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Echo Bay IOCG Thematic Map Series: Geology, Structure and Hydrothermal Alteration of a Stratovolcano Complex, Northwest Territories, Canada

A.H. Mumin (Editor)

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Echo Bay IOCG Thematic Map Series: Geology, Structure and Hydrothermal Alteration of a Stratovolcano Complex, Northwest Territories, Canada

A.H. Mumin[1] (Editor)

[1] Brandon University, 2-08, John R. Brodie Science Centre, Brandon, Manitoba, Canada.
Email: mumin@brandonu.ca

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Publications in this series have not been edited; they are released as submitted by the author.

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Introduction

Echo Bay is located along the eastern shores of Great Bear Lake, NWT, Canada. It is an area of exceptional beauty in the sub-arctic Canadian Shield, and constitutes an approximately 20 km long fiord-like inlet. The region played an important role in the history of Canadian mining, has a high mineral potential in polymetallic ore deposits and provides a unique insight into a continuum of iron oxide-copper gold (IOCG) associated deposits, including iron oxide apatite, IOCG sensu stricto, skarn and epithermal mineralization. The district is of considerable geological and metallogenic interest due to the excellent exposures of the internal geology of andesitic stratovolcano complexes and associated magmatic-hydrothermal alteration and mineralization. Its geological units are parts of the 1.87 Ga Labine Group of the 1.878-8.44 Ga Mac Tavish Supergroup and of the Early intermediate intrusive suite of the Great Bear magmatic zone, itself part of the Wopmay Orogen (Bowring, 1985; Hildebrand et al., 2010a, b). Within the Echo Bay region intrusive rocks of the Early intermediate intrusive suite have been referred to the Mystery Island intrusive suite (Hildebrand, 1982, 2011).

Past producing mines in the Echo Bay region extracted radium, uranium, silver, copper, cobalt, nickel, lead and bismuth. The most significant were the Eldorado and Echo Bay mines which operated between 1932 and 1982. Mining in the Echo Bay region had its origin with radium production from the Eldorado mine at Labine Point in 1932. In 1940 there was a brief closure of mining operations; however, the mine reopened shortly thereafter in 1942 for the production of uranium, a highly prized commodity during the second World War. The extraction of uranium ended in 1962 due to difficulties in logistics and economic considerations. However, the mine was re-opened shortly thereafter by Echo Bay Mines for the extraction of silver and copper which continued until 1982. There has been no further production since that time, although recent exploration indicates considerable potential for further developments at Echo Bay (Bothwell, 1984; Mumin, 2006; Mumin et al., 2007, 2010; Corriveau et al., 2010a, b).

This series of geological maps covering the Echo Bay region is a cooperative effort sponsored by Alberta Star Development Corporation. The work was carried out under direction of Hamid Mumin Ph.D., P.Eng., P.Geo. of Brandon University, Manitoba. Seventeen B.Sc., M.Sc. and Ph.D. students, post-doctoral Fellows and research associates contributed to the field mapping which was completed between 2005 and 2007. Contributors to this work include the Geological Survey of Canada through an activity within its phase 3 of the Targeted Geoscience Initiative as well as the Northwest Territories Geoscience Office. This work is compiled and published with the assistance of Natural Resources Canada, Geological Survey of Canada, phase 4 of the Targeted Geoscience Initiative program. Seventeen geological maps and one location map are included in this series. To facilitate locating attributes within the map, informal names have been given to series of lakes as labelled in the various map sheets.

Geological Mapping

Geological mapping carried out in 2005 was referenced to available topographic maps. The mapping carried out in 2006 and 2007 was referenced to high-resolution airborne photometry, which was orthorectified and georeferenced to a series of survey points established for the airphotos. The airborne photometry was conducted by Eagle Mapping for Alberta Star Development Corporation in 2006. Several of the maps are referenced to cut line field grids.

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Mumin, A.H. (ed.), 2015. Echo Bay IOCG Thematic Map Series: Geology, Structure and Hydrothermal Alteration of a Stratovolcano Complex, Northwest Territories, Canada; Geological Survey of Canada, Open File 7807, 1 .zip file. doi:10.4095/296602

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Sheet 1: The Echo Bay Stratovolcano Complex, IOCG Alteration, and Mineralization

Regional geological mapping of the Echo Bay area was carried out by Hildebrand (1982) and Reardon (1992) and is reproduced here as a location guide for the seventeen areas selected for detailed geological mapping (Sheet 1: Index map, Echo Bay Stratovolcano Complex, Northwest Territories). The Echo Bay area preserves a well exposed cross-section through the core of a 1.872–1.869 andesitic stratovolcano complex (Davis et al., 2011). It is comprised of subvolcanic source plutons, predominantly intermediate volcanic rocks, a large crater lake fill sequence, local mafic intrusions, and areas of locally derived conglomerate and arkosic sandstone cover. Superb outcrop exposure, low-grade metamorphism, and relatively moderate deformation, provide an excellent view into the core of this former dynamic volcanic system. Of particular interest are the extensive exposures of hydrothermal alteration and mineralization associated with iron oxide copper-gold (IOCG), iron oxide apatite, skarn and epithermal deposits. In addition to geology, these maps include information on structure, hydrothermal alteration, and megascopically-observed mineralization. More detailed discussions on the geology, structure, alteration and mineralization beyond this brief summary can be found in Hildebrand (1986), Mumin (2006), Fingler (2006), Mumin et al. (2007, 2010, 2014), Corriveau and Mumin (2010), Corriveau et al. (2010a, b), and Hildebrand et al. (2010b).

The Echo Bay volcanic field has been referred to as a subaerial andesitic stratovolcano complex (Hildebrand et al., 1987). It comprises a series of northwest trending sheet-like subvolcanic diorite and monzodiorite intrusions (Mystery Island intrusive suite), that range texturally from microcrystalline to medium grained and phaneritic to porphyritic. They are typically diorite at deeper levels of exposure, grading to monzodiorite and/or porphyritic in upper and marginal areas. Monzodiorite is believed to be the result of in-situ potassic alteration of diorite in its upper levels, and locally, monzodiorite grades to felsite that is nearly indistinguishable from intensely potassic altered andesite felsite. Mystery Island suite intrusions are the subvolcanic source for extrusive rocks of the Echo Bay stratovolcano complex. The majority of volcanic rocks are variations of porphyritic and amygdaloidal andesite flows, tuffs and breccia. Several internal rings, and an outer ring ca. 15.0 km in diameter of volcanic ash, tuff, epiclastic and volcaniclastic deposits show abundant laminations and evidence of graded bedding indicative of a water-lain probable crater lake fill sequence. Volcanic rocks appear to encircle and dip inwards towards a central collapsed cauldron, however, the geology is more consistent with multiple eruptive centres along a northwest trending linear belt. Gabbroic/diabase dykes and sills are widespread intrusions into the volcanic pile.

Virtually all rocks of the Echo Bay area are affected, at least minimally, by hydrothermal alteration associated with a variety of IOCG, IOA, epithermal and skarn mineralization. Varying types and intensity of propylitic (epidote, chlorite, carbonate), phyllic (quartz, sericite, pyrite), potassic, sodic, magnetite, hematite, apatite, amphibole (actinolite), biotite, epidote, chlorite, tourmaline, carbonate, sulphide and siliceous alterations have affected all rocks of the region. Alteration throughout the volcanic complex is pervasive in nature, but in spite of this much of the alteration pseudomorphs and preserves original volcanic textures. Textural preservation occurs with much of the propylitic, phyllic, potassic, sodic and hematite alterations, whereas textures are destroyed typically only in the most extreme cases and where structural disruption is also a factor. Hydrothermal alteration and mineralization of the Echo Bay stratovolcano complex are magmatic-hydrothermal in nature, and are directly linked to subvolcanic diorite/monzodiorite plutons of Mystery Island intrusive suite (Hildebrand, 1986; Reardon, 1990; Mumin et al., 2007, 2010; Corriveau et al., 2010b; Hildebrand et al., 2010b). The Echo Bay complex is of further geological interest due to similarities with some aspects of porphyry copper type systems. These include the direct association of alteration and mineralization with subvolcanic diorite intrusions, and the transition from hydrothermal alkali-iron alterations typical of IOCG deposits to more distal phyllic and propylitic alterations that are more commonly associated with porphyry copper type systems (Richards and Mumin, 2013a, b).

Sheet 2: Glacier Lake East Geology

The Glacier Lake geology sheet comprises an area of roughly 5.4 km^2 east of Glacier Lake and north of Glacier Bay. This area encompasses the western part of a large intermittent gossanous phyllic (quartz-sericite-pyrite) and potassic altered region that lies between Glacier Lake and the Cameron Bay fault. The Glacier Lake region is dominated by andesite flows and breccia, several of which are trachytic in nature. Porphyritic andesite is most common (pAnd) and contains 10–15% subhedral to euhedral plagioclase phenocrysts set in a dark aphanitic matrix. Overlying the andesite flows and breccia is a poorly sorted lithic tuff containing sub-angular to sub-rounded clasts of K-feldspar- and/or plagioclase- rich crystal tuff, lithic fragments and chert. Medium to coarse-grained monzodiorite of the Mystery Island intrusive suite locally intrude the andesite in the south-central map area, and a kilometre thick northwest trending monzodiorite pluton occurs in the southwest corner and immediately south of the map area.

Volcanic rocks of the map area are often highly fractured and sheared, particularly where alteration is most intense. One significant east-west striking fault (Cleaver fault) dextrally offsets the volcanic stratigraphy of the southern map area by approximately 800 to 900 m.

Extensive alteration occurs marginal to and locally within the monzodiorite. Volcanic rocks have been affected by widespread potassic (K-feldspar) alteration that locally grades to felsite (> 50% hydrothermal K-feldspar) near the contact with monzodiorite. A strong phyllic (quartz-sericite-pyrite) alteration is common in zones up to several hundred metres in extent, and they typically interfinger with and grade into potassic alteration. These phyllic-potassic alterations with 1–5% (locally more) pyrite produce the gossanous exposures observed at surface. Large areas with abundant quartz stringers and stockwork occur in the north-central and southwestern portions of the map area. Monzodiorite in the region typically has minor to moderate magnetism, and locally up to 2–3% pyrite.

Sheet 3: Cross Fault Lake Geology

The Cross Fault Lake area is bounded by Cross Fault Lake and Wop Lake to the northeast and Glacier Bay to the southeast. It comprises a complex and repetitive sequence of volcanic rocks and locally derived epiclastic sedimentary beds. Andesite flows, tuffs and breccias are interlayered and structurally juxtaposed with stratified, locally derived sedimentary rocks and pyroclastic beds. The stratified rocks are believed to be the remnants of a large crater-fill sequence. These rocks are both intruded and partially underlain by several variants of the Mystery Island intrusive suite (MIS) plutonic rocks, including parent diorite (as dykes), as well as fractionated and hydrothermally altered variants that include quartz monzonite, feldspar porphyry, granodiorite, and monzodiorite intrusions (Bateman, 1944; Mumin et al., 2007, 2010). MIS intrusions at Cross Fault Lake (along with their Port Radium equivalents in map sheet 4, this series) are the most significant examples of syn-volcanic igneous rocks directly related to the volcanic field that intrude in an orientation orthogonal to the main mass of MIS intrusions. Their zones of hydrothermal alteration also invade northeast oriented structures.

Structural deformation of the Cross Fault Lake region is characterized by complex faulting and broad amplitude folding. Brittle structures follow a dominant northeast trend; however, syn-deformational east-west to northwest trending faults segment the geology into a series of orthogonal blocks. Repetition of the geology appears to result from a combination of folding and fault displacements. The region is interpreted to be part of an extensional pull-apart (dilational) structure caused by an offset in major northeast trending structures, possibly due to a significant north-trending break that occurs in the Port Radium area, immediately west of the Cross Fault Lake map area. This pull-apart domain facilitated intrusion of northeast trending Mystery Island suite stocks at both Port Radium and in the Cross Fault Lake map areas (Mumin et al., 2014). Relative to the Port Radium area, the Cross Fault Lake region is a down thrown block within the pull-apart structure, thus preserving structurally higher levels of the Mystery Island suite intrusions, and higher levels (more distal levels) of the associated hydrothermal alteration (Mumin et al., 2014).

Hydrothermal alteration at Cross Fault Lake is extensive and pervasive. The alteration is predominantly potassic (K-feldspar ± biotite) which imparts a ‘pinkish-orange’ color to the rocks, and locally grades to felsite. Potassic altered rocks grade locally into strong phyllic alteration (quartz-sericite-pyrite), which results in weathered surface exposures with a thin veneer of rusty orange-brown gossanous staining. Locally, there is evidence of high temperature sodic (albitic) alteration. Least-altered rocks comprise a propylitic assemblage characterized by chlorite, carbonate and epidote.

The map area encompasses the former Echo Bay mine, a past producer of silver and copper with accessory zinc, lead, cobalt and bismuth mineralization. The former mine is centred around a large phyllic-potassic gossanous zone in the SW portion of the map sheet. Mineralized veins generally follow the main northeast structural trend, with some veins appearing as tensional fractures between northeast trending shears. Numerous other copper, silver ± lead, zinc, cobalt and bismuth mineralized veins of lesser significance occur throughout the map sheet, and invariably occur along fault structures of various orientations.

Sheet 4: Port Radium Geology

Port Radium is located at the mouth of Echo Bay along the east shore of Great Bear Lake. It is the site of the past producing Eldorado and Echo Bay mines. Eldorado is best known as the founding enterprise of Atomic Energy Canada. It originated as a radium mine for medical purposes, and during its 30 year life (1932 till 1962) also produced 6,223 tons of uranium, 8 million ounces of silver, and lesser amounts of copper, cobalt, nickel, lead and bismuth. The Echo Bay mine exploited the same area between 1962 and 1982, producing an additional ca. 24 million ounces of silver along with significant amounts of copper (Bothwell, 1984).

The area comprises a series of layered extrusive volcanic and volcaniclastic rocks, volcanogenic epiclastic sedimentary rocks and several intrusive phases, generally striking from north to northeast and having highly variable dips ranging from steep northeast to nearly flat lying, as well as steep northwest reverse dips. The oldest exposed rocks at Port Radium comprise a stratified epiclastic sedimentary and ash-tuff sequence of andesitic composition, believed to be part of a crater lake fill sequence. Tuff, lapilli tuff, and debris flow deposits are interlayered with the sedimentary rocks. However, the majority of rocks in the region are massive porphyritic andesite with local andesite breccia.

The main intrusions are microdiorite and lesser granodiorite of the Mystery Island intrusive suite (MIS). They invade northeast structures following the shoreline of Great Bear Lake. These Port Radium microdiorites (along with Cross Fault Lake (MIS) intrusions of sheet 3, this series) are the most significant examples of syn-volcanic igneous rocks directly related to the volcanic field that intrude in an orientation orthogonal to the main mass of MIS intrusions. In this region, hydrothermal alteration also invades northeast oriented structures. Microdiorites are interpreted to be structurally deeper levels of the K-altered, higher level monzodiorite equivalents (Mumin et al., 2010, 2014). Smaller intrusions of gabbro and diabase invade microdiorite and volcanic rocks in the northeast part of the map sheet. Minor granite exposures occur in the northwest part of the area, and are interpreted as part of a larger body that would mark the limits of the volcanic stratigraphy.

The Port Radium area was severely disrupted by northeast and north trending shearing, as well as faulting orthogonal to these main trends. The region is interpreted to be an extensional pull-apart structure due to an offset in the trend of major northeast structures, possibly the result of a significant north-trending break immediately east of the tailings pond. This pull-apart (dilational) structure facilitated the northeast orientation of Mystery Island suite intrusions at both Port Radium and in the Cross Fault Lake map area (Mumin et al., 2014). Relative to the Cross Fault Lake area, Port Radium is an up thrown block within the pull-apart basin, thus exposing at surface deeper levels of the Mystery Island suite intrusions, and deeper (more proximal) levels of hydrothermal alteration. Extensive veining, stockwork and breccias within the pull-apart structure are host to abundant hydrothermal alteration and mineralization throughout the area, as well as the veins that were economically exploited.

Hydrothermal alteration at Port Radium is extensive and intense, and represents a deeper level (more proximal level) exposure of the hydrothermal system as compared to most other areas in the Echo Bay stratovolcano complex, with the possible exception of the Mag-Hill region. Magnetite-actinolite-apatite-biotite-alkali feldspar and magnetite-actinolite-biotite alteration is very intense throughout the central Port Radium map sheet, and this alteration extends beyond the map area in the southeast. Alteration indiscriminately replaces all types of andesitic rocks and epiclastic sedimentary rocks in structural stockworks and breccia, and as pervasive replacement of host rocks. These magnetite-rich alterations grade to pervasive chlorite ± actinolite ± biotite, with local interlayered horizons of metal-bearing sulphides and sulpharsenides. Intermittent but intense zones of phyllic and potassic (K-feldspar) alteration follow the dominant northeast structural orientation. Late-stage epithermal type quartz, quartz-hematite, and quartz-carbonate ± hematite ± pitchblende ± sulphides ± arsenides in veins and stockworks is common at Port Radium, and directly hosts much of the economic mineralization.

Mineralization at Port Radium is extensive and includes several variants. The area is home to the past producing Eldorado and Echo Bay mines, which exploited epithermal vein deposits of quartz-carbonate-pitchblende ± hematite, and quartz-carbonate-hematite-sulpharsenides with copper-silver ± various combinations of cobalt, bismuth, uranium, zinc and lead (Robinson and Morton, 1972; Robinson and Ohmoto, 1973). Other types of mineralization not yet exploited or fully delineated include: 1) chlorite-carbonate ± actinolite, biotite, sulphide and arsenide zones with elevated copper-silver ± cobalt, bismuth, zinc, lead and gold contents, and 2) vanadiferous magnetite in magnetite-actinolite-apatite alteration (e.g. 224 metres @ 35.3% Fe, 0.278 % V_2O_5 in DDH PR-06-03, and 61.5 metres @ 38.6% Fe, 0.31% V_2O_5 in DDH PR-06-04, with the magnetite concentrate running roughly 0.7% V_2O_5) (Camier et. al., 2007; Mumin, 2010).

Sheet 5: Breccia Island Geology

Breccia Island is located near the southeastern end of Lindsley Bay, approximately 8 km southeast of the mouth of the bay at the main body of Great Bear Lake. It is a preserved domal remnant of a unique eruptive centre within the greater Echo Bay stratovolcano complex. This relatively small (ca. 1 km^2) island of is comprised of a complex sequence of volcanic flows, pyroclastic deposits, structural, hydrothermal and volcanic breccias, locally derived epiclastic sedimentary rocks, and compositionally diverse intrusions. Superficial deposits of talus and other unconsolidated sedimentary rocks form an envelope around much of the island.

The western two thirds of the eastern lobe of the island are underlain by andesite flows, and andesite tuffs interlayered with local deposits of course sandstone. The remainder of the eastern lobe is underlain by monzogranite of the Great Bear Batholith. Volcanic rocks that range in composition from rhyodacite and dacite to andesite form a layered sequence over much of the western lobe of the island. Andesites comprise porphyry, breccia, explosive breccia and other pyroclastic and volcaniclastic deposits. The western most portion of the island is underlain by a felsic volcanic sequence comprised of rhyodacite, dacite, and dacitic ashflow and ashfall tuffs.

The volcanic sequence is underlain by layered sedimentary rocks including mudstones, siltstones and fine-grained sandstones, which are exposed in the central part of the island connecting the eastern and western volcanic areas. Small synvolcanic intrusions invade andesite in the western lobe, including monzodiorite porphyry, granodiorite porphyry and diorite porphyry. A northwest trending diabase dyke or sill is exposed along the contact between felsic and andesitic volcanic rocks in the southwest corner of the island. The eastern most part of the island is occupied by younger monzogranite of the Great Bear Batholith.

Breccia Island is a complex mega-breccia resulting from two dominant sets of orthogonal structures that repeat relentlessly throughout the entire Echo Bay stratovolcano complex (see Mumin et al., 2014). Somewhat distorted variations of a northeast and southeast oriented fault set, and a north-south and east-west oriented fault set segment Breccia Island into a series of orthogonal to sub-orthogonal blocks. A prominent northwest trending structural breccia oriented sub-parallel to Lindsley Bay bifurcates the island into its eastern and western lobes.

A large portion of the island is strongly affected by hydrothermal alteration including structural and/or hydrothermal breccias, pervasive replacements, stockworks and veining. Potassic (K-feldspar) alteration is widespread. Actinolite-quartz-hematite and/or actinolite-quartz-magnetite, and local hematite alteration often overprint an earlier phase of potassic alteration. Quartz veining, stockwork and silicification is prominent along a northwest trending structural zone that bifurcates the island into two lobes. Silica alteration is also found along northeast trending structures in the eastern lobe. Extensive silicification of structurally brecciated rocks was encountered in drilling under the eastern portion of the western lobe of the island (not visible at surface). The western contact of the Cameron Bay Formation sedimentary rocks is disrupted by a north to north-northwest trending hydrothermal-structural stockwork-breccia with a dominant carbonate matrix. This carbonate-rich breccia zone is hosted within a combination of andesitic flows, volcaniclastic and pyroclastic rocks, including layered pumice-rich deposits (some of which contain xenoliths of porphyritic monzodiorite, granodiorite, andesite and dacite). Throughout the island, there is an obvious strong correlation between intensity of hydrothermal alteration and structural disruptions. Sulphides occur locally in hydrothermally altered rocks, and include minor amounts of pyrite and chalcopyrite with local patches of malachite.

Sheet 6: East Boundary Zone Geology

The East Boundary Zone map sheet extends from the southeastern end of Lindsley Bay due south for approximately 3.6 km. It straddles the boundary between part of the eastern margin of the Echo Bay stratovolcano complex and the Gilleran granodiorite intrusion of the Great Bear Batholith (Hildebrand et al., 2010b). This contact is marked by Boundary Lake which forms a north-south oriented linear topographic depression.

The East Boundary Zone is dominated by andesite tuff that is interlayered with interbedded sandstones, mudstones, ash tuff and conglomerate of the Cameron Bay Formation. Boundary Lake separates the sedimentary and volcanic rocks from granodiorite of the Great Bear batholith to the east. Several subparallel diabase dykes crosscut the aforementioned lithologies in a near east-west orientation.

Much of the map sheet is effected by strong hydrothermal alteration and/or by local contact metamorphism. Alteration includes hornfels in some areas of andesite near the contact with grandodiorite, and various combinations of hydrothermal actinolite, magnetite, potassic (K-feldspar), hematite and epidote. These alteration assemblages occur individually in local patches, together in various combinations, and commonly overprint each other. Strong hydrothermal modification of the rocks is most evident in volcanic and sedimentary rocks near their contact with the Great Bear Batholith. While the intensity of alteration decreases and style changes away from the contact with granodiorite, the relationship of hydrothermal effects to the granodiorite, if any, is unknown (except for contact metamorphism which is attributed to the granodiorite). This pluton is part of the biotite-hornblende monzogranite-granodiorite suite described in detail in Hildebrand et al. (2010b), and is much younger than the main magmatic-hydrothermal alteration in the district (Davis et al., 2011 versus Bowring, 1985).

Currently documented exposures of mineralization in the East Boundary Zone are minor and limited to secondary malachite in hydrothermally altered rocks, within both andesite tuff and the sedimentary rocks.

Sheet 7: Gossan Island Geology

Gossan Island is a distinctive 2.3 km by 1.4 km island within Echo Bay that is characterized by abundant rusty-coloured gossans. The island is underlain by a sequence of northwest trending interlayered andesites, with the exception of northeast oriented layers in the southeast lobe. Abundant Mystery Island suite intrusions outcrop in a general northwest trend along the southwest margin of the island. The island geology was first mapped by Feniak (1944).

Porphyritic and amygdaloidal andesites of the Echo Bay volcanic field comprise most rocks exposed on the island. Mystery Island suite quartz monzonite-aplite and granodiorite-diorite complexes intrude the volcanic rocks in a northwest oriented series of stocks and dykes. They are small exposures of larger underlying diorite/monzodiorite plutons. Andesitic lahar/debris flow deposits with occasional volcanic bombs are exposed along the shoreline near the western tip of the island. Bedding measurements taken from this deposit suggest that it was in place before the immediately adjacent andesites. Diabase and quartz-diabase/diorite dykes intrude the volcanic rocks, following the dominant northeast and northwest structural orientations.

Hydrothermal alteration is quite prominent following a northwest trend along the southwest side of the island, and is most prominent in close association with the quartz monzonite and granodiorite stocks. The most obvious alteration is an intermittent series of large and small zones of phyllic alteration (quartz, sericite, pyrite), that result in the prominent gossans visible at surface. Phyllic zones typically grade into interfingered potassic (K-feldspar) alteration which itself locally grades to felsite. All monzodiorite intrusions are potassic-altered diorite, a phenomenon that affects the upper portion of diorite plutons, stocks and dykes throughout the Echo Bay volcanic field. Strong potassic alteration of both andesite and monzodiorite is overprinted by magnetite-actinolite-apatite veining and stockwork in a small exposure along the northwest shoreline of the island. A unique alteration comprising abundant spotted tourmaline rosettes and disseminations in a zone of intense phyllic alteration occurs along the southwest margin of the island, and is a rare exposure of this type in the Great Bear magmatic zone. It resembles some types of epithermal gold-silver mineralization within modern day stratovolcano complexes. Local occurrences of course crystalline barite veining are found in the south-central neck of the island.

Mineralization on Gossan Island is most directly associated with intense phyllic ± potassic alteration, and is comprised mostly of pyrite, with trace amounts of chalcopyrite, galena and occasional arsenides. The presence of modest amounts of pyrite is responsible for the gossans, which prominently stain the surface of carbonate-free phyllic altered rocks. The phyllic and potassic alteration, and gossanous zones occur in all volcanic host rock types, and are not bound by geological contacts.

Sheet 8: Dowdell Peninsula Geology

Dowdell Peninsula lies west and north of Echo Bay between Great Bear Lake and the southwest arm of Echo Bay, and covers an area of roughly 7.5 km east-west by 4.3 km north-south. It includes many variations of the Echo Bay volcanic field and two significant subvolcanic monzodiorite plutons.

Dowdell Peninsula is underlain primarily by andesitic rocks that range from reworked autochthonous laminations of epiclastic volcanic material to volcanic flows, lahar and debris flows, to various pyroclastic rocks. Where possible to obtain measurements, the stratigraphy has an overall northwest strike and dips steeply to the northeast. Laminated reworked volcanic-derived sedimentary rocks interlayered with volcanic ash and tuff show local evidence of grading bedding, and are believed to be part of a large crater lake fill sequence. Layering of epiclastic sedimentary rocks and ash tuffs generally ranges in thickness from millimetres to decimetres. The laminated sedimentary and pyroclastic rocks are overlain by massive amygdaloidal and porphyritic andesite in the central part of the Dowdell map sheet.

Two large exposures of Mystery Island suite monzodiorite to quartz monzonite occur in the northeast and southwest portions of the map area. They are exposed parts of larger sheeted sub-volcanic monzodiorite plutons that are believed to be sources for the overlying volcanic rocks, alteration and mineralization (Hildebrand, 1986; Mumin et al., 2010; Corriveau et al., 2010b). The intrusions are texturally massive, and grade from fine to medium grained. Granite/granodiorite of the Great Bear Batholith underlies the extreme southwest portion of the map area, and essentially terminates the Echo Bay volcanic field. Diabase/gabbro dykes, sills and plugs intrude all rocks of the map area, and may represent more than one generation of mafic intrusions. They generally intrude along north-south, east-west and northeast trending structures.

Rocks of the western half of the map sheet show a general northwest trending bedding. However, in the eastern half, northeast trending brittle deformation structures (e.g. faults, fractures) dominate and largely mask original layering. Overall, rocks are segmented into orthogonal blocks as a result of dominant northeast shearing and faulting with synchronous northwest trending structural breaks. North- and east-trending faulting has also affected rocks, but to a lesser degree.

Metasomatism affects all rocks of the peninsula to at least some minor degree. Alteration occurs as zones of pervasive replacement of host rocks, as hydrothermal and structural breccias, stockworks and veins, and as pyroxene-garnet-epidote-K-felspar skarn. The more intense styles of hydrothermal alteration are intermittently dispersed throughout the region, and often correlate with areas of structural brecciation. The monzodiorite is potassic (K-feldspar) altered diorite. Propylitic alteration (epidote, chlorite, carbonate) is the minimum degree of hydrothermal alteration that effects volcanic rocks, while epiclastic sedimentary rocks tend to be siliceous, with varying degrees of local epidote, K-feldspar, hematite and other alterations. Alteration may occur as multiple superimposed phases, with hydrothermal mineral variations including one or more of magnetite, hematite, actinolite, apatite, K-feldspar, tourmaline, phyllic (quartz-sericite-pyrite), epidote, pyroxene, garnet, chlorite, carbonate and quartz. While all rocks of the Echo Bay volcanic field, including volcanic rocks, reworked sediments and sub-volcanic intrusions are affected by hydrothermal alteration, it is most noticeable and intense in the andesites and reworked volcaniclastic sedimentary rocks.

Mineralization is widespread throughout the map area. It includes past prospects such as the Bonanza Mine silver prospect, and the Mile Lake copper-zinc-lead-silver-tungsten-molybdenum skarn. Other minor vein-type or skarn showings enriched in one or more of copper, zinc, lead, silver ± cobalt are common in the volcanic rocks and derived sedimentary rocks.

Sheet 9: Hoy Bay Hydrothermal Alteration

Hoy Bay is a geographically small area within Dowdell Pennisula on the eastern shore of Great Bear Lake, immediately southwest of Echo Bay. The area is dominated by volcanic host rocks that include massive porphyritic andesite tuffs with layers of pyroclastic tuff and breccia.

Hydrothermal alteration and breccias are pervasive in the Hoy Bay area. The region is a good example of the consequences of magmatic-hydrothermal fluid interaction with permeable andesitic host rocks along faults, fractures and micro-brecciated zones. Potassic alteration (K-feldspar) pervades the entire mapped area with varying degrees of intensity ranging from weak to intense. Superimposed on potassic alteration are localized patches, veins and stockwork of epidote, actinolite, quartz and/or skarn. The most intense alterations are associated with hydrothermal/structural breccias, and include variations and combinations of potassic, epidote, actinolite and skarn altered clasts cemented by a matrix including one or more of magnetite, hematite and actinolite. The breccias may include veins of hematite, magnetite, actinolite, epidote, skarn and/or quartz.

Sheet 10: East Mile Lake Geology

The East Mile Lake Geology sheet covers a small area near the northeastern shore of Mile Lake. The northern part of the map sheet is dominated by andesitic volcaniclastic and epiclastic tuff, ash and sedimentary rocks. Siliceous ash deposits are interlayered with finely laminated sedimentary rocks and the occasional pyroclastic tuff or breccia layer. Graded beds indicate waterlain, reworked sedimentary rocks which are thought to be part of a crater lake fill sequence. Plagioclase and lesser plagioclase-hornblende porphyritic andesite tuffs underlie most of the southern part of the map sheet, with one small area of amygdaloidal andesite along the southern edge. Localized exposures of volcaniclastic breccia occur as layers within both andesitic tuffs and epiclastic sedimentary rocks. The general strike of bedded deposits in the East Mile Lake area is northwest with a 40^0 to 50^0 northeast dip. Documented structures form a northeast and northwest trending orthogonal pattern, with prominent, but less common north-south oriented faults.

Propylitic alteration with or without pyrite, chalcopyrite and/or hematite is widespread throughout the volcanic rocks at Echo Bay, particularly in the East Mile Lake area in patches south of Glen Lake, and south of the skarn breccia. More prominent hydrothermal alteration at East Mile Lake occurs as pervasive potassic ± actinolite, epidote or hematite, generally associated with fracturing and/or brecciation. Quartz-cemented breccia and stockwork, sometimes with hematite, occurs locally in association with structural fracturing.

The most significant mineralization in the map area occurs along a narrow stratabound skarn (garnet-pyroxene-epidote-K-feldspar-hematite±vesuvianite) horizon that extends in a northwesterly direction beyond the map sheet for almost 2 km. The skarn is associated with a coarse fragmental horizon within laminated tuff and epiclastic sedimentary rocks, and is believed to be directly related to an underlying diorite/monzodiorite pluton exposed on the south side of Mile Lake. It is caused by an early phase of carbonate alteration with prograde skarn overprinting (Mumin et al., 2010). Mineralization is intermittent along the skarn, however, copper, zinc, lead, molybdenum and silver bearing sulphides plus elevated tungsten contents become significant where the zone thickens into a skarn breccia near the northeast end of Mile Lake. Other mineralized showings dominated by elevated copper contents occur in association with quartz-hematite bearing structures.

Sheet 11: Contact Plateau Geology

The Contact Plateau Geology sheet covers a ca. 14 km^2 area extending from the northwest end of Contact Lake to the southwest arm of Echo Bay. The region is dominated by volcanic rocks of the Echo Bay volcanic field, including massive porphyritic andesite flows with relatively large plagioclase phenocrysts, as well as lesser amounts of andesite breccia and tuff.

Monzodiorite of the sub-volcanic Contact Lake pluton (Mystery Island intrusive suite) is exposed in the eastern corner of the map area. Syenogranite of the Richardson pluton, Great Bear Batholith, outcrops over ca. ½ km along the northeast corner of Contact Lake in the south corner of the map area. Two small outcroppings of diabase intruding andesite porphyry are also located in the southern corner of the area.

Faulting in the region is dominated by the same two orthogonal faults sets that affect the entire Echo Bay stratovolcano complex, which are a northeast and southeast trending orthogonal set, and a north and east trending orthogonal set. North and east trending faults appear to dominate the region, however, the more prominent northeast and southeast faults are largely hidden or obliterated by Contact Lake and Echo Bay, and by the Contact Lake pluton, respectively. Perhaps the most interesting structural feature of the region is the high-elevation plateau located in the central part of the map sheet labeled "Contact Plateau", that rises over 300 m vertically above Echo Bay. It is an ovoid domal feature that has apparently collapsed in on itself, generating an anticlinal fold-like structure with a northwest trending axis. It is believed to have been caused by collapse of an underlying extension of the Southwest Arm monzodiorite, a subvolcanic plutonic intrusion running parallel to, and south of, the Contact Lake pluton. It is only exposed northwest of the map area on the opposite side of the Southwest Arm of Echo Bay (see Dowdell Pennisula Geology or Echo Bay Regional Geology map, this series).

Volcanic rocks of the Contact Plateau region have been subject to pervasive hydrothermal alteration. Pervasive but texture preserving propylitic alteration (epidote, chlorite, carbonate) forms the least altered rocks of the region. These are widely overprinted by intermittent weak to moderate potassic (K-feldspar) alteration, with only minor localized zones of felsite. Hematite alteration is intermittent throughout the area, and where present is generally a very weak to moderate overprinting of potassic altered rocks. The monzodiorite is potassic altered diorite (Mumin et al., 2010). Magnetite alteration of andesitic rocks occurs along a ca. 1.5 km by 0.5 km belt marginal to the monzodiorite pluton in the northeast part of the map sheet. Three small phyllic (quartz-sericite-pyrite) ± potassic (K-feldspar) gossanous patches occur in the northwest part of the map sheet. They contain minor to modest amounts of sulphide (mainly pyrite) ± minor arsenide mineralization. Localized zones of quartz stockwork occur in porphyritic andesite flows over several areas in the northeast part of the map sheet.

A significant magnetic anomaly underlies the plateau area, however, magnetic rocks are absent at surface where only weak to moderate potassic ± hematitic alteration is present. Consequently, the possibility exists for magnetite alteration at depth, with varying degrees of other alteration and mineralization between the magnetite and weak surface alteration, as is the case in other parts of the Echo Bay complex (Mumin et al. 2007, 2010).

Sheet 12: K1 Grid Geology

The K1 Grid is a small area (ca. 1 km^2) along the southwest shore of Echo Bay. This area is dominated by plagioclase phyric porphyritic andesite, which extends inland from Echo Bay for approximately 1 km to the contact with the Contact Lake pluton. Amygdaloidal andesites are present near the shore of Echo Bay in one localized area. Amygdules are 2–5 mm in size, quartz-filled, and some are partially filled with pyrite. The Contact Lake pluton is almost solely comprised of monzodiorite (K-altered diorite) of the Mystery Island intrusive suite. The intrusion is well exposed and pinkish-grey at surface. It is medium to coarse grained with equal amounts of plagioclase and K-feldspar, and lesser amphibole. Orthogonal faulting offsets geology of the K1 area along northeast and southeast structural breaks. Part of the contact between volcanic rocks and the monzodiorite pluton is a contact/structural breccia.

Pervasive hydrothermal alteration affects much of the map area, including hematite, magnetite and potassic (K-feldspar) alterations. These alterations occur alone, coevally or superimposed on each other to varying degrees. As with elsewhere in the Echo Bay stratovolcano complex, least-altered rocks are invariably pervasively altered to a propylitic assemblage. Hydrothermal iron oxide alteration dominates this region with hematite being most prominent as pervasive hematite dusting to stockwork veining which locally grades to small exposures of hematite-cemented breccia. Magnetite ± actinolite alteration is evident within parts of the monzodiorite intrusion and in adjacent volcanic rocks, and may occur along with hematite. Small patches of veins and/or stockworks of quartz-tourmaline are found locally in the K1 area. Pyrite dominant sulphides occur as veins and in breccia in several locations within the porphyritic andesite. Mineralization is mainly vein associated, and occurs along with quartz, hematite and carbonate with elevated copper ± one or more of zinc, lead, silver and cobalt contents.

Sheets 13, 14 and 15: Mag Hill Northeast, Central and Southwest Blocks: Geology and Hydrothermal Alteration

Mag Hill is located immediately south and southeast of the southeast tip of Echo Bay. The area is subdivided into three adjacent map sheets, the Mag Hill Northeast, Central and Southwest Blocks which are described here together. The region is underlain primarily by porphyritic and amygdaloidal porphyritic andesites, with local areas of andesitic breccia (described herein as flow top breccia). The volcanic rocks are intruded by numerous east to east-northeast trending subvolcanic microdiorite and monzodiorite plugs and dykes of the Mystery Island intrusive suite (Somarin and Mumin, 2014).

The area has been affected by intense hydrothermal alteration, due to the close proximity of high-level sub-volcanic Mystery Island suite intrusions. Both the alteration and mineralization at Mag Hill have similarities to the Port Radium-Echo Bay mine areas. The region preserves a cross-section from deep-seated albite and magnetite-actinolite-apatite, to intermediate potassic, and distal phyllic (quartz, sericite, pyrite) and propylitic (epidote, chlorite, carbonate) alterations. The alteration sequence progresses outwards from hypabyssal intrusions of the Mystery Island suite, although multiple prograde and retrograde superposition occurs, which along with structural brittle deformation has resulted in complex irregular patterns (Mumin et al., 2007, 2010; Somarin and Mumin, 2014). Distal and late-stage effects of the hydrothermal system have caused wide-spread occurrences of quartz ± carbonate ± hematite ± sulphide ± arsenide ± pitchblende epithermal veins (e.g. South Contact Lake polymetallic vein), and localized zones of siliceous alteration. The alteration and mineralization at Mag Hill (and throughout the Echo Bay volcanic complex) is described as forming a transition from iron-oxide-apatite (IOA) through to IOCG sensu-stricto systems. It is also mechanistically similar (but not identical) to porphyry copper type systems in terms of its relationship to source sub-volcanic, intermediate composition calc-alkaline intrusions, and to the intermediate to distal alterations that grade from potassic (K-feldspar) to phyllic to propylitic (Mumin et al., 2007, 2010; Richards and Mumin 2013a, b; Somarin and Mumin, 2014). Widespread and intense magnetite-actinolite-apatite grades to peripheral magnetite-actinolite and then actinolite alteration in the Mag Hill area. It includes kilometre scale zones of a very unique alkali feldspar megacrystic to micropegmatic alteration with interstitial magnetite-actinolite-apatite alteration which gives the impression of being an igneous rock (Corriveau et al., 2010a, b; Mumin et al., 2010; see also Hildebrand 1984 for examples in the Camsell River district). This texture is thought to result from sealing of the hydrothermal system, resulting in recrystallization of the andesitic rocks under excess pressure and temperature. Outwards from the alkali-feldspar megacrystic rocks is a large halo of magnetite-actinolite-apatite veining, stockwork and breccia. The magnetite-actinolite-apatite alteration invades andesites that are K-feldspar, alkali feldspar, and/or hematite altered, and may include local areas with epidote, carbonate, silica and/or tourmaline alteration.

The Central and Southwest Blocks of the Mag Hill area are best known for the large areal extent of modestly vanadiferous magnetite in zones of magnetite-actinolite-apatite alteration. A stratiform, massive, hydrothermal hematite bed replaces porphyritic andesite in the Central Block, northwest of Hematite Lake. Trending eastwards along the shore of Contact Lake in the Southwest Block is the South Contact Lake polymetallic epithermal vein prospect. It is a quartz-carbonate-hematite vein, stockwork and breccia up to 2 m wide with copper, silver, uranium, cobalt, bismuth, zinc and gold enrichments in sulphides, arsenides and pitchblende. Other minor copper ± silver bearing quartz ± carbonate ± hematite veins are scattered throughout the area. A large pyritic gossan associated with southeast trending structures occupies the central area of the Northeast Block. It is an intense phyllic gossan that interfingers with potassic (K-feldspar) alteration. The zone is characterized by 1–10% pyrite (locally more) and trace chalcopyrite. However, drilling has revealed significant silver mineralization associated with the pyrite in parts of the zone (Fingler, 2006; Camier et al., 2007; Mumin et al., 2007, 2010; Somarin and Mumin, 2014).

Sheet 16: Skinny Lake Geology

The Skinny Lake map sheet lies southeast of the southeastern tip of Echo Bay, and covers an area of ca. 5.4 km^2. Stratigraphy is dominated by plagioclase porphyritic and amygdaloidal andesites of the Echo Bay volcanic field. They comprise several texturally unique andesite flows and tuffs. Most abundant are porphyritic and amygdaloidal andesite flows and tuffs that cover the central and southwestern portions of the map. Lithic, pyroclastic and laminated ash/crystal tuff and lapilli tuff are common in the northeastern map area, and include both subaerial and waterlain tuffs with or without pumice clasts. They typically strike northwest and dip northeast from 50^0 to 60^0. In several blocks, porphyritic andesite is intermixed with pyroclastic tuff. Microdiorite dykes of Mystery Island intrusive suite affinity invade volcanic rocks along the main NW-SE structural trend, with diabase cross-cutting in an east-southeast direction. Microdiorites are believed to be unaltered equivalents of sub-volcanic monzodiorite plutons (Mumin et al., 2007, 2010).

Skinny Lake provides an excellent example of orthogonal block displacement of the volcanic stratigraphy caused by a set of northwest-southeast and northeast-southwest trending tectonic disruptions. Illustrated in the map are major displacements only, as myriad minor disruptions are too small and complex to map and display at this scale. The Skinny Lake region, as with the entire Echo Bay stratovolcano complex can be interpreted as a "tectonic mega-breccia" which reflects the dynamic environment within which it formed. Abundance of structural disruptions documented here and elsewhere at Echo Bay are not normally visible in similar stratovolcano settings, due to overburden and younger volcanic cover. Excellent exposure and preservation of outcrop is due to the sub-arctic environment and an optimal erosion level, revealing the core of the volcanic complex. Northeast trending structures are believed to have been active before, during and after volcanic activity, and generally systematically offset stratigraphy in a right-lateral direction. Northwest trending structures are thought to displace rocks in both vertical and lateral offsets (Mumin et al., 2014).

Common alteration of the porphyritic andesite includes intermittent K-feldspar ± epidote ± actinolite ± magnetite with the alteration intensity and occurrences increasing to the southwest in proximity to sub-volcanic monzodiorite plutons (outcropping southeast of the Skinny Lake map sheet). Localized areas are affected by hematite replacement, including one lens northwest of Hematite Lake where andesite grades into massive hematite replacement beds. Intense phyllic alteration that is interfingered with potassic (K-feldspar) alteration replaces volcanic rocks in several areas. These zones form striking gossans at surface due to the presence of 1–5% pyrite (rarely up to 25% pyrite).

Mineralization is chiefly concentrated around the northern end of Skinny Lake and the northeast margin of Hematite Lake. Similar to the rest of the Echo Bay region, obvious gossans are the surface weathered expression of intense phyllic/potassic hydrothermal alteration accompanied by modest amounts of disseminated pyrite ± other sulphides. Copper as chalcopyrite ± bornite and malachite are located around the northern end of Skinny Lake in phyllic and or potassic altered volcanic rocks. One of the two drill holes through the gossanous area at the northwestern tip of Skinny Lake encountered significant copper, zinc, lead and silver mineralization (Alberta Star, pers. comm. 2007).

Sheet 17: Richardson Pluton Uranium Anomaly

The Richardson Pluton Uranium Anomaly map sheet is centered approximately 4 km south of Contact Lake, Echo Bay region, Northwest Territories, and covers the immediate area of strong uranium enrichment in plutonic rocks of the Great Bear Batholith south of the Echo Bay stratovolcano complex. The area was investigated due to highly anomalous gamma-ray responses in airborne radiometric surveys that were carried out for Alberta Star Development Corporation (Watson, 2007). High uranium contents in the granite are the apparent result of fluorine enrichment and extensive crystal fractionation of biotite, plagioclase and apatite from normal granitic magma of the Richardson Granite pluton (Somarin and Mumin, 2012). The uranium-enriched granite occupies the central part of the map sheet with normal granite along the western margin. Zones of porphyritic granodiorite occur at the center of the uranium-enriched phase and along the eastern part of the map sheet; the age relationships to the enclosing units are not defined. Spectrometer readings show that normal granite contains 3.0 to 4.9 ppm U, with anomalous readings of between 6.5 and 24.6 ppm U in the enriched phase (higher readings are recorded for occasional sub-mm pitchblende veins and from weathered crusts on fracture surfaces (Somarin and Mumin, 2012). The large and strong uranium anomaly detected in the airborne survey can be attributed to the cumulative impact of moderately anomalous gamma radiation being emitted from the exposed uranium-enriched granite.

Sheet 18: Contact Lake Belt Hydrothermal Alteration

The Contact Lake Belt encompasses an approximately 13 km by 4 km region between Echo Bay and Contact Lake. This map provides an overview of the geology, and illustrates the extent to which hydrothermal alteration can affect rocks of the Echo Bay stratovolcano complex, and the relationship to subvolcanic intrusions.

The central area of the belt is host to the linear Contact Lake monzodiorite pluton and other minor intrusions of the Mystery Island intrusive suite. It is surrounded and overlain by amygdaloidal and porphyritic andesite flows and breccia, and local lahar/debris flow. The monzodiorite is the upper potassic altered variant of subvolcanic diorite intrusions that fed the Echo Bay volcanic complex. Locally, fresh to weakly altered diorite dykes invade both monzodiorite and volcanic rocks. Reworked and often finely laminated locally-derived sedimentary rocks and volcanic tuffs occur in a belt along the northeast side of Echo Bay. They include arkose and conglomerate, and finely laminated volcanic ash tuffs, and are more extensive than indicated on the map due to lack of detailed mapping in this area (see also Skinny Lake map sheet, this series). The volcanic complex is bordered to the south by syenogranite and to the east by granodiorite of the Great Bear Batholith.

Structural disruption along the Contact Lake belt is complex and pervasive, (see Mumin, 2006, Figure 23, and Mumin et al., 2014). The belt follows a northwest trending series of structural breaks that are systematically right-laterally offset along northeast trending faults. Many of the major structures are obliterated by the pluton, and/or hidden under lakes and bays. Mumin et al., 2014 interpret the linear nature of subvolcanic plutons and the volcanic sequence to result from a post-collisional extensional relapse. However, some earlier investigators suggest that the volcanic episode is part of a collisional orogenic event (Hildebrand et al., 1987, 2010a).

The focus of the Contact Lake map is to illustrate the pervasive nature of hydrothermal alteration throughout the region. During field mapping, no hydrothermally "unaltered" rocks were encountered in the Contact Lake Belt area. Least-altered volcanic rocks of the belt are affected by a texturally preserving, but nevertheless pervasive recrystallization of volcanic rocks to a propylitic alteration assemblage, characterized by chlorite, epidote, carbonate, quartz ± albite. A pervasive and locally intermittent potassic alteration (K-feldspar ± biotite) is present in most rocks of the belt, and potassic alteration is also characteristic of the monzodiorite pluton. The potassic alteration grades from weak to strong, and locally forms significant areas of felsite in andesitic volcanic rocks. Locally, felsite is found along and straddling the contact of monzodiorite and andesite, and can be so intense that it becomes visually impossible to identify the contact between igneous and volcanic host rocks. Potassic alteration grades both locally and extensively into one or more of sodic (albite), magnetite-actinolite ± apatite, hematite, phyllic (quartz, sericite, pyrite) and tourmaline alteration (Hildebrand, 1986; Mumin et al., 2007, 2010). Alteration may occur as veins, stockworks and/or patchy to pervasive replacement. Alteration often preserves original volcanic and igneous textures, even to the extent of complete intense recrystallization such as in felsites, intense phyllic zones and pervasive propylitic and hematitic alteration. However, original textures may be obliterated as is the case when accompanied by structural disruptions and some types of complete recrystallization such as mosaic-textured magnetite-actinolite-apatite (see Mag-Hill sheets, this series), local felsites and albitites, and massive hematite. Other alterations include quartz veining and silicification, quartz-carbonate ± hematite (iron, calcium, magnesium and manganese carbonates) veining and stockworks. Field relationships and petrographic investigations indicate multiple pulses of superimposed alteration types, with both prograde and retrograde overprinting (Mumin et al., 2007; Corriveau et al., 2010b; Somarin and Mumin, 2012). The extensive hydrothermal alteration along the Contact Lake Belt is due to proximity to monzodiorite (diorite) plutons, and comprises at least four coalescing hydrothermal centres combined with the effects of irregular and diffuse fluid migration and alteration.

Copper, silver, uranium, zinc, lead, iron, vanadium, gold, cobalt and bismuth mineralization occurs intermittently in varying combinations as sulphides, arsenides and oxides throughout the belt. The most significant mineralized areas documented to date include: 1) the former Contact Lake mine (uranium, silver, copper, cobalt, bismuth) associated with quartz-carbonate-hematite veining hosted within the south-central Contact Lake pluton, 2) the K2 copper, silver ± gold and cobalt deposit, which forms a large deposit of disseminated low-grade mineralization in potassic-phyllic-tourmaline alteration. An upper sulpharsenide mineralized zone at K2 grades to massive hematite and magnetite-actinolite-apatite stockwork and veining at depth, 3) a large area of vanadiferous magnetite in magnetite-actinolite-apatite alteration in the Mag Hill area near the southeast end of Echo Bay, 4) some high-grade but small polymetallic epithermal deposits hosted in quartz-carbonate-hematite bearing veins such as the South Contact Lake and Bornite Lake prospects, and 5) silver and copper-zinc-lead-silver mineralization hosted in phyllic-potassic alteration zones at the southeast tip of Echo Bay and the northwest end of Skinny Lake. Other small vein and/or breccia hosted showings occur throughout the belt. The Thompson polymetallic vein prospect is unique in that it is hosted in a gabbro dyke within syenogranite south of the belt (Mumin, 2006; Fingler, 2006; Camier et al., 2007; Mumin et al., 2007, 2010; Somarin and Mumin, 2014).

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