Precambrian Melasyenite of Ute Creek, San Juan Mountains, Colorado—Chemistry, Petrology, and Strontium Isotopes

GEOLOGICAL SURVEY BULLETIN 1311-C

Precambrian Melasyenite of Ute Creek, San Juan Mountains, Colorado– Chemistry, Petrology, and Strontium Isotopes

By FRED BARKER, Z. E. PETERMAN, *and* R. F. MARVIN

CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY BULLETIN 1311-C

Hornblende-biotite melasyenite, exposed in an erosional window through Tertiary and Quaternary rocks, is similar in age and composition to rocks near Powderhorn, Colorado

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1970

UNITED STATES DEPARTMENT OF THE INTERIOR

WALTER J. HICKEL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 20 cents (paper cover)

CONTENTS

ILLUSTRATIONS

TABLES

CONTRIBUTIONS TO GENERAL GEOLOGY

PRECAMBRIAN MELASYENITE OF UTE CREEK, SAN JUAN MOUNTAINS, COLORADO—CHEMISTRY, PETROLOGY, AND STRONTIUM ISOTOPES

By Fred Barker, Z. E. Peterman, and R. F. Marvin

ABSTRACT

A stock of hornblende-biotite melasyenite is exposed in an erosional window through Tertiary rocks and Quaternary deposits at Ute Creek in the north-central San Juan Mountains, Colo. This rock contains about 22–49 percent hornblende, 17–25 percent biotite, 17–38 percent microcline-microperthite, 3–17 percent plagioclase, and 3–9 percent quartz. Chemical analyses show approximately 54 percent SiO_2, 12 percent Al_2O_3, 7.5 percent $FeO+Fe_2O_3$, 7–10 percent MgO, 5–6.5 percent CaO, 2.3 percent Na_2O, and 5 percent K_2O. Petrographically, this intrusive is an oversaturated melasyenite, but it shows marked chemical kinship with potassic shonkinites and lamprophyres. The presence of high trace amounts of barium, strontium, and phosphorus supports this affinity. Crystallization of quartz from such a hydrous magma is due to early and median crystallization of hornblende and biotite which, compared with augite, are deficient in SiO_2 and cause the remaining liquid to become residually enriched in SiO_2. Water content, by stabilizing hornblende and biotite, thus is an important controlling factor; if this magma had contained less H_2O, it would have precipitated augite and would have produced a shonkinite.

The Precambrian age of the melasyenite is given by K–Ar apparent ages of 1,380±50 m.y. (million years) and 1,410±50 m.y. on biotite of two samples. The Ute Creek intrusive is similar in age and composition to the potassic augite syenite and shonkinite of the Powderhorn area, which lies about 45 miles north-northeast.

The ratio Sr^{87}/Sr^{86} of the melasyenite, corrected for an age of 1,400 m.y., is 0.7031. This value compares well with a predicted figure of 0.7022 in the mantle and also is lower than the ratios (corrected to 1,400 m.y.) found in nearby pre-existing crustal rocks. Thus, origin of the melasyenite magma from the mantle, with little or no assimilation of crustal material, is not unlikely.

INTRODUCTION

The existence of a body of Precambrian melasyenite at Ute Creek, in the north-central San Juan Mountains of Colorado, was first pointed out by Cross and Larsen (1935, p. 21, pl. 1). Later, Larsen and Cross (1956, p. 29) briefly described this rock. This syenite was revisited by members of the U.S. Geological Survey in 1965 and 1966 during geologic mapping for the Durango 1:250,000 sheet, being prepared under the general direction of T. A. Steven. The senior author of the present paper has restudied the Precambrian rocks of this area (Barker, 1969). The present paper presents petrographic data, major- and minor-element contents, and petrologic interpretations by Barker, Sr isotopic analyses by Peterman, and two K–Ar age determinations by Marvin. The radiometric age measurements were made to determine whether the melasyenite is of Precambrian age or whether it is of Cambrian age and is related to the complex at Iron Hill of the Powderhorn area (Larsen, 1942), which lies 41–46 miles north-northeast of Ute Creek and which recently was restudied by Hedlund and Olson (1968).

AREAL GEOLOGY

There are two exposures of melasyenite in the valley of Ute Creek. Both are erosional windows bounded on all sides by Tertiary and Quaternary deposits. The larger window is 3½–5½ miles southwest of the mouth of Ute Creek at Rio Grande reservoir (fig. 1). The smaller exposure is 3 miles west-southwest and is not discussed in this report. Whether or not these two masses are parts of the same stock is not known.

The large mass of melasyenite is well exposed and underlies about 1½ square miles. The melasyenite is fresh, massive, homogeneous in outcrop, and dark pinkish green to pinkish gray. Dikes of fine- to medium-grained pink massive microcline alaskite cut the melasyenite. The dikes range in thickness from a few inches to about 25 feet. They lie at various attitudes and are found throughout the melasyenite. They are similar in composition to a stock of alaskite in Rincon La Osa, 5 miles south, and to alaskite dikes that cut schist of the Precambrian Uncompahgre Formation, 6 miles south. The latter two intrusives probably are related to the nearby batholith of Precambrian Eolus Granite (Barker, 1969).

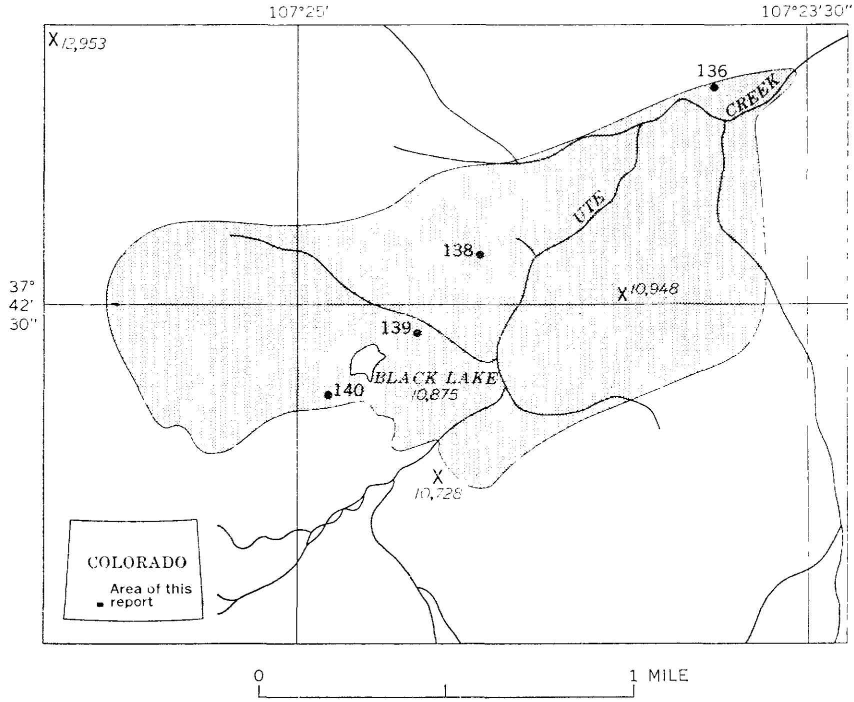

FIGURE 1.—Precambrian melasyenite body (patterned area) of Ute Creek described in this report. Tertiary volcanic and Quaternary glacial deposits are unpatterned. Sample localities BSJ–136, –138, –139, and –140 are shown. Elevations shown are in feet above mean sea level.

PETROGRAPHY AND ANALYTICAL DATA

The melasyenite of Ute Creek consists principally of hornblende, biotite, microcline, and oligoclase. The stock shows minor variation from place to place in its proportions of minerals, but its texture and mineralogy are virtually uniform. The rock is seriate inequigranular, and most of the minerals are ½–3 mm (millimeters) in maximum dimension. Grains of microcline, however, commonly are 5–10 mm in size. Hornblende, plagioclase, and biotite occur as anhedra and subhedra, but microcline and quartz are anhedral only. Plagioclase is the only mineral to show more than very mild alteration to deuteric minerals.

Hornblende occurs typically as single prismatic grains, but aggregates of several 1- to 2-mm grains and of many ¹⁄₁₀- to ⅕-mm grains are scattered throughout the melasyenite. The hornblende is pleochroic with X=pale brown, Y=olive green, and Z=green. Local bleaching to very pale green and straw colors has occurred in a few grains per thin section. The angle between z and c is about 28°.

Biotite is present as chunky tablets and irregularly shaped grains, partly showing ragged edges. Its pleochroism is X=straw, Y=Z= olive brown.

Microcline has formed both as $\frac{1}{2}$- to 2-mm anhedra, which are interstitial to hornblende, biotite, and plagioclase, and as 2- to 10-mm blocky anhedra. Grid twinning is well developed, and most of the larger grains are carlsbad twinned. Most grains contain 10–30 percent by volume of veinlets and patches of albite, and so this mineral actually is microperthite. A mild, widespread alteration to sericite and a very fine grained brown clay(?) has affected most of the microcline.

Plagioclase occurs as stubby laths and anhedra. The bulk of most grains is sodic oligoclase, but rims of albite are common. Grains in contact with microcline typically are myrmekitic. Sharply defined to faded albite twinning is present in all grains, and carlsbad twinning is abundant. The cores of most grains are partly to wholly sericitized, and veinlets of sericite extend outward toward the margins of many of these grains.

Quartz typically is present as interstitial single and compound grains, $\frac{1}{8}$–1 mm in size, that show mild undulatory extinctions. None of the quartz shows any evidence of being xenocrystic.

Equant to blocky elongate grains of graphic granite are a minor but important part of the melasyenite. The units of quartz and alkali feldspar are typically 0.02–0.03 mm thick.

Colorless clinopyroxene occurs only as residual cores in a few of the hornblende grains and probably was one of the first minerals to crystallize. This mineral is dusted with very fine grained opaque inclusions, and so in aggregate it is pale brown. Several grains show (100) twinning, which in one slide extends outward as twin planes in the rim of hornblende.

Wedge-shaped euhedra and subhedra of sphene lie in and marginal to biotite grains. The sphene is faintly pleochroic from pale straw to pale straw yellow. The grains range in size from about $\frac{1}{30}$ to $1\frac{1}{2}$ mm, but most are in the range $\frac{1}{10}$–$\frac{1}{2}$ mm.

Magnetite, in octahedral to anhedral grains $\frac{1}{40}$–$\frac{1}{2}$ mm in size, occurs mostly as concentrations in hornblende.

Apatite, in hexagonal prisms $\frac{1}{10}$–$1\frac{1}{2}$ mm long, is scattered through the rock. Zircon is the least abundant accessory mineral.

Four specimens were collected across the exposure of melasyenite (fig. 1). Modal and chemical analyses of these are given in table 1.

TABLE 1.—*Chemical analyses, C.I.P.W. rock norms, and modal analyses of Precambrian melasyenite of Ute Creek, and analyses of augite syenite and shonkinite from the Powderhorn area*

[Localities: BSJ-136, -138, -139, and -140 from northwest of Ute Creek, as shown in fig. 1; augite syenite and shonkinite from Wildcat Gulch, 7.6 miles north-northwest of Powderhorn (Hunter, 1925, pl. 1). Tr., trace; n.a., not analyzed]

Sample	BSJ-136	BSJ-138	BSJ-139	BSJ-140	Augite syenite	Shonkinite
Chemical analyses [1]						
SiO_2	54.25	53.13	54.23	54.93	54.99	50.86
Al_2O_3	12.99	11.49	12.02	13.16	12.98	11.14
Fe_2O_3	2.23	2.14	2.04	2.03	3.13	2.93
FeO	5.96	5.74	5.31	5.47	3.92	5.21
MgO	7.12	10.05	9.38	7.35	5.50	11.26
CaO	5.56	6.55	6.06	5.13	5.67	6.97
Na_2O	2.34	2.06	2.25	2.43	2.83	1.73
K_2O	5.06	4.83	4.90	5.55	7.08	5.85
H_2O+	1.22	1.24	1.28	.94	.58	.95
H_2O-	.20	.04	.16	.18	.41	.64
TiO_2	.98	.77	.69	.87	.99	.84
P_2O_5	.79	.66	.60	.69	1.00	.79
MnO	.14	.15	.14	.14	.13	.13
CO_2	.24	.18	.01	.02	------	------
Cl	.06	.08	.07	.05	n.a.	n.a.
F	.35	.30	.28	.35	n.a.	n.a.
Subtotal	99.49	99.41	99.42	99.29	------	------
Less O	.16	.15	.14	.16	------	------
Total	99.33	99.26	99.28	99.13	99.99	100.02
C.I.P.W. rock norms						
Quartz	1.21	------	------	------		
Orthoclase	29.90	28.54	28.95	32.80		
Albite	19.36	16.84	18.52	20.19		
Anorthite	10.23	8.15	8.50	8.81		
Halite	.10	.13	.12	.08		
Wollastonite	3.49	7.06	6.57	4.04		
Enstatite	17.73	17.93	19.09	17.50		
Ferrosilite	7.74	5.57	5.87	6.86		
Forsterite	------	4.97	2.99	.56		
Fayalite	------	1.70	1.01	.24		
Magnetite	3.23	3.10	2.96	2.94		
Ilmenite	1.86	1.46	1.31	1.65		
Apatite	1.87	1.56	1.42	1.63		
Fluorite	.65	.56	.52	.66		
Calcite	.55	.41	.02	.04		
Salic minerals	60.80	53.67	56.09	61.88		
Femic minerals	37.13	44.34	41.77	36.15		

See footnotes at end of table.

365-570—70——2

TABLE 1.—*Chemical analyses, C.I.P.W. rock norms*—Continued

Sample	BSJ-136	BSJ-138	BSJ-139	BSJ-140	Augite syenite	Shonkinite
Modal analyses [2]						
Quartz	9	3.5	3	5		
Microcline	17	30.	27.5	38		
Plagioclase	17	6.5	3.	15		
Graphic granite	3.5	Tr.	1	2		
Biotite	25	21.5	16.5	17		
Hornblende	27.5	35.5	49	22.5		
Pyroxene	Tr.	2	Tr.	Tr.		
Fe-Ti oxides	Tr.	1	Tr.	Tr.		
Apatite	Tr.	Tr.	Tr.	Tr.		
Sphene	Tr.	Tr.	Tr.	Tr.		
Zircon	Tr.	Tr.	Tr.	Tr.		

[1] Analysts: BSJ-136, -138, -139, and -140 by V. C. Smith; augite syenite and shonkinite by George Steiger (Hunter, 1925, p. 67, 73).
[2] All values rounded to the nearest ½ percent.

The modes in table 1 show (1) less than 10 percent quartz in all specimens, (2) a dominance of microcline over oligoclase in three of the four specimens, and in BSJ-136, these minerals are proportioned roughly 1:1, (3) 40 percent dark minerals in BSJ-140 and 53–66 percent in the other three specimens, and (4) more hornblende than biotite in all specimens. Thus, we class specimens BSJ-138, -139, and -140 as hornblende-biotite melasyenite, and BSJ-136 as hornblende-biotite melamonzonite. On the basis of proportions of minerals only, however, the three specimens that contain more than 50 percent dark minerals, if hypabyssal, would be classed as lamprophyre of the variety biotite vogesite (Johannsen, 1937, p. 32–39). The usual definition of lamprophyre, however, specifies a fine-grained or fine-grained porphyritic texture (Rosenbusch, 1907, p. 653) and "notable idiomorphism" of the ferromagnesian minerals in the groundmass (Knopf, 1936, p. 1749); so the term "lamprophyre" is not applicable to the Ute Creek rocks.

Notable features of the modal analyses are the sympathetic variations of the amounts of hornblende versus plagioclase and of biotite versus microcline. The rock with the most hornblende, BSJ-139, has the least biotite. Also, biotite-rich BSJ-136 contains less hornblende than BSJ-138 and BSJ-139. Compositional differences, especially of MgO, are responsible for these variations in mineral content.

In the four chemical analyses (table 1), the melasyenite shows only slight variations in percentages of SiO_2, Fe_2O_3, FeO, Na_2O, and K_2O. The silica content of about 54 percent and potash content of about 5 percent are characteristic. Alumina shows a moderate range, from 11.49 to 13.16 percent. Magnesia and lime, however, show variations of

30–40 percent of the amounts present—the former from 7.12 to 10.05 percent and the latter from 5.13 to 6.55 percent. The central part of the body, as now exposed, contains more CaO and MgO than do the margins. Specimens BSJ–138 and –139 contain more MgO and CaO, as well as less Al_2O_3 and SiO_2, than do BSJ–136 and –140. These differences also result in higher amounts of hornblende in the modes of BSJ–138 and –139. On an Alk–F–M diagram (fig. 2), the four

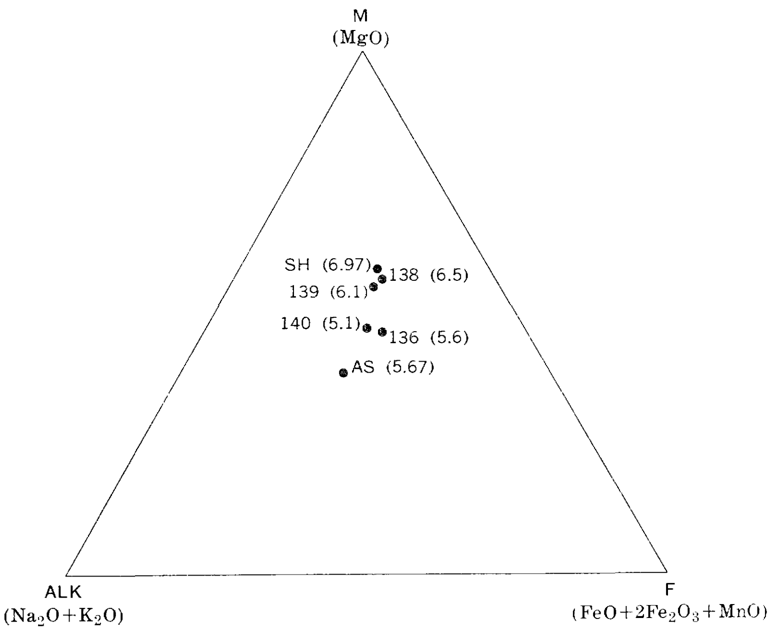

FIGURE 2.—Alk–F–M diagram of four analyzed melasyenites of Ute Creek, and of augite syenite (AS) and shonkinite (SH) of the Powderhorn area (Hunter, 1925, p. 67, 73), in molecular proportions. Weight percentages of CaO in each sample are given in parentheses after the sample numbers.

analyses very nearly lie on a line radial to the MgO corner. This arrangement, in conjunction with the fact that the most magnesian melasyenite also is the most calcareous, means that the four rock compositions are roughly related by a simple gain or loss of MgO and CaO. We thus suggest that these variations in CaO and MgO are due to differentiation, in the very early stages of crystallization, by loss or gain of diopsidic pyroxene and perhaps of olivine also.

Rock norms of the melasyenite are given in table 1. These are especially interesting in that three show normative olivine and one

(BSJ–136) is quartz normative. The back-to-back ternary plot (fig. 3) of normative feldspars, pyroxene, olivine, and quartz shows that the four rocks straddle the line between normative olivine and quartz.

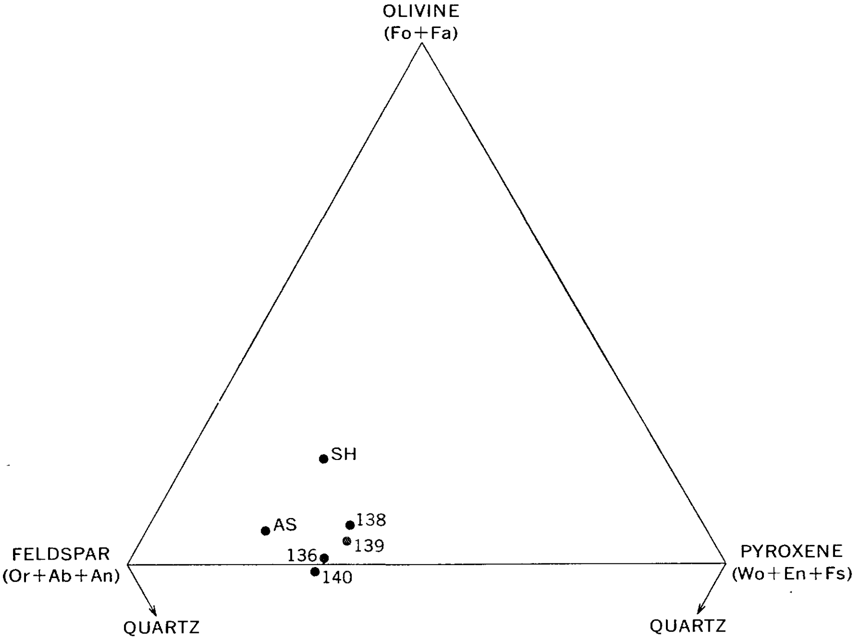

FIGURE 3.—Ternary plot of normative minerals of the melasyenite of Ute Creek and of augite syenite (AS) and shonkinite (SH) of the Powderhorn area (Hunter, 1925, p. 67, 73). Feldspar and pyroxene are plotted against olivine in the upper part of the diagram and against quartz in the lower part of the diagram. Abbreviations: Ab, albite; An, anorthite; En, enstatite; Fa, fayalite; Fo, forsterite; Fs, ferrosilite; Or, orthoclase; and Wo, wollastonite.

Contents of some trace elements in the melasyenite were determined by the semiquantitative spectrographic method by G. W. Sears, Jr. These analyses show, in parts per million:

Barium	3, 000–5, 000
Beryllium	1. 5–2
Cobalt	20–30
Chromium	500–1, 000
Copper	30–70
Lanthanum	70–150
Nickel	150–200
Lead	30
Vanadium	150–300
Yttrium	10–50
Zirconium	70–150

The following elements were not detected: Antimony, arsenic, bismuth, cadmium, gold, lead, molybdenum, niobium, palladium, platinum, silver, tantalum, tellurium, tungsten, and zinc. The values for chromium are noteworthy. The association of conspicuous amounts of cobalt, chromium, copper, and nickel with 70–150 ppm (parts per million) of lanthanum is unusual. The melasyenite contains 120–159 ppm of rubidium and 1,017–1,088 ppm of strontium (table 4).

PETROLOGY

Three aspects of the melasyenite deserve further comment. (1) Quartz has formed in all of this rock in spite of the fact that three of the four specimens analyzed are olivine normative. (2) The melasyenite not only shows a close compositional affinity to the potassic augite syenite and shonkinite of the Powderhorn area but probably is also of the same age. (3) The melasyenite also shows compositional kinship to other alkalic-mafic igneous rocks, especially those of Tertiary age in the Navajo-Hopi country of Arizona and New Mexico, in Spanish Peaks, Colo., and in Little Belt Mountains, Mont.

The melasyenite contains about 3–10 percent quartz (table 1), including that in the graphic granite. However, three of the analyzed melasyenites have 0.80–6.67 percent olivine in their C.I.P.W. norms. Quartz apparently crystallized because the early and median crystallization of so much relatively silica-poor hornblende and biotite resulted in silica enrichment of the last one-third or one-fourth of the magma. We estimate that the hornblende in the melasyenite contains 42–46 percent SiO_2 (based on compilation of Deer and others, 1963a, p. 275–281), that the biotite probably contains about 37 percent SiO_2 (based on an analysis of biotite in minette by Williams, 1936, p. 166), and that the microcline perthite and oligoclase contain roughly 64 percent of SiO_2 (based on analyses reported by Deer and others, 1963b, p. 38, 112). Augite in this type of magma apparently is more siliceous than biotite or hornblende, because Larsen and W. F. Jenks (Larsen, 1942, p. 46) found that the augite in a shonkinite near Powderhorn contains 49 percent SiO_2. Thus, in the melasyenite magma of Ute Creek, the 40–57 percent hornblende and biotite present contains appreciably less SiO_2 than the remaining 60–43 percent of the rock. Simple calculations (with densities assumed for biotite and hornblende) indicate that the liquid remaining after crystallization of the mafic minerals contained more than 65 percent SiO_2, and this resulted in crystallization of quartz and graphic granite from the last fraction of magma. Had the original magma been less hydrous and had more than very minor amounts of the more siliceous mineral augite formed instead of hornblende, the late liquid would have contained less than 65 percent SiO_2, and a nepheline shonkinite would have formed. Thus, the water content, and hence the activity of H_2O in the magma, can exert a strong influence on the course of crystallization—in this case, causing the hydrous silica-poor minerals to crystallize first and so producing a silica-oversaturated residual magma from which feldspars and quartz crystallized.

The melasyenite of Ute Creek is compositionally similar to augite syenite and shonkinite of the Powderhorn area, as shown by the analyses in table 1. One petrographic difference, however, is that the Powderhorn rocks typically contain the anhydrous mafic minerals augite and olivine which almost certainly indicate crystallization under less hydrous conditions than the Ute Creek body. Subordinate amounts of dark quartz-bearing hornblende syenite and biotite syenite, however, do occur in the Powderhorn region (Hunter, 1925, p. 70–71), and their brief petrographic descriptions indicate that they are very similar to the melasyenite of Ute Creek. Gravitationally driven migration of H_2O toward the upper regions of these intrusives (Kennedy, 1955), while these magmas were largely liquid, may have caused these variations in H_2O content. Larsen and Cross (1956, p. 37–38) pointed out that the alkalic-mafic rocks of the Powderhorn area are potassic, in distinction to the sodic, ultramafic, and mafic rocks of the nearby complex at Iron Hill (Larsen, 1942). The potassic syenites are cut by dikes of pegmatite and aplite, and Larsen and Cross considered them to be Precambrian. The Iron Hill rocks, in contrast, are not cut by such dikes.

TABLE 2.—*Analytical data and K-Ar ages of biotite from melasyenite of Ute Creek*

[Decay constants K^{40}: $\lambda_\beta=4.72\times10^{-10}$ per yr; $\lambda_\epsilon=0.584\times10^{-10}$ per yr. Abundance: $K^{40}=1.22\times10^{-4}$ g/g K. Analysts: R. F. Marvin, H. H. Mehnert, and Violet Merritt]

Sample	K_2O[1] (weight percent)	Radiogenic Ar^{40} (moles per gram)	Radiogenic Ar^{40}/K^{40}	Percentage radiogenic Ar^{40}	Apparent age (m.y.) $\pm2\sigma$
BSJ–139[2]	9.64; 9.60 (9.62 avg)	2.979×10^{-8}	0.122	99	1,410±50
BSJ–140[2]	9.01; 8.81; 9.08; 9.13 (9.01 avg)	2.717×10^{-8}	.119	99	1,380±50

[1] Potassium determinations made by flame photometer with lithium internal standard.
[2] Melasyenite samples collected at approximately lat 37°42'30" N., long 107°24'40" W., in Hinsdale County.

We have determined the K-Ar ages of biotite from BSJ–139 and BSJ–140 as 1,410±50 m.y. and 1,380±50 m.y., respectively, using the general techniques of Evernden and Curtis (1965). Our analytical data are given in table 2. These two determinations fix a younger limit of about 1,400 m.y. on the age of the melasyenite. Furthermore, we suggest that the melasyenite is 1,400–1,460 m.y. old because of the position of the 1,460–m.y.–old (Silver and Barker, 1968; Bickford and others, 1969) Eolus batholith less than 4½ miles south (Larsen and Cross, 1956, pl. 1), and because biotite from a sample of the Eolus collected 12 miles south of the melasyenite gave an apparent K-Ar age of 1,390±50 m.y. (R. E. Zartman and R. F. Marvin, unpub. data).

Radiometric ages of the Powderhorn rocks, obtained by the K-Ar method on biotite, indicate that the augite syenite and shonkinite are about 1,400 m.y. old and also that the complex at Iron Hill is of Cambrian age (J. C. Olson and R. F. Marvin, unpub. data). Thus, there is a real possibility that these Precambrian potassic-mafic intrusives of the Powderhorn area were comagmatic with the melasyenite of Ute Creek.

TABLE 3.—*Analyses of syenites, shonkinites, and lamprophyres from Colorado, New Mexico, and Montana*

	Ute Creek, Colo.	Shiprock, N. Mex.[1]	Spanish Peaks, Colo.[2]		
	Melasyenite (table 1)	Biotite lamprophyre	Shonkinite	Augite lamprophyre	Biotite-augite lamprophyre
SiO_2	53.13–54.93	51.80	52.90	47.63	46.37
Al_2O_3	11.49–13.16	11.10	10.20	12.01	11.98
Fe_2O_3	2.03–2.23	3.55	3.61	4.20	5.05
FeO	5.31–5.96	3.42	4.44	4.99	5.16
MgO	7.12–10.05	8.15	9.06	8.31	8.38
CaO	5.13–6.55	7.95	6.91	7.28	9.33
Na_2O	2.06–2.43	2.25	2.20	1.98	2.84
K_2O	4.83–5.55	5.97	6.36	5.40	4.34

	Little Belt Mountains, Mont.[3]			
	Shonkinite	Biotite lamprophyre	Melasyenite (yogoite)	Augite-hornblende syenite
SiO_2	48.49	52.26	54.42	61.65
Al_2O_3	12.29	13.96	14.28	15.07
Fe_2O_3	2.88	2.76	3.32	2.03
FeO	5.77	4.45	4.13	2.25
MgO	9.91	8.21	6.12	3.67
CaO	9.65	7.06	7.72	4.61
Na_2O	2.22	2.80	3.44	4.35
K_2O	4.96	3.87	4.22	4.50

[1] Williams (1936, p. 166); analysis by Frank Herdsman.
[2] Knopf (1936, p. 1780–1781); analyses by George Steiger and R. B. Ellestad.
[3] Weed and Pirsson (1895, p. 478); analyses by W. F. Hillebrand.

The compositional similarity of the Ute Creek intrusive to some of the Tertiary lamprophyres, shonkinites, and dark syenites of the

Rocky Mountain area can be seen in table 3. This similarity is sustained by analyses of one shonkinite and three lamprophyres of vogesitic type from the Barker area of the Little Belt Mountains (I. J. Witkind, unpub. data). The melasyenite also contains relatively large amounts of Sr, Ba, and P_2O_5, and thus shows another compositional similarity with lamprophyres (Knopf, 1936, p. 1781; Turner and Verhoogen, 1960, p. 255). These likenesses almost certainly indicate a similar mode of origin, despite the obvious differences of geologic environment and age.

In their summary discussion of potash-rich basic volcanic rocks and lamprophyres, Turner and Verhoogen (1960, p. 235–256) pointed out that lamprophyres commonly are associated with granitic rocks. The melasyenite of Ute Creek shows this association in that it probably was emplaced at the same time as or shortly after the Eolus batholith and in turn was intruded by alaskite dikes. However, the Ute Creek body does not exhibit the otherwise common occurrence of granite or quartz xenoliths in biotitic lamprophyres and potassic trachybasalts (Williams, 1936, p. 159–161; Turner and Verhoogen, 1960, p. 256).

The genesis of the melasyenite of Ute Creek thus is tied to the much larger problem of the origin of magmas that are potassic and mafic and generally have low to medium silica contents. Hypotheses of origin by direct injection of a partially melted mantle rock, by differentiation of mantle-derived magma, by assimilation of potassic crustal rock by mantle-derived magma, or by some other means cannot be properly tested by work on one rock type of such a small areal extent as that at Ute Creek. Nevertheless, a general knowledge of the Sr^{87}/Sr^{86} ratios both of the preexisting rocks of the Needle Mountains uplift immediately to the south and southwest (Bickford and others, 1969) and of the melasyenite appears to be of potential help in separating a strictly mantle origin from one involving crustal contamination of a mantle-derived magma.

Table 4 presents Sr and Rb data for the melasyenite. We calculated initial Sr^{87}/Sr^{86} ratios from the analytical values of Sr^{87}/Sr^{86} as corrected for the accumulation of radiogenic Sr^{87}, produced by the radioactive decay of Rb^{87} in 1,400 m.y., and from using the measured abundances of Rb. A mean value of 0.7031 for the four samples may be compared with the predicted ratio of Sr^{87}/Sr^{86} in the mantle 1,400 m.y. ago and with the 1,400-m.y. Sr^{87}/Sr^{86} ratios of nearby crustal rocks.

TABLE 4.—Rb-Sr *analytical data and calculated values of the ratio* Sr^{87}/Sr^{86}, *1,400 m.y. ago, for melasyenite of Ute Creek*

[Rb and Sr values by X-ray fluorescence method. Sr standards: USGS Shelf, 0.7100; MIT Shelf, 0.7080]

Sample (BSJ–)	Rb (ppm)	Sr (ppm)	Rb/Sr	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86} (Present)	Sr^{87}/Sr^{86} (1,400 m.y. ago [1])
136	135	1, 039	0. 130	0. 377	0. 7109	0. 7034
138	120	1, 085	. 111	. 322	. 7094	. 7031
139	125	1, 088	. 115	. 333	. 7094	. 7029
140	159	1, 017	. 156	. 542	. 7118	. 7029
Mean value						. 7031

[1] Calculated using Rb^{87}: $\lambda_{\beta}=1.39\times10^{-11}$ yr^{-1}.

In figure 4, the isotopic data are illustrated on a strontium evolution diagram. The variation of Sr^{87}/Sr^{86} in the mantle is assumed to increase linearly from a value for achondritic meteorites of 4.55 b.y.

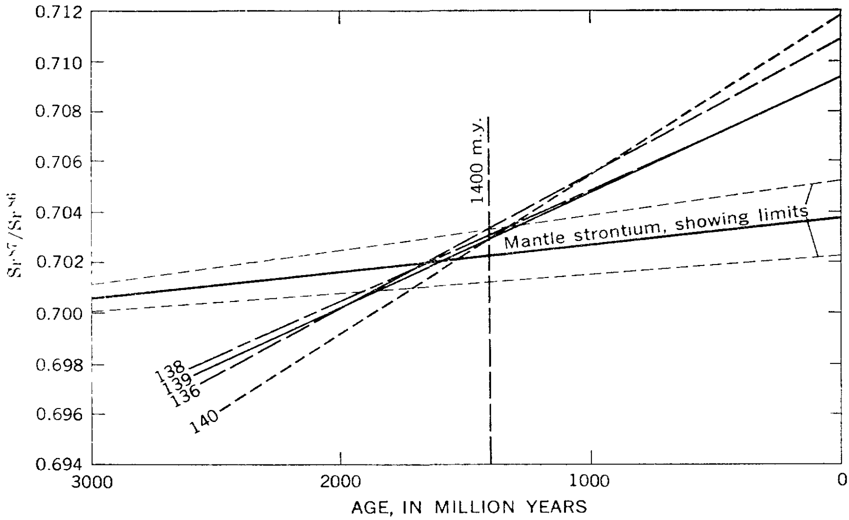

FIGURE 4.—Plot of age versus Sr^{87}/Sr^{86} ratio, showing model curve and approximate limits of Sr^{87}/Sr^{86} in the mantle, and age (Sr^{87}/Sr^{86}) relations of samples BSJ–136, –138, –139, and –140.

(billion years) ago to a present mean Sr^{87}/Sr^{86} value for oceanic basalts (Hedge, 1966). The upper and lower limits of this curve are based on the range of values for oceanic basalts.

Data for the melasyenites project back to a mean Sr^{87}/Sr^{86} value of 0.7031 at 1,400 m.y., which is within the predicted range (0.7010–0.7035) for mantle-derived rocks of this age. Thus, the value of 0.7031 for the melasyenites is compatible with a mantle-derivation for these rocks.

The immediate wallrocks of the melasyenite probably were quartzite and schist of the Uncompahgre Formation (Larsen and Cross, 1956, pl. 1). This formation, however, forms a synclinorium of no great depth (Fred Barker, unpub. data) and is underlain by a complex of amphibolite, quartzo-feldspathic gneiss, and granitic rocks that are about 1,700–1,800 m.y. old. The Eolus batholith intruded both the Uncompahgre Formation and the underlying complex 1,460 m.y. ago (Silver and Barker, 1968; Bickford and others, 1969) and is the youngest rock known to have been in this area when the melasyenite was intruded. Of these rocks, the one with the lowest Sr^{87}/Sr^{86} ratio 1,400 m.y. ago is the amphibolite found in the Twilight Gneiss (Fred Barker, Z. E. Peterman, and R. A. Hildreth, unpub. data), whose value was about 0.7037. The other rocks had values 1,400 m.y. ago, as calculated from data given by Bickford, Wetherill, Barker, and Lee-Hu (1969), ranging from 0.7060 for Eolus Granite to 0.7310 for the 1,720–m.y.–old granite at Whitehead Gulch, which lies 4 miles south of Silverton and 13 miles west of the Ute Creek deposit. The high strontium content of the melasyenite would render the Sr^{87}/Sr^{86} values rather insensitive to small amounts of contamination by granitic rocks of the area. However, the lack of petrographic evidence indicating xenocrystic or xenolithic material in the syenites and the low Sr^{87}/Sr^{86} initial values indicate that a crustal component need not be invoked as a significant feature in the petrogenetic history of these alkalic rocks. This interpretation is in accord with strontium isotopic data on carbonatites and on related alkalic rocks from other areas (Powell and others, 1966).

REFERENCES CITED

Barker, Fred, 1969, Precambrian geology of the Needle Mountains, southwestern Colorado: U.S. Geol. Survey Prof. Paper 644–A, 35 p.

Bickford, M. E., Wetherill, G. W., Barker, Fred, and Lee-Hu, Chin-nan, 1969, Precambrian Rb-Sr chronology in the Needle Mountains, southwestern Colorado: Jour. Geophys. Research, v. 74, p. 1660–1676.

Cross, Whitman, and Larsen, E. S., Jr., 1935, A brief review of the geology of the San Juan region of southwestern Colorado: U.S. Geol. Survey Bull. 843, 138 p.

Deer, W. A., Howie, R. A., and Zussman, Jack, 1963a, Chain silicates, v. 2 *of* Rock-forming minerals: New York, John Wiley & Sons, Inc., 379 p.

——— 1963b, Framework silicates, v. 4 *of* Rock-forming minerals: New York, John Wiley & Sons, Inc., 435 p.

Evernden, J. F., and Curtis, G. H., 1965, The potassium-argon dating of Late Cenozoic rocks in East Africa and Italy: Current Anthropology, v. 6, p. 343–385.

Hedge, C. E., 1966, Variations in radiogenic strontium found in volcanic rocks: Jour. Geophys. Research, v. 71, no. 24, p. 6119–6120.

Hedlund, D.C., and Olson, J. C., 1968, Geologic map of the complex of alkalic rocks at Iron Hill, Gunnison County, Colorado: U.S. Geol. Survey open-file map.

Hunter, J. F., 1925, Pre-Cambrian rocks of Gunnison River, Colorado: U.S. Geol. Survey Bull. 777, 94 p.

Johannsen, Albert, 1937, The intermediate rocks, v. 3 *of* A descriptive petrography of the igneous rocks: Chicago, Ill., Univ. Chicago Press, 360 p.

Kennedy, G. C., 1955, Some aspects of the role of water in rock melts, *in* Poldervaart, Arie, ed., Crust of the earth—a symposium: Geol. Soc. America Spec. Paper 62, p. 489–503.

Knopf, Adolph, 1936, Igneous geology of the Spanish Peaks region, Colorado: Geol. Soc. America Bull., v. 47, no. 11, p. 1727–1784.

Larsen, E. S., Jr., 1942, Alkalic rocks of Iron Hill, Gunnison County, Colorado: U.S. Geol. Survey Prof. Paper 197–A, 64 p.

Larsen, E. S., Jr., and Cross, Whitman, 1956, Geology and petrology of the San Juan region, southwestern Colorado: U.S. Geol. Survey Prof. Paper 258, 303 p.

Powell, J. L., Hurley, P. M., and Fairbairn, H. W., 1966, The strontium isotopic composition and origin of carbonatites, *in* Tuttle, O. F., and Gittins, John, eds., Carbonatites: New York, John Wiley & Sons, Inc., p. 365–378.

Rosenbusch, Harry, 1907, Mikroskopische Physiographie der massigen Gesteine: E. Schweizerbartsche Verlagshandlung, Stuttgart, v. 2, pt. 1, 716 p.

Silver, L. T., and Barker, Fred, 1968, U–Pb zircon results, pt. 1 *of* Geochronology of Precambrian rocks of the Needle Mountains, southwestern Colorado, *in* Abstracts for 1967: Geol. Soc. America Spec. Paper 115, p. 204–205.

Turner, F. J., and Verhoogen, John, 1960, Igneous and metamorphic petrology [2d ed.]: New York, McGraw-Hill Book Co., 694 p.

Weed, W. H., and Pirsson, L. V., 1895, Igneous rocks of Yogo Peak, Montana: Am. Jour. Sci., 3d ser., v. L, no. 300, p. 467–479.

Williams, Howel, 1936, Pliocene volcanoes of the Navajo-Hopi country: Geol. Soc. America Bull., v. 47, p. 111–172.