Gravity, aeromagnetic and electromagnetic study of the gold and pyrite mineralized zones in the Haile Mine area, Kershaw, South Carolina

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Abstract

New high resolution gravity, electromagnetic (EM) and magnetic data are tested for the detection of disseminated sulfides in the area of the Haile Gold Mine, South Carolina. Geophysical interpretations were constrained with densities and mineral concentrations measured for 49,183 samples from 448 drill holes. Positive residual gravity anomalies from spectral analysis correlate with the mineralized ore zone. Similar correlations between positive anomalies and the ore zones are observed in the first vertical derivative of Bouguer anomaly and tilt derivatives of the residual gravity. Euler deconvolution of the gravity field also shows numerous shallow sources in the ore zone. Drill core measurements show that metasediments (Richtex unit), (2.76 g/cm3) and gold bearing samples (2.73 g/cm3) are slightly denser than metavolcanics (Persimmon Fork Formation), (2.69 g/cm3). Correlation coefficients for sample density and mineral percentages are pyrite (0.18) and sericite (0.15), indicating that pyrite is the main mineral increasing sample density. 2D forward gravity models constrained by dense drilling match the predicted depth range of density anomalies from Euler deconvolution. Drilling results confirm a spatial correlation between high densities, high pyrite concentrations, and the mineralized zones. High conductivity anomalies are observed over the Haile ore zone as well as over the metasediments. Core drilling and 2D inversion show that high conductivity anomalies coincide with zones of high pyrite concentrations. The magnetic field is dominated by anomalies produced by granite plutons 3 km north and 5 km west of Haile and northwest-trending Jurassic diabase dikes. East-northeast trending linear anomalies have been sampled and dated as Alleghanian lamprophyre dikes providing the first magnetic map of these intrusions in the southeastern United States.

Introduction

The study area (Fig. 1) is located in the northern part of South Carolina between Kershaw and Jefferson. The deposit at Haile consists of multiple discontinuous ore bodies with disseminated gold in silicified and pyrite-rich metasediments (Richtex). The ore bodies trend east-northeast, subparallel to the structural trend of the Carolina terrane (SRK Consulting, 2017).

In the Haile Mine area in South Carolina, the ore deposits and bedrock geology are covered by a 10 to 40 meter thick blanket of saprolite, kaolin-rich residuum derived from intense weathering in sub-tropical climates. On top of that, an apron of coastal plain sand, up to 23 meters thick, covers much of the Haile property (SRK Consulting, 2017). In this study we show that the high resolution residual gravity anomalies correlate with the ore mineralized zones at Haile and offer a possible explanation for this correlation.

Methodology

Power spectrum method used to separate long (deep) and short (shallow) wavelength potential field anomalies, the cutoff wavelengths and information about the contribution of the short and long wavelengths in the spectrum can be obtained from the calculated radially-averaged power spectrum of the data using fast Fourier transform (FFT) (Spector and Grant, 1970; Bhattacharya, 1965). The filtered residual Bouguer gravity anomaly maps over the Haile Mine (Figs. 3b) were produced by applying a Butterworth highpass filter to isolate wavelengths less than 2 km for gravity. To enhance the signal related to near-surface geological structures, Bouguer gravity data filtered using the first vertical derivative (Fig. 2b).

Results

The residual gravity anomaly map (Fig. 3b) shows a correlation between positive residual anomalies and the mineralized ore zone in the Haile mine area (also compare to bedrock geology in Fig. 1).

Why are the metasediments and gold-bearing rocks denser than the metavolcanics? Densities were measured and mineral concentrations visually assessed for 49,183 samples from 448 drill holes in the Haile Mine area (Fig. 4) from OceanaGold 2016 drilling as well as from previous drilling by Romarco. The measurements included 36,061 metasediments, 13,091 metavolcanics, and 31 gold-bearing samples. The average densities (Fig. 3a) are metasediments: 2.76 g/cm3, metavolcanics: 2.69 g/cm3, and gold bearing samples: 2.73 g/cm3. Fig. 4d shows the correlation coefficients for sample density and mineral percentages. The highest density correlations are pyrite (0.18) and sericite (0.15), indicating that pyrite is the main mineral increasing sample density. A scatter plot (Fig. 4c) also shows that density and % pyrite have a positive linear correlation: density (g/cc) = 2.73 + 0.014 (% pyrite). Fig. 4b shows that the average concentration of pyrite in the gold-bearing rocks is 1.5%, metasediments: 1.1%, and metavolcanics: only 0.25%.

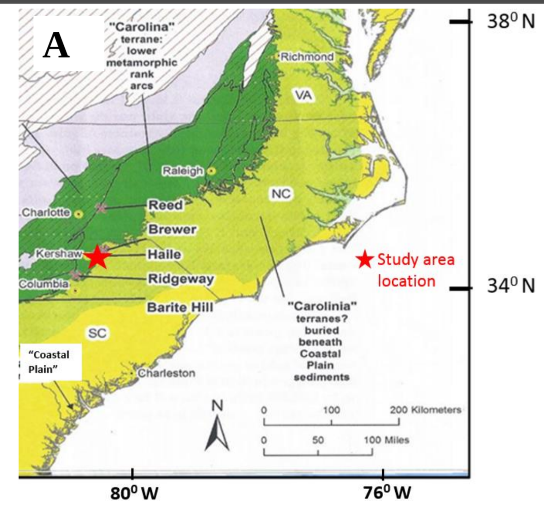
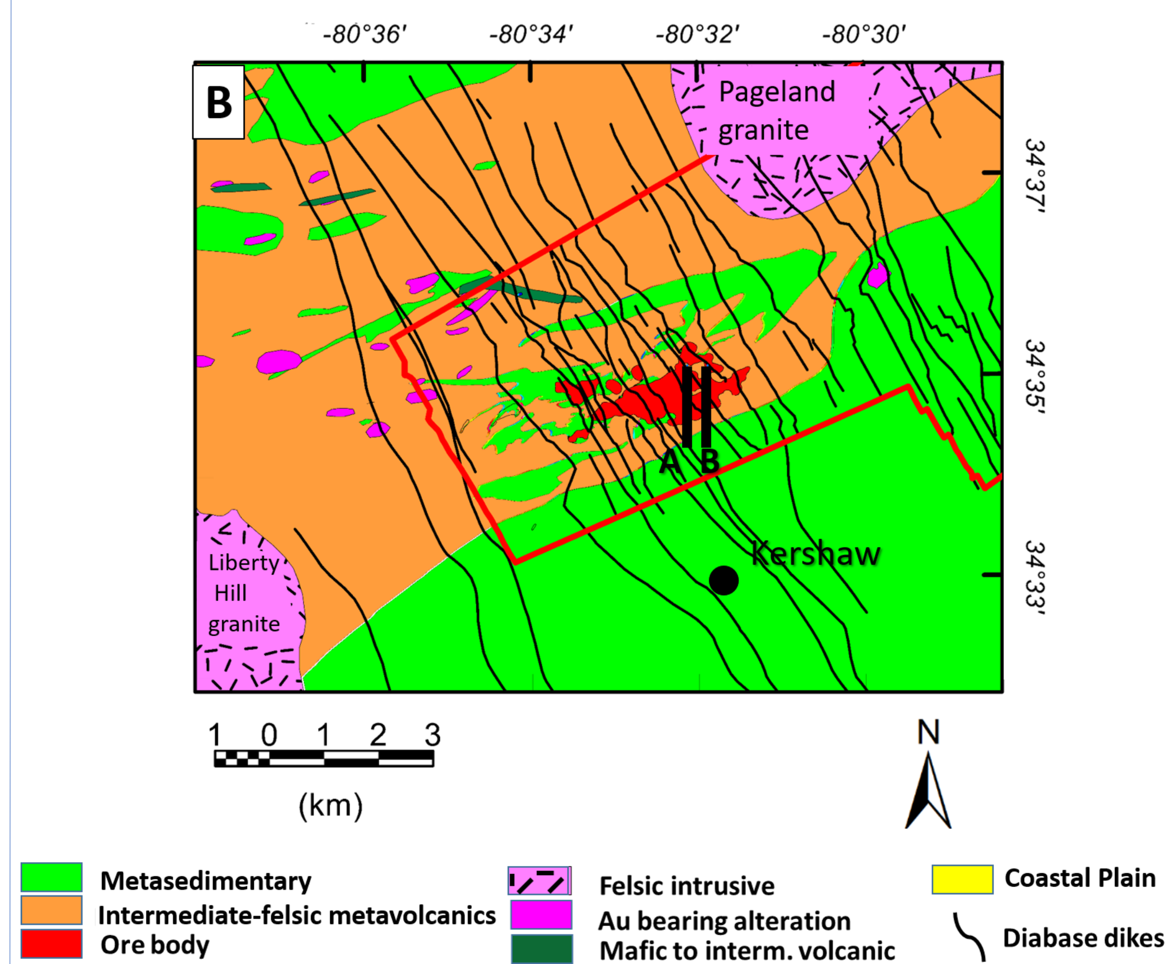


Fig.1: A) is location map . B) is geological bedrock map at 300 ft (91 m) above sea level. The red polygon outlines the southwest area covered by the helicopter survey. The black lines are A and B profiles after Mobley et al. (2014).



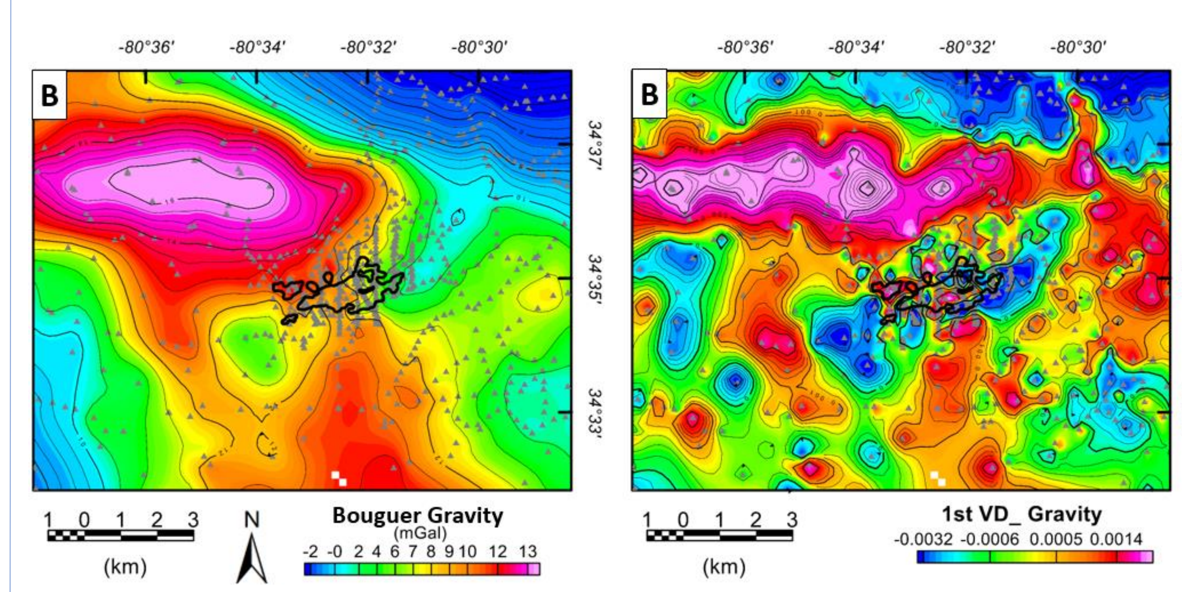


Fig.2: A) Bouguer anomaly map showing all gravity stations. B) First vertical derivative of Bouguer gravity map. Black outline is Haile Mine ore body extent.

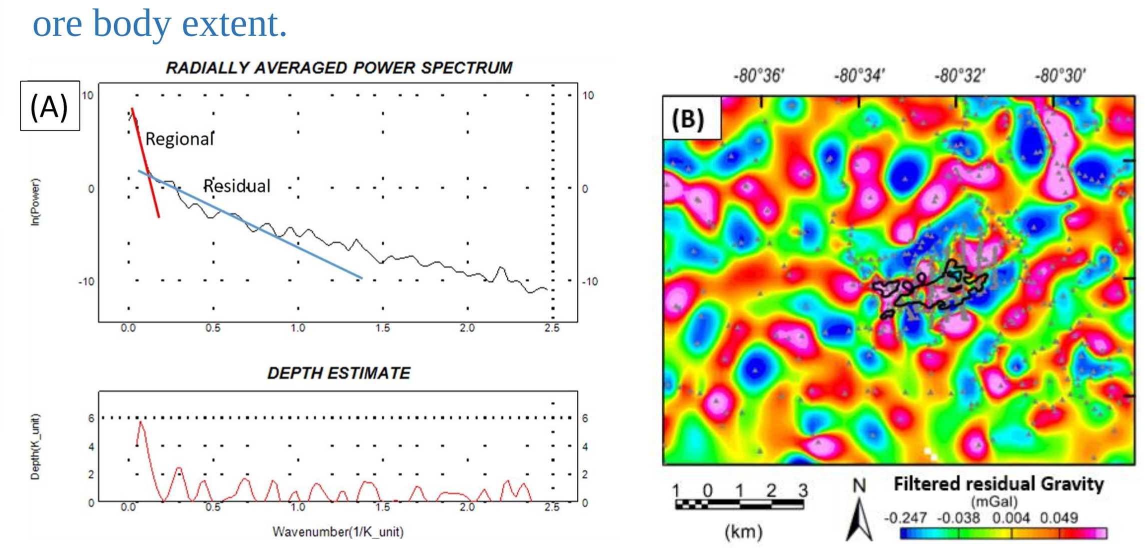


Fig.3: A) Power spectrum of Bouguer anomaly map. B) Filtered residual Bouguer anomaly map. Map B is produced by applying a Butterworth highpass residual filter with wavelength cutoff of 2 km. Black outline is Haile Mine ore body extent.

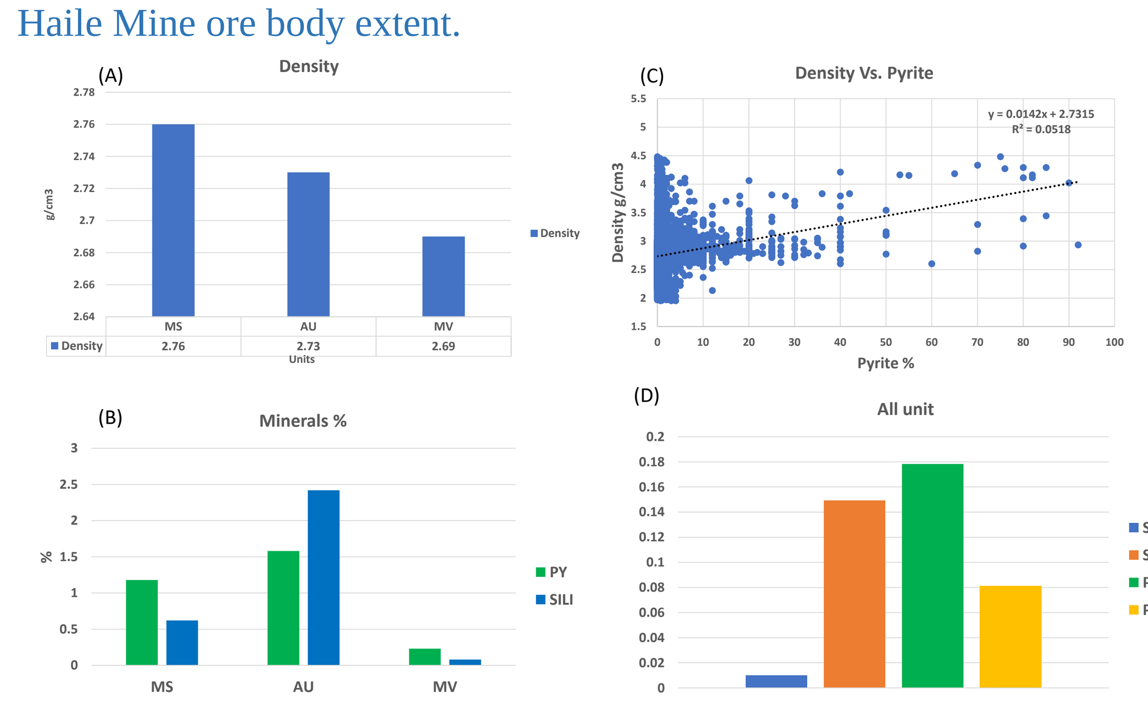


Fig.4: A) Average densities of metasedimentary units (MS), gold bearing metasedimentary units (AU) and metavolcanic units (MV) from 49,183 measurements from 448 drill holes (OceanaGold). Number of measurements: MS: 36,061, AU: 31, MV: 13,091. B) Average percentages of pyrite (green) and silicification (blue). C) Sample density vs pyrite %. D) Correlation coefficient results for minerals and density: silicification (SILI), sericite (SER), pyrite (PY), pyrrhotite (PO).

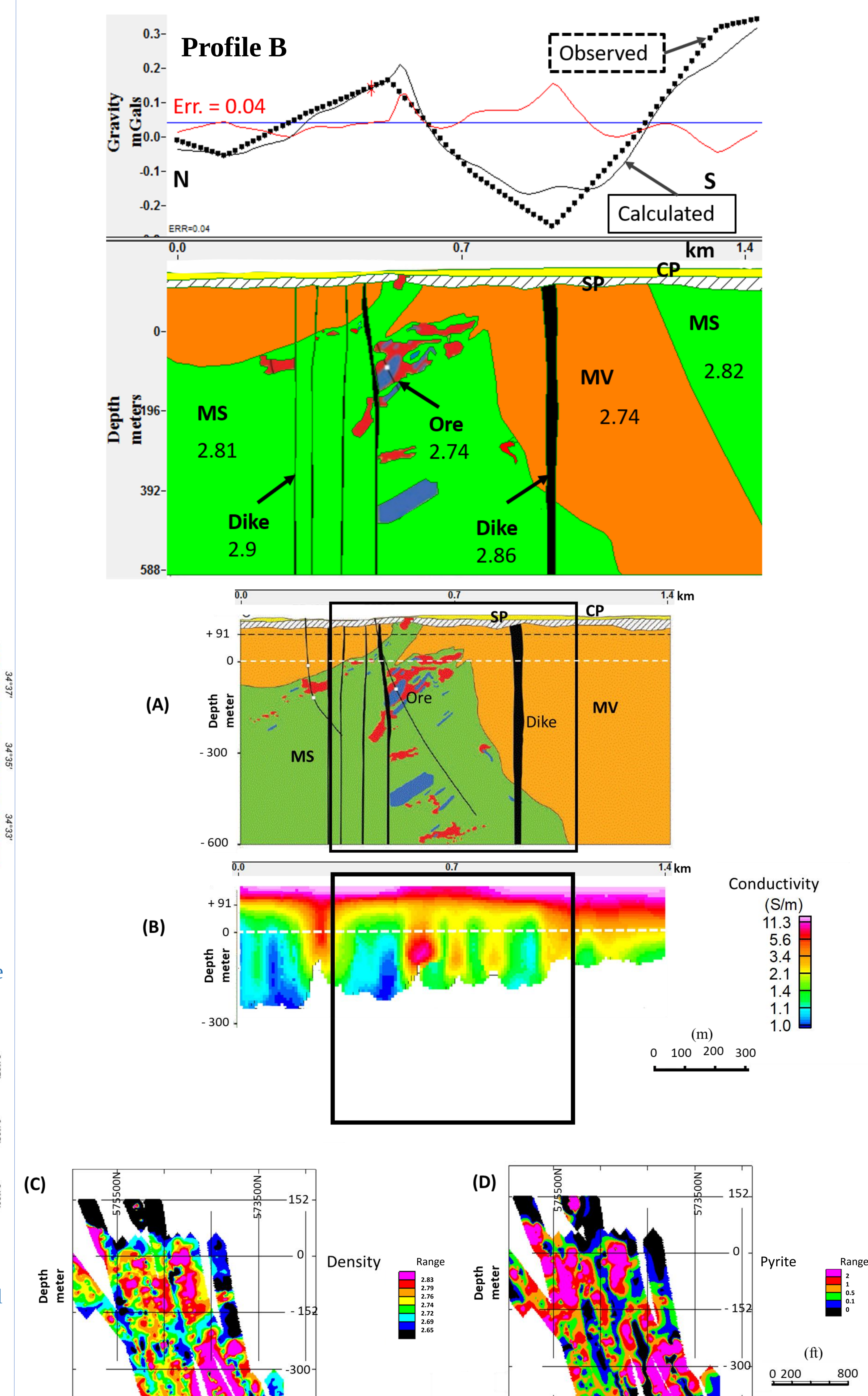


Fig.5: 2-D forward density modeling. Gravity station spacing is approximately 100 m. Note that the gravity values are filtered residual anomalies, and the total amplitude of the modelled anomalies is only 0.5 mGal! Geology after Mobley et al. (2014) and SRK Consulting (2017). Density of saprolite: 2.45 g/cc, Coastal Plain sediments: 2.6 g/cc(James Berry, personal communication, Romarco). Red areas: ore, blue areas: molybdenite, MS: metasedimentary unit, MV: metavolcanic units, SP: saprolite, CP: coastal plain sediments. For geology map see Fig. 1. 0 meters depth is sea level. No vertical exaggeration: scale is 1:1. A) Geological profile B (location: figure 1) after Mobley et al. (2014). No vertical exaggeration and same scale in all profiles. B) Conductivity inverted for depth along profile B. C) OceanaGold measured core densities from drillholes along profile B. D) OceanaGold lab estimated pyrite concentrations from drillcore along profile B. Small black box in A and B: boundary of figures 5c and 5d. Dashed white line in 5A and 5B: sea level. Black dashed line at 91 m (300 ft) above sea level in 5a is the depth of the bedrock map (Fig. 1).

To identify the source of the positive gravity residual anomalies over the Haile ore zone, forward density models were constructed constrained by the extensive drillhole sampling available. 2-D gravity forward models were constructed using Oasis Montaj and 2-D GM-SYS software (Fig. 5). The models were based on previously published geologic profiles (Mobley et al., 2014) and constrained by core drilling to depths of up to 650 meters. Figure 5 shows drilling results along profile B. The geology after Mobley et al. (2014) (Fig. 5a) is compared to the core sample densities (Fig. 5c) and the laboratory estimated pyrite concentrations (Fig. 5d). The drilling results (Fig. 5) show a spatial correlation between high densities, high pyrite concentrations, and the mineralized zones.

Conclusion

1) The filtered residual Bouguer gravity anomaly map shows a correlation between positive anomalies and the mineralized ore zone in the Haile mine area.
2) The models are sensitive to the measured thicknesses of the saprolite and Coastal Plain sediments. The drilling results confirm a spatial correlation between high densities, high pyrite concentrations, and the mineralized zones.
3) Core drilling and 2D inversion show that high conductivity anomalies coincide with zones of high pyrite concentrations.

Reference

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