Musquodoboit Batholith Project and the Geology of the Tangier Grand Lake Area

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Introduction

The Musquodoboit Batholith is the second largest peraluminous granitoid body in the Meguma Terrane of mainland Nova Scotia (Fig. 1). The batholith intruded deformed Cambro-Ordovician rocks of the Meguma Group during the Devonian Acadian orogeny (ca. 370 Ma; Clarke and Halliday, 1980; Reynolds *et al.*, 1981). It covers an area of ~800 km^2 and extends from Halifax to the Sheet Harbour area, roughly parallel to the coastline on NTS map sheets 11D/13, 11D/14 and 11D/15. A 100-200 m wide contact aureole of biotite and cordierite is well developed around the contacts. Bedrock mapping of the Musquodoboit Batholith was initiated to compare and contrast its lithology and mineralogy with the larger (~7300 km^2) South Mountain Batholith of southern Nova Scotia (Fig. 1).

Results of the mapping project were plotted digitally on 1:10 000 scale maps using Fieldlog® and AutoCAD® and were subsequently merged to create 1:50 000 scale maps. This report summarizes the results of mapping with emphasis on the geology and mineral occurrences in the Tangier Grand Lake area on NTS map 11D/15 (Figs. 1 and 2).

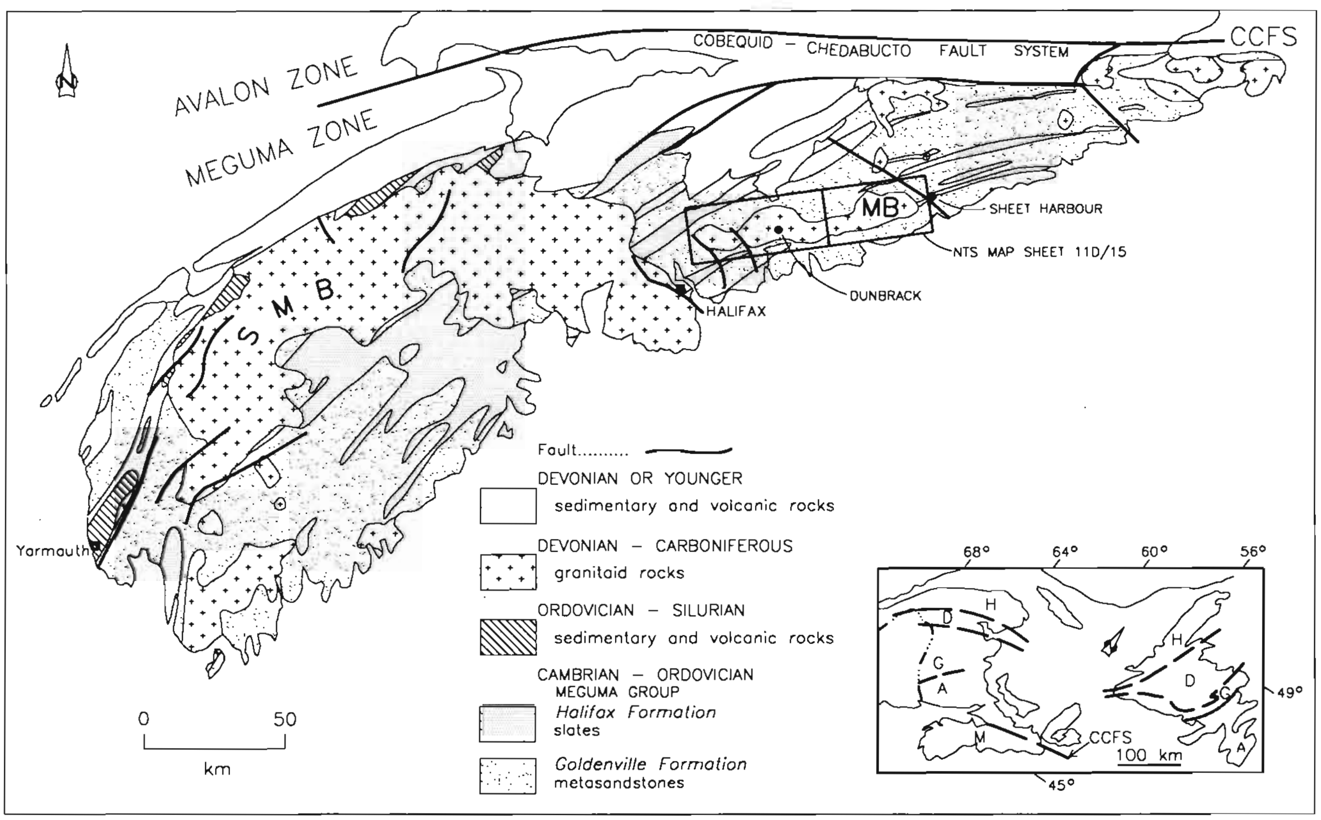


Figure 1. Simplified geological map of the Meguma Zone showing the location of the Musquodoboit Batholith (MB) and the South Mountain Batholith (SMB) . The boundary between the Meguma and Avalon zones is marked by the Cobequid-Chedabucto Fault System (CCFS). Abbreviations on the inset map are: Avalon Zone (A), Dunnage Zone (D), Gander Zone (G), Humber Zone (H) and Meguma Zone (MZ), representing zones of the Appalachians from Williams (1979).

Previous Work on the Musquodoboit Batholith

The extent of the Musquodoboit Batholith was first outlined by Fletcher and Faribault (1887); however, it was not until the work of McKenzie and MacGillivary (1974) and Jones and MacMichael (1976) that the batholith was mapped again. The first work to systematically subdivide the batholith was carried out by MacDonald (1981).

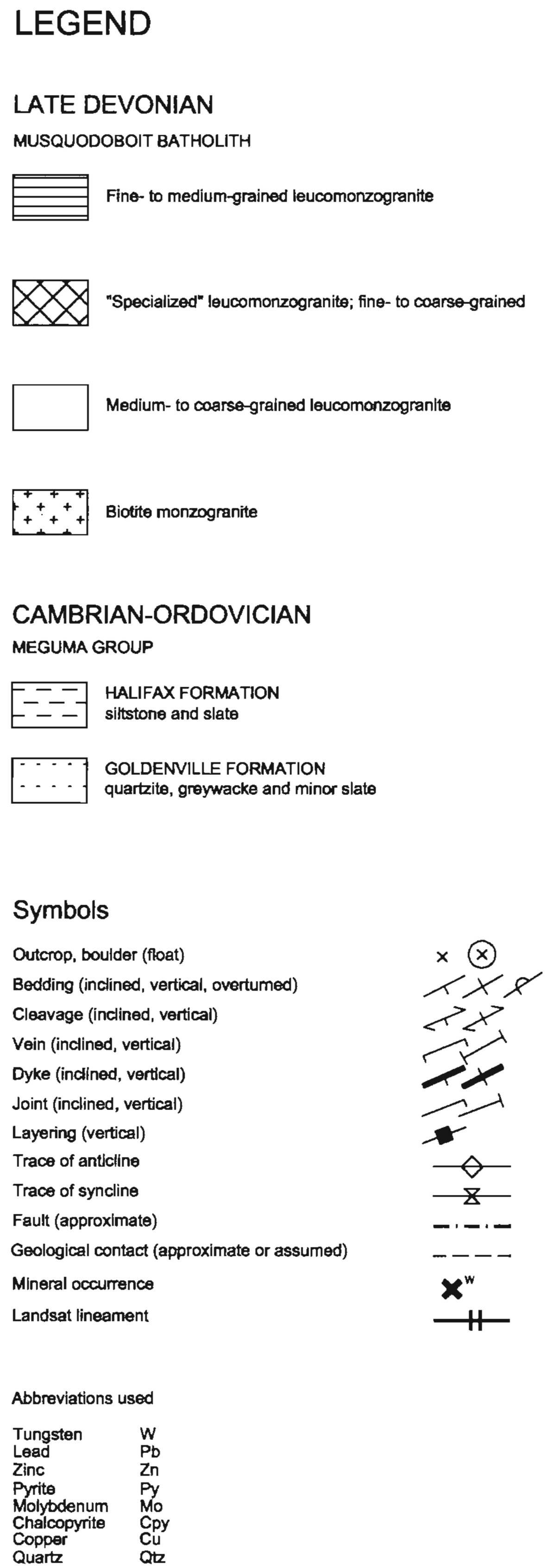
The batholith has been extensively explored for its economic mineral potential by numerous exploration companies and several mineral occurrences have been delineated (see Ham, 1993, 1997). The most significant of these is the Dunbrack Pb-Zn-Ag-Cu deposit located in the central portion of the batholith (Fig. 1). This deposit has been studied in detail by MacMichael (1975), Dickie (1978), Chatterjee (1983) and more recently by Kontak (1997). Their results suggest that the fluids involved with mineralization were not genetically related to the magma. A remote sensing (Landsat) survey was completed by Genereux (1985) on the eastern half of the batholith, and documented several northeast- to east-trending lineaments. Based on field studies, these lineaments are coincident with numerous tungsten occurrences. An airborne gamma-ray spectrometric survey was undertaken over the Musquodoboit Batholith by the Geological Survey of Canada (Ford, 1991) to enhance mapping in areas where outcrop is limited or inaccessible.

Results of Mapping

The Musquodoboit Batholith was mapped following the same methodology and terminology used to map the South Mountain Batholith (e.g. MacDonald *et al.*, 1992) in the middle to late 1980s. Based on field mapping, thin section petrography and geochemistry, the Musquodoboit Batholith can be subdivided into four lithologically distinct units similar to some of those found in the South Mountain Batholith. These units are described below in the assumed order of oldest to youngest, based on cross-cutting relationships.

Medium- to Coarse-grained Biotite Monzogranite

The apparently oldest rock type is a buff-white and pink, medium- to coarse-grained (locally K-feldspar megacrystic) biotite monzogranite. This unit contains biotite (6-12%), muscovite (<1%) and cordierite (<1%). Metasedimentary xenoliths are common, as are aplite and



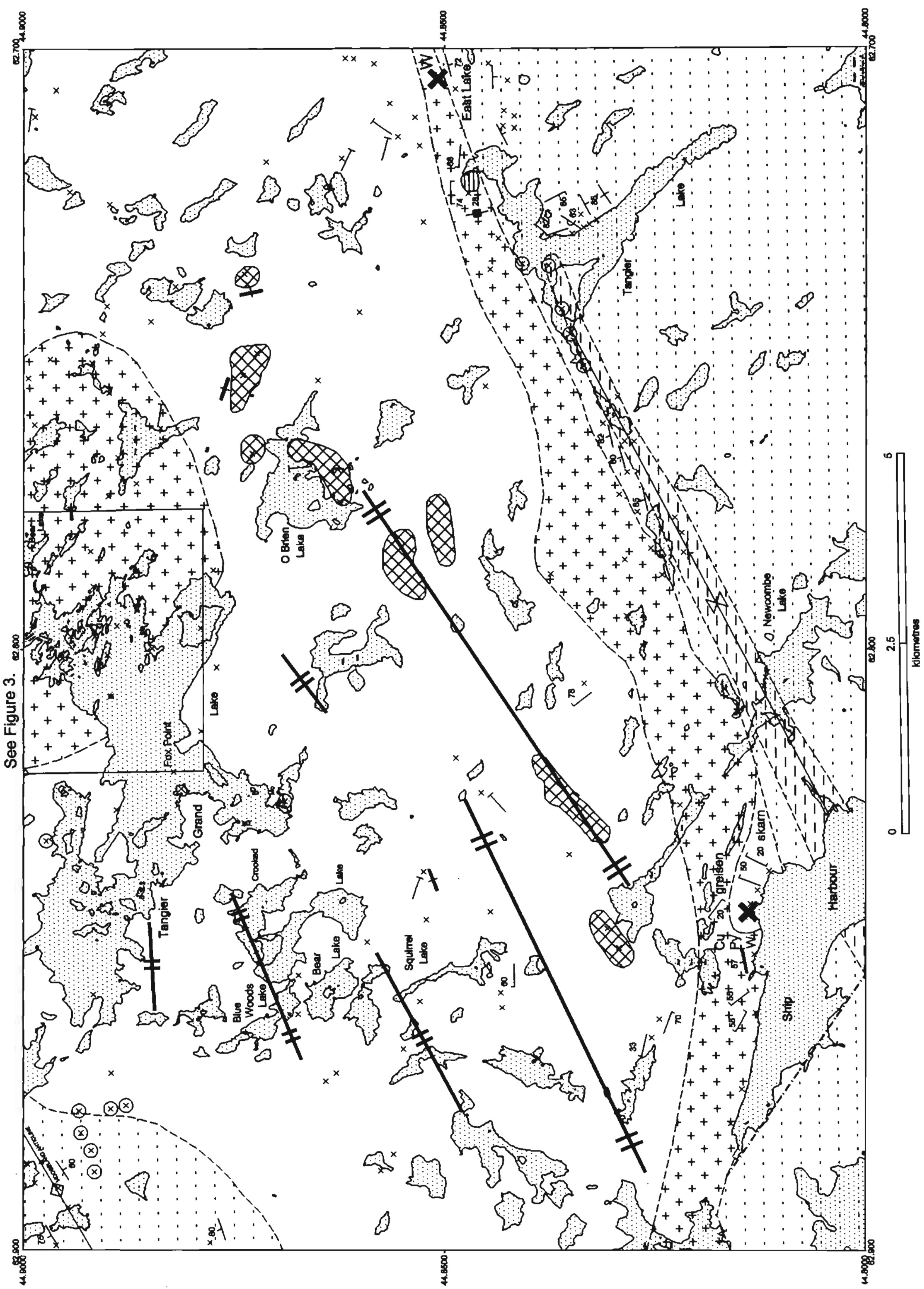


Figure 2. Simplified geology map and legend of the selected part of the study area.

quartz dykes, many of which host several polymetallic mineral occurrences. This unit typically occurs along the margin of the batholith near the contact with Meguma Group rocks (Ham, 1993). However, a large (~25 km^2) body of biotite monzogranite outcrops over the eastern portion of Tangier Grand Lake (Fig. 2).

Medium- to Coarse-grained Leucomonzogranite

The main body of the batholith is predominantly a buff-white to pink, medium- to coarse-grained (locally K-feldspar megacrystic) biotite leucomonzogranite. It is mineralogically similar to the biotite monzogranite but contains less biotite (4-8%). Cordierite is generally present in all leucomonzogranitic rocks, and in the western portion of the batholith this unit can be divided into a cordierite-rich (≤4%) phase and a cordierite-poor phase (Ham, 1993).

"Specialized" Leucomonzogranite

This minor unit in the Musquodoboit Batholith consists of texturally and mineralogically varied leucomonzogranite that ranges from fine- to medium-grained and equigranular to porphyritic and pegmatitic. This unit occurs as small bodies and contains biotite (4-8%), muscovite (< 4%) and cordierite (<2%). In rocks with high muscovite contents (e.g. 2-4%), biotite contents are commonly below average (~4%). These bodies are associated with abundant quartz and aplite dykes.

This unit is clearly delineated in the airborne gamma-ray spectrometric survey as having high equivalent uranium/equivalent thorium ratios (Ford, 1991; Ham, 1993). In the Tangier Grand Lake area, these "high-ratio" granitoid rocks form a northeast-southwest linear belt that extends from O'Brien Lake to Ship Harbour (Fig. 2).

Fine- to Medium-grained Biotite Leucomonzogranite

This minor unit in the batholith consists of a buff-white to pink and red, fine- to medium-grained, equigranular to slightly porphyritic leucomonzogranite. Locally it contains coarse-grained phenocrysts of feldspar, biotite and/or cordierite and is mineralogically identical to the main leucomonzogranite unit. This unit is associated with minor pegmatite bodies. North of Tangier Lake (Fig. 2), this unit occurs as a small (~1 km^2) plug consisting of fine-grained leucomonzogranite with minor coarse-grained phenocrysts.

Mineral Occurrences

Tangier Grand Lake

Jones and MacMichael (1976) reported a sulphide-bearing (pyrite, bornite and chalcopyrite) occurrence to the north of Tangier Grand Lake, but no specific location was given. Kidd Creek Mines Ltd. explored extensively in the area of Tangier Grand Lake in the 1980s. In 1982, wolframite- and scheelite-bearing quartz veins (0.5-5 cm wide) with associated pyrite, chalcopyrite and molybdenum were discovered by the author on one of the islands of Tangier Grand Lake (Hayward and Ham, 1982; Duncan, 1983b). These veins contain abundant small (≤ 1 cm long) wolframite crystals with minor associated scheelite in a series of narrow (< 5 cm), northeast-trending quartz-greisen veins. Stylolite-like laminations are parallel to the vein walls and fractured wolframite crystals and shear-banded muscovite are common. Subsequent work in the Tangier Grand Lake area involved additional geological mapping, and numerous geochemical surveys involving soils and tills (Duncan, 1983a, 1983b, 1984, 1985; Sexton, 1985). Outcrop exposure on the eastern portion of Tangier Grand Lake is good, but exposure on the rest of the map area is poor. Figure 3 is a map of the eastern portion of Tangier Grand Lake, expanded to illustrate the information (structural geology, mineral occurrences) collected in this area.

In 1983, regional sampling of C-horizon tills revealed anomalous concentrations of tungsten (up to 2000 ppm) in heavy mineral concentrates from two areas, the Squirrel Lake area (Bear Lake, Crooked Lake and Blue Woods Lake) and Fox Point of Tangier Grand Lake (Fig. 2; Duncan, 1985; Sexton, 1985). Near Fox Point, the survey outlined an area (1000 m x 500 m) of anomalous tungsten concentrations (greater than 10 ppm), with one sample containing 110 ppm W (Sexton, 1985). This anomaly lies 200-400 m south (down-ice) from and parallel to the major Landsat lineament through Tangier Grand Lake. This area is underlain by medium- to coarse-grained leucomonzogranite, but Fox Point itself is geographically adjacent to a "high ratio" granite.

Further sampling revealed additional anomalous tungsten levels and subsequent work involved line cutting, boulder mapping and prospecting, detailed soil geochemistry, and trenching to determine a bedrock source of the mineralization (Duncan, 1985; Sexton, 1985). Tungsten occurrences in the Squirrel Lake-Crooked Lake area are dominated by scheelite with only minor wolframite and molybdenite occurring within a series of narrow (≤1 cm wide) quartz-greisen veins

(Corey, 1993). Three types of wolframite occurrences were found in boulders in the Squirrel Lake area: (1) joint-controlled quartz veins (1 mm-2 cm wide) commonly having greisen selvages and hosting both molybdenum and wolframite; (2) irregular quartz-feldspar pegmatite veins (1-3 cm wide) containing both wolframite and scheelite, and (3) thin (<1 mm) quartz veins with abundant muscovite and containing wolframite in close association with scheelite (Duncan, 1985).

This area is also host to several sphalerite- and galena-bearing quartz breccia boulders which occur near the eastern end of Tangier Grand Lake on a waterway connecting to Bear Lake (Figs. 2 and 3; Duncan, 1984). Coarse disseminated galena and sphalerite occur in vuggy boulders (0.1-1.0 m in diameter) which contain angular to rounded clasts of altered and sheared biotite monzogranite and greywacke in a banded quartz matrix (Corey, 1993).

Ship Harbour

Sulphide-bearing quartz-greisen veins occur (Fig. 2) along the southern contact of the batholith in the Ship Harbour area (along Highway 7). These veins are located along a zone of relatively high density fracturing with individual fracture spacing of 5-10 cm (MacDonald, 1981). Fractures commonly contain narrow (1 cm wide) quartz veins with cross-cut aplite dykes. The main greisen zone consists of an assemblage of quartz and muscovite. Quartz veins lead away from the greisen and contain small amounts of pyrite, bornite and chalcopyrite. Also, wolframite and scheelite have been reported in a quartz vein and skarn zone, respectively, at several localities along the granite/metasedimentary contact, both within the granite and within the metasedimentary rocks (Dimmell, 1983). Anomalous tungsten and base metal levels were found in heavy mineral concentrates from panned tills collected by exploration companies in this area (e.g. Shell Canada Limited, Noranda Exploration Limited).

Elevated concentrations of bismuth (up to 1504 ppm), gold (43-489 ppb) and silver (up to 37 ppm) are reported from this area in apatite-rich greisens hosted by leucomonzogranite to leucogranite (leucoporphyry; Corey, 1993).

East Lake

Another style of tungsten mineralization occurs near the southern contact of the batholith near East Lake (Fig. 2; Doucette *et al.*, 1983; Corey, 1993). Coarse (≤2 cm), disseminated scheelite with minor wolframite and abundant, black tourmaline occur in quartz veins ranging from 1 to 20 cm in width. These veins have little or no associated greisen selvages or greisenization, but are associated with zones of intense desilicification (pervasive K-feldspathization, vuggy texture and vugs commonly filled with secondary minerals) in the leucomonzogranite, resulting in an altered rock termed episyenite. Similar alteration has been reported within mineralized zones (e.g. Millet Brook U-Cu-Ag deposit in the New Ross area) of the South Mountain Batholith (Logothetis, 1984).

Fine-grained, disseminated scheelite was also found associated with skarn zones (e.g. narrow (< 10 cm), banded, stratabound, calc-silicates zones) developed in the metasedimentary rocks of the Goldenville Formation adjacent to the contact east of East Lake (Corey, 1993). Four diamond-drill holes were drilled in 1991 by the Department of Natural Resources (Corey, 1994) , two drilled to investigate the mineral occurrence associated with the granite-hosted quartz veins and two drilled to investigate the nature of the granite-metasediment contact. Types of granite intersected in the drillholes consist of biotite monzogranite and muscovite-biotite monzogranite, leucomonzogranite and leucogranite. Geochemical analyses from samples of drill core indicate that the East Lake samples have geochemical signatures distinct from some of the mineral showings in the western portion of the batholith.

Discussion

The Musquodoboit Batholith can be successfully classified using the same terminology as used for the South Mountain Batholith. The rock types include coarse- and fine-grained leucomonzogranites and biotite monzogranite. Minor amounts of more leucocratic rocks (biotite ≤2%), leucogranite and leucogranite porphyry, are not common in the area discussed in this report, but are found in other portions of the batholith. The majority of the batholith is underlain predominantly by coarse-grained, biotite-muscovite-cordierite leucomonzogranite, with two phases, cordierite-rich (≤4%) and cordierite-poor, found in the western portion of the batholith (Ham, 1993). Biotite-rich rocks (average 8% biotite) occur discontinuously in areas either speculated or observed to be close to the Meguma Group metasedimentary/granite contact. These rocks commonly occur as a discontinuous margin found along the observable contacts of the batholith and in the eastern portion of Tangier Grand Lake. This latter area is speculated to be close to the roof of the batholith, on the basis of numerous contact-related phenomena (numerous xenoliths, biotite schlieren, abundant aplite ± pegmatite and quartz dykes) in the rocks.

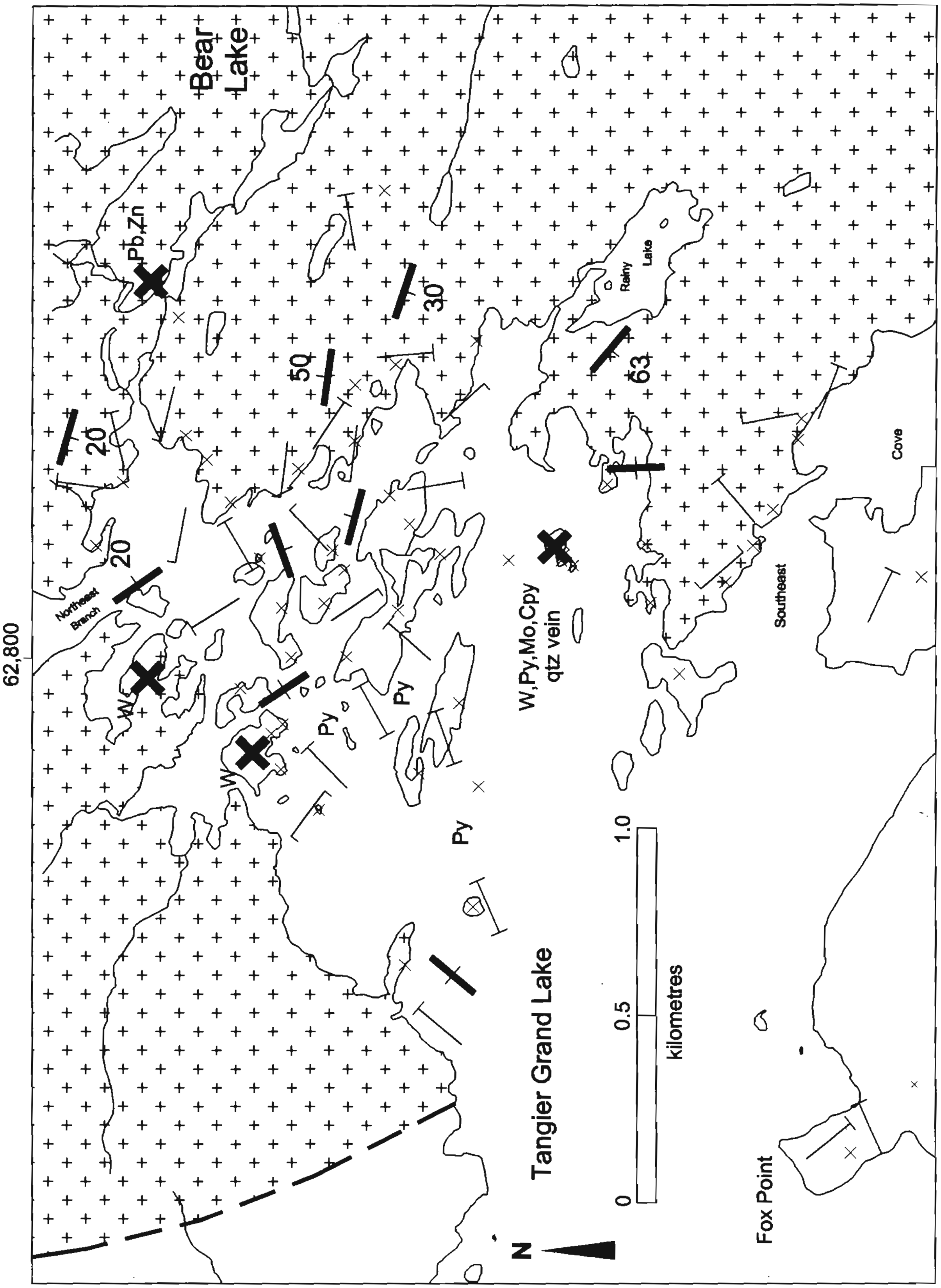


Figure 3. Area of the eastern portion of Tangier Grand Lake underlain by biotite monzogranite and hosting numerous mineral occurrences. Legend is similar to that of Figure 2.

Additional division of the leucomonzogranitic rocks was made based on texture (porphyritic, fine grained, equigranular), mineralogical differences (abundances of biotite, cordierite and muscovite), and also on the ratio of equivalent uranium/equivalent thorium (eU/eTh), following the work of Ford (1991). Several areas of the eastern portion of the batholith, and particularly the area discussed in this report, are outlined as high ratio granites (having an eU/eTh ratio of greater than 1). These areas are underlain by leucomonzogranitic rocks which display heterogeneties (mineralogical, textural) on outcrop scale.

The erosional level of the batholith is speculated to be close to the top in the Tangier Grand Lake area (Fig. 2). In this area, the eastern portion of the lake is underlain by biotite monzogranite which contains many contact-related features (e.g. biotite schlieren; abundant, small (<0.5 m) metasedimentary xenoliths; abundant aplite and/or pegmatite segregations or veins). Jones and MacMichael (1975) also noted swarms of xenoliths (up to 50% of the rock) with the largest one being 60 cm in length (most less than 20 cm) occurring on the north shore of Blue Woods Lake, south of Tangier Grand Lake. Based on the presence of biotite and cordierite in the 100-200 m wide contact aureole, the level of emplacement of the Musquodoboit Batholith is estimated at 6-10 km depth, similar to that of the South Mountain Batholith (Mahoney, 1996).

Mineral occurrences in the Musquodoboit Batholith are generally restricted to quartz-greisen veins which host tungsten (± Mo, Cu, Bi) occurrences with several associated types and styles of alteration. In the Tangier Grand Lake area, several occurrences are found in outcrop. These veins are speculated to be shear-related (Corey, 1993), based on the fracturing and shearing present in both wolframite and muscovite in the veins.

Southwest of Tangier Grand Lake, in the Crooked Lake and Squirrel Lake area, numerous tungsten showings were discovered by soil and till geochemistry. The orientation of these veins and showings is generally northeast and east, coincident with numerous lineaments throughout the batholith. Located near the northeast end of Tangier Grand Lake is a lead-zinc showing of quartz breccia boulders. The characteristics of these boulders and their restricted occurrence (confined to an area ~ 50 m^2) suggest a breccia-pipe. This showing lines up in a northeasterly orientation with a major linear through Tangier Grand Lake, and with other tungsten showings on the lake and in the Crooked Lake and Squirrel Lake areas. These major linears, coupled with the presence of numerous high ratio granites, suggest a target for future exploration. Additionally, many of the mineral occurrences are found in biotite monzogranite host rocks, and further exploration efforts could be concentrated in these rocks.

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