Petrophysics revealing alteration zones of ore deposits

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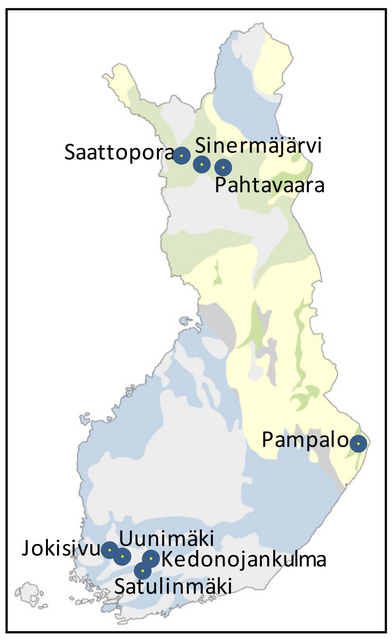


Circulation of hydrothermal fluids and consequent fluid–rock interaction can significantly modify the magnetic properties of ore-bearing deposits. Petrophysical and rock magnetic studies can reveal these alteration processes and are thus important for interpretation of magnetic anomalies and 3D modelling.

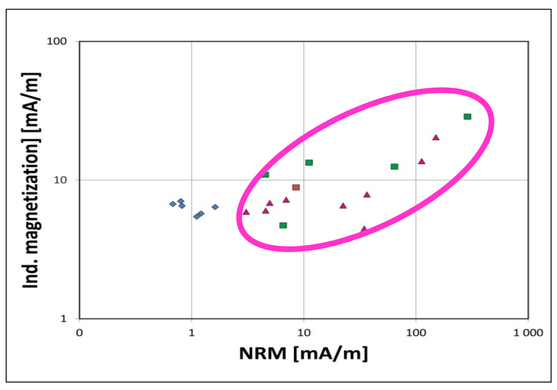
Aim of studies:
1) Detailed petrophysical investigations at outcrop scale to characterize differences between the barren host rock and ore-bearing alteration zone.

2) Usage of combined remanence and AMS data to constrain timing for the hydrothermal alteration and precipitation of ferromagnetic minerals + gold in relation to deformation.

The magnetic properties of orogenic gold or porphyry copper type Cu-Au deposits have been studied in Satulinmäki, Kedonojankulma and Uunimäki of the Häme Belt, in Jokisivu of the Pirkanmaa Belt, in Saattopora, Sinermäjärvi and Pahtavaara in the Central Lapland Greenstone Belt and in Pampalo in the Hattu greenstone belt.

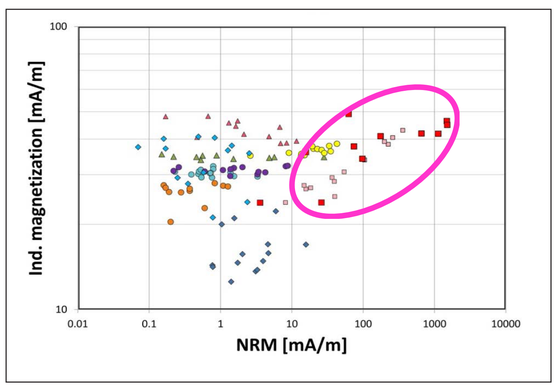
PETROPHYSICS

Kedonojankulma



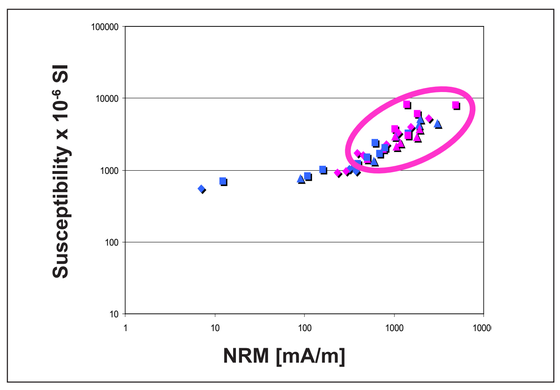
The host rock is quartz-plagioclase porphyry. Samples in the circeled area were taken from a profile accross the auriferous shear zone containing pyrrhotite.

Uunimäki



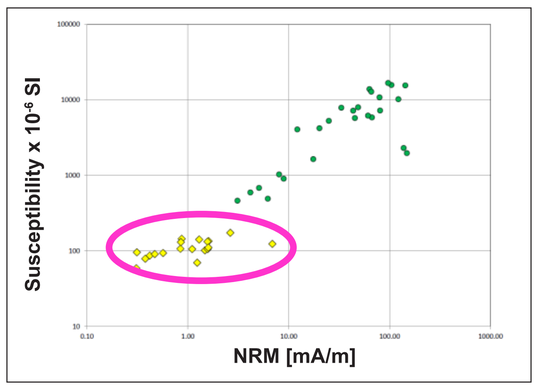
The host rock is gabbro. Samples in the circeled area were taken from the highest IP anomaly where pyrrhotite was formed at the expence of ilmenite.

Jokisivu



The host rock is diorite-gabbro. Samples in the circeled area were taken accross an auriferous shear zone where pyrrhotite was formed at the expence of magnetite.

Pampalo



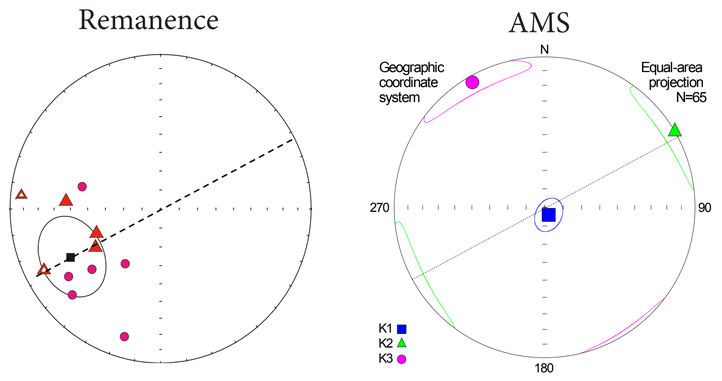
In the Pampalo mine samples were taken from unaltered tonalite and strongly altered felsic feldspar porphyry (circeled area) where magnetite has partly vanished.

In the auriferous shear zones of Kedonojankulma, Uunimäki and Jokisivu the overall susceptibilities and remanence intensities and consequently, the Koenigsberger ratios (Q-values) are slightly increased. This is due to increased amounts of pyrrhotite which is typically associated with gold. The magnetic properties can thus be used to delineate the barren host rock and the hydrothermally altered ore bearing rock.

In Pampalo the hydrothermal alteration is clearly seen as much lower susceptibility and remanence values of the felsic feldspar porphyry compared with the unaltered tonalite.

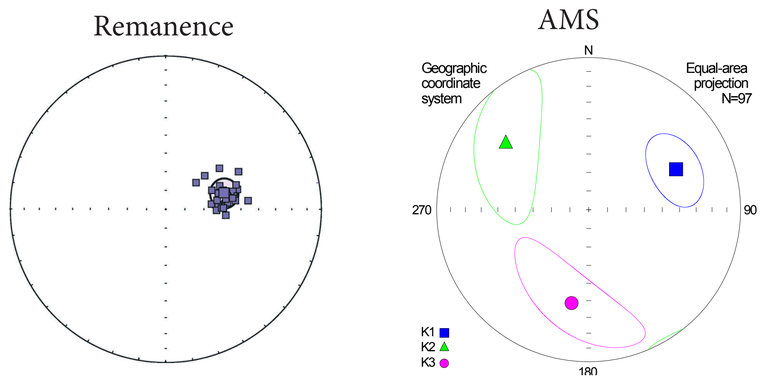
REMANENCE AND AMS

Satulinmäki



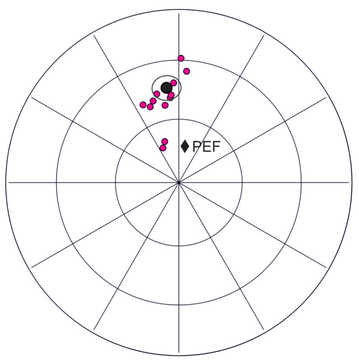
In Satulinmäki the remanence directions and the magnetic foliation plane defined by K3 (AMS) follow the general fault direction (broken line) of the outcrops. The remanence direction deviates from the expected Svecofennian remanence direction. Therefore it is interpreted that the remanence and AMS directions reflect the deformation of the area. Consequently, the emplacement of hydrothermal fluids, coupled with occurrence of pyrrhotite and gold, preceded or was simultaneous with deformation.

Jokisivu



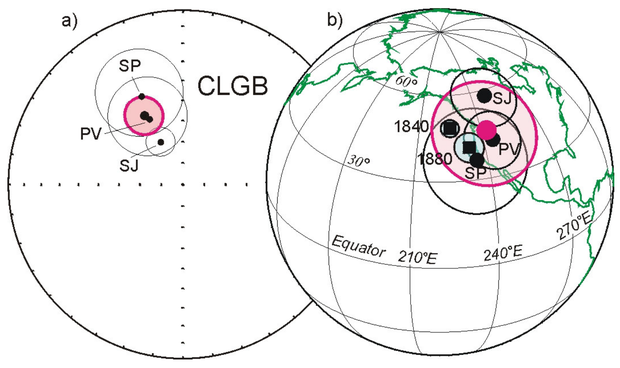
In Jokisivu the mean AMS lineation K1, the remanence directions and the geologically defined lineation have about the same direction. It is interpreted that blocking of remanent magnetization towards the direction of K1 took place simultaneously during the growth of pyrrhotite grains in the ductile-brittle transitional phase. The remanence (CRM) was formed when the grains grew from the hydrothermal fluids in the existing stress field. Consequently, the pyrrhotite and gold are pre- or syntectonic.

Uunimäki



In the Uunimäki gabbro the remanence directions are typically highly scattered with no stable directions. Only at one site that shows the highest IP anomaly a consistent remanence direction was isolated. It represents a typical Svecofennian age (ca. 1.8 Ga) direction. Provided that pyrrhotite and the gold mineralization were formed in a simultaneous process, the gold must be post-tectonic.

Central Lapland Greenstone Belt



In the Central Lapland Greenstone Belt a Svecofennian age remanence direction was revealed in all studied formations. The palaeomagnetic poles form a coherent group around the 1.88–1.84 Ga 'key poles' of Fennoscandia suggesting the maximum age of 1.84 Ga for the acquisition of remanence. Preservation of a Svecofennian age remanence confirms that the rocks have not been deformed after the remanence was blocked. The hydrothermal fluids were emplaced into already existing brittle structures in the post-tectonic stage of the area.

Conclusions

In all studied formations the magnetic properties have altered due to fluid infiltration.

In the Häme and Pirkanmaa deposits the auriferous shear zones show higher magnetizations than the host rocks due to formation of pyrrhotite.

In Pampalo the auriferous rocks have partly lost their magnetization when pyrrhotite was formed at the expense of magnetite.

The general absence of Svecofennian remanent magnetization in the Au mineralizations of South Finland indicates that the Au bearing fluids were injected in the pre- or syntectonic stage of the Svecofennian orogeny.

Occurrence of a Svecofennian age (1.9-1.8 Ga) remanent magnetization in the gold mineralization of the Central Lapland Greenstone Belt indicates that the Au bearing fluids were injected into already existing structures in the late stage of the Svecofennian orogeny.

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