Automated gold grain counting: a quantum leap in drift exploration

Alexandre Néron, L.Paul Bédard
Université du Québec à Chicoutimi, Chicoutimi, Québec, Canada

Réjean Girard
IOS Services Géoscientifiques inc., Chicoutimi Québec, Canada

Abstract. Counting gold grains in glacial drift is a well-proven exploration technique. However, it is limited by the size of grains that can be recovered and observed, experiencing a recuperation collapse below 50 micrometres. Since ore petrography indicates the overwhelming abundance of very small gold grains, concentrating observation on the smaller fractions will improve accordingly the efficiency of the method. A dependable counting of very small particles is beyond the realm of human skill and requires automation. First, recovery must be conducted by methods which achieve constant concentration factors in the orders of 1:100,000 with constant recovery. Second the identification process requires the use of fully automated scanning techniques based on visible light image analysis and scanning electron microscope (SEM) interoperability. The technique here described enable recovery and counting of gold grains down to a few microns, plus the acquisition of high magnification images to characterize grain shape and EDS-SDD analyses. Results not only enable the detection of faint gold grains dispersion trains, but also characterized the grains in regard of their source rocks taking into account their chemical signature and morphology. A new classification of “pristine” grains in regard of their relation to host minerals is proposed.

1 Introduction

The counting of gold grains in glacial sediment remains one of the most efficient exploration tools in glaciated terrain. Glaciers erode ore bodies and the resulting gold grains are distributed through the deposited glacial till. The relative proximity of a gold ore body can be determined by the amount of gold grains counted in a till sample. Typically, heavy minerals are concentrated from 10 kg of till using a shaking table and/or panning. Gold grains are then counted and characterized by an operator using a stereomicroscope. Since 88% of gold grains in the original ore bodies are smaller than 50 micrometres (Figure 1) (Wood et al. 1986), small gold grains dominate in till samples.

Despite the historical success of this approach, two major areas of this protocol must be improved to enhance the quality of the signal for small particles: 1) on the shaking table, the successful recovery of gold grains collapses for grains smaller than 50 µm and their recovery is highly dependent on operator skills (Nichol 1986; Wang and Poling 1983)); and 2) the identification of gold grains using a stereomicroscope is difficult for small particles (<50 µm (DiLabio 1990) becoming nearly impossible for very fine grains (<20 µm) and again this is directly related to the operator skills. Despite some statistical treatments can be applied to geochemical data to estimate a realistic amount of gold grains within a till sample (Trepanier 2010), we propose a rethinking of till samples processing to improve recovery of very small grain sizes.

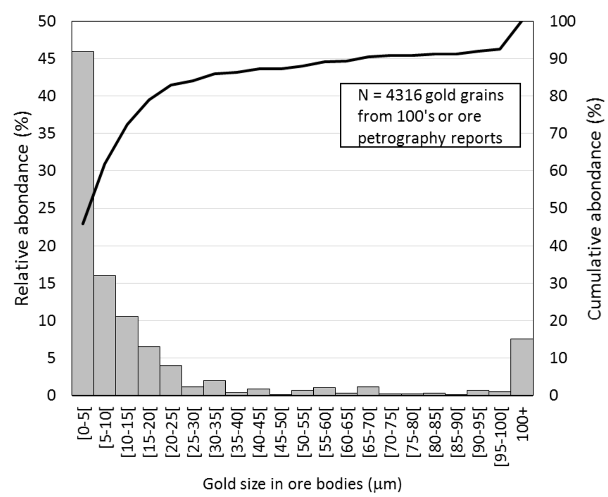

Figure 1. Size distribution of gold grains (N = 4316 gold grains) from hundreds of ore petrography reports published by IOS Services Géoscientifiques from Abitibi and James Bay mineral occurrences. Grey bars represent the relative abundance of a specific size fraction and the solid black line represents the cumulative abundance. As such, note that 88% of all gold grains within the sampled ore bodies are smaller than 50 µm.

2 ARTGold™

Since early 2016, IOS Services Géoscientifiques has commercialized an innovative approach for measuring gold grain abundance in tills using a proprietary gold grains concentration device similar to a fluidized bed. Known as the Advance Recovery Technique (ARTGold™), heavy minerals form a super-concentrate—about 150 milligrams—representing a concentration factor of 30,000 to 100,000x. The efficiency of this step is not much dependent on the technician’s skills. The super-concentrate is sieved at 50 µm. The>50 µm fraction is checked optically and the <50 µm fraction is sent to a SEM. The optical count, which mimics the conventional technique, is done under an apochromatic stereomicroscope at a magnification up to 106x. Grains are extracted, photographed and their identification is confirmed under the SEM. The fine fraction (<50 µm) is dusted on a custom-made holder and checked under a Zeiss EVO MA15-HD SEM having a backscattered electron detector. The thoroughly automated routine, based on the Oxford Instruments' Aztec platform, scans a mosaic of the grain holder surface in search of heavy minerals, acquires an EDS-SDD spectrum of detected grains and classifies the minerals. Finally, it acquires a high magnification image of the gold grains for shape classification and measurements that are presented in a certificate.

3 Recovery

Figure 2 compares the size distribution of gold grains recovered through the ARTGold™ approach (light grey) with that recovered using conventional method (dark grey). The abundance is normalized to a 10 kg sample to compare the average absolute abundance of gold grains in a standard till samples. The sampled tills were collected in the Abitibi and the James Bay area northern Québec. Given that grain sizes determined by the conventional method is estimated by a technician using a stereomicroscope, accurate measurements are not available and the size classes are broader than those of the ARTGold™ approach.

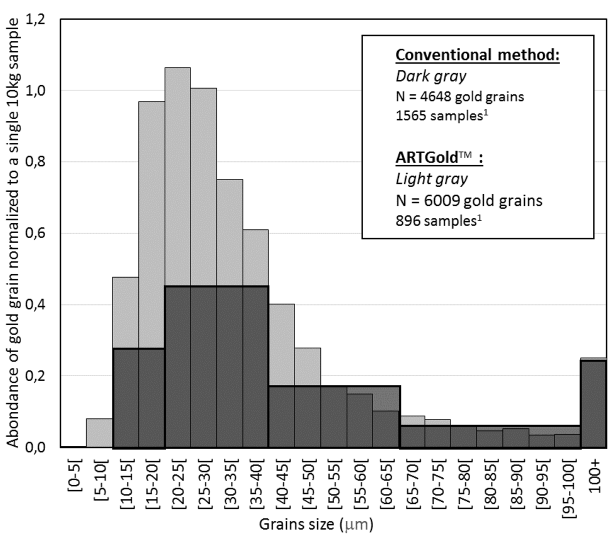

Figure 2. Size distribution of gold grains in till. Dark grey bars represent gold grain counts in samples processed using the conventional method (Bajc (1996), GM-67959, GM-67961, GM-68406, GM-68423 and GM-68407). Light grey bars represent gold grain counts in samples processed with the ARTGold™ technology. Till samples are from the Abitibi or James Bay areas of northern Quebec and are representative of both regional and propriety-scale surveys. [1] Abundance of the gold grains for both techniques is normalized to a 10 kg sample.

The absolute number of coarse gold grains (>50 µm) recovered from a 10 kg till sample is similar for both the ARTGold™ (1.07 grains/sample) and conventional method (0.94 grains/sample). However for the <50 µm fraction, 5.64 grains/sample and 2.82 grains/sample were counted for the ARTGold™ and conventional method, respectively. This difference demonstrates the difference between the two methods: 1) gold grains recovered by the ARTGold™ approach were finer than those observed using the conventional method (with a modal grain size equal to 20 µm and 30 µm, respectively); and 2) ARTGold™ recovered about four times the number of fine grains than the conventional method.

4 Identification

In our opinion, the best way to minimize errors in identifying fine particles is to automate the identification process. Despite the robustness and the efficiency of using a fully automated SEM routine, the technique is limited by its high operational costs and throughput. Automated detection of grains using optical imaging prior to SEM is needed to reduce operational time. This detection must be interoperating with the SEM to enable transfer of coordinates from an optical to electronic microscope.

Gold has a unique visible light reflectance spectrum characterized by a steep slope between 450 and 800 nm (Clark et al. 1990; Clark et al. 2007) that is not greatly affected by the silver content (Simard et al. in preparation). Therefore, spectral analysis is efficient for recognition of gold and this can be achieved by image analysis obtained from a petrographic microscope. Figure 3 summarizes the steps of the fine grain localization process from the super-concentrated heavy mineral phase to SEM.

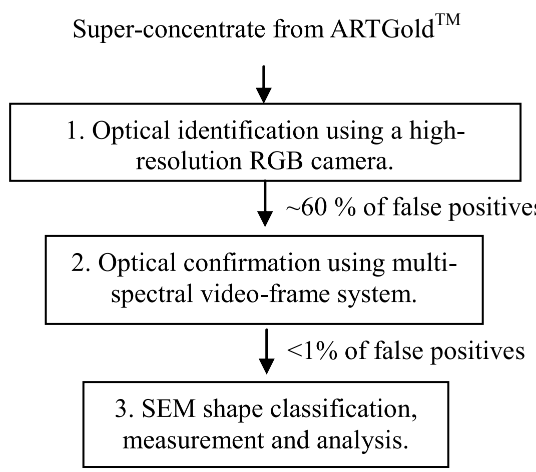

Figure 3. Flow chart summarizing the identification process from the super-concentrated heavy minerals to SEM classification and measurement.

4.1 Step 1: RGB localization

The super-concentrate mounted on a shuttle holder is fully scanned under an optical binocular microscope using a motorized stage and high resolution RGB camera. By simple subtraction of the red and blue channels, pixels potentially representing a gold signature are detected and gold grain images are reconstructed. Location of every single grain is stored in an output file. This basic optical method can scan an average sample comprising about 2 million grains as small as 10 µm within 20 minutes. However, it also generates false positives (~60%) due to the spectral similarity with some silicates such as grossular garnet.

4.2 Step 2: Multi spectral confirmation

Each grain localized by the first optical step is then confirmed using a multispectral acquisition system. The shuttle holder is transferred to a laboratory microscope having a 500X magnification, a video stream multispectral camera based on 11 spectral pass bands from 475 nm to 650 nm (blue through red) and a motorized stage. The application software is applied to each grain, a multispectral image is acquired and the presence (or absence) of gold is then confirmed. The system produces five interpreted frames per second. The total scanning time depends on the number of grains identified in the previous step but typically lasts a few minutes. More than 95% of the gold grains are correctly identified. Identification errors occur if gold grains are coated by iron oxide or other coating material. High magnification images are also acquired for reporting purposes.

4.3 Step 3: SEM classification and measurements

Once gold grains are localized and confirmed the shuttle holder is transferred to a SEM for high magnification back scattered imagery and EDS-SDD acquisition. The fineness of gold (Ag %) is measured as well as contaminants and alloying metals such as Cu, Hg, Bi, Te, Pt, Pd, Pb, Sb, As and S down to a detection limit of about 0.2%. Precise measurements are made to extract the length, breadth, axis ratio, surface, perimeter and ECD of the grain. More complex parameters can also be calculated such as roughness and angularity.

Contaminant signature is used to discriminate diverse dispersion trains as well as to fingerprint the metallogenic environment. As examples, Hg-rich gold suggests a low-temperature orogenic system such as Hemlo; Cu-rich gold is related to porphyry or a mantos deposit such as Troïllus; Pt- and Pd-rich gold grains are related to systems associated with ultramafics such as those from Sudbury area; and some other dispersion trains have been noted having distinctive Bi or Pb signatures. Silver content is highly variable, but its depletion is typically related to oxidation and the residence time of the sediments.

DiLabio (1990) proposed the classification of grain shapes based on the malleability of gold grains to estimate the distance of transport. The grains are considered "pristine" when the shape is minimally modified by transport thereby suggesting a proximal source. Inversely, grains that are "modified" or "reshaped" with increasing deformation, are interpreted to be related to longer transport distances. The shapes of gold grains from the conventional methods are dominated by "reshaped" or "modified" morphology. Figure 4 presents a compilation of the size distribution of gold grains measured using ARTGold™ according to shape. "Pristine" grains clearly dominate the small size fraction, a character that "does not appear until they are viewed at high magnification (~1000x)" (DiLabio (1990). The systematic use of SEM images considerably reduces misclassification of minute grains. Moreover, smaller grains have a lower probability of being deformed during transport, an aspect that can explain the abundance of "pristine" grains.

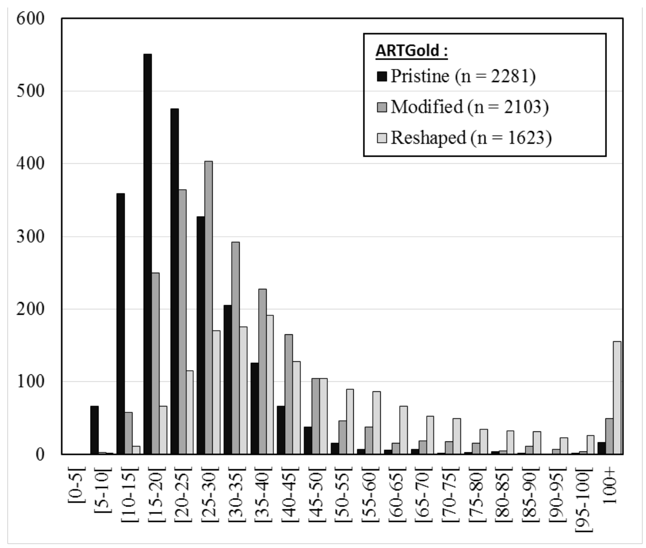

Figure 4. Size distributions of gold grains in till processed through the ARTGold™ method classified by the gold grain shape (DiLabio 1990).

Considering the abundance of pristine gold grains, we propose a sub-classification based on the original morphology of the grain that reflects the type of relation to the adjacent minerals in the source rock:

- Remobilized grains (Fig. 5a) are gold flakes that filled cracks in other minerals. These grains are typically very delicate and their shape is rapidly altered into "reshaped".
- Crystalline grains (Fig. 5b) are gold grains that developed their own crystalline form according to gold cubic crystalline structure. This means that these gold grains had a stronger crystallization strength than the host minerals. These grains are either small or more-or-less stubby or grown as dendrites. They were likely originally embedded in quartz.
- Mutual grains (Fig. 5c) are gold grains that grew within sulfides developing a mutual relationship, in which the gold and their host minerals had similar crystallization strength. They are characterized by curvy and typically

convex shapes. Such grains are typically small and minimally modified.

- Intergranular grain shapes (Fig. 5d) are gold grains having irregular and complex shapes that mimic the boundaries of various other minerals, suggesting they filled intergranular boundaries.
- Spherules (Fig. 5e) are spherical gold grains. Their origin remains uncertain. DiLabio et al. (1988) suggested they may originate from *in-situ* chemical precipitation.

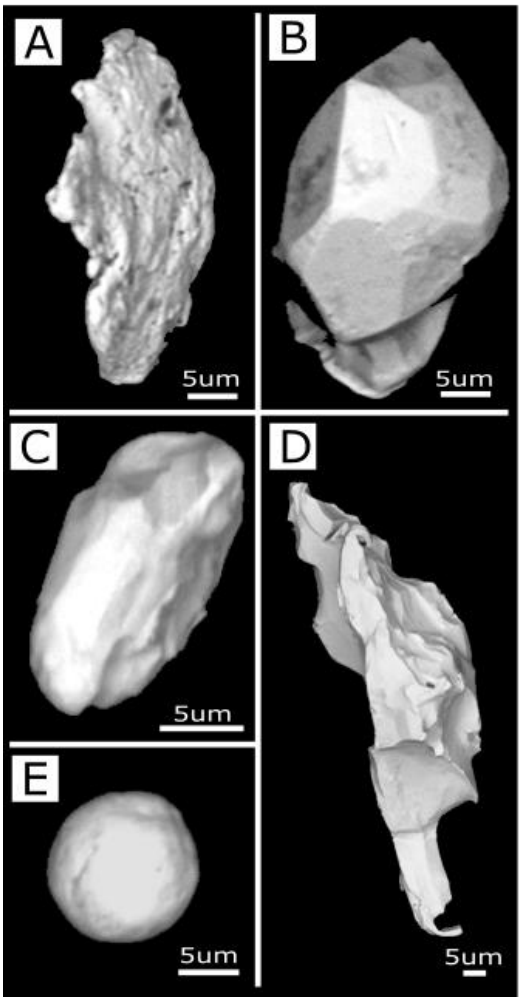

Figure 5. Pristine gold grains classification. **a** Remobilized, **b** Crystalline, **c** Mutual, **d** Intergranular and **e** Spherule.

Quantification of surface textures, morphology, angularity and sizing can reduce misclassification errors related to technician skills. As such, we have developed an artificial intelligence algorithm that is currently in a learning process in order to obtain a satisfactory level of recognition.

5 Conclusion

Gold, both in rocks and glacial sediments, is dominated by minute gold grains. Application of proper techniques to recover, count, image and analyze these gold grains have many advantages for exploration, both in terms of lower detection limits (hence, the use of smaller samples) and characterization of the source material. Recognition of the metallogenic context suggested by gold grains enables more efficient exploration targeting.

Acknowledgements

Authors thank their various co-workers for their innovative and constructive team work as well as the MERNQ, FRQ-NT (Recherche orientée en partenariat) and NRC for their financial support.

References

Bajc AF (1996) Regional Distribution of Gold in Till in the Peterlong Lake-Radisson Lake Area, Southern Abitibi Subprovince: Potential Exploration Targets. Ontario Geological Survey.

Clark RN, King TV, Klejwa M, Swayze GA, Vergo N (1990) High spectral resolution reflectance spectroscopy of minerals. Journal of Geophysical Research: Solid Earth 95:12653-12680.

Clark RN, Swayze GA, Wise R, Livo KE, Hoefen T, Kokaly RF, Sutley SJ (2007) USGS digital spectral library splib06a. US Geological Survey, Digital Data Series 231.

DiLabio R, Newsome J, McIvor D, Lowenstein P (1988) The spherical form of gold; man-made or secondary? Economic Geology 83:153-162.

DiLabio R (1990) Classification and interpretation of the shapes and surface textures of gold grains from till on the Canadian Shield. Current Research, Part C, Geological Survey of Canada Paper 88:61-65.

Nichol I (1986) Geochemical exploration for gold: a special problem Applied Geochemistry in the 1980s. Graham and Trotman London, pp 60-85.

Simard PTr, Higgins MD, Bédard LP, Girard R (in preparation). Optical spectral reflectance of natural gold-rich grains. For submission to Minerals Engineering

Trepanier S (2010) Optimisation des données de till pour l'exploration. Consorem report:05.

Wang W, Poling GW (1983) Methods for recovering fine placer gold. Can Min Metall Bull 76:47-56.