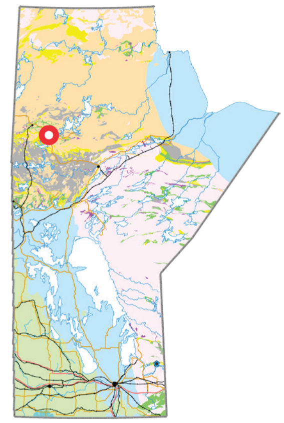
Rare Metals *in* Manitoba

Eden Lake carbonatite complex



UTM: 427000E, 6283600N; NAD83, UTM Zone 14

Area: Eden Lake, north of Granville Lake; Lynn Lake–Leaf Rapids domain

NTS: 64C9

Access: via Provincial Road 391 between Leaf Rapids and Lynn Lake, and by boat from the Eden Lake landing; via floatplane or helicopter out of Lynn Lake or Thompson

Exploration summary

Exploration in the Eden Lake area dates back to the 1950s mostly focused on Au, Ni and base metals. Several airborne aeromagnetic surveys were conducted by both government and private industry, in support of exploration programs for these commodities. An airborne gamma ray spectrometer survey by the Geological Survey of Canada in 1977 outlined radiometric anomalies in K, U and Th at Eden Lake, and regional mapping at 1:50 000 scale was initiated in 1978 during which fluorite and andradite were noted (Cameron, 1978). Elevated light rare earth element (REE) values were identified by McRitchie (1988) and this was followed up by a ground scintillometer reconnaissance program (McRitchie, 1989). These studies clearly identified the REE potential of the Eden Lake area, although at that time there was little economic interest in these commodities. The nature and extent of the REE mineralization was not fully recognized until 1998, after a massive forest fire cleared the vegetation over an extensive area around Eden Lake (Assessment File 73514, Manitoba Growth, Enterprise and Trade, Winnipeg). Focused exploration of the Eden Lake complex (Assessment Files 73635 and 73721, Manitoba Growth, Enterprise and Trade, Winnipeg) lead to the discovery of carbonatite (Mumin, 2002), placing Eden Lake on the map as the first carbonatite recognized in Manitoba. Additional prospecting, exploration work (including diamond drilling in 2006, Assessment File 74371, Manitoba Growth, Enterprise and Trade, Winnipeg) and scientific research has subsequently improved knowledge of the Eden Lake carbonatite complex (ELCC; e.g. Halden and Fryer, 1999; Mumin, 2002; Couëslan, 2005; Chakhmouradian et al., 2008; Assessment File 73866, Manitoba Growth, Enterprise and Trade, Winnipeg). The most recent exploration work by Medallion Resources Ltd. targeted fenitized syenite and other REE-bearing rocks, and involved mapping and channel sampling. The summary report concludes that there is no potential for an economic REE deposit within the fenitized syenites and suggests that exploration should refocus on the REE-bearing carbonatite (Assessment File 64C1124, Manitoba Growth, Enterprise and Trade, Winnipeg). Comprehensive review of exploration work carried out in the Eden Lake area (including airborne geophysical, vegetation, radiometric, mineralogical and metallurgy studies) can be found in Mumin (2010).

Geological setting

The ELCC is located in the volcanic-dominated Lynn Lake-Leaf Rapids domain near the northern flank of the Kisseynew domain, a metasedimentary basin in the internal zone of the Trans-Hudson orogen (Figure 1). The Lynn Lake–Leaf Rapids domain includes volcanic and associated sedimentary rocks dated at 1.90–1.88 Ga (Baldwin et al., 1987), and has been broadly correlated with the La Ronge domain in Saskatchewan (Maxeiner et al., 2001). In Manitoba, this domain includes two metavolcanic belts with unique stratigraphic successions, chemistry and structure (Baldwin et al., 1987): the Lynn Lake and Rusty Lake belts.

The Lynn Lake belt is further divided into two east-trending belts, northern and southern, both characterized by mafic metavolcanic rocks that represent a wide variety of tectonic affinities. This suggests that the assembly of the greenstone belt involved significant tectonic juxtaposition early in its deformational history (Zwanzig, 1999). The northern belt is dominated by a variety of submarine, tholeiitic, mafic metavolcanic and metavolcaniclastic

Compiled by T. Martins

Published by Manitoba Geological Survey 2016

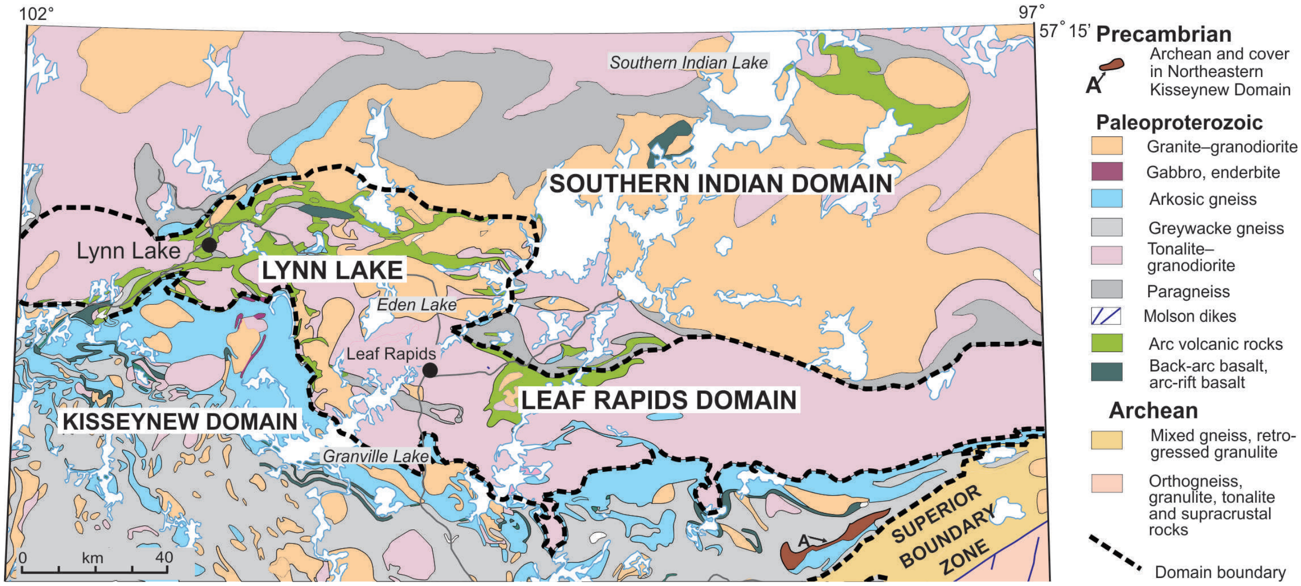


Figure 1: *Regional geological map showing the location of Eden Lake and the various domains of the Trans-Hudson orogen in northern Manitoba.*

rocks that are interpreted to represent an overall north-facing, upright, antiformal structure (Gilbert et al., 1980). The southern belt is composed of lens-shaped mainly tholeiitic basalt and calc-alkaline basalt, and sedimentary units (Gilbert et al., 1980) interpreted as having been overlapping, predominantly submarine metavolcanic piles with flanking aprons of volcaniclastic sediments and tuff (Baldwin et al., 1987). The Rusty Lake greenstone belt contains metamorphosed mafic and felsic volcanic rocks, volcanic-derived sedimentary rocks, and small mafic and felsic subvolcanic plutons (Baldwin et al., 1987). Field relationships suggest that the various volcano-sedimentary assemblages of the Lynn Lake–Leaf Rapids domain were assembled into a tectonic collage prior the emplacement of ca. 1876 Ma calcalkaline plutons (Baldwin et al., 1987). The area is affected by greenschist- to upper-amphibolite–facies metamorphism (Baldwin et al., 1987).

Along the southern part of the Lynn Lake belt, Cameron (1988) and McRitchie (1988) recognized several undeformed plutonic complexes, including the Eden Lake pluton, which comprise silica-saturated felsic rocks distinct from the surrounding orogenic granitoids.

Geology of the Eden Lake carbonatite complex

The ELCC occurs within a regionally extensive intrusive complex composed of granite, tonalite, monzonite, diorite, granodiorite and pegmatite, with minor supracrustal rafts (Cameron, 1988). The core of the ELCC is located in the eastern part of Eden Lake and has several distinct intrusive phases showing complex field relationships resulted from multiple phases of intrusions (including monzogranite, granodiorite, syenite and tonalite), assimilation and Na- and K-metasomatism (Chakhmouradian et al., 2008). The same authors describe the oldest units of the ELCC as cumulate ultramafic to mafic rocks, namely clinopyroxenite, glimmerite and alkali-feldspar clinopyroxenite, found as small disaggregated xenoliths in aegirine–augite melasyenite units or as angular to subrounded xenoliths in polymictic intrusive breccias with a syenitic groundmass. The melasyenite also occurs as fragments in younger intrusions (mostly, heterolithic breccias and syenites). All intrusive units, including the carbonatites, are cut by late pegmatite and aplite dikes. Carbonatite xenoliths up to 1 m in size were observed in some of the pegmatites. The pegmatitic groundmass surrounding the xenoliths contains large crystals of andradite (Figure 2a) with inclusions of allanite, apatite and britholite [$(Ce,Ca)_5(SiO_4,PO_4)_3(OH,F)$] (Chakhmouradian et al., 2008).

The carbonatites identified at EL to date are plutonic calcite carbonatites (sövite; Chakhmouradian et al., 2008). They vary in thickness from a few mm to ca. 4 m and have different orientations, and can be traced over several tens of meters in trenches and outcrops intruding the syenitic rocks (Figure 2b). The mineralogy of the various carbonatite veins at Eden Lake is mostly calcite (with inclusions of celestine [$Sr(SO_4)$], bastnäsite-(Ce) [$Ce(CO_3)F$] and strontianite [$Sr(CO_3)$], clinopyroxene, fluorapatite and locally feldspar (Figure 2c). Accessory mineral phases include: titanite, andradite garnet, allanite-(Ce), zircon, amphibole, phlogopite, magnetite, barite, fluorite, pyrite and other sulphide minerals (Chakhmouradian et al., 2008).

Chakhmouradian et al. (2008) describe evidence of intense alkali metasomatism at the contacts of the carbonatite veins with the silicate hostrocks. This metasomatism is manifested by grain coarsening toward contacts, increasing proportions of clinopyroxene and microcline in the syenite, recrystallized coarse-grained patches with abundant interstitial calcite identical to

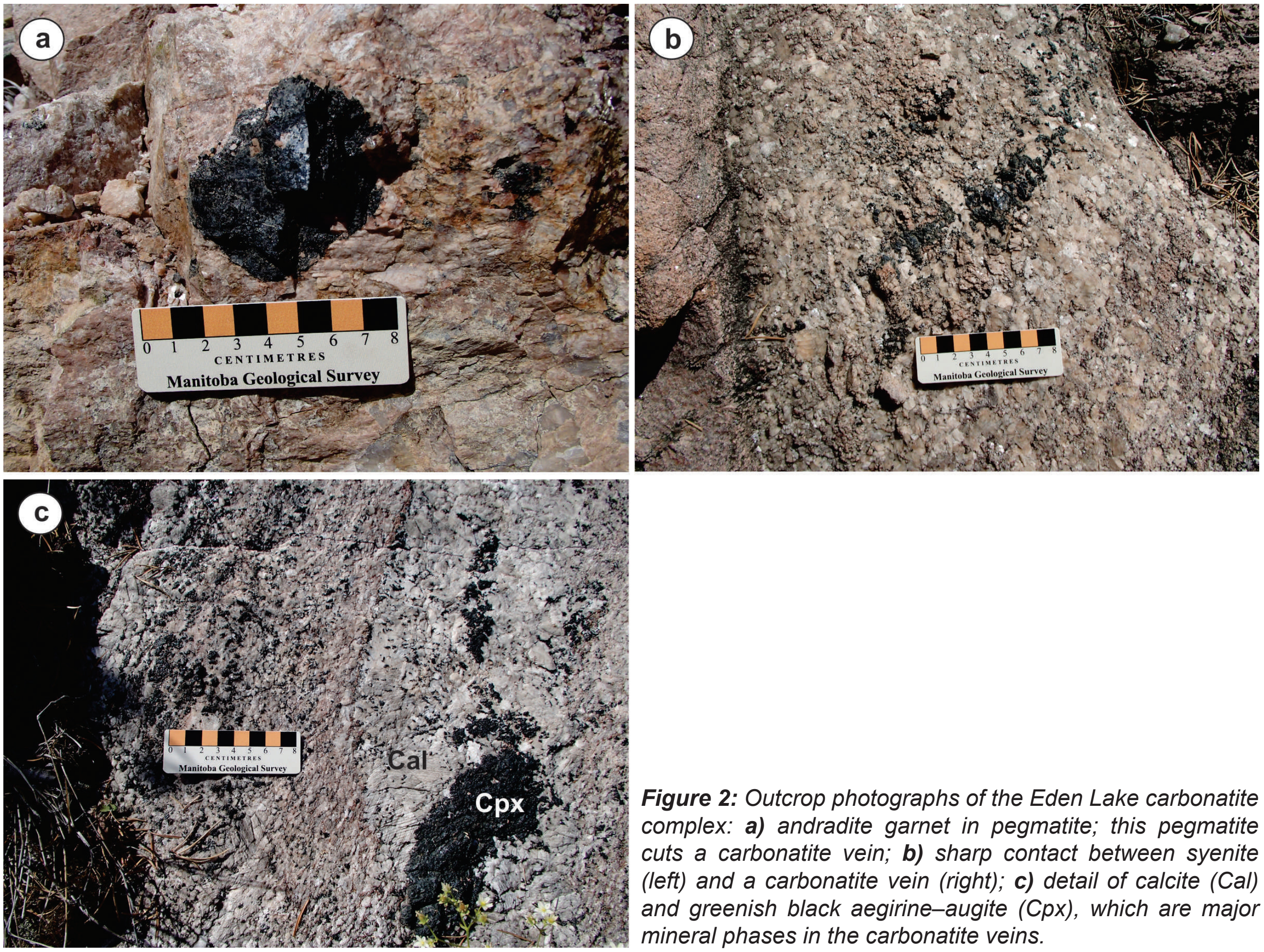


***Figure 2:** Outcrop photographs of the Eden Lake carbonatite complex: **a)** andradite garnet in pegmatite; this pegmatite cuts a carbonatite vein; **b)** sharp contact between syenite (left) and a carbonatite vein (right); **c)** detail of calcite (Cal) and greenish black aegirine–augite (Cpx), which are major mineral phases in the carbonatite veins.*

that in the carbonatites (in terms of its chemical composition). Local assimilation of silicate material by carbonatitic magma through xenolith digestion and wallrock reaction (e.g., fringes of titanite and allanite around silicate xenoliths and resorbed feldspar crystals) is also observed.

Exploration potential

The REE mineralization at Eden Lake is mostly confined to coarse-grained veins composed predominantly of alkali-feldspar and clinopyroxene, with subordinate amounts of REE-rich Ca minerals, namely apatite, allanite, britholite, titanite and fluorite. More information and detailed description of the above mentioned silicate rocks and mineralized veins are available in the literature (e.g. Arden and Halden, 1999; Halden and Fryer, 1999).

The ELCC is enriched in REE, P, Y, Th, U, Sr, Ba and F (e.g. Chakhmouradian et al., 2008; Mumin, 2010). The most important economic targets at Eden Lake include five different mineral and petrological associations: apatite-bearing carbonatite; cumulate apatite±pyroxene layers and bodies; carbonate fenite; apatite-pyroxene veins and alteration; and britholite-allanite-bearing veins (Mumin, 2010). The most abundant REE present at Eden Lake are Ce, Nd and La comprising about 87% of total REE–Pr and Sm represent about 9%, Gd and Dy about 3%, and the other REE represent the remaining 1% (Mumin, 2010). All the different mineral associations are considered to be derived from primary carbonatite crystallization and carbonatite associated fluids.

Mumin (2010) describes extreme REE enrichment in three different rock types:

1) Apatite-rich bands in carbonatite dikes and veins: the principal host mineral for REE is reddish-brown turbid Sr-REE-apatite, with microscopic inclusions of other REE phases. Apatite-rich bands in fresh carbonatite have enrichment up to 19 332 ppm total REE, up to 1037 ppm heavy REE (HREE; Eu to Lu), 6610 ppm Sr, and 840 ppm Y. The carbonatite bodies are consistently enriched in Sr, with values up to 11 110 ppm. Margins of the carbonatite are often characterized by vuggy-weathered, megacrystic feldspar-pyroxene-carbonate-apatite rich fenite-altered rocks (in some cases strong enrichment is present with values up to 7700 ppm total REE).
2) Apatite-pyroxene veins: these veins are common in the core of the complex as cm-scale veins that may extend for several metres. Apatite content ranges to about 50% of the veins and seems to be

proportional to REE concentration. Results from two assays of this material indicate 25 260 ppm and 22 343 ppm total REE.

3) Britholite-allanite bearing REE veins: the highest grades reported at Eden Lake are from this rock type, in which REE occur primarily as allanite-britholite intergrowths, with minor Sr-REE-apatite. These veins range up to 50 cm in width and have lengths that can exceed 50 m. Total rare metal contents ranged up to 148 742 ppm, including up to 6851 ppm total HREE, 3490 ppm U, 4560 ppm Th, and 5307 ppm Y.

Work by the same author concludes that apatite and REE-bearing minerals, alteration and veins are derived from primary carbonatite and carbonatite metasomatism; their data also indicates that the abundance ratio of the different REE is consistent throughout the complex in all mineralized and altered rock types, perhaps indicating a common source. Therefore, future exploration should focus on locating additional carbonatite veins as a potential means of vectoring towards their source (Mumin, 2010).

Due to the nature of carbonatite (soft, brittle, chemically unstable, and therefore easily weathered) it is believed that the carbonatite is under-represented in outcrop. Mumin (2010) concludes that there may also be other potential economic targets within the ELCC that are presently unknown due to poor exposure; the presence of large xenoliths of carbonatite in pegmatite dikes strongly suggests that larger carbonatite intrusions may be present.

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