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MINERALIZED ENVIRONMENTS, METALLOGENESIS, AND THE DOUCERS VALLEY FAULT COMPLEX, WESTERN WHITE BAY: A PHILOSOPHY FOR GOLD EXPLORATION IN NEWFOUNDLAND

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ABSTRACT

Gold and other mineral occurrences in the White Bay area of western Newfoundland have a spatial and possible genetic relationship to the Doucers Valley fault complex. This structure may have originated during Late Precambrian rifting that initiated development of the Iapetus Ocean, and gold mineralization in Grenvillian granitoid rocks may be related to the early rifting. Later gold, base-metal and uranium mineralization resulted from the generation of hydrothermal activity when the structure was periodically reactivated during the Paleozoic orogenies.

INTRODUCTION

Gold mineralization is commonly spatially and genetically related to major fractures or lineaments in the earth's crust. Examples are the Mother Lode deposits in California (Knopf, 1929; Albers, 1981), lode deposits in British Columbia (Nesbitt *et al.*, 1986), epithermal deposits in the western United States (Berger and Eimon, 1983) and British Columbia (Pantaleyev, 1986), Carlin-type epithermal gold deposits in Nevada (Roberts, 1966; Shawe and Stewart, 1976), and Archaen gold deposits (Colvine *et al.*, 1984). It is fashionable to study mineralization and metallogenesis in a plate-tectonic framework (cf. Strong, 1974, 1982; Sawkins, 1984), and the main structures associated with gold mineralization are considered to be either major transcurrent faults (cf. Nesbitt *et al.*, 1986), Basin and Range-style block faults (cf. Berger and Eimon, 1983), or detachment thrusts (cf. Ridenour *et al.*, 1982).

Gold-bearing rocks in the western White Bay area have not been extensively studied. Current exploration activity (including drilling) is focused on gold occurrences in Grenvillian granitoid rocks and in Silurian sequences. However, the distribution of mineralization in space and time permits observations on the relationship of gold and other mineralizing systems to the major structure in the area, and to a possible fundamental tectonic control on mineralization.

Speculations on tectonic controls of gold mineralization in western White Bay contribute to a philosophical model for gold exploration in Newfoundland and elsewhere. This work is an entension of ideas suggested by Tuach and French (1986).

GEOLOGY

Tectonic Setting

Northwestern Newfoundland (Figure 1) forms part of the northeastern end of the Appalachian Orogen, and the rocks record the evolution and destruction of the western margin of the Iapetus Ocean (Lock, 1969a, 1972; Bird and Dewey, 1970; Williams and Stevens, 1974; Williams and Hatcher, 1983). Cambro-Ordovician quartzite, carbonate and shale represent a platformal sequence deposited on Grenvillian basement rocks, and metasedimentary rocks of the Fleur de Lys Group represent a continental-rise wedge (Stevens, 1970). The mafic dikes in the Long Range Inlier were emplaced during the rifting that formed the Iapetus Ocean (Strong and Williams, 1972) and provided $^{40}Ar/^{39}Ar$ ages of 605 Ma (Stukas and Reynolds, 1974). Cambro-Ordovician ophiolitic, volcanic, and volcaniclastic sequences represent vestiges of rocks formed in the Iapetus Ocean (Williams, 1979). Ophiolite in western Newfoundland was obducted and emplaced onto platformal rocks during Ordovician closure of Iapetus, and lineaments that are accentuated by ophiolitic rocks and ultramafic-bearing mélanges represent either basal thrusts for obduction (e.g., the Baie Verte Lineament; Williams and St. Julien, 1982) or infolded, obducted ophiolite.

The Silurian rocks are predominantly silicic volcanics, representing continental epiclastic caldera deposits formed after closure of Iapetus, and Siluro-Devonian granitoid rocks may be related to this event (Coyle and Strong, 1987). Carboniferous rocks formed in continental successor basins (Hyde, 1979). The Doucers Valley fault complex, and the Wigwam, Birchy Ridge and Hampden–Cabot faults are Carboniferous structures, with possible transcurrent movements (Lock, 1969a, b, c, 1972; Coyle and Strong, 1987).

General Geology of Western White Bay

The Paleozoic geology in western White Bay is summarized from Smyth and Schillereff (1981, 1982) and the Grenvillian geology is taken from Erdmer (1986a, b).

Within the Long Range Inlier (Unit 1), foliated, augen-textured granitoid rocks—the French-Childs granodiorite (subunit 2a) and the Main River granite (subunit 2b)—provided zircon ages around 1042 Ma, and have intruded

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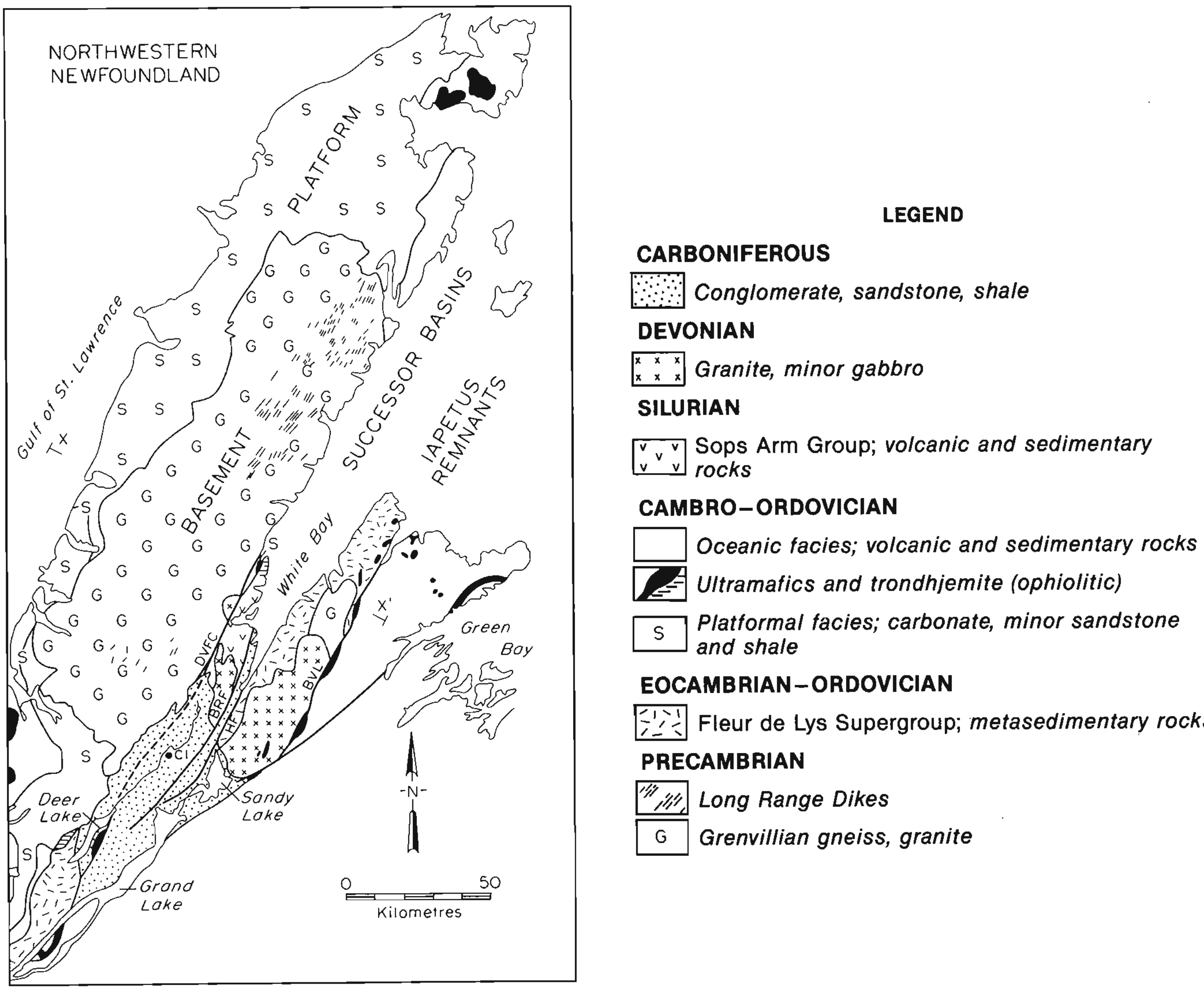


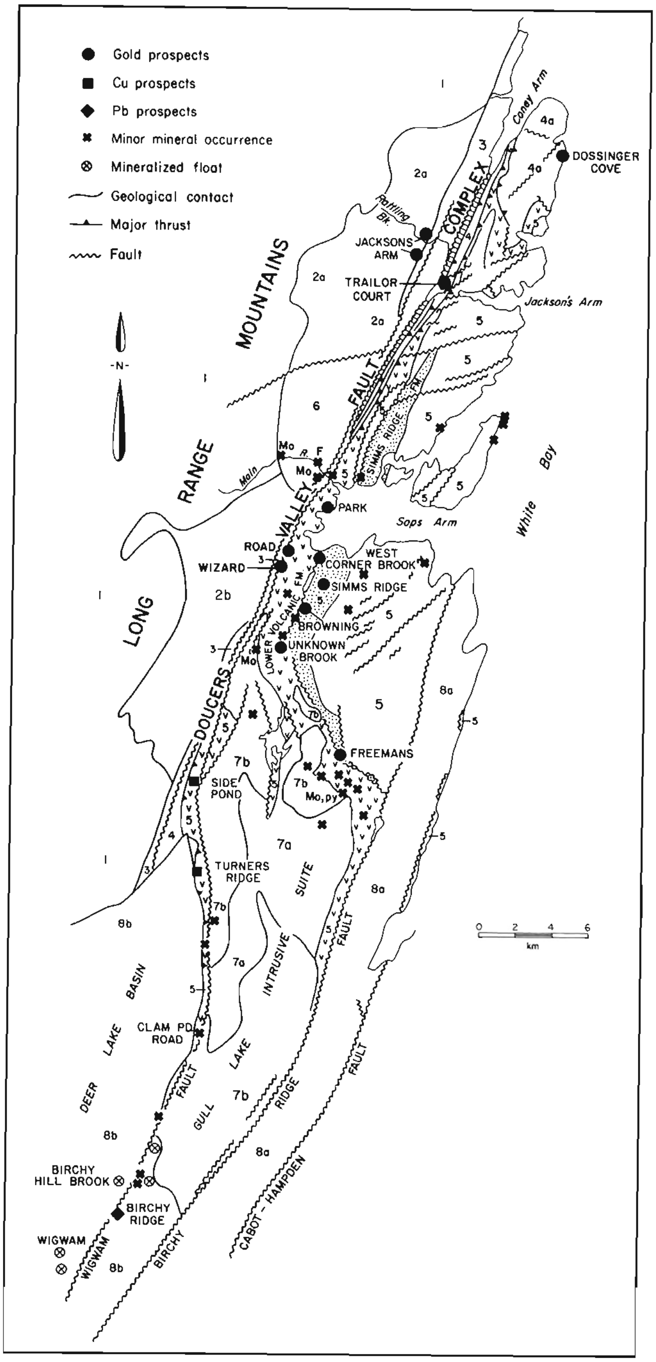
Figure 1: *General geology and tectonic elements of northwestern Newfoundland.*

granitic paragneisses (Unit 1) (Erdmer, 1986a). These rocks were intruded by the Long Range mafic dikes (ca. 605 Ma; Stukas and Reynolds, 1974).

The foliated granitoids in the Long Range Inlier are unconformably overlain by Eocambrian quartzite and minor conglomerate (Plate 1) of the Beaver Brook Formation (Lock, 1969a; Smyth and Schillereff, 1982). The quartzite and conglomerate form the basal unit of the Coney Arm Group (Unit 3), which consists predominantly of limestone, marble, phyllite and minor quartzite that correlate with less deformed, Cambro-Ordovician platformal sequences elsewhere in western Newfoundland (Lock, 1969a; Smyth and Schillereff, 1982). The Coney Arm Group is steeply dipping, tight isoclinal folds are common, and steep east-dipping thrust planes occur within the sequence.

The ophiolitic, Southern White Bay Allochthon (Williams, 1977) consists of a narrow linear belt of mafic volcanic schists and mélange (Unit 4) containing minor ultramafic blocks (Taylors Pond Formation, Second Pond

Plate 1: *Coarse conglomerate of the Beaver Brook Formation above foliated Precambrian granodiorite; Cat Arm road. F—single feldspar crystals weathered from Precambrian granodiorite.*



LEGEND

UPPER PALEOZOIC (Basin-fill sequences and intrusions)

CARBONIFEROUS

8 8b, Deer Lake Group (Visean): *conglomerate, sandstone, siltstone;* 8a, Anguille Group (Tournaisian): *graywacke, shale, minor sandstone and conglomerate*

DEVONIAN (approximately 398 Ma)

7 Gull Lake intrusive suite; 7a, *granites;* 7b, *intermediate and mafic intrusive rocks*

6 Devils Room granite

SILURIAN

5 Sops Arm Group

LOWER PALEOZOIC ALLOCHTHON

CAMBRIAN–MIDDLE ORDOVICIAN

4 Southern White Bay Allochthon: *partially ophiolitic (mélange containing ultramafic blocks is cross-hatched)* 4a, Coney Head Complex

LOWER PALEOZOIC AUTOCHTHON (Platform)

3 Coney Arm Group: *carbonate, shale, quartzite*

PRECAMBRIAN (Grenvillian basement)

MIDDLE PROTEROZOIC AND EARLIER

2 *Massive to foliated, feldspar-megacrystic, granitoid plutons;* 2a, French–Childs granodiorite; 2b, Main River granite

1 *Leucocratic gneiss, amphibolite, and gabbro*

Figure 2: *General geology and mineral occurrences in western White Bay; from Smyth and Schillereff (1981, 1982), Erdmer (1986a,b) and Hyde (1982). The Lower Volcanic formation and the Simms Ridge Formation of the Sops Arm Group are patterned.*

mélange, Murray's Cove schist; Williams, 1977), which outcrops immediately to the east of the Coney Arm Group. An area of granitoid rocks to the east of the Coney Arm Group, together with the Murrays Cove schist, has been called the Coney Head Complex (subunit 4a) (Williams, 1977). The contact between the Coney Arm Group and the Southern White Bay Allochthon is a steep fault zone. Several small areas of mafic schist occur in the eastern part of the area shown in Figure 2; they are in fault contact with Carboniferous rocks.

Silurian rocks of the Sops Arm Group (Unit 5) unconformably overlie the granitoids of the Southern White Bay Allochthon north of Jackson's Arm, and elsewhere they are faulted against the Coney Arm Group and mafic schists and mélanges of the Southern White Bay Allochthon. The Sops Arm Group is divided into five formations (Smyth and Schillereff, 1982). The Lower Volcanic formation (Figure 2) consists of silicic tuff, volcanic-derived sedimentary rocks, ash-flow units, massive rhyolite, minor vesicular mafic volcanic rocks, and carbonate beds. Coarse conglomerate and sandstone (Jackson's Arm and Frenchmans Cove formations) are ubiquitous in the northern exposures, and contain a few boulders of Grenvillian rock types (Smyth and Schillereff, 1982). A narrow conglomerate unit occurs at the top of the Lower Volcanic formation. The Simms Ridge Formation (Figure 2) overlies the Lower Volcanic formation and consists of shale containing minor carbonate beds (both rock types are commonly profusely spotted with siderite crystals). Shale, siltstone, and silicic volcanic rocks (Natlins Cove Formation) overlie the Simms Ridge Formation. The Sops Arm Group dips moderately to the east and the sedimentary formations have a well developed bedding-parallel foliation. Clasts show variable evidence of flattening. Isoclinally folded carbonate veins in narrow mylonitized zones indicate west-directed thrusting of the Silurian sequence, and deformation throughout the Sops Arm Group is probably related to this thrusting event.

The Devils Room granite (Unit 6) intrudes the Long Range Inlier, and is a Paleozoic, massive to porphyritic, biotite granite. It has provided a Siluro-Devonian zircon age of $398 \pm^{27}_{7}$ Ma (Erdmer, 1986a). The granite is in fault contact with the Coney Arm Group.

The Gull Lake intrusive suite of gabbroic to granitic rocks (Unit 7) cuts the Sops Arm Group after deformation of the Silurian rocks. A massive to porphyritic, biotite granite phase (the Moose Lake granite; Smyth and Schillereff, 1982) provided a Siluro-Devonian zircon age of ca. 398 Ma (P. Erdmer, personal communication, 1986). The western contact between the Moose Lake granite and the Sops Arm and Coney Arm groups is exposed on the Sops Arm road; it is a steep, east-dipping thrust (Plate 2).

Plate 2: *Steep thrust plane (T) within brecciated Moose Lake granite (right) thrust over schistose carbonate rocks of the Coney Arm Group; Sops Arm road. John O'Sullivan for scale.*

Carboniferous rocks (Unit 8) are represented by the Tournaisian Anguille Group (subunit 8a) to the east of the Birchy Ridge fault (Figure 2), and by the Tournaisian to Visean Deer Lake Group in the south (subunit 8b). The Anguille Group consists of upright, tightly folded, graywacke and shale, minor red conglomerate, and sandstone, and is in fault contact with other rock types in the area. Boulder conglomerate (Wigwam and North Brook formations) of the Deer Lake Group unconformably overlies folded shale and thin limestone beds of the Sops Arm Group (Plate 3). Basal conglomerates contain boulders of granitoid rocks of the Gull Lake intrusive suite, and Silurian rock types are also common. The Carboniferous basal conglomerate also unconformably overlies the Coney Arm Group and the Precambrian rocks of the Long Range Inlier. Boulder-size clasts and blocks of epidote-rich fault gouge in Visean conglomerate imply rapid uplift and faulting in Visean times. Locally, Silurian limestone of the Lower Volcanic formation is thrust westward over Carboniferous conglomerate (see Figure 4 after Dimmell, 1979), indicating minor late Carboniferous thrusting.

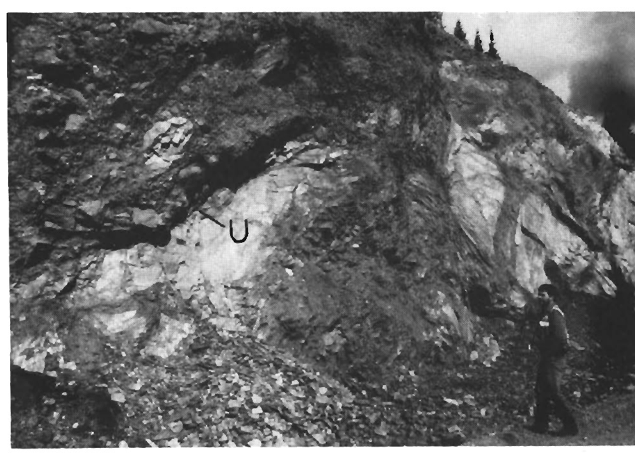


Plate 3: *Boulder conglomerate of the Visean North Brook Formation unconformably overlying folded shales and thin limestone beds of the Silurian Sops Arm Group; Sops Arm road. Dave Evans for scale; U—unconformity.*

The Doucers Valley Fault Complex

Lock (1972) described the north-northeast-trending faults between the Grenvillian and the Silurian rocks as the Doucers Valley fault complex (Figure 2), and suggested that there are two or three major, steep, east-dipping faults or thrusts at most localities. A well developed, north-northeast-trending, topographic lineament is centred on the discontinuous mélange and mafic schist zone that separates the Coney Arm Group (Unit 3) and the Silurian rocks to the east (Unit 5). Major changes in regional magnetic and gravity signatures are also present across the fault complex. Numerous accessory splays and faults occur. Lock (1969c, 1972) suggested that major brittle movement took place in the early Carboniferous, but recognized earlier ductile deformational events, dating back to the Ordovician.

The Doucers Valley fault complex separates platformal sequences in western Newfoundland from continental-slope/rise and oceanic facies to the east. It therefore marks a major tectonostratigraphic break in the Appalachian Orogen.

At its southern end, the Doucers Valley fault complex is overlapped by Carboniferous rocks in the Deer Lake Basin (Figure 2). However, the Wigwam fault (Hyde, 1982), a brittle, south-trending fault of the complex, affects the Carboniferous rocks (Figure 2). Therefore, minor tectonic activity continued into Late Carboniferous and possibly younger time.

The position of the Doucers Valley fault complex under the Carboniferous rocks (broken line on Figure 1) is defined by gravity and magnetic surveys (Miller and Wright, 1984) and by the presence of volcanic rocks in the lower part of bore hole C-1 (Figure 1; see Fleming, 1970 for drill logs). Northward, the regional geophysical and geological data indicate that the trace of the Doucers Valley fault complex follows the eastern margin of the Long Range Inlier.

ALTERATION AND MINERALIZATION

Mineralization in the Sops Arm–White Bay area is hosted by a wide variety of different rock types. Temporally and spatially separate hydrothermal-mineralizing events occurred throughout the geological development of the area. The relationship between tectonic activity and hydrothermal activity is convincingly demonstrated by the Late Silurian to Carboniferous mineral occurrences.

The Jackson's Arm–Rattling Brook Gold System (Precambrian)

In the Jackson's Arm area (Figure 2), a gold-bearing stockwork and shear system, exposed over a distance of 2 km on the Cat Arm road, was described by Tuach and French (1986). This system overprints foliated, megacrystic, Late Grenvillian granitoid rocks of intermediate composition that are unconformably overlain by Eocambrian quartzite. It consists of a core of alkali-feldspar granite (formed by pervasive replacement or potassic metasomatism of original plagioclase) containing silica–carbonate–sericite–pyrite–arsenopyrite-bearing shears, veins, fractures, fracture stockworks, and minor hydrothermal breccias (Plate 4). An outer, relatively unaltered zone contains mineralized carbonate–silica–pyrite–arsenopyrite-bearing fracture sheets and isolated shear zones (Figure 3). The potassic core has a minimum southwest-trending strike length of 2 km and is up to 300 m wide (Figure 3). It is probably bounded on the north side by a fault. Alteration and mineralization occur in granitoid rocks in association with several other lineaments north and south of the system exposed along the Cat Arm road, and minor anomalous gold has been reported in association with lineaments in the Grenvillian gneisses (Tuach and French, 1986).

Boulders of granite similar to the K-feldspar-altered zone are present in conglomerate immediately above the K-feldspar-rich zone, implying that the alteration zone had been formed and was actively being eroded during the

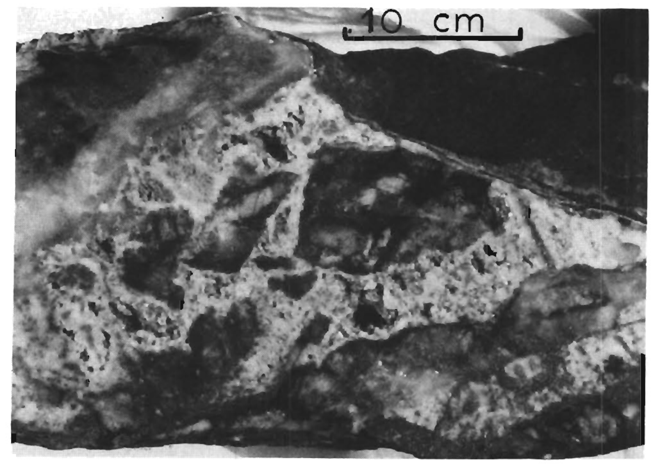


Plate 4: *Hydrothermal breccia vein in potassic-altered, foliated Precambrian granite. Matrix is cryptocrystalline quartz, Fe-carbonate, and feldspar; part of sample assayed 5.8 g/t Au. Cat Arm road.*

Eocambrian. In the same conglomerate outcrop, layers and clasts of siltstone and phyllite are not visibly altered. Mineralized shears and fractures trend at an oblique angle to the trend of the overlying Eocambrian unconformity, as does the fault on the north side of the main alteration system (Figure 3). Several of the shears have a mylonitic texture. The trace of the unconformity, which dips at 45 to 60 degrees to the southeast, is not noticeably displaced by fracturing or shearing, again suggesting that shearing and mineralization occurred prior to deposition of the quartzite.

The local presence of sericite, carbonate, pyrite, and isolated small quartz veins containing minor feldspar in the overlying quartzite could be interpreted to mean that the hydrothermal system postdated deposition of the quartzite. However, the structural and stratigraphic evidence strongly support a Precambrian age for alteration and mineralization. Additional alteration, fracturing, and element remobilization may relate to Paleozoic tectonic and magmatic events (particularly the intrusion of the Devils Room granite) during the Taconic or Acadian orogenies.

Ultramafic Rocks and their Gold Potential (Ordovician?)

Alteration and tectonic features associated with ultramafic rocks are characteristic of gold deposits in the Mother Lode belt of California (Albers, 1981; Landefeld, 1985), and in British Columbia (Nesbitt *et al.*, 1986). These altered rocks have been called listwaenite (cf. Buisson and Leblanc, 1985). Gold can be located either within shear and/or altered zones, or adjacent to them in a variety of host rocks. Ultramafic blocks, carbonate-altered shear zones, and magnesite-rich altered ultramafic rocks (virginite or mariposite) within the ophiolitic mélange zone in the Doucers Valley fault complex (Figure 2) indicate a potential for associated gold mineralization (Tuach, 1986a), and anomalous gold values have been identified in carbonate-altered zones (Trailor Court, Figure 2) to the southwest of Jackson's Arm (J. O'Sullivan, personal communication, 1986). The age of

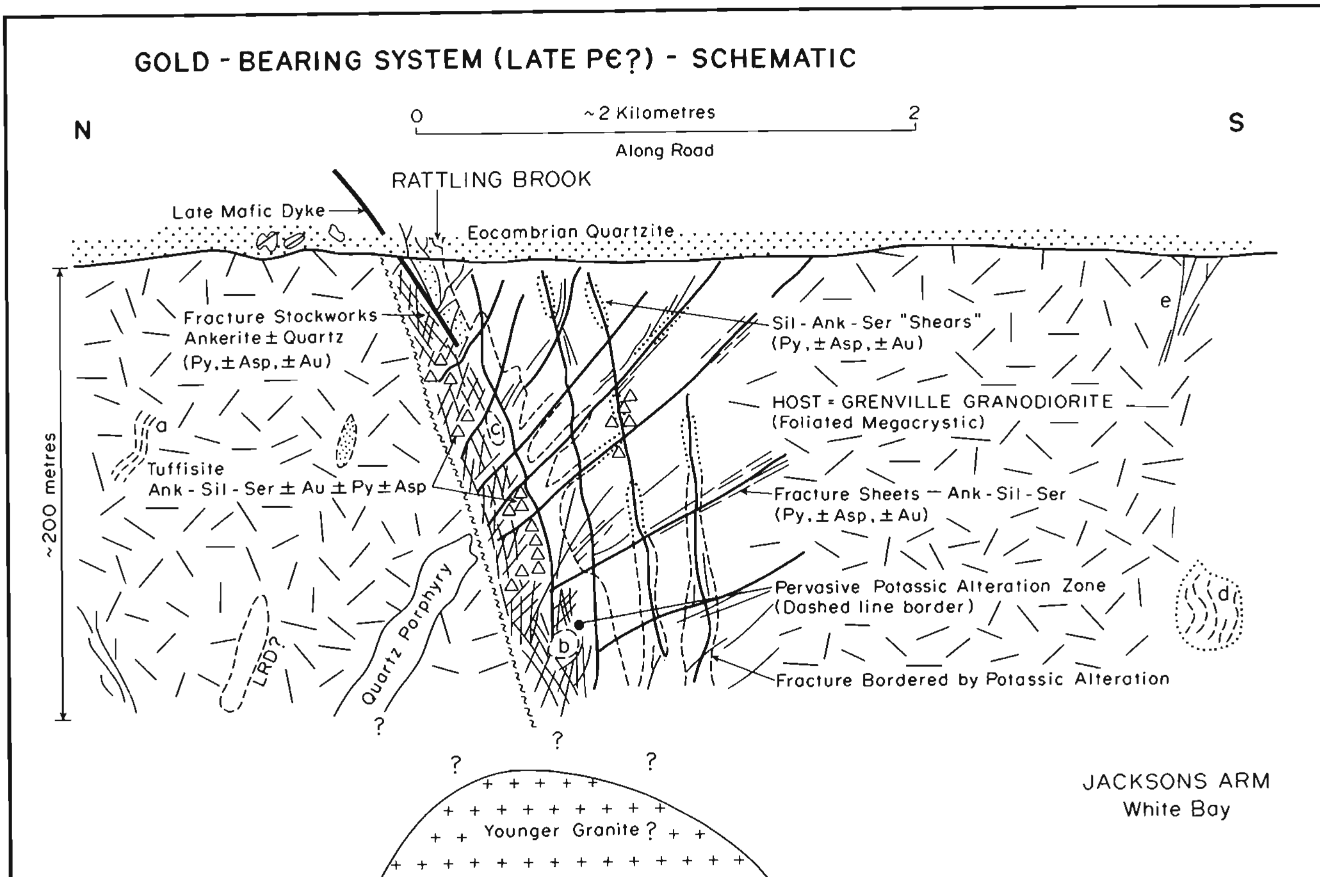


Figure 3: *Schematic section of the alteration system exposed on the Cat Arm access road. a—biotite schlieren, b—amphibolite pod, c—unaltered country rock, d—gneissic xenolith, e—isolated carbonate-bearing fractures. LRD?—Long Range Dike; from Tuach and French (1986).*

the alteration has not been determined. However, it may be related to ophiolite obduction in the Ordovician.

Gold has been located in a small quartz—sulfide vein in granitoid rocks at Dossenger Cove (Figure 2; V. French, personal communication, 1986). These rocks form part of the Southern White Bay Allochthon, and may be part of an ophiolite suite (Williams, 1977).

Silurian Gold-Bearing Systems

In the Silurian Sops Arm Group to the south of Sops Arm, silicic tuff and volcanic and sedimentary rocks of the Lower Volcanic formation, and shale of the Simms Ridge Formation host several gold—base-metal vein occurrences (Figure 2: Freemans, Unknown Brook, Browning, Simms Ridge, West Corner Brook, Wizard and Road prospects). Production of 5.1 kg of gold was achieved from the Browning Mine in 1906 (Snelgrove, 1935).

Alteration assemblages characteristic of epithermal environments (cf. Berger and Eimon, 1983) are spatially associated with these mineral occurrences (Snelgrove, 1935, Tuach, 1986a), and include quartz—feldspar veining, Fe-carbonate alteration, green micas (fuchsite?), minor chlorite-altered zones, extensive sericite- and clay-altered zones (Plate 5), and minor zones of silica alteration. Siderite cubes (Plate 5) are a characteristic feature of the Simms Ridge Formation (Lock, 1969b, 1972; Smyth and Schillereff, 1982), and are most abundant adjacent to areas of clay alteration and known mineralization. Tuach (1986a) suggested that the siderite formed in outer propylitic alteration zones of epithermal systems, and that these systems were active over the 20-km strike length of the Simms Ridge Formation.

The local presence of altered clasts in tuffaceous units implies that the alteration was at least in part contemporaneous with deposition of the Silurian sequence. Most of the altered and unaltered units in the Sops Arm Group have undergone the same degree of deformation and apparent metamorphism. The rocks exhibiting clay and sericite alteration are foliated, and pyrite and siderite crystals are commonly stretched. However, both pre-deformation or syndeformation, and postdeformation quartz veins host gold and base-metal mineralization. Two main models are possible. Alteration and mineralization may have accompanied or postdated deposition of the Silurian rocks prior to deformation, and were subsequently overprinted by postdeformation veining related to intrusion of the Gull Lake

Plate 5: *Clay-altered shale of the Simms Ridge Formation at the Browning prospect. Dark spots are siderite crystals.*

intrusive suite. Alternatively, a more dynamic model assumes thrusting and deformation of Silurian rocks were accompanied by deep magmatic activity (the 'Gull Lake magma chamber') and hydrothermal circulation within the Silurian sequences. In the second model, alteration and veining would be continuously deformed, and later undeformed veins would reflect the end of the deformation event and final emplacement of magma. This latter interpretation is analogous to those for the Carlin-type epithermal deposits (Roberts, 1984; Romberger, 1986).

Corals and brachiopods in limestone of the Lower Volcanic formation, and in limestone and shale of the Simms Ridge and Natlins Cove formations, indicate a shallow-marine environment during deposition of the Sops Arm Group (Lock, 1969b). This contrasts with a true epicontinental environment characteristic of many epithermal systems (Buchanan, 1981; Berger and Eimon, 1983). However, the occurrence of ash-flow tuffs in the Silurian may indicate emergence, and subaerial conditions may have prevailed locally.

Granophile Molybdenite–Fluorite Mineralization (Devonian)

Small molydenite and fluorite occurrences are present in granite of the Gull Lake intrusive suite (Figure 2). Fluorite-filled fractures were reported by Smyth and Schillereff (1982), and a 1-m-wide tuffisite vein containing a fluorite-rich matrix was reported in the Devils Room granite (Figure 2) (Tuach, 1986a).

The mineralization in the Gull Lake intrusive suite is dominantly hosted by a variable, fine to coarse grained, massive to porphyritic, biotite granite, which represents the roof-zone of the magma chamber. Minor coarse grained molybdenite occurs in granite pegmatite, quartz veins and pods within the granite. It also occurs as disseminations in aplite veins in the intruded rock, and in quartz veins in rhyolite. The Devils Room granite is texturally and chemically similar to granites of the Gull Lake intrusive suite, and contains traces of molybdenite in small quartz veins at two separate localities (Figure 2).

The style of mineralization is indicative of high-temperature magmatic devolatilization related to cooling and crystallization of the associated silicic magmas. It is possible that the posttectonic, auriferous quartz veins in the Silurian rocks are genetically related to the Devonian magmatic event.

Lead Deposits in Silurian Limestone

The largest known mineral deposit is the Turners Ridge lead prospect (Figures 2 and 4), which contains approximately 200,000 tonnes of 3 to 4 percent Pb (Dimmell, 1979). The deposit consists of coarse grained galena in fractures in tectonically brecciated Silurian limestone (Plate 6); lesser mineralization occurs in adjacent brecciated rhyolite (Figure 4). A smaller galena deposit occurs in the Silurian limestone at Side Pond (Figure 2), and traces of galena are ubiquitous in voids and fractures throughout the limestone, and locally in brecciated rhyolite. Significant gold has not been recorded, and only minor silver (less than 30 g/t) is associated with this style of mineralization.

The mineralized and brecciated Silurian limestone and rhyolite is thrust over Visean conglomerate (Figure 4). An absence of alteration and mineralization features in the underlying Carboniferous conglomerate indicates that mineralization predated the Carboniferous thrusting. The main deposits occur in structurally prepared rocks that were presumably brecciated by postdepositional movement along the Doucers Valley fault complex and the Wigwam fault prior to thrusting.

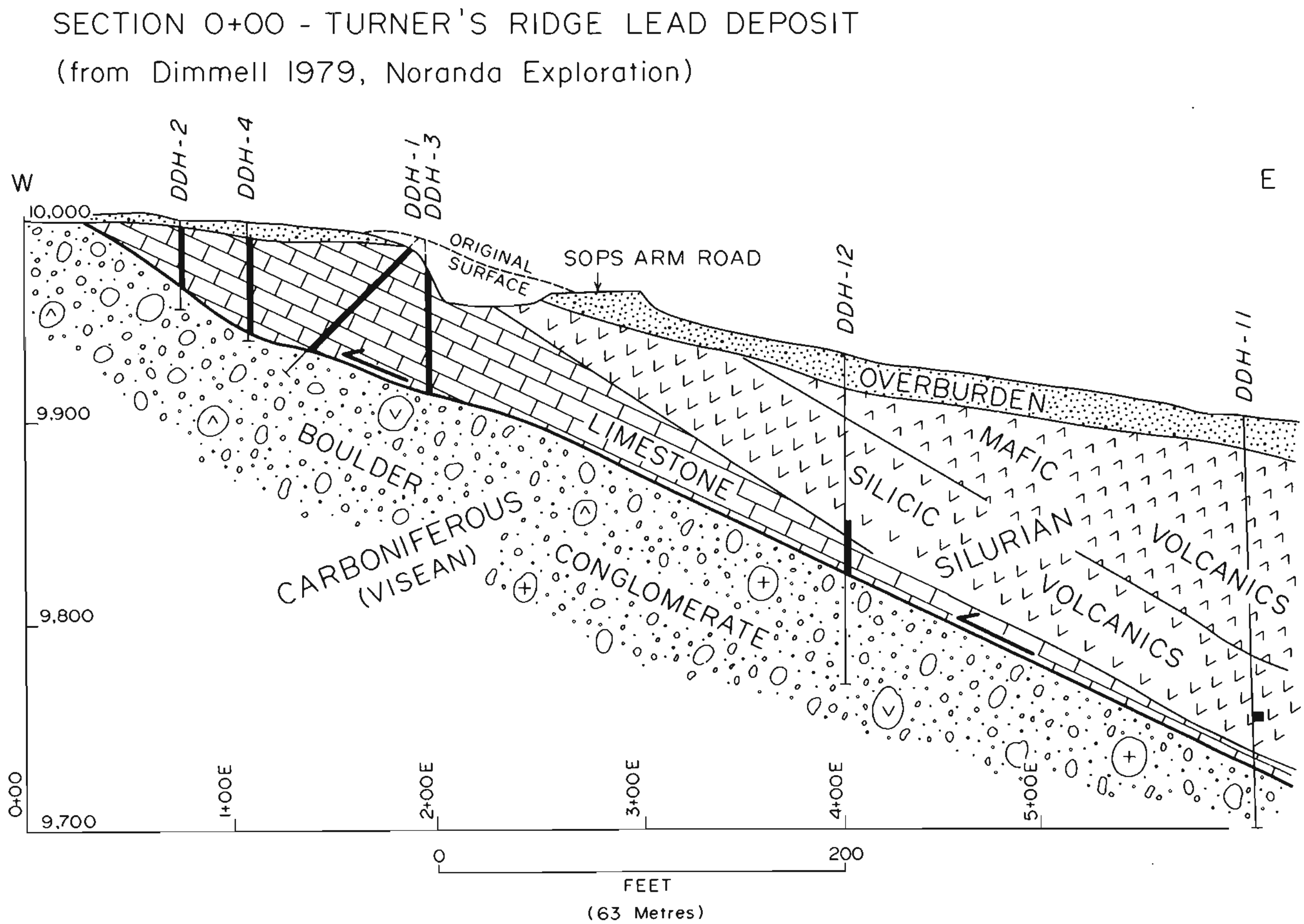


Figure 4: *West–east drill section across the Turners Ridge lead prospect; from Dimmell (1979). Mineralized portions of drill core are indicated by thicker lines. A thrust is interpreted to occur at the base of the Silurian limestone (block pattern). Parallel thrusts may occur at the top of the limestone and in the Silurian volcanic rocks.*

Copper in Silurian Rhyolite

At the Clam Pond road occurrence (Figure 2), a small area (100 m^2) of tectonically brecciated Silurian rhyolite contains bornite and chalcocite on fracture surfaces. Minor silver is associated with this mineralization; gold was not detected. The mineralization occurs in the Wigwam fault. Several boulders and pebbles of brecciated Silurian rhyolite containing similar mineralization (up to 2 percent copper) were found in the basal conglomerate of the Deer Lake Group immediately to the east of the Wigwam fault and south of the Gull Lake intrusive suite (Tuach 1980a; Patterson, 1981). Those relationships indicate a distinct hydrothermal event along the Wigwam fault that postdated the Silurian and predated the Carboniferous rocks.

Copper and Uranium in Carboniferous Rocks

At the Birchy Ridge prospect (Figure 2), vugs and fractures in Carboniferous limestone adjacent to the Wigwam fault contain bornite, chalcocite, chalcopyrite, and minor uranium (Figure 5) (Patterson, 1981). Mineralization is extremely erratic, but concentrations of 5 percent Cu and 60 g/t Ag over 1 m occur; gold has not been detected.

Hyde (1982) assigned the rocks hosting the copper mineralization to the Tournaisian Wigwam Group. Therefore, hydrothermal systems responsible for mineralization postdate the Early Carboniferous.

Uranium is also present within Carboniferous sandstone and conglomerate immediately to the west of the Wigwam fault in the Deer Lake Basin (Figure 2). Minor mineralization occurs in bedrock, and numerous boulders containing 1 to 2 percent U_3O_8, up to 0.05 percent V, 100 g/t Ag, trace Cu, and up to 0.4 g/t Au were located at the Birchy Hill Brook and Wigwam boulder fields (Byrne, 1979; Tuach, 1980b, Patterson, 1981). A Permian age for mineralization is suggested based on the U–Pb ratio in high-grade samples (Steed, 1979).

ORIGIN OF THE DOUCERS VALLEY FAULT COMPLEX

The Appalachian Orogen

Major unconformities in the Eocambrian, Silurian, and Carboniferous occur in western White Bay. The Eocambrian unconformity is part of a much more extensive unconformity

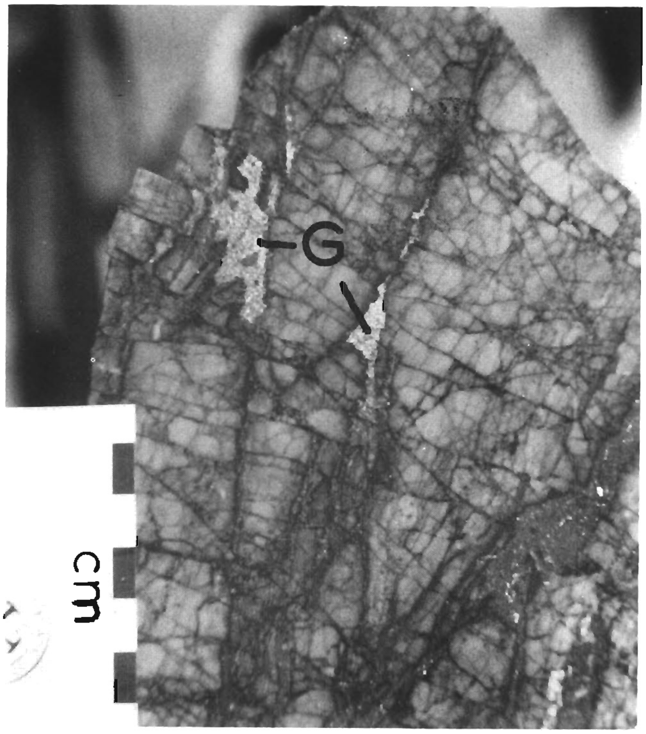


Plate 6: *Galena mineralization (G) in brecciated Silurian limestone; Sops Arm road.*

that occurs throughout western Newfoundland. However, the presence of coarse grained, locally derived debris in the Eocambrian rocks (Plate 1) indicates some tectonic instability at this time. The Silurian rocks rest unconformably on the Coney Head Complex, and locally contain fragments of Grenvillian rock types.

In the Doucers Valley area, major movements occurred in the Ordovician, Devonian, and Carboniferous orogenies. Thrust planes and tight isoclinal folding in the Coney Arm Group do not affect the Silurian rocks and formed during thrusting in the Taconic (Lock, 1972). The Acadian orogeny caused penetrative deformation (Plate 3) and thrusting of the Silurian rocks. Carboniferous deformation caused tight upright folding of the Lower Carboniferous rocks to the east of the Birchy Ridge fault, and steep brittle faults in the Upper Carboniferous rocks. Post-Devonian, left-lateral movement of approximately 15 km is suggested on the basis of possible displacement of the Devils Room granite northward from an original position adjacent to the Gull Lake intrusive suite (Lock, 1972).

The Carboniferous rocks were deposited in pull-apart basins controlled by transcurrent faults (Lock, 1972; Hyde, 1979). An analogy has been made with the Great Glen and San Andreas fault systems (Wilson, 1962; Lock, 1969c). In the Silurian, the Doucers Valley fault system may have formed the western margin of an area of epicontinental calderas and sub-volcanic intrusions in north-central Newfoundland (Coyle and Strong, 1987). In the Middle Ordovician, the area was one of extreme tectonic instability as the ophiolite klippen of western Newfoundland were thrust

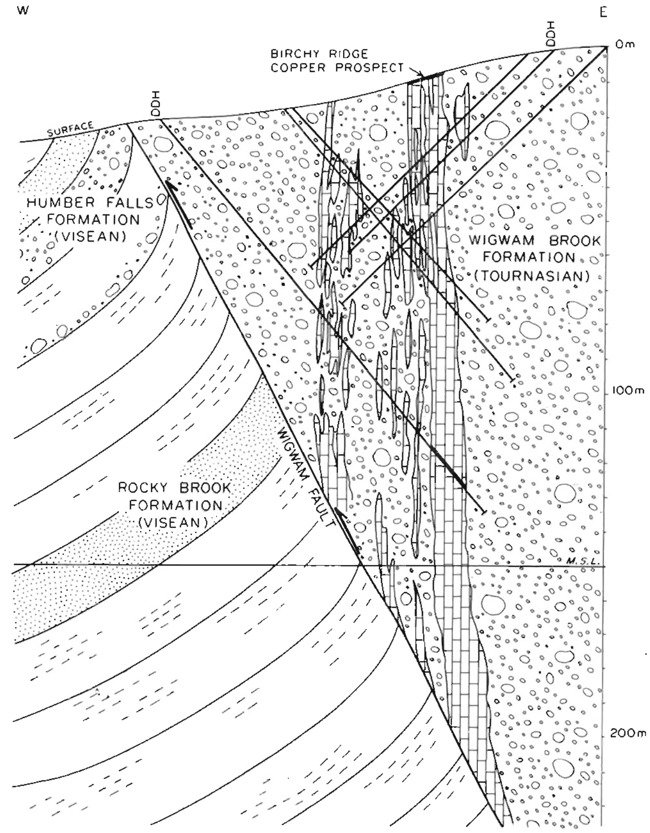


Figure 5: *Composite and schematic drill section across the Birchy Ridge copper-bearing limestone unit (block pattern); from patterson (1981). Significant mineralized zones are indicated by thick lines. The Tournaisian to Visean Rocky Brook and Humber Falls formations were tilted by reverse movement on the Wigwam fault; the attitude of the beds is based on drill sections to the north and south of the Birchy Ridge copper prospect.*

westward over the Coney Arm Group. Some deformation of the Coney Arm Group occurred at this time. During the Cambro-Ordovician, the environment of deposition of the Coney Arm Group is considered to represent the outer limits of the Iapetus continental shelf (Lock, 1972; Williams and Stevens, 1974). Prior to the development of these shelf deposits, the environment represented one of continental rifting of Grenvillian basement (Bird and Dewey, 1970; Strong and Williams, 1972).

Late Precambrian Rifting

Late Precambrian rifting of Grenvillian basement is documented by the tectonostratigraphic relationships of the Late Precambrian–Ordovician rocks. In particular, sedimentary facies indicative of continental-shelf environments, and their relationship to the metasedimentary rocks to the east, indicate a shelf–slope transition, which, by analogy with modern environments, implies a mature, rifted, continental margin as a precursor. The Long Range dikes (Figure 1), and mafic volcanic rocks at the base of the Cambro-Ordovician sedimentary shelf sequences, are

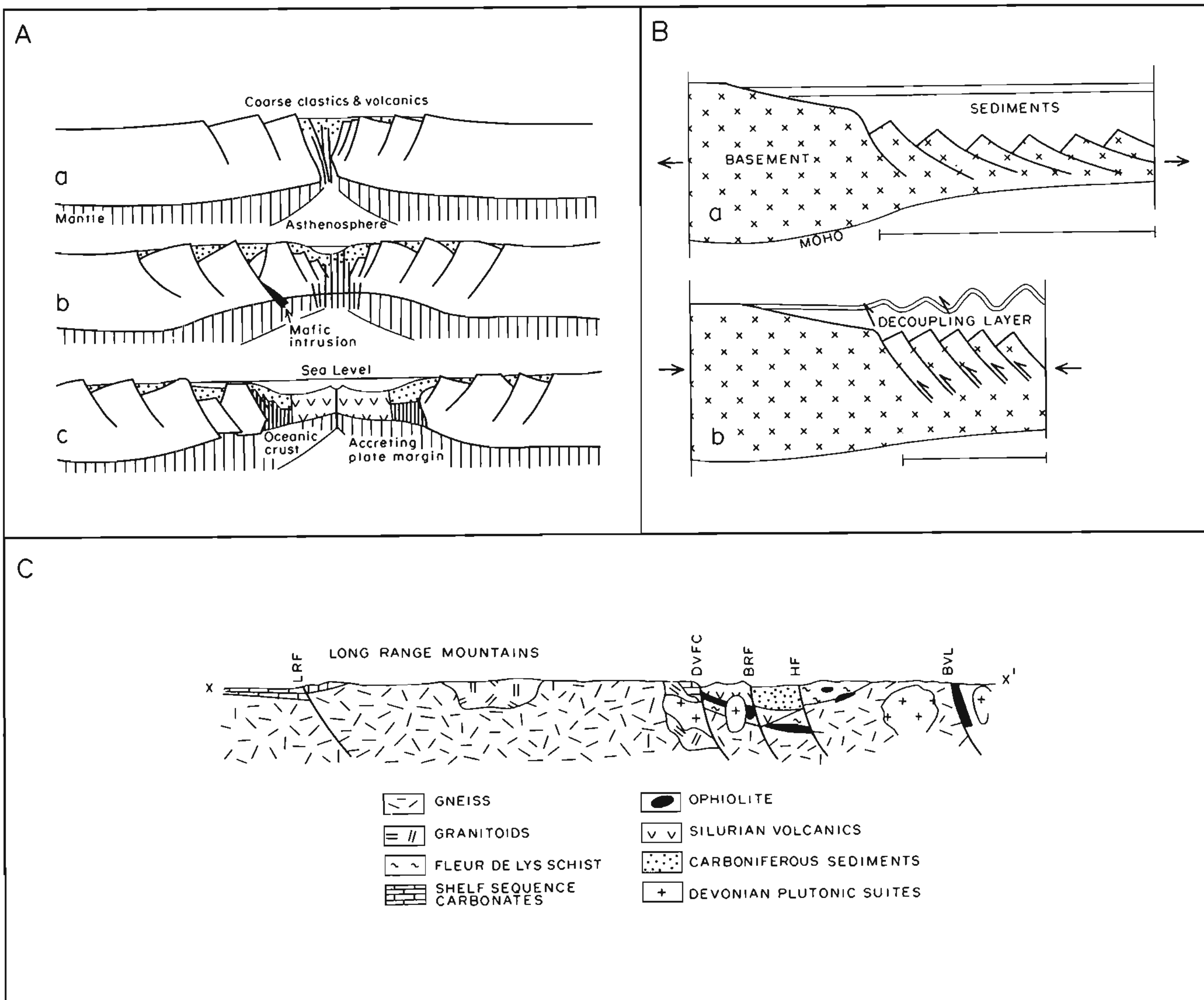


Figure 6: *Schematic sections of continental crust. A—continental rifting (from Bird and Dewey, 1970). B—Modal of crustal extension by listric faulting, and subsequent remobilization of faults during compression (from Jackson, 1980). C—Section across western Newfoundland (X—X' on Figure 1).*

tholeitic, and represent rift-related intrusion and volcanism (Strong and Williams, 1972). Williams *et al.* (1985) interpreted Eocambrian (zircon age ca. 605 Ma), high-level alkali granite (the Round Pond granite) and associated mafic and silicic volcanic rocks at the southwest end of Deer Lake (Figure 1) as a rift-related suite of rocks. The rift environment envisaged by Bird and Dewey (1970) for western Newfoundland is reproduced as Figure 6-A.

Eocambrian conglomerate and the indicated Eocambrian age for mineralization in the Jackson's Arm area also suggest that precursors to the Doucers Valley fault complex may have been active in the latest Precambrian. Intrusion of the Long Range dikes and/or rift-related granitoid rocks provided adequate heat sources to generate hydrothermal activity.

The Long Range dike swarm trends north-northeast and is presumably perpendicular to the direction of major extension during rifting. These trends also parallel the major faults and lineaments in the White Bay area, and suggest that the local north-northeast tectonic trend originated during rifting.

A simplified model of the development of listric normal faults in continental crust is reproduced in Figure 6-B (Jackson, 1980). This model is of particular interest since it indicates that major faults that developed during basement rifting acted as later thrusts, and continued to influence deformational events in the overlying sequences.

A similar model is invoked to explain the prolonged and complicated geological history extending from the

Eocambrian to the Carboniferous in the White Bay area. Major basement faults developed in response to rifting ca. 600 Ma, and some of these may have penetrated to the underlying mantle (see Figure 6-A). Similar deep structures that penetrate to the mantle are interpreted to occur in the present day Atlantic continental shelf (Keen *et al.*, 1987). It is unlikely that the Grenvillian rocks immediately underlying the Paleozoic sequences at White Bay attained metamorphic conditions to permit ductile deformation during the Appalachian orogenies. Thus, early brittle structures would remain and act as lines of weakness in the basement. These basement structures were a major control of tectonic, stratigraphic, magmatic and hydrothermal events in the overlying Paleozoic sequences. Periodic reactivation of the basement faults in response to Appalachian tectonic events is envisaged. The geology and major structures in western Newfoundland (Figure 6-C) may have evolved from processes depicted in Figure 6-A,B.

DISCUSSION

A close spatial association between mineralization in western White Bay and the Doucers Valley fault complex (Figure 2), implies a genetic relationship. A variety of mineralizing events, hosted by different rock types from the Eocambrian to the Carboniferous occurred. It is suggested that development and periodic reactivation of basement faults controlled magmatic, structural, and hydrothermal activity. Gold may have been introduced to the crustal rocks along deep Precambrian faults that penetrated to the mantle, and was subsequently remobilized. Alternatively, new magmatic and hydrothermal activity may relate to the same deep structures.

The evidence from White Bay indicates that environments of formation of mineral deposits (e.g., epithermal, vein, listwaenite or other categories) are a secondary feature related to local structural and stratigraphic features, and are controlled by major basement faults. The faults may develop as, or into, wrench faults or major deep thrusts. These conclusions can be extended from the White Bay area.

In Newfoundland, local gold-bearing environments generally have not been well defined. The locations of known gold occurrences and deposits with respect to major lineaments is illustrated in Figure 7, and the occurrences are listed in Table 1. There is an apparent spatial association of gold with some of the structures; significant gold mineralization occurs in a variety of geological settings adjacent to, or within, major faults, and further prospecting in all rock types is warranted.

Table 1. Gold deposits and occurrences in Newfoundland as of December, 1986

NO.	NAME	NO.	NAME
1	**Hope Brook Mine** (11.2 mt at 4.5 g/t Au)	30	Tulks Extension
2	Chetwynd	31	Tulks
3	Chetwynd South Extension	32	Star River
4	Woodmans Droke	33	Tulks East
5	Cing Cerf (Dolphin)	34	Costigan Lake
6	Phillips Brook	35	Roebucks Lake
7	Carrot Brook Copper/Carrot Brookstream	36	Jacks Pond
8	Strickland	37	Harbour Round
9	Big Pond Brook	38	Bobbys Pond
10	Diamond Cove/Rose Blanche	39	Southwest Brook
11	Stackhouse	40	Young's Pond
12	Isle Aux Morts	41	Glover Island South
13	**Main Zone/Cape Ray** (0.75 mt at 9.0 g/t Au)	42	York Harbour
14	Gulch	43	Gregory River
15	Window Glass Hill/Cape Ray	44	Angle Pond
16	Little Grandy's Lake/One Island Pond	45	Halfway Mountain
17	Moraine Pond	**46**	**Buchans Mines** (16.8 mt at 1.3 g/t Au)
18	Second Exploits	47	Little Sandy
19	Victoria Lake (South)	48	Connell Option
20	Pats Pond	49	Freeman's
21	South Brook	50	Unknown Brook
22	Stag Pond	51	Browning Mine (5.1 kg Au produced)
23	Glitter Pond	52	Road/Wizard
24	Victoria Lake (North)	53	Simms Ridge
25	West Tulks Pond	54	West Corner Brook/Claim 59
26	Midas Pond	55	Park
27	Valentine Lake	56	Jackson's Arm/Rattling Brook
28	Frozen Ear Pond	57	Trailer Court
29	Long Lake	58	Dossenger Cove South

Table 1. *(Concluded)*

NO.	NAME	NO.	NAME
59	Mustard Head/Englee Head	93	Coronation Lake
60	Southwest Five Mile Brook	94	Tally Pond
61	**Terra Nova Mine** (0.25 mt at 1.6 g/t Au est.)	95	Peter Snout
62	Goldenville Mine (5.2 kg Au produced)	96	Galena #1/Dog Cove Brook
63	Barry and Cunningham	97	D'espoir Lake
64	**Ming Mine** (2.12 mt at 1.9 g/t Au)	98	Partridgeberry Hills
65	**Rambler/Main Mine** (0.44 mt at 4.7 g/t Au)	99	Burnt Lake
66	Stuckey	100	South Pond
67	Lever—Tuach	101	Chiouk Brook/Great Bend
68	South Yak Lake West	102	Deadwolf Brook
69	Tilt Cove Mine (7.0 mt; 1,455 kg Au recovered)	103	Jonathans Pond/Gander Bay Road
70	Long Pond East	104	Wiers Pond
71	Nudulama	105	Cross Cove/Frost Cove/Stuckless Mine
72	West Pond	106	Taylors Room
73	Betts Cove	107	Little Harbour/Stewarts Mine
74	Burtons Pond	108	Indian Islands
75	Nippers Harbour	109	Cann Island
76	Nippers Harbour Road	110	Kim Lake
77	Rogues Harbour	111	Le Pouvoir
78	Colchester/Colchester West	112	Little River
79	McNeily	113	Long Jacks Bight/Bowers Tickle
80	Wells	114	Bois Island
81	Rendell Jackman	115	Hickeys Pond
82	Mine Pond/Lard Pond/Vein Pond	116	Chimney Falls
83	Hearn	117	Strange
84	Little Bay Mine (215 kg Au recovered)	118	Monkstown Road
85	Delaney	119	Chance Cove West
86	Jerrys Harbour	120	Brigus
87	Miles Cove	121	South Holyrood Big Pond
88	Measles Cove	122	Witless Bay Line
89	Kippens Pond	123	Oxley
90	Hand Camp	124	Rusty Zone
91	Southwest Shaft	125	Aquaforte
92	**Point Leamington**		

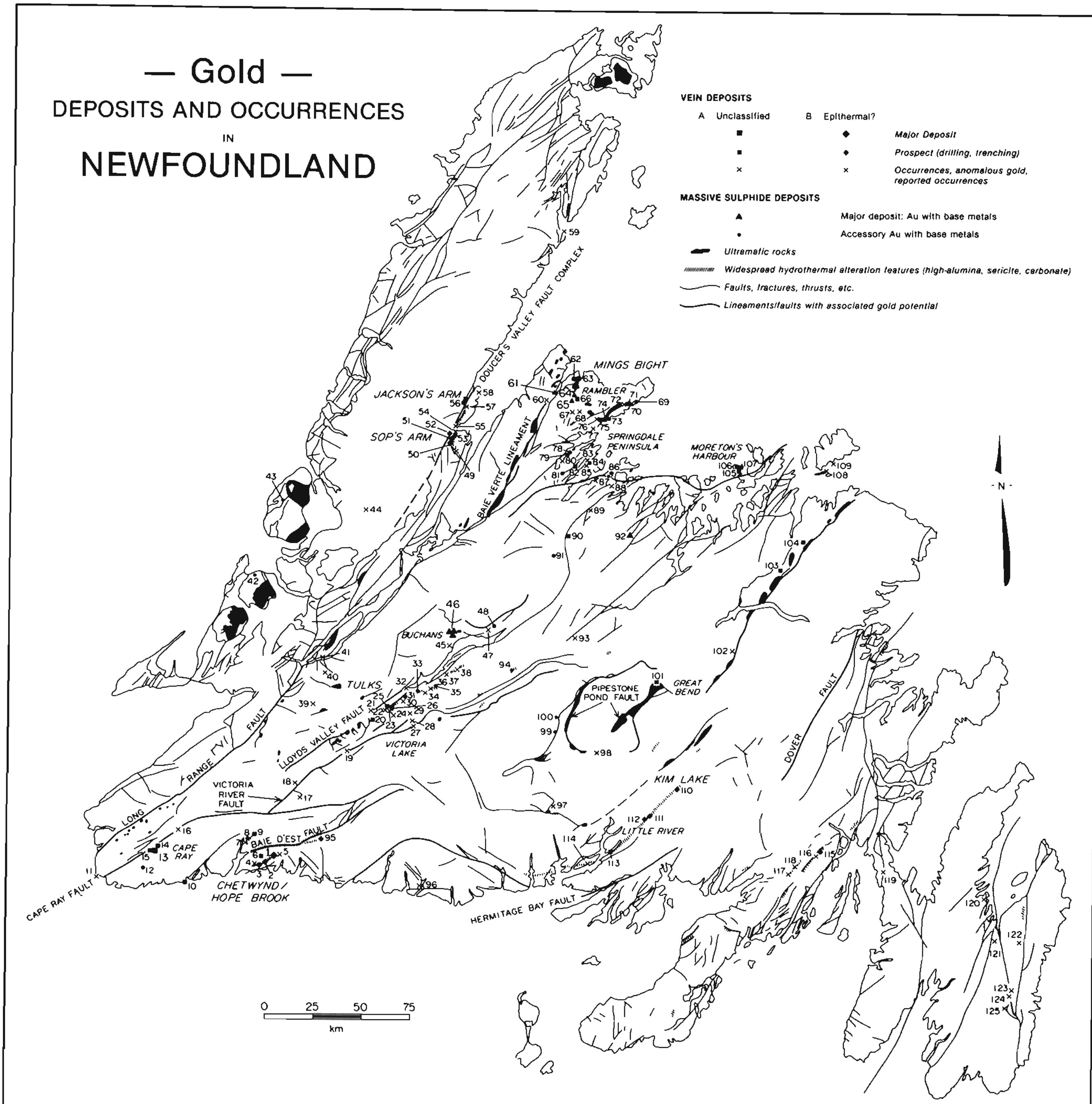


Figure 7: *Gold occurrences and deposits in Newfoundland showing location of lineaments, ultramafic rocks, and areas of extensive hydrothermally altered rocks (after Tuach, 1986b).*

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