Cinder Lake alkaline intrusive complex

Rare Metals *in* Manitoba

UTM: 382226E, 6090490N; NAD83, UTM Zone 15

Area: Cinder Lake, west of Knee Lake; Superior Province

NTS: 53L15

Access: via floatplane out of Thompson; Knee Lake is linked to the winter road network servicing Oxford House and Gods Lake Narrows

Exploration summary

The Cinder Lake–Knee Lake area contains numerous historical occurrences of base and precious metals and has been intermittently explored by various companies. This work included regional and property-scale airborne geophysics, geochemical surveys, geological mapping and diamond drilling. The Manitoba Geological Survey (MGS) conducted regional mapping in this area in the 1970s as part of the Greenstones Project (Gilbert, 1985), during which nepheline-cancrinite syenite, alkali feldspar syenite and alkali syenitic pegmatite and aplite were identified at Cinder Lake. Later, in the early to mid-1990s, Inco Exploration and Technical Services Inc. conducted exploration, including diamond drilling, for base metals in the metavolcanic country rocks immediately adjacent to the Cinder Lake syenitic rocks (Assessment Files 72612, 72752 and 94730, Manitoba Growth, Enterprise and Trade, Winnipeg). Several metres-wide intervals of massive and brecciated pyrite and pyrrhotite, with minor sphalerite and chalcopyrite, were intersected by this drilling, none of which proved to be of economic interest. Of note however, were several surface samples collected during this program that yielded total rare earth element (REE) oxide concentrations (excluding Gd, Dy, Ho, Er and Tm) greater than 0.10 wt.%, with the highest value exceeding 0.9 wt.% (Assessment File 72612); there was no follow up work on these REE occurrences. Following the discovery of kimberlite indicator minerals in the Knee Lake region (summarized in Fedikow et al., 2002), De Beers Canada conducted till and soil surveys as well as airborne geophysical surveys in the area in 2000 and 2001 (Assessment File 94884, Manitoba Growth, Enterprise and Trade, Winnipeg). This work included a high-resolution aeromagnetic survey that covered all of the Cinder Lake area and revealed a prominent, concentrically-zoned, elliptical anomaly over Cinder Lake and extending toward the northwest. In 2011 QMC Quantum Minerals Corporation carried out a geochemical orientation survey, analyzing 107 samples of rock, soil and vegetation (Assessment File 53L12141, Manitoba Growth, Enterprise and Trade, Winnipeg). Of particular interest in this study is the strongly enriched REE mineralization reported on Wickstrom Island from rock chip and channel samples. The mobile metal ions soil geochemistry for this area reflects this REE enrichment in addition to strongly elevated P and Th.

Despite the previous work done in and around the Cinder Lake area, the alkaline intrusive rocks have never been investigated in adequate detail. To better understand these rocks, the MGS initiated a joint project with the University of Manitoba in 2008. Chakhmouradian et al. (2008) and Kressall et al. (2010) reported preliminary results of this project, followed by the completion of a Master's thesis at the University of Manitoba (Kressall, 2012). At the present time geochronological studies are ongoing to gain a better understanding of the timing of emplacement and tectonic implications of these rocks.

Geological setting

Cinder Lake is located within the Oxford Lake–Knee Lake greenstone belt, which is part of the Oxford–Stull domain of the Superior province (Stott et al., 2010; Figure 1). Supracrustal rocks in this greenstone belt include the older basalt-dominant Hayes River Group (HRG) and the younger more diverse Oxford Lake Group (OLG; division and nomenclature introduced by Wright, 1932). The HRG is mainly composed of pillow basalt and gabbro with subordinate intermediate and felsic volcanic-sedimentary rocks (Hubregtse, 1978, 1985; Gilbert, 1985), which have been dated

Compiled by T. Martins
Published by Manitoba Geological Survey 2017

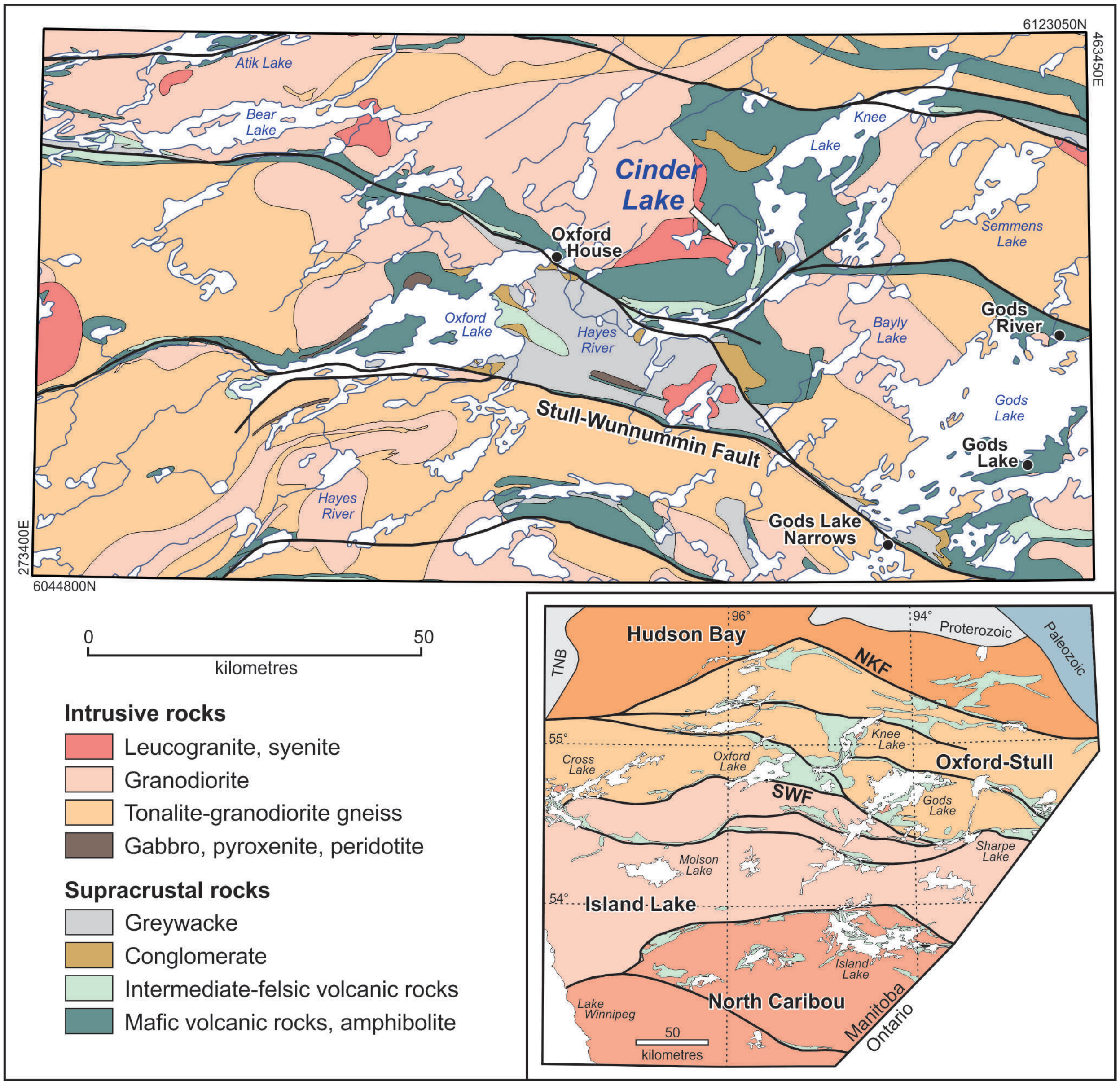

Figure 1: *Regional geological setting of the Cinder Lake alkaline intrusive complex and major geological domains, greenstone belts and shear zones in the Manitoba part of the Superior Province. Abbreviations: NKF, North Knife fault; SWF, Stull-Wunnummin fault; TNB, Thompson nickel belt.*

at 2834–2827 Ma (Corkery et al., 2000). The Bayly Lake plutonic complex intrudes the HRG (2.78 and 2.73 Ga; Corkery et al., 2000) and varies from tonalite to granite in composition. The OLG, which consists of a lower, ca. 2.72 Ga, volcanic subgroup and an upper, ca. 2.71 Ga, subaerial to shallow-marine sedimentary subgroup, is separated from the HRG and Bayly Lake plutonic complex by an unconformity (Corkery et al., 2000). The OLG is also intruded by tonalite–granodiorite–granite plutons, with a minimum age constrained by the Magill Lake pluton south of Knee Lake (U-Pb monazite age of 2668 ±1 Ma; Lin et al., 2006).

Geology of the Cinder Lake alkaline intrusive complex

Silica-undersaturated rocks at Cinder Lake were first mapped by Gilbert and Elbers (1972) of the MGS during the Greenstones Project, which was focused on the Gods–Oxford–Knee lakes area (Gilbert, 1985). Since then, this area was re-examined by the MGS in the 1980s (Lenton, 1985) and in 2008 (Chakhmouradian et al., 2008). As defined by Kressall (2012), the alkaline intrusive complex at Cinder Lake comprises a suite of syenitic rocks—thought to represent the main component of the complex—and a monzogranite pluton that outcrops in the centre and toward the northwestern corner of the lake.

Within the granitic rocks, the most common rock type is pink, massive, medium-grained monzogranite (Kressall, 2012). It is mostly composed of plagioclase, quartz and microcline with accessory hornblende (commonly altered to epidote), phlogopite, magnetite, titanite, apatite and zircon. This rock type is fenitized close to the alkaline intrusive complex, with intergrown microcline, albite, diopside and minor interstitial quartz, apatite, titanite, and magnetite as inclusions in diopside. Larger apatite crystals (up to 1 mm in length) are present in association with andradite and Fe-rich veinlets composed of minor Fe-oxides and abundant Fe-oxihydroxide material.

The suite of syenitic rocks is described in detail by Kressall (2012) and can be divided into three main units: alkali-feldspar syenitic pegmatite, cancrinite[1]-nepheline syenite, and vishnevite[2] syenite with spatially associated minor porphyritic cancrinite syenite. Dikes of alkali-feldspar syenitic pegmatite form a rocky ridge along the southeastern shore of Cinder Lake and crosscut HRG basalt on the southwestern shore. The pegmatite dykes vary in composition but for the most part their major components are microcline (often with albite lamellae) with accessory apatite, titanite, magnetite, ilmenite, and allanite. They have been variably replaced by phlogopite, albite, epidote, calcite, biotite and muscovite. The pegmatite dykes are commonly cut by fine-grained calcite and phlogopite veinlets up to 5 cm in thickness, especially in the northeastern portion of the ridge. Large veins of black andradite (up to 20 cm wide) also crosscut alkali-feldspar syenitic pegmatite. These veins are dominantly monomineralic with minor titanite, phlogopite, magnetite, riebeckite, clinopyroxene, albite, calcite and microcline that occur along fractures in andradite. The fine-grained mesocratic to leucocratic cancrinite-nepheline syenite is found on the southern island in Cinder Lake (Figure 2).

The clinopyroxene-bearing cancrinite-nepheline syenite consists mainly of fine-grained clinopyroxene prisms set in a groundmass of anhedral microcline and nepheline partially replaced by albite and cancrinite, respectively. Locally, secondary muscovite, natrolite [$Na_2(Si_3Al_2)O_{10}\cdot 2H_2O$] and minor stronalsite [$Na_2SrAl_4Si_4O_{16}$] also occur in association with cancrinite and albite as well as calcite and allanite. Accessory minerals are phlogopite, calcite, titanite, magnetite, apatite, monazite, britholite [$(Ce,Ca)_5(SiO_4, PO_4)_3(OH,F)$] and thorite. The vishnevite syenite is fine-grained and mesocratic with local veins and lenses of microcline, vishnevite and calcite. It differs from the cancrinite-nepheline syenite by the presence of vishnevite and absence of nepheline, and is mostly composed of microcline set in a mosaic of vishnevite, albite, calcite and phlogopite with rare sodalite [$Na_4(Si_3Al_3)O_{12}Cl$] and fluorite. Accessory mineral phases are pyrite, aegirine, magnetite, apatite, allanite, zircon and celestine [$Sr(SO_4)$]. The porphyritic cancrinite syenite associated with the vishnevite syenite is only distinguished by the presence of dark-brown microcline phenocrysts.

Exploration potential

The Cinder Lake alkaline intrusive complex, and specifically its potential for REE mineralization (Chakhmouradian et al., 2008), has not been the focus of targeted exploration. As described above, the complex is composed of a suite of silica-undersaturated syenites and feldspathoid-free alkali-feldspar syenitic pegmatite

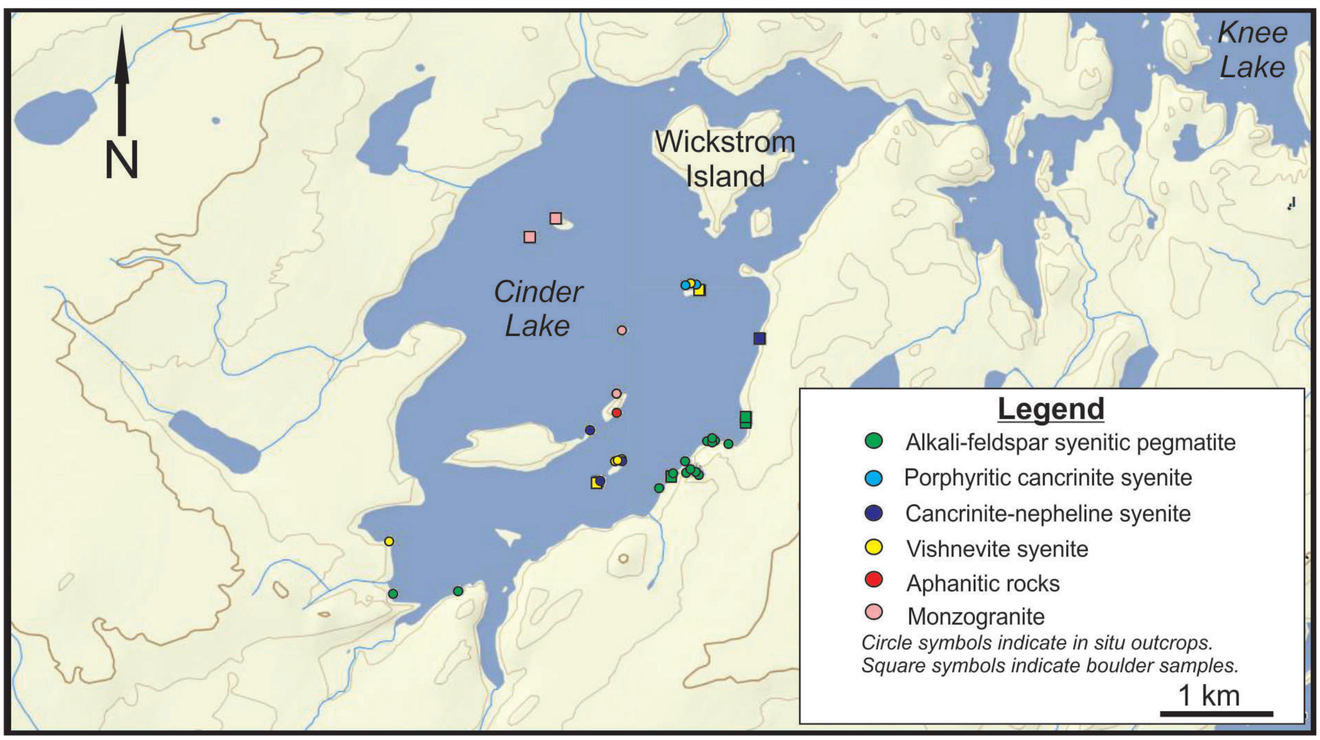

Figure 2: *Location of samples collected at Cinder Lake by the MGS in 1985 and 2008. Petrographic classification is colour-coded for each sample. Modified from Kressall et al. (2010).*

[1] Cancrinite: [$(Na,Ca,\square)_8(Al_6Si_6)O_{24}(CO_3,SO_4)_2\cdot 2H_2O$]; ☐ represents a vacancy

[2] Vishnevite: [$Na_8(Al_6Si_6)O_{24}(SO_4)\cdot 2H_2O$]

dykes (Kressall, 2012). Until recent work by MGS at Knee Lake (Anderson, 2016b), no carbonatite was identified associated with the Cinder Lake alkaline complex, but its presence was inferred by Chakhmouradian et al. (2008) and Kressall (2012) based on indirect textural evidence, C-O and Sr isotopic data, and estimated geochemical and modal compositions (an estimation of the composition of the hypothetical carbonatitic liquid taking into account the major- and trace-element compositions of calcite, phlogopite, apatite, magnetite and monazite, and the modal abundances of these minerals, as explained in detail by Kressall, 2012).

Mapping conducted by MGS in the Knee Lake area lead to the discovery of a swarm of calcite carbonatite dikes in the western most bay of south-central Knee Lake, immediately east of Cinder Lake (Figure 3; Anderson, 2016b). The dikes were identified in four locations over a north–south distance of approximately 3 km, and generally appear to become thicker and more abundant toward the south. The dikes trend generally east; dip steeply north or south and range up to 1 m in thickness. Anderson (2016b) describes the dikes as having sharp planar contacts with the hostrock (gabbro, basalt and volcanic sedimentary rocks), weathering earthy brown, and typically fine-grained and equigranular. The gabbro hostrock adjacent to the dikes contain dark green metasomatic haloes (Anderson, 2016b) interpreted to be product of potassic fenitization (Donak, 2016). Petrography and microprobe work by Donak (2016) reveals that the calcite carbonatites are dominated by coarse-grained (up to 7 mm) elongate calcite (35–40%) and anhedral fine-grained calcite (15–20%). Other constituents include phlogopite (15–20%), layered and disseminated magnetite (10–20%), apatite (5%), talc (3–5%). Trace amounts of pyrite, chalcopyrite, pyrrhotite, monazite, allanite, synchysite, rutile and ilmenite are observed throughout. Other accessory minerals, which occur only as inclusions in calcite and apatite, are celestine and barite.

Calcite carbonatite can be highly enriched in REE, in some cases up to economic concentrations. For example, calcite carbonatite of the Maoniuping syenite-carbonatite complex in southern China hosts the second largest REE deposit in the world, with 1.45 million tons of REE oxides in primary and enriched secondary ores ranging in grade from 2.7 to 13.6 wt. % REE_2O_3 (Xu et al., 2004). The geological setting and estimated size of this complex are similar to those of the Cinder Lake alkaline intrusive complex (ring structure anomaly over Cinder Lake is estimated to cover an area of about 25 km^2; Figure 3). Similarities are also found in the trace element distribution of the calcite carbonatite from the Maoniuping complex, estimated whole-rock composition of calcite veinlets from the Cinder Lake

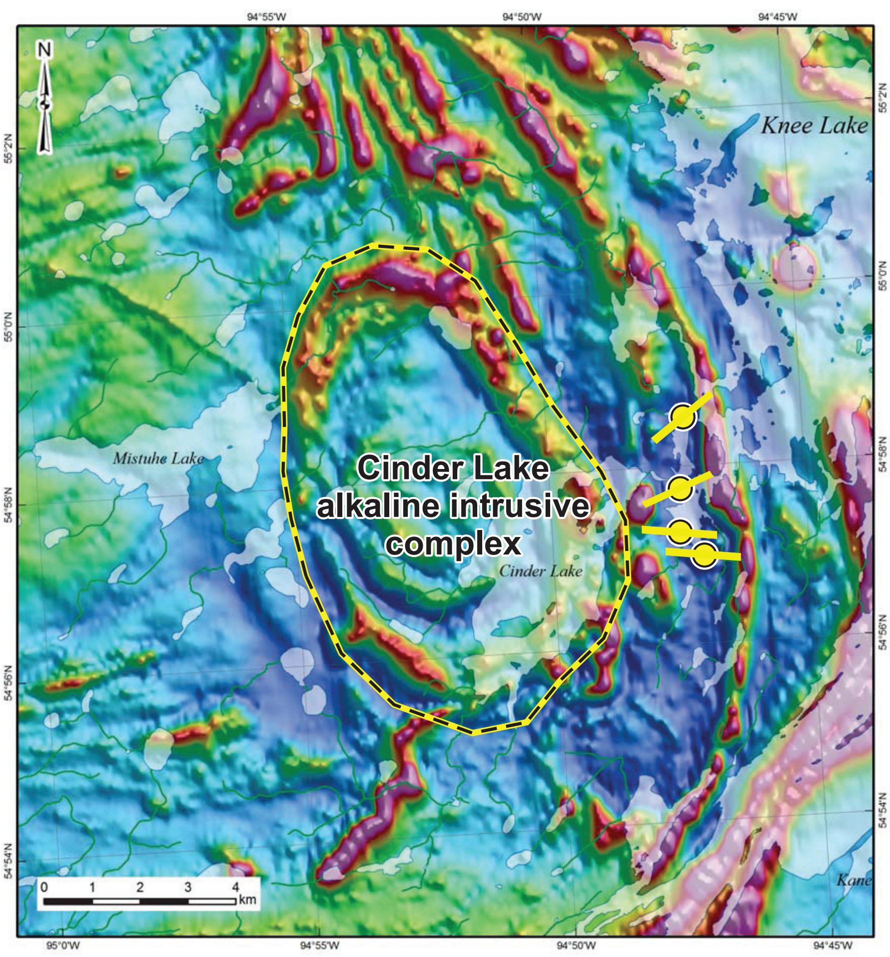

Figure 3: Aeromagnetic pattern over Cinder Lake, showing the probable concentric ring structure of the complex (after Anderson, 2016a).

complex (Kressall, 2012) and whole rock geochemistry for the Knee Lake calcite carbonatite dikes. The extent and proximity of the Knee Lake dikes to the Cinder Lake alkaline complex (Kressall, 2012), coupled with the occurrence of carbonatite roughly 60 km to the west at Oxford Lake (Reimer, 2014), suggest that carbonatitic magmatism may have been regionally extensive in the Oxford Lake-Knee Lake greenstone belt.

References

Anderson, S.D. 2016a: Geology and economic potential of the Oxford Lake–Knee Lake greenstone belt, Manitoba; Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, Manitoba Mining and Minerals Convention 2016, Winnipeg, Manitoba, November 16–18, 2016, poster presentation.

Anderson, S.D. 2016b: Preliminary results of bedrock mapping at central Knee Lake, northwestern Superior province, Manitoba (parts of NTS 53L15, 53M2); *in* Report of Activities 2016, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 1–15.

Chakhmouradian, A.R., Böhm, C.O., Kressall, R.D. and Lenton, P.G. 2008: Evaluation of the age, extent and composition of the Cinder Lake alkaline intrusive complex, Knee Lake area, Manitoba (part of NTS 53L15); *in* Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 109–120.

Corkery, M.T., Cameron, H.D.M., Lin, S., Skulski, T., Whalen, J.B. and Stern, R.A. 2000: Geological investigations in the Knee Lake belt (parts of NTS 53L); *in* Report of Activities 2000, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 129–136.

Donak, T.B. 2016: Carbonate dikes at Knee Lake, Oxford Lake-Knee Lake greenstone belt, northwestern Superior Province, Manitoba; B.Sc. Technical Report, University of Manitoba, Winnipeg, Manitoba, 40 p. with four appendices.

Fedikow, M.A.F., Nielsen, E., Conley, G.G. and Lenton, P.G. 2002: Operation Superior: compilation of kimberlite indicator mineral survey results (1996-2001); Manitoba Industry, Trade and Mines, Manitoba Geological Survey, Open File Report OF2002-1, 60 p.

Gilbert, H.P. 1985: Geology of the Knee Lake–Gods Lake area; Manitoba Energy and Mines, Geological Services, Geological Report GR83-1B, 76 p.

Gilbert, H.P. and Elbers, F.J. 1972: Greenstones project: Parker Lake-Knee Lake-Oxford House area; in Summary of Geological Field Work 1972, Manitoba Department of Mines, Resources and Environmental Management, Mines Branch Geological Paper 3/72, p. 34–37.

Hubregtse, J.J.M.W. 1978: Chemistry of cyclic subalkaline and younger shoshonitic volcanism in the Knee Lake–Oxford Lake greenstone belt, northeastern Manitoba; Manitoba Department of Mines, Resources and Environmental Management, Mineral Resources Division, Geological Paper 78/2, 18 p.

Hubregtse, J.J.M.W. 1985: Geology of the Oxford Lake–Carrot River area; Manitoba Energy and Mines, Geological Services, Geological Report GR83-1A, 73 p.

Kressall, R.D. 2012: The petrology, mineralogy and geochemistry of the Cinder Lake alkaline intrusive complex, eastern Manitoba; M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, 396 p.

Kressall, R.D., Chakhmouradian, A.R. and Böhm, C.O. 2010: Petrological and geochemical investigation of the Cinder Lake alkaline intrusive complex, Knee Lake area, east-central Manitoba (part of NTS 53L15); *in* Report of Activities 2010, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 146–158.

Lenton, P.G. 1985: GS-40 Granite-pegmatite investigations: Knee Lake–Magill Lake area; *in* Report of Field Activities 1985, Manitoba Energy and Mines, Geological Services Mines Branch, p. 203–208.

Lin, S., Davis, D.W., Rotenberg, E., Corkery, M.T. and Bailes, A.H. 2006: Geological evolution of the northwestern Superior Province: clues from geology, kinematics, and geochronology in the Gods Lake Narrows area, Oxford–Stull terrane, Manitoba; Canadian Journal of Earth Sciences, v. 43, p. 749–765.

Reimer, E.R. 2014: Petrography, mineralogy and geochemistry of carbonate rocks at Oxford Lake, Oxford Lake–Knee Lake greenstone belt, northwestern Superior Province, Manitoba; B.Sc. thesis, University of Manitoba, Winnipeg, 112 p.

Stott, G.M., Corkery, M.T., Percival, J.A., Simard, M. and Goutier, J. 2010: A revised terrane subdivision of the Superior Province; *in* Summary of Field Work and Other Activities 2010, Ontario Geological Survey, Open File Report 6260, p. 20-1–20-10.

Wright, J.F. 1932: Oxford House area, Manitoba; *in* Canada Department of Mines, Geological Survey, Summary Report, 1931, Part C, p. 1C–25C.

Xu, C., Zhang, H., Huang, Z., Liu, C., Qi, L., Li, W. and Guan, T. 2004: Genesis of the carbonatite-syenite complex and REE deposit at Maoniuping, Sichuan Province, China: evidence from Pb isotope geochemistry; Geochemical Journal, v. 38, p. 67–76.