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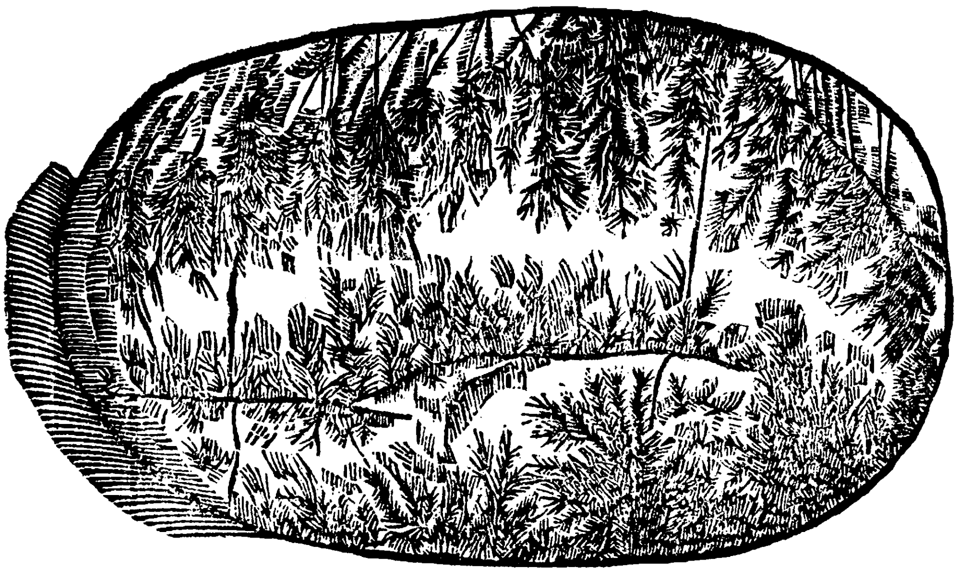
A Changeable World of Stone

A Glimpse into the 17th- and Early 18th-century Discussion on the Generation of Crystals

God created the world in six days. Mountains were created on the third of these, when He separated earth from water. This biblical truth was the frame of reference for the discussion on the generation of minerals that was carried on in natural philosophy, the natural science of intellectual Sweden in the 17th and early 18th centuries. Because there was a hitch: given that all mountains were created at once *before* plants and animals, how was it then possible to find and distinguish particles of organic materials, embedded animals and plants, in minerals, indeed, even plants and other things that had become stone? There was one possibility: that minerals could be 'born' and grow and that they had done so a long time *after* minerals were created, and that in this growth, or coming into being, minerals could encapsulate animals and plants.[1]

1 Cf. Tore Frängsmyr, *Svensk idéhistoria. Bildning och vetenskap under tusen år.* Part I, Stockholm, 2004, pp. 250–255; same author, *Geologi och skapelsetro: föreställningar om jordens historia från Hiärne till Bergman*, Stockholm, 1969, and Gustaf Harmens (praes.), Jacob Öjebom (resp.) *Dissertatio mineralogica de generatione lapidum & crystallisatione*, Lund, 1752, pp. 7–13. • Image below from *Illustrerad folk-Bibel*, Stockholm, 1854.



A stone that reflect the image of a forest, with no human intervention. From F. Imperato, *Historia Naturalis,* Coloniae, 1625.

Our older book collections today contain many works that reflect the discussion of that day concerning processes of mineral growth, both out in Europe and here at our Swedish universities.

Interest in the genesis of minerals

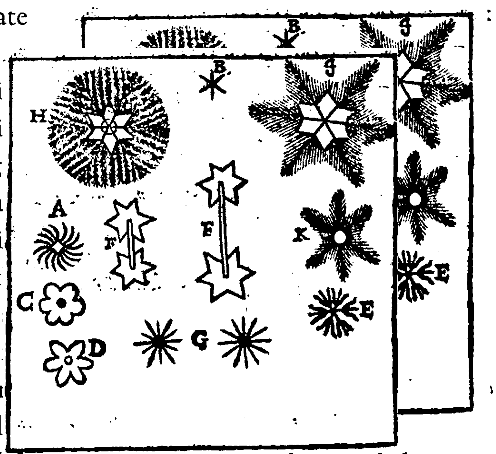
The question of the generation of minerals was largely pursued by natural philosophers, apparently as a matter of pure curiosity. But it was also of interest to other branches of science. Medicine was able to demonstrate many examples of mineral transformations and mineral growth inside the human body. Not all of them were harmful, but one type of stone was the cause of painful disease: kidney stones and gallstones. To find a cure for these, physicians tried to understand how these stones were created, what they were composed of, and, consequently, how they could be dissolved.

Odd mineral formations were also a topic of discussion in philosophy. Before the 17th century, in 16th-century Europe, especially crystals and minerals that reflect images constituted an important aspect of a truly fundamental question: who actually created these apparently useless and remarkable minerals, and why? Was it God who had created them for some special reason, or was it nature itself that had created them, somehow following an agenda of its own alongside that of God?[2] The question challenged the premise of God's omnipotence and monopoly when it comes

2 Lorraine Daston and Katharine Park, *Wonders and the order of nature*, 1150–1750, New York, 1998, pp. 286–301. For comments on the discussion in Swedish works, see e.g. Magnus von Bromell, *Inledning til nödig kundskap at igenkiänna och upfinna allahanda berg-arter, mineralier, metaller, samt fossilier, och huru de måge til sin rätta nytta anwändas*, Stockholm, 1730, p. 41 and Torbern Bergman, "Variae crystallorum formae e spatho ortae" in *Nova acta Regiae Societatis Scientiarum Upsaliensis*, 1773, p. 150.

to taking the initiative to create things in the world.

But the question of how mi erals are formed was also of i terest from an economic ang The idea was not merely to u cover and identify valuable mi erals, but also to understand t processes themselves, with eye to controlling them. Expe ments were performed to cr ate hard materials and dissol them.[3] There was a great deal for entrepreneurs to exploit, and the quest for knowledge at the universities went hand in hand with the growth of the mining industry in Sweden.



Snow crystals depicted in the dissertation *De nive* (On Snow) by Andreas Spole (*praes.*) and Gustav Lallerman (*resp.*), Uppsala, 1697.

A special branch of the discussion about the growth of minerals had to do with crystals. Crystallography, as we call it today, did not exist in those days, but various forms of crystals nevertheless aroused great interest. Salt, snow, and ice, which consist of crystals, of course, were part of the discussion. Scientists were interested in the special properties and growth of crystals, and this was studied as a piece of the puzzle regarding the emergence of minerals. Mineral assessors had also noted that crystals often occurred together with metals. At the universities in Uppsala and Lund scientists discussed not only transparent crystals but all types of minerals with "polyhedron, geometrical bodies, with many facets that are flat and delimited, and many proportional angles".[4] Of special interest were quartz and spar, two types that are abundant in our country. These types were found often to have other bodies encapsulated inside them and were thus of interest in terms of the discussion about the origin of minerals.

Mineral collections, lectures, and dissertations

In connection with the discussion and instruction in the subject, the universities' collections of minerals and crystals grew. At Uppsala University in the mid 18th century, Johan Gottschalk Wallerius and Carolus Linnaeus both taught students about minerals, and they both used collections of stones and minerals in their teaching.[5] Lectures and teacher colloquia were

3 See e.g. Johan Gottschalk Wallerius, *Mineralogia, eller mineral-riket*, Stockholm, 1747, p. 92.

4 Translated from the Latin text in Carolus Linnaeus (praes.), Martin Kähler (resp.) *De crystallorum generatione*, Uppsala, 1747, Thesis II, p. 4.

5 See the section below about the dissertation *De crystallorum generatione*. The collection of stones and minerals that Uppsala University owns today is based on a collection assembled by Anton von Swab (1702–1768), a mineral scientist and mineral assessor. The collection was purchased in 1750 for the newly established Department of Chemistry and at the time was considered to be "one of the most significant collections in Europe" (*Svenska män och kvinnor*, "Swab, Anton von").

part and parcel with dissertation writing. Stone and mineral studies were treated by Swedes in individual monographs that were of great importance, but also to the same extent, if not greater, in the University's dissertations. However, in the 17th century there were no publications that dealt exclusively with crystals; they were treated in sections of scientific works and dissertations that were about other main subjects.

The early 17th century

During this period scientists' understanding of the generation of crystals was closely connected to their knowledge of the formation of minerals in general. One example of the state of knowledge at the time of the University's earliest new start, in 1625, is found in the dissertation *De lapidibus* (On stones), submitted under the supervision of the professor of medicine, Johannes Chesnecopherus.[6] *De lapidibus* is entirely based on the earlier European discussion in the subject. That discussion revolved around the idea of a mineral-generating seed and mineral-generating breathing, sometimes called Gorgonian breath (after the Gorgon sisters in Greek mythology) as the cause of the birth and growth of minerals.[7]

A Gorgon, whose gaze could turn things to stone, provided the name for the "spirit" that certain 16th-century natural scientists assumed could penetrate things and turn them to stone. *Medusa* by Arnold Böcklin, ca. 1878.

In *De lapidibus* a clear distinction is drawn between this mineral breathing (*spiritus*, *exhalation*) and the fact that a mineral could have its own spirit (*anima*): A mineral, it is said, is a body, perfectly mixed, without a spirit (*inanimatus*), hard, a mixture of a dry earth exhalation (*exhalatio*) and a kind of watery muck (*unctuositas*), "as put together by the course of time and the force of heat or cold and the mineral's special capacities and properties".[8] According to *De lapidibus* minerals do not grow in any true sense of the word. After all, they receive no nourishment – for how could it be ingested and digested?[9] But minerals nevertheless *can* grow, on the surface of another mineral. This occurs because moisture coming out of the mineral lies on the surface of the mineral and combines with something coming from outside, under the influence of heat. This moisture coming from the mineral (for example it may have been the case that the mineral was previously under water and had absorbed moisture) contains something called "mineralness", or a mineral quality that makes it turn to stone when it comes in contact with air.

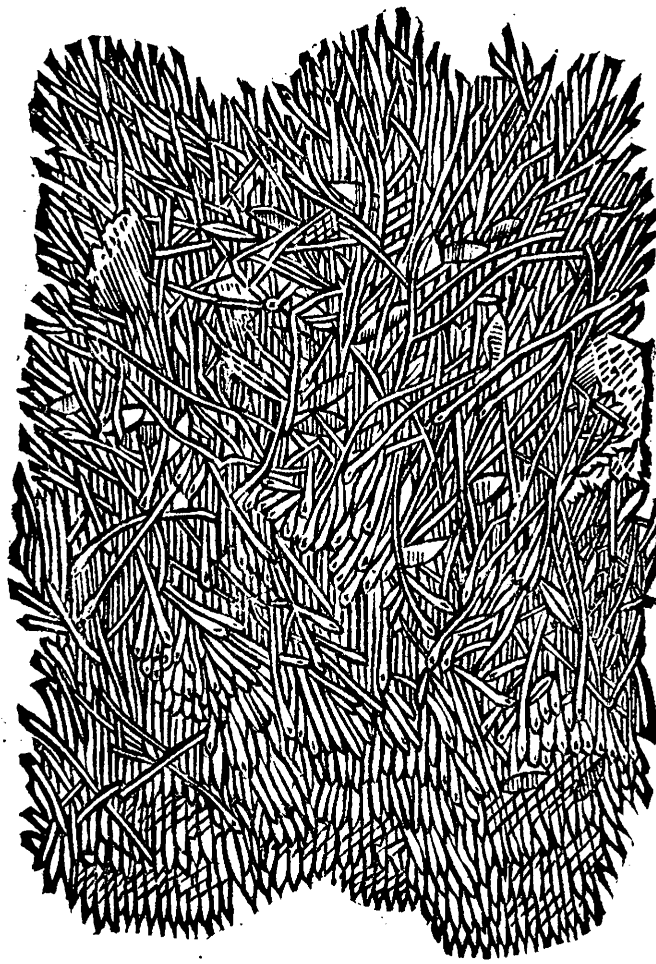
The principal authority in this matter in Chesnecopherus/ Kilius was the German mineralogist Georg Agricola. Agricola is generally thought

6 Johannes Chesnecopherus (praes.), Zacharias Olai Kilius (resp.), *De lapidibus*, Uppsala 1625. The public defence was presided over by a *praeses*, while the *respondent* was responsible for defending the thesis.

7 Frank D. Adams, *The Birth and Development of the Geological Sciences*, Baltimore, 1938, pp. 78–102; esp. 84–90; Daston & Park, Wonders, pp. 286–287.

8 Translated from the Latin text in *De lapidibus* Thesis I:2.

9 Cf. the account of the European discussion in Adams, *The Birth*, pp. 94–95.

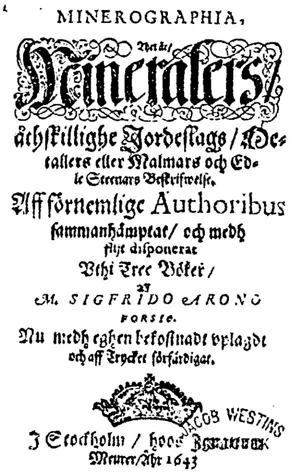


Stone in the form of flax. From F. Imperato, *Historia Naturalis*, Coloniae, 1625.

to have been the first to clearly express the idea that a stone arises from stone juice (*succus*) in combination with heat or cold.[10] Prior to this the idea of the stone-generating seed (*semen petrificum*) had been dominant. What was meant by stone juice was a liquid containing extremely small stone or mineral particles, for example as a result of water rubbing off stony substances, as it flows through stony areas, and taking them with it.[11] It was thought that cold or heat caused the stone or mineral matter in the juice to precipitate and be deposited. This stone juice in liquid form could also be ingested by other creatures, plants and animals, and this could turn them to stone.

In the Uppsala dissertation *De lapidibus*, crystals are given their own section: it is said here that crystals are a mineral that is transparent, light, "born of ice through a violent force of cold".[12] A crystal is not plain water that has congealed: in that case glaciers would be made of crystal, and

10 Adams, *The birth*, 93–94.
11 The word *succus* is used in classical Latin for a liquid that is somewhat syrupy.
12 Translated from the Latin text in *De lapidibus*, Thesis I: 29–30.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there would be many more crystals in cold regions than in warm ones. Nor do crystals thaw in sunlight. No, according to the dissertation, a crystal consists of a juice (*succus*) that is "condensed by cold", and put together in the ground. There is no discussion of what this juice might consist of.

Mineralogy in Swedish

Some twenty years after *De lapidibus*, in 1643, a "non-academic" work appeared in Swedish about minerals, *Minerographia* by Sigfrid Forsius.[13] Forsius, too, presents the same composition of minerals as in *De lapidibus*, minerals, an exhalation of earth and moisture that through "the inborn mineral force" becomes stone when it is exposed to heat or cold.[14] But in the case of gems and crystals a "peculiar influence and force of the heavens" is involved, and gems contain within them "remarkable forces and virtues". This harks back to basically Aristotelian reasoning that the influence of heavenly bodies was part of the creation of minerals in the ground.[15] Interestingly, Forsius' reasoning about crystals also seems to be of an older vintage than what was put forward in *De lapidibus* twenty years earlier. To be sure, Forsius writes that crystals are "born of the purest fluid that the earth conceals",[16] but Forsius also quotes the medieval Albertus Magnus, who claims that crystals originate from long-standing snow in the mountains, a thought which had already been refuted in *De lapidibus*. On the other hand, the two works agree that extreme cold or heat plays a critical role in the growth of crystals.

Later 17th century

In the late 17th century, in 1687, Johannes Unonius at Uppsala University presented the dissertation *De augmentatione in genere et de generatione lapidum metallorumque in specie* (On growth in general and on the generation of stones and metals in particular) with the professor of medicine Andreas Drossander as *praeses*. The dissertation has no section devoted to crystals, but it shows how the Swedish discussion about the growth of minerals had progressed. Drossander/ Unonius are convinced that there must exist "*a kind of principium* (cause, principle) *that not seldom converts things it happens upon to stone*".[17] *De augmentatione* refers to the notion that air could contain extremely small mineral particles, just as water is described as doing in the above-mentioned dissertation *De lapidibus*. The particles are so tiny that they can penetrate other bodies through their pores and "invest and

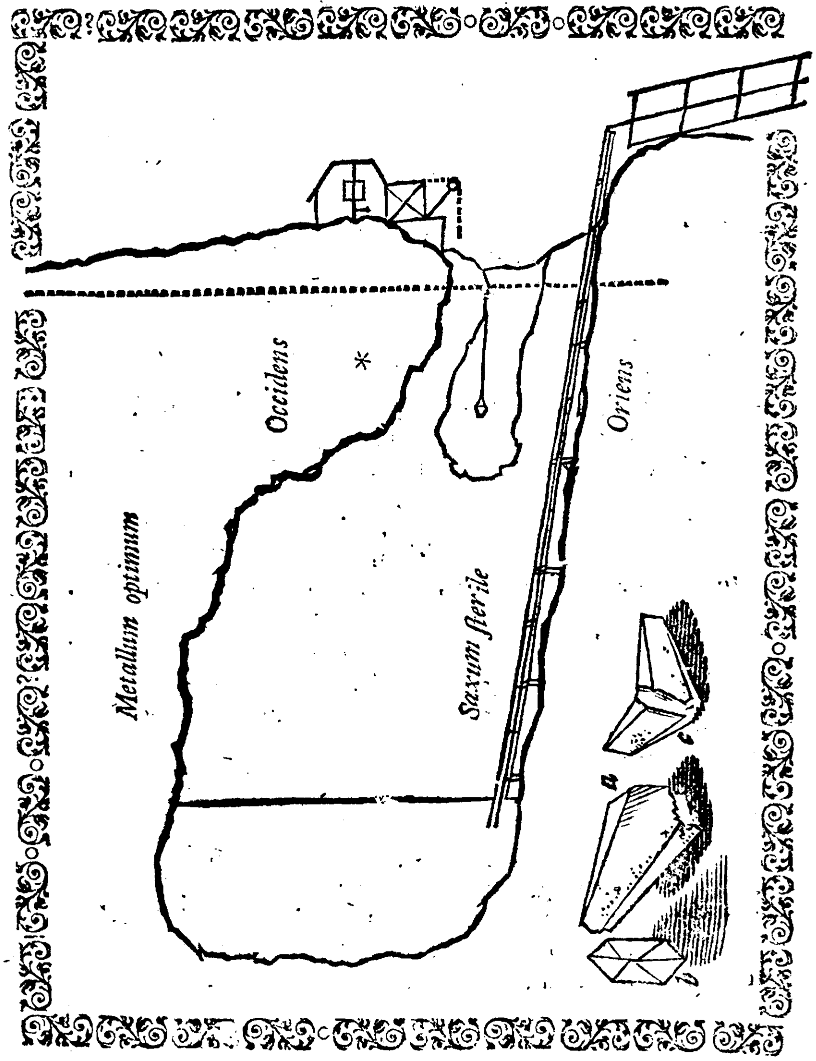
13 Sigfrid Aron Forsius, *Minerographia, thet är, mineralers, åthskillighe jordeslags, metallers eller malmars och edle steenars beskrifwelse*, Stockholm, 1643; Cf. Frängsmyr, *Geologi och skapelsetro*, pp. 17–69.

14 Translated from the Swedish text in Forsius, *Minerographia*, pp. 82–83.

15 Adams, *The Birth*, pp. 83–84.

16 Translated from the Swedish text in Forsius, *Minerographia*, p. 117.

17 Translated from the Latin text in *De augmentatione*, Cap. II, Thesis VII–VIII (pp. 19–22).



Depiction of the Dannemora Mine and of crystals found there. From the dissertation *De metallo dannemorensi* by Lars Roberg (praes.) and Magnus Sunborg (resp.) Uppsala, 1716.

involve them from all directions".[18] One of the authors Drossander/ Unonius rely on, Johannes Helmontius, supports the idea that minerals can emanate some kind of mineral quality to their surroundings.[19] In this way various things can also be turned to stone in a mineral-rich environment. *De augmentatione* suggests that salt would be a suitable object of study for those wishing to further pursue the study of the generation of minerals.

Mineralogy, mining science, and the mining industry

The late 17th and early 18th centuries saw a growing number of books and dissertations on the theme of stones and minerals. In 1694 Urban Hiärne

18 This thought is also expressed in Hiärne, *En kort anledning*, [see note 20] p. 78ff.
19 Johannes Baptista Helmont, *De lithiasi*, Coloniae Agrippinae, 1644, which is thus about *lithiasis*, stone disease.

published a book in Swedish about how ore and minerals can be located;[20] at the universities several dissertations were submitted on the subject, with especially many under the presidencies of professors Per Kalm (1716–1779), Åbo, Pehr Adrian Gadd (1727–1797), Åbo, Gustaf Harmens (1699–1774), Lund, and Johan Gottschalk Wallerius (1709–1785), Uppsala. During this period, Uppsala professor of medicine Lars Roberg supervised a dissertation on "Dannemorametallen" (The Dannemora Metal, 1716).[21] This study also includes images of several different crystals found in the famous Dannemora Mine, and certain types are said to have indicated that there was iron ore in the vicinity. Magnus von Bromell's successor (1730) to Hiärne's mineralogy also mentions Dannemora and its crystals, pointing out that it is important to "carefully observe places where Crystals grow abundantly, as underneath them marvellous metals are likely to lie concealed".[22] Around this time some books also appeared that have become known as pioneering works in mineralogy: Linnés *Observationes in Regnum lapideum* (1739) and the third part of his *Systema naturae*, which deals with the mineral kingdom, along with J. G. Wallerius' *Mineralogia eller mineral-riket* (1747).[23]

The first dissertation about crystals

In 1747, under the presidency of Linnaeus, a dissertation was put forward with the title of *De crystallorum generatione*, "On the Generation of Crystals", the first Swedish work to deal solely with crystals, in particular "stone crystals".[24] In the foreword it is stated, in the voice of the respondent, Martin Kähler, that the *praeses* (that is, Linnaeus) has already presented the dissertation's theories in his *Observationes in Regnum Lapideum* (Observations concerning the Mineral Kingdom), but that there were those who felt that his word lacked weight.[25] But that must be because, according to the respondent, they had never heard the highly celebrated *praeses* explain these things personally, and that they have not had the opportunity to see the large collection of crystals from the Museum that he usually shows to his audience.

20 Urban Hiärne, *Een kort anledning till åtskillige malm- och bergarters, mineraliers, wäxters, och jordeslags, sampt flere sällsamme tings effterspöriande och angifwande*, Stockholm, 1694.

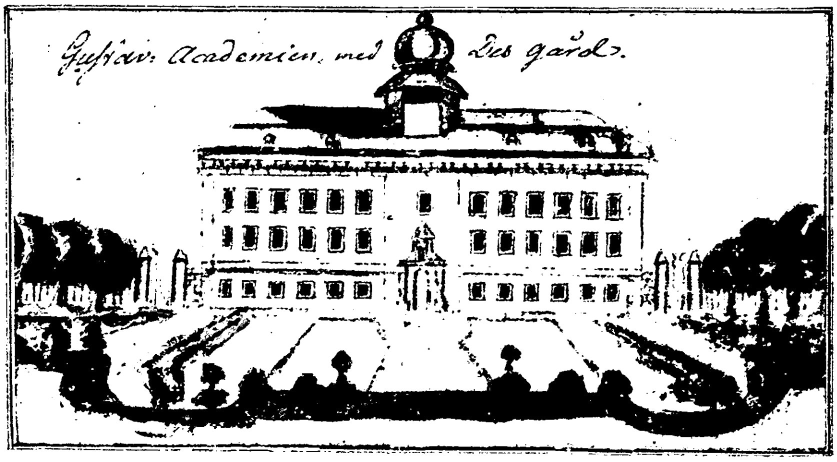
21 Lars Roberg (praes.), Magnus Sunborg (resp.) *Dissertatio mineralogica de metallo Dannemorensi*, Upsaliae, 1716.

22 Translated from the Swedish text in Magnus von Bromell, *Inledning til nödig kundskap*, pp. 39–40.

23 Carl von Linné, *C.Linnæi M.D. observationes in regnum lapideum*, [Uppsala], 1739; Johan Gottschalk Wallerius, *Mineralogia, eller mineral-riket*, Stockholm, 1747. Cf. Frängsmyr, *Geologi och skapelsetro*, pp. 228–291.

24 Carl von Linné (praes.), Martin Kähler (resp.), *Specimen academicum, de crystallorum generatione*, Upsaliae, 1747.

25 *De crystallorum generatione*, Praefatio (s. 2). It is stated that Chapters II and III of the dissertation are actually taken from Linnaeus' *Observationes in Regnum lapideum*.



The Gustavianum, where Linnaeus lectured as a professor. Illustration by J. G. Härstedt, reproduction: Uppsala University Library.

In *De crystallorum generatione* it can clearly be seen how the assumptions about the growth of minerals in the 17th-century dissertations discussed above constitute the foundation for the dissertation's reasoning about how crystals are formed. Among other things, the introduction points to the fascinating phenomenon of crystals being able to grow *without* any "seeds" being involved. Therefore, crystals are deemed to be "the most difficult question to bend the intellect of the sharpest philosophers".[26]

The theory put forward in *De crystallorum generatione* is basically familiar. Linnaeus/ Kähler present a combination of several causes that had previously been proposed. The authors are convinced that quartz and spar, for example, are actually formed in crevices in rocks, where water lingers. The water that accumulates in crevices contains particles of stone, salt, and grease.[27] These particles lie on the bottom of the crevice and, together with the stone evaporation coming from the cliff itself, make the deposits coagulate as the water evaporates. It is possible that air also somehow contributes to this formation, but nothing is said about extreme cold or heat.

As in *De augmentatione* from 1687, salt is claimed to play a crucial role in the formation of crystals.[28] According to Linnaeus/ Kähler, salt is the unique cause of crystallisation, as no other body was known to become crystallised. The fact that crystals can have the same form as mineral salt and earth salt was thus taken as proof that they are fundamentally composed of salt. Quartz often has the same forms as saltpetre, spar the same forms as calcium salt, etc.

Concerning the processes themselves, Linnaeus/ Kähler go one step further into the inner structure of minerals in their reasoning than the earlier dissertations had ventured. The author claims here that salt (which is

26 It was quite common at this time for the introduction to a dissertation to state that the subject is particularly challenging (and, for that matter, the author's abilities are highly limited in relation to it).

27 *De crystallorum generatione*, Cap. II (pp. 5–11).

28 *De crystallorum generatione*, Cap. III (pp. 11–14).

only active in dissolved, liquid form) shapes the stone particles into a fixed figure like its own.[29] Together they form the substance (crystal-)stone: "Without this conformation of particles, crystallisation could hardly take place. We have thus seen that salt unites and determines the stone particles in such a way as to create a figured stone."

Crystal science at Lund

On the heels of Linnaeus'/ Kähler's dissertation on crystals and a dissertation submitted under Johan Gottschalk Wallerius *Om Qvarts* [On quartz] (1753),[30] a dissertation was presented at Lund, *De generatione lapidum et crystallisatione* (On the Generation of Minerals and on Crystallisation, 1752) with Gustav Harmens as *praeses* and Jacob Öjebom as respondent.[31] Harmens/ Öjebom clearly summarize the state of knowledge and also devote considerable space to reasoning about which minerals were present at Creation and which were not.[32]

Harmens'/ Öjebom's dissertation contains wholesale quotations from Linnaeus'/ Kähler's *De crystallorum generatione*, and Wallerius' *Mineralogia* is also cited and referred to, as are a number of foreign authorities. But Harmens nevertheless takes up older reasoning that cold has something to do with the formation of crystals, and the idea is that crystals are a kind of ice.[33] He describes how saltpetre lowers the temperature of water and ice, so that ice can be produced in the middle of summer. Salt and ice together can get down to 72 degrees, "if a mercury thermometer is used". For that reason, among others, Harmens/ Öjebom are also favourably inclined towards the view that by using "nitrous cold" it is possible to produce water as hard as diamond, even if the surroundings are otherwise warm. They are also sympathetic to the view that all crystals, "gemstones", are mainly formed in this way. But when it comes to precisely how this happens, Harmens/ Öjebom demur: "Who would dare to declare how such a degree of cold through a large admixture of saltpetre suddenly, under unknown circumstances, can be achieved that the entire mass of muddy water (according to the hypothesis) will become like a crystal." For, he states, no matter what, one has not managed to create ice that does not melt again when it gets warm. Nor has one managed to create crystals from saltpetre.

An outgrown suit of clothes

Harmens/ Öjebom conclude their presentation by stating that examining nature is a remarkable source of pleasure for humans. This is because na-

29 *De crystallorum generatione*, p. 14.

30 Johan Gottschalk Wallerius (praes.), A. Hedman (rsp.), *Om Qvartz.* Uppsala, 1753.

31 Harmens, Gustaf (praes.), Jacob Öjebom (resp.), *Dissertatio mineralogica de generatione lapidum et crystallisatione*, Lund, 1752.

32 *De generatione lapidum et crystallisatione*, §V–IX (pp. 6–13).

33 *De generatione lapidum et crystallisatione*, §XII (pp. 15–16).

ture is a divine work of art, against which all human arts are to be measured. This type of comment occurs frequently in scientific writings during this period and can, of course, be seen as an ambition, typical of the day, to place their research in the context of a grand understanding of the cosmos. But such statements can also be seen in the light of a discussion of the new natural science in relation to the knowledge of nature presented in the Bible: At Uppsala University, this was right after the end of the Cartesian disputes, which concerned, among other things, whether natural science must regard the Bible as the highest authority.[34] All mineralogists and geologists had to find their own position in regard to this tradition in flux. Linnaeus raises a delicate and cautious question in his dissertation *Cui bono?* (To What Good?) (1752).[35] There he notes: "In our minerals we notice animals, shells, and corals, very rare and immersed as if in a balm, living specimens of which we would search for in vain throughout Europe." This, Linnaeus maintained, prompts us to wonder about the ancient form of the earth, how it has grown and been transformed.[36]

Of course, the efforts to understand the essence of crystals that Swedish scientists participated in and contributed to in the 17th and early 18th centuries laid the foundation for our knowledge of the formation of crystals today. To my mind, trying to understand how they reasoned and experimented, following all their side-tracks and dead ends, is the most charming aspect of the history of science. We recognize in this our own quest for knowledge today, at once naive and well grounded, a quest that has never followed a straight path – and never will.

34 Sten Lindroth, *Svensk lärdomshistoria. Stormaktstiden*, Stockhom, 1997, pp. 447–465; Frängsmyr, *Geologi och skapelsetro*, pp. 182–216; Rolf Lindborg, *Descartes i Uppsala: striderna om "nya filosofien"* 1663–1689, Stockholm, 1965, pp. 158–161; 175–179.
35 Carl von Linné (praes.), Kristoffer Gedner (resp.), *Quæstio historico naturalis, Cui bono?* Uppsala, 1752.
36 From the Latin text in *Cui bono?*, pp. 11–12; see also pp. 28–39 and cf. Frängsmyr, *Svensk idéhistoria* Part I, pp. 251–252.

Photo of amber: Mats Knutsson/ Geobiten