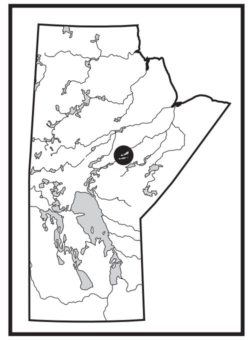
GS-10 Nature, evolution and gold potential of the Utik Lake greenstone belt, Manitoba (parts of NTS 53M4, 5, 63P1, 8): preliminary field results

by C.O. Böhm, P.D. Kremer and E.C. Syme



Böhm, C.O., Kremer, P.D. and Syme, E.C. 2007: Nature, evolution and gold potential of the Utik Lake greenstone belt, Manitoba (parts of NTS 53M4, 5, 63P1, 8): preliminary field results; *in* Report of Activities 2007, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 98–113.

Summary

An Archean mafic metavolcanic–dominated greenstone belt at Utik Lake, central Manitoba, was mapped and studied in detail to 1) determine the nature, age and composition of the supracrustal rocks, in order to compare them with greenstone belts elsewhere in the northwestern Superior Province (e.g., Knee and Oxford lakes areas); 2) analyze the kinematics and structural evolution of the Utik Lake greenstone belt; and 3) reassess the potential of the area to host volcanogenic massive sulphide and orogenic and epigenetic gold deposits.

The greenstone belt at Utik Lake is up to 12 km wide and forms an east- to northeast-trending, subvertically dipping and southward-facing homoclinal succession intruded and bounded by younger granitoid rocks. The greenstone belt can be subdivided into several east- to northeast-trending panels of mafic metavolcanic and mafic intrusive rocks that are separated by metasedimentary sequences, including iron formation, mudstone and mafic volcanic–derived conglomerate. The metavolcanic rocks at Utik Lake have compositional and textural similarities, occur along strike with, and may thus be correlative with mafic metavolcanic rocks of the ca. 2.83 Ga Hayes River Group at Knee Lake. In contrast, the felsic to intermediate, tuffaceous and volcanogenic sediment–dominated rocks of the supracrustal belts at nearby Bear and Oxford lakes likely form parts of the Neoarchean, ca. 2.73–2.71 Ga Oxford Lake Group.

The mafic metavolcanic and associated volcanogenic metasedimentary rocks at Utik Lake are overlain by a sequence of clastic sedimentary rocks that includes polymictic conglomerate, siltstone-mudstone turbidite, cordierite- and garnet-porphyroblastic wacke, and quartz arenite to sandstone. This younger metasedimentary sequence is similar in composition and tectonic position to the Opischikona metasedimentary rocks at central Knee Lake, whose age is estimated to be between 2.82 and 2.78 Ga. All supracrustal rocks at Utik Lake were intruded by at least three suites of felsic plutonic rocks of dominantly granitoid composition. Regional metamorphic grade is upper greenschist to amphibolite facies, with increased temperature conditions recorded in rocks (sillimanite zone in pelitic rocks) at the margins of the belt, likely due to contact metamorphism by the bounding plutonic rocks.

The voluminous mafic metavolcanic and igneous rocks at southwestern Utik Lake were locally pervasively altered by hydrothermal and fumarolic vein and dike systems that formed chemical seafloor sedimentary rocks (chert-magnetite iron formation), capped by auriferous chert and shale. The entire supracrustal assemblage was locally highly strained and sheared prior to, during and after the felsic plutonism that invaded and enveloped the supracrustal belt. The tectonic evolution of the belt is thus very favourable for orogenic and possibly epigenetic gold occurrences similar to those along regional strike at Knee Lake and Monument Bay.

Introduction

Utik Lake is located approximately 130 km southeast of Thompson, Manitoba, within the northwestern part of the Archean Superior Province. The lack of road access and distance to traditional mining camps (e.g., Thompson, Bissett) has limited the amount of geological and exploration work in the area, but previous geologists (Milligan, 1951; Milligan and Take, 1954; Hargreaves, 1975; Hargreaves and Ayres, 1979; Weber, 1975) have noted well-exposed mafic metavolcanic–dominated supracrustal sequences (greenstone) in the area. The supracrustal rocks have been regionally metamorphosed, but the prefix ‘meta’ is omitted in specific rock names (e.g., basalt) in the following discussion for purposes of brevity.

The greenstone belts at Utik and Bear lakes were selected for multidisciplinary stratigraphic, structural, geochronological and geochemical analyses because this part of the northwestern Superior Province has experienced little mineral prospecting and exploration attention during the past several decades. The present work aims to re-evaluate the mineral potential of this area, particularly the potential for orogenic and/or epigenetic gold deposits. The approach is to incorporate into existing map data the results from modern analytical and field techniques that were not available or applied during the previous mapping projects. The new data from the Utik Lake and Bear Lake greenstone belts can then be compared and integrated with those from the greenstone belts in the Knee and Oxford lakes areas (Figure GS-10-1).

Previous studies

The first geological survey work in the Utik–Bear lakes region was undertaken in the 1950s by Milligan (1952) and coworkers (Allen, 1953; Milligan and Take,

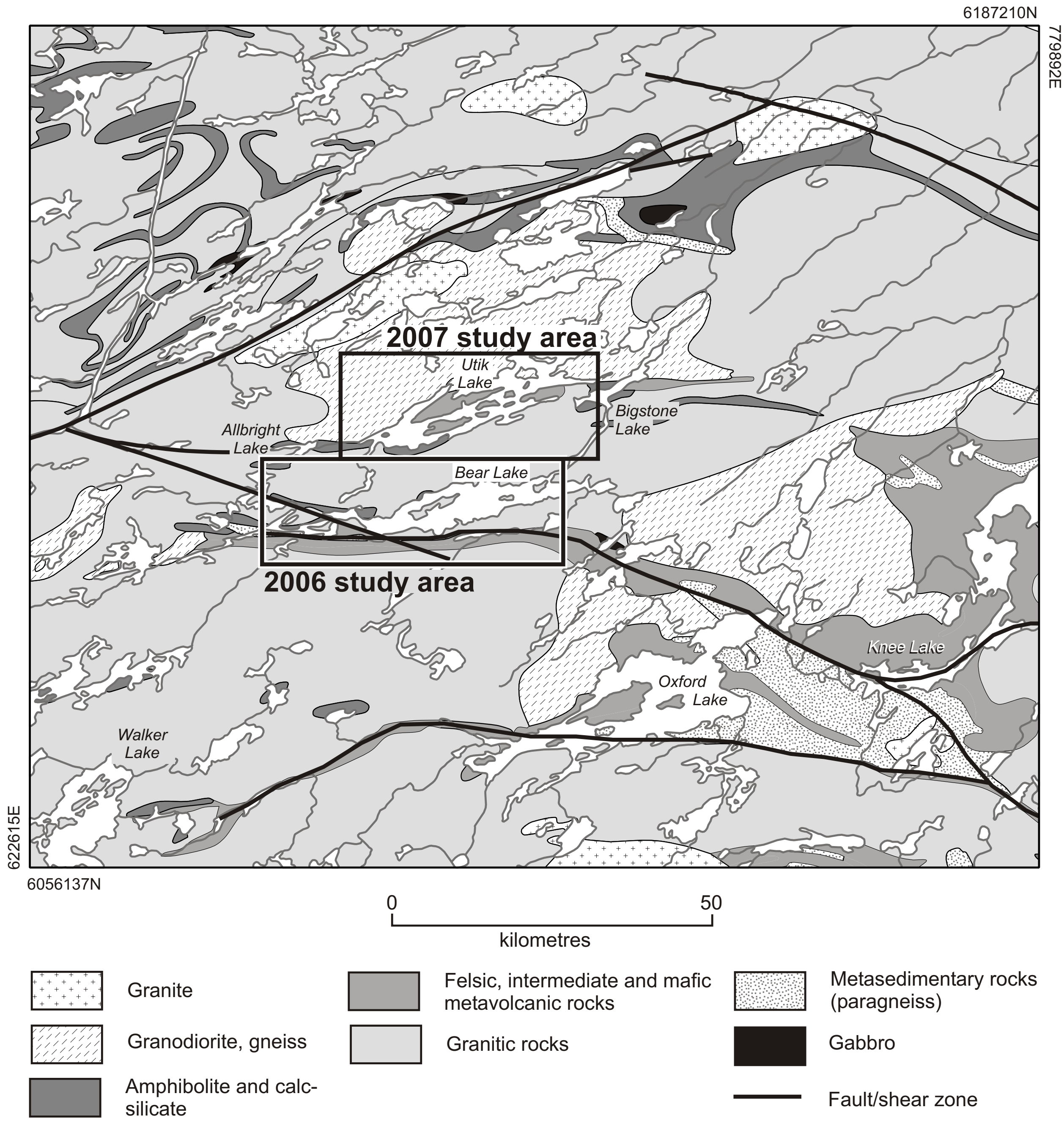


Figure GS-10-1: *Simplified regional geology of part of the northern Superior Province in Manitoba, with the Utik Lake (2007) and Bear Lake (2006) mapping areas outlined.*

1954). This early mapping (1:31 680 scale), combined with systematic prospecting for base and precious metals, represents a solid lithological framework for the larger study area, and resulted in the discovery of copper and gold showings. Subsequent investigations by Weber (1974, 1975) were aimed at subdivision of the supracrustal rocks into subunits and the development of a regional tectonic interpretation. In addition, Weber (1975) initiated studies of mafic metavolcanic flows and synvolcanic hydrothermal alteration pipes in the southern Utik Lake belt; these were followed up in more detail by Hargreaves and Ayres (1979) and Bernier and MacLean (1989).

Mineral exploration at Utik Lake experienced a minor spike in the mid- to late 1980s, when Westmin Exploration Ltd. examined some of the previously identified volcanogenic massive sulphide and gold occurrences in the Utik Lake mafic metavolcanic rocks (e.g., Assessment Files 94560, 94563, 94342, Manitoba Science, Technology, Energy and Mines, Winnipeg) and encountered significant zinc mineralization during their drilling campaigns (A.F. 94317, 94318). After that, minor prospecting and mineral exploration activities at Utik

Lake were part of regional surveys in 1998 by BHP Minerals Canada Ltd. (A.F. 73539); in 1999 by Hudson Bay Exploration and Development Co. Ltd. (A.F. 73614) and by Kennecott Canada Exploration Inc. and Montello Resources Ltd. (A.F. 73615); and in 2000–2001 by De Beers Canada Exploration Inc. (A.F. 94882). These regional heavy mineral and soil surveys detected encouraging anomalous mineral and/or element concentration trends within the larger Utik Lake area, but statements on the amount and direction of upstream ice transportation were generally missing or vague.

Modern analytical and field techniques

Characterization of the supracrustal rocks beyond the field and thin section observations (texture, mineralogy) hinges largely on major- and trace-element geochemical analysis. Detection limits, precision and accuracy of modern trace-element geochemical analytical techniques (i.e., the application of inductively coupled plasma–mass spectrometry [ICP-MS]) far exceed the quality of analyses used during previous geoscientific studies at Utik Lake (e.g., Milligan and Take, 1954; Weber, 1975; Bernier and MacLean, 1989). Geochemical analyses of rocks collected at Utik Lake in 2007 are still pending; nevertheless, the dominant mafic metavolcanic rocks are herein termed basalt, based on sparse existing whole-rock data (Milligan and Take, 1954; Bernier and MacLean, 1989) and field appearance.

Similarly, the present study incorporates isotope geochemical (Sm-Nd) and radiometric dating (e.g., U-Pb geochronology) not available or applied during previous studies. The new isotopic data will allow, in conjunction with geochemical and field data, direct comparison of the supracrustal rocks at Utik Lake with greenstone belts elsewhere in the northern Superior Province, and thus enable a tectonic analysis of the area.

During the 2007 field mapping, personal digital assistants (PDA) loaded with customized ArcPad® field data collection systems and Bluetooth-linked to GPS devices allowed the collection of all data digitally and in spatially integrated format on the outcrop. The new map data are being digitally combined and complemented with earlier mapping (Milligan and Take, 1954; Weber, 1974) in preparation for a final geological map, planned for release in 2008. The 1:25 000 scale preliminary geological map of Utik Lake (Böhm and Kremer, 2007) that is a companion release to this report summarizes the field data collected during five weeks of mapping in June and July of 2007.

Regional setting

On a regional scale, the Utik Lake greenstone belt lies along the northern margin of the Gods Lake Domain (Weber and Scoates, 1978), which is now referred to as the Oxford Lake–Stull Lake Terrane (Skulski et al., 2000) and is located south of the Pikwitonei Granulite Domain (Figure GS-10-1). The Utik Lake greenstone belt has a first-order east-west trend that parallels the regional structure of the Superior Province (Card, 1990) and is transposed along northeast-trending dextral shears, resulting in a dextral mega-boudin structure measuring approximately 30 km by 12 km (Figure GS-10-2). In the field, the megascopic structure is reflected at outcrop and smaller scales. Based on regional correlation using magnetic data and field lithological descriptions, the Bear Lake and Utik Lake greenstone belts likely form westerly continuations of the greenstone belts at Oxford and Knee lakes (Figure GS-10-1), which host a complex assemblage of supracrustal sequences partially unrelated in nature and age. At Knee Lake, three distinct but juxtaposed supracrustal sequences have been recognized (Gilbert, 1985; Syme et al., 1997, 1998, 1999): 1) the ca. 2.83 Ga, mafic metavolcanic–dominated Hayes River Group; 2) the <2.82 Ga but >2.78 Ga (Corkery et al., 2000), metasedimentary-dominated Opischikona sequence; and 3) the ca. 2.71 Ga, metasedimentary and bimodal metavolcanic Oxford Lake Group (Corkery et al., 2000).

Dating of the metavolcanic and metasedimentary rocks at Utik Lake is one of the main foci of this study and will, together with detailed major- and trace-element geochemistry and isotope geochemistry, facilitate correlation with the dated supracrustal rocks in the region. Based on comparison with results from 2006 investigations on the supracrustal rocks at Bear Lake (Böhm and Hartlaub, 2006; Hartlaub and Böhm, 2006), metavolcanic and metasedimentary rocks at Bear Lake are largely dissimilar in composition and may not be coeval with those at Utik Lake. Preliminary U-Pb zircon data for a felsic tuff from south-central Bear Lake indicate an age of 2716 ±2 Ma, interpreted as the formation age of the tuff (C. Böhm, unpublished isotope dilution–thermal ionization mass spectrometry data, 2007). This age supports the hypothesis that (part of) the supracrustal rocks at Bear Lake are contemporaneous and likely correlative with metavolcanic and metasedimentary rocks of the Oxford Lake Group.

Utik Lake greenstone belt

The Utik Lake greenstone belt represents a northeast- to east-trending supracrustal remnant that occupies much of the central and southern parts of Utik Lake (Figure GS-10-2) and extends semicontinuously along strike into Allbright Lake to the west, and Bigstone Lake–Knee Lake to the east (Figure GS-10-1). The Utik Lake greenstone belt is a homoclinal, south-facing sequence of mafic metavolcanic and volcanogenic metasedimentary rocks that underwent medium- to high-temperature and low-pressure (upper greenschist and amphibolite facies) regional metamorphism. Faulting and shearing strongly affected the belt margins and caused pinching out of the supracrustal rocks to the southwest and northeast, resulting in dextrally asymmetric,

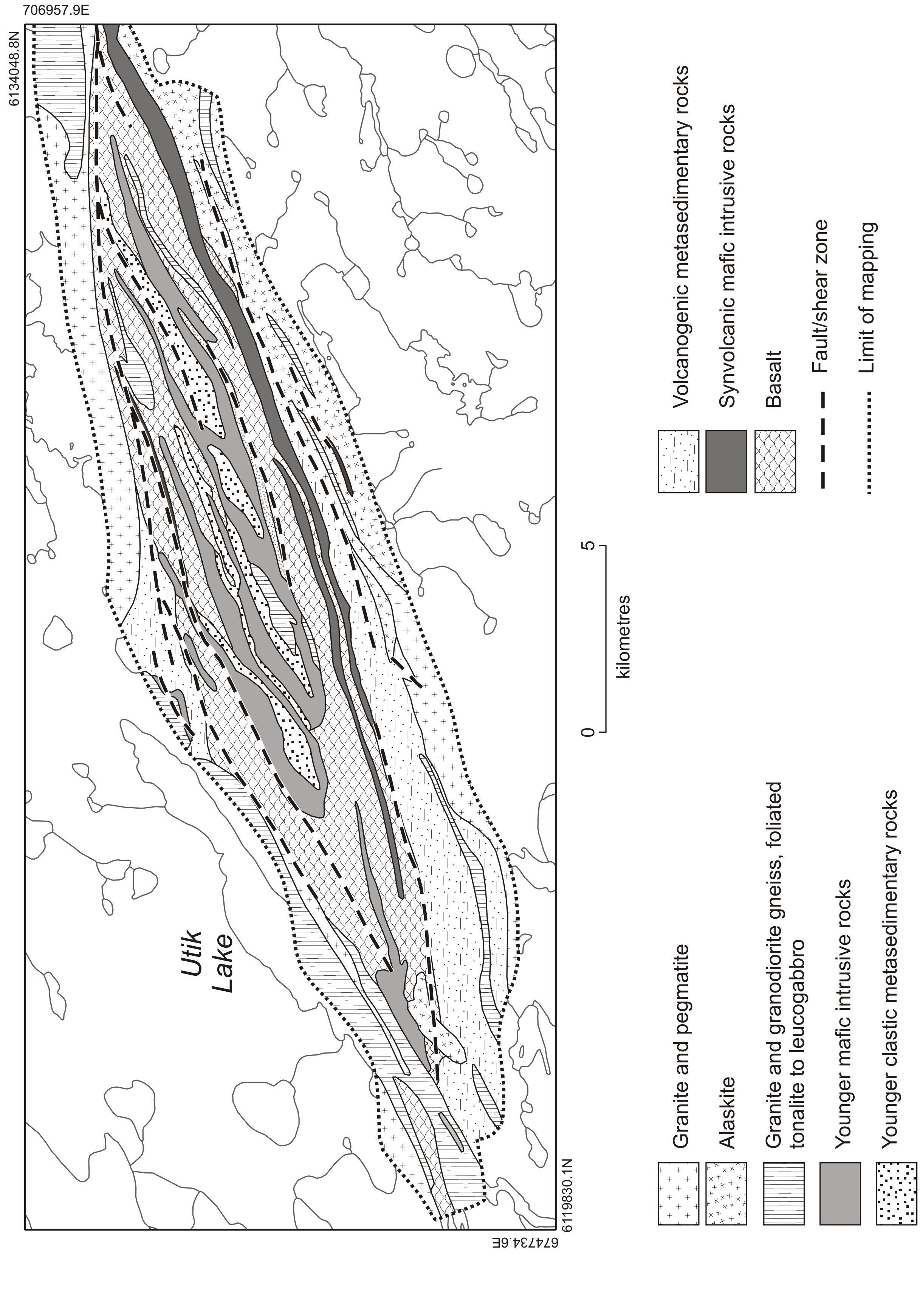


***Figure GS-10-2:** Schematic bedrock geology of the Utik Lake greenstone belt* (simplified from *Böhm and Kremer, 2007*).

large-scale deformation of the belt at Utik Lake (Figures GS-10-1, -2). Compared to the highly strained greenstone belt margins, primary volcanic and sedimentary structures important for identifying the detailed lithostratigraphy and architecture are well preserved in internal portions of the belt.

The supracrustal sequence at Utik Lake is subdivided into a number of 'panels', composed of pillowed and massive basalt, and associated diabase and gabbro. The panels are internally stratigraphically coherent and differ in, for example, the proportion and type of basalt or the abundance of metasedimentary rocks. Contacts between panels are typically covered (by the long easterly-trending channels that characterize Utik Lake) and may be stratigraphic, structural or a combination of both.

Panels composed of mafic rocks are separated by conformable metasedimentary rock sequences comprising banded iron formation, greywacke siltstone to mudstone turbidite, and conglomerate. These metasedimentary rocks are interpreted to represent two distinct sequences: 1) those derived from and coeval with intercalated mafic metavolcanic and intrusive rocks, and 2) a younger clastic sequence whose source was different and distinct from the underlying mafic-dominated supracrustal rocks. The metavolcanic rocks and all metasedimentary rocks were intruded by a suite of diabase and gabbro dikes and sills, and the greenstone belt was subsequently invaded and enclosed by several generations of granitoid rocks.

The main rock types at Utik Lake, as outlined on the 1:25 000 scale geological map (Böhm and Kremer, 2007), are schematically summarized in Figure GS-10-3 and their distribution delineated in Figure GS-10-2.

Figure GS-10-3: *Schematic lithostratigraphy of the Utik Lake greenstone belt and bounding intrusive terranes.*

Basalt

The mainly mafic metavolcanic flows (tholeiitic normal mid-ocean-ridge basalt [N-MORB]; Bernier and MacLean, 1989) at southwestern Utik Lake have been described in detail by Weber (1974) and Hargreaves and Ayres (1979). These authors focused on the large island in southwestern Utik Lake (Mistuhe Island), where the well-exposed basalt flows are predominantly massive in the central and southern parts of the island but largely pillowed along its northern shore, particularly towards the east. The focus of these previous studies was to document detailed flow stratigraphy, morphology and primary volcanic processes. In comparison, the present mapping focuses on a more regional approach, to better constrain the variations in texture, composition and extent of the several metavolcanic panels of the belt. Common characteristics used to describe and subdivide the basaltic sequences include colour and texture, amount and size of plagioclase phenocrysts and/or glomerocrysts, amount of amygdules and/or spherulites, thickness of selvages, pillow sizes, and amount and composition of interpillow hyaloclastite and/or interpillow sediment and peperite.

All observed basaltic flow sequences and interlayered or intercalated metasedimentary rocks are consistently southward facing, resulting in one homoclinal supracrustal sequence. Facing direction criteria in pillow basalt include pillow shape, pillow shelves and eyebrow structures, and amygdule concentration.

As indicated by previous mapping (Milligan and Take, 1954; Weber, 1974), the basaltic sequences at Utik Lake can be subdivided into several 'panels' that possibly represent individual pulses of volcanic activity and, in some cases, are separated by metasedimentary rocks or shear zones. At a first level, the basalt flows are subdivided into an older, northwestern panel that is separated from a southern panel of basaltic and associated mafic igneous rocks by a continuous central sequence of metasedimentary rocks and younger intrusions up to 2 km wide (Figure GS-10-2). The northwestern panel is best preserved in exposures in north-central Utik Lake (e.g., UTM Zone 14, 688317E, 6128877N [NAD83]), where aphyric and nonamygdaloidal basalt is characterized by large (up to few metres long) and irregularly shaped, closely packed pillows that are devoid of shelves, have thick selvages (up to 3 cm) and little (≤5%) interpillow material (Figure GS-10-4a). To the southeast, variably plagioclase-phyric and/or glomerocrystic (up to 1.5 cm; Figure GS-10-4b), amygdaloidal pillow basalt represents part of a separate metavolcanic panel. Along the southern margin of this flow panel, the basalt is highly strained with strongly flattened pillows, suggesting that the panel is, at least in part, bounded by a shear zone.

In comparison, the much thicker and more extensive southern panel has generally smaller pillows (up to ~1.5 m, averaging a few decimetres) and can be internally subdivided into the following subunits (from northwest to southeast): 1) aphyric nonamygdaloidal basalt with thin selvages and minor interpillow material (Figure GS-10-4c); 2) quartz-feldspar amygdaloidal basalt with thick selvages (~2 cm) and abundant (up to 20%) interpillow material (epidote-plagioclase-quartz±carbonate ±amphibole); 3) aphyric basalt with thick selvages and containing little interpillow material; and 4) a major panel of variably plagioclase-phyric (up to ~3 cm) basalt, up to several kilometres wide, that is well exposed on Mistuhe Island (Figure GS-10-4d).

Complete flows are, in some instances, exposed in the southernmost panel of basalt. Typical flow thickness is approximately 15–20 m, which is comparable to the 10–35 m flow thicknesses observed by Hargreaves (1975). An excellent exposure of a complete flow, located along the northwest shore of Mistuhe Island, is illustrated in Figure GS-10-5. The following schematic succession of internal flow structures was observed in a number of instances (from flow base to top):

- up to a few metres of pillowed basalt, grading into pillowed and massive basalt (Figure GS-10-5a)
- a central zone of up to 15 m of massive basalt, variably fractured
- up to 5 m of brecciated basalt (Figure GS-10-5b, -5c) and flow-top breccia (Figure GS-10-5d), with injections of massive basalt from the central zone; variably altered due to high porosity

Commonly, outcrops that are several metres to tens of metres in size are composed entirely of either pillowed or massive basalt, and flow contacts were not observed or not exposed. These relationships suggest that thick, laterally continuous pillow and massive flow units are intercalated. Locally the flows are separated by chert (Figure GS-10-6a), banded iron formation (Figure GS-10-6b), and/or shale/mudstone turbidite, presumably deposited during periods of relative volcanic quiescence.

The basalt is commonly altered, which can assume a variety of expressions: 1) primary, seafloor hydrothermal alteration (Figure GS-10-6c); and 2) secondary, tectonometamorphic–related, pervasive, patchy and fracture-, vein- or shear-controlled alteration, such as epidotization, silicification (Figure GS-10-6d) and sulphidization. At a few localities on southwestern Utik Lake, a special type of primary volcanogenic alteration is developed in and adjacent to structures interpreted as fumarolic pipes (Bernier and MacLean, 1989).

Alteration pipes

Volcanogenic hydrothermal alteration and gold-bearing chert were first noted on Mistuhe Island in southwestern Utik Lake by Weber (1974) and subsequently studied in detail by Bernier and MacLean (1989). Comparable to 'black smokers' at mid-ocean ridges of the modern seafloor, alteration pipes in basalt at southwestern Utik Lake produced pervasive magnesian, iron and silica alteration in the host basalt and sulphidization along

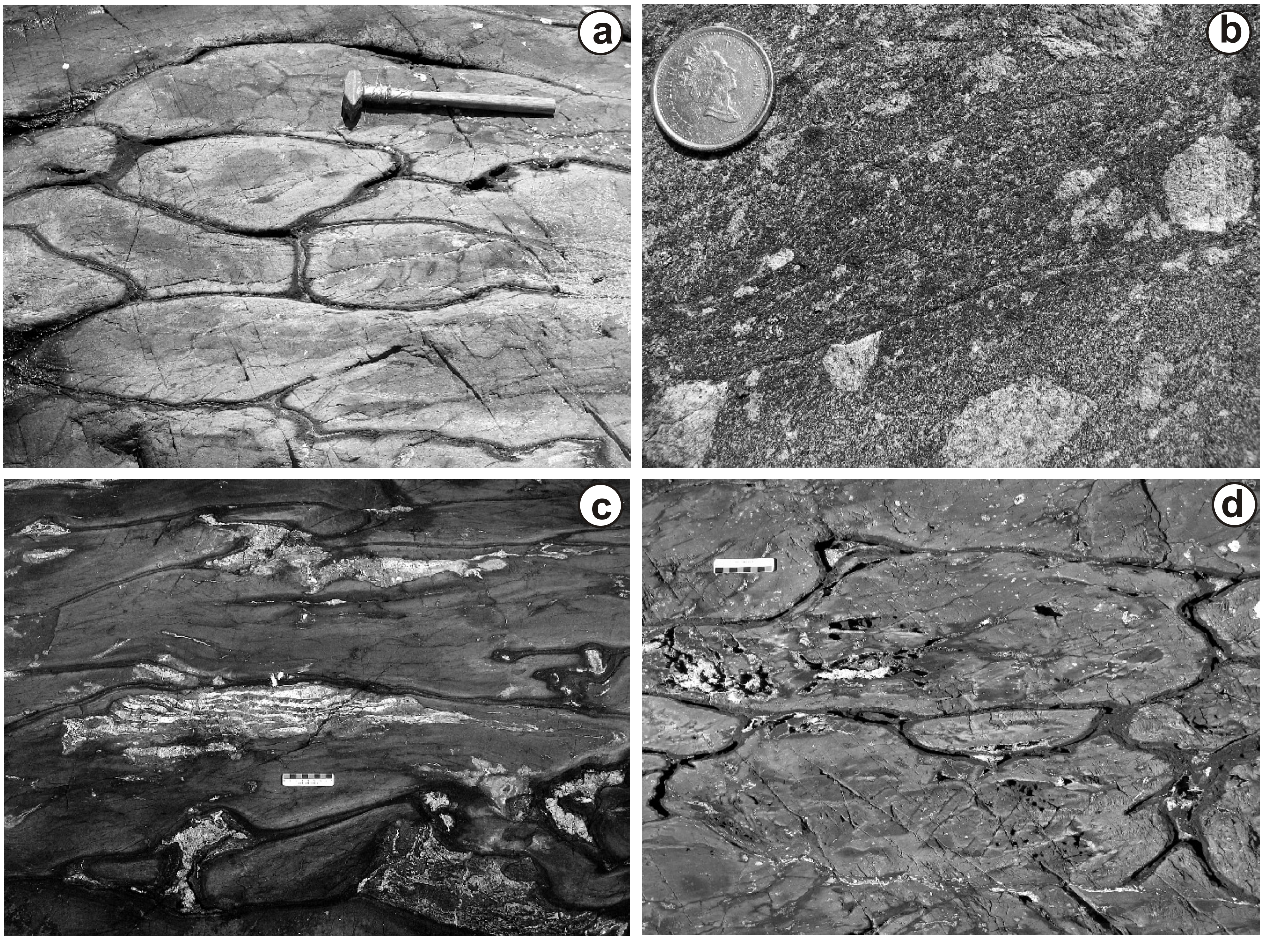


***Figure GS-10-4:** Outcrop photos of basalt flows from the Utik Lake greenstone belt: **a)** aphyric, nonamygdaloidal pillowed basalt with thick selvages and little interpillow material, north-central Utik Lake (UTM Zone 14, 688356E, 6128820N [NAD83]); **b)** plagioclase-phyric and glomerocrystic basalt (coin is 2 cm in diameter), northeastern Utik Lake (UTM Zone 15, 315211E, 6130103N); **c)** pillow shelves in aphyric basalt, central Utik Lake (top is up [=south] in photo; UTM Zone 15, 315488E, 6128145N); **d)** flattened, plagioclase-phyric pillowed basalt, south shore of Mistuhe Island, southern Utik Lake (UTM Zone 14, 688488E, 6124585N).*

synvolcanic veins and fractures. Major alteration pipes (e.g., 'pipes 1 and 2' in Bernier and MacLean, 1989) are up to 2 m wide, extend downsection for at least 20 m in variably plagioclase-phyric and glomeroporphyritic pillowed and massive tholeiitic basalt, and are oriented dominantly subvertical to the flow contact (Figure GS-10-7a). The alteration pipes are the exhalitive source for chemical sediments (mixed with detritus) that are prominently preserved as continuous chert-magnetite banded iron formation up to 4 m thick, as well as discontinuous auriferous sulphide-bearing chert locally interbedded with graphitic argillite (Bernier and MacLean, 1989). The latter unit may be similar to up to 2 m of siliceous grey sediment observed between the flow top and the iron formation (Figure GS-10-7b). Where transected by alteration pipes, basalt is commonly altered to a fine-grained, greenish white, bleached- to rusty-weathering material. The flow top and immediate wallrock exhibit the highest degrees of alteration and metasomatism along contact zones, up to a few decimetres wide, that contain abundant garnet±andalusite±anthophyllite±cordierite porphyroblasts, suggesting that they were recrystallized under lower amphibolite-facies conditions (550°C and 2.5 kbar; Bernier and MacLean, 1989).

The chemical and clastic metasedimentary rocks that were deposited directly on the basalt flow surface at southwestern Utik Lake represent a unique example of a Mesoarchean ocean-floor environment that hosts an alteration system similar to that in Noranda-type massive-sulphide deposits (e.g., Morton and Franklin, 1987), whereas the trace-metal association in the auriferous chert (Bernier and MacLean, 1989) is similar to that in modern seafloor hydrothermal environments (e.g., Hannington et al., 1986). In addition, the Utik Lake example may be an analogue to the well-documented volcano-hydrothermal Black Chert Member (massive and laminated black chert, siliceous shale, tuffaceous chert) of the ca. 3.2 Ga Cleaverville Group of the coastal Pilbara terrane, northwestern Australia, which hosts possible microbial material (Kiyokawa et al., 2006).

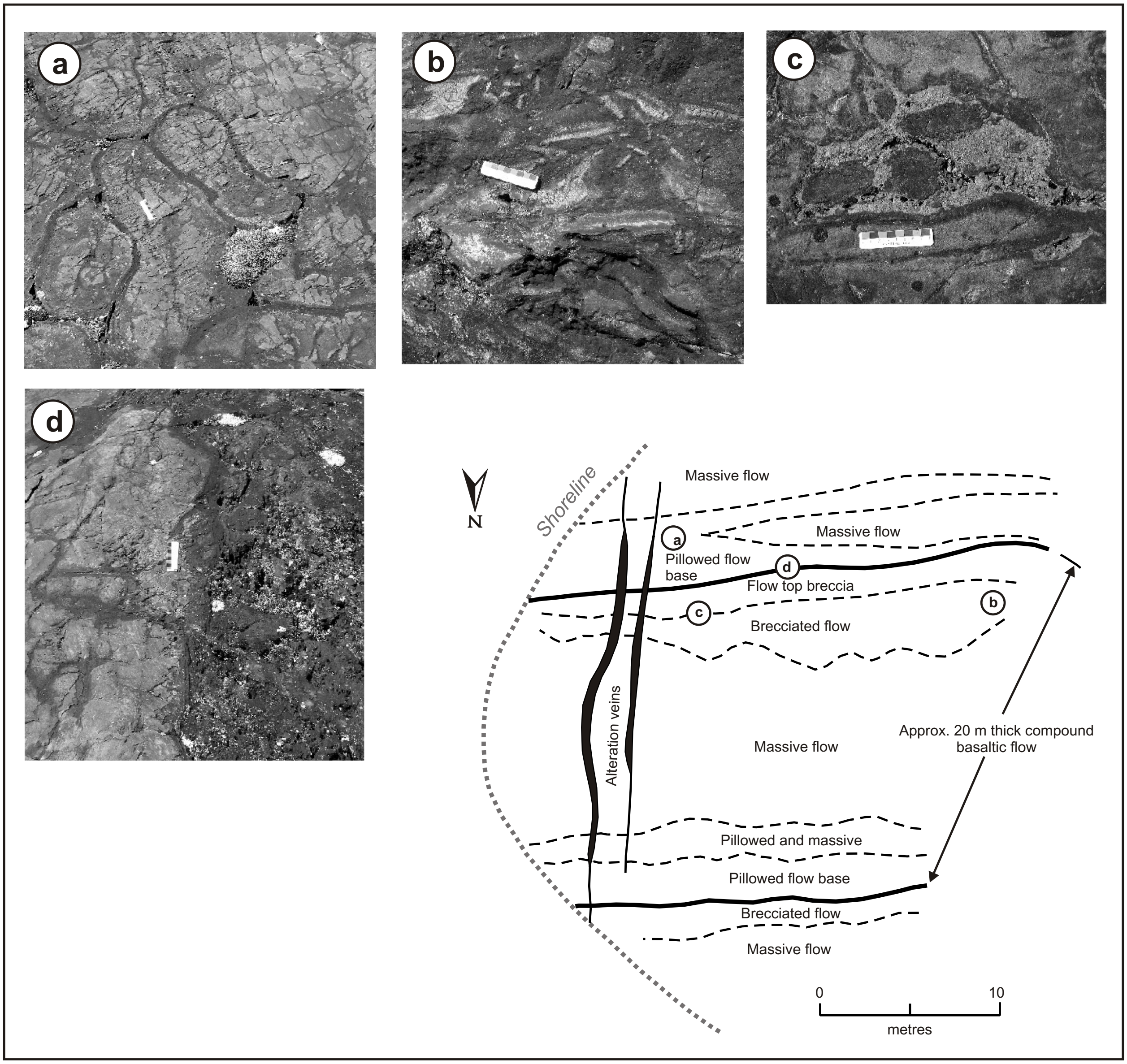


Figure GS-10-5: *Outcrop sketch of well-exposed and preserved basaltic flow sequence, northwest shore of Mistuhe Island, southwestern Utik Lake (UTM Zone 14, 689365E, 6125626N [NAD 83]). Outcrop photograph inserts are:* ***a)*** *pillowed basalt grading into massive basalt (upper right);* ***b)*** *brecciated pillowed basalt flow;* ***c)*** *brecciated flow with sediment-filled cavities produced by sediment-flow interaction (peperite); and* ***d)*** *flow-top breccia (right), with base of pillowed basalt flow at left (photo facing west).*

Synvolcanic, mafic intrusive rocks

Based on field relationships, mafic intrusive rocks in the Utik Lake greenstone belt can be subdivided into two main groups: 1) gabbro and diabase sills and dikes that are comagmatic with basalt flows; and 2) a younger suite of diabase, gabbro and minor pyroxenite that forms intrusive bodies in, and carries xenoliths of, marine clastic metasedimentary rocks (*see* below).

Gabbro and diabase form sills and dikes in basalt that range in thickness from a few decimetres to several hundred metres (Figure GS-10-2). The bulk compositions of basalt, gabbro and diabase are similar and suggest a comagmatic relationship. In addition, primary hydrothermal alteration pipes are developed in both the mafic flows and the intrusions, where they are present together. Diabase dikes were observed to form feeders into basalt flows, whereas major mafic intrusive bodies are predominantly differentiated gabbroic sills, such as those exposed on central Mistuhe Island. Fine-grained gabbro and diabase intruded into basalt flows are commonly equigranular to weakly ophitic, and can be locally difficult to distinguish from aphyric, massive, medium- to coarse-grained basalt. As a consequence, the proportion of mafic intrusive versus mafic massive flow units cannot be readily determined. Detailed studies focusing on basalt flow morphology at southwestern Utik Lake show that

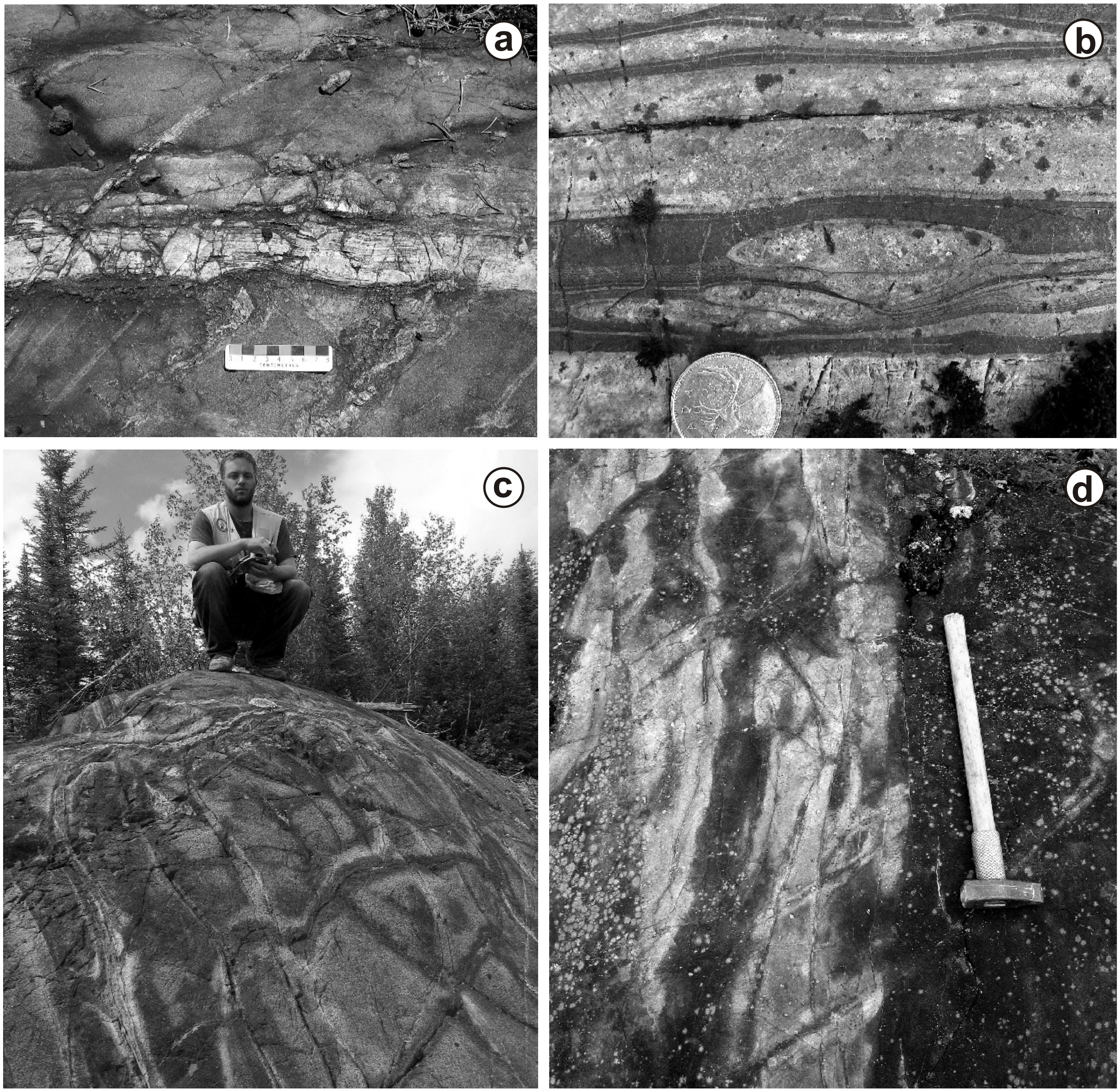


Figure GS-10-6: *Outcrop photos of basaltic, associated chemical sedimentary and altered rocks:* ***a)*** *chert interlayer in basalt, north-central Utik Lake (UTM Zone 14, 687830E, 6128124N [NAD83]);* ***b)*** *silicate-oxide–facies banded iron formation along south shore of Mistuhe Island, southwestern Utik Lake (UTM Zone 14, 687297E, 6124301N);* ***c)*** *amphibolitized alteration envelopes along polygonal fractures in gabbro that mimic 'pseudopillows', southwestern Utik Lake (UTM Zone 14, 689214E, 6124939N); and* ***d)*** *concordant silicification in basalt, Mistuhe Island, southwestern Utik Lake (UTM Zone 14, 688034E, 6124710N).*

massive flows make up more than half of the entire mafic flow sequence (Hargreaves and Ayres, 1979, Table 1 and Figure 3). Massive and pillowed flows are commonly interlayered, and massive flows can laterally grade into pillowed flows, which makes mapping of pillowed versus massive flows unfeasible at a regional scale.

Volcanogenic metasedimentary rocks

Metasedimentary rocks associated with the Utik Lake mafic metavolcanic formations are commonly derived from intermediate to mafic volcanic rocks, and include conglomeratic, tuffaceous and turbiditic members. Volcanic conglomerate is clast to matrix supported and composed of subrounded pebble- to cobble-sized (up to ~15 cm) clasts of andesitic to basaltic composition in a silty to sandy matrix of similar composition (Figure GS-10-8a). Mafic conglomerate lies conformably on, or in sheared contact within, basalt (Figure GS-10-8b) and, in some localities, together with silicate±sulphide iron formation. One exposure on southwestern Utik Lake (UTM Zone 14, 686996E, 6124234N) shows basalt and mafic conglomerate in a conformable contact relationship.

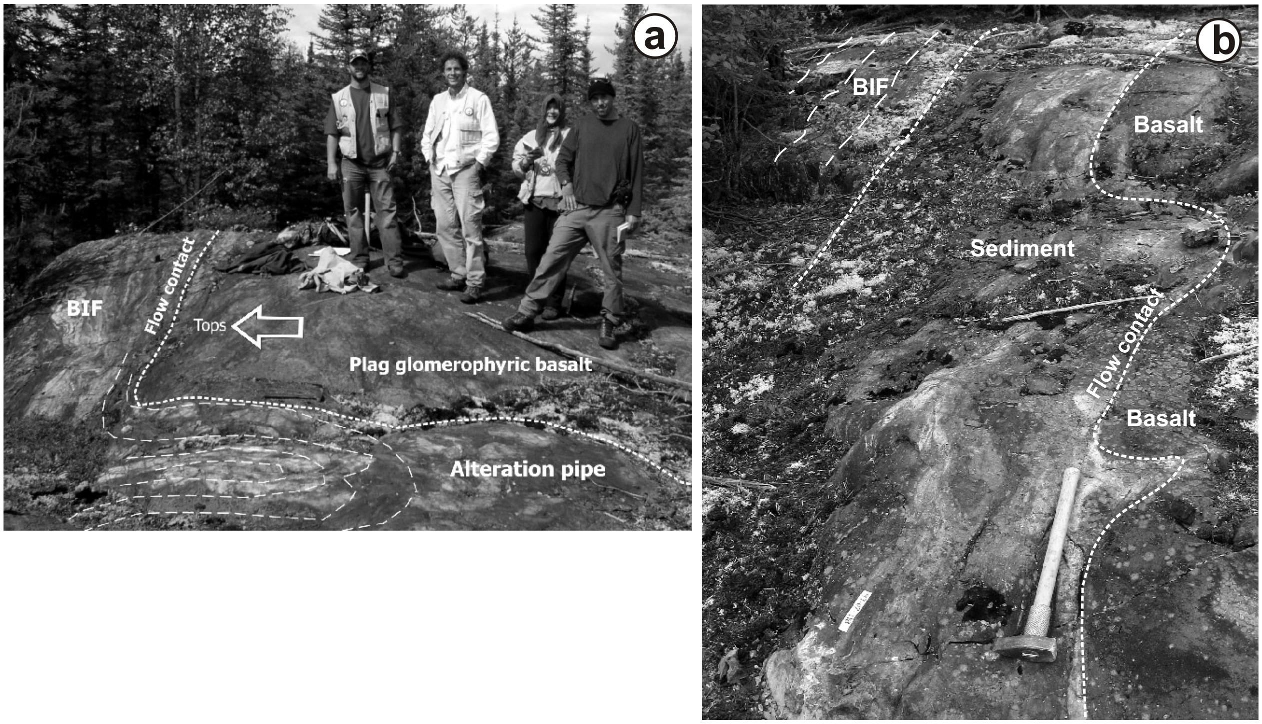


Figure GS-10-7: *Outcrop photographs of alteration pipes in basalt and associated banded iron formation and metasedimentary rocks on Mistuhe Island, southwestern Utik Lake (UTM Zone 14, 688132E, 6124706N [NAD83]):* ***a)*** *alteration 'pipe 1' of Bernier and MacLean (1989), with banded iron formation (BIF) draping into the pipe;* ***b)*** *siliceous sediment between basalt flow top (right) and banded iron formation (upper left), approximately 100 m west and along strike of iron formation at 'pipe 1' location (photo facing west).*

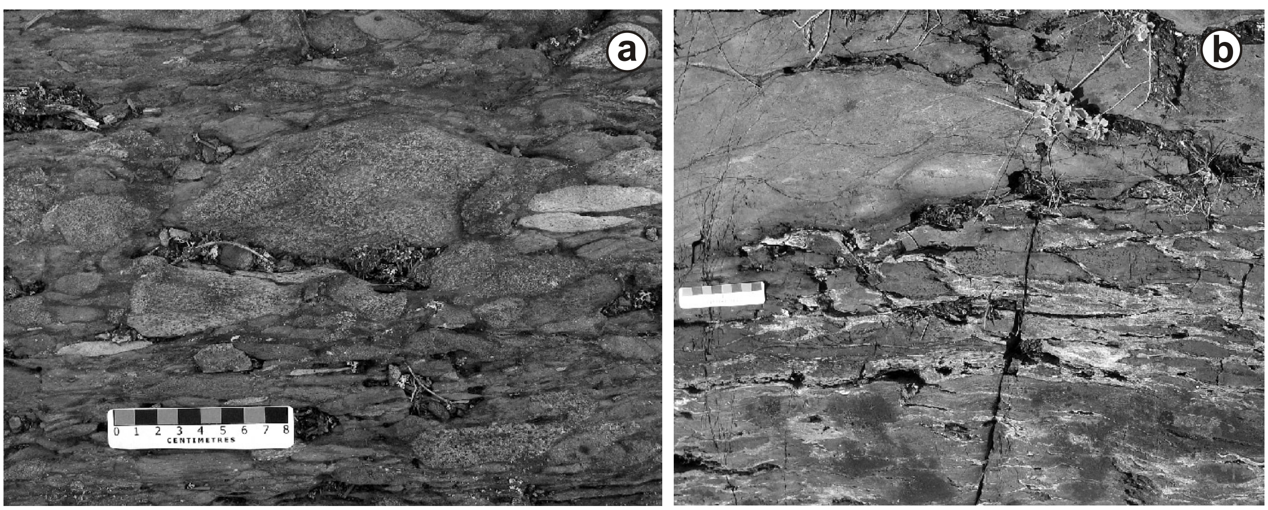


Figure GS-10-8: *Outcrop photographs of volcanic-derived metasedimentary rocks, southwestern Utik Lake:* ***a)*** *strongly foliated, clast-supported, dominantly mafic volcanic conglomerate with few intermediate and felsic intrusive clasts (UTM Zone 14, 686043E, 6123978N [NAD83]);* ***b)*** *conformable contact between foliated and sheared basalt (top) and mafic conglomerate (bottom UTM Zone 14, 686996E, 6124234N).*

In an adjacent exposure to the east (UTM Zone 14, 688920E, 6124720N), the basalt is highly strained, altered and associated with locally sulphidized and garnet-rich conglomeratic and mudstone-siltstone turbiditic wacke.

Younger clastic metasedimentary rocks

A younger suite of fluvial-alluvial and marine clastic metasedimentary rocks lies in sheared, likely unconformable contact on the mafic metavolcanic rocks and associated volcanogenic metasedimentary rocks. The earlier supracrustal assemblage was likely tilted, deformed and eroded prior to deposition of the younger clastic metasedimentary rocks in synclinal structural basins between the metavolcanic panels. The metasedimentary sequence is up to several hundreds of metres thick and includes conglomerate, greywacke and lesser amounts of interlayered arenite. Stratigraphic facing determinations (using graded bedding, trough crossbedding, scouring, flame structures and rip-up clasts) consistently indicate tops to the south, conformable with the earlier basaltic succession.

The Opischikona Narrows metasedimentary succession exposed on south-central Knee Lake consists of greywacke, pebbly sandstone and conglomerate; these lie in a synclinal structural basin unconformably on Hayes River Group basalt (Syme et al., 1998). Based on their tectonic position and nature, the younger clastic metasedimentary rocks at Utik Lake may be correlative with the Opischikona succession. Age constraints on the Opischikona rocks are preliminary but confirm sedimentation younger than the ca. 2.83 Ga Hayes River Group supracrustal rocks (Corkery et al., 2000); the youngest dated detrital zircon in sandstone yielded a maximum sediment age of ca. 2822 Ma, and a feldspar-porphyry sill emplaced into the metasedimentary rocks is ca. 2783 Ma. Alternatively, the clastic metasedimentary rocks at Utik Lake could be related to the ca. 2.70–2.71 Ga Oxford Lake Group (Corkery et al., 2000), which also contains conglomerate, pebbly greywacke and sandstone-siltstone turbiditic wacke, and is fault bounded within the Hayes River Group metavolcanic rocks at Knee Lake (Syme et al., 1998).

At Utik Lake, conglomerate and pelitic to psammitic wacke are the dominant metasedimentary rocks. In addition to the mafic volcanic–derived conglomerate described above, more than one generation of conglomerate likely exists within the younger metasedimentary sequence. A variably sulphidic quartz-pebble conglomerate (Figure GS-10-9a) forms the base of the younger sedimentary sequence and is interlayered with and/or

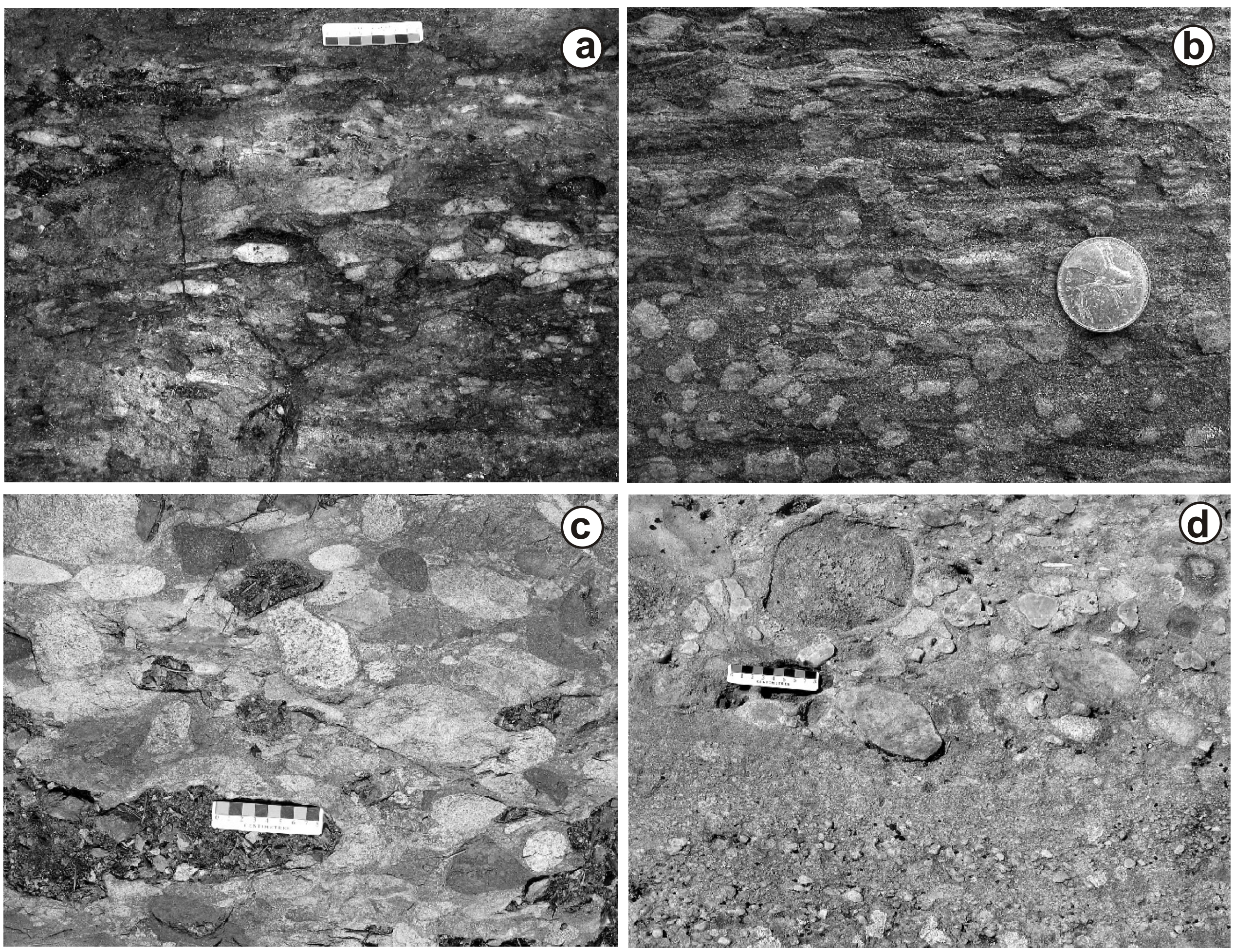


Figure GS-10-9: *Outcrop photographs of clastic metasedimentary rocks, Utik Lake:* ***a)*** *foliated and rodded, clast-supported gossanous conglomerate with dominantly quartz, chert iron formation and lesser mafic volcanic clasts (UTM Zone 14, 690752E, 6129020N [NAD83]);* ***b)*** *fine, foliation- and layering-parallel, sillimanite-quartz–rich lamellae in partially pinitized cordierite porphyroblasts in pelitic greywacke (UTM Zone 15, 315854E, 6128380N);* ***c)*** *polymictic conglomerate with quartz, chert iron formation, gabbro, hornblende tonalite, mafic metavolcanic and psammitic clasts (UTM Zone 14, 687526E, 6126645N);* ***d)*** *scour channel of polymictic conglomerate bed into pebbly greywacke, stratigraphic top to the south (UTM Zone 14, 689775E, 6127977N).*

grades into greywacke, where exposed in direct contact with the underlying mafic metavolcanic rocks and volcanic metasedimentary rocks.

Layered greywacke gneiss, ranging from pelite-semipelite to interlayered psammite, is most voluminous and best exposed in the northernmost part of the Utik Lake greenstone belt (e.g., UTM Zone 14, 688625E, 6129308N), where locally intense cordierite, garnet±sillimanite-quartz (faserkiesel)±anthophyllite blastesis indicates metamorphism at temperatures in excess of 600°C (sillimanite Barrovian zone, as defined in Bucher and Frey, 1994). Alternating garnet- and cordierite-rich porphyroblastic layers likely reflect primary compositional layering, except where garnet-rich zones form around intermediate to mafic lenses (amphibolite) or where related to iron-silica–rich fluids permeating along veins and fractures in metasedimentary rocks. The fact that the pelitic to psammitic turbiditic metasedimentary rocks are locally interlayered with and grade into conglomeratic beds indicates that the sequence was likely deposited in a shallow-marine shelf environment.

In the central parts of Utik Lake, abundant layered intermediate to felsic greywacke has a peculiar, knotty to coarse porphyroblastic texture (Figure GS-10-9b). This unit was described by previous workers (Milligan and Take, 1954; Weber, 1974) as 'cordierite schist'. The authors' interpretation is that these layered rocks represent magnesium-iron–rich peraluminous pelitic rocks that were originally mudstone and shale. Their largely intermediate composition (*see* major element compositions in Milligan and Take, 1954, p. 45) may reflect (partial) derivation from the underlying mafic metavolcanic and intrusive rocks.

Polymictic conglomerate forms extensive and semi-continuous exposures at several localities on Utik Lake, with the best examples along the north shore of the southernmost lake channel and in the central portion of the lake (e.g., UTM Zone 14, 689775E, 6127977N; Figure GS-10-9c). The polymictic conglomerate is clast supported and poorly sorted, with clasts and cobbles up to approximately 30 cm. Rare large cobbles are leucocratic felsic intrusive rock and minor altered gabbro to pyroxenite, whereas medium- to smaller sized (a few centimetres) clasts range in composition from abundant (vein) quartz to lesser mafic metavolcanic rocks (amphibolite), psammitic rocks, and sulphidic chert and banded iron formation (Figure GS-10-9a). Better sorted, pebbly, matrix-supported interlayers have a grey psammitic groundmass similar to the matrix of the coarse clastic conglomerate. Greywacke and psammite interbeds are up to a few decimetres thick and display locally well-preserved trough crossbedding and fining-upward graded bedding that, together with local scour channels of conglomerate into greywacke mudstone (Figure GS-10-9d), define southward younging of the subvertically tilted metasedimentary package. The polymictic clast composition of the conglomerate and its contained bedforms suggest deposition in a fluvial-alluvial environment, representing continental erosion of a terrane that is at least partially exotic compared to the underlying mafic-dominated rocks preserved at Utik Lake.

Younger mafic intrusive rocks

The younger suite of mafic intrusive rocks, consisting of gabbro, diabase and minor pyroxenite, forms bodies up to several kilometres in size in the older mafic metavolcanic and metasedimentary rocks. The mafic intrusions are typically massive and only weakly to moderately foliated along the margins or in higher strain zones. Texture in medium- to coarse-grained gabbro is equigranular, ophitic, clotted or porphyritic, and locally pegmatitic, with leucocratic to mesocratic compositions (~20–70% plagioclase). Diabase is fine to coarse grained and ophitic, with plagioclase laths up to a few millimetres long. It can be equigranular or pyroxene±amphibole porphyritic. The mafic intrusions are generally nonmagnetic and homogeneous, and show gradual variations in grain size and/or composition. Within the central and southeastern mafic intrusions (Figure GS-10-2), coarse-grained melanocratic gabbro to pyroxenite appears to be enclosed or intruded by gabbro and diabase; however, at other locations, the contact between layered gabbro and pyroxenite is layer parallel and may be comagmatic (e.g., UTM Zone 15, 310748E, 6128137N).

Felsic intrusive rocks at Utik Lake

Although not a primary interest of this study, felsic intrusive rocks within and immediately to the north and south of the Utik Lake greenstone belt have been included in the present mapping (Figure GS-10-2) in order to study the greenstone belt evolution in context with the younger granite terranes. Based on combined field observations, all mapped felsic intrusive rocks at Utik Lake are interpreted to be younger than, and therefore intrusive into, the mafic intrusive and supracrustal rocks. Apart from the presence of smaller pegmatite and porphyry dikes, which increase in abundance toward both belt margins, the granitoid terranes north and south of the Utik Lake greenstone belt differ significantly in nature and composition.

To the north, the greenstone belt is flanked by a relatively homogeneous suite of pink to beige, leucocratic, variably K-feldspar–porphyritic, biotite-bearing granodiorite and granite with K-feldspar–rich pegmatite patches and dikes. These granitic rocks are generally massive to weakly foliated, but locally developed a stronger foliation close to the presumably structurally modified contact with the supracrustal rocks. In the northwest corner of the map area, where 060°–070° and 090° fabrics join, strongly foliated hornblende±biotite–rich tonalite and granodiorite appear to be cut by leucogranite.

Along the southern margin of the greenstone belt, alaskite is the predominant intrusive phase and appears to have been preferentially emplaced along the southern belt margin, where it is locally highly strained and sheared (protomylonite; Figure GS-10-10a, -10b). Intrusions of alaskite (graphic-textured K-feldspar-quartz–rich granite) weather characteristically light grey to white, are pegmatitic in places and contain up to 15% muscovite±biotite±garnet.

In addition to variable amounts of alaskite, a complex suite of relatively older, intermediate to felsic intrusive rocks outcrops along the south shore of Utik Lake. They bound the supracrustal belt and include granite to granodiorite gneiss, *lit-par-lit* S-type orthogneiss, hornblende- and/or biotite-rich granodiorite, which is locally K-feldspar porphyritic, and fine- to medium-grained, strongly foliated hornblende tonalite to quartz diorite and leucogabbro. This orthogneiss was described by Milligan (1952) as "grey gneissic granite" and occupies much of the area between Utik and Bear lakes. Its age is uncertain but relatively constrained by xenoliths of older gabbro and greywacke (maximum age) and by alaskite injection (minimum age). Preliminary U-Pb zircon data from a possibly related granite that is intrusive into the basalt at north Bear Lake (Hartlaub and Böhm, 2006) yielded an emplacement age of ca. 2.70 Ga (unpublished multicollector laser-ablation ICP-MS data, 2007).

Lit-par-lit gneiss along the south shore of Utik Lake likely formed by injection of granitic melt into the metamorphosed supracrustal rocks, prior to high-strain overprint that transposed the rocks into gneiss. Within the gneiss, medium to coarse porphyritic hornblende±biotite granodiorite and granite form structurally discontinuous transposed bodies. The compositional and structural complexities, particularly along the southwest shore of Utik Lake, speak to the need for further field studies.

Structures and kinematics of the Utik Lake greenstone belt

The Utik Lake Shear Zone, as delineated by Milligan and Take (1954) and Weber (1974), is best exposed along the south shore of Mistuhe Island and is traceable to the east-northeast all the way into the narrows of southeastern Utik Lake (Figure GS-10-2). Previous mapping interpreted the Utik Lake Shear Zone to represent the southern boundary of the greenstone belt, as it is adjacent to a suite of younger felsic intrusive rocks along the south shore of the lake. In contrast, this new mapping revealed similar metasedimentary rocks along both sides of the southernmost lake channel, which may imply that the southern margin of the Utik Lake greenstone belt is south of the Utik Lake Shear Zone, as defined by previous mapping (Figure GS-10-2). Alternatively, the Utik Lake Shear Zone forms the northern edge of a much wider shear zone extending across the southern channel to the south shore of the lake. The northern boundary of the greenstone belt, in comparison, is much more tightly constrained and located in the channel south of the north shore of central and northwestern Utik Lake. Except for rare mafic dikes, the latter is composed entirely of granodiorite, granite and pegmatite that are void of supracrustal inclusions (Figure GS-10-2).

Within the greenstone belt, most outcrops of supracrustal rocks display at least two planar fabrics. The main, commonly layering-parallel foliation generally strikes east and dips steeply. Dip direction gradually changes from steeply south along the northern margin of the belt, to subvertical in the central part of the belt, to steeply north in the southern parts of the belt. As a result, the greenstone belt forms a keel-shaped structural wedge within the bounding felsic plutonic rocks. A second

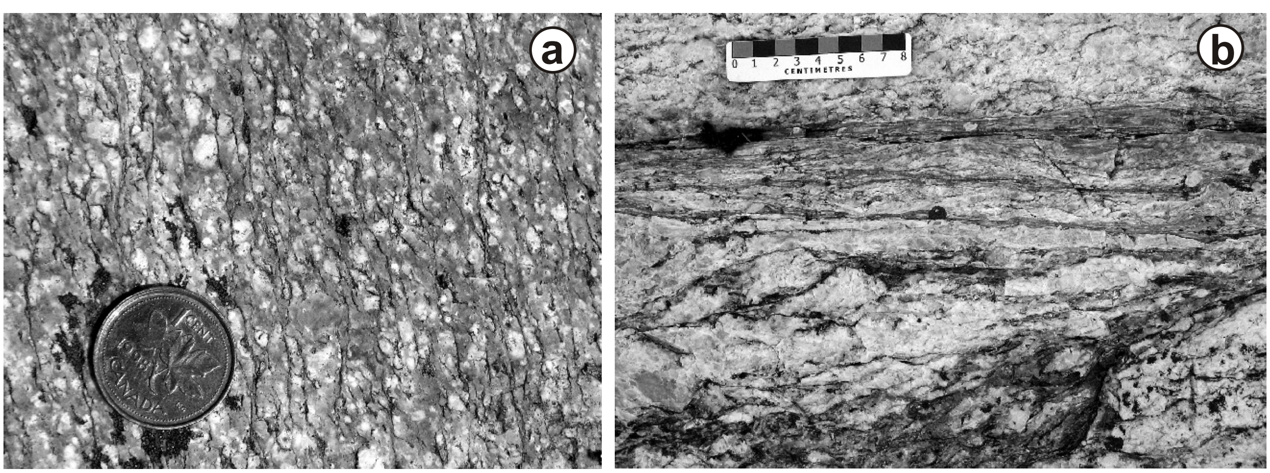


Figure GS-10-10: *Outcrop photographs of highly strained, leucocratic, K-feldspar–rich granite (alaskite) along the Utik Lake Shear Zone, southern Utik Lake:* ***a)*** *ductile recrystallized quartz and brittle-ductile K-feldspar in protomylonitic alaskite (UTM Zone 15, 318730E, 6127451N [NAD83]);* ***b)*** *strongly foliated and dextrally sheared K-feldspar–rich pegmatitic leucogranite or alaskite (UTM Zone 15, 317713E, 6127391N).*

major fabric (S_{n+1}) is a commonly northeast-striking (060–070°) foliation that overprints the main, layering-parallel foliation (S_n). The overprinting foliation (S_{n+1}) is locally developed as dextral shear surfaces, with the two planar fabrics then mimicking the large-scale dextrally sheared lens shape of the greenstone belt at Utik Lake. The S_{n+1} foliation is also axial planar to small-scale (metre to outcrop), open to tight, consistently Z-asymmetric folds that are locally developed on Utik Lake, indicative of an overall dextral sense of shear associated with this deformation event. The east-trending main fabric (S_n) of the belt was reactivated during late-orogenic movement (late- to post-S_{n+1}) and strongly transposed the supracrustal and felsic intrusive rocks along and near the belt margins, resulting in highly strained, locally protomylonitic gneiss (Figure GS-10-10a).

In addition to intersection lineations of the two main planar fabrics, linear structures such as mineral extension lineations are rarely well developed. Where observed, mineral lineations plunge moderately to steeply south-southwest, except for along the northeastern and southwestern margins of the belt, where lineations tend to plunge northeast. In the rare outcrops that display fold structures, fold axes are subparallel to stretching lineations. At map scale, open traceable marker units such as conglomerate and iron formation seem to be openly folded. Folds tend to be Z-asymmetric with sheared limbs subparallel to S_{n+1} shear fabric planes.

A strongly developed early fabric (S_n) in the supracrustal rocks is postdated by the younger suite of diabase and gabbro. These mafic intrusive rocks are variably foliated to massive, and their relationship with the granitoid rocks is uncertain except where alaskite pegmatite is clearly intrusive. On southern Utik Lake, medium- to coarse-grained alaskite bodies are variably foliated and sheared, and underwent cataclasis or mylonitization along high-strain zones (post-S_{n+1}; Figure GS-10-10a), whereas presumably older felsic intrusive gneiss may preserve earlier (S_{n+1}, S_n) fabrics.

Economic considerations

The main economic mineral potential in the Utik Lake area is for orogenic gold and volcanic-associated massive sulphide (VMS) deposits, with minor potential for epithermal and paleoplacer gold mineralization. Volcanic-associated massive sulphide deposits commonly occur within volcanic arcs, particularly those that have undergone extension (Cathles et al., 1983; Syme and Bailes, 1993; Syme et al., 1999). Orogenic gold deposits, in comparison, are known to be localized near or within major transpressive shear zone structures, such as along regional strike at Knee Lake and Monument Bay. At Utik Lake, the potential for volcanic-associated vein and shear-zone gold (e.g., Thorpe and Franklin, 1984) is likely to be highest along the east-trending high-strain zones (and locally developed, subparallel alteration zones) along the northern and southern margins of the greenstone belt. Subsidiary fault structures branching from regional shear zones are common sites of gold mineralization (Eisenlohr et al., 1989).

The principal dextral shear lens geometry of the Utik Lake greenstone belt, caused by the major northeast-trending dextral shears that overprint the generally east-trending fabrics, resulted in dilational structures with net northeast-southwest extension. Areas particularly favourable for focusing gold-bearing metamorphic fluids would thus occur along the transposed belt margins and contacts between major lithological assemblages within the belt (i.e., between metavolcanic flow panels and metasedimentary assemblages). Shear-hosted sulphide occurrences, consisting of disseminated and stringer pyrite±pyrrhotite±chalcopyrite were noted, and samples collected for assay in a high-strain zone along the northeastern and southwestern margins of the greenstone belt. In a similar zone farther to the west, discontinuous sulphide mineralization was traced along strike in a variably but generally strongly altered high-strain zone separating the northern and southern panels of the Utik Lake belt.

Previous prospecting and mineral exploration in the Utik Lake greenstone belt discovered Au, Cu and Zn mineralization of significance (*see* assessment files listed in 'Previous work' section), whereas scientific studies focused on the unique occurrences of alteration pipes in basalt, associated banded iron formation and auriferous chert (Weber, 1974; Bernier and MacLean, 1989). Silicate±oxide–facies banded iron formation is known to form potential traps for sulphide and precious metal (Au) fluids along veins and fractures, where the iron formation was reduced (e.g., Phillips et al., 1984). Several occurrences of sulphidized, silicate-oxide banded iron formation were observed at Utik Lake (located on Böhm and Kremer, 2007). The alteration pipes (black smokers) in pillow basalt in the southernmost mafic metavolcanic panel at Utik Lake are associated with discordant silicification and iron-magnesium alteration. Exhalite deposits from these pipes formed banded iron formation and auriferous, sulphide-bearing chert up to several metres thick on top of the basalt flows (Bernier and MacLean, 1989). In addition, disseminated and structurally controlled sulphide is concentrated within and along the pipes and the overlying banded iron formation, chert and argillite. Associated magnetite-sulphide iron formation resulted from volcanic hydrothermal processes, and thus indicates an environment favourable for the formation of epithermal gold deposits.

Potential for paleoplacer gold deposits needs to be further investigated in the locally voluminous fluvial-alluvial conglomerate units at Utik Lake. Their volcanic-associated setting and high fluid permeability make these units highly prospective for Witwatersrand-type placer gold enrichment.

Acknowledgments

The management and staff of North Star Resort at Utik Lake lodge are gratefully thanked for their generous support and splendid hospitality. N. Brandson and D. Binne supplied excellent expediting services. Field assistance at Utik Lake was provided by E. Reid and J.G. Ching. B. Lenton helped considerably with drafting of the figures.

References

Allen, C.M. 1953: Geology of the western Bear Lake area, Oxford Lake Mining Division, Manitoba; Manitoba Mines and Natural Resources; Mines Branch, Publication 52-4, 19 p.

Bernier, L.R. and MacLean, W. H. 1989: Auriferous chert, banded iron formation, and related volcanogenic hydrothermal alteration, Atik Lake, Manitoba; Canadian Journal of Earth Sciences, v. 26, p. 2676–2690.

Böhm, C.O. and Hartlaub, R.P. 2006: Bedrock geology of the Bear Lake area, Manitoba (parts of NTS 53M4 and 63P1); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2006-2, scale 1:50 000.

Böhm, C.O. and Kremer, P.D. 2007: Bedrock geology of the Utik Lake greenstone belt, Manitoba (parts of NTS 53M4, 5, 63P1, 8); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2007-4, scale 1:25 000.

Bucher, K. and Frey, M. 1994: Petrogenesis of metamorphic rocks (sixth edition); Springer-Verlag, New York, New York, 318 p. (complete revision of Winkler's textbook).

Card, K.D. 1990: A review of the Superior Province of the Canadian Shield, a product of Archean accretion; Precambrian Research, v. 48, p. 99–156.

Cathles, L.M., Guber, A.L., Lenagh, T.C. and Dudas, F.O. 1983: Kuroko-type massive sulphide deposits of Japan: products of an aborted island-arc rift; Economic Geology, Monograph 5, p. 439–487.

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.

Eisenlohr, B.N., Groves, D. and Partington, G.A. 1989: Crustal-scale shear zones and their significance to Archaean gold mineralization in Western Australia; Mineralium Deposita, v. 24, p. 1–8.

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

Hannington, M.D., Peter, J.M. and Scott, S.D. 1986: Gold in sea-floor polymetallic sulphide deposits; Economic Geology, v. 81, p. 1867–1883.

Hargreaves, R. 1975: Volcanic stratigraphy of Utik Lake; *in* Summary of Geological Fieldwork, 1975, Manitoba Mines, Resources and Environmental Management, Mineral Resources Division, Geological Paper 75-2, p. 26–29.

Hargreaves, R. and Ayres, L.D. 1979: Morphology of Archean metabasalt flows, Utik Lake, Manitoba; Canadian Journal of Earth Sciences, v. 16, no. 7, p. 1452–1466.

Hartlaub, R.P. and Böhm, C.O. 2006: Preliminary results from geological mapping of the Bear Lake greenstone belt, Manitoba (parts of NTS 53M4 and 63P1); *in* Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 65–73.

Kiyokawa, S., Ito, T., Ikehara, M. and Kitajima, F. 2006: Middle Archean volcano-hydrothermal sequence: bacterial microfossil-bearing 3.2 Ga Dixon Island Formation, coastal Pilbara terrane, Australia; GSA Bulletin, v. 118, no. 1, p. 3–22.

Milligan, G.C. 1951: Geology and mineral possibilities of Utik Lake and adjacent areas; Manitoba Mines and Natural Resources; Mines Branch, 3 p.

Milligan, G.C. 1952: Geology of the Utik Lake–Bear Lake area; Manitoba Mines and Natural Resources; Mines Branch, Publication 51-4, 25 p.

Milligan, G.C. and Take, W.F. 1954: Geology of the eastern Bear Lake area; Manitoba Mines and Natural Resources; Mines Branch, Publication 53-1, 51 p.

Morton, R.L. and Franklin, J.M. 1987: Two-fold classification of Archean volcanic-associated massive sulphide deposits; Economic Geology, 82, p. 1057–1063.

Phillips, G.N., Groves, D.I. and Martyn, J.E. 1984: An epigenetic origin for Archean banded iron-formation-hosted gold deposits; Economic Geology, v. 79, p. 162–171.

Skulski, T., Corkery, M.T., Stone, D., Whalen, J.B. and Stern, R.A. 2000: Geological and geochronological investigations in the Stull Lake–Edmund Lake greenstone belt and granitoid rocks of the northwestern Superior Province; *in* Report of Activities 2000, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 117–128.

Syme, E.C. and Bailes, A.H. 1993: Stratigraphic and tectonic setting of volcanogenic massive sulphide deposits, Flin Flon, Manitoba; Economic Geology, v. 88, p. 566–589.

Syme, E.C., Corkery, M.T., Bailes, A.H., Lin, S., Skulski, T. and Stern, R.A. 1999: Towards a new tectonostratigraphy for the Knee Lake greenstone belt, Sachigo Subprovince, Manitoba; *in* LITHOPROBE Western Superior Transect Fifth Annual Workshop, February 1–3, 1999, R. Harrap and H. Helmstaedt (ed.), LITHOPROBE Secretariat, University of British Columbia, Report 70, p. 124–131.

Syme, E.C., Corkery, M.T., Lin, S., Skulski, T. and Jiang, D. 1998: Geological investigations in the Knee Lake area, northern Superior Province (parts of NTS 53L/15 and 53M/2); *in* Report of Activities 1998, Manitoba Energy and Mines, Geological Services, p. 88–95.

Syme, E.C., Corkery, M.T., Bailes, A.H., Lin, S., Cameron, H.D.M. and Prouse, D. 1997: Geological investigations in the Knee Lake area, northwestern Superior Province (parts of 53L/15 and 53L/14); *in* Report of Activities 1997, Manitoba Energy and Mines, Minerals Division, p. 37–46.

Thorpe, R.I. and Franklin J.M. 1984: Volcanic-associated vein and shear zone gold; *in* Canadian Mineral Deposit Types: A Geological Synopsis, O.R. Eckstrand (ed.), Geological Survey of Canada, Economic Geology Report 36, p. 38.

Weber, W. 1974: Utik Lake–Bear Lake project; *in* Summary of Geological Field Work 1974, Manitoba Department of Mines, Resources and Environmental Management, Mineral Resources Division, Exploration and Geological Survey Branch, Geological Paper 74-2, p. 27–32.

Weber, W. 1975: High Hill–Utik Lake area; *in* Summary of Geological Fieldwork 1975, Manitoba Mines, Resources and Environmental Management; Mineral Resources Division, Geological Paper 75-2, p. 24–25.

Weber, W. and Scoates, R.F.J. 1978: Archean and Proterozoic metamorphism in the northwestern Superior Province and along the Churchill–Superior boundary, Manitoba; *in* Metamorphism in the Canadian Shield, J.A. Fraser and W.W. Heywood (ed.), Geological Survey of Canada, Paper 78-10, p. 5–16.