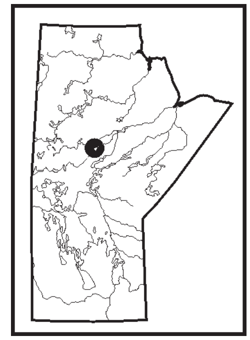
GS-13 Mafic-ultramafic magmatism of the Bah Lake assemblage, Ospwagan Group, Upper Ospwagan Lake, Manitoba (NTS 63O9)

by H.V. Zwanzig



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Summary

A sequence of the Bah Lake mafic-ultramafic volcanic and subvolcanic intrusive rocks is exposed in a homoclinal section on the northwest shore of Upper Ospwagan Lake. Pillow basalt dominates this section, but about 30% consists of megacrystic (olivine) picrite and komatiitic basaltic to ultramafic flows. Preserved primary structures, particularly flow and intrusive contacts, suggest that the full range of rocks is part of a single volcanic edifice. Although a comagmatic relationship between this succession and the more Mg-rich ultramafic intrusions associated with mineralization throughout the Thompson Nickel Belt (TNB) is highly unlikely (unpublished CAMIRO report, Project 97E-02, 2004), the relationship between the local volcanic section and nearby ultramafic bodies at Ospwagan Lake may be further explored using stratigraphy, geochemistry and Nd isotope data.

Introduction

The ultramafic intrusions in the TNB, which are associated with the nickel deposits, have been shown to be chemically and isotopically different from the mafic-ultramafic volcanic rocks (Bah Lake assemblage) at the top of the Ospwagan Group, which hosts the intrusions (CAMIRO report, Project 97E-02). The work showed that the volcanic rocks are not cogenetic with the underlying intrusions and therefore do not provide a guide for mineral exploration. Nevertheless, there may be an association between an ultramafic intrusion at Mystery Lake and overlying volcanic and subvolcanic rocks, as seen from trace-element data. The Bah Lake assemblage at Ospwagan Lake comprises basaltic flows with a picrite sill (Stephenson, 1974) and overlies the largest of the ultramafic intrusions in the TNB (Thompson Nickel Belt Geology Working Group, 2001; Figure GS-13-1). Mapping and sampling for geochemical and Nd isotope analysis were carried out in 2004 to test whether a genetic link exists between these various rock types at this locality. A mafic flow that appears to be isotopically evolved, somewhat like the intrusions, received particular attention. This report is concerned only with the preliminary field data from the top of the Ospwagan Group (the Bah Lake assemblage).

Fieldwork was carried out on the north and west shores of Upper Ospwagan Lake for seven days in June 2004. Low water levels provided good exposures of the mafic-ultramafic volcanic and intrusive rocks at the top of the Ospwagan Group. These were sampled for geochemical analysis and Nd isotope work to detect a possible systematic variation in the stratigraphic section. Mapping of the complete section was designed to augment previous work on Ospwagan Lake (Stephenson, 1974; Scoates et al., 1977; Macek and Russell, 1978a, b; Theyer and Freund, 1998; Thompson Nickel Belt Geology Working Group, 2001) and recent work elsewhere, including the type section at Bah Lake (CAMIRO report, Project 97E-02).

The recent work on Upper Ospwagan Lake has shown that the MgO contents of basalt to picrite or komatiite (from those samples judged to be little altered) ranges from 7 to 27% (volatile free). Rocks reported as metapicrite from Ospwagan Lake by Stephenson (1974) contain 16–26% MgO and therefore include komatiitic basalt and ultramafic members, whereas reported tholeiitic basalt contains 6.4–11% MgO, showing a small compositional gap with picrite. Basalt generally has positive initial εNd values in the TNB, in contrast to the negative values of ultramafic intrusions (CAMIRO report, Project 97E-02). Nevertheless, basalt with initial εNd = -0.3 and -2.3 occurs, respectively, on Fish Lake on the Kisseynew Domain margin and on Upper Ospwagan Lake.

Field characteristics and stratigraphy

During the remapping, basalt, high-Mg (komatiitic) basalt and fine-grained picrite were tentatively identified by weathering colour and locally by flow characteristics. Coarse spinifex texture indicates the presence of (ultramafic) komatiite or komatiitic basalt near the stratigraphic top of the Bah Lake assemblage. The true composition of these units is presently uncertain and awaits analysis. A distinctive unit of megacrystic picrite contains metamorphic or altered olivine, probably pseudomorphic after olivine phenocrysts. The presence of the olivine megacrysts is indicated by prominent reddish weathering pits or less obvious brown spots that may also be pseudomorphs after pyroxene. Rocks with gabbroic and diabasic texture were also easily identified. It is generally uncertain, however, whether such layers are thick flows or sills.

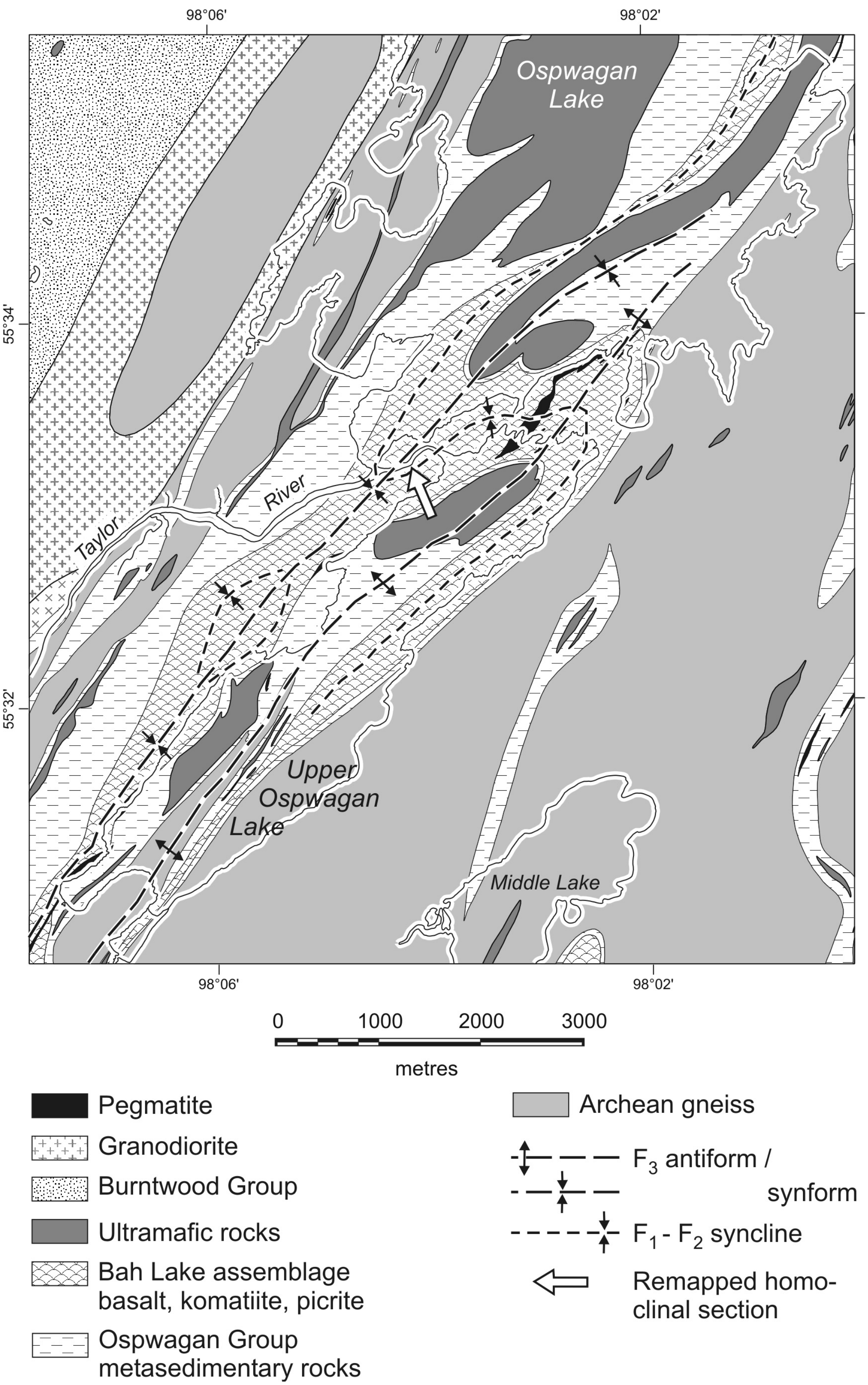

Figure GS-13-1: *Simplified geology of Upper Ospwagan Lake and part of Ospwagan Lake, showing the location and structural setting of the sampled sequence of mafic-ultramafic rocks of the Bah Lake assemblage.*

Consistently north- and west-facing units of basalt and interlayered picrite start above the top of the Setting Formation quartzwacke in the northwest limb of an F_3 antiform and extend to the centre of the belt of mafic rocks exposed in the core of an F_1 or F_2 syncline developed in the Bah Lake assemblage (Figure GS-13-1). This homoclinal part of the crossfolded sequence allowed relatively complete sampling and remapping of the locally exposed stratigraphic section. No simple systematic upward variation in composition, however, was apparent in the section. Primary structures, including pillow tops used to determine way up, are recognizable on the clean shoreline outcrops on Upper Ospwagan Lake despite the strong deformation and amphibolite-grade metamorphism. Local difficulty in sampling was encountered where units are highly flattened or sheared in the limb of the F_3 fold, or folded in the F_3 hinge zone. Some outcrops, however, furnished good samples of apparently unaltered material for analysis in spite of the metamorphic grade and common quartzofeldspathic veins.

The only systematic stratigraphic variation is that the megacrystic picrite appears to be more abundant in the lower part of the section, and aphyric picrite or komatiite to komatiitic basalt are prominent in the upper part. One documented body of picrite must be intrusive, whereas several mafic-ultramafic bodies in the upper part of the section are best interpreted as flows. The similar variation in composition within flow units and intrusive units suggests that the entire section is part of a single volcanic edifice and that some original liquids were probably komatiite.

Metabasalt

About 50% of examined outcrops are basalt, generally pillowed. The pillow basalt has clearly defined selvages with a grey, plagioclase-rich outer rim and dark green or black, hornblende-rich inner rind. The body of the pillows is fine grained, aphyric and weathers greenish grey. More greenish weathering pillows probably consist of high-Mg (komatiitic) basalt. Plagioclase-phyric flows are rare. Flow units are 3–10 m thick (8 m median), but flattened pillow shapes, especially in vertical sections, indicate that they were several times that thickness before deformation; in addition, some are composite units. Thicker units would exceed the outcrop size and thinner units may have no visible contacts. One observed pillowed unit appears to form the top of a thick flow because it grades down into gabbro-textured rock. Thinner pillowed flows locally merge with underlying, fine-grained massive flows. The flows also vary considerably along strike.

Pillows are relatively large; mattress pillows that overlie several oval pillows are not uncommon (Figure GS-13-2a), with individual pillows being up to 3 m long. Some units of large pillows have smaller pillows at the top or massive basalt that grades into large pillows overlain by small pillows. Pillow breccia, however, is not very abundant. Altered hyaloclastite locally forms small volumes where pillows abut. A dearth of amygdules suggests deep-water deposition or magma with very low volatile content. Variolites are preserved as rims inside the selvage or throughout the pillows (Figure GS-13-2b). Lenses rich in epidote and diopside are common, and these are interpreted as seafloor alteration domains (Figure GS-13-2c).

Massive basalt forms 2–20 m thick units that weather dark to medium greenish grey. They are locally topped by pillowed flows or flow-top breccia. Some units may be intrusive (diabase). Flows mapped as komatiitic pillow basalt weather dark grey-green to brown. They are thinner (2–8 m) and less abundant than the greenish grey flows. Most high-Mg flows are massive but some are pillowed. Alteration along premetamorphic fractures and partly resorbed pillow rinds are locally present.

Picrite to komatiitic basalt and gabbro

Approximately 30% of examined outcrops are picrite and komatiite to komatiitic basalt. These rocks weather medium green to brown and grey-green to dark green. Picrite flows and sills range from olivine megacrystic (2–10 mm, 20–40%) to possibly less magnesian aphyric varieties that occur in about equal proportions. These mafic-ultramafic bodies are 1.2–12 m thick (4.5 m median, deformed) and locally show gradational contacts between megacrystic and fine-grained varieties. The fine-grained rock is most prominent on the northeast side of individual units, suggesting that they are flows or sills facing northwest like the enclosing pillows. The fine-grained portions are interpreted as chill zones and zones that have lost olivine through crystal settling. Some observed changes in texture at the contacts are clearly due to chilling or supercooling. Basal chill zones, where observed, are narrow. Although no clearly orthocumulate layers or modal layering were seen, in situ fractionation cannot be ruled out since some layering has been reported by Theyer and Freund (1998).

Aphyric komatiite and high-Mg basalt cannot be clearly distinguished without geochemical analysis. These green- to grey-weathering flows and possible sills are 2–8 m thick (deformed). Some massive units appear to form the

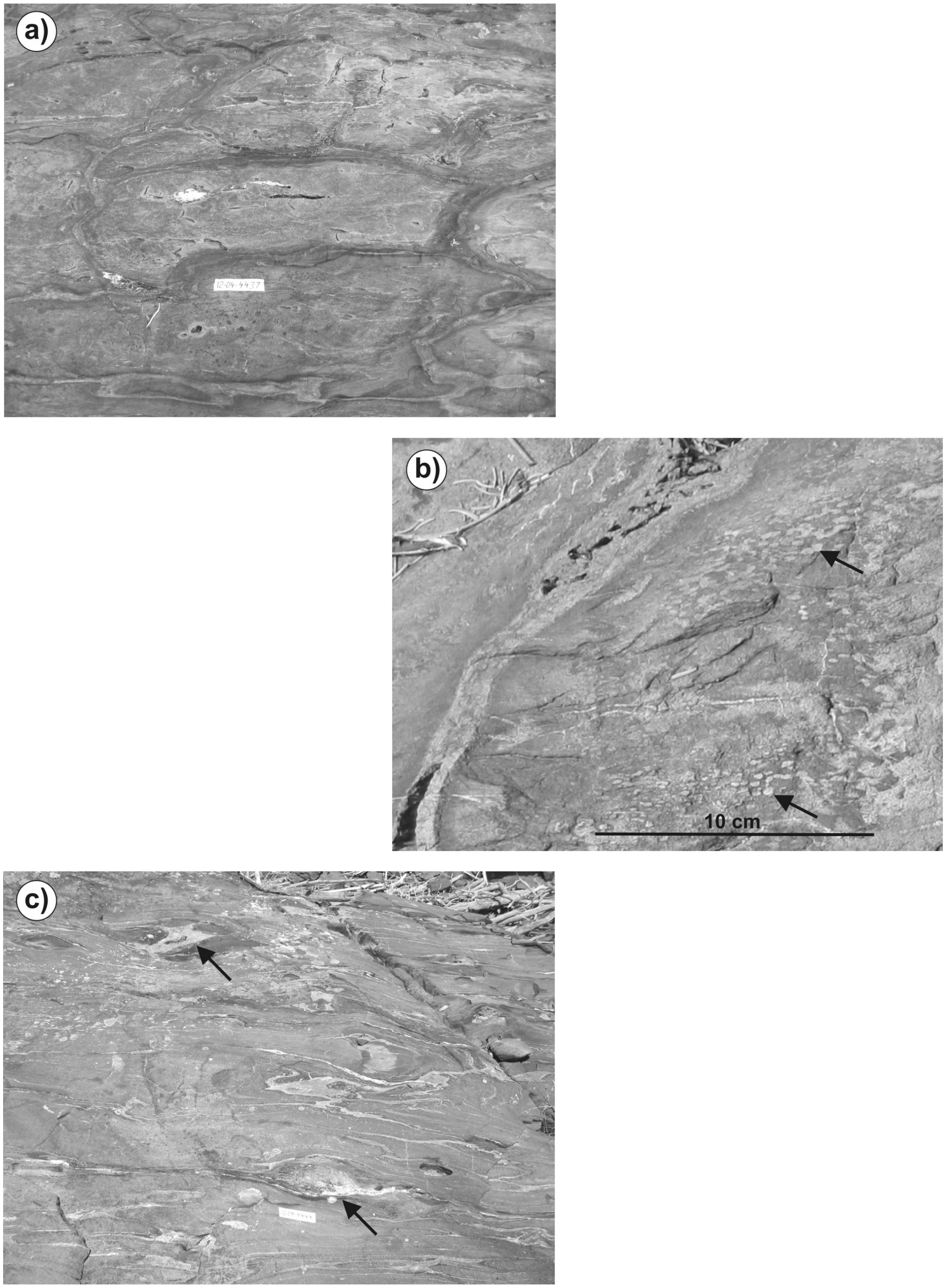

Figure GS-13-2: *Outcrop photographs of pillows in metabasalt, Bah Lake assemblage, Upper Ospwagan Lake:* ***a)*** *mattress pillow with buds (e.g., at the 10 cm long tape), overlain by smaller pillows;* ***b)*** *variolitic zone (at arrows) in pillow; selvage to the left;* ***c)*** *deformed pillowed flow with epidote-diopside (seafloor) alteration lenses (arrows) and metamorphic plagioclase-rich veining (e.g., lower arrow).*

upper portion of the megacrystic picrite. Other massive units show primary polyhedral fractures throughout (Figure GS-13-3a), more closely spaced at the top of the flow, a structure typical of finely spinifex-textured flows (Donaldson, 1982). Rare flows have coarse spinifex texture, best developed at the top (Figure GS-13-3b). The medium-grey weathering colour of these flows and a xenolith of pyroxenite suggest that this is komatiitic basalt and that the books of spinifex are pseudomorphs after pyroxene rather than olivine, as opposed to many Archean komatiites. Some massive units can be recognized as flows by the character of their contacts (Figure GS-13-3c). Pillows in komatiitic basalt typically have thinner, amphibole-rich inner selvages than the normal basalt.

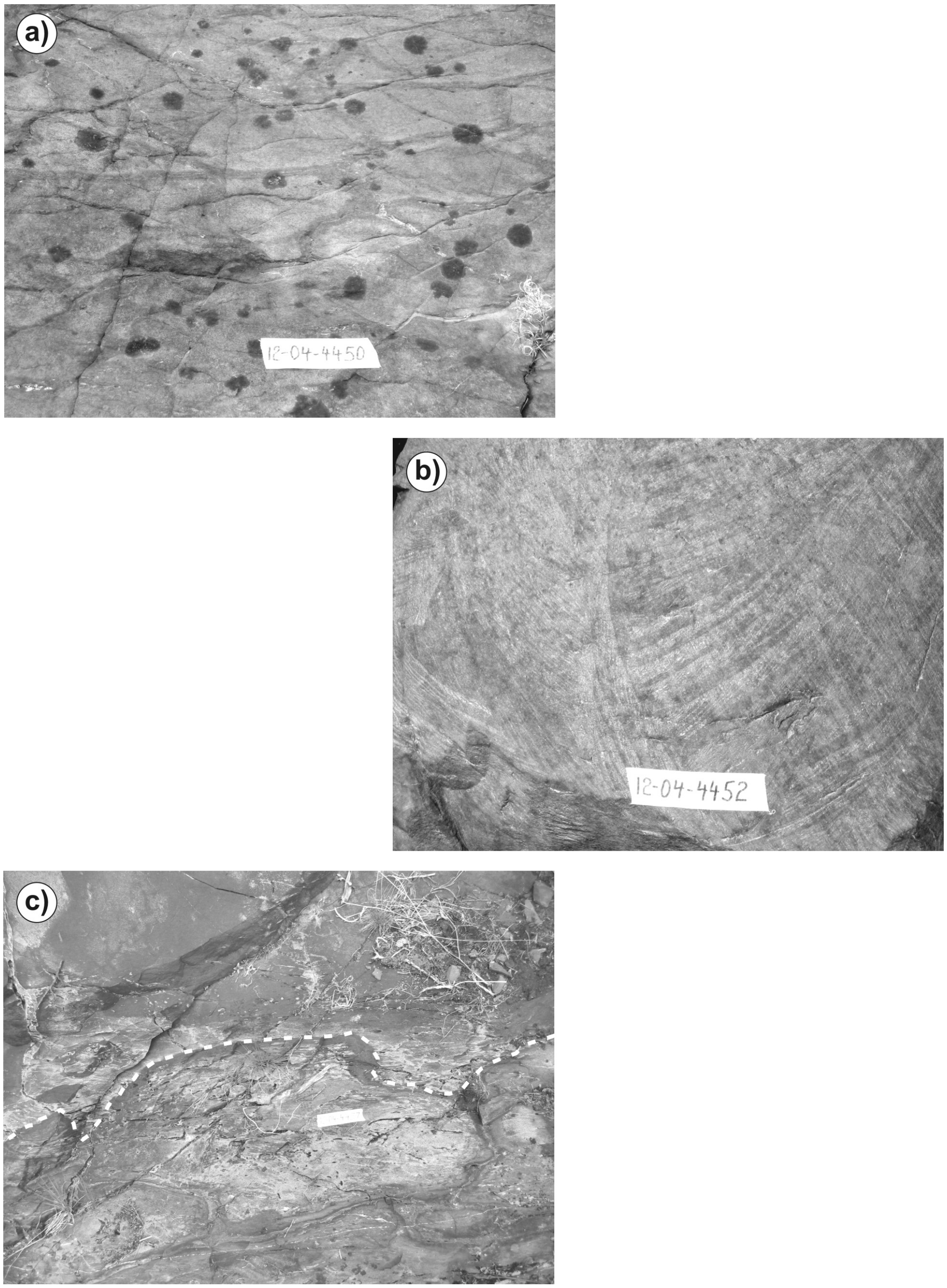

Figure GS-13-3: *Outcrop photographs of komatiitic basalt, Bah Lake assemblage, Upper Ospwagan Lake:* ***a)*** *basaltic komatiite with premetamorphic polyhedral fractures (spots are lichen); tape is 10 cm;* ***b)*** *coarse spinifex texture in upper part of komatiitic flow;* ***c)*** *altered basal contact (marked) of massive komatiitic flow filling depressions in underlying pillowed flow.*

Megacrystic picrite contains 20–45% olivine grains that are 2–10 mm long. Colour-zoned subhedral grains and a possible glomerocryst suggest that these may be pseudomorphs after olivine phenocrysts (Figure GS-13-4a), a conclusion also reached by Stephenson (1974). A body interpreted as a probable picrite sill contains xenoliths of altered basalt up to 70 cm long and coarse-grained (20 mm) pyroxenite inclusions (Figure GS-13-4b). A chill zone displays local spinifex texture arranged radially around some blocks of basalt. This relation suggests that the intruding magma fractured already-consolidated lava and was supercooled against the entrained fragments.

Approximately 20% of the examined outcrops feature rocks with gabbroic to diabasic texture. Bodies with these textures are 2–12 m thick (7.5 m median), weather medium grey to dark greenish grey and probably have a range of compositions with different MgO contents. Two varieties are recognized: those with 50% clearly visible (metamorphic) amphibole, and finer grained units with 60–70% macroscopic amphibole.

A complex unit comprises 2 m of dark grey, fine-grained amphibolite at the base, commingled with overlying gabbroic-textured rock that appears to grade into 4 m of grey spinifex-textured komatiitic basalt. The spinifex grades from sheaves of subparallel needles more than 20 cm long to 5 cm needles higher up and 1–2 cm random needles at the top.

Lack of abundant cumulate layering indicates that the distinct varieties of flows and sills with different compositions fractionated in a deeper magma chamber, whereas the limited zonation of flow units shows that some fractionation continued in situ. The megacrystic picrite was possibly intruded as a fine-grained crystal mush that was too viscous for significant fractionation but fluid enough to allow crystals to settle out of the top. Lack of oval megacrysts around inclusions suggests that these unusually large grains grew during slow crystallization of the main body of the sill or flow.

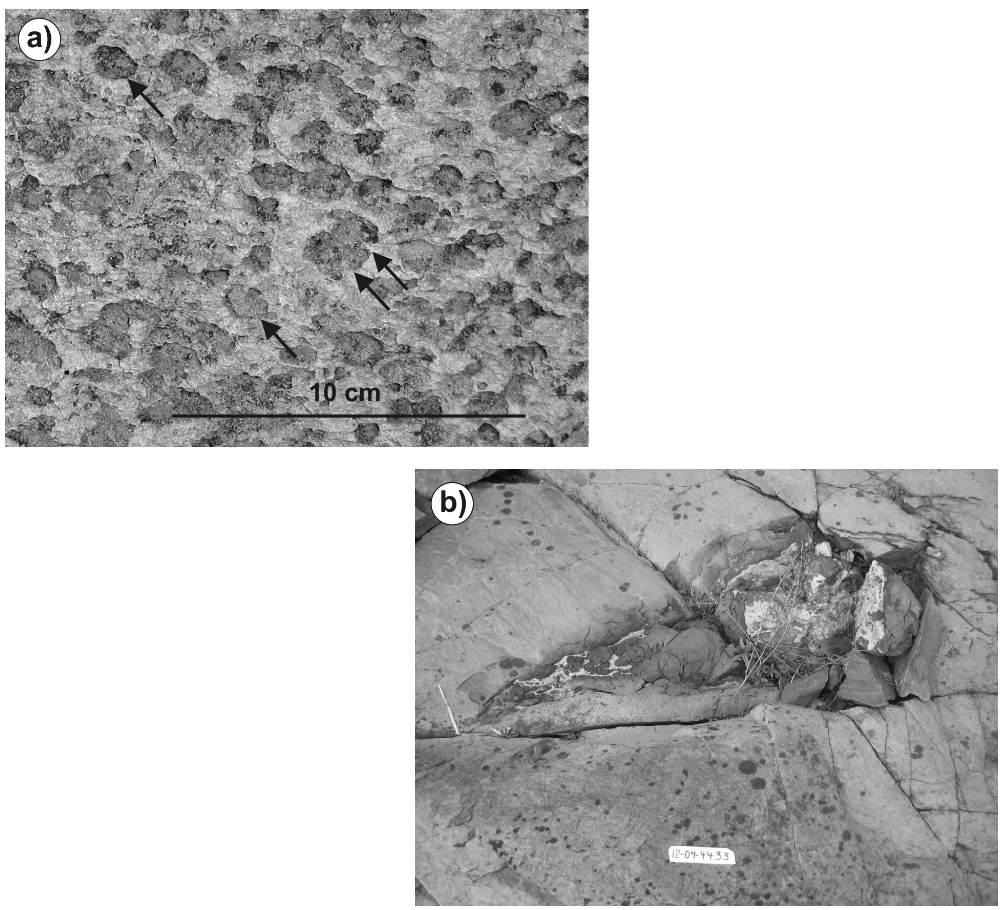

Figure GS-13-4: *Outcrop photographs of picrite, Bah Lake assemblage, Upper Ospwagan Lake:* ***a)*** *megacrystic picrite showing preservation of some nearly euhedral grains that are probably pseudomorphs after primary olivine (single arrows) and a possible glomerocryst (two arrows);* ***b)*** *northwest (upper) part of picrite body with xenoliths of altered basalt 70 cm long surrounded by a chill zone (lighter); the area near the tape (10 cm long) contains approximately 25% olivine porphyroblasts; black spots are lichen.*

Economic considerations

Sampling for geochemistry and Nd isotope analysis was carried out to further test the possibility of a comagmatic relationship between mafic-ultramafic flows of the Bah Lake assemblage and the ultramafic bodies associated with nickel deposits. The latter are contaminated by granitic crustal material, as indicated by geochemistry and negative εNd values, whereas the mafic rocks that constitute most of the Bah Lake assemblage do not generally show significant crustal contamination (CAMIRO report, Project 97E-02). Visiting the site of the unusual basaltic flow with negative εNd on Ospwagan Lake at low water has shown that granitoid pegmatite dikes and veins, and apparent biotitic alteration of pillow rinds, are prominent there. The sample also has about 3 wt. % extra SiO_2, 1% extra Na_2O and 0. 4% extra K_2O, compared to other samples with similar MgO contents. This, and about 0.6% 'additional' K_2O recorded in a sample with negative εNd from the margin of the Kisseynew Domain, strongly suggest that the anomalous Nd isotope ratios were affected by mixing with metamorphic fluids that had an Archean source component from underlying rocks. This conclusion further negates any direct genetic relation between mineralized ultramafic bodies and the exposed volcanic rocks. Nevertheless, continued investigation of the relation between mafic and ultramafic rocks is warranted and may yet establish a genetic link, based on 1) low εNd in massive picrite near Bah Lake; 2) the identical trace-element geochemical fingerprint of contaminated ultramafic intrusions and overlying flows and sills at Mystery Lake; and 3) the occurrence of most komatiitic flows adjacent to the two largest ultramafic bodies in the TNB. The new samples will be submitted for high-precision Sm-Nd isotope analysis at the University of Alberta to ensure that no spurious results are obtained due to the low rare earth element contents of these rocks.

Acknowledgments

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