Mine Site Exploration and Ore Delineation

Paper 93

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APPLICATION OF BOREHOLE GEOPHYSICS TO GOLD EXPLORATION

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INTRODUCTION

Although gold possesses physical properties that are substantially different from most rock-forming minerals (e.g., conductivity, specific gravity), it does not occur in large enough concentrations to produce a measurable effect on the physical properties of the host rocks. Exploration for gold by geophysical techniques depends on measuring changes in physical properties caused by alteration associated with the gold, or detecting structures or lithological units known to host the gold.

The Borehole Geophysics Section of the Geological Survey of Canada has recorded borehole geophysical measurements in a number of holes in gold deposits in Ontario to document the physical properties of the deposits and to determine if alteration, structures or lithologies associated with the gold mineralization can be delineated by some of the geophysical techniques. The geophysical logs acquired include: spectral gamma-ray (total count, potassium (K), equivalent uranium (eU) and equivalent thorium (eTh)), density, spectral gamma-gamma (SGG) ratio (heavy element indicator), resistivity, induced polarization (IP), self potential (SP), magnetic susceptibility (MS), temperature and temperature gradient. Using examples from the Kirkland Lake area, Urbancic and Mwenifumbo (1986) demonstrated that borehole geophysics can be used to map lithology and to outline silicified, carbonatized and sericitized zones. In this paper, we present further examples of the application of borehole geophysics to gold exploration.

Alteration that may be associated with gold mineralization includes sericitization, feldspathization, silicification, pyritization, carbonatization and hematization (Boyle, 1979). Sericitization and feldspathization may increase the K content in the altered zone, which can be detected by gamma-ray spectral logging. Gamma-ray spectral logging can also detect changes in the U and Th concentrations that may result from metamorphism and hydrothermal alteration. Pyritization may be detected by an increase in the chargeability (IP) and a decrease in the resistivity. Pyritization may also result in increased densities and SGG ratios if it involves an increase in the iron content. Silicification and carbonatization tend to reduce the porosity and hence increase the resistivity and density of the host rock. Hematization may involve the oxidation of primary magnetic minerals (e.g., magnetite) to weakly or non-magnetic minerals (e.g., hematite) and hence reduce the MS of the rock. Spectral gamma-ray, density, SGG ratio and MS logs generally correlate with changes in rock type and can be useful in lithologic mapping. The above applications of geophysical logs are discussed in more detail in Pflug *et al.* (1997).

VICTORIA CREEK GOLD DEPOSIT

Geophysical logs from the Victoria Creek gold deposit, located in the Abitibi greenstone belt, east of Kirkland Lake, Ontario, are shown in Figure 1. The gold occurs in felsic volcaniclastics of the Gauthier Group and is associated with up to 15% pyrite. Alteration includes iron carbonatization and silicification (P. Hubacheck, W.A. Hubacheck Consultants, pers. comm.). All of the geophysical logs clearly distinguish between the "Mafic Volcanics (flow)" unit and the volcaniclastic rocks below. The high IP values and low resistivities and SP values from 271.5–277.7 m and from 297.2–299.9 m are due to graphitic layers. Another thin graphitic layer, inferred from the geophysics, occurs at 303.6–304.9 m.

Figure 2 shows the K, eTh, resistivity, IP and MS logs in the volcaniclastic rocks only. The "Felsic Volcanics (fragmental)" unit which contains the gold and pyrite (274.07–343.3 m) has a slightly lower Th concentration and higher resistivities and chargeabilities (IP) than the other volcaniclastic rocks. A negative correlation between gold and Th in the Kirkland Lake area has been cited in the literature (Tihor and Crocket, 1975). The higher resistivities may reflect a decrease in porosity due to silicification and/or carbonatization while the higher chargeabilities are due to the presence of disseminated pyrite. The chargeabilities in this unit increase slightly between 310 m and 340 m where the highest pyrite concentrations occur.

The highest K concentrations in this hole occur between 307 m and 332 m. The highest gold values occur at the bottom of this zone. A slight decrease in magnetic susceptibility between 319.5 m and 334 m in the "Felsic Volcanics (flow)" unit suggests alteration of magnetite to hematite. This zone correlates with the highest gold values.

GOLDEN GIANT DEPOSIT

Geophysical logs from the Golden Giant deposit, located in the Hemlo gold mining camp east of Thunder Bay, Ontario, are shown in Figure 3.

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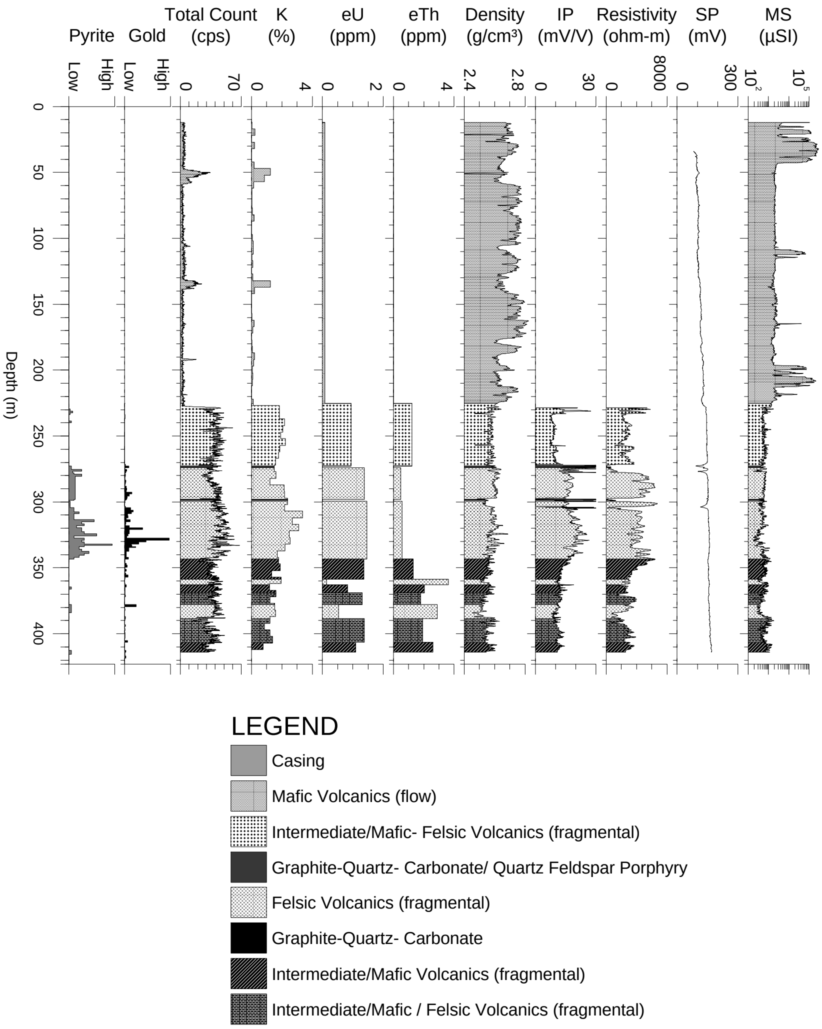

Figure 1: *Geophysical logs acquired in hole LG 94-21 at the Victoria Creek deposit.*

Note: resistivity and IP logs are not shown in the "Mafic Volcanics (flow)" because the resistivities were too high for the equipment to measure.

cps = counts/second,

IP = induced polarization,

SP = self potential,

MS = magnetic susceptibility.

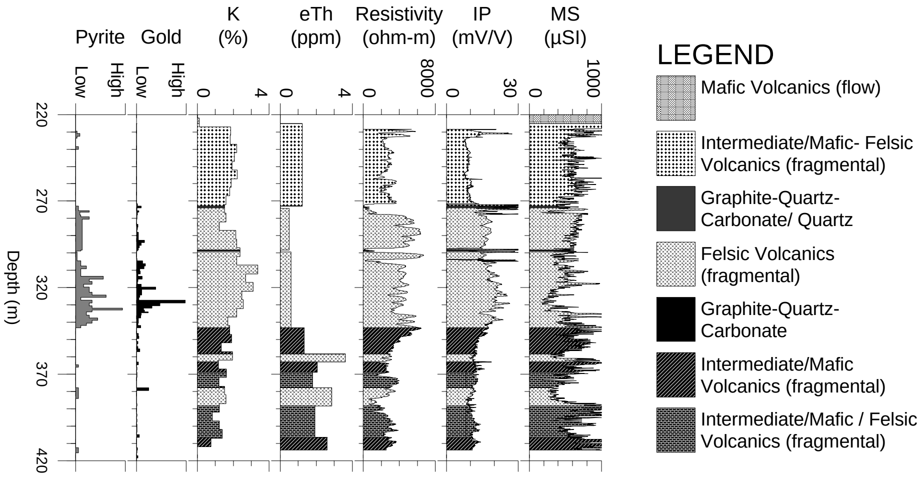

Figure 2: *Selected logs from Figure 1, shown only in the volcaniclastic rocks.*

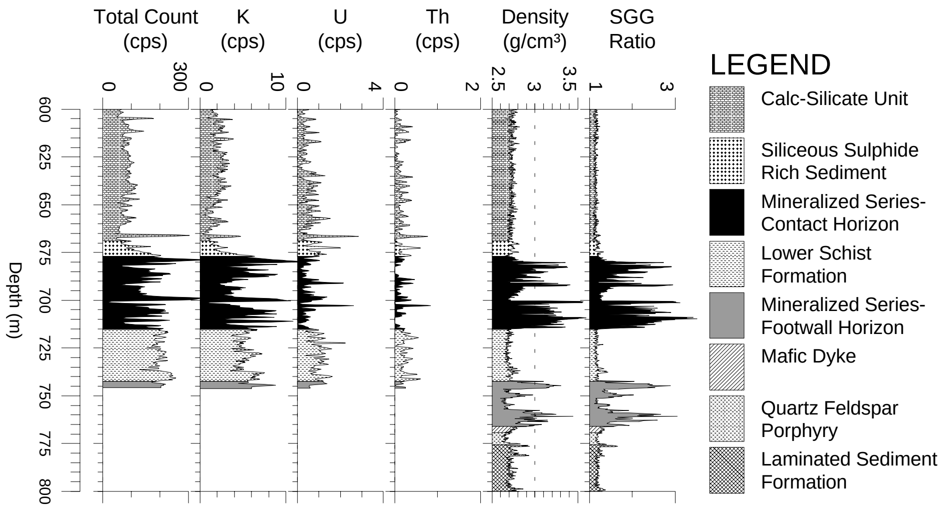

Figure 3: *Geophysical logs acquired in hole NGG-18 at the Golden Giant deposit. K, U and Th are in counts/second not concentrations. cps = counts/second, SGG = spectral gamma-gamma.*

The deposit is stratiform and hosted by metasedimentary and metavolcanic rocks. Sericitic alteration occurs in the ore zone and the hanging wall and footwall. The ore zone contains up to 8% pyrite, and is enriched in potassium and barium (Harris, 1986; Kuhns *et al.*, 1986).

The mineralized zones are easily distinguished from the non-mineralized zones by the total count, K, density and SGG ratio logs (Figure 3). The K, U and Th logs clearly show that the increased total count gamma-ray activity in the mineralized zone is due to K enrichment. The high densities and SGG ratios in the mineralized zone are due to barium enrichment and, possibly, pyrite.

SUMMARY

The examples presented here demonstrate several possible applications of borehole geophysics to gold exploration. Although some of the correlations are not definitive, the results suggest that geophysical logging may be used to delineate alteration associated with gold mineralization. In the Victoria Creek hole, gold mineralization appears to be associated with high IP values and increased resistivities. Increased K and decreased Th responses were also observed in the "Felsic Volcanics (fragmental)" unit containing the gold. The highest gold values were associated with low magnetic susceptibilities. In the Golden Giant hole, potassium enrichment in the mineralized zone produced increases on the total count and K logs. High densities and SGG ratios in the mineralized zone are due to barium and, possibly, pyrite enrichment. The use of borehole geophysics to aid lithological mapping was also demonstrated.

ACKNOWLEDGEMENTS

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