Bérubé CL, Olivo GR, Chouteau M, Perrouty S, Shamsipour P, Enkin RJ, Morris WA, Feltrin L, Thiemonge R, 2018, Predicting rock type and detecting hydrothermal alteration using machine learning and petrophysical properties of the Canadian Malartic ore and host rocks, Pontiac Subprovince, Quebec, Canada, Ore Geology Reviews, 96, 130-145

The Canadian Malartic deposit is a world class intrusion-related Archean gold deposit hosted in the Pontiac Subprovince, Superior Province, in Québec, Canada. Laboratory petrophysical properties measurements were performed on 824 rock samples collected from the various rock types observed within the ore body and peripheral host rocks. The various rock types present in the Malartic District, mainly meta-sedimentary rocks, felsic-intermediate intrusive rocks and mafic dykes have contrasting grain densities and magnetic susceptibilities. Using support vector machines, it is shown that these two physical properties can be used to predict the rock type of a sample with an average precision and recall rate of 89%. Within the meta-sedimentary rocks class, variations in magnetic susceptibility are due to the changes in mineralogy associated with hydrothermal alteration. These are caused by the destruction of iron-bearing silicate minerals and magnetite in unaltered rocks (10^{-4} to 10^{-3} SI) to form pyrite, carbonates, K-feldspar and Fe-depleted hydrothermal biotite in altered rocks (10^{-5} to 10^{-4} SI). Within the felsic-intermediate intrusive rocks, grain densities below 2.7 g/cm³ and magnetic susceptibilities in the 10^{-6} to 10^{-4} SI range yield the highest probabilities that a rock has been submitted to carbonate and pyrite alteration. However, magnetic susceptibility and grain density of these intrusive rocks are also dependent on their Fe_2O_3/Al_2O_3 and TiO_2/Al_2O_3 ratios, which are not related to the hydrothermal alteration footprint, but are rather due to distinct protolith compositions. Within the mafic dykes, grain density is the best indicator of hydrothermal alteration. Unaltered mafic dykes (2.95 to 3.10 g/cm³) are mostly composed of amphibole, whereas altered mafic dykes (2.70 to 2.95 g/cm³) have reduced amphibole contents and higher abundances of carbonates, pyrite, quartz, and biotite alteration. The support vector machine classifier is extended to predict if meta-sedimentary rocks, felsic-intermediate intrusive rocks and mafic dykes have undergone hydrothermal alteration with average F1 scores of 73%, 69% and 93%, respectively. In altered meta-sedimentary rocks, the integration of grain density and magnetic susceptibility allows the identification of altered but unmineralized samples. The classifier is further extended to predict if the gold content of meta-sedimentary rocks is above or below threshold values of 0.01, 0.1 and 1 ppm with average F1 scores of 83%, 80%, and 76%, respectively. Using conceptual models of the rock physical properties at the Malartic District scale, it is shown that ground magnetic surveys are the most promising geophysical tool for early-stage greenfield exploration of this type of deposit. However, depending on the scale at which the surveys are conducted, magnetic susceptibility contrasts between the various investigated rock types can overshadow the specific signatures of hydrothermally altered rocks. This in part explains why past airborne geophysical exploration campaigns for this type of deposit in the Malartic District were inconclusive. Finally, the machine learning process used in this case study can be applied in advanced exploration stages, during which drilling and either subsequent laboratory petrophysical analyses of core samples or downhole geophysical surveys produce large amounts of data that can be used to train prediction models.

NSERC-CMIC Mineral Exploration Footprints Project Contribution 160.

https://doi.org/10.1016/j.oregeorev.2018.04.011