

GEOLOGY AND GEOCHEMISTRY OF UNUSUAL GOLD MINERALIZATION IN THE CAT ARM ROAD AREA, WESTERN WHITE BAY: PRELIMINARY ASSESSMENT IN THE CONTEXT OF NEW EXPLORATION MODELS

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ABSTRACT

The Rattling Brook gold deposit, located along the Cat Arm Road, is an important gold resource that has some unusual characteristics. It is a large, dispersed, low-grade system in which auriferous sulphides are generally disseminated or present in myriad tiny veinlets. The larger and more continuous quartz-vein systems typical of most mesothermal gold deposits are conspicuously absent. The dominant host rocks are altered Precambrian granites, but some of the best mineralization occurs in altered Precambrian (?) metadiabase dykes and in Cambrian quartzites, limestones and phyllites. The mineralization must be post-Cambrian, but its timing is otherwise unconstrained, although a Silurian or younger age is implied by its undeformed character. The commonality of textures in mineralized rocks, and broadly similar alteration sequences, suggest that a single process deposited gold in all of these host rocks. Petrological and metallurgical studies indicate that free gold is very rare and imply that much of the gold is refractory, likely held within sulphides. The most likely candidates are gold-rich arsenopyrite or gold-rich arsenian pyrite, but more detailed work is required to confirm their occurrence.

Geochemical data indicate that there is very little associated Ag, and essentially no enrichment in Cu, Zn, Pb, Co or Ni in mineralized rocks. There are strong Au–As–S correlations, and a diffuse Au–Ag correlation, but essentially no correlation between gold and the base metals. Auriferous samples are also commonly enriched in Te and W, and there is more diffuse enrichment in Sb. A few auriferous samples display marginal enrichment in Tl, but no consistent enrichment in Hg or Se is present. Mineralized carbonate rocks become depleted in CaO and MgO and enriched in SiO₂ as their Au concentration increases, implying decalcification and silicification.

These preliminary results suggest that the Cat Arm Road gold mineralization has broad affinities with sedimentary-rock-hosted micron gold deposits (also known as “Carlin-type” deposits) or generally similar noncarbonate-hosted stockwork-disseminated gold deposits. These conclusions are encouraging in the context of current exploration in the area, which is based on models of this general type, but there remains a need for more extensive and precise trace-element geochemical data, and for more information on sulphide mineral assemblages and the precise habitat of gold within the mineralized zones.

INTRODUCTION

Gold mineralization in western White Bay is hosted by Precambrian granites, parautochthonous Cambro-Ordovician sedimentary rocks, and Silurian volcanic and sedimentary rocks (e.g., Tuach, 1987; Saunders and Tuach, 1988, 1991; Saunders, 1991; Kerr, 2004). The most significant gold resource is at the Rattling Brook deposit (McKenzie, 1987a; Poole, 1991a; Saunders and Tuach, 1991; Kerr, 2004) located along the Cat Arm Road southwest of Great Coney Arm (Figure 1). This deposit was initially explored in the late 1980s, by BP Resources Canada, who focused mostly upon mineralization hosted in Precambrian granites. Current exploration by Kermod Resources Limited and South

Coast Ventures is directed instead toward the discovery of additional gold mineralization in adjacent Cambro-Ordovician sedimentary rocks. This shift in exploration emphasis reflects the adoption of a “Carlin-type” exploration model for this area (e.g., Wilton, 2003).

Carlin-type deposits (termed sediment-hosted micron gold deposits by Poulsen *et al.*, 2000) are large disseminated gold deposits that are typically hosted by carbonates and associated sedimentary rocks, but also involve other host rock-types, including clastic sedimentary rocks and plutonic rocks. The deposits of the type area in the Great Basin of Nevada and adjacent states are the most important source of gold in North America, and make a significant contribution

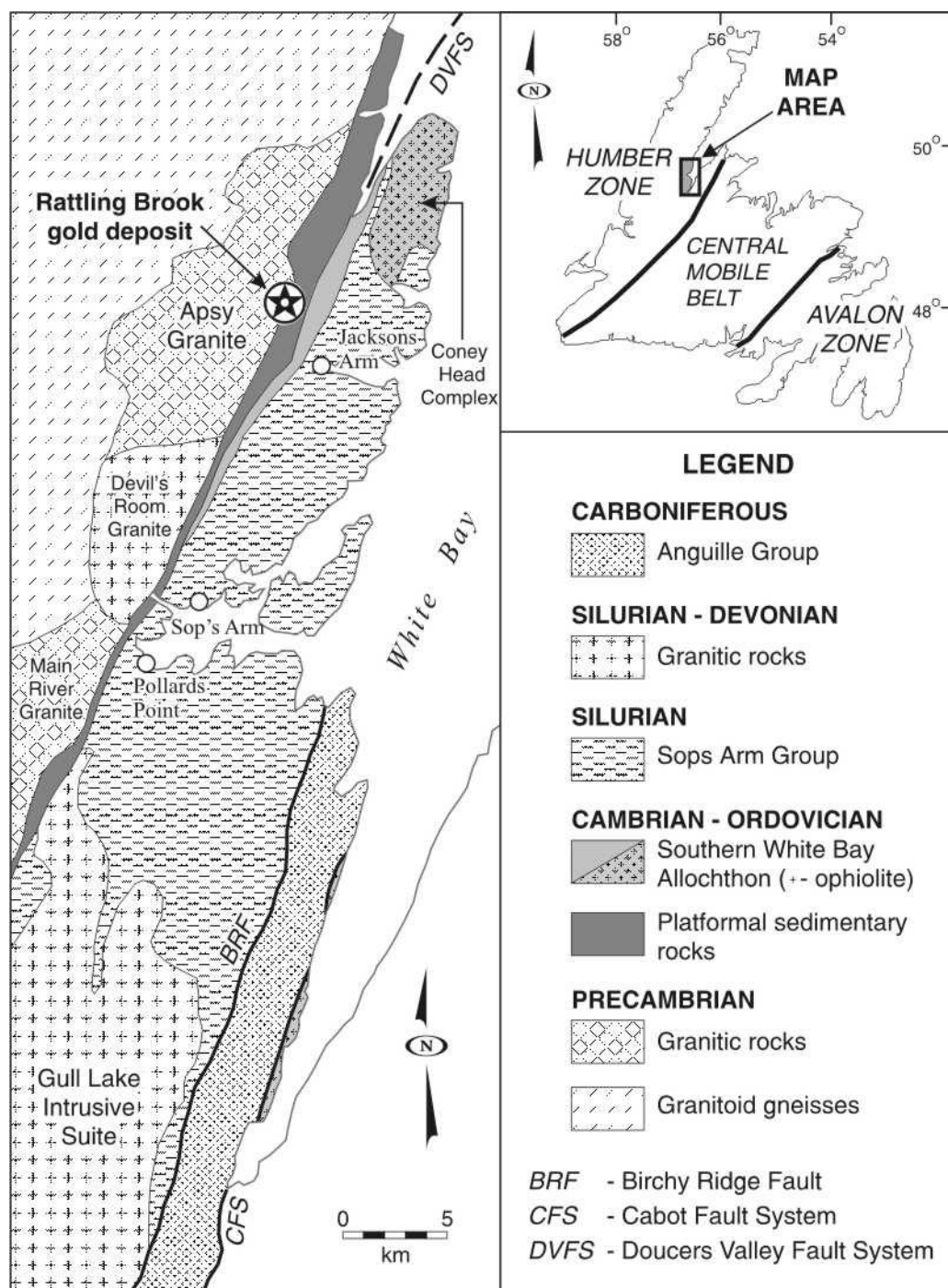


Figure 1. Location and regional geology of the Western White Bay area, showing the location of the Rattling Brook gold deposit.

to world gold production. Carlin-type deposits in the Great Basin exhibit varied settings and characteristics, and their origins are controversial. However, these diverse deposits have features in common, including distinctive geochemical traits and element associations (e.g., Arehart, 1996; Hofstra and Cline, 2000; Poulsen *et al.*, 2000). Another important type of disseminated gold mineralization, termed “non-car-

bonate stockwork-disseminated deposits” by Poulsen *et al.* (2000) has many features in common with Carlin-type mineralization, and is sometimes included within this broad category. Non-carbonate stockwork-disseminated gold mineralization is also very important economically, and may include well-known large deposits such as Muruntau in Uzbekistan (Poulsen *et al.*, 2000). Indeed, some workers

(e.g., Sillitoe, 1991) consider both these disseminated gold deposit types as distal manifestations of magmatic–hydrothermal systems related to major intrusive bodies. This report summarizes the geology of the Rattling Brook deposit, and discusses old and new geochemical data in the context of patterns and relationships reported elsewhere from Carlin-type and similar deposits. It extends a previous descriptive treatment of sedimentary-rock-hosted mineralization in the area (Kerr, 2004) and expands earlier discussions of the granite-hosted mineralization (Saunders and Tuach, 1988, 1991).

GEOLOGICAL AND METALLOGENIC FRAMEWORK

REGIONAL GEOLOGY

Western White Bay contains rocks that range in age from Proterozoic to Carboniferous (Figure 1). Kerr and Knight (2004) summarize regional geological relationships, partly after Smyth and Schillereff (1982) and present revised interpretations of stratigraphy and structure in Cambro-Ordovician rocks. An abbreviated summary of the regional geology is presented below.

The area lies along the eastern edge of the Precambrian Long Range Inlier. The oldest rocks are granitoid gneisses, possibly as old as 1500 Ma, that are intruded by granitoid rocks of 1030 to 980 Ma age (Heaman *et al.*, 2002), and late Precambrian Long Range dykes. These Precambrian rocks are bounded to the east by a narrow belt of Cambro-Ordovician sedimentary rocks (Figure 1) consisting of a lower clastic sequence overlain by dolostones and limestones. The Cambro-Ordovician sedimentary sequence includes most of the formations recognized in the undeformed platformal succession along the Gulf of St. Lawrence (Kerr and Knight, 2004). The basal Cambrian unconformity is well preserved in White Bay, but the higher parts of the sequence are disrupted by thrust faults. The Precambrian basement and its autochthonous to parautochthonous cover rocks are bounded to the east by the Doucers Valley fault system, an important lineament that essentially divides western White Bay into two halves (Figure 1). This structure probably has a complex history of reactivation throughout the Paleozoic (e.g., Tuach, 1987). Cambro-Ordovician rocks east of the Doucers Valley fault system are considered to be part of a disrupted Taconic allochthon termed the Southern White Bay Allochthon (Smyth and Schillereff, 1982). The allochthon includes assorted clastic sedimentary rocks, metavolcanic rocks, minor ultramafic rocks and trondhjemites of the Coney Head Complex (Figure 1). Collectively, these rocks represent deeper water sedimentary facies and samples of oceanic crust transported westward across the ancient continental margin of North America. The east-

ern part of the area also includes the Silurian Sops Arm Group (Figure 1), consisting of mafic to felsic volcanic rocks, conglomerates and mostly clastic sedimentary rocks. The Sops Arm Group is considered to have been deposited unconformably on the Southern White Bay allochthon, but definitive relationships are preserved only at one locality, where deformation is superimposed on both, and most contacts between the two are faults. Both the Sops Arm Group and the Southern White Bay allochthon have been subjected to significant Silurian or post-Silurian deformation. Syn- to posttectonic granitoid rocks of probable Silurian age are abundant in the south of the area, where they intrude the Sops Arm Group and older rocks (Figure 1). A similar granite that intrudes Precambrian basement west of Sops Arm (Devils Room Granite) has been dated at 425 Ma (Heaman *et al.*, 2002). Diabase dykes cut Cambro-Ordovician carbonate rocks, but are not reported to cut the Sops Arm Group. The youngest rocks in the area are Carboniferous sedimentary rocks of the Anguille (Figure 1) and Deer Lake groups, which unconformably overlie all Ordovician and Silurian rocks, including those of plutonic origin.

Excluding multiple Precambrian events recorded in gneisses of the Long Range Inlier, the area records at least three major orogenic events. The Ordovician Taconic Orogeny is believed to have involved emplacement of the Southern White Bay Allochthon over autochthonous Cambro-Ordovician rocks (Smyth and Schillereff, 1982; Kerr and Knight, 2004). The Silurian Salinic Orogeny and/or the Devonian Acadian Orogeny strongly affected Silurian and older rocks and probably created much of the present geological architecture. These events were accompanied and followed by granitic plutonism. Carboniferous or post-Carboniferous events (Variscan Orogeny) were also important, as rocks of the Anguille Group are tightly folded and older Silurian rocks have locally been thrust over the Deer Lake Group. Major lineaments such as the Doucers Valley fault system are inferred to have been sites of significant strike-slip motion during Carboniferous and post-Carboniferous times, but these structures were likely established during earlier Paleozoic events (Tuach, 1987; Kerr and Knight, 2004).

REGIONAL METALLOGENY

Western White Bay contains a wide variety of metallic and nonmetallic mineral occurrences, and has a long (albeit sporadic) history of mineral exploration. The area contains some of the first gold prospects discovered in Newfoundland, including the first commercial gold mining operation (ca. 1904) at the Browning Mine, south of Sops Arm (Figure 1). The Silurian rocks of the Sops Arm Group contain most of the gold mineralization known prior to the 1980s, and most of these localities were initially described by Snel-

grove (1935). Most consist of sulphide-bearing quartz–carbonate veins in either felsic volcanic or siliciclastic rocks. Disseminated gold mineralization was discovered in the early 1980s in Precambrian granitoid rocks, during construction of the access road for the Cat Arm hydroelectric project. Similar mineralization was later found in adjacent Cambrian sedimentary rocks. This area, now known as the Rattling Brook gold deposit, was extensively explored in the late 1980s, and is currently enjoying renewed exploration attention. It is the principal subject of this paper, and is discussed in more detail below. There are no official resource figures for the Rattling Brook gold deposit, but informal estimates by Dearn (1991) propose that it contains over 1 million ounces of gold, albeit at average grades of only 1 to 2 ppm Au (i.e., 1 to 2 g/t Au).

Lead and Zinc mineralization occurs in thin carbonate units within volcanic rocks of the Sops Arm Group, notably at the Turners Ridge and White Star prospects, and is generally considered to be of Carboniferous age (Saunders, 1991; Kerr *et al.*, 2004). Minor Zn enrichment is also reported in some of the Cambro-Ordovician carbonate rocks, and Cu–Ag mineralization is present in Carboniferous sandstones at the Birchy Ridge prospect (Tuach and French, 1986; Saunders, 1991). Minor occurrences of fluorite, molybdenite and galena are reported from plutonic rocks in several parts of the area (Saunders, 1991).

THE RATTLING BROOK GOLD DEPOSIT

INTRODUCTION AND EXPLORATION HISTORY

The term Rattling Brook gold deposit is used here for several discrete auriferous zones located around the Cat Arm hydroelectric access road, 3 to 4 km north of its junction with highway 420 near Jacksons Arm (Figures 1 and 2). The four main mineralized areas are termed the Incinerator Trail zone, Beaver Dam zone, Road zone and Apsy zone (Figure 2). The mineralization was summarized in previous survey reports (Tuach and French, 1986; Tuach, 1987; Saunders and Tuach, 1988), and discussed in a short paper by Saunders and Tuach (1991). Voluminous descriptive and numerical data are contained in assessment reports (Bruneau, 1984; French, 1985; Avison and French, 1985; McKenzie, 1986, 1987b; Holmes and Hoffman, 1987; Poole, 1991b). The results of exploration in the 1980s were summarized more succinctly by McKenzie (1987a) and Poole (1991a). Kerr (2004) provides a general history of exploration activity up to 2003, and describes both granite-hosted and sedimentary-rock-hosted mineralization.

Kermode Resources and South Coast Ventures commenced work in the area in 2001, and completed a 17-hole (2040 m) diamond-drilling program in late 2003 and early

2004. The first 11 holes of the program tested the continuity of mineralization previously defined in Cambrian sedimentary rocks at the Beaver Dam zone. Five holes tested the northern part of the Apsy zone and a soil geochemical anomaly (“anomaly 14”) some 4 km to the north (Figure 2), and one hole was drilled within granite-hosted mineralization at the Road zone. Most of these holes encountered gold mineralization, for which selected results were released (Kermode Resources, press releases, February 23 and June 1, 2004). The drill core was donated to the Department of Natural Resources core library, and provides valuable information because key mineralized intersections from the earlier exploration work in the 1980s are unavailable for study. Also, the recovery and integrity of the NQ core retrieved in 2004 is far superior to that of the narrower diameter BQ core retrieved during the 1980s. Information derived from examination of the new drill core is explored in this report; ongoing petrographic and geochemical studies of this material should add further to our knowledge of the deposit.

GEOLOGY

The regional geology of the area west and southwest of Great Coney Arm is discussed elsewhere (Smyth and Schillereff, 1982; Kerr and Knight, 2004), and the description below applies only to the area around the Rattling Brook gold deposit. The deposit is located along and immediately west of the contact between Precambrian granites of the Long Range Inlier and adjacent Cambro-Ordovician sedimentary rocks (Figure 2). This contact is a tilted (east-dipping) unconformity, which runs along the course of the Cat Arm road. The unconformity is well exposed north of Apsy Cove Pond, and is also visible just north of Prospect Pond (Figure 2). Diamond-drill core suggests that this original sedimentary contact is preserved through much of the deposit area shown in Figure 2, although it is locally sheared (Kerr, 2004). The sedimentary rocks immediately above (east of) the unconformity consist of grey quartzites of the Cambrian Bradore Formation, which are in most areas overlain by a thin carbonate unit that marks the base of the overlying Forteau Formation. In most of the area, calcareous phyllites of the Forteau Formation sit above (east of) this basal carbonate unit, and are locally up to 200 m thick. The phyllites become progressively thinner southward, and are only a few metres thick in the northern part of the Beaver Dam zone, and absent completely in its southern part (Figure 2). The upper (eastern) contact of the calcareous phyllites is a composite fault zone, which is mostly unexposed, but represented in drill core by intense fracturing and fault gouge development, locally accompanied by pervasive hematization. Most of the rocks east of this fault zone are massive dolostones, assigned to the Late Cambrian Petit Jardin Formation (Port au Port Group). However, grey limestones of very different appearance are present locally

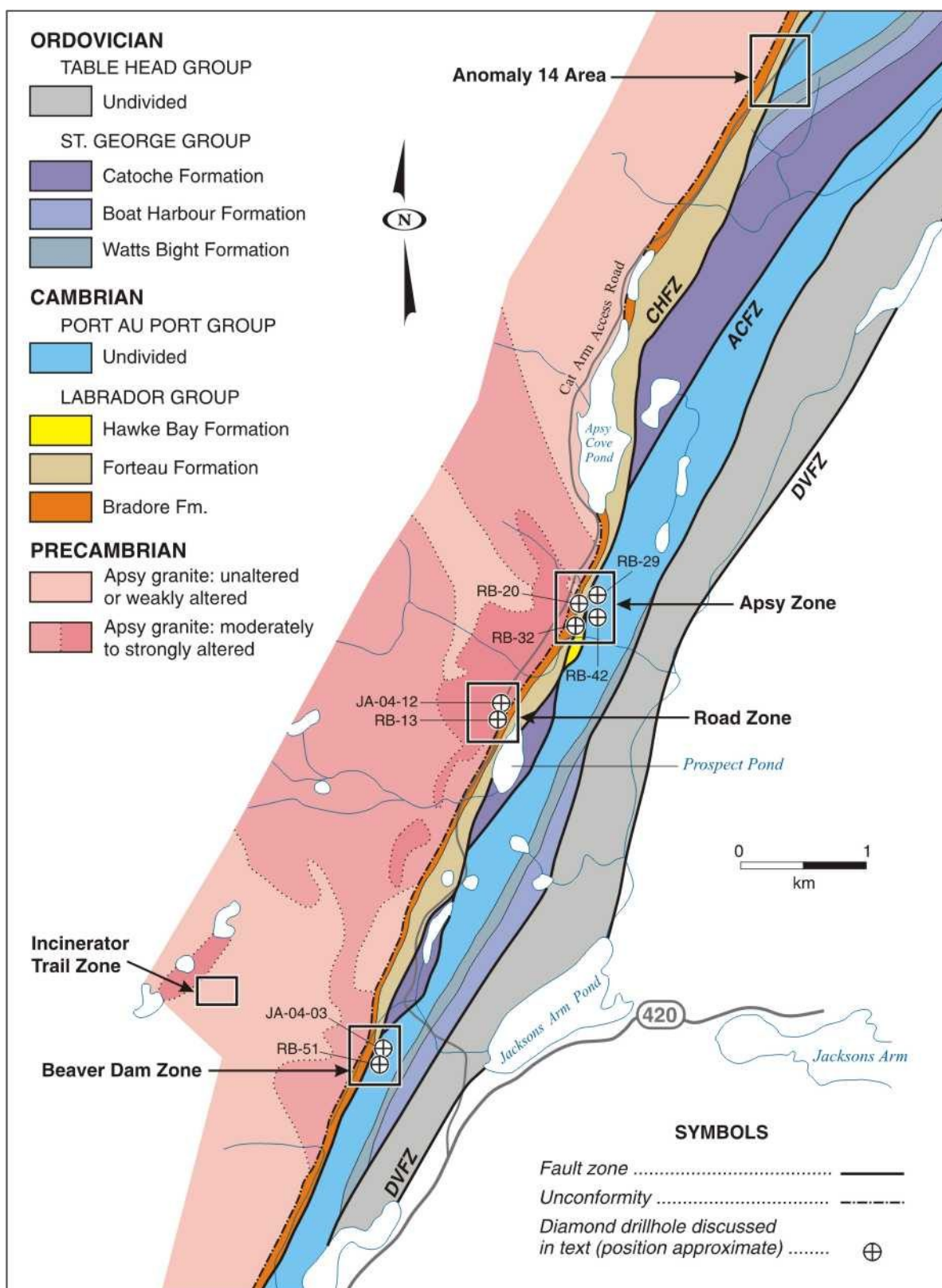


Figure 2. Generalized and simplified geological map of the area around the Rattling Brook gold deposit, based upon mapping by BP Resources in the late 1980s, and subsequent work in 2003 and 2004 by the author. No strikes and dips are shown for reasons of clarity, but the sedimentary rocks dip steeply eastward (50° to 80°).

immediately east of the fault zone. These commonly show extensive bioturbation and include distinctive white marbles, and are believed to represent part of the Ordovician St. George Group, likely the Catoche Formation (Kerr and Knight, 2004). There is some localized hydrothermal dolomitization of these rocks, associated with porosity development. Contacts between these grey limestones and massive dolostones to the east also appear to be fault zones, and the grey limestones are interpreted as fault-bounded lozenges of Ordovician rocks caught between thicker slices of Cambrian rocks. More extensive areas of Catoche Formation are mapped along strike to the north, east of Apsy Cove Pond (Figure 2), where they occupy the same structural position. In the area of the Beaver Dam zone, the fault zone juxtaposes Port au Port Group dolostones in the east against Bradore Formation quartzites and Forteau Formation carbonates in the west. Kerr (2004) provides several cross-sections from the Beaver Dam and Apsy zones that illustrate these relationships.

At least two generations of diabase dykes are present in the deposit area. The older set are considered to be late Precambrian Long Range dykes, that were affected by Paleozoic events. These dykes are visible in several places along the Cat Arm road (Figure 3), where they trend roughly north-south. These dykes commonly show marginal foliations and transformation of original mafic minerals to amphibole and biotite. They are locally cut by auriferous fracture zones, and drilling shows that they are altered and mineralized (*see below*). A younger and less common set of diabase dykes has a general ENE trend and are unaltered and undeformed. These dykes are green, fine grained, locally plagioclase-porphyritic, and resemble similarly oriented diabase dykes that cut Cambro-Ordovician rocks along the shores of Coney Arm (Kerr and Knight, 2004). A roadcut outcrop of mineralized granite about 100 m south of the Apsy zone is cut by a fresh diabase dyke that lacks any alteration or mineralization (Figure 3), implying that younger dykes postdate the introduction of gold. Unmineralized diabase dykes having well-preserved chilled margins cut auriferous granites in drill core from the Road zone, notably in drillhole RB-09. Diabase dykes are uncommon in the sedimentary rocks to the east of the Rattling Brook deposit, although a wide (3 to 4 m) dyke cuts foliated quartzites just south of Apsy Cove Pond. Felsic dykes are not known in surface outcrops, but drillhole RB-13 at the Road zone contains an orange quartz-feldspar porphyry that also appears to postdate surrounding mineralization.

The composite fault zone that runs through the deposit area is interpreted to result from the confluence of two major structures, termed the Cobbler Head and Apsy Cove fault zones (Kerr and Knight, 2004). The Cobbler Head fault zone is a complex imbricate zone localized mainly within cal-

careous phyllites of the Forteau Formation; it is interpreted as a major detachment structure within the sedimentary sequence. The Apsy Cove fault zone probably originated as a thrust, which brought Cambrian rocks of the Port au Port Group over Ordovician rocks of the St. George Group. In the gorge of Rattling Brook (Figure 2), this composite fault zone also contains quartzites interpreted as middle Cambrian Hawke Bay Formation of the Labrador Group (Figure 2). Minor faults are commonly observed within the sedimentary rocks in drill core, where they cause repetition of lithological boundaries. Mylonitized carbonate rocks are locally present along the trace of the composite fault zone, but in the drill core it is mostly characterized by (presumably later) brittle deformation and intense fracturing, locally accompanied by hematitic staining. There is no sign of any gold mineralization east of this composite fault zone.

The relationship of these faults to the Doucers Valley fault system, which defines the eastern boundary of the Cambro-Ordovician rocks some 1 to 2 km farther east, is not entirely clear (Kerr and Knight, 2004). However, it seems likely that all were sites of late (Carboniferous ?) motions. Paleokarst features of probable Carboniferous age (Kerr and Knight, 2004) suggest that the sub-Carboniferous unconformity was at one time not far above the present land surface.

GOLD MINERALIZATION

Mineralization in Precambrian Granitoid Rocks

Precambrian granitoid rocks are the main hosts for gold mineralization at the Road zone and Incinerator Trail zone and contain much of the mineralization at the Apsy zone (Figure 2). Also, there is gold enrichment in some granites in the deeper parts of drillholes at the Beaver Dam zone, but this area remains incompletely explored at depth. The character of mineralization is best known at the Road and Apsy zones. The host rocks are various facies of the ca. 1000 Ma Apsy Granite (Saunders and Tuach, 1988), which was once known as the French-Childs granodiorite (Tuach and French, 1986), but is generally referred to in exploration company reports as the Rattling Brook Granite (e.g., McKenzie, 1987a; Poole, 1991a). The dominant rock type within the Apsy Granite is coarse-grained, K-feldspar megacrystic granodiorite to monzogranite, also containing biotite, magnetite and local hornblende. Accessory minerals, generally intergrown with hornblende and biotite, include apatite, sphene and zircon. In the study area, biotite (variably altered to chlorite) is the most common mafic mineral, and plagioclase is extensively saussuritized, lending it a green colour. Mantled-feldspar (rapakivi) textures are common, and heavily saussuritized varieties develop spectacular green rings around pink ovoidal microcline megacrysts.

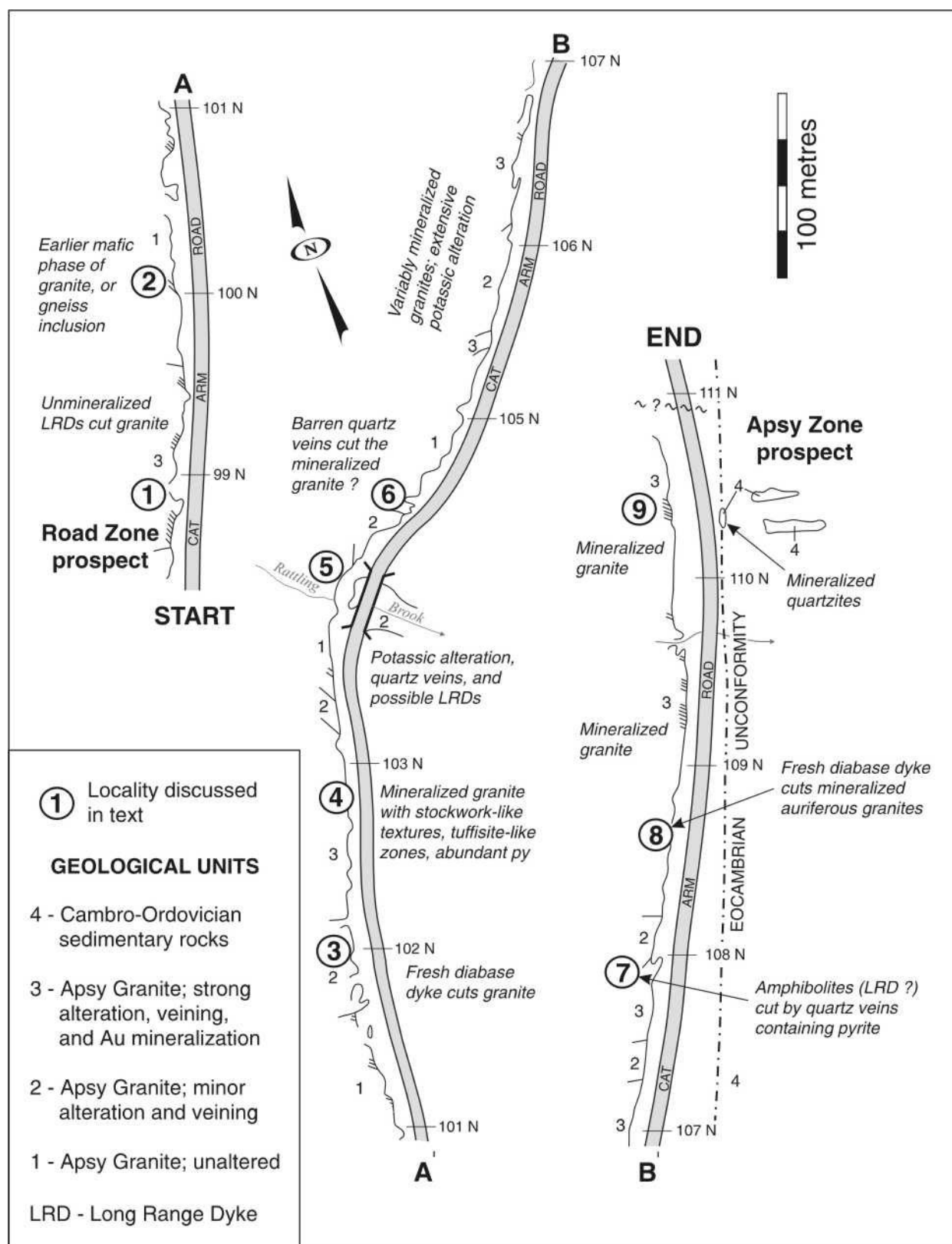


Figure 3. Detailed map of the outcrops and key localities associated with the Ratting Brook gold deposit along a 1 km stretch of the Cat Arm Road, modified after an original diagram by Tuach and French (1986). For detailed descriptions of the numbered localities, see Kerr et al. (2004).

In the vicinity of the Rattling Brook gold deposit, the granodiorites are altered. Petrographic and geochemical studies (Saunders and Tuach, 1988, 1991) indicate that this alteration is mostly potassic, resulting in transformation to a pink alkali-feldspar granite dominated by microcline and quartz, with lesser albite and sericite. The original texture of the Apsy Granite (including variable recrystallization) is preserved, even though the mafic minerals and plagioclase are largely obliterated. This potassic alteration is well displayed along the Cat Arm road in the area around Rattling Brook bridge, where its contacts with unaltered and less altered granodiorite are visibly gradational (Figures 2 and 3). Saunders and Tuach (1988, 1991) suggested that gold mineralization was associated with a second stage of alteration and veining, which affects both potassic-altered and unaltered granites. This stage 2 alteration is associated with numerous veinlets containing very fine-grained quartz, albite, Fe-carbonate and sericite, accompanied by sulphides. Microcline feldspar in the host altered granite is replaced by fine-grained albite. Most veinlets are just millimetres wide, and larger quartz or quartz-feldspar veins having widths of 1 to 10 cm are uncommon; however, discrete quartz-feldspar veins were noted within mafic dykes and sedimentary host rocks in the recent drill core. Marginal alteration around veinlets is locally visible, but is more commonly cryptic. However, a melanocratic, magnetite-rich variant of the Apsy Granite intersected within hole JA-04-12 (and possibly exposed on surface, *see* Figure 3), contains sulphide-bearing veinlets that have very clear bleached marginal alteration zones. This interval is also Au-rich (>5 ppm Au), suggesting that the more mafic, Fe-rich rock types are advantageous hosts (Figure 4). White quartz veins are common in surface outcrops at the Road zone and Apsy zone (Figure 3), but these are sulphide-free and do not appear to be mineralized. Similar veins are observed in drill intersections of mineralized granites. Plate 1 shows typical examples of granite-hosted gold mineralization and related alteration.

Sulphides are present within the narrow veinlets, but are more obviously present as disseminated material throughout the altered host rock. The dominant sulphides are fine-grained pyrite and arsenopyrite; very minor chalcopyrite, pyrrhotite and galena are reported as inclusions in pyrite, but gold is exceedingly rare. It is present only as inclusions in pyrite, with a maximum diameter of about 15 μm (Saunders and Tuach, 1988, 1991). Mineralogical studies commissioned by BP-Selco examined heavy-mineral concentrates produced from some of the higher grade intersections, and came to very similar conclusions (Sinclair, 1988). Pyrite and arsenopyrite were by far the most common sulphides, but galena, sphalerite, chalcopyrite, tennantite and silver telluride were noted in very small quantities. Gold was observed very rarely, and was mostly present as tiny inclusions within pyrite, down to a size of approximately 1

μm . Mass balance calculations by Sinclair (1988) indicate that more than 50 percent of the gold in the processed samples was retained in the light fraction (density <2.8), which is dominated by silicates. This implies that significant amounts of gold occur in silicate-hosted sulphide inclusions of a size range below the particle size of the samples (-45 mesh; <0.2 mm). Furthermore, the observed gold content of the heavy-mineral separates was too high to be explained by the rare visible gold inclusions, suggesting that much of the gold must be present either in solid solution or as sub-micron-sized particles within the sulphides (Sinclair, 1988).

The extent of mineralization in altered granites at the Road and Apsy zones is impressive, but the grades are generally low; typically 0.5 to 2 ppm Au, with local enrichment to 6 ppm Au or more, most notably where the host rocks are more mafic. Figure 4 demonstrates the general relationship between Au grades and rock types in drillhole JA-04-12, which is typical of mineralization at the Road zone. Note that the highest grades occur in the more mafic phase of the Apsy Granite, and in altered dykes (*see below*).

Mineralization in Precambrian Dykes

Mineralized metadiabase dykes form only a small part of the Rattling Brook gold deposit, but they are important in understanding alteration and the timing of mineralization. Altered and mineralized dykes occur at the Incinerator Trail zone, the Road zone and (to a lesser extent) at the Apsy zone. These dykes are visible locally in surface outcrops, but their characteristics are best known in drill core. A recent vertical drillhole (JA-04-12; Figure 4) intersected at least two mineralized dykes within mineralized Apsy Granite, and reveals interesting geological relationships, illustrated in Plate 2. Fine- to medium grained unaltered metadiabase is dark and amphibolitic in appearance, having a foliation sub-parallel to the core axis, consistent with the subvertical foliations observed in similar surface outcrops within this area (Figure 3). Altered sections of the dykes range from variably sericitized to silicified and/or pyritized, and reveal at least 2 stages of alteration. The earliest is clearly sericitic, with the initial development of sericite along the foliation planes. More advanced alteration of this type produces pale yellow-green featureless, sericitic rocks that are not readily recognized as originally mafic in composition. However, unaltered diabase is preserved as “islands” within this material. The sericitic alteration is overprinted by thin quartz and quartz-feldspar veinlets around which are developed grey marginal zones of silicification and sulphidization. These later alteration zones occur only within sericitized material, and sericitic zones invariably separate sulphide-bearing zones from unaltered metadiabase. “Islands” of unaltered metadiabase in silicified intervals commonly show “fringing reefs” of intense sericitization. Intervals containing silicified

and pyritized zones are Au-enriched, whereas intervals with sericitic alteration alone contain little or no Au (Figure 4). The highest grade intervals contain sulphides both in narrow veinlets and as heavily disseminated material. Locally, discrete inner pyrite-rich and outer arsenopyrite-rich haloes are

visible around individual veinlets. Several discrete intervals representing quartz or quartz-feldspar veins are also present in this drillhole (Figure 4; Plate 2). Massive white quartz veins generally do not contain sulphides and show no gold enrichment. However, quartz veins containing red and

Drillhole JA-04-12 (Road Zone): Lithology and Au distribution

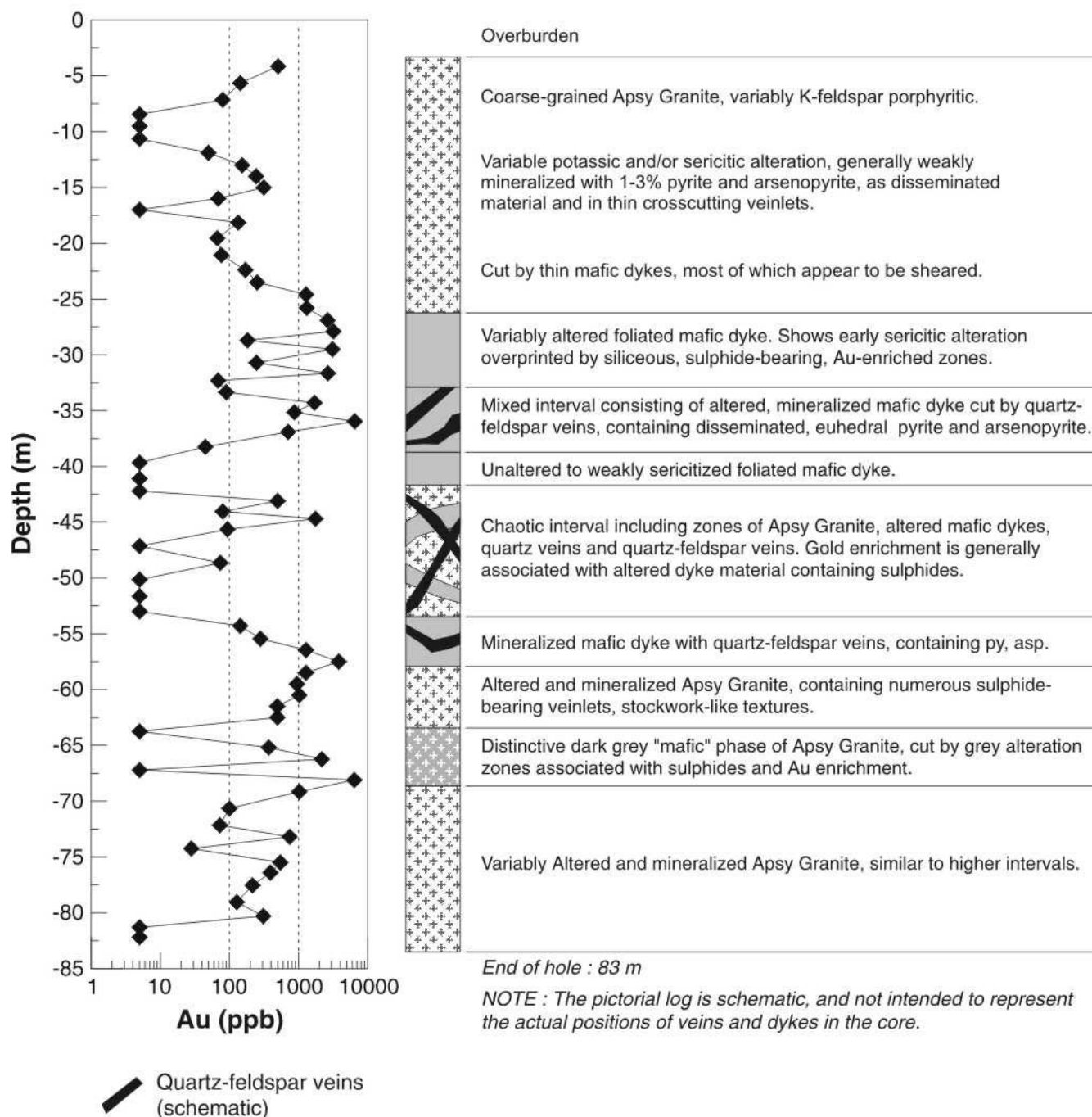


Figure 4. Annotated schematic log of drillhole JA-04-12, showing the variation in Au grades from various host rocks. Gold assays used with permission of Kermode Resources, descriptions based on 2004 field work.

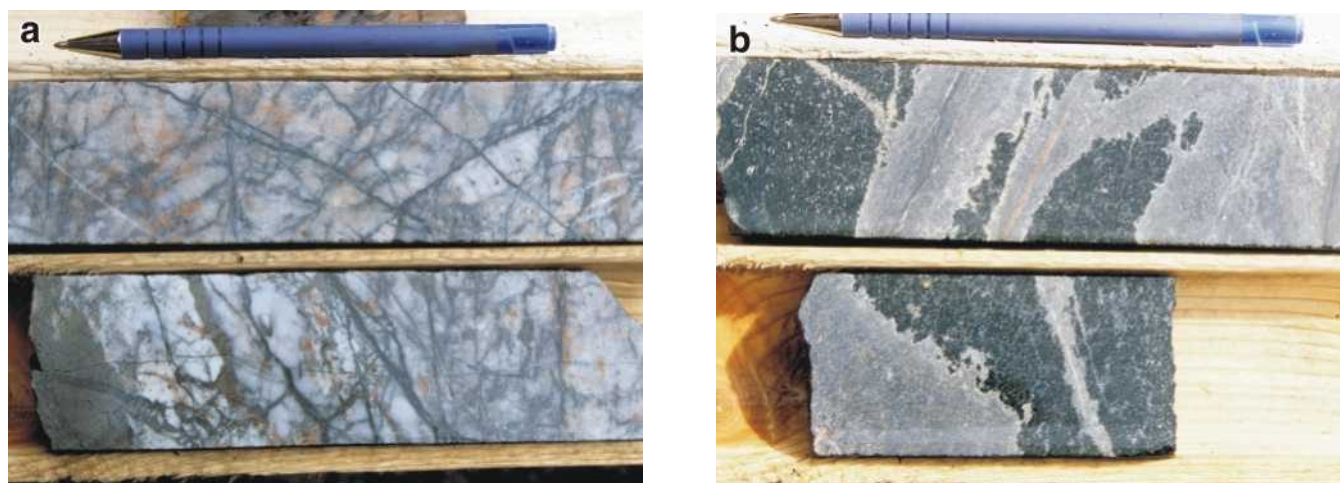


Plate 1. Examples of gold mineralization and alteration in Precambrian Apsy Granite. a) Numerous sulphide-bearing veinlets cutting altered granite, drillhole JA-04-12. b) Bleached auriferous alteration zones containing disseminated sulphides cutting a dark, more mafic phase of the Apsy Granite, drillhole JA-04-12.

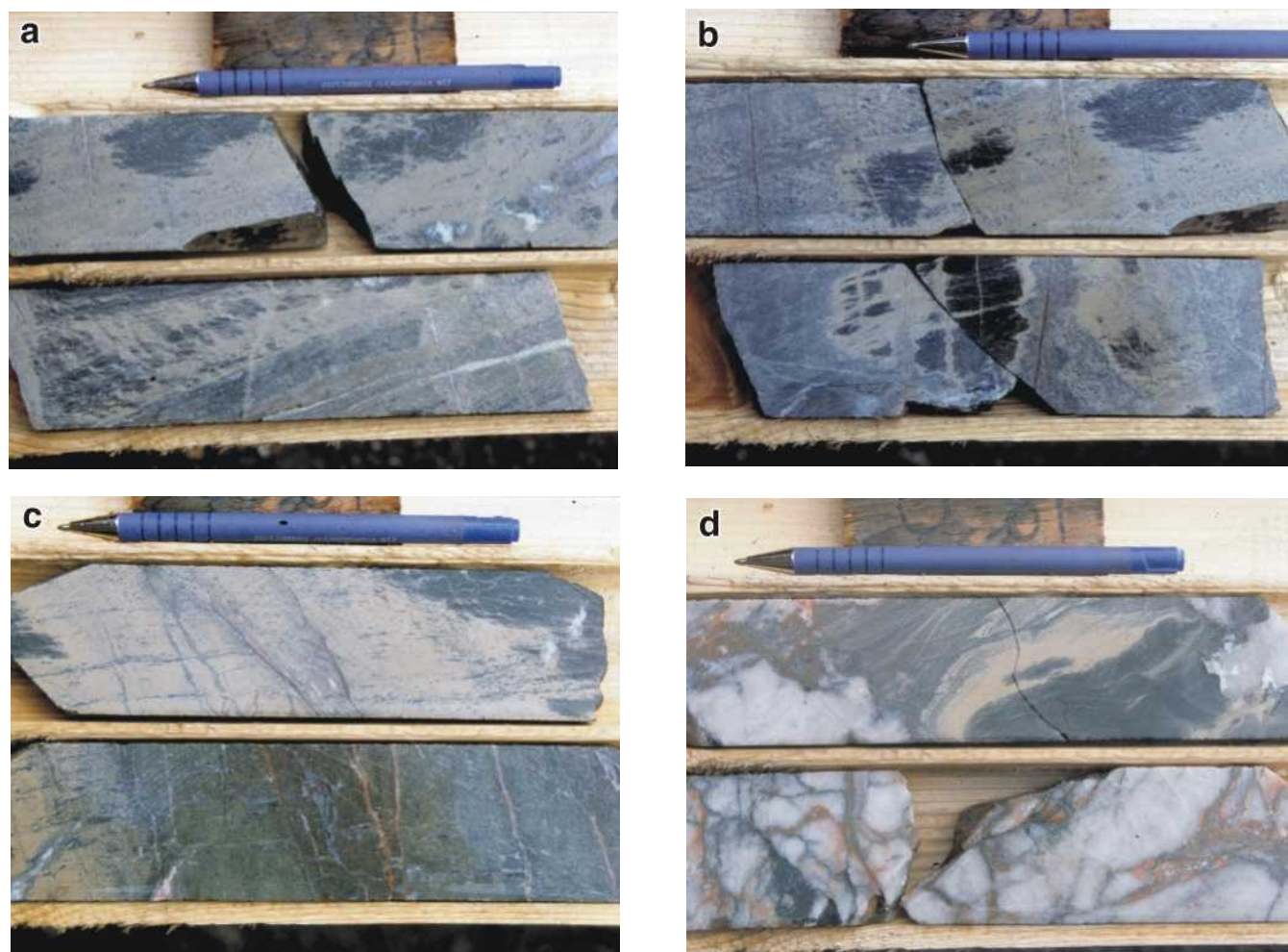


Plate 2. Examples of gold mineralization and alteration in Precambrian metadiabase dykes. a) Intense sericitic alteration in metadiabase, partly controlled by a foliation subparallel to the core axis; note dark areas of unaltered diabase. b) “Islands” of unaltered metadiabase, surrounded by “fringing reefs” of sericitic alteration, preserved with pervasively silicified and pyritized gold-bearing metadiabase. c) Siliceous veinlets with marginal zones of silicification and pyritization cutting yellow sericitized metadiabase. d) Quartz-feldspar veins cutting sericitic alteration in metadiabase, but in turn cut by sulphide-bearing veinlets. The veins also contain euhedral pyrite and arsenopyrite. All examples from drillhole JA-04-12.

cream feldspars (K-feldspar and albite ?) contain patches of coarse, euhedral pyrite and arsenopyrite, and locally show enrichment up to 6 ppm Au (Figure 4). These veins truncate zones of sericitic alteration, and truncate some thinner sulphide-bearing veinlets but they are also cut by some of the latter. Such relationships imply that these quartz-feldspar veins were an integral part of the mineralizing process(es), and were not simply introduced at a later time.

The metadykes in drillhole JA-04-12 exhibit a range of gold contents, from background values (5 ppb) in unaltered material to about 3.8 ppm (3800 ppb) where strongly altered and pyritized. In general, the grades from mineralized metadykes are higher than those from surrounding mineralized granites, with the exception of the more mafic granitoid rocks in the lower part of the hole (Figure 4). This pattern is true also of mineralized dykes intersected by drilling in the 1980s, although the relationships are nowhere as well preserved as in drillhole JA-04-12.

Mineralization in Cambrian Quartzites

Most sedimentary-rock-hosted mineralization at the Beaver Dam zone and the Apsy zone is hosted by quartzites of the Bradore Formation. Although the entire thickness of this unit is locally mineralized, gold distribution is more commonly erratic. However, many intersections have the highest grade material in the upper part of the sequence, below the basal carbonate unit of the Forteau Formation (Kerr, 2004). The distribution of units, and their relationship to gold content, is illustrated by the profile from drillhole JA-04-03 (Figure 5). Important features are illustrated in Plate 3.

The quartzites are detrital rocks that contain distinctive blue-grey quartz grains; most examples are fairly pure, containing only minor feldspar; arkosic rocks are less common, but are present locally in the lower part of the sequence. Where the original sedimentary textures are locally well preserved, the detrital grains are accentuated by the presence of fine-grained sericite and iron oxide in the surrounding matrix. However, many quartzites are recrystallized to homogeneous grey rocks with a relict detrital texture, defined by pale blue spots representing the interiors of the original grains. Locally, the recrystallization is intense and the rocks become completely featureless and saccharoidal. Magnetite is commonly an accessory mineral, and is locally abundant, particularly in the upper part of the sequence.

Alteration in mineralized quartzites is far less obvious than in other rock types discussed above, but the locally intense recrystallization may reflect the introduction of fluids and silica. Veinlets and stockwork-like zones of very fine-grained to amorphous silica cut and dissect detrital tex-

tures in some of the holes drilled in 2004. A red mineral associated with quartz in some of these veins is interpreted as potassium feldspar, and there is locally abundant sericite in the matrix to the detrital grains. This incipient alteration is generally not associated with significant gold enrichment (Figure 5). Strong gold enrichment is everywhere associated with sulphides, principally pyrite and arsenopyrite. Both minerals are present in finely disseminated form, but pyrite also forms larger (1 to 5 mm) “framboidal” clots that probably formed by sulphidization of detrital magnetite. Where the transformation is incomplete, magnetite remains in the central parts of these clots. Sulphides also occur in numerous dark, crosscutting, stockwork-like veinlets that are typically only millimetres wide. These were also noted by Kerr (2004) but are much harder to see in drill core from the 1980s, due to fracturing. These veined quartzites are texturally similar to mineralized Apsy granite and strongly mineralized metadiabase dykes. Sulphides are also present in disseminated form around individual veinlets. It is difficult to identify gangue minerals in the narrowest veins, but wider veins (up to 1 cm wide) have white quartz-rich interiors and marginal dark sulphide concentrations. The strongest gold enrichment is associated with heavily disseminated to semi-massive pyrite, which appears to have pervasively replaced the matrix between detrital quartz grains, or replaced magnetite in quartzites near the top of the sequence.

Quartzites are cut by discrete quartz-feldspar veins, which locally contain coarser grained pyrite and euhedral arsenopyrite. These quartz-feldspar veins are themselves cut by thin sulphide-bearing veinlets, and appear to be Au-enriched (Figure 5). The relationships between larger quartz-feldspar veins and smaller sulphide-bearing veinlets are essentially identical to those described above from mineralized metadiabase units.

Mineralization in Limestones

The basal limestone unit of the Forteau Formation is less commonly mineralized than the underlying quartzites. In most cases, the highest grades are localized at the base of the limestone unit, where there is commonly a rather diffuse transition zone into the quartzites, associated with magnetite-rich rocks, termed “calcareous ironstones” by Poole (1991a, b). This part of the stratigraphy seems to contain interbedded clastic and carbonate rocks, but is generally very poorly preserved in drill core. The relationships between Au and rock types are illustrated in Figure 5, and features of limestone-hosted mineralization are revealed in Plate 4.

The basal limestone unit of the Forteau Formation varies widely in appearance, but it generally consists of white, pale grey or yellowish limestones, locally finely lam-

Drillhole JA-04-03 (Beaver Dam Zone): Lithology and Au distribution

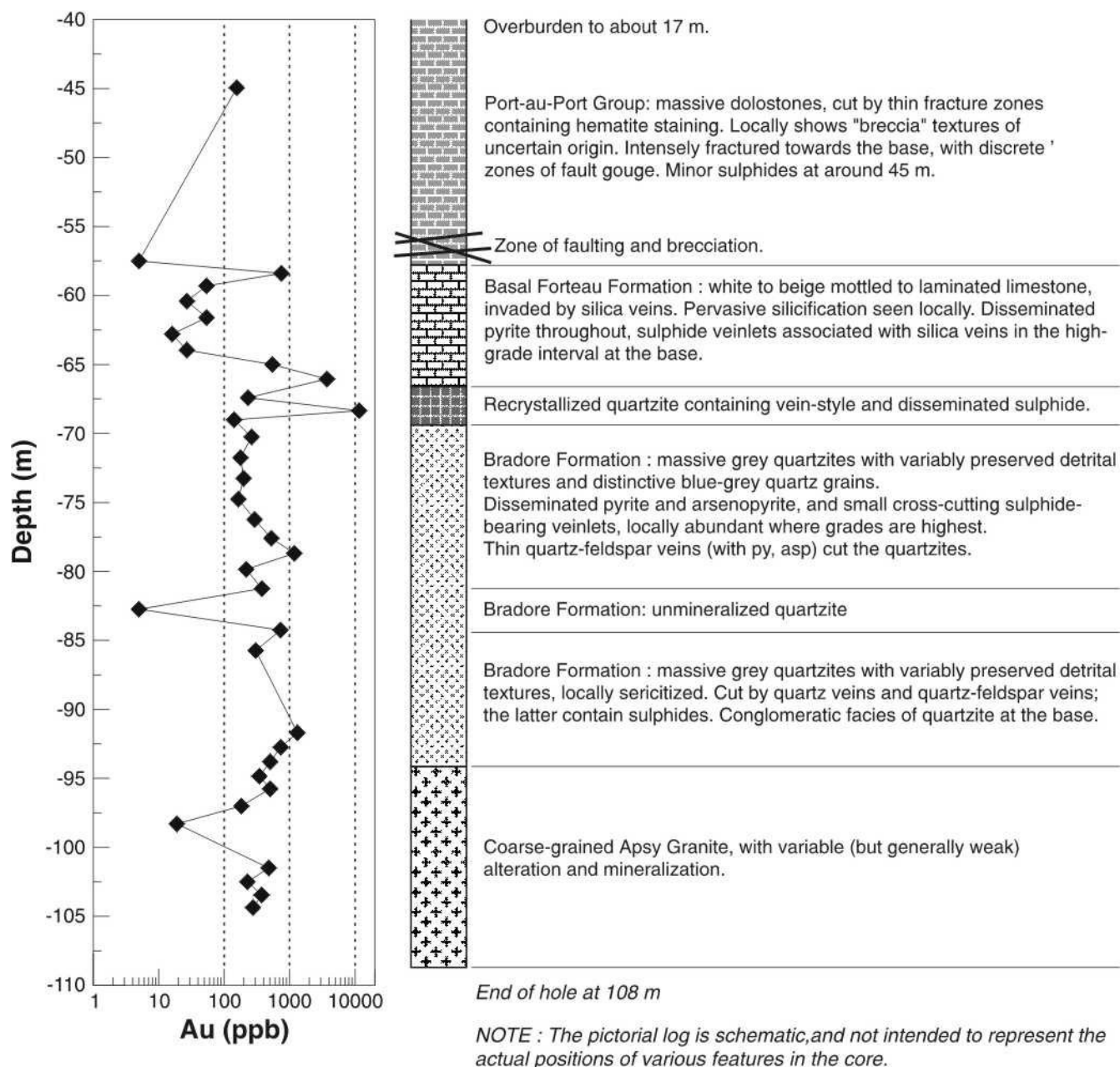


Figure 5. Annotated schematic log of drillhole JA-04-03, showing the variation in Au grades from various host rocks. Gold assays used with permission of Kermode Resources, descriptions based on 2004 field work.

inated, but commonly structureless and massive. Locally, parts of the unit have a heterogeneous, breccia-like appearance, but this is believed to represent effects of brittle deformation, alteration and silicification rather than a true depositional texture. The laminated limestones are cut by numerous randomly oriented, siliceous veinlets that create spectacular stockwork-like textures, but there is little or no introduction of silica beyond the veins. At the other extreme,

there are massive, hard white rocks that contain discrete quartz-rich zones associated with a red mineral thought to be K-feldspar. These structureless rocks are interpreted as silicified limestones. Heterogeneous, breccia-like rocks that seem to consist of a mixture of soft carbonates and hard siliceous material probably represent an intermediate stage in this process, where fluids have percolated outward from the original veins, to replace the surrounding rock. These

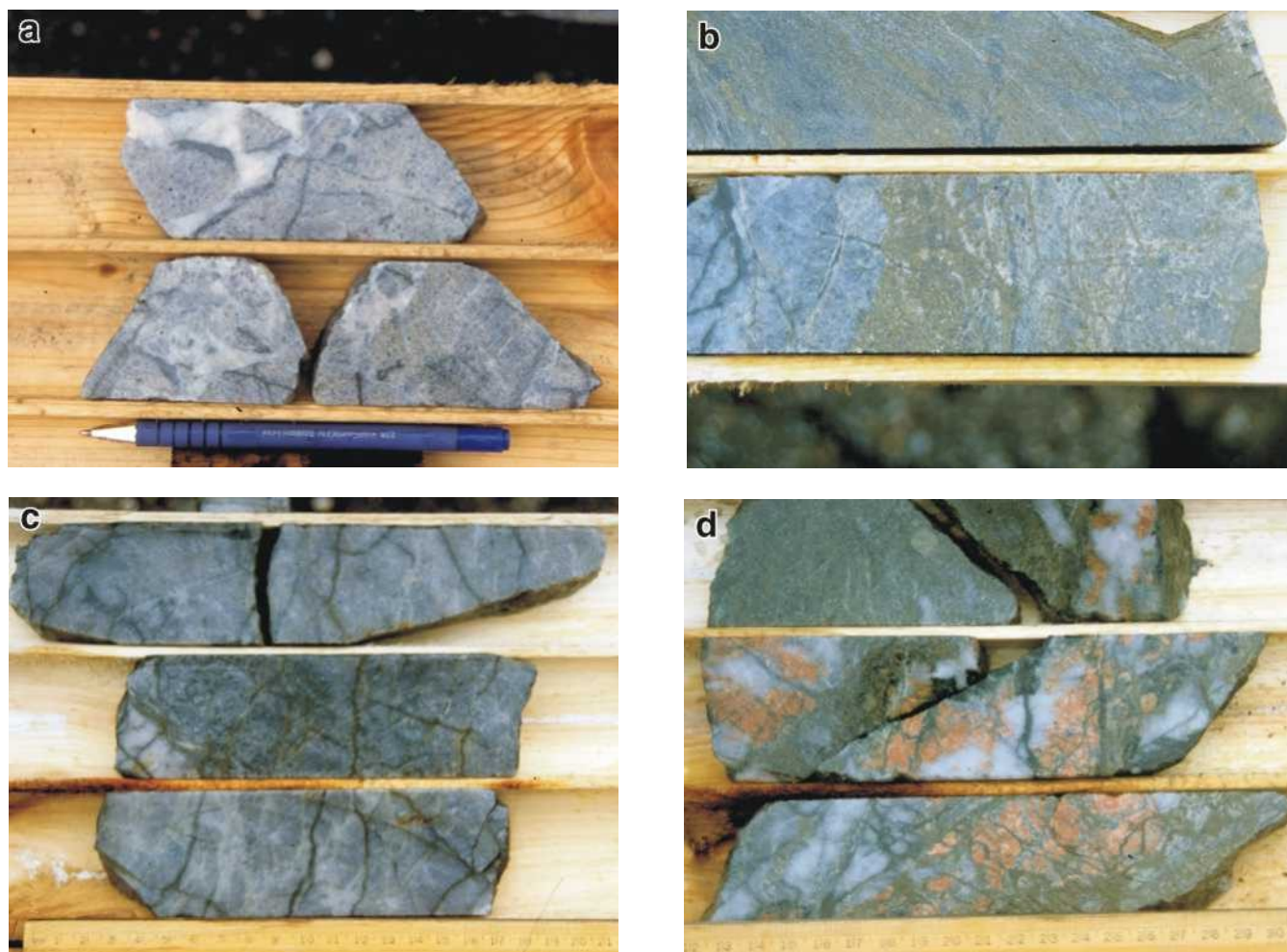


Plate 3. Examples of gold mineralization and alteration in Bradore Formation quartzites. a) Discrete silica veins cutting recrystallized quartzite; note the dark sulphide-rich margins to some of the veins, drillhole JA-04-03. b) High-grade gold mineralization associated with strong pyritization of quartzite, drillhole JA-04-03. c) Sulphide-bearing veinlets in mineralized quartzite, drillhole JA-04-01. d) Quartz-feldspar veins cutting quartzites; note that both veins and quartzites are cut by sulphide-bearing veinlets, drillhole JA-04-01.

variably altered and possibly silicified limestones contain fine-grained disseminated pyrite, but generally show only slight enrichment in gold (Figure 5). As in the quartzites, higher grade mineralization is associated with heavier sulphide concentrations, most of which appear to have a vein-like form, and random orientation. These sulphide-bearing veins appear to be thicker than the hairline to millimetre-scale veinlets typical of the quartzites (Plate 4).

Mineralization in Calcareous Phyllites

The calcareous phyllites that constitute most of the Forteau Formation in the deposit area are generally devoid of significant mineralization. Most assays reported from drilling in the 1980s are at background levels of a few ppb

Au, with a few scattered anomalous samples containing up to 100 ppb (0.1 ppm) Au. The host rocks commonly contain minor amounts of pyrite, and outcrops are rusty-weathering, but the sulphides are evidently not auriferous. Drilling in 2004 at the “anomaly 14” area, located about 4 km north of the Apsy zone (Figure 2) provided the first clear indication of anomalous gold in these rocks, and some intervals contain up to 0.9 ppm Au (Kermode Resources, press release, June 1, 2004). These grades are low compared to those in other rock types described above, but are significant in that they extend both the strike length and stratigraphic interval of known gold mineralization. There is no sign of sulphides in the Apsy Granite intersected in the lowermost parts of the four drillholes in the anomaly 14 area.

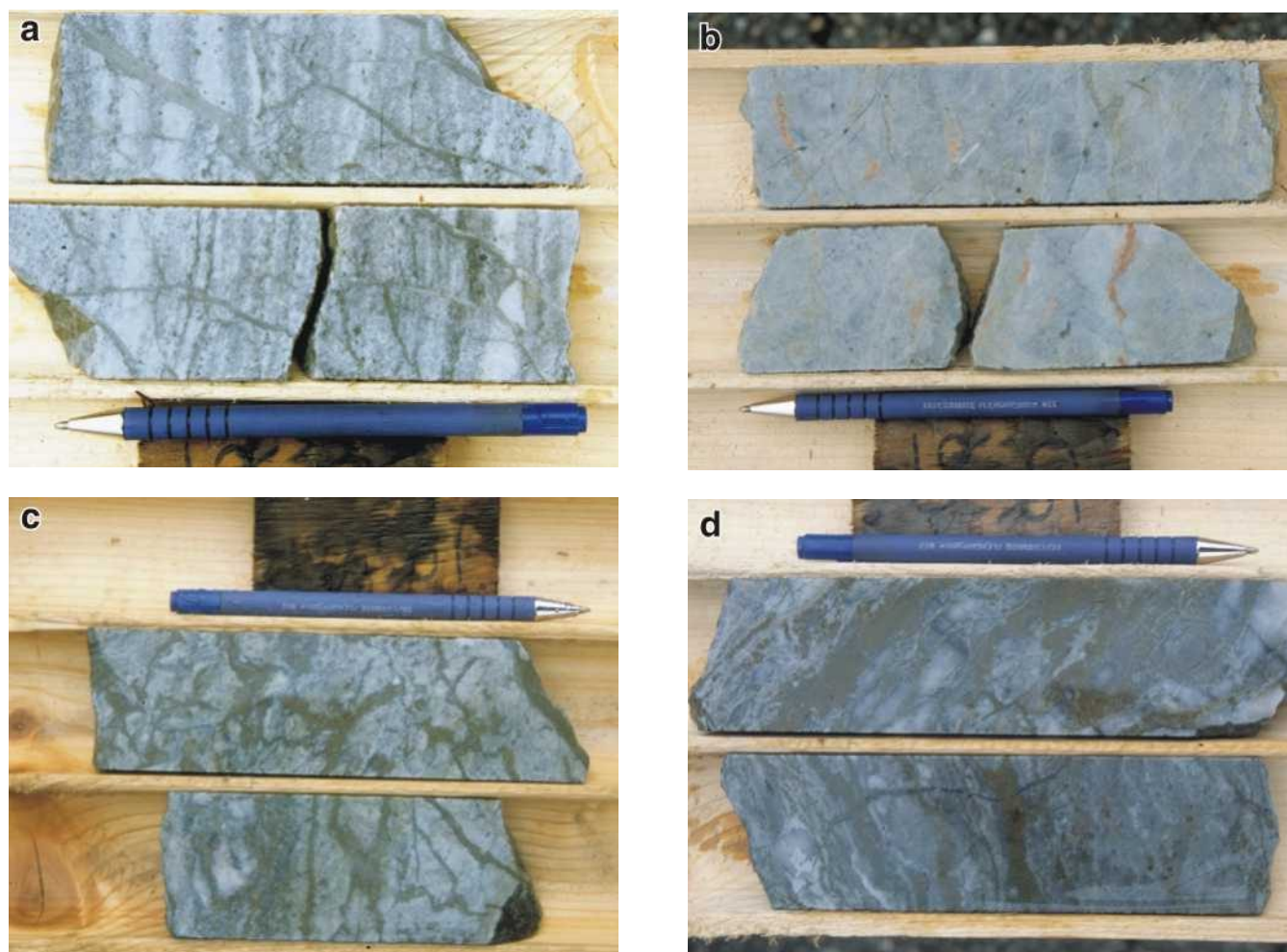


Plate 4. Examples of gold mineralization and alteration in Forteau Formation carbonate rocks. a) Silica veinlets invading laminated limestones; note offsets across some of the veinlets, drillhole JA-04-03. b) Pervasively silicified limestones, containing red mineral interpreted as K-feldspar, drillhole JA-04-01. c) Sulphide-bearing veins in silicified limestones containing high-grade gold mineralization, drillhole JA-04-09. d) Strongly pyritized limestones containing high-grade gold mineralization, drillhole JA-04-03.

GEOCHEMISTRY

OVERVIEW

This section presents geochemical data from two different sources. A large database comes from exploration programs conducted in the 1980s, under which drill cores were routinely analyzed for Au, Ag, base metals and assorted trace elements; these results are presented in numerous assessment reports, notably McKenzie (1986, 1987b), Holmes and Hoffman (1987) and Poole (1991b). In many cases, particularly in mineralized granites, drillholes were analyzed in their entirety. Gold was analyzed by fire-assay atomic absorption spectroscopy (FA-AAS), and other elements were analyzed by multielement "scans" using inductively-coupled-plasma emission-spectroscopy (ICP-ES). Data of the latter type have inherent limitations, as the

detection limits for some elements are rather high. However, the samples are relatively large (typically 0.5 to 1.5 m of core), and these data provide a good picture of grade and metal distributions. They are also very useful in the assessment of correlations between precious metals and base metals, and broad relationships between metal enrichment and rock types. However, because of the large sample size, these geochemical data cannot always be tied to specific rock types, textures or alteration patterns. A smaller database represents field and drill-core samples from 2003, analyzed at the Department of Natural Resources laboratory. These data are more complete in that they include both major and trace elements, acquired by ICP-ES methods with generally better detection limits than the 1980s exploration data. These samples were also analyzed for Au and selected trace elements using a commercial analytical package that uses a combination of instrumental neutron-activation (INAA) and

ICP-ES methods. The latter (provided by Actlabs, Inc.) is specifically formulated for use in exploration for epithermal-type gold deposits. The samples are smaller than those from earlier exploration programs (typically 10 to 15 cm of drill core; or 1 to 2 kg of outcrop material), but they are deliberately chosen to represent specific rock types, textures or alteration assemblages. The samples in this database are biased toward mineralized and unmineralized sedimentary rocks, but it also includes mineralized granites and diabase dykes.

These two databases are used for slightly different interpretative purposes below. The 1980s exploration program data are used to examine broad patterns and interelement correlations within selected (representative) drillholes. The recent Departmental data are used to assess major- and trace-element data in terms of the element associations and relationships reported from Carlin-type gold deposits.

RELATIONSHIPS BETWEEN PRECIOUS METALS, BASE METALS AND ARSENIC

This section focuses upon results for precious metals (Au, Ag), selected base metals (Cu, Zn and Pb) and As, using 1980s exploration program data. The geochemical relationships are illustrated by profiles of six selected drillholes (Figure 6, approximate locations indicated in Figure 2), which are representative of the patterns observed in a larger database of some 60 drillholes, and also represent the full range of rock types in the deposit area. Drillhole RB-13 (Road zone; Figure 6a) is entirely within mineralized Apsy Granite. Drillholes RB-20 and RB-32 (Apsy zone; Figures 6b and 6c) are dominated by mineralized Apsy Granite, but include mineralized sedimentary rocks in their uppermost sections. Drillholes RB-29 and RB-42 (Apsy zone; Figures 6d and 6e) contain both sedimentary rocks and mineralized Apsy Granite in subequal proportions. Hole RB-51 (Beaver Dam zone; Figure 6f) is almost entirely within mineralized sedimentary rocks. The profiles for Au in drillholes RB-20, 29, 42 and 51 were previously illustrated by Kerr (2004).

The profiles for gold in drillholes RB-13, RB-20 and RB-32 illustrate the typical grades of mineralized granites at the Rattling Brook deposit (Figure 6). For example, most of drillhole RB-13 contains less than 1 ppm Au (1000 ppb), with maximum values of about 2 ppm Au (2000 ppb). The upper 80 m of the hole is consistently mineralized, with >500 ppb Au, but the lower section has more sporadic enrichment, and includes intervals of essentially background Au concentrations (5 ppb). Very similar grades and variation patterns are shown by the lower granitic portions of drillholes RB-42 and RB-51. The mineralized sedimentary rocks in all drillholes show the same general range of 0.5 to 2 ppm Au, but there are narrow high-grade (up to 10 ppm Au)

intervals associated with the boundary zone between the Forteau Formation and underlying Bradore Formation quartzites. This stratigraphic control on gold distribution was noted previously (Poole, 1991a; Kerr, 2004) and is visible in all profiles that contain both formations (Figures 6c, 6d, 6e and 6f).

The most striking feature of the six profiles is the strong correlation between Au and As, noted also by Saunders and Tuach (1991) and discussed by Kerr (2004). No other elements in the database correlate so faithfully with gold. Although the similarity of the profiles is remarkable, note that the correlation is not strong enough to allow prediction of Au concentrations from arsenic concentrations on an individual sample basis, because samples with modest Au concentrations of a few hundred ppb may have several thousand ppm As. However, strong Au enrichment is always associated with strong As enrichment, and As enrichment is never seen where samples have near-background gold concentrations of 10 ppb or less. The Au–As correlation appears to be completely independent of the host rock type(s).

Silver concentrations in mineralized rocks of all types are generally low, with many analyses at the detection limit of 0.2 ppm Ag. Most samples contain less than 1 ppm Ag, and the maximum value in the six selected holes is only 3 ppm Ag (Figures 6b and 6d). The correlation between Ag and Au is poor compared to the strong correlation between As and Au (*see above*). However, all of the selected drillholes exhibit a diffuse Ag–Au correlation in that anomalous Ag (i.e., >0.5 ppm Ag) is seen only in intervals that have significant Au enrichment (i.e., >1000 ppb Au). This correlation appears as a series of “spikes” in the silver profile, commonly associated with the highest Au analyses. The gold-enriched interval at the Forteau–Bradore formation boundary is picked out well by Ag enrichment in drillholes RB-32, RB-42 and RB-51, but not in drillhole RB-29. In less strongly mineralized intervals, the Ag enrichment appears more sporadic and variable than the gold enrichment, but this likely reflects the greater analytical uncertainty for Ag. Mineralized sections containing <0.5 ppm (500 ppb) Au generally contain Ag at detection-limit levels. An examination of several other drillholes that contained little or no gold mineralization (not shown) indicates that Ag generally remains below detection limit (0.2 ppm, or 200 ppb).

Copper concentrations in mineralized rocks are very low. Most intervals of the selected drillholes contain 10 ppm or less Cu, irrespective of their gold concentrations, and there is no clear correlation between Cu and Au. Although there are intervals where anomalous Cu (10 to 100 ppm) coincides with Au enrichment, there are many more intervals where Cu concentrations remain near the detection limit of 1 ppm even where gold concentrations exceed 1000

Figure 6a. The variation of Au, As, Ag, Cu, Zn and Pb with depth (metres) in selected drillholes from the Rattling Brook gold deposit, using data from 1980s exploration programs; drillhole RB-13, Road zone.

ppb. The highest Au concentrations at the Forteau–Bradore formational boundary are associated with mild Cu enrichment in drillholes RB-32, RB-42 and RB-51 (Figures 6d, 6e and 6f), but there is no such correlation in drillhole RB-29 (Figure 6c). Examination of data from drillholes that lack significant Au mineralization reveals a similar range of Cu contents, i.e., 2 to 50 ppm, with most intervals containing <10 ppm Cu.

Zinc concentrations in mineralized rocks are generally higher than Cu concentrations, and are typically in the range of 5 to 100 ppm. There is no consistent correlation between Zn and Au, or between Zn and Cu, although anomalous values for all three locally coincide. Lead concentrations in mineralized rocks are also low, mostly falling between 2 ppm Pb and about 50 ppm Pb. Scattered high values (10 to 1000 ppm Pb) have no obvious correlation with enrichment in precious or base metals. There does not appear to be any correlation between Pb and the other base metals or between Pb and Au or Ag.

The correlations between Au and selected elements (Ag, As, Cu, Zn) are also illustrated using scatter plots for four of the selected drillholes (RB-13,

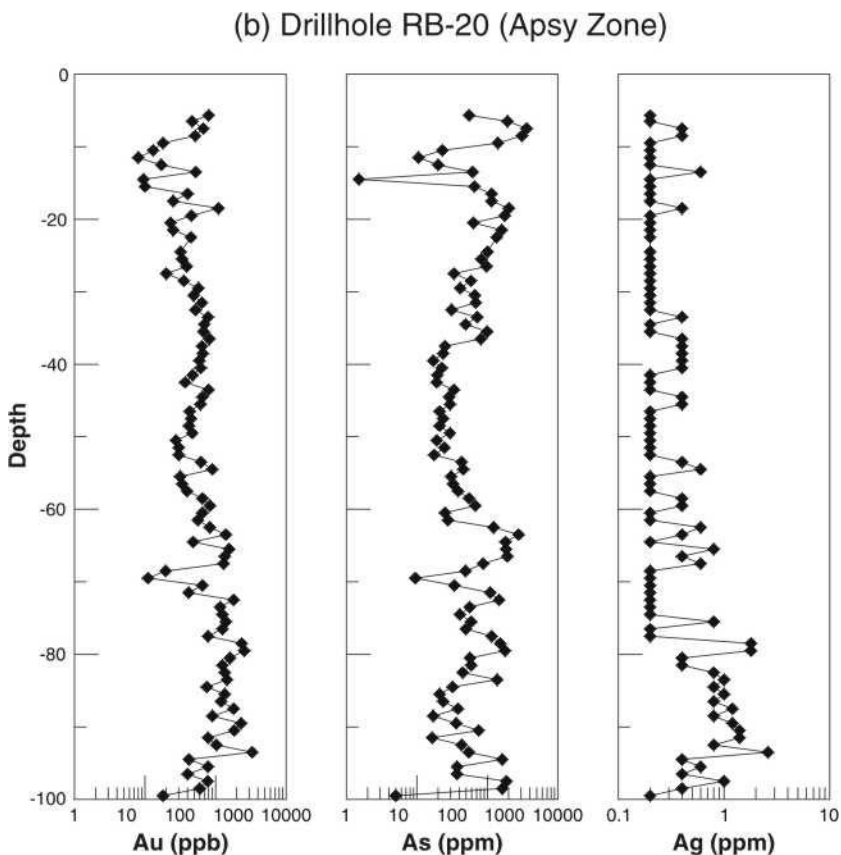
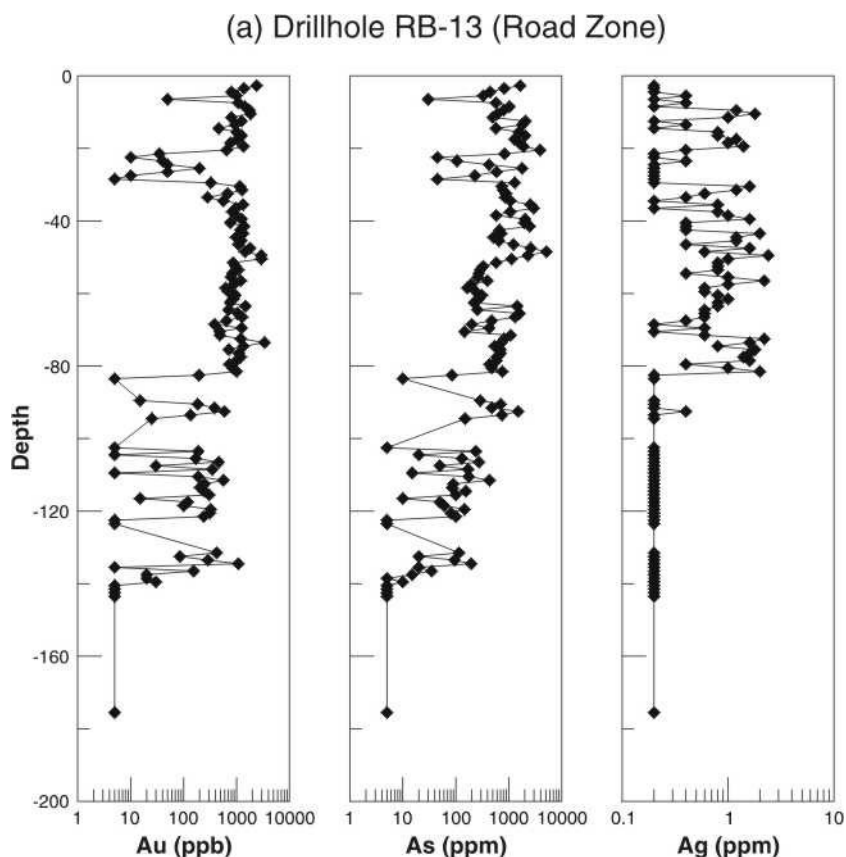
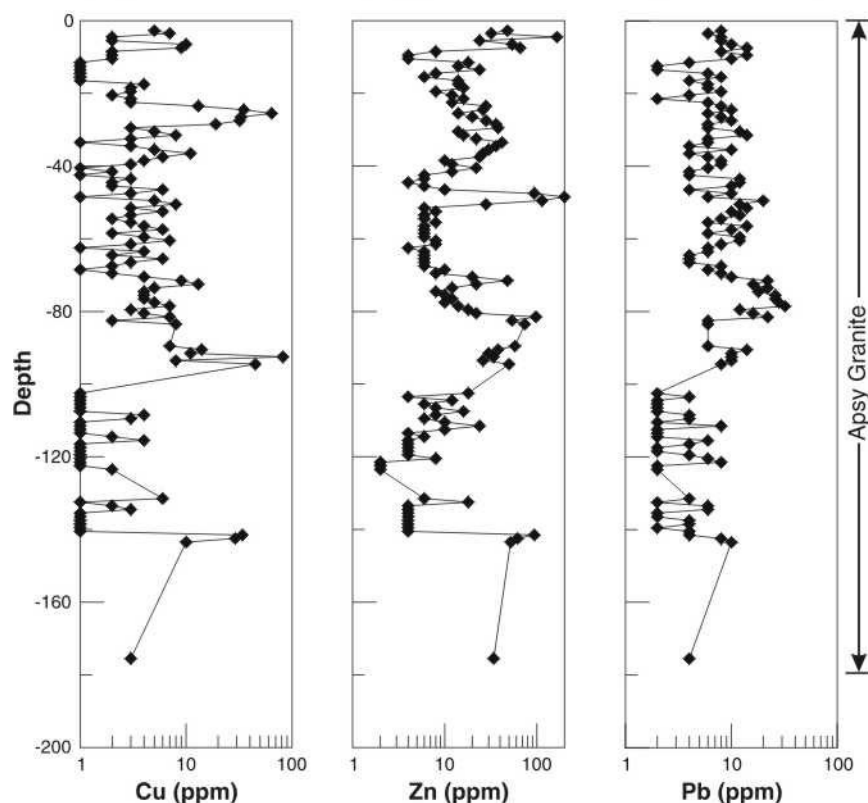
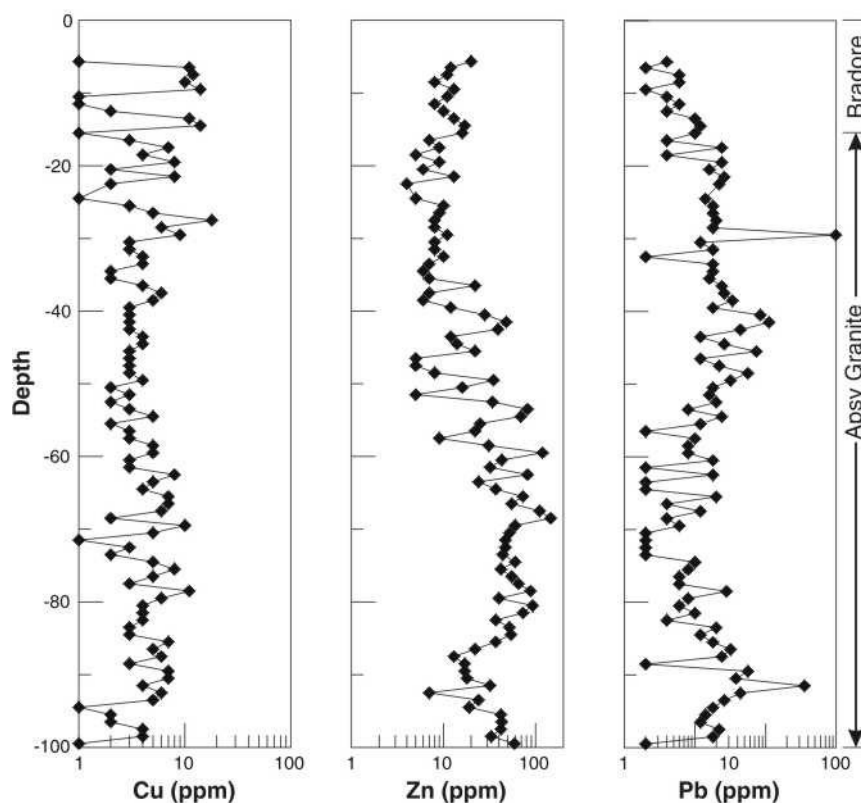


Figure 6b. The variation of Au, As, Ag, Cu, Zn and Pb with depth (metres) in selected drillholes from the Rattling Brook gold deposit, using data from 1980s exploration programs; drillhole RB-20, Apsy zone.

(Figure 6a continued). (a) Drillhole RB-13 (Road Zone)



(Figure 6b continued). (b) Drillhole RB-20 (Apsy Zone)



20, 42 and 51; Figure 7a-d). Gold and As show very strong correlation (Figure 7a), and there is a more diffuse correlation between Au and Ag (Figure 7b). It is clear that there is very little correlation between Au and Cu (Figure 7c) or Au and Zn (Figure 7d). The lack of correlation between Cu and Zn is illustrated by scatter plots of the same four drillholes (Figure 8). Comparisons of Cu and Pb, and Zn and Pb (not shown) confirm the general lack of correlation indicated by individual profiles in Figure 6.

RELATIONSHIPS BETWEEN GOLD AND OTHER TRACE ELEMENTS

Geochemical data from the 1980s exploration programs also include a wide range of trace elements including Be, Cd, Co, Cr, Ga, Hg, La, Mo, P, Sb, Se, Tl, U, V and W. The relationships between these and Au were also investigated using scatter plots for the four selected drillholes illustrated in Figures 7 and 8. The trace elements Co, Cr, La, Ni, P and V revealed no correlation with Au. Data for the remaining trace elements are mostly below detection limits, and thus provide no useful information.

A more complete investigation of the links between gold and other trace elements was undertaken using the Geological Survey data from outcrops and drill cores sampled in 2003. This smaller database emphasizes variably mineralized sedimentary rocks, although some mineralized granites and diabase dykes are included. Scatter plots confirm the patterns discussed above and illustrated by Figures 6, 7 and 8. There appears to be good correlation between Au and S (Figure 9a), indicating that the most auriferous samples are also the most sulphide-rich. This link is not surprising, and was noted during examination of the cores, and also by Saunders and Tuach (1988, 1991). There is excellent correlation between Au and As (Figure 9b), a more diffuse relationship between Au and Ag (Figure 9c), and an overall lack of correlation between Au and Cu or Au

Figure 6c. The variation of Au, As, Ag, Cu, Zn and Pb with depth (metres) in selected drillholes from the Rattling Brook gold deposit, using data from 1980s exploration programs; drillhole RB-29, Apsy zone.

and Zn (not shown). No correlation was noted between Au and the trace elements Ge, Se, Rb, Sr, Y, Zr, Nb, Mo, Cd, Ba, La, Ce, Dy, Hg and Bi. However, it should be noted that the data for Ge, Hg, Mo and Bi mostly lie close to detection limits and thus provide little useful information.

The only trace elements that show marked correlation with Au are Te (Figure 9d), and W (Figure 9e). Auriferous samples contain up to 5 ppm Te, and there is a clear relationship between high Au analyses (>500 ppb) and anomalous Te (>0.5 ppm, 500 ppb). There is also a marked W enrichment, up to 50 ppm or more, in many auriferous samples, although not all samples containing >1 ppm Au contain anomalous W. However, the detection limit for W is relatively high at 4 ppm (Figure 9e). Tungsten data from the 1980s exploration program are compromised by high detection limits and do not reveal these patterns; but Saunders and Tuach (1991) previously noted that some Au-enriched samples were anomalous in W.

The trace elements Sb, Tl and Pb also show interesting relationships to Au. There is no well-developed Sb–Au correlation, but there does appear to be

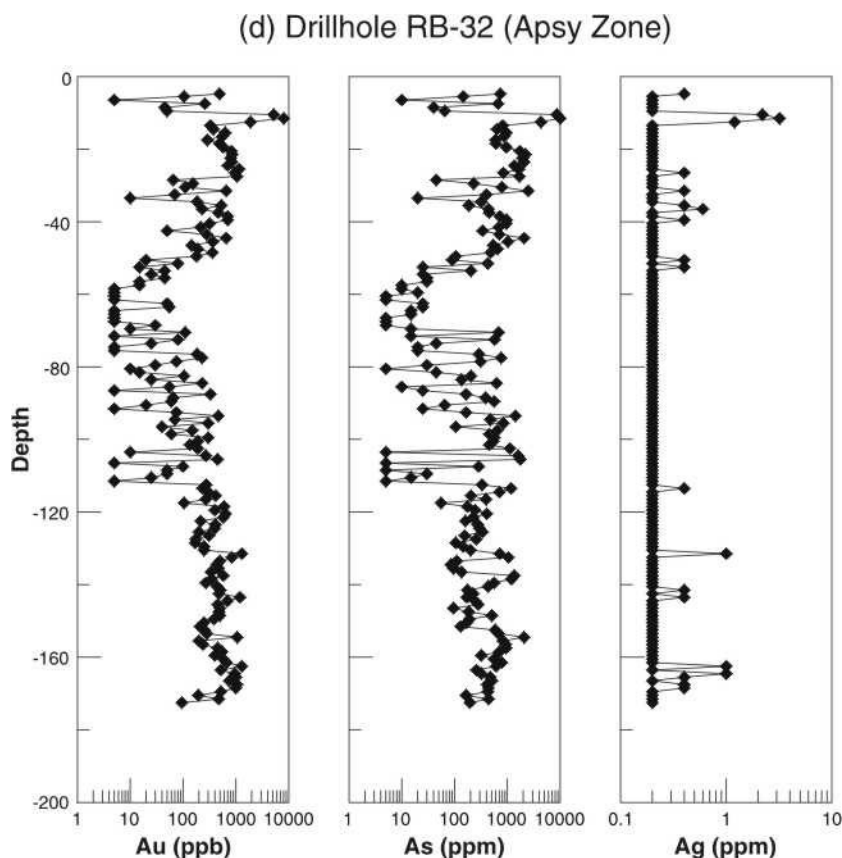
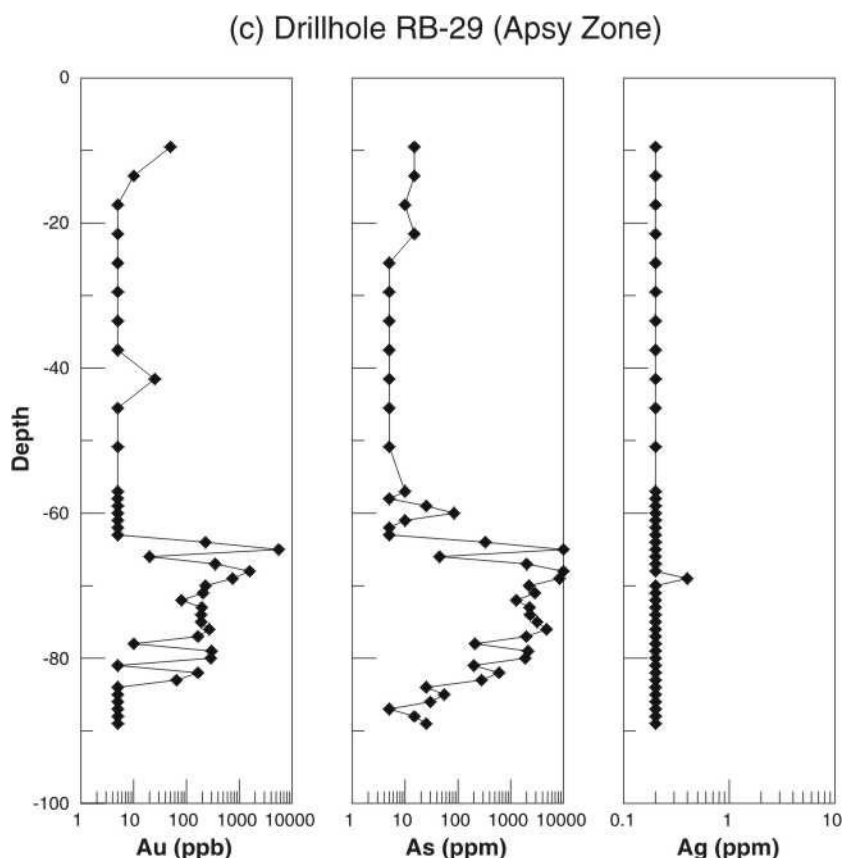
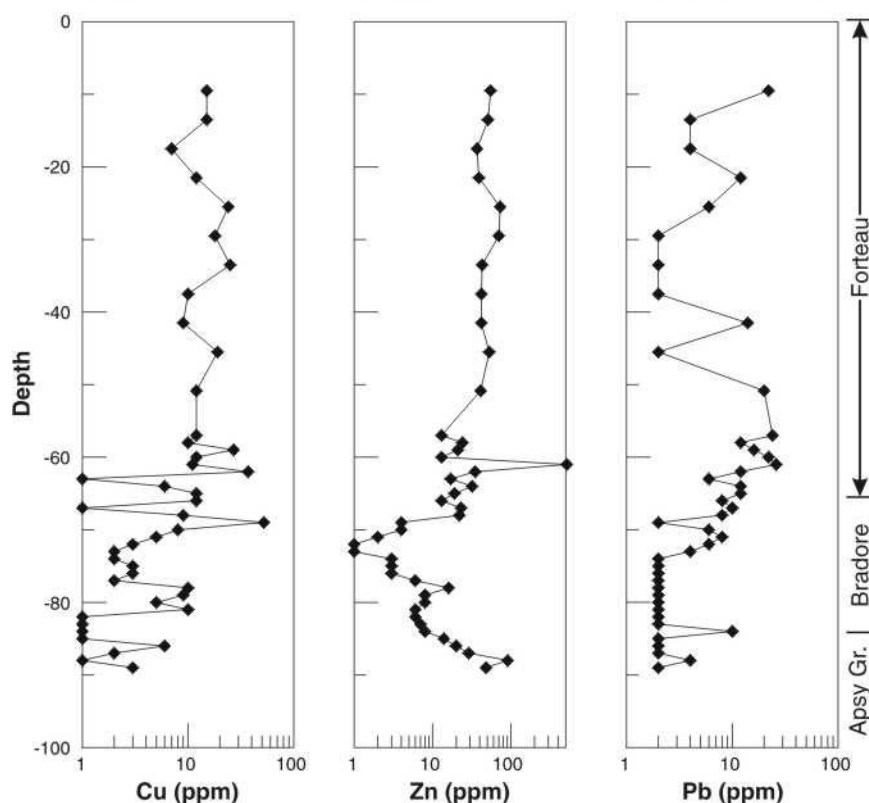
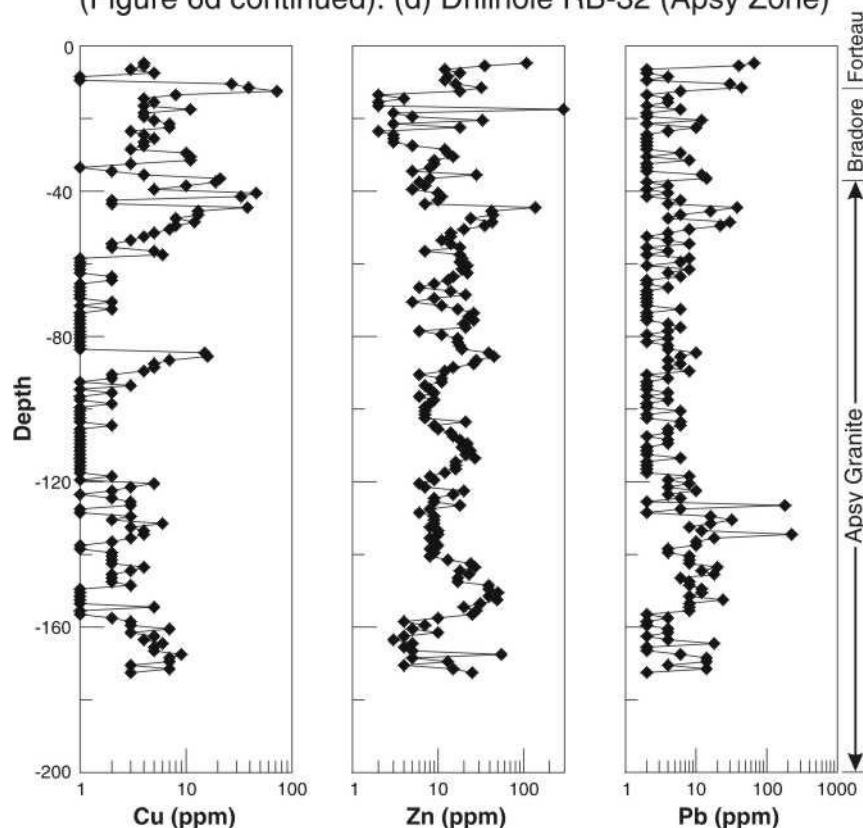


Figure 6d. The variation of Au, As, Ag, Cu, Zn and Pb with depth (metres) in selected drillholes from the Rattling Brook gold deposit, using data from 1980s exploration programs; drillhole RB-32, Apsy zone.

(Figure 6c continued). (c) Drillhole RB-29 (Apsy Zone)



(Figure 6d continued). (d) Drillhole RB-32 (Apsy Zone)



variable enrichment in Sb in many of the samples, with local values up to 100 ppm Sb (Figure 9f). Thallium is for the most part at detection limit (0.1 ppm, 100 ppb), but a few samples are (relatively) Tl-enriched, containing up to 0.6 ppm (600 ppb) (Figure 9g). The relationship between Au and Pb is diffuse, but there does appear to be a tendency for Pb-rich samples to be associated with variable gold-enrichment (Figure 9h). This pattern was less obvious in the 1980s data, which emphasize the granite-hosted mineralization.

RELATIONSHIPS BETWEEN GOLD AND MAJOR-ELEMENT OXIDES

The relationships between Au and major-element oxides were investigated using scatter diagrams for the 2003 Geological Survey data. In general, there are no obvious correlations between Au and any of the major-element oxides SiO_2 , TiO_2 , Al_2O_3 , Na_2O , K_2O and P_2O_5 . If the data are treated without regard to rock type, there are poorly developed negative correlations between Au and CaO and between Au and MgO . Nevertheless, these patterns, and the superficially uninformative relationship between Au and SiO_2 , become more significant if the data are examined in the light of the various mineralized rock types involved.

The CaO -Au plot (Figure 10b) reveals no relationship between the two elements in quartzites, granites and diabbases; unmineralized and auriferous samples have essentially the same CaO contents. However, there is a marked negative correlation amongst the carbonate rocks, most of which represent the basal limestones of the Forteau Formation. Unmineralized carbonate rocks contain 25 to 55% CaO , but their mineralized equivalents have much lower CaO contents, in some cases less than 10% CaO . The MgO -Au plot (Figure 10c) reveals a broadly similar pattern, but it is less marked. SiO_2 and Au are uncorrelated if the rock type is ignored,

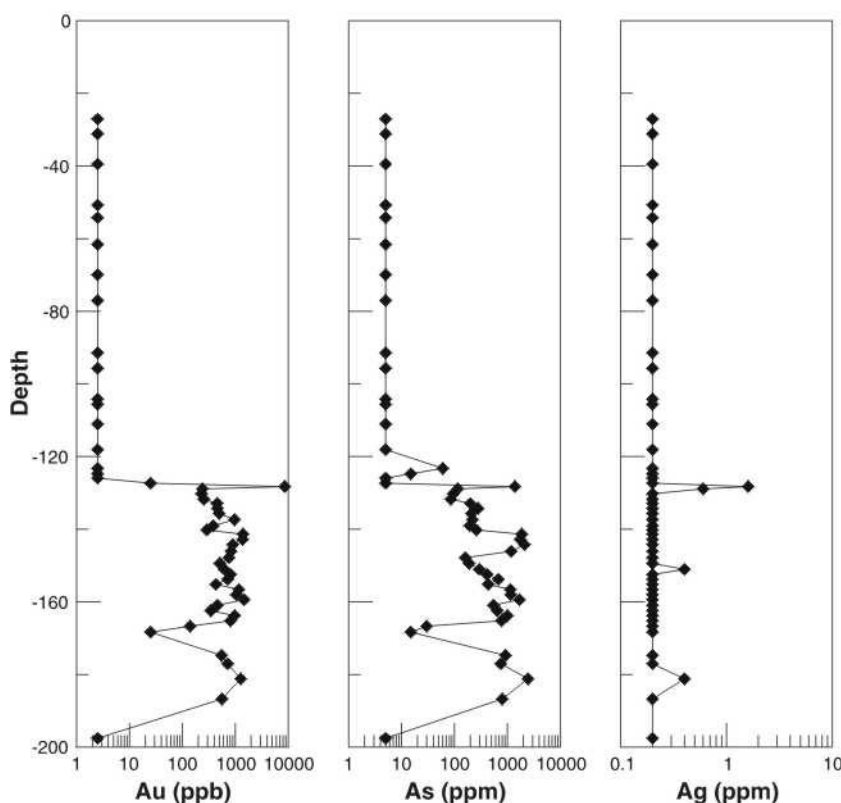
Figure 6e. The variation of Au, As, Ag, Cu, Zn and Pb with depth (metres) in selected drillholes from the Rattling Brook gold deposit, using data from 1980s exploration programs; drillhole RB-42, Apsy zone.

and all mineralized quartzites are SiO_2 -rich, which is hardly surprising (Figure 10a). However, there is a positive correlation between SiO_2 and Au amongst the carbonate rocks of the Forteau Formation, in which auriferous samples are Si-enriched, locally containing up to 70% SiO_2 (Figure 10a). This observation is consistent with observations of the 2004 drill core, indicating silica veining and pervasive silicification of mineralized carbonate rocks (*see above*). The Fe_2O_3 -Au plot (Figure 10d) mostly illustrates the link between gold mineralization and pyrite, but less effectively than the S-Au plot (Figure 9a).

SUMMARY AND DISCUSSION

The Rattling Brook deposit represents a significant gold resource, possibly containing more than 1 million ounces of gold. The bulk of this disseminated mineralization is in altered Precambrian granitoid rocks, and it is generally low grade (1 to 5 ppm Au). These low grades, and the possibly refractory “invisible” character of the gold (Sinclair, 1988) have to date impeded commercial development of the deposit. Subordinate amounts of gold mineral-

(e) Drillhole RB-42 (Apsy Zone)



(f) Drillhole RB-51 (Beaver Dam Zone)

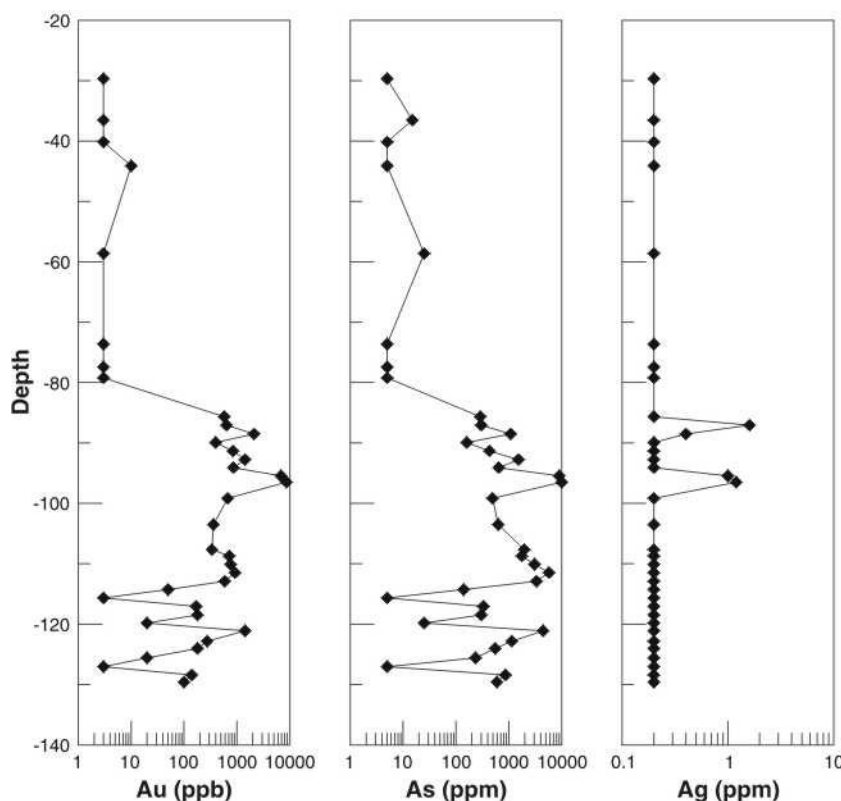
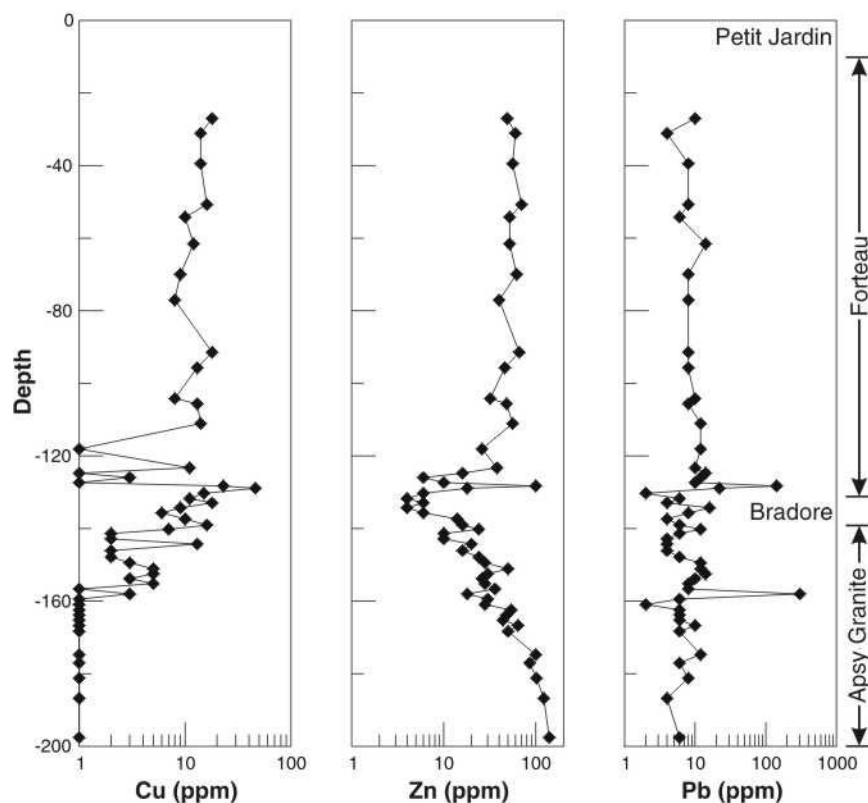
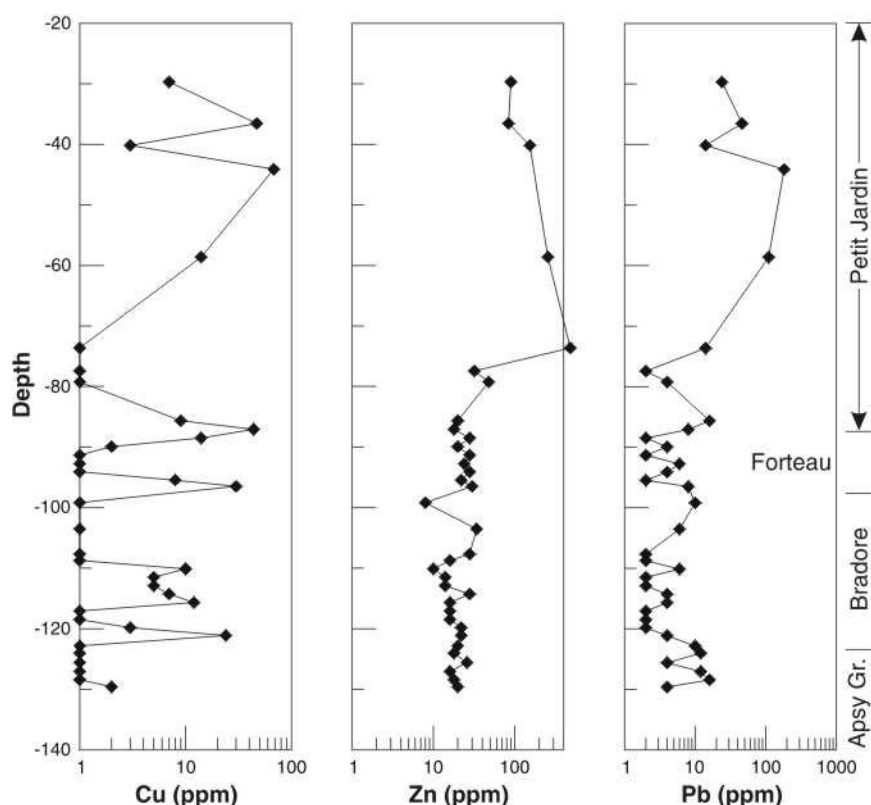


Figure 6f. The variation of Au, As, Ag, Cu, Zn and Pb with depth (metres) in selected drillholes from the Rattling Brook gold deposit, using data from 1980s exploration programs; drillhole RB-51, Beaver Dam zone.

(Figure 6e continued). (e) Drillhole RB-42 (Apsy Zone)



(Figure 6f continued). (f) Drillhole RB-51 (Beaver Dam Zone)



ization occur in Cambrian sedimentary rocks of the Bradore Formation and lowermost Forteau Formation, and in altered dykes. Mineralization in host rocks other than granite has a similar grade spectrum, but locally exhibits much higher grades, up to 16 ppm Au (Kermode Resources, press releases, 2004; A. Kerr, unpublished data). Recent exploration activity has thus focused mainly upon the sedimentary rocks, with a deposit model based upon the giant “Carlin-type” deposits of the Great Basin area of the southwestern United States. Wilton (2003) provided a qualitative summary of the possible parallels with mineralization of this type for Kermode Resources Limited. The final section of this report presents a preliminary assessment of new observations and quantitative data in the context of the documented characteristics of such deposits. A detailed review of the geology of Carlin-type and similar gold deposits is beyond the scope of this report, but a wealth of information is provided by Arehart (1996), and Hofstra and Cline (2000) in review papers.

HOST ROCKS, CHARACTERISTICS AND TIMING OF MINERALIZATION

Key Features of the Rattling Brook Deposit

Most previous studies of the Rattling Brook deposit apply largely to mineralized granitoid rocks. The 2003 to 2004 exploration program by Kermode Resources Limited provides new insights into all host rock types by finally providing wide-barrel drill core with good core recovery and core integrity. Examination of this material confirms previous conclusions concerning the granite-hosted Au mineralization (McKenzie, 1987a; Saunders and Tuach, 1988, 1991;) and allows new inferences about mineralization in other rock types.

Gold mineralization everywhere at Rattling Brook is associated with the introduction of sulphides, principally

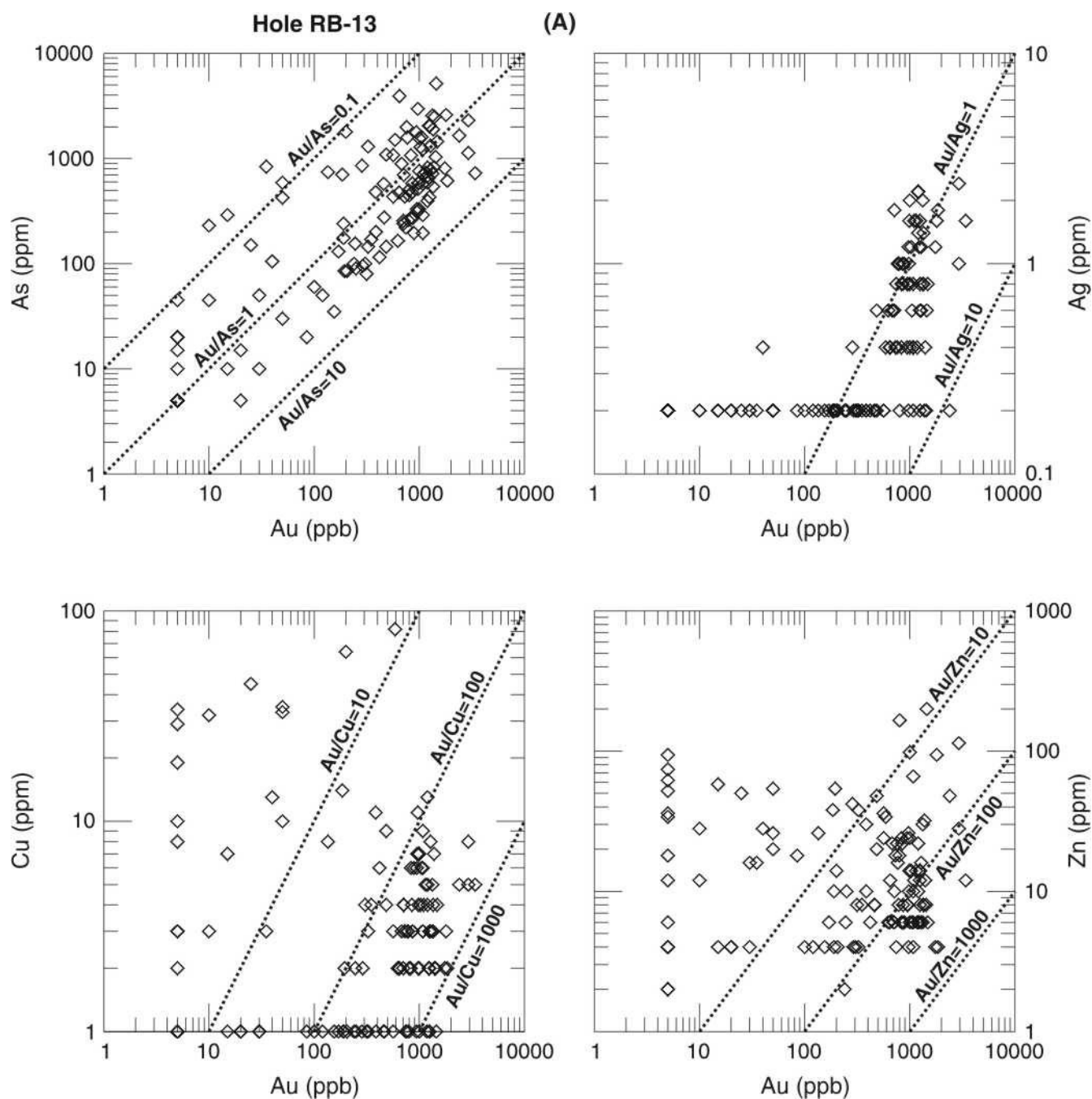


Figure 7. Scatter diagrams illustrating correlations (or lack of correlation) in data from selected drillholes. **(A)** Au against As, Ag, Cu and Zn, drillhole RB-13. Data from 1980s exploration programs. Note that Au/Ag ratios are calculated using identical units, whereas Au/As, Au/Cu and Au/Zn ratios are calculated using Au in ppb and As, Cu or Zn in ppm.

pyrite and arsenopyrite. The sulphides are present generally in two forms, i.e., within narrow, stockwork-like veins and veinlets, most of which are less than 1 mm wide, and as disseminated material of variable grain size. These styles of mineralization are seen in altered granites, in diabase dykes, in quartzites and in limestones; in all cases the heaviest disseminated sulphides are found adjacent to cross-cutting sul-

phide-bearing veinlets, implying that sulphide deposition was related to the same broad process. The presence of discrete arsenopyrite- and pyrite-rich haloes around some of these vein-like structures indicates that both minerals were deposited together. In some cases, notably in quartzites, at least some of the disseminated sulphides formed by partial to complete replacement of detrital magnetite grains.

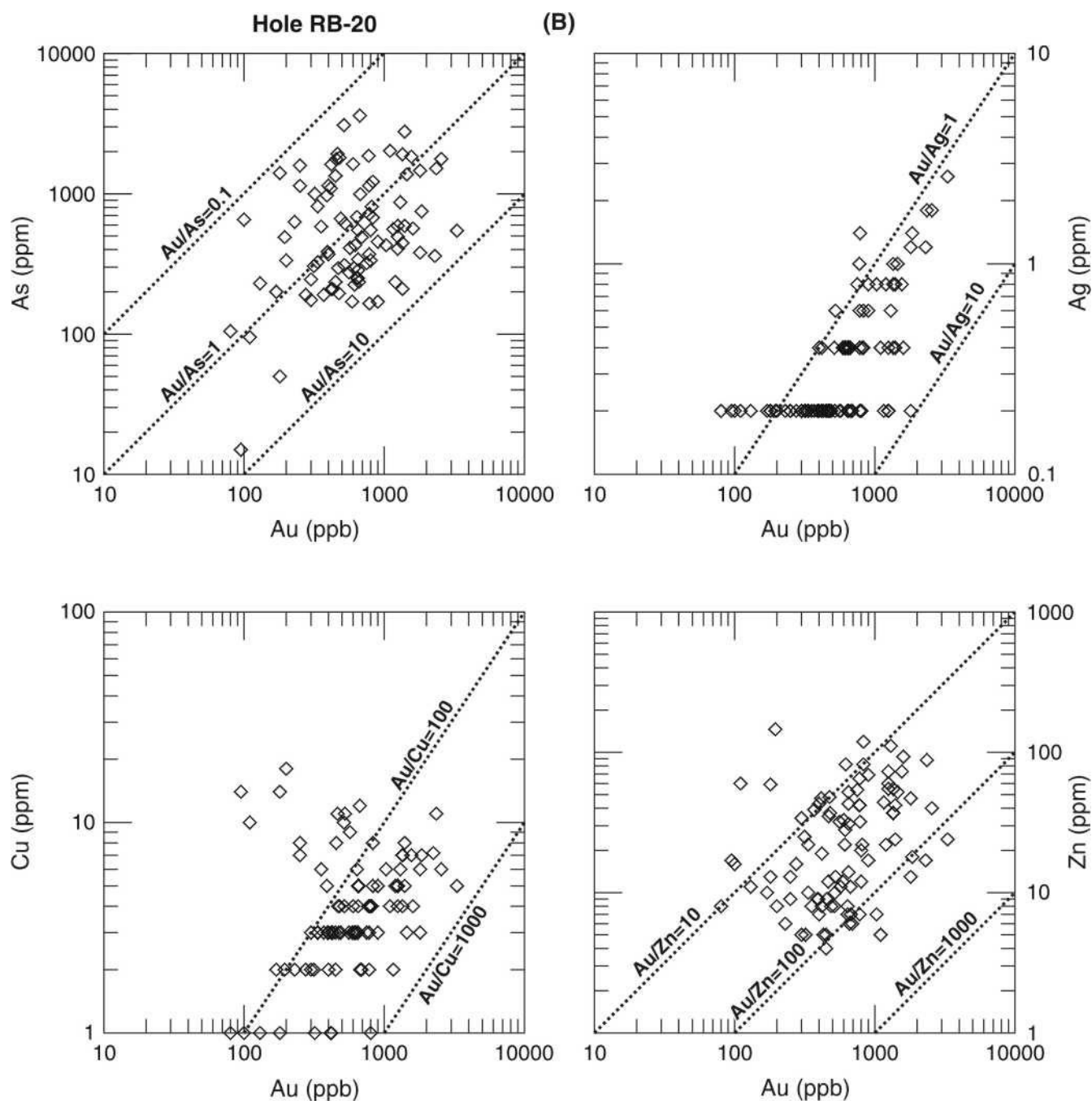


Figure 7. (Continued) Scatter diagrams illustrating correlations (or lack of correlation) in data from selected drillholes. **(B)** Au against As, Ag, Cu and Zn, drillhole RB-20. Data from 1980s exploration programs. Note that Au/Ag ratios are calculated using identical units, whereas Au/As, Au/Cu and Au/Zn ratios are calculated using Au in ppb and As, Cu or Zn in ppm.

Replacement of magnetite was also locally important in the granite-hosted mineralization.

Saunders and Tuach (1988, 1991) documented an early potassic alteration in granitoid rocks, followed by more localized sodic metasomatism and carbonatization associated with auriferous veinlets. The alteration assemblages rec-

ognized in mineralized Long Range Dykes (see above) similarly indicate an early period of intense sericitization (based on visual criteria), overprinted by more localized silicification and sulphide introduction, more closely associated with gold introduction. The gold grades in altered metadiabases and mafic variants of the Apsy Granite are typically better than those from the "normal" granites, suggesting that these

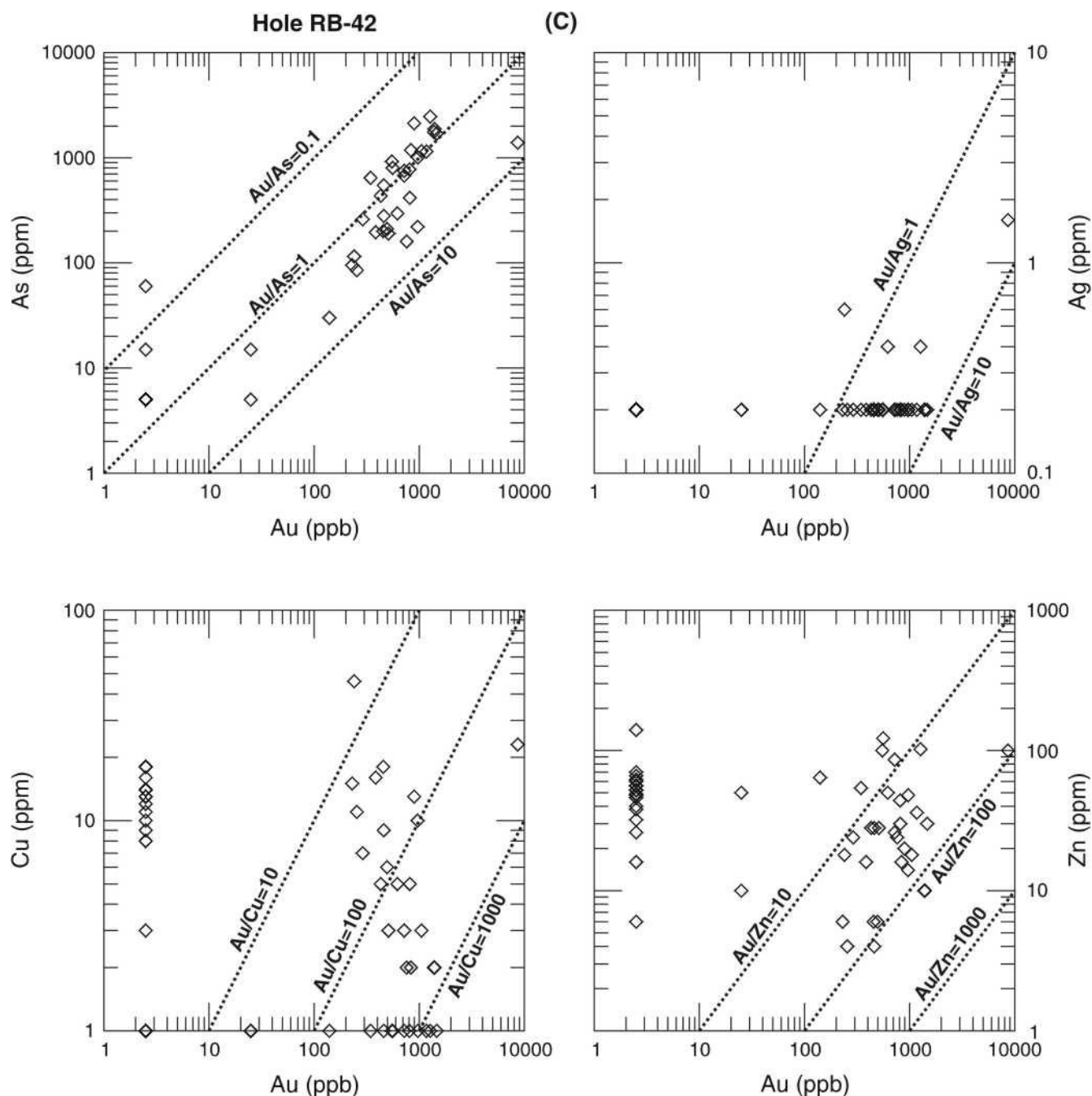


Figure 7. (Continued) Scatter diagrams illustrating correlations (or lack of correlation) in data from selected drillholes. **(C)** Au against As, Ag, Cu and Zn, drillhole RB-42. Data from 1980s exploration programs. Note that Au/Ag ratios are calculated using identical units, whereas Au/As, Au/Cu and Au/Zn ratios are calculated using Au in ppb and As, Cu or Zn in ppm.

Fe-rich host rocks precipitated gold more effectively. The magnetite-rich sedimentary rocks at the Forteau–Bradore formational boundary also appear to have promoted gold deposition. The alteration sequence in the metadiabase in drillhole JA-04-12 corresponds well with the more subtle patterns documented in the mineralized granites by Saunders and Tuach (1988, 1991). Alteration in mineralized sed-

imentary rocks is not as easily documented, but the presence of K-feldspar in weakly mineralized quartzites and silicified carbonate rocks implies an early potassic episode. A soft white mineral (presently unidentified) observed in some mineralized carbonate rocks may be a clay mineral (Kerr, 2004), suggesting the presence of argillic alteration, and this could be an important component of the pervasively sericit-

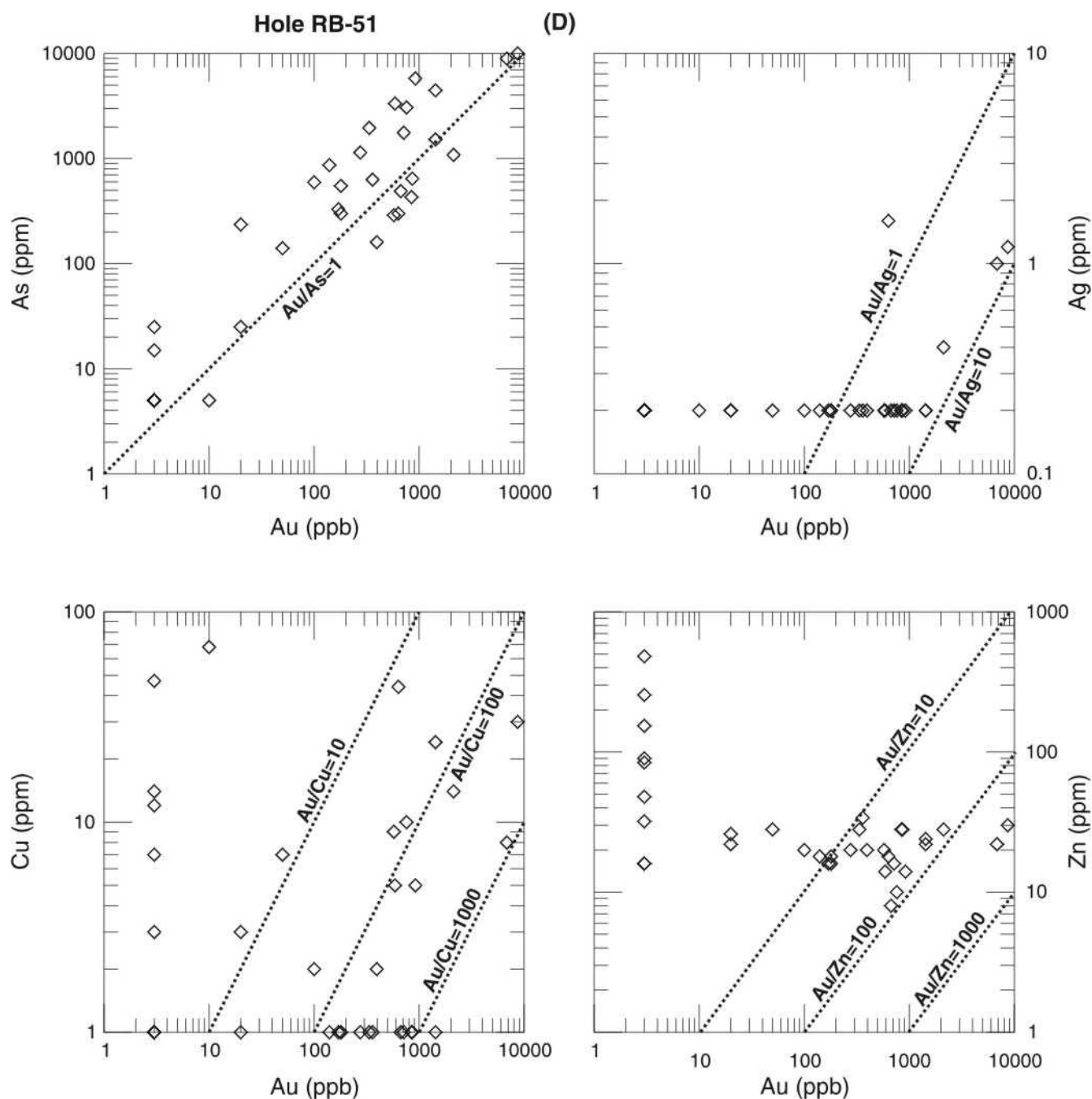


Figure 7. (Continued) Scatter diagrams illustrating correlations (or lack of correlation) in data from selected drillholes. **(D)** Au against As, Ag, Cu and Zn, drillhole RB-51. Data from 1980s exploration programs. Note that Au/Ag ratios are calculated using identical units, whereas Au/As, Au/Cu and Au/Zn ratios are calculated using Au in ppb and As, Cu or Zn in ppm.

ized dykes. Silica veining is obvious in many of the carbonate rocks, and there also appears to be some pervasive silicification of these host rocks; such effects are harder to document in quartzites due to their siliceous nature, but there is certainly evidence of silica introduction associated with sulphides and gold. The common alteration sequence observed in several different host rocks supports previous conclusions

(Saunders and Tuach, 1991; Kerr, 2004) that all the gold in the deposit was introduced by a single hydrothermal episode of late timing with respect to local deformation.

Several of the 2004 drillholes contain quartz-feldspar veins that appear to be younger than the surrounding sedimentary rocks, but these veins are not “granitic” in the

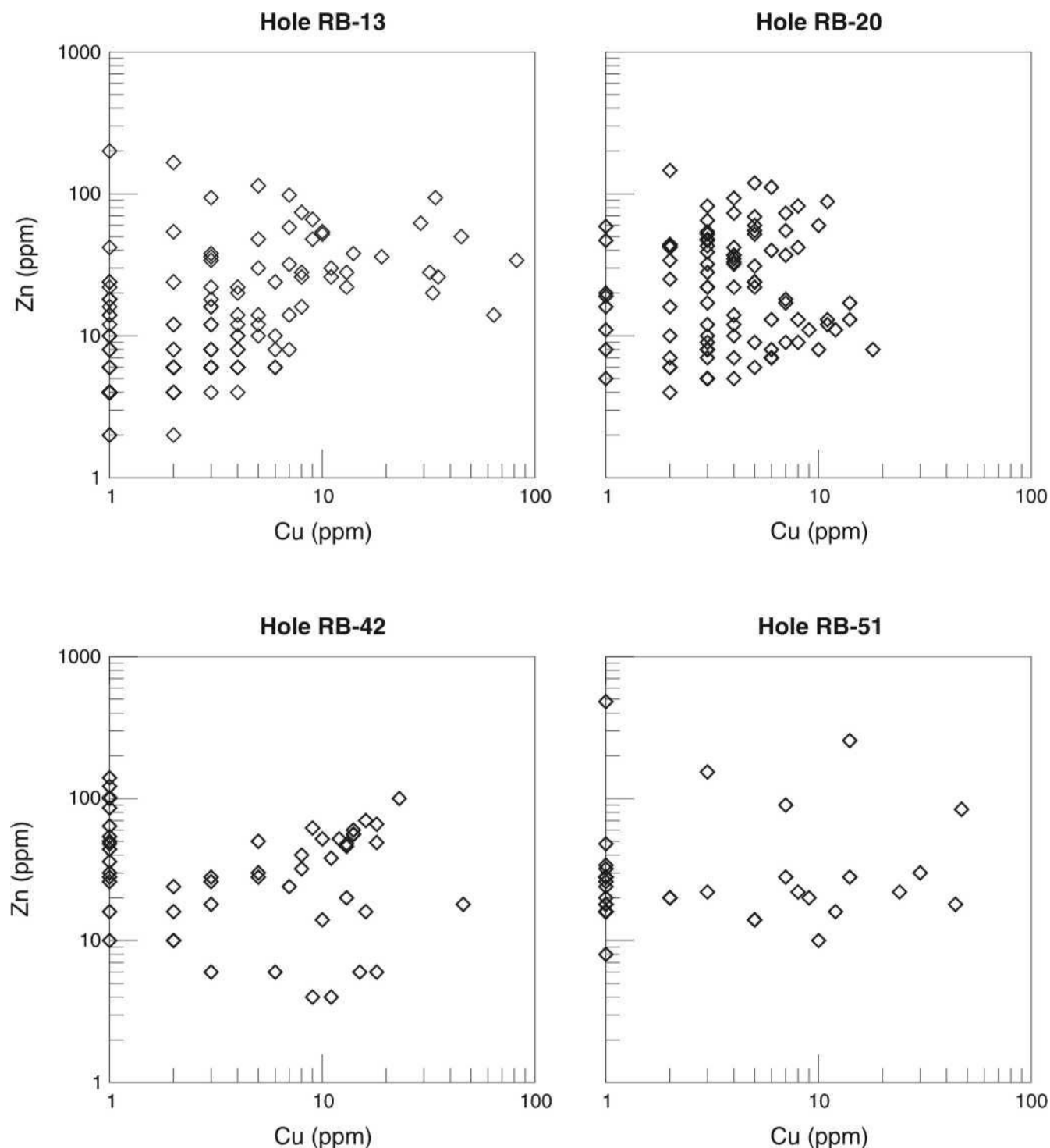


Figure 8. Scatter diagrams illustrating lack of correlation between Cu and Zn in drillholes RB-13, Rb-20, RB-42 and RB-51. Data from 1980s exploration programs.

strict sense of the word, because they generally contain >80 percent quartz. These veins cut the early sericitic alteration in metadiabase dykes, and they also cut at least some of the sulphide-bearing veinlets associated with the gold mineralization. However, they are themselves cut by narrow sul-

phide-bearing veinlets, contain euhedral pyrite and arsenopyrite, and carry gold. Quartz-feldspar veins of this type are more rarely been observed within the dominant mineralized granites, but “pegmatites” noted in some of the early BP drillholes probably represent similar material.

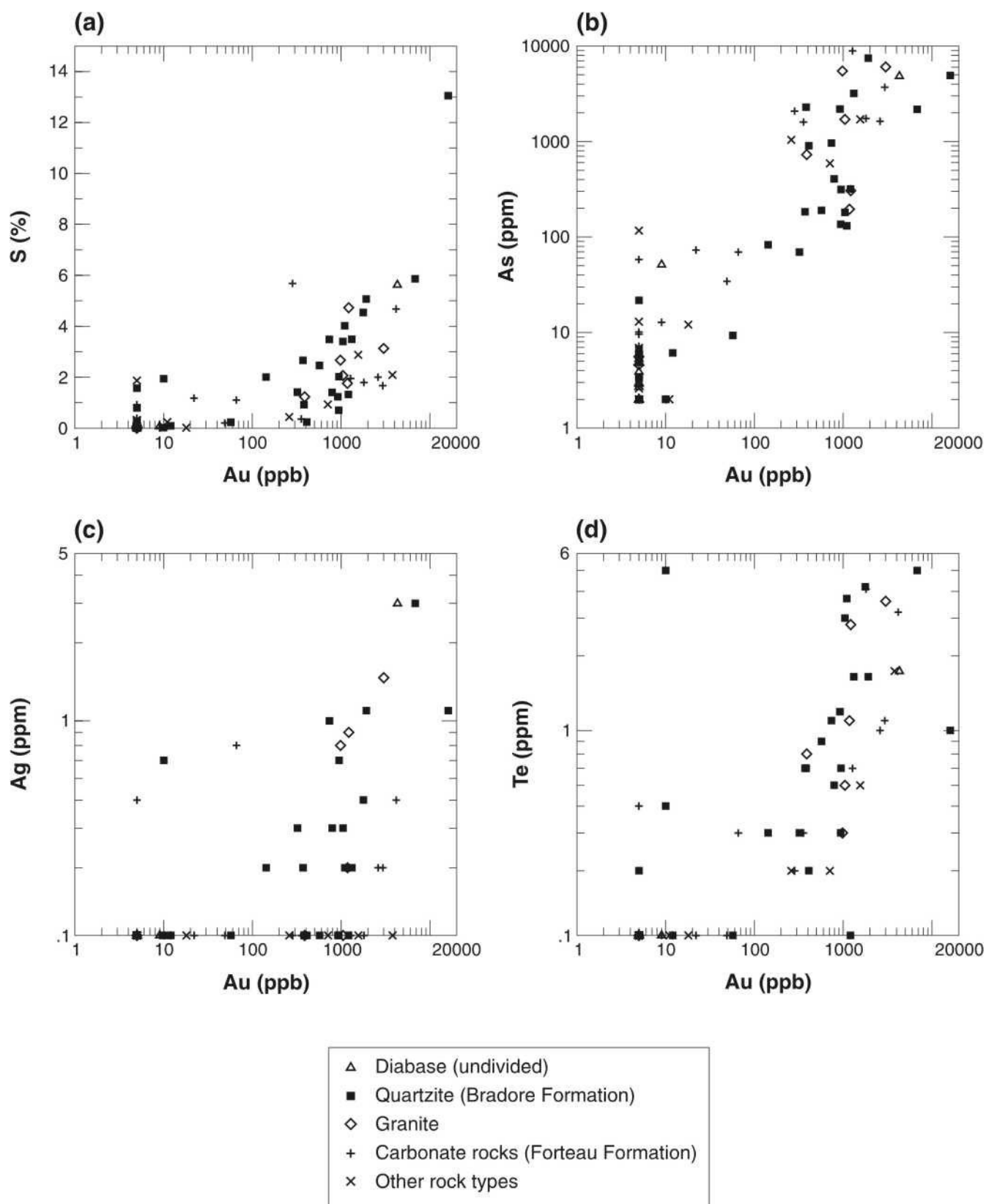


Figure 9. Scatter diagrams illustrating relationships between gold and various trace elements, using Geological Survey data from 2003-04. (a) Au-S plot; (b) Au-As plot; (c) Au-Ag plot; (d) Au-Te plot.

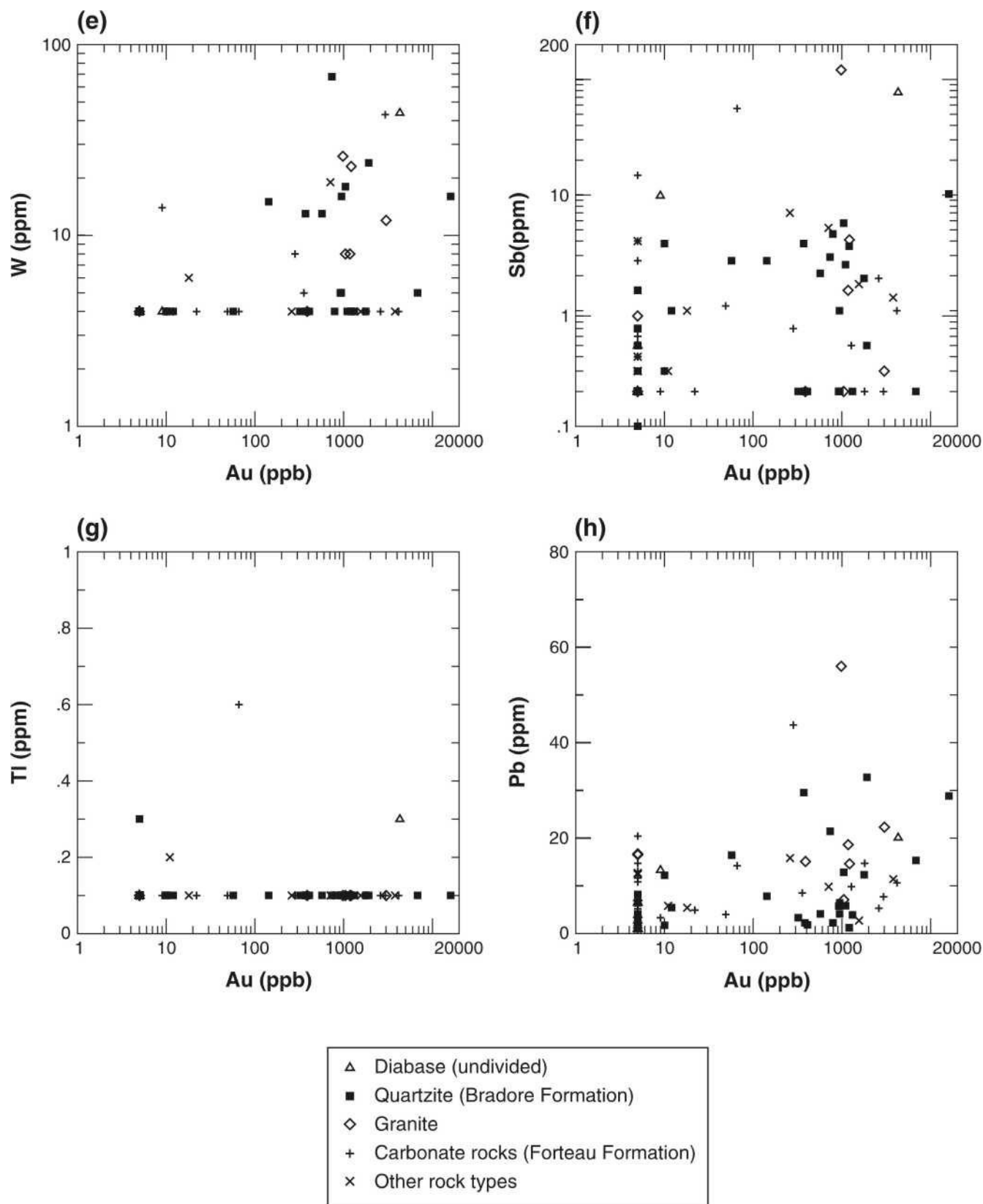


Figure 9 (Continued). Scatter diagrams illustrating relationships between gold and various trace elements, using Geological Survey data from 2003-04. (e) Au-W plot; (f) Au-Sb plot; (g) Au-Tl plot; (h) Au-Pb plot.

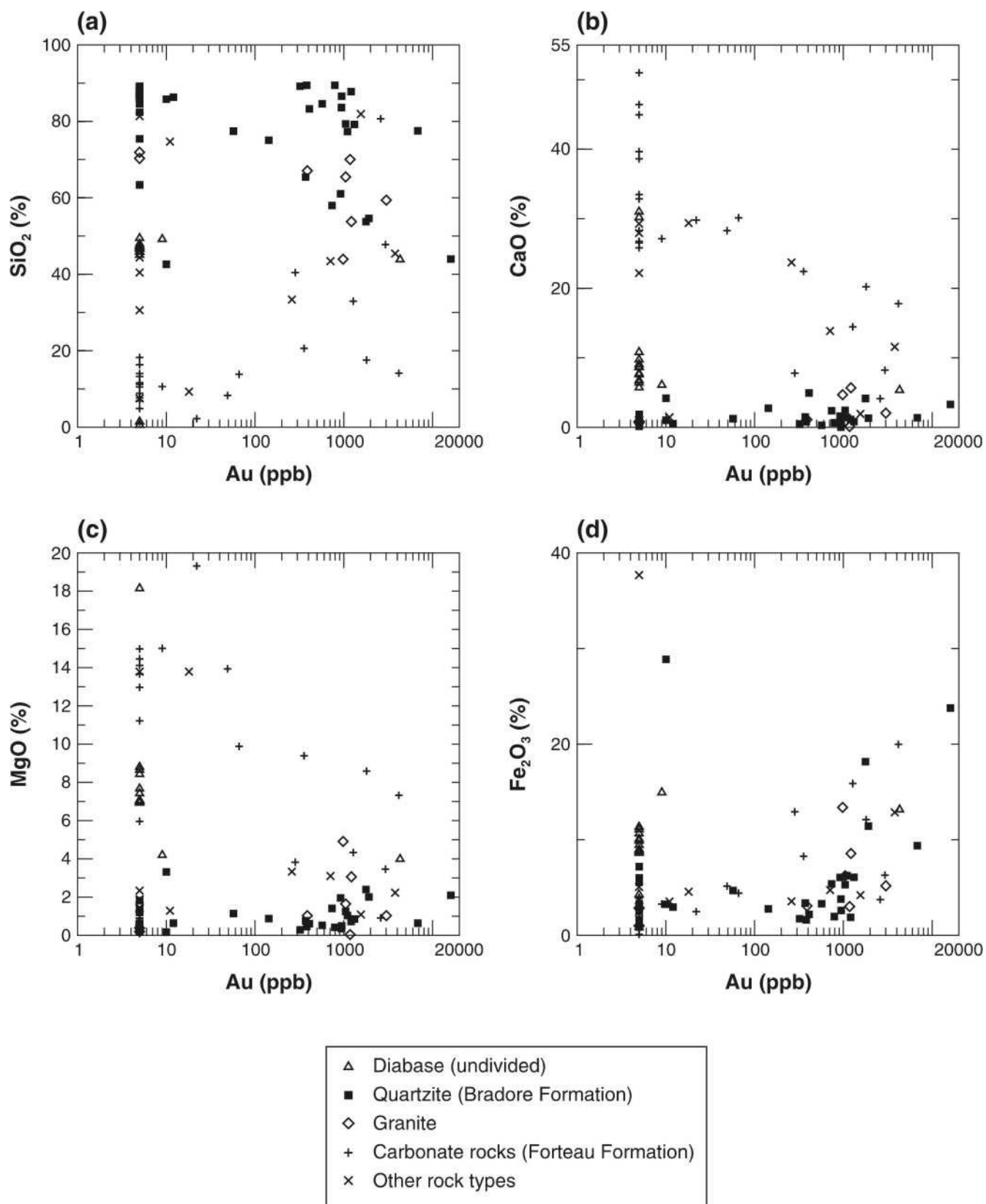


Figure 10. Scatter diagrams illustrating relationships between gold and various major-element oxides. (a) Au– SiO_2 plot; (b) Au–CaO plot; (c) Au–MgO plot; (d) Au– Fe_2O_3 plot.

These crosscutting auriferous quartz-feldspar veins provide the best evidence to date for hydrothermal activity that might be related to plutonic rocks.

The absolute age of mineralization at Rattling Brook remains unconstrained, although it must be post-Cambrian. Previous suggestions of a Silurian age (Saunders and Tuach, 1991) are based upon the supposition that mineralization is linked to local plutonic suites of this age, but there is no proof of such a relationship. There is no evidence for deformation of mineralized veinlets, and alteration in Long Range Dykes cuts internal fabrics and penetrates along pre-existing foliation planes. Similarly, alteration and mineralization in granites overprints mylonitic fabrics in several drillholes from the 1980s. The foliations in the metadiabase dykes are presumed to be Paleozoic. The silica veining observed in basal Forteau Formation limestones and some Bradore Formation quartzites has a completely random orientation, and appears to have exploited late brittle fracture patterns. Given that there is significant Silurian or younger deformation throughout much of western White Bay (Smyth and Schillereff, 1982; Kerr *et al.*, 2004) such features imply (but do not prove) a Silurian or post-Silurian age for mineralization and alteration. The best relative constraints upon the age of mineralization come from mineralized and unmineralized dykes. The mineralization and alteration affects Precambrian Long Range dykes (~615 Ma; Stukas and Reynolds, 1974) but is cut by fresh diabase and a single example of quartz-feldspar porphyry. Geochronological studies have thus been initiated to obtain maximum and minimum ages from mineralized and unmineralized mafic dykes by Ar–Ar methods. Rhenium and osmium geochronological studies of the sulphides are also in progress; initial results yielded imprecise data that could not be interpreted in any rigorous manner, but new analyses of coarser grained arsenopyrite are underway.

Comparisons with Carlin-type and Similar Gold Deposits

Carlin-type gold deposits in the Great Basin of the southwestern USA are mostly hosted in impure carbonate rocks, but Au is not restricted to this setting. It is present more rarely in siliciclastic rocks and in various intrusive rocks including granites and mafic to felsic dykes. For example, at the huge Betze–Post deposit of the Carlin trend, significant Au occurs in a Jurassic granodiorite that was originally intrusive into the Devonian sedimentary rocks, which contain most of the gold (e.g., Arehart, 1996). Gold also occurs in Cenozoic dykes of both mafic and felsic composition at Betze–Post and other Carlin trend deposits (Henry and Ressel, 2000; Ressel *et al.*, 2000). Quartzites are an uncommon host rock for gold in Nevada, but they are important at the Marigold deposit (Graney and McGibbon,

1991). The age of mineralization in Carlin-type deposits is a controversial topic (Arehart, 1996; Hofstra and Cline, 2000), but it is now generally accepted that they are epigenetic, and variably younger than their host rocks, which range in age from Ordovician to Eocene. An Eocene age has been suggested for several important deposits in the region, and a link to extensional tectonics and synchronous magmatism is widely debated (e.g., Hofstra and Cline, 2000; Henry and Boden, 1998).

As presently understood, most of the mineralization in the Rattling Brook deposit is within Precambrian granitoid rocks or Cambrian quartzites; carbonate rocks of the Forteau Formation are a less common host. However, this may to some extent reflect the focus of previous exploration programs in the area along the basal Cambrian unconformity (Figure 2). In terms of timing, mineralization at Rattling Brook postdates almost all deformation, and could therefore be linked to regional post-orogenic extension, uplift and major transcurrent or extensional faulting, as envisaged for many Carlin-type gold deposits.

Alteration in Carlin-type gold deposits is complex and includes argillization, silicification and carbonatization of various host rocks. Argillic alteration is considered commonly to be well developed in mafic dykes (Hofstra and Cline, 2000), and silicification characteristically affects limestones and dolostones, to create the distinctive rocks known as “jasperoids”. The sericitic alteration described above from mineralized Long Range Dykes may be broadly equivalent to this argillic alteration, but more work is required to firmly establish its characteristics. There is also textural evidence for silicification (and hence decalcification) of basal Forteau Formation limestones in areas of gold enrichment. The major-element geochemical data for rocks of the basal Forteau Formation are also of interest in this context, as they indicate a loss of CaO and MgO, and increasing SiO₂, as the gold concentrations of samples increase (Figure 10a-d). This pattern provides further evidence for decarbonatization, decalcification and silicification. Noncarbonate-hosted stockwork-disseminated gold deposits are associated with potassic and/or sodic alteration, carbonatization and local silicification (Poulsen *et al.*, 2000). All three alteration types are present at Rattling Brook, notably where mineralization is present in granitoid rocks and mafic dykes. The mineralization thus has affinities to both types of disseminated gold deposit.

TRACE-ELEMENT GEOCHEMISTRY OF MINERALIZED ROCKS

Key Features of the Rattling Brook Deposit

The Rattling Brook deposit is very much a gold deposit, and most other metals are present in insignificant concen-

trations. For example, Au/Ag ratios (both elements expressed in ppb or ppm) are typically 1 to 10 (Figures 7 and 9). The Au/base-metal ratios are most conveniently expressed using ppb for Au and ppm for base metals. Au/Cu ratios vary widely, because there is very little correlation, but auriferous (>500 ppb Au) samples typically have Au/Cu between 100 and 1000 on this basis (Figure 7). Gold/zinc ratios are similarly variable (10 to >1000) but most auriferous samples have Au/Zn ratios between 10 and 100 on this basis (Figure 7). Gold/lead ratios (not shown) are also typically >100 in Au-enriched rocks on this basis. Examination of drillholes that lack significant Au mineralization suggests that there is little difference between the average base-metal contents of mineralized and unmineralized rocks, implying that the mineralizing fluids did not introduce significant base metals.

There is a very strong correlation between Au, S and As throughout the Rattling Brook gold deposit, regardless of host rocks (Figures 6, 7 and 9). The relationship between Au and S is simple to understand, because gold mineralization is visibly associated with sulphides. The correlation between Au and As is similarly consistent with the presence of visible fine-grained arsenopyrite. Links between Au and As are not uncommon in gold mineralization, but rarely are such correlations as well developed as they are at Rattling Brook. In conjunction with the evidence that visible gold is extremely rare and that gold is refractory (Sinclair, 1988), the Au–As link suggests that gold is intimately associated with an arsenic-bearing mineral. Although arsenopyrite is the most obvious candidate, it is also possible that some of the pyrite at Rattling Brook contains arsenic in solid solution, i.e., it is gold-enriched arsenian pyrite. This would certainly explain the excellent Au–As correlation, but also allow the variation in Au/As ratios to be explained by the presence of variable amounts of gold-poor arsenopyrite. This is an important line of investigation for future research.

Other trace elements of interest at Rattling Brook include Te and W, both of which are enriched in auriferous samples and correlated with Au. There are also indications of Sb enrichment, albeit with less marked correlation against Au, and a few samples are anomalous in Tl. No significant enrichment of Hg or Se was noted, as most of the data lie close to detection limits for these elements.

Comparisons with Carlin-type and Similar Gold Deposits

Arsenian pyrite is a diagnostic feature of Carlin-type gold deposits, where it commonly forms overgrowths and rims on earlier barren pyrite (e.g., Arehart, 1996; Hofstra and Cline, 2000). Gold occurs as submicron-sized inclusions in the arsenian pyrite, and possibly in solid solution

within the crystal lattice. Strong enrichment in As is also a common geochemical characteristic of Carlin-type gold deposits, which locally contain unusual minerals such as realgar and orpiment in addition to arsenian pyrite and arsenopyrite. Carlin-type gold deposits are also well-known for their low levels of base metals and for their high Au/Ag ratios (e.g., Arehart, 1996; Hofstra and Cline, 2000). In addition to As, Carlin-type gold deposits are commonly enriched in the so-called “toxic element suite”, which includes Sb, Tl, Te, W, Hg and Se. The geochemical associations of noncarbonate-hosted stockwork-disseminated gold deposits are less well established, but these generally also have high Au/Ag ratios and are locally enriched in Te, W, B and F (Poulsen *et al.*, 2000). Arsenian pyrite is not generally reported, but gold mineralization is commonly associated with As enrichment. Deposits of this type are generally not rich in base metals, although some modest Cu enrichment is noted by Poulsen *et al.* (2000).

The data from the Rattling Brook deposit indicate that it is characterized by high Au/Ag and Au/base-metal ratios, and exhibits well-developed Au–As correlations, although there is no proof that arsenian pyrite occurs. Several of the distinctive “toxic” indicator elements are enriched in mineralized rocks. The limited information on sulphide petrography shows that free gold is extremely rare and, where found, is present as very small inclusions only a few microns in diameter (Saunders and Tuach, 1988, 1991; Sinclair, 1988). In summary, there appear to be several geochemical parallels between Rattling Brook and Carlin-type gold mineralization, and perhaps also with noncarbonate-hosted stockwork-disseminated gold mineralization.

CONCLUSIONS

Gold mineralization in the area along the Cat Arm Road is unusual in terms of its setting, host rocks, alteration, mineralogy, textures and geochemistry. The Rattling Brook deposit is a large-scale system dominated by disseminated sulphides and sulphides hosted in myriad tiny veinlets. It is presently the only location in the Province where gold mineralization occurs in Cambro-Ordovician sedimentary rocks of the Laurentian platformal sequence. There remains significant room for further exploration in these sedimentary host rocks, because most previous exploration was focused in granitoid rocks.

More extensive and more precise geochemical data are required from the deposit, and there is a pressing need for information on the nature of the sulphides and the exact habitat of the gold in the deposit. However, the geological information and preliminary geochemical data discussed in this article are interesting in the context of new exploration deposit models for this part of Newfoundland. Several fea-

tures of the mineralization along the Cat Arm Road resemble those reported from Carlin-type deposits (e.g., Arehart, 1996; Hofstra and Cline, 2000) and also from broadly similar noncarbonate stockwork-disseminated gold deposits (e.g., Poulsen *et al.*, 2000). Both observations are encouraging for further exploration in this area, notably within the Cambro-Ordovician sedimentary rocks.

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