Data mining to discover the causes of internal reflectivity within the Ni-Cu-PGE-bearing Kevitsa intrusion

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The Kevitsa Ni-Cu-PGE disseminated sulphide deposit is hosted by the Kevitsa mafic to ultramafic intrusion, located within the Central Lapland Greenstone Belt in northern Finland. A 3D seismic reflection survey was conducted in Kevitsa in 2010 for mine planning and deep mineral exploration purposes. Within the Kevitsa resource area, the 3D seismic data are characterized by laterally continuous reflections. Here we use data mining, namely Self-Organizing Map (SOM), analysis to better understand the possible causes of reflectivity within the Kevitsa intrusion. The results show that the mineralized zones within the intrusion could be potential causes of reflectivity, and hence could set potential exploration targets in the area.

Keywords: data mining, reflection seismic data, exploration, self-organizing maps (SOM)

1. Introduction

Data mining approaches, such as Self-Organizing Maps (SOM), can be used for objective analysis of the complex and sparse geophysical and geological data sets typical for mining camps, to better understand the underlying linear and non-linear relationships between the different data. The SOM analysis (Kohonen, 2001) is based on vector quantization and measures of vector similarity. It is unsupervised, so no prior knowledge is required on the nature or number of clusters within the data. The underlying statistical relationships between different data are visualized with 2D maps that make the interpretation of the multidimensional, complex data possible. The main objective of this study was to use the SOM analysis to better understand the potential causes of observed internal reflectivity in the 3D seismic reflection data within the Kevitsa intrusion, and its relationship to the disseminated Ni-Cu-PGE-bearing sulphide mineralization.

2. Background and motivation of the study

The Kevitsa Ni-Cu-PGE deposit is hosted by the Kevitsa mafic-ultramafic intrusion located within the Central Lapland Greenstone Belt in northern Finland (Figure 1). The Kevitsa open-pit mine started in 2012 and is currently operated by Boliden. The mine was operated by First Quantum Minerals Ltd. until June 2016. It has been suggested (e.g. Standing et al., 2009) that the extent of economic mineralization is controlled by the extent of smaller-scale, laterally discontinuous and internally differentiated magma pulses that represent a spectrum of olivine pyroxenites consisting of plagioclase and orthopyroxenite rich tops that gradationally change into more olivine and clinopyroxenite rich bottoms. The mineralogical change within an individual pulse is gradational, meaning that no internal boundaries exist within a pulse, but the base of one pulse will grade relatively sharply into the top of another pulse. The mineralization is more strongly associated with the bases of these individual magma pulses.

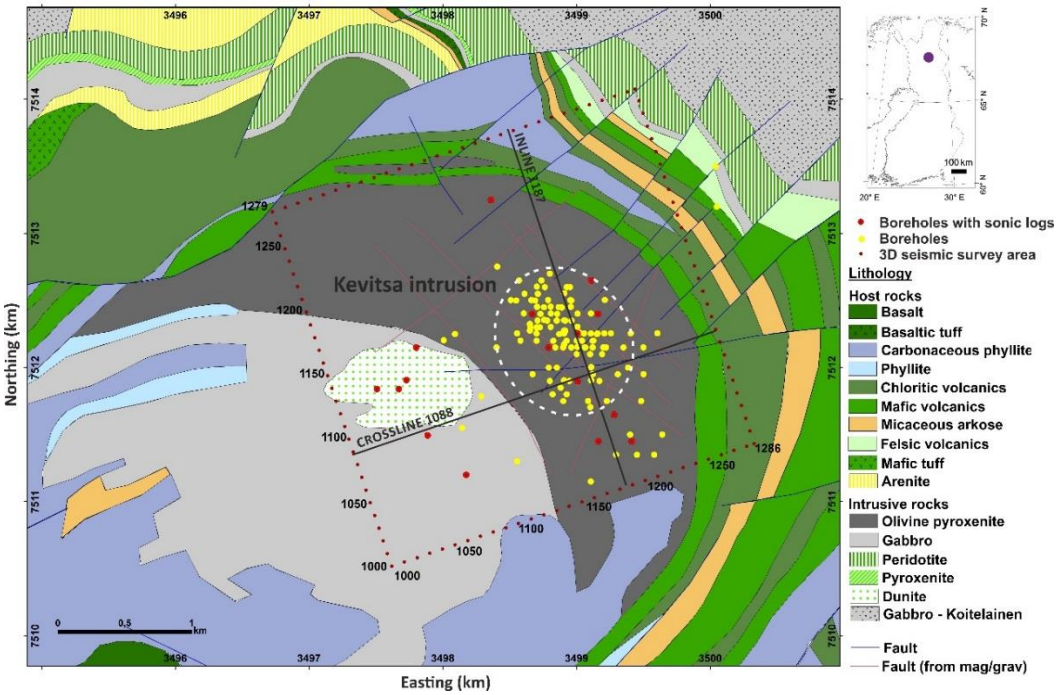

Figure 1. Geological map of the Kevitsa area. Location of the open-pit in dashed white line.

A 3D seismic reflection survey was conducted in Kevitsa in 2010 for mine planning and deep mineral exploration purposes (Malehmir et al., 2012; 2014). The 3D seismic survey area, corresponding to about 9 km^2, is located over the Kevitsa resource area (Figure 1). In earlier studies (Malehmir et al., 2012; 2014; Koivisto et al., 2015), laterally continuous reflections were observed in the 3D seismic data within a constrained area inside the Kevitsa intrusion (Figure 2). It was suggested that this internal reflectivity originates from the contacts between the tops and bottoms of the individual magma pulses controlling the extent of the main economic mineralization. On average, the physical properties of the olivine pyroxenite variants constituting the tops and bottoms of these magma pulses differ enough to produce detectable reflections (e.g., Koivisto et al., 2015). However, the interpretation is not fully supported by the borehole data and therefore, requires further research.

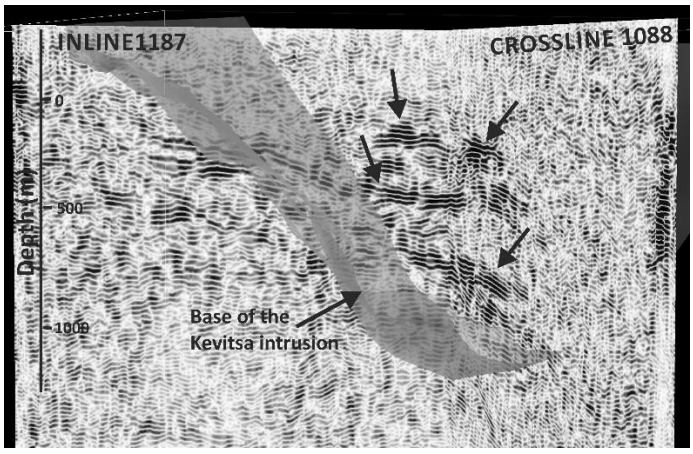

Figure 2. Observed internal reflectivity in the 3D seismic reflection data (Malehmir et al., 2012) within the Kevitsa intrusion. See location of inline 1187 and crossline 1088 from Figure 1. Sections viewed from northwest.

3. Method

In this study, data mining, namely the SOM analysis with SiroSOM (Kohonen, 2001; *SiroSOM*: Fraser and Dickson, 2007), is used to better understand the origin of internal reflectivity observed in the 3D seismic reflection data within the Kevitsa intrusion and its relationship to the Kevitsa Ni-Cu-PGE deposit. At this stage, only borehole data was used to conduct the analyses. In the SOM, the clustering of the complex multidimensional (nD) input data is represented by node vectors that are trained in an unsupervised learning process, based on vector quantization and the measures of vector similarity. Regression is used to map these node vectors from nD to 2D maps. This process preserves the topology of the node vectors. The underlying statistical relationships between different data are visualized with the help of these 2D maps that make the interpretation of the complex multidimensional data possible.

4. Results

The results show that the contacts between the tops and bottoms of the suggested magma pulses do not alone fully explain the observed internal reflectivity within the Kevitsa 3D seismic reflection data (Figures 2 and 3). This is partly because in the Kevitsa borehole data there are not enough samples of the plagioclase and orthopyroxenite rich olivine pyroxenite variant to comprehensively determine the physical properties of the tops of the suggested magma pulses, and map the overall extent. This could partially be attributed to the possible dunitic magma contamination that has resulted in more olivine and clinopyroxenite rich magmas, thus overprinting the extent of the plagioclase and orthopyroxenite rich variants. Most interesting finding in the SOM results is the division of olivine pyroxenite into a lower and higher seismic velocity group (Figure 3), which seem to differ enough to produce detectable reflections (Figures 4). It seems that the mineralization associated with the olivine pyroxenite lowers the seismic velocity, while densities remain about the same, resulting in necessary acoustic impedance difference. The main ore-bearing sulphide minerals in Kevitsa are pyrrhotite, pentlandite and chalcopyrite that tend to lower the seismic velocities of the hosting silicate rocks.

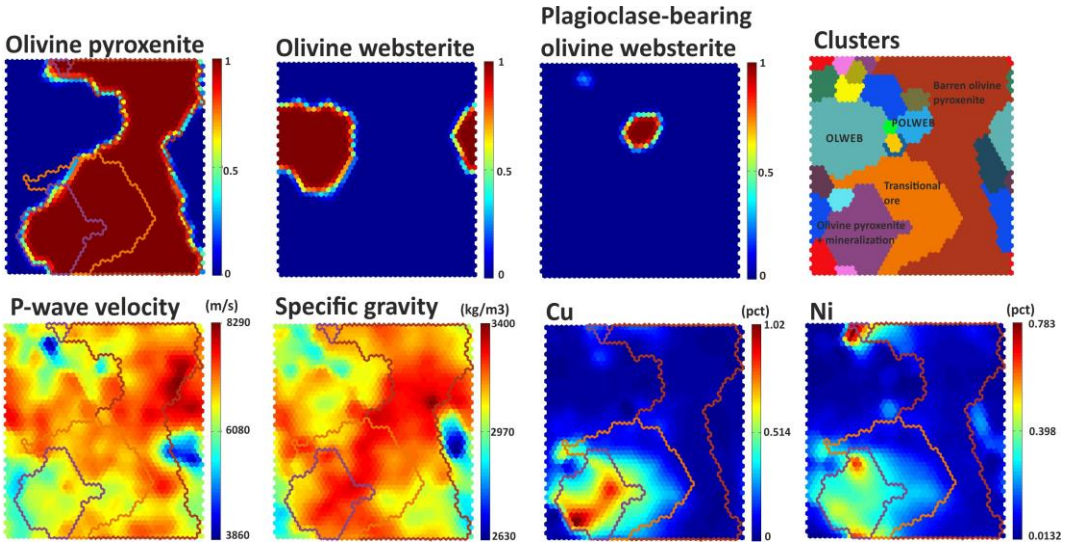

Figure 3. Component plots showing possible causes of reflectivity within the Kevitsa intrusion. The most interesting finding is the lower seismic velocity area that exists within the olivine pyroxenite unit associated with the mineralization (highest Cu and Ni) that makes the olivine pyroxenite itself internally reflective.

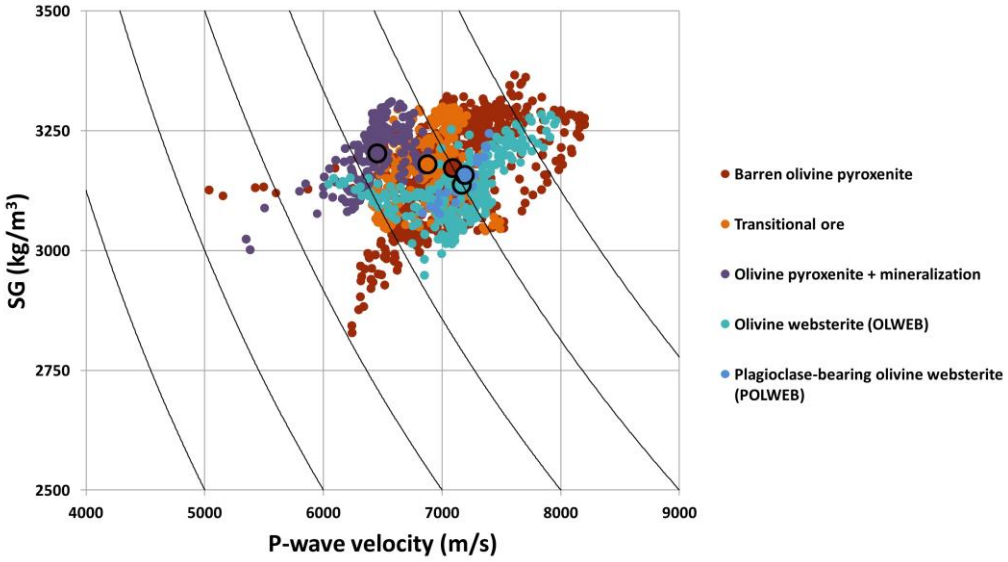

Figure 4. P-wave velocity versus specific gravity (SG) plot for different clusters showing that on average (larger black circled dots) the barren olivine pyroxenite group (maroon) has higher seismic velocity than the olivine pyroxenite group with mineralization (purple). Density does not seem to differ much at all (similar range of densities defines all the groups) resulting in acoustic impedance difference that is enough to produce a detectable reflection.

5. Conclusions

The contacts between the tops and bottoms of the suggested magma pulses do not alone fully explain the observed internal reflectivity in the 3D seismic data within the Kevitsa intrusion. The mineralized zones within the intrusion could be potential causes of the observed internal reflectivity, and hence could set potential exploration targets in the area.

6. Acknowledgements

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