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Tungsten-rich rutile as a potential indicator mineral in surficial till for Canadian Malartic-type gold deposits

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Abstract. It is challenging to trace detrital indicators in glacial sediments from gold deposits that are characterized by disseminated very fine gold particles. Other indicator minerals are needed. W-enriched rutile is associated with Au mineralization at Canadian Malartic and could be a useful indicator for gold deposits of this type. As a first test, 31 till samples were collected around the deposit and analysed for rutile content and matrix geochemistry. W-enriched rutile (> 0.40 WO_3%) was recovered from the 0.125 to 0.500 mm fraction, the number of W-rutile grains was counted per sample site and mapped, and they were then compared to spatial distribution of W from the till matrix geochemistry. Overall, patterns are in agreement with the predicted net effect of recognized ice flow phases on the known extent of W-enriched rutile in bedrock. Future work will increase the density of control points, which should better constrain the patterns, source zones, and background levels. Finer fractions will also be analysed as they may contain more indicators specifically derived from Malartic than the coarser fractions. In summary, W-rich rutile is a promising candidate indicator mineral in till for Malartic-type gold deposits.

1 Introduction

As discoveries of high-grade gold deposits become increasingly rare and more difficult, there is demand for innovation in exploration techniques to discover large-tonnage, low-grade gold deposits.

The open-pit Canadian Malartic gold mine in Quebec is an example of such a deposit. There is no clear geophysical footprint at Malartic; instead, the potential for an open-pit mine was first realized as a result of targeted searching for key characteristics through a public geoscientific database (Wares and Burzynksi 2011). We are using this deposit as a case study to develop new footprint and exploration techniques.

Drift prospecting is a well-established exploration technique for many deposit types, including gold deposits (McClenaghan 2005), in areas covered by glacial sediments. Detrital gold in glacial sediments (e.g., till) is an obvious indicator of gold mineralization from a source located up the ice flow direction, but standard gold grain picking techniques focus on sand-sized gold particles and are therefore less effective for tracing a deposit like Malartic, where gold particles rarely exceed 30 μm (Helt et al. 2014) in diameter. Furthermore, drift prospecting is more effective when a suite of indicators (e.g., as in kimberlites) can be used together to fingerprint a particular source that has distinct assemblages (e.g., diamondiferous kimberlite). It would therefore be useful to identify other indicator minerals for gold deposits, especially for more elusive high-tonnage low-grade deposits like Malartic.

Rutile (TiO_2) is a good candidate as an indicator mineral in till because it is physically resistant to weathering and can therefore survive glacial transport and post-glacial processes. More importantly, it often has anomalous tungsten (W) concentrations that vary in association with different ore deposit types (Clark and William-Jones 2004), including Malartic (Helt et al. 2014). An alternate potential source of W in till is scheelite ($CaWO_4$), but this mineral is poorly represented in the till in Malartic because it is present in relatively low quantities within the local bedrock.

2 Methodology

2.1 Fieldwork

Initial samples for this project collected in and around Malartic, QC consist of 18 surficial till and 13 Pionjar drill samples. The surficial samples were used both for picking grains and for matrix geochemistry, while the small volume drill samples were used only for matrix geochemistry.

Due to limited till coverage in the study area, the majority of the samples were first taken southwest of the Canadian Malartic deposit, which corresponds to one of the down-ice directions. This introduces a bias in the sampling, but was considered appropriate for the purpose of this preliminary study, which was to identify W-rutile in till. More samples have recently been collected to fill gaps and to better define background, but results from the second phase have yet to be fully evaluated.

2.2 Mineral separation

Heavy mineral concentrates (HMC) were prepared from the coarser fractions by using heavy liquid separation, ferromagnetic and paramagnetic separation. Rutile and

gold grains were hand-picked from the 125-250 µm and 250-500 µm HMC fractions using a binocular microscope. This is not be the best size fraction for Malartic W-rich rutile, which is predominantly finer grained, but the use of a standard mineral separation approach was sufficient for a proof of concept, assuming that there is sufficient coarse W-rich rutile at Malartic or other mineralized zones in the vicinity along the Cadillac fault to produce a signal in the sand fraction of the till.

2.3 Electron probe microanalysis

Picked rutile grains were analyzed by wavelength dispersive X-ray emission spectrometry using a JEOL JXA-8900L electron probe microanalyzer using a focused beam, 20 keV accelerating voltage, 40 nA beam current, and ZAF correction. Counting time for W was 60s on the peak and 30s on each background. The lower limit of detection (3σ) for WO_3 is 0.04 wt%.

2.4 Q-Q plot

A Q-Q plot is a way to show deviation (z-score) from a normal distribution and is therefore a useful tool to identify anomalous values, potentially indicating association with an ore deposit (e.g., Grunsky 2010).

In this case, Q-Q plots were constructed for the measured WO_3 values in picked rutile grains, as well as for the W results from till geochemistry. Grain counts were normalized to 10g of HMC. Zoned grains were assigned their average WO_3 values. Anomalous WO_3 values were then determined from the graph by inspection, based on the location of a change in slope.

2.5 Geochemistry

Till matrix (<0.063 mm) was separated and analyzed for major and trace elements by ICP-MS following partial and total digestion, respectively. Partial digestion was achieved by digesting pulp in 8:1 ultrapure HNO_3:HCl for 1 hour at 95°C. Total digestion was achieved by heating pulp in ultrapure HF/HNO_3/$HClO_4$ until dry and then dissolving residue in dilute ultrapure HNO_3. The till matrix was also analyzed for gold following Pb fire assay pre-concentration. This allows tests of W alone as a geochemical pathfinder element acting as a proxy for W-rich rutile. Additionally, existing legacy geochemical data was levelled by Taves (2015) to be used in this context.

3 Results

3.1 Q-Q plot

Using the Q-Q plot method on this dataset, values of WO_3 ≥ 0.4 weight percent (wt%) were defined as anomalous.

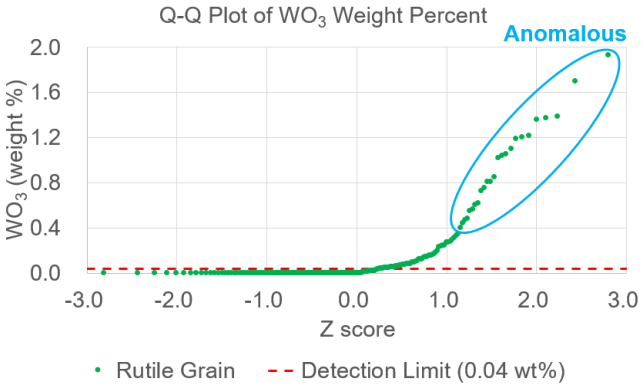

Figure 1. Q-Q plot used for the determination of anomalous WO_3 wt% values. Anomalous values are circled in blue and the lower detection limit is represented by a red dashed line.

3.2 Picked rutile

Figure 2 shows the legend for the Surficial Geology Map (Veillette 2004) that is used as a background for figures 3-4, and 6-7.

Figure 3 shows the spatial distribution of picked rutile grains (125-250 µm and 250-500 µm) in the context of the surficial geology and known ice flow phases.

Figure 2. Surficial legend for figures 3-4, and 6-7.

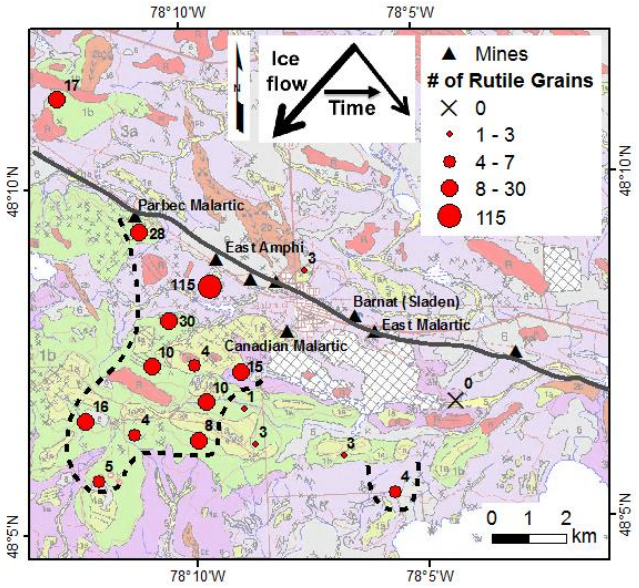

Figure 3. Distribution of picked rutile grains per 10g HMC from till in the Canadian Malartic area. Ice flow direction, relative strength, and evolution with time as indicated. The Cadillac-Larder Lake Deformation Zone (CLLDZ) is approximated by the bold line running NW to SE. The extent of the potential indicator dispersal fan is outlined by dashed lines.

3.3 Anomalous rutile

Based on our interpretation of the Q-Q plot, figure 4 shows the distribution of anomalous rutile grains (defined as ≥ 0.4 wt% WO_3) for the combined 125-250 µm and 250-500 µm size fractions.

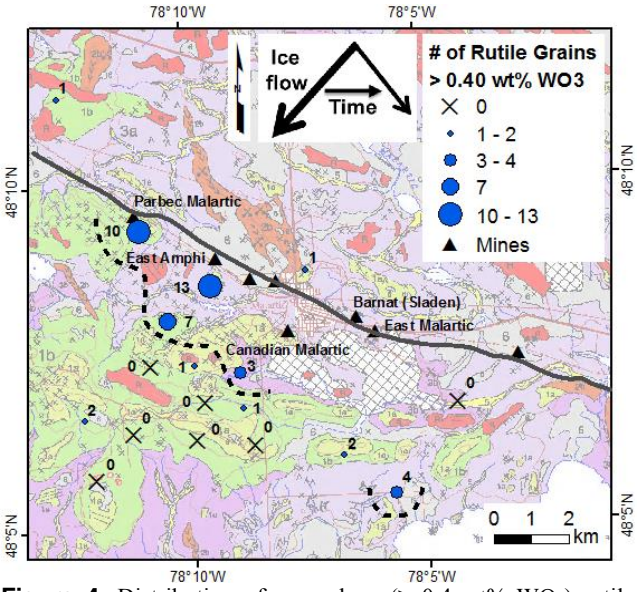

Figure 4. Distribution of anomalous (≥ 0.4 wt% WO_3) rutile grains per 10g HMC for the combined 125-250 µm and 250-500 µm size fractions. The extent of the potential indicator dispersal fan is outlined by dashed lines.

3.4 Geochemistry

Figures 5a-b show Q-Q plots for W (ppm) and Au (ppb) values, respectively, based on till matrix geochemistry, and figures 6-7 illustrate the distribution of measured and anomalous W and Au values, respectively. Three out of four locations that show anomalous values for Au also show anomalous W values.

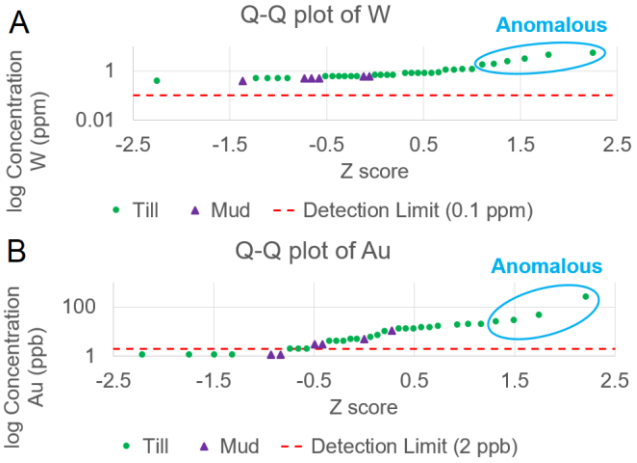

Figure 5. Q-Q plots showing the determination of anomalous values for **a** W and **b** Au in till matrix. Anomalous values were determined by visual inspection and are circled in blue. Detection limits are represented by a red dashed line.

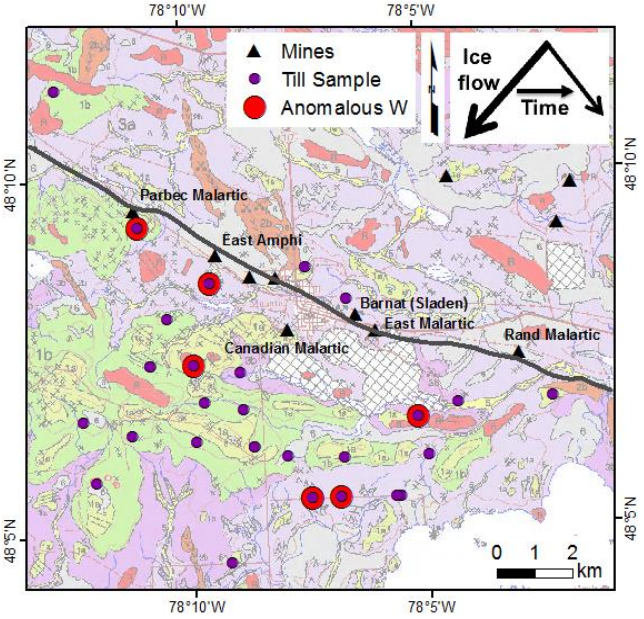

Figure 6. Distribution of measured and anomalous W values for samples.

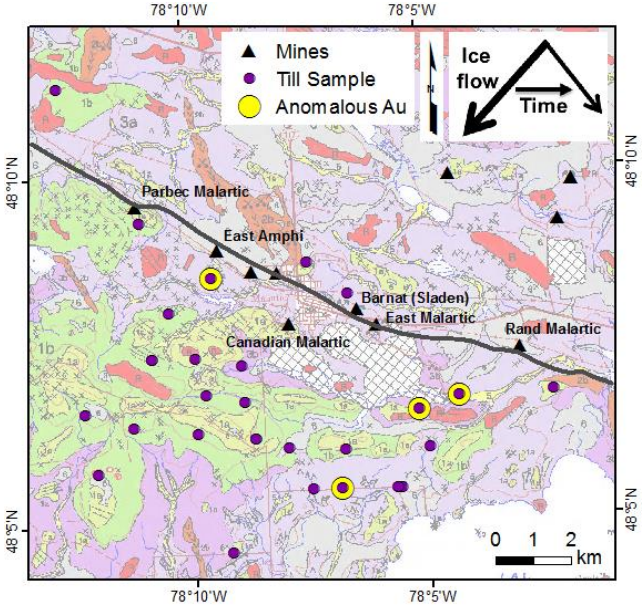

Figure 7. Distribution of measured and anomalous Au values for samples.

4 Discussion

Till in the Malartic region is discontinuous and there is also extensive cover of glacial lake sediments, which together pose a challenge for drift prospecting, as they restrict where till samples can be taken. Despite this limited sampling, figures 3-4 show a potential dispersal fan from potential sources along the CLLDZ (i.e., East Amphi, and possibly Canadian Malartic). The patterns may result from the net effect of the southwest ice flow phase followed by an ice flow shift to the southeast. Erosional ice-flow indicators on outcrops within the study

area are mostly related to the SW ice flow phase, but the till data suggest that the younger phases may also have had influence on sediment transport and overall dispersal patterns. Malartic may have contributed little as a source of relatively coarse W-rutile, which may explain the results and observed patterns.

Figures 6-7 show three coinciding Au and W anomalies, all of which occur in till. Two of these are to the south and SE of CM, and one appears to be associated with East Amphi. These patterns are consistent with the interpretation of the ice flow dynamics in the region, namely the net effect of the southwest ice flow phase followed by an ice flow shift to the southeast.

Overall, W-rich rutile grains occur in the till and appear to be derived from sources along the CLLDZ. Results are therefore encouraging for W-rich rutile as a potentially useful indicator mineral for gold deposits such as Canadian Malartic, that are associated with W-rich altered rocks (Helt et al. 2014). Furthermore, the related occurrence of anomalous values of W and Au suggest that W may be a potentially useful geochemical pathfinder element on its own.

5 Ongoing studies

Following up on this initial work additional surficial till samples have been collected in and around Malartic in order to fill in the distribution and geochemical mpa patterns, and to help delineate potential indicator mineral dispersal patterns. This larger set of samples will also establish background (i.e., up-ice) measurement values for the region.

Canadian Malartic is characterized by finer grained gold and rutile than the East Amphi or other local sources; the next phase of study will utilize rutile from the 75-125 μm size fraction to increase the likelihood of detecting an indicator dispersal pattern from Canadian Malartic. Our working hypothesis is that the smaller size fractions may reveal different patterns, and possibly a stronger signal from Canadian Malartic.

Similarly, geochemical analyses on till matrix are underway on the additional samples, and will be integrated into the overall interpretation of tungsten's geochemical pathfinder signal.

6 Conclusion

Till samples from the Malartic region have been analysed for W-rich rutile as well as W and Au in till matrix. Although the preliminary sparse sampling makes interpretation challenging, there is evidence for a potential dispersal fan in till down-ice from the Canadian Malartic and adjacent ore deposits. More extensive data from ongoing studies will help elucidate the dispersion pattern. Overall, W-rich rutile is a promising indicator mineral in till for Canadian Malartic-type gold deposits.

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