METALLOGENIC SUMMARY OF THE MEGUMA GOLD DEPOSITS, NOVA SCOTIA

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Abstract

The lower Ordovician Meguma Group of Nova Scotia consists of a lower thick unit of Goldenville Formation greywacke and an upper unit of black sulphidic Halifax Formation slate. The transition between the two units contains an Mn-rich horizon and Tremadocian fossils. The auriferous Goldenville formation comprises thick beds of light to dark grey sandy metagreywacke that contain thin beds of green chloritic silt and clay on the upper contact of each Bouma cycle. Occasionally at this stratigraphic horizon, the green slaty beds are replaced by a sequence of black sulphidic slate, which occurs abundantly throughout local stratigraphic sections.

Within these carbonaceous sections, auriferous ribbon (laminated, crack-seal) veins occur, commonly at the upper contacts of slate beds with the overlying metagreywacke. They may extend for several kilometres in length and 10s to 100s of bedding-parallel veins may occur in a single district. Also occurring are en echelon veins, various types of angular veins (smaller), pegmatitic veins, and cross cutting veins (larger). Veins that have undergone extensive deformation are sometimes juxtaposed with undeformed veins, indicating that the vein-forming process occurred over a substantial period of time during deformation. The veins and wall rocks both contain arsenopyrite with accessory pyrite, pyrrhotite, galena, and chalcopyrite; carbonate is ubiquitous. Isotopic studies suggest a biogenic origin for the sulphide and an origin for the carbonate as oxidized organic carbon. ^{40}Ar/^{39}Ar analyses of muscovite and other minerals related to the veins suggested an age circa 360 to 380 Ma and an origin related to Devonian granite emplacement has been suggested. More recently however, Re/Os dating of arsenopyrite suggests that the vein formation began with the onset of metamorphism circa 408 Ma. Other ages at about 375 Ma suggest a second vein-forming episode and perhaps continuous or episodic mineralization throughout deformation and intrusion of granites.

Résumé

Le Groupe de Meguma de l'Ordovicien inférieur en Nouvelle-Écosse se compose d'une épaisse unité inférieure de grauwacke attribuée à la Formation de Goldenville et d'une unité supérieure d'ardoise sulfurée de couleur noire rapportée à la Formation de Halifax. La zone de transition entre les deux unités renferme un horizon riche en manganèse et des fossiles trémadociens. La formation aurifère de Goldenville comprend d'épaisses couches de métagrauwacke gréseux de couleur gris pâle à gris foncé qui contiennent de fines couches de silt et d'argile chloriteuses de couleur verte formant le contact supérieur de cycles de Bouma individuels. Occasionnellement le long de cet horizon stratigraphique, les couches d'ardoiseuse verte sont remplacées par une séquence d'ardoise sulfurée noire qui est abondamment présente dans les coupes stratigraphiques locales.

À l'intérieur de ces intervalles carbonés, des filons rubanés (laminés, de scellement de fissures) à minéralisation aurifère sont couramment présents aux contacts supérieurs des lits d'ardoise avec les couches de métagrauwacke susjacentes. Ils peuvent se prolonger sur plusieurs kilomètres et des dizaines voire des centaines de ces filons parallèles à la stratification peuvent être présents dans un même district. Des filons en échelon, divers types de filons disposés à angle (plus petits), des filons pegmatitiques et des filons transversaux (plus gros) peuvent également être présents. Des filons qui ont subi une intense déformation sont parfois juxtaposés à des filons non déformés indiquant que le processus de formation des filons s'est échelonné sur une période substantielle au cours de la déformation. De l'arsénopyrite et, en quantités accessoires, de la pyrite, de la pyrrhotine, de la galène et de la chalcopyrite sont observées à la fois dans les filons et dans les épontes, et la présence de carbonates est généralisée. Des études isotopiques laissent croire que les sulfures sont biogènes et que les carbonates proviennent de l'oxydation de carbone organique. Les analyses ^{40}Ar/^{39}Ar de la muscovite et d'autres minéraux associés aux filons révèlent un âge d'environ 380 à 360 Ma et une origine liée à la mise en place des granites du Dévonien. Plus récemment, cependant, la datation Re/Os de l'arsénopyrite mène à croire que la formation des filons a commencé au début du métamorphisme aux environs de 408 Ma.. D'autres datations ayant livré un âge d'environ 375 Ma laissent croire qu'il y aurait eu un deuxième épisode de formation de filons et peut-être que la minéralisation a été épisodique ou continue tout au long de la déformation et de la mise en place des granites.

Introduction and History

The first confirmed bedrock discovery of gold in Nova Scotia occurred in September 1858 when Captain C. L'Estrange noticed the yellow metal in quartz outcrops at Mooseland on the Tangier River while hunting moose in the area. Two years later in May 1860, John Pulsiver of Musquodoboit was shown the Mooseland occurrence by Joe Paul, one of L'Estranges Indian guides. He traveled to Halifax to register his find and pointed out other favourable sites to Peter Mason who found gold at the head of Tangier Harbour in October 1860. Mooseland and Tangier were proclaimed "Gold Districts" and were surveyed under provincial legislation in April 1861. This sparked Canada's first gold rush and during the summer of 1861, prospecting based on similarity of rock lithologies to the Tangier and Mooseland areas resulted in the discovery of many other districts including Sherbrooke (Goldenville), Wine Harbour, Lawrencetown, Oldham, and Waverly (Malcolm 1929, 1976) (Fig. 1).

Sangster, A.L., and Smith, P.K., 2007, Metallogenic summary of the Meguma gold deposits, Nova Scotia, *in* Goodfellow, W.D., ed., Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, p. 723-732.

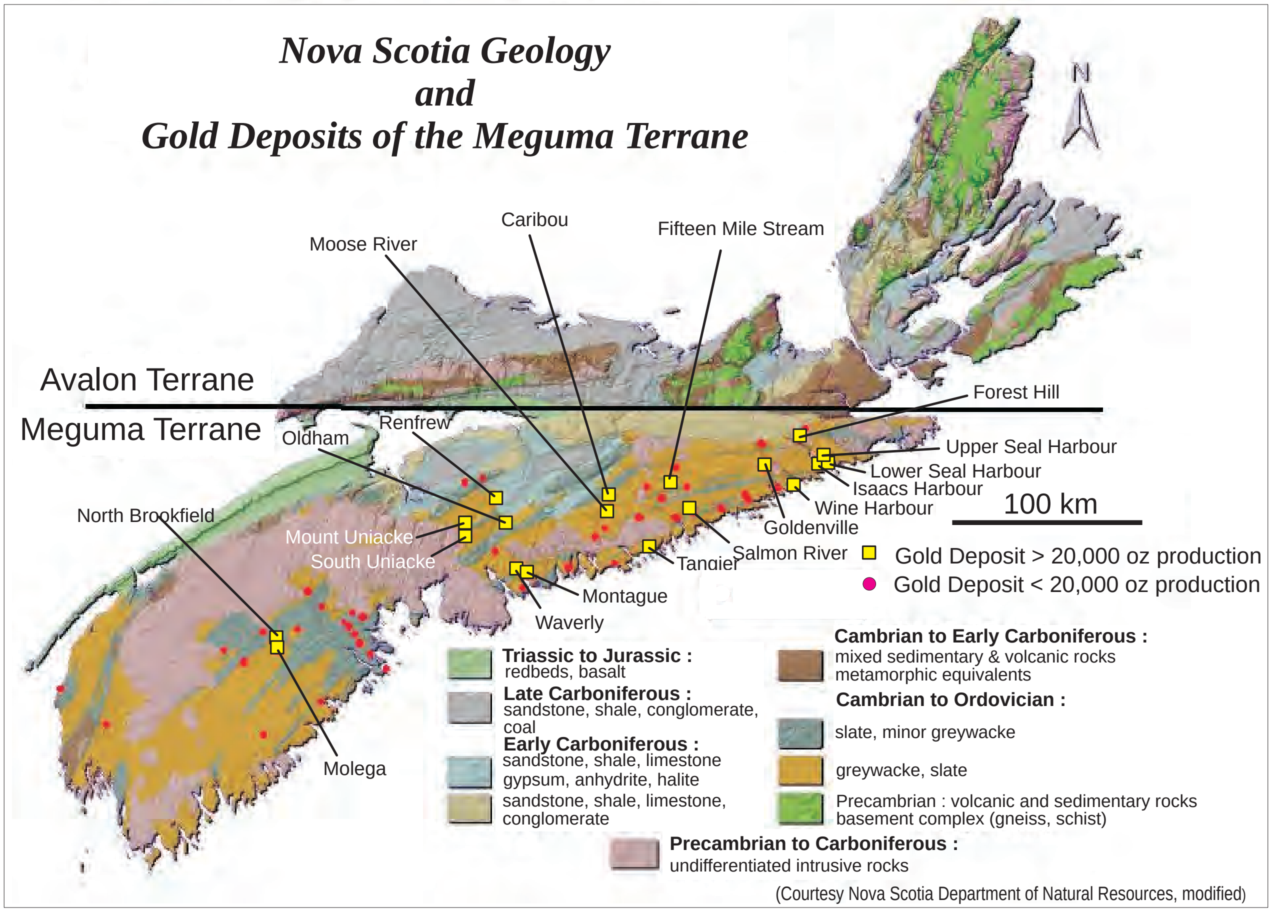


Figure 1. Regional geology of Nova Scotia and location of the 20 largest past-producing gold deposits. For smaller gold occurrences, the reader is referred to Malcolm and Faribault (1912) and Malcolm (1976) (courtesy Nova Scotia Department of Natural Resources).

Gold production from Nova Scotia gold veins has never reached the levels of districts discovered much later in the Abitibi, Kirkland Lake, or Timmins. Production in Nova Scotia remained between 15,000 and 30,000 troy ounces per year between 1862 and 1905 and dropped to less than 10,000 ounces per year after 1910 (Fig. 2). There have been brief periods of production at a few locations particularly late in the depression and during periods of higher gold prices between 1980 and the present (2006), but figures on total production for this period are not available.

Regional Geology and Tectonic Setting

Nova Scotia is divided geologically into two distinct parts, the Avalon Terrane to the north and the Meguma Terrane to the south (Fig. 1). The two terranes are separated by the east-west-trending Minas Geofracture (commonly referred to as the Cobequid-Chedabucto Fault System). Docking of the two terranes was accompanied by major sinistral, transcurrent motion along this fault, followed by minor dextral movement. Overlying Devono-Carboniferous sediments, which are common on both sides of the Minas Geofracture, stitch these two terranes together (Schenk, 1995).

The exposed Meguma Terrane is a 480 km long by 120 km wide (maximum) wedge of Lower Paleozoic metasedimentary rocks (Meguma Group) that were folded into long east-

Table 1. Production of the largest 20 gold deposits, Meguma Group, Nova Scotia.

Gold District	Years Active*	ounces	grams
Goldenville	1862-1941	209383	6511821
Caribou	1869-1968	91336	2840543
Oldham	1862-1946	85178	2649020
Waverly	1862-1940	72567	2256821
Montague	1863-1940	65197	2027624
Upper Seal Harbour	1893-1958	57846	1799001
Renfrew	1862-1958	51596	1604620
North Brookfield	1887-1936	43148	1341887
Wine Harbour	1862-1939	42347	1316976
Salmon River (Dufferin)	1881-1939	41805	1300148
Isaacs Harbour	1862-1958	39694	1234493
Lower Seal Harbour	1894-1949	34188	1063253
Molega	1888-1950	33460	1040612
Mount Uniacke	1867-1941	27737	862621
Tangier	1862-1919	26287	817510
Moose River*	1888-1939	25917	806025
Forest Hill	1895-1957	25102	780685
Fifteen Mile Stream	1879-1941	21220	659930
South Uniacke	1888-1948	20762	645701
Lake Catcha	1887-1961	17962	558603
Other		165889	5159154
Total		1198619	37277048

* Moose River production prior to 1888 included with Caribou

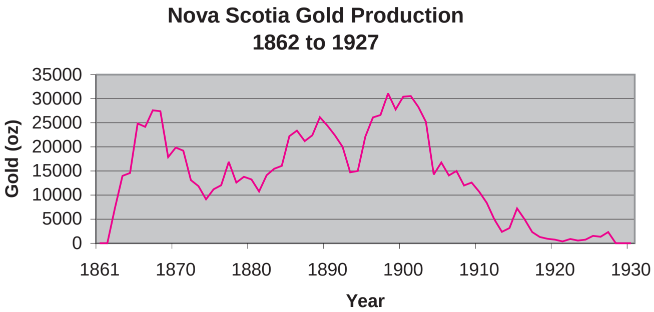


FIGURE 2. Nova Scotia Gold production, 1862 to 1927.

west trending, doubly plunging folds and regionally metamorphosed to greenschist and locally to amphibolite facies during the Devonian Acadian Orogeny (ca 400Ma). These metasediments were then intruded by voluminous Devonian per-aluminous granitoids (ca. 375Ma) and were subsequently overlain by carbonate and clastic sedimentary rocks and evaporates of the Horton and Windsor groups respectively. For the purpose of this summary, only the Meguma Group is discussed herein. The Meguma Group consists of the Cambrian Goldenville Formation metagreywacke, which is apporoximately 6.7 km thick with an unknown base. It is conformably overlain by black slate of the Halifax Formation, which, in one section near Halifax, is 11.8 km thick. Silurian volcanic and clastic rocks overlie these strata disconformably. The Goldenville Formation consists of massive, thick-bedded metagreywacke that is dark grey (carbonaceous) to light grey (calcareous) in colour. The thick coarser beds are commonly separated by thin slatey horizons that may either be chloritic or very carbonaceous. The Goldenville Formation grades upwards through manganese-rich strata into a basal unit of very carbonaceous sulphidic black slate. This in turn is overlain by typical Halifax Formation slate that consists of about 75% black carbonaceous sulphidic slate and 25% thinly bedded (~10 cm) to cross-laminated metasiltstone. The upper Halifax Formation most often consists of grey-green slates and siltstones. The proportions of the individual units is variable and most of the Halifax Formation seen in outcrop is carbonaceous and sulphidic.

Geology of the Gold Districts

Concordant and discordant gold-bearing veins occur throughout the Meguma Group, although most of the recorded 37 metric tons of gold has been recovered from the eastern part of the Meguma Terrane. Gold deposits are present throughout much of the exposed stratigraphy of the Goldenville Formation (Fig. 3), but are most common in the upper 1.5 km and between 3.5 and 4.5 km below the upper contact (Ryan and Smith, 1998). Disseminated gold mineralization is locally present (Moose River, North Brookfield). The auriferous veins occur either on or near the crests of regional anticlinal domes (Fig. 4A,B). Most of the districts occur within greenschist-facies rocks (Taylor and Schiller, 1966) and east of the South Mountain Batholith. However, several significant districts (e.g. Cochrane Hill, Forest Hill) are within amphibolite-grade metamorphic rocks that are spatially associated with numerous Devonian-Carboniferous granitic intrusions in the easternmost part of the province.

Most of the gold deposits and occurrences are associated with thicker than normal, interstratified slate and metasiltstone within the Goldenville Formation. Within these gold districts, the fine-grained lithologies are variably argillaceous, silty, carbon-rich and sulphidic with abundant pyrrhotite and arsenopyrite (Fig. 5A,B,C; Brunton, 1928; Malcolm, 1929; Smith, 1984) with pervasive carbonate alteration.

Concordant, auriferous quartz veins, which include bedding-parallel, stratiform, and stratabound geometry, are located within or immediately below the upper margins of incompetent, impermeable argillite horizons in the Goldenville Formation. Many of the districts are located on the steeper, sometimes overturned limb of anticlinal folds (e.g. Cochrane Hill, Beaver Dam, Fig. 6; Goldenville, Fig. 7; Tangier) (Smith and Kontak, 1986) or in parasitic second-order structures on the limbs of larger folds (e.g. Mt. Uniacke, Fig. 9: Dufferin, Fig. 8). Henderson and Henderson

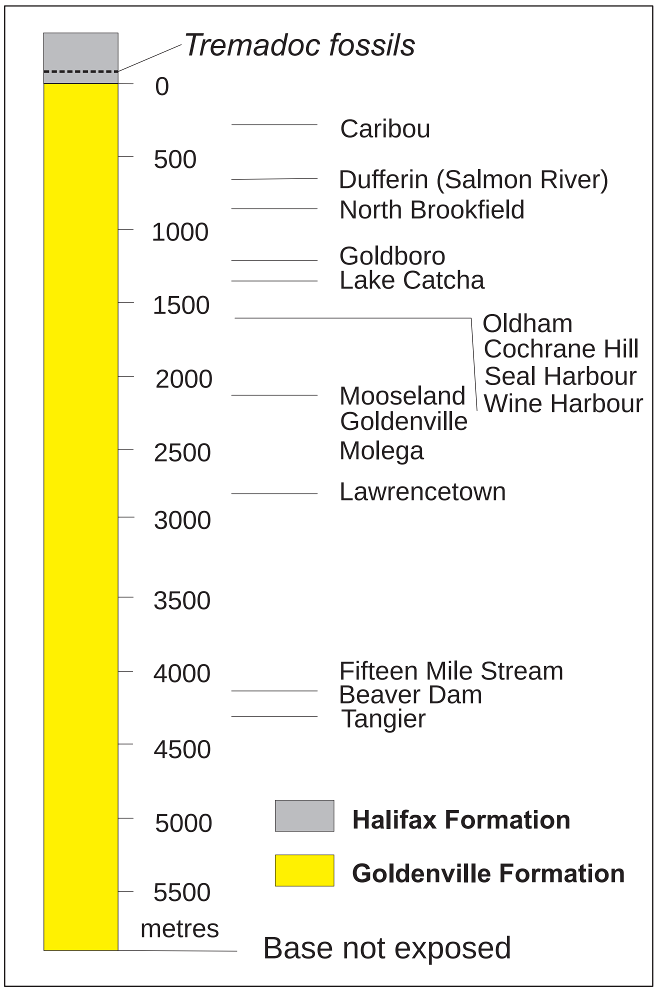
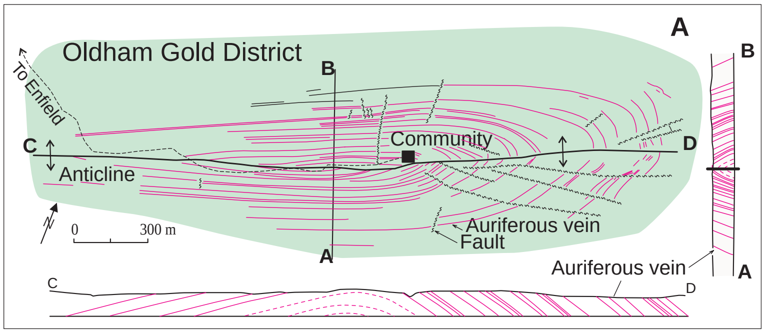


FIGURE 3. Stratigraphic location of selected gold deposits, Meguma Terrane, Nova Scotia. There is a concentration of occurrences at greater than 1500 metres and greater than 2000 metres below the upper Goldenville Formation contact, but these occurrences are widely separated and can not be demonstrated to be at the same stratigraphic horizon. Depths data was acquired by measuring the stratigraphic depth from sections on regional geological maps of Faribault (1898, 1901).



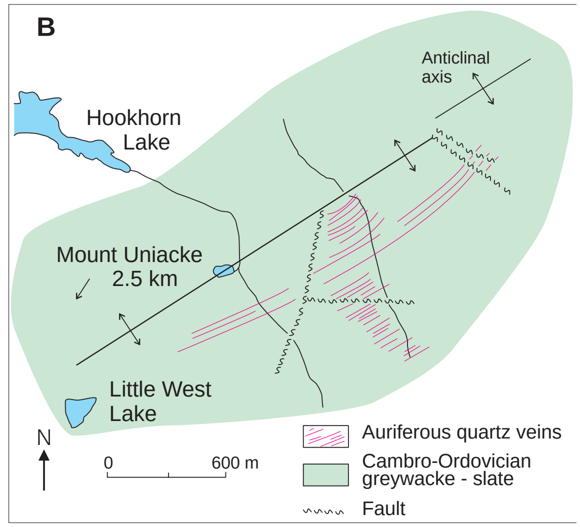


FIGURE 4. Geology of typical Nova Scotia gold districts. **(A)** Gold vein distribution in the Oldham gold district are more or less symmetrically distributed about the dome of a doubly plunging anticline. Black shale beds underlying the veins are too thin to show at this scale (modified after Faribault, 1898). **(B)** Gold veins only on the south side of the anticline at the Mount Uniacke gold district. It is probable that the veins formed on the crest of the fold and were left stranded on the south flank after migration of the fold hinge to the north (modified after Faribault, 1901).

(1986) pointed out that many workers mistakenly refer to the Meguma deposits as saddle reefs. True saddle reefs (Herman, 1914 in Boyle, 1979; Ramsay, 1980) are restricted to fold hinges and are considerably thickened in the axial zones with little down-limb extension. Meguma veins normally maintain constant thickness around fold hinges and have significant down-dip extent (e.g. Goldenville). However, the Dufferin deposit represents a significant exception in that large saddle-like, auriferous veins have been mined successfully on a small scale (Fig. 8).

Ore-grade gold mineralization commonly occurs in several settings including (1) along vein-wall rock contacts, as medium- to coarse-grained aggregates, (2) in massive white quartz, (3) less commonly as fine-grained films and wires between crack-seal laminae of concordant veins, and (4) at the intersections of discordant and concordant veins (Fig. 9). Where gold occurs with arsenopyrite, pyrrhotite, galena, and chalcopyrite, it is most commonly present as fracture fillings and coatings or as small blebs within or attached to individual crystals.

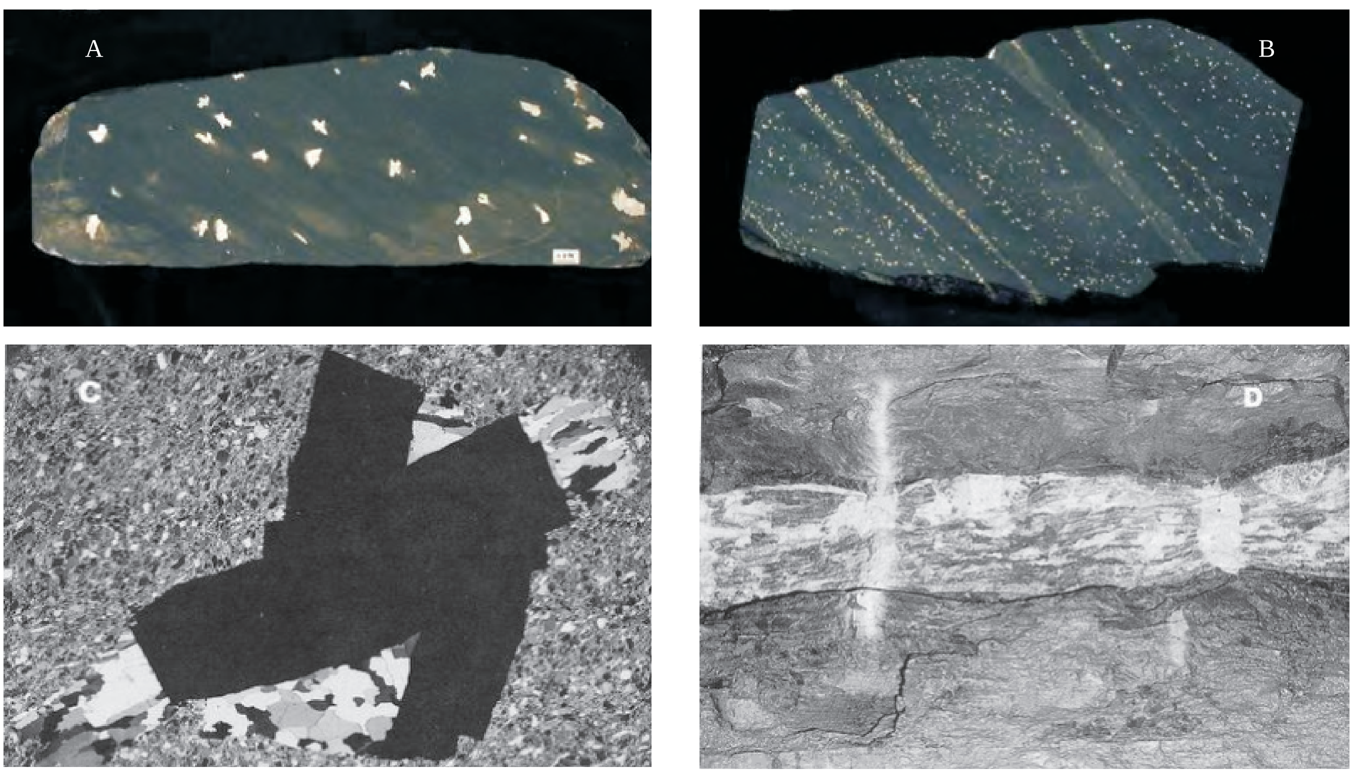


FIGURE 5. Geological features of Meguma gold Deposits. **(A)** Cruciform arsenopyrite crystals in metagreywacke from the Caribou deposit alteration aureole. Note lighter coloured silicification marbling the sample, particularly around arsenopyrites. **(B)** Bedding-parallel bands of disseminated arsenopyrite in black slate associated with veins at the Lawrencetown occurrence. Both lithologies in "A" and "B" may be auriferous. **(C)** Quartz pressure shadows on arsenopyrite crystals indicate crystallization prior to the last deformation. **(D)** Laminated "crack-seal" quartz (25 cm thick) from the Marker vein, Tangier mine. This is the most common vein-type and usually consists of laminated quartz overprinted by white bull quartz. (from Sangster, 1990).

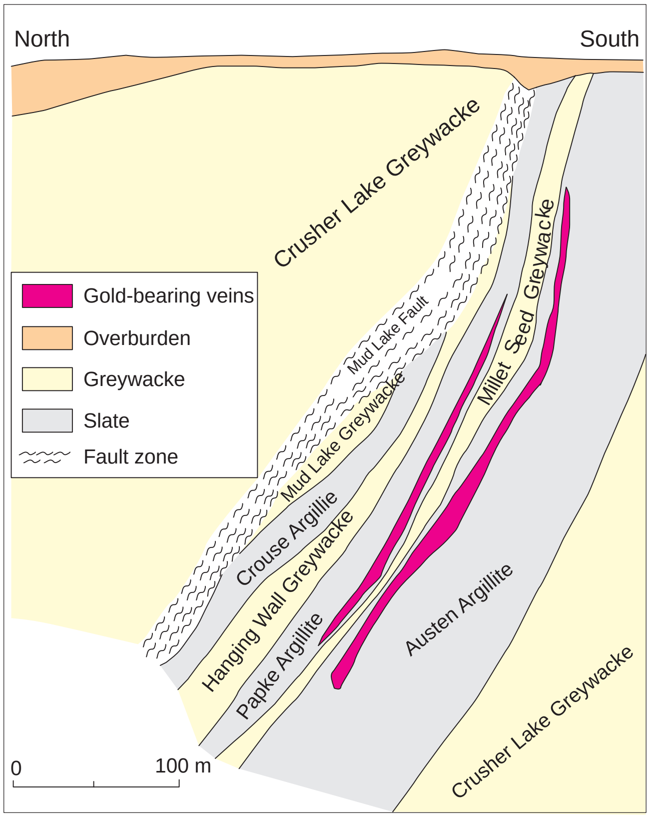


FIGURE 6. Section through en echelon gold veins at the Beaver Dam deposit, Nova Scotia (courtesy Seabright Resources Inc.).

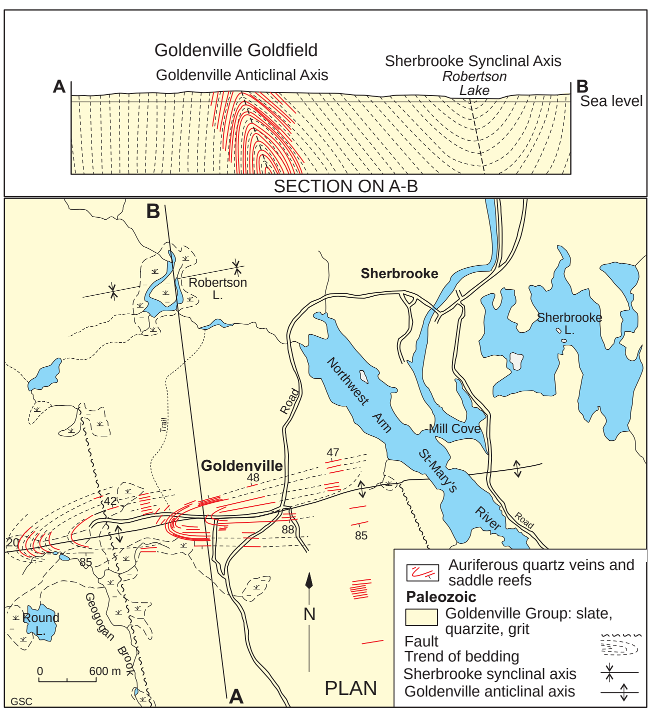


FIGURE 7. Geological plan of the Goldenville gold district. The best vein density occurred only on the western plunge of the culmination of the anticline (modified after Malcolm and Faribault, 1912).

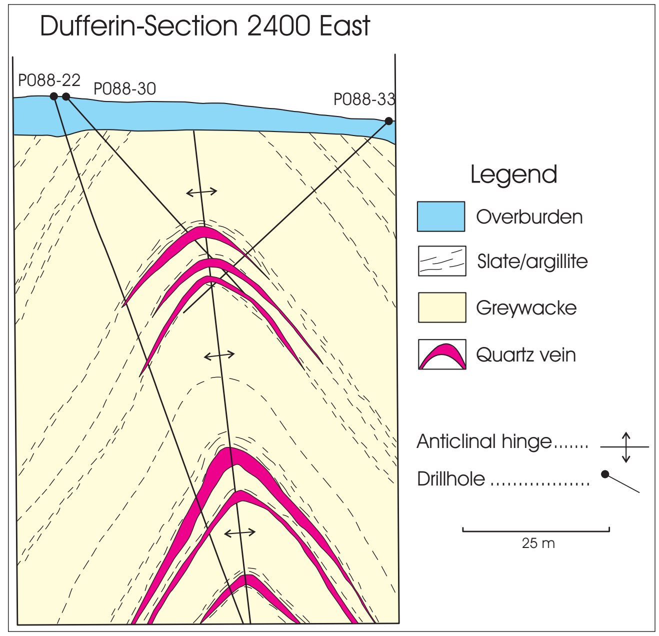


FIGURE 8. True stacked saddle reefs at the Dufferin extension deposit, Salmon River gold district. This deposit is the most recent discovery in the Meguma Group and is in production. It is the extension of the Old Dufferin Mine that has been faulted about 2 km north of the historic district, on a northwest fault (modified after Ryan and Smith, 1998).

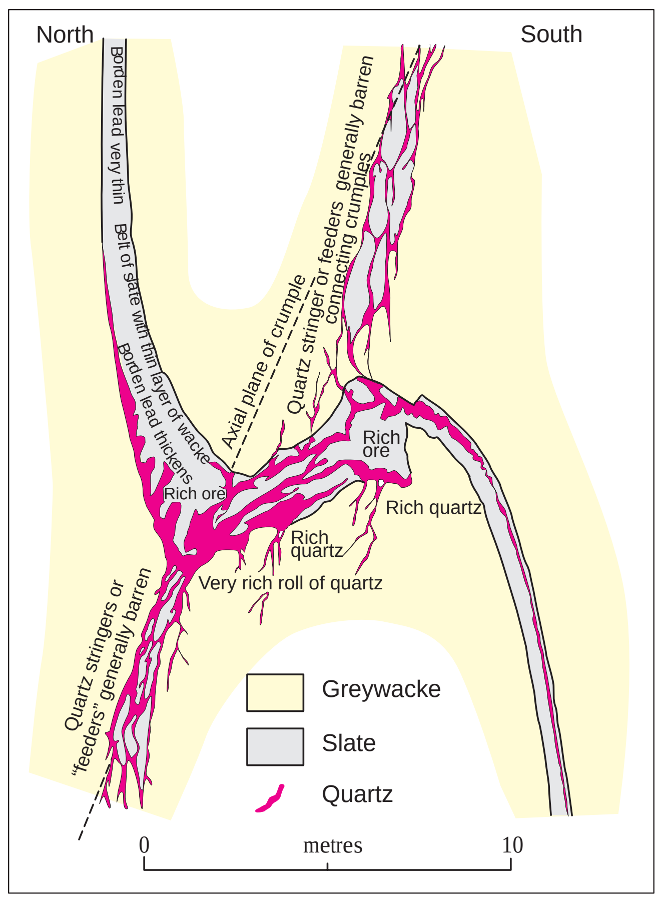


FIGURE 9. Geological section of a folded auriferous bedding-parallel vein intersected by a late barren vein breccia from the Mount Uniacke gold district. Note the gold enrichment in the bedding-parallel vein near the intersection with the late vein (after Malcolm and Faribault, 1912).

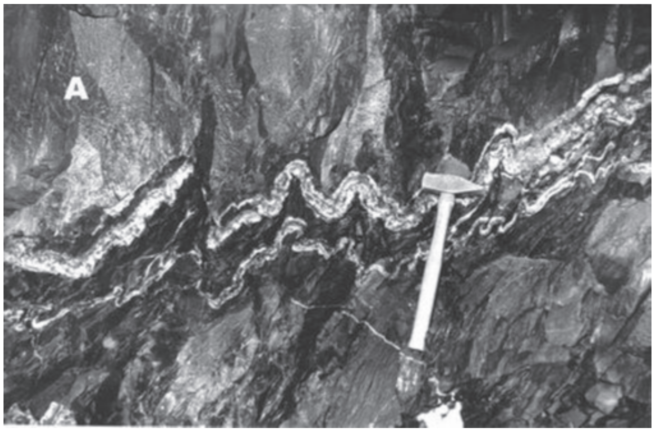


FIGURE 10. Geological features of Meguma gold deposits. **(A)** Twin vein, tangier gold district showing a pair of buckled, highly auriferous, quartz veins near the crest of the Tangier anticline. Also visible is the relationship of the veins to the overlying metagreywacke and underlying black slate. **(B)** Nugget vein, Tangier gold mine, showing chaotic quartz vein textures resulting from the development of superimposed, variably rotated en echelon veins in black, organic-rich, arsenopyrite-rich slate. Painted numbers are 25 cm high (from Sangster, 1990).

Throughout the Meguma Terrane quartz, ankerite (with variable calcite and ferroan dolomite), plagioclase, chlorite, biotite, and muscovite form abundant vein minerals (Kontak and Smith, 1988a). Arsenopyrite is variably present in all gold districts ranging up to ~15% locally in some wall rock lithologies. It is less abundant within the veins and constitutes an average of ~2% for the individual deposits. The gold distribution varies directly with the sulphide (pyrrhotite, chalcopyrite, pyrite, and galena) content. Scheelite is common at the Moose River deposit and locally present at the Beaver Dam, Mt. Uniacke, and Pleasant River Barrens deposits and is a minor accessory phase in several other gold occurrences. At the West Gore deposit, gold is genetically associated with antimony mineralization (Smith and Kontak, 1986).

Deposit Description and Classification

Several types of veins have been described at individual districts (Henderson, 1983; Smith, 1983b; Haynes 1986, 1987; Henderson et al., 1986a; Ryan and Smith, 1998).

Stratiform Veins (“Leads”)

In general, the earliest vein structures are concordant, laminated veins with crack-seal texture (Ramsay, 1980), which are interpreted to have formed during episodic hydraulic overpressure (Fig. 5D) (Faribault, 1899; Graves, 1976; Graves and Zentilli, 1982; Henderson, 1983; Mawer, 1985, 1986, 1987; O’Brien, 1985; Henderson et al., 1986b; Henderson and Henderson, 1990). These so-called “laminated”, BP, or “interbedded” veins are regionally concordant but crosscut bedding in detail and often extend from one stratigraphic horizon to another. On anticlinal hinges in the presence of an axial planar pressure solution cleavage, the veins are “buckled” (Fig. 10A) and gold grades are substantially higher than elsewhere. The ribbon veins commonly maintain their thickness over fold hinges and are not true saddle-reef veins.

In a few deposits, Dufferin (Fig. 8) being the best example, true saddle-reef veins are present with thick, massive, concordant accumulations of vein-quartz in fold noses that pinch out down-dip on fold limbs.

Also included in this category are “stratabound veins that consist of irregular accumulations of vein quartz that are restricted to one slate horizon (Fig. 10B). Gold veins in these veins are highly irregular

En echelon Veins

En echelon veins commonly form in slate or metasiltstone beds between massive metagreywacke units on the limbs of major folds. The veins fill extensional fractures that formed as a result of bedding-parallel shear during folding (Anderson et al., 1986a).

Angular Veins

These veins have discordant geometry and may be laterally extensive. They may attain a thickness of several metres and in gross scale resemble en echelon veins, except that they may crosscut several stratigraphic horizons at any one location and are typically continuous both above and below the concordant veins.

Pegmatitic Veins

Pegmatitic veins are restricted to areas around granitic intrusions and areas of higher grade metamorphism. At Cochrane Hill they occur both within and outside the mineralized horizons. These veins contain quartz, orthoclase, garnet, plagioclase, muscovite, biotite, andalusite, and rare traces of gold (Smith, 1983a,b).

AC Veins

Late extension parallel to regional fold axes has produced quartz-filled ac joints in the metagreywacke (Henderson, 1983; Williams and Hy, 1990). These veins are regionally present and occur irrespective of the presence of gold-bearing veins. However, these veins may contain trace amounts of gold where they occur in gold districts.

Northwest Faults and Veins

Subvertical quartz-calcite veins, vein breccias, and sinistral kink bands are parallel to regional, northwest-trending sinistral faults that cut all fold structures in the Meguma Terrane as well as the Devono-Carboniferous granitoids. They are thought to have a significant effect on gold distribution in some districts (e.g. Beaver Dam, Moose River). Gold grades in some concordant veins at the Tangier deposit increase near intersections with northwest faults (D. Forgeron, pers. comm.). In the Leipsigate, Brookfield, Caribou, and Rawdon districts (among others) the northwest faults host younger, goldbearing veins.

Miscellaneous Structures

Second-order structures located along regional folds are spatially and temporally associated with high-grade gold mineralization. At the Mount Uniacke gold district, gold ore was found at intersections of concordant and barren veins developed along a normal fault associated with a second-order parasitic fold (Fig. 9). At the Caribou mine, significant gold was mined from concordant veins and a younger, northwest-trending stockwork zone on the flank of the major fold (Fig. 11). At both the Leipsigate and Ecum Secum gold districts, gold mineralization occurs in faults lying subparallel to the regional fold axes.

Disseminated Non-Vein Gold I

In addition to vein-hosted gold, the Moose River district contains a substantial reserve of low-grade gold ore that is not directly associated with veining. At the Touquoy zone in the Moose River district (Bierlein and Smith, 2003), an indicated plus inferred resource of 6 million tonnes grading about 2 g/t gold has been identified by exploration in slate and metagreywacke in the vicinity of the auriferous veins. (Bierlein and Smith, 2003).

Individual deposits varied somewhat in the relative proportions of various mineralized features. For complete descriptions of most deposits the reader is referred to Malcolm and Faribault (1912), reprinted without photographs as Malcolm (1976).

Grade and Tonnage

Reliable grade and tonnage figures are not available for the Meguma Group gold deposits. Firstly, most of the mining occurred in the 19**th** and early 20**th** century and was effectively exploration by mining. “Winzes” were sunk on veins every 30 metres or so and ore-grade material encountered was mined laterally from these entries. The mining process itself was unorthodox by modern standards in that the easily mined slate in the footwall to the veins was removed and then the vein quartz was peeled off with a hammer and chisel. Grade figures available generally referred to tons of quartz crushed and not tones mined. In addition, research on old records by the Nova Scotia Department of Natural Resources indicates a possible average quartz vein grade of about 0.48 oz/ton. However, this figure does not account for the fact that at many mines, miners were paid in gold that did not form part of the recorded production and, as is the case of many locations that mine coarse-grained gold, much gold may have left the mine in the pockets of the miners.

The Goldenville district (Fig. 7) was the largest single producer in the Meguma Terrane with historical production of 6,535,730 g of gold (Sangster, 1990). The district included 105 veins, principally as concordant veins along an asymmetrical, east trending anticline. The veins are exposed over a 518 m section across the anticline (Malcolm, 1976) and occur primarily along the boundaries of slate beds and locally within the adjacent metagreywacke. Both bedding-parallel ("leads") and crosscutting ("angulars") veins are present. In addition to gold, the veins contain minor galena, sphalerite, pyrrhotite, pyrite, and arsenopyrite.

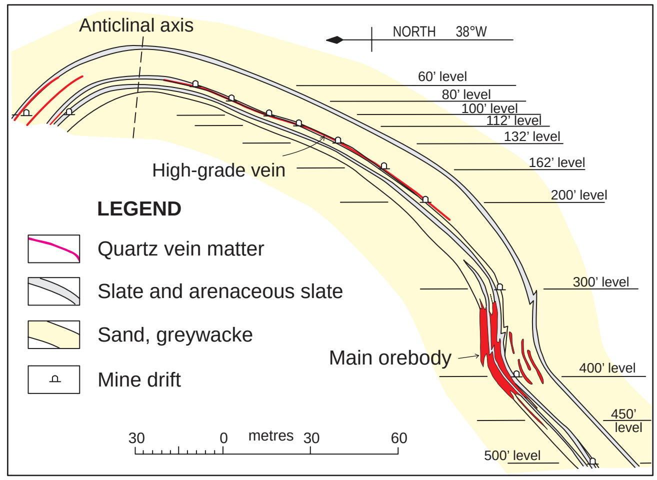


FIGURE 11. Geological section of the Caribou Mine, Nova Scotia. Note the two ore types: 1) a bedding-parallel, crack-seal vein in the upper part of the fold, and 2) quartz-healed breccia ore associated with a “kink” in the south flank of the fold (modified after Bell, 1948).

The Caribou Mine produced 2,841,950 g of gold between 1869 and 1945. Gold occurs in three settings. Like the Goldenville district, there are high grade concordant leads within slaty beds or at bedding contacts within quartzites as well as crosscutting lenses (angulars) branching off from the concordant veins. In addition, there is a large zone of network quartz veins in the metagreywacke confined to a flexure in the southern limb of the northeast-trending Caribou anticline (Douglas, 1948) (Fig. 11), which produced substantial amounts of gold.

Genetic Models

Three general mechanisms have been proposed for the origin of the gold veins: 1) syngenetic, hydrothermal deposition on the seafloor, 2) early syntectonic deposition from hydrothermal fluids of diverse origins, and 3) late syntectonic deposition from magmatic or deep crustal hydrothermal fluids. The genesis of the Meguma gold veins remains controversial. The syngenetic theories seem to have lost supporters but the early and late syntectonic theories still have substantial support.

Hunt (1868) was the first to propose a syngenetic origin for the quartz veins within the enclosing metasediments. Hind (1869, 1870, 1872) supported Hunt’s proposal for the laminated veins, but attributed other concordant veins to later processes. McBride (1978) reported a pyrite+carbonate-rich stratum 1300 m below the Goldenville-Halifax transition zone (GHT) that contains several small gold occurrences and proposed a syngenetic origin for the gold. Haynes (1983, 1986, 1987) proposed a complex, hydrothermal, hot spring model. Haynes (1987) interpreted the laminated, concordant veins as fumarole related geyserite, and the crosscutting and semiconcordant mineralized veins as subsurface feeders and parasites of the hydrothermal system.

Documentation of structural features (Henderson and Henderson, 1986; Henderson et al., 1986a; Mawer, 1986, 1987; Williams and Hy, 1990) does not support a synsedimentary origin for these veins, though it has been argued that synsedimentary components have been mobilized to form the veins.

Early syntectonic theories have been commonly used to explain the origin of the veins. Early workers, including Campbell and Poole (1862), Campbell (1863), Selwyn (1872), Gilpin (1888), Faribault (1899), Malcolm and Faribault (1912), and Malcolm (1929) stressed the importance of structure as a controlling factor and proposed the derivation of vein materials from the enclosing sedimentary rocks, and “ascending” or “descending” hydrothermal fluids as transporting agents. Boyle (1966, 1979) supported a lateral secretion model. Modern variants of these theories support an early syntectonic, pre-granite, and pre- to syn-folding origin for the veins, with the enclosing host rocks providing the vein source material mobilized by prograde metamorphic fluids (Graves, 1976; Graves and Zentilli, 1982; Henderson, 1983; Henderson and Henderson, 1986; Henderson et al., 1986b; Sangster, 1990, 1992).

Late syntectonic theories of vein origin include magmatic hydrothermal processes related to Acadian (Devono-Carboniferous) granites and vein formation from deep, crustally derived metamorphic fluids synchronous with Acadian plutonism, albeit, not directly from a magmatic source. A magmatic source for both quartz veins and gold was proposed by Rickard (1927), Newhouse (1936), Emmons (1937), Bell (1948), and Douglas (1948). Recent proposals allow for a source of vein materials either directly from a granitic source, from the lower crust or mantle, or from the enclosing sedimentary rocks, mobilized by magmatic or deep crustal metamorphic fluids driven by magmatic heat (Smith and Kontak, 1986; Kontak and Smith, 1987, 1988b, 1989a,b, 1993; Mawer 1985, 1986, 1987; Hy and Williams, 1986; Kontak et al., 1990, 1993; Kontak and Archibald, 2002). In support of this model, ^{40}Ar/^{39}Ar dates between 380 and 362 Ma have been measured for vein-fill amphibole and mica in several deposits (Kontak et al., 1990; 1993, 1998), which is consistent with models invoking protracted mineralization from metamorphogenic fluids broadly related to Acadian orogenesis and magmatism.

Many researchers contend that several generations of veins are present (Graves, 1976; Haynes and Smith, 1983; Henderson et al., 1986a,b; Mawer, 1986) representing semi-continuous vein development throughout an extended period of time. They point out the coexistence of undeformed crack-seal (ribbon) veins with highly deformed veins that have undergone extension on fold limbs. Sangster (1992) has argued, based on the presence of heavy sulphur biased vein sulphides, and host rocks, together with the fact that the vein carbonate is oxidized organic carbon, that gold was preconcentrated in Goldenville Group carbonaceous sediments in an anoxic oceanic environment and later remobilized and reconcentrated to form the gold deposits. Sangster (1992) suggested that the first gold veins to form would have been concordant veins during initial deformation and metamorphism. Vein formation and mineralization may have then proceeded episodically (perhaps including the period of 380 to 360 Ma suggested by Kontak et al. (1990)) in response to continuing deformation and intrusion of granite plutons, resulting in later generations of veins.

Recently, Morelli et al. (2005) published Re-Os ages on arsenopyrite for two deposits. The Ovens deposit on the coast 100 km west of Halifax gave an age of 407 ± 4 Ma similar to the age of onset of the initial age of metamorphism. The saddle reef veins at the Dufferin deposit gave an age of 380 ± 3 Ma, similar to former ^{40}Ar/^{39}Ar ages and the age of intrusion of the Devonian monzogranites of the Meguma Terrane. These data indicate at least two ages of mineralization and potentially episodic mineralization over a period of some 15 to 30 Ma.

Exploration Methods

Exploration for and discovery of these deposits has been mainly a boot and hammer process both for the original discoveries and for exploration in recent years. Most of the historical deposits were discovered by prospecting in outcrop or in float followed by trenching and, if promising, sinking regular declines along the vein.

Recent exploration has been based on historical records, prospecting, and undertaking of till geochemistry surveys and heavy mineral analyses. Some use has been made of induced polarization geophysical surveys with mixed results. The host rocks have a low magnetic relief, however gradient magnetic surveys have shown that the natural magnetism of the Goldenville Formation is often destroyed in the vicinity of gold districts but that there is a weak magnetic anomaly over the deposit due to the association of pyrrhotite with the gold-bearing veins.

Knowledge Gaps

1. The body of opinion on the origin of the Meguma gold vein districts prior to about 1990 was that the veins formed from hydrothermal fluids from a deep crustal source or fluids derived from within the Meguma Group prior to the intrusion of the Devonian granites. During the 1990s, ^{40}Ar/^{39}Ar dating of muscovite and other minerals gave consistent ages of about 370 Ma, which was interpreted by some to indicate that the deposits were related to the emplacement of Devonian granites, and by others to indicate that this age could not explain field observations indicating that the deposits are, at least in part, related to the onset of metamorphism circa 400 Ma.

   Recent Re-Os dating at several deposits shows that there are at least two distinct ages of mineralization (408 Ma and 376Ma). This is the first tangible isotopic evidence supporting field observation of distinct ages of vein formation. It is proposed that the careful, systematic Re-Os dating of key gold districts should aid greatly in establishing the paragenetic sequence of gold mineralizing events between these ages and potentially identify the better mineralizing events within this time range.

2. There is a growing realization that dark grey meta-greywacke is the unaltered variety of Goldenville Formation and that the regional lighter grey meta-greywacke may represent weak distal carbonate alteration that is prevalent at all gold districts in the Meguma

Terrane. Mapping the distribution of this lighter grey facies would assist greatly in understanding the genesis of these enigmatic deposits and would provide new criteria for exploration and evaluation of size and distribution potential of these gold districts. The mapping should be accompanied by lithochemical studies to provide a basis for comparison of the metagreywacke facies and alteration facies proximal to the gold districts.

Acknowledgements

The authors wish to acknowledge reviews by Bob Ryan of the Nova Scotia Departmant of Natural Resources and Wayne Goodfellow of the Geological Survey of Canada, which improved this manuscript.

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