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GOLD METALLOGENY OF THE EASTERN DUNNAGE ZONE, CENTRAL NEWFOUNDLAND

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ABSTRACT

Epigenetic gold occurrences, hosted by Paleozoic rocks of the eastern Dunnage Zone, are structurally controlled and spatially related to regionally widespread structures. Two broad belts of gold mineralization, an eastern arsenopyrite-rich belt and a western arsenopyrite-poor belt have been identified and may reflect variation in fluild–source area. The gold occurrences are classified as either mesothermal or epithermal. Mesothermal mineralization is subdivided into three subclasses; 1) shear-zone hosted, 2) disseminated, and 3) dilational veins.

Gold mineralization, which is hosted by a wide array of rock types of different ages, is the result of a prolonged Late Silurian–Early Devonian mineralizing event related to Silurian orogenesis. Source rocks for the mineralizing fluids would have been metamorphosed Gander Zone rocks, which were overthrust by Dunnage Zone sequences during the Ordovician and Silurian.

INTRODUCTION

The eastern Dunnage Zone (i.e., south and east of the Red Indian Line) has become the focus of extensive gold exploration since the 1980's. Significant discoveries have been made in the Victoria Lake, Bay d'Espoir, Great Bend, Glenwood and eastern Notre Dame Bay areas (Figure 1). In the fall of 1989, a metallogenic study was initiated in an attempt to classify and document the nature and setting of this mineralization. Work during the 1991 field season concentrated on occurrences in the area extending from Great Bend (Northwest Gander River) to eastern Notre Dame Bay. This work involved detailed mapping, sampling and diamond-drill-core logging.

Access to much of the area is provided by the Trans-Canada Highway and the Gander Bay, Lewisporte and Bay d'Espoir highways and via Route 340 from Lewisporte. Logging roads bisect much of the region and provide good access to the areas north and south of Glenwood, south of Loon Bay and Dog Bay, and east of the Bay d'Espoir Highway. The region is characterized by gently undulating topography comprising heavily forested tracts, large cutover areas, long, narrow lakes and extensive bogs. Thick, glacial till covers much of the region resulting in a paucity of bedrock exposure.

REGIONAL SETTING

Although this study is termed 'gold metallogeny of the eastern Dunnage Zone', the study actually includes all Paleozoic rocks east of the Red Indian Line and west of the Gander Zone *(sensu stricto)*. Rocks of the Dunnage Zone (Williams, 1979), record the development and subsequent destruction of the early Paleozoic Iapetus ocean. The geological evolution of the zone has been divided into two broad temporal stages involving pre- and post-accretionary events (Swinden, 1990):

1) Pre-accretionary volcanism and pre- and syn-accretionary sedimentation in a series of Cambrian to Middle Ordovician island-arcs and back-arc basins: e.g., Gander River Complex (O'Neill, 1991); Great Bend and Pipestone Pond complexes (Kean, 1974); Victoria Lake Group (Kean, 1977); Davidsville Group (Kennedy and McGonigal, 1972) and the Exploits Group, (Helwig, 1969). Emplacement of the Taconic allochthons during the Middle Ordovician resulted in cessation of island-arc volcanism. Closure of Iapetus, during the Late Ordovician and Early Silurian, resulted in the deposition of extensive flyschoid sequences in fault-bound basins in the central and eastern Dunnage Zone, and

2) Post-accretionary events marked by crustal thickening, resulting in Silurian epicontinental-style volcanism and fluviatile sedimentation (Coyle and Strong, 1987); e.g., Botwood Group (Williams, 1962), extensive regional deformation,

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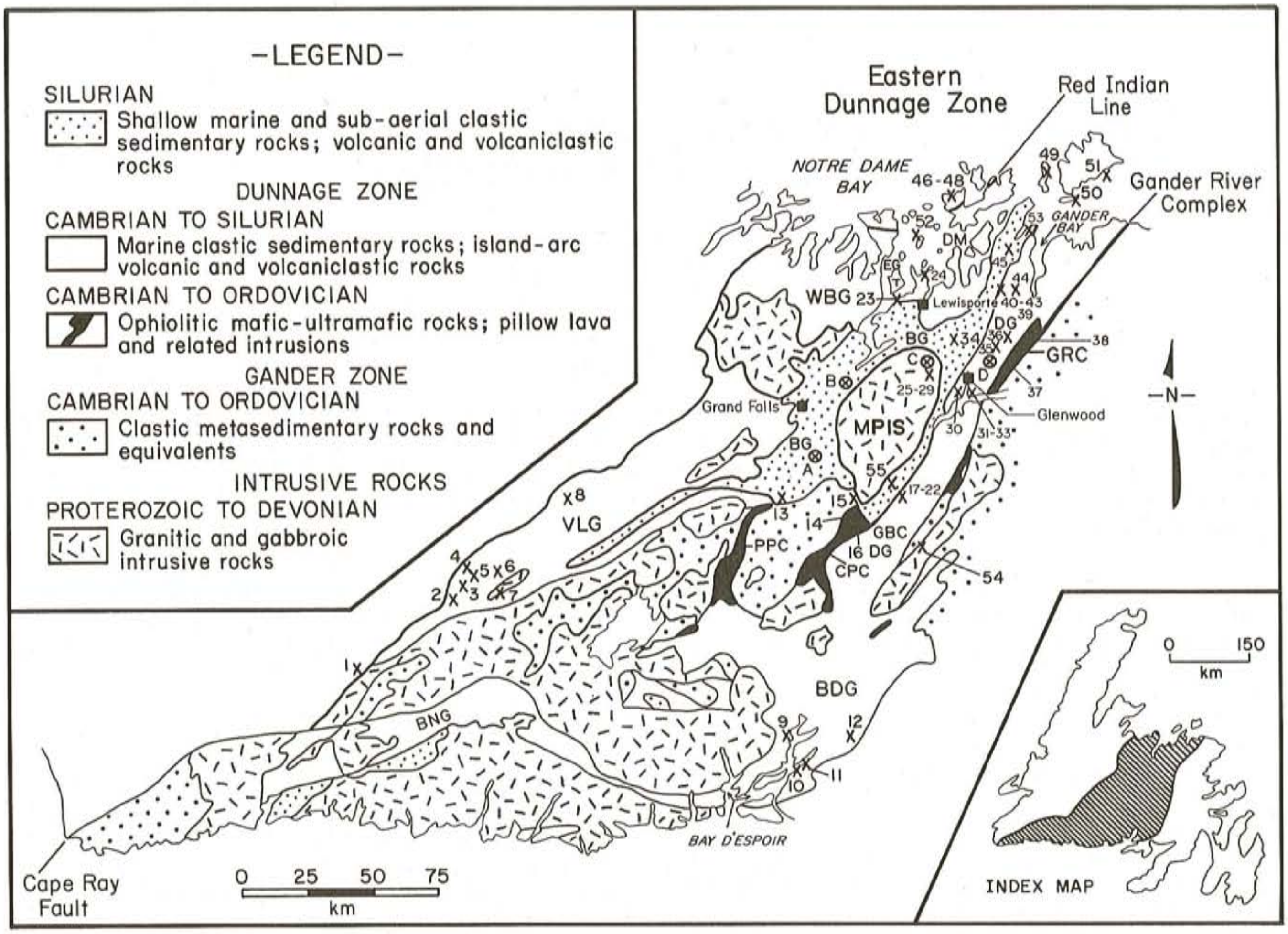

KEY TO FIGURE 1

	OCCURRENCE	CLASS	GRADES	MINERALOGY	HOST ROCK	ALTERATION
1	SECOND EXPLOITS	Dilational Veins	7.5 g/t Au	(Au),Gn,Sp,Hem,Pyr	Granite	Sil, Epi
2	PATS POND	Dilational Veins	1.9 g/t Au	Au,Ag,Cp,Gn,Sp	Felsic Volc	Sil
3	ROAD (CAMP)	Dilational Veins	5.5 g/t Au	Au,Gn,Sp,Py	Felsic Volc	Seri, Pyr
4	WEST TULKS	Dilational Veins	N/A	Au,Gn,Py	Felsic Volc	Seri, Sil
		Disseminated	N/A	Au,Hem		Sil, Hem
5	MIDAS POND	Shear-Controlled	7.3 g/t Au	Au,Pyr,Tour	Mafic Volc	Fe-carb, Pyr, Intense Argillic
6	LONG LAKE	Dilational Veins	N/A	Au,Pyr	Granite	Sil
7	VALENTINE LAKE	Dilational Veins	24 g/t Au	(Au),Pyr,W,Tour	Trondhjemite, Conglomerate	Seri, Alb, Sil Pyr
8	BOBBYS POND	Epithermal		Pyr,S,Pph,Ser, Alu,Orp	Felsic Volc	Intense Argillic
9	RATTLING BROOK	Dilational Veins	6.5 g/t Au	Au,Bi,Mo	Schist	
10	BOWERS TICKLE	Dilational Veins	13.7 g/t Au	Au,Sb,Ag	Schist	Sil
11	LONG JACKS BIGHT	Disseminated	12.34 g/t Au	Au,Ag,Pyr,Po,Ar,Gn	Schist	Sil
12	LITTLE RIVER	Dilational Veins	10.6 g/t Au	Au,Asp,Pyr,Po,Sb	Felsic Volc	
13	GREAT RATTLING Bk	Shear-Controlled	2.3 g/t Au	Au,Pyr	Ultramafic, Metasediments	Sil, Seri
14	LIZARD POND	Shear-Controlled	12.6 g/t Au	Au,Pyr,Asp	Ultramafic	Sil
15	CHIOUK BROOK	Disseminated	1.9 g/t Au	Au,Pyr,Asp	Altered Seds	Sil
16	BRECCIA POND	Shear-Controlled	< 2 g/t Au	Au	Ultramafic	Sil, Hem
17	AZTEC	Epithermal	<1 g/t Au	Au,Pyr	Altered Seds	Pyr, Argillic
18	HORNET	Dilational Veins	9.7 g/t Au	Au,Pyr,Asp	Granite	Sil
19	A-ZONE EXTENSION	Dilational Veins	2.6 g/t Au	Au,Pyr,Asp	Siltstone	Chlor, Potassic
20	ROAD GABBRO	Dilational Veins	7.9 g/t Au	Au,Pyr,Asp	Gabbro	Sil, Fe-Carb
21	GOOSE	Dilational Veins	1.3 g/t Au	Au,Pyr,Asp	Greywacke	Seri, Sil
22	LBNL	Dilational Veins	1.8 g/t Au	Au,Pyr,Asp	Porphyry	Sil
23	PORTERVILLE	Shear-Controlled	2.12 g/t Au	Au,Pyr,Asp	Gabbro	Fe-Carb Leucoxene
24	POWDERHOUSE COVE	Dilational Veins	78.2 g/t Au	Au,Pyr,Asp	Felsic Dike	Sil

KEY TO FIGURE 1 *(Continued)*

OCCURRENCE	CLASS	GRADES	MINERALOGY	HOST ROCK	ALTERATION
MOUNT PEYTON (25 to 29)					
25 HURRICANE	Shear-Controlled	4.6 g/t Au	Au,Pyr,Asp	Diorite	Seri
26 CORSAIR	Shear-Controlled	3.2 g/t Au	Au,Pyr,Asp	Diorite	Seri
27 COMANCHE	Shear-Controlled	1.3 g/t Au	Au,Pyr,Asp	Diorite	Seri
28 SABRE	Disseminated	2.1 g/t Au	Au,Pyr,Asp	Aplite Dike	Sil
29 APACHE	Shear-Controlled	1.3 g/t Au	Au,Pyr,Asp	Diorite	
30 THE OUTFLOW	Epithermal	12.23 g/t Au	Au,Pyr,Sb	Greywacke	Sil
31 BULLET	Shear-Controlled	83 g/t Au	(Au),Pyr,Asp,Gn,Cp	Shale	Fe-Carb
32 KNOB	Shear-Controlled	155 g/t Au	(Au),Pyr,Asp,Cp,Bou	Greywacke	Fe-Carb
33 BOWATER	Dilational Veins	<3 g/t Au	Au,Pyr	Greywacke	Sil
34 BIG POND	Dilational Veins	440 g/t Au	(Au),Pyr,Asp	Gabbro	Fe-Carb
35 THIRD POND	Dilational Veins	4.6 g/t Au	Au,Py	Greywacke	Sil
36 KNOB HILL	Dilational Veins	2.7 g/t Au	Au,Pyr	Greywacke	Chlor,Pyr
37 JONATHANS POND	Shear-Controlled	6 g/t Au	Au,Pyr,Asp		
38 BURSEY'S HILL	Disseminated	3.5 g/t Au	Pyr (?)	Ultramafic	Talc-Carb
39 CRIPPLE CREEK	Epithermal	9.6 q/t Au	Au,Pyr,Asp	Trondhjemite	Sil
DUDER LAKE (40 to 43)					
40 FLIRT	Dilational Veins	N/A	Au,Pyr,Asp	Gabbro	Fe-Carb, Chlor
41 GOLDSTASH	Disseminated	12.5 g/t Au	Au,Pyr,Asp	Gabbro	Sil,Seri,Fe-Carb, Leucoxene
42 CORVETTE	Disseminated	N/A	Au,Pyr,Asp	Gabbro	Sil,Seri,Fe-Carb, Leucoxene
43 STINGER	Shear-Controlled	N/A	Au,Pyr,Asp	Siltstone	Seri,Fe-Carb
44 BURNT LAKE	Dilational Veins	N/A	Au,Pyr	Greywacke	Sil
45 CLUTHA	Shear-Controlled	N/A	(Au),Pyr,Asp	Gabbro	Fe-Carb, Sil
MORETON'S HARBOUR (46 to 48)					
46 STUCKLESS COVE	Dilational Veins	20.2 g/t Au	Au,Sb,Asp	Felsic Dike	Sil
47 TAYLERS ROOM	Dilational Veins	13.3 g/t Au	Au,Sb,Asp	Felsic Dike	Sil
48 STEWARTS MINE	Dilational Veins	10.9 g/t Au	Au,Asp,Pyr,Sp	Felsic Dike	Sil
49 CHANGE ISLANDS	Dilational Veins	164.1 g/t Au	Au,Pyr,Po,Cp	Felsic Dike	Sil
50 WESTERN INDIAN ISLAND	Dilational Veins	8 g/t Au	Au,Pyr,Asp	Felsic Dike	Sil
51 CANN ISLAND	Shear-Controlled	3.1 g/t Au	Au,Pyr,Cp,Sp	Mafic Volc	Chlor
52 POND ISLAND	Dilational Veins	<1 g/t Au	Au,Cp,Sp,Sb,Bi,Ag, Asp,Tet	Granodiorite	Sil, Seri
53 CHARLES COVE	Dilational Veins	6.2 g/t Au	Au,Pyr,Asp,W,Cp,Mo	Granodiorite	Sil
54 MIDDLE RIDGE	Shear-Controlled	1 g/t Au	Au,Pyr,W	Granite	Seri, Sil
55 HUNAN	Dilational Veins			Greywacke	Seri, Carb
FLOAT					
A PARADISE LAKE	Epithermal			Sandstone(?)	Sil
B MOOSEHEAD	Dilational Veins	N/A	Au,Pyr,Asp	Sandstone(?)	Sil
C SALMON RIVER	Dilational Veins	N/A	Au,Asp,Ag,Sp,Gn,Cp, Pyr,Po	Diorite	Sil
D PANHANDLER	Dilational Veins	161 g/t Au	(Au)	Greywacke(?)	

Figure 1. *Simplified regional geology of the eastern Dunnage Zone, central Newfoundland showing the locations of the significant gold occurrences (see Table 1) and geology, (after Tuach* et al., *1988). Description and tentative classification are given in the accompanying key. DG-Davidsville Group; BG-Botwood Group; DM-Dunnage Melange; EG-Exploits Group; WBG-Wild Bight Group; VLG-Victoria Lake Group; BNG-Bay du Nord Group; BDG-Baie d'Espoir Group; PPC-Pipestone Pond Complex; CPC-Coy Pond Complex; GBC-Great Bend Complex; GRC-Gander River Complex; MPIS-Mount Peyton intrusive suite; T-Thwart Island. Sil-silicification; Epi-epidotization; Seri-sericitization; Pyr-pyritization; Hem-hematitization; carb-carbonate alteration; Alb-albitization; Chlor-chloritization.*

metamorphism, plutonism, e.g., Mount Peyton intrusive suite, (Blackwood, 1981); Charles Cove Pluton (Patrick, 1956); and the Middle Ridge Granite (Strong *et al.*, 1974) and activation or reactivation of major fault systems and thrusting of Dunnage Zone sequences over rocks of the Gander Zone (Colman-Sadd and Swinden, 1984; Keen *et al.*, 1986). These post-accretionary events are interpreted to be the product of a climactic Silurian orogeny (Dunning *et al.*, 1990). A review of earlier work has been completed by Evans (1991).

GOLD MINERALIZATION

This section details some of the significant occurrences examined during this field season and outlines a preliminary classification scheme for gold mineralization within the eastern Dunnage Zone (Figure 2). Dubé (1990) developed a similar classification scheme for gold deposits in western Newfoundland.

Powderhouse Cove

The Powderhouse Cove showing (Figure 1) was discovered by Mr. Quincy Sheppard in 1989. It is best exposed on the eastern shore of Powderhouse Cove, sporadic exposures can be traced westward across the peninsula and it is reported to outcrop on islands in Southwest Bottom. The showing comprises a 2-m-thick, east–west trending, siliceous, aphanitic felsic dyke, which has intruded black graphitic shales of the Dunnage Melange.

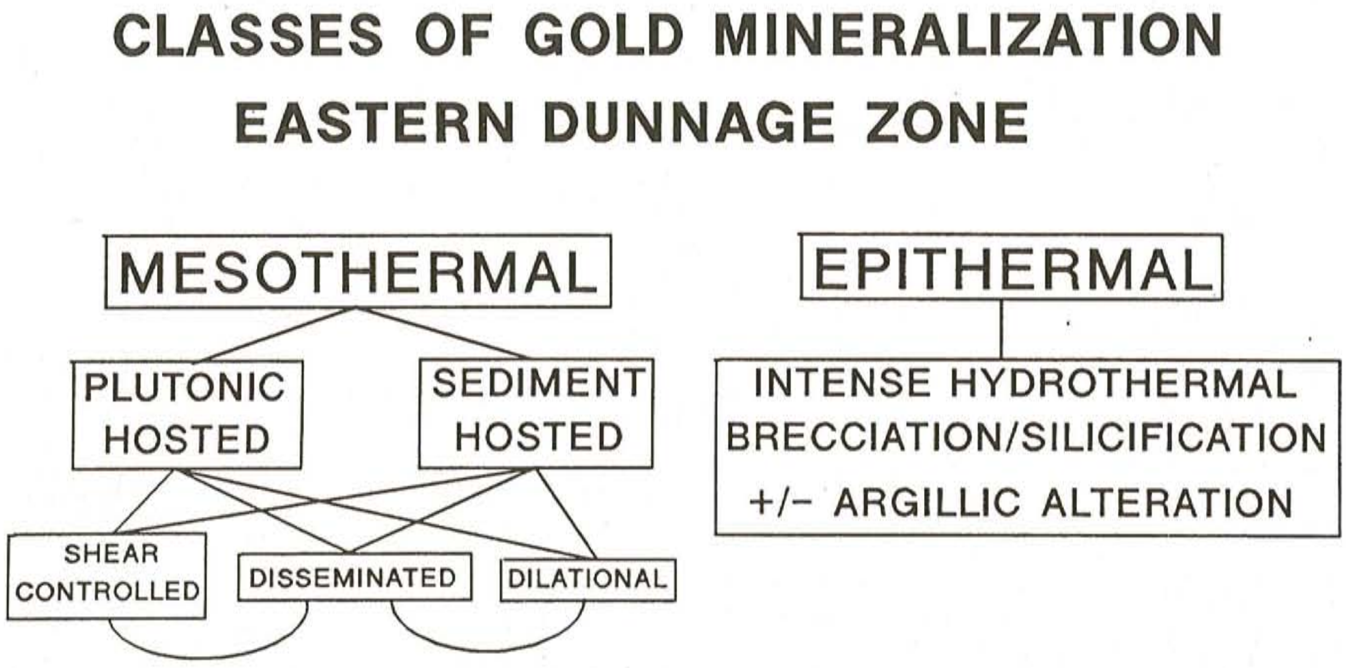

Figure 2. *Preliminary classification scheme for gold mineralization, eastern Dunnage Zone.*

The dyke is interpreted to have intruded during the early stages of regional deformation. This early deformation and intrusion were coeval as is evidenced by a strongly developed east–west-trending foliation that is absent in the shales. Continued deformation produced the main regional cleavage in the surrounding shales and developed a series of foliation-parallel faults that offset the dyke. These faults produced narrow (<3 cm), brittle, quartz-filled fractures within the dyke (Plate 1). Locally, these quartz veins contain massive patches of arsenopyrite and minor pyrite, which have assayed up to 78.5 g/t Au (Table 1). Preliminary results indicate that the mineralization is best developed near the dyke margins, suggesting that carbon complexing may have played a role in the mineralizing process.

Plate 1. *Brittle-controlled auriferous quartz vein (78.2 g/t Au) developed in siliceous felsic dyke, Powderhouse Cove.*

Porterville

Gold mineralization discovered by Mr. Roland Butler in 1990, is associated with narrow shear zones developed within and along the margins of gabbroic intrusive rocks in the Porterville showing area (Figure 1). These rocks, which intrude sedimentary rocks of the Ordovician New Bay Formation, of the Exploits Group (Dean, 1978), are fine to medium grained and locally porphyritic.

The shear zones exhibit Fe-carbonate alteration, minor silicification and local development of leucoxene. Quartz–carbonate veins and stockwork occur within some of the shears and may contain pyrite, arsenopyrite, minor chalcopyrite and sphalerite. The shear zones vary in width from less than 1 m up to approximately 100 m (Butler, 1990). A grab sample from the Porterville showing assayed 2.12 g/t Au. However, assays from the other zones generally assayed less than 2 g/t Au (Butler, 1990).

Similar styles of alteration and mineralization are widely distributed throughout the Bay of Exploits area. O'Brien (1991) stated that gabbro–diorite sheet intrusions in the New Bay area host structurally controlled vein arrays associated with pyritized, Fe-carbonate alteration zones. Similar zones, which assayed approximately 1 percent Cu (Figure 1 and Table 1), were observed on Thwart Island.

Lizard Pond

The Lizard Pond prospect (Figure 1) was discovered by BP Canada Limited in 1989. It comprises a series of sporadic, fault-controlled, quartz–breccia veins (Plate 2) developed within grey-brown, siliceous, locally brecciated magnesite-

Table 1. Selected assays from the eastern Dunnage Zone, refer to Figure 1 for locations. QV-quartz vein; GAB-gabbro; FD-felsic dyke; – not assayed

Sample	Au	Ag	Cu	Zn	Sb	As	Bi	Rock
Thwart Island								
TI-89-03	30 ppb	1.2 g	1.24 %	-	-	-	-	GAB
Charles Cove								
DE-90-181	89 ppb	130 g	-	-	36 ppm	0.57 %	-	QV
DE-89-182	200 ppb	40 g	-	-	33.6 ppm	1.78 %	-	QV
Pond Island								
DE-90-207a	<1 g	1330 g	5.82 %	1.67%	3.67%	1.83 %	0.993 %	QV
Clutha								
DE-89-33e	1.2 g	<2 g	-	-	34.2 ppm	0.78 %	-	QV
DE-89-50e	5.76 g	<2 g	-	-	28.5 ppm	0.04 %	-	QV
Powderhouse Cove								
DE-91-09	92 ppb	-	-	-	-	-	-	FD
DE-91-10a	48 ppb	-	-	-	-	-	-	FD
DE-91-10b	97 ppb	-	-	-	-	-	-	FD
DE-91-10c	145 ppb	-	-	-	-	-	-	QV
DE-91-10d	78.5 g	-	-	-	-	-	-	QV
DE-91-12	222 ppb	-	-	-	-	-	-	FD

Plate 2. *Structurally controlled quartz–breccia veins developed within silicified magnesite, Lizard Pond.*

altered serpentinite of the Great Bend complex. The veins are up to 1.5 m thick, have strike lengths up to 9 m and contain fine-grained disseminated arsenopyrite and pyrite. Assays from the veins have returned values of up to 12.58 g/t Au over 0.4 m (Graham, 1989).

The altered ultramafic rocks are interpreted, based on limited diamond drilling, to form a series of thin thrust slices separated by red siltstone (Graham, 1989). Based on regional correlations, these siltstones are interpreted to belong to the Silurian Botwood Group (L. Dickson, personal communication, 1991). The structurally controlled gold mineralization within the ultramafic units, if related to thrusting, must therefore be younger than Botwood Group.

Breccia Pond

The Breccia Pond prospect (Figure 1) was discovered by BP Canada Limited in 1989. It comprises a series of structurally controlled, narrow quartz–carbonate veins and minor stockwork having intense hematite alteration haloes (Plate 3). The veins are developed within silicified magnesite-altered ultramafic rock, which contains approximately 5 percent pyrite, arsenopyrite and millerite (Graham, 1989). A channel sample from this prospect assayed 3.24 g/t Au over 1.0 m.

An intensive zone of either hematite alteration or jasperoidal magnesite (Graham, 1989) is developed immediately southeast of the main prospect. Vuggy siliceous zones and small semi-massive patches of pyrite are sporadically developed. Tiny needles of millerite are present in fractures. A diamond-drill intersection revealed that the ultramafic rocks form thin fault-bound slivers separated by shale and sandstone.

Middle Ridge

Auriferous quartz veins, discovered by Noranda in 1988, while following up regional-till and lake-bottom sediment results, occur within the deformed and altered Middle Ridge Granite (Figure 1). The medium- to coarse-grained Middle Ridge Granite, which intrudes sedimentary rocks of the

Plate 3. *Shear-zone-controlled quartz veins with intense hematite alteration haloes developed within altered ultramafic rocks, Breccia Pond.*

Gander Zone, is interpreted as Devonian in age (Bell *et al.*, 1977).

Two generations of quartz veining are recognized (Tallman and Gower, 1988): 1) vuggy quartz veins up to 8 cm wide containing small patches of fine-grained pyrite and minor scheelite assaying up to 1 g/t Au, and 2) 1- to 2-cm-wide cross-cutting, locally anastomosing quartz veins. The vuggy vein set forms siliceous stockwork zones up to 30 cm wide.

Two styles of alteration were also described by Tallman and Gower (1988): 1) brown, pervasive, potassic alteration with disseminated pyrite, and 2) locally developed, narrow zones, 1 to 2 cm thick, of blue silicification containing pyrite and arsenopyrite. The intensity of the potassic alteration is related to both its proximity to the veins and to the degree of shearing within the granite (Tallman and Gower, *op cit.*).

Charles Cove (Tims Harbour)

The Charles Cove showing (Figure 1) discovered by Patrick (1953) comprises an impressive structurally controlled quartz vein developed within the Charles Cove granodiorite (see Plate 11). The showing was prospected, trenched and mapped by NALCO in 1953-54 and Norlex Mines Limited in 1970 for its tungsten potential. This work showed that the north–northwest-striking vein extended for more than 1 km and varied in width from 60 cm to 4.5 m. Three generations of veining were reported: 1) white milky quartz, 2) dark-grey dirty quartz, and 3) white glassy quartz.

A grab sample from the vein assayed 2.81 percent WO_3 (O'Toole, 1967). Grab samples collected by Noranda from the mineralized portion of the vein and containing abundant pyrite, arsenopyrite and minor molybdenite and chalcopyrite assayed up to 520 ppb Au (Green, 1989). A sample containing a 1-cm-wide band of arsenopyrite assayed 6.20 g/t Au. Patches of arsenopyrite up to 30 cm long were reported by O'Toole (1970). The mineralization is reported to be associated with the dark-grey quartz and is restricted to a narrow footwall zone adjacent to the granodiorite.

Green (1989) also reported the presence of additional quartz veins, up to 3 m wide, south of the original showing. These veins contain pyrite, arsenopyrite, trace molybdenite and assayed up to 2.05 g/t Au.

CLASSIFICATION

All of the gold occurrences examined during the course of this study are epigenetic and structurally controlled. Two broad classes or styles of mineralization have been identified: 1) mesothermal, and 2) epithermal (Evans, 1991). Mesothermal mineralization occurs in both plutonic and sedimentary rocks of widely varying ages. This style of mineralization has been divided on the basis of mode of occurrence into three subclasses: 1) shear-zone-hosted auriferous quartz veins; 2) disseminated, and 3) dilational auriferous quartz veins. These subdivisions are not individually exclusive and exhibit some degree of overlap.

Plutonic-hosted mesothermal systems occur in ultramafic, gabbroic and granitic rocks. Ultramafic rocks exhibit two of the mesothermal subclasses: 1) shear-zone-hosted veins; and 2) disseminated. Shear-zone-hosted occurrences, comprising quartz breccia veins (Plate 2), are developed in altered ultramafic rocks of the Great Bend (Lizard Pond and Breccia Pond) and Pipestone Pond (Great Rattling Brook) complexes (Figure 1).

Disseminated gold mineralization hosted by altered ultramafic rocks is restricted to a single occurrence located at Bursey's Hill, Gander Bay Highway (R. Strickland, personal communication, 1991). Gold mineralization (3.5 g/t Au) is hosted by sheared talc–carbonate-altered ultramafic rocks. Further study is required to ascertain the nature of the gold.

Gabbroic rocks are the most prolific host to mesothermal gold mineralization in the eastern Dunnage Zone. All three mesothermal subclasses occur within this rock type with the shear-zone-hosted quartz-vein subclass being the most common. This latter subclass is characterized by shear-zone parallel quartz–carbonate veins (Plate 4) and sigmoidal and oblique vein arrays. The veins are discontinuous, exhibit pinch-and-swell structures and contain patches and disseminations of pyrite, arsenopyrite and locally, free gold. Intense Fe-carbonate alteration haloes, which extend up to 2 m from the quartz veins, are characteristic of this style of mineralization (Plate 4). The best example is developed at the Clutha prospect (Figure 1; Evans, 1991).

The disseminated subclass of gold mineralization within gabbroic rocks has three modes of occurrence: 1) within sheared gabbro, 2) in the wall rock adjacent to the shear zone (Duder Lake; see Churchill and Evans, *this volume*), and 3) in altered wall rock adjacent to quartz veins (Clutha). Intense silicification, Fe-carbonate alteration, disseminated pyrite and arsenopyrite characterize this style of mineralization.

Dilational auriferous quartz veins hosted by gabbroic rocks are similar to the shear-zone-controlled veins in

Plate 4. *Shear-zone-controlled quartz–carbonate vein developed within deformed gabbro, Clutha. Note intense Fe-carbonate halo developed adjacent to the shear.*

mineralogy and wall-rock alteration. The veins exhibit multiple phases of fluid injection and contain abundant fragments of altered wall rock and earlier phases of quartz veining. Wall-rock margins show little evidence for shearing. This deposit type is best exemplified by the Big Pond (Blue Peter) prospect (Plate 5, Figure 1; Evans, 1991).

Plate 5. *Multiple phase dilational quartz–carbonate vein, developed in Fe-carbonate altered gabbro, Big Pond.*

Granitic-hosted auriferous mineralization comprises both shear-zone-hosted and dilational vein subclasses. The shear zones are intensely silicified and sericitized and contain abundant disseminated pyrite, arsenopyrite and quartz stockwork hosted by the Mount Peyton intrusive suite (Figure 1).

Dilational vein systems are developed in granitic or felsic dykes located in the eastern Notre Dame Bay area (Powderhouse Cove and Western Indian Island, Figure 1). These dykes contain brittle-controlled pyrite–arsenopyrite-bearing quartz veins (Plate 1). An impressive dilational quartz vein occurs within the Charles Cove pluton (Figure 1). This vein is the largest observed in the eastern Dunnage Zone and has been previously described in the manuscript.

Sediment-hosted mesothermal systems comprise both shear-zone controlled and dilational quartz vein subclasses. Shear-zone-controlled veins range from less than 1 cm up to 1 m in width (Plates 6 and 7). They comprise shear central, sigmoidal and oblique vein arrays. The veins contain patches of carbonate, pyrite and locally free gold. Fe-carbonate alteration is confined to the shear zone and does not extend into the wall rock beyond the shear. The shear zones vary in width from 30 cm to greater than 10 m. The zones are steeply dipping, oriented at a high angle to the regional foliation and pinch out quickly. The Bullet (Evans, 1991) and Knob (Collins, 1991) prospects (Figure 1) are the best examples of this style of mineralization.

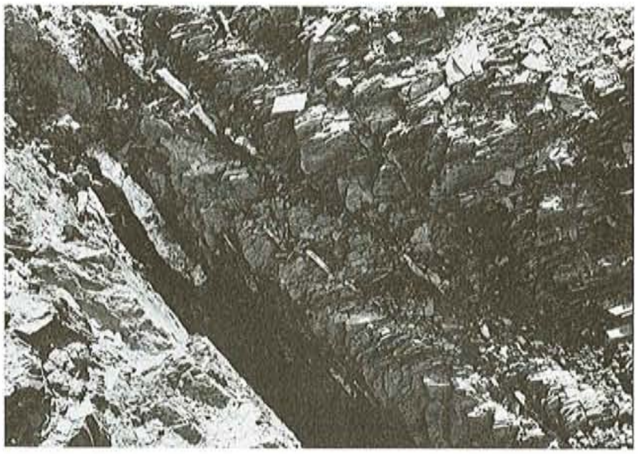

Plate 6. *Shear-zone-controlled auriferous quartz–carbonate veins developed within sheared shales, Bullet. Fe-carbonate alteration is confined to the shear zone.*

Dilational quartz veins developed within sedimentary rocks appear to be restricted to rheologically favourable units such as brittlely deformed greywacke (Bowater prospect, Figure 1, Plate 8). The veins are pyritiferous, vuggy, up to 10 cm wide and locally form narrow quartz breccia zones. Gold assays are typically low (< 3 g/t Au).

Epithermal-style mineralization comprises spectacular hydrothermal breccias and argillic alteration, the best example being the Aztec prospect (Figure 1; Evans, 1991). This prospect comprises a zone of multiple phase brecciation (cockade textures with chalcedonic rhinds) (Plates 9 and 10) and pervasive silicification underlain by a 70-m-thick zone of argillic alteration. Intense hydrothermal brecciation and pervasive silicification are also developed at The Outflow (Evans, 1991) and Cripple Creek prospects (Figure 1; R. Strickland, personal communication, 1991). The Cripple Creek prospect comprises intense multiple-phase hydrothermal brecciation and pervasive silicification developed within trondhjemite of the Gander River Complex.

DISCUSSION

Gold mineralization within the eastern Dunnage Zone forms two broad classes, mesothermal and epithermal. Both

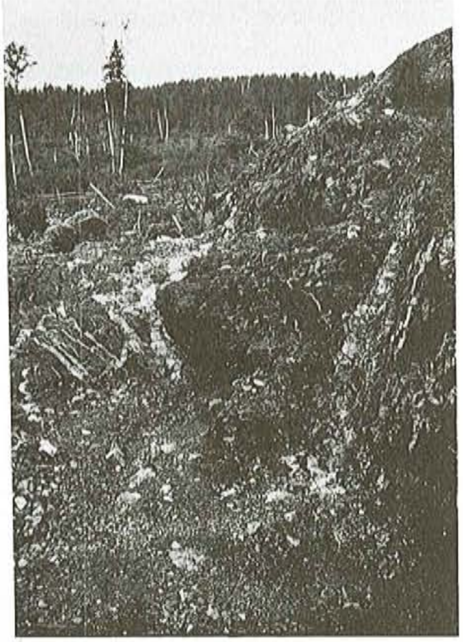

Plate 7. *Shear-zone-controlled auriferous quartz veins developed within sheared greywacke, Knob.*

Plate 8. *Dilational pyritiferous quartz veins developed within greywacke, Bowater.*

classes are structurally controlled and related to regionally extensive structures. The mesothermal systems were relatively shallow and formed either in the brittle-ductile transition zone or in the lower levels of the zone dominated by brittle deformation (Figure 3). Most of the host rocks were metamorphosed in the lower greenschist facies, indicating relatively shallow mineralizing systems. Three mesothermal subclasses are present; 1) shear-zone-hosted vein systems, 2) disseminated, and 3) dialational vein systems. The three subclasses overlap and each exhibits characteristics indicative of the others. Intense Fe-carbonate alteration, silicification, sericitization, pyrite, arsenopyrite and locally leucoxene are characteristic alteration assemblages associated with the mesothermal mineralization. The mesothermal class is independent to rock type; however, the gabbroic rocks appear to possess the best potential for economic mineralization (high grade, low tonnage) because they are rheologically and chemically favourable (i.e., Fe-rich). Similar deposits have been documented from the western Dunnage Zone (Hammerdown and Stog'er Tight; Huard, 1990; Andrews and Huard, 1991), from New Brunswick (Elemtree; Ruitenberg *et al.*, 1990; Tremblay and Dubé, 1991) and from the Archean (Barley and Groves, 1990).

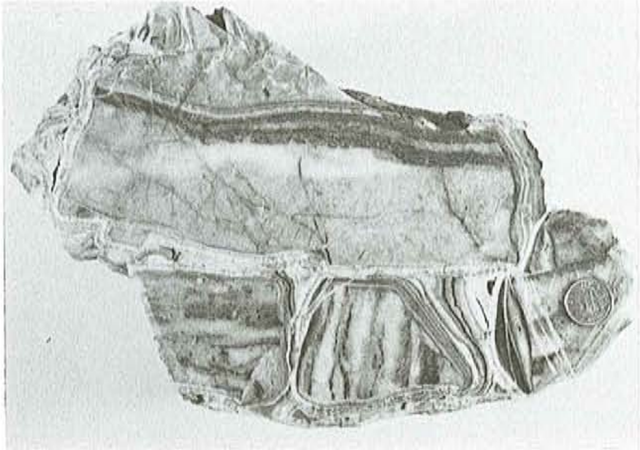

Plate 9. *Cockade-textured hydrothermal breccia, which exhibits multiple phases of brecciation and veining, Aztec.*

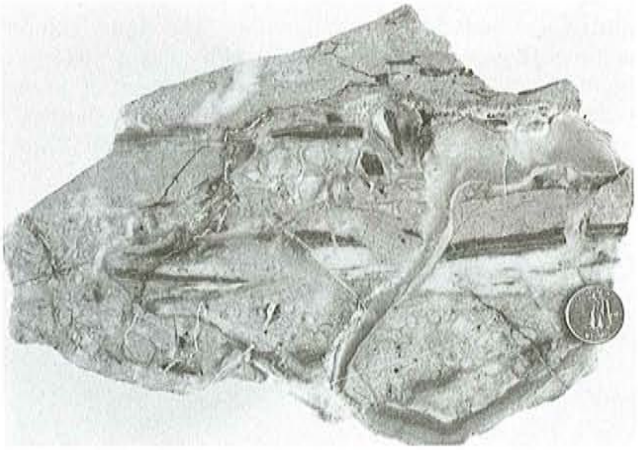

Plate 10. *Multiple phase brecciation, quartz veining and silicification, Aztec.*

The epithermal class exhibits features indicative of shallow or near-surface mineralizing systems (Berger and Eimon, 1983) such as intense multiple-phase hydrothermal breccia (cockade textures and quartz-crystal-lined vuggs), pervasive silicification (silica flooding), argillic alteration and relatively low gold values. This style of mineralization occurs in rocks of the Gander River Complex and the Davidsville and Botwood groups; however, it appears to be more widely developed within the Botwood Group. Intense brecciation occurs north of Big Pond, to the west of the Mount Peyton complex (L. Dickson, personal communication, 1991) and at Great Rattling Brook (MacKenzie, 1990). Float comprised

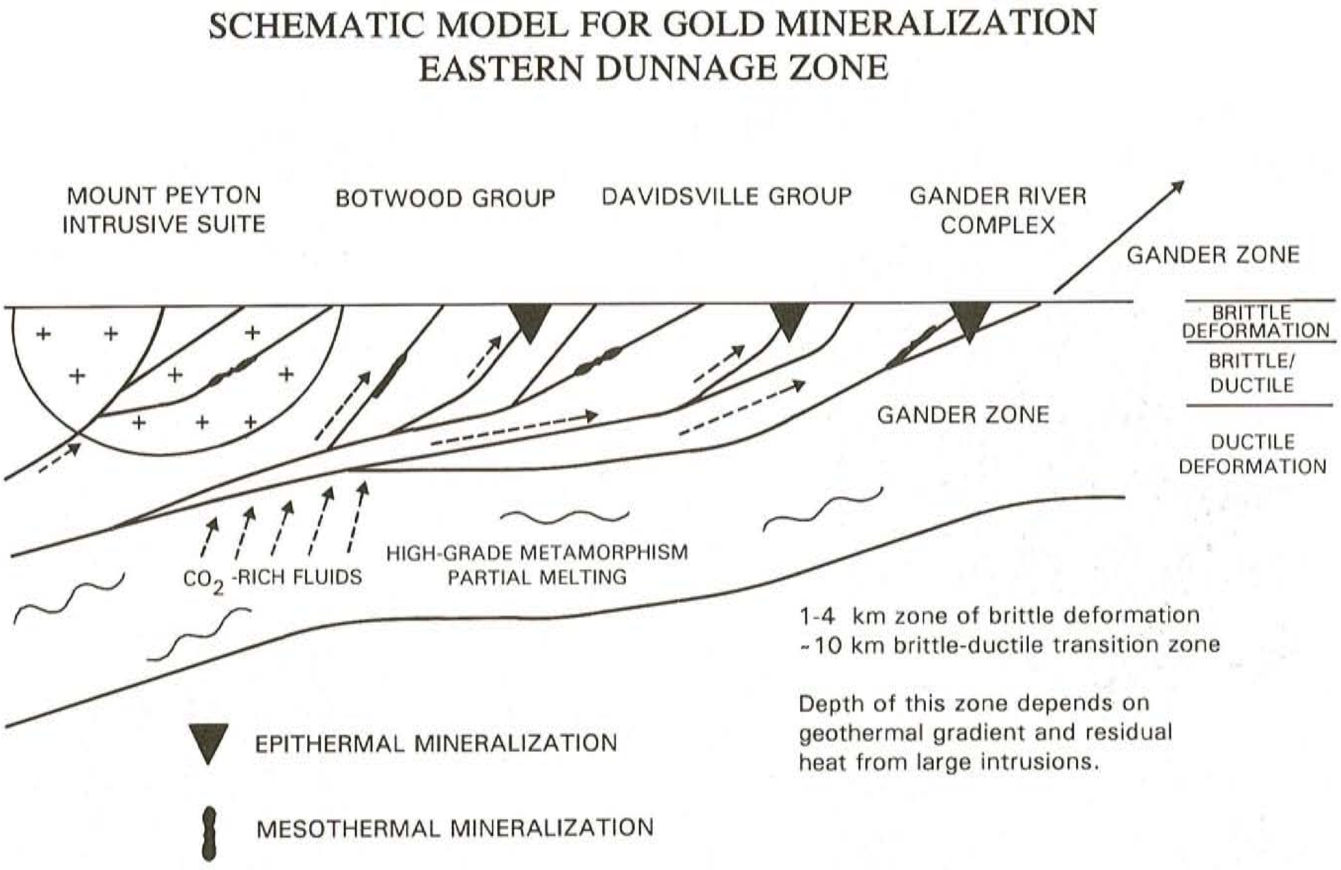

Figure 3. *Schematic model for gold mineralization in the eastern Dunnage Zone. This model is based on the release of CO_2-rich fluids during progressive metamorphism of Gander Zone rocks. These fluids ascend along thrust faults into second or higher order structures.*

of spectacular hydrothermal breccia containing geyserite eggs was found along the Paradise Lake road, south of Grand Falls (Figure 1). Large angular blocks of this float contain fragments of possible Botwood Group sandstone.

At least two broad belts of structurally controlled gold mineralization can be observed within the eastern Dunnage Zone; a western arsenopyrite-poor belt and an eastern arsenopyrite-rich belt. The western belt is restricted to the southwestern and western portions of the Victoria Lake Group and comprises auriferous quartz veins that contain pyrite, minor base metals and locally tourmaline. Tourmaline is absent from gold occurrences elsewhere in the eastern Dunnage Zone. The eastern belt extends from the Bay d'Espoir area to eastern Notre Dame Bay and includes the eastern portion of the Victoria Lake Group.

Distribution maps of Au, As, and Sb in lake sediments (Davenport and Nolan, 1991a, b; Plate 11) indicate high background levels for these elements, particularly As and Sb, in Exploits Subzone and post-accretionary rocks. These sequences either had high background values to begin with (i.e., are related to syngenetic mineralization) or the element anomalies resulted from epigenetic mineralization related to regionally extensive hydrothermal activity (Davenport and Nolan, 1991a). Both As and Sb are known to be associated with many of the massive sulphide deposits (i.e., massive sulphide deposits within the Tulks Hill volcanics, Victoria Lake Group and absence of arsenopyrite from gold occurrences in the southwestern Victoria Lake Group), suggesting that the distribution may be, in part, primary. However, areas with extensive gold mineralization (Glenwood, Great Bend and Bay d'Espoir) exhibit high concentrations of both these elements in lake sediments suggesting that the As and Sb may be related to gold mineralization.

The widespread nature of both As and Sb, their association with gold mineralization, the higher concentrations of these elements in the Exploits Subzone and post-accretionary rocks together with the spatial relationship between gold mineralization and major regionally extensive structures, favour a widespread, eastern Dunnage Zone, gold-mineralizing event related to late orogenic activity. Dunning *et al.* (1990) proposed that a climactic Silurian orogeny was responsible for the widespread regional deformation, metamorphism, plutonism and subaerial volcanism traditionally attributed to Acadian orogenesis. This orogenesis culminated with the final emplacement of the Dunnage Zone (Exploits Subzone) arc and back-arc allochthon onto the

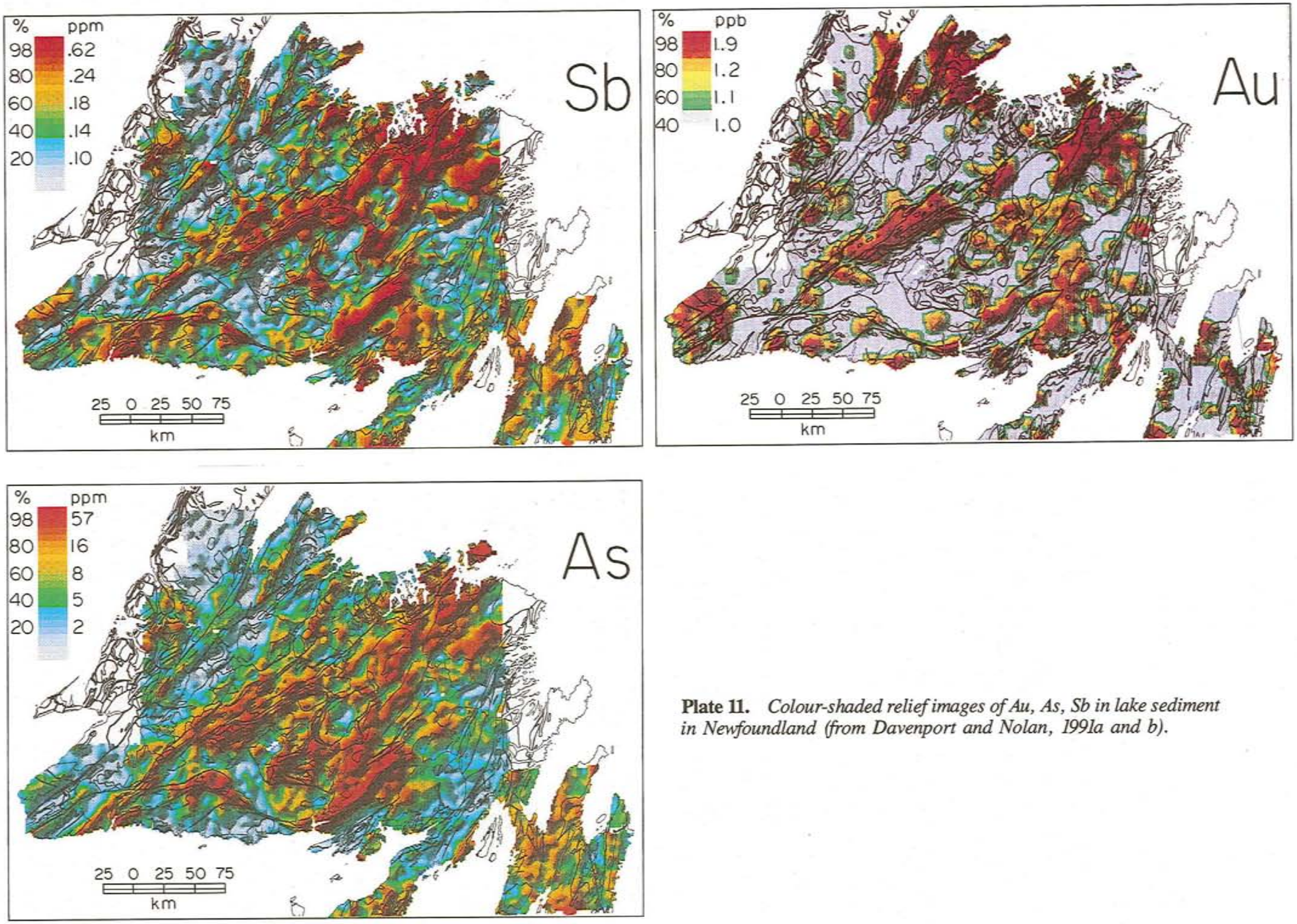

Plate 11. *Colour-shaded relief images of Au, As, Sb in lake sediment in Newfoundland (from Davenport and Nolan, 1991a and b).*

eastern margin of Iapetus (Gander Zone; Stockmal *et al.*, 1987; Williams *et al.*, 1988; Colman-Sadd *et al.*, *in press*). The orogenic event is bracketed between approximately 440 and 390 Ma, as defined by precise U–Pb age dating (Dunning *et al.*, 1990).

The $^{40}Ar/^{39}Ar$ age dating of sericite from an epithermal (Bobby's Pond; Figure 1) alteration zone and from three massive sulphide deposits within the Victoria Lake Group (Kean and Evans, 1988) yielded ages ranging from approximately 405 to 375 Ma, interpreted to represent the thermal metamorphic peak. Similar results ranging from approximately 434 to 374 Ma were obtained by O'Neill (1991) for the age of metamorphism of rocks of the Davidsville Group and Gander Zone.

Gold mineralization is believed to be characteristic of the late stages of convergent orogenic activity worldwide (Robert, 1991) and could be as much as tens of millions of years post-peak metamorphism and plutonism due to the evolution of tectonically overthickened crust. In the eastern Dunnage Zone, this late stage of orogenic activity represented by the thermal metamorphic peak suggests that Dunnage Zone gold-mineralizing processes may have begun as early as approximately 420 Ma (i.e., younger than the Botwood Group and gabbroic rocks that intrude it) and lasted 20 to 40 Ma. Remobilizing of low-grade mineralization along the major structural breaks could have occurred as late as the Carboniferous.

Metamorphic fluids, rich in CO_2 (as evidenced by quartz–carbonate veins, CO_2-rich fluid inclusions and intense Fe-carbonate alteration), could have been derived from the metamorphosed Gander Zone rocks that had been overthrust by the allochthonous Dunnage Zone sequences (Figure 3). The thrusting provided an extensive plumbing system, which allowed the fluids access to the near-surface environments. The nature of the host rocks, i.e., mineralogy (primary and greenschist-facies minerals) and rheological properties (brittle-ductile behaviour) provided conditions favourable for gold deposition (i.e., changes in the physical environment that produced rapid fluctuations in gold solubility and favoured demixing of hydrothermal fluids). Greenschist-facies rocks worldwide are known to provide ideal conditions for the formation of gold deposits (Robert, 1991). Mineralizing fluids responsible for the arsenopyrite-poor belt may have been derived from a different source, possibly the western Dunnage Zone sequence or Grenville basement. Grenville basement is interpreted to underlie a portion of the Dunnage Zone (Keen *et al.*, 1986).

If the metamorphosed clastic sequences (as exposed in the Mount Peyton and Meelpaeg subzones; Williams *et al.*, 1988) were the source of gold and antimony, it may explain why significant mineral occurrences are lacking in these sequences and why they are characterized by low Sb and, locally, Au and As on lake-sediment geochemical maps. Localized high background values of these elements over Gander Zone rocks (i.e., the area north of Gander Lake) may be the product of glacial dispersal. St. Croix and Taylor (1991) indicate that ice-flow direction in this area was from the west, originating in an area with a high density of gold mineralization (Davidsville Group and Gander River Complex).

Future field studies will concentrate on gold occurrences located in the southern portion of the eastern Dunnage Zone, chiefly in the Bay d'Espoir area and on selected occurrences previously visited, thus refining the deposit classification scheme and mineralizing models.

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