Chapter 9

ECONOMIC GEOLOGY

9.1 Introduction

The South Mountain Batholith is host to the past-producing East Kemptville (Sn-Zn-Cu-Ag) and New Ross Manganese (Mn-Fe-P) Mines, the Millet Brook (U-Cu-Ag) deposit and numerous polymetallic prospects and occurrences. Several workers including Chatterjee (1980) and Chatterjee and Strong (1984) noted similarities in the geological setting, petrochemistry and style of mineralization and attending alteration of the Meguma Zone granitoid bodies and Hercynian granites of central and western Europe and other worldwide Paleozoic and Mesozoic fold belts. In light of the gregarious nature of worldwide granophile deposits, Giles and Chatterjee (1984) proposed that the discovery of the East Kemptville deposit was possibly the "tip of the iceberg" for mineral potential in the Meguma Zone. The primary goal of the South Mountain Batholith project, conducted as part of the 1984-1989 Canada-Nova Scotia Mineral Development Agreement, was the evaluation of the mineral potential of the batholith through geological mapping.

All known mineral deposits and occurrences were investigated, and numerous new occurrences were found, during the course of this project. Brief descriptions for all occurrences are given in the marginal notes that accompany the fourteen 1:50,000 scale geological maps listed in Figure 2.1. Essential information for each mineral occurrence including location, commodities, deposit type and map sheet reference have been tabulated and are presented in Appendix B. In addition to these brief descriptions, several occurrences have been mapped and/or sampled for further petrographic and geochemical study. The results of these investigations are outlined in several reports by Departmental staff including Corey (1988b), Finck et al. (1988), MacDonald and O'Reilly (1989), Corey and Horne (1989c), O'Reilly (1992), O'Reilly et al. (1992) and references therein.

This section of the report includes: a brief description of the exploration history in the batholith; an overall classification scheme for mineralization, based upon data from this study; and some observations regarding the age, distribution and various factors that govern the distribution of mineralization in the batholith.

9.2 Exploration History

In the early 1900s most mineral exploration centred on the potential for gold in the metasedimentary rocks of the Meguma Group (Malcolm, 1976; Bates, 1987). Despite this predominance of gold exploration, sporadic base metal exploration has been conducted in the South Mountain Batholith for more than a century. A summary of the overall exploration trends, with major exploration and discovery milestones, is presented here.

The first reported mineral occurrences in the batholith were mainly in the New Ross area and were found by early settlers. Occurrences include the Keddy prospect (Mo-Ta-Nb), where test pits were first excavated in 1890, and the Reeves tin pit (Sn-W-Ta-Nb-F), which was originally prospected in 1903 (O'Reilly *et al.*, 1982). Other prospects in the New Ross area include the Turner tin prospect (Sn-Cu-W-Zn), found in 1908, and the Walker molybdenite prospect (Mo-W-Sn-U-Cu-Ag-Mo-Bi), which was discovered in 1911 (Farley, 1978). Detailed descriptions of many of the early discovered prospects are given in O'Reilly *et al.* (1982), Charest (1976), Farley (1978), Logothetis (1985) and Charest *et al.* (1985). Pits and shafts were excavated at many of these occurrences for the purpose of bulk sampling; however, no mine production has been reported for any of these prospects.

In addition to the New Ross discoveries an occurrence of copper (chalcopyrite and chalcocite) in a quartz vein at Alton in Kings County was first found in 1876. A shaft was sunk at this occurrence but no production has been reported (Faribault, 1920).

Fault-controlled Mn-Fe minerals were first discovered north of the New Ross area in 1891, leading to the development of the Cain and Riddle Mine in the late 1890s. A second discovery of Mn-Fe in 1907 led to the development of the Dean and Chapter Mine approximately 3 km from the Cain and Riddle Mine. Production at the two mines, collectively termed the New Ross Manganese Mines, continued sporadically until 1940 when the last ore was mined for the war effort. Since then the only Mn-related activities in the batholith include bulk sampling at the former Cain and Riddle Mine in 1958 and limited reconnaissance work in the New Ross area in the early 1980s (O'Reilly, 1992).

Much of the central part of the batholith was mapped by the Geological Survey of Canada between 1900 and 1930. Numerous mineral occurrences were discovered, including: Morley's pegmatite (W-Sn-Be-Ta-Nb-Li; Faribault, 1908); Long Lake deposit (Mo-W-Be-Cu-As-F), Lake

Darling (Cu) and Nevertell Lake (Sn-W; Faribault, 1924); and Lake Ramsay (Zn-Sn-Au-Mo-Cu) and the Wallaback Lake Sn occurrence (also called Grassy Brook; Faribault, 1931). Most of the previously discovered deposits, including those in the New Ross area and the Westfield deposit, were also investigated during these regional mapping programs (O'Reilly *et al.*, 1982; O'Reilly, 1985).

Following these early mineral exploration activities, there was very limited exploration, primarily centred in the New Ross area and including the work of Douglas and Campbell (1942) and Wallace *et al.* (1963; see O'Reilly *et al.* (1982) for complete summary). The low level of exploration activity continued until 1976 when mineralized metasedimentary boulders (Sn-Zn-Cu-Ag) were discovered in newly excavated road fill near Yarmouth by prospector Merton Stewart while working for Maritime Exploration Limited. This discovery led to extensive exploration by numerous companies including Shell Canada, who discovered the East Kemptville Sn-Zn-Cu-Ag deposit in 1978 (Richardson *et al.*, 1982). This mine had initial reserves of 56 million metric tonnes grading at 0.165% Sn (Moyle, 1985). The mine was put into production as a 10,000 ton per day open pit mine in October 1985 and operated until January 1992 when the mine ceased operations because of economic reasons. Total production for the mine was 21 350 t Sn, 1 582 t Cu, 2 008 t Zn and 201.82 kg Ag (Kontak, 1994).

The discovery of polymetallic tin deposits in the southwestern part of the batholith touched off a major base metal exploration `boom' that continued until the early 1980s. Numerous occurrences were discovered throughout the batholith including important discoveries near Upper New Cornwall (Corey, 1983), Caledonia (MacGillivray, 1982), Bezanson Lake (Sinclair *et al.*, 1980) and Little Tobeatic Lake (Dickie and Zwicker, 1983).

Concurrent with this burst of base metal exploration was a major exploration `boom' for uranium. This activity was partially in response to the energy crisis of the 1970s. One of the principal catalysts for uranium exploration was the production of airborne gamma-ray spectrometric surveys (5 km spacing) over the Meguma Zone (Geological Survey of Canada, 1977). These surveys enabled exploration companies to focus their attention on highly evolved or `specialized' leucomonzogranite and leucogranite rock units that commonly host uranium deposits worldwide. Spectrometric surveys also proved useful for delineating uranium concentrations in lesser evolved granitic rocks.

Exploration activities by Acquitaine Company of Canada Ltd. led to the discovery of the Millet Brook U-Cu-Ag deposit in 1978 (Chatterjee *et al.*, 1982). Diamond-drilling indicated total reserves of approximately 1.0 million pounds of U_3O_8 with an average grade of 0.15 - 1.20% U_3O_8 over a 2.0 m width (Chatterjee *et al.*, 1985). Numerous other vein-type $U \pm Cu \pm Ag \pm P \pm F$ occurrences were discovered throughout the batholith including the Gaspereau Lake (also named Aylesford Lake) occurrence (Low and Farstad, 1978a) and the East Dalhousie occurrence (Lowe and Farstad, 1978b) which were found by Esso Minerals Canada. Shell Canada focused much of their uranium exploration activity along the northern margin of the batholith, resulting in the discovery of several mineral occurrences, including those at Randall Lake (St. George, 1982; MacDonald and Ham, 1992), Inglisville Church (Dickie and Jensen, 1981; MacDonald and Ham, 1989b), Shortliff Lake (Dakers, 1982; MacDonald and Ham 1989a) and Lambs Lake (Dakers, 1982; Corey and Horne, 1989a). All uranium exploration activities in the batholith, including the development-related work at Millet Brook, were terminated by a province-wide uranium moratorium announced by the Government of Nova Scotia on September 21, 1981. The moratorium was still in effect at the time this report was prepared.

There has been minimal mineral exploration in the South Mountain Batholith since 1982. The most notable exception was the production- and exploration-related work at, and near, the East Kemptville mine, which was terminated in 1992. Also, there has been limited exploration for base metals and precious metals in the southwestern Nova Scotia tin domain (see discussion below).

9.3 Mineral Deposit Types

Mineral deposits of the South Mountain Batholith have been classified into five main groups: greisen, vein, breccia, pegmatite and peribatholithic deposits. The distribution of these deposit types is shown in Figure 9.1. A schematic diagram outlining the modes of occurrence of the main deposit types, including orientation of ore zones, proximity to granite-metasediment contacts, and host rocks, is given in Figure 9.2 and summarized in Table 9.1. Summaries of each deposit type, and brief descriptions of important occurrences, are given in the following sections.

9.3.1 Greisen Deposits (Sn, W, Mo, As, Cu, Pb, Zn, F, Au, Ag)

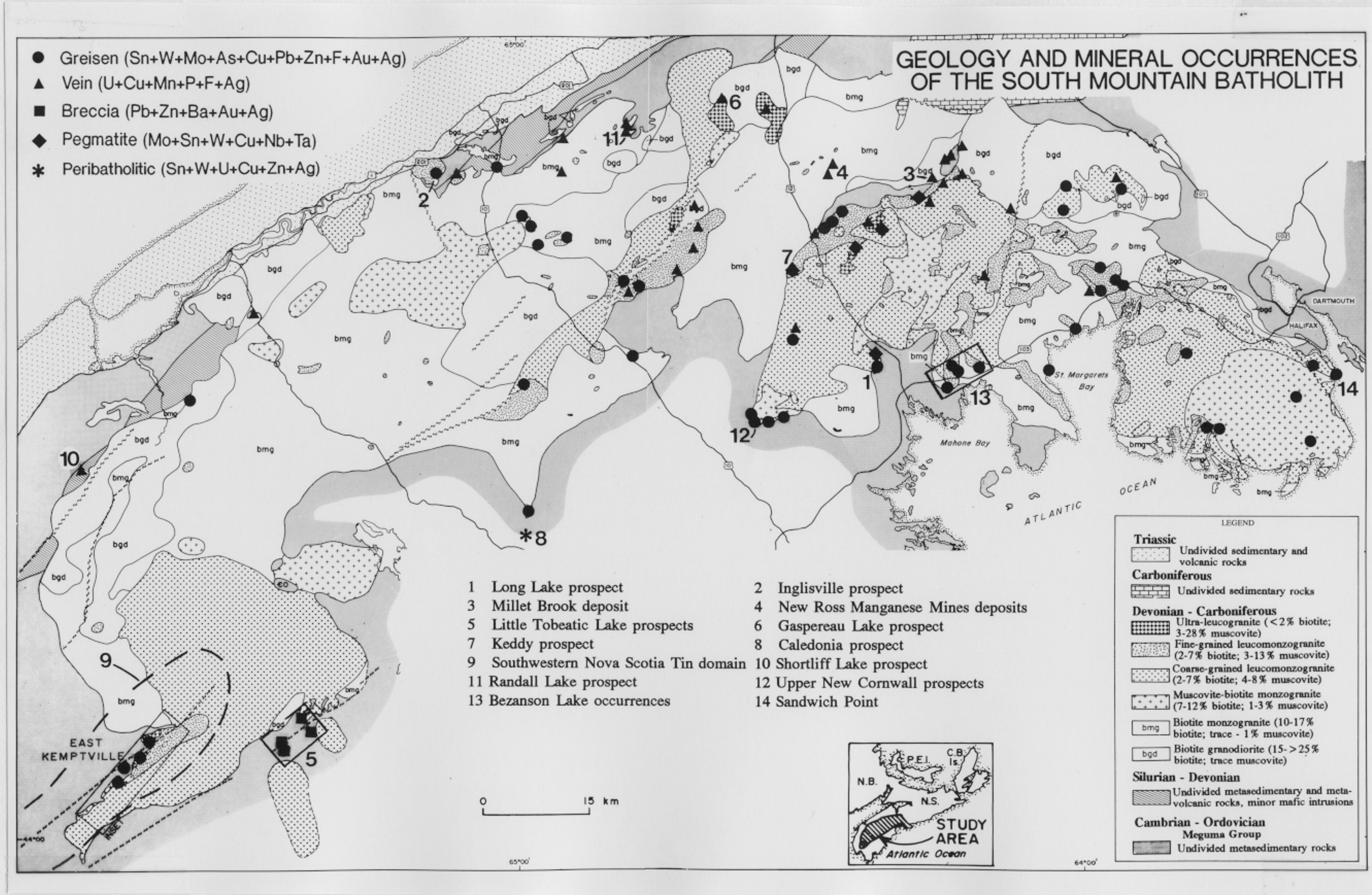


Figure 9.1 Geological map of the South Mountain Batholith showing the distribution of the major rock types. The location and type of all mineral deposits and occurrences are also indicated.

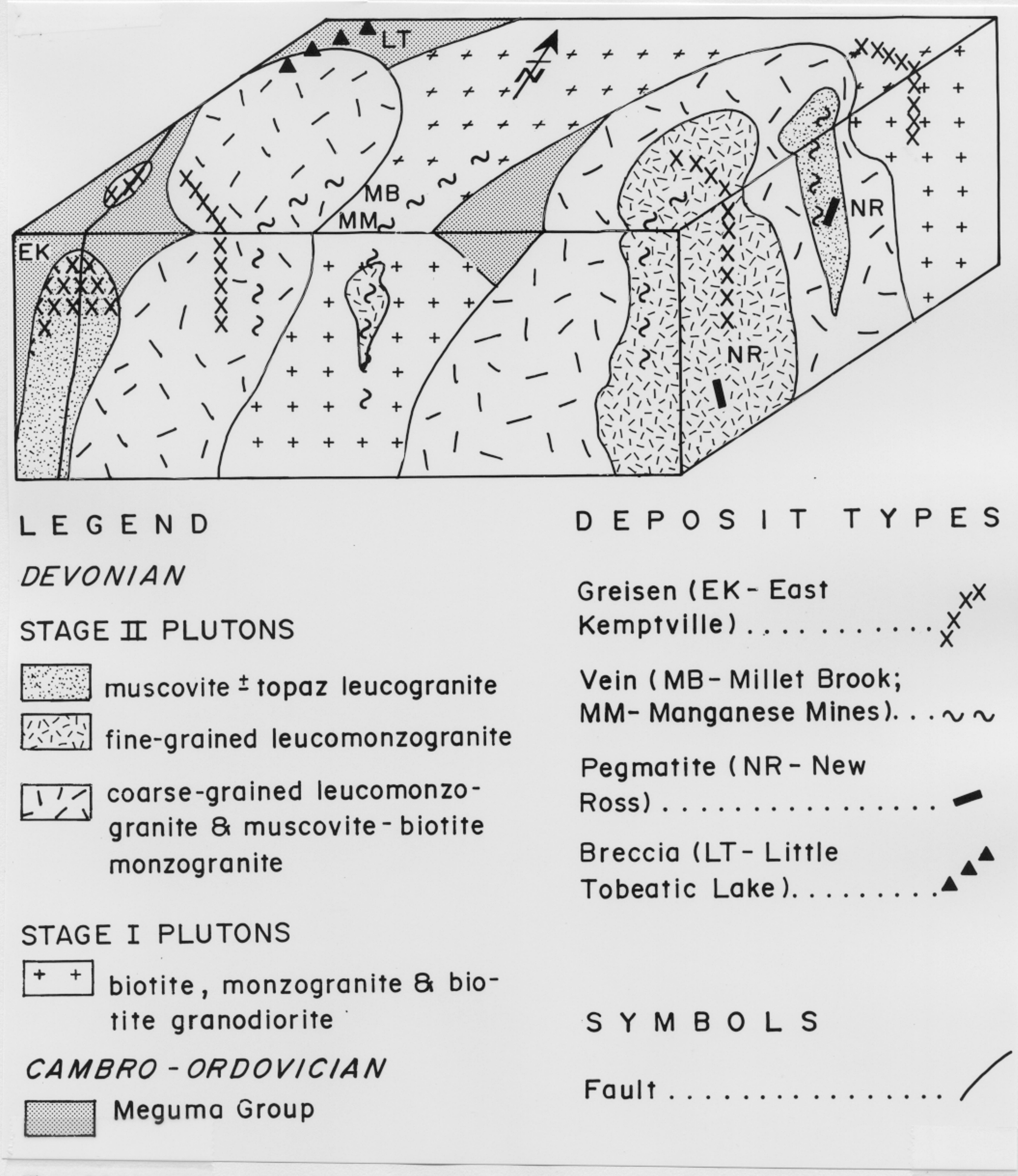


Figure 9.2 Schematic diagram outlining the distribution of the five deposit types in the Stage I and II plutons of the batholith.

Table 9.1 Summary of characteristic features of granite-hosted and peribatholithic mineral occurrences for the South Mountain Batholith.

Deposit Type	Elements	Host Rock(s)	Alteration	Structure, Orientation	Comments
Greisen	Sn,W,Mo,As,Cu,Pb,Zn,F,Au, Ag	granodiorite, biotite ± muscovite monzogranite, leucomonzogranite, leucogranite	greisenization (quartz, muscovite, tourmaline), albitization, K-feldspathization	NW-trending quartz-greisen veins	largest deposits at pluton margins at shallow-dipping contact(s) and are hosted by "specialized" leucomonzogranite or leucogranite. Good economic potential.
Vein	U,Cu,Mn,P,F,Ag	granodiorite, biotite ± muscovite monzogranite, leucomonzogranite, leucogranite	hematization, desilicification, albitization, clay alteration	NE-trending shear/fracture zones	largest deposits occur in interior portions of Stage I Plutons of the SMB and are hosted by granodiorite and biotite monzogranite. Good economic potential.
Breccia	Pb,Zn,Cu,Ba,Au,Ag,P	leucomonzogranite	silicification, kaolinization	Little Tobeatic Lake prospect is along part of the NE-trending TFZ, Dunbrack deposit in fault bounded dilation zone	mineralized zones show multiple superimposed episodes of silicification and brecciation, quartz textures typical of epizonal deposits. Potential for base- and precious-metal deposits.
Pegmatite	New Ross- Mo,Sn,W,Cu,Nb, Ta±Be±Li Southwest Meguma Zone- Be,Li±Sn±W±Ta±Nb	New Ross- fine and coarse-grained leucomonzogranite Southwest Meguma Zone- tonalite, granodiorite, monzogranite, leucomonzogranite, metasedimentary and metavolcanic rocks	minor greisenization, absent in most	New Ross- randomly oriented pods, lenses and dykes SW Meguma Zone- some sub-horizontal sheeted dykes	Good potential for gemstone and possibly spodumene in large dykes of SW Meguma Zone Low economic potential for small dykes near New Ross and rest of SMB.
Peribatholithic	Sn,W,U,Mo,Cu,Zn,Ag,Au	metasedimentary and metavolcanic rocks	hematization, chloritization and growth of spessartine garnets (e.g. Duck Pond), silicification, sericitization and development of skarn (i.e. calc-silicate) mineralogy	mineralized zones consist of: variably oriented veins and dykes; stratabound zones in N or NE trending regional structures; variably oriented alteration zones may be hosted by brecciated and hematized host rocks (e.g. Shortliff Lake)	Located outside the periphery of the batholith, often associated with contact metamorphism in host rocks Some occurrences have associated aplite, fine-grained leucogranite or pegmatite dykes Good economic potential

Mineral deposits in greisen occur throughout the batholith in both Stage I and Stage II plutons and are hosted by rocks ranging in composition from biotite granodiorite and mafic porphyry to muscovite-topaz leucogranite. Greisen-type occurrences are distributed throughout the entire batholith but the largest deposits and occurrences are either at, or proximal to, shallow-dipping contact zones between granite and metasediment, and to a lesser extent granite-granite contact zones. Some greisen-type deposits are spatially associated with major fault or shear zones, such as the East Kemptville tin deposit. However, at present it is not clear whether or not these structures have a genetic relationship with attending greisen mineralization; that is, whether structures served as loci for ore deposition. Many occurrences are restricted to, or have associated greisen-bordered quartz veins. These veins are predominantly oriented to the northwest (Fig. 9.3a), as noted by Horne *et al.* (1992).

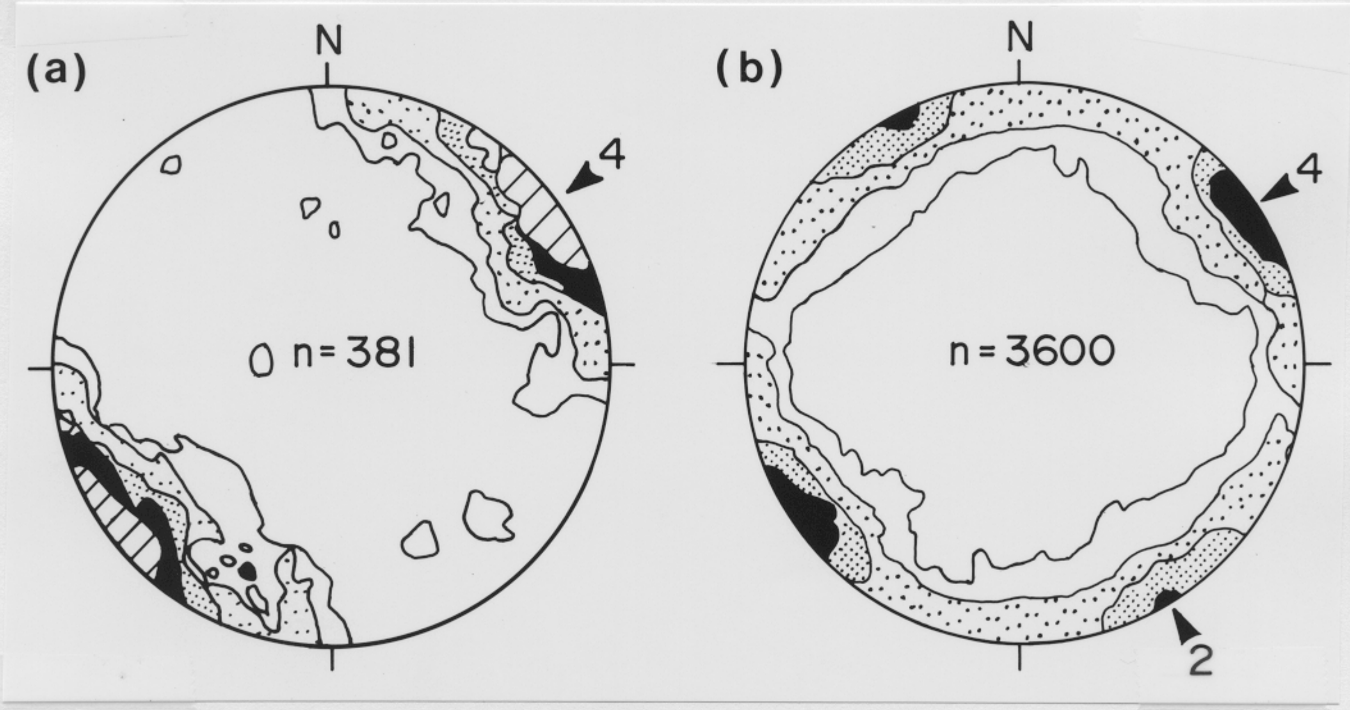


Figure 9.3 Contoured density plots (after Horne et al., 1988; 1992) of poles to: a) quartz veins (in 1% area; N=381) from the entire batholith; and b) all joints in the eastern part of the SMB (N=3600). Hematized joint, fracture and shear zones are mostly restricted to joint trend #2.

Greisen-type deposits occur as: (1) massive greisen zones generally ranging from 1-100 m in width and mostly occurring near contact zones. Some zones show development of zonation (e.g. Inglisville; O'Reilly *et al.*, 1992); (2) northwest-trending, quartz-muscovite greisen-bordered quartz veins. Greisen borders range from <1 cm to approximately 1 m in width; and (3) sheeted quartz vein and quartz-muscovite greisen zones that are up to 500 m in length (e.g. Sandwich Point; MacDonald and O'Reilly, 1989). Characteristic ore minerals for greisen-type deposits include cassiterite, wolframite, scheelite, molybdenite, arsenopyrite, chalcopyrite, chalcocite, bornite, malachite, sphalerite, galena, fluorite and pyrite. A wide range of alteration mineral assemblages is associated with these deposit, including combinations of quartz, albite, K-feldspar, muscovite (phengite), topaz, tourmaline, fluorite and garnet.

Greisen-type mineral deposits may be dominated by quartz-topaz, quartz-muscovite, quartz-tourmaline or quartz-muscovite-tourmaline-topaz mineral assemblages, presumably reflecting the dominance of Si-F, Si-K, Si-B and Si-K-B-F elemental assemblages in the hydrothermal fluids that formed the greisens. The following are descriptions of significant greisen deposits that characterize three of these elemental assemblages.

Quartz-Topaz Greisen - East Kemptville Deposit (Sn-Zn-Cu-Ag)

The East Kemptville Sn-Zn-Cu-Ag deposit (Fig. 9.1) is a greisen-type deposit hosted by the muscovite-topaz-bearing East Kemptville leucogranite (Kontak, 1988) along the southwestern margin of the Stage II Davis Lake Pluton (Ham and MacDonald, 1991). As noted above, the deposit was discovered using geochemical and drift prospecting techniques by Shell Canada Resources in 1978 (McAuslan *et al.*, 1980). Subsequent diamond- drilling delineated a deposit consisting of an estimated 56,000,000 tonnes of 0.165% Sn (Richardson, 1984; Moyle, 1985). Open pit production of ore began in 1985 and continued until January 1992 when mine operations ceased. Estimated reserves as of January 1991 were 15,200,000 tonnes of 0.206% Sn (O'Reilly *et al.*, 1992). The East Kemptville deposit is arguably the most significant deposit in the South Mountain Batholith that has been discovered to date.

The deposit consists of two separate ore zones: the `main zone' which forms an elongate embayment of leucogranite and associated greisens and the `baby zone' consisting of greisenized leucogranite (Fig. 9.4a). Kontak (1990) concluded that the muscovite-topaz leucogranite that hosts the deposit was intruded into the metasedimentary rocks of the Meguma Group and later overprinted by mineralized greisens. Ore grade enrichment (>0.165% Sn) is present in the

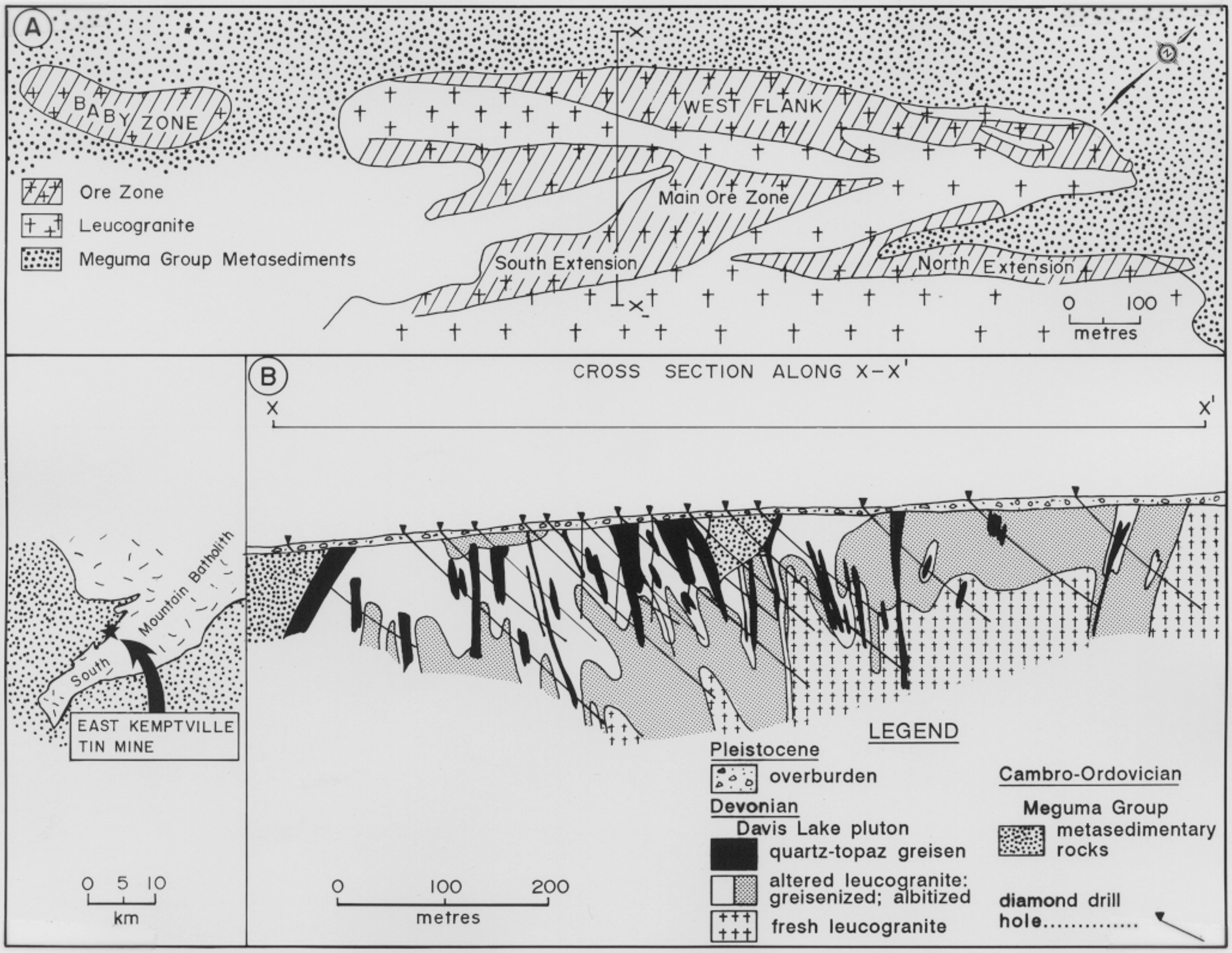


Figure 9.4 Plan map (A) and cross-section of the East Kemptville Sn-Zn-Cu-Ag deposit showing the location of the main and baby ore zones (after O'Reilly et al., 1992). Note the ore zones are proximal to the granite/metasediment contacts as shown in the plan map. Also note the close spatial association of quartz-topaz greisens to greisenized and albitized muscovite-topaz leucogranite.

upper 200 m of the 'baby zone' and ranges from absent to 200 m depth in the main zone (O'Reilly *et al.*, 1992). The ore zones in the main zone are directly adjacent to, and beneath, a shallow-dipping contact with metagreywacke of the Goldenville Formation, as shown in Figure 9.4b (Richardson, 1988; Kontak, 1990; O'Reilly *et al.*, 1992).

Minerals occur in two styles: (1) disseminated cassiterite, chalcopyrite, bornite, sphalerite and pyrite in dark grey to black quartz-topaz greisen. These greisen zones are mostly bordered by greisenized leucogranite, which in turn is bounded by zones of albitized leucogranite; and (2) zoned greisen veins with cores of massive cassiterite bordered by inner zones of quartz-topaz±muscovite greisen and outer zones of quartz-muscovite greisen grading into unaltered muscovite-topaz leucogranite (Richardson, 1984; Kontak, 1990; O'Reilly *et al.*, 1992). Most of the ore along contact zones consists of the first type of greisen and surrounding greisenized or albitized leucogranite, as depicted in Figure 9.4b, whereas the second type of greisen occurs throughout the pit areas. Richardson (1984) reported a complex series of later or cross-cutting quartz±sulphide±phosphate± fluorite±beryl±carbonate±zeolite veins. She reported an extensive list of ore and gangue minerals, with accompanying paragenetic sequence, that includes cassiterite, chalcopyrite, sphalerite, pyrite, pyrrhotite, arsenopyrite, wolframite, molybdenite, galena, topaz, fluorite, quartz, muscovite, stannite, fluorapatite, triplite, illite, siderite, dolomite, marcasite, dickite, stilbite, childrenite, vivianite, rhodochrosite, rozenite, covellite, native copper, kellyite, beryl and columbite.

Several models have been proposed for the origin of the East Kemptville deposit and its leucogranite-leucomonzogranite host rocks. Richardson *et al.* (1982) and Chatterjee and Strong (1984, 1985) concluded that the East Kemptville greisens and associated greisenized leucomonzogranite were produced by alteration of a coarse-grained megacrystic phase of the circa 370 Ma South Mountain Batholith. In light of Rb-Sr geochronological data Richardson (1988) concluded that the deposit and indeed the entire Davis Lake Pluton was intruded and crystallized circa 330 Ma, approximately 40 million years after the main intrusion of the South Mountain Batholith. Kontak (1990) concluded that the deposit was formed by hydrothermal alteration of a discrete body of muscovite-topaz leucogranite. Kontak *et al.* (1989), Kontak and Cormier (1991), and Kontak and Chatterjee (1992) concluded that the East Kemptville deposit and associated granitoid rocks of the Davis Lake Pluton were emplaced and crystallized circa 370 Ma and the `younger' date acquired by various workers in this pluton represents later thermotectonic overprinting and resetting.

Quartz-Muscovite Greisen - Long Lake Prospect (Mo-W-Sn-Be-Cu-Zn-Ag)

The Long Lake Mo-W-Sn-Be-Cu-Zn-Ag prospect (Figs. 9.1 and 9.5) is a greisen-type deposit along a shallow-dipping granite-metasediment contact zone in the southern portion of the Stage II New Ross Pluton (O'Reilly *et al.*, 1982). The deposit was drilled during several stages

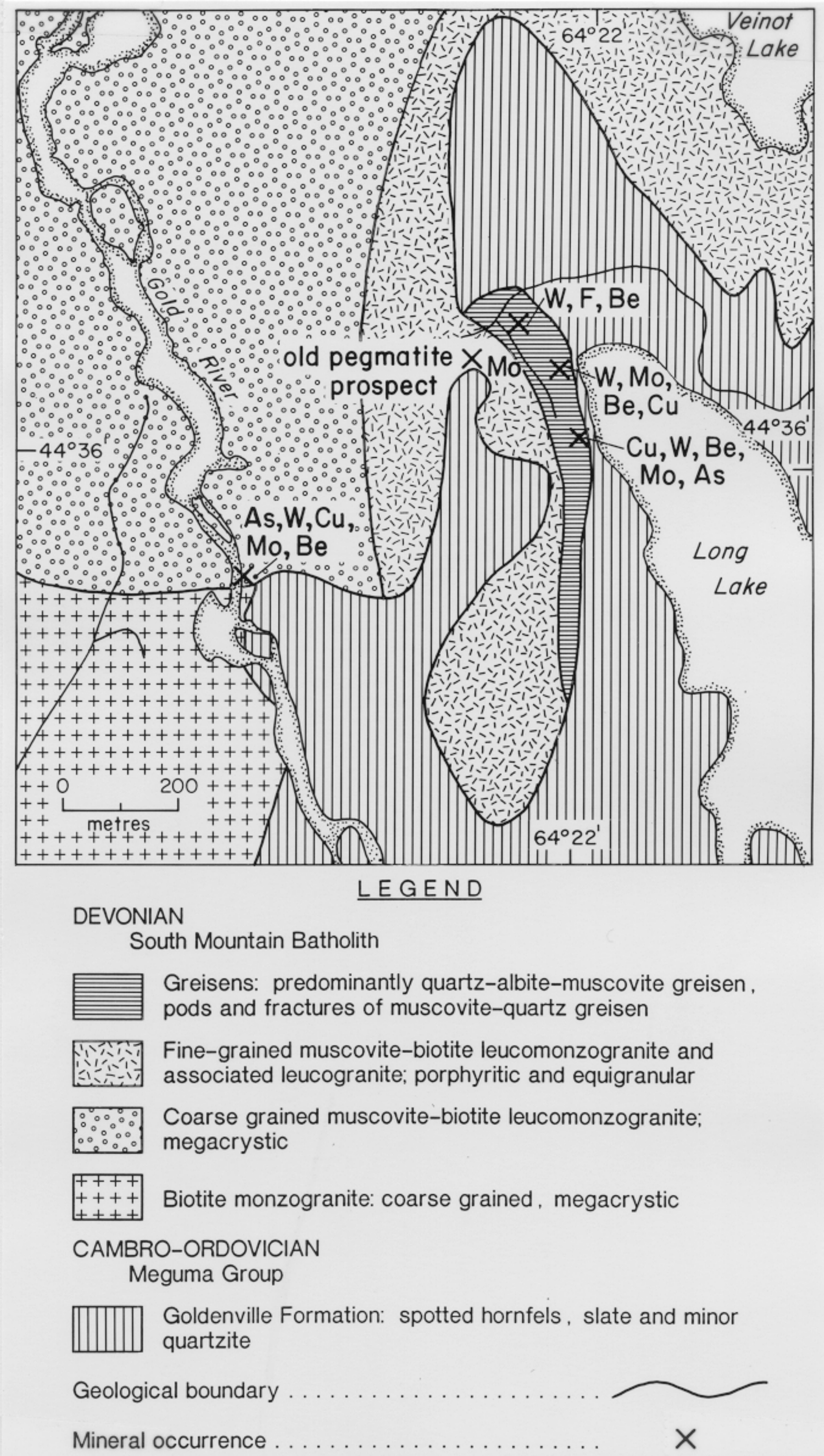


Figure 9.5 Geology map of the Long Lake Mo-W-Sn-Be-Zn-Cu prospect (after O'Reilly et al., 1982). Mineralized and barren greisens are mostly restricted to quartz-muscovite-albite greisen zone developed along the shallow-dipping granite/metasediment contact. Pegmatite-hosted Mo mineralization occurs mostly in a microclinized fine grained leucomonzogranite.

of exploration but no estimates of the reserves are available.

The greisens and associated minerals at Long Lake are hosted by fine-grained leucomonzogranite and associated leucogranite at the contact with greenish slate of the Green Bay Formation (Corey, 1988a). Quartz-muscovite greisen pods and infillings are locally developed along irregular fractures, in addition to the pervasive quartz-muscovite-albite greisen. Both greisen types are host to mineralized disseminations, vugs and fracture fillings consisting of chalcopyrite, pyrite, arsenopyrite, wolframite, scheelite, molybdenite and fluorite. These greisen zones have been traced for 230 m along the granite metasediment contact and mainly range in width from 50-100 m (O'Reilly *et al.*, 1982).

Adjacent to the intensely greisenized zone is a larger band of microclinized leucomonzogranite and associated leucogranite. Most rocks in this band contain the assemblage quartz-orthoclase-albite-muscovite which is gradational with the greisen assemblage described above. Minerals occur in quartz-microcline veins and pegmatites, with local bands and scattered blebs of molybdenite.

MacDonald *et al.* (1988) noted that the leucogranite associated with the Long Lake deposit is gradational with the host leucomonzogranite. They, and later Clarke *et al.* (1993), concluded, based on field, petrological and geochemical data, that the muscovite leucogranite was formed by hydrothermal alteration of fine-grained leucomonzogranite, possibly by fluids that also produced the Long Lake greisens and associated mineralization.

Quartz-Tourmaline Greisen - Inglisville Prospect (Mo-As-Bi-Au)

A series of complexly zoned greisens are developed at Inglisville along the margin of a body of fine-grained leucomonzogranite immediately adjacent to the contact with hornfelsed slate of the Halifax Formation (Figs. 9.1 and 9.6; MacDonald and Ham, 1989b; Cormier, 1989). The greisen assemblage consists of a pervasive quartz-muscovite greisen that contains trace to minor amounts of biotite, tourmaline, garnet, chloritoid, chlorite and apatite. Superimposed on this assemblage are numerous zoned greisens consisting of tourmaline-greisen cores and quartz-greisen rims. The tourmaline greisens contain minor amounts of quartz and muscovite and trace amounts of chlorite and scheelite, whereas the quartz-dominant greisens contain minor muscovite and trace garnet, chloritoid, chlorite, wolframite and arsenopyrite. Small zones of greisen consisting of >95% muscovite occur in several of the greisen exposures. No detailed petrographic information

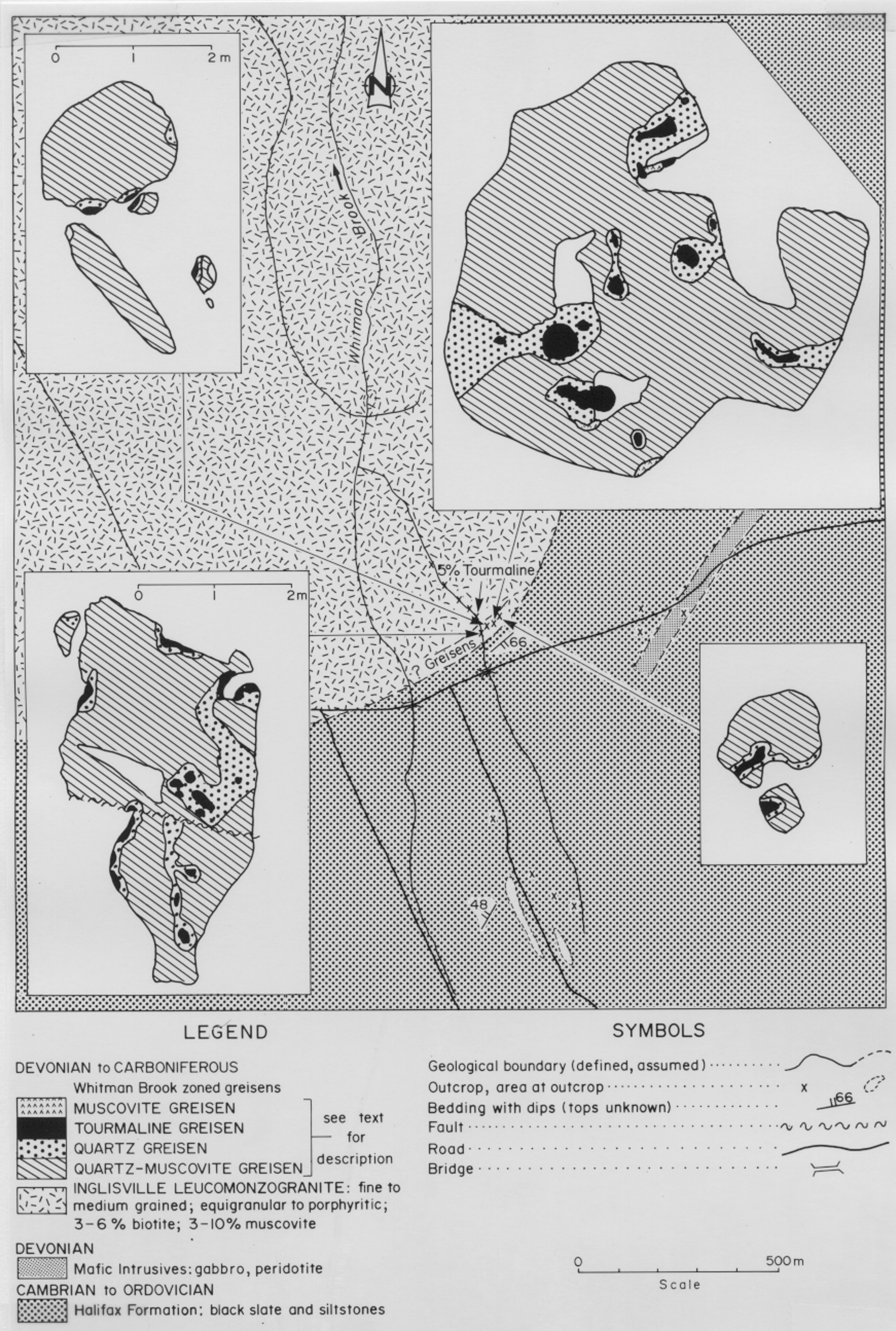


Figure 9.6 Detailed geological map of the Inglisville zoned greisens (modified from Cormier, 1989). Note the zonal distribution of quartz muscovite-, quartz- and tourmaline-dominated greisens with erratically distributed "pinch and swell" features. Several small ($\leq$30 cm) patches of muscovite-dominated greisen are randomly distributed throughout the area.

is available for this greisen type. The muscovite-dominant greisens do not form part of the zoned greisen assemblage and their distribution appears to be random with respect to other greisen types.

Virtually all of the feldspars have been obliterated in all four greisen types at Inglisville. The paucity of feldspars is reflected in the low concentrations of CaO, Na_2O and K_2O in the greisens compared with the host leucomonzogranite (O'Reilly *et al.*, 1992). The high levels of SiO_2 correspond to high modal percentages of quartz in the quartz-muscovite and quartz greisens. In general the greisens are depleted in P_2O_5, Ba, Rb and Sr and enriched in Ta, Nb, U, F, B, As, Au and W when compared with the host Inglisville leucomonzogranite. The erratic distribution of most major and trace elements in the greisen assemblage reflects the mineralogy of individual greisen types. For example, the highest B concentration is in the tourmaline greisen whereas the highest F and Li levels are in the muscovite-rich greisens.

The Inglisville greisens contain the first reported occurrence of chloritoid in a Meguma Zone granitoid body (Cormier, 1989). Chloritoid has also been reported in the sediment-hosted, exo-contact Duck Pond deposit (O'Reilly *et al.*, 1992). The Inglisville greisens also have the first reported occurrence of loellingite ($FeAs_2$) in a granitic rock of the Meguma Zone. Trace amounts of loellingite were noted in a few samples of quartz-muscovite greisen. The presence of this sulphur-deficient mineral is interesting, particularly in light of the occurrence of trace amounts of sulphide minerals (e.g. molybdenite and arsenopyrite) within the same greisen system.

The Inglisville greisens are variably enriched in both Bi and Au with concentrations of up to 2400 ppm Bi and 690 ppb Au in samples of quartz-muscovite greisen. A Bi-bearing metallic mineral was detected by microprobe analysis. This mineral may be native bismuth or possibly a Bi-Au mineral phase similar to a mineral phase in the Big Indian Lake Pluton (M. C. Corey, personal communication) which would explain the high Au concentrations. MacDonald and O'Reilly (1989) noted significant gold enrichment in several greisen zones at, or near, granite-metasediment contacts throughout the South Mountain Batholith. They suggested that circulation of hydrothermal fluids through Au-bearing metasediments could be the source for the observed Au ($\pm$Bi) enrichment.

9.3.2 Vein Deposits (U, Cu, Mn, P, F, Ag)

Vein deposits occur throughout the batholith (Fig. 9.1), in both Stage I and II plutons, and are hosted by rocks ranging in composition from biotite granodiorite to muscovite-topaz leucogranite. Unlike greisen-type deposits the largest vein deposits do not occur near contact zones but are in the interior of the batholith. Also the largest vein deposits, which include the Millet Brook U-Cu-Ag deposit and the former New Ross manganese mines (Fig. 9.7), are hosted by Stage I plutons, in contrast to greisen-type deposits primarily hosted by Stage II plutons. Vein-type deposits are invariably developed along northeast-trending fracture, fault or shear

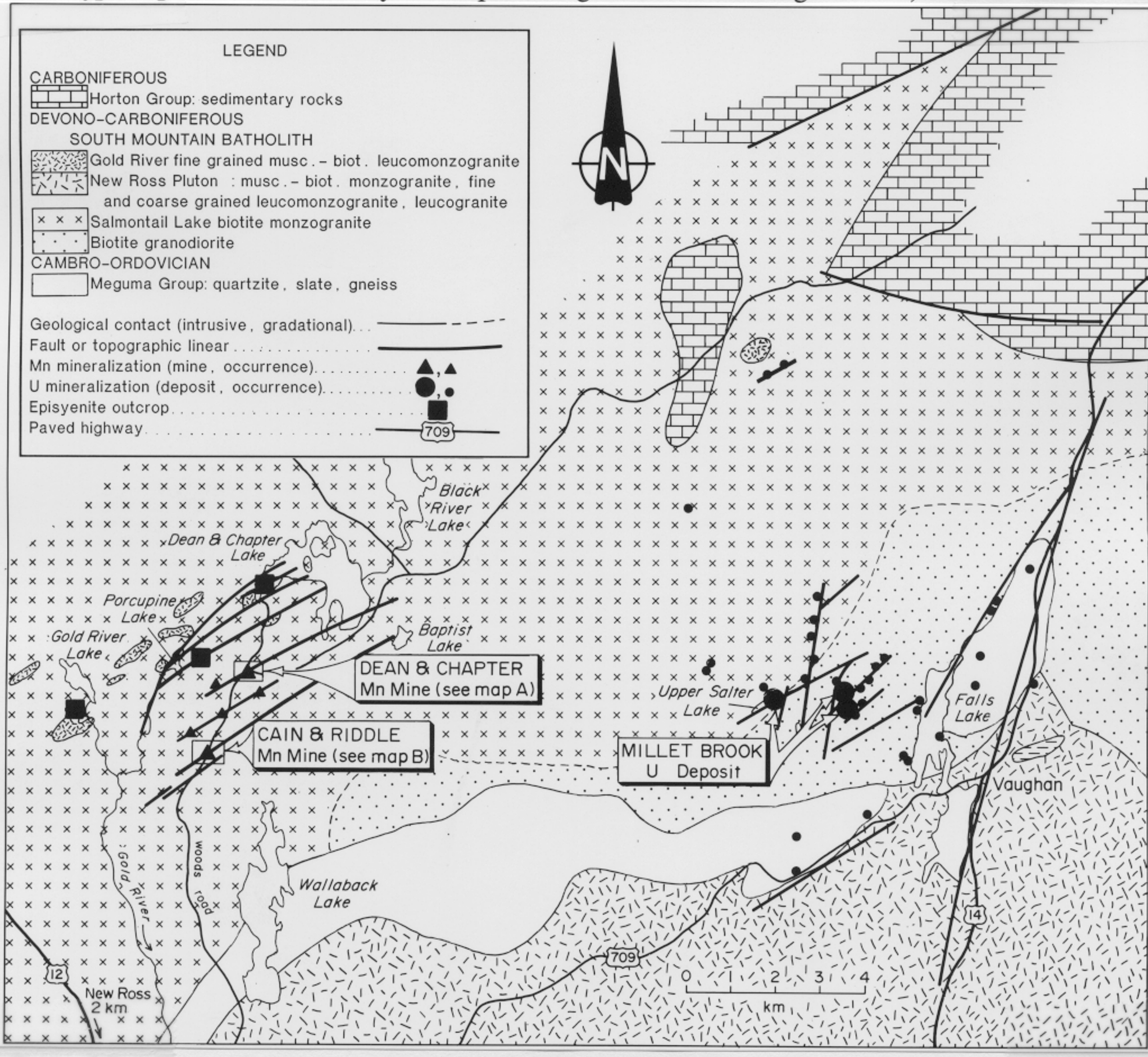


Figure 9.7 Geological map showing the location of the Millet Brook U-Cu-Ag Deposit and the New Ross Manganese (Mn-Fe) Mines (after O'Reilly et al., 1992).

zones, as noted by Horne *et al.* (1992; trend #2 in Fig. 9.3b). These zones are always intensely hematized and may display variable amounts of desilicification, albitization and clay alteration.

Vein-type mineral deposits may be dominated by U±Cu±Ag±P±F or Mn-Fe±P assemblages. The following are descriptions of the largest deposits that characterize these two vein-type metal associations.

Millet Brook Deposit (U-Cu-Ag)

The Millet Brook U-Cu-Ag deposit consists of mineralized veins in steeply-dipping, northeast-trending, en-echelon fracture zones (Fig. 9.8; Chatterjee *et al.*, 1985). The Millet Brook deposit is hosted by biotite granodiorite and Salmontail Lake biotite monzogranite and is situated approximately 2.5 km north and northwest of a metasedimentary inlier that extends from New Ross to Vaughan and forms the boundary between the Stage I Salmontail Pluton to the north and the Stage II New Ross Pluton to the south (Fig. 9.7). The en-echelon fracture-related nature of individual ore zones is graphically depicted in Figure 9.8. Veinlets and dykes of muscovite

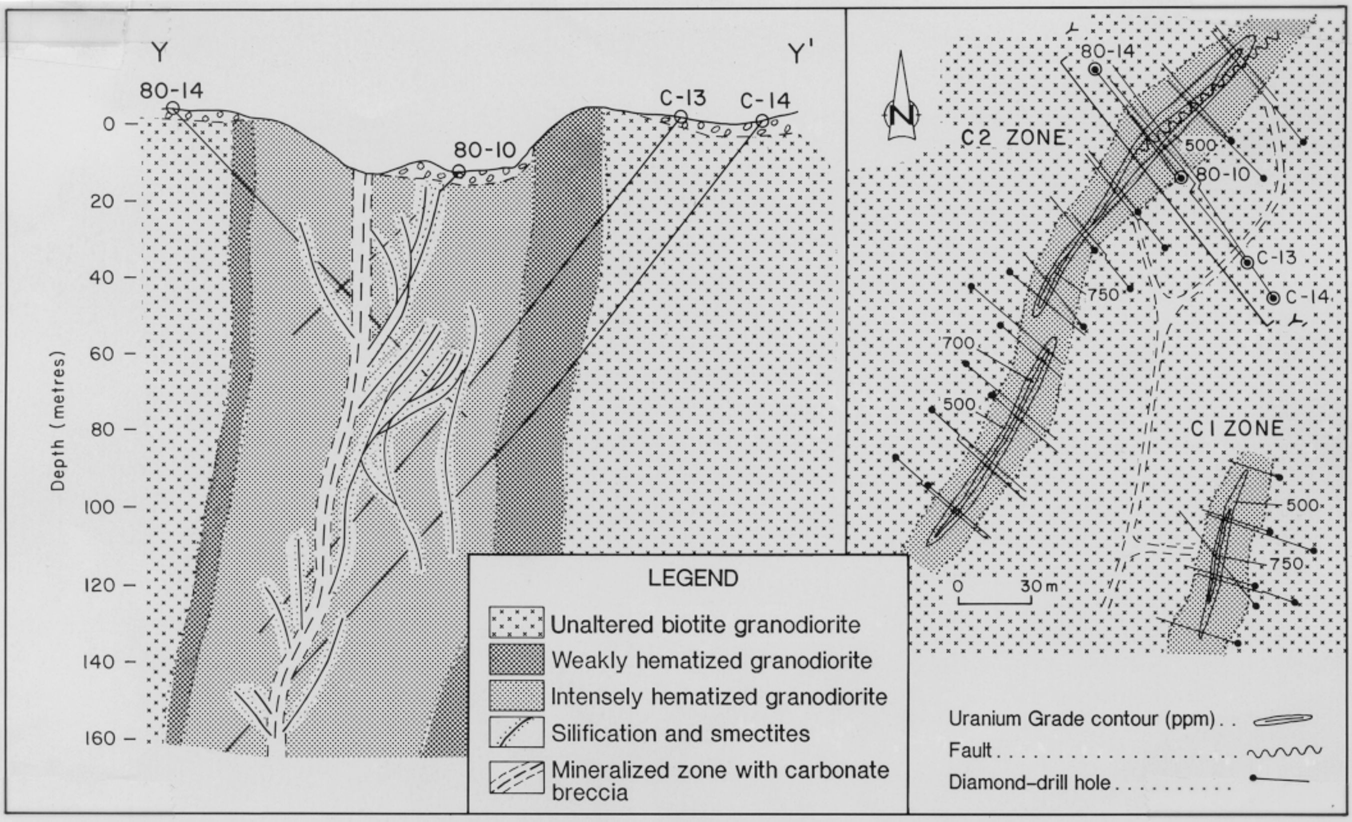


Figure 9.8 Plan map and cross-section from the Millet Brook U-Cu-A deposit showing the fracture-related nature, and en-echelon distribution, of individual ore zones (courtesy of G.A. O'Reilly).

leucogranite, texturally and mineralogically similar to the Lake Lewis leucogranite of the New

Ross Pluton, were noted in drill core from several mineralized zones in the northern part of the Millet Brook deposit area (Chatterjee at al., 1985). The deposit has drill-estimated reserves of 1.0 million pounds U_3O_8 with average grades of 0.15-0.20% U_3O_8 over a 2.0 m width with a cut-off grade of 0.10% U_3O_8 (Chatterjee *et al.*, 1982).

Pitchblende is the dominant uranium-bearing mineral in ore zones below 50 m depth, as outlined by drilling, whereas the U-phosphate minerals torbernite, autunite and Pb-meta-autunite are the dominant minerals above 50 m depth. This feature is as a result of surface weathering processes. Other ore minerals present in minor amounts at all depths include chalcopyrite, bornite, covellite, chalcocite, proustite, galena, sphalerite and wolframite. Gangue minerals include quartz, feldspars, micas, illite-smectite, andalusite, hematite, kaolinite, tourmaline, chlorite, calcite-ankerite, pyrite, Mn-oxides and anatase (Chatterjee *et al.*, 1982).

Alteration of the host biotite granodiorite is mainly confined to approximately 30 m from mineralized fractures and consists of albitization, muscovitization, biotitization, chloritization, K-feldspathization and carbonatization. Widespread hematization, consisting mainly of turbid or cloudy plagioclase and to a lesser extent K-feldspar, is partially as a result of the chloritization of biotite, a process that liberates Fe. Intense hematization and biotitization are closely associated with some ore zones (Corey, 1988b) and indicate the net introduction of Fe. Additionally, some ore zones have associated episyenite (desilicification) and/or silicified zones (Clarke and Chatterjee, 1988). The above alteration features are complexly inter-related in the Millet Brook deposit and there is no single characteristic alteration configuration surrounding mineralized veins.

New Ross Deposits (Mn-Fe-P)

As previously noted, the New Ross deposits, located approximately 10 km north of New Ross (Fig. 9.7), consist of two main centres, the former Cain and Riddle Mine and the former Dean and Chapter Mine. Manganese minerals occur in Mn-oxide veins and lenses along steeply-dipping, northeast-trending faults. Weeks (1946) estimated 41,000 tons of combined ore reserves from both mines. A full description of the geology, petrography and geochemistry has recently been published (O'Reilly, 1992), and the following description draws extensively from this work.

The manganese deposits are hosted by the Salmontail Lake biotite monzogranite of the

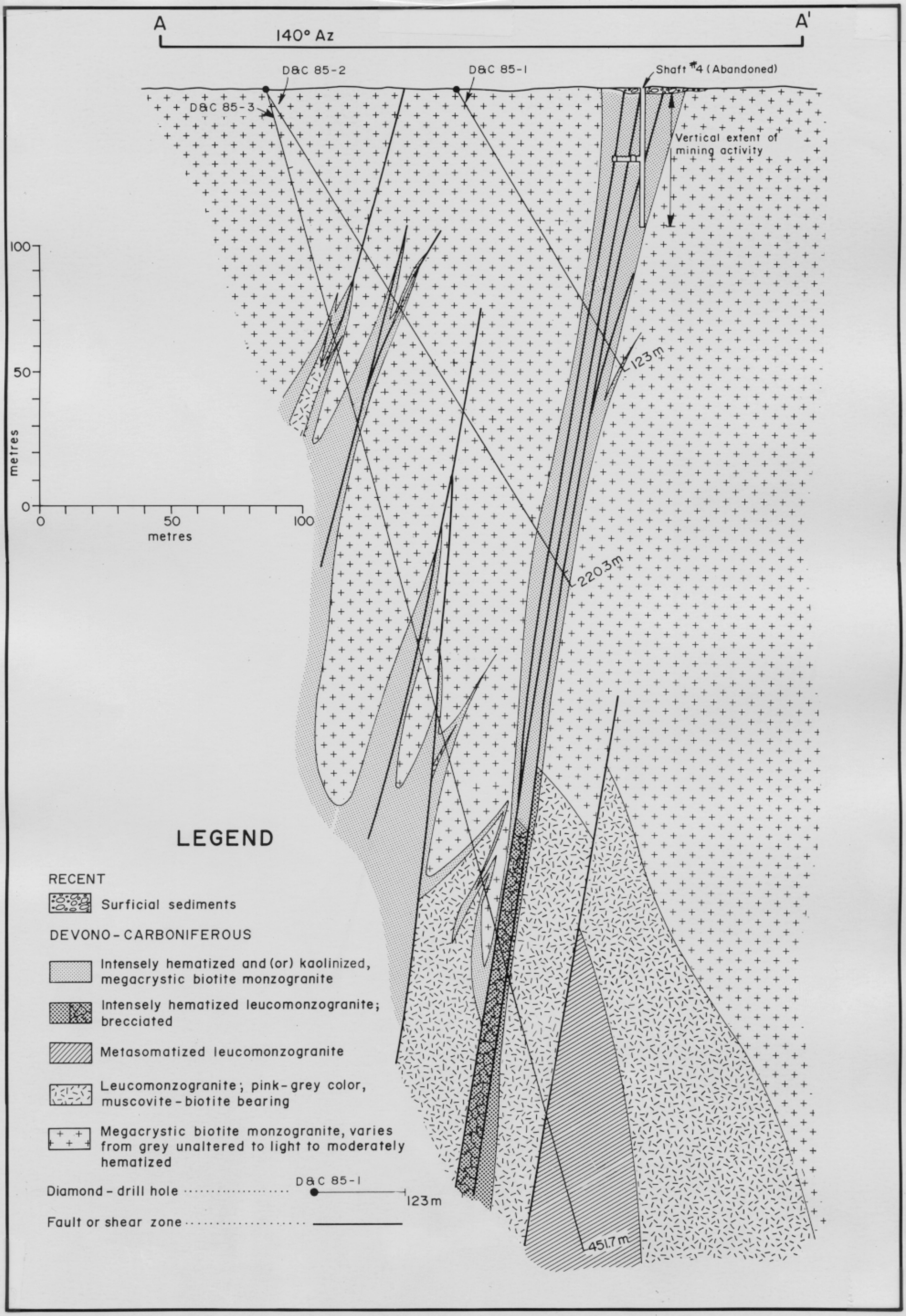
Stage I Salmontail Lake pluton. Several small (<1 km^2), elongate plugs of Gold River fine-grained leucomonzogranite outcrop near the deposits. These bodies are in both fault and intrusive contact with the biotite monzogranite and are interpreted as being localized along a pre-existing structural feature during emplacement (Ham, 1990; O'Reilly, 1992). A fine-grained body, interpreted as Gold River leucomonzogranite, was intersected in drill core at the former Dean and Chapter Mine (O'Reilly, 1992).

Pyrolusite and manganite are restricted to several northeast-trending, hydrothermally altered fault zones (Figs. 9.7 and 9.9). Mineralized veins pinch and swell both along strike and down dip, and range in width from a few centimetres to 1.8 m. O'Reilly (1992) noted that the Mn-oxides "occur as lensoid or chute-like masses in brick-red hematite-ochre breccia and hydrated Fe oxide". Enrichment in P_2O_5 (up to 9.95 wt. %) in ore zones is reflected by the presence of fluorapatite.

The most pervasive alteration attending the Mn mineralization is hematization, which is reflected by a range in intensity from a slight reddening of plagioclase and chloritization of biotite to a brittle and friable, brick-red rock with completely obliterated feldspars and biotite. Carbonatization is closely associated with hematization and is manifest as disseminated and vein calcite, including black (Mn) and red (Fe) varieties. Some calcite is replaced by Mn-oxides indicating carbonatization preceded the main mineralization stage (O'Reilly, 1992). Argillic alteration, consisting of smectite (montmorillinite) replacement of plagioclase, is superimposed on hematite zones and extends into the biotite monzogranite.

Minor episyenite alteration, or desilicification, was noted in the Gold River leucomonzogranite and along some northeast-trending faults. This alteration, which consists of the destruction and removal of quartz, may impart a `vuggy' porosity on the biotite monzogranite. Minor silicification and greisenization were noted within and adjacent to the Gold River leucomonzogranite and below the former Dean and Chapter Mine.

Figure 9.9 (Following page) Geologic cross-section (A-A' from Fig. 9.8) through the Dean and Chapter Mine (modified after O'Reilly, 1992). Mn-Fe-P mineralization is hosted by northeast-trending hematized and variably brecciated alteration zones that cross-cut biotite monzogranite. Fine-grained leucomonzogranite similar to the small plugs (,1 km^2) of Gold River Leucomonzogranite that outcrop nearby, were intersected in a single drill hole (D & C 85-3).



A
A'
140° Az
D&C 85-2
D&C 85-1
D&C 85-3
Shaft #4 (Abandoned)
Vertical extent of mining activity
123m
2203m
451.7m
100
50
0
metres
0
50
100
metres
LEGEND
RECENT
Surficial sediments
DEVONO-CARBONIFEROUS
Intensely hematized and (or) kaolinized, megacrystic biotite monzogranite
Intensely hematized leucomonzogranite; brecciated
Metasomatized leucomonzogranite
Leucomonzogranite; pink-grey color, muscovite-biotite bearing
Megacrystic biotite monzogranite, varies from grey unaltered to light to moderately hematized
Diamond-drill hole
D&C 85-1
123m
Fault or shear zone

O'Reilly (1992) noted that the Mn-Fe-P ore zones also had enrichments in Be (90 ppm), W (140 ppm), Mo (28 ppm), Pb (3000 ppm) and Cu (1400 ppm), compared with samples of unmineralized Salmontail Lake monzogranite.

9.3.3 Breccia Deposits (Pb, Zn, Ba, Au, Ag)

Breccia-type deposits are restricted to the trace of the northeast-trending Tobeatic fault zone (Giles, 1985) along, and near, the southern margin of the Stage II Davis Lake Pluton, near Little Tobeatic Lake (Figs. 9.1 and 9.10). Bedrock exposure in this portion of the batholith is very poor and much of the following geological interpretation is based on boulder and subcrop mapping. The contact between coarse-grained Davis Lake leucomonzogranite and the slate and metagreywacke of the Meguma Group is very irregular and is interpreted as representing an undulating roof-zone of the Davis Lake Pluton. This interpretation is supported by the presence of three large (5-15 km long) `roof-pendants' of Meguma Group metasediments near the main granite-metasediment contact. A large leucomonzogranite body to the south of the batholith may actually be an extension of the Davis Lake Pluton. A small plug of fine-grained muscovite leucogranite is exposed to the north of the mineralized zone.

The Tobeatic Fault Zone has been traced for approximately 8 km and averages 100 m in width in the study area. These dimensions are primarily based upon the occurrence of milky-white quartz-breccia boulders and subcrop (Fig. 9.10; Corey and Horne, 1989b). Brittle and ductile deformation and silicification of wall rocks are visible for up to 500 m from the quartz-breccia zone.

Combinations of galena, sphalerite, barite, chalcopyrite, arsenopyrite and pyrite occur as fine and coarse disseminations in quartz-breccia boulders. Barite was also noted as "colloform crust infilling vugs and as large fan-shaped white crystal masses within vuggy quartz-breccia boulders" (Corey and Horne, 1989b). Associated alteration mainly includes silicification and kaolinization with minor hematization.

Analysis of mineralized boulders returned maximum assays of 4.9% combined Pb-Zn and 2% Ba (Dickie and Zwicker, 1983). Analysis of sulphide-rich breccia boulders revealed anomalous concentrations of gold with values ranging from 135-2035 ppb Au (Corey and Horne, 1989b). A compilation of company assessment reports (Corey and Horne, 1989b) indicated that heavy-mineral till separates from a large part of the Tobeatic Fault Zone near the southern

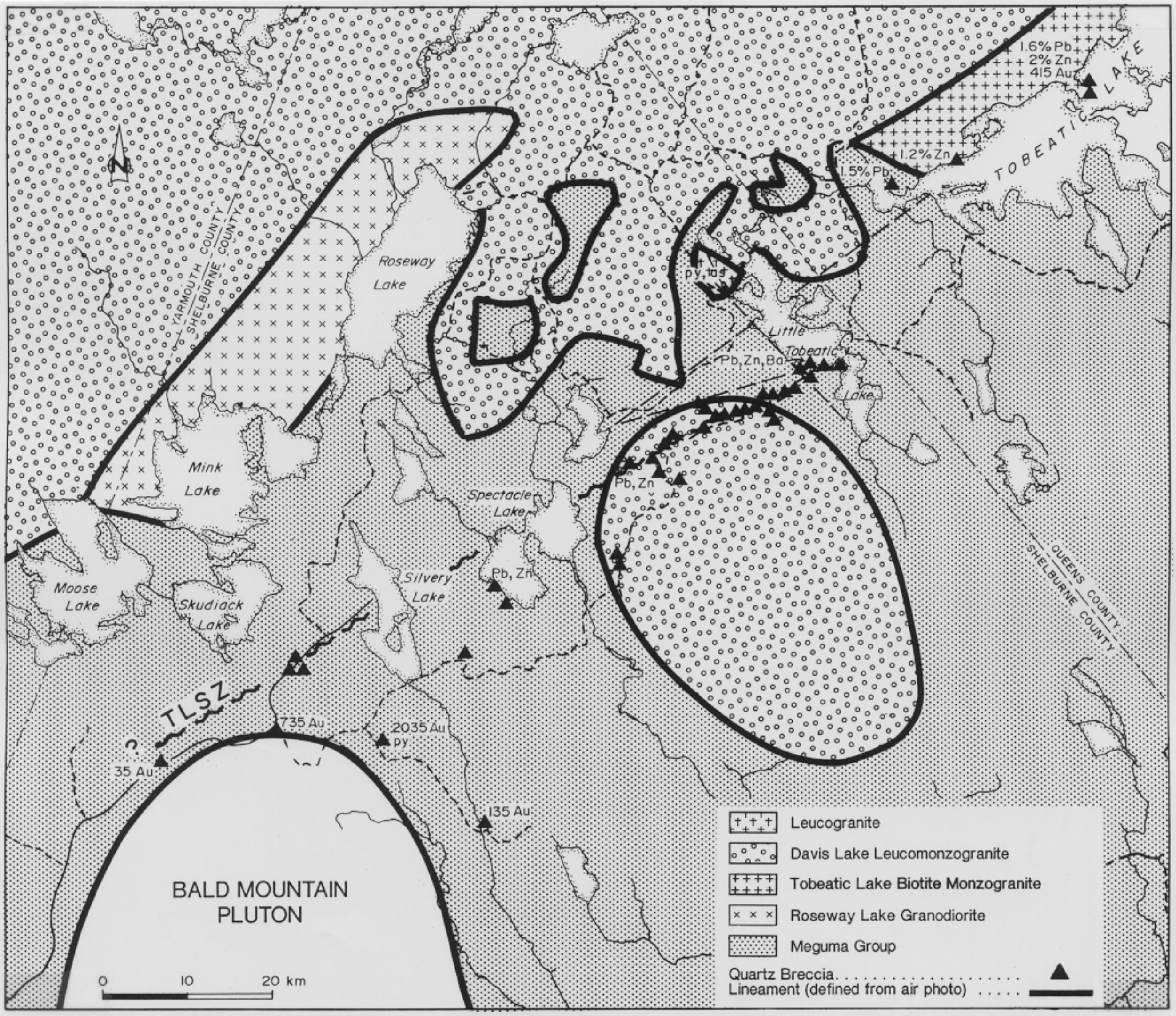


Figure 9.10 Geological map of the Little Tobeatic Lake area showing the distribution of quartz-breccia boulders and outcrop (modified after Corey and Horne, 1989c). Mineral occurrences with sporadic assay data are also indicated where available.

margin of the Davis Lake Pluton contained anomalous concentrations of Zn, Pb, Sn, W and Au when compared to regional till samples (Fig. 9.11). This area is considered to be an excellent exploration target for base metals and precious metals.

9.3.4 Pegmatite Deposits (Mo, Sn, W, Cu, Nb, Ta)

This group is only reported in the New Ross Pluton (east-central portion of batholith; Fig. 9.1) although it should be stated that unmineralized pegmatite dykes and pods are also

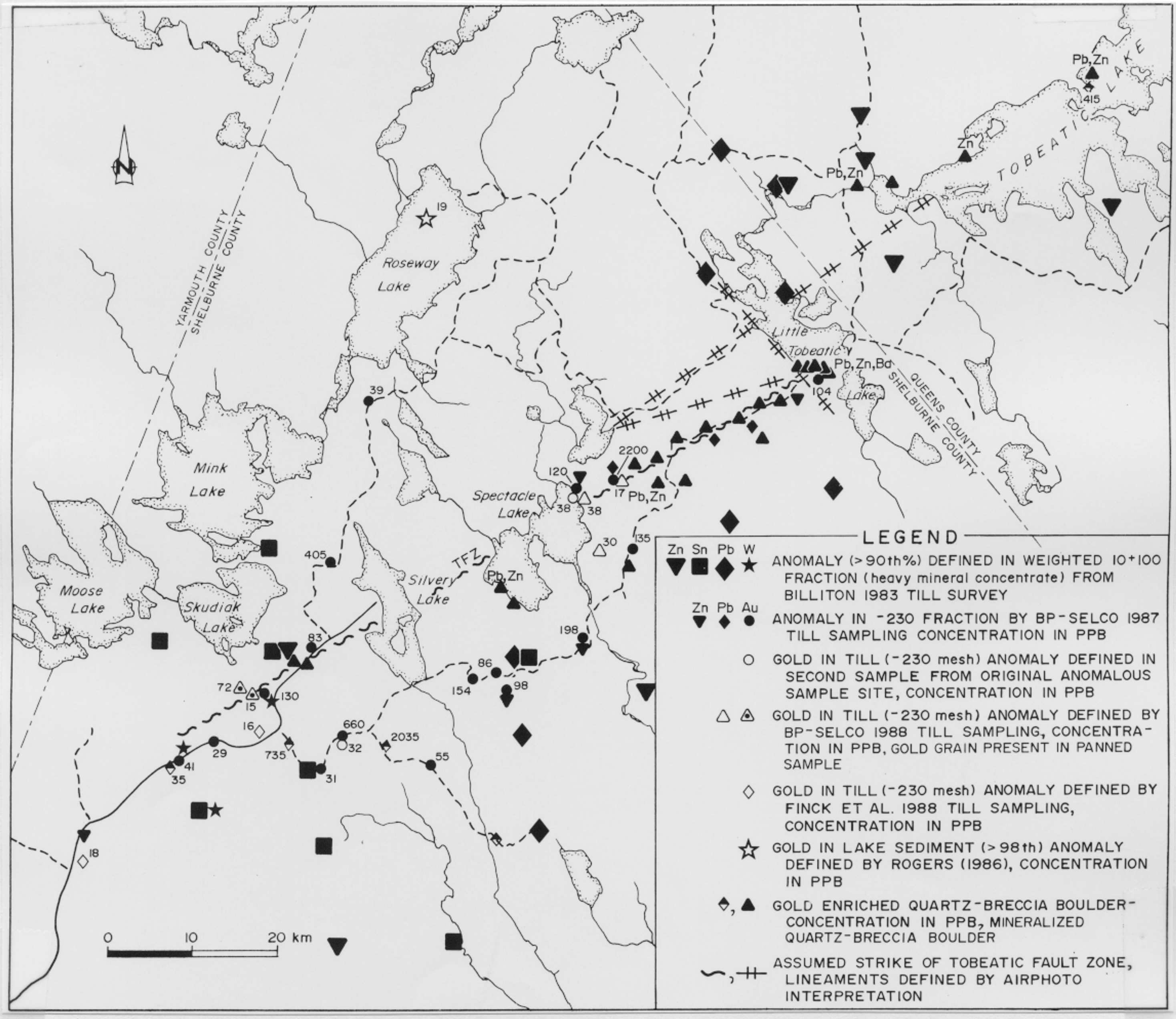


Figure 9.11 Compilation map showing the location of "anomalous": heavy mineral separates (-60+230 mesh) and silt and clay (-230 mesh) fractions from till samples; lake sediment samples; and mineralized boulders from the Little Tobeatic Lake area (after Corey and Horne, 1989c).

present in numerous other mineral deposits including the former East Kemptville Sn-Zn-Cu-Ag Mine (Kontak, 1990), the Gaspereau Lake U-P-F prospect (MacDonald and Ham, 1992) and Long Lake deposit (O'Reilly *et al.*, 1982). Pegmatite-type deposits are hosted only by fine- or coarse-grained leucomonzogranite and muscovite$\pm$topaz leucogranite. Individual pegmatite bodies are mostly $\leq$10 m in the maximum dimension. Mineralized zones occur in isolated pods, lenses and dykes that, unlike the greisen- and vein-type deposits, have no preferred orientation.

In addition to the common minerals quartz, alkali feldspar, muscovite, biotite, garnet and cordierite, characteristic minerals in pegmatite include cassiterite, wolframite, scheelite, columbite, tantalite, tapiolite, beryl, fluorite, tourmaline, lepidolite, amblygonite and metatorbernite. Most mineralized pegmatites have quartz-muscovite greisenized borders and selvages, whereas others, including the Long Lake and Keddy occurrences (Fig. 9.1), are associated with extensive greisen zones (O'Reilly *et al.*, 1982).

The Keddy Mo-Ta-Nb prospect typifies pegmatite-type mineral deposits. The deposit consists of a series of pegmatite pods that intrude the Keddy-Reeves muscovite-topaz leucogranite. A few greisen and greisenized leucogranite zones are developed at the margins of some pegmatite pods. Pegmatite dykes and pods are only reported to contain molybdenite, whereas the occurrence of molybdenite, topaz, dumortierite, scheelite, andalusite, fluorite and columbite have been reported in the associated greisens (O'Reilly *et al.*, 1982).

9.3.5 Peribatholithic Deposits (Sn, W, U, Cu, Zn, Ag)

These mineral occurrences are, by definition, located in the periphery of the batholith and are hosted by metasedimentary and/or metavolcanic rocks of the Cambro-Ordovician Meguma Group and the overlying Silurian to Devonian White Rock, Kentville and Torbrook formations. Most of the occurrences are located near the southwestern end of the batholith near the East Kemptville deposit, along the northwestern margin of the batholith near the Annapolis Valley and along the southern margin of the batholith near Caledonia.

Several of the deposits, including those at Caledonia (O'Reilly, 1985) and the Duck Pond deposit (Pitre and Richardson, 1989) approximately 2 km northwest of the East Kemptville deposit (Fig. 9.1), have associated Bouguer gravity anomalies that reflect the presence of less dense underlying granite bodies. Some deposits have fine- grained aplite, leucogranite or pegmatite dykes, such as those in the Caledonia area. Other deposits have small granite plugs, as at the Kempt Snare Lake prospect southwest of the East Kemptville deposit (Soehl, 1988; Soehl *et al.*, 1989) where a `cupola' of black, graphite-bearing, greisenized leucogranite (approx. 200 x 500 m) is enriched in W, Sn, Pb, As, Cu and Ag. In the absence of outcropping granite dykes or plugs, a possible genetic link to the South Mountain Batholith or associated buried cupolas can commonly be established on the basis of contact metamorphic mineral assemblages in metasedimentary host rocks. These minerals primarily include andalusite, commonly the chiastolite variety, and cordierite which are most readily observed in the pelitic sedimentary layers. Other evidence for the peribatholithic association with granitic rocks includes the development of skarnoid-type mineral assemblages and the granophile element assemblage with strong enrichments in Sn, W, F, Rb, Li or U, such as in the Caledonia occurrences (O'Reilly, 1985). Lastly, the styles of alteration superimposed on the host metasedimentary and metavolcanic rocks may be interpreted as resulting from granite-related fluids from associated intrusions, as at the Duck Pond deposit (Hattie, 1989; O'Reilly *et al.*, 1992) where intense hematization, chloritization and the growth of spessartite garnets in the host argillite are linked either to the East Kemptville deposit or an underlying granite cupola.

The following section briefly describes the three main areas near the batholith where peribaltholithic deposits have been noted.

Southwest Nova Scotia Tin Domain

The Southwest Nova Scotia Tin Domain (Figs. 9.1 and 9.12) was first described by Chatterjee (1983) and Chatterjee and Strong (1984b) and was later studied by Kontak *et al.* (1990) and O'Reilly *et al.* (1992). It forms a northeast-trending band (approximately 20 x 70 km) that extends from a few kilometres northeast of the East Kemptville deposit to the Atlantic coastline near Yarmouth and Wedgeport. It is host to numerous polymetallic tin, base- and precious-metal, granite-hosted and metasediment-hosted (i.e. peribatholithic) deposits. A description of the geology and metallogenic significance of the tin domain is given in Kontak *et al.* (1990).

The largest peribatholithic deposit in the tin domain is the Duck Pond deposit (Fig. 9.12) with drill-indicated reserves of 5.1 million tonnes of 0.129% Sn (O'Reilly, 1988). The deposit has been studied by Pitre and Richardson (1989), Hattie (1989) and O'Reilly (1988). Details about exploration activity have also been reported in various assessment reports from Shell Canada Resources and Rio Algom (O'Reilly *et al.*, 1992). Kontak *et al.* (1990) summarized the geology of the deposit and the following description draws liberally from their work.

Mineral deposits occur as three main types including: (1) stratabound cassiterite in altered

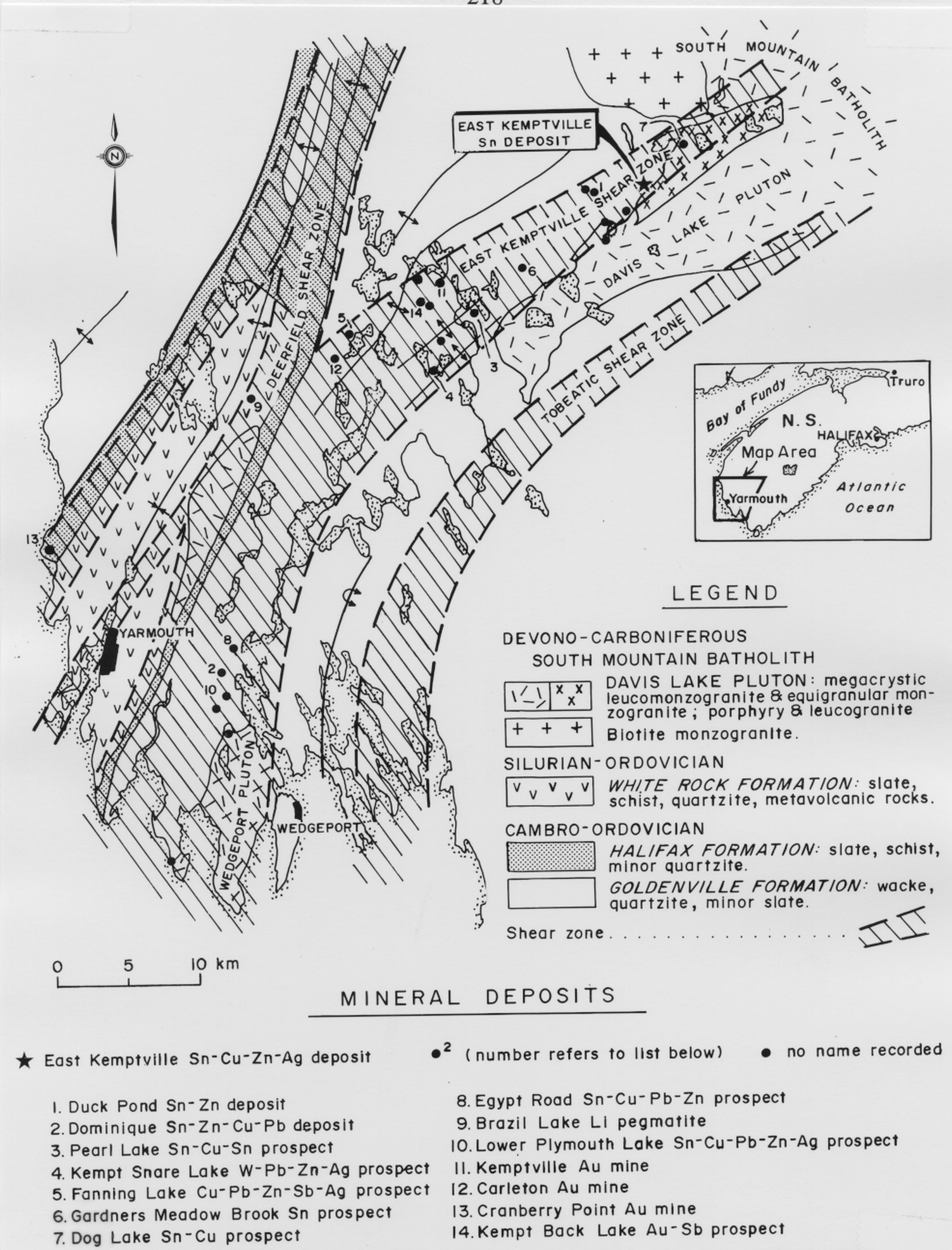


Figure 9.12 Geological map of southwest Nova Scotia tin domain showing the location of the peribatholithic mineral occurrences and deposits.

strata (chlorite, chloritoid, garnet); (2) quartz-chlorite-cassiterite-sulphide veins; and (3) pyrite±cassiterite±base metal sulphides in silicified and sericitized zones. All types show subsequent hematization (Kontak *et al.*, 1990). The Duck Pond deposit is hosted by the transition zone between the Goldenville and Halifax formations of the Meguma Group which shows a northeast-trending penetrative fabric that has been locally overprinted by a similar-trending shear fabric. Three mineralized zones occur subparallel to bedding contacts at the Duck Pond deposit (Hattie, 1989; O'Reilly, 1987).

Other Sn-bearing peribatholithic occurrences in the tin domain include those at Kempt Snare Lake (Pb-Zn-W-Cu-Ag), Dominique (Sn-Zn) and Pearl Lake (Sn-Cu-Zn; Fig. 9.12). The geology of these occurrences is summarized in Kontak *et al.* (1990). The Kempt Snare Lake deposit (Soehl, 1988; Soehl *et al.*, 1989; Kontak *et al.*, 1990) consists of (in descending order of abundance) arsenopyrite, sphalerite, galena, scheelite, and chalcopyrite in quartz veins and greisens. Diamond-drilling at the Kempt Snare Lake deposit revealed the presence of an underlying graphite-bearing greisenized leucogranite cupola (Jensen, 1987; Soehl, 1988). Kontak *et al.* (1990) noted that the greisens at this deposit bore striking resemblance to the dark-coloured greisens at the East Kemptville deposit.

The Dominique deposit (Chatterjee *et al.*, 1985; Wolfson, 1983; Kontak *et al.*, 1990) consists of cassiterite, sphalerite, pyrite, pyrrhotite, galena, arsenopyrite and chalcopyrite in extensively chloritized zones in metagreywacke of the Goldenville Formation. Mineralized zones are restricted to three en-echelon east-northeast-trending fault zones with maximum grades of 0.72% Sn and 2% Zn over 4.14 m apparent width (O'Reilly *et al.*, 1992). Kontak *et al.* (1990) suggested that the Wedgeport Pluton extends to the north, beneath the metasedimentary rocks of the Meguma Group, and that the Dominique deposit represents the effects of granite-derived fluids from this body that migrated upward along structural features.

In summary, most peribatholithic mineral occurrences within the Southwest Nova Scotia Tin Domain are interpreted to represent exo-contact mineralization, either from extensions of the Davis Lake, Scrag Lake or Wedgeport Plutons, or from discrete buried cupolas. This observation is in accord with the work of Kontak *et al.* (1990) who postulated that sediment-hosted mineralization in the tin domain is a surficial manifestation of buried granite cupolas, possibly similar in composition to the topaz-bearing East Kemptville leucogranite.

Annapolis Valley U-Ag-Cu Domain

The Annapolis Valley U-Cu-Ag Domain was first outlined by Chatterjee (1983). It extends along the north-central margin of the batholith from near Weymouth to Aylesford Lake and contains both endo- and exo-contact mineral occurrences. Two main areas of peribatholithic mineral occurrences are the Shortliff Lake (MacDonald and Ham, 1989a) and Randall Lake (MacDonald and Ham, 1992) areas (Fig. 9.1). The uranium occurrence at Randall Lake consists of pitchblende and autunite in brecciated and hematized metasediments and granite at the contact between metasediments of the Halifax Formation and the Cloud Lake biotite monzogranite (MacDonald and Ham, 1992). Trenching by Shell Canada Resources (St. George, 1982) revealed that uranium was restricted to the roof zone of the batholith. A pitchblende-bearing boulder from this area returned assay values of 5% U_3O_8. Analysis of drill core from Randall Lake indicated levels of up to 0.85% Cu and 0.12 oz./ton Ag over 1.0 m (St. George, 1982).

The Shortliff Lake (U-Cu-Ag) occurrence consists of veined, brecciated and hematized metasediments containing pitchblende, pyrite, covellite, chalcocite, chalcopyrite, bornite, native copper and specular hematite (Dakers, 1982). This occurrence is hosted by calcareous metasediments of undivided White Rock and Kentville formations (MacDonald and Ham, 1989a). O'Reilly *et al.* (1992) noted that several peribatholithic occurrences in the Annapolis Valley polymetallic domain have "... anomalous, but sporadic, levels of Bi-Cu-Ag-Co-Zn". They concluded that the anomalous concentrations of Bi and Co in these deposits set them apart from F-, CO_2- and P-rich vein-type occurrences of the central and eastern batholith (e.g. Millet Brook, Gaspereau Lake).

Caledonia (Sn, W, base-metal)

The Westfield - Caledonia area is situated along the south-central margin of the batholith (Fig. 9.1). This area is host to W-Sn-Mo-Ag endo-contact mineral occurrences (Westfield) in a greisenized leucomonzogranite protuberance of the Little Round Lake Pluton, and Sn-W-Mo-base metal-precious metal exo-contact mineral occurrences (Caledonia and Westfield) in a series of quartz fissure veins and associated greisenized zones (O'Reilly, 1985). The following section focusses on the occurrences near Caledonia.

Regional exploration near Caledonia by Shell Canada Resources Ltd. (Wilson, 1978) resulted in the discovery of Sn-W mineralized boulders and outcrops. Subsequent follow-up work by Shell Canada Resources Ltd. and Billiton Canada Ltd. in the late 1970s and early 1980s included geochemical and ground gravity surveys (MacGillivray, 1982; Dickie, 1983). This work indicated the presence of a buried granite cupola beneath a gravity low southeast of the village of Caledonia and was supported by the presence of two dyke-like bodies that intrude the Meguma Group metasediments. One dyke consisted of a narrow (<2 m wide) quartz-albite-chlorite-pyrite porphyry dyke while the other consisted of a 200 m long composite dyke containing albitite, quartz-albite rhyolite porphyry, and an albite- and tourmaline-bearing breccia with angular metasedimentary clasts (i.e. xenoliths; O'Reilly, 1985).

Subsequent diamond-drilling of three holes (197 m depth @ 85° inclination and 236 m depth, vertical hole: MacGillivray, 1983; 681 m depth, vertical hole: O'Reilly, 1987) failed to intersect a buried granite body. However, several features encountered in the core supported the presence of a buried cupola. These include the increased size of porphyroblasts with increased depth in `spotted slates' and the presence of mineralized skarn layers (Sn-W-Cu-Pb-Zn) which are typically developed in close proximity to igneous bodies (O'Reilly, 1987).

Mineralization in the Caledonia area is represented by greisen veins and associated breccia pipes containing cassiterite, scheelite and base metal sulphides (O'Reilly, 1987). In addition, coarse crystals of cassiterite and wolframite were noted along contacts between "bull quartz" veins and host metasedimentary rocks (MacGillivray, 1983).

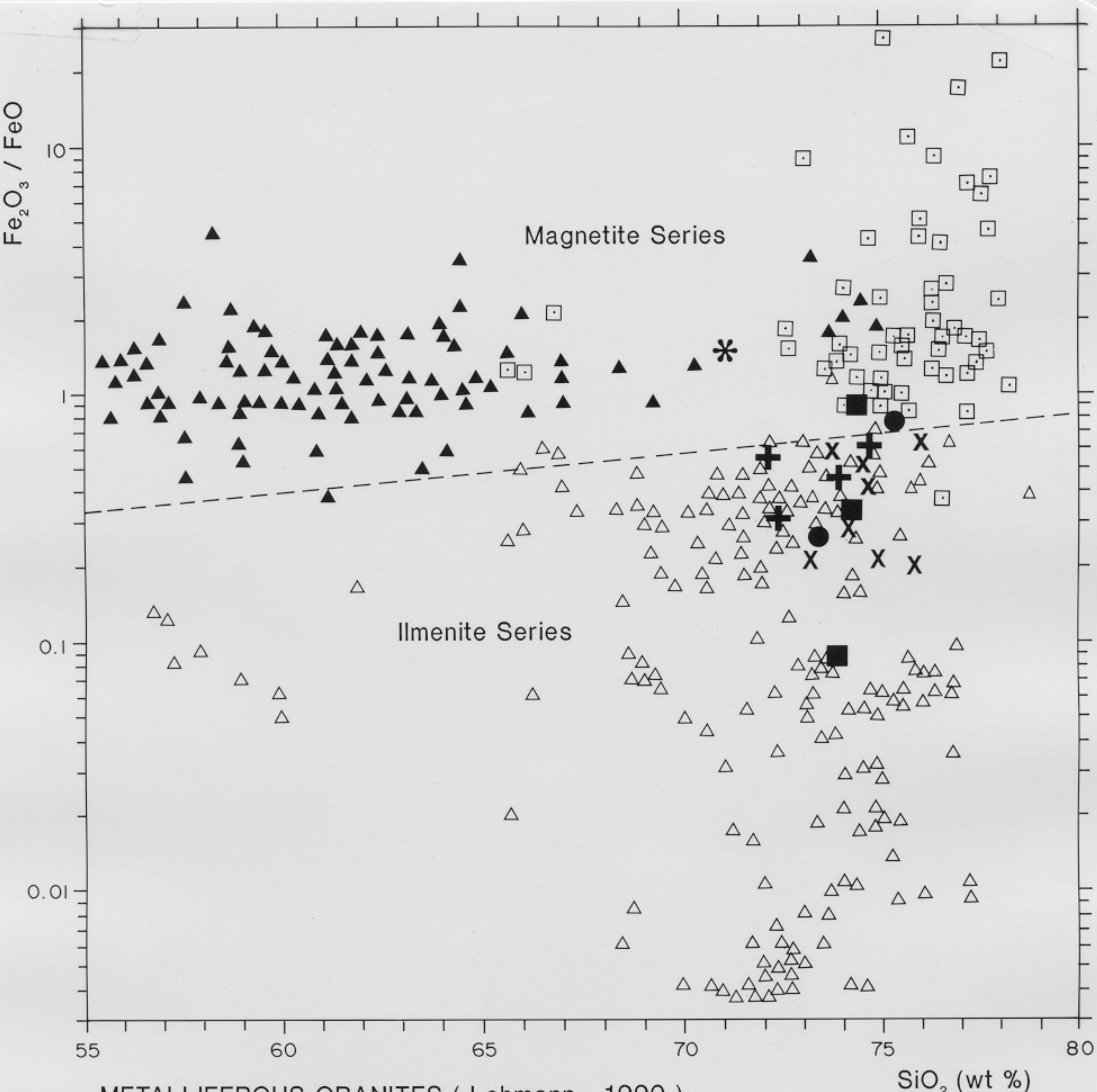
9.4 Discussion

It is widely accepted that the type of granite-related mineralization is dependent upon the overall composition of the host granitoid intrusions (e.g., Strong, 1988; Lehmann, 1992; and references therein). Detailed petrographic studies indicate that all of the rocks of the various plutons of the South Mountain Batholith have similar mineralogical characteristics. The presence of low Mg/Fe biotite, muscovite, andalusite, cordierite ($\leq$5%), garnet, tourmaline and ilmenite, combined with the absence of hornblende and rare occurrence of titanite, is consistent with the characteristic mineral assemblages for peraluminous, S-type and ilmenite-series granitoid rocks.

Additionally, detailed chemical studies demonstrate that all rocks of the batholith are peraluminous (i.e., molecular proportions $Al_2O_3/(CaO+Na_2O+K_2O)<1$) and have similar overall chemical characteristics with high levels of SiO2 ranging from average values of 67.12 (Std. Dev. 1.73) in biotite granodiorite to 73.62% (Std. Dev. 0.89) in muscovite$\pm$topaz leucogranite. Conversely the rocks of the batholith have low concentrations of CaO ranging from average values of 1.94% (Std. Dev. 1.73) in biotite granodiorite to 0.39% (Std. Dev. 0.14) in muscovite$\pm$topaz leucogranite. These features are consistent with worldwide granitoid rocks that are mainly host to SWUM-type (i.e., Sn-W-U-Mo) mineral deposits (Strong, 1988). A plot of Fe_2O_3/FeO versus SiO_2 for a select suite of samples (Fig. 9.13) indicates the batholith is similar in composition to other worldwide Sn-bearing, ilmenite-series granitoids.

From the previous descriptions, it is apparent that there is a close spatial association between `specialized granites', consisting mainly of muscovite-topaz leucogranite and to a lesser extent fine-grained leucomonzogranite, and the mineral deposits of the South Mountain Batholith. These rocks collectively have very high levels of large ion lithophile and other `incompatible' elements compared with the rest of the batholith. Specifically these rocks are enriched in Rb, Cs, Li, Nb, Ta, Sn, W, U and F and depleted in Sr, Eu, Ba, Ti and Fe compared with the rest of the batholith or "normal" granitoid rocks (MacDonald *et al.*, 1992b). This association between mineral deposits and specialized granites is consistent with other tin districts throughout the world (cf. Lehmann, 1990, and references therein). Many of the greisen- and pegmatite-type occurrences in the batholith are actually hosted by leucomonzogranite and leucogranite of Stage II plutons. The East Kemptville deposit, for example, is hosted by a muscovite-topaz leucogranite. Similarly the breccia-type mineral occurrences near Little Tobeatic Lake are proximal to several small plugs of fine-grained leucomonzogranite. Vein-type mineral occurrences are mainly hosted by non-specialized biotite monzogranite or biotite granodiorite in Stage I plutons. However, leucogranite dykes and/or plugs occur at, or in close proximity to, these occurrences. Examples include leucogranite dykes that were intersected in drill core at the Millet Brook deposit (Chatterjee *et al.*, 1985) and several leucomonzogranite

Figure 9.13 (Following page) SiO_2 versus Fe_2O_3/FeO variation diagram for granitic rocks in association with Cu, Mo and Sn deposits from various locations worldwide (modified after Lehmann, 1990). The ilmenite series/magnetite series dividing line (after Ishihara et al., 1979) is for granitoid rocks from Japan. The asterisk is for a brecciated and hydrothermally altered albite-magnetite-bearing leucomonzogranite from the Davis Lake Pluton that was first noted by Richardson (1988), and is the only known magnetite-bearing sample in the batholith.



METALLIFEROUS GRANITES (Lehmann, 1990)

Tin .... △

Molybdenum .... ⊡

Copper .... ▲

DAVIS LAKE PLUTON

Muscovite-Topaz Leucogranite .... ■

Fine Grained Leucomonzogranite .... ●

Coarse Grained Leucomonzogranite x

Muscovite-Biotite Monzogranite .... ✚

Albite-Magnetite Breccia .... ✱

plugs that occur along the trace of northeast-trending shear zones at the New Ross Mn deposits (O'Reilly, 1992).

Chatterjee and MacDonald (1991) established a genetic link between leucomonzogranite, leucogranite and hosted greisens (including those at the East Kemptville deposit) in the Davis Lake Pluton, using trace element and rare earth element geochemical and isotopic evidence. They noted the presence of two series of leucomonzogranite, leucogranite and greisen (arbitrarily termed A and B) with distinct geochemical and isotopic characteristics. Series A rocks are characterized by flat or slightly-fractionated REE patterns (Figure 9.14a) whereas series B rocks have much more fractionated heavy REE (i.e. Gd to Lu) patterns (Fig. 9.14b) and lower ΣREE values that the A series rocks. Chatterjee and MacDonald also noted a clear separation between the two rock series on a plot of $^{206}Pb/^{204}Pb$ versus $^{208}Pb/^{204}Pb$. They noted that in spite of the two separate trends in the thorogenic ($^{206}Pb/^{204}Pb$ versus $^{208}Pb/^{204}Pb$) diagram there were linear variations in the $^{208}Pb/^{204}Pb$ versus $^{232}Th/^{204}Pb$ and $^{238}U/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ diagrams which imply immobility of U, Th and Pb since the time of crystallization of leucomonzogranite and leucogranite and the overprinting greisenization. Two important observations can be made on the basis of REE and Pb isotopic data. Firstly these data reveal clear genetic relationships between the greisens mineralization and associated leucogranite in the Davis Lake Pluton. This is the best documentation of a genetic link between deposit and "specialized" granites that exists for the batholith.

Kontak (1994) established a similar genetic link between the leucogranite and greisens at the East Kemptville deposit and the leucomonzogranite of the Davis Lake Pluton. The implication of these studies is that a genetic link can be made between 'specialized granites' and mineralization in the Davis Lake Pluton.

As previously noted, an evaluation of published geochronological data (MacDonald et al., 1992) indicates that all thirteen plutons of the South Mountain Batholith were emplaced and crystallized within a very narrow time interval, say $\leq$5 Ma at ca. 370 Ma. The concordance of all the radiometric dating techniques (e.g. K/Ar and $^{40}Ar/^{39}Ar$ on biotite and muscovite, Rb/Sr, Pb/Pb and U/Pb methods for whole-rock and mineral separates) which collectively have a large range in terms of blocking temperatures (i.e. near the granite solidus to ca. 250°C) implies rapid post-crystallization cooling. Younger dates within the batholith reflect variable degrees of updating during subsequent thermal and tectonic disturbances. Several studies of the mineral deposits and occurrences indicate a narrow time interval between crystallization and mineralization. Chatterjee and MacDonald (1991) conducted a Pb-Pb study of leucomonzogranite, leucogranite and attending mineralized greisens from the Davis Lake Pluton. They noted a remarkable co-linearity in the $^{206}Pb/^{204}Pb$ versus $^{207}Pb/^{204}Pb$ diagram for the entire sample suite which represented an age of 365.7 ± 2.7 Ma (MSWD 1.95, 2 sigma). They concluded that the mineralized greisens formed contemporaneously with the crystallization of the Davis Lake Pluton. Kontak and Chatterjee (1992) measured the Pb-Pb isotopic concentrations for a suite of leucogranite and mineralized greisens from the East Kemptville Sn deposit. They concluded that the deposit formed ca. 366 Ma, shortly after the crystallization of the host leucogranite. Kelpie et al. (1993) measured an age for muscovite from the Millet Brook U deposit by the $^{40}Ar/^{39}Ar$ technique. They noted an age of 369.9 ± 6 Ma for the deposit which was very similar to ages for nearby biotite monzogranite (366.1 ± 5) and leucomonzogranite (373.1 ± 6) indicating the deposit was essentially contemporaneous with the nearby Stage I and II plutons.

Several studies have indicated that structure played a role in mineral deposition in the batholith. Horne *et al.* (1992) presented a detailed synthesis of structural data for the batholith, including data for planar features including joints, dykes (i.e. aplite, pegmatite), quartz veins (mineralized and barren) and fracture or shear zones and faults (Fig. 9.3a,b). These authors and MacDonald *et al.* (1992b) concluded that these planar features developed during northwest, horizontal compression accompanying uplift during the waning stages of the Acadian orogenic event. These workers noted the strong structural control on northeast-trending uraniferous and barren hematized shear zones and northwest-trending polymetallic and barren quartz veins throughout the batholith. These observations are consistent with features at several deposits, including the former New Ross manganese mines. Kontak (1990) and Halter *et al.* (1993) reported mylonite zones and en-echelon quartz-sulphide veins in the East Kemptville tin deposit. Corey and Horne (1989b) documented the close spatial association of brecciated and silicified rocks and Pb-Zn-Ba-Au-Ag mineral occurrences in the Little Tobeatic Lake area. The exact role of structure in some deposits remains somewhat contentious; however, most evidence indicates that there was some component of structural control on the localization of greisen-, vein- and breccia-type mineralization.

It is clear from previous sections that greisen- and vein-type deposits occur throughout the entire batholith (Fig. 9.1). However, it should be noted that the largest greisen deposits (e.g. East Kemptville, Long Lake, Upper New Cornwall, Inglisville) are located at contacts between Stage II plutons and their metasedimentary country rocks. This has been interpreted by many authors (Richardson *et al.*, 1982; O'Reilly *et al.*, 1982; MacDonald and O'Reilly, 1989) to reflect 'ponding' of granite-derived hydrothermal fluids beneath an impermeable metasedimentary 'cap'. In contrast, the largest vein-type mineral occurrences (e.g. Millet Brook, New Ross) occur along northeast-trending structures in central portions of Stage I plutons, possibly above the buried cupolas of specialized granites.

Smith and Turek (1976) evaluated the economic potential of three composite plutons (mostly Stage II plutons with some adjoining Stage I rocks) using petrological indices and geochemical parameters. They concluded that the three plutons had differing economic potential. Chatterjee (1983) proposed a series of metallogenic domains within the batholith based on the styles and elemental assemblages of all known mineral occurrences. The domains were established independent of the existing bedrock geology. Numerous occurrences have subsequently been found, both during the South Mountain Batholith project and by mineral exploration activities. The elemental associations and styles of these occurrences (Fig. 9.1) are generally consistent with the previously proposed metallogenic domains. In fact, MacDonald *et al.* (1992b) concluded that many of the domains of Chatterjee (1983) occur within one or more plutons with several domain boundaries corresponding to pluton margins. This suggests that individual plutons are directly responsible for their respective deposit types and associated suites of elements, presumably through prolonged crystal fractionation. Differences in the polymetallic character of the various domains probably reflect variations in bulk composition and physico-chemical conditions during emplacement and crystallization, and possibly varying amounts of crustal contamination during emplacement, within the various plutons of the batholith. If so, the economic mineral potential of each pluton should be considered individually, as suggested by Smith and Turek (1976).

9.5 Summary

Mineral exploration has been conducted in the South Mountain Batholith for more than

100 years. Early activities lead to the discovery of small polymetallic Sn-W occurrences and the former New Ross manganese mines, whereas an exploration 'boom' in the 1970s and 1980s resulted in the discovery of the East Kemptville (Sn-Cu-Zn-Ag) and Millet Brook (U-Cu-Ag) deposits and numerous additional polymetallic occurrences. All deposits can be classified into five main types. These include greisen, vein, breccia, pegmatite and peribatholithic deposit types. The first four types are defined on the basis of their mineralogy, attending alteration assemblages and field relations. In contrast, peribatholithic deposits are defined only on the basis of field relations and may represent mineralization types similar to the first four categories.

To date, only greisen- and vein-type deposits have proven to be economically viable. The potential for additional deposits of these types is considered excellent. A project designed to evaluate the potential of breccia-type deposits in the Little Tobeatic Lake area is currently being conducted as part of the 1993-96 Canada - Nova Scotia Cooperation Agreement on Mineral Development (Corey and Graves, 1993). Pegmatite-type deposits within the batholith are generally considered to have a low economic potential; however, the spodumene (Li)- and tourmaline-bearing Brazil Lake pegmatite (Fig. 9.12; MacDonald *et al.*, 1992a; Corey, 1994) may have potential as a source for industrial minerals (e.g. spodumene, feldspar) or gem quality minerals (e.g. blue tourmaline). The potential for peribatholithic deposits similar to the Duck Pond deposit and Caledonia occurrences is considered to be very high, particularly in the Southwest Nova Scotia Tin Domain, and merits future exploration.

The impetus for the South Mountain Batholith project was the potential for polymetallic mineral deposits, particularly in light of the increased exploration and development activity in the late 1970's and early 1980's. Accordingly, most of the work focused on polymetallic mineralization, however, there are several industrial mineral commodities that have excellent potential for development. Firstly, dimension stone quarries have been operated in the batholith and adjoining satellite plutons for more than 100 years. The wide range of colours, textures, grain sizes and mineralogy of the granitic map units coupled with wide joint spacing (i.e. >1-10m spacing) in some regions of the batholith suggest excellent potential for future dimension stone development. The rock units also have excellent potential for crushed aggregate for various applications. The glacial sediments overlying the batholith have a wide range of compositions from well-sorted glacial outwash deposits of sand and gravel to large poorly sorted eskers, extensive, proximally-derived ground moraines and distally-derived allocthonous drumlins and ground moraine (Finck et al., 1989). Many of these glacial deposits have been exploited for aggregate or sand and gravel and continue to have excellent potential for future development. Several minerals including alkali feldspar, muscovite, fluorite, topaz and beryl have good potential for industrial mineral applications. The economic viability of the above industrial mineral commodities have not been evaluated as part of the project but clearly merit further work.