THE GEOLOGY OF THE AVERILL PLUTONIC COMPLEX, GRAND FORKS, BRITISH COLUMBIA*
(82E/9W)

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KEYWORDS: Economic geology, Averill plutonic complex, Franklin mining camp, ultramafic, alkalic, syenite, platinum, palladium.

INTRODUCTION

The Averill plutonic complex is an informal name given to a suite of alkalic intrusive rocks exposed in the Franklin mining camp 70 kilometres north of Grand Forks, British Columbia (Keep and Russell, 1988). The complex comprises syenites to pyroxenites and is no younger than Eocene in age. The alkaline character of the rocks, the probable age of the intrusions and their regional setting suggest the complex is correlative to the Coryell intrusions centred around Grand Forks.

The 1988 field season saw the completion of a 1:5000-scale map of the Averill complex begun last year. This entailed extension of the field mapping and resulted in improved definition of lithologic contacts and understanding of their nature. The map presented here (Figure 1-3-1) is reduced from the final 1:5000 map produced through the two field seasons. This report discusses the petrology of the major map units and postulates an origin for the intrusive rocks.

PREVIOUS WORK

The Franklin mining camp has been known for its mineral potential since the early 1900s. C.W. Drysdale of the Geological Survey of Canada first mapped the area in 1911 (Drysdale, 1915) at which time most of the camp had already been extensively prospected. Drysdale's work was the first comprehensive study of the area and little subsequent mapping has been published.

In 1965, Franklin Mines Ltd. re-examined the property (Lisle and Chilcott, 1965) and in 1968 Newmont Mining Corporation of Canada undertook a regional study in the area (Norman, 1969). In 1986 the property came under the control of Longreach Resources Ltd. which completed a surface and underground drilling program. In the summer of 1987, Placer Dome Inc. began a regional exploration program in the area of the old Franklin camp which involved surface mapping, drilling and soil and heavy mineral geochemical sampling (Pinsent and Cannon, 1988).

REGIONAL GEOLOGY

The Averill plutonic complex lies at the southern end of the Omineca crystalline belt, which in southern British Columbia comprises basement gneisses, deformed and metamorphosed rocks of the North American continental margin sequence, allochthonous rocks of the Intermontane superterrane and Paleozoic, middle Jurassic, late Cretaceous and Paleogene granitic rocks, all of which have been affected by "widespread crustal extension superimposed on pre-existing compressive structures" (Parrish *et al.*, 1987). In the Grand Forks area there are also two late dyke swarms and late north-trending normal faults (Granby fault, Kettle River fault) sympathetic to structures related to Eocene extension in the Republic graben.

The oldest rocks exposed in the Franklin camp are Permo-Carboniferous tuffs, tuffites and sandstones of the Franklin (Anarchist) Group (Drysdale, 1915; Pinsent and Cannon, 1988) which are often difficult to distinguish in the field. These rocks have been intruded by Mesozoic granites and granodiorites (Figure 1-3-2). The Averill plutonic complex in turn intrudes the Mesozoic plutons and is unconformably overlain by conglomerates and fanglomerates of the Kettle River Formation, interpreted to be graben-fill sediments (Little, 1957). The end of Kettle River deposition is marked by an extrusive volcanic phase locally referred to as the McKinley rhyolite. Trachytes of the Marron Formation are the youngest rocks in the area, and lie disconformably over the Kettle River rocks (Pinsent and Cannon, 1988).

LOCAL GEOLOGY

The Averill plutonic complex (Figure 1-3-1) comprises seven intrusive phases (Units 1 to 7). Units 1 to 4 are the oldest and are distinguished on the basis of colour index. The lithologies grade from clinopyroxenite (Unit 1), through monzogabbro and monzodiorite (Units 2 and 3 respectively), to monzonite (Unit 4). Unit 5 is an alkaline syenite which cuts Units 1 to 4. Two late phases of dykes (Units 6 and 7) cut Units 1 to 5. The dykes are trachyte and plagioclase-rich porphyry respectively.

The boundaries between Units 1 to 4 outline a concentric zoning pattern which predates intrusion of the syenite of Unit 5 which is comprised of a coarsely crystalline core, with alkali feldspar phenocrysts 3 to 8 centimetres in length, mantled by a finer grained syenite. Brecciation of surrounding lithologies, especially Units 1 and 2, is evident where the syenite has intruded the ultramafic/alkalic suite. Syenite also occurs as ubiquitous veins and dykes within the older rocks. The late dykes cut Units 1 to 5 but do not cut each other. These dykes trend north to north-northeast, parallel to the trend of the Republic graben in northern Washington, immediately south of Grand Forks (Little, 1957).

* This project is a contribution to the Canada/British Columbia Mineral Development Agreement.
British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

Two smaller fault-bounded intrusions outcrop east of the main alkalic body (Pinsent and Cannon, 1988). The zoning in these smaller bodies is poorly developed, with Units 2 and 4 commonly missing from the sequence.

In the easternmost outlier (covered by the Tenderloin claim) the pyroxenite is poorly exposed and monzonite is missing from the sequence. Most of the claim area is underlain by monzodiorite and syenite with a coarsely crystalline syenite core (Figure 1-3-1). Both the trachyte and the plagioclase porphyry dykes intrude this area, although they are not as abundant as in the main part of the complex.

The second outlier (covered by the Maple Leaf claim) is comprised mainly of finely crystalline syenite, with a weakly developed rim of pyroxenite and monzodiorite (Figure 1-3-1) in contact with hornfelsed sediments of the Franklin Group. A dyke of pegmatitic syenite in this area is mineralized with chalcopyrite containing the highest concentrations of platinum and palladium found in the Franklin camp (Hulbert, personal communication, 1987).

PETROLOGY

Petrography of the Averill plutonic rocks is summarized in Table 1-3-1. Electron microprobe analyses of representative pyroxenes from all of the units are presented in Table 1-3-2 and the variation in composition is plotted in Figure 1-3-3.

PYROXENITE (UNIT 1)

The pyroxenites consist of primary augite, biotite, minor apatite, sphene, iron oxides and sulphides, and locally individual grains of alkali feldspar. Hornblende and biotite occur as secondary minerals and there is a very close spatial associ-

TABLE 1-3-1
MODAL MINERAL OCCURRENCE

Unit No.	Sample No.	Primary Mineralogy Aug	Hb	Bt	K	Pe	Pl	Rh	Secondary Mineralogy Sp	Ap	Op	Q	Cc	Ser
5	88-2	x	x	x	x		x		x	x	x			x
5	88-4(i)	x			x	x	x	x	x	x	x			x
5	88-4(2)	x			x	x	x	x	x	x	x			x
4	88-7	x	x	x	x		x			x	x	x		x
3	88-8	x	x	x	x		x		x	x	x			x
2	88-10(i)	x	x	x	x		x			x	x		x	x
2	88-10(2)	x	x	x	x		x			x	x		x	x
1	88-11	x		x					x	x				
5	88-13	x		x	x	x		x	x	x	x		x	x
1	All	x		x	x						x			
2	182	x	x	x	x			x	x	x	x			
3	635	x		x	x		x			x	x			x
3	AA1C	x	x	x	x	x				x	x			

Aug = augite; **Hb** = hornblende; **Bt** = biotite; **K** = alkali feldspar; **Pe** = perthite; **Pl** = plagioclase; **Rh** = rhoenite; **Sp** = sphene; **Ap** = apatite; **Op** = opaques; **Q** = quartz; **Cc** = calcite; **Ser** = sericitic alteration.

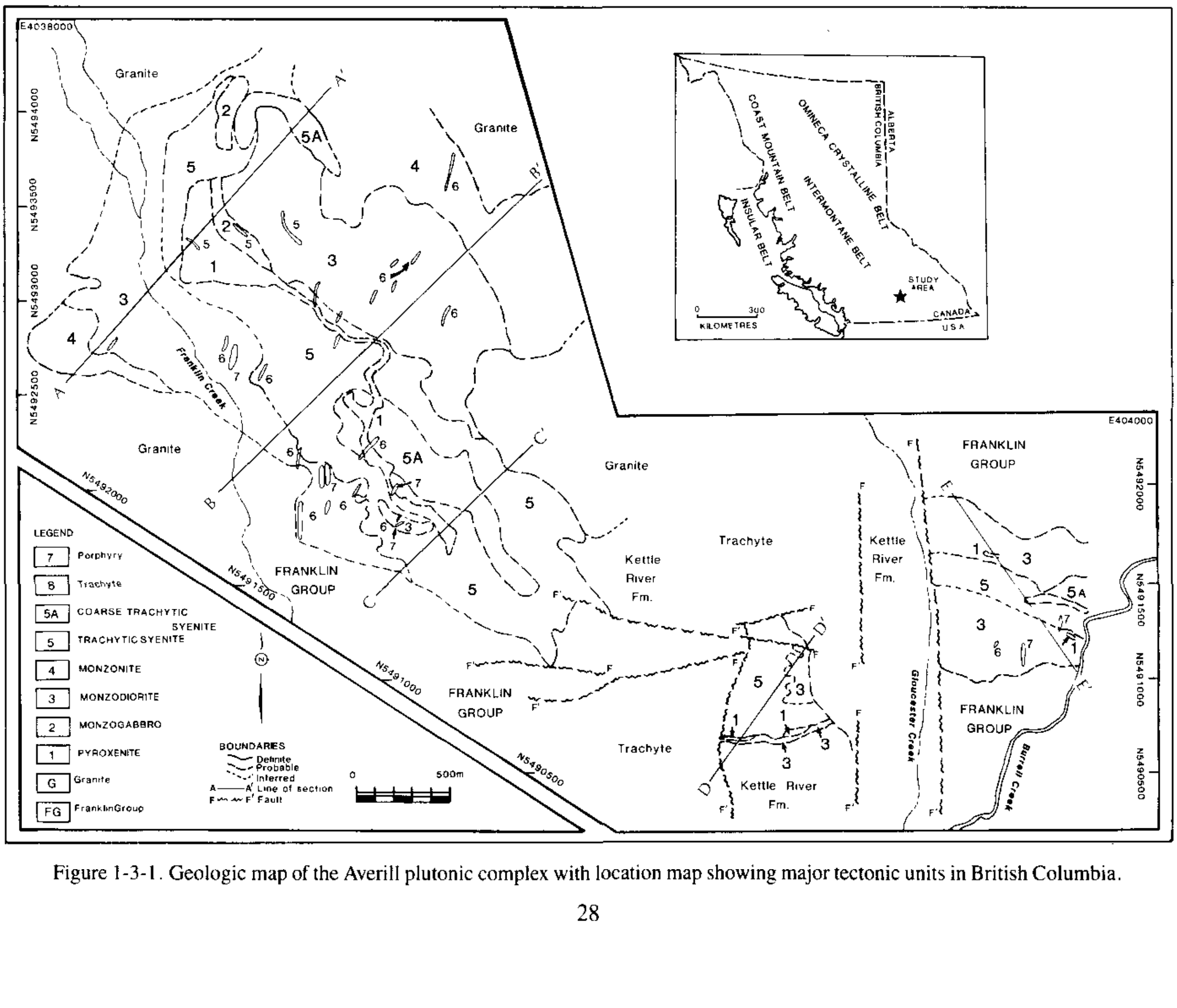


Figure 1-3-1. Geologic map of the Averill plutonic complex with location map showing major tectonic units in British Columbia.

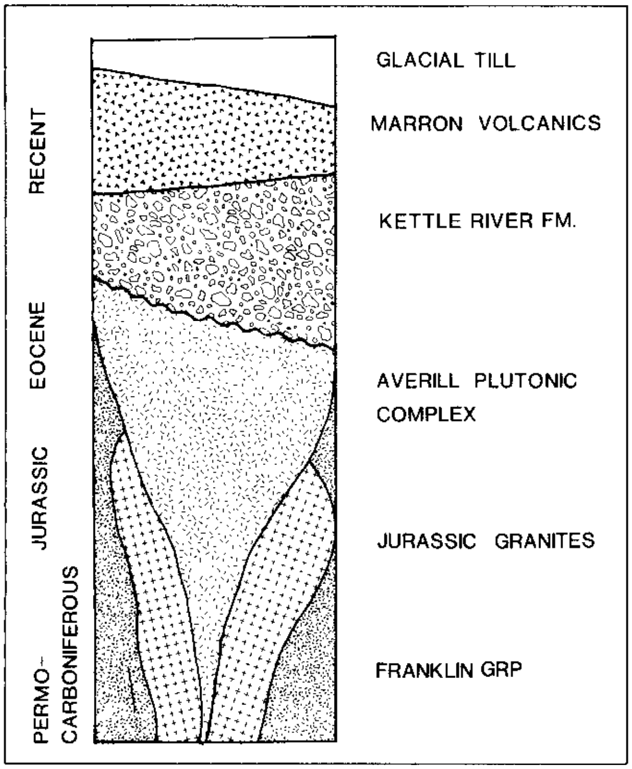


Figure 1-3-2. Stratigraphy of the Franklin mining camp.

ation between all mafic minerals. Two types of pyroxenite are recognized in the field. In general the pyroxenite comprises very fresh, well-formed augite crystals but in some outcrops pyroxene is completely replaced by biotite. Biotite-rich pyroxenite is commonly found near contacts with the syenites of Unit 5, and is thought to result from the hydrothermal effects of its intrusion.

Exposures of pyroxenite are somewhat limited and are mainly confined to pits and adits that have been driven through the syenite unit. Large outcrops, where they occur, are usually heavily vegetated and weathered.

MONZOGABBRO (UNIT 2)

The monzogabbro is identified in the field as having between 60 and 90 per cent mafic minerals, and there is a gradational boundary between it and Units 1 and 3. The mineralogy of this unit is essentially the same as Unit 1, consisting of primary augite, biotite, apatite, sphene, alkali feldspar and iron oxides and sulphides. The alkali feldspar occurs as interstitial grains, and veins of alkali feldspar and sometimes calcite are visible in thin section. Hornblende occurs as a secondary mineral. Variation in composition of the augites is very similar to Unit 1 (Figure 1-3-3).

MONZODIORITE (UNIT 3)

This unit is the most abundant of the four units comprising the ultramafic/alkalic suite and is clearly gradational into both Units 2 and 4. The mineralogy is similar to Units 1 and 2 although the proportion of mafic minerals, by definition, is between 30 and 60 per cent. Augite is ubiquitous, and biotite and hornblende are common. Only a few samples have sphene, but apatite, iron oxides and sulphides are found in all samples. All of the alkali feldspar is interstitial.

MONZONITE (UNIT 4)

The monzonite unit is the most felsic of the ultramafic/alkalic sequence and is identified as having between 0 and 30 per cent mafic minerals. It has a gradational boundary with Unit 3 on one side and on the other side the contact with

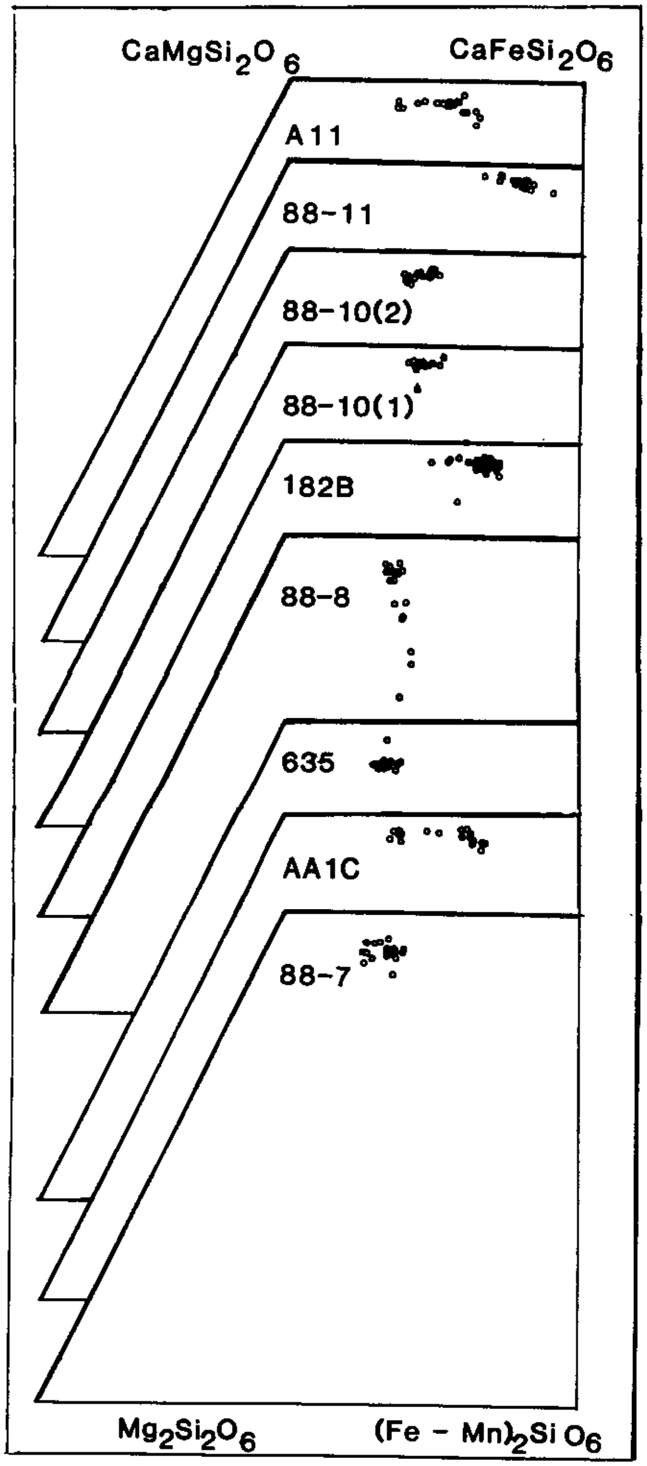
TABLE 1-3-2
PYROXENE ANALYSES

Representative pyroxene analyses of the plutonic rocks. The weight per cent of oxides in the pyroxenes are followed by the calculation of the number of ions in each grain analysed. Where there is sufficient chemical variation in a sample, both the most magnesium-rich (Mg) and the most iron-rich (Fe) analyses are shown.

Sample No.	**A11 (Mg)**	**A11 (Fe)**	**182 (Mg)**	**182 (Fe)**
Unit No.	**1**	**1**	**2**	**2**
SiO_2	52.28	49.73	48.41	48.10
TiO_2	0.31	0.70	1.07	1.19
Al_2O_3	0.94	2.38	3.33	3.63
FeO	7.34	10.68	13.03	13.31
MnO	0.35	0.35	0.44	0.42
MgO	14.17	11.77	10.49	9.88
CaO	22.93	22.95	22.49	22.47
Na_2O	0.92	0.96	0.97	1.17
Total	99.24	99.52	100.22	100.17
No. of ions on the basis of 6 oxygens				
Si	1.96	1.90	1.86	1.84
Ti	0.01	0.02	0.03	0.03
Al	0.04	0.11	0.15	0.21
Fe	0.23	0.34	0.42	0.40
Mn	0.01	0.01	0.01	0.02
Mg	0.79	0.67	0.60	0.60
Ca	0.92	0.94	0.93	0.90
Na	0.07	0.07	0.07	0.07
Total	4.03	4.06	4.07	4.07

Sample No.	**635 (Av)**	**88-7 (Av)**	**88-2 (Mg)**	**2 (Fe)**
Unit No.	**3**	**4**	**5**	**5**
SiO_2	51.28	52.46	51.60	47.55
TiO_2	0.15	0.00	0.00	0.00
Al_2O_3	1.70	2.62	2.31	4.69
FeO	7.57	8.33	13.38	16.11
MnO	0.47	0.45	0.51	0.62
MgO	14.81	14.48	9.83	7.57
CaO	22.91	20.89	20.30	21.41
Na_2O	0.52	0.65	2.34	1.42
Total	99.56	99.88	100.27	99.37
No. of ions on the basis of 6 oxygens				
Si	1.93	1.95	1.86	1.96
Ti	0.00	0.00	0.00	0.00
Al	0.08	0.11	0.22	0.10
Fe	0.24	0.26	0.53	0.43
Mn	0.02	0.01	0.02	0.02
Mg	0.82	0.80	0.44	0.56
Ca	0.91	0.83	0.90	0.83
Na	0.04	0.05	0.11	0.17
Total	4.04	4.01	4.08	4.07

The microprobe analyses of pyroxenes were obtained on a Cameca SX-50 microprobe at The University of British Columbia. The operating conditions were: (i) accelerating voltage of 15kv, (ii) beam current of 20na (iii) count times of 10 seconds per element. Concentrations of eight major element oxides were measured and the structural formula for the data was reduced using the FORMULA-1 program developed by Dr. J.K. Russell and associates at The University of British Columbia (Mäder *et al.*, 1988).



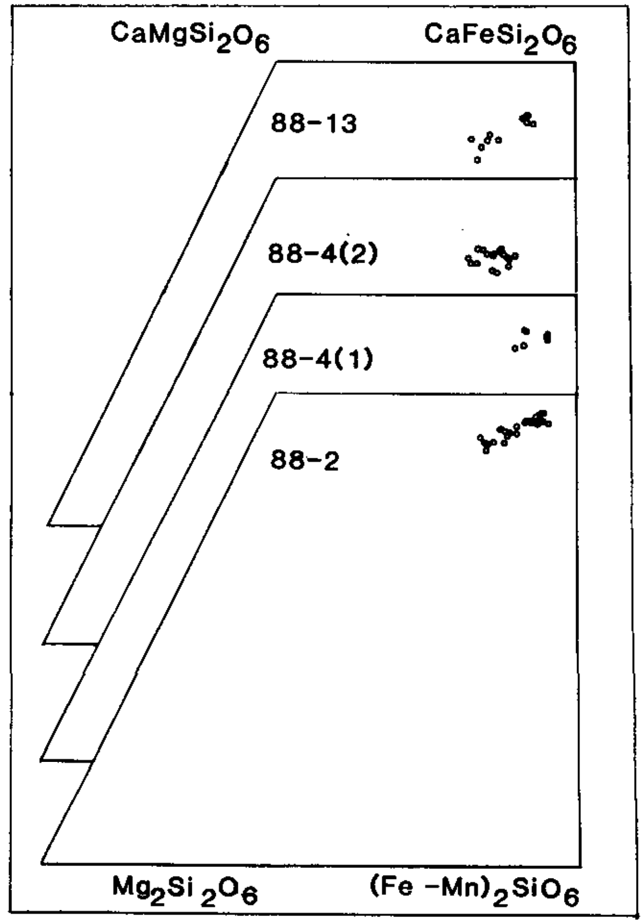


Figure 1-3-3. Composition variation of the pyroxenes in (a) the syenite series and (b) the ultramafic/alkalic series, grading from pyroxenite at the top to monzonite at the bottom. Samples 88-2, 4(i), 4(2) and 13 are syenites; 88-7 is a monzonite; 88-8, AA1C and 635 are monzodiorites; 88-10(i), 10(2) and 182 are monzogabbros; and 88-11 and A11 are pyroxenite samples.

Mesozoic granodiorites is well defined. The monzonites comprise augite, hornblende, biotite, apatite, orthoclase, and minor plagioclase and quartz.

TRACHYTIC SYENITE (UNIT 5)

Both the coarse and fine-grained syenites are characterized by a very well-developed trachytic texture which does not seem to define any coherent pattern. The individual laths of alkali feldspar vary between 1 and 8 centimetres in length. Coarse-grained syenites are defined as having feldspar laths greater than 3 centimetres long. The more coarsely crystalline material is confined to a narrow central core. Mafic minerals such as augite, hornblende, biotite, sphene, apatite and iron oxides and sulphides are present only in minor amounts, as interstitial grains. In some of the coarser material there are large grains of a mineral which appears to be garnet or rhoenite; plagioclase and perthite have also been identified. In the northernmost part of the area the coarse-grained core is not mantled by finer grained syenite but is in direct contact with Units 3 and 4.

TRACHYTE (UNIT 6) AND PLAGIOCLASE PORPHYRY (UNIT 7)

These units represent two later dyke phases which intrude the alkalic suite but have no interaction with each other. They are relatively unimportant although the porphyry does contain minor pyrite and chalcopyrite. There is a possibility that the trachyte may be related to the Marron volcanics which cap peaks in the area, but there is no visible contact between the two within the Franklin camp.

MINERALIZATION

Three styles of mineralization were first recognized in the Franklin camp by Drysdale (1915). These are:

(1) Platinum and palladium-bearing chalcopyrite mineralization associated with the pyroxenite phase (Unit 1) of the ultramafic sequence.

(2) Contact metamorphic skarn deposits which occur where rocks of the Franklin Group have been cut by later intrusions.

(3) "High-grade" precious and base metal mineralization associated with a later suite of quartz veins.

Only the first of these styles is seen in the Averill complex. Pyrite and chalcopyrite, together with malachite and azurite staining, are commonly found in the pyroxenite at or near contacts with syenite. These contacts are relatively common as the whole area is cut by veins and dykes of syenite. The association of platinum and palladium with copper mineralization derived from the syenite intrusion is also manifest in the results of soil geochemical surveys, where platinum, palladium and copper anomalies are closely associated and all three are restricted to the outcrop area of the syenite (Pinsent and Cannon, 1988).

CONCLUSIONS

The Averill plutonic complex consists of a mineralogically gradational ultramafic/alkalic pluton ranging in composition from pyroxenite to monzonite. The pyroxenite is thought to represent the core of the pluton with the composition becoming less mafic away from the centre. Shortly after emplacement the ultramafic sequence was intruded by a large body of syenite. This intrusion must have occurred when at least the inner parts of the concentrically zoned pluton were relatively cool, as the syenite clearly brecciates the pyroxenites.

The alkalic suite is cut by two later dyke swarms and is unconformably overlain by conglomerates and rhyolites of the Kettle River Formation. Above the Kettle River rocks are trachytes of the Marron Formation but there is no visible contact between the Coryell intrusions and the Marron in the Franklin camp.

CORRELATION TO THE CORYELL

Units 1 to 5 have similarities, both chemically and physically, to rocks of the nearby Coryell batholith. Unit 5 has identical mineralogy to known bodies of Coryell syenite and also has a similar regional setting. (Daly, 1912; Drysdale, 1915; Little, 1957, 1963). The Coryell intrusions have been dated as being between 54 and 60 Ma (Baadsgaard *et al.*, 1961).

ACKNOWLEDGMENTS

Funding for this study was provided by the Canada/British Columbia Mineral Development Agreement and Natural Sciences and Engineering Research Council operating grant A0820 to J.K. Russell. Logistical support was given by Placer Dome Inc., and by David and Diane Onions.

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