GS-19 GEOLOGICAL INVESTIGATIONS IN THE KNEE LAKE AREA, NORTHERN SUPERIOR PROVINCE (PARTS OF NTS 53L/15 AND 53M/2)

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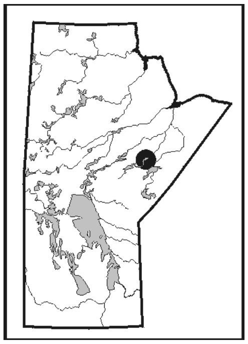

SUMMARY

Multidisciplinary stratigraphic, structural, geochronologic and geochemical investigations in the Knee Lake greenstone belt are being conducted to better constrain the setting of base- and precious-metal mineral occurrences and deposits in the area. Results of the 1998 mapping include: 1) construction of a regional stratigraphy for the Hayes River Group metavolcanic rocks, 2) identification of a previously unrecognized unconformity between the Hayes River Group and younger metasedimentary rocks on central Knee Lake, 3) definition of two generations of folds, and multiple generations of faults on central and northern Knee Lake, and 4) reinterpretation of the stratigraphic setting of metasedimentary rocks north of northern Knee Lake.

INTRODUCTION

One of the primary objectives of Manitoba's Northern Superior projects is to better understand the volcanic, structural and tectonic evolution of greenstone belts in the Manitoba portion of Sachigo subprovince/Gods Lake domain. Central to this objective is an understanding of the largest contiguous greenstone belt in the Sachigo, the Oxford Lake - Knee Lake Belt (Fig. GS-19-1).

To achieve this objective we began a renewed study of the Oxford Lake - Knee Lake Belt in 1997 that involved mapping of the extensive shoreline of southern and central Knee Lake at a scale of 1:20 000. In 1998 we extended this mapping to central and northern Knee Lake (Fig. GS-19-1), completing the mapping portion of this study. During the course of remapping approximately 100 geochemical samples were collected to define the petrogenetic evolution of the volcanic sequences. Geochronology of key rock units is being conducted under the auspices of the Geological Survey of Canada, by Dr. T. Skulski. In a related project, Lin et al. (this volume) followed up on 1997 results to develop a structural model for the southern basin of Knee Lake. These stratigraphic, geochemical, structural and geochronological studies are being conducted as part of the Western Superior NATMAP project.

Previous work

Work in the Knee Lake area prior to 1970 was conducted by Bruce (1919), Wright (1925, 1931), Springer (1947), Quinn (1955) and Barry (1959, 1964). The Parker Lake map sheet of Barry (1964) was particularly useful as a resource in our remapping the central and northern parts of Knee Lake. Barry's (1964) report makes it clear that a considerable amount of effort was expended to locate and map inland outcrops and his 1:63 360 map remains the primary source of information for these areas.

In the early 1970's, the Knee Lake area was mapped as part of the 'Greenstone Project' (bibliography in Gilbert, 1985). For the area under consideration in the current study, three 3-colour 1:50 000 maps are available: GR83-1-7, -1, and -2. The geology of southern Knee Lake and the southern portion of central Knee Lake is depicted on Map GR83-1-7 (Gilbert, 1985). Map GR83-1-1 (Parker Lake sheet) is also included in Gilbert (1985), although most of the mapping on that sheet was done by F. Elbers. Map GR83-1-2 (Semmens Lake sheet) was to accompany a report that was never completed and is published alone (Elbers, 1984). The focus of Elbers' investigation was directed towards larger scale relationships and correlations rather than remapping, so his study complements, but does not replace, Barry (1964). A review of the exploration history of the area up to 1977 is given by Southard (1977).

Regional setting

Supracrustal rocks in the Oxford Lake - Knee Lake Belt have been assigned to two principal stratigraphic entities, the Hayes River Group (HRG) and Oxford Lake Group (OLG; Gilbert, 1985, and references therein). These Groups are the principal focus of our recent work in that they have more potential to host gold and base metal deposits than the voluminous granitoid terrains in the Superior Province.

The Hayes River Group (HRG; ca. 2830 Ma at Knee Lake, D. Davis, pers. comm., 1986, cited in Syme et al., 1997) is a predominantly volcanic sequence dominated by pillowed basalt and related gabbro, minor intermediate to felsic volcanic rocks and minor volcanogenic sedimentary rocks. The HRG section is estimated to be 9.7 km thick at Knee Lake (Gilbert, 1985); neither the base nor top is exposed. The Knee Lake section has been interpreted to represent the upper portion of the HRG, the lower portion being that exposed on Oxford Lake (Manitoba Energy and Mines, 1987). The base of the HRG has been intruded by tonalitic to granitic plutons and related gneisses of the Bayly Lake Complex (2883-2730 Ma, D. Davis, pers. comm., 1986).

The Oxford Lake Group is younger (ca. 2706 Ma at Oxford Lake, D. Davis, pers. comm., 1986), largely sedimentary, and lies unconformably on Hayes River Group volcanic rocks at Gods Lake (Gilbert, 1985). The OLG consists of a lower, dominantly volcaniclastic subgroup of limited extent, overlain by more extensive sedimentary rocks extending in a 12 km wide belt from Oxford Lake to Magill Lake (40 km; Gilbert, 1985; Manitoba Energy and Mines, 1987). Volcanic rocks in the lower subgroup are shoshonitic to calc-alkalic in character (Hubregtse, 1976; Brooks et al., 1982; Gilbert, 1985). Sedimentary facies within the OLG suggest that the rocks were deposited in shallow- to deep-water basinal environments (Manitoba Energy and Mines, 1987).

All of the rocks in the study area have been metamorphosed, and contain greenschist to amphibolite facies mineral assemblages. The prefix 'meta' is not used in this report in the interest of brevity, and rocks are described according to their known or inferred protolith.

NORTHERN KNEE LAKE

Hayes River Group

Hayes River Group mafic volcanic rocks are best exposed on the south-central shore of northern Knee Lake, east and southeast of Mines Point (Fig. GS-19-1; sections 'a' and 'b', Fig. GS-19-2). Primary structures and textures are well preserved, although the rocks have amphibolite grade metamorphic mineral assemblages and are recrystallized. The amount of strain recorded in the pillowed flows increases to the southeast, such that adjacent to the composite granitoid plutonic terrane the rocks are best described as variably banded mafic gneisses and mafic tectonites. Major faults and shear zones within the section are largely conformable with stratigraphy; the thickest intact sequence is only 4 km thick (Fig. GS-19-2a).

The northernmost exposures of HRG stratigraphy on Knee Lake occur southwest of the mouth of the Hayes River, where the river exits Knee Lake (Fig. GS-19-1, section 'b' on Fig. GS-19-2). This section is dominated by pillowed aphyric to weakly plagioclase phyric basalt, spherulitic basalt, and minor plagioclase megaphyric basalt. The spherulitic basalt is potentially important because similar rocks form marker units on central Knee Lake (see below). Flows in this 600 m thick unit contain abundant cm-scale spherulites that coalesce in pillow cores, thick selvages and thick interpillow hyaloclastite. The base of the unit is truncated by a large shear zone.

Aphyric to weakly plagioclase phyric basalt southeast of Mines Point (unit A' in section 'a', Fig. GS-19-2) comprises a 2.5-3 km thick sequence of pillowed and massive flows, and subordinate amoeboid pillow flow top breccia. The basalt has a characteristic medium green weathering colour, quite distinct from the pale grey basalt on central and

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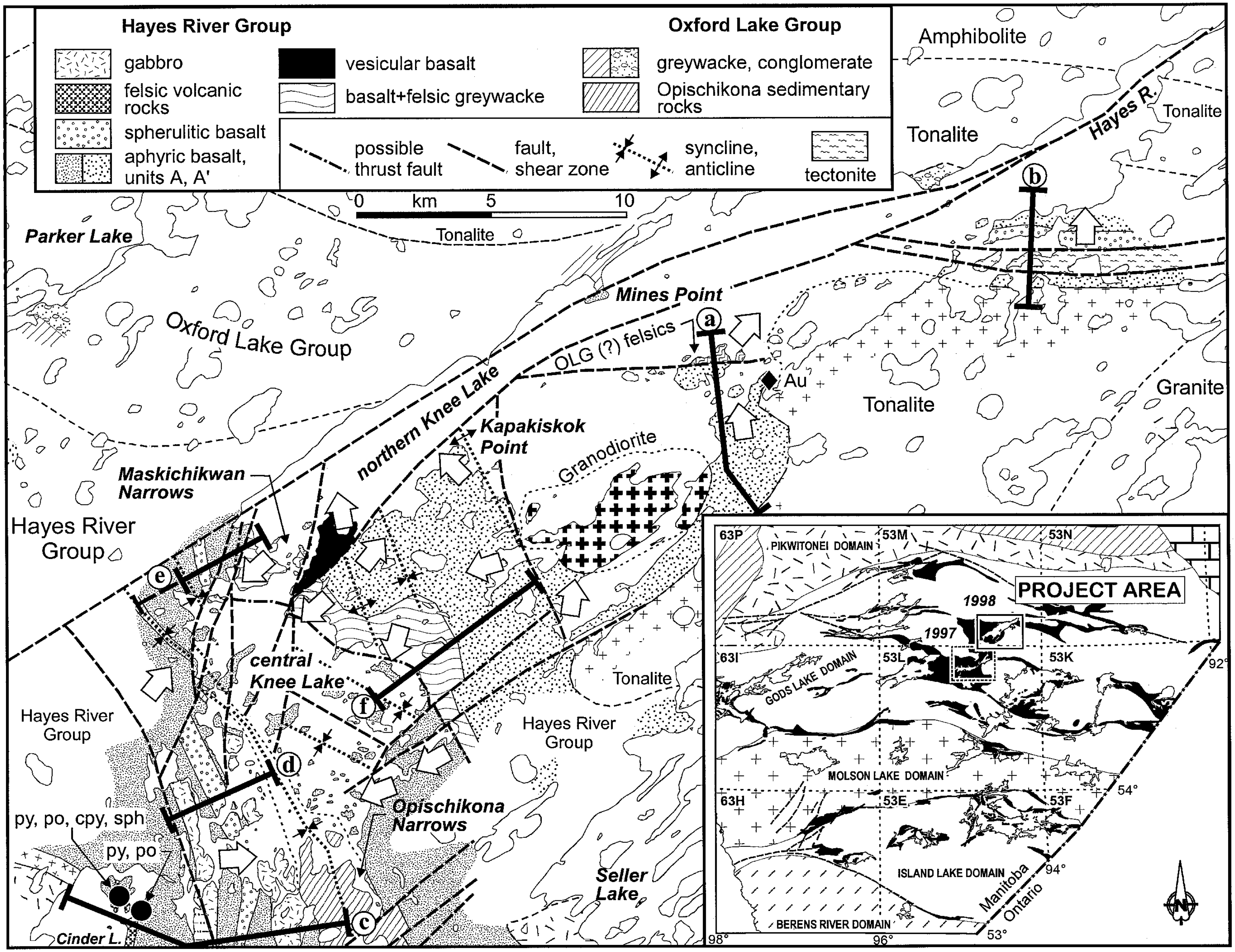

Figure GS-19-1: *General geology of central and northern Knee Lake, modified from Manitoba Energy and Mines (1987) and Gilbert (1985). Stratigraphic younging indicated by solid white arrows. Locations of stratigraphic sections 'a' to 'f' (Fig. GS-19-2) are shown by heavy lines. Areas of no outcrop are not patterned. Inset: Location of the Knee Lake project area in the northwest Superior Province. Areas mapped in 1997 and 1998 are indicated by rectangles.*

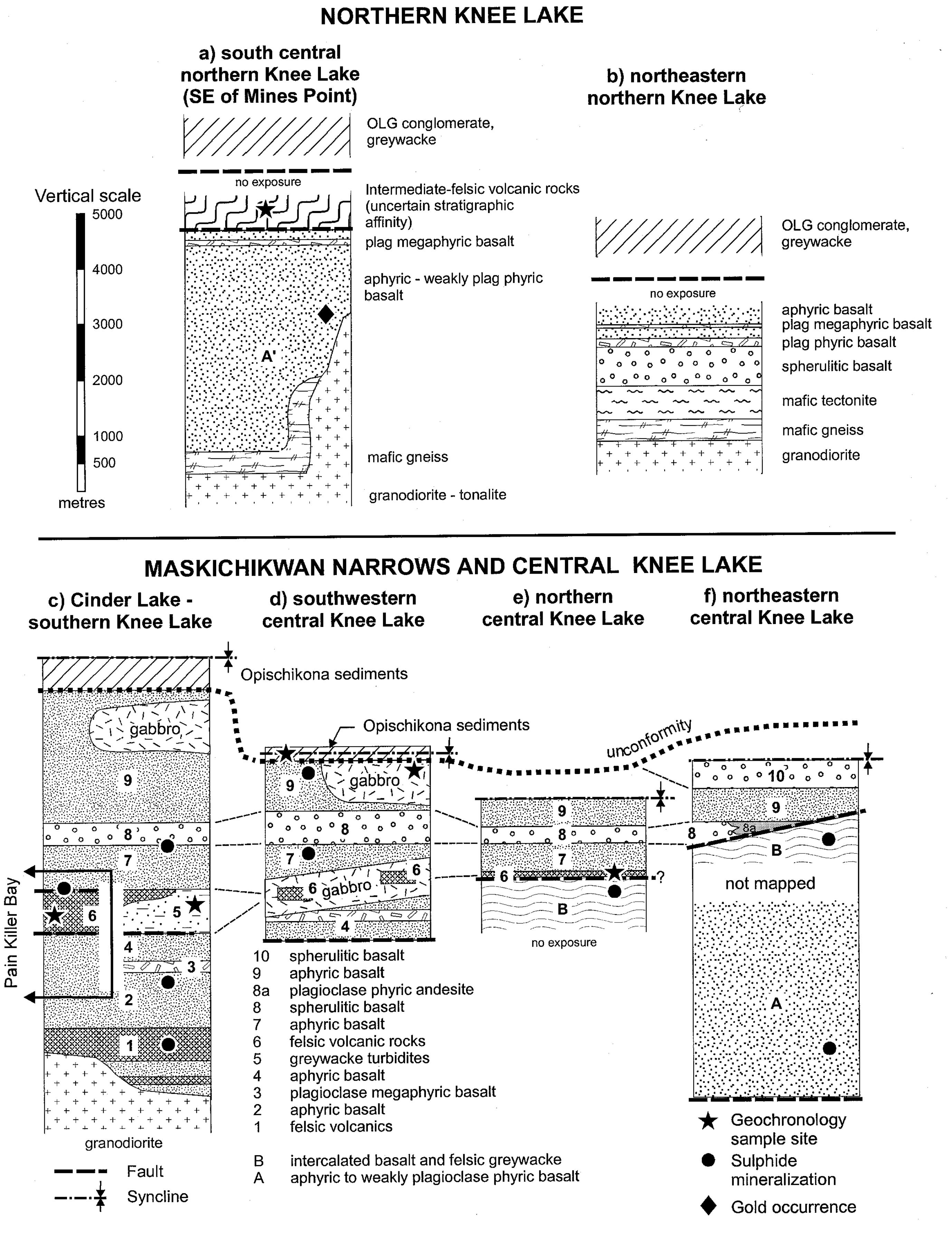

Figure GS-19-2 Stratigraphic sections depicting relationships in northern and central Knee Lake. Vertical scale applies to all sections. Numbered units are stratigraphic equivalents of 'formations' within the Hayes River Group. Units A and A' are separated by a fault and may not necessarily be equivalent. Datum for sections on southern and central Knee Lake = base of first spherulitic basalt (unit 8). Stratigraphic location of sulphide and gold occurrences modified from Southard (1977).

southern Knee Lake (Syme et al., 1997; below). Pillows have thin, dark green selvages and thin interpillow hyaloclastite and are generally non-amygdaloidal. Some pillows have bleached margins, and some flows have up to 5% plagioclase phenocrysts (1-5 mm). Metamorphic grade increases to the northwest, away from the pluton contact: recrystallized basalt on islands in central northern Knee Lake has a 0.5 mm equigranular texture.

Plagioclase megaphyric basalt is exposed on the large island southeast of Mines Point (section 'a', Fig. GS-19-2), where it occurs at the top of, and grades downward into, the aphyric to weakly plagioclase phyric succession (unit A'). The megaphyric section is only ca. 100 m thick, and comprises massive and pillowed basalt flows containing plagioclase phenocrysts and glomerocrysts up to 3 cm across. It is overlain by 200 m of aphyric basalt in fault contact with OLG (?) intermediate to felsic rocks.

Aphyric basalt (unit A) in the Kapakiskok Point area (Fig. GS-19-1, section 'f' in Fig. GS-19-2) is correlated with unit A' (Fig. GS-19-2a) on the basis of close lithologic similarity and the fact that the pillow basalt sequence can be traced basically along strike, from south of Mines Point to east of Maskichikwan Narrows (18 km). However, the stratigraphic relationship between HRG basalts in section 'a' and section 'b' (Fig. GS-19-2) is not known.

Volcanic rocks of uncertain stratigraphic affinity

Intermediate to felsic volcanic and volcaniclastic rocks of possible OLG age (see below) are exposed on the large island southeast of Mines Point (Fig. GS-19-1, section 'a' in Fig. GS-19-2). They are in fault contact with HRG basalts to the south. Stratigraphic younging directions in this suite are to the northeast, implying that the east-trending fault that parallels stratigraphy in the HRG basalts truncates stratigraphy in the intermediate-felsic succession. Contact relations between the intermediate-felsic succession and supracrustal rocks to the northeast are unknown due to absence of outcrop. However, the structural juxtaposition in northern Knee Lake of distinctly different units is reminiscent of structural relations on southern Knee Lake, where a major shear zone juxtaposes HRG basalts and OLG intermediate-felsic volcanic and volcaniclastics rocks (Syme et al., 1997; Lin et al., GS-20, this volume). A sample for U-Pb zircon geochronology was collected from the felsic portion of the sequence to test the notion that these rocks may be Oxford Lake Group in age. We have assigned the intermediate-felsic package to an 'uncertain stratigraphic affinity' until their age is determined.

Massive dacite occurs in the stratigraphically lowest portion of the sequence, on the westernmost part of the island (Fig. GS-19-1). Dacite weathers a chalky cream colour, is very fine grained, and contains minor small (0.5 mm) quartz phenocrysts or, locally, 2-4 mm plagioclase phenocrysts.

The upper 400 m of the sequence consists predominantly of thick layered, plagioclase phyric (1-2 mm) andesite-dacite breccia. The breccia layers are generally unsorted to poorly sorted with 5 - 30 cm fragments in a fine grained matrix. Units (up to 20 m thick) of feldspathic siltstone, fine grained intermediate tuff, and rare quartz-plagioclase phyric rhyolite breccia are interbedded with the andesite-dacite breccia.

Oxford Lake Group

Metasedimentary rocks, including polymictic conglomerate, pebbly greywacke and greywacke, are sporadically exposed on the north shore of northern Knee Lake and in the Parker Lake area (Fig. GS-19-1). These rocks were assigned to 'Rocks of uncertain age' by Barry (1964) and to the Hayes River Group by Gilbert (1985) and Elbers (1984). Our interpretation is that these poorly exposed sedimentary rocks are in fact members of the Oxford Lake Group, based on their lithologic similarity to OLG rocks on southern Knee Lake. They are separated from HRG basalts on the islands and south shore of northern Knee Lake by a major northeast-trending fault.

Conglomerate north of Mines Point contains flattened clasts (originally rounded) of mafic volcanic rock, felsic volcanic rock, sugary quartz, grey chert, feldspar porphyry and minor granitoid rocks. The conglomerate is too poorly exposed and deformed to determine sedimentary structures.

The cobble conglomerate exposed on Parker Lake is polymictic and contains abundant metavolcanic clasts (mafic-felsic), quartz porphyry, quartz, chert, diorite, amphibolite, and minor massive to gneissic granitoid rocks (Barry, 1964).

Finer grained sedimentary rocks on Mines Point are strongly deformed, probably due to proximity to one of the northeast-trending faults (Fig. GS-19-1) separating the sedimentary rocks from HRG basalts on the southern headlands of Mines Point. The sedimentary rocks are fine grained, dark grey, garnet-bearing, mafic sandstone-siltstone with a few highly attenuated clasts.

Barry (1964) describes rubbly exposures of greywacke that occur north and south of the Parker Lake conglomerate, and an iron formation (inferred from aeromagnetic data) in the drift-covered 'contact' area between HRG basalts and the sedimentary rocks of uncertain age. We speculate that the iron formation may be the basal unit in the sedimentary succession; if so, up to 11 km of sedimentary rocks form the northern margin of the Knee Lake Belt at Parker Lake. A sedimentary succession of this thickness and extent is much more likely to be OLG in age than HRG. A result of this interpretation is that, on the scale of the of the entire Oxford Lake - Knee Lake Belt, OLG sedimentary rocks flank HRG volcanic rocks on both the northern and southern sides, possibly reflecting a large-scale, easterly-trending anticlinorium.

MASKICHIKWAN NARROWS AREA

The structurally complex area comprising the narrows between central and northern Knee Lake is key to our understanding of stratigraphic relationships within the HRG on Knee Lake (Fig. GS-19-1). Stratigraphic links between HRG rocks on northern and central Knee Lake (sections 'e' and 'f' in Fig. GS-19-2) suggest that the northern succession either underlies, or is in fault (thrust?) contact with, the succession on central and southern Knee Lake. Evidence for a fault lies in the fact that four successive stratigraphic units on central Knee Lake (units 6, 8, 8a, 9) are all in contact with unit B (Fig. GS-19-2). On northern central Knee Lake (section 'e' in Fig. GS-19-2), however, there is no direct evidence or stratigraphic requirement for a fault between units B and 6.

Below we outline the stratigraphic components of the HRG in the area of central Knee Lake. Note that this succession is the same as that in southern Knee Lake, except for some significant facies variations in units 5 and 6 (Fig. GS-19-2; Syme et al., 1997).

Hayes River Group

A distinctive unit of highly vesicular basalt occurs in a fault-bounded block just east of Maskichikwan Narrows (Fig. GS-19-1). The exposed thickness of the unit is ca. 1100 m, but because it is fault bounded its stratigraphic relationships with other units in northern Knee Lake are unknown (thus it is not shown on Fig. GS-19-2). The basalt weathers a distinct medium to dark green and has a relatively high density, suggesting that it may be iron-rich. Pillows have thick (2-3 cm) recessive selvages and interpillow hyaloclastite. Amphibole pseudomorphs after primary pyroxene phenocrysts are common (0.5-2 mm, 10%). All pillows contain abundant 0.5-2 mm carbonate- and quartz-filled vesicles, imparting a scoriaceous texture locally; non-vesicular basalt is restricted to portions of rare massive flows in the sequence. Significant portions of the unit display pervasive hydrothermal alteration (epidote+ feldspar+quartz), resulting in a light cream weathering colour. Selective alteration of pillow margins results in 'doughnut'-shaped alteration domains. Amoeboid pillows in flow-top breccia is invariably altered.

Interlayered basalt and greywacke form a highly distinctive unit at least 1300 m thick, exposed on the peninsula west of Maskichikwan Narrows (unit B in sections 'e' and 'f', Fig. GS-19-2). The true thickness of the sequence and its precise stratigraphic relationships with other units in northern Knee Lake are unknown because of its isolated occurrence, tectonic contact with other units (e.g., with vesicular basalt, above), and a general paucity of outcrop in the northern lake basin. However, Barry's (1964) inland traverses, interpreted in the light of our new mapping, leads us to suggest that unit B overlies unit A in the area northeast of central Knee Lake (Figs. GS-19-1, 2). Basalt flows in the sequence weather dark green and are pillowed or massive. Pillows have thin, dark green selvages, thin interpillow hyaloclastite, carbonate-filled vesicles in pillow margins, and carbonate in inter-pillow voids. Radial pipe vesicles occur in some pillow margins. Light grey weathering sandstone interlayered with the basalt flows is felsic in composition, composed of sand-sized white feldspar crystals and crystal fragments, clear grey quartz (ca. 20%), and local cm-scale felsic pebbles. The sandstone is thick bedded, with turbidite bedforms: graded bedding (Bouma A and AE beds), flame structures, dark grey siliceous siltstone ripups, siltstone-mudstone interbeds, and minor pebbly layers. Thick sections of this felsic turbidite (to ca. 200 m) occur with little or no intercalated basalt. The stratigraphic significance of the basalt-turbidite unit is that it is potentially equivalent to the turbidite section on southwest central Knee Lake (Syme et al., 1997; units 5 and B in sections 'c', 'e', and 'f', Fig. GS-19-2). However, our preferred interpretation is that this sequence is in tectonic contact with the volcanic succession on central Knee Lake.

Felsic volcaniclastic rocks occur at the top of the interlayered basalt and greywacke unit, 2 km west of Maskichikwan Narrows (unit 6, section 'e' in Fig. GS-19-2). The unit is probably thin (a few tens of metres), and directly overlies ca. 100 m of felsic sandstone. The volcaniclastic rocks are thick bedded (>2 m) and contain subrounded, quartz phyric dacite-rhyolite clasts supported in a felsic, quartz crystal-bearing matrix. Some beds display normal size grading of the contained felsic clasts. Beds are defined by abrupt differences in quartz crystal size, and the size and composition of contained clasts; some beds are essentially monolithologic, some are heterolithologic. The bedforms and nature of clastic components suggests that the felsic volcaniclastics were deposited from subaqueous density flows, similar to the underlying felsic sandstones. The occurrence of these felsic volcaniclastic rocks in the HRG of northern Knee Lake is significant. Our structural interpretation (Fig. GS-19-3) is that these felsic volcaniclastic rocks correlate with felsic rocks on southwest central Knee Lake and, by extension, with the Pain Killer Bay felsic complex on southern Knee Lake (Syme et al., 1997; sections 'c', 'd', and 'e' in Fig. GS-19-2). A sample for U-Pb zircon geochronology was collected to test this hypothesis.

CENTRAL KNEE LAKE

We conducted fairly detailed shoreline mapping in central Knee Lake, to: 1) define a stratigraphy within the HRG mafic volcanic succession; 2) define the geometry of northwest-trending folds in the HRG that are depicted in different ways by Barry (1964) and Gilbert (1985); 3) define the stratigraphic and structural relationships between the HRG and Opischikona sedimentary package; and 4) confirm the presence of felsic volcanic rocks shown by Barry (1964), Gilbert (1985) and Elbers (1984).

Hayes River Group stratigraphy

Definition of stratigraphy and structure within the HRG on central Knee Lake is made possible because of the existence of readily identifiable map units that can be depicted at 1:20 000 - 1:50 000 scale (Syme et al., in prep.). These units include interlayered basalt and greywacke (described in the Maskichikwan Narrows section, above), aphyric basalt, spherulitic basalt, plagioclase phyric andesite, and gabbro-quartz diorite plugs and sills (Fig. GS-19-2).

Aphyric flows on central Knee Lake (units 4, 7 and 9 in sections 'd-f', Fig. GS-19-2) include pillowed, composite and massive types. Pillowed flows are most common, and are characterized by medium to small, bun-shaped to irregular pillows with narrow selvages and thin interpillow hyaloclastite. These flows typically weather pale grey and are generally non-amygdaloidal, and are readily distinguished from, for example, green-weathering pillow basalts (units A and B) in northern Knee Lake, and the vesicular basalts in the Maskichikwan Narrows area.

Spherulitic flows form highly distinctive marker units up to 700 m thick within Hayes River Group stratigraphy in southern and central Knee Lake (Syme et al., 1997; units 8 and 10 in sections 'd-f', Fig. GS-19-2). In these flows, cm-scale concentrically zoned spherulites occur in pillow margins and coalesce to a dense mass in pillow cores. Contacts between km-scale spherulitic and aphyric units are sharp, and there is no small-scale intercalation of the two flow types. Spherulitic flows also differ from non-spherulitic flows in that pillows tend to be larger and elongate, with thicker selvages and thicker interpillow hyaloclastite than aphyric flows. On central Knee Lake, a single spherulitic unit 200-550 m thick provides a key stratigraphic marker used to construct the structural interpretation (Fig. GS-19-3).

Plagioclase phyric andesite (unit 8a in section 'f', Fig. GS-19-2) forms a unit 300-600 m thick in the eastern part of central Knee Lake. Flows weather a distinctive medium grey and contain abundant (40%) euhedral plagioclase phenocrysts (2-6 mm). Flows include pillowed and composite massive and pillowed types; pillows tend to be large and equant in shape.

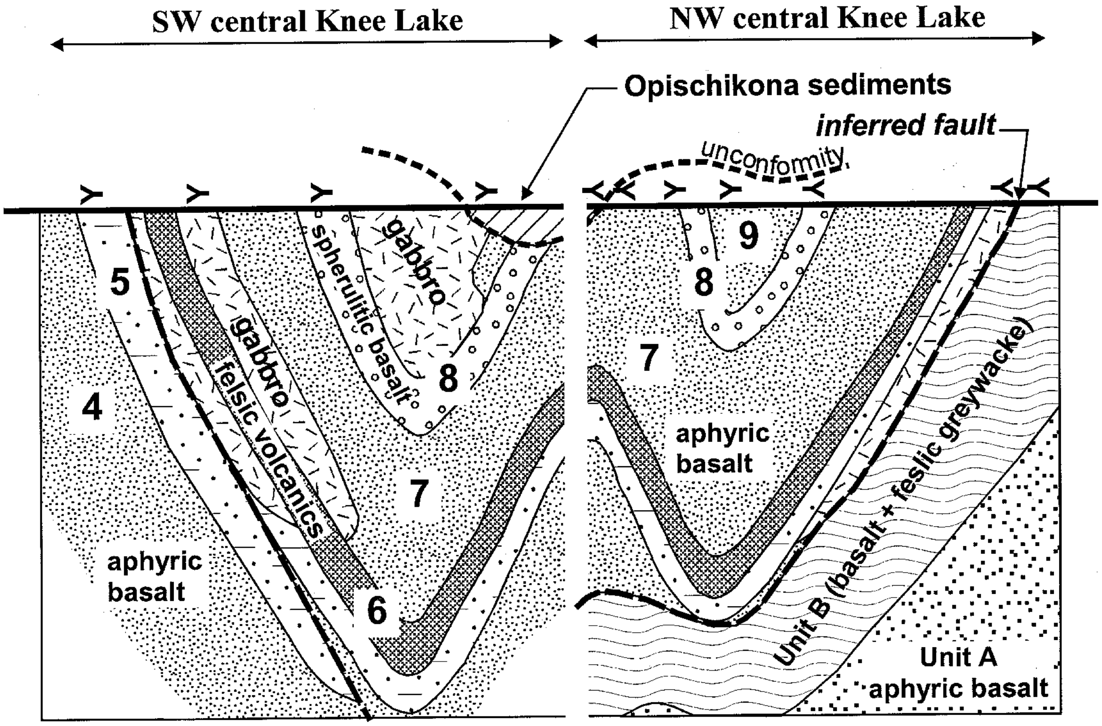

Figure GS-19-3 Schematic cross-section through central Knee Lake, showing the inferred geometry of structures discussed in the text. Section lines: southwest central Knee Lake - upper portion of section 'c' (Fig. GS-19-2); northwest central Knee Lake - section 'e' extended (dashed on Fig. GS-19-2) to synclinal axial trace. Horizontal axis is to scale.

Sills and plugs of gabbro to quartz diorite abound in the Hayes River Group on central Knee Lake, ranging from minor intrusions (not shown on the map) to a compositionally zoned sill (gabbro-quartz ferrodiorite-granophyre) 1 km thick (Fig. GS-19-2).

Felsic volcanic rocks shown on earlier maps (Barry, 1964; Gilbert, 1985; Elbers, 1984) within the HRG mafic succession proved to include a variety of rock types, none of which is *sensu stricto* an HRG rhyolite. The reported 'felsic' rocks were found to include: silicified basalt and basaltic amoeboid pillow breccia, plagioclase phyric andesite, sedimentary interbeds, quartz feldspar porphyry dykes, and fault breccia. Unequivocal felsic volcanic rocks in the HRG occur within what we interpret as a single stratigraphic interval (unit 5) that correlates with the Pain Killer Bay felsic complex of southern Knee Lake (Fig. GS-19-2c, d).

Opischikona Narrows sediments (probable Oxford Lake Group)

At Opischikona Narrows (between southern and central Knee Lake) a sedimentary sequence occupies a structural basin (Fig. GS-19-1; Syme et al., 1997). Chert-magnetite iron formation and argillite mark the base of this sedimentary section in the few locations where it is exposed on southern central Knee Lake. Greywacke, pebbly sandstone and conglomerate form the bulk of the overlying stratigraphic section at Opischikona Narrows. A range of primary sedimentary structures are preserved, indicative of deposition in both submarine and possible subaerial environments.

Gilbert (1985) shows these sedimentary rocks to be part of the Hayes River Group, but the age of the sequence was considered equivocal because its stratigraphic and structural relationships with the underlying Hayes River Group basalts were not well constrained. In 1997 we depicted these rocks as having unknown stratigraphic affinity (Syme et al., 1997), but our work in 1998 clearly shows that they lie unconformably on HRG basalts and contained intrusions (sections 'c' and 'd' in Fig. GS-19-2). Thus, we interpret the sediments to be most likely Oxford Lake Group in age. In order to bracket the depositional age of these sediments, two samples for U-Pb zircon geochronology were collected: 1) a feldspar porphyry sill emplaced in the sediments (providing a minimum age of deposition), and 2) a sandstone (the youngest contained detrital zircon will provide the maximum age of deposition).

The main body of Opischikona sediments that are exposed at southern central Knee Lake were described by Syme et al. (1997). In 1998 we mapped the northwesterly, narrow extension of the syncline containing the sediments, and a second sediment-cored syncline was discovered to the northeast (Fig. GS-19-1). These new exposures add to the lithologic diversity within the Opischikona sequence.

Polymictic boulder-cobble conglomerate is exposed in the narrow, northwest-trending synclinal keel (Fig. GS-19-1). This unit, which was not found in the main body of Opischikona sediments, is important because it represents a sample of the source terrane. The conglomerate is >10 m thick, clast supported, poorly sorted, and thick bedded. Clasts (all rounded to subrounded) include cream-weathering plagioclase phyric andesite, cream-weathering aphyric andesite, grey-green-weathering mafic volcanic rock, white chert, and siltstone. The conglomerate is underlain by interlayered polymictic pebble conglomerate and sandstone-siltstone. The feldspathic sandstone (5-10% quartz) is medium to thick bedded, normally graded, with fine grained laminated bed tops. Some of the sandstone is pebbly; small (3-10 mm) fuchsite pebbles occur in some beds. This section is intruded by a ca. 7 m thick massive feldspar porphyry sill containing 1-3 mm feldspar phenocrysts (30%) in a fine grained feldspathic (dacitic) groundmass.

Much of the fine grained sedimentary section on west central Knee Lake consists of thin- to medium-bedded, fine grained feldspathic sandstone and pebbly sandstone with turbidite bedforms. Pebble lithologies include felsic volcanic, quartz, chert and minor mafic volcanic. The sand is dominated by detrital feldspar and quartz (up to 20% quartz, including sporadic blue quartz phenoclasts to 1 mm) and are generally well sorted.

STRUCTURAL EVOLUTION

We have taken a stratigraphic approach to mapping the Hayes River Group volcanic sequence at Knee Lake because this method results in a coherent interpretation of the structural geology of the area. For example, through paying close attention to lithology and stratigraphic younging we now know that mutually inconsistent structures (folds, faults) shown by previous workers (Barry, 1964; Elbers, 1984; Gilbert, 1985) are due in large measure to the non-recognition of key marker units. In turn, an understanding of structure aids stratigraphic interpretation, for example where younging criteria are absent.

The most enigmatic, and potentially oldest, structure in the area is the fault between unit B and units 6, 7 8, 8a and 9 (Fig. GS-19-2). No physical evidence for this structure was observed in the field (the contact between unit B and other units is never exposed); however, as discussed above, the presence of stratigraphic cut-offs in a succession characterized by regional continuity of units (Fig. GS-19-2) strongly suggests that a fault exists. The fault/contact is clearly curvilinear and we suspect that it is folded with the stratigraphy (Fig. GS-19-1; Syme et al., in prep.). We speculate that the fault may be a thrust; however, the relative age of the juxtaposed sequences is currently unknown. Geochemical characterization of the various members of the juxtaposed sequences is in progress.

Hayes River Group volcanic rocks are folded in a series of moderately closed, northwest-trending, anticlines and synclines (Fig. GS-19-1, 3). These folds have a weak axial planar foliation and steeply plunging (subvertical) lineation. They are clearly defined by variation in younging direction in well-preserved pillow basalts and by repetition of marker units (e.g., spherulitic basalt; turbidites).

The Opischikona sedimentary sequence (provisionally correlated here with the OLG) was deposited on already-deformed Hayes River Group rocks (Fig. GS-19-3). The HRG and Opischikona rocks are locally in apparent stratigraphic conformity, but mapped relations throughout central Knee Lake clearly show a large-scale angular discordance between them (Syme et al., in prep.; Fig. GS-19-3). Folds in the Opischikona sedimentary sequence are coplanar with, but younger than, folds in the HRG (Fig. GS-19-3). Folding of the sediments was strongly controlled by the anisotropy (i.e., earlier folds) in HRG rocks underneath them (e.g., Watkinson and Cobbold, 1981). The sedimentary rocks have an axial planar foliation and steep stretching lineation that are by and large indistinguishable from structures in the HRG.

The presence of an angular unconformity and the subaerial nature of at least part of the Opischikona sequence suggests that sedimentation occurred on an uplifted and deeply incised terrain. Uplift of the 'oceanic' HRG succession may have been the result of the emplacement of voluminous granitoid plutons. Both the OLG and Opischikona sediments are notable *vis a vis* HRG sediments in that they contain granitoid clasts.

Faults and shear zones cut the folded HRG - Opischikona - OLG rocks, resulting in a complex map pattern (Fig. GS-19-1; Syme et al., in prep.). These structures include ductile shear zones and brittle faults; northeast-trending structures tend to be dominantly ductile shear zones, whereas the north-northeast-trending structures are discrete brittle faults. Some of the shear zones in northeastern Knee Lake have dip-slip components of displacement.

The most significant shear zone in the area is a northeast-trending structure that extends the length of northern Knee Lake, separating OLG sediments in the north from HRG volcanic rocks in the south. The horizontal component of deformation in this zone appears to be sinistral, based on the manner in which the OLG outcrop belt curves into the fault zone. Secondary structures parallel to this large fault occur in northeastern Knee Lake, where fault-bounded panels of OLG conglomerate, only a few 10's of metres wide, occur within the HRG.

Horizontal offsets along north-northeast-trending faults tend to be dextral. Fault breccia associated with the latter is locally well exposed, comprising a wide variety of foliated, dominantly HRG clasts supported by a fine grained, unfoliated, fault gouge matrix. Breccia-filled faults are locally more than 30 m wide in the Maskichikwan Narrows area, and contain fragments up to 3x5 m.

ECONOMIC GEOLOGY

A summary of known mineral occurrences and exploration activity (to 1977) is contained in Southard (1977). A compilation of post-1977 assessment work is in preparation but not yet completed.

The sulphide and gold occurrences in central and northern Knee Lake documented by Southard (1977) can, in light of our new mapping, be placed in a stratigraphic context (shown in generalized form on Fig. GS-19-2).

Sulphide occurrences

Notable on Figure GS-19-2 are the abundance of sulphide showings in the presumed upper part of the HRG stratigraphy (i.e., units 1-9), and the paucity of showings in the inferred lower part of the sequence (units A, A'). Showings in unit B are likely related to the intercalated sedimentary units.

The Cinder Lake area hosts a number of significant massive sulphide occurrences (Fig. GS-19-1). The massive sulphides (mainly pyrite, pyrrhotite and minor chalcopyrite, sphalerite) are associated with felsic volcanic rocks (Southard, 1977) near the (intruded) base of the HRG succession (Fig. GS-19-2). Southard (1977) reports that the massive sulphides (up to 23 m thick) occur at the contact between rhyolitic rocks and more mafic ('andesite') flows.

A number of showings are located at or near the contact between units 7 and 8 (Fig. GS-19-2). During our mapping it was apparent that unit 8, spherulitic basalt, commonly displays widespread 'silicification' (feldspar+quartz alteration) and is locally gossaned (Syme et al., 1997).

Gold occurrences

Gold occurrences in the Knee Lake area are structurally controlled (Southard, 1977; Richardson and Ostry, 1996; Syme et al., 1997; Lin et al., GS-20, this volume). In general, gold mineralization in the Archean is widely assumed to be associated with regional scale shear zones, but many of the largest deposits are hosted by much smaller fault structures having minor displacements (Vearncombe, 1998). In the Island Lake area, Lin et al. (GS-20, this volume) have distinguished two distinct episodes of gold mineralization, an earlier one that took place during movement along regional ductile shear zones parallel to the dominant planar fabrics in the greenstone belt, and a later one that occurs in ductile-brittle shear zones that cut across the dominant planar fabric in the belt. The latter is potentially Proterozoic in age (Lin and Cameron, 1997). This is similar to the timing of gold mineralization (relative to age of host rocks) in the Yandal Belt (Yilgarn craton, Australia), where mineralizing fluids were focused by a network of Late Archean, middle to upper crustal brittle faults (Vearncombe, 1998).

Our work has defined many shear zones and faults that were not shown on previous maps of the area, and provide an improved structural framework for gold exploration. These structures range in age from early (the fault separating unit B from units 4-9, Fig. GS-19-2), to late (e.g., brittle, north-northeast- and northeast-trending faults on central Knee Lake). Between these end-members are a wide array of ductile shear zones whose precise age is not known. Some, such as the major, northeast-trending structures separating OLG sediments from HRG volcanic rocks, obviously must post-date deposition of the Oxford Lake Group. For others, such as the minor structure hosting the Knee Lake Gold Mines/Johnson Knee Lake Mines occurrences on northern Knee Lake, there is currently no control on the age of deformation or the contained gold mineralization.

Mineralization at the Knee Lake Gold Mines and Johnson Knee Lake Mines gold-silver occurrences ('Au', Fig. GS-19-1, east of section line 'a') occurs in a sheared and locally silicified, 2 m thick 'tuff' unit at the contact between pillow basalts and a quartz porphyry dyke; visible gold occurs in a ≤15 cm thick quartz vein at the contact with the dyke (Southard, 1977). Arsenopyrite occurs in the 'tuff' and increases in abundance (up to 7%) towards the pillow basalt. The highest grades reported by Southard (1977) are 2.65 oz. Au/ton and 0.45 oz. Ag/ton, for mineralized 'tuff' on the Knee Lake Gold Mines dump. Underground work begun in 1935 at Knee Lake Gold Mines (shaft sinking to 99 m, crosscutting, drifting) failed to prove mineable grades; ore shoots were extremely erratic and could not be correlated with diamond drill values (Southard, 1977). A similar exploration and development history characterized the nearby (350 m west) Johnson Knee Lake Mines operation.

CONCLUSIONS

1. Hayes River Group mafic volcanic rocks in northern Knee Lake (units A, A', B; Fig. GS-19-1) are interpreted to either 1) underlie the sequence of aphyric and spherulitic basalts on central Knee Lake, or 2) be in tectonic contact (thrust?) with the central Knee Lake sequence (sections 'e' and 'f', Fig. GS-19-2).

2. Felsic and intermediate flows and volcaniclastic rocks exposed on northern Knee Lake (section 'a', Fig. GS-19-2) are possibly Oxford Lake Group volcanic rocks, based on lithologic similarity with OLG volcanic rocks in southern Knee Lake and their tectonic contact with HRG basalt.

3. Poorly exposed sedimentary rocks north of northern Knee Lake, shown on Barry (1964) as 'Rocks of uncertain age (upper Hayes River unit or Oxford)' and in Gilbert (1985) and Elbers (1984) as Hayes River Group, are interpreted here as Oxford Lake Group based on their lithologic similarity to OLG sedimentary rocks and their tectonic contact with HRG basalts (Fig. GS-19-1).

4. The Opischikona sedimentary sequence (Syme et al., 1997), interpreted as Hayes River Group in Gilbert (1985), are interpreted here as Oxford Lake Group on the basis of their mapped unconformable contact with Hayes River Group volcanic and intrusive rocks (sections 'c' and 'd', Figs. GS-19-2, 3).

5. Northwest-trending folds in the Opischikona sedimentary sequence are younger than, but coplanar with, northwest-trending folds in the HRG. The folds in HRG rocks occur between Kapakiskok Point and central Knee Lake; east of Kapakiskok Point the HRG faces uniformly north.

6. The potential for base metal massive sulphide deposits appears to be concentrated in the felsic members of the upper HRG stratigraphy (units 1 and 6, Fig. GS-19-2). Regional silicification/albitization occurs within and at the base of the first spherulitic basalt unit (unit 8).

7. Major, northeast-trending faults post-date the OLG; brittle faults trend north-northeast. Known gold occurrences in the central-northern Knee Lake area appear to be related to minor structures whose age relative to larger mapped faults is unknown.

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