes of prediction work in mineral exploration and the stepwise structure through which predictions are developed, revised, and tested as they are moved through the exploration process. This process-oriented approach also extended to the sampling strategy, which involved a stepwise theoretical sampling strategy based on Glaser and Strauss's (2009) grounded theory methodology. As a result, each moment of data collection was followed by a reflection upon how each new data point contributes to the understanding of the prediction work process and what additional data would be needed to complete and develop this understanding. The outcome of this reflexive process was the creation of a map of the exploration process where each new "piece" of empirical material laid the ground for the next and where each wave of data collection was followed by reflection on what information was necessary to complete the emerging picture and add new dimensions to the data gathered to date. This reflexive process also involved triangulation as the sampling of different types of data made it possible to gather empirical materials that illuminated and illustrated different dimensions of the same fact. One example of this is how observations of a training session on financial modelling in mineral exploration helped create a richer and more grounded understanding of the models and estimates presented exploitation concession application materials and other parts of the archival material.

The continuation of this chapter accounts for the details of the methods employed in compiling the dataset upon which this thesis builds. The chapter also describes the coding and analysis of the collected empirical materials and ends by discussing ethics in research as it relates to this dissertation. In addition, the contents of this chapter are supplemented by four appendices. Appendix 1 provides an extended methodological discussion and reflection on the work involved in producing the materials discussed here. Appendix 2 and 3 provide tables detailing the observational field work and the archival materials included in the dataset. Appendix 4 offers an example of one of the interview guides used in this study.

4.2 Methods and data

The majority of the empirical data was collected in Sweden, a country that, thanks to its long history of mining, relatively stable legislature, and beneficial freedom of information legislation allows for sampling of archival materials concerning mineral exploration over long time spans. The materials that originate outside Sweden consist of ethnographic field notes taken at an international metals and minerals trading site as well as at the 2018 Prospectors & Developers Association of Canada (PDAC) conference, which is a major industry conference and trade show that gathers a large international attendance of explorationists, consultants, and governmental agencies, including geological survey offices.

In assembling the dataset, interviews, observations, and archival research methods were employed in parallel. Eighteen open in-depth interviews were carried out with informants in key positions within the field. All informants either work or have worked in mineral exploration, within related governmental agencies, or in proximity with the industry. The sample of informants contains both senior and junior members of exploration organizations, governmental agencies, and consultancy organizations. Because of the relatively small size of the Swedish mineral exploration sector, the sampling of informants for interviews needed to manage the relative scarcity of potential informants and the complexity of the exploration process. Therefore, the sampling of informants for interviews were directed towards identifying and interviewing informants based on their areas of expertise and their position in the mineral exploration process. Efforts were also made to ensure that the different types of organizations (e.g., mid-tiers, juniors, and consultants) as well as domestic and foreign organizations were represented in the sample. The sample of informants is skewed in terms of gender: three of 18 informants identified as female. This distribution roughly corresponds to the distribution of female workers in the entire Swedish mining industry.[44] Contacts with informants were made by e-mail, telephone, or as part of ethnographic fieldwork. A summary of the informants' positions and fields of expertise is provided in Table 1. To ensure the informants' confidentiality, several measures were taken. First, pseudonyms are used for all informants. Second, although the pseudonyms reflect the informants' gender, the use of Anglophone names does not connect to informants' backgrounds but were chosen to better match the language of this thesis. Third, informants' expertise is described in general terms so as to avoid presenting any information that can help in identifying any individual person.

All interviews were carried out by the author, who used a brief interview-guide containing a small set of themes to be raised in relation to what the informants related in the interview. The interviews began with the informants being asked to describe their work and continued with questions regarding when in the exploration process their expertise comes in and how they work with uncertainty. Informants were furthermore encouraged to describe actual practices rather than merely express their views about mineral exploration in an abstract sense. The shortest interview lasted 36 minutes and the longest lasted 2 hours and 21 minutes. The interviews were conducted in either Swedish or English depending on the informants' language preferences. The location for the interviews was chosen by the informants to ensure the least possible inconvenience to informants. Interviews have therefore been carried out in offices, hotel lobbies, office lobbies, and conference rooms at governmental agency buildings, university campuses, and airports. Three informants were not able to find a suitable day for a meeting wherefore interviews were conducted via telephone or Skype. Interviews were recorded with the informants' permission using a recording device in order to enable subsequent verbatim transcription. Transcripts were anonymized through the removal of identifiable information such as names of persons, organizations, and locations. On

[44] According to SGU statistics, the proportion of female workers in the Swedish mining industry stood at 17 percent in 2018, while the number of female office workers at Swedish mines the same year stood at 30 percent (Geological Survey of Sweden 2019b). While these numbers concern the industry in its entirety, no specific information has been found on the proportion of male and female workers and officers in mineral exploration.

some occasions, noise from the surrounding environment rendered brief parts of the recording inaudible. This was noted in the transcripts and made a point for consideration in subsequent analysis. Two informants declined the use of recording equipment wherefore only 16 of the 18 interviews were recorded and transcribed in this way. For these two interviews, extensive notes were taken during the interview and transcripts were made immediately after the interview. Notes were furthermore taken before and after each of the 18 interviews; before interviews as preparation and after the interviews to catch any immediate reactions, thoughts, or ideas resulting from the interview. These notes were also used for reflection as they enabled an objectification of any reactions, pre-cognitions, and pre-judices contained in them (Schütz 1953; see also; Overgaard 2015).

Table 1. Summary of informants (gender in parentheses)

Alias	**Area of Expertise**
Anne	Senior governmental agency officer (F)
Briana	Person with experience from working in mining and smelting at a Swedish mining company. *Non-recorded interview* (F).
Carl	Mining engineer and qualified person working in consultancy (M).
Dave	Mining engineer working in mining regulation and supervision with governmental agency (M).
Eric	Geologist working in a senior position in a junior mineral exploration organization (M).
Frank	Geologist and retired mineral explorer (M).
George	Geologist and former mineral explorer now working as consultant in environmental impact assessment (M).
Hank	Geologist working in geological mapping and with consulting and providing information to mineral exploration organizations. Holds senior position at governmental agency (M).
Ian	Senior member of a junior exploration organization (M).
John	Geologist, consultant and qualified person. Working with international consultancy firm (M).
Keith	Geologist working in mineral exploration with a domestic major organization. *Non-recorded interview* (M).
Lars	Senior member of major Swedish mining corporation, head of valuation division (M).

Maxwell	Senior member of junior mining company (M).
Niels	Chairperson of Sámi district located in a mining region (M).
Olaf	Geologist working with major Swedish corporation, previous experience of senior position within international corporation and governmental agency (M).
Peter	Geologist working with Swedish governmental agency (M).
Quinn	Geologist working as a consultant for foreign corporations operating in Sweden (F).
Richard	Geologist and senior member of major Swedish mining corporation, previously with other major Swedish mining corporation (M).

Ethnographic observation amounting to approximately 90 hours was carried out at active mining operations, governmental agencies, and different industry related events such as training events, seminars, and conferences. The material includes classes on mineral exploration, a course on financial modelling in mineral exploration, industry conferences and presentations, exploration project presentations, and a trading session at a major international market site for metals and minerals. Artefacts collected during observations included photographs, exploration material, books, leaflets, presentation materials, project overviews, and prospectuses.

The observations undertaken in this study served three purposes. First, they allowed for additional dimensions to be added to the understanding of prediction work in mineral exploration. For example, being able to ride in a four-by-four with a mine engineer to the edge of a large open pit mine and, standing on the edge of the mine, be able to ask them about how they work when they plan their mining schedules arguably adds depth to the descriptions of mine planning available in technical studies and other archival materials. Second, the observations provided first hand experiences and insights into some of the techniques used by mineral explorationists. Third, observations also made it possible to explore and map the professional culture and current debates in mineral exploration and the mining industry. By participating in conferences and trade-shows it was possible to capture the discourses at play in talks given at these events while informal conversations during lunch, coffee breaks, and dinner at conferences offered insights into how mineral explorationists talk about mineral exploration and about themselves. Together, these approaches offered ample opportunities not only to check descriptions in interviews and documents against facts (Becker and Geer 1957) but to gain a richer and more detailed and multifaceted account than would have been possible through interviews and documents alone.

As the ethnographic observations were carried out in different settings and with the observer in different roles, the degree of participation varied not only between sites but also between times of day. At industry conferences, for example, participation during sessions was reduced to the anonymity of a "fly-on-the-wall" as the author sat among the audience taking notes of what was said in the presentation. However, between and after sessions, the degree of participation rose as the observer mingled with the crowd, talked to informants and their associates, and played the participatory part of "just another attendee." As a result of this, the type of observation varied between situations as the relation between observer and actors in the field moved from one of mutual awareness between informants and observer, a characteristic that Gold (1958) calls the "participant-as-observer," to that of a detached observer anonymously sitting in a crowd or walking the aisles of a trade show taking notes of what is going on around them.

Extensive field notes were taken as part of ethnographic observations. Whenever possible, notes were taken during observations (e.g., during a training sessions, presentations, or class). When the situation did not permit notetaking, notes were instead produced immediately after leaving the field for the day. All notes were furthermore transcribed from the notebooks into a digital format for later analysis. At the beginning and end of each day of participant observation, as with the interviews, preparation for the observations included writing down thoughts and ideas in notes. Reflections after the observations were also written down in notes.

The archival material consists of texts and materials produced by mineral exploration organizations and related actors as well as industry standards and other private regulation documentation. Although the materials consist of multiple types of documents from different sources, these all sort under four corpuses of materials. The first corpus is a collection of annual reports published by mineral exploration organizations in Sweden. The second corpus is a collection of 43 applications for exploitation concessions filed with the Mining Inspectorate of Sweden between 2010 and 2016.[45] This second corpus contains concession applications summarizing exploration efforts in projects as well as supporting documentation such as environmental impact assessments, mineral resource estimates, technical studies, and protocols from meetings with governmental agencies, Sámi districts, and local interests or property owners. The materials also includes the rulings delivered by the MIS on each application. The third corpus consists of the three main industry standards: the JORD, PERC, and NI 43-101 as well as private regulation specific to Sweden. The fourth corpus is a collection of the relevant laws and ordinances regulating mineral exploration in Sweden.

[45] The time span was chosen to allow for a significant but manageable number of documents for analysis.

The 151 annual reports that make up the first corpus were collected from the individual webpages of SveMin members.[46] The exploitation concession application materials were accessed through freedom of information requests to the MIS. In total, these requests returned 43 cases of applications amounting to 577 documents consisting of a total of 7,855 pages. The industry standards were collected from each issuing organization and the legal documents were assembled through the Swedish Code of Statutes.

In addition to the three main strands of data, this project benefited from access to information in the form of newsletters, reports, and databases available through the websites of The Geological Survey of Sweden (sgu.se), The Mining Inspectorate of Sweden (sgu.se/bergsstaten), The British Geological Survey (bgs.ac.uk/mineralsuk), The U.S. Geological Survey (minerals.usgs.gov/minerals/), Bundesministerium für Wissenschaft, Forschung und Wirtschaft (bmwffw.gv.at), and The World Bank (worldbank.org). The resources provided by these agencies were of great assistance in the early stages of this project and with building an understanding and an orientation of the industry. They also helped the author keep himself updated about events and trends in mineral exploration and extraction also during the writing stage of this thesis.

4.2.1 Learning the ropes

One important step in approaching and interacting with the field was to grow successively more familiar with its logics, with engineering, and with theoretical and applied geology. The field of industrial mineral exploration is a highly specialized field in which different professionals, experts, and other skilled personnel come together in projects to explore and valuate potential mineral deposits. As such, it is also a field that relies on specialized knowledge and uses highly specialized language. For a non-geologist with no engineering background, it can therefore be challenging to grasp what is going on in the field and to understand what people are actually talking about during interviews and fieldwork.[47] One informant referenced this saying that:

> Yeah, as a non-geologist this can get pretty heavy. But if you've really read up on it, then some of it may fall into place (John).

[46] The decision to sample based on SveMin membership was to identify and sample documents from exploration companies with established operations in Sweden.

[47] An illustrative example of how impenetrable geological language can be to the uninitiated person can be found a piece of archival material that in its discussion of the geology in a location stated that the rocks "in the Köli Nappe" included rocks from the "Tjopasi Group" or that an area may consist of "phyllite and felsic to mafic metavolcanics."

To prepare for the field work, the author visited closed down mining operations around Sweden to develop a sense of what a mining operation entails and what the ultimate end-point of the mineral exploration process looks like. Across the span of the years leading to the finalization of the thesis, six closed mines have been visited in addition to the active mines visited as part of the ethnographic field work. Image 1 below shows the author at one of the mines visited for this dissertation.

Written sources were furthermore employed in attempts to gain orientation and overview. Such written sources include newspaper articles and field specific materials such as information folders, exploration guidelines, exploration reports, and standards. The initial stages of sampling were guided by the insight that some informants' knowledge and experiences would be too advanced for an uninitiated sociologist so the first contacts were made with informants in positions and organizations that work in more generalized rather than technical areas.

Image 1. The ethnographer underground (photograph by author)

4.3 Coding, analysis, and presentation

The transcribed interviews and ethnographic fieldnotes were coded with the aid of computer software Atlas.ti and consisted of a three waves coding strategy derived from the grounded theory approach developed by Anselm Strauss and Juliet Corbin (1998). The first wave consisted of open coding using the line-by-line approach where descriptive codes are created for each line or sentence of the transcripts and field notes.[48] The second wave consisted of systematizing the codes produced in the first wave and on combining sub-codes to reduce the complexity across the materials by using themes to gather related codes into code families based on what type of activity or experience they described. In the third and final wave of coding, the coded material was arranged into super-codes based on the dimension of prediction work in mineral exploration they related to, (i.e., prediction production, justification, and the later use and assessment of predictions). These super-codes were then ordered to produce a narrative of coded materials that gathered that was structured them along the parameters outlined in the research questions. The result of this coding procedure was that the 2176 codes produced in the descriptive line-by-line coding were gathered into 71 code-families, which were then joined together into seven super-codes according to their position in the narrative constructed around the exploration process and this thesis's three research questions.

Due to the bulkiness of the archival material, line-by-line coding was rendered inefficient and therefore a less fine-grained approach was used for each corpus of materials. The analysis of the annual reports was explorative in nature and focused on understanding how mineral exploration organizations work in exploration and on mapping the types of risks discussed by explorationists in these materials. The first focus was accomplished by reading through the materials during which extensive notes were taken. The second focus used the auto-code function in Atlas.ti. Set to extract each mention of risk and uncertainty,[49] the auto-code procedure returned a body of codes that were later coded manually in a second wave where the coded statements on risks were divided into categories depending on what type of risk they described (e.g., geological risks, currency fluctuation risks, and commodity price risk). The exploitation concession applications and their supporting materials were coded more closely and in greater detail than were the annual reports.

[48] Occasionally, whole paragraphs of field notes were coded as one unit. This was especially true in instances when the paragraphs contained one multi-sentence descriptions of a single event or situation.

[49] This was accomplished using a search string defined to return chunks of text containing some variation on the two terms. As the documents were written in either Swedish or English, the procedure were adopted to include mentions of the terms in both languages.

However, because the extensive volume of this material also rendered it unsuitable for the line-by-line approach, a more thematic approach was selected in which each document in the corpus was read through and entered into an index together with details of the type of document[50] and a summary of its contents. Memos pertaining to capture analytical ideas and reflections were written throughout the coding process.[51]

When constructing the empirical narrative, the ambition has been to provide a detailed account and exploration in the form of "a collection of composed set-pieces" (Fine 2003a:54) that reflects the activities involved in explorationists' prediction work. In order to accomplish this, empirical examples from interviews, observations, and archival materials were included in the narrative on the basis of their ability to illustrate and explain the different dimensions of practical work involved at each stage of predicting the future minability in an exploration project. The quotations were selected by reviewing the narrative of coded materials for examples that best illustrated the everyday practices in the field.[52] However, care was taken to ensure that any instances of conflict and disagreement are accounted for and that all sides are made visible in the narrative. Finally, in cases where the data were recorded or produced in language other than English, translations of quotations are provided in the text and the original transcript is provided in the footnotes.

4.4 Ethical considerations

The mineral exploration and extraction industry is a relatively small world that at times faces heavy contestation, wherefore it has been necessary to take

[50] The classification of documents contained the following types: application formulae, technical reports, mineral resource estimates, technical report supplements, drill profiles, maps, environmental impact assessments, environmental impact assessment supplements, MIS rulings, MIS administrative notes, letters (including details on sender), and government rulings.
[51] The industry standard corpus was coded into the themes constructed in the analysis of the interviews and field notes. The corpus of laws and ordinances was read through and relevant paragraphs were highlighted and ordered according to which point in the exploration process they apply to.
[52] This focus on the quotation's ability to illustrate general practices means that some informants and observations feature more often in the narrative than others. This is merely a reflection of their ability to provide more illustrative and exhaustive examples and not of any deficiency on part of other informants or visits to the field. This is also true of the primacy of interviews and observations over archival materials. As the interviews and observations to a larger extent concerned general practices and generalizations across individual projects, these have been selected as examples to a larger extent than were documents, which tended to concern specific projects at specific points in the exploration process.

measures to protect the confidentiality of the informants. Therefore, steps were taken to de-identify informants and de-contextualize the informants, locations, and organizations present in the materials to whatever extent possible. Although full anonymity may not be possible, steps were taken to ensure that the identities of those who feature in the empirical materials are kept as confidential as possible. Confidentiality was primarily accomplished by removing names of persons, organizations, and locations in the transcriptions of the field-notes and interviews. In addition, the corpus of permit applications were anonymized by removing any names from the database constructed during the analysis of the materials and by placing the code key necessary to de-anonymize the database in a separate and password-protected document. Finally, pseudonyms were used when referring to informants and the companies or corporations they work for.[53]

All participants in this study participated in their professional capacities except for one informant who had retired from the profession before the interview and whose participation was based on their former profession. Throughout the project, all contacts made and all interactions in the field were taken place in accordance with the recommendations put forward by the Swedish Research Council (The Swedish Research Council 2002, 2011). The 18 informants were informed of the purpose of the interviews, their right to confidentiality, the nature of the research project, and their rights to withdraw their participation. Having received information on their rights as participants, all participants featured in this dissertation gave their oral consent to participate and, in the cases where recording equipment was used, consent to have the interview recorded for future transcription, analysis, and possible reproduction. When participant observation was carried out this was done with full disclosure of the author's name and place of work. The author made sure to inform anyone with whom they interacted of the purpose of their presence in the space in question. The notebooks used in the field as well as any materials gathered during fieldwork were stored in locked compartments to ensure that no outsider would be able to gain access. Informants who requested it where given copies of the interview guide before the interview. One informant also asked to review the transcript of their interview. The informant was therefore sent a copy of the transcript and given the opportunity to comments on the transcripts. The informant chose not to provide any additional comments after having received the transcript.

[53] On the few occasions when actual names are given, this is done only to relate publicly available information, e.g., as in the case of the Northland bankruptcy.

5. Prediction Work in Mineral Exploration

The remainder of this thesis will present the results from the analyses of the empirical materials in relation to the research questions presented in chapter 1. Across the following five chapters answers to how predictions are produced and justified in mineral exploration, and of what consequences predictions have when they are put to use by explorationists in their interactions with publics will be presented. The first question–i.e., How mineral explorationists produce predictions and how predictions help them manage uncertainty?–is the focal point of this and the next chapter. This chapter focuses on predictions produced in the beginning and early stages of the exploration process. Based on the discussions in chapter 3, the chapters make particular reference to the prerequisites for prediction outlined by Rescher (1998) and the valuation procedures and devices that help produce projectable patterns. The chapters in this section also investigate what methods of linkage are used to project these patterns to construct present futures. By outlining how predictions are made in mineral exploration, what data and methods are used to identify projectable patterns, and what linkages are used in projection, these two chapters provide not only an answer to how minability is predicted under uncertainty, but also provide a foundation for the coming chapters on prediction justification and consequences.

The first section of this chapter provides an initial orientation of the exploration process in general terms whereafter it closes in and focuses on describing the exploration work undertaken in the beginning and early stages of the exploration process. This focused account is divided into two sections: the first focusing on how explorationists select areas in which to located exploration projects and the second focusing on the work carried out in order to generate targets within the selected area. Each of the two sections contains in-depth accounts of how explorationists produce data for prediction work by strategic use of valuation devices and how they project patterns found in the data into the future as predictions. Following these in-depth accounts, the chapter then moves to account for the larger picture emerging from exploration work in these early stages before it ends with a discussion that summarizes the findings presented in this chapter. Chapter 6 picks up where this chapter ends as it looks closely at the later stages of mineral exploration before it ties together the findings presented across the two chapters in one concluding discussion on how mineral explorationists predictions of the future minability in exploration projects can be understood in a theoretical, or second order (Schütz 1962), perspective. The empirical section of the dissertation then continues with chapters 7 and 8, which focus on the questions of prediction justification and its consequences in use, respectively. This empirically focused part of the dissertation ends with chapter 9, which summarizes the results of this dissertation in a concluding discussion of the results presented here and of their implications for the sociological literature on mineral exploration and the overall problem of predictions and actors' attempts to manage uncertainty.

5.1 The exploration process

In its entirety, mineral exploration is a long process that begins with the search for areas of exploration potential and continues with the initiation of exploration and then moves between different stages at which different lines of explorationists work the project towards maturity. The time it takes to move a project from initiation to an operational mine is often said to be around ten years and sometimes more.[54] However, the vast majority of projects will not last ten years as only a small portion of all projects manage to identify deposits and resources that are of such quantity and quality that they are estimated to be able to support a future mine. The few projects that are carried through the entire exploration process will be subjected to a range of activities through which explorationists from various fields of expertise gather, process, and analyze data in order to produce predictions both for the long-term minability of the project and its short-term exploration potential. Each stage of the exploration process, in other words, involve explorationists valuating projects and making predictions that help answering questions as to whether or not to move forward and invest in the measures to be taken at the subsequent stage. Retired exploration geologist Frank explained how this takes place in a, so to say, high stakes decision tree as exploration means making decisions about moving projects forward while often having very little data to base such decisions on wherefore the basis for evidentiation often is relatively weak. Asking whether it would make sense to take a project to the next stage in the exploration process, one must therefore look backwards to see what is ahead, Frank explained:

[54] This is primarily true of mineral exploration in the field of industrial mining. Other forms of mining may rely on different practices or logics producing different conditions. For an example of such practices, see Lanzano (2018).

> If you look at it from an economic point of view, then you've got the budget for the work you're to do. And then, when you have done it, then you have to look at the results of that work and ask "Do I know enough about this [deposit]? Would it be worth it to spend any more on it, or should we write it off?" If you write it off then you leave it. If you want to do some more work then you decide; "What information should I go look for now?" and then you go get financing for that. And then you get this tree.[55]

Mineral exploration is, as Frank emphasized, a stepwise process that contains several decision points; while this is not unique for mineral exploration, it offers a structure around which one may build an understanding of mineral explorationists' prediction work as consisting of many predictions with different temporal orientations. The decisions being made at the different points Frank pointed to revolve around explorationists asking questions about what might potentially come–short-term and long-term–from doing one thing or another based on the information that is presently available as explorationists valuate projects' potential and in relation to the costs of obtaining more data. In his discussion on the decision points in exploration, Frank also explained that investments into additional information come with uncertain returns. This problem of uncertainty reduction, which is highlighted in Knight's (2006) work on uncertainty, complicates decision making as explorationists need to consider not only the geo-economical potential in a project, but also the cost of further investigating a project's potential, or as Frank said:

> You're constantly asking: How much will this cost? What chances do I believe there is that this will turn up something? Do I believe it is worth it to spend this much money here, or should we close this project down? That's a question you have to ask yourself repeatedly.[56]

Across the exploration process there are, roughly speaking, four stages at which the decision making discussed by Frank comes to the foreground as they involve changes in what work is carried out by explorationists. These four stages, summarized in Figure 3, are as follows: (i) conceptual studies and project generation in which areas expected to hold exploration potential are selected and surveyed; (ii) target generation in which the geological environment and identified deposits of mineralized materials are mapped; (iii) resource definition and resource evaluation where the quality, quantity, and geometry of identified deposits are valuated to produce an estimate of a mineral

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[55] Och ser du från ekonomisk synpunkt så har du ju en budget på det du ska göra. När du har gjort det, då får du ju titta på det resultatet och ställa dig frågan "Vet jag tillräckligt om den här nu? Är den värd att göra något mer på, eller ska vi avskriva den?" Avskriva, då lämnar man den. Vill man göra mera, då bestämmer man sig för "Vilken information ska jag söka nu?" och sedan tar man fram budgeten för att söka den. Och sedan får man ett sådant här träd.

[56] Det är hela tiden: Hur mycket kostar det nu? Hur stora är chanserna, tror jag, för det här? Tror jag att det är värt att lägga så mycket pengar, eller ska vi lämna det? Och den frågan får man ställa hela tiden.

resource; and (iv) feasibility studies that provide comprehensive evaluations of exploration projects as well as their estimated economic value. Connected to each stage in the exploration process are sets of activities that need to be accomplished for the process to move forward. However, as all deposits and all projects are different, how much work is required at each stage differs. If, for example, one seeks to identify new deposits near an operating mine, one may be able to spend less time and energy on project generation as the general area of exploration has already been identified. If, however, one seeks to identify new deposits in previously unmined areas, one may need to spend much more time undertaking field surveys and examining available data on existing geological environments to tease out and select areas for exploration. The same goes for the resource definition and evaluation stage. Certain types of mineralization are harder to define and evaluate than others. Large magnetic iron ore deposits, for example, tend to be more homogenous and therefore are more easily defined than, for example, gold deposits found in narrow quartz veins. The differences in how challenging the estimation between these two is because of the properties of the two kinds of deposit. While a large magnetite deposit stands out against the surrounding bedrock due to its magnetic properties, gold is often deposited as nuggets distributed unevenly throughout narrow quartz veins wherefore more samples need be collected to support an estimate of the gold deposit's grades and tonnages. Despite these differences between mineral deposits and projects, there are enough commonalities between the works carried out at the different stages to discuss them jointly. Each of these stages are discussed in detail below.

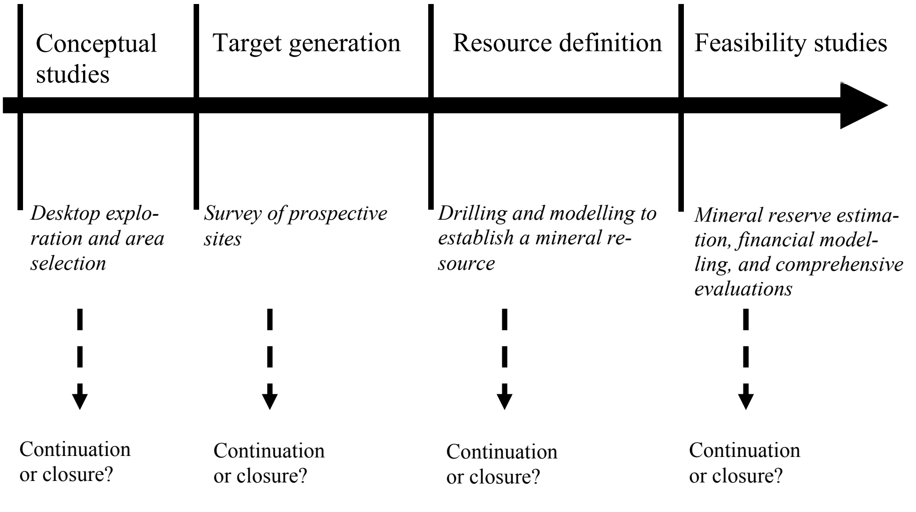

Figure 3. A stylized outline of the exploration process

5.1.1 Early stage exploration: Desktop exploration

While the term "mineral exploration" might conjure up images of exploration geologists scouring a far afield area in search for mineral discoveries, mineral exploration projects tend to begin far from the rugged terrains with which it is so connected.[57] The reason for this is very simple; before explorationists put their boots on the ground and begin the work to discover mineral deposits, they first need to figure out where to look. Therefore, the first stage of mineral exploration focuses on identifying and selecting areas in which to search for exploration targets. In practice, this means asking in what jurisdiction, region, and location it is likely that discoveries of significant deposits of mineralized material can be made. Prediction work in early stage exploration is therefore primarily about using global and regional data to predict where future discoveries are more likely to be made and this work often begins in one of two places: in an office somewhere or in a large unheated warehouse in a remote Swedish town.[58]

As different minerals are formed in different geo-tectonic environments, explorationists may begin their exploration work by looking at regions characterized by geological make-ups that tend to host certain types of mineral deposits. Understanding something about plate tectonics, junior exploration company CEO Ian said, is therefore important in early stage exploration as "you need to be in the right place to look for the right thing." Identifying areas that may be suitable for exploration work can therefore be based partially in applications of geological theory and supported by already existing geological and exploration data. This information is then analyzed with a view to identify prospective sites that fit what explorationists refer to as their *exploration models*. An exploration model details what minerals explorationists are looking for, what geological environment they believe may host deposits of these minerals as well as what size of project they wish to work and what region they wish to work in. There are many exploration models available; when used, they may be adapted to fit the particularities of a project. One example of a model that has been used successfully to identify new mineral deposits is the Lowell-Guilbert porphyry copper model describes a type of copper deposits characterized by rings of hydrothermally-altered rock that may extend several hundred meters from the mineralized deposit (Lowell 2014; Lowell and Guilbert 1970; Misra 2012). Using an exploration model, explorationists narrow and delimit their search to types of deposits and environments that suit their expertise or the profile of their organization.

[57] A connection that is highly visible in the type of images returned from a simple online search for images of mineral exploration.

[58] This is not to say that exploration fieldwork to map unexplored territories and areas no longer take place, but that the volume of available historical exploration data available (e.g., in Sweden) today means that much of that work has already been done.

The majority of exploration work at the early stage is therefore not primarily fieldwork, but desktop exploration. However, in order for desktop exploration to be possible, someone will have to have made the initial work to gather the information that may be pooled by desktop explorationists. Such data include survey work done by a Geological Survey Department such as the SGU,[59] historical exploration work, or modern remote sensing data such as the mappings done using LANDSAT satellite imagery (see Sabins 1999). One important resource for the desktop explorationist working in Sweden-and a resource that is relatively unique in an international perspective-can be found in the small Swedish town Malå. Located in the Swedish northern inland, the relatively unassuming town is home to one of the world's largest exploration archives and therefore is a popular destination for domestic and international exploration organizations looking to find new areas to explore. The SGU, which owns and manages the archive, agency officer Peter explained, provides consultation services as well as access to exploration reports, hundreds of thousands of geological maps, and a drill core archive containing three and a half million meters of drill core.[60] In addition to archiving and maintaining these materials, the office is part of SGU's larger mission to map the general geology of Sweden and providing the results for popular consumption, for example, through resources such as the geological Survey's website where users may access a range of maps from the SGU's databases. An example of the more general services available from the SGU is depicted in Figure 4, which shows three examples of maps available from the agency's archives and online services. The three maps describe the Swedish bedrock in geological and geophysical terms. Moving from left to right, the first map details the geology of Sweden's bedrock, the second shows the gravimetrical variation (i.e., the different strengths of gravity) across the country, and the last outlines the magnetic characteristics of the bedrock. Together, the three maps provide examples of how the underground is measured and codified using geological and geophysical methods.

When asked how the SGU usually approaches inquiries from explorationists, two SGU officers, Peter and Hank, outlined the services the agency offers and explained that the exploration companies that come to them often do so with a particular exploration model in mind. These models consist of the explorationists' approach to project generation and what type and size of mineralization they are looking for and in what geological environment they believe

[59] Other countries have also undertaken significant amounts of state-led exploration. Accounts of government-led prospecting and geological mapping by the U.S. Department of the Interior is, for example, available in Black's (2018) historical research on the same agency.
[60] Had these cores been gathered from one single drill hole, this drill hole would span the entire diameter of the moon, 55 percent of the way from the earth's surface to its core, or the full 2175 miles of the renowned Appalachian Trail between Springer Mountain, GA to Mount Katadhin, ME, USA.

they will be able to make such discoveries. Peter also said that most explorationists who come to Malå had previously studied Sweden's geology to find areas that fit their exploration model. Peter outlined what services explorationists can use in Malå:

> If we're talking about those who are coming to spend a few days here, then we usually email them ahead of time to see what it is they would like to know and what ideas they have, what they could work with, and then we go find out where there are deposits that are available, because many deposits are already placed under exploration permits, and then we pull out reports concerning the area in question. So when they get here they can go sit down in a room and review this information. And then, you know, some people want access to maps, to be able to pull up maps on a computer and look through it to see what is there and so forth. So based on the [explorationist's] assessments, they then pick out what they themselves see as most promising leads.[61]

In addition to reviewing maps and exploration reports, the office's clients can also access its drill core archive. The drill cores available in the archive are stapled in long rows that make corridors in the vast hall where the SGU stores materials stemming both from their own work over the years but also from the now closed governmentally-owned exploration company Swedish Geological (SGAB). In addition to these materials, the archive includes cores handed over to the SGU by private companies working in Sweden.

[61] Är det sådana som verkligen ska hit och kanske spendera några dagar, så mailar vi i regel före och klargör vad dom vill veta och möjliga uppslag, vad dom skulle kunna jobba med, så tar vi reda på var det finns fyndigheter som dels då är lediga, för det är ju väldigt mycket upptaget under undersökningstillstånd, och så kan man ta fram rapporter som rör det här området. Så när dom kommer hit så kan dom sätta sig i ett rum och gå igenom det här själva. Plus att en del vill ju ha kart-service, att man kan gå in och ha en karta på datorn och kolla vad som finns och så vidare. Så utifrån deras bedömning så plockar dom sedan ut vad dom själva tycker ser mest vettigt ut.

Image 2. Inside the drill core archive (photograph by author)

One important aspect in relation to the drill cores stored in the archive is that the majority of the cores stored in Malå have not been analyzed or are under-analyzed. The reason for this, Peter explained, is because core analysis has historically been very expensive wherefore many older projects could not afford comprehensive analyses of the cores wherefore analyses were only made for a smaller spectrum of metals and minerals. In addition, many cores were gathered in a time when the span of marketable minerals was much narrower than today as recent technical development has introduced markets for minerals that previously lacked industrial and therefore economic value. In addition, Peter explained, methods for analyzing drill core material have developed significantly over the years wherefore explorationists today have access to a larger scope of analyses than did their predecessors. The lack of analysis of these cores have consequences for explorationists as it means that new discoveries are possible without having to spend a single moment doing survey work in the field. Instead, one can just go to Malå and explore the archive. Exploration geologist and consultant Quinn, who has worked with the archive materials, described the archives at Malå as a “Pandora’s box” that can reveal potential discoveries. Developing this point, Quinn explained that old drill cores can be used to identify new projects and that access to this archive of largely un-analyzed cores means that new discoveries can be made also in cores that were previously believed void of interesting mineralization:

> Only fifty, sixty, seventy years ago, when they were looking for zinc, analyzing for gold was too expensive. So they never did that. Maybe twenty years ago too, undertaking gold analyses was very expensive. And maybe even for lithium, cobalt [. . .] the technology has changed so much with batteries and all that, so today we have telephones and TVs and cars that need cobalt and nickel and lithium and vanadium. But twenty years ago, fifty years ago, and a hundred years ago you did not need those minerals.[62]

Because of the richness of data available in their archives, the SGUs Malå office and provides an important starting point for many exploration projects in Sweden. Having access to maps, reports, and cores at a low cost provides a cheap alternative to early stage exploration field work, especially as the SGU allows explorationists to take pieces of core for analysis as long as the agency receives a copy of the results,[63] which reduces the need for exploration drilling in the field.

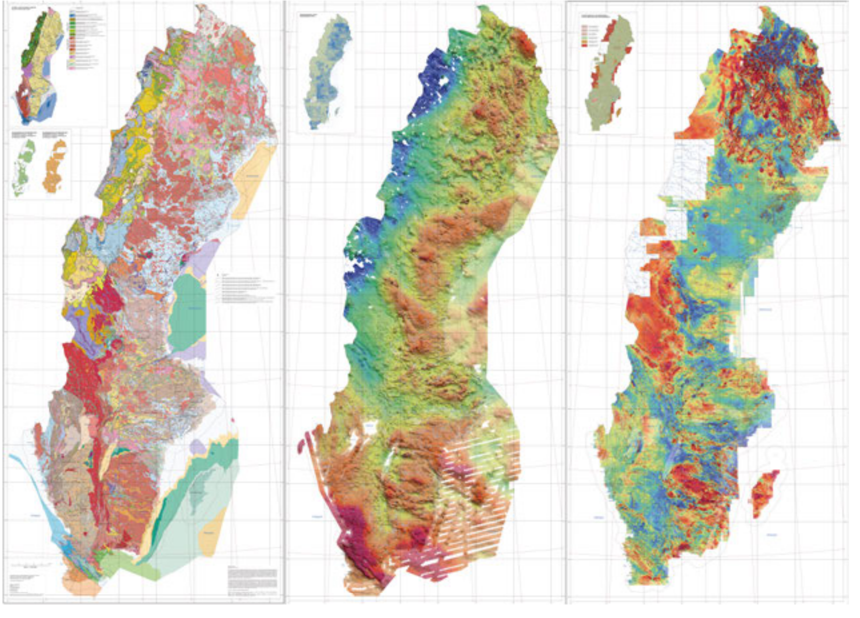

Figure 4. SGU's maps of Sweden's bedrock geology, Bougher (gravimetrical) anomalies, and magnetic anomalies (Bergman et al., 2012; Jönberger, 2012; Wedmark, 2012)

[62] Men för kanske femtio-sextio-sjuttio år sedan när dom letade efter zink.. det kostade för mycket att analysera för guld. Så dom gjorde aldrig det. Men även för kanske tjugo år sedan var det jättedyrt att ta guldanalys. Och kanske till och med litium, kobolt.. teknologin har förändrats så mycket med batterier och allt möjligt att idag har vi telefoner och TV och bilar som behöver kobolt och nickel och litium och vanadin. Men för 20 år sedan, 50 år sedan och 100 år sedan behövde man inte dom mineralerna.

[63] The SGU permits those who rent access to the archive to examine, split, and analyze cores as long as at least one-quarter of the core remains in the archives.

Exploration models and philosophies

Although many explorationists turn to resources such as the SGU Malå office, exploration projects can begin in different ends and may be initiated in different ways. One may, for example, look for sites of interest directly in the field or one may begin one's search by looking through available data in archives such as the one in Malå, or one may combine the two to assemble a more comprehensive material. However, no matter what first approach is used, the overall goal at this stage is to identify areas where one may situate exploration projects. How this is done, informants such as Peter and John explained, boils down to the aforementioned *exploration model* with which explorationists delimit their work as well as their *exploration philosophy*. The two terms–models and philosophies–suggest two ways in which explorationists describe how they approach project generation. As was hinted at earlier, an exploration model outlines the type of mineralized deposit explorationists are looking for in terms of the minerals they interested in, what indicators are associated with this type of deposit, what type of geological environment the minerals are expected to be found in, and how large a project they desire to establish. Therefore, exploration models help reduce the complexity of desktop exploration as they delimit the scope of potential targets. Although some informants argue that the use of models place unnecessary limitations on desktop exploration, exploration models remain a common way for explorationists to define the scope of their early stage work. In addition, explorationists furthermore tend to base their early stage approach on their own profiles and strengths, combining them with the models used. Different explorationists have experience working different types of projects–e.g., gold projects, copper projects, or iron ore projects–in different environments. Additionally, as exploration organizations of different sizes lend themselves better to small or large projects, the exploration model also helps them narrow their search further.

Moreover, exploration models consider geological theory to define geological signs of exploration potential. Hank discussed one example of this explaining that a model emerged in the 1990s based on the mineral deposit at Olympic Dam in Australia and its characteristic combination of iron oxide, copper, and gold. Armed with a description of this new type of ore, an Australian company visited the SGU Malå office proposing the hypothesis that the Kiirunavara-type hematite iron oxide ore found in northern Sweden was another type of this form of iron-copper-gold deposit. Working this new angle, the company searched for exploration targets in Sweden that matched the model and telltale signs found in the Olympic Dam deposit, Hank explained:

> And then this Australian company came over and started talking about these iron oxide-copper-gold type deposit. And we didn't know anything about it. But they began describing it, what it looks like and that it featured something called ”red rock alteration,” y'know, a transformation in the types of rock that

> make it turn red and so. And that's when the penny hit the floor. And y'know, we knew where the apitite deposits are so on. So we could point to some areas that we thought could be of interest.[64]

Unfortunately (at least for the Australian company), the majority of the areas of interest had already been picked up by another company. Nonetheless, this example helps demonstrate how explorationists develop and use geological knowledge to fine-tune their exploration efforts using different models.

In addition to the exploration model, explorationists also approach early stage exploration with different views on how to best identify potential targets. This is known in the field as the "exploration philosophy," which has to do with whether explorationists prefer to go in broad by surveying many sites or whether they prefer to work with a smaller set of projects and focus their resources more narrowly. Which philosophy is preferred, exploration geologist and consultant John explained, depends on both explorationists' preferences and the financial resources they have to spend on exploration. A small exploration company is often restricted, for example, by the limits of their financial resources, which determine how many projects they can afford to work simultaneously. Another dimension of the exploration philosophy, which also ties in with the exploration model used by explorationists, is whether one chooses to explore in previously non-explored regions or whether one chooses to situate one's exploration work in already established mining regions. The difference between these two is the difference between green field and brown field exploration. Whereas green field exploration means starting more or less from scratch, guided perhaps by some historical data and maps of the general geological make up of a region, brown field exploration focuses on areas with historical or established mines. As mineral deposits seldom exist in isolation but as parts of larger systems of mineralized materials, the existence of one substantial deposit in an area may therefore often be used as an indication that there are other deposits in the area.

Early stage concerns: Non-geological aspects and hindrances to exploration

While desktop exploration depends on reviewing available geological knowledge, geology is not the only dimension at play when explorationists

[64] Och då dök det upp ett australiensiskt bolag var det, som började tala om just den här Iron oxide-copper-gold. Och vi hade ju inte hört talas om den. Men dom beskrev litegrann hur den såg ut och det var bland annat någonting som kallas "red rock alteration" alltså en omvandling av bergarterna så att den blir röd och sådär. Så då började det ringa klockor, och sen apatitjärnmalmer visste vi ju vart dom låg och sådant där. Så vi kunde peka ut några områden som skulle kunna vara intressanta.

valuate areas for their exploration potential. In addition, environmental and social factors may prevent future exploration work or mining. National parks and areas designated as Natura 2000 areas and other protected locations are examples of areas where mineral exploration may come into conflict with other interests. Exploring and working a site in such a location may either be impossible from the start or hit dead ends as explorationists find themselves unable to carry out the necessary work to successfully execute a project due to regulatory restrictions. In some cases, such limitations are relatively straightforward. For example, Keith, an exploration geologist, explained that few would even imagine attempting to explore in a city or town or around docks, railroads, or freeways as the chances of mining eventual discoveries would be limited by present land use in such areas. However, some limitations may be harder to spot at first. This is particularly true of different social limitations that also need be considered as local communities opposing exploration and mining may either slow down the exploration process or even force it to a halt. This is, for example, the case for the much publicized projects in Norra Kärr and Kallak.

Among the communities affected by exploration and mining, Sámi communities often play a central role. The centrality of Sámi communities in general and reindeer herding Sámi in particular is due to mineral exploration and mining impacting reindeer herding, an activity of significant tcultural and economic importance to the Sámi. Reindeer are migratory animals and herding them requires large areas that allow the reindeer to migrate from summer grazing at higher altitudes to winter grazing at lower altitude woodlands. Exploration activities, and more so mining operations, risk disturbing grazing reindeer wherefore explorationists, together with other rural industries such as forestry, motorized tourism such as snowmobile tourism and tours, and infrastructure such as freeways and railroads, are often at odds with reindeer herding Sámi and the districts into which they are organized. Niels, a reindeer herder and Sámi district officer, explained how reindeer herders within his district see cumulative effects from the many industries that encroach on reindeer grazing lands and migration routes:

> It makes many things harder. It disturbs the reindeers, and then they don't get any peace when gracing. After all, it's harder to grace reindeer close to these mines. And when you carry out exploration in the winter in these locations, where we have winter gracing lands, then the reindeer get frightened and run off, you know. And that's not only here close to the mines. When reindeer are frightened and set off from near a mine, you get a chain reaction. It's like domino tiles falling, you know.[65]

[65] Det försvårar ju mycket. Och sen blir renarna störda också så får dom ju ingen betes-ro. Det är ju svårare att beta i närheten till dom här gruvorna. Och gör du då en prospektering också vintertid i sådana land där vi har sådana vinterbetesland, då blir ju renen skrämd på flykt. Och det är ju inte bara just här i närområdet. När du skickar bort renar i närområdet så blir det som en dominoeffekt. Det är ju som brickor som rasar.

The potential impact to reindeer herding caused by mineral exploration activities come as reindeer are disturbed or frightened when grazing. According to Niels, exploration activities force reindeer herders to work harder to keep the herds together, work that ultimately translates into increased costs and labor. Therefore, mineral exploration can contribute to the increased challenges experienced by reindeer herders in Sweden and this, in turn, feeds into the possibility of potential resistance to mineral exploration in reindeer herding areas.

Quinn, an exploration geologist and consultant, discussed how these social and environmental dimensions factor into desktop exploration. Referring to her own work on a gold project, Quinn said that when she had taken the project as far as having identified an area that showed signs of geological potential, she made sure to check that there were no other factors present at the site that could affect the project negatively and reduce the likelihood that the project would survive permitting processes:

> I have a few things I check up myself, and these things need to fit already from the start. So, are there any parks or Natura 2000 zones there, yes or no? Is there any other piece of nature or environment, it could be anything, is there some bird or something there in this place that may affect the project, yes or no? What is the situation with the Sámi? Are there any reindeer migration routes, or vast gracing land, or reindeer calving place in the area, or is it merely Sámi district land? The community, is the site close to a town or something like that? And already then, as soon as possible, am I going to file for a permit or not, I have to ask myself, if I apply, will that bring a lot of problems on my hands, should I not apply?[66]

In Quinn's case, she chose not to apply for an exploration permit before she was satisfied that there were no social or environmental factors that could cause difficulties attaining an exploration permit. However, how explorationists weigh the different dimensions discussed here varies from person to person and company to company. After all, environmental restrictions can be waived, technical solutions can reduce impacts to the socio-environmental surroundings, and corporate social responsibility engagements can help sway unfavorable public opinion. Nevertheless, there are two things that cannot be circumvented by any measures on the explorationists' part: the geology and the deposit. Most exploration geologists will remind you that deposits are where they are. They are locked in position somewhere and cannot be moved. Therefore, geology remains the key dimension in the valuation and evaluation undertaken in desktop exploration. The prediction work undertaken in early

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[66] jag har några saker som jag kollar själv och dom måste passa redan då. Så, finns det någon park eller Natura 2000, ja eller nej? Om det finns det, då vill inte jag vara där. Finns det någon annan natur eller miljö, det kan vara vad som helst, finns det någon fågel eller någonting där som kanske kan påverka ett projekt, ja eller nej? Hur ser det ut med samerna? Finns det någon led eller jättebetesområde eller kalvningsområde eller är det bara i deras område, ja eller nej? Samhället, är det jättenära en stad eller något sådant där? Och redan då, så tidigt, om jag ska ansöka eller inte, jag måste fråga mig själv; ska jag ansöka, får jag jättemycket problem eller ska jag inte?

stage mineral exploration therefore pertains to identifying localities where there is a potential that further exploration efforts will reveal mineral deposits that can be carried forward throughout the remaining exploration process. Desktop exploration lays the foundation for doing so as well as for future fieldwork in the target generation stage when the area is valuated and evaluated further on the basis of early-stage predictions.

Exploration permits and the end of desktop exploration

The sections above describe how mineral explorationists identify and select areas deemed to possess sufficient potential to warrant future exploration. Although uncertainty and complexity are prominent issues at this stage, the combination of exploration models and resources such as regional geological data and historical exploration materials help explorationists narrow their search for areas of exploration potential and allow them to move towards establishing exploration projects in these locations. Asking where discoveries may be made, prediction work in desktop exploration pertains to tracing geological clues while attempting to avoid locations pregnant with factors that may stand in the way of future exploration work and eventual mining before applying for exploration permits and leave the desktop for more boots on the ground type of work.

As discussed in chapter 2, exploration permits grant the holder the exclusive right to explore an area, and obtaining this permit is the first step towards later stage exploration and the use of invasive exploration methods.[67] Anne, a senior MIS officer, explained how exploration permit applications are assessed by the MIS. To be receive an exploration permit, explorationists need to demonstrate that there is reason to believe that discoveries can be made in the area. That is, areas are off limits that previous exploration has ruled out unless applicants can persuade the MIS to open up the area for more exploration work. A second criterion to be met by exploration permit applicants is that they should have the means, resources, and intent to carry out exploration work within the area applied for. Explorationists, in other words, may apply for permits covering areas no larger than they have the resources to explore, and they are not allowed to amass exploration permits for other reasons than

[67] Invasive methods are any methods that cause such impact or disturbance to a location that the activity cannot be carried out under Swedish freedom to roam rights. To use invasive methods, explorationists need to formulate a work plan detailing the exploration activities to be undertaken in the project. Moreover, before work can commence, the work plan needs to be accepted by affected property owners and interested partners and confirmed by the MIS (see chapter 2).

mineral exploration.[68] Applications, therefore, need to be supported with material that outlines the area's potential and the area needs to be limited so as to ensure successful exploration. If they have been successful in their desktop exploration, explorationists can apply for exploration permits and begin preparations for the next stage of exploration, target generation.

5.2.2 Target generation and drilling

Following the exploration permit and approval of the work plan outlined in chapter 2, explorationists go on to seek out particular locations within the chosen exploration area that may host sizable deposits of mineralized materials. Selecting an area at which to place a mineral exploration project allows explorationists to take the step from area selection to target generation. This transition means that explorationists begin work to identify and outline exploration targets in the form of deposits of mineralized material. After identifying a location, work begins to actually locate, map, and valuate deposits of mineralized material. During this step, mineral explorationists have access to a range of methods that provide a closer assessment of an area than was possible based on the historical, global, or regional data employed during desktop exploration. Three methods commonly used to accomplish this are geochemical sampling and analysis, geophysical surveys, and different forms of exploration drilling. This section will outline the roles these methods play in exploration work and how they aid in explorationists' prediction work at this stage in the exploration process.

Geochemical methods

Geochemical exploration methods rely on analyses of samples drawn from soils, till, riverbeds, and rock outcrops. The method works by combining sampling and analysis with stratigraphy and knowledge of the glacial morphology–i.e., how ice age ice sheets and ice melts have shaped and affected an area–in order to identify areas of relatively high concentration of mineral traces. As deposits do not exist in isolation and as minerals have been spread across larger areas by erosion, faults, and the movement of the ice age ice

[68] Although this may seem farfetched, the reason for why this may be done is similar to why environmentalists may buy up of carbon emission quota to prevent carbon emissions. Given that exploration permits in practice supplant property ownership, one could imagine an interested party not willing to accept mineral exploration on their lands applying for an exploration permit to render the area unavailable to explorationists.

sheets, analyses of the geochemical composition in an area can direct explorationists toward localities with a greater concentration of minerals deposited in soils and rock. Frank, a retired exploration geologist, explained the theory behind this use of geochemical methods in Sweden and other areas affected by the ice age saying that

> the theory guiding this is that the cover in these places is usually made up of moraine, and moraine was formed when the ice sheets shaved off pieces of the bedrock. And then you figure out what direction the ice sheets moved in. Most of the time it moves downhill when it melts, like most things in life [laughs]. And when it moves it drags along soil with it. So if this was a deposit that the ice sheet had moved across [refers to a candle holder on the table in front of him] then you get traces of it down-stream, so to say, in the direction of the ice's movement.[69]

Using geochemical methods, Frank continued, is therefore a way of assessing the exploration potential of an area. If there are plenty of traces of mineral in the samples drawn, then chances are that there is a deposit from which these traces originate somewhere nearby.

Using geochemical methods, explorationists are able to assess the general presence of mineralized materials in an area, but they may also use the methods to attempt to trace dispersed mineral matter back to their point of origin in a deposit. George, a former exploration geologist and experienced gold explorationist, provided examples of the latter. Talking about his experiences from gold projects he had worked on he recalled how they used geochemical analysis of soil samples to identify gold deposits by following the traces of gold dispersed across the area by the movements of the ice sheets in the last ice age. By tracing the prehistorical movement of the ice, George and his colleagues worked their way toward the gold deposit. This method, George explained, relies on observations of variations in the concentrations of mineral in the samples. Identifying where the samples showing the highest concentrations of gold were taken, George and his colleagues produced a new wave of samples and successively worked their way to the point where the traces stop and where one may assume is the far edge of the deposit. Geochemical methods, in other words, can identify localities within areas that show greater potential based on traces of desired minerals in surface materials and riverbed sediments.

[69] teorin bakom det, det är ju att jorden som ligger det är ju för det mesta morän och moränen har bildats utav att inlandsisen har hyvlat av berggrunden. Och då tar man reda på vad isen har gått åt för något håll. För det mesta går den neråt när den smälter. Som det mesta gör här [skrattar]. Och då drar den med sig jord i den riktningen. Om man då säger att det här skulle vara en malm som isen har gått över [visar med en värmeljushållare på bordet], då får man ju spår av den nedströms, så att säga, i is-riktningen.

The use of geochemical sampling and analysis, therefore, provides a way to evaluate and valuate an area in order to identify targets for further exploration as well as offer a way for explorationists to confirm or refine the predictions made in desktop exploration. John, a geologist and qualified person, described this refinement of previously made predictions as "grounding" the results produced thus far. Speaking before a class of advanced level geology and geo-engineering students, John continued by saying that fieldwork such as geochemical sampling allows explorationists to confirm, or ground, the desktop predictions. By gathering and analyzing physical samples, new layers of data are added that can be used to guide explorationists in the subsequent exploration efforts. A second method that helps explorationists ground their early stage predictions are geophysical surveys.

Geophysical surveys

Geophysical methods map qualities of the bedrock and can produce both global and regional data. Global data are an important resource to explorationists when seeking to locate areas of interest and one prominent source of such data are the airborne geophysical surveys carried out by the SGU. Regional data, on the other hand, are used to map the bedrock's geological properties within project areas. Like geochemistry, regional geophysics is another tool that explorationists can use to identify targets within larger areas, and since much of the equipment can be carried by hand or on the back of a person walking or skiing across an area, geophysical surveys can often be carried out without causing much impact to the area surveyed. Although much geophysical work can be carried out with relatively mobile equipment, some methods are more cumbersome and invasive. For example, bedrock conductivity measurements use long cables placed in the terrain and some methods include mounting the equipment on terrain vehicles, airplanes, and helicopters.

By measuring differences in the bedrock's conductivity, variations in radiation levels, shifts in gravity, or variations in the magnetic properties of the bedrock, it is possible to identify differences in the bedrock compositions and use these to identify potential exploration targets. This is more easily done for some types of mineralization than for others, however. The magnetic properties of some iron ores (e.g., magnetite) make them stand out against the non-magnetic rock surrounding them, explained exploration geologist Olaf. Although all types of deposits come with their challenges, compared to other metals and minerals, magnetic iron ores lend themselves comparatively better to geophysical methods, he continued. Exploration for other types of deposits still rely on and benefit from the use of geophysical methods, but the results tend to be more ambiguous than for magnetic iron ores. One example of how geophysical methods often provide less clear-cut results in exploration for other types of deposits than iron is the case of copper bearing mineralization, where it is hard to know whether the anomaly observed really is a copper deposit or a deposit of some non-economic mineral with similar geophysical properties. Eric, a geologist and senior officer at a junior exploration company, explained why this is, saying that

> if you were to take a bit of copper and burry it under the ground, let's say fifty meters underground, and you didn't know it was there; the signal that it would, ehm, or the character that it would have in your survey method is not unique. It could be the same as a lump of metal that doesn't have copper in it. So you've probably heard of fool's gold, pyrite? It would probably have a similar character. You can drill that and not have any copper.

Because different styles and types of mineralization may produce the same readings on the geophysical instruments used, geophysical surveys alone cannot provide sufficient information for any concrete prediction work beyond saying that based on the different physical properties of the rock in an area, there might be a copper-bearing deposit here. However, the indications given in the studies might also be something else, like pyrite, as different minerals share physical properties, effectively meaning that telling one mineral from another based solely on its magnetic or conductive properties may be comparable to attempting to tell a glass of water from a glass of gin on the basis of color alone. Therefore, it is important, Eric said, to gather many different layers of information using different exploration tools, summarizing it by stressing that

> The whole, ehm, one of the most important things of mineral exploration is that there's no one method that gives the answer for everything. So you build up layers of information.

That is, geophysical methods provide one layer of information used in exploration work and by identifying geological anomalies through geophysical survey, explorationists are able to outline areas that differ in their geological make-up from the surrounding bedrock. This helps explorationists construct maps of different underground zones, narrowing the area of exploration to marked anomalies that can be explored further using a third layer of information, analyses of drill cores produced through diamond drilling.

Exploration diamond drilling

While geochemical analysis and geophysical surveys are important resources in mineral exploration, exploration drilling is the premiere tool on the explorationist's workbench. Although other exploration methods produce depictions of geophysical anomalies or show traces of mineralized materials in riverbeds, soil, or till, drilling produces drill core samples from holes punched into the bedrock and allows explorationists to see, touch, and study the rock itself rather than approximations of the rock.[70]

In early stage target generation, drilling is used to check the results of desktop exploration and the geochemical and geophysical surveys, thereby grounding the predictions further. Based on the results accrued so far, Frank said, explorationists, or often the companies contracted by the explorationist's to produce the drilling, position the drill rigs and punch the first hole into the predicted deposit. Having done so, explorationists study the core produced and then decide on how to proceed. If the drill core does not contain the mineral sought, explorationists, Frank continued, will have to ask themselves whether they are "stupid" and have succeeded in missing the deposit all together or whether it is that no deposit is present there, despite what the desktop exploration and fieldwork predicted.

[70] There is also a second method of drilling available to explorationists: the cheaper but less detailed coax drilling, which extracts materials from the top of the bedrock, allowing explorationists to analyze the more general composition of the bedrock.

Image 3. Drill cores, intact and split (photograph by author)

How exploration work proceeds when drill cores have been produced depends on whether the materials in the cores confirm the likely existence of exploration grade targets. Based on analysis of the drill core, explorationists decide how to proceed–perhaps the drill core contained too low amounts of mineral or perhaps it contained more mineral than expected. When faced with low levels of mineralization in the core, explorationists follow up on these by repositioning the drill rig and continue the search for the expected mineral deposit by punching another hole into the bedrock. However, while it is necessary to follow up on negative results, many informants discussed how continuous drilling without producing viable targets that support further exploration work is a poor strategy as it puts explorationists at risk of spending resources without finding any minerals. Drilling the "wrong" targets is perceived as an important risk in mineral exploration as core drilling is both expensive and time consuming. While, early stage desktop exploration costs little more than the salary of the person doing it, diamond drilling is expensive and contributes to the steadily increasing costs of mineral exploration over a project's lifetime. Each meter drilled cost about SEK 700 to 1000 ($74 to $105) and the cost of collecting and analyzing the tens of thousands of meters of drill cores that are typically needed to carry a project all the way to a mine development is a significant post in explorationists' budgets. Moreover, Olaf explained, in addition to being costly, diamond drilling is also time consuming as, depending on the quality of the rock and the depth of drilling, one day of drilling[71] will only produce about 50 meters of core. Therefore, making sure that one is drilling in the right place is key to successful exploration, or as junior company senior officer Maxwell put it:

> And I can tell you that, it sounds a bit weird, but you often have to kill your babies, you know, kill your darlings. It is easy to spend too much money on bad projects, y'know. So what you need to do, is to find ways to kill off projects as quickly as possible [laughs] so that you are not spending time and money on the wrong things.[72]

While an important resource and a necessary undertaking in mineral exploration, as Maxwell notes drilling also comes with risks. Therefore, deciding where to position the drill and being prepared to abandon a location at the earliest signs of poor exploration results is the next step in the chain of decisions that began with explorationists choosing what areas to explore and which to ignore. Given a project returns results that keep it going, analysis of drill core materials allow explorationists to assess the mineralized materials in the cores, begin work to generate and define potential targets, and build a picture of what the deposit looks like in terms of its grades and mineralogy (i.e., mineral composition).

Target generation drilling is the culmination of the target generation phase and provides an important line of data with which explorationists can further ground the predictions they made during desktop exploration and geochemical and geophysical work. That is, target generation in essence builds on combining different methods and materials to produce a foundation for predicting whether a deposit is likely to possess qualities that validate spending more time and money drilling, defining, and evaluating. Moreover, target generation involves comparing and ranking different projects according to their estimated exploration potential. Therefore, ranking projects means ranking them not only into categories of "go" and "no go," but in terms of their estimated potential. This approach implies explorationists are open to dropping projects that have discovered mineral deposits but which have been deemed less promising than other projects. Richard, a senior officer with a mid-tier organization, explained how he and his colleagues approach this and provides an example of how target generation combines all the different aspects discussed here to compare and rank the targets generated:

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[71] The time it takes to drill a meter of core increases with depth as the drill rods need be taken apart as the core is lifted; the deeper one drills, the more rod there is to take apart.

[72] Och det kan jag säga, det låter lite konstigt men många gånger är det så att du måste kill your babys, alltså kill your darlings. Alltså, det är lätt att spendera för mycket pengar på dåliga projekt. Så därför gäller det att hitta vägar att döda projekt så fort som möjligt [skrattar] så att du inte håller på och ödslar tid och pengar på fel grejer då.

> You have many parameters; geophysics, geochemistry, all these that you combine to figure out that: Alright, if you have two drill holes that are fifty or five hundred meters apart and you have a clear anomaly between these two holes, then of course the anomaly between the holes five hundred meters apart is more interesting than the one with only fifty meters between the drill holes.[73]

However, although target generation helps explorationists determine which potential targets to drop; target generation ranks possible targets using a very limited understanding of the geological qualities at the different sites. Several informants confirmed that project generation and the subsequent evaluation and valuation of the targets generated aim to identify projects that possess sufficient qualities to warrant more work. Therefore, target generation is not meant to identify the best project, but to identify the projects that are good enough. It is not even certain that explorationists will work all the projects they have on hand, as this would strain resources. Maxwell provided an example of this: if one has five projects and gets lucky with projects 1 and 3 (but not with project 2), one may choose not to do any work on projects 4 and 5. According to Maxwell, this would allow one to concentrate exploration efforts and resources on the projects that have already been shown to host potentially minable deposits instead of risk spreading resources too thin by also carrying out exploration work on projects 4 and 5.

5.2.3 Geological mapping

Whereas the outcome of desktop exploration are predictions of exploration potential and an application for an exploration permit, the outcome of target generation work described here is a map of the geological environment where a project is located. Such geological maps contain the qualities and shapes (i.e., lithology and morphology) of different host rocks[74] and other rock in the area, an outline of mineralized zones, and statements on ore genesis in the area – i.e., a description of how the mineralization was formed, where it came from, how it was transported, and how it was trapped in its position. Peter, compared this assemblage of information to a large jigsaw puzzle where explorationists need to sort the pieces into piles and then assemble them section by section. Using the picture that emerges in these assemblages, geologists create geological maps that outline the geology of the area complete with a story of how it

[73] Man har ju många parametrar; geofysik, geokemi, alla dom här som man kombinerar för att se: Okej, om du har liksom två hål som har femtio meter mellan sig eller två hål som har fem hundra mellan sig och du har en tydlig anomali mellan dom här femhundra, det är klart att den är mer intressant än den som är bara femtio meter mellan hålen.
[74] Host rocks are bodies that host mineralized material or other types of rock.

originated and of its mining potential. Keeping with the jigsaw analogy, creating these assemblages involves two very different skillsets: one skill is to grasp the overall pattern of colors, shapes, and motives of the jigsaws pieces and a different skill is to be able to act on the emerging patterns and to begin putting the jigsaw together. Maxwell explained how these two different skillsets apply in mineral exploration:

> One can say that you work with two kinds of exploration geologists; first, you have the ones who want to write the third chapter in the Book of Genesis, and then you have the ones who want to open a mine. And you need both, right? For the first bunch, it's all about understanding how the geological environment was formed, right? You know, who want to make a sort of origin story for how this has come to be, right? So you need them. But at the same time, these guys are perhaps not really on the ball "tschikk-tschikk let's go make a mine!" [. . .] So you need to make sure to have the right kind of people working on that dimension so that you get it forwards, so to say. For the first group, risk does not exist. To them it's all about knowledge, right? To build knowledge. For the second group it's all about risk and benefit. To those prospectors it's like: Is there enough here to make this a success or not?[75]

The creation of geological maps and the outline of host rocks, transformation zones, and mineralized bodies depend on explorationists building an understanding of the geological events that took place in the area. Ian, a junior exploration company CEO, explained this as an attempt to understand events that took place a long time ago and relate these events to the present mineralization and its future minability:

> It's a very forensic kind of way of thinking. Because you're dealing today with, you know, probably in our area anyway, just under two billion years of earth's history. So how does that apply?

The geological maps produced during these early stages support further exploration work as they provide the foundation for the addition of new information. As such, geological maps play an important part in reducing the uncertainty of what geological qualities there are in the project, and accomplishing this depends on the combination of several layers of information. Signs of

[75] Då kan man säga att man jobbar med två sorters prospektörer, prospekteringsgeologer; dels är det dom som vill skriva tredje kapitlet i skapelseberättelsen, och sedan är det dom som vill starta gruva. Och båda behövs, va? För det handlar om att förstå hur den här geologiska miljön skapats, va? Alltså att göra ett slags skapelseberättelse för hur det här blivit till, va? Så att man behöver dom också. Men dom är samtidigt lite mer, kanske inte sådär på hugget ”tschikk-tschikk att här ska det jäklar starta en gruva” (…) Utan då måste du se till att man har rätt människor som jobbar med den delen också så att man får upp, så att säga.. För dom första finns inte risk, då är det kunskap det handlar om, va. Att bygga kunskap. För dom andra handlar det om risk och benefit, liksom, för dom prospektörerna; ”Finns det tillräckligt mycket för att det här ska kunna bli en framgång?”

geophysical anomalies or intercepts of mineralized materials in drill cores, after all, are not necessarily evidence of large bodies of minable mineralized rock. For example, the mineralized materials found in two drill holes might have originated in small isolated lenses of mineralized material rather than from one large mineralized deposit. Combining early stage exploration data in geological mapping, explorationists make interpretations of the geological make-up of the underground so that the patterns produced from survey work and drill core analysis can be extrapolated into an estimated deposit of mineralized rock.

After explorationists have surveyed a project area's geology and outlined an anomaly by surveying and drilling to confirm its mineral content, composition, and grades, work can begin to transform it from a geological entity into a second nature artefact based on its economic, technical, legal, and socio-environmental qualities. Such a transformation relies on the combination of information about the past and present in the form of the forensic information on plate tectonics and ice age ice sheet movements described by Ian and George, and present day observations on geophysical anomalies and grade distributions. Based on these efforts, explorationists are able to outline the potential minability of the project. It is at this point that prediction work turns from being primarily concerned with answering questions about the potential for discovery to answering questions about future minability as defined in relation to present future resource exploitation and mineral markets. However, before turning attention to the next stages of the exploration process, some concluding remarks on early stage exploration are needed.

5.4 Concluding remarks

Based on the accounts above, what stands out about early stage mineral exploration is that the high levels of complexity and uncertainty involved in the search for areas of exploration potential makes early stage exploration work sound almost like looking for a needle in a haystack.[76] However, early stage exploration is something very different altogether. The work through which explorationists use different valuation devices to search for patterns of exploration potential is, actually, nothing like looking for a needle in a haystack. Rather, the search for areas of exploration potential and the work to identify and drill exploration targets is more like looking for a certain quality of needle

[76] The use of this expression "a needle in a haystack" as a reference point in discussing explorationists decision making is borrowed from March and Simon's discussion of rationality in choice situations (1958).

in a stack of needles. Deposits of mineralized material can be found in many places in the earth's crust, but only a few of these deposits are of such quantity and quality that they are minable, so mineral exploration is a very different activity to the idiomatic search in a haystack, and there are two reasons for this. First, mineral explorationists have access to a wide range of support, a condition the analogy does not consider. For example, explorationists have access to historical data and support from actors such as the Swedish Geological Survey, who provide a general foundation of data, which can be combined with theoretical and experiential models to allow explorationists to value the potential in different localities in order to narrow down their search for discoveries. Moreover, the haystack analogy does not consider whether the needles are more likely to be found in some parts of the haystack and not in others. That is, explorationists use information, albeit incomplete, to uncover trends or patterns that they can use to make predictions about where minerals might be located. The haystack analogy implies a search for a needle will be random–i.e., exploration without any knowledge that can be used to predict where the needle might be located. In addition, explorationists regularly work in localities that are far from blank slates. Mining is a human activity with a very long history and has left traces both physically and in historical accounts. Even green field explorationists working in new areas where no mines have been established are often aided by materials such as the Geological Survey of Sweden's archives and global or regional geological survey work. Furthermore, desktop exploration and target generation use tools that provide explorationists with increasing volumes of information that allow them to highlight areas of interest for further exploration while dropping other areas.

The second and most important difference between early stage mineral exploration and searching for a needle in a haystack is that mineral exploration does not aim to identify any deposit but one that appears rich and large enough to warrants further exploration work. Explorationists, in other words, are not looking for any old needle, but for specific needles, targets that indicate a project should continue to the increasingly costly and complex stages of intermediate and advanced mineral exploration. Maxwell emphasizes the importance of "kill darlings" (i.e., dropping projects) as quickly as possible, and Frank emphasizes how each step along the exploration process means asking oneself whether the expected gains from investing in further exploration justifies the costs of doing so. Therefore, early stage mineral exploration entails a form of prediction work that asks two questions: What areas are likely to hold sufficient exploration potential and does the targets generated in this area possess the qualities sought? Moreover, these two questions make prediction in mineral exploration different to predictions discussed in the existing sociological literature on predictors. The source of these differences can be found in how explorationists make predictions. Although explorationists follow the same logic of data collection, pattern identification, and projection as meteorologists (Fine 2010; Sundberg 2005) or financial analysts (Leins 2018; Pilmis

2018), few would expect prediction workers in these fields to first have to go out and look for weather or roam the streets of large cities looking for financial markets. As a result, mineral exploration involves a first step of prediction work not present in meteorology or financial analysis as explorationists must first predict where to find a mineral deposit before they can predict what its minability prospects are.

Following the selection of an area in which to situate an exploration project, work begins to generate and map targets. As was discussed in chapter 3, predictions are meant to help answer questions and the way explorationists seek to accomplish this is by gathering data in which they identify projectable patterns. As long as a project shows potential, they keep working on the project. To determine whether a project should continue, explorationists rely on a set of valuation devices that are deployed to produce the geochemical, geophysical, and drill core data and to establish patterns in the gathered materials that can then be projected onto the future. Among these valuation devices, the exploration models that outline the geological environment and mineralization sought for as well as what social and environmental circumstances are tolerable play a central role. The importance of exploration models comes from how they enable explorationists to delimit the scope of materials and patterns sought for in exploration work. This delimitation is one of the first valuations that explorationists undertake and it helps them negotiate the complexity of geological nature and provide a baseline against which projects can be valuated and ranked, an approach similar to March and Simon's (1958) discussion of the role of rationality in the discovery and selection of optimal contra sufficient alternatives.

According to March and Simon, most human decision-making concerns itself with identifying and selecting alternatives that are sufficient rather than optimal. This, March and Simon argue, is because identifying optimal alternatives is an exercise "several magnitudes more complex" than merely identifying and selecting a satisfactory alternative as the former implies "searching a haystack to find the *sharpest* needle in it" and the latter implies "searching the haystack to find a needle sharp enough to sew with" (March and Simon, 1958:141). Based on the accounts above, it is fair to say that the first two stages of mineral exploration work primarily on sufficiency and this sufficiency is determined in relation to the estimated geological and economic potential in a project and the socio-environmental circumstances surrounding it. However, these criteria do not primarily concern the present but they concern the present future in that they revolve around the potential of something turning out to be of such quality that it warrants more exploration work or that the socio-environmental circumstances are of such a nature that they will not cause issues in future exploration and permitting processes. That is, although a project may be sufficiently promising, these promises are mere projections of potential futures and therefore remain uncertain. This concludes the discussion of the desktop exploration and target generation stages. The next chapter outlines the final two stages of the exploration process and the prediction work carried out as explorationists turn from attempts to predicting the likelihood of making discoveries to predicting the future minability of discovered mineral deposits.

6. Intermediate and Advanced Stage Exploration

This chapter focuses on the stages in the exploration process that follow the initial exploration work outlined in the previous chapter. At this point in the exploration process, explorationists tend to have reduced the number of active projects; they have, as Maxwell put it, effectively "killed their darlings" and are now focusing their efforts and capital on a smaller number of projects. By reducing the number of areas under exploration, explorationists give themselves room to move in closer and study the most promising sites in greater detail. Intermediate and advanced stage exploration entails that explorationists begin work to ground their estimates even further by confirming the quantity and quality of mineralized material in the ground. However, to predict the minability of the mineral, explorationists also need to lift their gaze to look at the deposit's minability as second nature, taking into account future economics as well as its location within and potential impacts on a social and natural environment. What are, for example, the projects potential environmental impacts and how can they be managed? Are there any foreseeable challenges that need be overcome to obtain the necessary permits? What will the market look like when the projected mine is expected to begin operations? While early stage exploration needed to find ways to manage the complexities and uncertainties of geological nature, intermediate and advanced stage exploration projects face economic, technical, legal, and socio-environmental uncertainties that need to be managed before explorationists are in a position to establish confident predictions regarding the future minability of the projected mine. This chapter will outline the work undertaken by explorationists to produce such confident predictions as well as the different stages of prediction work they go through to get there. The first of the following sections outlines the data collection activities undertaken by explorationists at this stage. Following this first section, the chapter follows explorationists as they return to the desktop where they assemble the data collected in the field and use it to construct geological models of the deposit and estimate the quantity and quality of minable mineral. The chapter's third and final section outlines the different studies that assess overall project feasibility and deposit minability in light of what is known and what is predicted at the time.

6.1. Intermediate stage fieldwork

The previous chapter ended with explorationists establishing geological maps and reducing the number of active projects in order to focus their efforts and capital on the project or projects seen to possess the greatest potential to turn out producing minable mineral deposits. Picking up where the previous chapter left off, this chapter will now map the prediction work undertaken in the subsequent stages of mineral exploration and the exploration efforts that go into building increasingly detailed predictions of the projects' future minability. This first section focuses on how explorationists assemble increasingly detailed data on their projects to facilitate predictions, and it does so by focusing on three areas of exploration work that come into play in intermediate and advanced stage mineral exploration: (i) intermediate and advanced stage follow up and resource drilling; (ii) metallurgical analyses and pilot studies; and (iii) environmental impact surveys and analyses.

6.1.1 Drilling a project

The exploration drilling initiated in the final stages of the early exploration work is intensified during the intermediate and advanced stages. Moreover, while early stage drilling aims to confirm the results of other geological survey methods and generates exploration targets, intermediate and advanced stage drilling aims to establish a knowledge base of deposit quality, quality, and geometry based primarily on drilling results and analyses of drill core materials. However, while more data ultimately translates into reduced complexity and better estimates, drilling is a time consuming and expensive exploration method wherefore explorationists need to balance the need for and cost of drilling. George, the former exploration geologist, emphasized this point saying that: drilling should be deployed to obtain as much information as possible from as few holes as possible. This is evident in the archival materials such as the exploitation concession applications where explorationists-in order to support the claims they make about the minability of a deposit-provide detailed descriptions of the exploration work undertaken on the deposit. Across different projects, one can follow how explorationist have drilled their projects in increments, using the results from previous drilling to justify further drill holes. Senior exploration geologist Olaf provided additional depth to this description when he explained how this stepwise movement between data collection and decisions to continue drilling differs between projects:

> At first, you have something like two or three drill holes in a profile, and then you continue a bit to the side. What happens then depends on what you are looking for. If it's iron ore, then you can space the profiles a bit further apart. If it's gold, then you might have to space them more closely.[77]

Starting with a few drill holes, explorationists adapt their work according to what type of mineralized deposit they are working on so that their drill work matches the challenges and properties of the type of mineralization explored. For example, large iron ore deposits are easier to estimate then are nuggety deposits such as gold or diamonds wherefore explorationists working on iron ore projects are free to space their drill holes more sparely than they would if they were working a gold project. Nevertheless, despite these adaptations, drill plans essentially follow the same logics and if the results from the initial drilling is promising enough, Olaf continued, additional drilling will be undertaken:

> Well yeah, you try to keep the drilling to a minimum in these initial stages. But when you begin to see that there might be a mineralization of some significance here, then you will want to drill even more closely in order to confirm what the deposit looks like.[78]

Exploration drilling in the intermediate and advanced stages of a project, in other words, entails a trade-off between data collection and costs as explorationists need to gather more data to improve their estimates and confirm the continuation of the mineral deposit between drill holes while at the same time keeping expenditures as low as possible. Drilling profiles along the length of the deposit, explorationists thereby add to the results from the target identification and generation stages and this allows them to develop an increasingly detailed picture of a mineralized deposit's quantity, quality, and geometry.

In addition to the trade-off between data collection and costs described by by Olaf, Richard, a senior mid-tier company officer, identified projections of a deposit's minability as a third important factor in intermediate and advanced stage drilling. According to Richard, the way explorationists approach drilling is generally more abductive than inductive as the guiding question remains–as it was in early stage exploration–whether or not the deposit can be expected to be sufficiently minable. The important question is therefore not how large a deposit is, but whether it is large enough to support a profitable mining operation. When approaching drilling, Richard said, explorationists begin by drawing up what they perceive to constitute a minable deposit given what they

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[77] I början så har man ju kanske två-tre borrhål i en profil och sedan går man lite längre åt sidan. Sedan beror det på vad man letar efter. Är det järnmalm då kan man ta lite längre mellan profilerna. Är det guld så kanske man måste ha tätare mellan

[78] Men alltså, man försöker ju hålla ner borrningarna i det här första skedet. Men sen när man börjar se att det kanske är en mineralisering av någon dimension, då vill man ju gå in och borra ännu tätare för att bekräfta att det verkligen är så den ser ut den här kroppen.

know about the mineralization under exploration and what they believe will be the future conditions for mining it in terms of costs and potential incomes. Drilling in intermediate and advanced exploration, Richard said, begins with the observed grades in the drill cores produced in target generation. These observations are then combined with cost estimates for the projected mining operation. Using these two factors, explorationists estimate how rich and large a deposit would need to be to carry the costs of exploiting it. Given the observed grades and proposed mine plan, explorationists calculate the potential minability of a project, Richard explained:

> You say that this is the situation right now and then you make an estimate; "We are going to need so and so many tons" and then you see that "We have two drill holes five hundred meters apart, but for this deposit to be minable we are going to need it to be two kilometers long, and two hundred meters deep, and of a certain width" so it's nothing more than setting up a volume that contains enough copper for it to carry itself economically. And then you develop your strategy; "How are we going to drill this thing?"[79]

As explorationists add more data to the image they are developing of the deposit, they are able to reduce complexity and evaluate the minability of the estimated deposit against a background of grades and volumes taken to mark sufficient minability in a project. However, while complexity is reduced, uncertainty remains, as it is still far from known whether the deposit can be mined and concentrated at a profit.

Having identified deposits believed to possess such qualities and quantities that they warrant further exploration, further drilling commences as explorationists begin to work toward improving the foundations for prediction. Such improvements often mean increasing the total volume of data. Exploration projects regularly produce many kilometers of drill cores as large volumes of data are necessary to build accurate and precise estimates of the tonnages, grades, and geometries of the mineralized deposit underground. Exactly how much core is produced varies from project to project and between new green field projects and projects where explorationists rely to some extent on reusable historical exploration work. This variation is visible in the archival material and the exploitation concession applications that cite intermediate stage exploration drilling amounting to between 1.5 km and almost 16 km. When asked how much work is typically put into drilling, Carl, a mining engineer and qualified person, stated that, depending on the size of a project, most projects end up producing between 50 and 100 drill holes, which together amounts to thousands of meters of cores. As drilling progresses, these holes

[79] Man säger att den ser ut såhär ungefär och sedan räknar man ”Vi behöver så många ton” och då ser du ”Två, borrhål, fem hundra meter, men ska den vara brytvärd så behöver den vara två kilometer lång och två hundra meter djup med en viss mäktighet då, bredd” så det är helt enkelt så att du målar upp en volym som innehåller tillräckligt med koppar för att det ska bära sig. Och då lägger du upp en strategi för ”Hur ska vi borra upp den här?”

begin to form a grid of successive cross-sectional profiles that stretch the length of the deposit.

In addition to producing significant volumes of drill core material, explorationists also seek to ensure that the quality of the data is sufficiently high. As deposit estimation depends on each inch of core being relatable to a position in the mineralized deposit, drill-hole deviation and sample integrity are important factors in determining the quality of the data produced. To facilitate sample integrity and data quality, CRIRSCO standards outline quality assurance and quality control programs (often abbreviated as QA/QC), including everything from drill-hole deviation measurements to drill core storage security and tests for accuracy and precision in metallurgical analyses.

6.1.2 Drill core analyses

Once pulled out of the bedrock, the drill cores produced in exploration drilling are logged, photographed, and divided into sample sections before they are sent to a laboratory for preparation and metallurgical analysis. The preparation of drill cores for analysis generally includes halving or quartering them using either a diamond cutting blade or a core splitter[80] whereafter one half the core is archived and the other half is used for analysis. The sample lengths of at least a quarter of the core[81] are then crushed, ground, and divided down into small samples of a few hundred grams[82] before they are sent to a laboratory. The images below depict examples from this process. The first image shows the un-split cores stored in a core box with blocks inserted between the core sections; the core sections and sample intervals are marked on the partitions (Image 4). The second image shows a bag of finely ground sample material (Image 5).

The laboratory analysis used, of which there are many, depends on the type of mineralization. Carl explained that, as there are many different tests available at the laboratories and different tests are better or worse suited for analyzing different types of deposits, explorationists always need to be able to argue for why they selected one method of analysis over another. When the core has been prepared for analysis and a method of analysis has been selected,

[80] A core splitter consists of a diamond-encrusted blade that is dropped on the core along its length in order to cleave it.
[81] Whether half cores or quarter cores are sampled depends on the explorationists' approach as they may be using the other quarter of the non-archived half for further analyses later in the exploration process.
[82] The recommended size of the ground samples depends on what diameter drill core is used, but lie in the regions of between 200 and 700 grams.

explorationists usually send their samples to an accredited laboratory. As accuracy of test results is a prerequisite for high quality mineral deposit estimation, the procedures involved in shipping drill core samples for analysis are relatively intricate. Explorationists may choose to send their samples to different laboratories and then have the results from these laboratories analyzed against each other. Examples of this can be found in the reports present in the archival material describe explorationists comparing the precision of laboratory analyses using regression analysis and comparing R^2 values for the variance between two populations of laboratory analyses. Standard practice furthermore involves additional QA/QC measures to test laboratory accuracy and precision. These tests involve including different forms of controls with the samples such as duplicate samples, standardized samples with known grades of mineral content (such samples can be purchased from different laboratories), as well as blank samples. When used, these duplicates, standards, and blanks are included with the drill core samples and help explorationists establish confidence in the laboratory results. By analyzing the drill cores, explorationists are able to assemble data on the grades of mineral in the deposit and relate these results to specific locations in the bedrock.

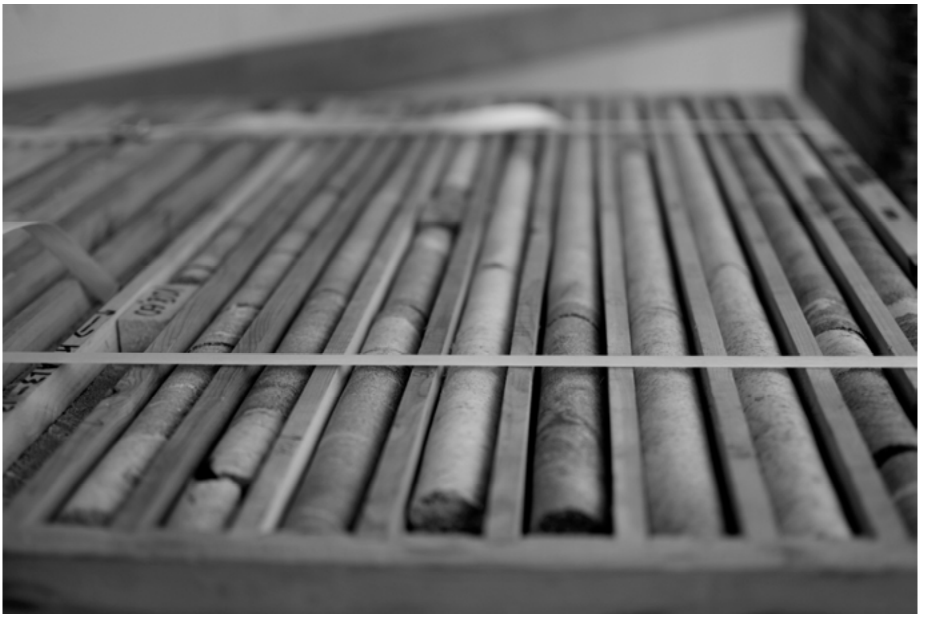

Image 4. Drill cores laid out in boxes and marked for sample intervals (photograph by author)

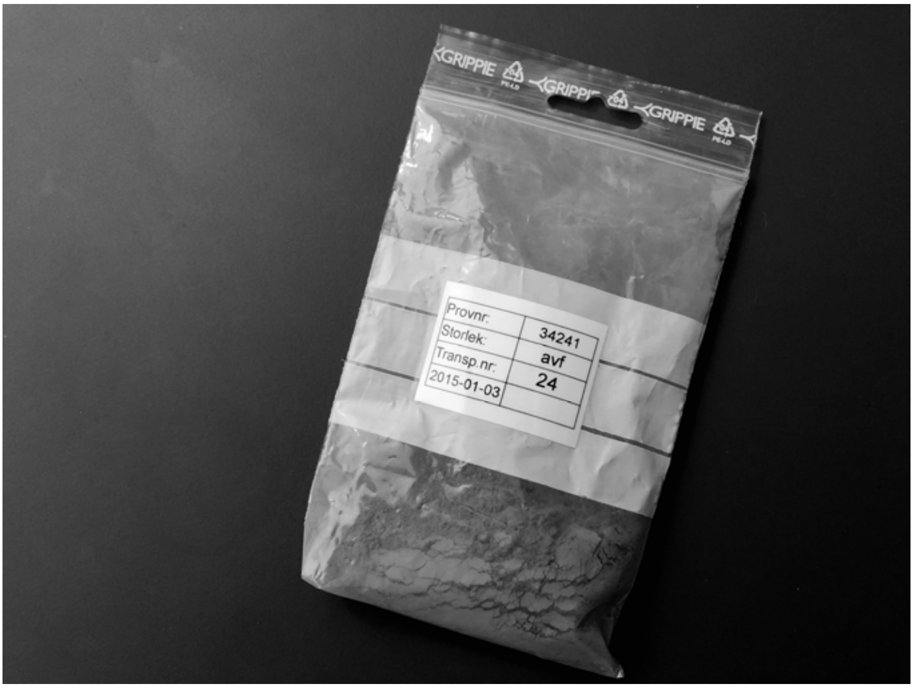

Image 5. A bag of finely ground sample material (photograph by author)

In addition to data on grades and grade distributions, analyses of drill core samples also provide information on the metallurgical qualities of the mineralized materials. Deposit metallurgy (i.e., its properties and behavior in relation to its purification and concentration) is a central dimension in determining the minability of a mineral deposit as it determines what rate of the mineral can be recovered in concentration processes as well as to what degree of concentration can be achieved in the resulting product. While small scale metallurgical testing uses drill cores materials, later stage analyses may use samples drawn from test mining to provide sufficient volumes of material for the processes. At either stage, the test work analyzes the composition of the mineralized deposit and studies how the materials react to concentration processes in order to estimate how much mineral can be recovered from the ore using a certain processing method. Using small or pilot-scale analysis methods, one can evaluate the returns produced when using a certain method such as magnetic concentration, gravity concentration, flotation processes, or leaching[83]

[83] The listed processes are different means of extracting mineral from the ore and reducing it down to a sellable product. Reduction typically involves beneficiation of the extracted or and

as well as what degree of beneficiation (i.e., crushing and grinding) of the ore is required to achieve sufficient mineral recovery. The exact circumstances, such as where these tests are carried out, depends in the explorationist's organization. Some organizations hire laboratories or consultants and some, mainly mid-tier and major organizations, own their own pilot testing facilities. Mining engineer Lars, who works in project evaluation for such an organization, explained that his organization uses metallurgical pilot testing to estimate the potential future value of a mineral deposit:

> And then of course, when the project has come a bit further, then we do actual concentration tests. We have a so-called pilot plant at hand where we can crush, grind, and concentrate using drill cores, for example. Those are the first studies undertaken. And when doing this, we create a sellable concentrate in miniature format. And this can then be valuated.[84]

Following such analysis, explorationists are able to select the methods showing the greatest promise as well as begin work to design and optimize concentration process to be used in the mining operation. Metallurgical analysis also alerts explorationists to any presence of polluting minerals or materials in the ore. Polluting materials are an important risk in mining operation design as impurities in the sold ore concentrate may cause problems further down the value chain, so market actors such as smelters tend to apply premiums to concentrates of grades above market standard and penalties to concentrates of lower grade or with too many impurities. The problems of impurities relate to the chemical properties of different materials. For example, phosphorus or magnesium have such metallurgical properties that they cause problems in iron ore smelting and in the quality maintenance in iron ore processing. In addition to affecting the quality of the product, ore impurities can also produce higher costs of concentration as in the cases of uranium in copper ores. However, phosphorous, magnesium, and uranium are far from the only substances that may affect the minability of a deposit. According to exploration geologist

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later treatment using one or a combination of concertation methods. Magnetic separation is based on the magnetic properties of certain ores through which they can be separated from the gangue by means of magnetic sorting. Gravity concentration separates ores from rock by use of differences in their movement when subjected to a force such as shaking. Flotation concentration relies on methods of rendering finely ground ores hydrophobic or hydrophilic depending on the method and then separating ore from gangue by blowing bubbles through the solution whereby the ore adheres to the surface of the bubble and floats to the top of the solution. Leaching concentration methods use chemicals such as cyanide, ammonia, alkalis, and acids that convert the ores into soluble salts. An alternative method of leaching is bioleaching, which relies on mineral oxidizing bacteria.

[84] Sedan är det klart att när projektet kommer lite längre, då gör vi ju faktiska försök. Vi har ju ett så kallat pilotverk där vi kan krossa, mala och anrika från borrkärnor, till exempel. Det är ju de första försöken som görs. Och skapar då i miniformat en säljbar slig. Och då kan ju den värderas.

Keith, toxic heavy metals such as mercury, arsenic, and cadmium are, what he called, "show stoppers" as too high concentrations of these metals in ore significantly increase the complexity and cost of concentrating the product, thereby decreasing the chances of successfully mining and concentrating the ore. The metallurgical properties of a mineral deposit are therefore crucial for determining its minability. The presence of impurities and challenges to achieve sufficiently high recovery rates, thereby producing too low grade product are therefore two potential "show stoppers" that explorationists need to manage in the intermediate and advanced stages of the exploration process. Explorationists therefore often conduct repeated metallurgical studies in order to analyze and fine-tune their product and concentration processing.[85]

6.1.3 Environmental investigations and impact assessment

A third domain of fieldwork and studies in intermediate and advanced stage exploration is the work that goes into assessing the degree of future environmental impacts as defined in the Environmental Code. Consisting of surveys of the socio-environmental landscape and a classification of environmentally valuable objects as well as archeological remains and mappings of the flora and fauna in the area, environmental impact work in mineral exploration focuses on producing a knowledge base for environmental impact assessment. Regulated by the Swedish Environmental Code, an Environmental Impact Assessment (EIA) is required to account for the direct and indirect effects that the projected mine could have on the environment (The Swedish Riksdag 1998, 6th chapter 3 §). An EIA, a relatively large undertaking, requires explorationists to undertake surveys as well as studies in which the present conditions of the flora, fauna, air and water quality, landscape, climate, and sociocultural environment are mapped and the mine's potential impacts on each of these dimensions are analyzed. In addition, an EIA requires explorationists to estimate a mine's impact on national and regional environmental quality objectives and environmental quality standards.

In practical terms, EIAs are often produced by specialized consultants and are based on a combination of surveys and models. The surveys undertaken

[85] This is regularly done on table top or pilot scale in order to fine tune the processing before scaling up to operational size. Risk do remain, however, as the product from the full scale processes may produce different results than the small scale versions did.

include mapping and classifying any environmentally valuable species, substrates, and biotopes in the area around the deposit,[86] surveys of the water quality, fish stock sampling using nets or electrofishing, studies of river and lakebed faunas, surveys of archeological remains around the site, as well as noise, vibrations, and pollutant emission analyses. Based on these surveys, a present day status is produced for each of the dimensions listed in the Environmental Code as well as for the 16 national environmental quality objectives[87] and the environmental quality standards. Estimated impacts based on studies and assessments are then presented in relation to the present day values in each dimension. Examples of such estimations are common in the archival material and include the use of continuous measurements of the noise emitted from an established mine to estimate the likely implications of increased production levels, model-based estimations to project a mine's impact on the water table, and geological mapping to estimate the volume of acidifying rock in future gangue (i.e., commercially valueless materials) piles. In addition, a subset of an EIA analyzed for this dissertation rated the predicted environmental impact along a scale of positive impact, no impact, negative impact, and temporary negative impact. In EIAs that did not employ ratings for the predicted impacts, these impacts were described in qualitative accounts of the impacts and the magnitudes of the impacts.

The explorationists' approach to EIA in mineral exploration is a relatively straight forward method of establishing a knowledge base, checking it against existing regulation, and estimating whether impacts can be expected to exceed the limits defined in regulation. Exploration geologists and consultant John, for example, explained that to him, the environmental dimensions of mineral exploration and project feasibility are primarily to do with engineering and finding technical solutions that limit the environmental impact. The challenging part of environmental work, he continued, is instead the social dimension, as while environmental impacts may be solved through technical solutions, disgruntled stakeholders may slow down permit processes to the point of increasing uncertainty.

However, while explorationists tend to approach the environmental dimensions of a project's minability as issues to be resolved in engineering, the Swedish environmental agencies, the environmental courts, and contemporary environmental policy often take a broader perspective. As a result, approaches come into conflict, which can be expressed either in terms of frustration with a lack of transparency in Swedish environmental regulation or in cynicism.

[86] Environmental value classification in Sweden is often conducted using a four tier system denoting particularly valuable environmental values, high environmental values, some environmental values, and low environmental value.

[87] The 16 national environmental quality directives include targets such as limited impacts to the climate, preservation of the ozone layer, reduced acidification, and were put in place by the Swedish Riksdag in 1999 and revised in 2005.

Exploration geologists and consultant Quinn expressed the former when suggesting that the broad approach of Swedish environmental agencies introduces uncertainty into the process. Therefore, she proposed, Swedish agencies have a lot to learn from their counterparts in other mining jurisdictions such as Western Australia, where environmental issues are dealt with in, what she perceived as, a more straightforward manner. Maxwell, on the other hand, had a distinctly cynical view on environmental impact assessment and regulation saying that:

> As an engineer, one would like to think that one should be able to calculate what the right thing to do is. But then you realize, as you get older that, it is the power over the words that matters [laughs]. And this is important. Classifying iron ore mining as environmentally hazardous, for example, that's awful, really! Sure, it causes environmental impacts, but there is nothing hazardous about it. There are many things in our lives that pose greater hazards to the environment than iron ore mining does![88]

Based on the explorationists' accounts of the permit process, the practical work described in EIAs, and the agencies' management of environmental factors described in the permit process documentations, environmental impact investigation in mineral exploration is a contested site. For explorationists, environmental impact assessment revolves around estimates of how existing socio-environmental values and conditions in an area could be impacted by the projected mining operation. Although engineers and CEOs such as Maxwell may wish to reduce this issue to manageable and calculable problems, the environmental regulation demands that explorationists prove that a projected mining operation will contribute to long-term resource husbandry; and doing so is a much broader question than merely finding technical solutions to minimize environmental impacts. However, building up a knowledge base with which to demonstrate that impacts are likely to be within the legal limits is a big step towards establishing minability in a project.

6.1.4 Summary

Although the early stages of exploration work focused on locating sites of exploration potential, intermediate and advanced stage exploration work require explorationists to engage extensive data collection activities as the questions at hand shift from where a significant deposit may be located to assessment of

[88] Som ingenjör vill man ju gärna tro att man ska kunna räkna fram allt vad som är rätt, men så inser man med stigande ålder att det är makten över ordet som är viktigt [skrattar]. Och det är det som är viktigt. Så att klassa järnmalmsbrytning som miljöfarligt, till exempel, det är ju hemskt egentligen! Visst, det är miljöpåverkande men det finns ingenting farligt med det. Det finns många saker i våra liv som är mycket farligare för miljön än vad järnmalmsbrytning är

the qualities of the deposit itself as well as its socio-environmental impacts. The systematic data collection work undertaken by explorationists at this stage sets the foundation for predictions of deposit minability as explorationists use drilling, drill core analyses, and environmental investigations and studies to assemble bodies of heterogeneous values to be used as data in predictions of present futures. This section has provided an account of how explorationists produce these assemblages. The next section will outline how explorationists use the data produced in exploration work to produce models of the geological environment, estimate the quantity and quality of minable mineral resources, and estimate the total economic value of the mine in the present.

6.2 Laboratories and desktop work: Modelling and prediction

Parallel to intensified drilling, drill core and metallurgical analyses, and socio-environmental investigations, explorationists begin working towards pooling these different pieces of information together to produce improved estimates of deposit minability. Such estimates involve geological modelling as well as models of the minable sections of deposits and calculations of the best approach to mining them in reference to maximizing the available economic value in a future mining operation. As part of this work, the exploration geologists and geophysicists who perform most of the exploration work up to this stage are joined by new categories of explorationists: deposit geologists and mining engineers. Senior mid-tier company officer Richard explained how their company is organized with these two different groups collaborating to manage the growing complexity of exploration projects as they mature to the intermediate and advanced stages:

> [O]n one hand we have the prospecting crew and then we have what we call a technology crew where we have the mining engineers and metallurgists, and it's a back and forth between them and you work together. [. . .] And it's a continuous collaboration between these two as when projects move forward. If you're having success, then more and more people are going to get interested and then you get more people to help you with prioritizing what needs to be done.[89]

[89] [V]i har dels prospekteringsgänget och sedan har vi det vi kallar för ett teknologi-gäng och där har vi gruvingenjörer, metallurger och det är som ett bollande fram och tillbaka och man jobbar ihop […] Och det är ett samspel hela tiden mellan dom här olika därför att allt eftersom det här projektet går framåt; har du framgång då blir fler och fler intresserade och då får du fler som hjälper till med prioriteringar av vad som ska göras.

Together the prospectors, who are often exploration geologists, and the technicians work to add new layers to the predictions of the projected mine's minability. Doing so, they move back and forth between first and second natures: estimating geological properties in a project before turning to estimate what consequences the geology has in terms of the volumes of minable second nature resources. This section describes how these estimates are made, what valuation devices are used, and how using them enables explorationists to translate heterogeneous values into common metrics in geological modelling and resource classification.

6.2.1 Geological modelling

Like early stage geological mapping, deposit modelling gathers geological information into a unified estimate of the geological reality underground and it does so using calculative devices that relies on geostatistical interpretation of the geological data in order to expresses the relation of observed grade samples as the result of a random function in a three-dimensional space.[90] The results of the geostatistical estimates are used in combination with topographical data to produce a three-dimensional model of the mineral deposit.

There are generally two types of models used to estimate mineral deposits where the first is a geological model that describes the geological reality underground while the second type is known as a block model and consists of an estimate of the volumes of minable material in the deposit. The difference between the two types of model was explained by a lecturer in a class on mineral exploration, economy, and risk and was captured in the field notes taken during this class:

> Geological models are wireframes of deposit volumes that differentiate the geological environment into sections of different characteristics. A block model, on the other hand, divides the mineral or ore model into geometrical shapes. Before you can develop a block model, you need to establish a geological model that differentiates different sections of the bedrock depending on their characteristics. This means that geological models precede block models in the estimation process.

Building a geological model entails loading observed and estimated mineral grade concentrations onto wireframes to describe the geometry and grade distribution underground. In contrast to this relatively descriptive approach, the more analytical block model takes the estimation further on the road towards

[90] This distinguishes geostatistics from general statistics as the latter holds samples to be realizations of a random variable rather than function and usually ignores sample positions.

becoming a prediction of second nature resources. This is done by explorationists adding layers of economic and technical considerations to the model to essentially cut away sections of the deposit that are deemed non-economic, leaving only its minable parts. However, while modeling may appear straight forward it requires explorationists to consider several issues related to the model's quality. Models need to be specified in such a way that they best corresponds to what is known about the deposit. As the geological realities underground do not necessarily correspond to the logics of geo-statistical estimation, explorationists therefore need to divide their model of the overall mineralized body into homogenous zones in terms of zone lithology, structure, mineralogy, weathering or structural alteration, grade distribution in space, degree of sampling, and analytical precision. Were explorationists to fail in correctly zoning the deposit, the resulting geostatistical estimate would be skewed meaning that the resulting image of the underground would be flawed.

The way in which a block model estimates the quantity of minable material is through dividing the estimated mineralized deposit into blocks between half to one-third the size of the drill spacing. Using statistical estimation, these blocks are then populated with grades based on the results from drill core analysis whereby also blocks lying between drill holes are assigned grade values based on a weighted composite of observed grades. Common statistical methods used in block modelling include inverse distance weighting and variations on Gaussian process regression analysis, or "kriging." Kriging analysis provides an interpretation of block grades based on the grades of the surrounding blocks and the relative distance to observed grades. When the block model has been populated with grades, explorationists begin work to delimit the minable sections of the deposit and divide them into categories based on their qualities. Such delimitation is done by applying cut-off grades to the model. Cut-off grades provide thresholds of minability and come in different levels corresponding to the estimated economics of extracting ores at different levels of profitability. Marginal cut-off grades denote the limit for when the extracted ore is economic to process if already mined. Such material can be extracted and stockpiled for later processing but does not in itself cover the cost of extraction. Operating cut-off grades are the limit for when the value of the extracted ore is estimated to cover all costs involved in extracting, processing, and selling it. Exploration geologist and consultant Quinn stressed the importance of working with appropriate cut-off grades: "[I]t's the geologist who has to decide what cut-off grade that fits the deposit best and that really is a lot of responsibility for a resource geologist." The grades included in the block model depend on what is appropriate for each project and therefore the expected cost for the project's products, the cost of mining, and type of mine. Carl explained how he uses different cut-off grades depending on what type of operation is planned:

> Yeah, you make an estimation. You set a lower limit for what to include. For example, it could be that if you're going down to a depth of 150 meters then it might be that you need at least one percent or 0.8 percent copper in terms of value if you're going to afford to mine this underground. It's more expensive to mine underground than in an open pit, right? While in an open pit mine, then you might be able to get by with zero-point-five percent copper. So you're taking this into consideration already when you're making your model. And when you do this you have a cut-off. So when you're drawing the boundaries of the ore body underground, then you're following that [cut-off] limit.[91]

In a break during the interview, Carl decided to show how block models work by turning on his computer to demonstrate a block model he was working on at the time. The model, which to an untrained eye resembles a jumble of Legos, is depicted as many brightly colored blocks and a series of thin lines representing drill holes all set against a dark background. The colors in the model, Carl explained, represent different mineral grades at different the cut-off levels. Using the translation of geological data into a block model, explorationists are then able to estimate the volumes of mineralized material at different cut-off grades. By doing so, explorationists can estimate the minable deposit at different future metal and mineral prices and to divide the overall deposit into units of varying profitability. Geologist and consultant John explained how this is done:

> It's pretty common to have an internal part of the ore body that is high grade and then you have some material out here that is low grade and perhaps even something here that is really low grade. If prices were to drop, then that's usually not good for the mine, but then you may alter this cut-off grade [. . .] until you're mining only high grade material in order to adapt to this new price or cost situation. And that's a way to manage this risk.[92]

Using block models and cut-off grades is one way to valuate mineral deposits as future mining operations. This method allows explorationists to combine geological data, technological considerations, and economic forecasts to outline a potentially minable mineral body. Mineral deposit models, in other words, help explorationists project and plan for different present futures as

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[91] Jo, men man räknar. Man sätter ju en lägsta gräns för vad man tar med. Till exempel då, det skulle kunna vara, om du ska ner på hundrafemtio meters djup att du, det kanske behövs minst en procent koppar eller noll komma åtta procent koppar värdemässigt för att du ska ha råd att bryta under jord. För det är dyrare att bryta under jord än i ett dagbrott, medan du kanske i ett dagbrott kan nöja dig med noll komma fem procent koppar. Så redan när man gör sin modell så tar man hänsyn till det där. Och då säger man att man har en cut-off. Så när man ritar sina malmgränser då under jord så följer man den där gränsen.

[92] Det är ganska vanligt att man har en intern del i malmkroppen som är high grade och sedan en del som ligger här ute som är low grade och kanske till och med någonting här som är riktigt low grade. Om metallpriserna skulle sjunka, oftast är det inte bra för gruvan men man kan ju ändra den här cut-off grade (…) tills man bryter bara det som är high grade ore för att möta den nya pris- eller kostnadsbilden. Och det är ju också ett sätt att hantera den där risken.

they allow them to divide the proposed mining operation into different sections that can be mined given different future circumstances. The importance of models in predicting the future value of a mining operation is even more evident in the application of block model results in pit-optimization studies. Pit-optimization assesses different mine construction alternatives of open pit mines. That is, a large number of mine pits are estimated and valuated. In essence, an open pit mine consists of a series of cuts where each level is cut into the previous level resulting in a pit whose walls descend in step-wise increments creating a stair-like design where the ridges provide stability as well as surface for driving trucks, drill rigs, and other equipment into and out the mine. As the slope of the pit walls as well as the breadth and height of the ridges affect the costs of extraction, different pit designs produce different overall valuations of the exploitable deposit. A mining engineer working at an open pit mine explained how pit optimization is done saying that when running pit optimization, explorationists begin with the model of the mineralized body and then estimate 45 or so different pits before selecting the option that is estimated to deliver the highest economic value.

In creating models, mineral explorationists use different valuation devices that assemble geological data and economic assumptions to produce three types of depictions of the underground that to an increasing degree, starting with the geological model and ending with the pit optimization model, translate geological nature into marketable second nature commodities to be realized in a future mining operation. This translation is accomplished by first drawing up and categorizing the bedrock according to its geological properties before adding socio-environmental, technical, and economic layers of assumptions to cut away the unminable sections of mineralized bodies.

6.2.2 Resource classification

Although block models provide one estimate of the minable volumes, the models do not necessarily distinguish between the levels of knowledge associated with different sections of the overall deposit. However, when reporting on their exploration results in adherence with industry standards (see chapter 2), explorationists need to distinguish between exploration results, mineral resources, and ore/mineral reserves, a process that adds further layers to the projected image of the deposit.

As discussed above, a mineral resource is a technical term for an occurrence of mineralized material for which explorationists have amassed enough data to classify it as such. Data sufficiency in mineral resource classification depends in part on the degree of confidence placed on the geological estimates in terms of what knowledge there is about the grades of mineralized material and their continuity in space. In addition, mineral resource estimation also considers the spacing of the data (i.e., the distance of the drill holes) and the quality of the interpolation of grades (e.g., in the block model) as well as a certain amount of economic considerations in terms of there being reasonable prospects for the mineral resource to be extracted and concentrated at a profit. Assessments of future profitability in mineral resource estimates are often based on the results of the pit-optimization analyses discussed above.

As shown in chapter 2, the standards for classifying mineral resources under the CRIRSCO umbrella provide a number of sub-classes of the mineral resource and reserves. One sub-class, the inferred resource, is estimated with higher confidence than an exploration result, but is still connected to a large amount of uncertainty in terms of its tonnage, grades, and mineral content. To upgrade an inferred resource to the next level (i.e., an indicated resource), explorationists must reduce the uncertainty of estimates by carrying out additional drilling and analysis in order to increase the quantity and quality of data to increase the confidence in estimates of grades, tonnages, deposit geometry, and density. The highest degree of confidence is found in the final sub-class of mineral resources, measured mineral resources. A measured resource requires more data still from more drilling and analysis as well as a review of the estimates by an accredited qualified person who certifies that the estimates represent an acceptable degree of confidence. As valuation devices, the classifications of mineral resources follow the exploration process. As explorationists undertake more work, they are able to produce ever more specified and precise models and measurements upon which better resource classifications may be produced as the geological complexity is reduced.

As confidence in the estimates increases, explorationists also begin work to turn the mineral resource estimate into estimates of minable reserves. Classifying a section of a mineral deposit as a probable or proved mineral reserve requires that additional layers are added to the calculation as the criteria for classifying a deposit a mineral reserve include accounting for, what the CRIRSCO standards call, the "modifying factors" involved in determining the amounts of minable mineral in the ground. Junior company senior officer and geologist Eric explained the difference made by adding this additional layer of modifying factors:

> So there's this concept in exploration and mining about a mineral resource and a mineral reserve. They're two different things. A mineral resource is an estimate of how much metal is in the ground, and a mining reserve is how much metal you'll be able to recover; so it has a lot of commercial layers wrapped around it.

Mineral reserves, in other words, are the parts of a mineral resource that are minable whence commercial factors have been considered. The following factors make up the modifying factors described in CRISCO standards: mining, processing, metallurgical, economic, legal, environmental, infrastructure, social, and governing factors.[93] As reserves depend on these dimensions for their estimation, any changes in these (e.g., in the commodity prices) means that the reserve grows or shrinks depending on how the economically minability is affected by the change. Junior company CEO Ian outlined how this happens in response to the observation that reserves decreased substantially in 2012 due to a drop in ore prices:

> Major! Yeah, yeah! Yeah, yeah! So, you make a study and you put, like, a shell around your deposit, but it's set at a current price. So the boundaries of the rock to be mined attach to a certain business plan, a financial model, yeah, then if that metal price changes by 30 percent, then, wow! You got another shape. So you have to factor these in.

Therefore, mineral reserves are second nature techno-economic projections of the degrees of first nature resources that are estimated to be able to support its future exploitation. Furthermore, reserve estimates are advanced stage exploration products that rely on large volumes of exploration work to identify the geological and metallurgical dimensions, outlined earlier in this chapter, as well as considerations of foreseeable investment and operation costs, future commodity prices, and assessments of a project's environmental impacts. Assessments of these modifying factors mean assembling data with which explorationists seek to reduce uncertainty in the minability of the mineral deposit. The end products of this work are estimated volumes of resources or reserves within different categories of certainty. In other words, the heterogeneous assemblages of drill core data, price forecasts, and environmental impact negotiation are translated, commensurated, and expressed in a unified metric tons of mineral resource or reserve with grades of certain percentages or grams per ton. What began as a set of indicators of exploration potential has, in other words, here been translated into a body of second nature described along the lines of 2500 ktons inferred mineral resource of 0.3% Cu, 0.1% Zn, and 0.6 g/ton Au.[94] However, while the increasing amount of geological data means that the material dimension of minability in terms of the first nature properties of the deposit become increasingly known and less complex, the introduction of economic, social, and environmental parameters at the same time means that the project grows increasingly uncertain.

[93] The list of factors is taken from the Australasian JORC Code (see The Joint Ore Reserves Committee of The Australasian Institute and of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia 2012).

[94] Or 2,500,000 tons of inferred mineral resource consisting of 0.3 percent copper, 0.1 percent zinc, and 0.6 grams per ton of gold.

6.2.4 Summary

Intermediate and advanced stage exploration work pulls together different types of data amassed through exploration fieldwork and analysis and translates them into measurements of minable mineral material and three-dimensional models of deposit geology and mineral bodies. These translations are produced using a range of valuation devices through which measurements are pooled to estimate quantities and qualities of different values in the ground and around the exploration area. The most clear-cut example of this is the geostatistical calculations and subsequent application of modifying factors through which explorationists take measurements from drill core samples and use these to produce a model of the geological realities underground and to predict the amount of minable mineral resources and reserves within the geological body. However, the EIAs discussed in the previous section are instructive of the exploration process movement from measurement to estimate. The environment is valuated in terms of classifications of environmental values and inventories of fauna in the area combined with measurements of potential emissions and environmental alteration which are then rated according to the estimated degree of foreseeable impacts to the dimensions of the environment outlined in the environmental code and additional regulations.

Although these efforts of valuation and prediction reduce much of the heterogeneity of the amassed data, this is not the final definition of minability. Until this point, the majority of exploration work has been carried out in different lines of work and the estimates of minability have been denoted in different dimensions. The next section outlines how these estimates are pooled to translate the remaining heterogeneity into a unified metric of minability in the form of a net present value (NPV).

6.3 Project feasibility studies: Estimating the net present value of a future mine

As described above, the exploration process is not a unified process, but rather a number of parallel efforts that produce a range of predictions about the future minability of a projected mine. However, while each line of work is important in outlining the overall minability, they mainly answer questions particular to each individual line of work such as a project's geological properties and quantities, mine engineering, or socio-environmental impact. A comprehensive overview of the overall mine and its minability is accomplished first in a feasibility study. A feasibility study, the last in a series of studies undertaken in exploration, consists of a document that gathers all the results of the exploration efforts into one unified assessment of a project's feasibility as determined by the projected minability of the mineral deposit. The feasibility study is therefore the culmination of many years of exploration work and as such plays a vital role in explorationists' decisions on whether to go ahead and begin development and construction of a mining operation. Senior junior company officer Eric explained the role of the feasibility study saying that it is the report where you say:

> This [feasibility study] is how we're gonna build our mine. This is the size we're gonna build it at. This is how much metal we're gonna produce. This is how many trucks we're gonna buy." All of that is what's put in front of a board of directors to say "Yes, we're willing to provide two-hundred million dollars to build this mine." and the banks will say "Yes, we agree with all your assumptions. We are willing to give you a hundred million dollars of debt to enable you to build your mine."

Although the feasibility study in many ways is the final piece of the exploration puzzle, it is a long way to walk to get there. As there are significant costs involved in bringing a project to, what explorationists call, the feasibility stage the need to sort out the most promising projects remain. Before arriving at the feasibility stage, explorationists therefore bring projects through a series of smaller studies aimed at outlining the future costs and potential involved in bringing a project further along the exploration process. The remainder of this section will outline these smaller studies and provide a closer analysis of the feasibility study as a prediction of future minability.

6.3.1 Scoping studies or preliminary economic assessments

A scoping study, or preliminary economic assessment as they are called in the Canadian NI 43-101 standard, is the first step towards a comprehensive evaluation of a project, and it pertains to answering questions of whether it makes sense to spend more money and effort on a project or whether one would better close the project down. Undertaken at a relatively early point in the intermediate to advanced stages of exploration, scoping studies are inherently uncertain but provide some guidance as to the potential minability of a project.

In an advanced class on mining economy and risk evaluation, John told the attendees that a typical scoping study reviews existing data to produce a first mineral resource estimate. Moreover, as the data hitherto assembled by the explorationists at this stage tend to be sparse, data accessible from public sources or from an organization's experience base is used to fill in any gaps in the estimation process. Carl explained the practical realities of this: explorationists seldom have access to the resources or time necessary to collect first-hand data for all dimensions in a scoping study, so they tend to rely on publicly available data to estimate possible costs and incomes for the project:

> Tobias: So you're making comparisons with other mines working under similar conditions [Yes] in terms of projects too?
>
> Carl: Yeah, definitely. And you do the same thing when you begin working on estimating the profitability in a project. At that point you usually have only a small team, you usually don't have time and money to collect quotes on everything you need for a concentration plant, for example, or for all the mining vehicles you're going to need. Therefore, when you're doing your scoping study or your preliminary economic assessment, you usually rely on public figures, or figures you can get from other projects that are similar to yours.[95]

Because data is sparse at this stage, public and experience based information is an important resource when estimating the potential minability in a project. Being able to pull data from an organizations experience and previous work therefore provide explorationists working for mid-tier and majors that already operate producing mines an advantage compared to junior exploration organizations. Exploration geologist Keith and mining engineer Lars, both working in mid-tier organizations, expressed how the availability of experience-based data helps in minability prediction as it can be used as inputs when calculating future mining costs and sale incomes. This, they continued, means that organizations who have experience-based data to draw on can compare their own data with data from public sources. According to Lars, not having to "start from zero" to estimate the future costs of mining a deposit the way juniors must is a significant advantage.

No matter what data they have access to, public or experience-based data, explorationists' scoping studies all feature a series of dimensions through which they try to predict the short-term benefits of bringing the project forward as well as the long-term minability of the project. These dimensions are as follows: geological measurements in the form of exploration results or inferred mineral resources; initial mine designs with outlines of flat-lined production schedule (i.e., a production schedules that assume homogenous outputs and do not consider details such as differences in the production volumes and grades at different points in time); a processing outline in the form of a

[95] Tobias: Så du jämför och tittar du på gruvor med liknande förutsättningar [Ja] projektmässigt också?
Carl: Jajamän. På samma sätt när man börjar med att kalkylera på lönsamhet på ett projekt så.. Då har man ju i regel ett litet team, man har inte tid och råd att gå ut och ta in offerter på allting som behövs till ett anrikningsverk till exempel, eller alla dom gruvmaskiner som behövs. Så när man gör sin scoping study eller preliminary economic assessment, då använder man i regel bara sådana siffror som är publika eller, eller som man får tag på ifrån andra likvärdiga projekt.

costed rudimentary flowsheet design using processing cost data from comparable projects (own or public); and rudimentary studies for the design of tailings and gangue management, water management, and environmental impacts. In addition to these dimensions, financial models are developed in order to test the project's sensitivity under different future scenarios defined as ranges of positive and negative variations in dimensions such as prices, grades, costs, recovery grades, and other modifying factors. Based on the relative access to data in these dimensions, the scoping study mainly discusses geological and processing data in combination with assumptions and estimates on the remaining dimensions. Therefore, the scoping study outlines a predicted minability in terms of the geological knowledge and the estimated costs of extracting and processing the mineralized deposit using a particular mining and processing method, whereas most other dimensions are placed in the background pending further exploration work.

Being based on early to intermediate stage exploration work, the uncertainty of the estimates included in a scoping study is significant as many dimensions affecting the minability of a project have yet to be sampled and analyzed thoroughly while other dimensions will not be studied in any detail until much later in the exploration process. Despite this, scoping studies are generally held by explorationists to be accurate to between +/- 30 percent to +/- 50 percent. Now, a positive or negative 30 percent is a large span, but to the outsider it still may seem surprisingly confident given that estimates are produced using limited knowledge of the complex geological and ecological systems in a project as well as of the social dimensions involved, such as markets, public opinions, and juridical permitting processes. This confusion signals an important distinction which has been growing ever since the start of the exploration project, that is, that between a site as a host of complex systems and relations, and a site as an exploration project vis-à-vis other exploration projects. Remembering the distinction Maxwell drew between geologists wanting to understand a site as a result of geological processes and geologists wanting to start new mines, the +/-30 to 50 percent uncertainty of the scoping study estimates does not denote uncertainty in relation to the first type, but rather to the second type. What the scoping study does, in other words, is to produce an account of the site as an exploration project and second nature and not an account of the site as a set of complex relations and processes, which is first nature; and it is the estimates attached to this second nature that are said to be accurate to +/-30 to 50 percent. Following from this, the scoping study valuates the exploration project along the lines of what is seen to be relevant from the explorationists' and their publics' horizons; that is, the site is translated into standardized qualities and in the end made commensurable to any other exploration project. This translation reduces the complexity of first nature into a standardized series of measurements, a second nature, and this is the whole point of a scoping study as it enables explorationists to compare their project and its predicted resource potential to other exploration projects and even other investment opportunities in general.

The scoping study is therefore a first overview of an exploration project and this overview helps explorationists introduce equivalences between the still complex and uncertain project and already operating mines. By doing so, explorationists put themselves in a position to evaluate the project both in terms of what can be estimated from the exploration results as well as what the project promises in terms of exploration potential was it to be subjected to further investment. Carl described this role of the scoping study and provided an idea of what further investments entail in terms of costs:

> So when you've reached this stage, the stage where you're undertaking a scoping study, the purpose of doing that is to see "Should we move forward? Is it worth it to spend twenty million dollars to take this to a feasibility study from where we are now, when we might have spent twenty or twenty-five million already? Should we move ahead or should we go somewhere else? Are there better places for us to invest our money in?"[96]

The first overview of an exploration project and the first evaluation of its potential is based on relatively uncertain predictions of a mineral deposit's future minability. In summary, scoping studies provide important guidance against the uncertain future as they form a basis for a first comprehensive review of a project to determine whether to put more work and capital into it. Despite being based on sparse geological data and a large number of assumption regarding the future costs and incomes from constructing the mine and extracting, concentrating, and selling the ore product, the scoping study builds a point of reference against which explorationists can orient themselves in order to navigate the uncertainty in their projects. If the project is found to be of sufficient potential to be brought ahead it will then be subjected to more intensive studies both in terms of drilling and analysis but also in terms of an increase in the scope of dimensions used to assess minability.

6.3.2 Pre-feasibility studies

If explorationists decide to take a project further, they will eventually have amassed enough data to warrant a second study of the project, a pre-feasibility study (PFS). Compared to the scoping study, a PFS is based on considerably

[96] Så man brukar säga att när man kommit till steget, stadiet att man gör en scoping study, syftet med den det är ju att se "Ska vi gå vidare?" "Är det värt att lägga tjugo miljoner dollar på att gå till feasibility study ifrån det här där vi är nu, när vi kanske har lagt då tjugo tjugofem miljoner? Ska vi gå vidare eller ska vi gå någon annan stans? Finns det bättre ställen att investera våra pengar?"

more data as projects will have undergone at least some of the data assembly and analysis work outlined in the first sections of this chapter. Following from this, the PFS uses geological data minimally consisting of indicated mineral resources and combines this information with plans for the necessary infrastructure to develop and construct a projection of the future mine, including geo-technological considerations, environmental investigations, intermediate mining and mineral processing plans, hydrological surveys, and tailings and waste disposal plans. As more data are involved in producing a PFS than producing a scoping study, the PFS can be seen as a more detailed study than a scoping study. However, it is not only the increased quantity of data that separates the PFS from the scoping study; the precision of data used to estimate the feasibility of a project will have increased between the scoping study and PFS stages. That is, instead of relying on publicly available data on construction and operation costs, explorationists may have worked to narrow down the cost estimates to bring them closer in line with the geological, environmental, and technical dimensions in a project. Moreover, also the quality of the geological data will have improved at this point, as explorationists, at the time of the PFS, will have subjected the mineral deposit to infill drilling so to increase the frequency of core samples. In addition to this, the introduction of results from laboratory analysis and quality assurance and control measures also provide a stronger foundation for grade estimates.

The practical implications of the increased quantity and quality of data is that when they arrive at the PFS stage, explorationists have undertaken work to qualify and quantify a series of dimension seen as relevant to a mineral deposit's future minability. On the technical side, PFS work is based on mineral resource estimates at the indicated level or higher, technical proposals for how the mine is to be designed, a rough production schedule including the quality of ore to be mined at different points in time, and a model of the operation costs for the proposed mine design. In addition, explorationists are to have produced improved processing flowsheets outlining how the ore is to be crushed, milled, and refined as well as plans for how waste material and tailings are to be removed and stored. Moreover, the qualities of the rock material at the site will have been analyzed to test the properties of the waste material in terms of leaching and acidifying materials In addition, explorationists will have made a design of the future industrial area complete with locations for gangue storages and tailings dams. Finally, the PFS also sees the introduction of hydrological and hydrogeological considerations as studies at this level demand that explorationists study the water supply in the area and the potential inflow of surface or ground water into the mine.

Located between the scoping study and the full scale feasibility study, the PFS assesses what has been learned since the scoping study and asks what are the impacts of the exploration work undertaken at the PFS level on the scoping study's assumptions about the project's minability. Second, in addition to assessing whether the addition of PFS level data has strengthened or weakened the predicted minability in a project, the PFS is also used to identify and select different options for how the project can be developed. Therefore, the PFS looks both backwards and forwards as it reviews whether the assumptions put into the scoping study are still relevant or whether they need to be updated following the addition of new and more detailed data. The forward-looking dimension of the PFS, on the other hand, consists of PFS outlining a scope of different alternative mines that may be developed from the project, alternatives that will be studied in detail in future studies–given that the project is moved forward following the PFS. Geologists and junior exploration company senior officer Eric explained how they worked with the PFS in an ongoing exploration project:

> So the concept of a pre-feasibility study is a study that will provide to you various options that are then assessed in the feasibility study. So an example with [the project] would be that we would identify, ehm, the building of a mine at a certain scale or the building of a mine at a different scale and both of those would then be studied in more detail during a feasibility to tell you which one is the appropriate scale.

When discussing the role played by PFSs, Eric connected their use to the overall ambition to reduce risk in exploration projects, or as an investment banker at an international conference and trade show put it, to "de-risk" projects. In mineral exploration, de-risking is accomplished by increasing the volume of data as well as improving the quality of the measurements in each dimension deemed relevant in exploration. According to this logic, it is through the introduction of better measurements that makes the future minability of a project increasingly calculable and therefore less uncertain. De-risking is approached as a continuous process where project risk is reduced step by step as the quantity and quality of data increase and less is left unmeasured or uncertain.

In the PFS, the scoping study's +/-30 to 50 percent risk is reduced to +/-25 to 30 percent meaning that explorationists, supported by the increased volumes of data and more accurate and precise measurements, employ narrower margins of error to their estimates and to the scenarios used to test project sensitivity. Moreover, PFS level work ties into the reporting on the mineral deposit as a resource and reserve as PFS level work is the minimum level for reporting mineral or ore reserves. That is, the PFS determines whether there is sufficient confidence both in the geological estimates and the work on modifying factors to translate resources into profitable minable reserves. The PFS stage is also the stage at which most exploration organizations have produced more detailed studies of a project's environmental impacts. Armed with these studies, explorationists usually begin to consult the local communities in order to assess the social impacts of the proposed mine and to seek to gain acceptance (i.e., a social license to operate) for their plans from local actors.

Situated much later in the exploration process, the PFS thereby provides a much more comprehensive and detailed review of the project in many of its different parts than does the scoping study. However, the PFS is only an intermediate study that allows explorationists to attempt to predict the costs and potential gains involved in investing time and resources to take the project further. What emerges as the result of the PFS is a number of variations of present futures in which the projected mine takes different shapes depending on the approaches, techniques, and other considerations that make up the scope of alternatives to be investigated in an eventual feasibility study.

6.3.3 Feasibility studies

What has been described so far is the path to a feasibility study. The feasibility study is the most in-depth, laborious, and comprehensive study in the exploration process and as such it contains the most detailed examples of prediction work in the exploration toolkit. As with the scoping and pre-feasibility studies, the feasibility study is made up of an assemblage of diverse information gathered and analyzed in order to de-risk an exploration project in relation to its minability as determined by the geological estimates and modifying factors.

As with two previous studies, the feasibility study is a multi-disciplinary valuation and evaluation of a project. Being an advanced stage product, however, the feasibility study stands apart from the scoping study and PFS in that often it is not based on data from ongoing exploration work, but from completed field and laboratory work. The authors of feasibility studies, in other words, have access to the totality of data in each domain and pools them together in the study. In practice, the feasibility study data consist of the following parameters: improved geological models and block models based on additional drilling; completed laboratory test work to assess grades; metallurgical analysis using pilot plants rather than desktop studies; analyses of the water supply and flow; a detailed EIA; and detailed mine and process designs for the one option chosen following review of the different potential designs of the mine laid out in the PFS, including the waste and tailings management facilities. In addition to these advances in data quantity and quality, the feasibility data tend to be based on actual quotations of the costs for all significant capital investments rather than assumptions based on publicly available or experience-based data from other mines.

It is, perhaps, at the feasibility study that the overall complexity of an exploration project is at its clearest and at which the diversity of the group here, simply referred to as explorationists, is at its most apparent. The feasibility study pulls together the work done by a range of different groups of professionals working in exploration geology, exploration geophysics, drilling, laboratory analysis, geological modelling, environmental investigations, rock mechanics and engineering, community relations, legal permitting, financial analysis, geo-hydrology, and even commercial archeology. Some of these professionals work within the exploration organization, but many work in one of the many consultancy firms that provide their services in drilling, modelling, environmental impact assessment, legal support, and etcetera. Given the range of professionals involved in providing the materials for a feasibility study, it is not surprising that these studies are described by informants as being "gigantic exercises" that are very capital intensive and lengthy, taking between 12 and 24 months to complete.

This advanced stage work also tends to see exploration project change hands as new divisions within an exploration organization may take over the project, as in the case of the previously described Swedish mid-tier organization where the prospectors handed over management of projects to the company's technical team as projects mature. This handover, mining engineer Lars explained, takes place when projects have reached the point where the quality and quantity of exploration data support estimates at the indicated mineral resource level. At this point, the technical division takes over and, while supported by the prospector team, begin work to raise the project from resources to reserves by conducting a feasibility study. A second group of actors that make their entrance into the exploration process in full in the feasibility stage are the accredited qualified persons described in chapter 2.[97] While they feature in earlier stages as well, qualified persons are important actors at this stage as industrial standards and practices require the use of qualified persons in all feasibility studies. Along with the managers, financial modelers, and mining engineers, who together tend to make up project management divisions, the qualified persons possess a privileged position within the exploration process, as they are the ones responsible for bringing together the many different dimensions of exploration work into one coherent measure of minability. Because of this, they are the first people to see a project in its entirety and therefore the first people positioned in such a way that they are able to produce predictions based on a comprehensive view of a project. John, a qualified person and consultant, explained that because they are the first to gain a comprehensive view of a project, the authors of feasibility studies often see projects in a very different light compared to those working in the different lines of exploration work that contribute data to the feasibility study:

[97] As stated in chapter 2, a qualified (or competent) person is someone accredited under an industry standard for the reporting on exploration results, resources, and reserves. While the present thesis uses the term qualified person, the standards have different ways of referring to this function with the European PERC reporting standard using the terms interchangeably while, qualified person is the term used by the Australian JORC code and competent person is the term used in the Canadian NI 43-101 standard.

> And the interesting thing is that sometimes, if you're working on a financial model and you have this birds-eye view of the project, you often come with.. I'm gonna pick on environmental engineers, they come to you and they'll say "Shit, we have a rehabilitation cost that will be sky-high! This will be impossible. You've gotta see this! How are we gonna manage this?" And then you feed it into the model and view the project in its entirety and realize that it will only have a marginal impact, if any.[98]

Explorationists working in their respective domains, John continued, mainly provide information to the project managers and the rest of the team working on the feasibility study and therefore only see their own part of the project. Therefore, were they to make any predictions, like the environmental engineers in the quotation above, they are usually based on their expectations regarding how what they observe in their specific domain will affect minability. As John put it, "they seldom give a green light, they give red lights." In isolation, therefore, the valuations undertaken to assess and predict minability in mineral exploration only provide parts of the answer, as different valuations need to be brought together and weighed to comprehensively assess the minability of a future mine.

The result of prediction work in advanced stage exploration may therefore differ significantly between those made by explorationists working in data production and analysis and the explorationists responsible for pulling together all available data into a definite valuation of a project. But what is this definite valuation? The answer to this question was hinted at earlier in this chapter: the net present value (NPV) of the projected mine. The NPV is an estimate for the overall value of a future mine given predicted capital expenditures (CAPEX), operational expenditures (OPEX), and price, including any penalties or premiums as determined by predicted quality of the ore product. Therefore, the fundamental determinant of the NPV is the relative proportion of sellable material that can be produced in the mine and the costs involved in doing so. Valuing future mines therefore works by pricing the estimated volumes of sellable ore and the process of extracting it. Exploration geologist Quinn explained this by paraphrasing an old and well-known geologist in her region:

> Yeah, moving dirt is expensive and there's this well-known geologist, especially around these parts, who's been very successful in his career. And I remember him telling me that there are only two types of rock, there's "dollar rock" and "waste rock." And it's only the proportion between them that make

[98] Och det intressanta är att ibland, om man sitter här och jobbar med en finansmodell och har den här överblicken över projektet, man brukar oftast komma med, I'm gonna pick on environmental engineers, dom kommer fram och säger att "Shit, vi har ju en rehabiliteringskostnad som kommer vara skyhög! Det kommer att vara omöjligt det här. Du måste se det här! Hur ska vi klara det?" Och så sätter man det i modellen och ser projektet i sin helhet och man inser att det påverkar projektet ytterst lite.

> or break projects. And like I said, you could have the best deposit in the world, but if you can't get it out of the ground making a profit, then that deposit isn't worth anything.[99]

At the end of the day, it is therefore the relative proportions of dollar rock and waste rock that determine the NPV in a project and to minability in general. Whether the mineral can be mined profitably is the central question in feasibility studies and this further highlights the privileged position project managers and qualified persons have as predictors. While explorationists working on resource definition or evaluation learn a great deal about the geological properties of the deposit under exploration, they do not have access to the perspectives of other domains, such as rock mechanics engineering or metallurgy, that are important co-determinants of minability. John explained that in order to estimate the NPV, one first needs to know what everyone else is doing in this process. Moreover, one needs to have an understanding of what is important in the process so that one can ask the right questions. Saying this, John then went on to draw up the content of a feasibility study and how they relate to the NPV:

> And then you get the first overall image. Both of the physical flow of materials from the mine to the concentrator and to the tailings dam. [. . .] I'm talking tons and grades for all stages and what happens when you get to the concentrator, yeah. Then this tonnage with these grades are there and there and there and there. And then maybe this is the tailings dam and this is residue product and this is low grade product and this is high grade product. And this is the first time you see how the entire mine will behave under its whole live-span. And from this you get the NPV.[100]

While saying this, John grabbed a pen and paper and began drawing a mine as two elliptical shapes, one situated within the other. Pointing at different locations within this very rudimentary open pit mine, he then began placing the tons and grades at different locations in the mine before drawing lines and boxes denoting high grade product, low grade product, residue product, and the tailings dam. From all of this, comes the NPV: an economic measure of

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[99] Ja, det kostar pengar att flytta jord och det finns en välkänd geolog, särskilt här ikring, som har varit väldigt framgångsrik i sin karriär. Och jag kommer ihåg hur han berättade för mig att det finns ”dollar rock” eller ”waste rock” och det finns ju det bara. Och det är bara mängden som styr projektet egentligen. Och som sagt, man kan ha världens värsta fyndighet men om man inte kan få ut det på ett lönsamt sätt då är han värdelös.

[100] Och sedan har man den här första helhetsbilden. Både på det fysiska flödet av material från gruvan till anrikningsverk till sandmagasin (…) jag pratar då ton och halter för alla steg och jag menar då vad som händer när man kommer in i anrikningsverket. Ja då far det här tonnaget med dom här halterna dit och dit och dit och dit. Och det här kanske är sandmagasinet och det här är restprodukt och det här är low grade product och det här är high grade product. Och det är första gången man ser hur hela gruvan under hela gruvans livslängd kommer att bete sig. Och det man får ut härifrån då är NPV.

the projected mine's overall worth expressed in terms of an up front, present day price tag. But how precise is this valuation?

Figure 5 below shows an estimated pre-tax NPV, expressed in terms of millions of Canadian dollars, for a training example worked on by the author while doing ethnographic fieldwork in a day-long training class on mining financial modelling. The section of the model depicted here is the final stage after a long line of data points, estimations, and assumptions that together lead to the estimated NPV visible in the lower left corner of the figure. Technically speaking, the NPV is estimated using the following equation:

$$\sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

where i is the discount rate and R_t is the net cash flow at time t.

In practical terms, the calculation of the NPV as expressed in the model is as follows: the NPV is the sum of the discounted pre-tax unlevered free cash flow ("Pre-Tax UFCF" in the model) across the mine's life span and this sum is in turn estimated by dividing the pre-tax unlevered cash flow by one plus the weighted average cost of capital (WACC) raised to the power of the discount period. Tracing this operation across the section of the model depicted in the figure, one can derive the NPV from dividing the sum of the annual pre-tax unlevered cash free cash flow–which in turn is the sum of the cash flow including EBITA, royalties, cost of goods sold, exploration expenditures, and reclamation contributions–with one plus the WACC raised to the discount period. The NPV, in other words, is an expression of the estimated difference between the cash inflow and the cash outflow from constructing and operating the mine and concentration plant. By tracing the NPV back through the mechanics of measurements used to produce it, it becomes apparent that the relative certainty of the NPV as a comprehensive valuation of the projected mine is less solid than it may first appear. It is, for example, worth noting that the EBITA is an estimate based on subtracting assumed costs from the yearly revenues estimated as the combination of the scheduled annual production of ore materials and the annual price per unit of concentrate. Put briefly, the NPV therefore still harbors uncertainty as much of the measured inputs remain far from certain while other inputs are based on mere assumptions. This ability of valuations to express certainty and clarity while rendering opaque the uncertainties upon which they are based have been described as a form of "uncertainty absorption" (March and Simon 1958). Absorption of uncertainty arises when valuations summarize relatively complex questions into straight forward answers and ties in with how valuations reduce complexity by assigning values to heterogeneous and therefore, as Knight (2006) argued, uncertain phenomena or circumstances. In the feasibility study, this type of absorbtion of uncertainty occurs as the uncertainties embedded in the geostatistical modelling, flowsheet designs, cost projections, EIAs, and market forecasts are summarized into a straightforward value here in the form of a certain number of millions of Canadian dollars.

Mine Valuation Schedule

			2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
545	**Mine EBITDA**												
546	Gross Revenue	C$m	-	-	-	-	291,6	372,9	389,3	400,0	400,0	400,0	401,1
547	Less: Corporate Royalties	C$m	-	-	-	-	(4,4)	(5,6)	(5,8)	(6,0)	(6,0)	(6,0)	(6,0)
548	Less: Cost of Goods Sold	C$m	-	-	-	-	(76,3)	(69,8)	(46,4)	12,9	12,9	12,9	13,0
549	Less: Exploration	C$m	(5,0)	(5,0)	(5,0)	(5,0)	(5,0)	(5,0)	(5,0)	(5,0)	(5,0)	(5,0)	(5,0)
550	Less: Reclamation Contributions	C$m	-	-	(2,0)	(2,0)	(3,0)	(3,0)	(3,0)	(3,0)	(3,0)	(3,0)	(3,0)
551	**Mine EBITDA**	C$m	(5,0)	(5,0)	(7,0)	(7,0)	202,9	289,5	329,1	398,9	398,9	398,9	400,2
554	**Pre-Tax Unlevered Free Cash Flow**												
555	Mine EBITDA	C$m	(5,0)	(5,0)	(7,0)	(7,0)	202,9	289,5	329,1	398,9	398,9	398,9	400,2
556	Changes in Working Capital	C$m	-	-	-	-	(8,7)	(3,6)	(1,6)	(2,9)	-	-	(0,0)
557	Capital Expenditure	C$m	(93,8)	(546,9)	(606,3)	(340,6)	(31,3)	(31,3)	(31,3)	(31,3)	(31,3)	(31,3)	(31,3)
558	Pre-Production Mining Costs	C$m	-	-	(50,0)	(50,0)	-	-	-	-	-	-	-
559	Pre-Production Operating Labour	C$m	-	-	(8,0)	(8,0)	-	-	-	-	-	-	-
560	Pre-Production Other	C$m	-	-	(1,5)	(1,5)	-	-	-	-	-	-	-
561	Pre-Tax Unlevered Free Cash Flow	C$m	(98,8)	(551,9)	(672,8)	(407,1)	163,0	254,7	296,3	364,8	367,7	367,7	368,9
563	**Pre-Tax Mine IRR**												
564	WACC	%	8,0%										
565	Internal Rate of Return (IRR)	%	14,1%										
567	Discount Period		0,5	1,5	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5
568	Pre-Tax UFCF (Discounted)	C$m	(95,0)	(491,7)	(555,0)	(311,0)	115,3	166,8	179,7	204,8	191,1	177,0	164,4
570	**Pre-Tax Mine NPV**												
571	Net Present Value (NPV)	C$m	897,3										
573	**Payback Periods**												
574	Cumulative Cash Flows	C$m	(98,8)	(650,6)	(1 323,4)	(1 730,5)	(1 567,5)	(1 312,8)	(1 016,5)	(651,8)	(284,1)	83,6	452,5

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READY

Figure 5. A financial model

In addition to the NPV, explorationists also have access to additional tools with which they can evaluate the minability of a project. One such tool is the cash cost curve. A cash cost curve is a comparative tool where explorationists valuate their project in relation to other projects in order to rank the project's future minability vis-à-vis existing mines. Using publicly available data, explorationists plot the predicted costs and incomes in their project together with the known costs and incomes in similar projects, thus ranking the plotted mining operations and projects according to their relative cost of producing mineral product. Technically, the cash cost curve produces histograms of the ranked companies with the Y-axis denoting a mine or a producer's cost per unit of production (e.g., tons or ounces of mineral concentrate) and the breadth of the bar representing each respective company along the X-axis denoting the company's share in the cumulative volume of produced mineral product.[101] Layered on top of this histogram are horizontal lines reflecting the predicted commodity price (or prices); that is, the bars with Y-vales (costs of producing one unit mineral product) that intersect the predicted price are producing their ore product at higher costs than what is estimated to be the future price. Cash cost curve ranking provides explorationists with another dimension through which to valuate their projects in terms of their relative minability compared to other projects. A "better" position in the cash cost curve denotes the project as being less susceptible to variations in commodity prices than those in "poorer" positions as well as the potential supply deficiencies to be created were a less favorably positioned producer to exit the market. Together with NPV estimates, cash cost curves, in other words, provide explorationists with opportunities to commensurate and compare their projects against operating mines to evaluate whether the project appears sufficiently minable given the value and cash cost of existing projects.

This section has outlined how advanced stage exploration projects undergo comprehensive, multi-disciplinary valuations through which a project's overall value in the form of its NPV is predicted. Such comprehensive valuation is the final stage of the exploration project and predicts a unique value of a project in terms of the estimated difference between the estimated present value of the inflow and outflow of cash in the mine. In addition to these project unique valuations, explorationists also produce predictions about a project's position in cash cost rankings to predict the project's relative susceptibility to future market movements. However, while all these efforts pertain to de-risking projects by increasing the quantity and quality of the data available to explorationists in prediction work, the uniqueness of each project poses hinders on the road to establishing the equivalences necessary to truly transform uncertainties to risks. According to the Knightian rule (chapter 1), assessing risk (i.e., measurable uncertainty) is only possible when cases or situations are sufficiently similar for actors to be able to infer similarities and differences among them. According to Knight, true risk is therefore very rare, as uncertainty is only made measurable if there is a significant degree of equivalency between situations. Similarly, explorationists face specific challenges related to uniqueness of a case as uniqueness presents more potential for uncertainty with respect to quantifiable and translatable risks. Therefore, it is not surprising that some mines fail despite all efforts spent on establishing credible estimates of their future minability. The next section takes a closer look at the main reasons for failed predictions and ultimately failed mines.

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101 Cash cost curves can also use individual mines as their unit of analysis.

6.3.4 Blown predictions

Prediction work throughout the exploration process produces both long-term and short-term predictions where the long-term predictions pertain to answer questions about the would be mine and its minability and the short-term predictions support decision makers in determining whether they see a project fit to be taken forward in the exploration process. The goal of prediction work in mineral exploration is therefore to provide resources to explorationists facing decisions as to whether they should continue to work a project or whether they would do better closing it down and re-focus their efforts somewhere else. In an enterprise characterized by a low probability of success as well as significantly rising costs of working projects as they move through the exploration process, mineral explorationists need to balance their investments into uncertainty reduction and improved data for prediction with the likelihood that the project they are currently working most probably will turn out to be unminable. It is therefore not surprising that Eric claims optimism to be a mineral explorationist's most important characteristic. In a world where failure is a likely companion, the belief in striking gold is an important driver and motivation. Maxwell summarized this by saying

> And then you know, this thing to explore.. like, at the end of the day you're doing exploration because you believe [that you will have success], and when you've been doing this for a while then you realize that many of the projects you work on will never become anything, right? You have some indication there might be something there but you never succeed in proving it. Instead, you're hoping and believing that someday you'll make that one in a thousand discovery that motivates all the work you're putting into this, right?[102]

Making discoveries and carrying them through the entire exploration process is challenging work. Failure is therefore a common companion in mineral exploration. Despite this, failure as a topic has led a peripheral existence in the discussions of exploration methods and risk reduction above. However, as mineral exploration is rife with uncertainty both because the deposits can only be accessed, so to say, from a distance and because the future itself is uncertain. Unpacking Maxwell's reflections on how most projects never become mines, one finds two types of failures that explorationists need to navigate. These two types of failure were first discussed in the introductory chapter but can now be appreciated in in detail. First there are the false negatives The first

[102] Och då just det här att leta.. alltså ytterst så vill du ju leta därför att du tror [att du kommer lyckas], och du inser ju då du hållit på med det här ett tag att många av dom projekt du har kommer aldrig bli något, va. Du har en indikation på någonting men du lyckas aldrig leda i bevis att här finns någonting. Utan du hoppas ju och tror att du ska hitta den där en på tusen som motiverar allt det arbete du lägger ner, va?

type of failures are failures to establish any certainty in whether the many projects deemed unminable are actually unminable or merely false negatives. While explorationists, as this and the previous chapter shows, have access to a wide scope of exploration methods, these methods do not guarantee that explorationists be able to accurately and precisely measure the actual distribution of mineralized material in the ground. There are therefore no guarantees that one may end up predicting a deposit unminable because of failures to produce valuations that better corresponded to the true distribution of *minable* mineralized material in the ground. However, while false negatives may weigh heavily on individual explorationists and exploration organizations, they are not as problematic from an industry perspective as they produce results that future explorationists going through the Malå archives might discover and pick up. In addition, chasing potential false negatives in ongoing exploration work is a problematic strategy for the individual explorationists as this can easily lead explorationists spending resources on projects that will eventually turn out unminable. Discussing this problem, Eric referred to economic theory and, what he referred to as, "the gambler's ruin" saying that:

> There's a concept in economics called gambler's ruin. Hm.. Gambler's ruin is the concept of continuing to think that you're going to be successful so you keep spending money, you keep gambling. But the odds against you are so high that you actually go bankrupt before you get to your successful point.

In mineral exploration, the gambler's ruin involves spending capital chasing good results as drilling is expensive and ultimately translates to poking needles into a big and complex body; such chases may end up costing explorationists capital that could have been better spent elsewhere. This is why, Eric said, the "decision to say stop is as important as the decision to say keep going" and why it is important, as Maxwell phrased it, to work with experienced people who "can tell a dead horse when they see it and who know that there's no point of whipping it because it'll never run anyway."[103]

Nevertheless, while false negatives may cause explorationists to have headaches, false positives keep them up at night. For example, the Northland bankruptcy discussed in chapter 1 in many respects came down to false positive minability predictions. Part of the incorrectness of the predictions made in the case of Northland had to do with a large unforeseen drop in commodity prices that slashed iron ore prices by 50 percent in mere months. However, there were other miscalculations factoring into the bankruptcy as well. Amomg these were the optimistic estimate that the mine would be able to carry the costs of transporting the ore product by truck all the way from the mine's inland no-railroad location 165 kilometers to a railroad for continued transport

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[103] Och det är där det kommer in att, liksom, ha erfaret folk som har varit med förut och som kan känna igen en död häst och vet att det är ingen idé att piska den här för de kommer aldrig röra på sig i alla fall [skrattar].

to a dock from where it would be shipped to the buyers. In fact, when talking about the Northland bankruptcy, George went as far as stating that the predicted minability of Northlands mine was been based on unrealistic "blue-skies estimates." In other words, the predictions made in the case of Northland fell short both in terms of foreseeing a huge drop in prices and in terms of the profitability of mining and shipping iron product from the mine.

One lesson from the Northland bankruptcy is that overconfidence is a poor bedfellow when making predictions about a project's minability, but Northland is far from alone in having been seduced by overconfidence in prediction work. In August 2006, ScanMining began mining the Blaiken zinc deposit in Swedish Lappland. According to the company, the Blaiken deposit contained a significant mineral resource that could sustain a mining operation for many years. However, by the end of 2007, the company had filed for bankruptcy. Following the bankruptcy, other companies took over the operation but the mine was never economically viable. The MIS finally revoked the exploitation concession in 2014 and since 2018, the SGU has worked on cleaning up the significant environmental destruction that resulted from the mine's brief existence. Today, the Blaiken mine stands as one of the dark examples of how dire the consequences of mining failures can be: both in terms of failures to identify false positives in exploration work and in terms of failures in mine management and environmental impact negation. Do the examples of Northland and Blaiken accurately reflect the risks and consequences of blown predictions in mineral exploration?

Today, many explorationists distance themselves from black sheep such as the Blaiken project. For example, Maxwell, in a conversation with a social relations consultant, responded to a claim that the public's negative view of the mining industry might be informed by failures such as the Blaiken project. Maxwell's response was to argue that a case such as Blaiken is highly unlikely today as regulation has grown stricter in recent years. Maxwell's reasoning was captured in the field notes produced in relation to this event and contains a series of disclaimers for why Blaiken should be singled out as an abnormality:

> During a break for coffee, Maxwell was talking to one of the social relations consultants contracted to manage a workshop on sustainable mining featuring the company and local community representatives. Talking about the general public's view and experiences of mining, the consultant raised the issue of the Blaiken mine. Maxwell responded by saying that it is when people mention examples such as Blaiken that pisses him off the most. He explains to the consultant that Blaiken was operated by ScanMining, a company that was generally referred to as Scam Mining in mining and exploration circles. Many were doubtful of the project's ability to sustain its mining operation as its zinc grades were too low and felt that the company was under poor management. As an example of the latter, he explained that the company had bought used equipment from Australia without considering how Australia uses a different power

> system to Sweden. In addition to this, he added, Blaiken was developed before the current regulation was put in place.[104]

Maxwell was not alone in describing how the Blaiken project had been perceived of as a failure in the making. SGU officer Peter, for example, explained how the people behind the Blaiken project had visited the agency while working towards opening the mine. At the meeting, Peter said, the company spent an afternoon showing images, sketches, and numbers explaining how the project would be minable. However, based on his experience of the area and deposits around Blaiken, Peter said, he had subsequently told them that the project would never fly. This was not the end of the warnings. George told of how the company even ignored the concerns put forth by the person in charge of producing the mineral resource estimates. According to George, the person in question had highlighted the fact that the data did not support the grades the company claimed to have in the deposit and that this would lead to the concentration costing more than what was estimated as more ore would need to be processed to produce the same grade product. According to George, the company did not listen to these warnings but decided to push ahead. However, he continued, this was the 1990s, a different time, characterized by high optimism and eager investors.

The Northland and ScanMining bankruptcies are two of the most dramatic examples of blown predictions in Swedish mineral exploration today. However, failures need not be so dramatic as to produce newspaper headlines. While false positives carried too far before they are discovered can wreak havoc with both the exploration organization and the surrounding community (in the Northland case, the local municipality had made sizable investments towards accommodating the new mine and all the members of the mining crew that would come with it), some failures go by more or less unnoticed as the miner is able to manage any issues caused by inaccurate predictions or because the failure does not capture the attention of the media. For example, the Mertainen mine south of Kiruna was mothballed before ever going into production because of falling prices on iron ore. In a press release dated December 19, 2016, the mine owner, LKAB, stated that in 2010, when the mine was being planned, the market had looked completely different from the market that faced the mine whence permitting and development was finished in 2016. In this new market, the products from the mine were not profitable. Before this

[104] Informanten säger då att det är när folk lyfter exempel som Blaiken som han blir som mest förbannad. Han förklarar för konsulten att Blaiken sköttes av Scan Mining som i allmänhet kallades Scam Mining i gruvkretsar. Många var tveksamma till projektet och för att de hade för dåliga zink-halter för att kunna bära sig, att bolaget sköttes dåligt. Som ett exempel på detta berättar han att företaget köpte in begagnad utrustning från Australien utan att tänka på att de i Australien använder ett annat elsystem. Till mig säger även informanten att Blaiken kom till innan den nuvarande lagstiftningen trädde i kraft.

happened, however, the company had moved ahead with all preparations, including felling 200 hectares of primeval forest to make room for a gangue disposal site. Despite this, the mothballing of the Mertainen mine did not result in many headlines in mainstream media. However, Sami district chairperson Niels strongly questioned the sustainability and economic logic behind the Mertainen project as did the Swedish Society for Nature Conservation (2017), which sought to raise public awareness on the matter, even labeling the project a "crime scene" in their promotional materials.

This section has discussed three exploration projects and mines and the flawed predictions involved. Together, the three examples provide insight into potential consequences of flawed predictions in mineral exploration. What general lessons are there to be learned from these examples? A session from a class on mining economy and risk evaluation provides some insights. According to John, who led the class, most mines fail because of one or more of the following reasons: (i) the costs of capital or operations turn out to be higher than expected; (ii) the recovery grades produced are lower than the metallurgical analyses predicted; (iii) sales revenues are lower than estimated; (iv) ramping up production takes longer than expected; and (v) because of failures to sustain initial performance throughout the life of the mine. Following from this, most problems arising when mines are moved into production relate to blown predictions that, because of their foundation in flawed valuation or incorrect assumptions, produce incorrect estimates of what the mining realities will look like in the future present. Turning to the three examples at hand, it becomes apparent that the Northland, Blaiken, and Mertainen mines suffered from at least one of these five reasons for failure. For example, bot Northland and Mertainen experienced lower prices than expected when they were predicted minable while the Blaiken mine experienced lower recovery grades than predicted from the metallurgical test work.

In addition, John told the class that some of these issues are more common. According to John, flawed mine design and flawed scheduling cause the greatest proportion of problems, followed by poor resource and reserve estimates and issues with metallurgy. In relation to this, the class was shown lists of common mistakes in these three domains. This list included overly optimistic ramp-up and production schedules, failure to consider local variations in mineral deposit quantity and quality, overconfidence in statistics and modelling rather than common sense, failure to understand metallurgical domains within the ore body, unrepresentative samples used in testing, failure to identify contaminants, and unanticipated variation in the process inputs (e.g., differences in water chemistry). In relation to this, it may be observed that cost estimation was not listed among the common problems; not by John nor by the informants. Instead, informants often expressed confidence in their cost estimations, which were based on experience-based data, publicly available data, and the use of real-time quotes for each significant investment. The prediction work carried out in mineral exploration thus appear to run into more problems in some areas than others. Although the problems seem to be general, they relate to the specificity of each project and of the mineralized bodies they are trying to translate into mineral resources and minable reserves. Therefore, one may argue that cases such as Blaiken and Northland are not perfectly indicative of what happens when explorationists blow their predictions but exist as extremes on a continuum that begins somewhere in the region of slight deviations from predicted production and financial results and ends in social, environmental, or economic catastrophe.

This chapter shows how mineral exploration sees a range of actors come together to valuate a piece of the underground in order to identify patterns of mineral qualities and quantities, which can be projected into a present future when combined with other patterns and assumptions forecasting the future price of metals and the cost of extraction. Through this work, the projected mine is given a series of price tags that together measure up its minability expressed as a net present value. Accomplishing this is hard work and the likelihood that the work put in will produce success is slim given the many uncertainties involved. When it comes to blown predictions, it is perhaps more interesting to ask how grave the consequences of the failure are than to focus on the failure itself. After all, most mineral exploration projects are born to fail and to explorationists the important question is therefore whether they fail well and manage to, as Maxwell put it, kill the bad projects in time, or whether they fail bad.[105]

6.4 Concluding remarks

In her study of how the U.S. Bureau of Reclamation valued and weighted different potential dam projects, Wendy Espeland (1998) shows how rational quantification is colored by the assumptions upon which it is based. This is because rationality, Espeland argues, is a cultural, organizational, and political construct. Rationality, in other words, is not a neutral view from nowhere, but a context-dependent mode of reasoning. Calculative practices, Natalia Besedovsky (2018:252) adds, “shape ideas” and “calculative devices are concrete manifestations of these ideas.” That is, efforts to de-risk a project by increasing the quantity and quality of projectable data are inherently shaped by the choices made in terms of what valuation devices to use, what data to assemble, and how to weight one datum in relation to other data. The previous

[105] Put somewhat boldly one may ask whether explorationists manage to kill the bad projects or whether they fail, thereby killing their companies or–as in the case of the Blaiken mine–end up killing much of the surrounding natural environment.

two chapters have detailed how explorationists work to produce quantifiable knowledge about geological, economic, environmental, and social past, present, and future in order to establish projectable patterns to guide their exploration both short-term and long-term. What emerges across the pages of these two chapters is an in-depth account of the process in which explorationists' prediction work is embedded as well as a series of outlines of different forms and stages of exploration work. This section takes this account as its basis for an analytical discussion of how predictions of future minability are produced in mineral exploration.

As discussed in chapter 3, predictions attempt to answer questions about the future and rely on predictors producing data in which they can identify patterns of such stability that they may be projected into the future with the aid of some linkage (see Rescher 1998). The work of explorationists follow this outline as much of exploration work consists of assembling data from heterogeneous sources to support both short-term decision-making and long-term minability valuation. Supporting decisions on where to locate an exploration project, whether to move projects forward and invest more time and capital into further exploration, and whether to move the project out of the exploration stage into development and construction, the prediction work carried out by explorationists operates on different temporal horizons. First, there is the immediate problem at hand. Where should the project be located? Is there evidence that there is a discovery to be made here? Have we managed to define the mineralized body or are there more to be discovered by drilling more? Is there enough potential in this project to warrant intensified drilling and analysis? Did the pre-feasibility study provide results that support undertaking a feasibility study? These are all questions about the next stage of exploration and they are questions motivated by the low probability of success, which encourages explorationists to hold on to their capital so not to spend their time "beating a dead horse." At the same time, there are the long-term horizons, the mine that might become. Mineral exploration, after all, is not about producing projects that survive yet another cycle of exploration work, but attempts to produce that one project that is strong enough to go through the ten or so years of exploration work, attain all relevant permits (and in many cases a considerably sized loan), and emerge on the other side as a profitable mine. In exploration, these two temporalities run in parallel as explorationists work to assemble data that grow cumulatively as the project matures.

One central dimension to the logics under which mineral exploration operates is through the cumulative assembly of data, which plays a vital role in the prediction work undertaken by explorationists. However, because of its heterogeneity, this growing volume of data needs to be translated into a common metric that expresses minability in the form of a de-risked prediction of a future mine's economic value. Initially, this common measure is the estimated quality and quantity of mineral product derived from geophysical and geochemical surveys and from drill cores. A project estimated to possess significant quantities of good grade mineralized material is predicted minable in early stage exploration. As the project matures, the heterogeneity of the assembled data grows and minability becomes more of a composite term determined by heterogeneous values ultimately translated into monetary terms. Intermediate and advanced stage predictions therefore predict a slightly different type of minability: a minability determined by the potential profitability of exploiting a deposit. Here the geological value in the project is supplemented with other values arising from valuations of the project as a technological entity, as a case of socio-environmental impact management, and as a balance between costs and revenue. Although the foundations for determining minability in the later stages of exploration work are heterogeneous, the measure is not infinitely complex as much data that could potentially be used to predict minability in a project are left outside the estimation. Prediction work in mineral exploration focuses on a narrowly defined set of dimensions–i.e., geology and modifying factors. Although projects are valued in multiple domains, they are valued using a pre-determined set of valuation devices outlined in industry standards and practices. The reliance on this standardized narrow set of dimensions enables explorationists to commensurate different projects and their respective conditions and challenges and treat them as equivalents. It is through commensuration that explorationists can rate and rank their projects based on their NPV and position in cash cost curves and it is on basis of these commensurative efforts that projects are de-risked. However, does this mean that uncertainty is truly reduced as exploration projects mature? From a techno-scientific perspective, the answer would be affirmative, but there is a paradox to this as exploration projects appear to fall under more uncertainty the further along the process they come.

In the early stages of mineral exploration, explorationists primarily deal with the complexity of geological nature. Being the result of billions of years of geological processes, geology as first nature may be infinitely complex, but enough regularity exists to allow explorationists to use more or less developed theories and hypotheses in order to narrow down and delimit their search parameters. However, as a project moves forward and begins to consider mineral deposits as second nature, it is exposed to infinitely uncertain phenomena in the form of socio-environmental and economic indeterminacies. The open-endedness of future commodity markets, techno-environmental interventions used to negotiate environmental impact, as well as socio-juridical matters such as social licenses to operate and permitting processes remain despite explorationists' efforts to order their projects under standardized measures and models. Because of this, the products to come out of explorationists' prediction work effectively reduce many of the complexities that explorationists face in early stage exploration, but at the same time they stand as "as if statements" (Beckert 2016) that construct a "second reality, more structured and manageable than the uncertain world modern society has to face" (Esposito 2015:97).

That is, uncertainty management in mineral exploration follows a dual line where the work to reduce complexity reduces the uncertainties to do with a deposit's geological qualities as first nature (i.e., its grades, volumes, geometry, and metallurgical properties) while the work to determine a deposit's minability as second nature re-introduces uncertainty.

Given how so much uncertainty remains at the end of the exploration process, the true answer to the question of whether predictions help explorationists manage uncertainty is not straight forward. Instead, there exists a puzzle as to how explorationists can claim to have de-risked projects while their future minability remains uncertain. Chapter 5 outlines how the sorting of exploration projects is to do with a rationality based around sufficiency (March and Simon 1958) rather than with finding the most minable mineral deposit; this focus on finding a sufficiently minable project answers part of this puzzle. However, sufficiency does not remove uncertainty, so the present future depicted in feasibility studies and mineral reserve reports remain potentially unruly (Wynne 1988) as any unexpected development may cause these predictions to collapse in on themselves. Therefore, it remains an open question as to how explorationists justify the merit of their predictions in the face of the unforgiving uncertainties of the future. The next chapter looks closer at this second dimension of prediction work: the justification of minability predictions as correct depictions of desirable present futures.

7. Justifying Predictions: Claims of Correctness and Desirability

> "In order to call something a mineral resource, you need to justify how you may actually mine it at a profit."
> John, to a class on mining economy and risk evaluation

The two proceeding chapters describe and analyze how mineral explorationists work to produce predictions and in doing so they provide a first set of pieces for the puzzle of how explorationists use prediction work to manage uncertainty. However, making predictions is only the first step: after all, few predictions possess any real merit unless they are recognized as correct and relevant. This opens the door for approaching the second question posed in this thesis: How do mineral explorationists justify their predictions? As discussed in chapter 3, a central conceptual component in understanding justifications is in the use of particular values through which worth can be ascribed to an actor or object. Astrology is one example from the history of predictions and provides a good example of this connection between values, objects, and justifications of worth. Once a highly respected form of scientific prediction (Curry 1987), astrology is now seen as little more than superstition. Using the bare-bones version of Boltanski and Thévenot's (2006) work on justifications outlined in chapter 3, the change in the status of astrology over time can be traced to how the *signifiers of worth* that once supported claims for the worth of astrology as a rational method of prediction ceased to apply to astrology. The decline of astrology from prediction to superstition in recent history is therefore less to do with astrology *viz.* prediction than with historical changes in norms and other institutions that led to there being no justificatory basis upon which the correctness or relevance of present futures produced through astrology, palm readings, or any other "superstition" can be justified as a rational method of prediction. This historical change helps highlight the importance of justification in prediction work and the role of values in granting credibility to predictors and their predictions.

In formal terms, signifiers of worth describe the relation between the actor or object for which a justification is made and the value actualized as a measure of the worth being ascribed to this actor or object. The definition of signifiers of worth therefore follow the definition of justification put forth by

Boltanski and Thévenot (2006) but without the epistemological baggage of locating these values in predefined "orders of worth." Justifications, it follows, consist of claims that link one person or object to a certain worth based on this object or person being of or possessing some quality perceived to be relevant in a particular context. John's discussion of the worth of a mineral reserve by referring to its profitability (above) hints at how this takes place within the context of mineral exploration.[106]

This chapter will outline how explorationists justify the products of their prediction work. It focuses on the content of justifications made and what signifiers of worth are called upon to justify the worth and merit of predictions in mineral exploration. Based on the contents of the empirical materials, the chapter distinguishes two distinct trends in the signifiers used in justifying predictions. The first of these trends considers the prediction's correctness and contains justifications based on claims of precision and accuracy as signifiers of a prediction's worth. The second form of justification are justifications of the desirability of the present futures outlined in the predictions. This second factor is of some importance here as the predictions made by explorationists not only describe a present future, but also seek to realize it. Explorationists, at the end of the day, are not only describing what a future mining operation would entail in terms of its profitability or socio-environmental impacts, but also are seeking to persuade others that building and operating this mine is the preferable course of action. This chapter accounts for both types of justification and is divided into two sections with each section focusing on one of the two.

7.1 Claims of correctness: Accuracy and precision in prediction

As outlined in the previous chapters, the use of valuation devices in exploration work builds a growing corpus of values across the exploration process. Using these values, explorationists are then able to identify patterns describing the past and present and which they can project into the future as predictions. Based on these predictions, explorationists gain access to a future present that they can then use to justify whether a particular exploration project should be

[106] A more general example of how justifications depend on the use of values to signify the worth of something or someone is perhaps the justification put forth in the following sentence: "Marxism is not a scientific theory because it cannot be falsified." By actualizing falsifiability in the Popperian sense as a signifier of worth, Marxist theories are thereby said to be of the (negative) worth of "not being a scientific theory" because they do not meet the criteria of falsifiability that is central to Popperian positivist theories of science.

abandoned or be granted further attention and resources. Although the justification of a project's potential can be made referencing the measured qualities of the mineralized deposit, justification of the prediction of the same deposit's future minability is trickier. Arguably, a prediction needs to be correct for it to be useful. Predictions are, after all, answers to questions about the future and in an industry that constantly needs to look out for dead ends and false positives, correct answers are generally better than incorrect ones. However, given the uncertainty that underlies explorationists' predictions, despite the steps taken to reduce risk in projects, correctness is hard to ascertain in a straightforward manner, as the future in which a prediction will emerge as having been either correct or incorrect is yet to materialize. The peculiar status of predictions as claims about the future based on observations of the past and present (discussed in detail in chapter 3) means justifications of predictive correctness needs to be based on something other than a direct correspondence between a predicted present future and the future present it pertains to depict. In mineral exploration, this chapter argues, this "something" consists of claims of accuracy and precision in relation to the data and linkage that allow explorationists to perform the epistemic leaps (Rescher 1998) from past and present to the future described in the two previous chapters.

In explorationists' terminology, the data collection and analysis undertaken to improve the knowledge base available for prediction work fall within the efforts to de-risk exploration projects by assembling data on the aspects of the project's material and future dimensions seen as relevant from an exploration perspective. As described in the previous chapters, efforts to de-risk projects take different shapes depending the stage of the exploration process. Ian, a CEO of a junior company, discussed these differences in de-risking efforts by explaining that sometimes de-risking might be as simple as drilling a hole so one can actually having a look at what is down there beneath the surface. While costly and time consuming, drilling, after all, offers the only opportunity to valuate the geological qualities in a project by drawing samples from the actual bedrock in the form of drill cores. From this data, explorationists can justify any predictive claims about short-term future discoveries and long-term minability. However, as the previous chapters have shown, de-risking is not only about drilling. Instead, each step and method used in mineral exploration in some way pertains to a reduction of risk and uncertainty. Therefore, de-risking is the central motivation behind each step of the exploration process. According to Ian, mineral exploration is in and of itself a process of risk reduction where explorationists employ different tools in their tool box to reduce risk:

> We could do geophysics, and then we could do some drilling, and then we could do some more geophysics, and do some more drilling. And the techniques may vary subtly and the types of drilling might vary, or the depths or whatever it might be. So the more you go down the line, the more you reduce

> the risk, the more you can actually be confident that you will get an outcome from a given spend. But all of it, ultimately, is about risk reduction; all of it! So when you make your mine, it's there.

Talking about reducing risks and effectively about attempts to manage uncertainty, Ian described the importance of confidence as a value signifying worth in predictions. The source of this confidence is found in the belief that the cumulative work put into exploration work actually increases knowledge in such a way that it helps de-risks a project both in the long-term and short-term. This confidence in turn posits that the each subsequent stage of exploration contributes to raising the quality and quantity of data in a project in such a way that a project's minability can be made known and that the predicted volumes and grades will actually be found the day the ground is opened up to build the mine. The corpus of heterogeneous values produced in exploration is therefore not only the, so to say, raw materials for prediction work, but also one of its most important justifications as it helps explorationists develop confidence in their estimates and predictions. Maxwell, for example, sees such confidence as evidence that predicting minability lies in establishing a sufficiently strong geo-statistical material that one is able to predict with relative confidence what grades one would pull out of the deposit where one to drill a new hole into it.

While Ian and Maxwell emphasized the importance of gaining confidence by measuring and mapping the underground to manage the geological complexity in a project, exploration geologist and consultant John provided a bridge between confidence and justification. According to John, justification and the reduction of risk go hand in hand, as it is the reduction of risk that ultimately justifies predictions of future minability. When asked to explain this, John made use of an outline of the exploration process and its different stages and described how the best justification for predictions of future minability varies along the process. Referring to early stage exploration, he made the following observation:

> What's the best justification? What are the biggest risks here? They're geology, aren't they. The geology, the understanding of the resource, is the biggest risk here. So the best justification for continuing with something here is a good understanding of the geology and economically interesting grades. Those are your biggest risks in this area here.

As projects are moved further along in the exploration process, the growing body of data on the mineralized deposit allows explorationists to establish confidence in the geological dimensions of a project and move to work on other risks in order to justify the project's future minability in additional dimensions. Referring again to the outline of the exploration process, John began talking about the justification of advanced stage predictions:

> What's the best justification here? I would say the technical, the modifying factors, because you've gone from understanding your geology, okay, if you've kept going here, then your geology must be easily understood, you must be getting reasonable grades of economic interest you've got to, say, this point here where you've defined your mineral resources, then your biggest risks are in the modifying factors, so your technical, economic, political, if you call them modifying factors, those are your biggest risks. Then your best justification is to say "Those risks we understand, and they're manageable, and the economic model is reasonable and it shows us that we're gonna make a profit, and within the context of the study phase we're at, the NPV looks good."

Here, John bridges risk reduction in first and second natures. As John describes it, explorationists in advanced stage exploration justifications of their predictions on future minability shift from focusing on measurable dimensions such as the quantity and quality of first nature mineralized material in a deposit to focusing on the uncertainties connected to the second nature mineral resource and reserve. These uncertainties are then approached through the methodologies in place for managing modifying factors and from the economic model with its combination of measurements and assumptions from which explorationists estimate the projected mining operation's NPV, the ultimate measurement of future minability. However, as the previous chapter argued, also the NPV is a highly uncertain measurement so its use as a low risk estimate requires explorationists to bracket or leave aside any uncertainties not accounted for in their estimations.

The means of justification outlined in the quotations above consist of continuous investments in more data in order to understand the physical properties of the mineralized deposit and the consequences of the modifying factors on the project's minability and bottom line. In practical terms, the process of building confidence and justifying predictions in mineral exploration is intimately tied to the standards for reporting on mineral resources and mineral reserves outlined in the previous chapter. The use of these standards allows explorationists to translate their findings into categories where each category corresponds to a certain class of risk and confidence.

In early stage exploration, there are no codified risks or confidence levels; instead, explorationists can only refer in their justifications of exploration potential to the data produced so far and to other qualities that speak to why their projects may one day be found to be of such quantity and quality that they can be turned into minable resources and reserves. Justifications of exploration potential, in other words, relate to dimensions such as exploration potential, early stage findings, and a project's proximity in type or location to known minable deposits. Examples of this were observed in a venue at an international industry conference and trade show. At this event, there was a large number of booths set up by prospectors and explorationists seeking to attract investors to their early stage exploration projects and to do so they had brought with them sections of early stage drill cores containing promising concentrations of mineralized materials as well as maps and other pieces of information detailing the potential in their projects. However, as soon as explorationists are able to move from early stage exploration results and produce a mineral resource, they gain access to a universe of values with which to justify their claims of a deposit's future minability; this is an important difference between the early and later stages of exploration. That is, early stage exploration is motivated and justified by references to the potential for significant discoveries inferred from interesting exploration results, whereas advanced stage exploration predictions are justified using other values such as those put forth in industry standards.

By dividing the exploration process into increments based on estimate confidence and categories of risk, industry standards help explorationists justify their predictions as projects are moved from one category to the next and from high to lower levels of risk. This points to an important aspect of the confidence building and justifications discussed by the informants above: how institutionalized values contained in standards play a central role in guiding what risk reduction is supposed to look like in mineral exploration. It is against this backdrop of standards and practices that the values derived from exploration work are made sense of. A discussion of certainty in predictions by mid-tier mining company senior officer Richard provides an example. When asked whether explorationists use any rules of thumb in relation to how certain a prediction can and should be, Richard stated that:

> For reserves, you need to have a high probability that the estimate is correct. However, if you go down to a mineral resource and you take the lowest class of mineral resource, which is called *antagen*–or inferred in English–there you have probabilities of something like plus-minus 100 percent. And that's an indication of "how certain is this information." And then when you're at reserves then you might say that "we're somewhere between perhaps five or ten percent." There's still some uncertainty, but that uncertainty depends on many different things, like method of analysis and so on. But I believe that you're pretty pleased at that stage. If you've done everything correct throughout the process, then you usually find the estimated metals when you begin mining it.[107]

[107] För reserver där ska du ju ha en bra sannolikhet att det där stämmer. Men sedan när du går ner till mineraltillgång och du går till den lägsta mineraltillgångstypen som kallas för antagen – eller inferred på engelska; där är sannolikheten plus-minus kanske 100 procent. Och det är en indikation på ”Hur säker är den här informationen?” Medan när du är på reserver så kommer vi kanske att säga att ”Vi ligger någonstans mellan kanske fem och tio procent.” Det är fortfarande en viss osäkerhet, men den beror på många saker, liksom, analysmetod, allt möjligt. Men jag tror att där är man ganska nöjd. Har man gjort det rätt genom hela processen så brukar man ju hitta metallen ingen när man plockar ut den.

That is, what ultimately defines the quality of predictions is whether explorationists have "done everything correct" and followed the principles laid out in industry standards, managing their projects, so to say, "by the book." Now, doing exploration by the book has three consequences. First, it guarantees that the exploration project ascribes to what the standard issuing organizations deem to be sufficient quality exploration work, thereby reducing uncertainty in as much as it becomes more certain how a project has been worked.[108] Second, it allows explorationists to claim confidence while at the same time disregarding any uncertainties not covered in standards. Third, it serves a form of signaling function, as doing things by the book and stating that one has done so becomes a marker of "good" exploration work.[109] Due to their role as determinants of what constitutes sufficient quality in exploration work, private regulation such as industry standards also provide a system of signifiers of worth with which the quality of the work from which one is making a prediction can be justified. Justifying predictions, in other words, means establishing legitimate confidence that the data from which the prediction is made are accurate and precise. Getting everything right in exploration therefore means producing good data in which to identify projectable patterns concerning those aspects deemed relevant in mineral exploration practice and standards. Successfully doing so means that the mineral reserve predicted to be there in the ground is probable to materialize once mining commences, but there is a possibility it will not. That is, industry standards provide a map for making predictions but they do not comprehensively cover every dimension that may possibly affect the minability in a project whence mining commences. Instead, they offer a set of conditions that stock exchange listed exploration organization need to meet when reporting mineral resources and reserves; and the way they do so is through the data quality assurance/quality control programs and the accreditation systems they have put in place to ensure the quality of the data used in prediction.

7.1.2 QA/QC and QPs

The quality assurance (QA) and quality control (QC) procedures outlined in industry standards and partially described in the preceding chapters consist of efforts to assure and control the quality of data used to predict minability in

[108] For a discussion of how standards help reduce uncertainty, see Aspers (2018).
[109] Compare this with how other standards such as organic farming certificates act as markers of status in markets for meat (Bååth 2018); the certification stand in as short hand for a whole range of values connected with the standard of the issuing body.

exploration work. Quality assurance procedures are protocols for checking accuracy and precision in laboratory metallurgical analyses by means of adding blank, duplicate, and standard samples in the material sent to the laboratories as well as by conducting external lab checks and comparing the results returned from analysis of materials from the same source (e.g., a drill core) but analyzed at different laboratories. Quality control, on the other hand, pertains to controlling the quality of the data produced in a project. Examples of quality control issues include controlling drilling performance to prevent the drill from bending in some unaccounted direction causing drill hole deviation as well as strategies to maintain sample quality be preventing cores from breaking or shattering, both issues that introduce sampling problems as they make it harder to pin point samples to a certain position in the bedrock. In addition, quality control also involves protocols for monitoring how drill cores are stored and prepared to prevent any tampering with or contamination of samples.

Because of their role in industry standards, QA/QC procedures are central to the classification of resources and reserves and therefore are important dimensions in predictive exploration work. One example that highlights just how central the role quality assurance and control hold in the industry are the industry standards. For example, the European PERC-standard states that references to recognized QA/QC programs are essential to mineral resource and reserve reporting. When reporting a resource or a reserve, the code continues, explorationists must include what measures they have taken to assure and control sample and analysis quality:

> The name of the laboratory responsible for analyzing samples, the assay methods used, and the laboratory's level of accreditation for the assay method used must be reported. If the assay methods used are not generally established, an explanation shall be given. Quality Control procedures and Quality Assurance for the assays shall be described.

Taken together, the reporting standards and the QA/QC procedures included therein build a body of values and practices that legitimize explorationists' predictions by providing a foundation for what counts as accurate, precise, and rigorous exploration work and by providing a regulative foundation for prohibiting what Maxwell referred to as "blue skies mining." Before reporting standards were introduced as a result of the frauds committed in the Bre-X exploration scandal, according to Maxwell, many people in exploration "made whatever claims about the state of things," liberally interpreting exploration results and painting overly optimistic images of the potential minability in their projects. Industry standards regulating what can be said in public reports of mineral resources and reserves were put in place in order to curtail such behaviors and have since grown to become standard practice in the field.

In addition to the demanding QA/QC procedures, the industry reporting standards also provide a system of accreditation for actors who have sufficient exploration experience to review and produce public reports on exploration targets, mineral resources, and reserves. As described previously, people with such accreditation are referred to as either qualified or competent persons depending on the standard used, and they play a central role in the application of standards in the estimation of and reporting on mineral resources and reserves. According to industry standards, any public report on exploration results, resources, and reserves must be prepared by or under the direction of and underwritten by someone accredited under the adequate industry standard.[110]

To qualify for accreditation as a qualified person, one must provide evidence of adequate credentials. These credentials include a university degree or a similar qualification in geoscience or engineering, good standing with a professional association, and sufficient experience in the mineral type and activity they are seeking accreditation for. What constitutes sufficient experience varies between standards. The Australasian JORC code and the Canadian NI 43-101 define sufficient experience as at least five years relevant experience in the style of mineralization and activity in question, whereas the Pan-European PERC code provides a looser definition, "probably at least five years." Accredited person Carl explained how the accreditation system works:

> And if you've been working with sulfide deposits, copper, lead, zinc and so on, for five years, for example, that doesn't mean that you know pure gold deposits. So you need, like, five years for each group. And then there are some overlaps. But you need to be able to show that you've worked with this for at least five years [. . .] and if someone would ask me today if I could, ehm, do something on the uranium deposit around you hometown I can say that I haven't worked with uranium before [. . .] so there my knowledge would come up short. And that's the way it should be.[111]

To become a qualified person, explorationists therefore need to demonstrate competence not only in exploration in general, but in relation to having worked on a specific type of mineral deposits. Moreover, Carl continued, qualified persons are also to be prepared to defend their work in front of their peers. The standards thereby create a system of private regulation where accredited persons are held responsible by their colleagues for the statements they sign

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[110] The adequacy of the standards depends on what jurisdiction one is reporting under, as the Australasian JORC Code is not valid in Canada, where a NI 43-101 accreditation is needed, but both standards are recognized as adequate in Sweden.

[111] Och att man då har jobbat till exempel med sulfidmalmer, koppar, bly, zink och så vidare, i fem år. Det gör ju då inte att man kan rena guldmalmer. Så du ska ha liksom fem år per grupp. Och sen finns det vissa överlappande bitar. Men du ska kunna visa att du har jobbat med det här i minimum fem år (…) och om jag skulle bli tillfrågad nu till exempel om, ehm, uranfyndigheten som finns i dina hemtrakter så kan jag säga att jag har inte jobbat med uran. (…) Så att, där faller liksom mina kunskaper till korta. Och så ska det vara [kursivering speglar betoning i inspelningen].

off on in public reports. Carl spoke of this as an important factor of the accreditation system, saying that qualified personship is not the same as a license to practice; instead, qualified persons have to claim their expertise and part of this is to be prepared to defend their work in the face of criticism from other qualified persons:

> In particular, the rule is that if I make a statement of some sort, it is said that I shall be prepared to defend it in front of my peers, meaning that another qualified person may come and question my statement and then I need to be able to demonstrate that my work is correct. And I believe that's only reasonable. And there are examples of people who have been qualified persons and who aren't anymore because they did some mistake in one way or another. It's not common, but it happens.[112]

In relation to this almost peer review-like system of qualified persons self-regulating their activities by reviewing each other's statements, the standards furthermore prescribe that the reports underwritten by qualified persons are to be transparent and provide a reader with sufficient and unambiguous information (PERC code) and information such as the prices used in estimation should be made clear (JORC code). Moreover, in the case of the Canadian NI 43-101 code, forward-looking information (e.g., metal price assumption, cash flow forecasts, costs, and recovery rates) is to be identified as such in the report.

Together, the QA/QC procedures and the system of accredited qualified persons are designed to ensure that the reports produced on the estimated mineral resources and reserves in exploration projects are transparent and based on accurate and adequate data. Prediction work in mineral exploration is therefore not a place for creative narration as in financial analysis, for example (Leins 2018; Pilmis 2018). Rather, the standards that guide important aspects of prediction making in mineral exploration, such as the estimation of resources and reserves, invoke techno-scientific ideals for what makes "good" mineral exploration work. For example, Eric, a senior officer at a junior exploration company, discussed the mineral exploration process using metaphors borrowed from science. The step-wise reduction of risk in mineral exploration, Eric argued, is accomplished through the use of short-term predictions in the form of hypotheses that are tested to develop the knowledge from which to predict minability in a project:

> Well, it's like a science experiment, really [. . .]. You know, you have a hypothesis, you test it, you get a different result to what you expected, you modify

[112] Framför allt så säger man ju att, om jag gör det uttalande av nått slag så sägs det att jag ska kunna defend in front of my peers, det vill säga att en annan qualified person då kan komma och ifrågasätta mitt uttalande och då ska jag kunna visa att det är korrekt. Och det tycker jag är bra rimligt. Det finns ju exempel på människor som har varit qualified persons och som inte är det därför att dom har gjort då.. tabbar på ett eller annat sätt. Det är inte vanligt men det finns.

> your hypothesis and as you go through those stages your risk, ehm, either reduces and you keep going, or the risk doesn't reduce and you might stop.

Through using metaphors such as hypotheses and experiments, Eric places the prediction work of explorationists within the realm of science and of techno-scientific risk management in the form of data driven hazard management. However, although science may be a compelling metaphor for how explorationists manage uncertainty in exploration projects, the complexities and uncertainties of mineral exploration make it very different from the controlled situations upon which the scientific method in its usual conceptualization rests. Still, science and scientific rigor are important ideals in mineral exploration and a source of values used in justifications of predictions as correct depictions of the future present. Moreover, science as an ideal also appears in some of the industry standards in the form of calls for scientificity in mineral resource and reserve estimation.[113] For example, the Canadian NI 43-101 standard states its purpose as establishing "standards for disclosure of scientific and technical information regarding mineral projects," and the PERC code lists "ensuring that the scientific and technological contributions [to the report] are thorough, accurate, and unbiased in design, implementation and presentation" as one of the responsibilities of qualified persons.

Together, the different checks and balances listed in this section emphasize transparency, accuracy, precision, and scientificity as important qualities in mineral exploration and predictions of deposit minability. These checks and balances add another layer of values to the exploration work and the predictions made by explorationists. These values hang together in sets of signifiers of worth that define targets that explorationists are to ascribe to as well as a series of institutionalized measures put in place to ensure that exploration is transparent and based in data qualifying as facts. To ensure that everything is done correctly, data collection should be transparently outlined, analysis results should be crosschecked and validated for accuracy and precision, and qualified persons should be able to rationalize their work to other professionals. By abiding by the expectations on exploration work put in place by the standards, explorationists gain access to signifiers of worth that they can draw upon when justifying the qualities of their predictions as correct depictions of the future.

[113] The sole exception being the Australasian JORC code, which instead emphasizes values such as clarity and enabling investors to make "balanced judgements."

7.1.3 Summary: Accuracy and precision as correctness

The present day incarnation of industrial mineral exploration is situated in a landscape of values originating both from the exploration process itself and from regulatory sources such as standards and other private regulation. Together, these bodies of values provide a repertoire that explorationists can draw on when justifying the correctness of their predictive claims. As discussed here, these values tend to revolve around notions of scientificity in the exploration methods used in assembling data for prediction work, and this relates to how data that display stable and projectable patterns are a prerequisite for making predictions. As discussed in chapter 3, Rescher (1998) outlines two ideal types of prediction: one originating in the expertise of the predictor and the other based on the use of predictive models and procedures. Based on the descriptions above, industrial mineral exploration tends toward the latter rather than the former. Although experience and expertise are important in exploration in general and in the systems of accreditation in particular, the justifications of predictions greatly emphasizes the appropriate use of models and precise and accurate data rather than individual expertise as values characteristic of good predictions.

In a broader perspective, the values put forth in informants' accounts and in industry standards, correspond to a broader universe of values in which quantified measurements are held to be rational and objective descriptions of the world both past and present as well as future. Expectations that strict quantification through a mechanically objective approach leads to objective measurements, Theodore Porter (1996) writes, feeds into a trust in numbers as being accurate and true depictions of reality. Porter based his analysis of numbers as technologies of trust on an historical analysis on the development and use of cost-benefit analysis in engineering and other studies of risk reduction in engineering echo Porters account (e.g., Espeland 1998; Vaughan 1996). As outlined here, mineral explorationists also trust in numbers. In mineral exploration, numbers reduce risk: the more and the better the numbers, the better the prediction. This view is hardly surprising. However, what is interesting about how explorationists justify their prediction work is that they combine a highly quantitative approach that uses geo-statistical estimation to facilitate the epistemic leap from past and present to the future with a view of exploration as a fundamentally uncertain enterprise. This combination of quantitative de-risking and inherent uncertainty forms the foundation for an interesting tension between uncertainty and the struggle to quantify the exploration project and de-risk it. The center of this tension is the conceptualization of risk. As noted earlier, Knight (2006) emphasized that risk as measurable uncertainty relies on situations being similar to each other. Therefore, uniqueness in, e.g., an exploration project, reduces the degree to which uncertainty can be translated into risk. To de-risk a project, explorationists therefore need to do away with uniqueness by standardizing their projects, making them as similar as possible to other exploration projects, and they accomplish this by using institutionalized standards and procedures. This tension between recognizing that each exploration project is different and simultaneously working to standardize and homogenize exploration projects by submitting them to the same standards and practices is one of mineral exploration's central paradoxes; ultimately, this paradox means bracketing uncertainty in order to focus exploration towards reducing risk. What emerges from this is a particular epoché (Schütz 1944) that explorationists subject themselves to in order to reconcile the rigorously measurable reality created in exploration work and the messiness of geology as uncertain future second nature; and they do so by bracketing unaccounted for uncertainties.

7.2 Desirable futures

While justifications of accuracy and precision in prediction work are important factors in claiming that the present future depicted in prediction is a correct image of a future present, a second important factor in the justification of mineral explorationists' futures is the desirability of a particular future. Compared to meteorologists and financial analysts described in the sociological literature (e.g., Fine 2010; Leins 2018; Pilmis 2018; Sundberg 2005), explorationists not only seek to describe the future, but also seek to realize those projects estimated to be minable; and they often do so in competition with other interests desiring other futures. It is here the prediction work in mineral exploration expands beyond the values discussed above to engage in a conversation about broader repertoires of values to do, in part with, socio-environmental values as defined in public regulation and in part with values called upon to persuade affected communities and interested parties of the benefits of a mining future.

This section analyzes the justifications made by explorationists in relation to the juridical and public domains. First, the section approaches the justifications put forth by explorationists in environmental permitting where the appropriateness of realizing a projected mining operation needs to be justified in relation to terms set out in environmental regulations. Here, values such as land use and long-term resource management are discussed in relation to the claims put forth by explorationists in interviews, observations, and in the body of preliminary EIAs attached to concession applications. Second, the section describes and discusses the justification of predicted mining futures in relation to competing futures. Central to this discussion are explorationists' assertions of the benefits expected to arise from a future mining operation as well as arguments regarding the relative and absolute costs of mining in Sweden and in other localities.

7.2.1 Justification in environmental permitting: Costs and benefits from resource exploitation

> Everyone alters the environment from self-interest, and all persuade themselves of their respect for it. (Fine 2003b:44)

The legal and juridical conceptualization of "nature" in Swedish regulation and in exploration practices calls forth images of the natural world as a passive entity under the dominion of man. This is perhaps not surprising as such images were plentiful in Western enlightenment philosophy and remain strong in Western culture today (Tsing 2015). However, while modernization drove a hard distinction between nature and society, such division has recently been challenged by scholars such as Bruno Latour (1993). In mineral exploration, the blurriness of such divisions between nature and culture become apparent when one begins to consider the hybridity of the second natures such as mineral resources. Furthermore, the arrival of the Anthropocene (Lewis and Maslin 2015) has worked to break down this divide even further, in essence producing a counter-Copernican revolution (Latour 2014) as humanity again stands at the center of a world, which carries the scars of human impact. This breakdown of nature and culture as distinct categories provides a fitting background for an analysis of the justification of future mining operations in environmental permitting processes as these assume human superiority as managers of "nature" as the environmental courts are to determine what future best fits with ambitions of sustainable resource management and the preservation of environmental values.

As mentioned previously, environmental impact reviews take place on two occasions in the exploration process: in a preliminary assessment within the frame of the exploitation concession process with the MIS and local County Administrative Boards (CAB) and in the environmental permitting through environmental courts assessing the legality of the planned operations. Moreover, these processes are guided by the principles and rules laid out in the Swedish Environmental Code of 1998, which guides what is a valid justification in terms of the predicted costs and benefits of a projected mining operation.

At the center of the environmental permitting procedure stands the question of whether mining a location corresponds to the regulatory demand that land is to be used for the purpose that best benefits long-term resource management. The Swedish Environmental Code is written in such a way that it requires explorationists to rationalize how the futures they seek to realize contribute to "good" resource management and why any other values and resources at a location should be sacrificed to make way for a future mining operation.

The archival material contains 29 preliminary EIAs produced as part of the exploitation concession process. In addition to these preliminary EIAs, the materials also contain significant volumes of supporting documentation. These materials include water quality surveys, archeological surveys by commercial archeologists, environmental value surveys, social impact assessments, and protocols from meetings with affected communities such as the Sámi and the Sámi districts. These materials are not definitive EIAs, but preliminary impact assessments and are reviewed by the local County Administrative Board (CAB) and the MIS as part of exploitation concession processes.

The justifications put forth in the corpus of preliminary EIAs provide examples of how explorationists balance costs and benefits that stretch beyond those outlined in the feasibility studies discussed in the previous chapter and the accuracy and precision that make up the foundation for justifications of prediction correctness discussed above. Starting from the economic and technical valuations of projects, the typical preliminary EIA in this corpus begins with a report on the estimated quantity and quality of mineral resources and reserves in a project and moves to outline the socio-economic benefits these mineral riches are expected to provide the local communities. Moreover, the outline of these expected benefits is made in relation to the predicted environmental costs of realizing them.

The implicit argumentation involved in contrasting benefits against costs is at its most apparent in the sections in the EIAs covering the so-called "zero alternative." A zero-alternative describes the future that is expected to arise were the projected mining operation to go unrealized. In the preliminary EIAs, the costs and benefits of the zero alternative (i.e., not mining the minerals) are contrasted against the costs and benefits of the projected mining operation in order to discuss and justify the appropriateness of moving ahead and eventually mining a deposit. Examples of the justifications made of projects under the zero alternative heading include operating mines applying for extensions of their operations claiming that not fully exploiting the whole mineral deposit would reduce the benefits from the operation while keeping the costs of the present operation and new projects citing loss of estimated contributions to local and regional economies and employment opportunities. An example of the latter can be found in a preliminary EIA for a project in northern Sweden that cited the loss of 300 potential jobs were the projected mine not opened:

> The zero alternative means that the deposits at [Name of location] is left unexploited. This in turn would means that there will be no conflict between other interests and mining in the area and that the planned investments will not materialize. This in turn means that the near 100 jobs that the [Mine] is estimated to generate directly during its operation, as well as the equal number of jobs created at the construction stage, will not be realized.[114]

The document furthermore states that if the zero alternative is realized, also 100 additional jobs expected to be generated indirectly (i.e., in services and industries supplying the mine and servicing its workers and their families) will be lost as well. In other words, turning down the mine would mean turning down 300 jobs, a significant loss to many of the sparsely populated rural counties in the mineral rich parts of Sweden.

The prominence of cost-benefit dimension in justifications for why a projected mine should be realized means that these justifications largely come down to arguments about which values should be prioritized and questions such as whether the values realized by opening a mine pose a larger benefit than would the values preserved were the mineral to be left in the ground. An illustrative example of this type of prioritization is evident in an EIA from a large nickel project in northern Sweden. The EIA for this project proposed a series of locations for a tailings dam and clarification pools, but these locations required draining large sections of a lake. To identify the alternatives that would produce the best trade-off between costs and benefits, the applicant rated and ranked different dam locations according to their impact in several dimensions: (i) the relative volume of water available to a hydro plant downstream of the mine; (ii) reindeer migration routes in the area; (iii) the surrounding land areas; (iv) the ground and surface water in the area; (v) the landscape; (vi) cultural heritage remains in the area; (vii) existing terrestrial environmental values; (viii) existing aquatic environmental values; (ix) reclamation and restoration following the closure of the mine. In addition to the alternatives were also rated according to cost dimensions: (x) the volumes of materials needed for constructing each alternative; (xi) the costs of transporting and depositing tailings at the different alternative dams; (xii) the costs of constructing the respective alternatives; and (xiii) the estimated impacts from a dam breach. When ranking the alternative plans for waste management in the project, the applicant used a three-degree scale to establish which alternative produced the best trade of between benefits and costs. Reviewing the resulting ranking, the applicant proposed the alternative that resulted in the lowest overall score although scoring relatively high on dimensions such as impact on reindeer herding and migration in the area, impacts on land areas, surface and

[114] Nollalternativet innebär att fyndigheten i [Namn på plats] inte bearbetas. Det innebär således att det inte finns några motstående intressen med gruvbrytning inom området samt att de planerade investeringarna uteblir. Det innebär i sin tur att knappt 100 direkta arbetstillfällen som [Namn på gruva] beräknas generera under driftperioden, samt lika många under uppbyggnadsfasen, inte kommer till stånd

ground water, terrestrial environmental values, and the scope of potential impacts from a dam breach.

Another example of explorationists weighting different values when making justificatory claims as to a project's environmental impacts can be found in a case in which the applicant had been refused an exploitation concession on basis of the project's potential negative impacts on an area classed as a Natura 2000 zone. In communications with the MIS, the applicant argued against the CAB's unfavorable evaluation of the project. The MIS's documentation of the case made the following observation:

> The Company responded to the statement made by the County Administrative Board and stated, in principle, the following. The County Administrative Board had made an incorrect assessment of the risk of damage to the Natura 2000 area, the establishment of a mine would affect only a very small part of the vast Natura 2000 zone and The Company has designed the operations in such a way to cause the minimum degree of impacts to the area. The Company believes that their investigation convincingly shows that the establishment of a mine will not cause any substantial damage to the environmental values in the Natura 2000 zone [Name of location]. It is furthermore stated that according to chapter 4, 1st paragraph of the Environmental Codex extractive operations may be approved in exceptional cases, if there are particular reasons concerning the size and extent of the deposit. The copper deposit holds, in itself, a most significant economic value. Where the mine to be developed also the mining operation in itself would mean a great economic contribution to the region, for many employees, consultants and suppliers.[115]

In their response to the criticism delivered in the CAB's assessment, the applicant challenged the CAB's position and they did so in legal terms. The challenges focused on the Natura 2000 zone and the juridical procedures that allow applicants to waive Natura 2000 protection for their project. Doing so, the applicant claimed to have fulfilled the requirements for a waiver by studying and outlining the precautions necessary to prevent unnecessary environmental damage to the Natura 2000 zone. This claim was made in reference the Environmental Code, specifically the paragraphs that allow concessions to projects concerning deposits of certain qualities. Based on their interpretation of these

[115] Bolaget bemötte länsstyrelsens yttrande och anförde i huvudsak följande. Länsstyrelsen har gjort en felaktig bedömning av risken för skada på Natura 2000-området, en gruvetablering skulle påverka en mycket liten del av det stora Natura 200-området och Bolaget har utformat verksamheten på ett sådant sätt som medför så liten påverkan som möjligt. Bolaget anser att deras utredning övertygande visar att en gruvetablering inte kommer att medföra påtaglig skada på naturvärdena i Natura 2000-området [Namn på plats]. Det påpekas även att utvinningsverksamheter kan tillåtas undantagsvis vid en avvägning enligt 4 kap. 1 § MB när det finns särskilda skäl med hänsyn till fyndighetens storlek och omfattning. Kopparfyndigheten i sig har ett mycket betydande ekonomiskt värde. Vid en gruvetablering skulle även själva gruvdriften ha en mycket stor ekonomisk betydelse för regionen för många anställda, konsulter och leverantörer.

paragraphs, the applicant listed several arguments for why the CAB was mistaken in its "flawed" assessment of the projected mine's impact on the area. These arguments concern economics of worth, including economic values expected to arise not only for the applicant but also for the local communities and the region, and these values are weighted against the potential damage to the Natura 2000 zone.

By placing these values side by side, the applicant put forward a challenge, or a "test" in the terminology of Boltanski and Thévenot (2006), in which they related the relative benefits of going ahead with the projected mine against the, in the applicant's view, limited costs to the Natura 2000 zone, the reason CAB refused the concession. In their challenge, the applicant contended that the relative rarity of the two values should be considered when deciding whether the mine or the Natura 2000 area should be prioritized. Furthermore, the application claimed that the impact to the Natura 2000 protected biotope would be limited to only a small area of the total Natura 2000 zone making the cost of the environmental impact comparatively low compared to the cost of not mining such a sizable high quality deposit as the one discovered by the applicant:

> Considering that a deposit of such a size as [Name of location] is very rare, and considering what The Company has further stated, The Company believes that the national interest of mineral extraction should be granted priority at [Name of location] as this is the purpose most appropriate for the promotion of the long-term management of the land, waters and the physical environment.[116]

By referencing relative scarcity as a measurement of relative costs and benefits, the applicant frames the abundance of nature as something that forgives small incursions into select natural environments. Such reasoning exposes the core of the Swedish environmental regulation and the practices through which it is implemented, as the justifications made by the applicant in this case are part of a larger discussion in the industry and between different governmental agencies in Sweden. At the end of the appeal, the applicant references the national interest system of classification, where different governmental agencies can classify areas as being of national importance for reasons of containing values deemed important (see chapter 2). In the project above, the deposit in question is a copper deposit classed as a national interest by the SGU. However, while the deposit should therefore be protected from any intervention that may limit its exploitability, the area has also been classed as an important site for environmental preservation, first by the Swedish Environmental Pro-

[116] Med hänsyn till att en fyndighet av [Namn på plats]:s storlek är mycket sällsynt och vad Bolaget anfört i övrigt anser Bolaget att riksintresset för mineralutvinning bör ges företräde i [Namn på plats] eftersom det är det ändamål som på lämpligast sätt främja en långsiktig hushållning med marken, vattnet och den fysiska miljön.

tection Agency and second by The Swedish Government, which has designated the area as a Natura 2000 zone in accordance with European Union regulation.

In Sweden, situations often occur where different governmental classifications overlap, as they do in this case. This is somewhat surprising given how the national interest classification of mineral deposits are supposed to be protected from measures that obstruct their exploitation. Also in the case with the project proposing to drain sections of a lake discussed above there were overlapping classifications. The nickel deposit was classified a national interest, but so was also the reindeer migration route on the opposite shore and the cultural heritage sites upstream of the proposed mining site. These conflicting classifications, which are to be ranked and prioritized in the CAB's assessments of exploitation concessions and in later environmental permit trials in the environmental courts, are part of a larger discussion on values and land use taking place in Sweden and around the world. The next section will zoom out, so to speak, from the permitting processes and the justifications made therein to look at claims that seek to justify mining on a broader level.

7.2.2 Global benefits and local costs: Swedish and foreign futures

In relation to justifications of predicted mining futures, it is worth noting the central role of metals and minerals in contemporary societies as well as in industry and security.[117] Today, metals and minerals are everywhere–in our computers, our cell phones, our buildings, and our vehicles. They play vital roles as parts of the "green" technologies that, supposedly, will solve the climate crisis by replacing hydrocarbon-based energy with renewable electrical power from wind farms and solar panels. This prominence of metals and minerals in 21st century technology and life is something that explorationists and the overall exploration and mining industry often point to as one of the ultimate justifications for their work,[118] positioning metals in a peculiar place–

[117] For a historical account of this changed status of metals and minerals since the late 19th century, see Black (2018). For examples of how minerals have been treated as a matter of security, see the following original works assessing the reserves of resources available to the U.S. and other countries and its implications for peace and the war effort during the period leading up to the Second World War, see Leith (1938, 1939).
[118] It is also something explorationists at times criticize their critics for failing to understand. For example, Ian discussed the criticism directed against the industry saying that critics of mining "are free to behave with that view," but that before doing so, they should return anything in their possession that has come from a mine as they "shouldn't benefit from something and then complain about it."

simultaneously vital for and detrimental to environmental conservation and preservation.

One illustration of how mineral explorationists and miners in Sweden signal the “green” qualities of metals and minerals was observed at an annual meeting and conference with the Swedish Association of Mines, Mineral and Metal Producers (SveMin). At the event, presenters were asked to perform a small ritual before finishing their talks and leaving the stage: they were asked to select a piece of electronic waste from a set of drawers and place it in a recycling bin with the name of one of Sweden’s largest miners and smelters written across it. The theme of the conference was “The Swedish Mining Industry: Proud to Contribute to a Better World” and besides this ritual displaying renewability it also featured sessions on topics such as the mining industry’s role in the transition to a climate friendly society, sustainability in mining, and innovation. This focus on mining as a part of “green” solutions to the challenges brought on by the climate crisis has been an ongoing theme with SveMin and their annual meetings over the last four years and it is part of a larger story. This story, the story of mining as good, beneficial, and desirable, circles around two bodies of signifiers of worth: the relatively lower costs of mining in Sweden compared to mining in other localities and the absolute benefits of mining in general. This section will outline the contents of each of these two sets of signifiers and how they are called upon in justifications of why realizing predicted mining futures is desirable, morally right, and necessary.

Relative costs and benefits

Claims about relative costs and benefits of realizing one mining future over another are rife in the empirical materials, and they are often made in relation to proposed moral consequences of mining in different localities. According to some informants, the decisions on where to locate exploration projects entail a moral dilemma: although mining is generally environmentally impactful, the degree of negative outcomes is proposed to be lower in some jurisdictions than in others as some jurisdictions are seen to be stronger on environmental protection or social sustainability and have more resources to manage social and environmental impacts than other jurisdictions.[119] Ian described the nature of this dilemma in terms of how one may choose to locate exploration work in such environmentally sound jurisdictions or to locate them in jurisdictions

[119] This conundrum has also been the topic of scholarly debate in the fields of business and resource supply chain with scholars seeking ways to attain low-carbon goals while at the same time seizing on new mineral supply chain possibilities and taking steps making mineral extraction more sustainable (Sovacool et al. 2020).

that tend to favor mining over other interests such as the interests of aboriginal people and first nation communities or environmental interests. Situating one's exploration and mining efforts in such jurisdictions that are soft on mining, he said, might benefit the individual company but risks giving the industry in general a poorer name when stories of conflicts between miners and local communities pushed aside by a mining friendly government or regime are eventually picked up by western media. Ian developed his thoughts using two examples: Alaska's refusal to allow mining at the environmentally sensitive Pebble Beach and Romania's refusal to allow mining operation that risked damaging archeological sites, including a 2000-year-old Roman mine. Based on these examples, Ian made the following hypothesis:

> And maybe you would say that in the case of, certainly, the American government in Alaska, you're not going to push them over, never! Obviously, the Romanian government was pretty strong too, and maybe they would have been tempted down the years to let that become a mine, but they stood with it.

However, not all countries have the luxury of resisting such temptations, and this is what produces the dilemma that explorationist refer to in their justifications for mining futures in locations with, so to say, strong regulation and the ability to resist offers from miners seeking to realize projects that carry with them significant environmental or social costs. Ian elaborated on this idea:

> But you can imagine other poorer countries on the planet that don't have any choice. So then here comes the, sort of like, the moral dilemma. So it's easier to go to a country like Mali, okay, that has historically been mined for gold, or Ghana, another one, and set up a new mine. And you know, there a lot more potential for corruption in the system. And that's not just today, that's developed. So now it's an industry, if you like, y'know. Which is largely benefitting the people that work on these mines and also the officials in power of these countries, y'know. But they probably wouldn't want to stop such a project because it might affect some environmental thing, some bush or some frog or some tree or something like that. There, there would be no chance. In the case of Pebble Beach, no! But in the case of other poorer countries that need this revenue, would they, let's say, the governments of those countries are tempted by that revenue, they'll go for it. So you end up then with less control, generally. And you end up with more environmental problems. More corruption comes because then the money really does start to flow. So you end up with issues and the industry gets a poor name.

One way to resolve this dilemma, Ian and other informants concluded, is to choose to locate one's projects in countries that have good regulation such as the US, Canada, or Sweden, regulation that demand that

> Whatever you find must be the real thing and it must actually meet the requirements of becoming a human activity that is in favor of all of us that live here. Not just this party or that party.

These claims in light of existing social scientific research suggest that there are many examples of how the mineral industries cause problems and harm in communities in the Global South (see chapter 2). It is also true that some jurisdictions see greater complications from mineral resource exploitation than others. Jurisdictions with poorly functioning governmental organizations have been shown to be susceptible to a "resource curse" where the exploitation of mineral riches feed into pre-existing corruption (Butkiewicz and Yanikkaya 2010). However, explorationists tend to take these trends one step further. When explorationists justify why their projected mines in jurisdictions like Sweden should be realized, problems such as resource curses and corruption are used to distinguish "good" jurisdictions from "poor" jurisdictions in such a way that resolving the problems related to exploration and mining in dysfunctional and corrupt (i.e., "poor") jurisdictions requires opening up "good" jurisdictions to more exploration and mining. This is where the relatively low socio-environmental costs of mining in Sweden become a vehicle of justification.

At SveMin's annual meetings, Swedish regulation is often described as being one of the best and strictest environmental regulations in the world, so strict in fact, that it can be argued that it practically makes mining in Sweden environmentally positive. And the mineral industry is not alone in making these claims as this sentiment is echoed in the Swedish Mineral Strategy launched by the Swedish government in 2013. Moreover, although members of the minerals industry often criticize the Swedish environmental regulation for making permit processes slow and unpredictable, the same actors are quick to point out that they do not wish for fewer regulations or less strict regulations, only clearer regulations and more predictable regulatory processes. The perceived strictness of environmental regulation in Sweden and comparable jurisdictions are actualized in explorationists' justifications of the desirability of their proposed mining futures as they signal a better form of mineral exploitation than what is taking place in the Global South. These justifications are constructed around a perception of the superiority of Swedish environmental regulation, which in turn forces Swedish miners to adapt their operations to become as environmentally sustainable as possible.

This form of regulatory nationalism therefore provides a strong narrative for why new mines in Sweden can be said to produce fewer costs than mines in other countries. For example, Carl (as well as a senior officer with a Swedish governmental agency) justified the benefits of uranium mining in Sweden by pointing to a strong moral dilemma related to how Sweden benefits from nuclear power but does not mine its own uranium deposits:

> We have nuclear power in Sweden and import our uranium from Russia and Namibia and Canada. And we probably have the strictest environmental regulation in the world here in Sweden. Is it then morally correct that we purchase our uranium from Namibia, which has a poorer environmental regulation than

> we do, and use it unless we are also prepared to mine our own uranium, under stricter environmental regulation? That's something to think about, whether that's hypercritical or not. I believe it is. Nevertheless, that's my personal view. I believe we should mine our deposits.[120]

According to Carl and others, keeping the uranium stored in the Swedish bedrock out of bounds for miners while using Namibian uranium to fuel Swedish nuclear reactors is an immoral and hypocritical arrangement: outsourcing the environmental damages of uranium mining to other jurisdictions less capable of managing its impacts and still benefiting from the products of uranium mines. Such claims of relatively lower costs are, in other words put forth by explorationists as justifications for why it is better to build and operate a mine in Sweden than in other jurisdictions. Furthermore, discussions of the relative benefits of mining metals and minerals in Sweden than elsewhere are not limited to environmental concerns but are tied to a large scope of values such as social sustainability, slavery, and conflicts. This is, for example, highly visible in the debates on cobalt mining in the Democratic Republic of the Congo (Mantz 2008; Smith 2011) and in the cases of conflict gold or blood diamonds as well as other minerals.

Whether it is true that the Swedish environmental code is, as some informants claim, the world's strictest environmental regulation is not relevant here.[121] What is important is how such statements provide a foundation for justifying mining projects in Sweden by favorably contrasting mining in Sweden against mining the same minerals elsewhere. By calling on values such as environmental protection, explorationists are able to justify the worth or desirability of the present future depicted in their work and contrast this worth against other possible futures.

Although comparative costs acts as a powerful signifier of worth in the examples above, the use of such relative values in justifications of mining futures such justifications run up against problems when faced with cases such as Northland, Blaiken, or Mertainen. Because of this, these types of justifications need to do away with problematic examples of significant environmental costs from mines also in Sweden. After all, it is challenging to maintain claims of environmental superiority if the mine next door is an environmental liability.

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[120] Och som vän av ordning kan man ju argumentera.. Vi har ju kärnkraft i Sverige och importerar vårt uran från Ryssland och Namibia och Kanada. Och vi har väl kanske världens strängaste miljölagstiftning i Sverige. Är det då moraliskt riktigt att vi köper uran från Namibia, som har sämre miljölagstiftning, och så använder vi det, om vi inte är beredda att själva bryta vårt uran, med strängare miljölagstiftning? Det kan man ju fundera över om det är hyckel eller.. Jag anser att det är det. Men det är min personliga åsikt. Jag tycker att vi borde bryta våra fyndigheter.

[121] The reason for why the actual strictness of Swedish regulation is of less relevance is because such a ranking depends on how one chooses measure regulatory strictness. Here one may want to note that some informants, among them Peter and Quinn, actually experiences environmental regulation in Western Australia or Canada as being stricter than is the Swedish environmental code.

The common solution to this conundrum of why this particular mine would produce less environmental impacts than other mines is to draw distinctions between the proposed project and problematic examples such as the failures discussed in the previous chapter. Anne, a senior MIS officer, provided an example of such a distinction when she said that many of the environmentally problematic mines are actually abandoned mines from another era. Similarly, SGU officer Peter stated that he could understand if old mines were operated in such a way that they left lasting environmental damages as "the word environment hardy even existed back then" when these mines were operating. However, these distinctions were not only made between modern and historical mines; they were made between more contemporary examples, such as the Blaiken mine and the new mines proposed by explorationists. When drawing these latter distinctions, informants point to how Blaiken was developed under a regulation that pre-dates current regulation. By drawing this distinction between older and current regulation, explorationists maintain the ability to actualize the values proposed to be safeguarded by Swedish regulation and claim that mines developed today would face stricter regulation and therefore would be less costly than Blaiken and similar cases.

Another common way that explorationists maintain claims of relatively lower costs of situating mines in Sweden rather than in other jurisdictions is by individualizing problems, thereby drawing another line of distinction between one's own project and problematic projects. This second form of distinction is made by relating failed or impactful projects to individual shortcomings of particular exploration or mining companies. Informants made many references to projects that they describe as problematic and poorly managed exceptions that have given the industry a bad reputation. George, for example, expressed that it is very unfortunate how some poor examples such as the Northland mines paint the industry in a poor light. Furthermore, Anne stressed that while there are mines that have left environmental debts that need to be managed, it would be wrong to "paint all mines with the same brush." This notion was most forcefully expressed by Maxwell. Addressing a workshop on social sustainability, Maxwell told representatives from the municipality and civil society that while mines may cause environmental impacts, they are not harmful to the environment. In relation to this, Maxwell was asked by one representative from the consultancy firm hired to organize the workshop if it is not so that some of the worst polluters are mines. Faced with this question, Maxwell responded by saying that just because Hitler was German that does not mean that all Germans are bad; that is, just because some mines produce significant environmental damage, mining in itself is not environmentally damaging.

To summarize, justifications of mining futures based on the relatively lower costs of mining in Sweden actualizes values such as the adherence to strict environmental regulation to signify to justify the desirability of realizing mines in Sweden. These signifiers, based around sustainability themes, also feature in justifications of new mines compared to historical mines and between "good" mines and "bad" mines. Such signifiers of worth are based on comparisons across boundaries. Through such comparisons, some jurisdictions are characterized by negative values such as corruption or a willingness to turn a blind eye to environmental deterioration, human rights violations, or corruption and others are said to be good jurisdictions characterized by regulatory systems strong enough to force explorationists and miners to adopt better practices and strive towards better outcomes. Using these distinctions, explorationists can access repertoires if values that can be used to signify, often in highly moralistic terms, the worth of a future mining operation and thereby justify why this predicted future should be realized and why the social or environmental impacts expected from the mining operation are tolerable.

Absolute benefits

A second set of values used to signify the desirability of mining futures is based on claims to do with absolute benefits of realizing a projected mining operation. These absolute values tend to concern the role of mining in the downstream production of new "green" technologies that will solve the climate crisis and with values such as job creation and growth in rural municipalities, counties, and regions.

At one of the SveMin annual meeting and conferences observed as part of this study, former Swedish Prime Minister and then chairperson of LKAB, Göran Persson told the assembled participants that: "Without Sweden and Finland, Europe would grind to a halt," and that the European Union ought to understand "that without our metals there will be no green transformation." At the same event, then Swedish Minister for Business and Innovation, Mikael Damberg, stated that metals and minerals are crucial for successfully carrying out a green technological turn. This anticipated "greenification" of technology and societies is present across the empirical material and was described by actors in the field in part as a necessary solution to the climate crisis and in part as a business opportunity for environmentally-minded miners. Based on this, the exploration and mining industry looks to greenification not only as a business opportunity–as David Kneas (2020) has shown–but also as a source of moral arguments for why mines are an integral part of a "green" future.

Arguments stressing "green" metals and minerals as both environmentally friendly and a business opportunity were repeated on multiple occasions in this study. For example, a market analysts speaking at an international trade show and conference spoke animatedly on the expected increases in demand for technology minerals and copper as the world turns towards "green" technologies. Another example is how representatives from a Swedish mid-tier miner at another industry event gave a talk that stressed just how much more metals and minerals go into building an electric car compared to a regular gasoline car and projected that the rise of demand for electric cars would benefit the industry.[122] Over coffee in her office, Quinn too talked about how the minerals industry has a role to play in the transition to a "green" society, emphasizing that if society really wants to turn towards green technology solutions to the climate crisis, then the Swedish mining sector should play a role:

> To me, it is, how do you say, an opportunity for Sweden. To say that: "We know that the mining industry is important. We want green energy; we want all kinds of things, a high-tech society." But we also know that we need mines to achieve those things.[123]

According to Quinn, realizing projected mining operations is necessary if Sweden is to play any role in establishing a green energy future and a future high-tech society. Given that the present levels of metal and mineral recycling is much too low to supply enough metals and minerals to meet even the present demand (Ciacci, Vassura, and Passarini 2017), explorationists and miners have plenty of reason to argue that new mines are a necessary part of green futures built around new technology and green energy. Ian also emphasized the necessity of new mines for meeting future demands. However, he went one step further, saying that to provide enough metals and minerals to meet the aspirations of electrifications, also new deposits need to be discovered and exploited, so prospectors and explorationists with promising ideas need to be heard:

> If we want to have enough copper for all these views about electrification, y'know, electrification of cars, getting away from fossil fuels and what have you. Shi[t] there is a lot of work to be done, ey? So every person that is out there right now with an idea about trying to find something somewhere, needs to be taken seriously.

According to Ian, the current pipeline of projects alone cannot meet the emergent rise of electrified transports and "green" technology. These projects provide a needed addition to the stocks of metals and minerals for new, "green" technology, but also currently unknown deposits need be developed and exploited if humanity is to be able to turn society on to electricity and get away from climate crisis fueling fossil fuels.

When the solution to the climate crisis is electrification and new technology, future mines become a necessary good or evil (depending on how one

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122 According to a representative from a mid-tier organization who gave a talk at a SveMin annual meeting and conference, a regular gasoline car contains 20 kg of copper, 4 kg nickel, 10 kg zinc, 0 kg cobalt, and 10 kg lead, whereas an electric car contains 70 kg copper, 46 kg nickel, 17 kg zinc, 14 kg cobalt, and 12 kg lead [field notes: SveMin annual meeting and conference].

123 Och för mig är det, vad säger man, möjligheten för Sverige. Att säga att ”Vi vet att gruvindustri är viktigt. Vi vill ha grön energi, vi vill ha allt möjligt, high-tech society." Men vi vet också att vi måste ha gruvor för att få dom sakerna.

chooses to phrase it). Therefore, the absolute benefits of aiding the struggle to combat climate crisis provide yet another layer of values that explorationists can draw on to justify their projects. Despite their environmental impacts, mines are here claimed to provide part of the answer to one of society's most pressing issues and in doing so an environmentally impactful industry suddenly becomes environmentally beneficial and sustainable. Reducing carbon emissions is a vital part of keeping global average temperature rise below the 2º C target (Intergovernmental Panel on Climate Change 2015). By calling forth the idea that electrification can help reduce carbon emissions explorationists, so to say, plug into a narrative of the necessity of mining and corporate environmentalism for environmental preservation.[124] Doing so, they frame their projects as integral parts of supplying the raw materials for innovative new technology that will aid in tackling climate change and this helps them justify the desirability in realizing their present and future exploration and mining projects.

Besides arguing for the environmental benefits of mining, explorationists also justify their projected mines by actualizing narratives about the mining and natural resource industries' role in sustaining rural communities. Talking about how the Australian mining industry, when healthy, brought prosperity to geologists and local communities, Eric said that "the mining industry can bring a lot of very, very good things, so long as it's properly done and properly managed." In Western localities, job creation is often one of the premier goods that mining is said to offer local communities. While communities in the Global South may see the mining companies around them build schools, invest in infrastructure, and contribute other CSR initiatives, creating jobs for the local community is a value that is often referenced in contemporary political discourse in Sweden.[125] The use of these values as signifiers of worth were hinted at in the weighting of environmental impacts against job creation in the section on justifications within the environmental permitting process, but these will be reviewed in detail here.

Narratives of job creation features frequently in the sections of the preliminary EIAs where explorationists list the benefits expected to come from realizing the projected mine. Many of these benefits are social in nature and revolve around contributions to regional growth, the sizable investments involved in developing and constructing the mine, increased tax incomes for local municipalities, and the job opportunities expected to arise at and from the mine; and as discussed above, these social benefits are often contrasted against the environmental costs of a mine. In contrasting these two categories

[124] Such narratives of corporate environmentalism have been demonstrated to be a highly potent justificatory resource for corporations seeking both to make their operations or products more sustainable and to capitalize on the new markets for all things "green" despite simultaneously being a self-destructive dead end in terms of solving the climate crisis (Wright and Nyberg 2015).

[125] For an example of this discourse, see the Swedish Government Official Reports (2017).

of expected outcomes and impacts from a future mine, preliminary EIAs propose justifications for a mine's desirability by comparing, and commensurating, environmental impacts and the expected economic benefits of the mine for local and regional economy. Although explorationists make these comparisons, they do not experience that the comparisons receive sufficient recognition in the permit process. Maxwell discussed this, saying that in his view the environmental permitting process was biased towards the environmental dimensions and regularly overlooked the social benefits of mining. According to Maxwell, the lack of focus on social sustainability and mining stems from a failure to realize that the environment also includes those living in it:

> The regulation was written by those who, if you allow for some simplifications, visit nature and view it, not by those who live and work in it. So the Swedish Environmental Protection Agency, who is a powerful actor in these matters, you know, have their main office [in central Stockholm]. I believe it would be better if they'd move out closer to nature so that maybe they'd have a better understanding for how you need to build opportunity structures so that they who want to live and work in the countryside can do so. That's how you create a sustainable society.[126]

Stating that the agency charged with environmental protection fails to recognize social values such as economic sustainment of rural communities, Maxwell challenges the values taken to signify sustainability. In addition, he claims that the problem, at least partly, stems from those who promote the value of nature in and of itself; that is, those holding such a view are not qualified to make these judgments as they are people who only visit nature and not live, so to say, "in it." In northern Sweden, Quinn explained, the villages and towns around the mines depend on them for their existence. The conditions in northern Sweden, she continued, are different to those in southern Sweden. While the people in the south can rely on plenty of other industries for jobs, people in the north have limited opportunities. Using the local community where she lives and works as an example, she made the following observation:

> And also here in [Name of town], y'know, we've got [Mid-tier miner's operation] and many here are employed, yeah if not directly then as consultants or in businesses, yeah, like the vulcanizing shop does a lot of business with both [Mine A] and [Mine B] and if just one of those two mines would close down, it would really affect a lot of people out here. The thought is actually quite frightening. So having these mines is important for us who live up here, that

[126] Men regelverket har skapats av dom som, tycker jag då lite granna om man ska förenkla det, som besöker och betraktar naturen, inte dom som bor och verkar i den. Så att Naturvårdsverket som är en stark spelar i det här liksom har sitt huvudkontor på Vallhallavägen. Jag tycker det skulle vara bra om dom flyttat ut närmare naturen kanske, så hade dom haft större förståelse för att man måste också skapa levnadsstrukter så att dom som vill bo och verka på landsbygden också klarar av att fixa det. Så att vi får ett hållbart samhälle.

> we have mines and mining, definitely! Southern Sweden is different, absolutely; they have many other industries and job opportunities. That's a fact![127]

As with the justifications of mining as contributing to the fight against the climate crisis, the values of community support and regional growth as a signifier of worth tie into larger narratives within contemporary society. In the case of rural sustainment, the narrative ties in with a larger narrative to do with the relation between rural and urban regions, a narrative that in modern Swedish history has been summarized in the notion that "the whole country should live." This narrative, which revolves around the metaphorical death of rural communities in Sweden, is often expressed in terms of maintaining and developing economic incentives and conditions for rural Sweden. Although these narratives can easily be criticized for over emphasizing growth and entrepreneurship (Olofsson 2019), they still maintain a strong presence in Swedish debate and governmental reports. For example, the Swedish Government's Rural Community Committee frames the "survival" of rural Sweden as a question of incentivizing and nurturing entrepreneurial activities in the countryside (Swedish Government Official Reports 2017).

Mining sustains communities. One only needs to look to Kiruna for an example. For more than a hundred years, the government-owned Kiirunavaara and Loussavaara mines have provided generations of Kiruneese with jobs while at the same time supplying a steady stream of tax revenue. In these justifications, the mining industry is given a role akin to that oil has played in Norway. Former Swedish Prime Minister Fredrik Reinfeldt told the assembly at SveMin's annual meeting in 2018 as much. Bringing forth a large-scale industrial operation where there was previously none is one of the curious abilities of explorationists and miners. However, the values created from the exploitation of industries come with significant costs not only in terms of irreparable environmental impacts but also in terms of social costs as other interests must be sacrificed for a mine.

[127] Och även här i [Namn på plats], vi har ju [Med-tier-bolags gruva] och det är många här som är anställda som, ja om inte direkt men någon sorts konsult eller verksamhet som, typ, gummiverkstaden har mycket att göra med både [Gruva A] och [Gruva B] och [Gruva C] och även om bara en av dom gruvorna skulle stänga ner så skulle det påverka många här på landet, faktiskt. Så det är lite skrämmande. Så det är väldigt viktigt för oss här uppe att ha gruvor och gruvindustri, absolut! Det är lite annorlunda i södra Sverige, absolut, där är det många andra industrier och jobb. Så är det!

7.2.4 Summary

The desirability of explorationists' predicted futures is often justified by means of references to sets of signifiers of worth that support claims for why constructing and operating the projected mine is the most appropriate and desirable course of action. In terms of the content of these sets of signifiers, the signification of environmental values as defined in the Environmental Code consists of a series of juridical measures put in place to ensure long-term resource management and to regulate land use. The sets of signifiers around which explorationists build claims of relative costs and absolute benefits, on the other hand, reference larger debates and narratives within society into which explorationists can place their predicted futures. Metals and minerals are only found in a limited number of places, and by drawing distinctions between better and worse jurisdictions, explorationists make claims about the relative costs of mining in worse (and often Southern) jurisdictions from better (often Northern) jurisdictions. Finally, explorationists together with the exploration and mining industry in general also tap into existing narratives and debates that provide absolute values that may be called on to act as signifiers of worth. When used as signifiers, these values help justify explorationists' predicted future by showing a realized mine as contributing to resolve societal challenges and developments by aiding in the struggle to reduce greenhouse gases or supply jobs and growth that can help revitalize struggling rural communities.

7.3 Concluding remarks

This chapter has outlined two ways in which explorationists justify their predictions and by doing so it has provided more pieces to the overall puzzle of how prediction work is carried out under the uncertainties that characterize mineral exploration. The previous chapter argued that despite all work put into exploration projects in order to "de-risk" them, the minability predictions produced by explorationists remain uncertain. This chapter has outlined how explorationists, despite this uncertainty, justify their claims about and on the future. When claiming that their predictions are correct depictions of a future present, prediction makers in mineral exploration use sets of signifiers of worth that denote what makes for good exploration work in terms of the accuracy and precision of the data from which predictions are made. This line of justification focuses on the internal qualities of prediction work–i.e., that the data assembled are unbiased and therefore serve as a good starting point for projections into the future. To explorationists, values such as accuracy and precision in their data are key to increasing the potential for correct prediction work. By collecting more data and ensuring its quality, explorationists work to translate uncertainty into risk and to reduce risk towards certainty. This work follows a logic of rational measurement in quantification as signifying risk reduction, an approach to rationality, uncertainty, and risk management observed also in other domains (Espeland 1998; Espeland and Stevens 2008; Porter 1996). However, the previous chapter shows that while explorationists claim to successfully de-risk their projects, much of this work relates to reducing the complexity of the geology in a project while many other risks are bracketed away and unaccounted for.

As the decision to launch the Challenger Space Shuttle speaks to how risk assessments and their justification are shaped by the organizational structures such as that at NASA (Vaughan 1996) and evaluation of creditworthiness is shaped by the institutional embeddedness of banks (Guseva and Rona-Tas 2001), the predictions of minability in mineral exploration are shaped by the universe of institutions, organizations, and politics within which explorationists carry out their work. In practice, this means that the predictions produced as part of exploration work follow the logics set out in the industry standards put in place to regulate and reduce risk and uncertainty in mineral exploration and it is the same standards that provide the means to justify the predictions that come out of these processes. Industry standards therefore help reduce uncertainty in mineral exploration along the lines proposed in the institutionalists approach to risk discussed previously, but primarily because they support and provide a logic for how uncertainties are to be re-constructed as measurable and therefore reducible risks. It is therefore important to consider also the performative dimensions of industry standards. While they were initially put in place to prevent foul play on part on explorationists, their institutionalization has meant that following standards and doing things by the book–or doing them correctly as Richard put it–has come to signify doing good exploration work and, ultimately, to reduce risk.

However, there is more to the matter than just a performance of standardized best practice. Approaching the justification of prediction correctness from a practical view, it becomes apparent how important the role played by shared understandings is in explorationists' justifications of predictive qualities of their predictions. Such shared understandings, or culture as Howard S. Becker (1982) would put it, constitute the backdrop against which the use of these particular values is made sense of in mineral exploration. These values revolve around the quantification and measurability characteristic of the trust in numbers described by Theodore Porter (1996, see also; Reinertsen and Asdal 2019); it is a trust in projectable numbers that that can satisfy the *modo potentiali* (Schütz 1959) harbored in the anticipation that each datum pulled, so to say, out of the ground is another step on the path towards de-risking a future mine. It is therefore not the industry standards alone that are performed here, but a much larger culture of quantification.

Justifications of a predicted future's desirability, on the other hand, focus less on the internal coherence or accuracy of the prediction than on the position of the predicted future in a universe of values. This chapter describes three such universes that together help explorationists make claims not only about what the future will look like but also on these futures. Jenny Andersson (2018) stresses the importance of analyzing how actors use predictions to make claims on the future and this chapter provides some insights into how this is accomplished in mineral exploration by tracing the values explorationists call upon in justifying why realizing mining futures is a desirable course of action. First, the chapter described how justification in environmental permitting weights the many different values present in the Environmental Code against each other in order to formulate and support claims for why mining an area is the more appropriate and desirable alternative from a legal perspective. Here, justifications rely on a view of nature as managed and under a juridical domain in which the worth of a predicted mine is to be determined on legal grounds and in competition with other potential interests and land uses. Second, justifications of a predicted future's desirability based on its relatively lower costs rely on comparisons of the predicted future to other potential futures such as a future in which the minerals sought are mined in a less sustainable mine in the Global South. To make these claims, explorationists rely on distinctions between different jurisdictions in terms of being better or worse at managing and protecting environmental values and between good and bad explorationists and miners. Moreover, the values used to signify worth here draw on morally powerful imperatives connected to claims of a responsibility to a mine in "developed" nations in order to prevent unnecessary suffering in less "developed" localities. Finally, the third form of justification described above is based on a predicted future's contribution to some absolute value such as contributing to the struggle against the climate crisis or helping reverse the decline of rural communities. The signifiers of worth invoked in these justifications speak to current debates and positions a projected mine in a larger political domain where the benefits of a future mining operation (e.g., a supply of metals for green technologies and economic growth in disadvantaged communities) are weighted against its costs to the environment and to non-mining interests. Together, these three groups of values provide a repertoire of signifiers that explorationists actualize in order to make claims of the worth of their futures and for why they should be realized.

However, the efforts spent on connecting values to predictions to justify their worth matter little unless those actors whom explorationists need to convince recognize the predictions as correct or desirable. The next chapter takes a close look at these interactions between explorationists and their publics to analyze what takes place when predictions have been produced, justified, and let out into the world.

8. Metapredictors in Mineral Exploration

While the previous chapters detailed how explorationists make and justify predictions the present chapter will, so to say, take a step back and look at the context of explorationists' prediction work. This shift from a detailed study of the internal processes that produce predictions to a more contextual view resembles a move to what Marion Fourcade (2011) calls a "then what" question. Here, the "then what" question addresses the consequences of the prediction work outlined in the previous chapters in the context of explorationists using predictions and communicating them in interactions with their audiences. As has been outlined across the three previous chapters, predictions serve a number of purposes in mineral exploration: they describe future values, they guide explorationists in rating and prioritizing their projects, and they allow explorationists to make claims on the future by promoting their predicted present futures as the more desirable alternative. In addition, predictions also help explorationists reduce the complexities of first nature into measurable chunks that can be treated and translated into projections of second nature mining futures. In serving these purposes, predictions make uncertainty manageable by providing points of reference and guidance, not only for the explorationists themselves, but also for the different publics that make use of predictions in anything from investment decisions to ruling on permit applications. It is among the interactions between explorationists and these publics of investors, permit granting agencies, and the affected communities that this chapter will seek to answer what consequences predictions have for have for explorationists' ability to realize their predicted futures.

Returning to Rescher's (1998) work on predictions, he writes that assessing a prediction's qualities in terms of its ability to correctly depict a future present means making a *metaprediction*, a form of second-order prediction in the form of a prediction about the prediction. Just as predictions provide answers to questions about the future, metapredictions answer questions about whether to believe that a prediction will turn out to be correct. For example, are there reasons to believe that the financial estimate for the project mining operation is correct? Is it likely that realizing the mine would produce the social and economic benefits claimed in the EIA? Might the predictions be off target, and if so, by how much? Combining this approach to predictions about predictions with the distinction drawn by Rescher (1998) between formalized prediction and judgment-based prediction, metapredictions may take two different approaches to ascertain the likely trajectory of a prediction. First, a metaprediction can be based on an assessment of the technical apparatus used in the prediction work. Such an assessment would mean asking questions about whether the models used in prediction were correctly specified or whether the data used were adequate for the purpose. The second approach is to assess the qualities of the predictors themselves, asking whether the prediction was made by trusted experts who, because of their experience and expertise, are likely to be able to foresee future developments. Examples of the former type of metaprediction can be found in discussions such as those on whether risk analysis models underperformed in the lead-up to the 2007-2008 financial crisis (e.g., Turner 2009, see also; Besedovsky 2018; Langley 2013; Lockwood 2015). Meanwhile, the latter form of metaprediction has been described in studies on fields such as financial analysis where expertise, creativity, and experience are perceived as hallmarks of good prediction workers (Leins 2018). In mineral exploration, metapredictions of both poles can be found as some metapredictors choose to take the experience of the team behind a prediction as a basis for their assessments, whereas others focus more or less exclusively on the quality of the data and the prediction methodology. These variations, it will here be argued, depend on what stage of exploration work is concerned in the predictions as well as on what types of values matter to the public engaging with explorationists' prediction work.

Among the publics that engage with the predictions produced in mineral exploration, one finds actors such as investors, governmental agencies handling permit processes, debt financers, and other interested parties. In this chapter, this multiverse of interactions is described and analyzed with particular reference to the outcomes of these publics' metapredictions and their consequences for the future of exploration projects. The chapter begins with metapredictions made within exploration organizations and then moves to interactions between explorationists and external metapredictors engaging with the exploration industry within the contexts of exploration and mine investments and permit processes. The chapter also analyzes and discusses instances of conflict and disagreement between explorationists and metapredictors.

8.1 Metapredictors within exploration organizations: "Project killers" and management

A reoccurring theme in this study has been the importance of identifying and "killing" less-promising projects in order to free up resources to be spent on the select few projects seen to poses greater exploration potential. In the previous chapters, several examples of how this is strategized have been discussed with senior explorationists having been quoted discussing project evaluation as a key element in successful mineral exploration. This section revisits this dimension in exploration work and analyzes the metapredictions involved in how exploration organizations evaluate their exploration projects.

One illustrative account of how exploration organizations evaluate projects in the early stages of exploration can be found in a book celebrating a Swedish mid-tier company, Boliden Mineral's 99 years in mineral exploration. In this book, the mining engineer who heads the company's mineral resource office explains the mining engineer's role in the company's exploration efforts and jokingly admits that their department, which was responsible for sorting through exploration projects to select those that warrant further exploration work, are internally referred to as "the project killers" (Lundqvist 2016). In the book, the project killers at Boliden are described as a team of geo-engineers whose responsibility it is to review the projects worked up by the company's exploration geologists and to rate and select those projects deemed sufficiently promising to warrant further exploration work while effectively "killing" projects seen to show less potential. This division of labor is common also among the exploration organizations that feature in this study.

While exploration geologists together with geophysicists and geochemists are the groups of explorationists most often working on the early stages of mineral exploration, mining engineers often assume management of projects as they approach the intermediate stage of the exploration process in order to assess the findings of the geological work by adding technical and economic layers to the exploration puzzle. Lars, an engineer working on a team like that described above, explained how his team reviews projects in the early intermediate stage. When projects are handed over from the exploration geologists, Lars said, enough work would have been carried out by the geological team for there to be enough data in the project to allow them to undertake initial modelling and metallurgical analyses. The exploration geologists will, in other words, have taken a project through some drilling and begun amassing a body of data that can be used to make an initial assessment of the quantity and quality of mineralized material in the project. Talking about the Boliden book and the label "project killers," Lars noted that when they enter the process he and his colleagues take the project and the data available:

> And then we make an initial.. we make an estimate of what tonnages and grades you have [in the project] and then we also do a first economic valuation to determine whether we should take the project further or not. And I guess it's

> that project management role that may at times can be perceived by some enthusiastic geologists as us killing off their wonderful projects [laughs].[128]

When valuating projects at these early stages, Lars and his colleagues are engaging in metaprediction in as much as they constitute a second opinion about the exploration potential in the projects and take over from the exploration geologists. These projects have been taken through area selection, surveying, and target generation work and are now re-assessed based on the geological model and the estimates of its economic minability that are added to the project by the engineers.

This change from one set of predictors to another furthermore means that the decisive moment has arrived for the explorationists who have worked the project so far. In an industry characterized by very high likelihood of failure, working a project that actually is picked up and carried forward to later stages of exploration work means getting to enjoy something as rare as success. Junior exploration company senior officer Ian summarized this dimension of early stage exploration work saying that every explorationists wants to succeed, to be successful, and to "drill that next big fantastic deposit." In the interactions between the geologists and engineers–or in many smaller companies lacking such divisions within the exploration team and in relation to a scoping study or preliminary economic assessment prepared by a consultant–the outcome of the metapredictions made at this stage implicitly regulates whether you have initial success. Metaprediction in the early stages of the exploration process therefore works as a threshold that not only re-interprets the exploration potential predicted in a project into geo-technical and economic terms before determining whether or not a project should be given the go-ahead but also whether the team working it is to be counted among the successful few. Richard explained this duality in metapredictions in early stage exploration:

> Every geologists of course feel that they have the best project in the company [laughs] and of course, everyone wants to promote the thing they are working on. So you really need to have a system that makes prioritizes projects based on a set of facts that drive, like, the work forwards and sets aside that which is less exiting or that doesn't really live up to the criteria you have set up as you push forward.[129]

Evaluations of project potential in the early to intermediate stages of exploration work help exploration companies sort through their portfolios and "kill

[128] Och då gör vi ju en första.. dels gör vi ju en beräkning av vilka tonnage och halter som man har där [i projektet] och sedan gör vi ju en första ekonomisk värdering av om vi ska gå vidare med projektet eller inte. Och det är väl där då projektledarrollen av vissa entusiastiska geologer kan ses som att vi dödar deras fina projekt ibland [skrattar till]

[129] Alla geologer har förstås det bästa projektet i företaget [skrattar] så alla vill förstås prioritera sitt. Och där krävs det att du har ett prioriteringssystem baserat på ett antal fakta som driver, liksom, jobbet framåt och sätter åt sidan sådant som är mindre spännande eller inte riktigt möter dom krav man har medan man driver vidare.

off' projects that do not meet the criteria that denote sufficiency in terms of exploration potential. These evaluations are a first example of metapredictions within organizations and new examples follow along the exploration process with the scoping study, the pre-feasibility study, and the feasibility study being three examples where qualified persons are brought in to review the potential future minability in a project.

While the interactions between geologists and engineers are important when deciding which projects to take further and who gets to enjoy success, a more high-stakes case of intra-organizational metaprediction takes place when company boards decide whether to move a project to development and construction. Talking about the company hierarchy, Briana explained that at the company she worked for these decisions are made "in certain rooms" by a select few, a group of managers with experiences from different parts of the company. Consultant and qualified person John who had experience sitting in these meetings, explained that the authors of feasibility studies, either a qualified person working for the exploration organization or a consultant, presents the results of the study complete with an estimated NPV, an outline of the project's technical and economical dimensions, and a range of sensitivity analyses:[130]

> And these are the results that you take with you to the meeting with the board of directors. And say that as a consultant, but also as an employee, if you produce a model like this, then you sit with the board and they'll ask ”What have we got?” And they are primarily interested in these [technical dimensions] but also in the risks. What does the risk profile look like for the project? What are the greatest risks? Is it geology, or is it mining, or is it rock mechanics, or is it the tailings dam?[131]

The board of directors is a vital counterpart in prediction work as they are the ones who give the ultimate go ahead for an organization to move from predicting to actually realizing futures. Because of their position as the final group of metapredictors to evaluate a project within an exploration or mining organization, the board of directors are more arbiters of success than mining engineers. Moreover, the stakes are arguably higher still as greenlighting the development and construction of a project also means allocating significant resources or taking on substantial debt to finance doing so. This is, in other words, an example of an interaction between a predictor and a metaprediction where actual monetary resources are on the line. The examples outlined above

[130] As was discussed in chapter 6, sensitivity analyses are analyses of how a project's NPV is affected by variations of different inputs.

[131] Och det är ju det här resultatet man tar med sig till styrelsegruppsmötet. Om vi säger som konsult, och även som anställd, om man tar fram en sådan här modell, då sitter man med styrelsen och dom säger ”What have we got?” Och dom är mest intresserade av dom här [tekniska dimensionerna], men även riskerna. Hur ser riskprofilen ut för projektet? Var är de största riskerna? Är det geologi eller är det brytning eller är det bergmekanik eller är det sandmagasin?

provide an initial understanding of metaprediction and of what happens to predictions when they are communicated to a public set to assess the credibility of what the predictor has seen as a promising or minable project. The examples described in this section are examples of interactions between predictors and metapredictors who do not depend on the other for access to resources (beyond success and recognition). The next section, however, outlines interactions between predictors and metapredictors in different organizations, where the predictors' access to goods or resources needed to realize the predicted future is determined by the metapredictor.

8.2 Metapredictions in equity and debt financing: Adventure or qualified judgements?

Investors play a central role in mineral exploration as they provide financing for exploration work and mine development. Attracting investors to their projects is therefore a key dimension of many explorationists' work. This is particularly true of junior exploration companies, who depend on equity to finance their exploration work. Richard explained that mid-tiers and majors undertaking exploration work can rely on their cash flow and focus on "getting exploration done" whereas juniors need to consider how they are going to finance the next stage of exploration and they do so in competition with other juniors also looking to finance their most promising early stage projects. However, as there are limits to miners' cash flows, these differences tend to disappear when explorationists reach the stage where they need to start looking for ways to finance the multi-million dollar investments necessary to construct a mine. This section describes how explorationists and investors interact over exploration and development financing with particular reference to the strategies used by investors to assess the quality of explorationists' predictions and the metapredictions they produce based on these assessments.

8.2.1 Equity as adventure and explorationists as storytellers

When explorationists produce their prospectuses with which they seek to attract investors to finance the next wave of exploration work based on the exploration potential estimated in a project, they are engaging a world of actors that looks much broader than merely the exploration and mining industry. Equity finance is competitive and explorationists are competing for investments not only between each other but also with other industries. The challenges involved in attracting equity financing to early stage exploration work was a prominent topic of discussion at the international industry conference and trade show observed in 2018 both in discussions between explorationists and in the talks given by mining executives, investment fund managers, and representatives from financial institutions. One example of these discussions was how, one presenter representing a large mining corporation used a significant portion of his allotted time to talk about current trends in investment and how investors at the time had moved out of exploration into other sectors such as wheat futures and the, at the time, much discussed bitcoin and block chain sector.

However, that investors choose to move out of mineral exploration financing is perhaps not surprising. At the end of the day, mineral exploration is just one of many sectors financers may choose to invest in, and given the low probability of success in exploration as well as how trends come and go also among investors (e.g., Shiller, Fischer, and Friedman 1984), it is perhaps not too surprising that investors may at times choose to place their money in industries other than mineral exploration. Explorationists' dependence on investors therefore means that they face some intriguing conundrums. One conundrum is that of attracting investments to a sector that sees so little success. Because of the prominence of uncertainty in mineral exploration, senior junior company officer Eric explained, investors tend to demand high rates of return amounting to "five or ten times their investment." Qualified person and consultant Carl too discussed this and in his discussion, he compared the potential internal rate of return from backing an exploration project that ends up producing a mine to the many other investment opportunities equity financers have access to:

> Because if you imagine that you're getting an internal rate of return of say fifteen percent, that should then be weighed against, yeah, buying scratch cards with this money instead, then what would the internal rate of return be? Well, yeah, it would be in the negative because the state always wins. But if you were to place them in bonds or if you played the stock exchange or something? You always have to consider.. if you're gonna invest your money, which alternative would be the best possible investment.[132]

Now, while he was joking when suggesting investors may choose to invest in scratch cards, Carl highlights an important fact about the equity market: when

[132] För om du tänker dig då att du får en förräntning, internal rate of return, på säg femton procent, det ska ju vägas mot, om du gick och köpte penninglotter för dom där pengarna, vad får du för förräntning då? Ja då får du alltid en negativ, för staten vinner ju alltid. Men om du sätter dom, om du köper företagsobligationer eller du spekulerar på börsen eller någonting? Du måste ju alltid fundera.. om du investerar pengar, vilket är den bästa investeringen jag göra?

seeking to attract investors, explorationists not only need to compete with other explorationists to be the most attractive investment, but also with other actors in other sectors and they do so in an environment that wants premiums when investing in high risk industries and enterprises. Moreover, becoming an attractive investment opportunity is not easy. In fact, explorationists chasing equity are not necessarily in a position that helps them do the best exploration work they could do. Talking about the different conditions under which explorationists financed by cash flow and those financed by equity work, Richard again saw drawbacks to equity financed exploration as this may push explorationists to produce results that attract financers rather than results that bring projects forward. According to Richard, this may express itself in juniors undertaking more exploration drilling than necessary to get access to marketable results. Because of this, Richard continued, equity financed explorationists often have to engage in work that larger established companies do not have to concern themselves with. Financed by cash flow, he said, mid-tier corporations such as the one he worked with are freer to carry out only the necessary work and seek to "find, you know, the shortest path to success." Although not all explorationists would agree with this view,[133] it highlights one crucial thing about equity financed mineral exploration: explorationists financing their exploration through equity need to excite investors to the exploration potential of their projects. Ian spoke on this topic saying that because of its uncertainties, mineral exploration is one of the few remaining frontiers– besides, he continued, space and the deep oceans. Uncertainty here becomes a unique selling point with which to attract investors rather than a problem as it opens up the future for speculation and imaginaries of mineral riches (Beckert 2016; Engwicht 2018). Because of its uncertainties, Ian continued, mineral exploration:

> is about selling adventure. That's what exploration is about. It's people that join in with us, that come in for the ride because who knows what we're going to find here, it could be a monster! You know, it sets that expectation. So yes, it can be a negative if it doesn't work out. But it is the driver as well. That's why people invest in exploration. Especially discovery exploration. So it appeals to human nature, to take a risk and to have luck and to go places.

[133] Some might even argue that the reason larger corporations are freer in their exploration is because Swedish mid-tiers are benefiting from the privileged positions they were able to attain from operating in the restricted Swedish mining sector in the 20th century when only a select few companies were allowed to mine in Sweden and these companies could divided the country up between themselves. In addition, claims such as this one do not reflect the situation outside Sweden. As previously noted, actors at the international conference and trade show made repeated statements of juniors as the "life blood" of the industry as they tend to be the ones engaging in green field exploration and make significant discoveries while mid-tiers and majors, in an international perspective, tend to be more concerned with building their reserves than making new discoveries.

Ian's emphasis on frontiers and adventure illustrates the flip-side of uncertainty as it demonstrates how uncertainty implies a window for speculation on the future. The name for this phenomenon in mineral exploration talk is the discovery stage of a "Lassonde curve," named after mineral explorer extraordinaire Pierre Lassonde. A Lassonde curve reflects the value of an exploration project as a sudden rise in the discovery stage, when a first discovery has been made but there is far too little data to tell just how large or small the deposit is. An equally sudden drop then follows this sudden rise as more work is undertaken on the project whereby its limitless potential is reined in by the data produced, and finally a slow but steady rise as the project moves towards production.

Senior junior organization officer Eric too discussed the role of investors in early stage exploration but refrained from using terms such as frontiers, adventure, or human nature. Instead, he discussed what he called the "seed investors"–i.e., investors who join exploration companies early on and who may stand by explorationists through what Eric referred to as "some very tough times" where exploration success is far from certain. The seed investors supporting his company, Eric candidly stated, had chosen to support him and his team not because they "think were good guys" but because they "think that they'll get a significant financial return, so we [the team of explorationists] have to make sure that we deliver that financial return." Saying this, Eric provides another perspective on the same genre of high uncertainty metaprediction that Ian had described as adventure. Seed investors, in other words, join with companies in the early and highly uncertain stages of exploration because they see a potential for significant returns many years down the line, but what is it that makes them foresee this potential? What is it that adventurous investors see in projects that make them willing to take a chance and, to speak with investor's lingo, take on such a significant risk? As chapter 5 outlined, early stage mineral exploration is highly uncertain and complex as very little geological data have been produced beyond the initial desktop exploration and survey work. So how do investors assess the soundness of the predicted potential in a project when there is so little data to review? What do they base their metapredictions on? The answer to these questions were provided in accounts from a number of informants–some of whom have experience from both exploration and investment–and from field notes taken of panel discussions featuring investors and bankers at an international industry conference and trade show. Based on the informants' experiences and the panelists' discussions, a range of investors' strategies emerged.

Assessments of predictors

One of the most common strategies outlined in the materials focuses on assessments of the predictors. Here, metapredictors focused their assessments on the qualities of the explorationists working the exploration projects. This line of metaprediction assesses whether the people involved in a project appear to have the expertise to be successful rather than evaluating the project itself. Eric stressed how important the people one chooses to work with are for success, saying that; in mineral exploration, as in any other venture, a lot comes down to the quality of the people doing the work and the faith investors feel they can place in them. Mining company CEO Maxwell also explained the merits of this metapredictive strategy, and he did so by using an example of a project he said that he would never consider investing in. Earlier in his career when he was working for a Swedish mid-tier miner, Maxwell recalled:

> there was a visit from a British exploration company where the management consisted of a movie director working extra as the CEO for an exploration company and his favorite actress, who visited the mine wearing heels. There and then, I realized that I probably shouldn't invest even a single cent in that venture.[134]

While this first half of the quotation is more akin to a funny story about an odd encounter[135] than an investment strategy, what Maxwell said next provides a good summary of the predictor-based approach to metaprediction. Talking about his experience with the movie director-come-explorationist, he continued:

> However, it's not always that obvious. Instead you have to look at, so to say, if you're gonna reduce risk, then you have to look at the competence of the person doing it; what results have they produced before? That, I believe, is a big factor for investors sorting out projects, and it's a way to reduce risk.[136]

The predictor-based approach to metaprediction in practice works by reviewing a predictor's, or a group of predictors', previous work, experience, and expertise and using these as the foundation for metaprediction, asking whether a prediction is probable to be correct based on the qualities of the predictors

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[134] så kom det ett besök från ett engelskt prospekteringsbolag där ledningen bestod av en filmregissör som då knäckte extra som VD för ett prospekteringsbolag och hans favoritskådespelerska som kom i högklackat på studiebesök till gruvan. Då insåg jag att det här ska jag nog inte sätta en spänn i.

[135] However, the high level of uncertainty involved in the movie industry might have left the director accustomed to many of the uncertainties of mineral exploration.

[136] Men det är inte alla gånger det är så tydligt utan man ska ju titta på, så att säga, ska man riskreducera ska man ju titta på kompetensen hos människan som har gjort det; vad har dom skapat för resultat förut? Det tror jag är en sådan där viktig sorteringsfaktor för investerare, och det är ett sätt att riskreducera.

producing them. Explorationists who have had previous success are therefore granted more legitimacy in their present work as they have proven that they are able to make and work discoveries. This legitimacy granted to successful explorationists means that some investors are willing to pay what one industry conference panelist referred to as a “dream team premium” for projects worked by successful and experienced explorationists. However, while common, not all investors use such predictor-based approaches. One example of an alternative strategy was provided by a panelist working for a large investment company who stated that in their company they prefer to look at the value of the land where a project is located by comparing it to other areas with known mineral deposits when assessing the future value of a project. Another investor speaking at a panel expressed his doubts about predictor-based assessments, saying that he does not “trust success.” Referring to his background in engineering, he justified his position by arguing the mathematical improbability of repeated success, saying that: “If 3 in 1000 deposits are economical, what is the likelihood of getting it right twice? 9 in a million.” Instead of paying “the management dream super-team premium,” he continued, he had made a strategy of investing early in projects that he thought looked “good” and that were cheap. But what makes an early stage project look good?

One thing that investors may refer to when assessing the qualities of a project beyond the CVs of the explorationists working them is what a senior member of an investment bank called a project’s “pedigree.” A pedigree consists of a project’s geological similarity or physical proximity to other successful projects. Having a project whose geological make-up resembles other geological environments known to host minable mineral deposits or having a project that lies physically close to a profitable mining operation are here used as signifiers of exploration potential since mineral formations tend to follow certain patterns and seldom appear in isolation but as parts of large systems. Taken together, assessments of the explorationists working the projects and the project’s pedigree therefore make up two dimensions of metaprediction among investors. In early stage exploration, asking whether they trust the explorationist to possess sufficient expertise to be able to tell a promising project from a dead end and cross checking the available data on the project against known deposits therefore provide two points of entry for investors making metapredictions of whether they believe the predictions of a project’s potential.

Storytelling: Talking like an investor

One practical implications of how investors assess early stage exploration projects is that it opens up a door for explorationists to adapt their predictions to what investors look for in exploration projects. A senior international investment banker at the international industry conference and trade show outlined examples of how explorationist may take advantage of this opening and adapt their communications to better fit investors' expectations. In a panel discussion, he told the explorationists in the audience that what matters to investors in early stage exploration predictions are the *stories* explorationists are telling. What exploration companies need to do to stand out and attract capital, he continued, is to tell a story about the asset's quality as well as about the team working the project, their mindset, and what approach they are working from in the project. After listing these dimensions, the banker moved on to discuss them in detail saying that in order to attract capital, explorationists need to "focus investors' attention on key projects and how you are going to develop them." This does not mean that one should not talk about any additional projects in one's portfolio, he advised, but investors are more interested in hearing what you are doing on your "key project." In terms of the team working the project and their talents, he continued, investors tend to grow hesitant when being told that a team is going to take the project all the way from discovery to mining. Instead, he urged the audience to focus on what you and your team is good at and then move the project "down the value curve" by doing a joint venture with another miner or sell it on to someone with more mining experience. If you are good at grassroots exploration or drilling a project up to size do that and let others do the rest, he recommended the audience. Coming to the final dimension of the stories explorationists should tell investors; he said that

> Some explorationists tend to over promote. Try to find a message and a story you want to get out and focus on the investors you need rather than on quantity. Speak like an investor and not like a geologist; speak about returns and not size and so forth. Gain market interest; engage shareholders with purposeful marketing!

By telling the room of explorationists what he, in the role of an investor, wants to see from them, the international investment banker provided the audience with a recipe for how explorationists can be more successful in their interactions with investors by adapting how they communicate the qualities of their projects and their predicted potential to prospective investors. Moreover, by encouraging the assembled audience to talk "like an investor and not like a geologist" he highlighted how investors' metapredictions in early stage exploration is not entirely to do with geology per se. Instead, it is to do with whether the piece of geology in question is likely to be convertible into profitable commodities and what basis there is for believing this.

However, while explorationists might be able to find new financing opportunities by adapting how they communicate their predictions, explorationists and investors do not always communicate directly, one-on-one. Within the global exploration industry, there are actors that act as intermediaries between the exploration and financial industries. These intermediaries include market analysts who work for brokerage firms to seek out promising exploration companies and projects that they can recommend to the firm's clients in the financial sector. In a talk on brokerage given by an analyst to a room full of young geologists at an event for prospective explorationists, the job of an analysts was described as "pairing up companies and investors" and therefore bridging the two industries in order to facilitate investment. To accomplish this, the presenter continued, brokers analyze exploration companies and gather information "covering geology, mining, processing, permitting, geopolitics, and flow of funds" in order to produce "stories" accessible to investors. Behind brokerage as well as behind encouragements for explorationists to adapt their communications to better suit investors' expectations lies a need for the latter to be able to understand the predictions communicated by the former. When asking explorationists to formulate stories that investors can understand and assess, the talk by the international investment banker highlights how adaptation and expectations play important roles in the interactions between predictors and metapredictors. Moreover, when emphasizing how explorationists can better adapt to and accommodate investors' expectations, this investment banker put his finger on a second important dimension to the interactions between predictors and metapredictors, namely that these interactions contain a reflexive element. As explorationists interact with several actors within the same publics, such as different investors, and the interactions reoccur between different projects or even between different stages of projects (i.e., most junior exploration companies go through several financing stages for the same project), there are many opportunities for explorationists to reflect on and learn from previous interactions, lessons they can use to adapt their communication style and, so to say, begin talking like investors (and not like geologists). By doing so, explorationists would draw the content they put forth in predictions closer to the language and values that investors and other metapredictors understand and find important, repeating a trend already observed in finance where forecasters adapt their forecasts to fit front stage expectations held by their audiences (Svetlova 2012).

In other words, the use of predictions in explorationists' interactions with investors in early stage mineral exploration revolves around explorationists seeking to attract investors to the potential they see for their projects, a potential that, to junior exploration companies, hinges on them getting access to investment capital that can carry the project onwards to intermediate and advanced exploration. Because the scarcity of data at the early stages of exploration means that the situation is highly uncertain, investors focus their metapredictions on the qualities that stand-in for the detailed geological, metallurgical, and technical data that would become available further into the exploration process. In the examples described above, many of these stand-in values center on the perceived expertise of the explorationists, the pedigree of the project, and the combination of these two into a story about a project's potential for housing a significant discovery. But how do metapredictions in exploration and mining financing change as more data are made available through intermediate and advanced stage mineral exploration?

8.2.2 Advanced stage metaprediction: It is models all the way down

As described in chapter 6, the predictions produced at the later stages of exploration work are far more technical depictions of a projected future than are early stage claims about a project's exploration potential, and these technical dimensions characterize much of the engagements that take place between explorationists and a second group of investors, namely debt financers. Debt financiers such as banks tend not to be involved in early or intermediate exploration work as the outcomes are uncertain and mineral exploration does not produce any revenue with which explorationists could pay interest or repay loans. However, as exploration nears its end, Eric explained, any exploration company not large enough to finance mine construction from their own cash flow approach banks with the results of their feasibility studies. As was discussed previously, feasibility studies are comprehensive reports based on large amounts of geological data, metallurgical analyses, cost and income estimates, and techno-economic studies. Together, these sources of information construct a minability estimate for the whole projected mine in the form of an estimated NPV.

Being more mature products, the predictions made in feasibility studies enjoy the full weight of the industry standards, mineral reserve estimates, and qualified persons' assessments. This information helps explorationists justify the quality of their prediction work, and this is reflected in the interactions between explorationists and financers. Being more concerned with model specification and prediction correctness than they are with storytelling and adventure, advanced stage financiers such as banks therefore tend towards evaluations of the technical application of formalized predictions. According to one qualified person, banks, as advanced stage financiers approach metaprediction by employing independent engineers with qualified person accreditation to evaluate the technical qualities of projects. This use of independent engineers is part of the due diligence practiced by debt financers and involves the independent engineers producing their own feasibility studies based on the data provided by explorationists so they can produce their own valuation of the future minability of a project. Qualified person and consultant John explained how this plays out saying that "banks trust their consultant or independent engineer to evaluate the technical qualities of a project in order to produce a technical financial model." Based on the consultants' work, John continued, the banks "do their jiggery-pokery" and add additional layers of information to assess whether the explorationists' predictions hold when banks add their own macro-economic forecasts to evaluate the robustness of explorationists' predictions. Based on their metapredictions, financiers then evaluate whether the project's risk profile fits with the bank's preferences in terms of the levels and sources of risk.

Although the NPV is a central dimension in assessments of a project's risk profile, the metaprediction produced by banks and independent engineers features other values. One of these additional values is the estimated reserve tail. Ian described this as a measure of the health of the estimated NPV. In practice, the reserve tail is an estimate of the duration of production remaining in a project when debt has been paid. A reserve tail is, in other words, a safety margin that takes into account potential delays in loan repayment. If a company, Ian said, for example was to suffer a production delay or if they for some reason would have to postpone payment of debt, the reserve tail ensures the debtor has enough minable material remaining in their mine so that there is some security beyond the original loan repayment date; meaning that even if the predictions presented by explorationists were to come up short, there would still be enough money in a project for it to be minable.

Moreover, as mining operations permanently alter the landscape in which they are located and pose risks of environmental harm through emissions and accidents, financiers may seek to also assess a projected mine's environmental impacts as part of metaprediction. Therefore, banks may choose to incorporate environmental and social impact assessments before deciding whether to extend debt to mining developments. According to a 2015 survey conducted by the Financial Supervisory Authority of Sweden (2015), all major banks in Sweden use some form of internal regulation that demands that the bank assesses the environmental risks as well as the risks to the bank's reputation when evaluating whether to finance environmentally impactful enterprises such as mining. Two of these major banks were also members of the Equator Principle's Risk Management framework, which provides additional standards for how financial institutions work with risk and perform due diligence. Eric discussed this assessment as something banks do to make sure "that they're comfortable loaning money to a development that doesn't have significant negative environmental or social impacts." To assure the environmental and social soundness of the projected mine, banks therefore employ additional independent experts to assess projects. However, according to John, environmental impacts are largely a technical and economic matter as environmental challenges are dealt with within the realms of the costs of impact mitigation, the availability of technical solutions with which this can be accomplished, and the severity of the impact in relation to the regulatory definitions of sustainable resource management (see chapters 6 and 7).[137]

The NPV, the reserve tail, and a project's robustness in relation to price variations and other macro developments, and a mine's potential environmental impact are all technical dimensions in assessments of predicted futures. Because of this attention to the technical qualities in predictions, the interactions between explorationists and financiers over debt take a different form from those played out over equity financing. Whereas equity financers largely base their metapredictions on a trust in explorationists and their abilities to predict correctly the exploration potential in a project based on expert judgment, debt financers benefit from the standardized nature of advanced stage predictions. According to the system of industry standards for how mineral resources and reserves are to be reported, the core of the predictions debt financers are presented with consist of mineral reserve estimates underwritten by accredited qualified persons based on geological and metallurgical data that have been quality assured and controlled through the use of QA/QC protocols. Based on this, the metapredictions produced over explorationists' access to debt ultimately come down to whether the numbers and assumptions fed into the models are reasonable or whether the model, specified otherwise, would contradict the prediction put forth by the explorationists. Moreover, although the material realities of the geological first nature form the foundation for these assessments, the multiple layers of estimation are involved in predicting the minability of a deposit in terms of its second nature qualities. Metapredictions made for predictions made in advanced mineral exploration are an exercise in modelling the credibility of models based on how these models have modelled the minability of a project, making it appear that at this stage it is just models all the way, from the NPV and down.[138]

Compared to the intra-organizational metapredictions discussed earlier, the interactions that take place between predictors and metapredictors in finance more clearly demonstrate how the outcomes of these interactions have real consequences for the predictors. Because of this, the predictor-metapredictor

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[137] This can also be seen in how the environmental regulation in Sweden is implemented (see chapter 7).

[138] The phrase "models all the way down" here refers to the phrase "turtles all the way down" used to indicate problems of infinite regress and the alleged interactions between a prominent scholar. (There are different versions of this interaction and some of them have Bertrand Russel or William James as the scholar in question). A woman at the end of a lecture on astronomy is said to have engaged the scholar saying that they had got it all wrong. Contrary to what the scholar had said, the lady allegedly explained, the Earth is not a spheroid orbiting the sun. Instead, the Earth is really a crust of land on the back of a large turtle. Responding to this statement, the scholar asked the lady that given that her theory was true, what did in turn support the turtle. When pressed about this, the woman allegedly stated that, naturally, the large turtle was supported by an even larger tortoise, and when pressed again she simply stated that "it is no use young man, it's turtles all the way down!" The story exists in different versions with linguist John R. Ross (1967) attributing the interaction to William James while Stephen Hawking (1990) relates the story with Bertrand Russel.

interactions in relation to equity and debt financing take on a character akin to a game. In these games, predictors present metapredictors with the products of their prediction work for the metapredictors to make their own predictions based on their assessment of either the predictor's capacity for correct predictive judgment or the robustness of their estimations. Furthermore, the outcome of these "prediction games" in which predictors and metapredictors engage each other over the probable nature of the future have real consequences for the continuation of the exploration project for which the game is being played. This is because a favorable metaprediction is a condition for explorationists' access to vital resources such as investments necessary to finance the next step of exploration work, or the bank loan that makes it possible to move a project into construction. In the early stages of exploration work, these engagements revolve around highly uncertain estimates of a project's exploration potential where predictors set out to persuade equity financiers to take the chance and help them move the project forward. In the advanced stages, on the other hand, the engagements take place over much more detailed predictions based on multiple layers of exploration work as explorationists engage banks and other financiers seeking to convince them to extend debt with which explorationists can construct the projected mine.

To have success in these "games," explorationists need to adapt the way their predictions and the way they communicated them to the language used by metapredictors and the frame of values granted importance by them. The importance of communication in determining the consequences of the use of predictions in order to persuade others to extend resources is of some interest here as it demonstrates how a shared frame of reference can aid predictors in their interactions with metapredictors. The importance of a common language and a shared understanding of what makes good prediction work becomes even more apparent when looking at conflicts between predictors and metapredictors.

8.3 The Mining Inspectorate as a metapredictor

A third domain in which explorationists and metapredictors interact is in permit applications and processing. One clear example of this is the exploitation concession processes in which explorationists engage the MIS, seeking the right to exploit a mineralized deposit in the future. As stated previously, exploitation concessions grant their holders the sole right to a mineral deposit over a period of 25 years and in order to attain one, the Swedish Minerals Act of 1991 states, explorationists need to prove that the project for which they are seeking a concession is likely to be economically minable within this 25 year period. Therefore, when explorationists apply for exploitation concessions, they begin interactions with MIS officers around the correctness of their predictions of project minability and the robustness of these predictions. This focus on prediction robustness gives the exploitation concession process a technical focus resembling the metapredictions in debt financing discussed above. However, given their focus on the legal-technical dimension of future minability, the MIS's assessments of the predictions presented by explorationists are more technical still, wherefore the "games" played over exploitation concessions are probably the most clear-cut examples of metaprediction based on assessments of prediction methodology and model specification yet.

In exploitation concession evaluation, senior MIS officer Anne said, the mission of the MIS is strictly to "apply the law," meaning that the economic minability of a mineral deposit over the coming 25 years is solely a matter of juridical nature. In practice, this means that the MIS evaluates the quantity and quality of mineralized material estimated by the applicant in relation to what the MIS officers managing the case see as the technical requirements for making the deposit minable. Dave, a MIS officer, talked about how this is done saying that: "I look at the mineral estimate" provided by the applicant "to see if it is technically possible to mine the deposit the way they propose to do it." Based on the value of the mineral described in the estimate, Dave then makes what he and Anne both referred to as a "probability judgement" regarding whether they see that it is probable that the deposit will be minable in the coming 25 years. When asked to explain what information is weighted in such probability judgements, Dave specified the following:

> It is drill holes, geological data. And how they are planning to mine it. Where are they going to concentrate it and what the results from the metallurgical analyses look like? I calculate a value for the mineral reserve based on this. Thinking something along the line of: well, using this particular mining method, it will cost them about this much. And then I see what is left [of the mineral value], or if it's in the red [laughs].[139]

When evaluating the estimates for the mineral deposits reported by applicants, Dave continued, one can only rely on historical data: "No one owns a crystal ball" that can tell them what the future commodity prices will be, so the "only thing you can do to see if a project is profitable or not is to estimate what the value of the metal may be." Using historical prices from central trading places such as the London Metals Exchange as well as from the MIS's own data-

[139] Ja det är ju på all borrhål.. geologisk data. Och så hur dom har planerat att bryta. Vart ska dom anrika, hur ser anrikningsresultaten ut? Jag räknar ut ett malmvärde på det alltså, ja. Tänker ungefär: ja med den här brytningsmetoden kostar det såhär mycket, och den här anrikningen kostar ungefär såhär mycket. Och då ser jag, vad blir det kvar, eller blir det ingenting kvar [skrattar]?

bases, Dave and his colleagues weigh the reported quality and quantity of mineral and the expected costs of mining it against past prices to see if the project would be minable under those prices. If the project would have been economically viable "during eight out of ten years, well then you can assume that 25 years from now [. . .] there is a chance that this really is a profitable endeavor." However, Dave concluded, although estimates are a necessary part of the MIS's assessment of concession applications, the most important thing is that the applicant can show that there really is a significant body of mineralized material in the ground: "That's Alpha and Omega" [. . .] "that there is enough there to make something of it."

When asked if there is a standard or particular method for how MIS officers are to review exploitation concession applications Dave noted that there are no standards detailing how the MIS works in these matters. Instead, he said, how they work depends on the deposit for which the application is filed. An experienced MIS officer, he stated, can easily tell a good application from a poor one and will only have to make a closer review of applications containing deposits that lie somewhere between being minable and unminable:

> It depends on the deposit, you know. If you're experienced you can see that these grades and this rate of recovery, yeah, then you can tell that there is no question; here they will be making a billion in profits [laughs]. But when you get to stuff that is, you know, borderline, that's where you get cautious. Then you really go through it with a fine toothed comb. Is this correct and reasonable? And is the deposit rich enough? And where is it? Does it reach the surface or is at 200 meters depth or 1000 meters depth?[140]

However, what is a good deposit? Although there are no written standards for how the MIS evaluates economic minability practice has it otherwise as the MIS has been known to use mineral resources at the indicated level as a minimum level when assessing economic minability. In effect, the MIS therefore borrows the mineral resource and reserve classification provided in industry standards when assessing the economic minability of a mineral deposit described in exploitation concession applications. As was described in chapter 6, an indicated mineral resource is a standardized classification of exploration results based on the degree of confidence in estimates of the grades, tonnages, deposit geometry, and density of a deposit of mineralized material. Although a mineral resource should have reasonable prospects to be economic, economic minability is not part of a mineral resource estimate the way it is a part

[140] Det beror ju på fyndigheten. Alltså, är man erfaren så ser man att dom här halterna och det här utbytet, ja då ser man ju att det här är ju inga problem; här är det en miljard i vinst [skrattar till]. Men det är ju när det är riktigt såhär på gränsen man börjar bli tveksam. Då särskådar man ju verkligen. Är det här sant och rätt och riktigt? Och är han tillräcklig fyndigheten? Och vart ligger fyndigheten? Är den i dagen eller är den på två hundra meters djup eller på tusen meters djup?

of a mineral reserve estimate, which also considers modifying factors such as the assumptions of future costs and prices. Interestingly, there is no legal precedence for this use of industry standards as there are no mentions of standards or classifications in the Minerals Act of 1991 or in the Minerals Ordinance of 1992. However, the classification is described as the minimum requirement for exploitation concession in SGU's "Guidance for permit processing in mining."[141] In addition, indicated mineral resources feature as a requirement for a concession in MIS rulings. In 2013, the MIS advised an applicant that their application would be rejected unless the applicant provided the agency with additional materials to support their claims of deposit minability. The MIS order listed the reasons for their warning and among the listed flaws was that "the distance between the drill profiles [provided to support claims of economic minability] in some places is too great for them to meet the requirements for an indicated mineral resource."

Talking about the economic minability criteria in the Minerals Act and exploitation concessions processing in relation to mineral resource assessments, John critically summarized his view on the matter: "At times I think it gets quite hokey."[142] Recalling how the Minerals Act stipulates that concessions are to be awarded when "a deposit that is probable to be economically exploitable has been identified"[143] (The Swedish Riksdag 1991, 4 chapter 2§), he proceeded to comment on what counts as "probable" in this context, saying that:

> You have to prove that it's minable and that you can make money from it. And that is about the same definition as a PFS, a pre-feasibility study, the same definition as an ore reserve.[144, 145]

The Minerals Act stipulates that a concession is to be awarded when an applicant can show that the deposit is minable within a 25 year period, and according to John, this should require applicants to produce stronger evidence than a mineral resource estimate at the indicated level. Developing his views on what the appropriate level of work should be were explorationists actually to meet the legal requirements for an exploitation concession, John made the following observation:

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141 See, Geological Survey of Sweden (2016).

142 "Jag tycker att ibland är det där väldigt flummigt."

143 "[E]n fyndighet som sannolikt kan tillgodogöras ekonomiskt har påträffats."

144 As was stated earlier in this dissertation, an ore reserve is defined according to the same criteria as a mineral reserve with the only difference between the two being that different standards use either mineral or ore when discussing reserves.

145 Man måste bevisa att det är brytvärt och att man kan tjäna pengar på den. Och det är ju ungefär samma definition som en PFS, som en pre-feasibility study, samma definition som en ore reserve.

> However, I've seen more exploitation concession applications that have had scoping study level results, at the most! Documents that are this thin and that cover the largest geological and technical risks in a very superficial manner that I don't see meets the level described for exploitation concession applications and how it is maps onto international terms.[146]

According to John, there exists a significant discrepancy between what is stated in the Minerals Act and what the MIS takes to be sufficient work for a concession. Although the terms used in regulation present one set of expectations, the practice is quite different in his view. However, not all explorationists shared John's assessment of the "hokeyness" of concession permitting. Mining engineer Lars, for example, had a different take on exploitation concessions, seeing them more like a stage along the exploration process than an actual demand for detailed predictions. An estimate provided in an exploitation concession application, he said, "is not a detailed measure because it is handed in to give you more time to do the detailed exploration and estimation. It buys you time." For Lars, the exploitation concession is something you do when you are ready to move towards undertaking more time-consuming work in intermediate and advanced stage exploration. The exploitation concession makes this possible as it is valid for 25 years, but exploration permits need to be renewed every three years and at increasing costs. Any discrepancies between the legal definition of exploitation concession level work and the practical application of this definition was less of a concern.

In relation to John's observation that many exploitation concession applications quote mineral resource level estimates and his criticism against the use of indicated mineral resources to define minimum level requirements for economic minability of a deposit, a review was undertaken of the corpus of exploitation concession. Of the 41 cases in the corpus, 31 applications quoted mineral resource estimates at the indicated level. However, applications also included the higher level (measured) and lower level (inferred) resources. Of the remaining ten cases, two quoted mineral reserves and both of these applications concerned mines seeking a concession in order to add a continuation of a mineral deposit to the sections already being exploited. In the remaining eight cases, no information was available for the level of estimate quoted in the application. These eight cases included cases that, when filed, were exempt from reporting estimates (e.g., cases concerning transformations of older

[146] Men jag har sett fler bearbetningskoncessionsansökningar som har hat scoping study-nivå, i det bästa fallet! Som är ett dokument såhär stort och som täcker dom största geologiska och tekniska riskerna på ett väldigt ytligt sätt och som jag inte tycker når det här begreppet enligt vad bearbetningskoncessionsansökan beskriver och hur den kartläggs med internationella begrepp.

forms of permits into exploitation concessions),[147] older cases where the terminology used in applications and MIS rulings was unclear and non-indicative of estimate levels, and applications that had been withdrawn by the applicant and where no supporting material or details was available from the MIS.

In his complaints that the MIS uses a level of estimate as proof of minability other than the one best corresponding to the letter of the law, John drew attention to an important practical dimension of the MIS's role as a metapredictor. Due to their position, the MIS sets the standard for what is a viable prediction in the early to intermediate stages of exploration work in Sweden and what the MIS finds viable need not necessarily correspond to the values explorationists use to characterize high quality prediction work. The use of indicated mineral resources rather than reserves as a measure of minability in exploitation concession permitting goes hand in hand with how the MIS approaches concession permitting as a legal exercise. To the MIS, minability is solely to do with the legal aspects of a future mine; and anything not covered in regulation is taken into account. Therefore, Anne explained, the MIS focuses solely on the mineral deposit for which the application is made and not on other dimensions such as the suitability of the applicant. Talking about the Northland mine, she said that in the time that followed the bankruptcy, a prominent investigative journalism program on Swedish Television approached the MIS over their decision to award Northland their exploitation concessions. The journalists, Anne said, "tried to squeeze us on how we could approve that mine when it performed so poorly economically." However, she continued, that was the wrong question to ask. What the journalists failed to understand, she explained, was that reviewing the applicant is not part of the exploitation concession processing:

> Anne: We did a probability assessment, and we did that, you make them based on the deposit and the mineral resource, not of the company!
>
> Tobias: No?
>
> Anne: That's not within the law. And the point of that, yeah well, is that the mine that carries the value. If we've got an inept company that goes bankrupt at some point, then it should be possible for someone else to take this mineral resource further.[148] And that's, yeah well, that reasonable somehow. And then again, things change. They began their operations when prices were really high

[147] With the introduction of the Minerals Act of 1991, provisions were put in place that allowed permits rewarded under the previous mining regulation to be transferred to the exploitation concession system through a limited exploitation concession review in which the demand for proven economic minability was waived.

[148] The historically-minded person might wish to note that this line of reasoning with the MIS can be traced back to, at least, the mining law introduced by Queen Christina of Sweden in 1649, where it was stated that the MIS's predecessor, the *Bergskollegium*, was to assume management and "assist" those mines that failed to carry themselves financially.

> and when the drop came they did not keep up, they weren't skilled enough [laughs]. But then again, they had some bad luck with the prices collapsing too.[149]

Dave also stressed the separation of applicant and mineral resource in exploitation concession processing. Talking about why some mines fail despite having beneficial geological conditions, Dave explained that while a mineral deposit may be "okay" the people working it may have too little knowledge of how best to mine it and how to make it profitable. How to best mine a deposit is the central question in later stage feasibility studies and mineral reserve estimates, but not in the MIS's assessments of exploitation concession applications where "good" and "inept" applicants alike may gain a concession as long as the deposit is of sufficient quality to be deemed minable. In addition, Dave explained, most companies manage to produce mineral estimates that meet the legal requirements and that this is especially true for the established mid-tier companies in Sweden while junior companies may, at times, put forth applications that fail to correctly estimate a minable resource due to flawed estimation methods. In cases where this happens, he continued, the applicants are notified of their shortcomings and will often choose to retract their application.

The MIS assessments of the predictions presented by explorationists as part of proving the economic minability of the deposit in applications for exploitation concessions differ significantly from the stories about the deposit and the team working it as requested by investors. The MIS does not review the credentials of the applicants but focuses solely on the predicted minability of the deposit. This positions the MIS's interactions with explorationists closer to those between explorationists and banks than between explorationists and equity investors in terms of whether the focus of the prediction game played out is the credibility of the prediction itself or the credibility of the predictor. Nevertheless, although the MIS focuses on metapredictions based on the qualities of the prediction, both Anne and Dave expressed views and experiences that distinguished good explorationists from inept explorationists and the line between the two were at times drawn close to that between established Swedish mid-tier companies and junior companies.

As was discussed above, the MIS assesses more than just predictions of a project's economic minability. As part of the exploitation concession review,

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[149] Anne: Men då är det ju så att.. Vi gjorde en sannolikhetsbedömning, och vi gjorde det, man gör ju det av själva gruvan och den här malmfyndigheten, man gör det ju inte av företaget!
T: Nej?
Anne: Det ligger liksom inte i lagen. Så att det.. och vitsen med det är ju att, ja men, det är gruvan som ska bära värdet. Om vi har en.. ett klumpigt företag som någon gång går omkull ska det faktiskt vara möjligt att gå vidare för någon annan, med den här malmfyndigheten. Och det är något slags, ja men, vettigt tänkande med det. Och sen är det ju också, tiderna skiftar, dom kom ju igång när priserna var väldigt höga, och sen föll dom och dom hängde liksom, dom hade inte, dom var inte tillräckligt duktiga [skratt på en utandning] en sak, men sen hade dom också lite otur med prisfallet också.

the agency also assesses whether the predicted socio-environmental impact satisfies existing environmental regulation. When undertaking assessments of a project's predicted environmental impacts, the MIS follows the same legally focused approach as when assessing a project's economic minability. In the MIS's rulings on exploitation concession, one can follow the process as the MIS together with the local CAB review whether the project is located in a place unfit for a mining operation. When undertaking this review, the agencies look at whether the area that would be affected in the event of the realization of the projected mine has any prior legal status such as a national interest classification, a national park designation, and a municipal zoning or planning program. In addition, the agencies also review the project's projected impacts on socio-environmental values and cultural artefacts in the area (see previous chapters). The aim of these reviews, Anne explained, is to assess the impacts of a future mine on other land uses. In practice, she continued, it is the CAB that makes this assessment and reports the outcome of their evaluation to the MIS, which then decides whether to follow the evaluation provided by the CAB or go against it whereafter the matter would be referred to the government to decide upon.

8.3.1 When predictors and metapredictors disagree: Criticism of state actors as metapredictors

Based on their role as a permit granting agency, the MIS's work as a metapredictor forms an integral part as well as a critical moment in the mineral exploration process. Exploitation concessions are crucial to explorationists as projects that fail to attain a concession cannot be moved into development and construction and would therefore be doomed to close down. Therefore, the exploitation concession application process and the interactions that take place therein determine explorationists' access to a vital legal resource. It is therefore not surprising that many in the minerals industry has strong opinions about the performance of the MIS, the CABs, and the environmental courts as metapredictors. Moreover, while the dataset contains ample examples of such criticisms from the minerals industry, other scholars have shown that also Swedish conservationists and activists tend to be highly critical of how the government and its agencies conduct the permitting process (see Anshelm, Haikola, and Wallsten 2018). That is, both the explorationists and their critics are often critical and dissatisfied with how the agencies handle permit processing. However, while these conflicts are interesting in their own right, they also highlight important dynamics in the predictor-metapredictor interactions as they demonstrate the importance of shared understandings and common language when different actors come together to assess the quality of predictions. Keeping with the "game" metaphor introduced above, this section analyzes the role of disagreement in how predictors "play" metapredictors for access to legal resources.

During lunch at one of SveMin's annual meetings and conferences, a CEO of a Swedish mining company joined the authors and two officers working for the Confederation of Swedish Enterprise (*Svenskt Näringsliv*) at a table.[150] Having sat down to eat, he then began to discuss how his company had applied to the MIS for an extension of their concession area. Lamenting the slowness of MIS processing, the CEO described the application as a simple matter that should not have taken too long to rule on. However, the agency had taken over one and a half years to deliver a ruling, an unacceptable amount of time in his mind. After all, he continued, there had been no foreseeable hindrances to his company getting their request for expanding their concession approved. After all, the local CAB had been positive to the application, so there had not been any environmental concerns standing in the way of approving the extension. Nevertheless, processing had been slow. In addition to this, he continued, the MIS had been unable to provide an estimate of how long the process would likely take.

The CEO was not alone in complaining about the lengthiness of permitting processes. Over the years that observations were carried out at SveMin's annual conferences, a large number of actors and SveMin spokespeople used their allotted time on the conference's main stage to voice different complaints about permitting processes in Sweden. Permitting, according to these people, is too unpredictable and plagued by long processes; and they were heard. At the 2017 SveMin event, the government minister for business and innovation, Mikael Damberg gave a talk in which he promised that the government would look into whether permit processing could be improved. Framing the matter as a problem of international trade and investment, Damberg concluded that "no one gains from permitting processes being unpredictable or drawn out" as this would mean that Sweden might risk losing out on potential investments.

Although industry members often criticize the MIS, the main line of complaints was not directed towards them but towards the government and its environmental agencies and their work in assessing environmental impacts as part of permit processing. The CABs and the environmental courts, Maxwell argued, put too much emphasis on the environmental side when they should also consider the positive social impacts from a mining operation. Arguing that the environmental code covers both the "natural" and "social" environments, Maxwell concluded that the benefits to one should be included when assessing the costs of the other. Were the social benefits to be taken into con-

150 The Confederation of Swedish Enterprise is a Swedish political organization and an employer's organization for private and business sector organizations.

sideration, he continued, many of the environmental costs would grow insignificant in comparison. However, the slow moving processing and relative weighting of social benefits and environmental costs are not the only issues explorationists criticize.

A third and wider reaching theme of criticism levered against the governmental agencies' work as metapredictors has to do with their roles in reducing, or not reducing, uncertainty in environmental permitting. As previous chapters have demonstrated, exploration work uses measurements and classifications for a series of dimensions taken to denote minability in order to "de-risk" their projects and to predict and design minable mining operations. Uncertain and unpredictable processes in permitting therefore becomes a hindrance to explorationists' efforts to establish certainty in projects as it introduces additional uncertainty at important stages in the exploration process, and much of this uncertainty is said to lie on the environmental side of permitting. Although the proven economic minability required in exploitation concession applications in practice is fulfilled if the applicant can show an indicated mineral resource estimate for the project, the application of the environmental code in permitting lacks the institutionalized thresholds that would constitute appropriate land use and resource management. Quinn discussed how this becomes a problem for explorationists as they are rendered unable to form a rational expectation for whether EIAs and the measures put forth to safe guard environmental values will be deemed sufficient by the CABs and the environmental courts. This, she continued, becomes even more true when the MIS and CABs decide to suddenly change their practices. Pointing to the CAB's decision to deny an exploitation concession because the applicant had failed to obtain a waiver for the Natura 2000 protection in the area before submitting the concession application (see previous chapter), she said that at that time:

> a company could decide whether to apply for a waiver from Natura 2000, like, while doing their exploitation concession application or wait until they apply for an environmental permit with the courts.[151]

However, she continued, practice changed while this case was being processed as the MIS together with the local CAB decided to remove the possibility of deciding when to apply for a Natura 2000 waiver. Instead, the agencies determined the applicant could not obtain an exploitation concession without first applying for and obtaining a waiver, thereby taking away the option of leaving the matter until the environmental permit process. According to Quinn, the CAB and later the MIS made a sudden change to practice and said that: "No, we don't want to approve this. We think you should have done the survey and

[151] Från början kunde ett företag ta beslut att ansöka om dispens från Natura 2000 typ samtidigt som dom gör bearbetningskoncessionsansökan eller vänta till när dom ansöker om miljötillstånd från domstolen.

whatnot already with the exploitation concession application." This sudden turnaround, Quinn continued, affected explorationists who had been forced to restructure their exploration work by shifting more of the environmental work earlier in the exploration process.[152]

The changes to how Natura 2000 waivers are managed in permitting are not the only recent shifts in how the environmental impacts of a projected mine are managed in permitting. In February 2016, the Supreme Administrative Court of Sweden delivered a ruling that had far-reaching implications on the exploitation concession processing. According to senior MIS officer Anne, the ruling, which concerned the highly publicized Norra Kärr rare earth minerals project and which had at that point gone through several rounds of appeals, significantly altered the conditions for assessing the environmental impacts in exploitation concession processing. Before 2016 she explained, the MIS and CABs had only assessed the impacts from the mine itself and left the broader review of the impacts from the overall industrial complex around the mine to the environmental courts and the environmental permit processes. This, the Supreme Administrative Court ruled, was not in line with the spirit of the Environmental Code. Instead, the court ruled that the impacts from the full mining operation were to be assessed in the preliminary EIAs and in the MIS's review of exploitation concession applications. Following this ruling, Anne continued, the MIS saw itself forced to return all active applications to the applicants and ask that they do more work assessing the mine's environmental impacts before the MIS would be able to review their application.

The Supreme Administrative Court's ruling not only affected the MIS and the explorationists with active applications at the agency, but also the industry in general. Eric explained that through their ruling, the court introduced additional uncertainty into permitting in Sweden. The same instance that they decided to overturn the exploitation concession at Norra Kärr and send it back to the MIS to be processed anew, he suggested, mineral exploration became a little more uncertain. Discussing the implications of the ruling, he said that "twelve months ago you would have said Sweden is low risk. Now it's not as low, there's some uncertainty there." Having said this, he paused before continuing: Although Sweden has an active exploration and mining industry, he said, the industry is relatively small compared to Canada or Australia and this is reflected in the unpredictability of permitting. Few permits are issued in Sweden, he reasoned, which means that in Sweden explorationists have access to fewer "case examples of how things have gone" against which they can orientate themselves.

As data availability and stable projectable patterns are prerequisites for prediction making (see chapter 3), increased uncertainty in permitting relates both to a scarcity of historical permitting cases to orient oneself against and to how shifts in the permit process render historical data less suitable for predicting

[152] At the time of writing, the application had yet to receive a definitive ruling.

the outcome of future permitting applications. The low number of cases and the shifting regulatory practices thereby means that there is little ground for comparisons between present and past exploitation concessions and environmental permitting cases. Quinn believed that because of the lack of comparability between cases, she saw opportunities for the MIS and the CABs to work with explorationists and provide clear guidance as to what is expected of them in their applications. According to Quinn, unlike other countries, Sweden via the MIS does not offer support or guidance to explorationists. That agencies are reluctant to help exploration organizations obtain permits, she continued, is relatively unique in an international perspective as agencies in other jurisdictions usually work with explorationists to explain what materials are needed for a successful application. Based on this experience, Quinn continued, the Swedish system could be improved were the SGU and the MIS to take the time and visit their counterparts in Perth to learn about how permitting is done in Western Australia. Moreover, upon their return to Sweden, the agencies could then write a report to the Ministry of Enterprise and Innovation, to which the two agencies report, with suggestions for how permitting in Sweden could be improved. The Swedish agencies, Quinn continued, "don't have to reinvent the wheel" as solutions are already available that the agencies can draw on to improve how they work with permitting: "There are places where this works fucking great, absolutely!" The problem with the present system, she later said, is that as most projects are caught up in permitting issues, the supply of new projects are stifled. From an explorationist's perspective, if the Swedish agencies want to improve their performance as metapredictors and their relationships with permit seeking explorationists, this problem would be resolved.

Richard too discussed the reported lack of regrowth in Swedish mining and said that, at the end of the day this is a political question to do with what interests should be given priority in conflicts over land and water use. Talking about the conflicts around which environmentally permitting issues regularly revolve, he said that:

> You know, anyone can have an opinion on this. If you don't like the mining industry, then of course you're gonna think it's great to have the Sámi with their reindeers, and that doesn't have to be wrong. But somehow our society needs to make up its mind: What is it we want and where do we want it? And we haven't even managed to do that.[153]

In Richards view, political indecision is at the root of the problem in permitting, a view that may not come as a surprise to anyone familiar with Sweden's

[153] Liksom, alla kan tycka något. Gillar du inte gruvindustri så tycker du förstås att det är jättebra att ha samer med sina renar och det behöver inte vara fel. Men på något sätt så behöver samhället i stort bestämma sig; vad är det vi vill och vad är det vi vill vart?" Och inte ens det har vi riktigt lyckats med.

mineral strategy. The Swedish Minerals Strategy put in place in 2013 (Ministry of Enterprise and Innovation 2013) gives the impression that Swedish mineral policy is about having the cake and eating it. The mineral strategy stakes out a policy that promotes mineral exploration and mining as sources of regional growth and development; however, this policy stands side by side with political initiatives such as the European Union's Natura 2000 program that promote the protection of environmentally valuable habitats. Maxwell described the complications of these two parallel policies as the "two faces of Swedish mining policy," which ends up promoting mineral exploration while putting hinders in place of mining. In practice, this dual line of policy produces contradictory practices. While the SGU are tasked with promoting Sweden as an international mineral exploration and mining destination as well as with providing explorationists with services and low cost access to available exploration data, the MIS is tasked with strict application of the law and the Swedish Environmental Protection Agency often act as part in environmental permitting cases before the environmental courts. Were a project to move all the way from initiation to environmental permitting, it might, in other words, initially benefit from the support provided by the SGU before being evaluated by the MIS before it would finally face the Environmental Agency in the environmental court. During an informal conversation at an industry event, a senior officer with the SGU blamed governmental indecision for the different lines Swedish agencies follow in relation to exploration and mining: when government ministers cannot reach an agreement on mining and environmental issues, the officer said, they delegate the problem to their respective ministries, who then delegate the problem to their respective agencies. Tasked with finding a solution, the agencies do what they can to find a solution only to find themselves criticized by the ministries and ministers for having made too many compromises. This indecision, the officer continued, is also visible in exploitation concession cases as the number of concession that have been appealed and referred to the government for decision has been piling up while few have received decisive rulings.

The descriptions of the problems in permitting cited above fundamentally come down to how socio-environmental preservation and economic growth are balanced in Swedish policy and in the agencies' practical application of regulation in permit processing. Many in the exploration and mining sector are highly critical of this balance and foresee dire consequences for Swedish mining and the supply of metal and mineral resources to Swedish and European industries. However, others in the industry are more relaxed about the lack of new mine developments in Sweden. Olaf, for example, is positive that permitting is far from the only explanation of why the regrowth in Swedish mining has been slow in recent years. In his view, the lack of significant discoveries in Sweden combined with the economic crash of 2007-2008 explain the lack of new mine developments better than any deficiencies in the permit processing. However, while disagreeing with the diagnosis, Olaf recognized the symptoms described by other informants. That is, although he saw other explanations for why Sweden has seen few new mine developments in recent years, Olaf also saw that permitting had grown trickier and time consuming over the past ten years and that this meant that exploration companies today need increased “financial stamina” than they did before if they are to survive the lengthy permitting process.

Many different voices have expressed concern and frustration with how the MIS and other governmental agencies perform their roles as metapredictors in relation to mineral exploration. The conflicts and disagreement described here demonstrate how important the, so to say, “rules of the game” are to what predictors can achieve with the aid of their predictions. If they manage to “play” the game right and convince a potential investor to take on risk and invest in their project, explorationists are able to access resources necessary for moving their projects ahead. However, when the rules of the game are opaque and subject to differing interpretations, accessing such resources becomes challenging as it becomes more uncertain what predicted futures are more likely to pass a metapredictor’s assessment. Therefore, the predicted future becomes more uncertain in terms of what consequences they will have when predictors seek to put them to use in interactions with investors, governmental agencies, and other interested publics.

8.4 Metapredictors outside of mineral exploration: The general public’s acceptance of mineral project

Finally, lifting the perspective to look beyond the circle of exploration companies, their financiers, and the governmental agencies supporting and regulating them, one may ask what role the affected communities and the public play in all of this. Although often immediately affected by exploration and mining, local communities rarely feature directly in the discussions about the correctness or desirability of predicted mining futures. Instead, they are often given an indirect role as recipients of all the benefits that a future mine will bestow on its surroundings. In part, this is related to how some groups are never given an opportunity be heard in relation to the exploration process and partly with them failing to speak with one voice. For example, senior MIS officer Anne argued that the protests against mining and exploration that took place in Sweden during the 2010s were part of a global trend rather than an effect of local conditions or politics in Sweden. At the end of the day, Anne continued, protest and debate only have a marginal effect on what goes on in the mining industry and nothing the MIS takes into consideration when processing exploration permit and exploitation concession applications.

SGU officer Hank also talked about mining and exploration contestation as a "trend" and located its origins to protests against a uranium project outside of Helsinki, Finland. The movement contesting this particular project, Hank continued, grew and developed to encompass all minerals and all mineral projects in both Finland and Sweden. Moreover, during observations at an office of the SGU, two unnamed officers discussed the social movements protesting the Kallak project. The people protesting at Kallak, they said, were not actually members of a concerned public, but "professional activists" who had toured Scandinavia moving from protesting a lime stone project at Ojnare[154] in the Gotland Province before heading north to Kallak and eventually moving on to Norway "for more protesting." In fact, the two officers continued, the group of people contesting the project were mostly outsiders as the local community were in favor of the project, a distinction captured in the field notes from the occasion:

> They talk about the local community having a positive opinion on the mine. They tell of how a meeting with the community saw a man in his 40s stand up and argue against the mine and how an elderly woman had responded to this saying that "You bought a house and moved here. You don't work and you don't contribute because you're set already. But what about the rest of us? What are we gonna live off? You're not from here so you should just keep quiet!"[155]

In their discussions of the Kallak project, the two officers draw a distinction between the "real" community and, so to say, tourists who–while they live in the community–do not belong. Based on these distinctions, the officers paint a picture in which a silent majority supported the project while those contesting it could be dismissed as an insignificant but vocal minority of tourists and professional activist. The local Sámi district and reindeer herders–of whom many participated in the protests–are curiously absent from this discussion. However, while these agency officers represent one view of the role, or absence of a role, local communities play in mineral exploration processes others were more concerned about actually winning public acceptance for exploration projects.

A counter example to the views expressed above can be found in Quinn's approach to project generation (see chapter 5) and how she would seek to make sure to minimize the likelihood that some social or environmental issue

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[154] See, e.g., Anshelm, Haikola, Wallsten (2018a).

[155] Det talas även om hur lokalbefolkningen varit positiv till gruvan. Det berättas ett möte med lokalbefolkningen där en man i 40-års-åldern argumenterat mot gruvan och hur en äldre kvinna då svarat att ”Du har köpt hus och flyttat hit och du jobbar och bidrar inte för du har så mycket pengar redan, vad ska vi andra leva av då? Du har ingen anknytning till bygden så du har inget att säga till om!”

hampering exploration work before she would move ahead and apply for an exploration permit. When discussing this strategy, Quinn pointed to how explorationists benefit if they can gain a community's approval or at least acceptance as "it is really hard to build a mine if you don't have a community that want it and supports it." Explorationists often refer to such community support or acceptance as a "social license to operate." Receiving a license can be challenging, John explained, unless one spends time and resources talking to stakeholders and building trust by sitting down and explaining what one's plans are for a project. This sentiment was echoed by other informants and in particular in a conversation that took place in the lunch room at a consultancy firm. While on a coffee break, a group of mining engineers and geologists working at the exploration consultancy firm discussed the Kallak project and the importance of "people skills" in mineral exploration and mining. According to the four men engaged in the conversation, the company working Kallak were notoriously bad at communicating with affected parties, so it was not surprising that they had failed to gain any acceptance for their project. Gaining acceptance, it was said, would require the company to go door to door in the community and take the time to sit down and have coffee and explain the project.[156] Only then, they concluded, can a company secure a community's acceptance.

Gaining a social license to operate, it appears, depends on explorationists' ability and willingness to explain their project to stakeholders in a way that satisfies the stakeholders' circumspection and expectations: both in terms of what will happen in a project and in terms of when something will happen. Anthropologists have repeatedly pointed to how misaligned temporal perspectives give rise to friction between explorationists and stakeholders (Kesselring 2018; Lanzano 2018). Examples of this include how the establishment of a mineral exploration project can give rise to expectations of a better future built on resource exploitation (Wiegink 2018); expectations that, because of the uncertainties involved in mineral exploration as well as its distant temporal horizons, may either fail to realize themselves or which may not materialize in the time anticipated by community members (Weszkalnys 2008, 2015). Moreover, temporal perspectives may be misaligned also in the opposite direction as local stakeholders may look to a future far more distant than the future depicted in mineral explorationists predictions. Senior Sámi district member Niels provided an example of this. Talking about the projections for a planned mine in Northern Sweden, Niels made it clear that, to him, the limited time a community would benefit from a mine could not justify the lasting environmental impact the mine would produce. The mine in question was planned to operate for seven years with a potential for an extension depending on whether further resources would be discovered during operation:

[156] A similar sentiment was stated by a CEO of a large Canadian mining company only coffee was replaced with "a six pack of beer and a bag of frozen hamburgers."

> [The mine] was only planned for seven years and they said that "it could grow to become much bigger and last longer." But to cause so much destruction for just seven years.[157]

In Niels's view, whatever benefits the mine would bring the community in terms of job opportunities and taxes, the short time span would not justify the lasting impacts that would remain when the mine was eventually closed down.

Social licenses to operate depend on the expectations a community has for a project. If explorationists are successful in convincing stakeholders why their predicted mining futures are the more desirable option, then they may establish trust and acceptance for their project. However, this does not mean that local communities are part of the prediction games played between explorationists and their publics. Instead, the role played by communities is diffuse. In part, this ambiguity is because a community seldom speaks with one voice, as in the case with the elderly woman telling the newer resident to keep quiet, but also because communities seldom are acknowledged as part of a prediction game as they do not control access to any resources necessary for the realization of a predicted mining future. Instead, communities are often stripped of their agency and relegated to roles such as passive recipients of jobs (as in the preliminary EIAs) or potential sources of risk that needs to be managed through trust-building coffee drinking and other social license gaining interventions. Because of this, local communities local communities are less of a part in the negotiations over the future than variables in the prediction of the same. One extreme example of this view of communities as passive and void of any agency was voiced by a CSR consultant at an international conference and tradeshow. Speaking at a session on CSR and social license issues, the consultant discussed the work done by organizations that work to support local communities affected by mineral exploration and mining. Expressing a strong disdain for such NGOs, the consultant described how these organizations insert themselves as intermediaries between explorationists and communities and how this meddling on part of the NGOs make communities "think that they need a middle man" to speak for them. Exploration organizations and miners do not need middle men to talk to local communities, the consultant concluded: "you don't need a middle man to talk to your children."

[157] Den var ju bara tänkt på sju år och dom sade att "Det kan bli att det blir mycket större, att det ska vara" Men sju år, och förstöra så mycket.

8.5 Concluding remarks

This chapter provides a final piece to the emerging image of prediction work under uncertainty in mineral exploration: explorationists' use of predictions in interactions with their publics. By detailing the importance of metapredictions in mineral exploration, this chapter adds to the understanding of how the way in which predictions are communicated and presented shapes what predictions can be used to accomplish. As mentioned above, the importance of publics in shaping the outcome of prediction making has been stressed in previous research. In a study of financial forecasters, Ekatarina Svetlova (2012:157) found that the products of forecasting depend "not only on the cognitive schemata used" in the field, but also on how forecasters "are forced to talk about the future in organizationally structured interactions." This is also true of the communications between predictors and metapredictors outlined above, however, with an additional dimension. Compared to forecasters and predictors in meteorology and finance, mineral explorationists do not only make claims about the future; they also make claims on the future as they seek to persuade their publics to provide them with resources necessary for its realization.

From the analyses of the interactions between explorationists and their publics, a pattern emerges in which explorationists, so to say, release their predictions into the world seeking access to resources held by their publics. The outcome of these patterns are in turn answers to the "then what" question of explorationists' prediction work and captures how explorationists depend on the outcomes of the metapredictions performed by their publics for access to financial resources, legal resources in the form of permits, and, albeit to a lesser degree, social licenses to operate.

The consequences of predictions in mineral exploration are therefore found in how they perform when evaluated through metaprediction. Metapredictions take place both within exploration organizations and in explorationists' interactions with other actors such as financiers and permit granting agencies and it is the outcome of these interactions that determine whether a project is moved forward on the road towards realization or not. In some of the examples, the consequences of metapredictions are that projects are selected for future exploration work following a favorable review of their exploration potential. In other cases, the consequences of whether explorationists manage to convince their metaprediction counterparts that their predictions are correct have more far reaching implications. In the examples from financing and permit processing discussed above, vital resources are on the line wherefore a favorable metaprediction is key and determines whether a project is given the chance to succeed or whether it will go un-financed and without the necessary permits. In these instances, metaprediction becomes a type of game in which predictors are playing for access to goods and resources to be made available if they manage to convince the metapredictor of the exploration potential outlined in their "story" or of the correctness of their models.

However, the chapter has also shown that not all metapredictors are equal in their interactions with explorationists. Stakeholders such as local communities and the Swedish Sámi districts do not carry the same influence in their interactions with mining and exploration companies as do investors, banks, and governmental agencies. Therefore, stakeholders' assessments of the futures explorationists claim to have predicted and seek to realize weigh less than claims of actors who control financial or legal resources. This imbalance is related to the regulatory environment in which mineral exploration is embedded and with the actors who are provided space to make claims about and on the future in mineral exploration. In Sweden, minerals are public resources the access to which is determined by the premier spokesperson of the Swedish people, namely the government and its agencies. Furthermore, as the right to resources trumps property rights, local communities do not really have a voice in these matters. In addition, the data-driven logic and the front stage expectations in mineral exploration emphasizes de-risking projects through quantifying and measuring particular dimensions of a project also mean that certain forms of knowledge and uncertainties are excluded from explorationists' prediction work.

It is therefore no exaggeration to say that the mineral exploration process and the prediction work that takes place therein has political and ethical dimensions both as quantification (Espeland and Yung 2019) and as claim on the future (Andersson 2018) and through the knowledge practices through which present futures are created (Adam 2011). Although this political dimension to explorationists prediction work has been a recurring theme across this thesis, its implications are at their most apparent here as it is in the interactions between explorationists and publics it becomes clear who is invited to participate in "prediction games" and what knowledges are made to matter in these games over the future. After all, interactions between predictors and metaprediction are forms of conversation in which present futures are put forth, reviewed, revised, and ultimately co-created by the participants. Explorationists and investors, for example, co-create present futures when investors' metapredict the potential returns in a project by asking whether they believe the predictor's claims about a project's exploration potential as well as if they wish to be part of attempting to realize that potential. Moreover, as this co-creation depends on the assessments made in metaprediction, it is only those publics that possess a role as metapredictor and arbiter of resources that are invited to create the future together with explorationists.

In addition, this chapter has shown that the co-creation of predicted futures breaks down when disagreement arises over what makes qualifies as good or relevant prediction work. When predictors and metapredictors do not share the same understanding of what counts as signifiers of correctness and what values need be considered in predictions, the consequences of the prediction becomes uncertain and contentious. For example, the MIS and explorationists both understand and recognize (at least in practice) what it means that a mineral deposit is economic and what counts as proof thereof. This should be compared to situations like those arising in environmental impact assessment in permitting where the scarcity of guidelines or historical cases against which predictors may orient themselves create uncertainty as to the outcome of prediction games. One central implication of this is that the degree of institutionalization of these interactions does not in and of itself influence the level of uncertainty experienced by predictors, a conclusion contrary to the institutionalist's view on uncertainty and risk. To borrow Simmel's (2011) terminology, the crucial thing here is not that the form of these interactions is institutionalized as there is considerable conflict over how the content that flows through these forms are to be valued in terms of how well they help predict a minable mineral resource and what constitutes a correct prediction and a desirable future. Mineral exploration is a long process that continuously produces, reworks, and reproduces predictions of the future that are then used by explorationists and metapredictors to co-create present futures. At the heart of this process are the metapredictors' assessments of the predictions future's potential correctness that ultimately determine whether the predicted future is carried forward towards its realization and whether the explorationists seeking this future will be given access to the resources necessary to do so.

9. Concluding Discussion: Prediction Work and the Management of Uncertainty

This thesis began with an outline of some of the problems uncertainty may cause in mineral exploration. Using the Northland Minerals' bankruptcy and LKAB's unexpected discovery that the mineral resource beneath Kiruna is running out as springboards, this study argues that to understand mineral exploration as an industry characterized by high uncertainty and low probabilities of success one needs to read bankruptcies and unexpected turns not as extreme events but symptoms of uncertainty. Moreover, it means that in order to understand what happened in the two cases, one need first to understand the everyday workings of mineral exploration and how explorationists work with predictions to manage uncertainty. A review of Frank Knight's (2006) and John Maynard Keynes's (1937) seminal work on uncertainty and risk then expanded on the problem of uncertainty and uncertainty management while a review on the sociological and social science work on the same topic helped focus the inquiry and introduced the problem of prediction as a means to manage uncertainty. Following this, three research questions that capture different dimensions of the use of predictions to manage uncertainty were formulated:

1. How do predictions help explorationists manage uncertainty?
2. How do mineral explorationists justify their predictions in terms of their correspondence to present futures and the desirability of these developments?
3. What are the consequences of predictions in exploration work?

These three questions were accompanied by two additional questions that together specify the empirical focus of this study and help link the first three questions to practices and activities in the field:

4. How are predictions of the future minability of a deposit of mineralized material produced and what do these predictions look like?
5. How do explorationists use predictions in interactions with other actors and how do actors in explorationists' publics assess the quality of predictions?

The study then used interviews, ethnographic observations, and archival materials to map the exploration process and to carefully unpack the practical work that goes into making predictions as well as the logics that guide them at each stage of mineral exploration. Therefore, the workings and consequences of the use of particular valuation devices to produce projectable patterns for prediction work were laid bare. Moreover, analysis of the justifications provided by explorationists when making claims about the correctness of their predictions as well as of the desirability of their realization outlined how explorationists actualize particular values to justify the worth of their predictors. Some of these values are provided in private and public regulation that state criteria for what counts as accurate or legally satisfying prediction, whereas other values are found in current debates and are actualized by explorationist to justify how their predicted mining futures contribute comparatively less costs compared to other potential mining future while also producing important benefits. Finally, the thesis explored how explorationists engage their publics with predictions to persuade them to give access to resources necessary for the continuation of their projects, including equity, debt, permits, or social licenses to operate.

Following the in-depth accounts of the previous chapters, the present chapter takes a step back to review the larger picture that emerges throughout this study. Taken together, the findings outlined in this dissertation offer a series of implications for the sociological understanding of how predictions are used to manage uncertainty as well as for the current sociological literature on industrial mineral exploration. The chapter begins with a summary of the thesis and its findings. Next, it discusses the role of predictions as uncertainty management in mineral exploration and provides general theoretical reflections based on the findings reported here. Having done this, the chapter then turns to reflect upon some practical implications to the field of mineral exploration in Sweden before ending on a reflection on the limitations of this study and on openings and possibilities for future studies.

9.1 Summary: Prediction work under uncertainty

After the initial chapter had outlined the research problem, situated the study in relation to previous research on risk and uncertainty, and stated the three research questions listed above, chapter 2 explained the context in which the study was carried out. Drawing on a combination of sociological and social scientific work on mineral exploration and mining and primary sources such as industry publications, legal documents, and standards, the chapter provided the historical background as well as the contemporary realities of industrial mineral exploration in Sweden and elsewhere. In the chapter, the minerals industry was described as a small global industry and key figures and actors were presented before the chapter turned to an in-depth account of the public and private regulations that shape how mineral exploration takes place today.

Chapter 3 reviewed some theoretical and conceptual points of entry into a study of predictions and their use in uncertainty management. In doing so, the chapter built on the discussions of predictions and uncertainty in chapter 1 to provide a more thorough introduction of the term "prediction work" as an umbrella for the different activities actors engage in when producing, justifying, and using predictions in the face of uncertainty. Building towards a conceptualization of prediction work to help unpack the role of predictions in mineral exploration and explorationists work to manage uncertainty, the chapter assessed relevant sociological literatures in relation to their ability to capture prediction making under uncertainty in mineral exploration and beyond. The result of this assessment was an outline of a conceptual tool kit that enables a dismantling and analysis of explorationists work with predictions.

Chapter 4 provided the final step of preparations for the study; it accounted for the methodological approach used in this study and discussed how the different methods employed were brought together to enable the detailed study of facts highlighted by Arthur Stinchcombe (1978) as the necessary foundation for theorizing. The chapter presented the study's methodological inspirations as Chicago-school ethnography and pragmatism together with Alfred Schütz's (1962) characteristic combination of pragmatism, phenomenology, and Weberian sociology before moving to account for the practical work behind this thesis. Moreover, the chapter argued that that this combination of ethnography, interviews, and archival research under a pragmatist umbrella provided a dynamic approach that made it possible to adjust the study to accommodate the multi-sited and multi-temporal nature of mineral exploration in such a way that it supported the mapping and unpacking of the processes involved in producing, justifying, and using predictions in exploration work.

The empirical section began with an outline of the exploration process in its entirety and then moved on to a close analysis of the exploration process from the point of view of the three questions stated above. Chapter 5 began this detailed inquiry by unpacking the workings at the early stages of mineral exploration in which explorationists undertake desktop exploration to identify sites of exploration potential before putting boots on the ground to begin target generation and geological mapping. In this chapter, the importance of sufficiency in explorationists' selection of projects to carry forward to the next stages of exploration was highlighted. The chapter showed how exploration data are used to make repeated predictions in order to answer whether there is enough potential in a project to warrant spending more time and resources on it. As each additional step along the exploration process is harder on explorationists' resources, explorationists need constantly to look for reasons to close down projects before they have swallowed too much money, effort, and time. Connecting these realities of the exploration process with James March and Herbert Simon's (1958) work on sufficiency as a gauge of rationality, the chapter argued that explorationists in the early stages of exploration work assess their projects on the basis of them showing sufficient exploration potential. Explorationists in early stage exploration are therefore not looking for the most promising project, but for projects that carry enough potential when assessed against criteria consisting of qualities explorationists use to predict minability in a project. These are the projects that are picked up and taken forward to intermediate and advanced stage exploration.

These later stages were mapped and analyzed in chapter 6. At this point, as exploration projects are moved forward to more thorough considerations of their futures as second nature (Cronon 1991) mineral resources, they become exposed to infinitely more uncertain phenomena in the form of socio-environmental and economic indeterminacies. Despite explorationists working to de-risk their projects, the open-endedness of the future remains as measurements of the geological quantities and qualities in a project are combined with assumptions and estimates in dimensions such as the future commodity prices, the effectiveness of techno-environmental interventions to negotiate environmental impacts, and socio-juridical matters such as social licenses to operate and permitting. Therefore, explorationists' efforts to order their projects under standardized measures and models are not sufficient to manage uncertainty to such an extent that the future is, in any way, known. Uncertainty, therefore, remains in the advanced stages of exploration, and the predictions made by explorationists therefore effectively stand as "as if statements" (Beckert 2016) that enable explorationists to act as if they knew the future present.

Prediction work in mineral exploration is therefore more to do with a "second reality, more structured and manageable than the uncertain world modern society has to face" (Esposito 2015:97). Using such second realities as maps of potentially realizable futures, explorationists can navigate the messiness of the uncertain future as if it were knowable. Based on these findings, the chapter ended with a puzzle: Given that so much uncertainty remains at the end of the exploration process, how can explorationists claim to have successfully managed uncertainty and thereby de-risked projects? This puzzle is then resolved in the first sections of chapter 7, which looks at how explorationists make claims about prediction correctness by actualizing a repertoire of values found in industry standards and other regulation. This repertoire consists of a number of values centered on notions of "scientificity" in the exploration methods used when assembling exploration data, and are used by explorationists to justify why their predictions are accurate and precise depictions of the future present. However, in order to make such claims, explorationists need to reconcile the tension between using quantitative approaches such as geo-statistical estimations to facilitate the epistemic leap from past and present to the future with a view of exploration as a fundamentally uncertain enterprise. Here the chapter discussed this tension in relation to Knight's (2006) theorizing on risk as requiring equivalences between cases and the uniqueness of each exploration project before arguing that, in order to make possible risk calculations, explorationists standardize and commensurate projects by submitting them to standards that ultimately bracket any uncertainties not accounted for in these efforts of standardization.

Because explorationists also make claims about why their predictions depict "good" futures, chapter 7 also looked at how explorationists justify the desirability of their predicted futures. Compared to other groups of prediction workers featured in sociological work, mineral explorationists do not only work to describe the future, like meteorologists and financial analysts, but to realize the contents of their predictions in the form of future mining operations. Arguing that the desirability of explorationists' predicted futures is justified by means of references to sets of signifiers of worth that support claims for why constructing and operating the projected mine would be a desirable course of action, the chapter traced the connections of values and worth to find that explorationists' justifications actualize values expressed in contemporary debates and narratives on environmental preservation and social justice. By arguing that their future mining operation would be less costly to the environment and social values, explorationists use relative costs to justify why their mining future is more desirable, and more morally correct, than other alternative futures. Moreover, explorationists also make justificatory claims based on the future mining operation's ability to realize also absolute values such as contributing metals to be used in technological solutions to combat the climate crisis or providing struggling rural communities with jobs, tax revenues, and economic growth.

Chapter 8 addressed the "then what" question concerning the consequences the predictions produced and justified in mineral exploration have in exploration work. Using Nicholas Rescher's (1998) writings on predictions, the chapter analyzed the metapredictions that key actors in explorationists' publics produce in order to identify how these actors assess predictions and what consequences metapredictions have for the explorationists' access to financial and legal resources such as equity, debt, and permits. Showing instances of metapredictions, the chapter uncovered how predictors and metapredictors engage in conversation in which present futures are put forth, assessed, revised, and ultimately co-created by the participants. Moreover, as this co-creation depends on the assessments made in metaprediction, it is only those publics that play a role as a metapredictor and arbiter of resources that are invited to create the future together with explorationists. Finally, the chapter argued for the importance of shared understandings for these interactions around co-creating futures to take place. Based on an analysis of the conflicts between explorationists and the governmental agencies acting as metapredictors in mineral exploration, the chapter suggests that uncertainty is created when there is a scarcity of guidelines or historical cases against which predictors may orient themselves.

Together, these four empirical chapters traced the exploration process to understand whether predictions help explorationists manage uncertainty, how explorationist justify their predictions, and what the consequences of predictions are in mineral exploration. Although the answers have been summarized above, it may be of some benefit to present them jointly here. This study has shown that predictions do help explorationists manage uncertainty, but primarily in a pragmatic sense as the future, although many of its qualities may be foreshadowed in the present, remains unknowable and uncertain. However, and this is one of the peculiarities of mineral exploration, presently unminable deposits of mineralized material remains there in the ground awaiting the day that more favorable commodity prices or new mining technologies may render them minable–i.e., profitable. Uncertainty, it should therefore be remembered, strikes both ways as the future present may be host to many different circumstances that contribute to the minability of a deposit; at least as long as the mineral is actually there.

Because uncertainties remain also after exploration projects have been derisked, regulations such as standards and laws play important roles in helping explorationists justify the potential correctness of their predictions. This is possible thanks to the repertoires of values provided in public and private regulation of mineral exploration such as standards for what counts as sufficiently accurate and precise data in minability estimation as well as other values, which explorationists call upon to justify the merits of their predictions. Furthermore, explorationists also justify the desirability of the futures depicted in their predictions. Using values found in contemporary debates on social justice and environmental issues, explorationists connect their predictions with values such as comparatively low social impacts or contributions to growth in order to make claims on the future as a mining future.

The thesis has also shown that the consequences of predictions in exploration work partly relates to decision making as they help project evaluators and company management decide on which projects to take further and invest more work and effort into, and in part with determining explorationists' access to resources held by their publics. This latter set of consequences relates to how investors, permit granting agencies, and other publics rely on metapredictions to determine whether to invest in, grant an exploitation concession to, lend money to, or accept and tolerate an exploration or mining project. Therefore, one of the more important consequences of explorationists' use of prediction is in how it invites other actors to co-create exploration and mining futures together with the explorationists. Returning to the initial question of whether predictions actually help in uncertainty management, the sum of evidence provided here suggests that predictions do not remove uncertainty. Instead, they provide a point of references against which explorationists and those who join in the exploration effort to co-create futures can orient themselves. Predictions allow actors to treat the future as risk; and while explorationists are aware of the limitations of doing so, and often acknowledge how the unruliness of the future can collapse risks into uncertainties at any point, the use of predictions to manage uncertainty has many practical advantages. Both in terms of creating spaces for rational action and in enabling explorationists to make claims on the future. Having reached this point, this thesis has finally laid the final piece to the puzzle of prediction work in mineral exploration, so now it is possible to step back and look at the larger picture in the form of the implications of this study.

9.3 Theoretical implications

The breaking of ground for a mine is perhaps a good metaphor for what this study has accomplished. Like the mineral explorationist approaches a piece of the ground from afar and then moves in closer for detailed exploration work through which to valuate the underground, so has this thesis ventured to approach a social domain relatively untouched by sociologists in order to survey its content, its logics, and its ways of dealing with the immense uncertainties that characterize the domain. Moreover, like the explorationists, the thesis has relied upon a continuous addition of new data to build an image of the whole. To accomplish this, the chapters preceding this one have carefully removed the overburden, to use another mining metaphor, thereby exposing the mineral exploration process and laying it bare for examination.

On the substantive level,[158] this dissertation provides a rare account of an industry that has hitherto seen little sociological work except for within a limited scope (see chapter 2). The image that has emerged across the pages of this dissertation depicts an industry whose work is vital to many downstream industries but where success is very rare. Most mineral exploration projects fail to identify minable deposits and they do so, either because there simply is not enough mineralized material of sufficient quality in the ground or because limited exploration resources leave some sites underexplored. Failures of different kinds are therefore commonplace and part of the everyday life of mineral exploration. However, the more pregnant results presented in this thesis deal with how explorationists use predictions to manage these uncertainties, keeping failure at bay.

[158] Substantive in the sense of the term as defined in the grounded theory approach defined by Barney Glaser and Anselm Strauss (2005, 2009).

Max Horkheimer once remarked that the "history of man's efforts to subjugate nature is also the history of man's subjugation by man" (1947:105); however, in the context of mineral exploration in Sweden, this domination is not primarily a domination by force, but a domination by ideas. Across the pages of this thesis, a struggle to rein in and control uncertainty emerges in which both nature and society are made to succumb to the rationality of mechanical objectivity (Porter 1996). Through explorationists' efforts to measure, quantify, and estimate the complexities and uncertainties of geological nature and the environment as well as of the economic, technological, socio-environmental, and legal spheres are subdued in order to allow explorationists to predict the future minability in their projects. The commensuration processes involved here consist of repeated translations (Tsing 2015) of complex first nature and uncertain futures in which explorationists cut away not only those uncertainties that do not fit the valuation devices and models used in prediction, but also the future present experiences of those whose voices are not heard in prediction work.

Through the exploration process, the initial thrill of the hunt experienced by a prospector eventually evolves: from sets of indicators of exploration potential drawn from remote sensing data and, in time, a collection of historical data, geophysical and geochemical surveys, and the odd drill hole to Net Present Values expressed in millions of dollars. For this to happen, the projections produced by explorationists are moved through a series of incarnations, including geological maps, geological models, block models with cut-off grades reshaping the body of the deposit along its second nature boundaries, and mine plans that schedule and order the projected future mining operation. At each incarnation, the future is re-made as more exploration work increases the quality and quantity of data from which predictions can be made. However, while this repeated re-making of the present future produces increasingly precise and detailed claims about the future profitability of the projected mining operation, at the end of the day these are only speculations. At no point during the process outlined in this study has a single load of mineral product left the mine for the minerals markets. Instead, what has come out of all the work put into a project at this stage is predictive claims about what the future might be; that is, up until this point, mineral exploration remains primarily an exercise in the art of speculation (Marshall 1920).

Explorationists are aware that their work entails speculation. However, as has been described above, the speculative dimensions are bracketed in favor of standardization of exploration projects. One example of this is how retired exploration geologist Frank, after having been pressed on the matter, admitted that no one can know for certain whether the mineral riches predicted will actually materialize for mining. How much mineral there actually is there to be mined, Frank continued, will remain uncertain until the mine is mined dry and its total outputs added up to form a definite measurement of its minability. However, the central question here is not whether explorationists are actually able to accurately predict the qualities and quantities of minable minerals, but whether their methods used actually work in the sense that they help explorationists manage uncertainty. Recalling the discussion of the different ways in which uncertainty and risk have been approached in the social sciences, a number of implications of relevance for this discussion become apparent. First, although explorationists work with a techno-scientific framing when they seek to accumulate data with which to de-risk their projects, the experiences shared by explorationists demonstrate an awareness of the constructed nature of many of the economic and technical estimates and assumptions they use. Geology and environments can be mapped and measured, but economic, technological, social, and juridical domains can only be estimated, a difference that shows a discrepancy between a measurable "natural" domain and non-measurable "social domain" as well as between a measurable present and a non-measurable future.

A second implication is how the findings reported here stress uncertainty over risk. Of the different ways to conceptualize risk and uncertainty discussed in chapter 1, the findings reported here position the practical work to reduce uncertainty and risk in mineral explorationist closer to the constructivist understanding of risk. Explorationists, it has been argued, construct worlds within worlds in which uncertainties are re-cast as measurable risks in order to facilitate risk management. Nevertheless, these worlds are unstable constructions as their foundation, as Michael Power (2007) argues, remains uncertain. However, while the foundations for decision making in mineral exploration thereby appear to be nothing more than "as if" imaginaries (Beckert 2016), this does not reduce the decisions made by explorationists to whims, sentiments, or chance, to paraphrase Keynes (1936:162–63), but to rational decisions supported by the logics of the context in which they are made. However, as William James (1907) notes, just because a decision is rational it does not have to be good or right, at least not for all time, as long as it is true for now. This observation brings this discussion to the yet another implication.

Third, the study has employed tools from valuation studies that help open up valuations to a critical scrutiny of their inner workings (Doganova et al. 2014). Therefore, the thesis has carefully unpacked the processes in which predictions are made, justified, and used in mineral exploration, opening up the tools and knowledges employed in exploration to detailed scrutiny. Through this, it has been possible to show how heterogeneous values from different domains and disciplines are brought together, commensurated, and used to produce homogenous measurements of future minability that absorb any unaccounted for uncertainty (March and Simon 1958) in a project. Furthermore, this has made it possible to inquire about the epistemological, ethical, and political status of the values assembled by explorationists. In doing so, the thesis has shed light not only on what values explorationists call upon when making claims on the future, but also where these values come from, how they are produced, and what the rationale behind their production has been. That is, this thesis has made a small contribution to the much larger question put forth by Jenny Andersson (2018), who calls for investigations into how actors make claims about and on the future.

In his seminal work, Frank Knight (2006) stressed how equivalence is a central characteristic of risk or measurable uncertainty but that such equivalences are rare in the world of business. This thesis builds on this fundamental definition by adding yet another among many observations that while equivalences may not exist, there exists many ways in which actors in different domains seek to introduce them (see, e.g., Andersson and Keizer 2014; Besedovsky 2018; Espeland 1998; Porter 1996; Power 2007). These efforts, Elena Esposito (2015:97) argues, "builds a second reality, more structured and manageable than the uncertain world modern society has to face." In building this second reality, explorationists and others introduce calculability into the world to make it conform to certain measurable laws and tendencies for which the relative distributions of risk may be estimated and managed. In mineral exploration, for example, it is not possible to say with confidence that a project X will be minable at time $t + 1$ because it is an equivalent to mine Y which was minable at time $t - 1$. There are just far too many open circumstances that together determine minability for such equivalences to be realistic. However, in order to manage uncertainty as a practical problem in their day-to-day work, explorationists work with methods that bracket these limitations in order to facilitate decision making despite uncertainty, for example, by looking at project pedigrees or ranking them on cash cost curves. What is important to ask is therefore not whether uncertainty can be reduced, but how uncertainty is being managed through prediction work, what values are included, how they are measured, and which values have been left unmeasured. What values are commensurated and which ones are not? What uncertainties are absorbed and which ones are reported? Do predictors manage qualitative data in prediction, or are qualitative data shielded away in favor of quantitative measurements as they have been shown to be in other instances (see, e.g., Porter 1996; Reinertsen and Asdal 2019)?

9.3.1 Prediction work as uncertainty management

Uncertainty may have many different origins. Some are built into systems that have been tested and evaluated to be safe until the day they explode and lay bare the uncertainties and risks within them (Wynne 1992). Other uncertainties emerge as shocks when new innovations or changes to existing orders turn previous certainties on their head (Beckert and Bronk 2018; Pryke and Allen

2000). However, uncertainty is not a new or modern phenomenon, but an ontological reality. What people were there who did not turn to divination for advice, Cicero asked,[159] and medieval theologian and philosopher Saint Augustine (1631) explored the relation between a present thin as a knife's edge and the unknowable future yet to be realized. Because of this, also yesterday's mineral explorationists must have struggled with uncertainty. Although the world of mineral exploration and mining has changed much in the past centuries, also they who searched for and discovered mines in the past must have struggled to predict minability: Why else would the discoverers of the silver deposit at Nasafjäll have opened the mine only to see brutal failure (Bäärnhielm 1976)? What separates historical failures from contemporary ones such as the Northland Minerals bankruptcy is not that one was uncertain and the other was not, but the way in which uncertainty is made sense of and managed. While historical mines may have been able to rely on forced labor and royal assistance, contemporary mines rely on scientific methods, quantification, and financial modeling. Thereby has the relation between humanity and, to paraphrase Marx (1970), her inorganic body, "nature," changed over the years. That is, uncertainty is not new. While the late 20th and early 21st centuries have been described as more uncertain than preceding eras,[160] it is rather the ways in which uncertainty is approached in practice that have changed. Any study of how the uncertainty of the future is managed in a social domain is bound to reflect not only the uncertainty faced by actors in this domain but also the ideas that shape that domain.

Futures are produced all the time as countless presents create chain effects that "ripple out into an open future" (Adam 2010), which one cannot know until it arrives as present. Predictions, together with risk analysis, scenario building, and fortune telling stand in place of this future for the time being and provide fixed points against which actors can orient themselves and make the uncertainty of the future manageable in a practical sense. Moreover, while some of these points of orientation are descriptive in their character, others–like the ones produced in mineral exploration–are productive and pertain to realizing the future for their predictors. Therefore, managing uncertainty through prediction should be understood not only as an epistemic practice of prediction making, but also as a process involving justification and power. Predictions justified as being both correct and desirable by predictors and their

[159] "Quis rex umquam fuit, quis populus, qui non uteretur praedictione divina?" (Marcus Tullius Cicero 1730:43)

[160] Examples of such claims include Jens Beckert (2013, 2016, see also; Beckert and Bronk 2018), who argues that financial capitalism and its focus on speculation and innovation has rendered this period more uncertain than other historical periods. Beckert is not alone in making such claims, however. Similar arguments were presented already in 1966 when Harold D. Lasswell (1966:161–62) wrote that the forward looking nature of action and choice in contemporary culture leads to mankind "passing from the *primacy* of the *past* to the *primacy of expectations of vast future change*."

publics help these groups close down alternative futures, either through removing the conditions necessary for their realization, as when a forest gives way for a mine, or by becoming performative as their realization grows to be experienced as an already determined inevitability.

9.5 Practical implications for the field

The practical conclusions to be drawn from these findings are by necessity limited due to the ethnographic approach used in this project. However, there are some implications to be made in terms of how the analysis of the interactions between predictors and metapredictors in mineral exploration can be shown to work with less friction in cases where the parties share a common understanding of what values are taken to matter in predictions of the future. This can be seen in how engagements between explorationists and financers revolve around a set of predetermined values that have been aligned with the use of industry standards. These standards, which were put in place to counter fraud and misinformation in reports on exploration results, have since developed to become part of standard practice in the industry. Similar alignment can also be found in how explorationists and the MIS share a common understanding of what it means to prove that a deposit of mineralized material for which explorationists are seeking an exploitation concession is economic in the legal sense of the term. However, at the time of writing this dissertation, there exists no set definition or criteria for what values matter, and which do not, in the environmental impact reviews in exploitation concession applications or in environmental permitting with the environmental courts. The result of this is that significant friction exists between explorationists and governmental agencies that grant permits. Although more research into the matter is needed, the results presented here suggest that attempts to reduce this friction would either need to resolve the question of what constitutes sufficiently low environmental impact or strengthen existing regulation so that it can be implemented in a predictable way. Accomplishing the former might involve introducing regulation that clarifies what constitutes sufficiently low environmental impact and could look to lessons learned from the implementation of exploration reporting standards. However, while such reductions of uncertainty might also reduce conflict and tension in permit processing, it would also entail producing a framework that inevitably reduces environmental complexity and therefore increases the commensurability of natural environments. At the end of the day, any attempts at resolving the conflicts in permit application processes reported on in this dissertation are first and foremost political matters wherefore this dissertation can only point to the existence of these conflicts as well as to some of their complexities.

9.6 Limitations and future research

The choices involved in designing and carrying out a study produce both strengths and limitations in terms of what data become available, what the scope of the findings are, and what questions can be answered using these findings. In this thesis, the main limitations are connected to three aspects of the design of the study in which the work leading up to this publication has been undertaken. First, the study focuses on industrial mineral exploration in Sweden and although the industry is international in its character and the private regulation guiding exploration work is international in both its origin and application and while the dataset contains international examples, observations made in international settings, archival material originating in international exploration organizations, and interviews with informants with international experiences, one cannot neglect the possibility that important differences might be found if the study were repeated with another jurisdiction as its main focal point. That is, the lack of a comparative element makes it hard to identify results that are a product of local idiosyncrasies and results that could be generalized. Second, this dissertation focuses on the explorationists' work to produce and justify predictions as well as the consequences they experience when predictions are communicated to metapredictors in their publics. Therefore, the ethnographic account of mineral exploration has reached deep into the industry to provide a saturated account of the daily realities of mineral exploration while at the same time considering important counterparts; however, there is one important gap in the account: as the focus here has primarily been with the explorationists, other actors such as the County Administrative Boards (CAB) and the Environmental Courts have here primarily been represented through their presence in the archival materials and statements made by explorationists and not through direct observations or interviews with CAB and court personnel. These sorts of data collection were not possible due to limited resources and delimitation. Given the already significant undertaking involved in mapping and analyzing the exploration process, it would have been too difficult to include each regional and national agency involved in mineral exploration in this study wherefore the agencies that did not feature immediately in the exploration process were set aside. Third, although this dissertation traces the exploration process, it has not been possible to do so in real time as it would have been impossible to follow a process lasting about ten years and which may be interrupted or terminated before completion. Instead, the process has been reconstructed from several different exploration projects. That is, while the outline is thoroughly grounded in empirical data, the results may be blind to eventual nuances and variations in individual projects. However, as has been discussed earlier (chapter 4), while a different sampling strategy could have provided insights not available in this approach, the many practical challenges involved in these alternative designs would have produced significant limitations in sampling and in the ability of this study to produce a sufficiently broad as well as detailed account of mineral exploration and the prediction work taking place therein.

9.6.1 Future research

As the findings reported here have both empirical and theoretical implications, they also open up for further research both on a substantive and formative level. First, more observations need to be added to this line of research. This dissertation is only a first step towards understanding the use of prediction work to manage uncertainty in mineral exploration. Accounts from other jurisdictions as well as accounts expanding the investigation further afield from explorationists themselves would make important substantive additions to the sociological literatures on mineral exploration and prediction. More research is furthermore needed to better define prediction work in general and prediction making, justifications, and the consequences predictions produce on the formative level. This expansion of inquiry would mean expanding the current literature on uncertainty as a central factor in contemporary economic and social life to include a stronger focus on prediction as a means of managing uncertainty. However, such a focus should not look merely to the predictions themselves; it should examine how they are produced, how they are justified, and what consequences successful or unsuccessful prediction work has in terms of their interactions with metapredictors and access to goods such as resources, recognition, and power.

9.7 Concluding remarks

Now at its end, this thesis can be summed up and placed in a larger context of research into how futures are made and claimed by natural resource industries and beyond. The particular study that forms the basis for this thesis has made use of a combination of interviews, observation, and archival research to ask questions about how mineral explorationists use predictions to manage uncertainty. In exploring this question, the thesis has outlined how explorationists work to bring together geological events and transformations across millennia and recent socio-economic trends in order to produce predictions of the future minability of concentrations of mineralized material as well as what consequences explorationists' predictions have for the exploration process. As such, this is a simple and straightforward story of a not so simple and straightforward process. Nevertheless, telling a story about mineral exploration and prediction work, the dissertation is also telling larger story.

What has emerged between the lines of this thesis is a story about the future of resource capitalism. In her study on matsutake foragers on three continents, Anna Lowenhaupt Tsing (2015) demonstrates how resource capitalism turns people and things into assets by alienating them from their life worlds in order to make them stand alone as mobile assets, things that can be exchanged for other assets, also they pulled out of other life worlds and other localities. This thesis echoes Tsing's findings by demonstrating how this alienation takes place in mineral exploration as first natures are turned into second nature assets in the form of mineral resources and reserves produced through standardization processes in which minerals are de-contextualized and all "superfluous" nature cut away in order to form a body of minable second nature. More importantly, this thesis also demonstrates how this takes place, not only in relation to "nature," but also in relation to the future as predictors pick out particular patterns in the past and present to project them into the future in the form of a certain present future. This present future can then be used to claim not only what the future will be, but also whose future it should be. This alienation of one future from the realm of potential futures stands out both as a practical method of uncertainty management that allows explorationists to establish a placeholder future against which they can orient themselves and as a strong method of isolating an economically, socially, or morally "good" future and open them up to investments. That is, explorationists claim the future for themselves and anyone willing to become partners in its collaborative creation: if financiers, agencies, local communities, and other affected parties "buy" a prediction of the future, they may also buy into it by granting explorationists the resources necessary for attempting its realization.

10. List of references

Acuña, Roger Merino. 2015. "The Politics of Extractive Governance: Indigenous Peoples and Socio-Environmental Conflicts." *The Extractive Industries and Society* 2(1):85–92.

Adam, Barbara. 2010. "History of the Future: Paradoxes and Challenges." *Rethinking History* 14(3):361–78.

Adam, Barbara. 2011. "Wendell Bell and the Sociology of the Future: Challenges Past, Present and Future." *Futures* 43(6):590–95.

Ahrne, Göran, Patrik Aspers, and Nils Brunsson. 2015. "The Organization of Markets." *Organization Studies* 36(1):7–27.

Akerlof, George A., and Robert J. Shiller. 2010. *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism*. Princeton, NJ: Princeton University Press.

Alaszewski, Andy. 2015. "Anthropology and Risk: Insights into Uncertainty, Danger and Blame from Other Cultures – A Review Essay." *Health, Risk & Society* 17(3–4):205–25.

Alexeev, Michael, and Robert Conrad. 2009. "The Elusive Curse of Oil." *The Review of Economics and Statistics* 91(3):586–98.

Allen, Douglas W. 2007. "Information Sharing during the Klondike Gold Rush." *The Journal of Economic History* 67(4):944–967.

Anderson, Benedict R. O'G. 1991. *Imagined Communities: Reflections on the Origin and Spread of Nationalism*. New York City, NY: Verso.

Andersson, Jenny. 2018. "Arctic Futures: Expectations, Interests, Claims, and the Making of Arctic Territory." Pp. 83–104 in *Uncertain Futures*, edited by J. Beckert and R. Bronk. Oxford, UK: Oxford University Press.

Andersson, Jenny, and Anne-Greet Keizer. 2014. "Governing the Future: Science, Policy and Public Participation in the Construction of the Long Term in the Netherlands and Sweden." *History and Technology* 30(1–2):104–22.

Anshelm, Jonas, Simon Haikola, and Björn Wallsten. 2018a. "Politicizing Environmental Governance – A Case Study of Heterogeneous Alliances and Juridical Struggles around the Ojnare Forest, Sweden." *Geoforum* 91:206–15.

Anshelm, Jonas, Simon Haikola, and Björn Wallsten, eds. 2018b. *Svensk Gruvpolitik i Omvandling: Aktörer, Kontroverser, Möjliga Världar*. Möklinta, Sweden: Gidlunds Förlag.

Antal, Ariane Berthoin, Michael Hutter, and David Stark, eds. 2015. *Moments of Valuation: Exploring Sites of Dissonance*. First edition. Oxford, UK: Oxford University Press.

Armytage, W. H. G. 1968. *Yesterday's Tomorrows: A Historical Survey of Future Societies*. London, UK: Routledge & Kegan Paul.

Askland, Hedda Haugen. 2018. "A Dying Village: Mining and the Experiential Condition of Displacement." *The Extractive Industries and Society* 5(2):230–36.

Aspers, Patrik. 2009. "Knowledge and Valuation in Markets." *Theory and Society* 38(2):111–31.

Aspers, Patrik. 2011. "Markets, Evaluations and Rankings." *Historical Social Research/Historische Sozialforschung* 36(3):19–33.
Aspers, Patrik. 2018. "Forms of Uncertainty Reduction : Decision, Valuation, and Contest." *Theory and Society* 47(2):133–49.
Asplund, Johan. 1979. *Teorier Om Framtiden*. Stockholm, Sweden: Liber Förlag i samarbete med Delegationen för långsiktsmotiverad forskning.
Azarian, Reza. 2016. "Uncertainty as a Common Ground for a Dialogue between Economics and Sociology." *International Review of Sociology* 26(2):262–75.
Bäärnhielm, Göran. 1976. *I Norrland Hava vi Ett Indien: Gruvdrift Och Kolonisation i Lappmarken under 1600-Talet*. Stockholm, Sweden: Ordfront/Arkivet för Folkets Historia.
Bååth, Jonas. 2018. "Production in a State of Abundance: Valuation and Practice in the Swedish Meat Supply Chain." Dissertation, Uppsala University, Uppsala, Sweden.
Banchirigah, Sadia Mohammed, and Gavin Hilson. 2010. "De-Agrarianization, Re-Agrarianization and Local Economic Development: Re-Orientating Livelihoods in African Artisanal Mining Communities." *Policy Sciences* 43(2):157–80.
Barthe, Yannick, Damien de Blic, Jean-Philippe Heurtin, Éric Lagneau, Cyril Lemieux, Dominique Linhardt, Cédric Moreau de Bellaing, Catherine Rémy, and Danny Trom. 2013. "Sociologie Pragmatique: Mode d'emploi." *Politix* 3(103):175–204.
Bebbington, Anthony. 2007. "Social Movements and the Politicization of Chronic Poverty." *Development and Change* 38(5):793–818.
Bebbington, Anthony, Denise Humphreys Bebbington, Jeffrey Bury, Jeannet Lingan, Juan Pablo Muñoz, and Martin Scurrah. 2008. "Mining and Social Movements: Struggles Over Livelihood and Rural Territorial Development in the Andes." *World Development* 36(12):2888–2905.
Beck, Ulrich. 1992. *Risk Society: Towards a New Modernity*. London, UK: Sage.
Beck, Ulrich, Scott Lash, and Anthony Giddens. 1994. *Reflexive Modernization: Politics, Tradition and Aesthetics in the Modern Social Order*. Cambridge, UK: Polity Press.
Becker, Howard S. 1977. *Boys in White: Student Culture in Medical School*. New Brunswick, NJ: Transaction Books.
Becker, Howard S. 1982. "Culture: A Sociological View." *The Yale Review* 71:513–28.
Becker, Howard S. 1991. *Outsiders: Studies in the Sociology of Deviance*. New York City, NY: Free Press.
Becker, Howard S., and Blanche Geer. 1957. "Participant Observation and Interviewing: A Comparison." *Human Organization* 16(3):28–32.
Beckert, Jens. 1996. "What Is Sociological about Economic Sociology? Uncertainty and the Embeddedness of Economic Action." *Theory and Society* 25(6):803–40.
Beckert, Jens. 2013. "Imagined Futures: Fictional Expectations in the Economy." *Theory and Society* 42(3):219–40.
Beckert, Jens. 2016. *Imagined Futures : Fictional Expectations and Capitalist Dynamics*. Cambridge, MA: Harvard University Press.
Beckert, Jens, and Patrik Aspers, eds. 2011. *The Worth of Goods: Valuation and Pricing in the Economy*. Oxford, UK: Oxford University Press.
Beckert, Jens, and Richard Bronk. 2018. *Uncertain Futures: Imaginaries, Narratives, and Calculation in the Economy*. Oxford University Press.
Beckert, Jens, and Christine Musselin, eds. 2013. *Constructing Quality: The Classification of Goods in Markets*. Oxford, UK: Oxford University Press.

Bell, Wendell. 1999. “The Sociology of the Future and the Future of Sociology.” *International Review of Sociology* 9(3):295–310.
Bell, Wendell, and James A. Mau, eds. 1971. *The Sociology of the Future: Theory, Cases, and Annotated Bibliography*. New York City, NY: Russell Sage Foundation.
Benjamin, Walter. 2002. *The Arcades Project*. Cambridge, MA: Harvard University Press.
Bergman, S., M. B. Stephens, J. Andersson, B. Kathol, and T. Bergman. 2012. *Sveriges Berggrund, Skala 1:1 Miljon*. Uppsala, Sweden: Geological Survey of Sweden (SGU).
Besedovsky, Natalia. 2018. “Uncertain Meanings of Risk: Calculative Practices and Risk Conceptions in Credit Rating Agencies.” Pp. 236–56 in *Uncertain Futures: Imaginaries, Narratives, and Calculation in the Economy*, edited by J. Beckert and R. Bronk. Oxford, UK: Oxford University Press.
Beunza, Daniel, and Raghu Garud. 2007. “Calculators, Lemmings or Frame-Makers? The Intermediary Role of Securities Analysts.” *The Sociological Review* 55(s2):13–39.
Bissonnette, Jean François. 2016. “From the Moral to the Neural: Brain Scans, Decision-Making, and the Problematization of Economic (Ir)Rationality.” *Journal of Cultural Economy* 9(4):364–81.
Black, Megan. 2018. *The Global Interior: Mineral Frontiers and American Power*. Cambridge, MA: Harvard University Press.
Blyth, Mark. 2002. *Great Transformations: Economic Ideas and Institutional Change in the Twentieth Century*. Cambridge, UK: Cambridge University Press.
Bogusz, Tanja. 2014. “Why (Not) Pragmatism?” Pp. 129–52 in *The Spirit of Luc Boltanski: Essays on the “Pragmatic Sociology of Critique,”* edited by S. Susen and B. S. Turner. New York City, NY: Anthem Books.
Boltanski, Luc, and Ève Chiapello. 2007. *The New Spirit of Capitalism*. London, UK: Verso.
Boltanski, Luc, and Laurent Thévenot. 2006. *On Justification: Economies of Worth*. Princeton, NJ: Princeton University Press.
Borenstein, Severin, and Joseph Farrell. 2007. “Do Investors Forecast Fat Firms? Evidence from the Gold-Mining Industry.” *The RAND Journal of Economics* 38(3):626–647.
Borup, Mads, Nik Brown, Kornelia Konrad, and Harro Van Lente. 2006. “The Sociology of Expectations in Science and Technology.” *Technology Analysis & Strategic Management* 18(3–4):285–98.
Boschini, Anne D., Jan Pettersson, and Jesper Roine. 2007. “Resource Curse or Not: A Question of Appropriability.” *Scandinavian Journal of Economics* 109(3):593–617.
Bourdieu, Pierre. 1998. *Practical Reason: On the Theory of Action*. Stanford, CA: Stanford University Press.
Boyer, Robert. 2018. “Expectations, Narratives, and Socio-Economic Regimes.” Pp. 39–61 in *Uncertain Futures: Imaginaries, Narratives, and Calculation in the Economy*, edited by J. Beckert and R. Bronk. Oxford, UK: Oxford University Press.
Braun, Benjamin. 2015. “Governing the Future: The European Central Bank’s Expectation Management during the Great Moderation.” *Economy and Society* 44(3):367–91.
Brown, Nik, and Mike Michael. 2003. “A Sociology of Expectations: Retrospecting Prospects and Prospecting Retrospects.” *Technology Analysis & Strategic Management* 15(1):3–18.

Butkiewicz, James L., and Halit Yanikkaya. 2010. "Minerals, Institutions, Openness, and Growth: An Empirical Analysis." *Land Economics* 86(2):313–28.
Cairns, Robert D., and Pierre Lasserre. 1986. "Sectoral Supply of Minerals of Varying Quality." *The Scandinavian Journal of Economics* 88(4):605–26.
Carruthers, Bruce G. 2013. "From Uncertainty toward Risk: The Case of Credit Ratings." *Socio-Economic Review* 11(3):525–51.
Carruthers, Bruce G. 2017. "The Social Meaning of Credit, Value, and Finance." Pp. 73–88 in *Money Talks: Explaining How Money Really Works*, edited by N. Bandelj, F. F. Wherry, and V. A. Zelizer. Princeton, NJ: Princeton University Press.
Carter, Elizabeth. 2019. "From Myths to Markets: Power, Institutions, and the Reification of Imagined Histories." *European Journal of Sociology* 60(2):211–36.
Centemeri, Laura. 2015. "Reframing Problems of Incommensurability in Environmental Conflicts Through Pragmatic Sociology: From Value Pluralism to the Plurality of Modes of Engagement with the Environment." *Environmental Values* 24(3):299–320.
Choi, Stephen J., Mitu Gulati, and Robert E. Scott. 2017. "The Black Hole Problem in Commercial Boilerplate." *Duke Law Journal* 67(1):1–77.
Ciacci, Luca, Ivano Vassura, and Fabrizio Passarini. 2017. "Urban Mines of Copper: Size and Potential for Recycling in the EU." *Resources* 6(1):6.
Conde, Marta. 2017. "Resistance to Mining. A Review." *Ecological Economics* 132:80–90.
Coxshall, Wendy. 2010. "'When They Came to Take Our Resources': Mining Conflicts in Peru and Their Complexity." *Social Analysis* 54(1):35–51.
CRIRSCO. 2019. *International Reporting Template For the Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves*. Committee for Mineral Reserves International Reporting Standards.
Cronon, William. 1991. *Nature's Metropolis: Chicago and the Great West*. New York City, NY: W.W. Norton & Company, Inc.
Curry, Patrick, ed. 1987. *Astrology, Science, and Society: Historical Essays*. Woodbridge, UK: Boydell Press.
Dashwood, Hevina S. 2007. "Canadian Mining Companies and Corporate Social Responsibility: Weighing the Impact of Global Norms." *Canadian Journal of Political Science/Revue Canadienne de Science Politique* 40(1).
David, Paul A. 1994. "Why Are Institutions the 'Carriers of History'?: Path Dependence and the Evolution of Conventions, Organizations and Institutions." *Structural Change and Economic Dynamics* 5(2):205–20.
Dequech, David. 2001. "Bounded Rationality, Institutions, and Uncertainty." *Journal of Economic Issues* 35(4):911–29.
Desrosières, Alain. 1998. *The Politics of Large Numbers: A History of Statistical Reasoning*. Cambridge, MA: Harvard University Press.
Desrosières, Alain. 2001. "How Real Are Statistics? Four Possible Attitudes." *Social Research; New York* 68(2):339–55.
von Detten, Roderich, and Marc Hanewinkel. 2017. "Strategies of Handling Risk and Uncertainty in Forest Management in Central Europe." *Current Forestry Reports* 3(1):60–73.
Dewey, John. 1939. "Theory of Valuation." *International Encyclopedia of Unified Science* 2(4):7–67.
Dobeson, Alexander. 2016a. "Hooked on Markets: Revaluing Coastal Fisheries in Liberal Rural Capitalism." Dissertation, Uppsala University, Uppsala, Sweden.
Dobeson, Alexander. 2016b. "Scopic Valuations: How Digital Tracking Technologies Shape Economic Value." *Economy and Society* 45(3–4):454–78.

Dobeson, Alexander. 2018. “The Wrong Fish: Maneuvering the Boundaries of Market-Based Resource Management.” *Journal of Cultural Economy* 11(2):110–24.
Doganova, Liliana. 2018. “Discounting and the Making of the Future: On Uncertainty in Forest Management and Drug Development.” Pp. 278–97 in *Uncertain Futures: Imaginaries, Narratives, and Calculation in the Economy*, edited by J. Beckert and R. Bronk. Oxford, UK: Oxford University Press.
Doganova, Liliana, Martin Giraudeau, Claes-Fredrik Helgesson, Hans Kjellberg, Francis Lee, Alexandre Mallard, Andrea Mennicken, Fabian Muniesa, Ebba Sjögren, and Teun Zuiderent-Jerak. 2014. “Valuation Studies and the Critique of Valuation.” *Valuation Studies* 2(2):87–96.
Douglas, Mary. 1992. *Risk and Blame: Essays in Cultural Theory*. London, UK: Routledge.
Engels, Bettina. 2018. “Nothing Will Be as before: Shifting Political Opportunity Structures in Protests against Gold Mining in Burkina Faso.” *The Extractive Industries and Society* 5(2):354–62.
Engwicht, Nina. 2018. “‘It Can Lift Someone from Poverty’: Imagined Futures in the Sierra Leonean Diamond Market.” *The Extractive Industries and Society* 5(2):260–66.
Espeland, Wendy Nelson. 1998. *The Struggle for Water: Politics, Rationality, and Identity in the American Southwest*. Chicago, IL: University of Chicago Press.
Espeland, Wendy Nelson, and Stacy E. Lom. 2015. “Noticing Numbers: How Quantification Changes What We See and What We Don’t.” Pp. 18–37 in *Making Things Valuable*, edited by M. Kornberger, L. Justesen, A. K. Madsen, and J. Mouritsen. Oxford, UK: Oxford University Press.
Espeland, Wendy Nelson, and Michael Sauder. 2007. “Rankings and Reactivity: How Public Measures Recreate Social Worlds.” *American Journal of Sociology* 113(1):1–40.
Espeland, Wendy Nelson, and Mitchell L. Stevens. 1998. “Commensuration as a Social Process.” *Annual Review of Sociology* 24(1):313–43.
Espeland, Wendy Nelson, and Mitchell L. Stevens. 2008. “A Sociology of Quantification.” *European Journal of Sociology / Archives Européennes de Sociologie / Europäisches Archiv Für Soziologie* 49(3):401–36.
Espeland, Wendy, and Vincent Yung. 2019. “Ethical Dimensions of Quantification.” *Social Science Information* 58(2):238–260.
Esposito, Elena. 2013. “The Structures of Uncertainty: Performativity and Unpredictability in Economic Operations.” *Economy and Society* 42(1):102–29.
Esposito, Elena. 2015. “Beyond the Promise of Security: Uncertainty as Resource.” *Telos* 2015(170):89–107.
Esposito, Elena. 2018. “Predicted Uncertainty: Volatility Calculus and the Indeterminacy of the Future.” Pp. 219–35 in *Uncertain Futures: Imaginaries, NArratives, and Calculation in the Economy*, edited by J. Beckert and R. Bronk. Oxford, UK: Oxford University Press.
Evans, Robert. 1997. “Soothsaying or Science?: Falsification, Uncertainty and Social Change in Macroeconomic Modelling.” *Social Studies of Science* 27(3):395–438.
Fama, Eugene F. 1970. “Efficient Capital Markets: A Review of Theory and Empirical Work.” *The Journal of Finance* 25(2):383–417.
Ferry, Elizabeth Emma, and Mandana E. Limbert, eds. 2008. *Timely Assets: The Politics of Resources and Their Temporalities*. Santa Fe, NM: School for Advanced Research Press.
Financial Supervisory Authority of Sweden. 2015. *Miljö- och hållbarhetsperspektiv i kreditgivning till företag*. 15–14755. Stockholm, Sweden: Finansinspektionen.

Fine, Gary Alan. 1993. “Ten Lies of Ethnography: Moral Dilemmas of Field Research.” *Journal of Contemporary Ethnography* 22(3):267–94.

Fine, Gary Alan. 2003a. “Towards a Peopled Ethnography: Developing Theory from Group Life.” *Ethnography* 4(1):41–60.

Fine, Gary Alan. 2003b. *Morel Tales: The Culture of Mushrooming*. Urbana, IL: University of Illinois Press.

Fine, Gary Alan. 2010. *Authors of the Storm: Meteorologists and the Culture of Prediction*. Chicago, IL: University of Chicago Press.

Fourcade, Marion. 2011. “Cents and Sensibility: Economic Valuation and the Nature of ‘Nature.’” *American Journal of Sociology* 116(6):1721–77.

Frækaland Vangsnes, Gard. 2018. “The Meanings of Mining: A Perspective on the Regulation of Artisanal and Small-Scale Gold Mining in Southern Ecuador.” *The Extractive Industries and Society* 5(2):317–26.

Frère, Bruno, and Daniel Jaster. 2019. “French Sociological Pragmatism: Inheritor and Innovator in the American Pragmatic and Sociological Phenomenological Traditions.” *Journal of Classical Sociology* 19(2):138–60.

Friedman, Milton. 1994. “The Methodology of Positive Economics.” Pp. 180–213 in *The Philosophy of Economics: An Anthology*, edited by D. M. Hausman. Cambridge, UK: Cambridge University Press.

Fürst, Henrik. 2017. “Selected or Rejected?: Assessing Aspiring Writers’ Attempts to Achieve Publication.” Dissertation, Uppsala University, Uppsala, Sweden.

Gallardo, Gloria, Fred Saunders, Tatiana Sokolova, Kristina Börebäck, Frank van Laerhoven, Suvi Kokko, and Magnus Tuvendal. 2017. “We Adapt … but Is It Good or Bad? : Locating the Political Ecology and Social-Ecological Systems Debate in Reindeer Herding in the Swedish Sub-Arctic.” *Journal of Political Ecology* 24:667–70.

Gedicks, Al. 1998. “Corporate Strategies for Overcoming Local Resistance to New Mining Projects.” *Race, Gender & Class* 6(1):109–23.

Geertz, Clifford. 1988. *Works and Lives: The Anthropologist as Author*. Stanford, CA: Stanford University Press.

Geiger, Susi. 2020. “Silicon Valley, Disruption, and the End of Uncertainty.” *Journal of Cultural Economy* 13(2):169–84.

Gelpern, Anna, G. Mitu Gulati, and Jeromin Zettelmeyer. 2018. *If Boilerplate Could Talk. SSRN Scholarly Paper*. Rochester, NY: Social Science Research Network.

Geological Survey of Sweden. 2016. *Vägledning För Prövning Av Gruvverksamhet [Guidance for Permit Processing in Mining]*. 311-1808/2014. Uppsala, Sweden: Geological Survey of Sweden (SGU).

Geological Survey of Sweden. 2019a. “Active Mines in Sweden [Aktiva Gruvor i Sverige].”

Geological Survey of Sweden. 2019b. *Bergverksstatistik 2018 (Statistics of the Swedish Mining Industry 2018)*. 2019:2. Uppsala, Sweden.

Giddens, Anthony. 2003. *Modernity and Self-Identity: Self and Society in the Late Modern Age*. Cambridge, UK: Polity Press.

Glaser, Barney G., and Anselm L. Strauss. 2005. *Awareness of Dying*. New Brunswick, NJ: Aldine Transaction.

Glaser, Barney G., and Anselm L. Strauss. 2009. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. New Brunswick. NJ: Aldine Transaction.

Goffman, Erving. 1956. *The Presentation of Self in Everyday Life*. Edinburgh, UK: University of Edinburgh Social Sciences Research Centre.

Gold, Raymond L. 1958. “Roles in Sociological Field Observations.” *Social Forces* 36(3):217–23.

Guseva, Alya, and Akos Rona-Tas. 2001. "Uncertainty, Risk, and Trust: Russian and American Credit Card Markets Compared." *American Sociological Review* 66(5):623–46.
Gustafsson, Lars. 1971. "Ist Futurologie Eine Wissenschaft?" *Futurum: Zeitschrift Für Zukunftsforschung* 4(2):119–27.
Hands, D. Wade. 2006. "Frank Knight and Pragmatism." *The European Journal of the History of Economic Thought* 13(4):571–605.
Hawking, Stephen William. 1990. *A Brief History of Time: From the Big Bang to Black Holes*. New York City, NY: Bantam Books.
Hayek, Friedrich A. von. 1944. *The Road to Serfdom*. London, UK.
Heckscher, Eli F. 1954. *An Economic History of Sweden*. Cambridge, MA: Harvard University Press.
Helgason, Agnar, and Gisli Palsson. 1997. "Contested Commodities: The Moral Landscape of Modernist Regimes." *The Journal of the Royal Anthropological Institute* 3(3):451–71.
Hildebrand, Karl-Gustaf. 1987. *Svenskt järn: sexton- och sjuttonhundratal : exportindustri före industrialismen*. Stockholm, Sweden: Jernkontoret.
Hilson, Gavin. 2010. "'Once a Miner, Always a Miner': Poverty and Livelihood Diversification in Akwatia, Ghana." *Journal of Rural Studies* 26(3):296–307.
Hilson, Gavin. 2011. "Artisanal Mining, Smallholder Farming and Livelihood Diversification in Rural Sub-Saharan Africa: An Introduction." *Journal of International Development* 23:1031–41.
Hjortfors, Lis-Mari, Martin Hultman, Nils Johansson, Kristina Sehlin Macneil, Jonas M. Nordin, Anett Sasvari, Angelika Sjöstedt Landén, Eva-Lotta Thunqvist, Björn Wallsten, May-Britt Öhman, and Åsa Össbo. 2015. "Pausa Ny Gruvor Och Prospektering." *Svenska Dagbladet*, February 23.
Holden, William N., and Daniel R. Jacobson. 2008. "Civil Society Opposition to Nonferrous Metals Mining in Guatemala." *Voluntas: International Journal of Voluntary and Nonprofit Organizations* 19(4):325–50.
Holmes, Douglas R. 2018. "A Tractable Future: Central Banks in Conversation with Their Publics." Pp. 173–93 in *Uncertain Futures: Imaginaries, Narratives, and Calculation in the Economy*, edited by J. Beckert and R. Bronk. Oxford, UK: Oxford University Press.
Hong, Harrison, Jeffrey D. Kubik, and Amit Solomon. 2000. "Security Analysts' Career Concerns and Herding of Earnings Forecasts." *The RAND Journal of Economics* 31(1):121–44.
Horkheimer, Max. 1947. *Eclipse Of Reason*. Oxford, UK: Oxford University Press.
Howard-Payne, Lynlee. 2016. "Glaser or Strauss? Considerations for Selecting a Grounded Theory Study." *South African Journal of Psychology* 46(1):50–62.
Humphreys, David. 2019. "Mining Productivity and the Fourth Industrial Revolution." *Mineral Economics*.
Intergovernmental Panel on Climate Change. 2015. *Climate Change 2014: Synthesis Report*. edited by R. K. Pachauri and L. Mayer. Geneva, Switzerland: Intergovernmental Panel on Climate Change.
International Labour Organization. 2017. "Countries That Have Not Ratified This Convention." Retrieved June 29, 2020 (https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:11310:0::NO::P11310_INSTRUMENT_ID:312314).
James, William. 1907. "Pragmatism's Conception of Truth." *The Journal of Philosophy, Psychology and Scientific Methods* 4(6):141–55.

Jeong-han, Kang, and Han Sang Won. 2010. "A Typology of Organizational Behavior: At the Crossroad of Risk and Uncertainty*." *Development and Society; Seoul* 39(2):233–55.

Jönberger, Johan. 2012. *Sveriges tyngdkraftsfält Bougueranomalikarta 1:1 miljon*. Uppsala, Sweden: Geological Survey of Sweden (SGU).

Katzenstein, Peter J., and Stephen C. Nelson. 2013. "Reading the Right Signals and Reading the Signals Right: IPE and the Financial Crisis of 2008." *Review of International Political Economy* 20(5):1101–31.

Kennedy, Bruce A., ed. 1990. *Surface Mining*. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.

Kesselring, Rita. 2018. "At an Extractive Pace: Conflicting Temporalities in a Resettlement Process in Solwezi, Zambia." *The Extractive Industries and Society* 5(2):237–44.

Kessler, Oliver, and Christopher Daase. 2008. "From Insecurity to Uncertainty: Risk and the Paradox of Security Politics." *Alternatives* 33:211–32.

Keynes, J. M. 1937. "The General Theory of Employment." *The Quarterly Journal of Economics* 51(2):209–23.

Keynes, John Maynard. 1936. *The General Theory of Employment, Interest and Money*. London, UK: MacMillan.

Kneas, David. 2020. "Placing Resources: Junior Mining Companies and the Locus of Mineral Potential." *Geoforum* S0016718520301263.

Knight, Frank H. 2006. *Risk, uncertainty and profit*. Mineola, NY: Dover Publications.

Kornberger, Martin, Lise Justesen, Anders Koed Madsen, and Jan Mouritsen, eds. 2015. *Making Things Valuable*. Oxford, UK: Oxford University Press.

Koven, Peter. 2016. "Rubicon Minerals Corp Shares Plunge as Miner Slashes Its Gold Resources by 88%." *Financial Post*, January 11.

Labba, Elin Anna. 2020. *Herrarna Satte Oss Hit: Om Tvångsförflyttningarna i Sverige*. Stockholm: Norstedts.

Lamont, Michèle. 2012. "Toward a Comparative Sociology of Valuation and Evaluation." *Annual Review of Sociology* 38(1):201–21.

Lane, David A., and Robert R. Maxfield. 2005. "Ontological Uncertainty and Innovation." *Journal of Evolutionary Economics* 15(1):3–50.

Langley, Paul. 2013. "Anticipating Uncertainty, Reviving Risk? On the Stress Testing of Finance in Crisis." *Economy and Society* 42(1):51–73.

Lanzano, Cristiano. 2018. "Gold Digging and the Politics of Time: Changing Timescapes of Artisanal Mining in West Africa." *The Extractive Industries and Society* 5(2):253–59.

Lasswell, Harold D. 1966. "The Socio-Cultural Aspect Future-Oriented Man." *The American Journal of Psychoanalysis* 26(2):157–68.

Latour, Bruno. 1993. *We Have Never Been Modern*. Cambridge, MA: Harvard University Press.

Latour, Bruno. 1999. *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, MA: Harvard University Press.

Latour, Bruno. 2014. "Agency at the Time of the Anthropocene." *New Literary History* 45(1):1–18.

Lawrence, Rebecca, and Sara Moritz. 2019. "Mining Industry Perspectives on Indigenous Rights: Corporate Complacency and Political Uncertainty." *The Extractive Industries and Society* 6(1):41–49.

Lawson, Tony. 1994. "Uncertainty." Pp. 350–57 in *The Elgar companion to institutional and evolutionary economics: L-Z*. Vol. 2, edited by G. M. Hodgson, W. J. Samuels, and M. R. Tool. Cheltenham, UK: Edward Elgar.

Lehtonen, Turo-Kimmo, and Ine Van Hoyweghen. 2014. "Editorial: Insurance and the Economization of Uncertainty." *Journal of Cultural Economy* 7(4):532–40.
Leins, Stefan. 2018. *Stories of Capitalism: Inside the Role of Financial Analysts*. Chicago, IL: University of Chicago Press.
Leith, Charles Kenneth. 1938. "Mineral Resources and Peace." *Foreign Affairs* 16(3):515–24.
Leith, Charles Kenneth. 1939. "The Struggle for Mineral Resources." *The Annals of the American Academy of Political and Social Science* 204:42–48.
Lewis, Simon L., and Mark A. Maslin. 2015. "Defining the Anthropocene." *Nature* 519(7542):171–80.
Libecap, Gary D. 1978. "Economic Variables and the Development of the Law: The Case of Western Mineral Rights." *The Journal of Economic History* 38(02):338–362.
Linsi, Lukas, and Florian Schaffner. 2019. "When Do Heuristics Matter in Global Capital Markets? The Case of the BRIC Acronym." *New Political Economy* 24(6):851–72.
Lockwood, Erin. 2015. "Predicting the Unpredictable: Value-at-Risk, Performativity, and the Politics of Financial Uncertainty." *Review of International Political Economy* 22(4):719–56.
Lowell, J. David. 2014. *Intrepid Explorer: The Autobiography of the World's Best Mine Finder*. Tucson, AZ: Sentinel Peak.
Lowell, J. David, and John M. Guilbert. 1970. "Lateral and Vertical Alteration-Mineralization Zoning in Porphyry Ore Deposits." *Economic Geology* 65(4):373–408.
Luhmann, Niklas. 1976. "The Future Cannot Begin: Temporal Structures in Modern Society." *Social Research* 43(1):130–52.
Lundqvist, Olle. 2016. *The Prospectors*. Boliden, Sweden: Boliden Mineral.
Lupton, Deborah. 2013. *Risk*. London, UK: Routledge.
MacKenzie, Donald A., Fabian Muniesa, and Lucia Siu, eds. 2007. *Do Economists Make Markets? On the Performativity of Economics*. Princeton, NJ: Princeton University Press.
Maman, Daniel, and Zeev Rosenhek. 2020. "Facing Future Uncertainties and Risks through Personal Finance: Conventions in Financial Education." *Journal of Cultural Economy* 13(3):303–17.
Mantz, Jeffrey W. 2008. "Improvisational Economies: Coltan Production in the Eastern Congo." *Social Anthropology* 16(1):34–50.
March, James G., and Herbert Alexander Simon. 1958. *Organizations*. New York City, NY: Wiley.
Marcus Tullius Cicero, John Davies. 1730. *M. Tullii Ciceronis libri De divinatione et De fato*. Cambridge, UK: Typis Academicis sumptibus C. Crownfield.
Marjoribanks, Roger W. 2009. *Geological Methods in Mineral Exploration and Mining*. 2nd ed. Berlin, Germany: Springer.
Marks, Herbert, ed. 2012. *The English Bible : King James Version. Vol. 1, The Old Testament*. New York City, NY: W.W. Norton & Company, Inc.
Marron, Donncha. 2007. "'Lending by Numbers': Credit Scoring and the Constitution of Risk within American Consumer Credit." *Economy and Society* 36(1):103–33.
Marshall, Alfred. 1920. *Industry and Trade: A Study of Industrial Technique and Business Organization; and of Their Influences on the Conditions of Various Classes and Nations*. London, UK: Macmillan & co.
Martinez-Alier, Joan. 2001. "Mining Conflicts, Environmental Justice, and Valuation." *Journal of Hazardous Materials* 86(1–3):153–70.

Marx, Karl. 1970. *Ökonomisch-Philosophische Manuskripte:. Geschrieben von April Bis August 1844*. Leipzig, Germany: Reclam Verlag.
Mellor, Philip A., and Chris Shilling. 2016. "Arbitrage, Uncertainty and the New Ethos of Capitalism:" *The Sociological Review*.
Menger, Pierre-Michel. 2014. *The Economics of Creativity*. Cambridge, MA: Harvard University Press.
Mikes, Anette. 2011. "From Counting Risk to Making Risk Count: Boundary-Work in Risk Management." *Accounting, Organizations and Society* 36(4):226–45.
Ministry of Enterprise and Innovation. 2013. "Sveriges Mineralstrategi: För Ett Hållbart Nyttjande Av Sveriges Mineraltillgångar Som Skapar Tillväxt i Hela Landet [The Minerals Strategy of Sweden: Toward A Sustainable Use of Sweden's Mineral Resources for the Creation of Growth Throughout the Country]."
Misra, Kula. 2012. *Understanding Mineral Deposits*. Springer Science & Business Media.
Miyazaki, Hirokazu. 2003. "The Temporalities of the Market." *American Anthropologist* 105(2):255–65.
Mumford, Lewis. 1946. *Technics and Civilization*. London, UK: George Ruthledge & Sons, Ltd.
Murshed, Syed Manssob, and Zafar Altaf. 2007. "What Turns a Blessing into a Curse? The Political Economy of Natural Resource Wealth [with Comments]." *The Pakistan Development Review* 46(4):351–77.
Nabighian, Misac N., V. J. S. Grauch, R. O. Hansen, Thomas R. LaFehr, Y. Li, Jonathan W. Peirce, Jeffrey D. Phillips, and M. E. Ruder. 2005. "The Historical Development of the Magnetic Method in Exploration." *Geophysics* 70(6):33ND-61ND.
Nash, Stephen John. 2003. "On Pragmatic Philosophy and Knightian Uncertainty." *Review of Social Economy* 61(2):251–72.
Nelson, Stephen C., and Peter J. Katzenstein. 2014. "Uncertainty, Risk, and the Financial Crisis of 2008." *International Organization* 68(2):361–92.
Nicholls, Christopher C. 1999. "The Bre-X Hoax: A South East Asian Bubble." *Canadian Business Law Journal* 32:173–222.
Nowotny, Helga. 2016. *The Cunning of Uncertainty*. Malden, MA: Polity.
Olofsson, Tobias. 2019. "The Death of Place: Exploring Discourse and Materiality in Debates on Rural Development." Pp. 65–85 in *Death Matters: Cultural Sociology of Mortal Life*, edited by T. Holmberg, A. Jonsson, and F. Palm. Cham, Switzerland: Palgrave Macmillan.
Olofsson, Tobias. 2020. "Imagined Futures in Mineral Exploration." *Journal of Cultural Economy* 13(3):265–77.
Orléan, André. 2010. *The Impossible Evaluation of Risk*. Paris, France: Cournot Centre for Economic Studies.
Overgaard, Søren. 2015. "How to Do Things with Brackets: The Epoché Explained." *Continental Philosophy Review* 48(2):179–95.
Pallesen, Trine. 2015. "Valuable Assemblages or Assembling Values." Pp. 126–47 in *Making Things Valuable*, edited by M. Kornberger, L. Justesen, A. K. Madsen, and J. Mouritsen. Oxford, UK: Oxford University Press.
Peirce, Charles S. 1878. "Illustrations in the Logic of Science. Second Paper. - How to Make Our Ideas Clear." *Popular Sciecne Monthly* 12:286–302.
Peirce, Charles S. 1905. "What Pragmatism Is." *The Monist* 15(2):161–81.
Perry, Franscesca. 2015. "Kiruna: The Arctic City Being Knowcked down and Relocated Two Miles Away." *The Guardian*, June 30.

Perry, Martin, and James E. Rowe. 2015. "Fly-in, Fly-out, Drive-in, Drive-out: The Australian Mining Boom and Its Impacts on the Local Economy." *Local Economy* 30(1):139–48.
Persson, Sofia, David Harnesk, and Mine Islar. 2017. "What Local People? Examining the Gállok Mining Conflict and the Rights of the Sámi Population in Terms of Justice and Power." *Geoforum* 86:20–29.
Pilmis, Olivier. 2018. "Escaping the Reality Test: How Macroeconomic Forecasters Deal With 'Errors.'" Pp. 124–43 in *Uncertain Futures: Imaginaries, Narratives, and Calculation in the Economy*, edited by J. Beckert and R. Bronk. Oxford, UK: Oxford University Press.
Pixley, Jocelyn. 2012. *Emotions in Finance: Booms, Busts and Uncertainty*. Cambridge, UK: Cambridge University Press.
Polanyi, Karl. 2011. "The Economy as Instituted Process." in *The Sociology of Economic Life*, edited by M. Granovetter and R. Swedberg. Boulder, CO: Westview Press.
Pollock, Neil, and Robin Williams. 2010. "The Business of Expectations: How Promissory Organizations Shape Technology and Innovation." *Social Studies of Science* 40(4):525–48.
Poovey, Mary. 2018. "Risk, Uncertainty, and Data: Managing Risk in Twentieth-Century America." Pp. 221–35 in *American Capitalism: New Histories*. New York City, NY: Columbia University Press.
Porter, Theodore M. 1996. *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*. Princeton, NJ: Princeton University Press.
Porter, Theodore M. 2008. "Locating the Domain of Calculation." *Journal of Cultural Economy* 1(1):39–50.
Power, Michael. 2007. *Organized Uncertainty: Designing a World of Risk Management*. Oxford, UK: Oxford University Press.
Preda, Alex. 2007. "Where Do Analysts Come from? The Case of Financial Chartism." *The Sociological Review* 55(2):40–64.
Pryke, Michael, and John Allen. 2000. "Monetized Time-Space: Derivatives – Money's 'New Imaginary'?" *Economy and Society* 29(2):264–84.
Radivojević, Miljana, Thilo Rehren, Ernst Pernicka, Dušan Šljivar, Michael Brauns, and Dušan Borić. 2010. "On the Origins of Extractive Metallurgy: New Evidence from Europe." *Journal of Archaeological Science* 37(11):2775–87.
Reichmann, Werner. 2013. "Epistemic Participation: How to Produce Knowledge about the Economic Future." *Social Studies of Science* 43(6):852–77.
Reinertsen, Hilde, and Kristin Asdal. 2019. "Calculating the Blue Economy: Producing Trust in Numbers with Business Tools and Reflexive Objectivity." *Journal of Cultural Economy* 12(6):552–70.
Rescher, Nicholas. 1998. *Predicting the Future: An Introduction to the Theory of Forecasting*. Albany, NY: State University of New York Press.
Ross, John R. 1967. "Constraints on Variables in Syntax." Massachusetts Institute of Technology, Cambridge, MA.
Royal Society. 1992. *Risk: Analysis, Perception and Management*. London, UK: Royal Society.
Ruffell, Alastair, Niall Majury, and William E. Brooks. 2012. "Geological Fakes and Frauds." *Earth-Science Reviews* 111(1):224–31.
Sabins, Floyd F. 1999. "Remote Sensing for Mineral Exploration." *Ore Geology Reviews* 14(3):157–83.
Saint Augustine of Hippo. 1631. *Saint Augustines Confessions Translated: And With Some Marginall Notes Illustrated. Wherein, Diuers Antiquities Are Explayned; And the Marginall Notes of a Former Popish Translation, Answered. By William*

Watts, Rector of St. Albanes, Woodstreete. Reproduction of the original in Cambridge University Library. London, UK: John Norton, for John Partridge.
Sakai, Yasuhiro. 2016. "J. M. Keynes on Probability versus F. H. Knight on Uncertainty: Reflections on the Miracle Year of 1921." *Evolutionary and Institutional Economics Review* 13(1):1–21.
Schütz, Alfred. 1944. "On Multiple Realities." *Philosophy and Phenomenological Research* 5(4):533–576.
Schütz, Alfred. 1953. "Common-Sense and Scientific Interpretation of Human Action." *Philosophy and Phenomenological Research* 14(1):1–38.
Schütz, Alfred. 1959. "Tiresias, or Our Knowledge of Future Events." *Social Research* 26(1):71–89.
Schütz, Alfred. 1962. *Collected Papers. 1, The Problem of Social Reality*. edited by M. Natanson. The Hague, The Netherlands: Martinus Nijhoff.
Shiller, Robert J., Stanley Fischer, and Benjamin M. Friedman. 1984. "Stock Prices and Social Dynamics." *Brookings Papers on Economic Activity* 1984(2):457–510.
Simmel, Georg. 2011. *Georg Simmel on Individuality and Social Forms*. Chicago, IL: University of Chicago Press.
Simon, Herbert A. 1991. "Bounded Rationality and Organizational Learning." *Organization Science* 2(1):125–34.
Smith, James H. 2011. "Tantalus in the Digital Age: Coltan Ore, Temporal Dispossession, and 'Movement' in the Eastern Democratic Republic of the Congo." *American Ethnologist* 38(1):17–35.
Sniazhko, Sniazhana. 2019. "Uncertainty in Decision-Making: A Review of the International Business Literature." *Cogent Business & Management* 6(1):1–32.
Sörlin, Sverker, and Nina Wormbs. 2010. "Rockets and Reindeer : A Space Development Pair in a Northern Welfare Hinterland." Pp. 131–51 in *Science for welfare and warfare: technology and state initiative in cold war Sweden*, edited by P. Lundin, N. Stenlås, and J. Gribbe. Sagamore Beach, MA: Science History Publications.
Sovacool, Benjamin K., Saleem H. Ali, Morgan Bazilian, Ben Radley, Benoit Nemery, Julia Okatz, and Dustin Mulvaney. 2020. "Sustainable Minerals and Metals for a Low-Carbon Future." *Science* 367(6473):30–33.
Stinchcombe, Arthur L. 1978. *Theoretical Methods in Social History*. Orlando, FL: Academic Press, Inc.
Storey, Keith. 2001. "Fly-in/Fly-out and Fly-over: Mining and Regional Development in Western Australia." *Australian Geographer* 32(2):133–48.
Strauss, Anselm L., and Juliet M. Corbin. 1998. *Basics of Qualitative Research : Techniques and Procedures for Developing Grounded Theory*. Thousand Oaks, CA: SAGE.
Sundberg, Mikaela. 2005. "Making Meteorology: Social Relations and Scientific Practice." Dissertation, Stockholm University, Stockholm, Sweden.
Sundqvist, Frida. 2015. "Försökte Hela Tiden Informera." *Svenska Dagbladet*, January 27.
Svetlova, Ekaterina. 2012. "Talking about the Crisis: Performance of Forecasting in Financial Markets." *Culture and Organization* 18(2):155–69.
Swedish Government Official Reports. 2017. *För Sveriges landsbygder - en sammenhållen politik för arbete, hållbar tillväxt och välfärd: slutbetänkande av Parlamentariska landsbygdskommittén*. Stockholm, Sweden: Wolters Kluwer.
Swedish Society for Nature Conservation. 2017. "Brottsplats Sverige." *Naturskyddsföreningen*. Retrieved October 22, 2019 (https://www.naturskyddsforeningen.se/brottsplats-sverige).

Tarras-Wahlberg, N. Håkan. 2014. "Social License to Mine in Sweden: Do Companies Go the Extra Mile to Gain Community Acceptance?" *Mineral Economics* 27(2–3):143–47.
The Supreme Court of Sweden. 2020. *The Girjas Ruling [Girjasdomen]*.
The Swedish Research Council. 2002. *Forskningsetiska principer inom humanistisk-samhällsvetenskaplig forskning.* Stockholm, Sweden: The Swedish Research Council.
The Swedish Research Council. 2011. *Good Research Practice*. Stockholm, Sweden: The Swedish Research Council.
The Swedish Riksdag. 1991. *Minerals Act - Minerallag (1991:45)*. Vol. (1991:45).
The Swedish Riksdag. 1992. *Mineral Ordinance - Mineralförordning (1992:285)*.
The Swedish Riksdag. 1998a. *Environmental Codex - Miljöbalk (1998:808)*.
The Swedish Riksdag. 1998b. *Ordinance (1998:896) Regarding Water and Land Husbandry/Förordning (1998:896) Om Hushållning Med Mark- Och Vattenområden*.
Themsen, Tim Neerup, and Peter Skærbæk. 2018. "The Performativity of Risk Management Frameworks and Technologies: The Translation of Uncertainties into Pure and Impure Risks." *Accounting, Organizations and Society* 67:20–33.
Tsing, Anna Lowenhaupt. 2015. *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*. Princeton, NJ: Princeton University Press.
Turner, Adair. 2009. *The Turner Review: A Regulatory Response to the Global Banking Crisis*. London, UK: Financial Services Authority.
Tversky, Amos, and Daniel Kahneman. 1974. "Judgment under Uncertainty: Heuristics and Biases." *Science* 185(4157):1124–31.
Vaughan, Diane. 1996. *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA*. Chicago, IL: University of Chicago Press.
Vent, Glenn, and Ronald A. Milne. 1989. "The Standardization of Mine Accounting." *The Accounting Historians Journal* 16(1):57–74.
Verbrugge, Boris. 2015. "The Economic Logic of Persistent Informality: Artisanal and Small-Scale Mining in the Southern Philippines." *Development & Change* 46(5):1023–46.
Verschraegen, Gert, and Frédéric Vandermoere. 2017. "Introduction: Shaping the Future through Imaginaries of Science, Technology and Society." Pp. 1–11 in *Imagined Futures in Science, Technology and Society*, edited by G. Verschraegen, L. Braeckmans, and B. Segaert. London, UK: Routledge.
Waldbaum, Jane C., and James D. Muhly. 1980. "The First Archaeological Appearance of Iron and the Transition to the Iron Age." in *The Coming of the Age of Iron*, edited by T. A. Wertime. New Haven, CT: Yale University Press.
Walter, Mariana, and Joan Martinez-Alier. 2010. "How to Be Heard When Nobody Wants to Listen: Community Action against Mining in Argentina." *Canadian Journal of Development Studies / Revue Canadienne d'études Du Développement* 30(1–2):281–301.
Weber, Max. 1978. *Economy and Society: An Outline of Interpretive Sociology*. edited by G. Roth and C. Wittich. Berkeley, CA: University of California Press.
Weber, Max. 2002. *The Protestant ethic and the spirit of capitalism*. London, UK: Routledge.
Weber, Max. 2003. *General Economic History*. Mineola, NY: Dover Publications.
Wedmark, Mats. 2012. *Sveriges magnetfält, anomalikarta, skala 1:1 miljon*. Uppsala, Sweden: Geological Survey of Sweden (SGU).
Weszkalnys, Gisa. 2008. "Hope & Oil: Expectations in SãoTomé e Príncipe." *Review of African Political Economy* 35(117):473–82.

Weszkalnys, Gisa. 2015. “Geology, Potentiality, Speculation: On the Indeterminacy of First Oil.” *Cultural Anthropology* 30(4):611–39.
Whyte, William Foote. 1993. *Street Corner Society: The Social Structure of an Italian Slum*. Chicago, IL: University of Chicago Press.
Wiegink, Nikkie. 2018. “Imagining Booms and Busts: Conflicting Temporalities and the Extraction-‘Development’ Nexus in Mozambique.” *The Extractive Industries and Society* 5(2):245–52.
Wilson, Jeffrey D. 2016. “Killing the Goose That Laid the Golden Egg? Australia’s Resource Policy Regime in Comparative Perspective.” *Australian Journal of Political Science* 51(1):110–21.
Wright, Christopher, and Daniel Nyberg. 2015. *Climate Change, Capitalism, and Corporations: Processes of Creative Self-Destruction*. Cambridge, UK: Cambridge University Press.
Wynne, Brian. 1988. “Unruly Technology: Practical Rules, Impractical Discourses and Public Understanding.” *Social Studies of Science* 18(1):147–67.
Wynne, Brian. 1992. “Uncertainty and Environmental Learning: Reconceiving Science and Policy in the Preventive Paradigm.” *Global Environmental Change* 2(2):111–27.
Zachrisson, Anna, and Karin Beland Lindahl. 2019. “Political Opportunity and Mobilization: The Evolution of a Swedish Mining-Sceptical Movement.” *Resources Policy* 64:101477.
Zelizer, Viviana A. 1978. “Human Values and the Market: The Case of Life Insurance and Death in 19th-Century America.” *American Journal of Sociology* 84(3):591–610.
Zinn, Jens O. 2009. “The Sociology of Risk and Uncertainty: A Response to Judith Green’s ‘Is It Time for the Sociology of Health to Abandon “Risk”?’” *Health, Risk & Society* 11(6):509–26.

Appendix 1: A note on methodology

I came to this project having very little knowledge of mineral exploration or mining. I had heard the term *exploration drilling* and therefore had a vague idea of what some parts of exploration work might entail, but that was the extent of my knowledge. So how did I come to write a dissertation about mineral exploration? Why did I spend four years sleeping poorly on hard beds in perpetually too warm or too cold sleeping compartments on the overnight trains to interviews in far-a-way towns only to come home to a pile of archival materials to be read, sorted, catalogued, and coded?

What drove me to choose to spend my years as a PhD candidate researching mineral exploration was a sense that there ought to be something interesting, perhaps even fascinating, going on in an industry that so thoroughly depends on the destruction of some values to realize other values. With this as my starting point, I began collecting as much information as I could, reading annual reports from exploration organizations and miners in Sweden to map what kind of values they discuss with their shareholders and what risks they see along the way towards realizing these values. This review led me to begin thinking about the puzzle of how one values the future, something that is not there to be measured, weighed, or analyzed. At the same time, I had begun familiarizing myself with the existing literature on mineral exploration and mining realizing that much work had already been made on the conflicts of values played out between miners and aboriginal and first nation communities and other publics. Combined, these two developments pushed the topic of this dissertation towards its focus on predictions and the relationship between predictions and values.

Feeling pretty happy about this topic, I began planning how to study explorationists and how they make and justify predictions. The initial plan was to approach these questions using a classic ethnographical approach based on participant observation in which gatekeepers were to be identified and approached for opportunities to "be there" beside explorationists as they worked their projects. However, it soon became apparent that the long time span and the division of labor between different branches within exploration organizations, or even between different exploration organizations, meant that mineral exploration was a bad candidate for a clear cut standard issue ethnographic project, as I would not have the time or opportunity to be everywhere simultaneously. The poor rate of success in exploration also played a part; even if I had been able to set aside enough time to follow a project through the entire process, identifying that one of 999 projects that would make it through the entire exploration process would be impossible. Therefore, I found myself forced to reconsider how I could best approach the case.

The approach I finally settled on has been described earlier in this dissertation but involved mapping the exploration process using different sources. I would like to use the remainder of this section to talk about the choices and challenges involved in executing this composite approach within the context of this study, and I will do this in reference to research design, reflexivity, and the role of the ethnographer with particular reference to the *Ten Lies of Ethnography* by Gary Alan Fine as discussed in his 1993 article of the same name. Based on my initial experiences from the field and a reading of different methodological texts covering anything from relational ethnography to abductive analysis and case study methods, I settled on a methodological approach that combined an extended conceptualization of ethnography with elements from grounded theory. This dissertation project, I realized, was going to involve a lot of data from different sources that all needed to be combined and read in light of one another. Informants, it became clear, would never be able to give me any specific information on their ongoing projects, as they are obliged by the industry standards on exploration and resource reporting never to disclose information that may affect their share prices. However, given their experiences they would be able to provide me with insight into the practical exploration work. At the same time, the archival materials provide ample information on specific projects at different stages along the exploration process, but very little insight into the work behind the predictions and statements offered in the documents. And while interviews and archival materials complemented each other in this respect, they risked falling short when it came to understanding the industry in a broad sense and neither would they provide me with much practical insight into the field. I therefore decided that in order to accomplish this project, I needed a methodological approach that allowed me to tap into different sources and types of data and use the pieces collected there to build one large puzzle where each piece was related to the next. The methodological approaches that best allowed me to construct this puzzle, I decided, was to aim for the deep description provided in ethnography. To get there, I would have to take a detour through theoretical sampling and inductive work of grounded theory. This realization began a long hunt for data where each wave of data collection was followed by reflection on what information was missing and was needed to complete the emerging picture and add additional dimensions to the facts identified in the collected materials. One clear example of this is how I came to interview the person who in the dissertation is referred to as Niels. The archival materials often mention explorationists seeking to collaborate with the Sámi in the regions where they are undertaking exploration work and developing mining projects. But they often fail to mention what role the Sámi districts and representatives were invited to take in this collaboration. I therefore decided to reach out to a number of Sámi districts located in mining regions in search for potential informants. This eventually led me to Niels with whom I spent half a day during which I did not only interview him but joined him when he met with and talked to other Sámi in the district. I also helped out with administrative work for the Sámi District while talking about and learning more about the relationship between the Sámi and explorationists.

Finding informants able and willing to participate in this dissertation was hard at first. I remember a fellow PhD candidate expressing doubts of whether I would be able to find any informants at all and that if I did, these informants would probably be drill-rig operators without much experience or say in the prediction work and decision making in their respective organizations. Fortunately, this person was to be proven wrong in most aspects. It is true that it was hard to identify informants at first. Not having a natural point of entry into the field meant that I was forced to reach out to different exploration and mining companies and corporations in search for informants. Most of these attempts went unanswered or consisted of little more than an email from a public relations officer saying that the company had elected not to partake in the study. However, some attempts where fruitful and produced a small but important number of informants. I also searched for informants while undertaking fieldwork in different spaces. One space that was to become an important source of data and new informants was SveMin's annual meetings. Having spent the majority of my first SveMin meeting and conference cursing how most attendants tended to stand in closed circles talking to others from their own organization, offering little opportunity for spontaneous conversation, I finally found an opening at the end of the day and struck up a conversation with a person preparing to leave the auditorium at the same time as me. Seizing upon the opportunity, I struck up a conversation with this person (keeping with the system of providing informants with pseudonyms in alphabetical order, we may call him Steve) and talked for a moment about the conference and about my dissertation project. At the SveMin meeting the following year, I met Steve again and as we conversed about the talks and presentations given at the meeting as well as about how my project was going, people came up to talk to Steve who, courteously, introduced me to them and after some conversation some of them had agreed to exchange email addresses for later talks about possible interviews. This pattern occurred on a number of occasions, in different venues, and with different people (Steve is in truth an abstraction of several people who generously helped me at different stages of this project), and it has been vital for identifying and recruiting informants beyond those that emerged from me emailing and calling different exploration companies and corporations. However, while this method of identifying informants was relatively successful, it was very time consuming and allowed little room for strategic planning. Going to conferences and meetings and being friendly and approachable is, after all, not really that much of a sampling strategy. It was, however, one of the few routes available and as the network of contacts grew, it became a vital source of informants. To me, this speaks to the importance of time and patience in research and it illustrates how one initial investment into networking in an ethnographic field site can be a great resource down the line when the network begins producing potential informants.

Not every ethnographic engagement consisted of long-term networking and slow accumulation of data, however. Some of the periods spent in the field were of more immediate use. This is particularly true of the classes and training sessions I have participated in as part of this project. However, while these sites offered instant data in the form of lectures, seminars, and workshops, they were also challenging as they often required a significant level of understanding of anything from geology to Microsoft Excel. Luckily, I had worked with Excel enough not to lose myself in technical problems when taking a course on financial modeling in mineral exploration and mining and my training in quantitative research methods helped me in approaching topics such as geo-statistics and quality assurance through statistical cross-checks. However, I am not a geologist nor an economist and this was at times painfully obvious as I had to spend considerable time looking up the meaning of terms used in the field. Thankfully, there are a number of resources available to the struggling sociologists trying to make sense of what an informant meant when talking about the problem with faults (fractures and discontinuities in the bedrock) or what a qualified person means when they talk about the implications for the NPV from shifts in CAPEX or OPEX. Sometimes these challenges were resolved by simply asking the informant what they meant by a term of phrase they just used or which I had come across in the archival material, but sometimes this was not possible. On such occasions, I was very happy that Wikipedia's entries on geology are relatively good for answering quick questions about the meaning of a term while Investopedia does the same for investment lingo. For larger questions, the SGU and their international counterparts provide a lot for material on geology, exploration, and mining; and when all else fails, a trip to the university library's (for sociologists at least) more unchartered sections often resolved any remaining questions. Importantly, however, this is not a thesis in geology, exploration, or finance. It is a thesis in sociology wherefore all this knowledge, while necessary for understanding the context, does not have a material impact on the analysis beyond making sure that terminology and practical confusion do not stand in the way of engagement in the sociological questions at hand. It was, for example, useful to show informants that I had some understanding of their field as this tended to make them a little more relaxed in the interview situation. However, as I was not there to talk to them as their peer, but as someone whose job it is to ask questions, however disguised as conversational topics, I was conscious about the necessity to balance giving-off impressions of knowledge with impressions of ignorance. For example, knowing what a geological fault is helped when talking to informants as this meant they could focus on explaining in what way a fault was a problem in a project they worked a few years ago without first having to explain what a fault is and therefore potentially spending time on talking about the general rather than the particular realities of their work and their experiences.

A challenge of ethnographic research is, of course, how one positions oneself within the field. What types of roles are available to you and how do you choose to embody that role? This question was relatively easily resolved at times. Sitting as one of many in a training session on modelling meant stepping into an already defined role. Sitting in on classes and seminars on exploration and related topics required more thought on to what degree I could and should be an active or passive observer, however. During a two-day session observing a class I resolved this by talking to the instructor who had invited me to sit in on the class and asked him what degree of participation would work best for him and the class in general. He responded saying that he would prefer it if I joined in and answered a few questions when I could as this could spark the students to do the same, so I assumed a slightly more active role as a fellow advanced level student rather than the plainly passive observer.

Deciding what role to take as an ethnographer is not always straight forward the problem relates to the "lies" Gary Alan Fine sees ethnographers engaging in when working in the field. In reference to Fine's 1993 work *Ten Lies of Ethnography*, I, like most other ethnographers, sought to live up to the virtues expected of ethnographers performing, and most of the time seeking to be, a kind, friendly, candid, and fair ethnographer, to list just a few of the stereotypical virtues discussed and problematized by Fine. However, as Fine points out, there are inherent challenges to these virtues and some challenges were harder to manage than were others. First, I found it relatively easy to, so to say, fit in during field work and interviews and I realize that my upbringing in the northern parts of Sweden that gifted me a northern accent and an intimate familiarity with what is and what is not seen as appropriate office wear in Sweden's rural regions helped. I even had a conversation with one informant who was confident that the way you present yourself in the northern regions of Sweden plays a crucial role in how you are received by members of these communities, as many in these locations tend to have negative perceptions of smartly dressed and fast-spoken people from Sweden's metropolitan areas. However, while most challenges discussed by Fine can be resolved by being aware of and reflecting on the shortcomings involved in doing either the one thing or the other, there was one challenge I struggled with: of remaining fair and candid when faced with people making statements that fundamentally went against my beliefs and moral convictions. This happened on only a few occasions and is in no way descriptive of the entire field in general, but there are people within the exploration and mining industry that express and spread racial bigotry against the Sámi. Siting at a table with myself and two Confederation for Swedish Enterprise (*Svenskt Näringsliv*) representatives, a CEO of a Swedish mining company described the member of the Sámi parliament who had just given a talk on the importance of the Sámi and the mining industry finding ways to coexist in the northern regions as an “extremist.” Following this, the same CEO then went on to say that the Sámi and reindeer herding should be confined to the Lappland region and nowhere else; and this tirade did not stop there. Having said this, the CEO went on to say how “moronic” it is that there is a bilingual sign on the wall of the Jämtland County Library’s Östersund facilities that spells out “County Library” in both Swedish and the Southern Sámi language. Commenting on this, he said: “If they can’t even read the word library in Swedish, they don’t belong at the library.” While the mining CEO was expressing these views, the others around the table (myself included) refrained from saying anything or speaking up against this tirade of bigotry. In another setting, a person from an international mining and exploration corporation said that she was not a good friend of NGOs as they make local communities “think that they need a middle man” to mediate between the community and the exploration team. This is not so, she continued, as explorationists and local communities can get along just fine. “You don’t need a middle man to talk to your children,” she concluded, reducing local communities, aboriginals, and first nations to children, robbing them of any true agency.

While some of the actors who made racist and bigoted comments are involved in the private sector, others are officers at governmental agencies. One example, and a blissfully rare one, was an agency officer who explained to me that in his experience the way to manage Sámi opposition to an exploration or mining project on reindeer grazing land was to just pay them SEK 10 000 (approximately $1000) under-the-counter. The same agency officer also talked about how Sámi had tried to overcharge explorationists for the use of a helicopter to locate the reindeer before allowing a drill campaign in the area. Having agreed to a price initially, the officer continued, the explorationists later found out that the Sámi had tried to have the explorationists pay also for them using the helicopter for recreational purposes and not only for locating the reindeer. In saying this, the officer described the Sámi as cheats and liars who can be bought off when necessary. And he did so standing in his office at a Swedish government agency with other officers present.

I find these situations highly problematic, but I never did anything to challenge them. Instead I made sure to record it in my field notes, telling myself that “You’re in the field, you’re supposed to observe, don’t jeopardize access and data.” Therefore, I chose not to engage those making such statements. Instead, I chose to put the accounts of the events aside, as they often did not contribute towards answering the research questions and therefore bracketed them, engaging only with the contents of these people’s statements that related to the research problem. Although I thoroughly believe that this was the right thing to do, this side of the mining and exploration industry troubles me on a personal level.

Finally, there is the matter of what implications the choices outlined above have had in terms of the validity of the results presented in this thesis. Any choice one makes when designing and carrying out a research project means choosing not to do something or use some other method. One apparent choice that has had consequences for the results presented in this dissertation has been the choice to focus the project on industrial mineral exploration in Sweden. It would potentially had been possible to instead conduct a comparative study of two different jurisdictions. This would have meant introducing a significant strain on the resources available for this project and potentially meant that less depth in the descriptions and analyses. Nevertheless, a comparative approach would have likely provided more insights into matters that can only be inferred from the international use of the industry standards presented in this dissertation and the portion of data collected abroad. Similarly, the choice to study two or three exploration projects in a case study approach rather than focusing on the exploration process in its entirety would have meant that this would have been a quite different dissertation from what it has become. For example, accounts of how exploration and prediction work would had been more specific and less general. However, this approach would have been isolated to a few cases from which a general view of the field would have to be extrapolated speculatively. Although the present account discusses in-depth the overall facts and trends of prediction work in mineral exploration, any answers to specificities of individual cases must be inferred from the general. Another implication of directing the dissertation to a study of the entire process is that potential benefits of studying prediction work in a specific stage of the exploration process (e.g., mineral resource estimation or in feasibility studies and financial modelling) would be lost. However, while such accounts could have laid out more precisely the work in this particular stage, it would have meant losing important insights into what proceeds and follows any one particular phase in exploration.

A final drawback of the approach used in this dissertation is that it follows explorationists more closely than it follows other actors. There are, for example, no county administrative officers among those interviewed for this thesis wherefore the accounts of the CAB's participation in the prediction games and co-creation of futures discussed in chapter 8 are based on the boards' presence in the archival material and not on interview accounts from the actors directly involved in the CABs' reviews of exploitation concession applications. I am aware of the downsides of this and wish that there had been more time and resources to collect more first-hand data from the county administrative boards and the environmental courts. However, the research problem and questions that form the basis for this dissertation primarily concern mineral exploration and explorationists, so the resources were focused there. Having said this, I would highly recommend that future research engage with the county administrative boards and environmental courts as actors and sites of metaprediction. The question of relative environmental impact as a justification for establishing a mine or any other environmentally impactful industry is in my view one of the most important and intriguing questions to come out of this dissertation.

This dissertation has attempted to describe and analyze prediction work in industrial mineral exploration in Sweden and despite the challenges and pitfalls discussed above, I am confident that what has been presented across the dissertation's 250-something pages are truthful and theoretically pregnant answers to questions of how explorationists predict minability in exploration work, how they justify these predictions, and what happens when explorationist communicate prediction to their publics. I would like to conclude these reflections on the road to the publication of this thesis by saying the following: Mineral exploration and mining is an industry full of contradictions and paradoxes and I would never have been able to produce as detailed a depiction of it as the one contained in the pages of this thesis if I had not enjoyed the generous help of the informants and others who gave of their time and experience to help me understand how mineral exploration takes place and what role predictions play in the management of uncertainty in mineral exploration. I am aware of the actual and potential flaws and limits of this study and recognize them as my own while I thank those who have helped me do the utmost to manage and reduce them.

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Appendix 2: Table of observations

Table 2.

Title	Description	Duration	Location	Date
SveMin Annual Meeting 2016	Participant observation at The Swedish Industry Association of Mines, Mineral and Metal Producers (SveMin) Conference.	1 day	Sweden	2016
International trading site	Observed trading at an international trading site from an observation deck accompanied by a representative who guided me through the trading procedure and answered questions about the trading site and the trading therein.	1 hour	UK	2016
SveMin Annual Meeting 2017	Participant observation at The Swedish Industry Association of Mines, Mineral and Metal Producers (SveMin) Conference including the post-meeting reception and dinner.	1 day	Sweden	2017
Class on Mining Economy and Risk Evaluation	Participant observation in an advanced level class on mining economy and risk evaluation including exploration techniques, modelling, and mineral resource and reserve estimation at a technical university in Sweden.	2 days	Sweden	2017

Training session on mining financial modeling	Participant observation at a training event on financial modelling in mining. Participation included producing a financial model for a fictitious case.	1 day	Canada	2018
International Industry Conference and Tradeshow 2018	Participant observation at talks, seminars, and trade show.	4 days	Canada	2018
Workshop on mining, social sustainability, and community relations with Swedish miner, municipality representatives, and representatives from civil society	Participant observation in a workshop organized by a Swedish miner together with a social relations consultancy firm where representatives from the miner, the local municipality, and the local civil society met to discuss social sustainability issues and how to establish mutually beneficial relations between the miner and the local community. Participation by invitation from an informant.	3 hours	Sweden	2018
Visit to Swedish mine and tour of mine and offices by mining engineer	Visited an operating Swedish mine including tour of mining operation and facilities from senior officer and a mining engineer. Included first hand observation and on the spot interview of how the engineering team used pit optimization techniques to plan the mining operation.	3 hours	Sweden	2018
Visit to SGU drill core archives	Was guided through the SGU archives by an informant who also gave a tour of the SGU facilities and introduced me to the staff at the SGU office for spontaneous interviews with agency officers.	1 day	Sweden	2018
SveMin Annual Meeting 2018	Participant observation at The Swedish Industry Association of Mines, Mineral and Metal Producers (SveMin) Conference.	1 day	Sweden	2018
Visit to mothballed mine	Tour of above and underground facilities at a mothballed underground mine.	2 hours	Sweden	2019

Appendix 3: Table of archival materials

Table 3.

Title	Summary	Accessed	Number of pages
Annual reports corpus	Annual Reports or Financial Statement and Management's Discussion and Analysis for miners and exploration organizations who are members of Sve-Min (1997-2015)[161]	2016	9508
Exploitation concession applications and MIS rulings	Applications (with supporting materiel) and decisions by the MIS for the years 2010-2016	2016	7855
JORC Code	*Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves* – Australasian Joint Ore Reserves Committee	2017	44
NI-43-101	*NI 43-101 Standards of Disclosure for Mineral Project* – Geoscientists Canada	2017	44

[161] These materials contain 129 documents with the oldest having been published in 1997 and the newest in 2015. The corporations and companies included in these materials are Anico Eagle, Avalon, Beowulf, Boliden, Copperstone, Dragon Mining, Leading Edge, LKAB, Lovisa Gruvan, Lundin Mining, Mandalay, Nordic Iron Ore, and Nordic Mines.

FRB Standard	*Rekommenderade regler för publik information i Sverige, Finland och Norge om prospekteringsresultat, undersökningar, lönsamhetsstudier och värderingar av mineraltillgångar och mineralreserver* – Fennoscandian Review Board [Fenoscandian Reporting Standard formulated in accordance with CRIRSCO guidelines]	2016	8
PERC Reporting Standard 2017	*Pan-European Standard for Reporting of Exploration Results, Mineral Resources, and Reserves* – The Pan-European Resource Reporting Committee	2017	94
CRIRSCO template	*International Reporting Template for the Public Reporting of Exploration Results, Mineral Resources, and Mineral Reserves* – Committee for Mineral Reserves International Reporting Standards	2016	41
Legal documents	*Minerals Act of 1991* (Minerallag 1991:45) *Mineral Ordinance of 1992* (Mineralförordning 1992:285) *Environmental Code of 1998* (Miljöbalk 1998:808) *Ordinance on land and water husbandry of 1998* (Förordning (1998:896) om hushållning med mark- och vattenområden) All: Swedish Code of Statutes	Mixed dates	*
Vägledning vid prospektering i Sverige – SveMin**	Guide to exploration in Sweden published by SveMin	2016	47
Vägledning för god miljöpraxis vid prospektering i skyddade områden – SveMin**	Guide to best environmental practices in relation to mineral exploration in environmentally protected areas published by SveMin	2016	58
		Total	17 699

*Documents were provided in html format wherefore no page count is available.
**Supporting documents used for background understanding and therefore not analyzed.

Appendix 4: Example of Interview Guide

The interview guides used in this study followed a simple, thematic, and open structure where the informants were first asked to talk about their work, the tasks they perform, where in the exploration process they usually work before the interview turned towards the specificities of their work, the methods and strategies used, and how they work with and view risk. For example, the interview with informant George featured the following questions adapted to capture the informant's experiences as an exploration geologist:

1. Could you tell me a bit about the work you do?
   a. Where in the exploration process do you work?
   b. What type of organizations have you worked for? Have you worked with consultancies or for an exploration or mining company?
2. Could you tell me about how the exploration work you do is organized?
   a. How do you select areas and targets?
   b. What methods do you use?
   c. Do you follow any particular strategies?
3. What goals are you working towards?
   a. Does work change whence you have identified a target? If so, can you tell me how?
4. Could you give me an example of a project when you had/did not have success?