

THE BURIN GROUP: A LATE NEOPROTEROZOIC OPHIOLITE CONTAINING SHEAR-ZONE HOSTED MESOTHERMAL- STYLE GOLD MINERALIZATION IN THE AVALON ZONE, BURIN PENINSULA, NEWFOUNDLAND

C.F. O'Driscoll, M.T. Dean¹, D.H.C. Wilton¹ and J.G. Hinchey¹
Mineral Deposits Section

ABSTRACT

Burin Group rocks occur on the southeastern Burin Peninsula and consist of alkalic to tholeiitic volcanic and gabbroic rocks associated with sedimentary rocks and carbonate olistostromes. Also included within the Burin Group is a newly discovered belt of ultramafic rocks called the Burin Ultramafic belt. The Burin Group is interpreted to represent a late Neoproterozoic ophiolite sequence and can be correlated with similar sequences in the Pan-African Orogenic Belt.

Discoveries of significant shear-zone hosted, mesothermal-style gold have been recently made in Burin Group rocks. The Kitchen prospect is currently being explored and studied. It is hosted by a shear zone in gabbro close to the contact with the Burin Ultramafic belt. The setting is similar to mesothermal-style gold found in oceanic rocks on the Baie Verte Peninsula, Newfoundland, and the Motherlode Belt, California. Similar deposits have been mined for cobalt and gold in rocks of the Pan-African Orogenic Belt at Bou Azzer that are the same age. The Burin Ultramafic belt is significant and important as a focal point for gold exploration. The belt may represent a zone of major thrusting and, along with other related shear zones, acted as conduits for gold-bearing fluids.

The Burin Group also has potential for Cyprus-type massive sulphide ore bodies as well as magmatic sulphide (Ni-Cu) and Pt-group mineralization.

INTRODUCTION

Burin Group rocks are located on the southeastern part of the Burin Peninsula between Jean de Baie in the north and St. Lawrence in the south (Figure 1). Equivalent rocks occur on the islands in western Placentia Bay (O'Brien and Taylor, 1983) and as small isolated outcrops west of St. Lawrence in the Ragged Head area (Strong, 1976). The 2000 field season was devoted to a reconnaissance economic and metallogenic assessment of the group. This group of rocks was selected because of its similarities in age, lithology and depositional environment to rocks in other parts of the world that contain important deposits of gold, silver, base metals, cobalt and nickel.

The first mention of this area in geological literature was by Jukes (1843) and later by Murray and Howley (1881). Extensive work was carried out by mining and

exploration companies in the area around St. Lawrence. The reports of this work were mainly concerned with the fluor spar deposits and very little attention was paid to the adjacent Burin Group rocks. A major part of the group was mapped by van Alstine (1948) and he named it the Burin Series. He assumed the age of these rocks to be Ordovician because of similarities with the volcanic sequences of Notre Dame Bay. Williamson (1956) mapped part of the area and kept the name, but reassigned the unit to the Neoproterozoic. Greene (1973) worked in the northern part of the area and changed the name to Burin Group. Strong *et al.* (1978a, b) conducted a geologically extensive study of the southeastern Burin Peninsula. They mapped the area at 1:50 000, recognized the geochemical signature of the Burin Group and suggested an oceanic or island-arc origin. This work was expanded by Taylor (1978) and O'Brien (1979) and used as a basis for M.Sc. theses at Memorial University of Newfoundland. Strong (1976) and Wilton (1976) completed

¹ Dept. of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X5

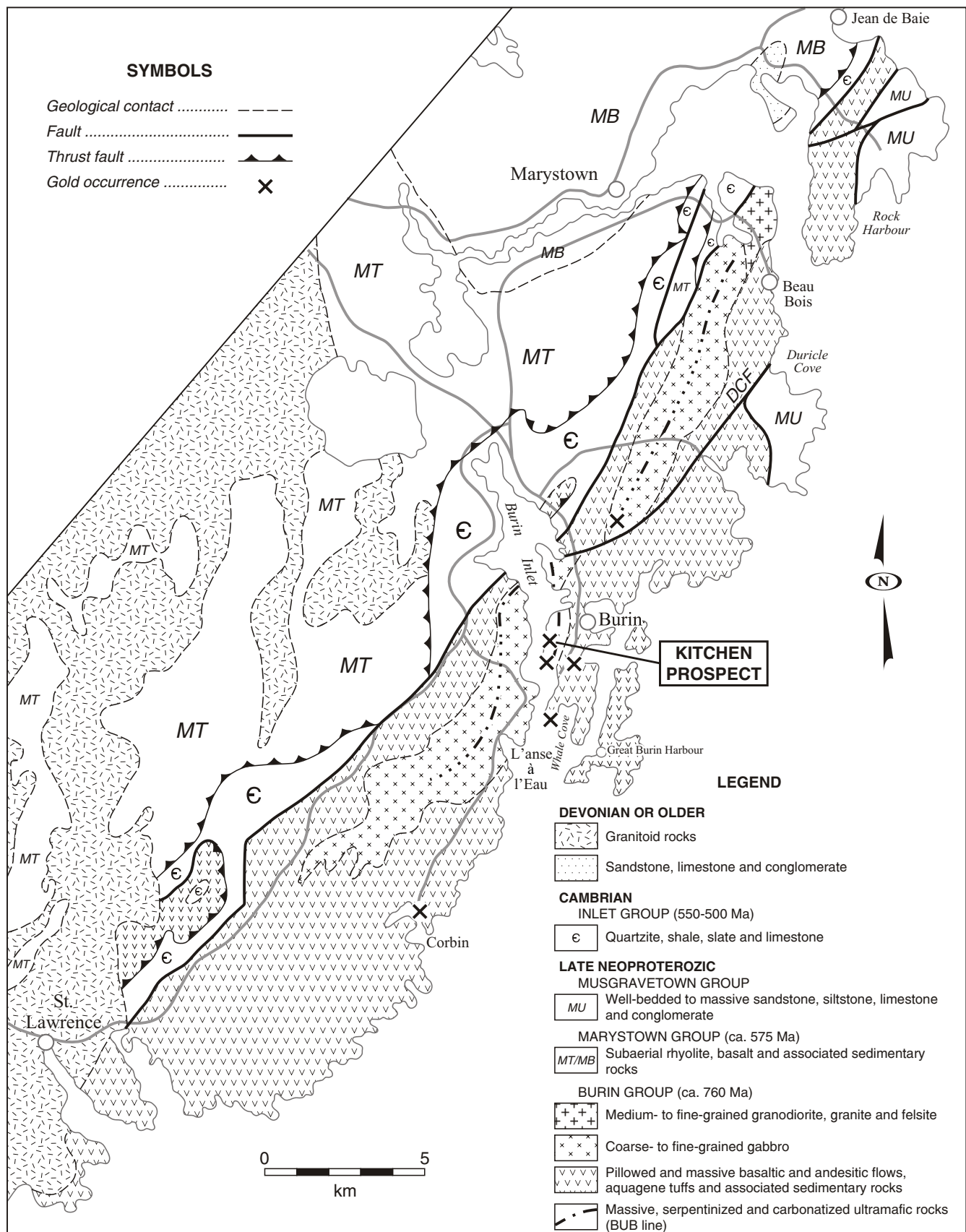


Figure 1. Simplified geological map of the Burin area. DCF, Duricle Cove Fault.

B.Sc. theses on the area. A precise U–Pb zircon age of 763 ± 3 Ma for the Burin Group (Krogh *et al.*, 1988) enabled a direct correlation with Pan-African orogenic belts.

REGIONAL GEOLOGY

The southeastern Burin Peninsula is located within the Avalon Zone, the easternmost tectonostratigraphic division of the Appalachian Orogen on the Island of Newfoundland (Williams, 1979). This zone lies east of the Appalachian mobile belt and comprises widespread sequences of volcanic, sedimentary and plutonic rocks of late Neoproterozoic age. At the current level of geochronological knowledge, the late Neoproterozoic of the western Avalon Zone records four main tectono-magmatic events. These are ca. 760, 680, 620 and 575 Ma.

Magmatism, sedimentation and tectonism within this zone generally predates the Paleozoic Appalachian cycle orogenic events (O'Brien *et al.*, 1983). The zone forms a complex disrupted chain that extends along the eastern seaboard of North America from the subsurface in Florida through Newfoundland and into the Caledonides of the United Kingdom. Rocks of similar age, setting and lithology also occur within the European Cadomian belt (e.g., D'Lemos *et al.*, 1990) and the Pan-African orogenic system (O'Brien *et al.*, 1983; Hefferan *et al.*, 2000). This contemporaneous Avalonian Cadomian Pan-African event has been named the Avalonian System and chronicles the development of an extensive orogenic belt that evolved at an active plate margin peripheral to the ancient continent of Gondwana (O'Brien *et al.*, 1998).

On the southeastern Burin Peninsula, late Neoproterozoic rocks of ca. 760 Ma (Burin Group) and ca. 575 Ma (Marystown Group) are juxtaposed and represent two widely different depositional environments. Burin Group rocks comprise submarine volcanics of oceanic affinity associated with ultramafic and gabbroic rocks interbedded with clastic sediments and carbonate-rich olistostromes. The Marystown Group consists of basaltic to rhyolitic flows, pyroclastics, ignimbrites and fluviatile sedimentary rocks deposited in a subaerial to subaqueous environment.

Within the Avalon Zone of Newfoundland, the late Neoproterozoic rocks are overlain both conformably and disconformably by Cambrian to Ordovician shales, limestones, quartzites and sandstones. On the southwestern Burin Peninsula, at Fortune Head, continuous deposition of shales and fine-grained siliclastic rocks is preserved from late Neoproterozoic through Early Cambrian times. This area is now designated the global stratotype section for the Cambrian–Precambrian boundary.

Devonian terrestrial clastic and volcanic rocks unconformably overlie Proterozoic and early Paleozoic rocks (e.g., Widmer, 1950; O'Brien *et al.*, 1990). Late Devonian high-level granitic rocks are common in the western Avalon Zone and intrude at all stratigraphic levels.

This report will concentrate mainly on a description of the Burin Group and its newly discovered mineral deposits, in particular, the Kitchen prospect. Descriptions of the Burin Group, have been derived from Strong *et al.* (1978a) and the 2000 field program.

BURIN GROUP

The Burin Group consists of a sequence of alkalic to tholeiitic mafic pillow lavas, waterlain pyroclastics, massive basaltic and andesitic flows, clastic sedimentary rocks, stromatolitic limestones, and gabbros (Strong *et al.*, 1978a). Also included in the Burin Group are recently discovered ultramafic rocks that form a sinuous, disrupted belt designated herein as the Burin Ultramafic belt or BUB line.

Strong *et al.* (1978a) described the group as a steeply dipping, westward-facing sequence and assumed that the base lay at its eastern contact with the formerly named Rock Harbour Group that they assumed was older. Later geochronological (T. Krogh, personal communication in O'Brien and Taylor, 1983) and stratigraphic (Hiscott, 1981) work, however, have indicated that the Burin Group is much older. The name "Rock Harbour" was later dropped and replaced with Musgravetown Group (O'Brien and Taylor, 1983). The contact between the two groups is now interpreted to be a fault within the Rock Harbour area and an unconformable relationship in the Flat Islands area of Placentia Bay to the northeast.

The Burin Group has been divided into seven formations; four volcanic units consisting of dominantly mafic pyroclastics, pillow lavas, interbedded sediments and limestones; one gabbro unit and two sedimentary units (Strong *et al.*, 1978a). The volcanic formations were named from bottom to top the Pardy Island, Port au Bras, Path End and Beaver Pond formations. The three lowest volcanic units are separated by two intervening sedimentary formations named the Corbin Head and Sculpin Point formations. The top two volcanic units are separated by a large sill-like gabbroic to granodioritic body that was named the Wandsworth Formation.

Although Strong *et al.* (1978a) separated these formations and implied a stratigraphically upright sequence, they also suggested that some units may be lateral equivalents and some may be repeated along the numerous faults with-

in the area. The Burin Group requires much more detailed sedimentological, structural and geochemical analyses before it is fully understood.

VOLCANIC ROCKS

All the volcanic rocks within the Burin Group are basaltic to andesitic. They consist predominantly of black to green, porphyritic to massive, locally vesicular, pillowed flows, aquagene tuff, agglomerate and breccia. Phenocrysts, where present, usually consist of plagioclase, clinopyroxene and rarely olivine. Pillows may be small and spherical or large and elongated. Interpillow material ranges from fine-grained volcanic tuff and sandstone to chert. Tuffs are generally fine-grained, crystal-lithic, and grade into agglomerates and breccia, rich in epidotized bombs and blocks of basalt. Aquagene tuffs display crude bedding and, in places, grade into bedded tuffaceous sandstone and siltstone.

The geochemistry of the volcanic rocks of the Burin Group ranges from alkalic to tholeiitic. The lowest unit, the Pardy Island Formation was determined to be alkaline in composition. The upper three volcanic units were classified as oceanic tholeiites (Strong *et al.*, 1978a, b).

SEDIMENTARY ROCKS

Many of the volcanic units contain some interbedded sandstones, shales and limestones. Two areas contain belts of sedimentary rocks with similar compositions. These were named the Corbin Head and Sculpin Point formations by Strong *et al.* (1978a) and were tentatively included in the Burin Group. The rocks consist of thick-bedded grey and red conglomerate, green and brown sandstone, and well-bedded green, grey, red and black siltstone, argillite and shale. The sandy beds have a dominant tuffaceous component. The sediments are locally interbedded with tuffs, basaltic flows and sills.

Numerous limestone beds and breccias occur within the volcanic and sedimentary units of the Burin Group. Massive limestone beds are blue-grey, locally dolomitized and, in some cases, stromatolitic. Limestone breccia and conglomerate contain angular and subrounded clasts in a black, tuffaceous matrix. These have been interpreted to represent carbonate olistostromes formed through the collapse of a shelf carbonate siliclastic sequence (Strong *et al.*, 1978b; O'Brien *et al.*, 1996). Strong *et al.* (1978a) indicated that these limestones occur at various levels within the volcanic pile and formed repeatedly as a carapace on top of the volcanic rocks that continuously sank during deposition.

WANDSWORTH FORMATION

Strong *et al.* (1978a, b) used the name Wandsworth Gabbro Formation for a large sill-like body that is regionally concordant and separates the top two volcanic formations of the Burin Group. In this report, it is called the Wandsworth Formation. The most extensive phase is medium- to coarse-grained equigranular, plagioclase-pyroxene gabbro. Cumulus plagioclase-pyroxene banding up to 2 cm thick is exposed on the western shore of Burin Inlet and exhibits some evidence of magmatic disruption and slumping (Strong *et al.* (1978a). On the eastern side of the inlet, the gabbro passes transitionally into a very fine-grained dark-grey microgabbroic or diabasic phase. In the area north of Beau Bois the gabbro grades into medium- to fine-grained, pink and beige granodiorite, granite and felsite.

The gabbro phase of the Wandsworth Formation displays an oceanic tholeiitic composition similar to that of the upper volcanic formations. Compositionally, the granodiorite phase in the north corresponds with quartz diorites of oceanic ridges and ophiolites (Strong *et al.*, 1978a). Contacts between the plutonic and volcanic rocks are commonly schistose and sheared, but some intrusive relationships are preserved.

The Burin Group is intruded by numerous diabase dykes. Most of these dykes are probably associated with the volcanics and intrusive rocks of the group and display similar greenschist-facies metamorphic alteration. However, some dykes consist of relatively unaltered dark-grey to black porphyritic and massive dykes. Phenocrysts consist of plagioclase, pyroxene and possibly amphibole. Strong *et al.* (1978a) noted the presence of unaltered alkalic mafic dykes at various stratigraphic levels and assumed that they are related to mafic flows in the younger Marystown Group.

BURIN ULTRAMAFIC BELT

Although pyroxenites were mentioned by previous workers, they were not separated from gabbroic rocks on their maps. The present work has delineated widespread occurrences of ultramafic rocks that form a disrupted, roughly linear belt trending southwestward from the area west of Beau Bois (Figure 1). The orientation changes direction to north south after crossing a major fault line (Duricle Cove Fault) and continues in that direction on the eastern side of the Burin Inlet. The belt is offset across the inlet and reappears farther north on the western side close to the gabbro volcanic contact. From there, it trends southwestward to the area west of L'Anse-à-l'Eau. The belt is approximately



Plate 1. *Sheared ultramafic rocks displaying moderately dipping thrust contacts with the Wandsworth Formation exposed at the edge of a linear valley.*

20 km long and has been named the Burin Ultramafic belt; the line along which it lies is known as the BUB line.

Where exposed, rocks of the Burin Ultramafic belt occupy topographic recessive areas (Plate 1), for the most part, within the Wandsworth Formation. They are composed of pyroxenite, peridotite, serpentinite and carbonatized ultramafic rocks (Plate 2) that contain talc, fuchsite, iron carbonate, magnesite, hematite, magnetite and chlorite.

The ultramafic rocks have steep westward-dipping schistose contacts with the surrounding rocks and are intensely sheared. They are interpreted to be tectonically emplaced slivers that were thrust into the gabbro.

AGE AND RELATIONS

The Burin Group has been dated at 763 ± 3 Ma (Krogh *et al.*, 1988) and as such, is the oldest known group of rocks in the Avalon Zone. It is bounded by post-Cambrian faults, although its northwestern boundary is interpreted to be a Proterozoic ductile shear zone, reactivated during Paleozoic brittle deformation (Gibbons, 1990). The group is interpreted to be a late Neoproterozoic ophiolite complex correlative with late Neoproterozoic oceanic crust on the margins of the West African Craton (e.g., Buisson and Leblanc, 1986; LeBlanc, 1986; Naidoo *et al.*, 1991; Hefferan *et al.*, 2000).

MINERALIZATION

Even though the mineral potential of Burin Group rocks was realized more than 20 years ago (e.g., Strong *et al.*, 1978a; Taylor *et al.*, 1979) and referred to many times since (e.g., O'Driscoll, 1985; O'Brien *et al.*, 1995) the area has not been extensively explored. Previously known mineral occurrences within the group consisted of limestone



Plate 2. *Serpentinized and carbonatized ultramafic rocks.*

deposits and minor showings of talc and copper.

In the mid-1990s, prospectors in the area found zones having elevated gold values up to 0.5 g/t. In the fall of 1998 significant gold was found on the Coldblow property of Braithwaite Minerals Inc. in shear zones within gabbroic rocks. This showing is called the Kitchen prospect. A petrographic and geochemical study of the alteration associated with this gold prospect is the subject of an ongoing B.Sc. (Hons) study at Memorial University (Dean, unpublished data). The following is a description of the Kitchen prospect and some preliminary results of that study. New gold discoveries were made during the summer of 2000. A brief field description of these will also be given.

THE KITCHEN PROSPECT

The Kitchen prospect (Figure 2) is a gold occurrence within the Wandsworth Formation of the Burin Group. The prospect is located in the southwestern part of the Burin townsite area, where the Wandsworth Formation is mainly composed of gabbro to microgabbro. The auriferous sulphide mineralization occurs primarily in a large zone within the gabbroic host rock where hydrothermal alteration is significant. The geology surrounding the prospect is structurally complex where a mineralized, plunging shear zone anastomoses around a competent block of gabbro. Outcrops in the area exhibit high degrees of localized shearing within gabbro and micro-gabbro, related to larger regional scale faulting, possibly of orogenic scale.

Local Geology

Basalt and gabbro of the Burin Group dominate the geology of the area surrounding the Kitchen prospect (Figure 2). In addition to these units, ultramafic rock of the Burin Ultramafic belt occurs within gabbro near the prospect. Volcanic rocks of the Path End Formation (Strong

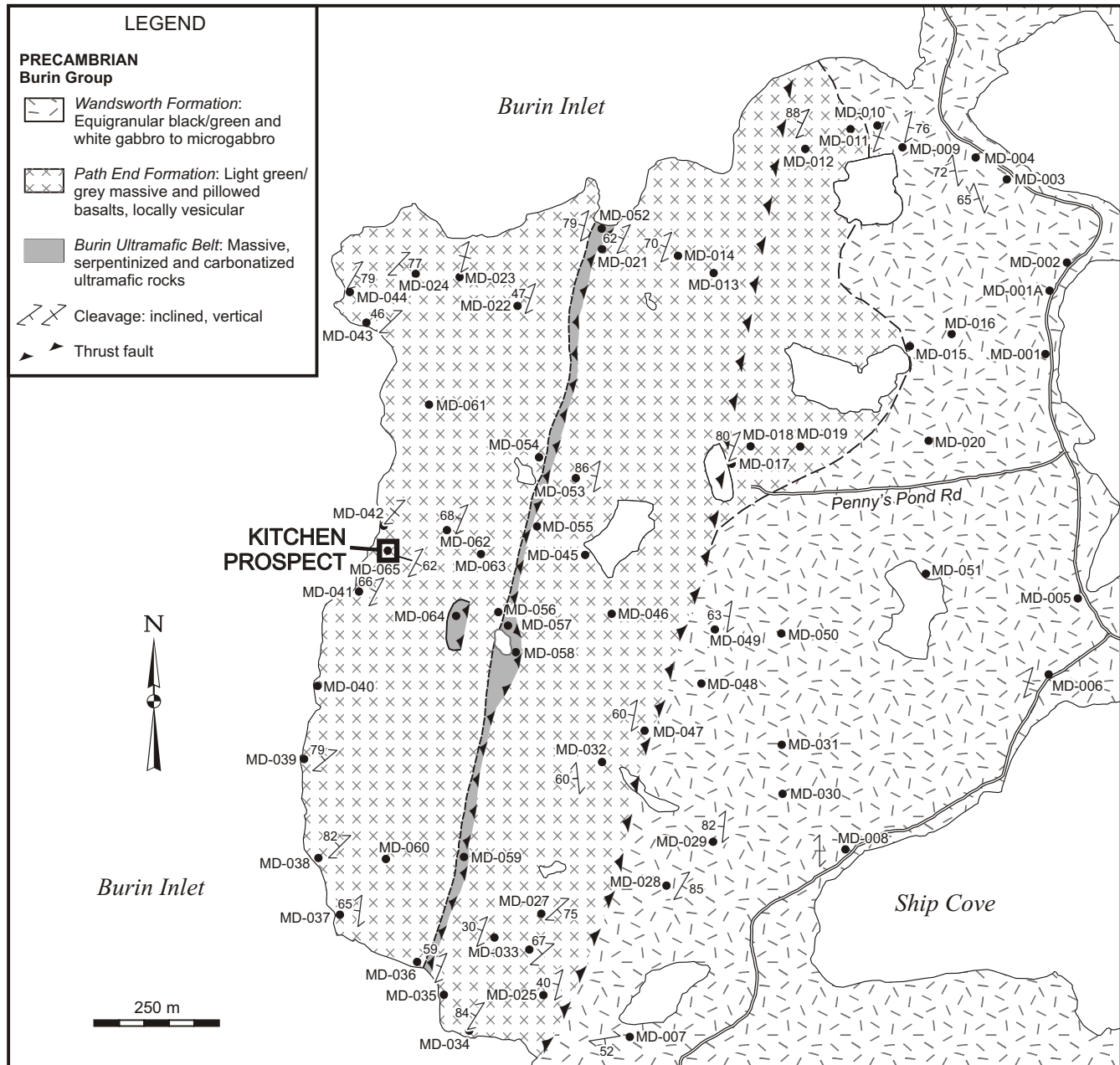


Figure 2. Simplified geological map showing distribution of rocks surrounding the Kitchen prospect.

et al., 1978a) occur to the east. This latter unit is dominantly vesicular, massive or pillowed basalt (Plate 3) containing phenocrysts of plagioclase and lesser clinopyroxene. Matrix constituents include variable amounts of sericitized and/or epidotized plagioclase laths and chlorite. Vesicles are commonly partially to completely infilled by calcite, chlorite or quartz. The unit has irregular thrust and intrusive contacts with the adjacent gabbro. Strong *et al.* (1978a) assumed that this contact marked the top of the Path End Formation.

Strong *et al.* (1978a) formally assigned gabbro surrounding the Kitchen prospect to their Wandsworth

Formation. This unit is dominantly medium to coarse grained, equigranular, with alternating proportions of plagioclase and clinopyroxene. There are, however, lesser occurrences of diabase and/or microgabbro. Rock types of this unit are strongly weathered, giving a reddish-brown colour. The plagioclase is commonly sericitized and epidotized whereas the clinopyroxene is, in many cases, altered to amphibole, chlorite and epidote. Numerous quartz veins and diabase dykes of varying proportions cut the medium- to coarse-grained gabbro. Contact relationships with the Path End Formation are commonly fault-related but some definite intrusive relationships are evident, defined by minor



Plate 3. *Pillow basalt of the Path End Formation.*

occurrences of chilled margins and gabbroic apophyses within basalt.

Ultramafic rock of the BUB line has been identified to the east of the Kitchen prospect (Figure 2). Original textures are commonly inconspicuous due to excessive alteration, which results in the development of quartz and Fe-carbonate rocks (Plate 4) \pm talc \pm fuchsite \pm serpentinite \pm sericite. Serpentinized ultramafic rock \pm chromite \pm chrysotile are also subordinate alteration assemblages. Contacts of the ultramafic rocks with gabbro are schistose, indicating that the ultramafic body has been tectonically emplaced as a westward-dipping thrust sliver. Lineations along cleavage planes give conflicting directions of movement. This may be due to multiple periods of movement, the latest being post-Cambrian folding and faulting. Cambrian rocks immediately to the west have been folded, sheared and overthrust from the west by 575 Ma rocks of the Marystown Group (Figure 1).



Plate 4. *Fe-carbonate-quartz altered ultramafic of the 'Burin Ultramafic belt'.*

Exploration History

Exploration of the Kitchen (gold) prospect near Burin began in 1999 with intermittent prospecting, sampling and hand trenching by Braithwaite Minerals Inc. Initial interest had been generated as a result of a 2.8 g/t Au assay value obtained from a rock sample in a 1.0-m-wide mineralized outcrop, located approximately 700 m southwest of Burin. This assay result led to the compilation of a geological map for the area (Jacobs, 1999). In addition to mapping, a trenching, channel sampling and soil sampling program for the prospect site was also planned.

Anomalous gold was discovered in a 28-m-long trench across the main shear zone, and in a 135 m trench across the bounding gabbro, southeast of the prospect, which was excavated to delineate other gold-bearing zones and/or shear zones (Figure 3). Additional trenching was completed slightly farther east of the Kitchen prospect, revealing elevated contents of Ni, Co and Au associated with Fe-carbonate altered ultramafics and gabbro. Following trenching at the Kitchen prospect, a channel sampling program was conducted across a continuous 28 m section of the main shear zone. Assay results from the channel sampling indicated gold values that ranged from 1.36 g/t Au over 1.0 m to 9.86 g/t Au over 0.6 m and 4.86 g/t Au over 4.0 m. Systematic soil sampling in the area provided striking results where, in one instance, gold values reached 6.26 g/t Au. Also, a number of grab samples taken from the main shear zone yielded assay results of up to 19.4 g/t Au (Jacobs, 2000).

Drilling of this prospect began in 1999 and was targeted solely on areas of high-grade mineralization within the main shear zone. Diamond-drilling data used in this preliminary investigation is limited to reporting assay grades.

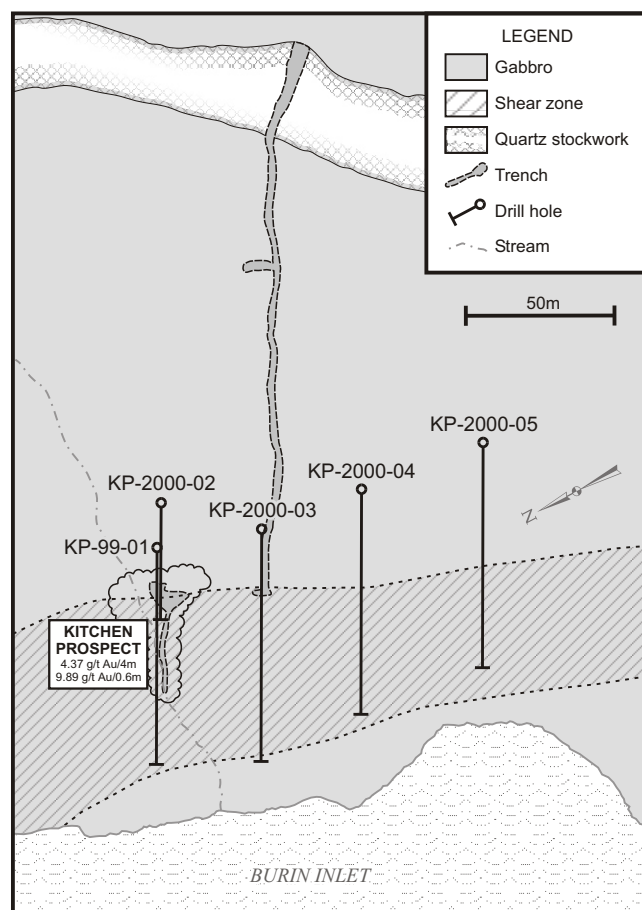


Figure 3. Schematic illustration of trenching at Kitchen prospect (after Jacobs, 2000).

Other pertinent data derived from the drilling project, however, will be used by Dean (unpublished data) to supplement field work detailing the geology of the area.

To date, five drillholes (KP-99-01 and KP-2000-02 to 05; Figure 3) have been completed on the Kitchen prospect with a cumulative length of 346 m (Jacobs, 2000). The best assay intersection was 2.63 g/t Au over 3.8 m, including a 4.8 g/t Au interval over 2.0 m in hole KP-2000-03. Hole KP-2000-05 contained an intersection with an assay result of 3.85 g/t Au over 1.5 m, including 9.1 g/t Au over 0.6 m. In addition, 2.86 g/t Au over 3.0 m was encountered in drill-hole KP-99-01.

Drilling at the prospect stopped in early 2000 due to non-compliance with municipal zoning regulations. This matter has since been resolved and drilling is expected to recommence with eight holes planned for 2001. Ground exploration work conducted during 2000, involved additional grab sampling and systematic soil sampling in the general prospect area.

Structural Relationships and Mineralization

The auriferous sulphide mineralization is located within a large shear zone that cuts the Wandsworth Formation gabbro. The shear zone strikes approximately north-northeast to south-southwest and dips steeply to both the west and east in the vicinity of the Kitchen prospect. Locally, opposing dip directions have been attributed to an anastomosing shear around a competent block of gabbro (D. Wilton, personal communication, 2000). The shear zone is approximately 30 m wide, but extent along strike has not been properly constrained due to the anastomosing structural pattern. An intense linear fabric with a gentle plunge averaging 15 SSW is associated with the main shear zone. The strong, steeply dipping schistosity locally has a second fabric superimposed on it. The rocks in this area exhibit greenschist-facies metamorphism.

From west to east across the shear zone, alteration ranges in composition from sericite-carbonate±quartz to sericite-chlorite ± carbonate ± quartz ± fuchsite. In addition, shear strain is variable across the zone and in many areas relict textures are visible. These textures indicate that the host rock of the shear zone is a medium-grained, equigranular, gabbro with plagioclase laths typically replaced by sericite, and clinopyroxene replaced by sericite, amphibole ± chlorite ± epidote. Syn- and posttectonic quartz and carbonate veins are also present in the shear zone. Two main sulphide phases are present, including very fine- to fine-grained, disseminated, pyrite and arsenopyrite that appear in variable amounts across the shear zone (Plate 5). Petrographic data indicate that sulphides are commonly rimmed by quartz and associated with sericite and chlorite. Sulphide concentrations appear to increase from west to east across the shear zone and the highest grades of Au mineralization are associated with areas of strong sericite-chlorite-sulphide ± carbonate ± quartz ± fuchsite alteration. Gold in the main shear zone may be linked to elevated concentrations of arsenopyrite as indicated by assay results. Grab samples from the surface mineralization that ranged between 0.7 and 19.4 g/t Au also contained >2000 ppm arsenic, indicating that arsenopyrite probably carries the auriferous phase.

Approximately 80 m southeast of the main shear zone, several small exposures of pale-green, strongly foliated, silicified, gabbro contain minor, fine-grained, disseminated pyrite and between 0.4 to 1.5 g/t Au. Quartz stockwork veinlets, hydrothermal breccia and dissolution cavities are also found at this location. An extensive hydrothermal quartz stockwork cuts through gabbroic host rock approximately 20 m east of the strongly foliated, silicified, gabbro. The stockwork is approximately 25 m wide and in selected areas it brecciates the gabbroic host rock (Plate 6). These quartz



Plate 5. Sericite-chlorite altered gabbro, which contains arsenopyrite and pyrite mineralization found at Kitchen prospect (16 g/t Au).

veins also contain brecciated, mafic fragments that appear to be basalt. The origin of these fragments, however, cannot be determined from surface relationships.

Massive gabbro east of the prospect contains an array of sub-parallel, minor shear zones that have visible chlorite, amphibole, and epidote alteration. Most have an approximate northeast–southwest orientation and an average dip of 65° W. In some instances, these shear zones contain varying amounts of fine-grained, disseminated pyrite mineralization. Grab samples from these zones did not show any significant amounts of gold. Syn- and posttectonic quartz, carbonate and epidote veins are also common in these zones and the surrounding host rock.

Fresh and altered ultramafic rocks east of the Kitchen prospect contain minor amounts of very fine-grained pyrite and arsenopyrite. For the most part, these rocks are carbonatized and serpentinized. This unit has an average dip of 60° W and can be traced along a north–south-trending linear valley.

Basalt in the easternmost portion of the map area is commonly massive and contains chlorite, calcite and/or quartz amygdules. This unit hosts a number of sub-parallel,



Plate 6. Hydrothermal, quartz-stockwork, brecciating medium-grained gabbro, east of the Kitchen prospect.

minor shear zones that have chlorite, epidote \pm amphibole alteration. Schistosity is commonly oriented north-northeast to south-southwest and typically dips steeply to the east or west but may be subvertical. There are rare occurrences where these shear zones contain minor, fine-grained, disseminated, pyrite mineralization that have insignificant amounts of gold. Syn- and posttectonic quartz and epidote veins are common in the shear zones and surrounding host rock.

Geochemistry

Seven grab samples were collected for assay across the main shear zone in a 28-m-long trench at the Kitchen prospect (Figure 3). Assay data for these samples (Table 1) indicate that gold has a very strong correlation with As content, as would be expected from the arsenopyrite-rich nature of the auriferous material. Other positive correlations with gold in the assay data include Sb, Ag and Pb.

Twenty-three representative whole-rock samples were also collected from the vicinity of the Kitchen prospect (Figure 2) and analyzed for major and trace element contents (Table 2) by X-Ray fluorescence techniques at the Department of Earth Sciences, Memorial University of Newfoundland, following the procedures outlined by Longerich

Table 1. Selected assay data for samples from the Kitchen prospect main shear zone

Sample No.	Au(ppb)	As(ppm)	Ag(ppm)	Sb(ppm)	Zn(ppm)	Pb(ppm)
JH-00-85a	2604	>2200	1.8	26	96	16
JH-00-85b	15865	>2200	3.1	15	64	26
JH-00-85c	715	>2200	0.7	5	54	17
JH-00-85d	5	131	0.2	5	29	2
JH-00-85e	5	35	0.2	5	3	2
JH-00-85f	8558	>2200	2.7	28	54	19
JH-00-85g	7928	>2200	2.1	20	50	22

Table 2. Major- and trace-element analyses of rocks in the Kitchen prospect area

Sample# Rock	MD-01a volc.	MD-03 volc.	MD-08 volc.	MD-09 volc.	MD-16 volc.	MD-28 volc.	MD-11 gabbro	MD-13 gabbro	MD-18 gabbro	MD-24 gabbro	MD-25 gabbro
SiO ₂ (%)	45.01	41.81	43.85	50.97	46.22	47.69	48.17	45.76	48.85	46.81	43.02
TiO ₂	0.67	0.31	1.04	0.83	0.57	0.93	0.91	0.22	0.85	1.05	0.15
Al ₂ O ₃	12.81	9.91	13.31	14.94	11.55	11.02	11.43	10.33	12.58	10.86	10.64
Fe ₂ O ₃	1.78	1.71	2.06	1.42	1.69	2.29	2.13	1.27	1.91	2.44	1.25
FeO	9.09	8.66	10.48	7.24	8.63	11.66	10.88	6.49	9.74	12.43	6.38
MnO	0.19	0.19	0.22	0.17	0.19	0.24	0.24	0.16	0.21	0.26	0.14
MgO	11.63	19.67	11.08	9.32	15.11	9.95	11.59	17.89	9.63	9.24	22.88
CaO	7.25	9.53	8.31	6.31	9.61	8.65	9.34	12.86	8.51	10.04	11.43
Na ₂ O	1.96	0.44	1.74	2.93	1.56	2.78	2.16	0.87	3.21	2.09	0.59
K ₂ O	0.71	0.01	0.07	0.88	0.45	0.06	0.06	0.09	0.15	0.04	0.06
P ₂ O ₅	0.09	0.05	0.13	0.11	0.05	0.03	0.03	0.01	0.13	0.05	0.01
Total	91.19	92.29	92.29	95.12	95.64	95.31	96.93	95.95	95.75	95.31	96.54
Mg#	65.95	77.47	61.56	66.11	72.62	56.37	61.72	80.68	59.96	52.96	84.46
Cr(ppm)	216	1811	127	99	821	103	177	377	78	83	136
Ni	82	457	34	19	139	45	60	119	34	50	165
Sc	44	69	33	28	44	46	58	53	42	56	44
V	295	236	385	215	314	376	360	176	384	412	107
Cu	58	105	64	46	28	49	87	73	19	81	7
Pb	0	0	0	0	0	0	0	0	0	0	0
Zn	37	34	43	29	35	52	47	25	37	51	8
S	360	151	176	388	74	134	128	92	358	166	44
As	0	0	0	0	0	0	0	0	22	0	0
Rb	14	0	1	19	10	0	1	2	4	0	1
Ba	134	0	0	214	66	0	0	0	0	0	0
Sr	187	125	331	267	225	66	115	176	153	56	459
Ga	14	10	17	16	12	15	14	8	15	17	8
Nb	2	1	2	3	2	1	1	0	1	0	0
Zr	44	16	47	81	29	47	40	8	46	58	9
Y	14	7	13	16	10	27	24	4	19	31	3
Th	0	0	0	0	0	0	0	0	0	0	0
Ce	0	0	0	0	0	0	0	0	0	0	0

(1995). The samples include six basalt from the Path End Formation, eleven gabbro from the Wandsworth Formation and two ultramafic rocks. Also included are one unmineralized and three mineralized samples of Wandsworth Formation gabbro from the main shear zone of the Kitchen prospect.

The four samples (MD-00-65a to d) from the trench at the Kitchen prospect were collected across the main shear zone and exhibit variable degrees of alteration and sulphide enrichment. Sample 65a is a strongly lineated, sericite–chlorite \pm carbonate \pm quartz \pm fuchsite altered rock that contains the most extensive amounts of disseminated arsenopyrite–pyrite found at the prospect. Sample 65b is a strongly lineated, slightly sericite–chlorite altered rock which has relict gabbroic textures visible, and no visible pyrite or arsenopyrite; it is the least sulphide-mineralized of the Kitchen

prospect samples. Sample 65c is notably different from the other Kitchen shear zone samples in that it is a strongly sericite–carbonate \pm quartz altered lithology that has only limited disseminated pyrite. Sample 65d is a strongly lineated, moderately altered sericite–chlorite \pm carbonate \pm quartz specimen that contains disseminated pyrite and lesser arsenopyrite.

Gabbroic rocks in the area of the Kitchen prospect have been variably metasomatized by an intense hydrothermal mineralizing event that overprints the regional sub-seafloor greenschist-facies metamorphism typical of the Wandsworth Formation elsewhere. Dean (unpublished data) provides a more comprehensive discussion of the greenschist-facies assemblages by correlating the chemical nature of these rocks with the petrological assemblages to indicate specific alteration trends.

Table 2. Continued. Major- and trace-element analyses of rocks in the Kitchen prospect area

Sample# Rock	MD-27 gabbro	MD-32 gabbro	MD-33 gabbro	MD-43 gabbro	MD-45 gabbro	MD-55 gabbro	MD-57 ultrama.	MD-64 ultrama.	MD-65a Kitchen	MD-65b Kitchen	MD-65c Kitchen	MD-65d Kitchen
SiO ₂ (%)	40.74	41.55	46.43	45.71	43.42	42.24	32.36	37.36	60.51	41.51	64.84	44.96
TiO ₂	0.12	0.14	1.59	0.34	0.22	0.24	0.11	0.11	0.29	0.37	0.11	0.46
Al ₂ O ₃	10.63	10.53	11.13	11.86	10.43	12.71	2.36	1.99	18.34	12.98	21.78	17.86
Fe ₂ O ₃	1.34	1.15	2.45	1.02	1.08	1.14	1.43	2.06	1.06	1.83	0.14	1.2
FeO	6.81	5.88	12.49	5.22	5.53	5.82	7.29	10.51	5.42	9.32	0.71	6.11
MnO	0.15	0.13	0.25	0.12	0.13	0.13	0.22	0.22	0.08	0.19	0	0.19
MgO	21.74	24.44	8.65	17.57	18.62	18.06	13.32	38.73	7.46	17.88	1.01	11.84
CaO	11.66	10.21	8.18	12.99	13.28	11.63	25.46	1.21	2.91	8.07	0.11	9.67
Na ₂ O	0.35	0.41	1.85	1.08	0.86	0.92	0.07	0.15	0.18	0.45	0.86	0.21
K ₂ O	0.03	0.01	0.01	0.16	0.07	0.04	0	0	4.15	0.02	4.14	3.29
P ₂ O ₅	0.01	0	0.14	0.03	0.01	0.01	0.01	0.01	0.06	0.06	0.01	0.06
Total	93.57	94.46	93.17	96.09	93.66	92.96	82.62	92.36	100.45	92.69	93.72	95.86
Mg#	82.86	86.31	51.21	83.61	83.61	82.45	73.45	84.81	67.58	74.39	68.49	74.57
Cr(ppm)	410	1009	24	896	338	898	4568	4569	545	644	12	570
Ni	202	253	20	165	174	122	744	1509	102	99	0	111
Sc	33	52	37	47	46	45	26	21	32	47	0	45
V	100	118	401	180	151	156	84	72	254	342	0	346
Cu	69	36	93	12	158	48	18	14	45	60	0	33
Pb	0	0	0	0	0	0	0	0	46	0	0	6
Zn	10	4	61	11	5	5	25	12	104	22	0	43
S	50	225	595	44	56	82	173	195	9172	153	110	5178
As	21	0	0	0	0	0	69	0	55699	32	19	1483
Rb	0	0	0	4	1	2	0	0	121	1	82	86
Ba	0	0	0	0	0	0	0	0	299	0	571	243
Sr	315	102	221	159	149	172	125	5	6	39	22	16
Ga	8	8	17	11	10	11	0	0	18	11	15	15
Nb	0	0	8	0	0	1	0	0	1	0	16	1
Zr	7	5	130	13	10	8	7	5	25	13	80	23
Y	3	3	34	8	6	6	3	3	8	6	17	12
Th	0	0	0	0	0	0	0	0	0	0	7	0
Ce	0	0	0	0	0	0	0	0	3595	0	58	187

The following summary includes standard discrimination diagrams that define the petrogenetic environments in which the igneous rocks were formed. A number of other diagrams are used to characterize the geochemical nature of the auriferous hydrothermal fluid system, and to classify the nature of the Kitchen prospect mineralization.

According to the classification diagrams of Irvine and Baragar (1971), the basalts are subalkaline tholeiites as are the plutonic Wandsworth Formation gabbro rocks (Figures 4a and b). A few samples from each group plot outside the main alkaline and calc-alkaline fields on the diagram because of alteration effects. Samples MD00-65a, c and d, from the main ore zone at the Kitchen prospect, plot toward the K₂O + Na₂O apex, presumably reflecting the addition of K₂O and/or Na₂O from the ore-forming hydrothermal fluids. Figure 5 (after Pearce and Cann, 1973) indicates that most

volcanic rocks appear to be low-K tholeiites or ocean floor basalts. Strong *et al.* (1978a, b) have also indicated an oceanic origin for the Burin Group rocks, suggesting that initial volcanism in the group began with alkali basalt eruptions that later became dominated by oceanic tholeiite volcanism; the Path End Formation basalts (i.e., the volcanic rocks sampled in this study) were defined as part of this later tholeiitic event.

Winchester and Floyd's (1977) immobile trace-element plot (Figure 6) verifies that most of the samples (volcanic and plutonic) have subalkaline basalt to andesite-basalt signatures. One mineralized gabbro sample (MD-00-65c), however, plots in the trachyandesite field apparently due to extreme alteration. As this diagram plots ratios of these four, supposedly immobile, elements, the alteration must be real rather than just a function of mass loss/gain. At this point,

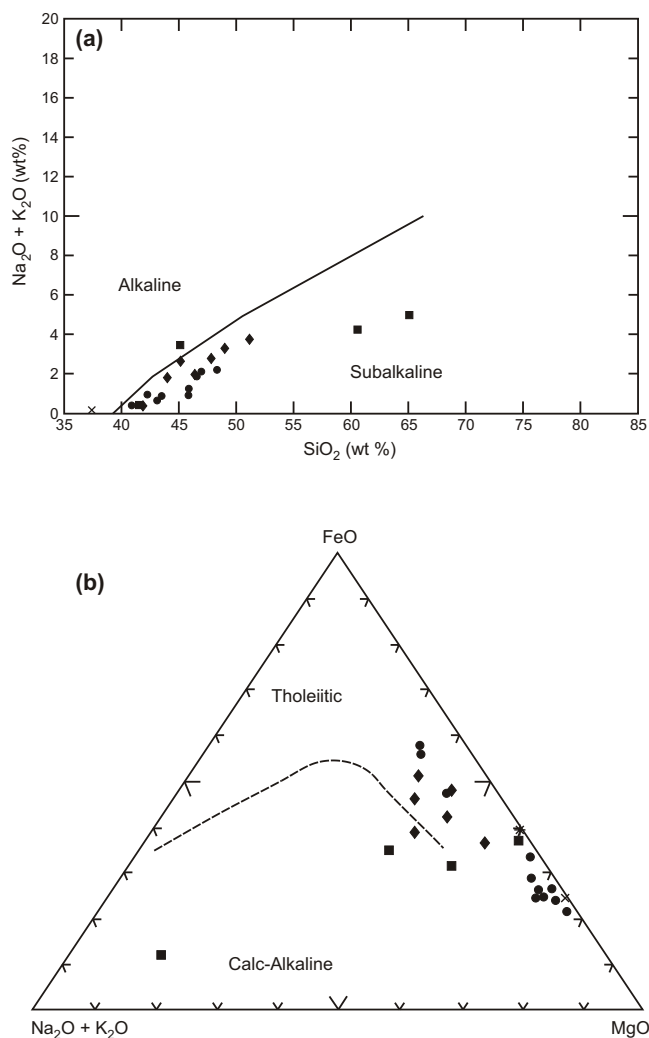


Figure 4a. Total alkalis vs. silica plot (Irvine and Baragar, 1971). Symbols as follows: circle - gabbro; square - mineralized gabbro; diamond - basalt; oblique cross - serpentinized ultramafic; cross and oblique cross - carbonitized ultramafic. **b.** AFM proportions. Note mineralized samples in calc-alkaline field (Irvine and Baragar, 1971).

the most plausible explanation is that TiO_2 was removed from the most altered gabbros by the auriferous hydrothermal fluids.

Relative gains of mobile elements in all rock types from the Kitchen prospect and surrounding area can be demonstrated using linear variation diagrams. The mobile elements plotted against [Mg] (i.e., $\text{Mg}/\text{Mg}+\text{Fe}$) include K_2O , Ba and Rb (Figure 7), which illustrates enrichment of these elements in mineralized gabbro of the Kitchen prospect in comparison to other samples from the adjacent area. The enrichment in Al_2O_3 probably reflects a mass loss effect rather than a true removal of Al_2O_3 . In addition, carbonatized ultramafic rock slightly southeast of the Kitchen prospect is also

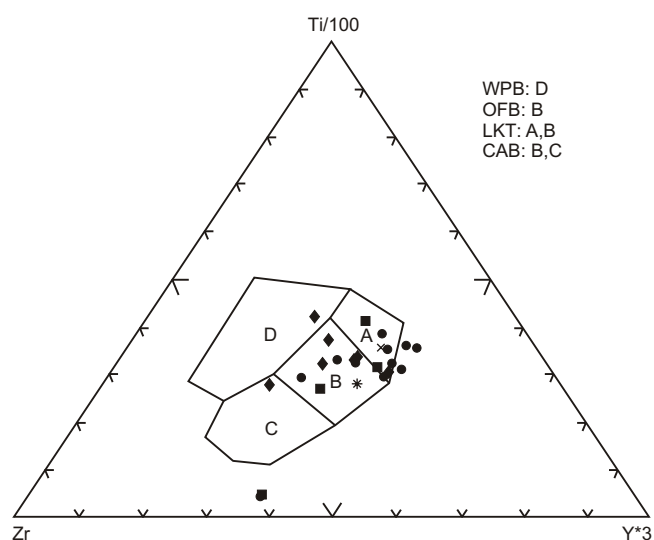


Figure 5. Ti-Zr-Y discrimination diagram indicating an ocean floor basalt signature for most volcanic rocks: WPB, within plate basalts; OFB, ocean floor basalts; LKT, low-potassium tholeiites; CAB, calc-alkaline basalts (Pearce and Cann, 1973).

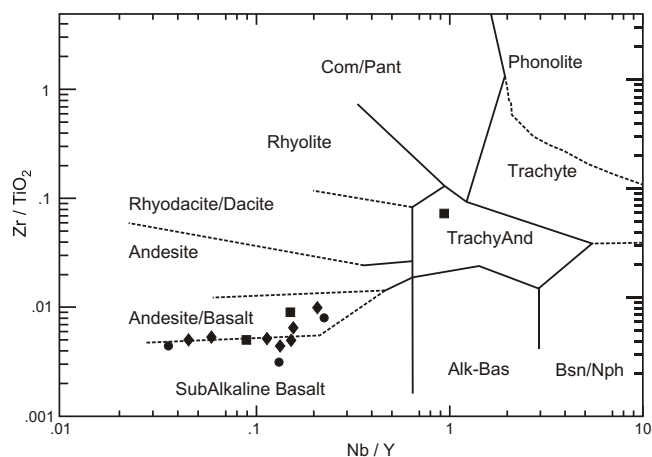


Figure 6. Winchester and Floyd's (1977) immobile trace element plot for rocks of the Kitchen prospect.

enriched in As and CaO (Figure 8) relative to all other samples, and most especially the non-carbonatized ultramafic rocks.

A more complete view of the relative losses and/or gains in element concentrations in rocks from the Kitchen prospect can be demonstrated using a normalized diagram, where a range of both mobile and immobile elements are normalized to the average Wandsworth Formation gabbro composition away from the Kitchen prospect (Figure 9). With minor exceptions, this diagram indicates that the mineralized gabbros at the Kitchen prospect are generally enriched in K_2O , As, Ba and Rb, and depleted in Sr and

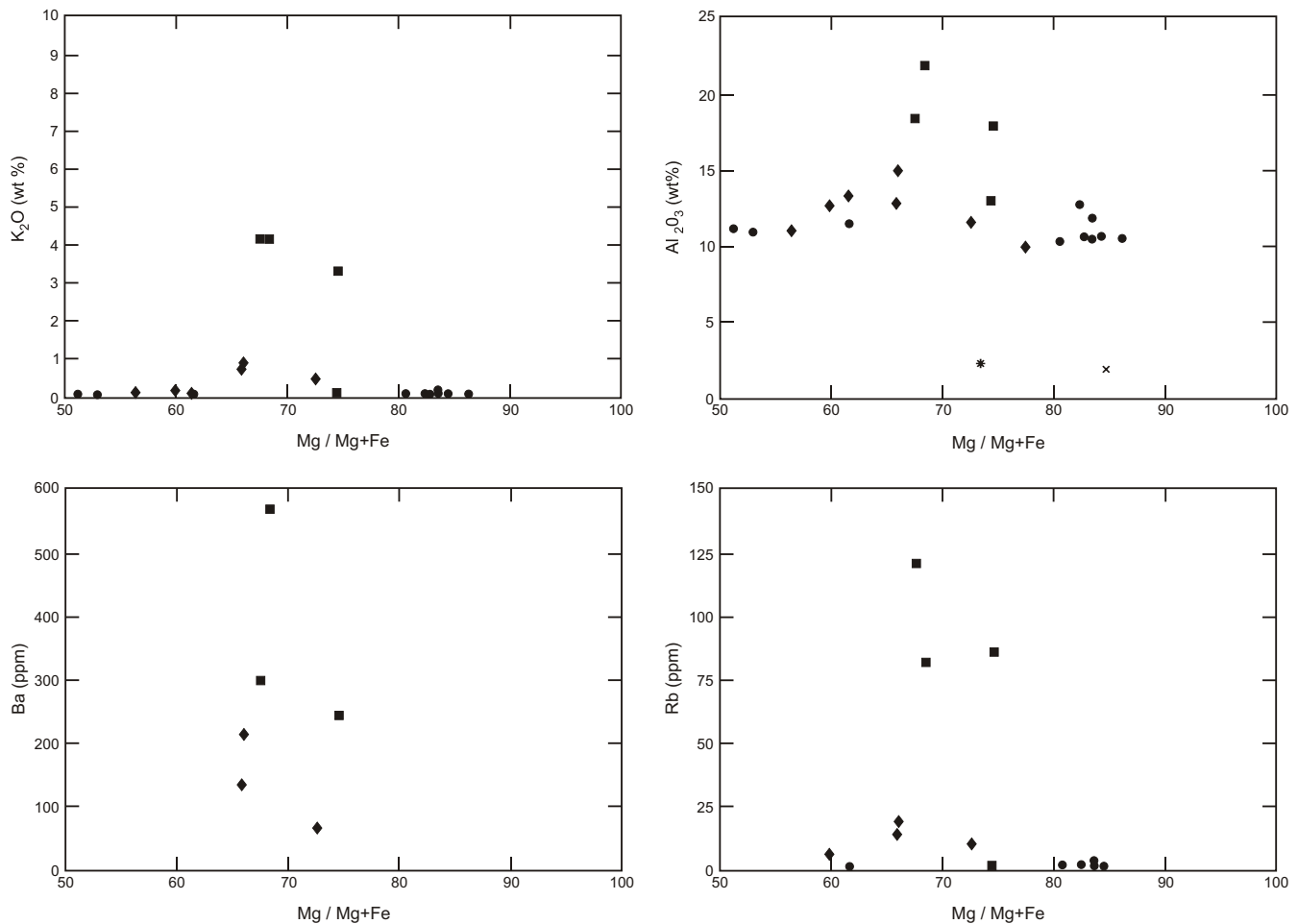


Figure 7. [Mg] variation diagrams illustrating enrichment and depletion of major and trace elements associated with mineralized samples, Kitchen prospect.

Na₂O relative to unmineralized gabbro. Sample MD-00-65c does not directly correspond with other samples from the prospect as it is more strongly depleted in TiO, Fe₂O₃, FeO, MnO, MgO, CaO and Cr. This sample has strong sericite-carbonate-quartz alteration as opposed to varied sericite-chlorite alteration in the other samples. The strong decrease in elements within the sericite-carbonate-altered sample may indicate greater breakdown and alteration of the host rock by the mineralizing fluids.

Ultramafic rocks in the vicinity of the Kitchen prospect include both carbonatized (Sample MD-00-057) and slightly serpentinized (Sample MD-00-064) varieties. Relative losses and gains of elements in these ultramafic rocks can also be demonstrated by using the serpentinized ultramafic composition as the normalization factor (Figure 10). The [Mg] plots (Figure 8) indicate that the carbonatized ultramafic has been enriched in As. Figure 10 indicates enrichment in CaO, Sr, As and Zn along with moderate depletions

of MgO and Ni in the carbonatized ultramafic rock compared to the slightly serpentinized version. The carbonatization may partially explain the Ca enrichment in sample MD-00-057 with Ca possibly being transported as carbonate complexes with the massive influx of CO₂, however, there may also be a more olivine and pyroxene-rich composition in the protolith of the serpentinized ultramafic. A coincident Sr enrichment in the carbonatized ultramafic sample is also to be expected since their similar ionic radii allows for Sr to readily substitute for Ca. The corresponding As enrichment in the carbonatized ultramafic rock suggests a link between the hydrothermal fluids that produced the mineralization at the Kitchen prospect and the carbonatized ultramafic (i.e., arsenopyrite is the gold-bearing phase at the prospect, and its presence in the altered ultramafic may, therefore, indicate a common fluid). Furthermore, such geochemical relationships suggest that carbonatization of these ultramafic rocks may actually reflect a much larger auriferous hydrothermal system in the greater map area.

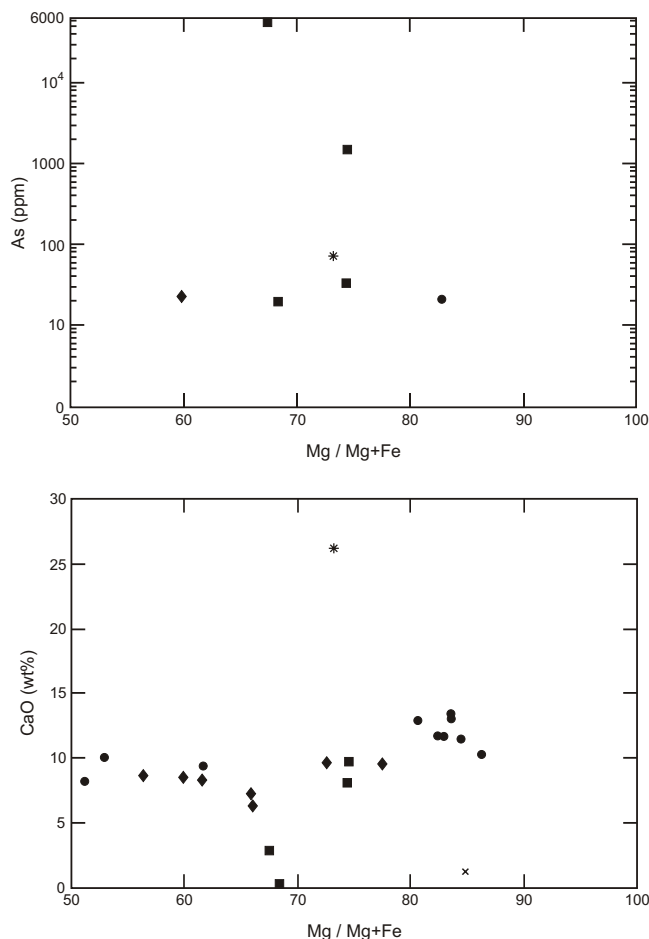


Figure 8. [Mg] variation diagrams illustrating relative amounts of As and CaO in ultramafic rocks.

DISCUSSION

In many respects the Kitchen prospect resembles archetypal mesothermal-type lode-gold deposits. These details include: 1) location within secondary or tertiary structures related to large regional structures (Kerrick and Cassidy, 1994); 2) ductile to brittle relationships of structures (Colvine *et al.*, 1988), 3) carbonate alteration, at least in part (Guha *et al.*, 1991), 4) simple sulphide mineralogy of Au associated with arsenopyrite (Evans, 1999). The alteration associated with Au mineralization involved sulphidation and finally carbonatization. Sulphide haloes are a characteristic alteration phenomena of many mesothermal Au deposits (Colvine *et al.*, 1988; Roberts, 1988; Kerrich, 1989).

Evans (1996) classified gold occurrences in the central and eastern Dunnage Zone into two broad groups, *viz.* mesothermal and epithermal. He further subdivided the mesothermal group into three classes as 1) auriferous quartz

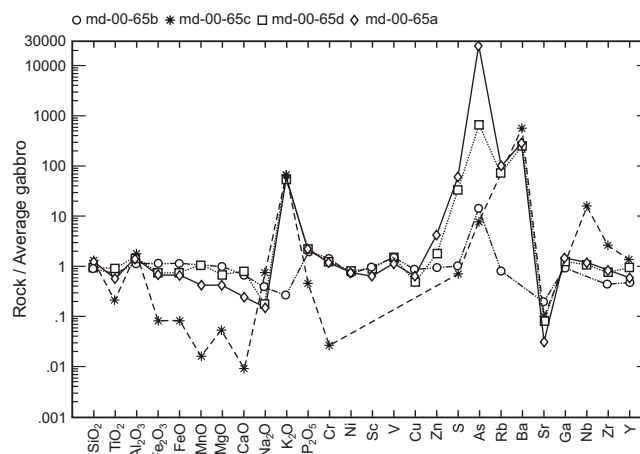


Figure 9. Multi-element plot for rocks from the Kitchen prospect normalized to the average composition of the Wandsworth gabbro outside the prospect area.

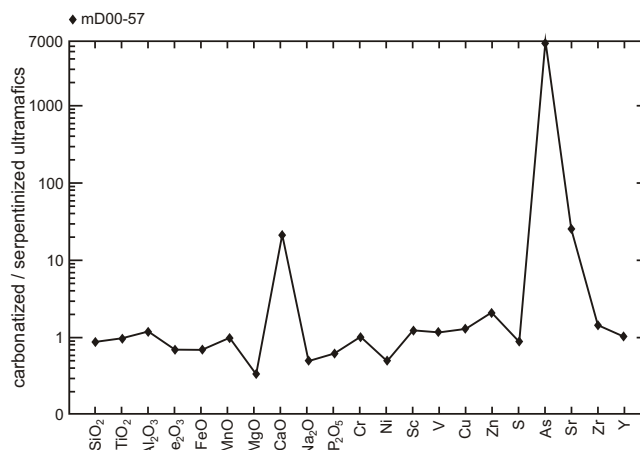


Figure 10. Multi-element plot comparing carbonatized and serpentinized ultramafic rocks using the serpentinized composition as the normalizing factor.

veins, 2) altered wallrock \pm quartz veins, and 3) disseminated gold. According to this scheme, the Kitchen prospect would be classified as Class 2, which Evans (*op. cit.*) defines as consisting of gold mineralization hosted in Fe-carbonate-silica-chlorite altered gabbroic to mafic intermediate volcanic rocks with attendant pyrite-arsenopyrite. He suggests that this type of auriferous mineralization is produced by metamorphogenic CO_2 -rich fluids that were focussed along regional structures.

Evans and Wells (1998) used a slightly different scheme to classify mesothermal lode gold occurrences from the Baie Verte Peninsula. Using this classification scheme, the Kitchen prospect could be categorized as altered wall-rock-hosted gold with a subclassification as quartz-pyrite \pm carbonate replacement type. The critical distinction being that

the Baie Verte examples, unlike those in the central and eastern Dunnage Zone, contain no arsenopyrite. This is an interesting observation as petrostructurally, the geology of the southeast Burin Peninsula is ophiolitic-like and more closely resembles the Baie Verte Peninsula collage of ophiolitic rocks (e.g., Hibbard, 1983) than the Dunnage Zone (Williams *et al.*, 1988). As is the case with volcanogenic massive sulphide mineralization, this chemical distinction may suggest a difference in Gondwanan margin vs Laurentian margin metallogenesis predicated on the different natures of the respective continental crustal blocks (*cf.*, Hall *et al.*, 1998).

Gold deposits in the Avalon Zone range from the Hope Brook-style epithermal high-sulphidation gold–copper deposits (Dubé *et al.*, 1998) to epithermal high-sulphidation (acid sulphate) gold–pyrophyllite and low-sulphidation (adularia–sericite) gold and porphyry-style gold–copper mineralization (O'Brien *et al.*, 1998). The Kitchen prospect, however, is most readily classified as a mesothermal-style epigenetic gold occurrence. The Kitchen prospect is defined as a metamorphogenic mesothermal gold occurrence with a subclassification as silica-sulphide replacement type after Evans (1999). Within the Avalon Zone, the only previously reported, although poorly documented, mesothermal auriferous mineralization (i.e., large, singular gold-bearing quartz veins) is that reported from 1880 near Brigus (Martin, 1983; Murray and Howley, 1881). Thus, the Kitchen prospect has important metallogenic implications as it is the first truly mesothermal-type gold prospect described in a modern context from the Avalon Zone. As such, it suggests a potential for similar mineralization elsewhere in the Burin Group and, in fact, within mafic volcanic rocks from the entire Avalon Zone.

OTHER MINERAL SHOWINGS

Whale Cove

A significant new gold discovery was made by prospectors in the summer of 2000. This showing is located on the peninsula on the western side of Whale Cove south of the Burin townsite (Figure 1). Gold (up to 3.4 g/t) was found to occur in a pyrite–arsenopyrite–sericite-rich shear zone in mafic volcanic rocks of the Path End Formation. Gold shows a positive correlation with the sulphides.

The 10-m-wide shear zone is well-exposed at the water's edge and can be traced inland in a northerly direction for approximately 350 m. There it is covered by soil and vegetation. Very little exploration work has been done on this prospect aside from minor stripping and grab sampling.

Numerous pre- and posttectonic quartz veins are exposed in the area associated with the shear zone. Some of these contain chalcopyrite and elevated gold values. Parallel sulphide-rich shear zones occur within the general area and have slightly anomalous gold.

Corbin Showing

An alteration zone in sheared mafic volcanics of the Port au Bras Formation occurs at Corbin, close to where the road crosses the inlet. Alteration consists of a 30-m-wide zone of pervasive pyritization, sericitization and silicification. Some thin massive pyrite bands occur associated with quartz-rich layers. Assays of grab samples gave gold values up to 0.5 g/t and zinc values up to 0.5%.

Old Water Supply Showing

Possible ultramafic rock is exposed at the western end of a pond about one kilometre east of Burin that is assumed to be the old water supply. Many pieces of definite ultramafic rock float are found in this area which lies along strike with the BUB line close to the Duricle Cove Fault. On the shores of the pond, there are sheared quartz veins in pyritiferous ultramafic rock. A sample taken from the quartz and surrounding material gave an assay value of 0.6 g/t Au. The sample was taken from a large block or possible outcrop on the shore of the pond. Other quartz veins were noted to occur in the area but were not sampled.

Copper, Nickel, and Chromium

Minor showings of copper, nickel and chromium were recorded at various areas within the Burin Group. Chalcopyrite was found in some quartz and calcite veins, including the Whale Cove gold showing. Another occurs southwest of Corbin (at West Bass Cove) and was reported by van Alstine (1948). Malachite and chalcocite occur within a carbonate-rich alteration zone in Great Burin Harbour that assayed 4460 ppm Cu. Elevated copper values were also obtained on a rusty rock that is exposed on the Corbin road. This rock consists of very fine quartz veins with intervening pyrite-rich carbonate that has been eroded away leaving a fine mesh of rusty quartz. A grab sample assayed 6125 ppm Cu.

Elevated values of nickel and chromium were found in parts of the Burin Ultramafic belt. In an area southwest of Beau Bois, the carbonatized and serpentinized ultramafic rock returned assays of 0.30% Ni and slightly anomalous gold values (0.74ppb). High amounts of chromium occur in the ultramafic rocks at a number of localities with assays of greater than 1100 ppm.

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REFERENCES

- Buisson, G. and Leblanc, M.
1986: Gold-bearing listwaenites (carbonitized ultramafic rocks) from ophiolite complexes. *In* Metallogeny of Basic and Ultrabasic Rocks. *Edited by* J.M. Gallagher, R.A. Iser, C.R. Neary and H.M. Prichard. Institute of Mining and Metallurgy, London, pages 121-132.
- Colvine, A.C., Fyon, J.A., Heather, K.B., Marmount, S., Smith, P.K. and Troop, D.G.
1988. Archean lode gold deposits in Ontario: a genetic model. Ontario Geological Survey, Miscellaneous Paper 139, 136 pages.
- D'Lemos, R.S., Strachan, R.A. and Topley, C.G. (Editors)
1990: The Cadomian Orogeny. Geological Society of London Special Publication 51, 423 pages.
- Dubé, B., Dunning, G.R. and Lauziere, K.
1998: Geology of the Hope Brook Mine, Newfoundland, Canada; A preserved Late Proterozoic high-sulphidation epithermal gold deposit and its implications for exploration. *Economic Geology*, Volume 93, pages 405-436.
- Evans, D.T.W.
1996: Epigenetic gold occurrences, eastern and central Dunnage Zone, Newfoundland. Newfoundland Department of Mines and Energy, Geological Survey, Mineral Resource Report No. 9, 135 pages.
- 1999: Volcanogenic massive sulphide and gold mineralization, northern and central Dunnage Zone, Newfoundland. Newfoundland Department of Mines and Energy, Geological Survey, Open File 2697, 208 pages.
- Evans, D.T.W. and Wells, C.
1998: Epigenetic gold mineralization, Baie Verte Peninsula, Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey, Report 98-1, pages 39-51.
- Greene, B.A.
1973: Geology of the Marystown and St. Lawrence map areas, Newfoundland. Mineral Development Division, Newfoundland Department of Mines and Energy, 30 pages.
- Gibbons, W.
1990: Transcurrent ductile shear zones and the dispersal of the Avalon superterrane. *In* The Cadomian Orogeny. *Edited by* R.S. D'Lemos, R.A. Strachan and C.G. Topley. Geological Society, London, Special Publication 51, pages 407-423.
- Guha, J., Lu, H-Z., Dube, B., Robert, F. and Gagnon, M.
1991: Fluid characteristics of vein and altered wall rocks in Archean mesothermal gold deposits. *Economic Geology*, Volume 86, pages 667-684.
- Hall, J., Marille, F. and Dehler, S.
1998: Geophysical studies of the structure of the Appalachian orogen in the Atlantic Borderlands of Canada. *Canadian Journal of Earth Sciences*, Volume 35, pages 1205-1221.
- Hefferan, K.P., Hassan, A., Karson, J.A. and Saquaque, A.
2000: Anti-Atlas (Morocco) role in Neoproterozoic western Gondwana reconstruction. *Precambrian Research*, Volume 103, pages 89-96.
- Hibbard, J.
1983: Geology of the Baie Verte Peninsula, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Memoir 2, 279 pages.
- Hiscott, R.
1981: Stratigraphy and sedimentology of the Rock Harbour Group, Flat Islands, Placentia Bay, Newfoundland Avalon Zone. *Canadian Journal of Earth Sciences*, Volume 18, pages 495-508.
- Irvine, T.N. and Baragar, W.R.A.
1971: A guide to the chemical classification of the com-

- mon volcanic rocks. *Canadian Journal of Earth Sciences*, Volume 8, pages 523-548.
- Jacobs, W.J.
1999: Geological assessment report: Kitchen Prospect. Braithwaite Minerals Inc., unpublished report.
- 2000: Diamond drilling exploration program: Kitchen Prospect. Braithwaite Minerals Inc., unpublished report.
- Jukes, J.B.
1843: General report of the Geological Survey of Newfoundland for 1839 and 1840, London, 160 pages.
- Kerrich, R.
1989: Geochemical evidence on the sources of fluids and solutes for shear zone-hosted mesothermal Au deposits. *Geological Association of Canada Short Course Notes Volume 6, Mineralization and Shear Zones*, pages 129-197.
- Kerrich, R. and Cassidy, K.F.
1994: Temporal relationships of lode gold mineralization to accretion, magmatism, metamorphism and deformation - Archean to present: A review. *Ore Geology Reviews*, Volume 9, pages 263-310.
- Krogh, T.E., Strong, D.F., O'Brien, S.J. and Papezik, V.S.
1988: Precise U - Pb zircon dates from the Avalon Terrane in Newfoundland. *Canadian Journal of Earth Sciences*, Volume 25, pages 442-453.
- Leblanc, M.
1986: Co - Ni arsenide deposits, with accessory gold, in ultramafic rocks from Morocco. *Canadian Journal of Earth Sciences*, Volume 23, pages 1592- 1602.
- Longerich, H.P.
1995: Analysis of Pressed Pellets of Geological Samples Using Wavelength-Dispersive X-Ray Fluorescence Spectrometry. *X-Ray Spectrometry*, Volume 24, pages 123-136.
- Martin, W.
1983: Once Upon a Mine: Story of pre-confederation mines on the Island of Newfoundland. *Canadian Institute of Mining and Metallurgy, Special Volume 26*, 98 pages.
- Murray, A. and Howley, J.P.
1881: Reports of the Geological Survey of Newfoundland for 1864-1880. Stanford, London.
- Naidoo, D.D., Bloomer, S.H., Saquaque, A. and Hefferan, K.
1991: Geochemistry and significance of metavolcanic rocks from the Bou Azzer - El Graara ophiolite (Morocco). *Precambrian Research*, Volume 53, pages 79-97.
- O'Brien, S.J.
1979: Volcanic stratigraphy, petrology and geochemistry of the Marystown Group, Burin Peninsula, Newfoundland. Unpublished M.Sc. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 253 pages.
- O'Brien, S.J. and Taylor, S.W.
1983: Geology of the Baine Harbour (1M/7) and Point Enragée (1M/6) map areas, southeastern Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-5, 70 pages.
- O'Brien, S.J., Wardle, R.J. and King, A.F.
1983: The Avalon Zone: A Pan-African terrane in the Appalachian Orogen of Canada. *Geological Journal*, Volume 18, pages 195-222.
- O'Brien, S.J., Strong, D.F. and King, A.F.
1990: The Avalon Zone type area: southeastern Newfoundland Appalachians. *In Avalonian and Cadomian Geology of the North Atlantic. Edited by R.A. Strachan and G.K. Taylor*. Glasgow, Blackie and Son, pages 166-193.
- O'Brien, S.J., O'Brien, B.H., O'Driscoll, C.F., Hayes, J.P., Dickson, W.L., Dunning, G.R. and Tucker, R.D.
1995: Tectonic and mineralizing events along the Avalonian/peri-Gondwanan margin of the Newfoundland Appalachians: An overview. *In Report of Activities*. Newfoundland Department of Mines and Energy, Geological Survey, pages 66-69.
- O'Brien, S.J., O'Brien, B.H., Dunning, G.R. and Tucker, R.D.
1996: Late Neoproterozoic Avalonian and related peri-Gondwanan rocks of the Newfoundland Appalachians. *In Avalonian and Related Terranes of the Circum-North Atlantic. Edited by R.D. Nance and M.D. Thompson*. Geological Society of America, Special Paper 304, pages 9-28.
- O'Brien, S.J., Dubé, B., O'Driscoll, C.F. and Mills, J.
1998: Geological setting of gold mineralization and related hydrothermal alteration in Late Neoproterozoic (post-640 Ma) Avalonian rocks of Newfoundland, with a review of coeval gold deposits elsewhere in the

- Appalachian Avalonian Belt. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey, Report 98-1, pages 93-124.
- O'Driscoll, C.F.
1985: A comparison of gold-bearing environments in Newfoundland, California and the Carolinas. Newfoundland Department of Mines and Energy, Mineral Development Division, Open File Report 1590.
- Pearce, J.A. and Cann, J.R.
1973: Tectonic setting of basal volcanic rocks determined using trace element analysis. *Earth and Planetary Science Letters*, Volume 19, pages 290-300.
- Roberts, R.G.
1988. Archean lode gold deposits. *In* *Ore Deposit Models*. Edited by R.G. Roberts and P.A. Sheahan. *Geoscience Canada*, Reprint Series 3, pages 1-19.
- Strong, D.F., O'Brien, S.J., Strong, P.G., Taylor, S.W. and Wilton, D.H.
1978a: Geology of the Marystown (1M/3) and St. Lawrence (1L/4) map areas, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 77-8, 81 pages.
- Strong, D.F., O'Brien, S.J., Strong, P.G., Taylor, S.W. and Wilton, D.H.C.
1978b: Aborted Proterozoic rifting in Newfoundland. *Canadian Journal of Earth Sciences*, Volume 15, pages 117-131.
- Strong, P.G.
1976: Geology of the Lawn area, Burin Peninsula, Newfoundland. Unpublished B.Sc. thesis, Memorial University of Newfoundland, St. John's Newfoundland.
- Taylor, S.W.
1978: Geology of the Marystown map sheet (east half), Burin Peninsula, southeastern Newfoundland. Unpublished M.Sc. thesis, Memorial University of Newfoundland, St. John's, 164 pages.
- Taylor, S.W., O'Brien, S.J. and Swinden, H.S.
1979: Geology and mineral potential of the Avalon Zone and granitoid rocks of eastern Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 79-3, 50 pages.
- Van Alstine, R.E.
1948: Geology and mineral deposits of the St. Lawrence area, Burin Peninsula, Newfoundland. *Geological Survey of Newfoundland*, Bulletin 23, 64 pages.
- Widmer, K.
1950: The geology of the Hermitage Bay area, Newfoundland. Unpublished Ph.D. thesis, Princeton University, Princeton, 439 pages.
- Williams, H.
1979: Appalachian Orogen in Canada. *Canadian Journal of Earth Sciences*, Volume 16, pages 792-807.
- Williams, H., Colman-Sadd, S.P. and Swinden, H.S.
1988: Tectonic-stratigraphic subdivisions of central Newfoundland. *In* *Current Research, Part B. Geological Survey of Canada*, Paper 88-1B, pages 91-98.
- Williamson, D.H.
1956: The geology of the fluorspar district of St. Lawrence, Burin Peninsula, Newfoundland. Newfoundland Department of Mines, Agriculture and Resources, unpublished report, 140 pages.
- Wilton, D.H.
1976: Petrological studies of the southeast part of the Burin Group, Burin Peninsula, Newfoundland. Unpublished B.Sc. thesis. Memorial University of Newfoundland, St. John's, Newfoundland.
- Winchester, J.A. and Floyd, P.A.
1977: Geochemical discrimination of different magma series and their differentiation products using immobile elements. *Chemical Geology*, Volume 20, pages 325-343.