Late Cretaceous age of the Hutshi, Mount Nansen, and Carmacks groups, southwestern Yukon Territory and northwestern British Columbia

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Volcanic rocks of the Hutshi, Mount Nansen, and Carmacks groups occur in the southwestern Yukon where they unconformably overlie the Yukon Crystalline Terrane and deformed strata of the Whitehorse Trough. The volcanic rocks are faulted and tilted, locally altered, and largely postorogenic. The more basic Carmacks volcanics locally overlie intermediate to acid rocks of the Mount Nansen Group, but are mostly in isolated exposures northwest of the Hutshi and Mount Nansen volcanics.

Hutshi – Mount Nansen volcanics of the Miners Range are porphyritic, partly vesicular calc-alkaline andesite flows and flow breccias intruded by calc-alkaline alkali-rich rhyolite and two-feldspar andesite dikes. A low-greenschist metamorphic overprint affects most rocks.

Carmacks volcanics, near Carmacks, are flows, epiclastic breccias, and sintered tuffs interbedded with immature volcanic sandstone. One analysed breccia clast is calc-alkaline andesite, but the flows are potassic basalt, trachybasalt, and tristanite.

Recent assignments of the Hutshi – Mount Nansen and Carmacks volcanic suites to early and mid-Tertiary ages, respectively, are incorrect as all are late Cretaceous. K–Ar dates for a Hutshi – Mount Nansen whole rock and plagioclase of 72.4 ± 2.5 and 69.1 ± 2.6 Ma and Carmacks whole rocks and biotite of 73.1 ± 2.5, 67.9 ± 2.3, and 68.0 ± 2.2 Ma are concordant among themselves and agree with a Rb–Sr whole-rock date of 72.4 ± 2.1 Ma for rhyolite from the Hutshi Group in northern British Columbia.

This widespread late Cretaceous volcanic episode has typical subduction-related volcanic arc chemical polarity: calc-alkaline to alkaline from active trench towards stable craton. There is a dearth of documented early to mid-Cenozoic rocks in the Yukon.

Les roches volcaniques des groupes Hutshi, Mont Nansen et Carmacks se rencontrent dans le sud-ouest du Yukon où elles reposent en discordances sur la terrane cristalline du Yukon et sur les strates déformées de la fosse de Whitehorse. Les roches volcaniques sont faillées et inclinées, localement altérées et en grande part post-orogéniques. Les roches volcaniques plus basiques de Carmacks recouvrent localement les roches acides et intermédiaires du groupe Mont Nansen, mais au nord-ouest des groupes Hutshi et Mont Nansen elles n'apparaissent presque seulement isolées.

Les roches volcaniques de Hutshi – Mont Nansen de la chaîne Miners comprennent des coulées d'andésite calco-alcaline porphyritique partiellement vésiculaire et des brèches de coulée coupées par des dykes de rhyolite calco-alkaline riche en alcalis et d'andésites à deux feldspaths. Une surimpression métamorphique de faciès à schistes verts de faible intensité affecte la plupart des roches.

Les roches volcaniques de Carmacks, près de Carmacks, sont formées de coulées, de brèches épiclastiques et de tufs agglomérés interstratifiés avec des grès volcaniques immatures. Un fragment de brèche analysé correspond à une andésite calco-alkaline, cependant les coulées sont constituées de basalte potassique, trachybasalte et tristanite.

Les âges récemment attribués aux séquences volcaniques Hutshi – Mont Nansen et Carmacks comme étant Tertiare inférieur et moyen, respectivement, sont incorrects car ils sont tous Crétacé supérieur. Les âges obtenus par K–Ar sur roche totale et plagioclase des groupes Hutshi – Mont Nansen de 72,4 ± 2,5 et 69,1 ± 2,6 Ma et sur roches totales et biotite du groupe Carmacks de 73,1 ± 2,5, 67,9 ± 2,3 et 68,0 ± 2,2 Ma concordent entre eux et sont en accord avec l'âge Rb–Sr obtenu sur roche totale de 72,4 ± 2,1 Ma pour la rhyolite du groupe Hutshi dans le nord de la Colombie-Britannique.

Ce volcanisme largement répandu au Crétacé supérieur possède les caractères chimiques d'arc volcanique relié à une subduction: de calco-alcalin à alcalin en passant de la fosse active vers le craton stable. Il existe très peu de renseignements sur les roches du Cénozoïque inférieur à moyen du Yukon.

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Introduction

Scattered through the southwestern Yukon and northwestern British Columbia are remnants of volcanic rock that overlie an erosion surface of considerable relief. The volcanic rocks include flow, breccia, and pyroclastic material ranging from basalt and andesite to rhyolite in composition. They are cut by dikes and stocks, are faulted and tilted, and are variably altered under zeolite to greenschist conditions. These volcanic strata postdate the major orogenic deformation that consolidated the Yukon Crystalline Terrane (Tempelman-Kluit 1976) and deformed the Whitehorse Trough (Wheeler 1961; Bultman 1979). They have not been dated by paleontologic or isotopic methods, and have a confusing history of nomenclature and age assignment.

At the suggestion of D. J. Tempelman-Kluit of the Geological Survey of Canada, we investigated the volcanic rocks in two areas (Fig. 1): in the Miners Range, 40 km north-northwest of Whitehorse (Grond 1980), and near Carmacks (Churchill 1980). These research projects provided the new chemical, isotopic, and age data reported here. A volcanic sample from the southwest corner of Table Mountain, west of Atlin, British Columbia, was dated to confirm previous inferred correlations.

Stratigraphic nomenclature

The Hutshi Group was named by Cairnes (1910) and the name was used by Bostock and Lees (1938) for, among others, the volcanic rocks of the Miners Range, 60 km northwest of Whitehorse. Later the name was applied to similar rocks in the Whitehorse area by Wheeler (1961) and used in northern Brit-

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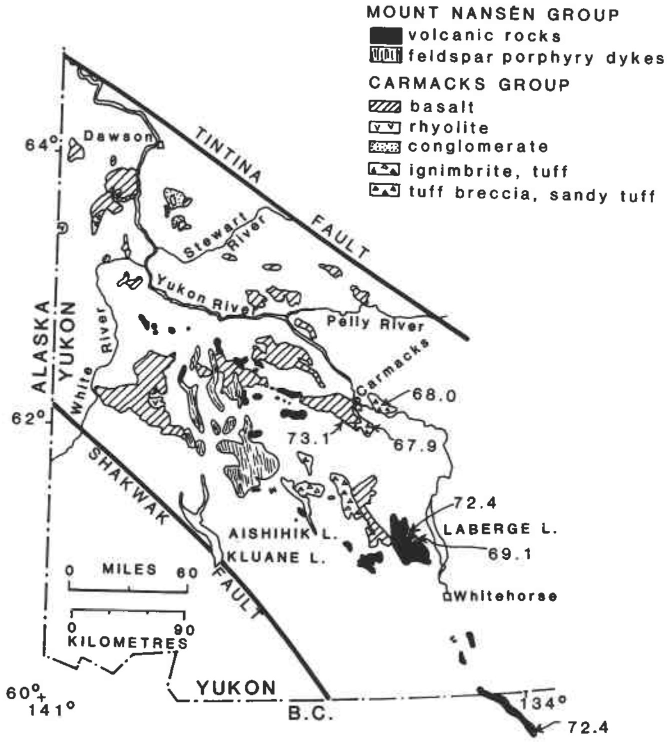

FIG. 1. Southwestern Yukon Territory showing distribution of Mount Nansen and Carmacks Group volcanic rocks and location of dated samples. Slightly modified from diagrams provided by D. J. Tempelman-Kluit.

ish Columbia by Bultman (1979). These rocks were considered Cretaceous by the workers cited but precise paleontologic or isotopic age determinations were lacking.

Bostock (1936) gave the name Mount Nansen to volcanics in the Carmacks district that he considered correlative with the Hutshi Group. Subsequent workers have partly accepted this correlation and on recent maps (Tempelman-Kluit 1978) the name Mount Nansen has been applied to the rocks in the Miners Range. Tempelman-Kluit (1974) found the Mount Nansen volcanic rocks to be closely associated with the Nisling Range Alaskite and considered them contemporaneous. K–Ar and Rb–Sr dates of 67–52 Ma for the alaskite were used to assign a latest Cretaceous to Eocene age to the Mount Nansen Group (Tempelman-Kluit and Wanless 1975; Le Couteur and Tempelman-Kluit 1976; Tempelman-Kluit 1980*a*). One whole-rock K–Ar date of 58.4 Ma for Mount Nansen from the Snag map area (Tempelman-Kluit and Wanless 1975) was thought to confirm an early Cenozoic age, and on recent maps and reports an age of Eocene or early Tertiary is given without question (Sawyer and Dickinson 1976; Noel 1979; Tempelman-Kluit 1976, 1978, 1980*b*).

The Carmacks basalts of Cairnes (1910) were called Carmacks volcanics by Bostock (1936) who observed that they locally overlie the Mount Nansen volcanics. He inferred a Miocene or older age on the basis of general appearance and structural setting. The Carmacks Group is now recognized over a large area in the southwestern Yukon Territory and is variously considered to be Eocene to Pliocene in age (Tempelman-Kluit 1976), Miocene (?) (Tempelman-Kluit 1974, 1978, 1980*b*; Noel 1979), or late Cretaceous to Eocene and almost contemporaneous with the Mount Nansen Group (Tempelman-Kluit 1980*a*). Resolution of this uncertainty was needed.

Miners Range area

A 30 km^2 area of Hutshi – Mount Nansen volcanic rocks was mapped around latitude 61°10′N, longitude 135°38′W by Grond (1980). The rocks there are layered lava flows, breccias, and immature sandstone, intruded by dikes and sills. The general structure is a homocline that dips 20° towards the southwest. A valley passing through the area probably contains a concealed high-angle fault. Approximately 2000 m of section is present, and is informally divisible into lower and upper parts. Volcanic rocks of the lower part are richer in hornblende phenocrysts and more injected by rhyolite dikes and sills, whereas in the upper part carbonate-filled vesicles are more abundant.

The abundant rock types are hornblende–feldspar porphyry (with abundant 2–8 mm andesine and hornblende phenocrysts and scarce augite phenocrysts in a dark trachytic–pilotaxitic groundmass), volcanic breccia, immature quartz-bearing sandstone, felsite porphyry (with buff-colored quartz–feldspar matrix and altered feldspar phenocrysts), felsite breccia, aphanitic andesite (composed mostly of trachytic feldspar microlites), vesicular porphyritic andesite (with abundant feldspar phenocrysts in an intergranular matrix), light green feldspar porphyry, and massive porphyritic andesite (with plagioclase phenocrysts, augite glomeroporphyroblasts, and hypersthene phenocrysts in a hyalopilitic matrix). The rocks show a weak greenschist overprint (chlorite, albite, sericite). Vesicles are filled with calcite, chlorite, quartz, and hematite.

Chemical analyses of five rocks (Table 1), including the two samples dated, show them to be calc-alkaline andesite and alkali-rich rhyolite (Fig. 2).

Carmacks area

Stratigraphic sections of the Carmacks Group were examined and sampled 5 km west, 14 km south, and 19 km east of Carmacks by Churchill (1980). In all three areas the layering is nearly horizontal. In the first two areas erosion-resistant epiclastic breccia predominates. This alternates with lava flows, sintered tuff, and immature sandstone. The breccia is composed of centimetre to metre diameter clasts of vesicular andesite (with plagioclase and clinopyroxene phenocrysts) and basalt (with olivine and clinopyroxene phenocrysts). The lava flows are vesicular and brecciated to massive, columnar-jointed andesite or basalt. Sintered tuff, with clinopyroxene and plagioclase phenocrysts in a vesicular, devitrified glass matrix, occurs in thick massive beds. Some thin sections show a low-greenschist metamorphic overprint.

The third stratigraphic section contains lava flows and quartz-bearing immature sandstone. The lavas range from plagioclase, clinopyroxene, and olivine phenocryst-bearing basalt with biotite in its groundmass and plagioclase, clinopyroxene, and olivine phenocryst-bearing trachyandesite with biotite and sanidine in its groundmass to tristanite with clinopyroxene, sanidine-rimmed plagioclase, and olivine phenocrysts in a groundmass that includes biotite and sanidine. The potassic nature of these rocks is quite evident in thin section.

Four samples were chemically analysed (Table 1), including three lava flows that were dated. The lavas are alkaline (Fig. 2), and one is even nepheline normative. Classified according to Irvine and Baragar (1971), these are potassic alkali basalt, trachybasalt, and tristanite. An alternative classification of these last two samples would be as shoshonite. The one subalkaline sample, a large clast from epiclastic breccia in the second stratigraphic section, is a calc-alkaline andesite.

TABLE 1. Chemical composition and CIPW norms

Sample	22-00	23-3	20-2	22-01	18-3	12-2d	15-1e	14	14-1h
Location	Miners Ra.	Miners Ra.	Miners Ra.	Miners Ra.	Miners Ra.	Carmacks	Carmacks	Carmacks	Carmacks
Lat. (°N)	61.18	61.16	61.17	61.18	61.17	62.07	61.97	62.07	62.07
Long. (°W)	135.63	135.62	135.62	135.63	135.63	136.40	136.20	135.95	135.95
SiO_2	58.36	60.36	57.06	59.03	75.62	51.31	54.64	56.61	56.93
TiO_2	0.62	0.76	0.82	0.90	0.14	0.94	0.82	0.90	0.90
Al_2O_3	16.25	15.68	15.92	17.37	12.83	13.94	17.37	16.20	16.16
Fe_2O_3	8.24	6.52	8.23	7.59	2.46	10.42	9.25	7.89	6.94
MnO	0.12	0.10	0.12	0.09	0.04	0.16	0.16	0.13	0.11
MgO	3.73	3.71	3.25	2.15	0.05	9.05	3.96	3.93	3.78
CaO	7.02	5.11	6.48	4.89	0.07	7.60	7.73	4.77	4.74
Na_2O	3.46	3.77	4.04	4.23	7.73	2.92	4.29	3.71	4.80
K_2O	1.77	2.72	1.76	2.57	3.07	3.19	1.47	5.27	5.06
P_2O_5	0.28	0.30	0.37	0.37	0.08	0.48	0.33	0.60	0.59
LOI	0.67	1.63	2.33	2.41	0.54	1.76	0.72	1.82	0.17
Total	100.52	100.66	100.38	101.57	102.63	101.77	100.74	101.83	100.18
Rock name	Andesite	Andesite	Andesite	Andesite	Rhyolite	Alk basalt	Andesite	Trachybasalt	Tristanite
Chem. series	Calc-alk	Calc-alk	Calc-alk	Calc-alk	Calc-alk	Alkaline	Calc-alk	Alkaline	Alkaline
Orthoclase	10.59	16.30	10.70	15.42	17.44	18.80	8.75	31.16	29.68
Albite	31.65	34.56	37.48	39.22	49.90	26.19	38.72	33.35	39.63
Anorthite	23.81	17.97	20.62	20.82	0.00	15.50	23.88	12.05	7.52
Nepheline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85
Diopside	7.70	4.61	7.98	1.09	0.00	15.20	9.99	6.23	9.61
Hypersthene	13.00	11.60	11.09	9.99	1.06	1.01	13.14	10.93	0.00
Forsterite	0.00	0.00	0.00	0.00	0.00	13.86	0.00	0.90	5.07
Fayalite	0.00	0.00	0.00	0.00	0.00	4.59	0.00	0.41	1.73
Quartz	9.55	10.89	7.69	8.87	24.24	0.00	1.26	0.00	0.00
Magnetite	2.23	2.37	2.45	2.52	0.00	2.53	2.41	2.50	2.47
Ilmenite	0.88	1.07	1.18	1.27	0.19	1.31	1.14	1.26	1.23
Apatite	0.59	0.64	0.80	0.79	0.16	1.00	0.70	1.24	1.21

NOTE: Norms are calculated and names given following the procedure outlined in Irvine and Baragar (1971).

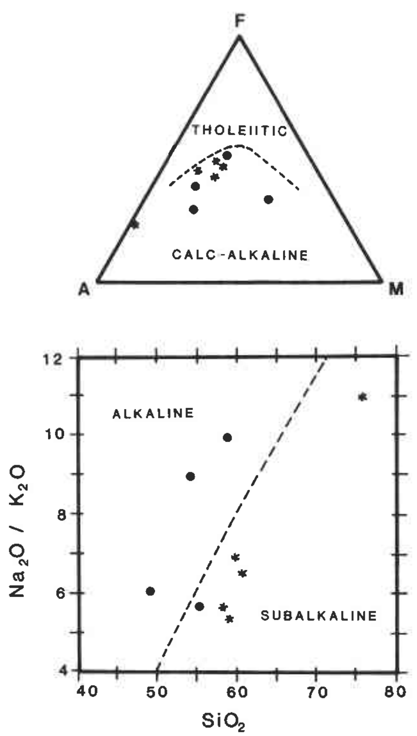

FIG. 2. AFM and alkalies–silica plots for chemical analyses of Mount Nansen (asterisks) and Carmacks Group (solid dots) volcanic rocks. Dashed field boundary lines are from Irvine and Baragar (1971).

Geochronometry

K–Ar dates (Table 2) from both suites are concordant and indicate a minimum age of late Cretaceous, older than anticipated by current opinion, but confirming some early inferences. One relatively fresh whole-rock sample and a plagioclase sample from the Miners Range gave 72.4 ± 2.5 and 69.1 ± 2.6 Ma. Two whole-rock samples and one biotite from near Carmacks gave 73.1 ± 2.5, 67.9 ± 2.3, and 68.0 ± 2.2 Ma (errors are one standard deviation).

A Rb–Sr isochron for three Carmacks samples (Table 3) indicates an age of 77 ± 20 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70489 ± 0.00015. Two samples from the Miners Range (Table 3) give an even more imprecise isochron date of 112 ± 48 Ma, with an initial ratio of 0.7045 ± 0.0002. The calculated initial ratio, accepting the K–Ar dates, is 0.70475 ± 0.00015. These imprecise Rb–Sr isochron dates are of little meaning themselves but show that the whole-rock Rb–Sr data are entirely compatible with the K–Ar dates just presented. A sample of flow-banded rhyolite from the Hutshi Group west of Atlin, British Columbia (Table 3; Fig. 3), has a high Rb/Sr ratio so that a date of 72.4 ± 2.1 Ma can be calculated, assuming an initial ratio of 0.70484 (an average given by the other rocks analysed in this study). Agreement of this date with the others reported here confirms the correlation of Mount Nansen and Hutshi groups across southwestern Yukon and into British Columbia.

Our dates for the volcanic rocks are about equal to the oldest dates reported by Tempelman-Kluit and Wanless (1975) for Nisling Range Alaskite and Ruby Range Granodiorite, identi-

TABLE 2. K–Ar dates

Sample	Rock type	Lat. (N)	Long. (W)	Material analysed	K (%)	Radiogenic ^{40}Ar ($\times 10^{-6}$ cm^3 g^{-1})	Radiogenic Ar in ^{40}Ar extracted (%)	K–Ar date (Ma ± σ)
22-00	Andesite	61°10′9″	135°38′1″	Whole rock	1.312	3.769	81.3	72.4±2.5
23-3	Andesite	61°9′8″	135°37′3″	Plagioclase	0.728	1.993	66.2	69.1±2.6
12-2d	Alk Basalt	62°4′12″	136°24′30″	Whole rock	2.49	7.219	89.9	73.1±2.5
15-1e	Andesite	61°58′5″	136°13′30″	Whole rock	1.26	3.386	63.4	67.9±2.3
14	Trachybasalt	62°4′7″	135°56′48″	Biotite	6.83	18.384	84.4	68.0±2.2

TABLE 3. Rb–Sr data

Sample	Rock type	Lat. (N)	Long. (W)	Sr (ppm ± 5%)	Rb (ppm ± 5%)	^{87}Rb/^{86}Sr (±2%)	^{87}Sr/^{86}Sr observed (±0.00015)	Initial ^{87}Sr/^{86}Sr
23-3	Andesite	61°9′8″	135°37′3″	431	93.0	0.625	0.7055	0.7049
22-00	Andesite	61°10′9″	135°38′1″	636	40.3	0.184	0.7048	0.7046
12-2d	Alk basalt	62°4′12″	136°24′30″	597	79.7	0.389	0.7054	0.7050
14	Trachybasalt	62°4′7″	135°56′48″	726	216	0.859	0.7058	0.7049
15-1e	Andesite	61°58′5″	136°13′30″	805	41.8	0.150	0.7050	0.7048
T75 305-8	Rhyolite	59°38′	133°57′	64.7	180	8.05	0.7131	

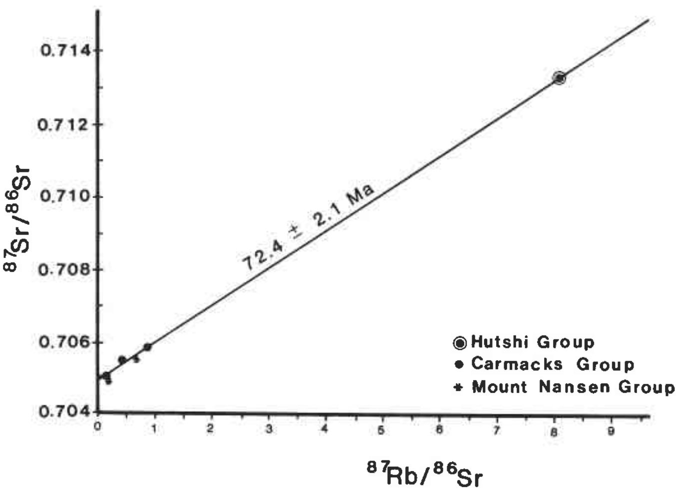

FIG. 3. Rb–Sr isochron diagram for Mount Nansen, Carmacks, and Hutshi Group volcanic rocks. The isochron shown was computed for all samples, equally weighted, but the age is defined solely by the Rb-rich Hutshi sample and the initial ratio by the cluster of Mount Nansen and Carmacks analyses.

cal to the dates reported by Godwin (1975) for the Casino Complex, and similar to several dates reported by Morrison *et al.* (1979) and Bultman (1979) for granitic rocks intruding the Whitehorse Trough.

The initial ^{87}Sr/^{86}Sr ratios show a moderate southwestward decrease from Carmacks to the Miners Range. A similar southwestward decrease across the Yukon was observed and discussed by Le Couteur and Tempelman-Kluit (1976), but our volcanic initial ratios are generally lower than those for the plutonic rocks in their study.

Conclusion

The Hutshi, Mount Nansen, and Carmacks groups are essentially contemporaneous, upper Cretaceous volcanic accumulations deposited on an erosion surface of considerable relief in the southwestern Yukon and northwestern British Columbia. The calc-alkaline to potassic alkaline chemical polarity demonstrated by this chemical study of these rocks is like that of modern volcanic arcs (Kuno 1966; Dickinson and Hatherton 1967; Miyashiro 1974, 1975, 1978). The presence of a northeast-dipping late Cretaceous subduction zone beneath the southwestern Yukon is consistent with our observations and previous tectonic syntheses (Tempelman-Kluit 1979).

Previous correlations of some of the rocks studied with Eocene volcanic rocks such as the Skukum and Sloko groups must be discarded. Except for patches of these Eocene rocks in the Whitehorse area (Wheeler 1961) the Yukon appears devoid of early to mid-Tertiary volcanic rocks. This volcanic gap requires a significant change in tectonic syntheses for the early Tertiary of the northern Cordillera. The late Cretaceous volcanic arc is a logical subject for future detailed stratigraphic and chemical studies and can provide suitable material for paleomagnetic measurements to detect motion of southwestern Yukon relative to the rest of North America.

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Appendix: Analytical methods and constants

Major elements and Rb and Sr contents were determined by X-ray fluorescence analysis of fused discs and pressed powder pellets according to procedures described by Armstrong and Nixon (1981). For dating, the K analyses were by atomic absorption and Ar by isotope dilution using conventional procedures (White *et al.* 1967). Sr isotopic analyses were made on a modified NBS-type mass spectrometer with automated digital data collection. All dates mentioned were calculated using the decay constants 4.962×10^{-10} year^{-1} and 0.581×10^{-10} year^{-1} for K, 1.42×10^{-11} year^{-1} for Rb, and 1.167×10^{-4} for the atomic ratio of $^{40}K/K$.