GEOLOGY AND DESCRIPTIVE PETROLOGY OF THE MOUNT BISSON ALKALINE COMPLEX, MUNROE CREEK, BRITISH COLUMBIA*

(93N/9E, 93O/12W, 5W)

By A.A.D. Halleran and J.K. Russell
The University of British Columbia

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INTRODUCTION

The Mount Bisson alkaline complex is located in the Wolverine Range, 64 kilometres northwest of the town of Mackenzie, British Columbia. The area studied during the 1988 and 1989 field seasons is covered by the southeastern corner of the Manson Creek map sheet (93N/9) and the west margins of map sheets 93O/12 and 93O/5 (Figure 2-9-1). Other alkaline complexes in the region (Figure 2-9-1A) include: the Lonnie (Halleran, 1980; Pell, 1987), Veril (Pell, 1987) and Aley carbonatite (Mäder, 1986, 1987) as well as the Prince and George carbonatites (Mäder and Greenwood, 1988). The Mount Bisson complex is unique in that there are no known associated carbonatites; it comprises mainly silica-saturated lithologies and consequently the host minerals to the rare earth element mineralization are dominantly silicates (allanite, cerorthite).

The objectives of this paper are: to summarize the field relationships of the alkalic rocks exposed in the Wolverine Range, to describe their petrology, and to describe the continuing research on their mineralogy and mineral chemistry.

PREVIOUS WORK

McConnell (1896) first described the lithologies of the Wolverine complex and proposed a geological boundary north of Manson Creek village between the Cache Creek Group and older rocks. This boundary remains virtually unchanged (Ferri and Melville, 1988). Later work includes: Dolmage's (1927) mapping of the Finlay River district north of Manson Creek, and Armstrong's (1949) work which provided the first petrologic data and age correlations for the Wolverine suite. Muller (1961) and Tipper *et al.* (1974) mapped the southernmost part of the Wolverine metamorphic suite and published age dates. More recently, geological mapping of the Manson Creek map area by Ferri and Melville (1988) has contributed to the understanding of the Mount Bisson lithologies by strengthening the regional geological framework.

Mineral exploration near Mount Bisson began with the discovery of graphite in carbonate units within the Wolverine rocks (Halleran, 1985). Rare earth mineralization was discovered in 1986 and 1987 (mineral occurrences on the Ursa Will and Laura claims). Chevron Minerals Ltd. conducted a limited exploration program for rare earth elements in the alkalic rocks in 1988 (Halleran, 1988).

REGIONAL GEOLOGY

The Mount Bisson alkaline complex occurs within a part of the Omineca crystalline belt termed the Wolverine metamorphic suite. The rocks comprising the metamorphic suite are inferred to be Proterozoic in age, although K-Ar age determinations for the metamorphic rocks range from 69 to 43 Ma. (Tipper *et al.*, 1974). Ferri and Melville (1988) divided the Omineca crystalline belt into, (1) the Wolverine suite comprising intensely metamorphosed and deformed high-grade calcsilicate, amphibolite and granitic gneisses, which are intruded by later felsic intrusions and, (2) relatively unmetamorphosed quartzite, argillaceous quartzite and schists to the west (Ingenika Group).

The Mount Bisson complex comprises a group of diverse rock types with common mineralogical characteristics, including:

- Modal primary quartz is rarely present in the alkalic rocks.
- Modal sodic-bearing ferromagnesian minerals (*e.g.* aegirine-augite) are abundant in all alkaline rock types.
- Modal sphene and/or rutile are common to all alkaline rocks.
- Rare earth elements are abundant in several alkalic lithologies and are a major component of the allanite pegmatites.

The rocks of the alkaline complex include small intrusions (*e.g.* syenite, monzonite), mappable alkalic dikes (*e.g.* syenite), pegmatite dikes, and metamorphic rocks of the Wolverine suite characterized by a strong alkalic overprint. At Mount Bisson, these alkalic rocks are exposed at five localities over a strike length of 10 kilometres (Figure 2-9-1); they coincide with a regional aeromagnetic anomaly, and contain rare earth element minerals. Unfoliated, fine-grained quartz monzonite to quartz syenite intrusions occur throughout the region. Mapping is incomplete but there are at least four large intrusions (1 by 3 kilometres in area) and numerous smaller satelite bodies. The relationship between these intrusions and the alkalic rocks is unclear.

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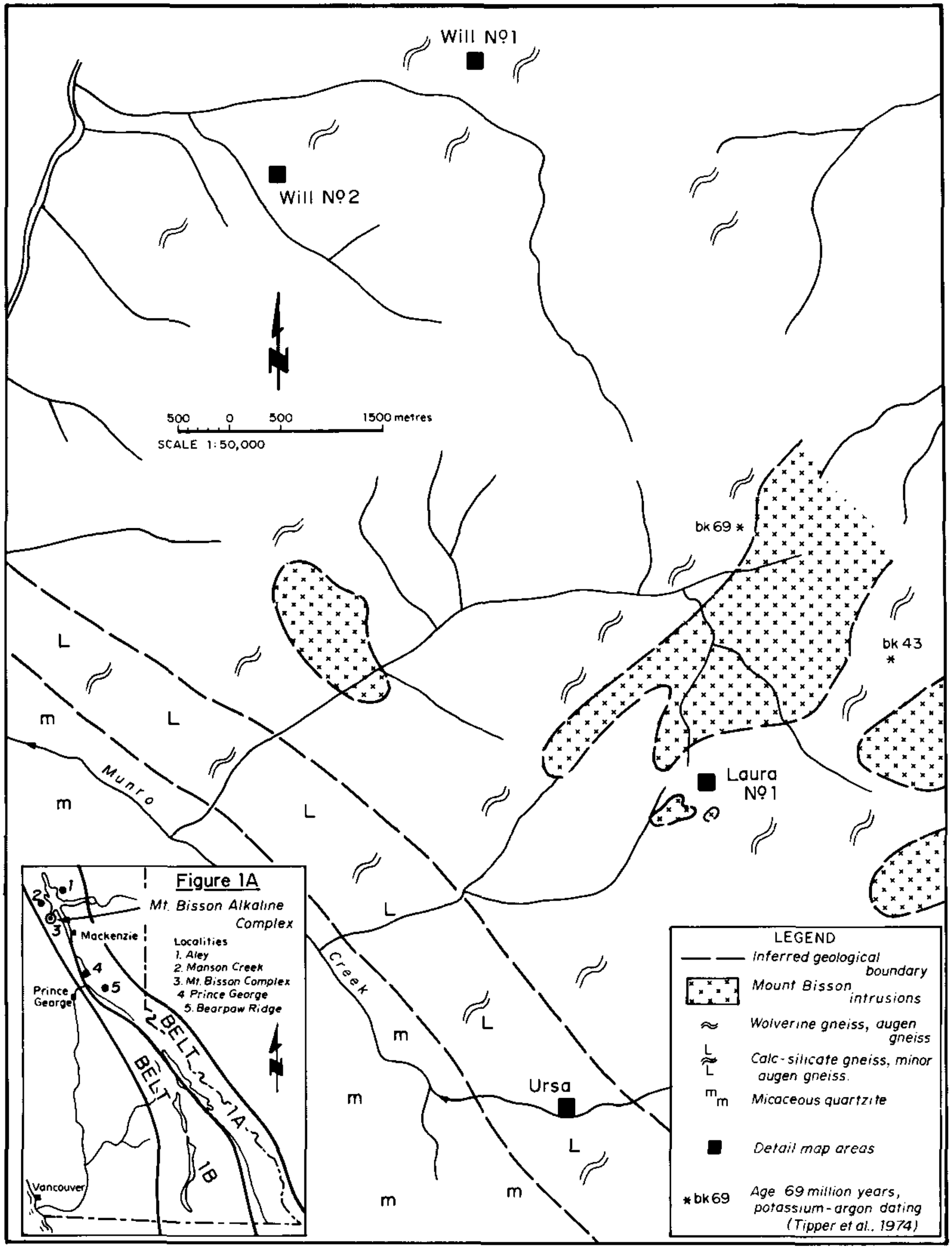

Figure 2-9-1. Geological map of the Mount Bisson area. Four occurrences of alkaline rocks include the Laura, Will (No. 1 and 2) and Ursa properties. Inset figure (1A) illustrates the location of the Mount Bisson alkaline rocks with respect to other alkaline rocks in the area. Belt 1A and Belt 1B are defined by their tectonic history and alkaline rock types (Pell, 1987). Belt 1A has subcircular to elliptical alkaline intrusions with extensive metasomatic alteration halos and which are hosted in Middle Cambrian to Middle Devonian rocks. Belt 1B alkaline intrusions are foliated, sill-like bodies, strongly deformed, metamorphosed to amphibolite facies, and hosted in Late Precambrian to Early Cambrian metasedimentary rocks.

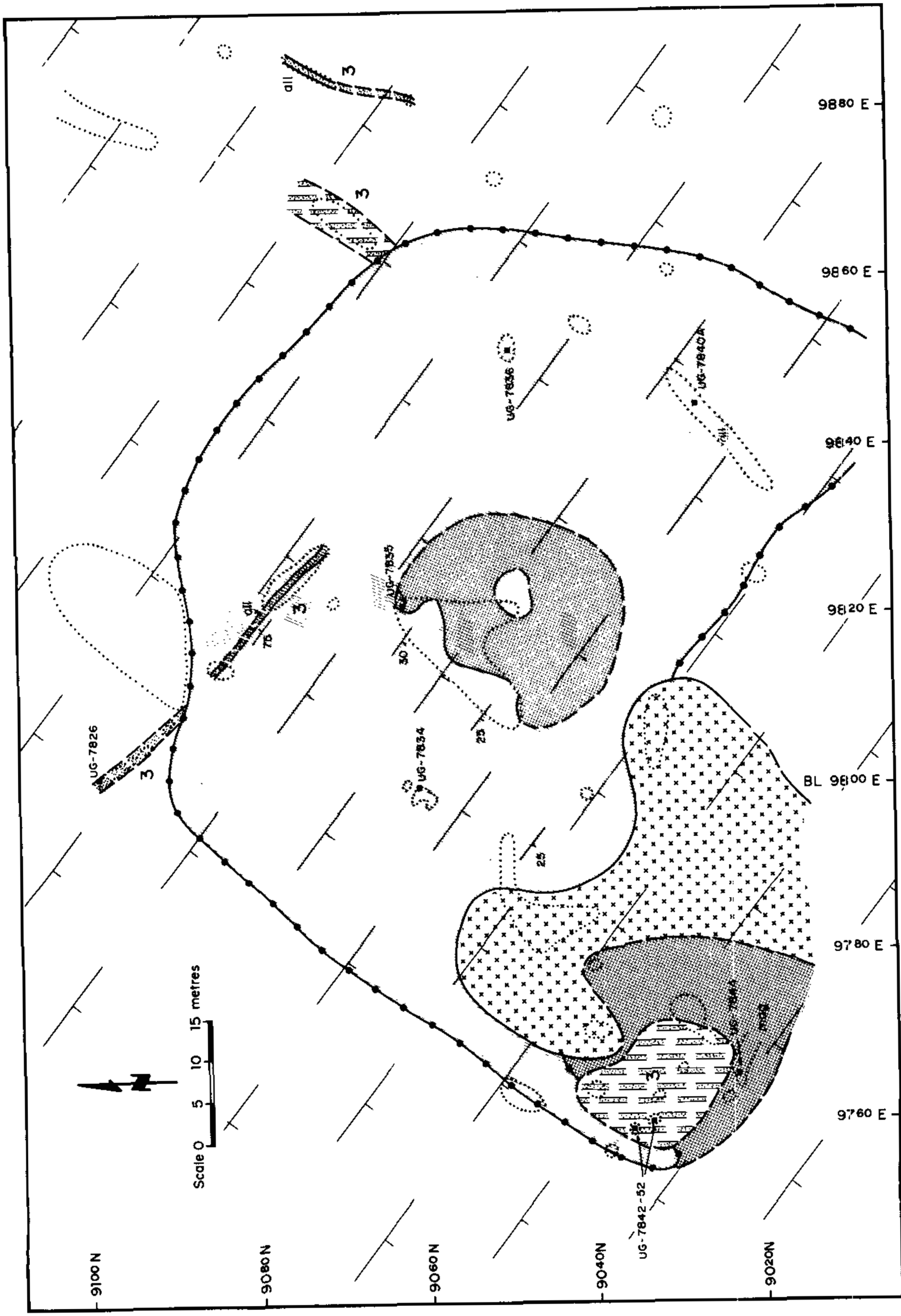

Figure 2-9-2. Detailed geological map for the Laura property. Lithologic and symbol legends are given in Figure 2-9-2A opposite.

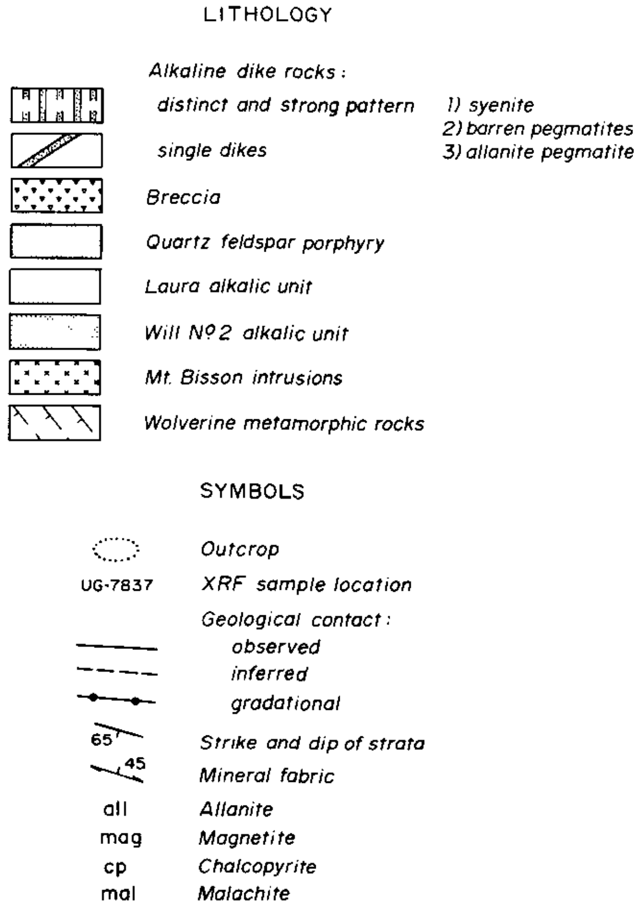

Figure 2-9-2a. Lithologic and symbol legends for Figures 2-9-2, 3 and 4.

LOCAL GEOLOGY

Four of the five localities have been mapped in detail (Halleran, 1988) and are summarized below. The fifth locality (Laura No. 2) has geology similar to that described for Laura No. 1.

LAURA NO. 1

Figure 2-9-2 is a detailed geologic map of the Laura No. 1 locality. The Laura No. 1 map area covers a series of intrusions which cut the metamorphic rocks of the Wolverine suite. The Wolverine metamorphic rocks include coarse-grained amphibolite, biotite schist and strongly foliated quartzofeldspathic gneiss. Locally, the gneisses are characterized by a metasomatic alkalic signature, here mapped as the Laura alkalic unit.

There are a variety of intrusive rock types which crosscut the structure of the Wolverine metamorphic rocks. Allanite pegmatites, 1 to 4 metres wide, are common and are enriched in rare earth elements. They have a minimum strike length of over 30 metres. Late quartz veinlets, 50 millimetres wide, cut the pegmatite. Mount Bisson rocks intrude the Wolverine suite and cut the metasomatic alkalic overprinting. No field relationships between the Mount Bisson intrusions and the pegmatite were observed.

The Laura alkalic unit (Figure 2-9-2) is a distinctive lithology comprising Wolverine metamorphic rocks, which have an alkaline character expressed by the presence of aegirine-augite and/or sphene, allanite and alkali feldspar. The map unit is massive, fine to medium grained and retains a strong fabric related to the original metamorphic fabric of the Wolverine suite. Specifically, the alkalic overprinted rocks are commonly banded on a millimetre to centimetre scale. Dark bands comprise aegirine-augite, hornblende, sphene and allanite, whereas more felsic bands are dominated by alkalic feldspar. This unit has a circular map pattern with a minimum diameter of 60 metres. The contact between the alkaline overprinting and the host Wolverine gneisses is gradational and some metamorphic lithologies (*e.g.* amphibolites) are more intensely metasomatized than others (*e.g.*, quartzofeldspathic gneisses). Furthermore, the replacement process commonly preserves the older regional structure. These observations suggest that the alkalic character is derived through preferential replacement of amphibolite gneisses of the Wolverine suite. The metasomatism may be related to a large, yet undefined, deep seated intrusion.

WILL NO. 1

The Will No. 1 map area is illustrated in Figure 2-9-3. There is little exposure and consequently the field relationships between lithologies are uncertain. The geology includes two separate aegirine-augite syenite dikes, which crosscut Wolverine gneisses and biotite schists, and several outcrops of Mount Bisson intrusion. The remaining lithology is a breccia with intrusive clasts supported by a green fine-

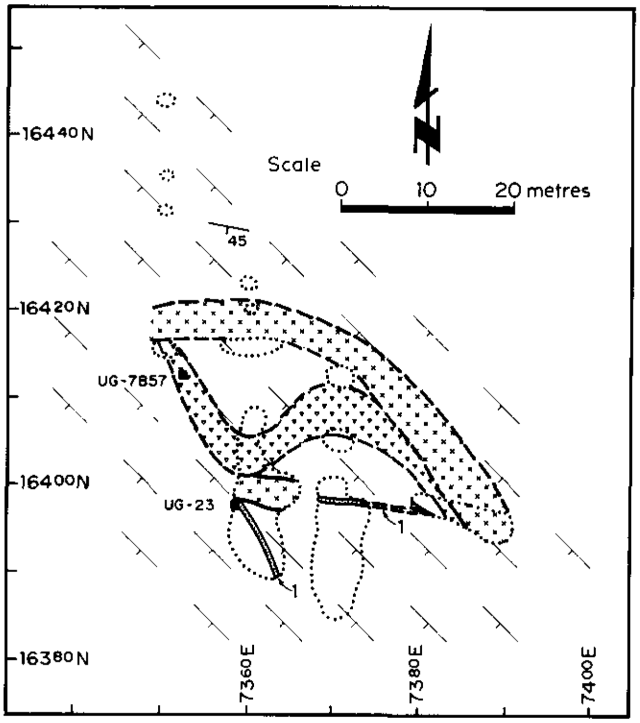

Figure 2-9-3. Detailed geological map for the Will No. 1 locality. Lithologic and symbol legends are given in Figure 2-9-2a.

grained matrix. In thin section the matrix comprises relic potassium feldspar (25 volume per cent), plagioclase (10 volume per cent), altered light yellow-green to blue-green pleochroic amphibole, trace sphene and apatite.

WILL NO. 2

The geology of the the Will No. 2 map area is shown in Figure 2-9-4. The main lithologies include: fine-grained Mount Bisson intrusions, a sequence of metasomatized Wolverine schists and gneisses (Will No. 2 alkalic unit), pegmatites, and late crosscutting alkaline dikes.

The Will No. 2 alkalic unit varies from a fine-grained, light-colored rock with a weakly developed mineral fabric to a darker, biotite-rich schist with millimetre to centimetre banding. The alkaline overprinting is differentiated from the surrounding Wolverine rocks by the presence of aegirine-augite and rare earth element bearing minerals, an increase in alkali feldspar content and a decrease in quartz content. Original metamorphic banding has been enhanced by increases in concentration of mafic and rare earth bearing minerals associated with metasomatic replacement. The alkaline overprinting is cut by syenite and barren alka- pegmatite dikes. No contact between the fine-grained Mount

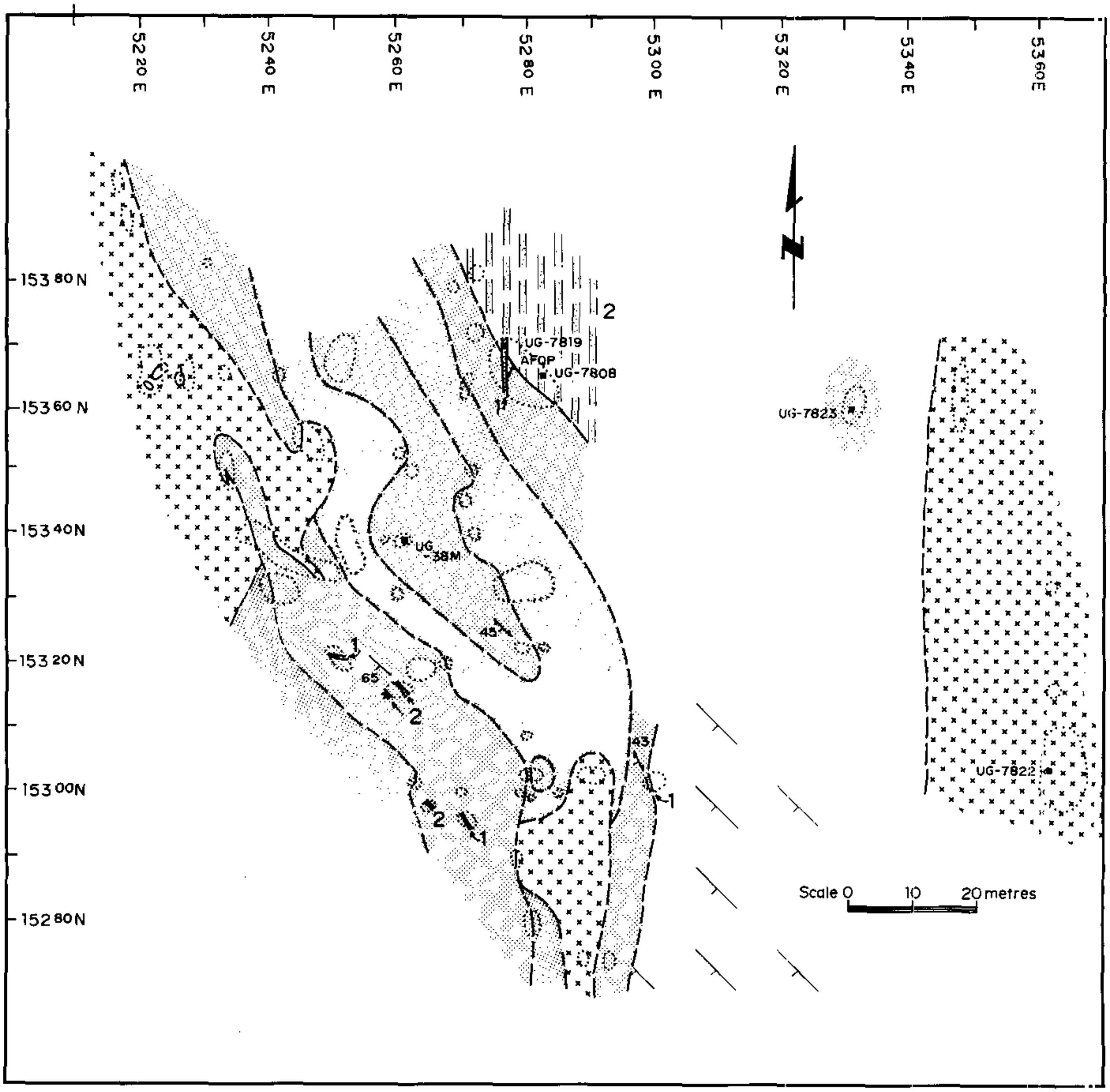

Figure 2-9-4. Detailed geological map for the Will No. 2 property. Lithologic and symbol legends are given in Figure 2-9-2a.

Bisson intrusions and the Will No. 2 alkalic unit was observed; however, angular xenoliths of metasomatized Wolverine rocks rarely occur within the intrusions.

Syenite dikes comprise two mineralogically distinct rock types: an aegirine-augite-rich (>70 volume per cent) dike and a fine-grained equigranular alkali feldspar (>90 volume per cent) dike which crosscut both the alkalic unit and pegmatites.

URSA

The Ursa showing (Figure 2-9-1) is a mylonitized, gneissic pegmatite 10 metres long and 1 to 2 metres wide. The rock comprises potassium feldspar, quartz, albite, monazite and traces of biotite and sphene. The biotite is partly altered to chlorite. This unit occurs within fine-grained phlogopite-bearing calcsilicate gneisses of the Wolverine suite. To the west, the pegmatite is truncated by a fine-grained felsic intrusion.

DESCRIPTIVE PETROLOGY

ALKALIC DIKE ROCKS

SYENITE

Three types of syenite dike occur within the Mount Bisson alkaline complex: alkali feldspar rich dikes (on the Will No. 2); aegirine-augite rich dikes (on the Will No. 1 and No. 2) and rare earth element enriched dikes (on the Will No. 2).

The alkali feldspar dikes contain 90 per cent potassium feldspar rimmed by plagioclase and only 10 per cent disseminated mafic minerals, principally aegirine-augite.

The aegirine-augite dike consists of 40 to 60 per cent, inclusion-filled aegirine-augite 1 to 15 millimetres long; 35 per cent perthite; 3 per cent sphene with rare allanite inclusions; 1 per cent euhedral apatite; and traces of magnetite, chalcopyrite, malachite and allanite. The mafic phases are concentrated in millimetre-wide bands.

The rare earth enriched dikes consist of 80 per cent intergrown, inclusion-filled aegirine-augite; 8 per cent potassium feldspar, 5 per cent apatite, 3 per cent allanite, 2 per cent sphene with traces of calcite and biotite (as inclusions in aegirine-augite). The rare earth elements reside in the allanite which occurs as intergrowths with sphene and aegirine-augite.

PEGMATITES BARREN OF RARE EARTH ELEMENTS

Quartz-feldspar pegmatites and aegirine-augite pegmatites (Figures 2-9-2, 2-9-4) are both characterized by the absence of rare earth elements. The contact relationships between them are not known; however, while the rock types commonly outcrop together, no lithologic contacts have been observed. Large xenoliths of Wolverine amphibolites commonly occur within the pegmatite bodies.

The quartz-feldspar pegmatite consists of 5 to 10-millimetre polycrystalline quartz, potassium feldspar, plagioclase (An_{27}) and trace to minor magnetite, biotite, chlorite, zircon, monazite and opaques. Rare, euhedral, zoned monazite is the only rare earth bearing mineral in this lithology.

The coarse grained aegirine-augite pegmatite comprises zoned, antiperthite (An_{23}), aegirine-augite, minor perthitic potassium feldspar, occasional elongate quartz crystals and late fracture-filling epidote. Subhedral aegirine-augite is broken and reorientated and includes plagioclase (An_{32}), euhedral sphene, hornblende and biotite.

PEGMATITES BEARING RARE EARTH ELEMENTS

The allanite pegmatites (Figure 2-9-2) are the only pegmatites with rare earth concentrations above geochemical detection limits; in several samples the allanite is so abundant that it becomes a rock-forming mineral rather than an accessory phase.

The mineralogy consists of perthite, up to 35 per cent allanite, 5 per cent sphene, plagioclase (An_{25} to An_{27}), apatite, minor to trace aegirine-augite, polycrystalline quartz, traces of pink pleochroic zircon and opaques. Subhedral to euhedral, zoned, green to brown-pleochroic, 0.3 to 20 millimetre allanite occurs with sphene and euhedral, grey-pleochroic apatite, sometimes as intergrowths. Sphene can be divided into two types: anhedral intergrowths with allanite and apatite, and euhedral crystals up to 1 centimetre long, found within the allanite mineralized zones. The latter also occur as smaller individual subhedral crystals in the feldspar-rich phases.

SECONDARY ALKALIC ROCKS

The Will No. 2 and Laura alkalic units (Figures 2-9-2 and 3) are secondary alkalic rocks and are identical except that: Will No. 2 variety has predominantly plagioclase in the felsic rock types whereas the Laura alkalic unit has potassium feldspar. Additionally, the Laura alkalic unit has better developed mineral banding.

These alkalic units are fine to medium-grained crystalline rocks with regular banding on a millimetre to centimetre scale. Commonly the original Wolverine fabric is still evident. The dark bands comprise aegirine-augite, sphene, allanite and apatite with minor hornblende (in the Laura alkalic unit). Light bands are dominanted by plagioclase (Will No. 2) or potassium feldspar (Laura unit). Euhedral sphene, apatite and allanite occur together, at times as aggregates, in the mafic bands. Minor apatite grains are also found in the felsic bands. Rare polycrystalline quartz occurs as interstitial filling.

MOUNT BISSON INTRUSIONS

This unit includes all of the fine-grained, light-colored, massive, fresh-looking aplitic intrusions; many of which have been examined only in handspecimen. The constituent minerals include quartz, plagioclase (An_{22} to An_{24}), potassium feldspar, biotite, chlorite, traces of magnetite, allanite, apatite and zircon. Plagioclase occurs as cloudy microphenocrysts and as smaller grains which exhibit undulatory extinction. Biotite is locally altered to chlorite and in some satellite bodies (*e.g.* Will No. 2) defines the rock fabric.

ECONOMIC GEOLOGY

The primary economic significance of the Mount Bisson alkaline complex is the occurrence of the light rare earth elements, cerium, lanthanum, neodymium, samarium, and praseodymiun in the minerals allanite, cerorthite, and monazite. The minerals are often very coarse (5 to 10 millimetres). Heavy rare earth elements are found in concentrations of hundreds of parts per million. Niobium is found at concentrations as high as 0.8 per cent. At this time two major rare earth deposit-types have been found within the complex: pegmatites, 1 to 4 metres wide and over 30 metres long, enriched in rare earth elements (combined 0.3 to 14.0 per cent, Table 2-9-1) and the Will No. 2 and Laura alkalic units with concentrations of 0.07 to 0.64 per cent light rare earth metals over widths of 1 to 2 metres and tens of metres in area (Table 2-9-1). In addition, rare earths have been found in a syenite dike (0.80 to 4.26 per cent, Table 2-9-1) and a mylonized gneissic pegmatite (2.1 per cent, Table 2-9-1).

The alkali syenite environments are characterized by the highest overall light rare earth content. Independent light rare earth element minerals are formed more frequently here than in other igneous rocks. This is very important for recovery of the rare earths as some of them are contained in the apatite, zircon, pyroxenes and other rock building minerals.

TABLE 2-9-1
RARE EARTH ANALYSIS SAMPLING DETAILS

Unit	Sample type	Per cent REM*	Description
AP	representative	0.30 to 0.64	samples of main pegmatite bodies (5 samples)
AP	representative	5.50 to 14.50	samples of mineralized zones in pegmatites (3)
SA	representative	0.14 to 0.55	numerous grab samples (6)
SA	Chip	0.13 to 0.64	Chip samples across 1.6 metres and 1.0 metre (2)
RED	representative	0.80 to 4.26	a sample of the main body and of the mineralization
URSA	representative	2.10	a sample of the monazite mineralization

AP = allanite pegmatite
SA = secondary alkalic unit (Will No. 2 and Laura)
RED = rare earth enriched dike
URSA = mylonitized pegmatite with monazite
REM* = cerium, lanthanium, neodymium, samarium and praseodymium
Preliminary data from Halleran (1988). Analysis by ACME using ICP.

CONCLUSION

The alkalic rocks on Mount Bisson include primary crosscutting dikes, pegmatites, and a secondary metasomatic replacement of Wolverine amphibolite gneisses. Where the original Wolverine gneisses have been been metasomatized, the alkalic overprinting is recognized and made a mappable unit by an increase of aegirine-augite, sphene, allanite, apatite and feldspar, and a decrease in quartz, hornblende and biotite. This secondary alkalic overprinting may represent a preferential replacement process associated with a deep seated, unexposed alkalic intrusion.

The youngest igneous events are represented by a single alkali feldspar syenite dike (included in the Alkaline Dike Rocks, No. 1) and the Mount Bisson intrusions which clearly intrude the secondary alkali units and crosscut the other dikes. In general, however, the temporal relationships of the dikes and pegmatites to the secondary alkalic unit are unclear. The emplacement of the dikes may have occurred before or after the metasomatic alteration, or been in part responsible for the alkalic replacement. The rotated amphibolite xenoliths in the pegmatites indicate magmatic injection into a more or less solid country rock.

The pegmatites are unique in that coarse allanite is a major constituent associated with high concentrations of light rare earth elements. Otherwise they contain similar rare earth element bearing minerals to the secondary alkalic units.

Major, minor, trace and rare earth element concentrations are being determined for 25 representive rock samples. Future work will involve electron microprobe studies of all phases to determine the nature of rare earth element zonation. This information will be used to interpret the crystallization history of the alkalic bodies, to characterize the rare earth element mineralization process, and develop a metallogenic model for the deposits.

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