The Whitehorn Granodiorite Of the Arkansas Valley In Central Colorado

GEOLOGICAL SURVEY BULLETIN 1394-H

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By CHESTER T. WRUCKE

CONTRIBUTIONS TO STRATIGRAPHY

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Description of a new formation of Cretaceous age in central Colorado

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1974

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog—card No. 74-600082

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington, D. C. 20402 - Price 25 cents (paper cover)
Stock Number 2401-02514

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By CHESTER T. WRUCKE

ABSTRACT

The Whitehorn Granodiorite is a new formation on the east side of the Arkansas Valley in the vicinity of Salida, Colo. It ranges in composition from syenogabbro to quartz monzonite and forms a pluton and three small satellitic bodies. The main body, 25 km long and as much as 8 km wide, intrudes Precambrian and Paleozoic rocks; it is interpreted as having a subhorizontal floor on upper Paleozoic strata and a steeply inclined feeder conduit. One of the satellitic bodies is a plug, one is sill-like, and the other is of complex form.

Most of the granodiorite, including rock at the type locality on Cameron Mountain, is fine to medium grained and medium gray. It contains 12–27 percent dark minerals and medium-gray plagioclase. A few light-colored varieties occur locally that contain only a few percent dark minerals. The syenogabbro is dark olive gray and forms small bodies at the margin of the plug.

The granodiorite is typically a hypidiomorphic seriate rock consisting of quartz, plagioclase, orthoclase, augite, hornblende, biotite, and a few accessory minerals. The plagioclase is as calcic as An_{63}. Chemical analyses show that the rock is lower in SiO_2, NaO_2, and higher in Fe_2O_3, MgO, and CaO than average granodiorite.

Potassium-argon ages range from 69.4 to 70.4 million years, suggesting that the granodiorite was intruded in Late Cretaceous (early Maestrichtian) time.

NAME, TYPE AREA, AND PREVIOUS WORK

The name Whitehorn Granodiorite is given here to the rock that forms a pluton and several small satellitic bodies (fig. 1) on the east side of the Arkansas Valley in central Colorado. This name is taken from the ghost mining town of Whitehorn founded in 1897 (Eberhart, 1959) at the east margin of the body. Names previously used for the pluton include Whitehorn stock (Burbank and Lovering, 1933, p. 290), Calumet Granodiorite (Behre and others, 1936, p. 786), Calumet stock (Behre and others, 1936, p. 790), Cameron Mountain stock (Young, 1972, p. 118), and Salida stock (McDowell, 1971). The name "Calumet" has been preempted (Keroher, 1966) for rocks in Michigan. Cameron Mountain, near the center of the pluton, is designated the type locality. It is accessible from a gravel road that extends northeast from Salida and crosses the west and north sides of the mountain.

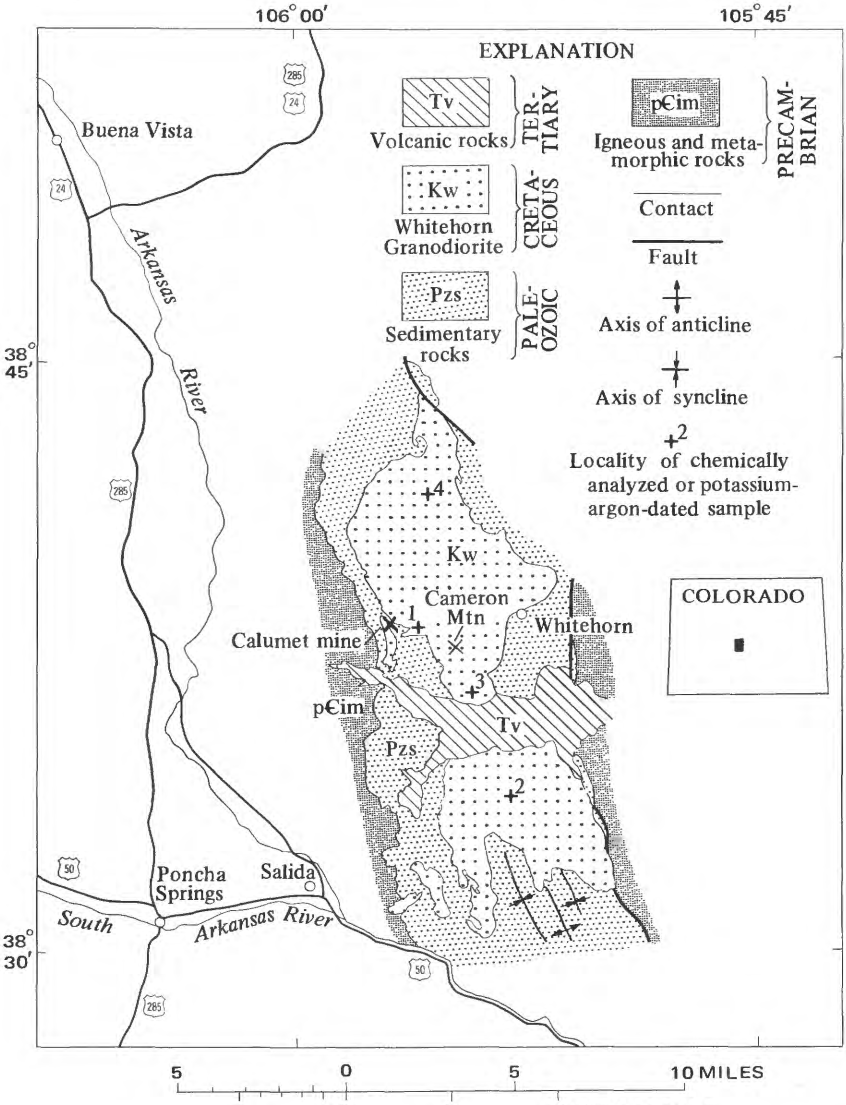

FIGURE 1.—Geology in the vicinity of Cameron Mountain and the location of the Calumet mine, Salida, and Whitehorn.

Burbank and Lovering (1933) mention the granodiorite at Whitehorn in a study of the stratigraphic and structural setting of ore deposits in Colorado. Behre, Osborn, and Rainwater (1936) describe the granodiorite in a discussion of the Calumet mine (fig. 1), and Harris and Wilbanks (1966) report on zircons in fresh and weathered samples of the rock. Data by McDowell (1971) on the age of the granodiorite and by Young (1972) on chemical analyses of the rock are discussed subsequently. Theses that contain maps showing large areas of the granodiorite or important contact relations are by Bhutta (1954), Normand (1968), Lowell (1969), and Pierce (1969).

GEOLOGIC SETTING, DISTRIBUTION, AND FORM

The granodiorite, which ranges in composition from syenogabbro to quartz monzonite, intrudes Precambrian igneous and metamorphic rocks and nearly flat lying Paleozoic sedimentary rocks (fig. 1). The main body of the granodiorite, 25 km (15.5 mi) long and as wide as 8 km (5 mi), lies almost completely in Paleozoic rocks. Exposures of this body are separated into two parts by a narrow band of Tertiary volcanic rocks deposited in an east-trending paleovalley (Chapin and others, 1970) 2.4 km (1.5 mi) wide across the central part of the pluton (fig. 1). The contact around the south and west sides dips inward subparallel to the nearly flat lying host sandstone and shale of Pennsylvanian and Permian age. Along the southeast side, the contact is steep, and the granodiorite invades Precambrian rocks that were upthrown against the Paleozoic rocks to the west before emplacement of the pluton. Around the east side of the northern part of the intrusion, the contact is vertical to steeply inward dipping and entirely in rocks of Pennsylvanian age. Although known imperfectly, the pluton is interpreted as having a subhorizontal floor on Paleozoic strata and to have been fed by a steeply inclined conduit. Roof rocks have been eroded away.

Three satellitic bodies crop out west of the main intrusion. The northern body is sill-like and intrudes faulted Paleozoic rocks. Of the other two bodies, the eastern mass is of complex form and has a subhorizontal eastern contact but a steep western contact. The western body is a plug that cuts Precambrian and Paleozoic rocks.

MEGASCOPIC CHARACTER

Most of the granodiorite, including rock at the type locality, is fine to medium grained and medium gray on fresh and weathered surfaces. It has medium-gray plagioclase and 12–27 percent dark minerals. At many places it contains very dark gray angular to subrounded biotite-rich inclusions less than 2.5 cm to about 30 cm across. Inclusions of carbonate rocks and sandstone or quartzite are reported by Behre, Osborn, and Rainwater (1936). Light-gray varieties of the granodiorite containing only a few percent dark minerals crop out locally, but aplitic and pegmatitic dikes are sparse. The distribution of these leucocratic rocks and the nature of the contacts with the more common medium-gray granodiorite are poorly known. A dark-olive-gray medium-grained syenogabbro occurs locally at the margin of the plug southwest of the main pluton.

A weak flow foliation occurs near the margin of the northern part of the main pluton. It dips gently eastward along the west side but steeply inward to almost vertical at the east margin. Lowell (1969) shows foliation with random attitudes in a small area in the southern part of the main intrusive, but most of this part of the pluton has not been studied in detail.

MICROSCOPIC CHARACTER

As seen in thin section, most of the granodiorite is a hypidiomorphic seriate rock in which plagioclase is conspicuous as euhedral to subhedral crystals generally 0.2–3 mm long. The plagioclase crystals have cores of labradorite as calcic as An_{63} and rims of oligoclase; many crystals have oscillatory zoning. Orthoclase ranges from small interstitial grains to poikilitic crystals 3 mm across. A few K-feldspar crystals are faintly perthitic. Most quartz is interstitial, but a few grains as large as 1 mm across are poikilitic. Subhedral to anhedral augite crystals 0.1–1 mm long occur as isolated crystals and in aggregates associated with green hornblende, brown biotite, and magnetite. Apatite is a common accessory mineral; hypersthene, sphene, and zircon are sparse. Porphyritic varieties of granodiorite at the border of the large pluton have blocky plagioclase phenocrysts in a microgranitic groundmass.

Examination of a few specimens of the light-colored rocks reveals that most are altered granodiorite in which feldspars are dusted with fine alteration products and the mafic grains are largely altered to chlorite. A relatively common leucocratic quartz monzonite in the southern part of the pluton has no more than 5 percent mafic grains, now largely chlorite. This rock is porphyritic and contains abundant quartz and partly sericitized plagioclase phenocrysts in a microgranitic groundmass of K-feldspar and quartz.

The syenogabbro border zone of the plug is a labradorite-K-feldspar-pyroxene-olivine rock containing both augite and hypersthene. Olivine has been converted to serpentine, clays, and magnetite. This rock has a higher color index (about 40) and a much larger grain size than the granodiorite. Plagioclase crystals are mostly 1–3 mm long, but some reach 6 mm; augite grains commonly are 0.5–2.5 mm across.

The K-feldspar in the granodiorite and syenogabbro was identified by X-ray examination using the 2θ value of the 060 and $\bar{2}04$ diffraction peaks, according to the method described by Wright (1968). Two samples of granodiorite, one collected near the south end of the main pluton and the other from the north part, contain K-feldspar close to the orthoclase end member of the orthoclase-albite series. Optic axial angles of this orthoclase are 50°–58°. K-feldspar from the syenogabbro is sanidine according to the method of Wright. Optic axial angles of the sanidine are 43°–48°.

MODAL AND CHEMICAL DATA

The composition of the Whitehorn Granodiorite ranges from syenogabbro to quartz monzonite as determined from modal analyses of 12 specimens (fig. 2). Modes of nine specimens of granodiorite collected from scattered localities throughout the main pluton show that the composition, in volume percent, is quartz, 9–20; plagioclase, 45–55; orthoclase, 9–18; biotite, 2–12; augite, 0–13; hornblende, 0–10; and accessory hypersthene, apatite, sphene, and magnetite. Although the anorthite content of the plagioclase in most specimens studied averages less than 50 percent, it is greater than 50 percent in a few samples. The rocks with high anorthite contents would be classified as granogabbro by Johannsen (1931). According to recommendations of the International Union of Geological Sciences (1973), some of the granodiorite with less than 20 percent quartz would be quartz monzodiorite and some would be quartz monzogabbro. Using available data, the common rock of the Whitehorn Granodiorite might best be termed augite granodiorite, except that some of it lacks augite. Quartz diorite and quartz monzonite in the Whitehorn differ from its granodiorite in the proportions of the feldspars.

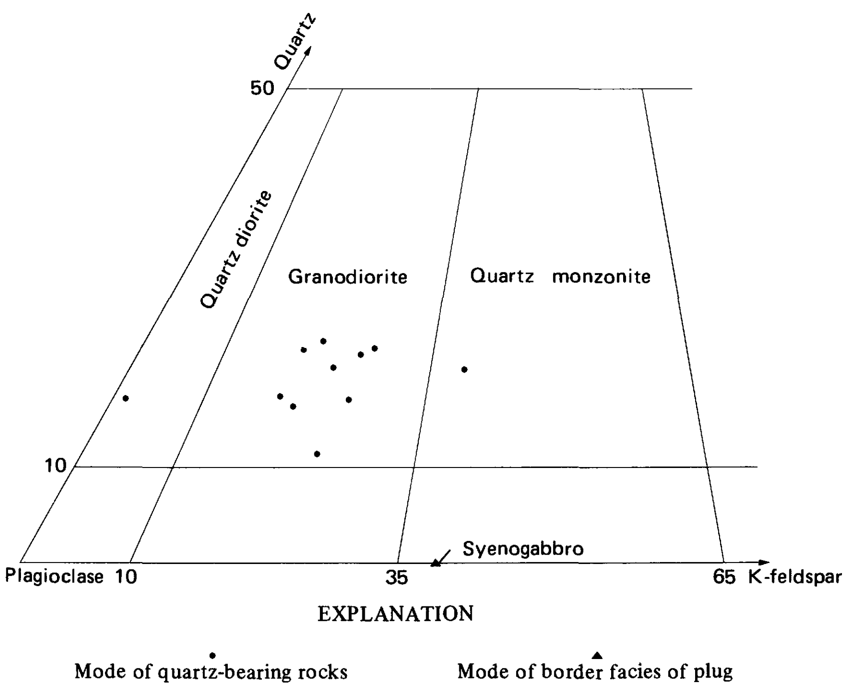

FIGURE 2.—Modal quartz, plagioclase, and K-feldspar in 12 specimens of the Whitehorn Granodiorite.

Chemical analyses of four samples of the rock are given in table 1. Specimens 1 and 2 have compositions similar to average hypersthene-bearing granodiorite of Nockolds (1954). Modes of these two rocks plot on the quartz side of the granodiorite field of figure 2. However, these granodiorites are unusual in containing plagioclase with labradorite cores, which may account in part for the higher CaO and lower Na_2O than in Nockolds' average hypersthene-bearing granodiorite. Specimens 3 and 4 have low contents of SiO_2, reflecting their mafic character. Modes of these rocks plot on the quartz-poor side of the granodiorite field of figure 2.

The modal composition of the syenogabbro, in volume percent, is plagioclase, 36; sanidine, 22; augite, 22; hypersthene, 5; clays after olivine, 3; biotite, 2; magnetite, 6; apatite, 2; calcite and other alteration products, 2. In the International Union of Geological Sciences (1973) classification, this rock could be termed a monzogabbro.

AGE

Biotite from a specimen collected near the north end of the large pluton (fig. 1, loc. 4) gave a potassium-argon age of 70.0 ± 2.6 million years (R. F. Marvin, written commun., 1971). McDowell (1971) reports that a sample collected west of Cameron Mountain had concordant ages from biotite and hornblende of 70.4 ± 2.1 and 69.4 ± 2.1 million years, respectively. These radiometric ages suggest that the granodiorite was intruded in Late Cretaceous (early Maestrichtian) time.

REFERENCES CITED

Behre, C. H., Osborn, E. F., and Rainwater, E. H., 1936, Contact ore deposition at the Calumet iron mine, Colorado: Econ. Geology, v. 31, no. 8, p. 781–804.

Bhutta, M. A., 1954, Geology of the Salida area, Chaffee and Fremont Counties, Colorado: Colorado School Mines, Golden, D. Sc. thesis, 173 p.

Burbank, W. S., and Lovering, T. S., 1933, Relation of stratigraphy, structure, and igneous activity to ore deposition of Colorado and southern Wyoming, *in* Ore deposits of the western states (Lindgren volume): Am. Inst. Mining Metall. Engineers, p. 272–316.

Chapin, C. E., Epis, R. C., and Lowell, G. R., 1970, Late Eocene paleovalleys and Oligocene volcanic rocks along the upper Arkansas Valley segment of the Rio Grande rift zone in Colorado [abs.], *in* Woodward, L. A., ed., Tyrone-Big Hatchet Mountains-Florida Mountains region: New Mexico Geol. Soc. Guidebook 21st Field Conf., p. 159–160.

Eberhart, Perry, 1959, Guide to the Colorado ghost towns and mining camps: Denver, Colo., Sage Books, 479 p.

Harris, R. L., Jr., and Wilbanks, J. R., 1966, Variations in zircon crop measurements caused by weathering, Whitehorn stock, central Colorado: Mtn. Geologist, v. 3, no. 3, p. 135–138.

International Union of Geological Sciences, Subcommission on the Systematics of Igneous Rocks, 1973, Plutonic rocks: Geotimes, v. 18, no. 10, p. 26–30.

Johannsen, Albert, 1931, A descriptive petrography of igneous rocks, v. 1: Chicago, Ill., Chicago Univ. Press, 318 p.

TABLE 1.—*Chemical and modal data of the Whitehorn Granodiorite*

[Rapid chemical analyses of specimens 1 and 3 by P. L. D. Elmore, James Kelsey, Hezekiah Smith, Roosevelt Moore, and J. L. Glenn and of specimens 2 and 4 by P. L. D. Elmore. Spectrographic analyses of specimens 1 and 3 by semiquantitative methods by Norma Rait and of specimens 2 and 4 by quantitative methods by Chris Heropoulos. Looked for but not found in specimens 1 and 3: Ag, As, Au, B, Bi, Cd, Eu, Ge, Hf, In, Li, Mo, Nd, Pd, Pr, Pt, Re, Sb, Sn, Ta, Te, Th, Tl, U, W, Zn]

Locality number (fig. 1)	1	2	3	4
Chemical analyses (weight percent)[1]				
SiO_2	62.4	60.2	57.6	55.6
Al_2O_3	15.4	17.6	15.6	16.9
Fe_2O_3	3.4	2.8	3.6	3.5
FeO	3.5	3.3	4.9	5.2
MgO	2.1	2.0	3.0	3.2
CaO	5.9	5.6	6.6	7.1
Na_2O	2.9	3.4	3.1	3.0
K_2O	2.3	2.4	2.6	2.4
H_2O-	.18	.12	.10	.06
H_2O+	.66	.88	.42	.64
TiO_2	.68	.79	1.0	1.2
P_2O_5	.50	.41	.68	.48
MnO	.10	.20	.18	.20
CO_2	<.05	.15	<.05	<.05
Total	100.07	99.85	99.43	99.53
Spectrographic analyses (weight percent)[2]				
Ba	0.07	0.062	0.15	0.044
Be	----	----	----	----
Co	.0015	.0007	.002	.0016
Cr	.002	.0008	.003	.0018
Cu	.002	.0009	.007	.005
Ga	.001	.0022	.0015	.0022
La	----	.0095	----	.0052
Mn	.07	.012	.1	.12
Nb	----	----	----	----
Ni	L	----	.003	.0008
Sc	.0015	.0013	.002	.0024
Sr	.07	.07	.07	.14
V	.015	.0078	.02	.02
Y	.0003	.004	.0003	.0046
Yb	.0003	.0003	.0003	.0004
Zr	.015	.019	.015	.019
Modes (volume percent)				
Quartz	17	20	9	13
Plagioclase	45	55	51	52
K-feldspar	12	13	17	13
Biotite	11	5	9	10
Hornblende	10	4	7	2
Augite	1	----	4	5
Opaques	3	2	2	3
Other	1	1	1	2
Total	100	100	100	100

[1]Methods used are those of Shapiro and Brannock (1962) supplemented by atomic absorption.

[2]Results of semiquantitative analyses of specimens 1 and 3 are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, etc., which represent approximate midpoints of interval data on a geometric scale. The assigned interval for semiquantitative results will include the quantitative value 30 percent of the time. Results for quantitative analyses of specimens 2 and 4 are reported to two significant figures and have an overall accuracy of $\pm$15 percent, except that they are less accurate near the limits of detection where only one digit is intended. L=detected but below limit of determination.

1. Granodiorite from west margin of main intrusive body. Collected by E. J. Young in quarry on Ute Trail Road. Analyses from Young (1972), sample 16–71.
2. Granodiorite from south-central part of main intrusive body at Federal quarry, SE¼ sec. 20, T. 50 N., R. 10 E.
3. Granodiorite from central part of main intrusive body. Collected by E. J. Young at quarry, SE¼ sec. 6, T. 50 N., R. 10 E. Analyses from Young (1972), sample 15–71.
4. Augite granodiorite from north-central part of main intrusive body at quarry, SE¼ sec. 1, T. 51 N., R. 9 E.

Keroher, G. C., and others, 1966, Lexicon of geologic names of the United States for 1936–60: U.S. Geol. Survey Bull. 1200, 4341 p.

Lowell, G. R., 1969, Geologic relationships of the Salida area to the Thirtynine Mile volcanic field of central Colorado: New Mexico Inst. Mining and Technology, Socorro, Ph. D. thesis, 113 p.

McDowell, F. W., 1971, K/Ar ages of igneous rocks from western United States: Isochron/West, no. 2, p. 1–16.

Nockolds, S. R., 1954, Average chemical compositions of some igneous rocks: Geol. Soc. America Bull., v. 65, no. 10, p. 1007–1032.

Normand, D. E., 1968, The geology of the Whitehorn stock area, Chaffee, Fremont and Park Counties, Colorado: Texas Technol. Coll., Lubbock, M.S. thesis, 61 p.

Pierce, W. H., 1969, Geology and Pennsylvanian-Permian stratigraphy of Howard area, Fremont County, Colorado: Colorado School Mines, Golden, M.S. thesis, 129 p.

Shapiro, Leonard, and Brannock, W. W., 1962, Rapid analyses of silicate, carbonate, and phosphate rocks: U.S. Geol. Survey Bull. 1144–A, 56 p.

Wright, T. L., 1968, X-ray and optical study of alkali feldspar: II, An X-ray method for determining the composition and structural state from measurement of 2θ values for three reflections: Am. Mineralogist, v. 53, nos. 1–2, p. 88–104.

Young, E. J., 1972, Laramide-Tertiary intrusive rocks of Colorado: U.S. Geol. Survey open-file report, 206 p.

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