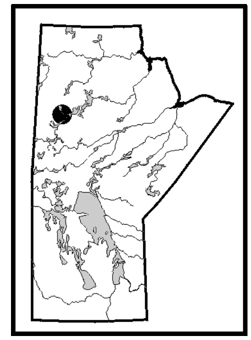
GS-21 DISCOVERY OF A CARBONATITE COMPLEX AT EDEN LAKE (NTS 64C9), MANITOBA

by A.H. Mumin[1]



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SUMMARY

Reconnaissance and detailed geological mapping and sampling carried out in the Kwaskwaypichikun region (KPK), near Eden Lake, has led to the recognition and discovery of a large carbonatite complex enriched in rare earth elements (REEs). The area was selected as a priority target with potential to host a hydrothermal iron-oxide copper-gold (IOCG- or Olympic Dam–type) deposit. The KPK region is underlain by alkaline igneous rocks ranging from K-feldspar–rich pegmatite and syenite to metasomatized intermediate, mafic and ultramafic bodies. The most striking feature of the complex is an extensive area of hydrothermal and magmatic stockwork veining and breccia exposed in outcrop over an area of at least 7 km^2. Early rocks of the complex include a series of intermediate (monzonitic) mafic and ultramafic rocks and paragneiss. These rocks are pervasively shattered and veined to produce blocky breccias. Syenitic veins, dikes and plugs invade the shatter zone in a complex stockwork. In the final phase of magmatic activity, K-feldspar- and quartz-rich pegmatite dikes form a late superimposed stockwork disrupting the earlier rocks.

Carbonatite dikes and plugs were unexpectedly discovered at three locations, and evidence suggests there may be many more. The carbonatite bodies are closely associated with syenite and fenitic alteration, and are presently thought to predate the pegmatite dikes. Alkali metasomatism affects the entire complex: Na alteration occurs as pervasive to patchy replacement of early phases and as ubiquitous hydrothermal veins and veinlets; and later stages of hydrothermal alteration include K±Na and K-carbonate metasomatism in veins and patches. The youngest phase of hydrothermal alteration includes large areas of pervasive hematization, and a few narrow, late quartz veins and veinlets.

The elements F, Ba, Sr, U, Th, Sc, Y, La, Ce, Sm, Nd, Pr, Eu, Gd, Dy, Tb, Tm, Er, Yb and Lu are variably enriched throughout the complex. Significant REE enrichments occur in all hydrothermally metasomatized rocks, including syenite and intermediate (monzonitic), mafic and ultramafic rocks. Hydrothermal veins, including aegirine-augite±K-feldspar or amphibole (usually mixed), K-feldspar and K-feldspar–carbonate, are strongly enriched in REE. The highest REE concentrations encountered to date are in the carbonatite dikes (up to 16 129 ppm total REE, 9764 ppm Sr and 745 ppm Y) and in hydrothermal REE-rich veins (up to 138 000 ppm total REE, 5307 ppm Y and 5465 ppm Th+U). Local enrichments in Cu and Ag were also encountered.

This paper reports only on the preliminary observations and results of work that was carried out mainly during a five-week period in July and August 2002. More detailed work on the geology, structure, mineralogy, geochemistry and mineralization of the complex is in progress.

INTRODUCTION

The eastern shore of Eden Lake in the Kwaskwaypichikun region was identified as a first-priority target with potential to host a hydrothermal iron-oxide copper-gold (IOCG- or Olympic Dam–type) deposit (Mumin, GS-11, this volume). The region of interest was previously mapped as aegirine-augite syenite and monzonite (Cameron, 1988; McRitchie, 1989; Fedikow et al., 1993), and was known to host several small radiometric U-Th and REE showings containing britholite and/or allanite (McRitchie, 1989; Young and McRitchie, 1990; Gunter et al., 1995; Fedikow et al., 1994; Arden and Halden, 1999). Geochemical investigations on aegirine-bearing monzonite by Halden and Fryer (1999) indicated anorogenic magmatism of probable depleted, altered, mantle-derived material. However, detailed mapping of the region had not been carried out until the present project. A five-week program of reconnaissance and detailed mapping and sampling was funded primarily by Rare Earth Metals Corp. of Vancouver. Reconnaissance work was carried out over an area of approximately 30 km^2, extending from Kwaskwaypichikun Bay south to within approximately 2 km of the Numakoos River (Fig. GS-21-1). Detailed mapping at 1:2000 scale was completed over two separate gridded blocks covering approximately 4 km^2 (Fig. GS-21-2), and four additional smaller blocks were remapped in greater detail (1:500 scale; Fig. GS-21-3).

Approximately 140 samples were collected and analyzed for 43 elements by inductively coupled plasma–mass spectrometry (ICP-MS), utilizing a lithium borate fusion technique for enhanced accuracy in REE detection. Check assays and geochemical orientation work are in progress.

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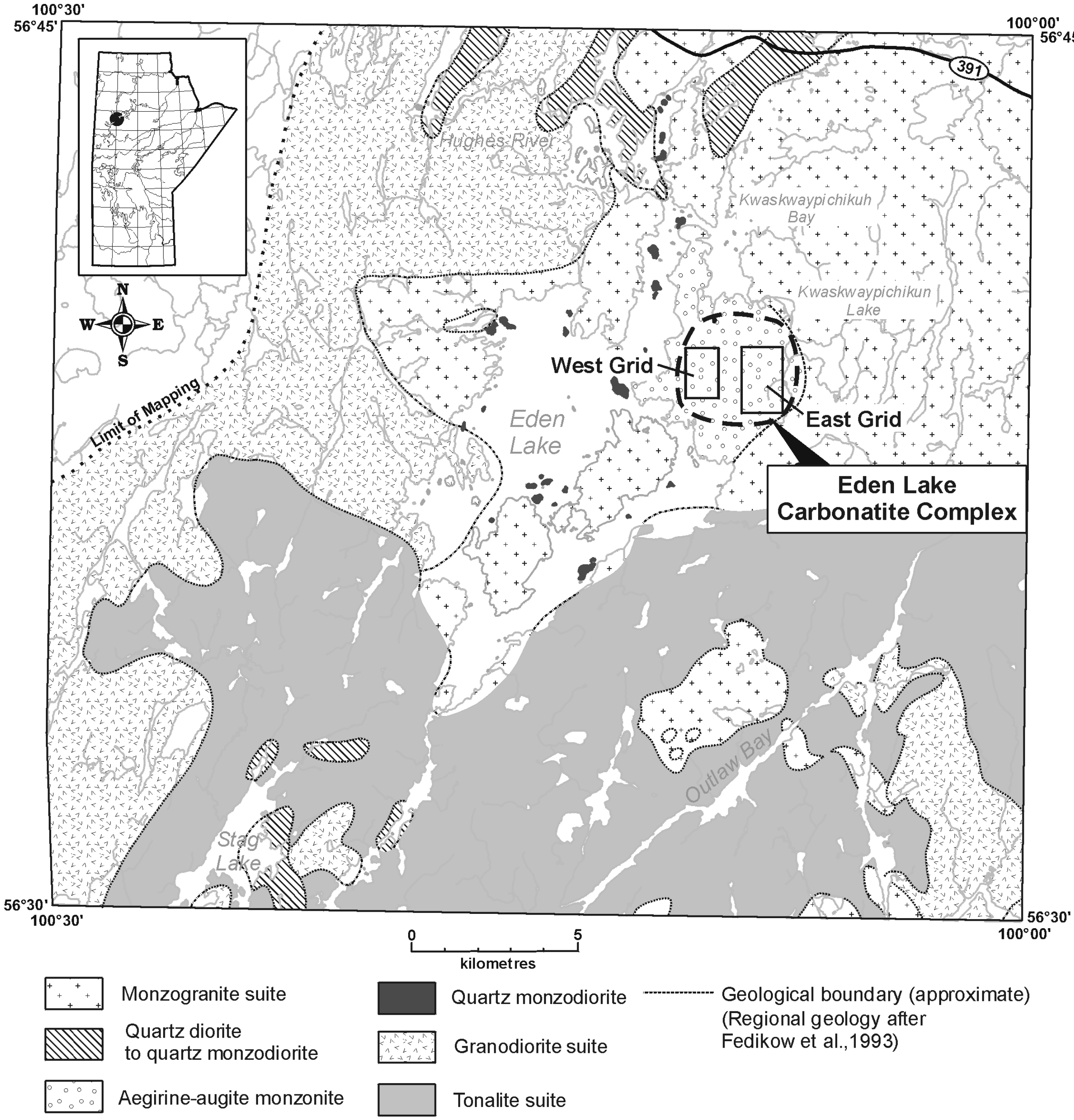

Figure GS-21-1: Regional geology of the Eden Lake area (after Fedikow et al., 1993), showing location of reconnaissance and detailed work.

PRELIMINARY OBSERVATIONS ON THE GEOLOGY OF THE EDEN LAKE CARBONATITE COMPLEX

The Kwaskwaypichikun region is underlain by an extensive hydrothermal and magmatic stockwork and breccia. Intermediate (monzonitic), mafic and ultramafic rocks occur as coarse blocky breccia and disaggregated stocks and dikes with varying degrees of metasomatic alteration (Fig. GS-21-4). Paragneiss of unknown affinity is associated with some of the monzonite and mafic rocks. These rocks are ubiquitously cut and disaggregated by a stockwork of aphanitic to medium-grained syenite to quartz syenite stocks, dikes and small veins (Fig. GS-21-4). The syenite bodies range from less than 1 cm to more than 100 m in thickness, with coalescing veins and dikes forming larger syenite bodies. The youngest magmatic rock in the complex is pyroxene-bearing quartz+K-feldspar pegmatite. It forms medium- to very coarse grained dikes and stockwork veins, with individual dikes up to 5 m thick and extending for several hundred metres along strike.

Remnants of early sedimentary hostrocks have not been identified, with the possible exception of the paragneiss.

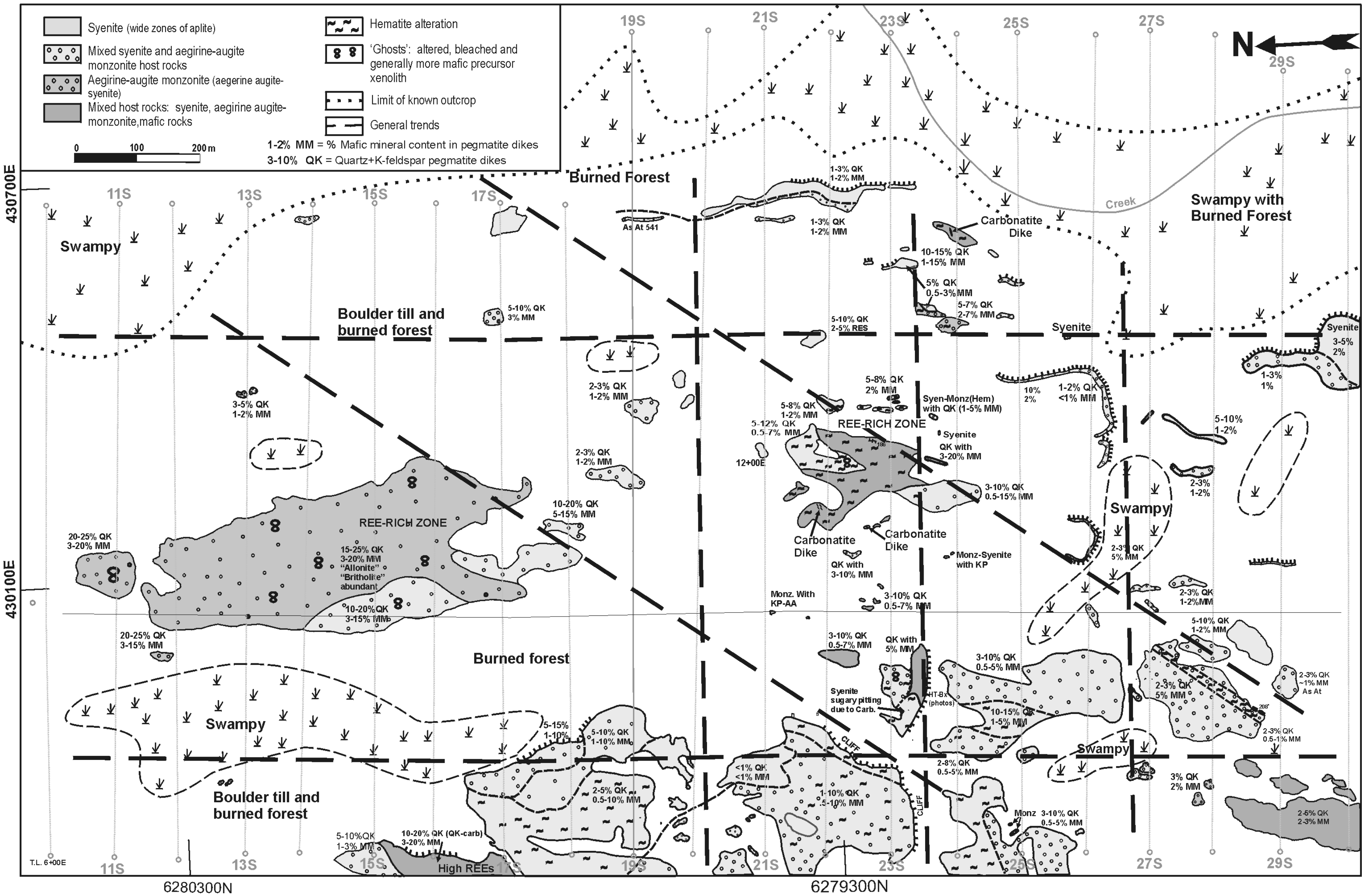

Figure GS-21-2: Geology of the East grid.

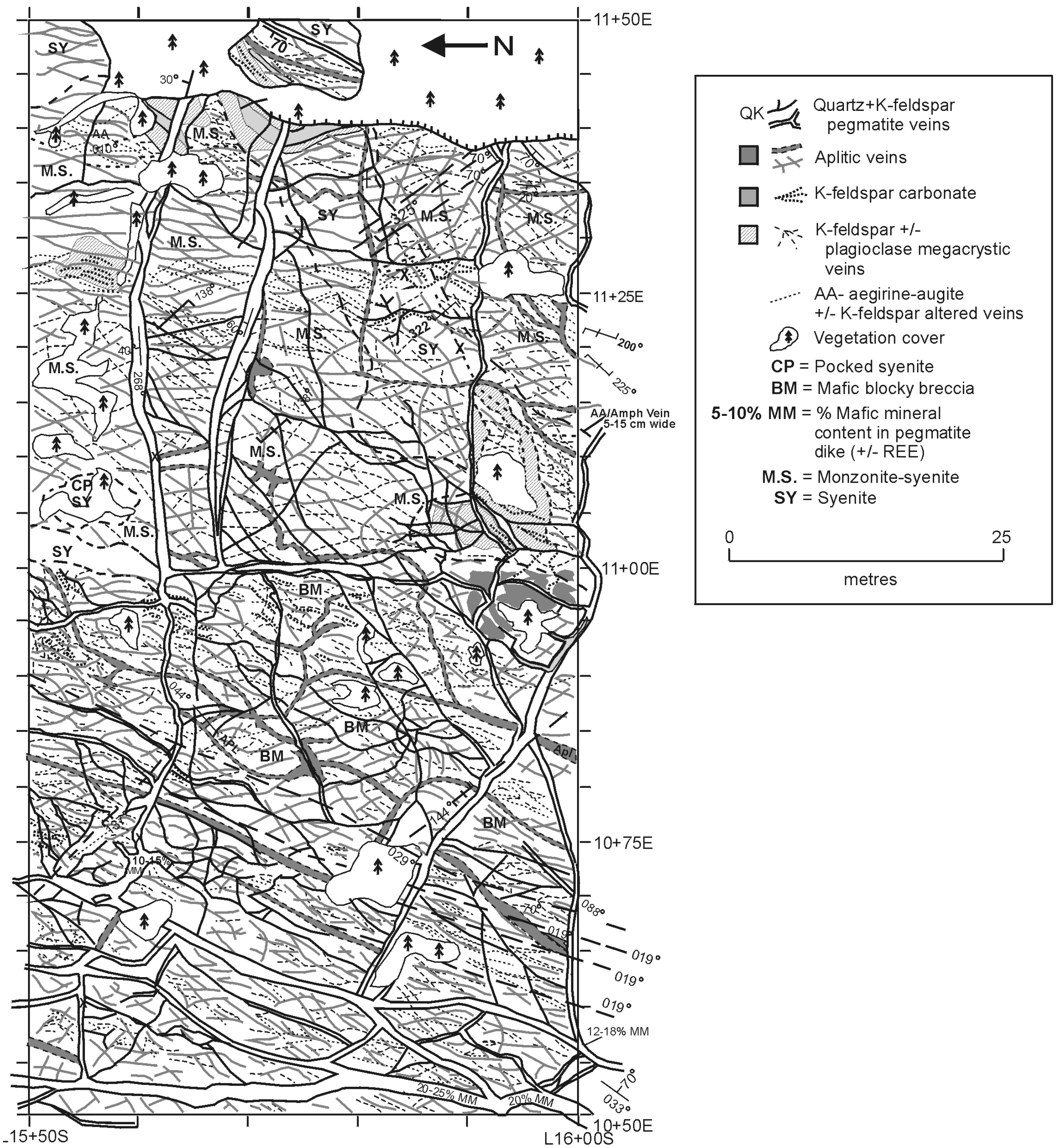

Figure GS-21-3a: Structural detail for part of the East grid, showing the intensity and complexity of veining in the shatter zone.

Some rocks may be volcanic in origin, with their primary textures obliterated, but this possibility remains uncertain. Large parts of the region were mapped as zones of 'mixed rocks', due to extensive intermixing and disaggregation of the different host units of the complex (Fig. GS-21-4).

Structure

Three distinct structural trends intersect in the Kwaskwaypichikun region. North-, east- and northeast-trending structures control the orientations of many veins and dikes (Fig. GS-21-2). Additionally, vein- and dike-filled fractures of the shatter zone occur in all orientations, with dips ranging from near-horizontal to vertical (generally

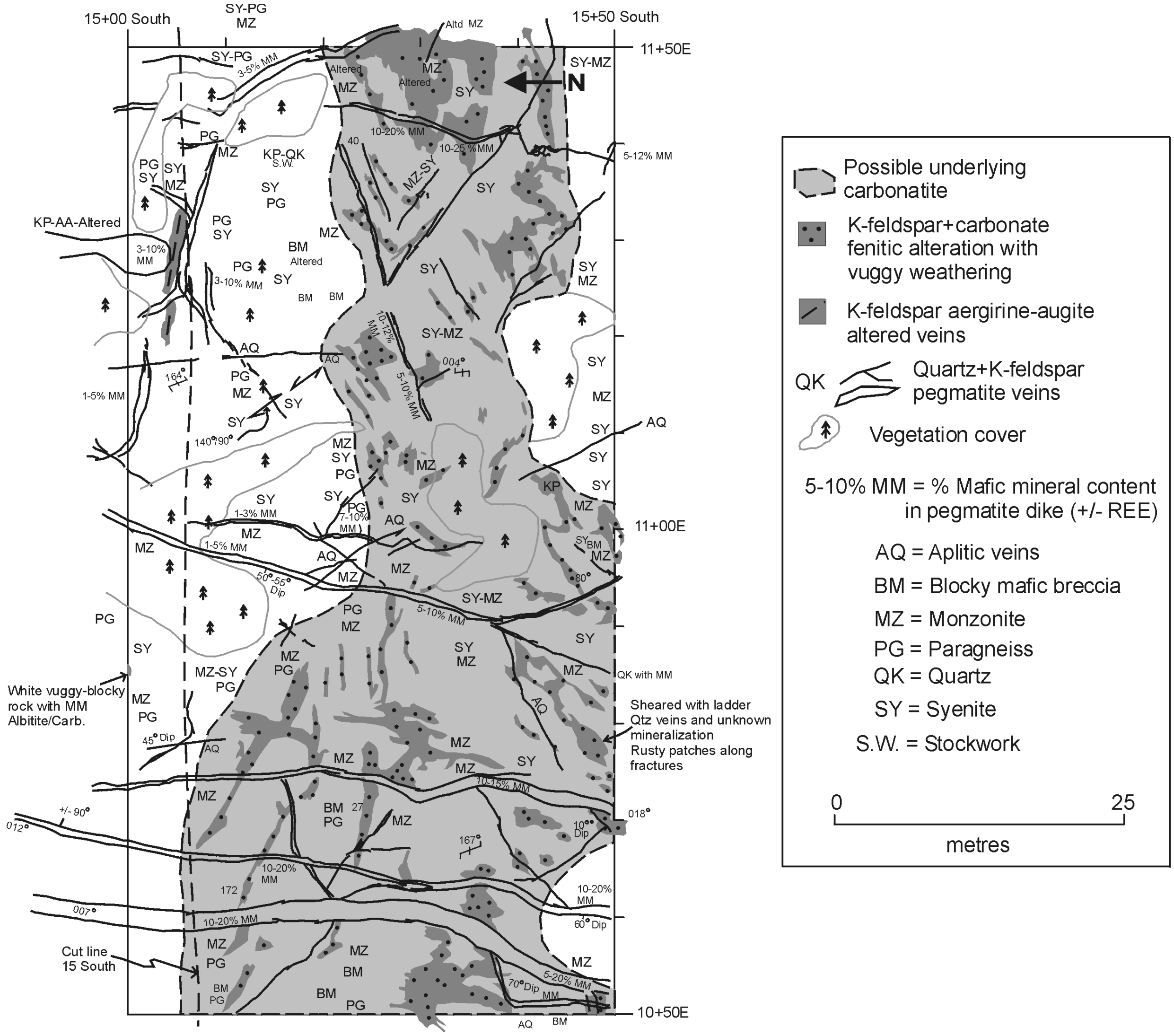

Figure GS-21-3b: Detailed geology, showing the relationship of K-feldspar–carbonate fenite bodies to quartz–K-feldspar pegmatite dikes and the 'shattered' host rocks, East grid. Location of possible underlying carbonatite is indicated.

ranging from approx. 30° to vertical). Evidence for domal jointing was observed at several localities as shallow-dipping, layer-cake, weathered syenite (Fig. GS-21-5). Domal jointing is known to occur in the domed rocks overlying large intrusions. The result of intersecting structural features combined with pervasive hydrothermal and magmatic injections is an extensive stockwork and angular blocky breccia covering at least 7 km^2 of the Kwaskwaypichikun region.

Polymictic, diatreme-like structural and hydrothermal breccias with partially milled, rounded to angular clasts are locally exposed in irregular patches (Fig. GS-21-6). One of these breccias with variably altered and milled clasts is exposed along an east-trending fault scarp (Fig. GS-21-7). Polymictic clasts are cemented in a K-feldspar– and carbonate-rich matrix. The nature of these breccias remains under investigation. Late fractures are common in some areas of the complex, most of them trending in a northeasterly direction. They are often associated with hematitic alteration, and some of these late fractures are filled with narrow (centimetre-scale), opaque to translucent quartz veins carrying trace amounts of sulphide and other minerals.

Hydrothermal alteration

Widespread hydrothermal alteration has affected host rocks throughout the carbonatite complex. Aegirine-augite is variably disseminated in syenite and intermediate (monzonite), mafic and ultramafic rocks (Fig. GS-21-4). Aegirine-augite also occurs as narrow, hydrothermal veins and veinlets, often intergrown with K-feldspar or with K-feldspar selvages, and occasionally with amphibole. These aegirine-augite–bearing veins typically constitute 0.5 to

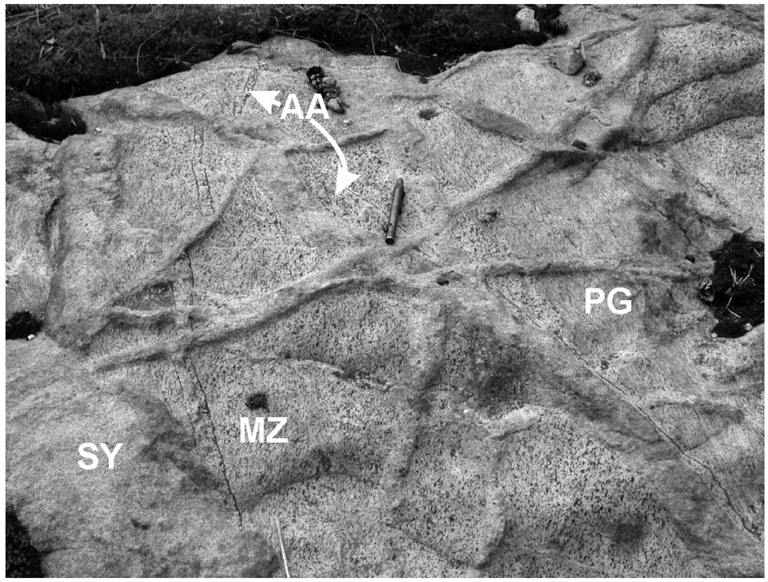

Figure GS-21-4: Monzonite and paragneiss host rocks are shattered and veined with fine-grained syenite to produce the coarse, blocky breccia, East grid. Abbreviations: AA, aegirine-augite–K-feldspar veins; MZ, monzonite; PG, paragneiss; SY, syenite.

Figure GS-21-5: Layer-cake weathered syenite, West grid.

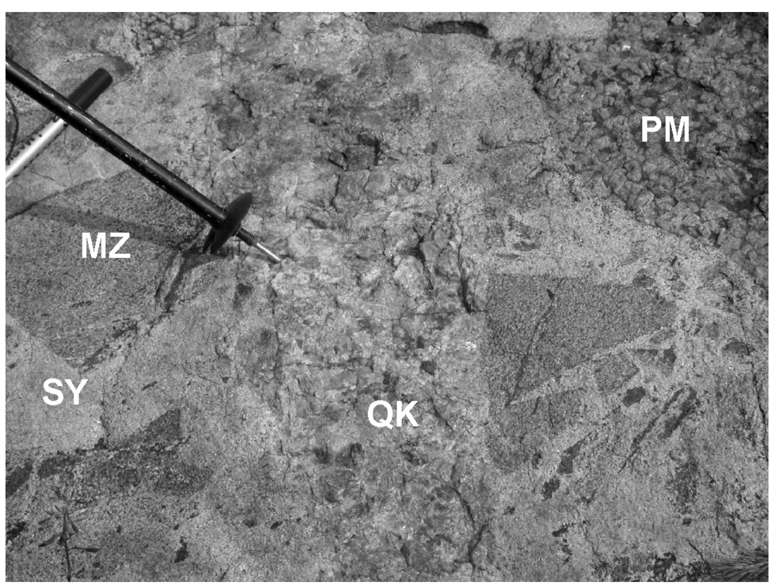

Figure GS-21-6: Blocky, angular, polymictic breccia cut by a small quartz+K-feldspar pegmatite dike, West grid. Abbreviations: MZ, monzonite; PM, porphyroblastic mafic rock; QK, quartz–K-feldspar pegmatite; SY, syenite.

Figure GS-21-7: Diatreme-like breccia with partially altered, subrounded to angular polymictic clasts, associated with an east-trending structure, East grid.

3% of the rock mass (Fig. GS-21-8). Whitish grey bleached zones, which appear to be the result of plagioclase metasomatism, occur locally in small patches. Some mafic and ultramafic rocks are altered to mica schist.

Coarse-grained to pegmatitic K-feldspar$\pm$aegirine-augite veins and dikes occur as late hydrothermal-magmatic features. In many areas, megacrystic K-feldspar rich veins and patches occur with abundant carbonate in the form of disseminated grains, blebs and veinlets. The carbonate weathers easily, leaving these rocks with a sugary to vuggy surface texture (Fig. GS-21-9).

Hematization is common and pervasive in some parts of the complex. It is particularly evident in altered syenite, and locally affects late quartz–K-feldspar dikes. The hematite alteration is most common as pervasive turbid zones in and around feldspar, but also occurs as small veinlets and locally as specularite. Hematization is commonly associated with late, northeast-trending fractures. Minor, narrow, opaque to translucent quartz veins also occupy some of the northeast-trending fractures and contain trace amounts of sulphide minerals.

The evolution in hydrothermal alteration of the complex appears to progress from early Na+Fe metasomatism to alkali metasomatism (K±Na), K+carbonate metasomatism, hematization and finally minor quartz veining.

Mineralization

The entire complex as presently delineated is variably enriched in rare earth elements plus or minus Sc, Y, Ba, Sr, F, U, Th, Cu and Ag. The enrichments vary according to rock type and/or degree of hydrothermal alteration, and include

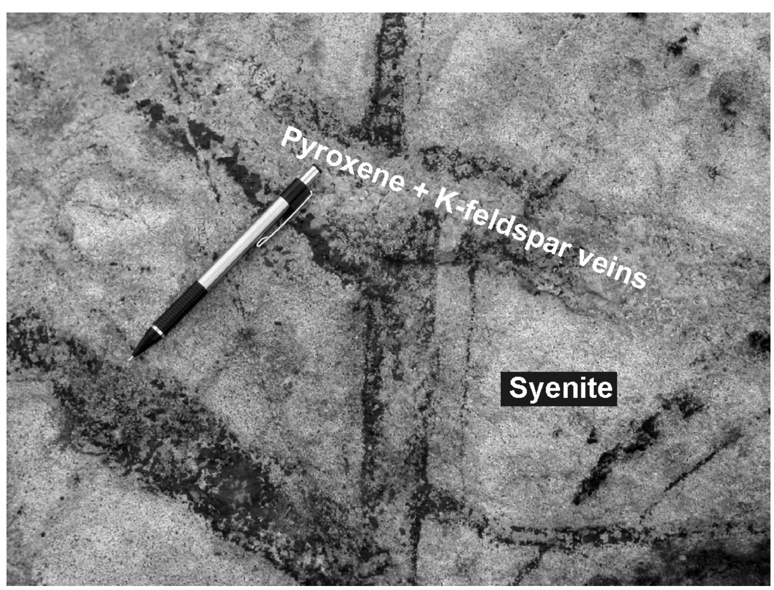

Figure GS-21-8: Pyroxene (aegirine-augite) and K-feldspar veins, East grid.

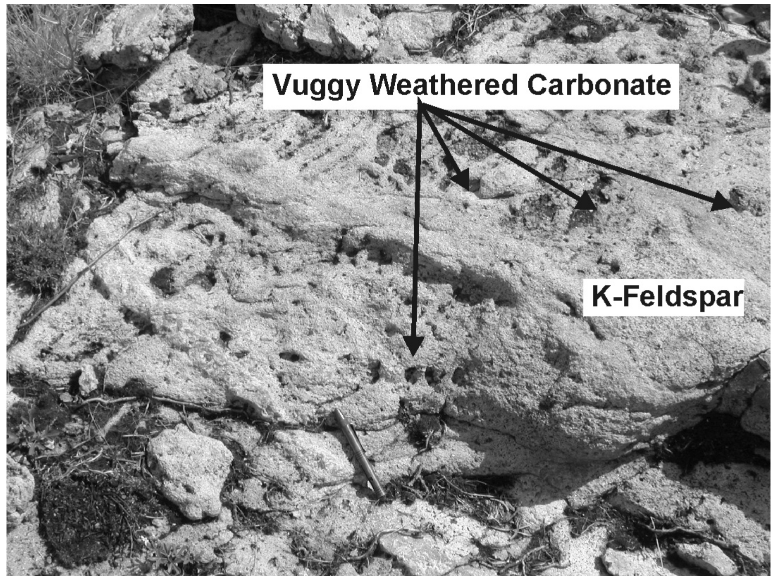

Figure GS-21-9: K-feldspar- and carbonate-rich veins with vuggy surface weathering, East grid.

several styles of potentially economic mineralization. All hydrothermally altered rocks, including syenite, intermediate (monzonite), mafic and ultramafic units, and quartz+K-feldspar pegmatite were found to be enriched in REEs. Altered syenite contains up to 4000 ppm REEs, intermediate and mafic hostrocks up to 1925 ppm REEs, and quartz+K-feldspar pegmatite (Fig. GS-21-10) up to 1150 ppm total REEs and up to 662 ppm total heavy rare earth elements (HREEs).

Ubiquitous hydrothermal veins with pyroxene (aegirine-augite), pyroxene+K-feldspar (Fig. GS-21-8) and pyroxene+amphibole+feldspar are also consistently enriched in REEs (up to 10 000 ppm). The most spectacular grades encountered to date are from REE-rich veins (mineralogy under investigation) that range up to 15 cm in width and have undelineated lengths that can exceed 50 m (Fig. GS-21-11). Total REE contents in these veins range from 34 000 to 138 000 ppm, including HREE contents ranging from 1416 to 6851 ppm. These veins are strongly enriched in Th and U, with values up to 3031 ppm Th and 2434 ppm U. The REE veins that were sampled follow the northeast-trending structures, but other orientations were also noted.

The carbonatite dikes and plugs discovered in the complex are also strongly enriched in REEs, Sr and Y. The carbonatite contains abundant calcite, with feldspar, pyroxene, apatite, other mafic minerals and as yet undetermined REE-bearing phases (Fig. GS-21-12). Values up to 16 130 ppm total REEs, 835 ppm HREE, 9764 ppm Sr and 745 ppm Y are present in samples of weathered carbonatite collected during the present program. The margins of the carbonatite are characterized by vuggy-weathered, megacrystic, fenite-altered rocks rich in feldspar+pyroxene+carbonate. These altered selvages are also strongly enriched in REEs, with values up to 7700 ppm total REEs, including 409 ppm HREEs (Fig. GS-21-13).

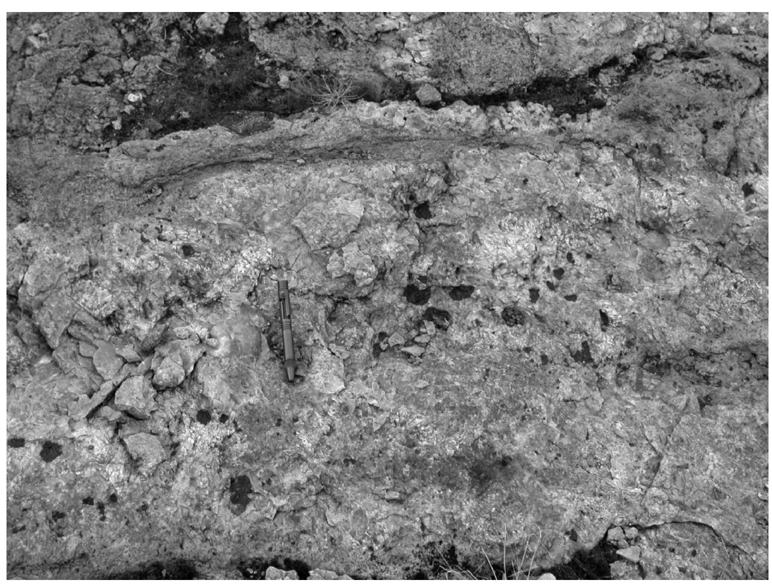

Figure GS-21-10: Quartz+K-feldspar pegmatite dike enriched in REEs, East grid.

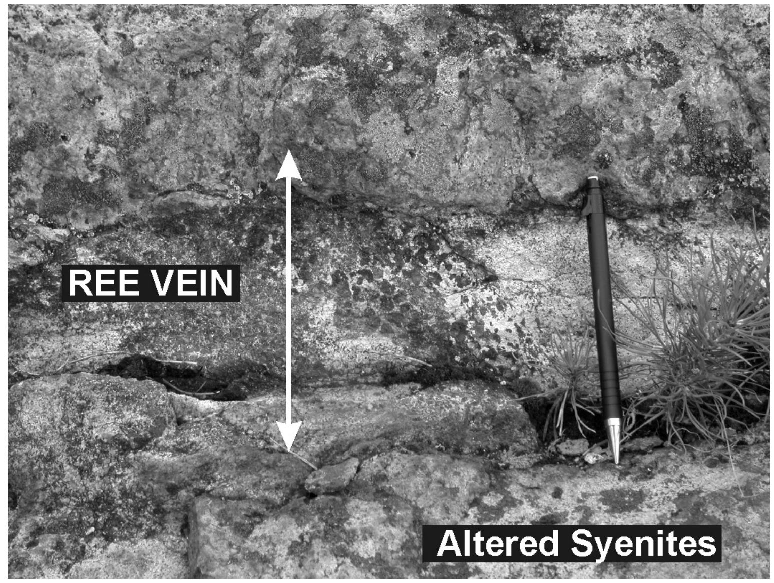

Figure GS-21-11: Detail of one of the high-grade REE-rich veins, East grid.

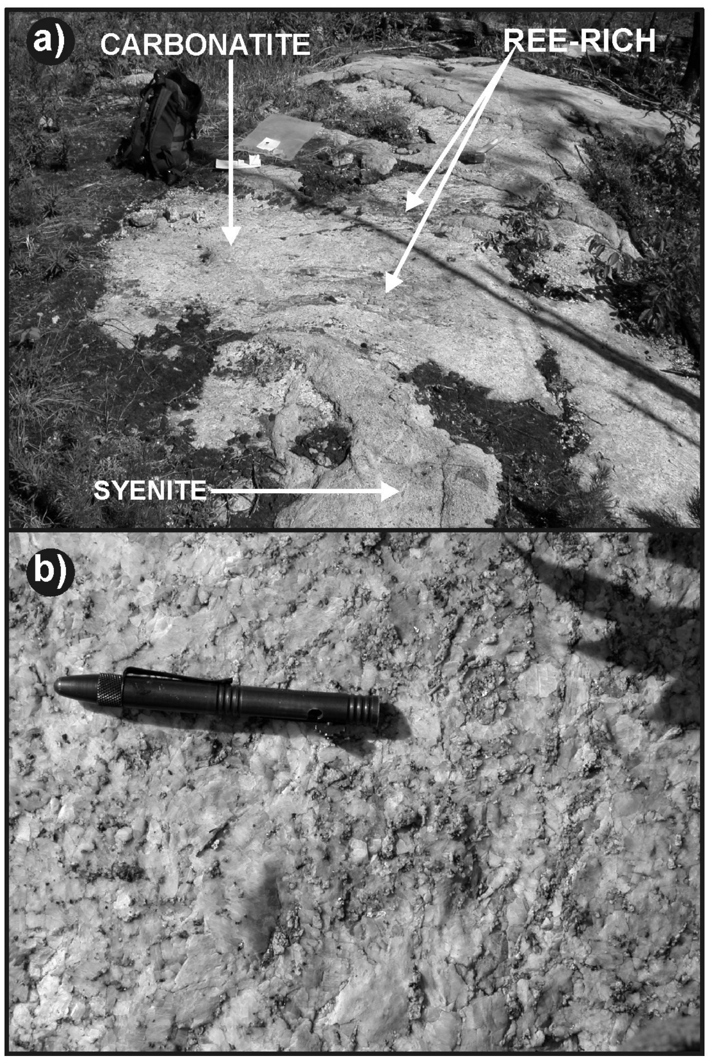

Figure GS-21-12: a) Part of a small group of REE-mineralized carbonatite dikes and plugs located near line 22S, East grid. b) Detail of the carbonate-rich portion of the carbonatite dike located near line 23S, East grid.

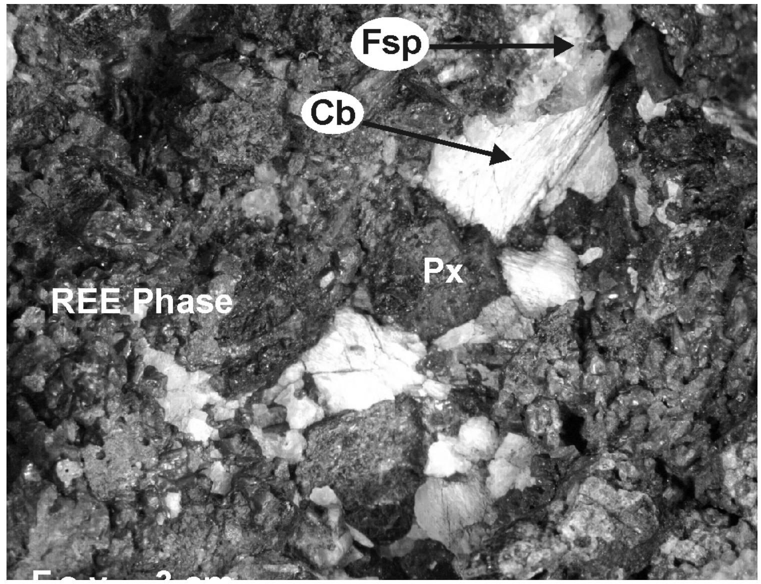

Figure GS-21-13: Fenite selvage of the carbonatite at line 22S, East grid. The selvage forms a vuggy-weathered aggregate of K-feldspar, remnant carbonate, pyroxene and REE-bearing minerals. Abbreviations: Px, pyroxene; Cb, carbonate; Fsp, K-feldspar.

DISCUSSION AND CONCLUSIONS

The hydrothermal and magmatic stockwork and breccia complex in the Eden Lake area has the characteristics of a large carbonatite complex, and is comparable in various aspects to carbonatite complexes worldwide. The extensive stockwork and breccia zone is indicative of 'shatter zones' capping major subvolcanic intrusions. The alkali-rich rocks, including syenite, aegirine-augite monzonite and mafic and ultramafic rocks, are a common intrusive suite hosting and genetically related to carbonatite. Alkali metasomatism (in the form of alkali-rich pyroxene, amphibole, feldspar and mica), carbonatization and hematization are typical hydrothermal-alteration types associated with carbonatite intrusions, and are lumped together under the term 'fenitic' alteration, after the Fen complex in Norway (Barth and Ramberg, 1966).

The nature and distribution of the intrusive rocks, stockworks, breccias and hydrothermal alteration strongly suggest the presence of one or more large, underlying carbonatite bodies. In particular, some types of fenitic alteration (e.g., the alteration zone illustrated in Figure GS-21-3b) are thought to proximally overlie hidden carbonatite bodies. The carbonatite bodies discovered in three areas during the present program are thought to be small fingers protruding through a shattered and fenitized carapace overlying one or more larger carbonatite bodies. The carbonatite bodies are very soft and unstable, compared to the syenite and other rocks of the complex, and consequently weather recessively. Any large carbonatite bodies presently subcropping at the bedrock surface will be hidden in low ground beneath glacial till, swamps or lakes.

The Eden Lake carbonatite complex is of particular interest due to its rare earth element enrichments over an extensive area. The complex contains several types of potentially economic mineralization, including 1) high-grade veins, 2) the carbonatite bodies, 3) fenitic selvages of the carbonatite bodies, and 4) altered syenite and other host rocks. In addition, the complex contains widespread enrichments in the more valuable HREEs, plus scandium. At the time of writing, ongoing work (trenching) had uncovered copper-sulphide+fluorite mineralization in altered syenite marginal to one of the exposed carbonatite dikes. The potential economic implications of the different types of mineralization are under investigation.

Discovery of the Eden Lake carbonatite bodies as a result of a search for hydrothermal iron-oxide copper-gold (Olympic Dam–type) deposits raises a number of very intriguing questions regarding a possible genetic relationship between IOCG (Olympic Dam–type) deposits and carbonatite complexes. The world's largest rare earth element deposits are Bayan Obo in China. They are routinely classified as IOCG-type deposits, although several investigators have suggested that they may be related to carbonatite complexes (Zhou et al., 1980; Mariano, 1989; Smith and Chengyu, 2000). Vielreicher et al. (2000) and Harmer (2000) have recently discussed the similarities of the Phalaborwa carbonatite to IOCG-type deposits. The relationship between carbonatite and kimberlite is well documented, and these two types of ultramafic-associated, mantle-derived magmas are often found within the same complex or district. The implications of these relationships have yet to be determined at Eden Lake.

RECOMMENDATIONS

A surprising variety of mineralization styles was encountered within the Eden Lake carbonatite complex, and several of these may have economic potential. The nature of the intrusive rocks of the complex requires detailed examination in order to properly identify and classify them, and to 'see' through the alteration overprints. Geochronology has already been initiated by the MGS to constrain the age of mineralization, to assist with the IOCG scoping study, and to help with further exploration in and around the complex.

A considerable amount of additional detailed mapping, sampling, petrography and geochemistry is critical to fully understanding this interesting geological phenomenon, and is imperative for the continued exploration and ultimate delineation of a mineral resource. Trenching was underway at the time of writing, and diamond drilling is required (following the detailed surface work) to test the complex below the surface cover, where any large carbonatite body is likely to be hidden.

ACKNOWLEDGMENTS

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