New frontiers for exploration in glaciated terrain

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INTRODUCTION
The Rainy River gold deposit, in the southwest corner of northern Ontario, Canada, near the border with Minnesota, U.S.A. (Fig. 1), consists of a cluster of six gold zones within a deformed Archean caldera in the Rainy River Greenstone Belt. The deposit is covered by unconsolidated glacial deposits ~30 m thick. Each of the gold zones was discovered by tracing glacially dispersed gold grains to their bedrock sources using till samples obtained by deep overburden drilling.

When the first gold-grain anomalies were identified, the Rainy River district was truly a “New Frontier” as
the bedrock geology and mineral potential were essentially unknown. The initial gold grain anomalies were identified by Andy Bajc of the Ontario Geological Survey (OGS) in 1987-88 (Bajc, 1991) in till samples obtained mainly by rotasonic core drilling. Two major mining companies immediately followed up these anomalies with till sampling by reverse circulation (RC) rotary tricone drilling. However, a junior company, Nuinsco Resources Limited, painstakingly acquired a better land position near the strongest anomaly and, using RC drilling, located the first gold deposit –– the 17 Zone –– in 1994, followed by the 433 Zone in 1998. Despite these successes, Nuinsco defined only a small, ~0.5 million ounce (Moz) gold resource and, following a long period of depressed gold prices triggered by the Bre-X scandal, sold the project to a newly incorporated junior company, Rainy River Resources Ltd. (RRR) in 2005. With continued till sampling by RC drilling, RRR discovered the large ODM Zone at the west end of the 17 Zone along with the smaller Beaver Pond, Cap, and South zones. These deposits are now at the pre-development stage with a combined NI 43-101 compliant measured + indicated gold resource of 6.2 Moz and an inferred resource of 2.3 Moz.

The discovery and delineation of the Rainy River gold deposit illustrates (a) the important role played by regional government surveys in driving mineral exploration in frontier areas of Canada; (b) the effective use of gold grains to detect, from afar, lode gold deposits hidden beneath thick glacial sediments; and (c) the importance of the entrepreneurial spirit and agility of junior exploration companies in the discovery process. Another key factor at Rainy River was the use of the same, highly experienced laboratory, owned and operated by Overburden Drilling Management Limited (ODM, for whom the largest gold zone is named) to extract and classify the gold grains from the till samples collected in each drilling campaign. As shown in the following sections, which summarize the successive OGS, major company, Nuinsco, and RRR overburden drilling campaigns, this constant permitted integration of the gold-grain data between surveys over the long, 20 year discovery odyssey.
ONTARIO GEOLOGICAL SURVEY, 1987-88

The OGS survey covered a 30 km wide x 120 km long lowland, partly shown in Figure 2, between the Rainy River waterway, which forms the Canada/USA boundary, and a thinly covered to rocky highland to the northeast (Bajc, 1991). During meltdown of the Laurentide ice sheet, which had advanced from the Labradorean ice centre southwestward (225º) through the Rainy River area (Dyke et al., 1989) and deposited a layer of stony till that directly overlies bedrock and thus is ideal for gold grain sampling, this lowland was flooded by meltwater that spread eastward from glacial Lake Agassiz on the plains to the west (Nielsen et al., 1981). An ice lobe, related to the Keewatin ice centre west of Hudson Bay, then advanced eastward through the lake, eroding its fine bottom sediments and depositing a thick, conductive layer of clay-rich, stone-poor Keewatin till upon the Labradorean till. This upper till layer impedes electromagnetic, induced polarization, and geochemical surveys and its presence precludes boulder prospecting. However, it has beneficially prevented any oxidation of dispersed sulphide mineral grains in the Labradorean till and these heavy sulphide grains can be recovered from till samples collected from overburden drillholes and, along with the dispersed gold grains, used as indicator minerals to locate covered mineral deposits.

The OGS drilled and sampled 71 rotasonic holes in the most thickly covered parts of the lowland, typically at 2 to 5 km spacing. Of these, 33 were in the central part of the lowland between the Rainy River gold deposit and the Canada/U.S.A. border (Fig. 2). Some additional samples were collected by backhoe in areas of thin cover around isolated bedrock outcrops within the lowland (Bajc, 1991). Four of the central drillholes yielded one or more till samples that were anomalous in gold grains using a normalized threshold value of 11 grains per 7.5 kg of processed -2 mm matrix (Fig. 2). The most distal anomaly was ~12 km glacially down-ice from the subsequently discovered 17 Zone, and the strongest anomaly, 70 gold grains, was in Hole F-88-11, located 2 km west of this zone. Eight of the samples obtained from backhoe pits between the anomalous drillholes were also anomalous. Being so far apart, the anomalies were assumed not to be directly related but rather to indicate a general, previously unknown gold fertility in the district (Bajc, 1991).

As is normal in till (Averill, 2001), ~90% of the gold grains were silt-sized, i.e., <0.063 mm or 63 microns wide, and the grains were variably of pristine, significantly modified, or fully reshaped morphology, reflecting their variable distance of glacial transport from source (Fig. 3). Many samples from the western part of the survey area also yielded grains of native copper. These grains were much larger than the gold grains, with some reaching 1 to 2 mm (Fig. 4). Their surfaces were bright and fresh, illustrating the completely unoxidized condition of the Labradorean till and underlying bedrock and thus the total immobility of any contained metals and consequent ineffectiveness of surface geochemistry for exploring the district.


In 1991, following the release of the OGS report (Bajc, 1991), two major mining companies staked all of the available Crown land in the vicinity of the anomalous drillholes and performed follow-up till sampling by RC drilling. One company focused on the central gold-grain anomalies and the other focused on the western native copper anomalies. However, the lowland is surveyed into quarter-section lots measuring 800 x 800 m and only ~10 percent is Crown land — the rest is privately held farmland and bush lots. The two companies tested only the Crown land, which occurs in an irregular patchwork. This piecemeal approach resulted in the identification of a series of seemingly unconnected
anomalies rather than substantive gold-grain or native-
copper dispersal trains that could be traced to source.
As a result, both major companies abandoned their
projects by 1994.

NUINSCO, 1994-1998

While the major companies were testing the deep till in
the lowland, Nuinsco was independently employing
RC drilling to explore thinly covered gold properties
on the highland to the north, thereby gaining experience
with gold grains and becoming interested in the
activity to the south. Nuinsco’s president, Douglas
Hume, patiently assembled, lot-by-lot, a large parcel of
privately held land east of the strong OGS gold-grain
anomaly in Hole F-88-11. This was a critical decision
as it allowed systematic anomaly follow-up to be per-
formed for the first time.

Nuinsco’s initial exploration in 1993 consisted of
diamond drill testing of airborne electromagnetic
anomalies on the more thinly covered eastern margin
of the property. The targeted anomalies were found to
be due to conductive pyrrhotite in thin, cherty sedi-
ments between basalt flows. In 1994, Nuinsco con-
tracted ODM to execute a 20-hole RC drilling program,
which identified the largest and strongest gold-grain
anomaly encountered in till in Canada to that date and
led the company to the 17 Zone. As a precaution,
Nuinsco immediately staked all of the available Crown
land to the southwest in the lowland and, in 1995-96,
tested it by RC drilling. Uniformly negative gold
results were obtained from both the till and bedrock.
However, the source of the native copper grains in the
till was resolved; the present bedrock erosional surface
is just below a formerly overlying Mesozoic redbed
basin, and Cu leached from the permeable basin sedi-
ments by acidic reservoir brines was precipitated errat-
ically, along with silica, marcasite, and Mn-rich
siderite, in pre-existing fractures in the underlying
basement rocks.

Nuinsco returned to the 17 Zone in 1997-98, after
establishing the unprospectivity of the rest of the
thickly covered lowland, and performed additional,
systematic RC drilling in the area surrounding the gold
zone, resulting in a final project total of 597 holes. The
1997-98 drilling defined the limits of the gold-grain anomaly in the Labradorean till and showed that it represents the head of a 3 km wide x 15 km long dispersal train (Fig. 5) that extends southwestward to include some of the weak gold-grain anomalies identified by the OGS ten years earlier. It also showed that the till within the head of the train was anomalous in gold grains from top to bottom. Therefore the relative strength of the anomaly in any drillhole could be measured very simply by averaging the number of gold grains per sample, normalized to the typical 7.5 kg weight of processed -2 mm till matrix.

Within the overall train, several subtrains averaging >100 grains per sample emerged (Fig. 6), indicating that undiscovered gold zones were present in addition to the known 17 Zone (Nuinsco, 1997). One of these subtrains appeared to be superimposed on the train emanating from the 17 Zone but continued northeastward across this zone, suggesting that another gold zone was present further up-ice. A detailed examination of representative gold grains from this train by scanning electron microscope (SEM) revealed that these grains were larger than those in the 17 Zone train, implying a higher grade gold source, and that the main sulphide and silicate minerals intergrown with the gold were chalcopyrite (Fig. 7a) and chlorite (Fig. 7b), rather than pyrite and sericite as in the 17 Zone train. The strongest gold-grain response was in RC Hole 433, ~400 m up-ice from the 17 Zone. Follow-up diamond drilling here intersected significant mineralization, the 433 Zone, but Nuinsco did not perform sufficient drilling to define this zone.

The RC drillholes also sampled 1.5 m of bedrock beneath the till. The bedrock cuttings were logged systematically and analyzed geochemically, resulting in the first meaningful bedrock map of the unexposed portion of the Rainy River Greenstone Belt in the lowland area. The generally unprospective part of the greenstone belt southwest of the gold deposit consists of a monotonous succession of basalt and greywacke. Near the gold deposit, these lithologies yield abruptly along
Figure 7. SEM images of representative gold grains from the 433 Zone dispersal train. a) Slightly modified grain with intergrown chalcopyrite. b) Slightly modified grain with intergrown chlorite.

Figure 8. Bedrock geology in the area of the Rainy River gold deposit. The bedrock is covered by ~30 m of glacial deposits and the geology was determined from 1.5 m bedrock intercepts at the bottoms of RC holes drilled by Nuinsco and Rainy River Resources. The thick dacite occurs in a basin structure, probably a caldera, on the western flank of a volcanic edifice and yields abruptly westward along strike to basalt. The volcanic rocks are folded and the dacite dips 50° south.
strike to a bimodal succession of dacite and basalt (Fig. 8). The dacite is mostly fragmental. It includes chaotic lenses of coarse, vent-facies breccia which is thought to have been deposited mostly subaqueously in a caldera basin on the western flank of a large volcanic edifice (SRK Consulting, 2009; RRR, 2010). A 2 km thickness of the permeable dacite within the caldera sequence was pervasively hydrothermally altered and is continuously mineralized with 2 to 5% pyrite and is anomalous in gold at the ~50 ppb level (Fig. 9). The higher grade mineralization found in the gold zones of economic interest appears to have been concentrated by fluid pooling at aquitards in the reservoir; consequently these gold zones are roughly stratiform.

The Rainy River Greenstone Belt area has been affected by regional folding and the caldera sequence is now tilted ~50º southward and metamorphosed to lower greenschist facies. The total area of pervasively altered and gold-anomalous dacite that was exposed to glaciation and now underlies the till was a remarkable 600 hectares or 6 km² (Fig. 9), accounting for the great, 3 km width and 15 km length of the gold-grain dispersal train in the till (Fig. 5). Shear deformation associated with the regional folding was concentrated in the most altered and best mineralized dacite units. Therefore, as at similar volcanogenic gold deposits, such as LaRonde in the Bousquet district of Quebec (Dubé et al., 2007), the Rainy River deposit superficially resembles a shear-controlled deposit. As at LaRonde, the introduced Mn alteration occurs as spessartine garnet (Mn₃Al₂(SiO₄)₃) and the excess alumina resulting from feldspar destruction occurs partly in kyanite (Al₂SiO₅) despite the lower greenschist grade of metamorphism.

RAINY RIVER RESOURCES, 2005-2013

The acquisition of the Rainy River gold project by RRR in 2005 was spearheaded by the company’s president, Nelson Baker, who recognized the great potential of such a large, gold-rich, volcanogenic, hydrothermal alteration system. From 2005 to 2010, RRR drilled another 278 RC holes to further define the gold-grain subtrains in the till and locate their bedrock sources. These subtrains were defined both by the normalized average number of gold grains per sample in the till section (Fig. 10) and the average analyzed Au content of the heavy mineral fraction of the samples (Fig. 11). The Au analyses were normalized to a constant 250:1 laboratory heavy mineral concentration factor because the weights of the concentrates varied greatly with pyrite abundance. Approximately 90% of the gold in the concentrates was found to be still encased in pyrite grains rather than occurring as liberated grains (RRR, 2010). The 433 Zone was found, as foretold by the size
and inclusion mineralogy (Fig. 7) of the gold grains in the till, to be of a significantly higher grade than the 17 Zone and to be characterized by chloritic alteration with significant chalcopyrite. The 17 Zone blossomed westward along strike into the large ODM Zone. A new gold zone, Beaver Pond, was found further west at the same stratigraphic level and two others, the Cap and South zones, were found to the south at a higher stratigraphic level.

Diamond drilling conducted in concert with the RC drilling has established significant gold resources in all six gold zones. Recently RRR’s early confidence in the project was again rewarded with the discovery further to the east of the new Intrepid Zone. This gold zone is in virgin ground east of the area shown in Figures 8 to 11. It is glacially across-ice from the area tested by RC drilling and is the first significant discovery made on the property without the aid of gold grains. It is expected that deep gold zones, which were not exposed to glaciation and thus are not reflected in the till, will also be discovered as the property is developed.

DISCUSSION AND CONCLUSIONS

The six gold zones currently comprising the Rainy River gold deposit were all discovered by tracing glacially dispersed, till-hosted gold grains to their bedrock sources. These gold deposits are of volcanogenic origin. They are stratiform and occur within a 6 km² area of hydrothermally altered and pervasively gold-anomalous fragmental dacite deposited within a probable caldera basin, resulting in an exceptionally large, 3 km wide x 15 km long gold-grain dispersal train in the till. Near the head of this train, the till section is anomalous in gold grains from top to bottom, regardless of its thickness, reflecting the great breadth of the gold-bearing source rocks. However, subtrains related to economically significant gold zones are readily recognizable from both the average number of gold grains per sample in the till section and the average analyzed Au grade of the heavy mineral fraction of the till.

The observed, glacially liberated gold grains represent only ~10% of the total gold present in the till because the grains are silt-sized and 90% are still encapsulated within pyrite grains. These pyrite grains have remained fresh since glaciation because the auriferous till is covered by a thick layer of younger, clay-rich impervious till. During glaciation, new gold grains were continually liberated from the pyrite along the length of the dispersal train such that even its distal part...
contains some pristine grains that may appear proximal. This, along with the patchwork land ownership in the area, may have contributed to the long odyssey from train discovery to deposit discovery.

The discovery of the Rainy River gold deposit and resolution of the six gold zones comprising the deposit is an excellent example of the effective use of gold grains in an area of thick cover that impedes most other exploration methods. The fact that the initial impetus was provided by a regional government survey illustrates the importance of such surveys, especially in a “New Frontier” such as the Rainy River district. However, the ~20-year period and long succession of companies required to complete the discovery is a reminder of the stamina, perseverance, and imagination needed to be successful in mineral exploration. The entrepreneurial spirit and agility of the two junior exploration companies, Nuinsco and RRR, were particularly important to the discovery process.

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