GEOLOGY AND MINERAL OCCURRENCES OF THE APHEBIAN WAUGH LAKE GROUP, NORTHEASTERN ALBERTA

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H.P Salat*, D.R. Eccles and C.W. Langenberg

Alberta Geological Survey
Box 8330
Edmonton, Alberta, T6H 5X2

*Joranex Resources Inc.

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ABSTRACT

An area underlain by the Waugh Lake Group in Northeastern Alberta was mapped on a scale of 1:10,000. Sedimentary and volcanogenic features are preserved in parts of the succession and consequently the Waugh Lake Group could be divided into sedimentary and volcanic units, which will help in better understanding the tectono-stratigraphic history of the package of rocks, as well as the origin of the mineral occurrences in the area. An unconformity at the base of the Waugh Lake Group has not been found and consequently its basement is unknown.

Volcanic rocks are mainly exposed in the central part of the area and include both mafic and felsic components. Massive flows can be distinguished from thinly laminated tuffs. Units with mafic and felsic fragments are interpreted as explosive rhyolitic pyroclastic flows and thick units with smaller fragments (previously largely mapped as phyllonites) are interpreted as accumulations of lapilli tuffs. A related more mafic unit shows structures that resemble trough cross-bedding, indicating that they might be water reworked lapilli tuffs.

Sedimentary rhythmites of graded sandstone, siltstone and mudstone are mainly exposed on the east side of the Waugh Lake area, but can also be recognized on the west side. They are associated with an extensive matrix supported conglomerate which could correspond to debris flows. Near the conglomerates, minor volcanic extrusions are present.

After the Waugh Lake Group deposition, large stocks of granite to diorite and associated pegmatites intruded the sequence. Deformation is expressed by extensive folding and mylonitization and resulted in a large scale synformal structure of the Waugh Lake Group. Deformation is associated with greenschist facies metamorphism. Late phase shearing with a steep stretching lineation has left a strong imprint on all rock formations of the Waugh Lake Group. A final event is indicated by the post orogenic intrusion of the Andrew Lake porphyritic granite.

Gold mineralized zones, which are hosted in gossaneous metasediments (rhythmites), occurring near the East shores of Waugh Lake, extends as far north as Doze Lake. Additional mineralized zones are mainly of the quartz-tourmaline type with gold and tungsten associated. Although no significant base metal mineralization was discovered in the Waugh Lake area, the presence of bimodal volcanism associated with a succession of fine grained sediments indicates the possible presence of massive sulfide deposits.

INTRODUCTION

The 1993 geological mapping of the Waugh Lake area covers an area of approximately 24 km^2 which is located between latitudes 59° 47' 30" N and 59° 52' 20" N, and longitudes 110° 00' 05" W and 110° 5' W (Figure 1). The 110° 00' 05"W longitude corresponds to the Alberta provincial boundary with Saskatchewan. The provincial boundary cut-line has disappeared as a result of successive fires in the area, although two survey monuments were found during mapping.

The area was mapped at a scale of 1:10,000 to improve the geological data and to provide an incentive to mineral exploration.

ACCESS AND PHYSIOGRAPHY

The Waugh Lake area is located approximately 110 km east of Fort Smith, N.W.T. and 140 km NE of Fort Chipewyan on the north shore of Lake Athabasca, Alberta. The best access to the area is by float plane and accommodation is available at Andrew Lake Lodge, 7 km west of the study area.

Most waters in the area flow into the Waugh Lakes, which drains to the north into Doze and Martyn Lake and eventually Andrew Lake.

The topography consists of hilly terrain and high plateaus occupied by extensive swamps and sand flats. The valleys are occupied by lakes or muskegs. Travel on foot is difficult because of a series of forest fires, which swept across the area from the Saskatchewan border to the Slave River in 1979 and 1981. Burns, deadfall and new growth make progress on foot slow and difficult; however removal of the moss, lichens and humus by the fires offers excellent rock exposures in many localities. Outcrop density varies greatly from place to place; it ranges from 10 to 20 percent in the eastern and central area to 50 percent in the western part of the Waugh Lake area.

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PREVIOUS GEOLOGICAL WORK

Watanabe (1961) mapped the geology of the Waugh Lake area at a scale of 1:15,840 as part of a M.Sc. thesis; his work was included in the geological map of the Andrew Lake map sheet, South District by Godfrey (1963). This mapping focussed on the tectonic characteristics and fabric of the different rock units, which were largely interpreted as tectonites rather than as sedimentary and volcanic rocks.

There are no known economic mineral deposits within the area. Godfrey (1958) reported specks of galena and pyrrhotite 400 m west of a large cove on the northwest shore of Waugh Lake (his locality #15) and pyrrhotite(?), pyrite and.arsenopyrite on the east side of Waugh Lake (his locality #16). Godfrey (1963) reported tourmaline-quartz-arsenopyrite veins cutting through rusty metasediments on the southeast shore of Waugh Lake, that contain anomalous amounts of gold, silver and nickel (amounts not given). All these occurrences were summarized on the 1:250 000 scale mineral showings map that was compiled by Godfrey (1986).

In 1963, an aeromagnetic survey was flown over the area by Aero Survey Ltd on behalf of the federal government and the map was published in 1964 (Geophysics Paper 2903).

In 1969 and early 1970's, Hudson Bay Oil and Gas Limited carried out an airborne survey over the whole area and conducted limited ground geophysics and completed 4 small trenches over an electromagnetic conductor that was discovered on the northeastern shore of Waugh Lake. No significant mineralization was found in the deeply weathered iron rich metasediments and no further exploration was carried out.

In 1992 under the auspices of the Canada-Alberta Partnership on Mineral Development, the Alberta Geological Survey examined the Andrew Lake area and the previously reported mineralized zones in order to define the type, size and geological context of the mineralizing events. Discovery of well preserved sedimentary and volcanic structures indicated the need for geological re-mapping in order to work out the stratigraphy and to search for favorable indications of prospective mineralized zones. That is, recognition of primary types of deposition of the different rock-units will provide the explorationist with clues to the understanding of the origin of reported mineral occurrences and where to search for more important mineral deposits.

METHODOLOGY

The present mapping of the Waugh Lake area was carried out at a scale of 1:10,000 by a crew consisting of one senior geologist and an assisting geologist over a period of 36 days. Four days were lost on account of heavy rain during the unusually wet 1993 summer season; one other day was taken for moving the tent camp from Doze Lake to Waugh Lake. Traverses were done on foot and used 1:10,000 photo enlargements from 1:60,000 Alberta government aerial photographs for control. All stations were located on the aerial photographs and transferred to a base-map obtained from blowing up the existing 1:50,000 scale topographical map. Details were added from the aerial photographs. A Magellan 5000 PRO-GPS unit was used to check the location of station sites, which were difficult to position accurately on the aerial photographs. However, because the precision of the GPS unit is only about 100 m or less some station locations may be plotted 100 m away from their true location. In general, it can be expected that stations near lakes have a higher positional accuracy than those away from lakes.

Traverses were spaced to provide coverage of the supracrustal rocks at no more than 500 m intervals. In areas of particular interest, traverses were spaced closer together. Area underlain by granitic rocks were investigated in less detail than those areas that are underlain by supracrustal rocks.

The field data were plotted on acetate overlays that were attached to aerial photo-enlargements. The availability of a battery powered Laptop computer enabled the crew to enter field data on adaily basis. The database was created using Fieldlog

V2.83 (Brodaric, 1992) and data was checked by plotting AutoCAD drawing-files on a portable plotter. In the office the data was transferred into a GSIS (Geoscience Information System) using ArcCAD software for future modelling in the Alberta Geological Survey's Mineral Information System. The final map (Figure 1) was plotted on a CalComp electrostatic plotter.

The present report is based upon field observation supported by studying thin sections of most rock-units and seven whole rock analyses of mainly structureless volcanic rocks.

GENERAL GEOLOGY

The Waugh Lake area is underlain by Aphebian rocks of the Churchill Structural Province and is situated in the Athabasca Mobile Belt (Burwash and Culbert, 1976). The Aphebian rocks consist of low grade metamorphic rocks in which primary sedimentary structures and volcanic influences were recognized or suspected by Watanabe (1961). However, their strong structural overprint due to polyphase folding, shearing and cataclasis, has obscured many prominent structures. Therefore, the rock units were previously mapped according to their structural aspect and mineralogical composition as schist, quartzite, phyllonite, etc. (Watanabi, 1961 and Godfrey, 1963).

The supracrustal rocks are assumed to unconformably overlie the Archean basement of granite gneiss and high grade metamorphic rocks in this part of the Canadian Shield. In the area, the contact between these two groups of rocks has not been observed. The supracrustal rocks are intruded by a series of granitic stocks considered to be part of the Colin Lake granitoids (Godfrey, 1963). However, the age relationship between the low grade metamorphic rocks and the Colin Lake granitoids remains uncertain. Peikert (1961, 1963) postulated that the Colin Lake granitoids formed by anatexis of the low grade metamorphic rocks. This hypothesis, however, seems improbable because temperatures in the greenschist facies are too low for partial melting to occur (Koster and Baadsgaard, 1970). The contact relationships between the Waugh Lake group of rock units and the Colin Lake granitoids appear to be intrusive (Watanabe, 1961; Koster, 1961). Koster (1961, p.18) clearly describes these intrusive relationships just east of the Alberta-Saskatchewan border, where Waugh Lake metasediments form inclusions up to 25 cm long in the granitoids with sharp contacts and corroded margins. A K-Ar age of 1760 Ma for biotite from the low grade prograde greenschist facies sediments (Baadsgaard and Godfrey, 1972) correlates with the retrograde greenschist facies found elsewhere in the high grade gneiss terrains in this part of the Canadian Shield. This gives a minimum age for the Waugh Lake supracrustal rock units. This is supported by geochronological studies by McNicoll et al. (in press), who show that the deposition of the Waugh Lake sediments happened between 2.01 and 1.97 Ga ago. This is based on detrital zircons from quartz-feldspar pebbles in a conglomerate with ages between 2.01 and 2.70 Ga, and a 1.97 Ga age for a quartz-diorite, which intrudes the Waugh Lake metasediments.

Recent glacial scouring during the Pleistocene has left numerous fresh rounded outcrops, roches moutonnées, grooves and glacial striae in the area. These indicate that the last ice movement was towards the southwest. In low lying areas, extensive sand flats and kames resulted from wide ancestral periglacial lakes. Large kettles in these sand flats are indications of late ground ice phenomena in the area.

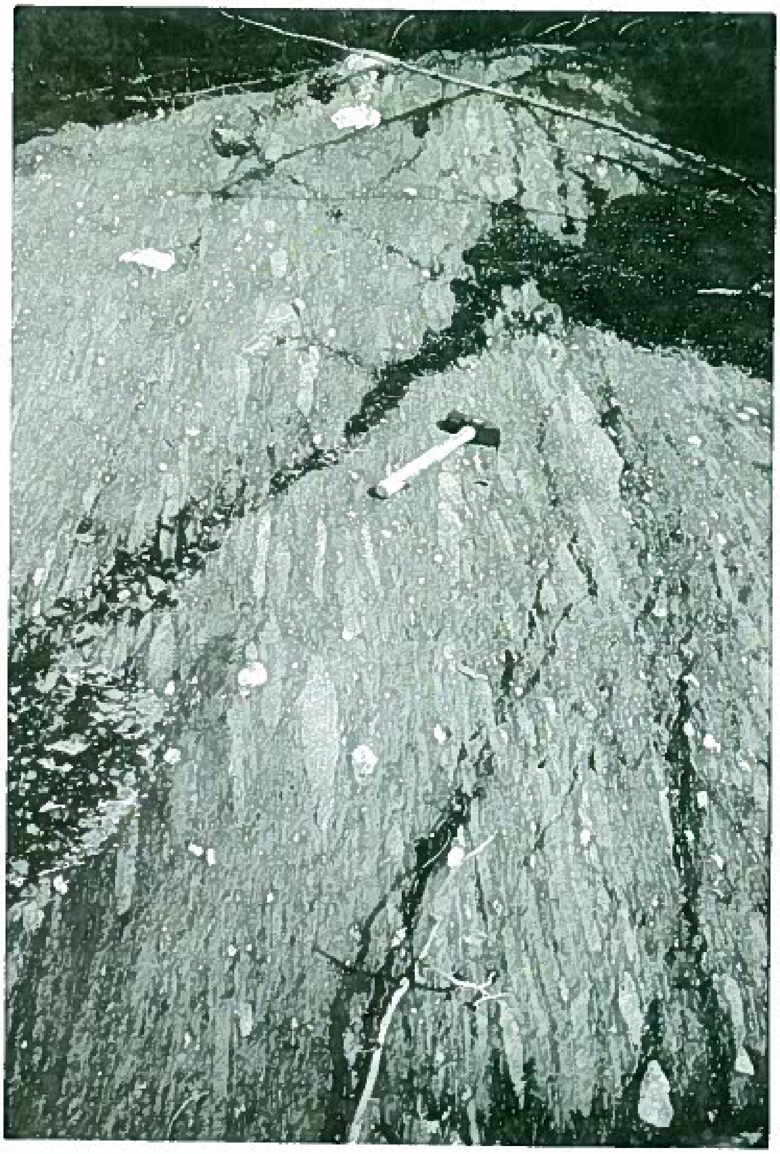

Figure 2. Map-unit DC. Outcrop showing flattened pebbles and cobbles in conglomerate, east shore of Doze Lake.

METASEDIMENTARY ROCK-UNITS (Map-units R, Rfe, DC)

The metasedimentary rock units crop out extensively near Waugh Lake and constitute the majority of rock formations encountered along the Alberta-Saskatchewan border. The sediments are also present in two separate series of outcrops: one is in the northwest corner of the mapped area (near Mineral Occurrences 131 and 135) and the other is in a sliver to the southwest (southeast of Mineral Occurrence 136, see Figure 1). There, the rock-units show complex interference fold patterns contrary to the more regular layering that exist to the east.

DESCRIPTION

The main type of metasedimentary rocks encountered in the eastern Waugh Lake area consists of clastic rock that vary from coarse arenite to pelite. No carbonate rock has been recognized. The rocks are composed of well-developed rhythmic sequences and, for that reason, are referred to as rhythmites (map-unit R), with each sequence being composed of light grey, coarse to medium grained sandstone (which is often arkosic), grading into siltstone and darker grey to brownish mudstone. Each sequence in the rhythmites rarely exceeds 6 to 7 cm in thickness and is often less thick.

An increase in fine material in this map-unit correlates with an increase in iron content. Iron, mostly pyrite is often oxidized in surface exposures and generates large gossanous outcrops. Such rusty iron-rich rocks reach mappable dimensions of 10 m to 15 m in thickness and can be followed over several hundred metres (map-unit RFe). The rusty mudstones also contain graphite. From the eastern shores of Waugh Lake to the southern tip of Doze Lake, iron rich mudstone are well exposed. They have been trenched in the past in four separate locations on the eastside of Waugh Lake. Unfortunately, the trenches have not reached sufficient depths and do not expose fresh rock.

Graded bedding is sometimes present, but it is often obliterated by the metamorphic development of phyllosilicates which can be equal or larger in size than the original detrital grains. Distribution of grain is often disturbed by displacement of quartz or feldspar grains along shear planes or by rotation. In thin sections, quartz shows metamorphic overgrowth as well as recrystallization after shearing. These features resemble the description of the development of metamorphic layering and cleavage in low grade metamorphic rocks given by Williams (1972).

Minor amounts of volcanic crystal tuffs and dark coloured mafic interlayers occur interstratified with the sediments. They form several metres thick layers, in contrast to the thinner rhythmites. However, thin bedded and finer grained light coloured volcanic units may have gone unnoticed.

Diamictites (map-unit DC) represent a unique rock formation interlayered with the rhythmites. It was first discovered on the shores of Doze Lake and subsequently found in large outcrops northwest of Waugh Lake. A similar looking outcrop was found on the south shore of West Waugh Lake. A gap exists between this outcrop and the main area of exposure of map-unit DC; this gap is not explained. The type section for the diamictites is located on the southern shores of Doze Lake where it reaches 200 m in apparent thickness and is well exposed along small cliffs and along ridges (Figure 2). The unit consists of varicoloured, often reddish to green-brown, pebble to cobble size flattened fragments, set in a reddish to purple matrix. On its eastern flank the formation is in sharp contact with a basaltic flow which shows a distinctive gradational brecciated flow top, with top to the west (Figure 3). Near the contact, a 30 cm thick green felsic tuff is found interlayered within the purple conglomerate. The purple to reddish conglomerate passes gradually westward into a conglomerate with greenish-grey matrix and fragments.

Figure 3. Map-unit M. Basalt flow top breccia near contact with unit DC, east of Doze Lake.

White quartzitic clasts (generally cobbles) are common and comprise over 50% of the clasts. In addition, granitic clasts are present and aphanitic to fine grained volcanic fragments were recognized in thin sections. The purple conglomerate contains hematitic sandstone and, sometimes, smaller massive hematite fragments. The matrix and most of the fragments have the same composition, which consists of quartz, biotite, muscovite and chlorite. Some fragments show preserved original layering and cross-laminations. Some aspects of this conglomerate resemble volcanic conglomerates of the Camsell River Formation of the Great Bear Lake area described by Hildebrand (1984). The fragments can make up 50% to 75% of the outcrops and are matrix supported. They range in size from 1 to 30 cm in length with an elongation ratio averaging 1:3 to 1:5. However, some fragments exhibit flattening and reach an elongation ratio of 1:15 parallel to a sub-vertical stretching lineation, which can be observed in vertical exposures. No gradation in size of clasts could be observed, although on the west shore of Doze Lake, some smaller clasts in finer grained beds and rusty shale beds are exposed on a low lying ridge. However, further away on the western edge of this outcrop, layers with very large fragments, which are up to 25 cm long, are present and the fragments are green to light grey within a greenish to purple matrix. A 1 m thick basaltic bed is interlayered with the conglomerate before it disappear under a swamp. The thickness of 200 m of the map-unit may not represent true original thickness, because of possible tectonic thickening.

DISCUSSION AND INTERPRETATION

Although Watanabe (1961) recognized some true conglomerates, he dismissed the rocks on the shore of Doze Lake as true conglomerates and called them crush conglomerates (see also discussion by Koster, 1961, p.17). Although shearing and intralaminae isoclinal folding as well as rootless folds are present in the area and more specifically in the rhythmites, the strain was not intense enough to dismember layered sediments and to create pseudo-conglomerates in quartzo-feldspathic rocks such as those described in the Dalradian of Scotland by Bowes and Jones (1958).

Presently, the main arguments for unit DC being a true conglomeratic unit are the following field relationships: 1) at the eastern contact of unit DC, the mafic flow is well preserved and shows a flow top breccia, 2) a well identified crystal tuff layer is interbedded with unit DC and does not show tectonic disruption, 3) the rocks are seen in sharp contact with well layered rhythmites on the southeastern shore of Doze Lake, and 4) it is difficult to account for the granitic, aphanitic volcanic and white quartzitic pebbles unless they are extraneously derived clasts, because there are no equivalent interlayered rock-units in the vicinity. This last conclusion is supported by the ages of between 2.70 and 2.01 Ga of detrital zircons from quartzo-feldspathic clasts in unit DC (McNicoll, in press).

The fragments in the conglomerate are matrix supported. A good exposure northwest of Waugh Lake (near Mineral Occurrence 134) shows less straining. Here, the clasts are from multiple sources and they are angular and floating in a coarse to medium grained matrix. The formation is best described as a diamictite.

Deposition of the diamictite is interpreted to have occurred proximal to an unstable platform where volcanism was active at some periods. A rift or fore-arc environment could be a good model for the deposition of the diamictites because they are spatially connected to rhythmites, which are interpreted to be turbidites. Uniformity of sequences, graded bedding, lack of cross-rippled lamination and iron rich mudstone favor a deep water environment compatible with turbiditic and hemipelagic sedimentation.

The presence of diamictite raises the question about the origin of the clasts. Where do they come from? If it is assumed that the metasediments of the Waugh Lake area lie unconformably on an Archean basement (Langenberg et al, 1993), it would be expected that all clasts be of granite gneiss type or at least from high grade metamorphic origin. This is not the case and therefore the diamictite must be assumed to be related to an intraformational disconformity or unconformity within the low grade metamorphic Waugh Lake rock group. It is possible that the diamictite is a younger unit on the basis of the presence of volcanic fragments similar to rocks in the volcanic sequence widespread in the Waugh Lake area (see next paragraphs).

Stratigraphic correlation is a difficult task in these deformed terrains. However, descriptions given by Koster (1961) of conglomerate in the map area east of Waugh Lake in Saskatchewan, matches very closely the description given above. The "Western Conglomerate" with its greenish matrix is in direct continuation of the Doze Lake diamictite. It is possible that the "Eastern Conglomerate" of Koster (1961), which has a variably coloured matrix from dark purple, buff, cream, and olive green, to pink and orange red, with white quartz and pink to red granitic pebbles,and which crops out east of the Tazin River, is equivalent to the purple member of the diamictites. In the southernmost exposure of the diamictites on the shore of West Waugh Lake, only the reddish to purple member is recognized.

METAVOLCANIC ROCK UNITS

Three metavolcanic rock units can be distinguished: (1) mafic metavolcanics, (2) felsic metavolcanics and, where they are interlayered in thin beds, and (3) mafic and felsic volcanics.

MAFIC METAVOLCANICS (Map-units M and Mb)

Map-unit M occupies a large area in the centre of the Waugh Lake district, where many exposures are practically made entirely of rock of mafic to intermediate composition (Figure 1). This area coincides with a large plateau covered with dense bush and extensive muskeg, which forms the height of the land

Map-unit M is also found in mappable bands trending in a north-south direction along the rolling slopes which parallel the granitic ridges to the west. Many thinner units are found interlayered with the more felsic rock units but are either too thin or too discontinuous to be mapped. Mafic rocks of mainly basaltic composition are also found in the northeast corner of the map area, east of Doze Lake where they appear interstratified with the metasediments.

DESCRIPTION OF UNIT

The mafic rocks are characterized by their high colour index (equal or higher than 60) which correlates well with the amount of dark mafic minerals. The most frequent mafic minerals in the area are amphiboles (actinolite or hornblende); biotite is also common as well as chlorite. No leucocratic rock of basic composition (such as leucogabbro, anorthosite, carbonatite, feldspathoid rich rocks, etc...) was recognized in the Waugh Lake area.

The mafic rock units are typically massive, dark grey to dark brown in weathered surface and often featureless. In two instances, pillow-like structures can be seen. In addition, the mafic rocks often contain many vesicles filled with quartz or are cross-cut by network of thin quartz veinlets. Compositionally the mafic units are andesitic to basaltic as indicated by bulk chemistry performed on 4 samples, which plot in the andesite to basaltic trachy-andesite fields of the total alkali-silica diagram.

Variation over a few metres from a schistose to a crystalline rock is common. When this feature is present, the mafic unit is considered to represent a flow-unit. Some flows display well developed mafic phenocrysts. In thin section, the phenocrysts consist of prismatic hornblende, which are sometimes broken off at the base of the prisms within the foliation as a result of tectonic deformation. At some locations, hornblende is rounded off and replaced by radiating actinolite. However, on the western border of the mafic sequence, newly formed needles of hornblende develop extensively after actinolite. In outcrop, the larger hornblende stands out as more resistive and sometimes results in a well polished surface due to glacier erosion. It could be mistaken for tourmaline.

In three different areas, autoclastic mafic breccia occur, which consists of lighter coloured fragments, often rounded and of any size floating in a darker matrix.

Fragments and matrix have the same composition. This unit is differentiated on the map as unit Mb (Figure 4). Map-unit Mb also includes some pyroclastic flows where fragments are more angular and apparently of slightly different composition. However, these features could also have been produced tectonically.

Figure 4. Map-unit Mb. Outcrop of autoclastic andesitic flow.

Some of the autoclastic units are gradational to more monotonous flows and could represent thick tops at the end of a volcanic cycle. In addition, a well preserved flow-top breccia is present in a mafic unit east of Doze Lake, which is in contact with a metaconglomerate.

In a few outcrops, a thin layering outlined by variable dark grey or brown tints, is present. The layering shows complex folding, but is believed to be primary. The unit is interpreted to be a tuff. In one outcrop this unit shows superposed folding and breaks up in a tectonically induced breccia.

DISCUSSION AND INTERPRETATION

The mineralogical content of the different rock-units lumped into map-unit M indicate a volcanic origin. It is also supported by the occurrence of flow top breccia and presence of flattened pseudo-pillows. The areal extent of the mafic unit in the central part of the area, together with its textural variation indicates the presence of flows. However, in separate units it is difficult to decide whether they are a flow or a dike. Repetitive layering of the mafic unit intercalated with the felsic units indicates they are interstratified flows. Alternatively, in some places, homogenous mafic units cut across the layering or the close-spaced foliation and hence these units could be dykes.

FELSIC METAVOLCANICS (Map-unit F)

Map-unit F occupies more than a third of the western part of the mapped area, wrapping around the large mass of mafic rocks (map-unit M).

DESCRIPTION OF UNIT

The felsic volcanic rocks are distinctly light or medium grey to light green and contain massive ribboned to laminated layers of rhyolitic to dacitic composition. When exposed in fairly massive and thick layers, the felsite is considered a flow unit. When it is thinly laminated or showing crystal fragments, it is considered a tuff. Good volcanic textures are rare but quartz phenocrysts are commonly preserved, as has been described from deformed rhyolites elsewhere (Williams and Burr, 1994). Some greenish coarse grained members show coalescing flattened quartz indicative of welded tuffs. Minor siltstone and fine grained sandstone are recognizable in a few places.

On its western margins in contact with the Colin Lake granitic rocks, the distinction between the felsic units and injected granitic or pegmatitic layers becomes problematic. Deformation, shearing and protomylonitization of granitic material contribute to make the two rock-units look alike in outcrops. In the field, the presence of regular thin layering and interlayered mafic flows or sills characterize map-unit F.

DISCUSSION AND INTERPRETATION

Although no clear primary volcanic textures were found in this unit, they are interpreted to be volcanic rocks; including flows and tuffs.

MAFIC AND FELSIC METAVOLCANICS (Map-unit MF)

Map-unit MF occurs mainly in the northern half of the mapped area and comprises a north-south belt which wraps around a large diorite stock near Doze Lake (Figure 1). On its southern extension, it is found west of the northernmost lake connected to Waugh Lake. A sliver of the map-unit MF is also found 800 m west of the approximate center of the north-south trending portion of Waugh Lake.

DESCRIPTION OF UNIT

The map-unit MF consists of thinly bedded mafic and felsic flows which are interlayered with minor lithic sandstone (greywacke), arkosic sandstone and siltstone.

Individual beds or layers are usually less than 50 cm thick. The amount of sediment interlayers seems to decrease from east to west. The mafic content of the map-unit MF varies considerably from place to place, with the highest concentrations being towards the northern and southern parts of the belt.

In thin section, the felsic flows in map-unit MF are characterized by feldspar phenocrysts which are poikilitic and altered, set in a fine grained matrix of quartz, chlorite and epidote. Tuff is recognized by oversized feldspars, which are broken, corroded and rotated together with sand sized quartz in a biotitic matrix. The mafic flows are darker in colour on account of their high content of amphibole; some are true amplibolite, others also contain biotite and are rich in plagioclase microliths. In some localities, the mafic rocks show many rounded clots of different sizes composed of actinolite, suggesting mafic lapillis. One sediment observed in thin section is a fine grained muscovite bearing sandstone containing aggregates of epidote; although sheared, it retains its original thin layering.

DISCUSSION AND INTERPRETATION

The assemblage of strata grouped under map-unit MF is characterized by its well-layered nature in outcrops. Field determination of mineralogical composition, layering and bed thickness suggests a volcanic origin. However, lack of obvious primary volcanic textures needed thin section work to confirm assumptions made in the field. The relatively thin and regular interlayering indicate a distal source for these volcanic rocks.

Figure 5. Map-unit FL. Possible cross bedding in lapilli tuff containing large white feldspar clasts.

HETEROLITHIC BRECCIA/CONGLOMERATES

Several mappable units composed of volcaniclastic rocks such as lapilli tuffs and pyroclastic breccias (Fisher, 1966) possess hybrid characteristics of sedimentary and volcanic origin. The overall modal composition of the units (map-units FL, FLl and FLb) is felsic, but one unit (Map-unit ML) has a high mafic content. The units represent a major volcanic environment and typically contain lithic fragments and clasts of highly variable size, shape and source. They can be classified as heterolithic or polygenic conglomerates or breccia depending on their textures. Their mode of deposition is not completely clear, although indications of water reworking (e.g. cross bedding and small troughs) exist in places.

All the units are found in close relationship with the felsic volcanic rocks, and occur around the large mass of mafic volcanic rocks which are west of Waugh Lake. The more mafic unit, ML, is present only on the western edge of the area, although some non-mappable slivers occur on the east side as well.

DESCRIPTION OF UNITS

Map-unit FL is readily identified in the field and consists of light to medium grey or pinkish layers containing lapilli-size (2 mm and larger) rectangular feldspar in a fine to medium grained matrix in which the percentage of quartz grains or granules varies greatly (Figure 5). Beside the often broken and disorganized feldspar, larger fragments are common. Unit FL is distinguished as such on the map where lapilli tuff make up at least 30% to 40% of the outcrop. Interlayers consist of felsic flows or tuffs, minor intermediate to mafic flows and possible sediments. Sediments are indicated by structures that are or resemble cross-bedding (Figure 5). Rare graded bedding has been observed in the more rhyolitic tuffs.

In thin sections, the mafic minerals are mostly biotite, chlorite and minor actinolite and epidote. Muscovite can be present in small quantities except in the west of the map area where muscovite can replace biotite as the main phyllosilicate. The phyllosilicates along with quartz and feldspar constitute the matrix of the felsic units. Clasts of sand to granule size consist of quartz, plagioclase, K-feldspar, and composite clasts of quartz and feldspar with mafic mineral inclusions. The clasts are always matrix supported.

Another unit labelled FLl, was defined associated with the lapilli tuff rich unit FL. The unit consists of large fragments (generally over 6 cm in diameter), that are sigmoidal in shape, sometimes frayed at the edges and floating in a coarse grained quartz and feldspar rich matrix. The fragments are made of light grey to brown felsic to intermediate volcanics, large quartz augens and leucogranitic material. The main difference with unit FL is that unit FLl has fragments that are larger than 6 cm in diameter. The unit is well developed on the west side of the mapped area and north of West Waugh Lake.

West of the main body of the mafic unit M, typical polygenic and proximal pyroclastic flows can be mapped separately as map-unit FLb over an area that is about 250 m wide by 1200 m long. The large pyroclasts are felsic and mafic in composition; they reach 50 cm in size and are matrix supported. The matrix is quartz rich indicating a rhyolitic composition. In general two sub-units are present: (1) one which is unsorted and non bedded and (2) the other which is similar in composition, but shows poorly sorted layers of cobble to boulder sized clasts interbedded with coarse grained gritty layers (Figure 6). It is suggested that these deposits are ground and base surge pyroclastic flows (Fisher, 1977).

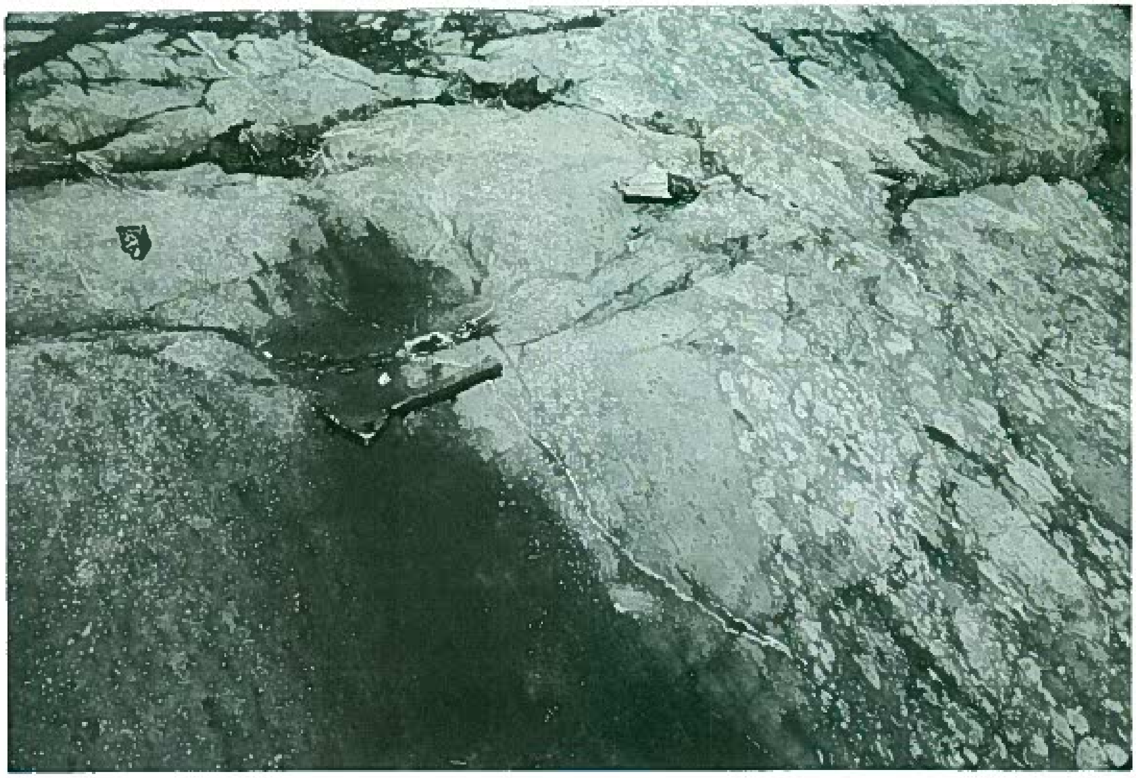

Figure 6. Map-unit Fb. Bedded, poorly sorted rhyolitic pyroclastic flows

Map-unit ML forms an easily recognizable map-unit that trends northerly in the western part of the mapped area. The unit consists of deep green amphibolite with many coarse quartz particles standing out in outcrop due to differential weathering that results in a rough or 'gritty' surface. The amphibolite unit crops out with a maximum width of 100 m. However, where widely exposed, the unit contains many interlayers of felsic pyroclastic flows. Locally, the unit is regularly laminated with dark green amphibolite alternating with light coloured gritty layers; each layer is a few millimetres to one centimetre thick.

The rock unit contains structures that are or resemble trough cross-bedding (Figure 7). On the basis of this cross-stratification, the map-unit represents deposition of mafic lapillistones which were reworked by water and current action. Small scale channels, re-activation surfaces and trough-cross-bedding indicate a fluvial environment. The bulk composition of the unit is close to that of a basalt or dolerite;

the amphibolite matrix represents volcanic material (mud?) in which coarse grained tephra of quartz and/or plagioclase were embedded.

Figure 7. Map-unit ML. Dark green striped amphibolite showing cross stratifications. The light bands consist of quartz and plagioclase; the dark bands consist of actinolite.

In the two thin sections presently available, map-unit ML is typically composed of 50% to 60% actinolite. In one of the sections, some actinolite is arranged in clusters of less than 1 mm in diameter made of sigmoidal prisms. This and the equant shape of the quartz clasts indicate a basal section and correlatively show the strong rodding in the rock fabric. Overall, the rock is made of clasts up to 4 mm in size with an average of 1.5 mm in diameter. The clasts are essentially polycrystalline, rounded to augen-shaped quartz and altered plagioclase which, in one section, is present in equal amount to the quartz grains.

DISCUSSION AND INTERPRETATION

The origin of the metamorphosed lapilli tuffs (map-unit FL) is not completely clear. It is possible that the lapilli tuffs were originally arkosic sediments, as indicated by the presence of structures that resemble cross-beds. However, it is difficult to explain the presence of so many large feldspar phenoclasts (many are more than 2 cm in size) coexisting and floating in a sand to silt sized matrix. A regolith or saprolith could have been present, but no basement rock is recognized in the vicinity.

Nevertheless, it seems reasonable to assume that this unit includes both tuff and volcaniclastic sediments. Williams (1991) describes heterogeneous deformation in a ductile fold-thrust belt, where in certain areas sedimentary structures are preserved close to other highly deformed areas, where no primary structures remain.

Interpretation of the origin of map-unit FLI also presents some problems. The matrix is always medium to coarse grained quartzo-feldspathic with a muscovite groundmass; fragments are often stretched (schlieren like) and floating in the matrix. The fragments consist predominantly of light coloured, coarse pinkish quartzo-feldspathic material, and the rest of the fragments are made of grey to brown fine grained volcanic material similar to the surrounding country rocks. Some of the fragments could be sediments. Where the unit FLI is thick and well exposed, it shows strikingly regular and straight layering, with each interbed ranging from 10 to 20 cm in width. Dips are vertical. The mixture of sand sized matrix with centimeter size fragments indicates a high density polydisperse low internal shear flow with characteristics more suggestive of pyroclastic sedimentation than turbiditic flow (Allen, 1983, p.419). Among the pyroclastic types of flows, unit FLI could be lahar deposits, although lahars usually have a finer to mud sized matrix.

Strong deformation resulting from tight folding, shearing and boudinage (features sometimes found in the area), offers an alternative explanation. Most fragments are rotated in relation to the layering and in a few places incipient transposition was noted. It is possible that the layering is not primary but corresponds to a very strong close-spaced cleavage accompanied by intense slip folding which intersects the regular stratification at a low angle. However, this is at the moment not the preferred explanation.

The origin of amphibolite unit (ML) is also still subject to discussion. On the basis of the cross-stratifications (Figure 7), the map-unit represents deposition of mafic lapillistones which were reworked by water and current action. Small scale channels, re-activation surfaces and trough-cross-bedding indicate a fluvial environment. Structural deformation of well layered mafic tuff or lava and the formation of shear bands (CS structures) offers an alternative explanation for these structures, but is at the present time not the preferred interpretation.

INTRUSIVE ROCK-UNITS

A number of intrusive bodies are found within the Waugh Lake area, and granitic rocks mark the western limit of the Waugh Lake Group (Figure 1). No mafic intrusive rocks exist in the area. The intrusive suites are described according to their spatial relationships with the low grade metamorphic rock units of the Waugh Lake Group.

THE COLIN LAKE GRANITE

The Colin Lake Granite (Map-unit CG) crops out extensively in the southwest and fringes the Waugh Lake metavolcanics to the west. These hills offer spectacular glacially rounded exposures of very coarse to pegmatitic leucogranite that contain large wispy and reticulate books of biotite and muscovite. The granite is foliated and has anastomosing layering; in places, large blobs show partial melting of quartzo-feldspathic material and represent a pegmatitic phase. The feldspar is mostly microcline and often pinkish in outcrops. Garnet can represent several percent of the rock mass.

Rhyolitic and mafic inclusions of the Waugh Lake group are common. The contact between unit CG and the low grade metamorphic rocks of the Waugh Lake Group is transitional. The Colin Lake granite has been injected within the layered rocks of the Waugh Lake Group in numerous pegmatoidal masses or sheets which decrease in frequency toward the east, away from the main stock. Further east of the contact, only boudins of pegmatitic material are encountered. The pegmatitic material is muscovite rich and tends to be concordant with the layering. The pegmatitic bands are also sometimes folded into complex folds along with the enclosing metamorphic rock units which, in this area, comprise mainly felsic volcanics (Figure 8). Where tight folding occurs, the distinction between the different units is obscured.

The Colin Lake granite is considered to be pre- to syn-tectonic with much anatectic remobilization. It is younger than the Waugh Lake group of rocks.

THE WAUGH LAKE GRANITOIDS

Large bodies of intrusive rocks (map-units G, Gb, Gp, S and D) intrude the Waugh Lake metasediments and metavolcanics, mainly to the north, east and south. The borders are well defined and are sharp to sheared over a limited distance. Internal deformation and mineral paragenesis indicate that two distinct suites of granitoids with different ages of emplacement are present.

The first generation of granitoids includes granite, syenite and diorite (map-units G, S and D), which share the distinctive association of hornblende and biotite as the main mafic components, but in variable amounts. These map-units are therefore differentiated on the basis of their felsic content, with syenite consisting exclusively of potassium feldspar and diorite consisting of oligoclase and andesine. Both the syenite and diorite contain small amounts of quartz. The units G contain both plagiocalse and K-feldspar. The intrusive rocks are typically equigranular and show on their borders much metasomatism with extensive development of myrmekite and granophyric texture. Where the amount of K-feldspar is prominent, the feldspar is strongly perthitic. These granitoids contains internal bands of deformation with good foliation; in the northeast corner, they become layered in some localities and show mylonitic textures. A sample from the southern body of map-unit G has been dated by McNicoll et al. (in press) at 1.97 Ga.

Figure 8. Metre size cylindrical fold of Colin Lake pegmatitic layers injected in felsic volcanics (map-unit F).

By comparison, the second generation consisting of biotite granites and porphyritic biotite granites (map-units Gb and Gp), show less deformation, are often leucocratic and contain biotite as the main mafic mineral. This is the main reason why these units are considered to be younger than units G, S and D. The biotite in units Gb and Gp is dark brown and rich in zircon and radioactive allanite. Unit Gp is distinguished by by being K-feldspar porphyritic. In the north, the biotite granite (unit Gb) interfingers with the metasediments, but these sills are never folded and are often in fault contact. The leucogranites of unit Gb are generally low in inclusions, but contamination with mafic material at contacts with other rocks results in the presence of tremolite.

THE ANDREW LAKE GRANITE

The Andrew Lake granite (map-unit AG) is a post tectonic intrusive stock. It contains quartz, K-feldspar (microcline) and plagioclase (mostly andesine) in equal amounts. The feldspar are phenocrystic, ranging from 0.4 to 4 mm in size. It is poor in mafic minerals, which are represented by biotite, but rich in zircon and allanite inclusions. Apatite is also common in these rocks.

The Andrew Lake granite crops out extensively in the west and northwest of the mapped area. It is also found in several small pods and lenses intruded into the large stock of Waugh Lake granite in the northern half of the mapped area. The Andrew Lake granite can contain abundant xenoliths especially when intruding other igneous rocks (Figure 9).

Figure 9. Xenolith rich lens of Andrew Lake granite

Map-unit Gb, because it is a biotite granite with common biotite rich-inclusions and relatively undeformed, could be genetically related to the late Andrew Lake Granite, rather than to the Waugh Lake suite of intrusions.

DYKES

A few mafic dykes were noted in the course of mapping, but are too thin and discontinuous to be presented on the map. Two lamprophyre dykes, 2m thick, of limited extension were observed during the 1992 field investigation. These two dykes cut across the granite unit G just above the high cliffs forming the northern shore of the west trending part of Waugh Lake. The lamprophyres consist of biotite and hornblende with some K-feldspar; they trend N100°E.

In this type of deformed terrane, mafic dykes may have been misinterpretated as flows. An example is provided by outcrops on the southshore of the lake west of West Waugh Lake, where the planar layering of felsic lapilli tuffs stops abruptly against irregular bodies of mafic rock (Figure 10). This indicates an intrusive character of the mafic rocks. Only a few aplite dykes were noticed next to the contact with the Andrew Lake granite. It is probable that some felsic dykes or sills have also been misinterpreted as flows.

Figure 10. Intrusive contact of mafic rocks and felsic lapilli tuffs.

STRUCTURAL GEOLOGY

FOLDING

The geological mapping indicates at least two phases of folding: one has an axial plane with an azimuth of N010° to 020°E, the second one has an axial plane with azimuth of N090° to 100°E. The second phase has more open, regular metre sized folds and exist mainly in the metasediments The first phase represents a large scale folding event, that resulted in the present distribution of the rock-units in the area. The overall large scale structure is possibly a basin, as indicated by westward younging directions in rhythmites on the east-side and eastward younging directions in lapilli tuffs on the west-side of the map area (Figure 1). This geometry would indicate that the mafic volcanics (unit M) are the youngest rocks of the Waugh Lake Group. However, shearing accompanying the folding and subsequent faulting has affected these rocks and the geometry might be more complicated

Throughout the area, the rocks are strongly foliated or sheared which has resulted in the presence of schists. However, fold exposures are rare and when present the main foliation seems to be axial planar. The metasediments contain more folds than the volcanic rocks. Near the eastern margin of the mapped area, shear folding is prominent, which have north trending fold axes (Figure 11). These folds possibly indicate a north trending shear zone parallel to Waugh Lake, which is probably coincident with the deformation phase which created the mylonitization present in the Waugh Lake granitoids. Outcrops of metasediments in the northwest around Mineral Occurrences 131 and 135 display interference fold patterns (Figure 12), illustrating on a small scale the two phase folding. Boudinage is common.

Much less folding is visible in volcanic sequences. Few folds are present in the felsic rock-units. In a few places and especially in the central northwest sector of the mapped area where vertical ledges perpendicular to the main foliation or layering expose felsic rocks, tight folds with vertical axial planes and downward closures (synformal) exist. Small sheath folds are also encountered with fold axes with a vertical plunge, whereas to the south a sheath fold with an horizontal fold axis is present.

The layering in felsic rocks is very linear and consistent over long distances; often it is very regularly spaced. The main layering has been taken as bedding. However, the rotation of "fragments" in map-unit FLI and trains of feldspar and quartz grains cross-cutting this layering indicates the possibility of transposition of bedding.

In the mafic units, distinct layering is rare. When present, it generally shows small scale folding. One rock exposure in mafic layers displays interference fold patterns (class II of Ramsay, 1967, with orthogonal axial planes but oblique fold axis), carried to the extreme. It results in a breccia like unit consisting of sharp, angular, bent fragments with frayed or sheared borders.

Figure 11. Isoclinal folding in metasediments.

Figure 12. Interference fold patterns in metasediments.

Vertical sheath fold and dome and basin structures exist within the pegmatitic layers of the Colin Lake granite that has been injected into the felsic volcanics. The same complex folding is also encountered among quartz-tourmaline veins that cut through the metasediments southeast of Waugh Lake. These observations indicate that the Waugh Lake area went through a complex tectonic history, probably involving more than two phases of structural deformation.

Mylonite zones exist in several areas underlain by the Waugh Lake granitoids. The strike of the mylonitization layering is slightly east of north. One mylonite zone is well exposed in the near the shore of the rectangular lake northeast of Mineral Occurrence 47, where the mylonitization has affected granite unit G in several places. A second mylonite zone is present at the north shore of West Waugh Lake, where it has affected granite unit Gb. In both instances the mylonite shows sets of right lateral kink bands and a crenulation cleavage transecting the mylonitic layering at a high angle.

FAULTING

Mapping in the Waugh Lake area has uncovered the existence of a major break which separates a sediment dominated area to the northeast from a volcanic dominated domain to the southwest. Evidence consists of intensely folded ferruginous rhythmites injected with discordant close-spaced folded tourmaline veins, are in abrupt contact with massive felsic flow and lapilli tuff near Mineral Occurrence 133 (Figure 13). This represents a fault contact. Other indications are topographical features such as alignment of outcrops forming a lineament, that may be underlain by a fault. The break relates to a jog in the granite-sediment contact to the southeast and also to a brecciated contact of the syenitic body against surrounding granitic rocks on the south shore of Waugh Lake.

A major fault coincides with a string of small lakes and deep ravines that are aligned with the western tip of the chain of lakes, which extend west of Waugh Lake (Figure 1). No direct observation was made of the existence of this inferred fault, but stratigraphic breaks in rock formations support the existence of this northeast trending structural break. Another fault is well expressed by the dextral displacement of the Andrew Lake granite in the northwest part of the mapped area and trends east-west. The latter fault is also outlined by a strong topographic signature.

Late brittle fault zones exist on both shores of West Waugh Lake (good examples are present in the diamictite exposure on the south shore). They consist of 5 to 10 m wide hematitic fault gouge with a network of exuded white quartz veins and are geologically similar to the Bonny Fault zone near Andrew Lake Lodge (Godfrey, 1963; Langenberg et al, 1993). Their direction varies from N90°E to N110°E.

A last brittle deformation is indicated by many conjugate sets of joints striking around N040°E and N140°E.

Figure 13. Mineral Occurrence 133. Quartz-tourmaline veins within metasediments near fault contact with felsic lapilli tuffs. Head of hammer indicates the contact.

METAMORPHISM

Metamorphic minerals consist mainly of biotite, muscovite, chlorite and epidote in the metasediments and felsic metavolcanic units, and actinolite, chlorite, tremolite, epidote and calcite in the mafic metavolcanic units. The mineral assemblage indicates upper greenschist facies to lower amphibolite facies ("hornblende-in" field of metamorphism of Winkler, 1979). Indeed, mafic rocks show that chlorite, which is common in the eastern part of the mapped area, becomes less common towards the west. In addition, towards the west, actinolite and tremolite are replaced by newly formed prismatic hornblende. This indicates an increase in the metamorphic grade towards the large masses of intrusives rocks that exist to the west. It is interesting to note that the "hornblende-in" reaction-isograd corresponds to temperatures of around 500°C and is not dependent on pressure. Yet no recrystallization or blastesis of feldspar is recognized anywhere in the area. This observation limits the temperature range to less than 500°C as above this temperature plagioclase with 17 to 20 percent anorthite starts to form in mafic rocks along with hornblende (Winkler, 1979).

The pronounced development of secondary hornblende in the mafic rocks in the western sector, could be explained in response to an increased thermal gradient next to the intrusives, whereas the nearby felsic volcanics lack the excess in alumina necessary to crystallize metamorphic alumino-silicates such as andalusite or cordierite. However, near the contact with granitic intrusives, the felsic rocks tend to look more hornfels-like in outcrop, possibly due to complete recrystallization. No microscope study has been done to confirm this possibility.

MINERAL OCCURRENCES

Indications of mineralized zones which include mainly gossans, rusty quartz veins and rusty spots near quartz tourmaline veining, were sampled in the course of mapping. A total of 34 samples were collected and sent to Loring Laboratories Ltd. of Calgary to be analyzed for gold by the Fire Assay/Atomic Adsorption (FA/AA) method, using a 20g aliquot method and for base metals by Induction-Coupled Plasma (ICP) spectrometry.

Any location from which a sample contains anomalous mineral contents, is given a mineral occurrence number. Anomalous metal contents are taken as above 25 ppb Au and 500 ppm in base metals (Cu, Zn, Pb, Mo, Ni, Cr, W). Seven locations have samples which contain anomalous to very anomalous amounts of gold in association with either Mo or As. As well, at one other location the sample contains an elevated tungsten content, and at an other location, the sample has elevated amounts of Ni and Cr. These nine anomalous locations are described hereunder as mineral occurrences numbers 128 to 136.

Some localities have produced samples with a high background content of Cu, Mo or Pb in the order of 100 to 500 ppm, but are not considered as mineral occurrences. The high background samples originated from very rusty fine grained clastic metasediments, except at one locale where the sample was collected from quartz veins which cut the metasediments. At this latter locale there is 513 ppm Mo.

Lastly, at one location near the south shore of the lake west of West Waugh Lake, small pods of blue quartz amethyst exist and were sampled. The pods are the results of swells in veins that occur over a 2 m length within a mafic body that has intruded into rhyolitic flows and lapilli tuffs. A sample of the amethyst contains 115 ppm Ba and 141 ppm Bi, and a sample from the rusty mafic host rock also yielded 255 ppm Ba. These barium contents are in contrast to a background of 40-50 ppm Ba in the Waugh Lake area.

Attempts were made to find more occurrences near Doze Lake, where Mineral Occurrence 126 had anomalous gold (two samples with 17 and 22 ppb Au) and Mineral occurrences 124 and 125 had anomalous base metal contents (samples from the AGS collection which auriferous were collected by Godfrey in 1960 and reported on by Langenberg et al., 1993). At these locations, rusty spots are present within slivers of metasediments or metavolcanics forming inclusions in different igneous intrusives. However, no significant anomalous mineral contents were measured in the 1993 samples collected from these sites.

Mineral occurrence 128-(UTM coordinates: 555687E - 6635924N)
(Station HS93-07-07-01)

A 30 to 50 cm wide rusty quartz vein trends conformably for a distance of approximately 3 ms along the eastern margin of a mafic flow interlayered with the metaconglomerate that crop out on the east shore of Doze Lake. At the contact with the quartz vein, the mafic rock is silicified and brecciated over 15 to 20 cm. The only metallic minerals seen in the quartz vein are pyrite and hematite. A sample of the quartz vein contains 36 ppb Au.

Mineral occurrence 129- (UTM coordinates: 555497E - 6636988N)
(Station HS93-07-08-13)

A spectacular stockwork of mainly parallel quartz-tourmaline veins are present in rusty, rhythmically layered metasediments that crop out on the large headland which protrudes on the north shore of a lake that is 1 km south of Doze Lake. The veining is typically 1 to 5 cm thick and is regularly spaced every 10 cm (Figure 14). The veining carries on for 20 to 25 m and strikes N050°E. In places, the quartz veins merge into large bodies (1 to 2 m in size) of white quartz breccia that contain many angular fragments of rusty metasediments. Near the contact with the biotite granite stock to the west, the quartz tourmaline veins become thicker and more contorted. Many specks of pyrite are present and a chip sample over 1.1 m assays 834 ppm W. No high gold contents were detected although the paragenesis and geological setting is very similar to the Au-bearing quartz-tourmaline veins that are reported to occur on both shores of Waugh Lake where it forms a sharp elbow (M.O. 44 and 45).

Mineral occurrence 130 - (UTM coordinates: 555461E - 6635145N)
(Station HS93-07-08-22 &23)

Within a belt of rusty, iron-sulfide rich, well layered and folded metasediments, many small quartz sweats are present. Only two spots of rusty sediments have been chip sampled and each contains anomalous gold contents (3,200 and 121 ppb Au) accompanied by elevated Mo contents (99 and 27 ppm). No arsenic was detected in the samples. The high content of gold in the samples was checked and the results of re-analysis are shown in Table 1.

Table 1. Check analysis on anomalous samples from M.O. 130.

Sample number	**Gold in ppb**	**Comments**
HS93-07-08-22	**3212**	Original pulp
--------------------	**3278**	Original pulp check
--------------------	**2370**	Reject recut
HS93-07-08-23	**121**	Original pulp
--------------------	**105**	Reject recut

This gold occurrence is geologically similar to the other gold showings found along the Waugh Lake eastern belt of iron sulfide rich metasediments (Mineral occurrences. 50,51,53).

Figure 14. Mineral Occurrence 129. Stockwork of regularly spaced quartz-tourmaline veining in rusty metasediments.

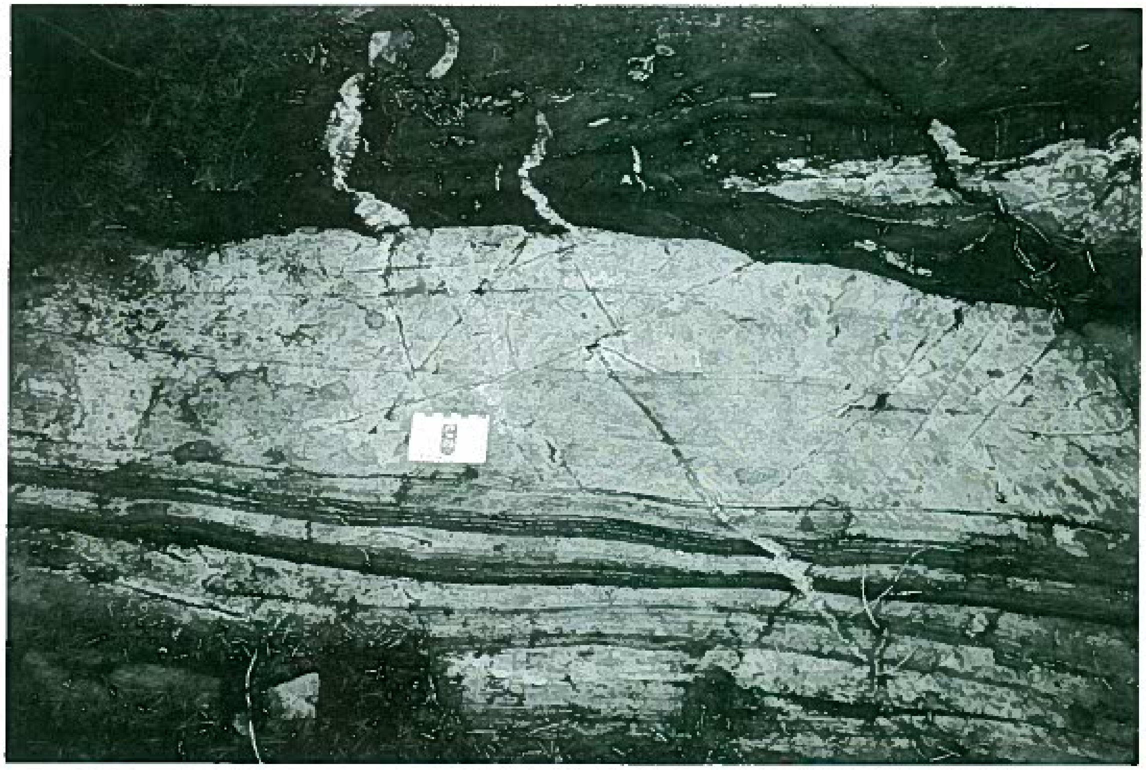

Figure 15. Mineral Occurrence 134. Massive tourmaline vein, thin tourmaline laminae and cross cutting quartz tourmaline veining.

Mineral occurrence 131 - (UTM coordinates: 553160E - 6634504N)
(Station HS93-07-12-10)

On the northwest edge of the Waugh Lake group, tightly folded metasedimentary bands contain rusty layers that are exposed over a strike length of 250 m. The rusty layers are 2 to 3 m wide and contain gossans 3 m by 10 m, where layers are more strongly boudinaged or folded into sheathfolds. Within the gossaneous zones, many pods of tourmaline, pyrite and arsenopyrite are present. Two of the gossan zones have been chip sampled over 3 m but no anomalous contents were found; however a third spot containing quartz-tourmaline sweats shows anomalous gold (59 ppb) and arsenic (844 ppm); these contents are indicative of the potential of this extensive sulfide rich area.

Mineral occurrence 132 - (UTM coordinates: 555629E - 6631884N)
(Station HS93-07-14-13)

This mineral occurrence is located on the west side of a long narrows between Waugh Lake and North Waugh Lake. Pyrite is present and there is a low, but anomalous gold content (28 ppb Au) within rusty layers interbedded in metasediments. Mineral occurrence 132 is geologically similar to mineral occurrence 50 which is about 230 m to the southeast, near the east shore of Waugh Lake.

Mineral occurrence 133 - (UTM coordinates: 554040E - 6632168N)
(Station HS93-07-17-21)

Numerous contorted and closely spaced, massive, 1 to 5 cm thick tourmaline veins exist at this location within strongly folded, rusty, thinly layered metasediments. The tourmaline veins account for 25% of the outcrop, and are discordant with the layering of the metasediments. Tension gashes filled with white quartz are regularly distributed perpendicular to the tourmaline vein walls. Interestingly, the tourmaline quartz veining stops abruptly at the contact of the metasediments with the felsic flows and lapilli tuffs that lie immediately to the west. This sharp contact trends N166°E and is interpreted as the expression of a major regional break or fault, which was discussed previously (Figure 12).

At two locations, 5% pyrite and 5% arsenopyrite exist within the quartz-tourmaline veins at the contact with the rusty metasediments. Assays show anomalous gold contents up to 26 ppb, and confirm the presence of arsenopyrite (1,706 and 6,571 ppm As).

Mineral occurrence 134 - (UTM coordinates: 554224E - 6632333N)
(Station HS93-08-01-02)

Mineral occurrence 134 is located 250 m northeast from mineral occurrence 133 and consists of tourmaline in thin laminae interbedded with thin sandstone beds within purple pebble diamictite. Massive tourmaline also occurs in thicker (2 to 5 cm) veins that are concordant to bedding in the country rock and in late thin (millimetre thick) cross cutting quartz rich veinlets as shown in Figure 15. A more rusty spot in gossanous diamictite with a sandy matrix was sampled and contains 93 ppb Au.

Mineral occurrence 135 - (UTM coordinates: 552591E - 6634019N)
(Station HS93-08-05-07)

Metre wide rusty layers of mudstone are complexly folded within a large belt of metasediments that crop out for more than 500 m on the northwestern edge of the Waugh Lake area. A 10 by 25 m area of rusty mudstone was sampled and contains an anomalous gold content (133 ppb Au). Although only pyrite and no tourmaline are present, this mineral occurrence is in continuity with mineral occurrence 131 which is located 650 m to the northeast.

Mineral occurrence 136 - (UTM coordinates: 551585E - 6629520N)
(Station HS93-08-07-09)

On the southwest corner of the mapped area, a band of greenish mafic lapillistone (map-unit ML) is rusty and contains 3 to 5% disseminated pyrite. The mafic unit is cut by 1 m wide pegmatites of the Colin Lake granite suite and both rock units are folded. A sample from the rusty unit indicates elevated contents of chromium and nickel (578 ppm Cr and 117 ppm Ni) and a low gold content (9 ppb).

CONCLUSIONS AND RECOMMENDATIONS

The 1993 geological mapping of the Waugh Lake area demonstrates that the various lithological units of the Aphebian Waugh Lake Group can be mapped according to their origin (sediments, volcaniclastics, lava flows etc.). However, it is an additional step towards deciphering the geological history of the Waugh Lake area and, more importantly, towards understanding its mineral potential.

The results show that gold is the main commodity found so far in the area. Gold is present in iron rich fine-grained clastic metasediments, often in association with quartz and tourmaline. Arsenic, barium and tungsten are often associated with gold and can serve as pathfinders. The rusty nature of the host rock (mudstone) provides a guide to gold enriched mineral occurrences and is very diagnostic. However, this is not the case for other types of rocks such as the thick sequences of mafic and felsic flows and pyroclastics. Many rhyolitic flows and tuffs were found to contain minor pyrite, but the rocks are rarely rusted. The package of volcanic rocks that contains thick sequences of rhyolitic material and especially large fragmental pyroclastics, offers a good potential for finding base metal mineralization. This package contains well differentiated volcanic rocks of mafic (andesite to basalt) composition and thick rhyolite units. The bimodal volcanism of the Waugh Lake Group compares favorably with the geological setting of well known mineral deposits, such as at Kidd Creek, Ontario. It is worth noting that the potential for volcanogenic base metal deposit in the area has never been tested by modern techniques of geochemistry or geophysics, nor by drilling.

The 1993 and prior geological mapping have left some questions unresolved. The most obvious problem concerns the age relationship of the different units. Only a few criteria, such as younging directions from possible sedimentary structures, were found which can establish a stratigraphic succession of the Waugh Lake Group. The eastward younging on the Westside of the area might indicate that felsic volcanics (unit F) are overlain by lapilli tuffs (units ML, FL and FLI), which are in turn overlain by mafic volcanics (unit M). However, this conclusion is tentative because the nature of the metasedimentary and metavolcanic rocks is not yet completely understood. In addition, the stratigraphic relationships between rhythmites, diamictites and volcanics is not completely clear. It is possible that the rhythmites represent the oldest rocks of the Waugh Lake Group, but a possibly significant fault through the center of the area has obscured the relationships. It is suggested that detailed petrographic and geochemical work on the clasts of the diamictite unit could provide some clues on the problem of relative age among rocks of the the Waugh Lake Group. Problematic and contentious units like the fragmental FLI unit and the mafic ML unit deserve to be looked at in more detail by additional sedimentological, petrographical and structural studies. Whole rock and trace element analyses could also be undertaken in order to gain a better understanding of the nature and chemistry of the felsic and mafic volcanic units.

Additional structural geological studies could provide answers about the nature of shear zones and brittle faulting, and their effects on the geometry and stratigraphy of the Waugh Lake area. Specifically, the nature of the northwest trending fault in the central area has to be elucidated.

Finally, it is recommended that the southern portion of the Waugh Lake Group be mapped at a scale of 1:10,000 because it appears that the belt of metasediments and metavolcanics is continuing in that direction.

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Geology and Mineral Occurrences of the Aphebian Waugh Lake Group, Northeastern Alberta

INTRUSIVE ROCKS

- AG Andrew Lake Granite
- CG Colin Lake Granite

Waugh Lake Granitoids

- G Equigranular hornblende–biotite granite
- Gb Biotite granite, often leucocratic
- Gp Porphyritic biotite granite
- S Hornblende–biotite syenite
- D Hornblende–biotite diorite
- MYL Mylonite zones in Waugh Lake Granitoids

METASEDIMENTARY ROCKS

- R Rhythmites: interbedded mudstone, siltstone and graded sandstone
- RFe Rusty zones within rhythmites
- DC Diamictite: includes pebble to cobble conglomerate

HETEROLITHIC BRECCIA/CONGLOMERATES

- FL Interlayered felsic lapilli tuff and volcaniclastic sediments
- FLl Interlayered felsic lapilli tuff and volcaniclastic sediments with larger fragments (over six centimetres)
- FLb Felsic pyroclastic breccia
- ML Interlayered mafic lapilli tuff and volcaniclastic sediments

METAVOLCANIC ROCKS

- F Felsic to intermediate flows and tuffs: includes rhyolite, dacite and latite
- MF Interlayered mafic and felsic flows and tuffs
- M Mafic flows and tuffs: andesite to basalt
- Mb Mafic pyroclastic breccia
- Darker shading represents outcrop areas
- Geological Boundary (defined, assumed)
- Fault
- Swamps
- Sand

MAP SYMBOLS

- Bedding, tops known (inclined, vertical, overturned)
- Bedding, tops unknown (inclined, vertical)
- First foliation (inclined, vertical)
- Second foliation (inclined, vertical)
- Mineral lineation
- Stretching lineation
- Shear bands
- Shear, normal
- Joint (inclined, vertical)
- Inclined axial surface (1st, 2nd generation)
- Vertical axial surface (1st, 2nd generation)
- Dextral kink bands (inclined, vertical)

EXPLANATION OF MINERAL OCCURRENCE SYMBOLS

★ 50 Mineral occurrence location, symbol and number

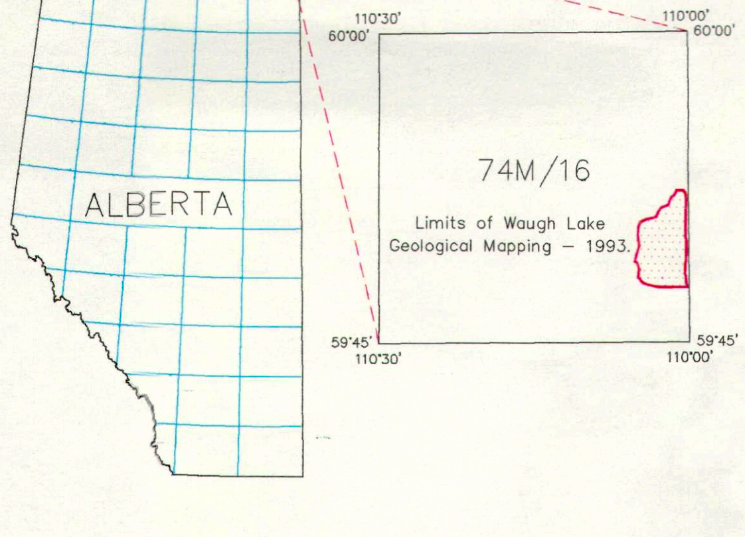
MINERAL OCCURRENCE SYMBOLS

- ★ Gold associated with sulfides
- ✡ Gold associated with tourmaline quartz veins
- ■ Base metals (Pb, Zn, Cu)
- ☒ Molybdenite
- ▲ Nickel–Chromium
- T Tourmaline quartz veins

Mineral occurrence numbers less than 128 are from Alberta Research Council Open File Report 1993–08.

Mineral occurrence numbers 128 and greater were located during the 1993 field season.

MAP AREA



Scale 1:10 000

Metres 0 100 200 300 400 500 750 1000 Metres

Transverse Mercator Projection

CANADA ALBERTA Partnership on Minerals

Finding Minerals and Technology for Tomorrow

Figure 1: To accompany report
Salat, H.P., Eccles, D.R. and Langenberg, C.W. 1994. Geology and Mineral Occurrences of the Aphebian Waugh Lake Group, Northeastern Alberta. Alberta Research Council, Open File Report 1994–4.

Digital editing by D.R. Eccles

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