GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 65-26

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D. K. Norris, R. D. Stevens, and R. K. Wanless

Price, 75 cents

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Price subject to change without notice

ROGER DUHAMEL, F.R.S.C.
Queen's Printer and Controller of Stationery
Ottawa, Canada
1965

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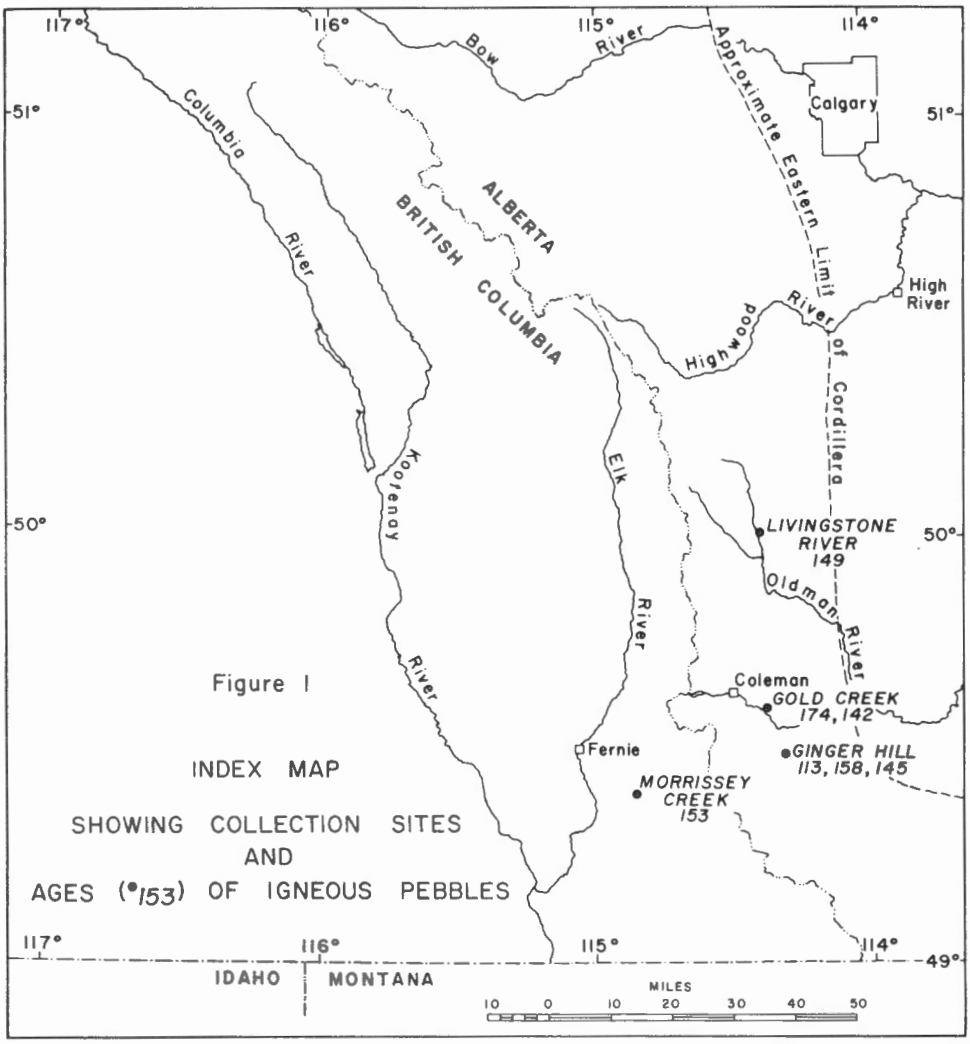
ABSTRACT

Seven igneous pebbles from the McDougall-Segur horizon of the Lower Cretaceous Blairmore Group and Crowsnest Formation of the southeastern Canadian Cordillera yielded K-Ar whole rock ages ranging from 113 to 174 m.y. Palaeontological evidence would suggest that the age of the McDougall-Segur and associated strata is Albian (100 - 106 m.y.); the radiometric ages of the included pebbles are, therefore, compatible with the stratigraphic position of the conglomerate.

The measured ages are taken to indicate a series of igneous events throughout the Jurassic and early Lower Cretaceous. The ages, the relatively unweathered condition of the pebbles and their association with cherts and quartzites suggestive of Palaeozoic and late Precambrian formations, support the postulate that they were derived from an actively uplifting terrane west of the area of deposition, possibly on the site of the present Purcell and Selkirk Mountains.



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K-Ar AGE OF IGNEOUS PEBBLES IN THE McDOUGALL-SEGUR CONGLOMERATE, SOUTHEASTERN CANADIAN CORDILLERA*

INTRODUCTION

Igneous pebbles are known to occur in conglomerates of the non-marine Lower Cretaceous Blairmore Group of the southeastern Canadian Cordillera. The provenance and geological age of these pebbles are factors that must be considered in the interpretation of tectonic events affecting the Cordillera. In order to identify or at least localize the source area of the pebble-bearing conglomerates and to provide evidence of the geological age of the pebbles it was decided to test the possibility of utilizing K-Ar whole rock age measurements in conjunction with petrography and field relations.

Although it seemed most probable that the pebbles originated from a highland area to the west of their present location (Anderson, 1951), the possibility of a Precambrian source southwest of the region (Leech, 1962) or even from the shield areas of the continent could not be completely discounted.

The pebbles are located within Lower Cretaceous beds and therefore a minimum age limit of 100 m.y. is placed upon them. The upper limit is uncertain but could most probably be assumed to be Mesozoic, i.e. less than 225 m.y. if the source was to the west, or Upper Proterozoic if they were derived from the east or southwest. Any indications of ages less than 100 m.y. would be evidence for significant argon loss subsequent to deposition in the Blairmore Group, while ages of 100 m.y. might indicate metamorphic re-setting of the K-Ar 'clock' at the time of deposition of the Blairmore rocks. Ages greater than 100 m.y. and less than 225 m.y. may result from partial loss of argon or may represent the true age of the source rocks, although a more complex history cannot be ruled out. In either case, a close grouping of ages would be indicative of a common provenance and history.

DEFINITION OF THE McDOUGALL-SEGUR CONGLOMERATE

The McDougall-Segur horizon was defined by Hume (1938, p. 12) to include a poorly defined sandstone and shale interval, up to nearly 200 feet thick, in the Blairmore Group of the northern part of the Turner Valley oil field. According to Hume, part of the McDougall-Segur may be a conglomerate in places, with black chert and quartzite pebbles predominant, but containing some pebbles of igneous origin. The type section is in the Turner Valley field in the New McDougall-Segur

*The authors are listed alphabetically and are jointly responsible for presentation and conclusions. Field investigations were by D. K. Norris who also made the stratigraphic interpretations. Laboratory studies and petrographic descriptions were by R. D. Stevens and R. K. Wanless.

No. 1 well (lsd. 14, sec. 12, twp. 20, rge. 3, W. 5th mer.; Oil and Gas Conservation Board, Schedule of Wells, 1949).

An igneous-pebble-bearing conglomerate was reported from near the top of the Blairmore Group as early as 1917 (Rose, 1917, p. 110) in outcrop in the York Creek area near Coleman, Alberta. Since that time numerous occurrences have been described in the southeastern Cordillera (see Norris, 1964, p. 521).

Because igneous pebbles have been observed or reported at only one stratigraphic level in any given unfaulted section of the Blairmore Group or equivalent strata, they would appear to be regionally diagnostic elements for the McDougall-Segur interval. As indicated by Hume (idem), the associated sandstones and shales within the zone and the coaly beds at the base are not persistent within the Turner Valley field and therefore cannot be expected to serve as reliable markers beyond the limits of the field. It is therefore proposed to extend the term McDougall-Segur to include all those late Lower Cretaceous horizons containing igneous pebbles, whether in outcrop or in the subsurface, throughout the southeastern Canadian Cordillera.

LITHOLOGY OF THE CONGLOMERATE

The McDougall-Segur conglomerate is polymictic, with pebbles, cobbles, and occasionally boulders of grey chert, grey, pink, and green quartzite and igneous rocks set in a greenish grey, arkosic sandstone matrix. Other pebbles include locally derived olive grey siltstone and feldspathic, volcanic conglomerate. Well indurated fragments larger than the granule grade are commonly subrounded to rounded and characteristically are not deeply weathered. Sorting of the coarser grades is generally poor; crossbedded sandstone lenses with stringers of pebbles are subordinate where the conglomerate is well developed and are predominant where the conglomerate interfingers with, and grades laterally into sandstone and siltstone. Many pebbles show pitting at their points of mutual contact. They are for the most part moderately fresh, although a few deeply weathered igneous pebbles were noted.

The maximum observed diameter of the ten largest pebbles at nine localities in the southeastern Cordillera south of Bow Valley ranged from 2.3 to 9.3 inches. Grey quartzite and igneous pebbles were commonly the largest.

The matrix is commonly a chloritic quartz-chert-feldspar sandstone, the most abundant feldspars being sodic plagioclase, and variably sericitized and kaolinized orthoclase. The clasts are characteristically angular to subangular, from 0.1 to 0.3 mm in maximum dimension, and commonly cemented with chlorite. The larger fragments are often poorly cemented in the matrix so that they strew the hillsides below the outcrops.

STRATIGRAPHIC RELATIONS AND AGE

The McDougall-Segur conglomerate has been observed or reported within the upper part of the Blairmore Group from within the Crowsnest Formation from about the latitude of Clearwater River (Beach, 1942, p. 9). It occurs within

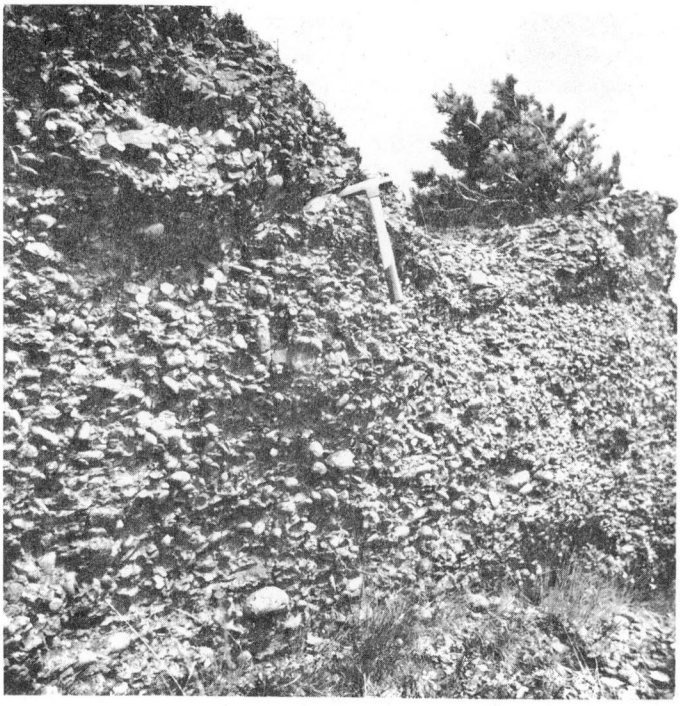

Plate 1. The McDougall-Segur Conglomerate, Ginger Hill, Alberta. (Note pitting of some pebbles and crude cross-lamination.)

sanidine- and garnet-rich arkoses of Crowsnest Formation as well as in arkosic sandstones typical of the uppermost part of the Blairmore Group. Beyond the erosional or depositional limit of Crowsnest rocks, the igneous-pebble bearing horizon occurs within arkosic sandstones near the top of the Blairmore Group. It would appear to represent a late Lower Cretaceous time surface and as such would be invaluable in demonstrating the temporal equivalence of Crowsnest Formation with part of the upper Blairmore Group.

The conglomerate occurs as localized deposits of chert-quartzite-igneous pebbles and cobbles. It averages about 25 feet thick and has a maximum observed thickness of 142 feet measured on the divide between Loomis and McPhail Creeks, near the headwaters of Highwood River. It is rarely traceable along strike for more than 100 yards as it interfingers with and grades laterally into coarse-grained, arkosic sandstone.

The McDougall-Segur is assigned to the Albian because of its association with strata containing the "upper flora" of the Blairmore Group, the earliest rich dicotyledonous flora of the non-marine Lower Cretaceous series of the southeastern Canadian Cordillera. Dawson (1886, p. 88 and Dawson's field note book no. 2 for 1883,

pp. 43 and 46) collected this flora on what is now named Slacker Creek approximately 15 feet stratigraphically below the conglomerate. On Ginger Hill (Plate I), Cladophlebis alberta (Dawson) Bell, a prominent constituent of this flora not known with certainty from older beds was collected by one of the writers (D. K. N.) approximately 50 feet above the McDougall-Segur (McGregor, unpublished internal report, 1958). Bell (1956, p. 15) regards the upper flora from the Blairmore Group to be of Albian age.

The younger limit of the palaeontological age of the McDougall-Segur horizon is set by the dating of the fauna in the lowermost beds of the overlying Upper Cretaceous Blackstone Formation. According to J. A. Jeletzky of the Geological Survey, the lowest or Sunkay Member of the Blackstone Formation carries a fauna of marine and brackist water clams and gastropods that appears to be diagnostic of the early Upper Cretaceous late Cenomanian to Turonian (see Norris, op. cit., p. 531).

In the Geological Survey of London Phanerozoic time scale (Harland, Smith, and Wilcock, 1964, p. 261) the Albian age of the upper flora of the Blairmore Group would be 100 to 106 m.y. and the base of the Upper Cretaceous in the area of study, 100 m.y.

Because of its association with sedimentary rocks derived from contemporaneous Crowsnest vulcanism, the McDougall-Segur must be regarded at least locally, as part of the Crowsnest Formation. Folinsbee et al. (1961, p. 355) report ages of 90 to 94 m.y. on pure sanidine from the Crowsnest Formation west of Coleman, Alberta, and 99 and 101 m.y. on biotite and sanidine respectively from the Crowsnest Formation on Mill Creek. Because these are minimum ages, the Crowsnest Formation must therefore be Cenomanian or older.

There is, therefore, reasonable agreement in the dating of the upper part of the Blairmore Group and associated strata, with both the palaeontological and isotopic data suggesting about 100 m.y. for the age of the youngest beds assigned to the Lower Cretaceous series.

LOCATION OF THE DATED PEBBLES

Igneous pebbles were selected from four localities (Morrissey Creek, Ginger Hill, Gold Creek, and Livingstone River) in southwestern Alberta and southeastern British Columbia (see Figure 1). The sites span a distance of twenty-five miles across the strike of the Cordillera and forty miles along strike. There has, however, been considerable crustal shortening as a consequence of the Laramide orogeny so that the dated pebbles have in reality been collected over an estimated pre-Laramide distance of eighty miles in an east-west direction and forty miles in a north-south direction.

All of the dated pebbles were collected from strata assigned to the upper part of the Blairmore Group. They ranged stratigraphically from 64 feet below the disconformity at the base of the Upper Cretaceous Blackstone Formation at the

Livingstone River locality, to approximately 1,000 feet at Morrissey Creek. The fact that no pebbles were dated from localities where the McDougall-Segur is interbedded with Crowsnest Formation was purely a matter of chance in that pebble size, alteration and potash content were the prime considerations in the selection of suitable material for isotopic dating.

PETROGRAPHY OF THE DATED PEBBLES

The igneous pebbles used for K-Ar age determination by the whole rock method are described as dacite porphyries, rhyodacite porphyries, microgranodiorites and a microadamellite. The "micro" rocks are texturally close to coarse-grained rhyodacites and dacites, but are non-porphyritic. Those with micrographic textures might have been classified as granophyres, while some of the porphyries have been called vitrophyres (e.g. Anderson, 1951).

Those pebbles showing least alteration were selected for dating purposes, however, it is apparent from the detailed descriptions that even these pebbles have suffered to some extent. Almost all original ferromagnesian minerals have been completely destroyed and the feldspars are variably kaolinized and/or sericitized. The individual pebbles are described in the Appendix.

EXPERIMENTAL PROCEDURE

Samples were ground to pass 150 mesh and fused in vacuo to release the radiogenic Ar^{40}. Standard isotope dilution techniques and high resolution mass spectrometry were employed to determine the Ar^{40} content and X-ray fluorescence techniques to determine the K^{40} concentration. Errors assigned reflect 95% confidence limits as outlined in Wanless et al. (1965).

RESULTS

The analytical results and calculated ages are shown in the accompanying table. The ages range from 113 to 174 m.y. and the average age is 148 m.y. Five of the ages are closely grouped between 142 and 158 m.y. and, considering the error limits assigned, could all correspond to the 148 m.y. average. One sample from Gold Creek yielded a relatively high age of 174 $\pm$ 22 m.y., while another from Ginger Hill gave a low age of 113 $\pm$ 16 m.y.

DISCUSSION

Stratigraphic considerations place a lower age limit of approximately 100 m.y. on the pebbles but do not provide a definitive upper limit. Various hypotheses have placed the source in Mesozoic terrane to the west and therefore ages as high as 225 m.y. might have been expected. Ages falling within this range may be

McDOUGALL-SEGUR CONGLOMERATE PEBBLE AGES

Locality	Rock Type	Coordinates	% K	K^{40}/Ar^{40}	% Radiogenic Ar	Age (m.y.)
Morrissey Creek	Microadamellite	49°23'N, 114°52'W	3.90	0.0093	88	153 ± 16
Ginger Hill	Dacite porphyry-1	49°29'N, 114°20'W	2.90	0.0068	65	113 ± 16
Ginger Hill	Dacite porphyry-2	49°29'N, 114°20'W	3.30	0.0096	84	158 ± 18
Ginger Hill	Rhyodacite porphyry	49°29'N, 114°20'W	1.70	0.0083	69	145 ± 18
Gold Creek	Microgranodiorite-1	49°36'N, 114°24'W	2.50	0.0106	80	174 ± 22
Gold Creek	Microgranodiorite-2	49°36'N, 114°24'W	4.20	0.0086	90	142 ± 15
Livingstone River	Rhyodacite porphyry	50°01'N, 114°25'W	3.20	0.0091	41	149 ± 17

Potassium decay constants used: $\lambda_e = 0.585 \times 10^{-10}\ yr^{-1}$ $\lambda_{total} = 5.30 \times 10^{-10}\ yr^{-1}$

the consequence of thermal alteration subsequent to the time of the formation of the pebbles, or may indicate actual periods of igneous activity. If the latter is true then the oldest activity represented by this particular group occurred 174 ± 22 m.y. ago and was followed by a succession of events culminating at 113 ± 16 m.y. It is noteworthy that there is no evidence for thermal events sufficiently intense to alter the K^{40}/Ar^{40} ratio of the pebbles subsequent to the time of deposition of the Blairmore Group rocks.

CONCLUSIONS

The stratigraphic position of the McDougall-Segur Conglomerate in the Albian stage necessitates a minimum age of 100 m.y. for the contained pebbles. The total range of 113 to 174 m.y. for the seven dated igneous pebbles is therefore compatible with the stratigraphic position of the conglomerate.

The ages obtained for the pebbles suggest igneous activity and/or alteration throughout the greater part of the Jurassic and Lower Cretaceous. The fact that no dates older than Jurassic were found would preclude the shield areas to the east or Precambrian areas to the southwest as sources of these pebbles, unless they had lost all of their radiogenic Ar^{40} during Jurassic time.

The dated igneous pebbles were collected from the pre-Laramide depositional basin between the Bow Valley and the 49th Parallel, and their ages and petrography suggest derivation from a common source. Moreover, as they occur at only one stratigraphic level in the late Lower Cretaceous series at widely separated localities, it is suggested that the McDougall-Segur horizon represents a time surface. The occurrence of the conglomerate in Crowsnest Formation in the vicinity of Crowsnest Pass and in Blairmore Group elsewhere, is additional evidence for the temporal equivalence of upper Blairmore and Crowsnest strata.

The palaeontological age and stratigraphic position of the McDougall-Segur would indicate that the pebbles were derived from a terrane exposing contemporaneously intruded and extruded igneous rocks, as well as cherts and quartzites, suggestive of parts of the upper Palaeozoic succession and the late Precambrian Purcell System respectively. The fact that nearly all of the pebbles are relatively fresh would suggest that they were derived from an area of tectonic activity and uplift with consequent rapid erosion and dispersal. In the Interior Plains east of the Cordillera there was apparently continuous marine sedimentation throughout the Lower Cretaceous so that the source area for the McDougall-Segur was most probably to the west. The ages of the igneous pebbles, and the stratigraphic position and composition of the conglomerate, support the views of Warren (1938, p. 66), Anderson (1951, p. 41), and others, that the provenance may have been in the general area of the Purcell and Selkirk Mountains.

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APPENDIX

Morrissey Creek - Microadamellite

The rock is a microadamellite consisting of 30% quartz, 40% plagioclase, 25% orthoclase, and 5% highly altered ferromagnesian minerals and iron oxides. Average grain size is about 1 mm.

The sodic plagioclase (oligoclase An 15-20, zoned to albite An 10) is subhedral, but highly corroded and resorbed. It is occasionally rimmed by K-feldspar, and is heavily kaolinized and sericitized. The K-feldspar is in smaller, anhedral grains, and is also heavily kaolinized. Quartz occurs as very irregular anhedra with undulose extinction and some fractures. Original brown biotite is almost completely altered to greenish brown chlorite, and a second original ferromagnesian mineral is completely altered to an indeterminate brown mass. Magnetite is the only prominent accessory mineral noted.

Ginger Hill - Dacite Porphyry-1

The rock is a dacite porphyry consisting of about 30% 2-3 mm plagioclase phenocrysts and 10% 1-3 mm quartz phenocrysts in a fine (about 0.2 mm) groundmass of quartz, micrographic quartz-orthoclase intergrowths, and a small amount of chlorite, epidote, muscovite and iron oxides.

The sodic plagioclase (oligoclase An 15-25) phenocrysts are partly single crystals, and partly glomeroporphyritic aggregates. In all cases the feldspar is highly kaolinized and sericitized. Most of the quartz phenocrysts are also crystal aggregates, but some are subhedral in form. All exhibit undulose extinction and healed fractures.

In the micrographic groundmass the potash-feldspar is heavily altered, the muscovite is probably primary, most of the chlorite appears to be pseudomorphic after biotite, and the epidote is probably a secondary mineral.

Ginger Hill - Dacite Porphyry-2

The rock consists of phenocrysts of feldspar (10%) in a cryptocrystalline, felsic groundmass. The phenocrysts are about 2 mm across, and the section is cut by numerous, very fine quartz veins.

The phenocrysts are mainly heavily kaolinized plagioclase (oligoclase - albite An 10-15) of subhedral shape, and some are riddled with inclusions and fine secondary minerals. Quartz occurs as small (0.1 mm) crystal aggregates throughout the rock. Ill-defined granular aggregates of iron oxides may represent original ferromagnesian minerals.

The groundmass is cryptocrystalline and its individual components cannot be resolved. Under ordinary light some relict flow texture is visible, but this disappears under crossed nicols. The section includes part of a small xenolith of microgranite with very diffuse and resorbed margins.

Ginger Hill - Rhyodacite Porphyry

The rock consists of phenocrysts of plagioclase (10%), quartz (25%), and orthoclase (20%) in a microcrystalline mosaic groundmass of quartz and orthoclase.

The sodic plagioclase (albite An 6-10) forms subhedral-tabular to anhedral phenocrysts about 1-2 mm across. It is moderately kaolinized and slightly sericitized. Quartz forms clear, relatively unstrained subhedral phenocrysts 3-5 mm across. Many quartz phenocrysts show evidence of considerable magmatic corrosion. Orthoclase phenocrysts measure up to 3-5 mm across and are heavily kaolinized. Many are of subhedral-tabular form.

The groundmass is a fine anhedral mosaic of quartz and orthoclase with accessory clots and specks of hematite, magnetite and chlorite. Very fine quartz veins cut through groundmass and phenocrysts alike.

Gold Creek - Microgranodiorite-1

This granophyric-textured rock consists of about 40% plagioclase, 50% quartz-orthoclase micrographic intergrowths, and 10% chlorite, epidote, and iron oxides. Average grain size is 1.5 to 2 mm.

The sodic plagioclase (An 10) is subhedral, highly corroded, heavily kaolinized, and charged with minute chlorite and epidote inclusions. Micrographic quartz-orthoclase intergrowths are a prominent feature of the rock. The feldspar phase is heavily kaolinized. Some of the larger (up to 1 mm) chlorite-epidote masses are apparently pseudomorphic after an original ferromagnesian mineral, while the smaller ones occur as abundant inclusions in the altered feldspars. Iron oxides appear to be partly primary and partly associated with ferromagnesian alteration products.

Gold Creek - Microgranodiorite-2

An anhedral-granular rock consisting mainly of quartz (50%), plagioclase (40%), orthoclase (8%), chlorite and iron oxides (2%). Average grain size is about 2 mm.

The plagioclase (albite An 10, zoned to An 0 in the rims) is anhedral and heavily altered. It is somewhat fractured and exhibits "exsolution" textures. The orthoclase is similarly heavily kaolinized and occurs in smaller anhedra. The green

to yellow-green chlorite-iron oxide aggregates may represent an original ferromagnesian mineral. Quartz is clear, anhedral and somewhat granulated.

Livingstone River - Rhyodacite Porphyry

This fine porphyry consists of 1 to 1.5 mm phenocrysts of altered plagioclase (20%), altered orthoclase (20%), and quartz (5%) in a very fine, microcrystalline, anhedral-granular groundmass of quartz and potash feldspar.

The feldspar phenocrysts tend to be subhedral, but many are corroded to varying degrees. The zoned sodic plagioclase (oligoclase-albite An 10-15) is relatively fresh in the cores but heavily kaolinized in the rims. The orthoclase is uniformly and more highly altered. The quartz phenocrysts tend to be smaller and anhedral or distinctly rounded, while some are glomeroporphyritic aggregates.

The microcrystalline groundmass appears to consist of quartz and feldspathic material in about equal proportions. The tiny, interlocking grains are charged with minute inclusions. Grains of iron oxide and occasional irregular patches of carbonate are found throughout the groundmass.