Gold Investigations in Precambrian Clastic and Pelitic Rocks, Southwestern Colorado and Northern New Mexico

GEOLOGICAL SURVEY BULLETIN 1272-F

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By FRED BARKER

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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CONTRIBUTIONS TO ECONOMIC GEOLOGY

GOLD INVESTIGATIONS IN PRECAMBRIAN CLASTIC AND PELITIC ROCKS, SOUTHWESTERN COLORADO AND NORTHERN NEW MEXICO

By Fred Barker

ABSTRACT

A search was made to find fossil placer deposits of gold in the Precambrian clastic rocks of southwestern Colorado and northern New Mexico. In Colorado, the Vallecito Conglomerate and conglomerates of the Uncompahgre Formation of the Needle Mountains were sampled. In New Mexico, the Ortega Quartzite, the Big Rock Conglomerate Member, the Jawbone Conglomerate Member, and the upper quartzite member of the Kiawa Mountain Formation in the Tusas Mountains, and the lower quartzite member of the Ortega Quartzite and the conglomerate member of the Vadito Formation of Montgomery (1953) in the Picuris Range were sampled. These rocks contain less than 0.1 part per million gold, and they apparently were derived from a terrane of quartzite, jasper, argillite, and iron-formation that contained virtually no gold.

In addition, carbonaceous slate and schist of the Uncompahgre Formation were sampled and analyzed for gold and for 29 other metals. These rocks are predominantly low in metals.

INTRODUCTION

This report describes a reconnaissance search for gold in Precambrian clastic and pelitic rocks of the Needle Mountains of southwestern Colorado and of the Tusas and Picuris Mountains of northern New Mexico. The possibility of finding fossil placers in pebbly quartzites and conglomerates, and deposits of very fine grained precipitated vanadium and gold in carbonaceous slates and schists, provided inducement for this work as part of the U.S. Geological Survey's search for heavy metals. Analyses show low amounts of gold—less than 0.1 part per million—in these rocks, and consequently no geochemically anomalous amounts of gold or commercially important deposits are indicated. The three areas involved are discussed separately.

NEEDLE MOUNTAINS, COLO.

GEOLOGIC RELATIONS

The Needle Mountains, which lie in La Plata, San Juan, and Hinsdale Counties, Colo., form the southwestern part of the San Juan Mountains and include the Grenadier Range, the Needle Mountains group, the West Needle Mountains, and adjacent peaks. They are underlain largely by Precambrian rocks.

The geology of the Needle Mountains was studied intensively in the period 1895–1910 by Cross, Howe, and Ransome (1905), Cross and Howe (1905), and Cross and Hole (1910). Reports of these studies included geologic maps at 1:62,500 scale. Later the geology was summarized by Cross and Larsen (1935) and Larsen and Cross (1956), whose reports included geologic maps at 1:250,000 scale. The Precambrian Uncompahgre Formation in Uncompahgre Gorge, about 14 miles north of the Needle Mountains area, was described by Kelley (1946), Luedke and Burbank (1962), and Burbank and Luedke (1964). Recent studies by the author (Barker, 1968a, b; 1969) have revealed a geologic history of the Precambrian rocks of the Needle Mountains that is somewhat different from that described by Cross and his associates and that consists of:

1. Deposition of the Vallecito Conglomerate.
2. Deposition of the largely metavolcanic Irving Formation, which comprises Cross and Howe's Irving Greenstone and Archean schist and gneiss.
3. Folding along north to northeast trends, metamorphism to high rank, and formation of the Twilight Gneiss and the Tenmile and Bakers Bridge Granites.
4. Deep erosion.
5. Unconformable deposition of sediments of the Uncompahgre Formation—now quartzite, slate, schist, and conglomerate.
6. Isoclinal folding along east to southeast trends, and metamorphism of low to medium rank.
7. Intrusion of the Eolus and Trimble Granites and the Electra Lake Gabbro.
8. Deep erosion, followed by deposition of sediments in Cambrian time.

These various geologic units are shown on the geologic map (fig. 1), but the older and younger intrusive rocks are shown undivided.

Radiometric studies by Silver and Barker (1968), using the uranium-lead method, and by Bickford, Barker, Wetherill, and Lee-Hu (1969), using the rubidium-strontium method, indicate that the Twilight Gneiss is about 1,780 m.y. (million years) old, the Tenmile and Bakers Bridge Granites are about 1,720 m.y. old, and the Eolus Granite and the Electra Lake Gabbro are about 1,460 m.y. old.

The Vallecito Conglomerate, the basal conglomerate of the Uncompahgre Formation, and the pebbly quartzite and pyritic pelitic rocks stratigraphically higher in that formation were sampled and analyzed for gold, with negative results. Descriptions of these units follow.

VALLECITO CONGLOMERATE

The Vallecito Conglomerate is found only in the southeastern Needle Mountains, along the lower valleys of Vallecito Creek and Pine River and underlying much of the complex ridge between these streams (fig. 2). This conglomerate forms many cliffs and is well exposed.

In outcrop the Vallecito Conglomerate is mostly gray, but locally it is pink or purple. It is thin to very thick bedded, and it shows conspicuous cross-stratification of the trough type described by McKee and Weir (1953, p. 387) or the pi type described by Allen (1963, p. 109), except that the cross-strata are lithologically heterogeneous; hematite laminae are interlayered with pebble conglomerate. The Vallecito contains randomly distributed beds of coarse-grained quartzite 1–18 inches thick and a few scattered, much thicker, beds of quartzite. Joints cut both clasts and matrix.

A few folds that have amplitudes of one hundred to several hundred feet were found, but folds that have amplitudes of a few inches to several feet are extremely sparse.

The Vallecito Conglomerate is overlain by amphibolite, metavolcanic rocks of intermediate composition, mica schists, quartzite, gneisses, and chlorite schists of the Irving Greenstone of Cross and Howe (1905), here termed the Irving Formation. The contact between the Vallecito and the overlying rocks has little or no angular discordance, and the sequence of deposition was determined from cross-stratification. The lower contact of the Vallecito is not exposed, and therefore neither the thickness of the formation nor the nature of rocks underlying it is known. However, at Granite Peaks Ranch in Pine River valley (fig. 2), good top and bottom control by cross-stratified beds enables measurement of a 2,400-foot thickness of the stratigraphically lowest part of the Vellecito Conglomerate. Larsen and Cross (1956, p. 24) gave "an estimated exposed thickness of more than 3,000 feet west of Pine River." This formation may well be more than 5,000 feet thick.

The Vallecito Conglomerate is metaconglomerate and pebbly quartzite that contains subangular to rounded fragments of milky quartz,

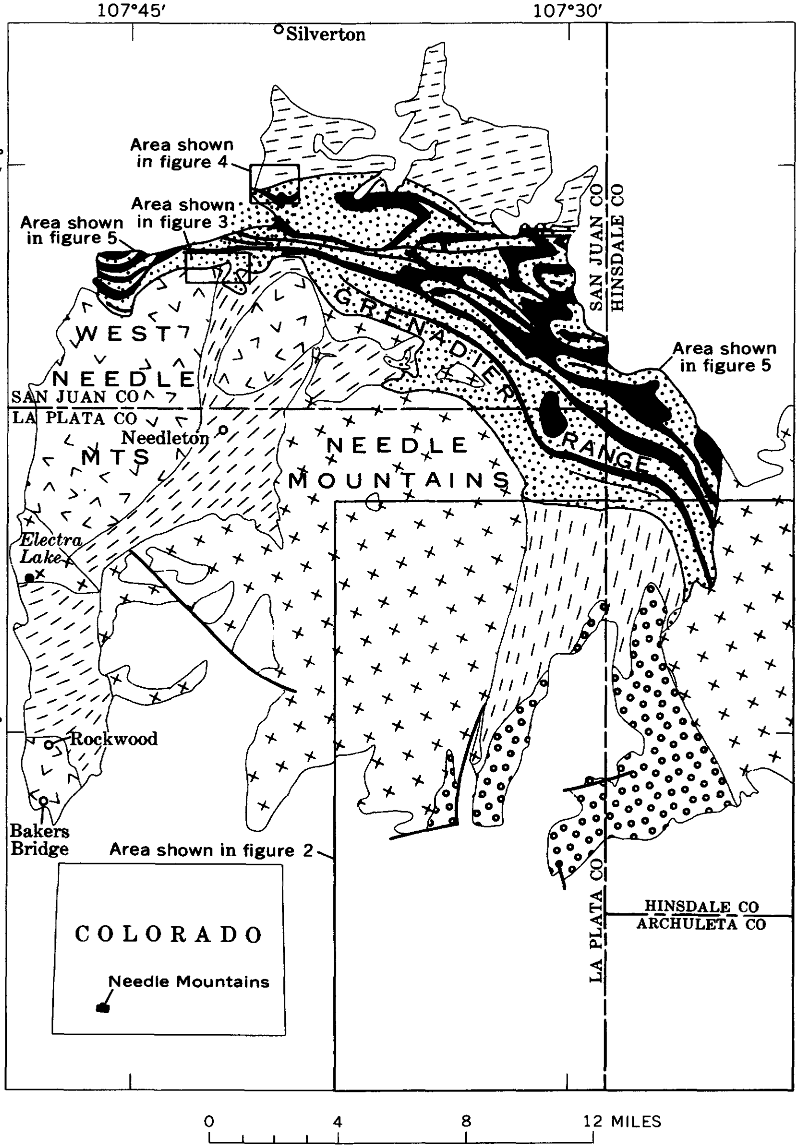


FIGURE 1.—Generalized geologic map of the Needle Mountains, Hinsdale, La Plata, and San Juan Counties, Colo., and index to location of areas shown in figures 2–5.

EXPLANATION

PALEOZOIC, MESOZOIC, AND CENOZOIC

Post-Precambrian rocks

PRECAMBRIAN

Younger intrusive rocks

Include Trimble Granite, Electra Lake Gabbro, and Eolus Granite

Uncompahgre Formation

Stipple, quartzite

Solid black, slate and schist

ANGULAR UNCONFORMITY

Older intrusive rocks

Include Tenmile and Bakers Bridge Granites and Twilight Gneiss

Irving Formation

Dashes show trend of foliation

Vallecito Conglomerate

Contact

Fault

351-385 O—69——2

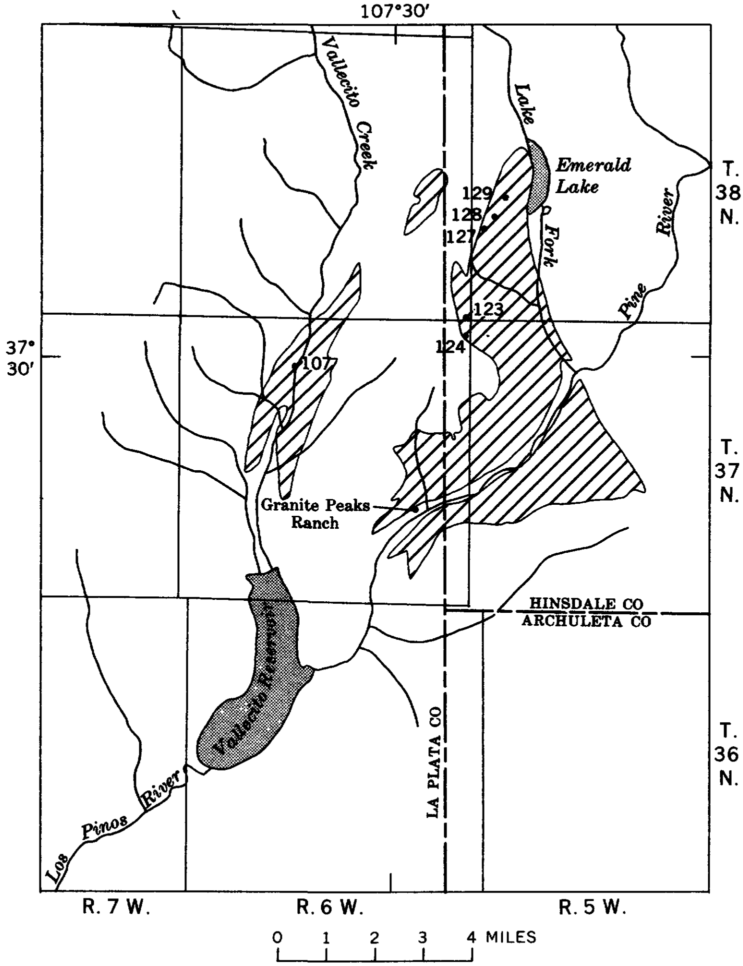


FIGURE 2.—Geologic map showing Vallecito Conglomerate (ruled areas) and sample localities, Needle Mountains, Colo.

red and black jasper, chert, gray argillite, ferruginous quartzite and iron-formation, intermediate volcanic rocks, epidote-rich greenschist, and muscovite schist. The clasts range in maximum dimension from less than 1 mm to about 12 inches, but very few are larger than 4 inches. The quartz clasts are polygranular, and most grains are equant and polygonal to irregular in shape and ⅛–1 mm in size; grains 1–2 mm in size and shaped like the smaller ones form 10–20 percent of many of the clasts. Such a fabric suggests that these clasts were derived from quartzite in which larger detrital grains were set in a finer matrix. Ovoid aggregates of sericite, sericite + quartz + albite, and sericite + epidote + biotite + quartz are interpreted as metamorphosed grains of feldspar or of relatively fine grained quartzose feldspathic rocks, probably volcanic rocks of intermediate to rhyolitic compositions, in which original potassic feldspar has been hydrolyzed to sericite and original plagioclase has been converted to albite and epidote. The matrix is a poorly sorted aggregate of quartz and sericite with minor hematite, leucoxene, garnet, albite, biotite, and epidote. It is mostly gray, but locally it is pink to purple; most grains are ⅛–1 mm in size. The rock was completely recrystallized during metamorphism: quartz, both in the matrix and in the various types of clasts in which it occurs, has grown into polygranular mosaic fabrics; the sericite is mostly well alined and gives a schistose aspect to the matrix; the sparse garnets all lie enclosed in sericite and may be metamorphic rather than detrital; and epidote grains only rarely show rounded outlines, suggesting detrital origin and later recrystallization. Dark laminae 1–3 mm thick are abundant in much of the formation. These are largely hematite, commonly with accessory ilmenite and rutile. The hematite commonly shows octahedral forms, indicating derivation from magnetite by oxidation (Barker, 1968b). No gold was found in the Vallecito Conglomerate within the limits of detectability.

Sampling of the Vallecito Conglomerate involved collecting a 170-lb sample (No. 107 in table 1 and fig. 2) in the canyon of Vallecito

TABLE 1.—*Localities and descriptions of samples analyzed for gold*

[Analyses showed that all samples, except first sample listed, contained less than 0.1 part per million of gold. All samples, except first sample listed, are chip samples. Analysts: W. L. Campbell, R. L. Miller, M. S. Rickard, and T. A. Roemer]

Formation	Sample locality		Remarks
	Fig. No.	Loc. No.	
			Needle Mountains, Colo.
Vallecito Conglomerate	2	107	170-lb sample collected in canyon of Vallecito Creek Description and analysis given in text.
		123, 124, 127–129	5-lb composite chip samples taken west of the Lake Fork of Pine River.
Uncompahgre Formation:			
Basal conglomerate	3	192	3–4 ft above base (base not exposed here).
		193	Basal 6 in.
		194	6 in. to 4 ft above base.
		195	4–8 ft (top) above base.
		196	Laterally 8 ft along base and in lowermost 2 in.
		199	Basal 12 in.
		200	1–8 ft (top) above base.
		201	Basal 12 in.
		202	1–8 ft (top) above base.
		203	2½–3 ft above base (base not exposed here).
(North side of formation, where basal conglomerate is 1½–3 ft thick).	4	197	0–18 in. above base of pebbly layer, about 20 ft vertically above railroad tracks.
		204	18-in.-thick conglomerate overlain by pebbly quartzite.
		205	4-in.-thick layer of conglomerate in a 2½-ft-thick layer of pebbly quartzite (equivalent to the basal conglomerate).

TABLE 1.—*Localities and descriptions of samples analyzed for gold*—Continued

Formation	Sample locality		Remarks
	Fig. No.	Loc. No.	
Uncompahgre Formation—Con.			
Pebbly quartzite and conglomerate (body of formation).	5	143	4-in.-thick pebble conglomerate.
		144	Pebble quartzite lens 3-6 in. thick.
		168	12-ft-thick pebbly conglomerate and quartzite.
		169	3-ft-thick layer of conglomerate.
		174	5- to 6-in.-thick lens of conglomerate.
		175	2- to 4-in.-thick lens of conglomerate.
		185	Across a 15-ft-thick conglomerate layer with 1 in. pebbles of quartz and jasper; layer lies in 300-ft thick unit of coarse-grained to pebbly quartzite.
		187	10-in.-thick conglomerate.
		188	4- to 5-in-.thick conglomerate in sparsely pebbly quartzite; 9 ft north of sample 187.
		189	6-in.-thick conglomerate lens; 100 ft north of sample 188.
		191	2- to 10-in.-thick conglomerate lenses in 2-ft-thick pebbly quartzite.
Tusas Mountains, N. Mex.			
Kiawa Mountain Formation: Big Rock Conglomerate Member.	6	12	SW¼SE¼ sec. 22, T. 27 N., R. 8 E.; Las Tablas quadrangle. Massive conglomerate with 1- to 4-in. clasts; muscovitic schistose matrix. Sampled across a 10-ft breadth normal to schistosity, bedding not visible. Lowermost conglomerate exposed on northeast flank of Big Rock syncline, sample within about 20 ft of base of this member.
		13	200 ft N. 70° W. of sample 12 locality, SE¼SW¼ sec. 22, T. 27 N., R. 8 E. Lithology like that of sample 12. Chipped across a 40-ft breadth normal to schistosity; bedding not visible.
		14	SW¼NW¼ sec. 27, T. 27 N., R. 8 E., Las Tablas quadrangle. Lithology similar to that of samples 12 and 13. Chipped across a 50-ft breadth normal to schistosity. Lowermost exposed conglomerate on southwest flank of Big Rock syncline. Bedding not visible in sampled section but is apparent in folded pebbly quartzite immediately to the northeast, which suggests that the conglomerate, also, contains minor folds.
		15	1,650 ft southeast of sample 14 locality, also on southwest flank of Big Rock syncline; SE¼NW¼ sec. 21, T. 27 N., R. 8 E., Las Tablas quadrangle Chipped across a 4-ft thickness of a small outcrop
Jawbone Conglomerate Member.	6	6	NE¼NE¼ sec. 24, T. 29 N., R. 6 E., Cebolla quadrangle, south ridge of Jawbone Mountain at 10,340-ft elevation. Chipped across a 10-ft thickness of mixed conglomerate and pebbly quartzite, each with hematite-rich laminae. Pebbles mostly ½–1 in. in maximum dimension and consist of about 80 percent quartz and 20 percent red and dark-gray jasper. The heavy minerals of 354 grams of this sample were separated with bromoform and yielded 56 grams of hematite, kyanite, rutile, and ilmenite.
		7	NE¼NW¼ sec. 19, T. 29 N., R. 7 E., Burned Mountain quadrangle, 10,400-ft elevation on southwest slope of east summit (10,601-ft elev.) of Jawbone Mountain. Chipped across a 3-ft thickness of conglomerate with ¾- to 1-in. pebbles of milky and pink quartz and red and dark-gray jasper. Underlying rocks not exposed; overlying rocks are cross-stratified fine-grained conglomerate and quartzite.
		8	SE¼NE¼ sec. 7, T. 28 N., R. 7 E., Burned Mountain quadrangle, 9,650-ft elevation. Chipped across a 30-ft thickness of poorly sorted conglomerate with ¼- to 2-in. pebbles of quartz and jasper.
		20	SW¼NE¼ sec. 24, T. 29 N., R. 6 E., Cebolla quadrangle, small knob at 10,200-ft elevation. Chipped across 8-ft thickness of about 80 percent of conglomerate with ¾-in. pebbles and 20 percent of fine-grained quartzose conglomerate and quartzite.
Upper quartzite member	6	9	West end of hill near 9,727-ft elevation, Burned Mountain quadrangle. Sample, largely of float, chipped across 30 ft of folded quartz pebble conglomerate that probably is 5–10 ft thick.
		10	200 ft east of sample 9 locality. Chipped across 12 ft of intricately folded quartzite that contains 25–30 percent conglomerate in layers 4–8 in. thick.
		11	About 525 ft east and 75 ft north of sample 9 locality. Chipped across 15 ft of mixed bedrock and float of a layer of conglomerate that is probably 10–15 ft thick.

TABLE 1.—*Localities and descriptions of samples analyzed for gold*—Continued

Formation	Sample locality Fig. No.	Sample locality Loc. No.	Remarks
			Picuris Range, N. Mex.
Ortega Quartzite, lower quartzite member.	7	5	NW¼NW¼ sec. 21, T. 23 N., R. 11 E., Trampas quadrangle, southeast side of Cooper Hill at 7,470-ft elevation. Chipped across a 2-ft thickness of gray hematitic quartzite with kyanite and staurolite.
		8	NW¼NE¼ sec. 15, T. 23 N., R. 12 E., Peñasco quadrangle, north end of summit of Picuris Peak. Chipped across 5-ft thickness of slightly rusty, massive quartzite that contains 10–15 percent of garnet and staurolite but no hematite or other opaque minerals.
		9	NW¼SW¼ sec. 24, T. 24 N., R. 11 E., Taos SW quadrangle, north side of Hondo Canyon at 7,090-ft elevation. Chipped across 6-ft thickness of sillimanite-muscovite quartzite with laminae of hematite and ilmenite spaced 8 mm to 8 cm apart; rock is not cross-stratified.
		(10–13)	NE¼NE¼ sec. 12, T. 23 N., R. 10 E., Trampas quadrangle, Glen Woody prospect (Jones, 1904, p. 158–161; Lindgren and others, 1910, p. 82, 91), east of Glen Woody bridge, about 6,070-ft elevation.
		10	Kyanite-bearing quartzite that contains disseminated hematite and ilmenite; from walls of shallow old adit.
		11	15 ft northeast of sample 10 locality. Red altered quartzite containing sericite, limonite, and leucoxene. Chipped across a 7-ft-thick altered zone that is subparallel to bedding.
		12	Interlayered quartz pebble conglomerate and quartzite with hematitic laminae. From talus blocks that fell from cliffs above old adit; from 5-in.-thick layer of conglomerate in a 2-ft-thick block.
		13	Same as sample 12, except from conglomerate and quartzite from 6 talus blocks.
Vadito Formation of Montgomery (1953) conglomerate member.	7	1	SW¼SW¼ sec. 24, T. 23 N., R. 10 E., Trampas quadrangle, south side of Canada de Piedra Lumbre, at 6,620-ft elevation. Chip of matrix across startigraphically lowest 3 ft of unit, here consisting of 70–80 percent pebbles and cobbles of milky quartz and felsite in matrix of quartz and muscovite with minor hematite, ilmenite, kyanite, and chlorite.
		2	From next 25 ft of strata above sample 1, and of similar conglomerate.
		3	NW¼NE¼ sec. 30, T. 23 N., R. 10 E., roadcut on north side of State Highway 75 in Arroyo del Ploma. Sample largely of matrix across a 10-ft-thick layer of conglomerate with about 90 percent by volume clasts of milky quartz as large as 12 in., and 10 percent clasts of pink felsite as large as 8 in. set in schistose gray matrix of quartz, muscovite, hematite, and minor chlorite and tourmaline.
		4	NE¼SW¼ sec. 22, T. 23 N., R. 11 E., Trampas quadrangle. Chipped across 7-ft thickness of peblby and cobbly quartzite, with 10–15 percent by volume of clasts of milky quartz.
		6	NW¼SE¼ sec. 15, T. 23 N., R. 12 E., Peñasco quadrangle, about 1,100 ft east of 9,315-ft elevation summit on south ridge of Picuris Peak (area contains only small scattered outcrops). Chip sample of 6 small outcrops in 20-ft thickness of pebble conglomerate and pebbly quartzite.
			Locality of sample 6; chip sample of conglomerate from a 2- by 6-ft outcrop, the largest found in this area.

Creek and collecting five 5-lb composite chip samples (Nos. 123, 124, 127, 128, and 129 in table 1 and fig. 2) west of the Lake Fork of Pine River. The five smaller samples were analyzed for gold, and no gold was detected. The large sample was crushed and processed through bromoform. The heavy fraction contained no visible gold and, moreover, showed an unusually sparse heavy mineral population that consists chiefly of hematite with minor amounts of subangular to subrounded zircon. A split of this heavy fraction was sieved, and the resulting four size fractions were analyzed for gold as shown in the following table:

Size fraction (mesh)	Weight (grams)	Method of analysis[1]	Gold (ppm)
+20	0.89	Fire assay	<0.3
−20, +100	15.0	Cyanide atomic-absorption	<.02
−100, +200	10.0	Fire assay	<.02
−200	2.2	do	<.1

[1] Fire assays by L. B. Riley, O. M. Parker, and Claude Huffman, Jr.; cyanide-atomic absorption analysis by J. A. Thomas.

UNCOMPAHGRE FORMATION

BASAL CONGLOMERATE

The Uncompahgre Formation unconformably overlies the older Twilight Gneiss and Irving Formation (fig. 1). Lying in gradational to abrupt contact with these older formations at and west of the Animas River (figs. 1, 3, 4) is an unusual rock, 4 to about 40 feet thick, that consists of about 10–50 percent 1/4- to 4-mm single grains and polygranular aggregates of quartz set in a schistose matrix of sericite and minor hematite, limonite, and leucoxene. This rock, which could be classified as quartz sericite schist, apparently is a phyllonite formed from the older rocks, in which the original quartz grains were not comminuted but were first severely strained and then recrystallized, and in which the original iron was oxidized. A granite dike in the Irving Formation, 75 feet north of the unconformity, shows similarly strained and recrystallized quartz and therefore is a possible source of such quartz in the basal Uncompahgre. The phyllonite is mostly in gradational contact with the underlying granitic and metamorphic rocks; its schistosity is parallel to bedding of the overlying metasedimentary rocks; and it is free of chert and jasper granules that are present in the overlying conglomerate.

The basal unit of the Uncompahgre Formation is a 1½- to 8-foot thick bed of interlayered quartzose conglomerate and pebbly quartzite. This rock is gray, and it is poorly stratified and sorted; it is cross-stratified in only a few places. Its matrix is largely recrystallized quartz, mostly of 1/20- to 1/4-mm grain size, with variable amounts of sericite and hematite; and its clasts are predominantly quartz, with red and black jasper, gray chert, and dark-gray argillite. The clasts range in size from 2-mm granules to 6-inch cobbles, but most are in the 1- to 8-cm range. Some of the quartzose clasts are quartzite and have a fabric in which $\frac{1}{2}$- to 2-mm original detrital quartz grains are set in a recrystallized matrix of $\frac{1}{40}$- to $\frac{1}{10}$-mm quartz grains, but others show irregular fabrics and perhaps were derived from quartz veins. The clasts, like those in the Vallecito Conglomerate, indicate that the source data contained much quartzite, jasper, chert, and iron-formation. This basal conglomerate grades upward for several feet through pebbly quartzite into about 1,000 feet of pale-violet to white sparsely laminated and cross-laminated rarely pebbly quartzite at Snowdon Peak (fig. 3) and into 300–600 feet of similar quartzite in the canyon of the Animas River (fig. 4).

The basal conglomerate was sampled in its three areas of exposure: west of Snowdon Peak, on the east bank of the Animas River, and below the west rim of the canyon of the Animas River. None of the samples contained detectable gold, with the limit of detection at 0.1 ppm. Descriptions and localities of samples are given in table 1 and in figures 3 and 4.

PEBBLY QUARTZITE AND CONGLOMERATE

The quartzite layers in the Uncompahgre Formation, for the most part, are well sorted, pale violet to light gray, thick bedded, sparsely

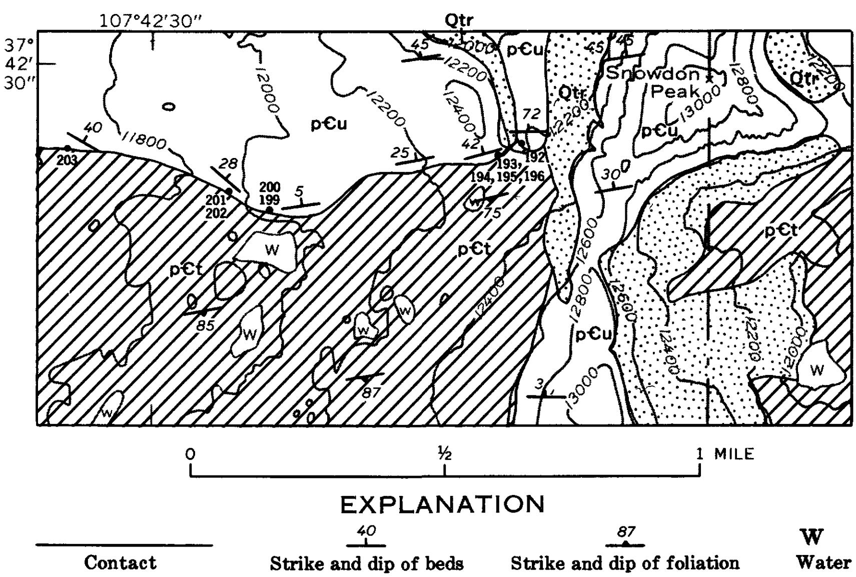
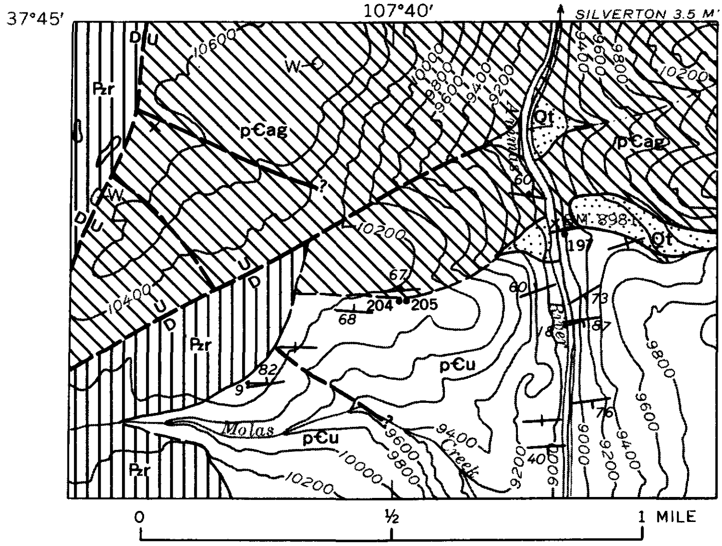


FIGURE 3.—Geologic map of the Snowdon Peak area, Needle Mountains, Colo., showing sample localities 192–196 and 199–203. p€t (diagonally ruled), Twilight Gneiss; p€u (no pattern), Uncompahgre Formation, here quartzite with an 8-foot-thick basal conglomerate, both of Precambrian age; Qtr (stippled), Holocene talus and rock glaciers. Base from U.S. Geological Survey, Snowdon Peak, 1:24,000.



EXPLANATION

Contact
Dashed where approximately located

Fault
Dashed where approximately located. U, *upthrown side;* D, *downthrown side; query, further extent unknown*

W
Water

Strike and dip of beds

Strike and dip of vertical beds

Strike and dip of beds and bearing and plunge of lineation

Strike and dip of foliation

FIGURE 4.—Geologic map of part of the canyon of the Animas River near Molas Creek, Needle Mountains, Colo., showing sample localities 197, 204, and 205. p€ag (diagonally ruled), amphibolite and granitic rocks, and p€u (no pattern), Uncompahgre Formation (here quartzite, slate, siltstone, and conglomerate), both of Preambrian age; Pzr (vertically ruled), Paleozoic rocks; Qt (stippled), Holocene talus deposits. Base from U.S. Geological Survey, Snowdon Peak, 1: 24,000.

laminated with hematite, and sparsely cross-laminated. Pebbly layers are sparse, and, of the 13 found and sampled, none showed detectable gold with the limit of detection at 0.1 ppm. Details of sampling are given in table 1.

SLATE AND SCHIST

The widespread pelitic rocks of the Uncompahgre Formation were sampled at the 13 localities shown in figure 5 and were analyzed for gold and other metals (table 2). These rocks are mostly carbonaceous

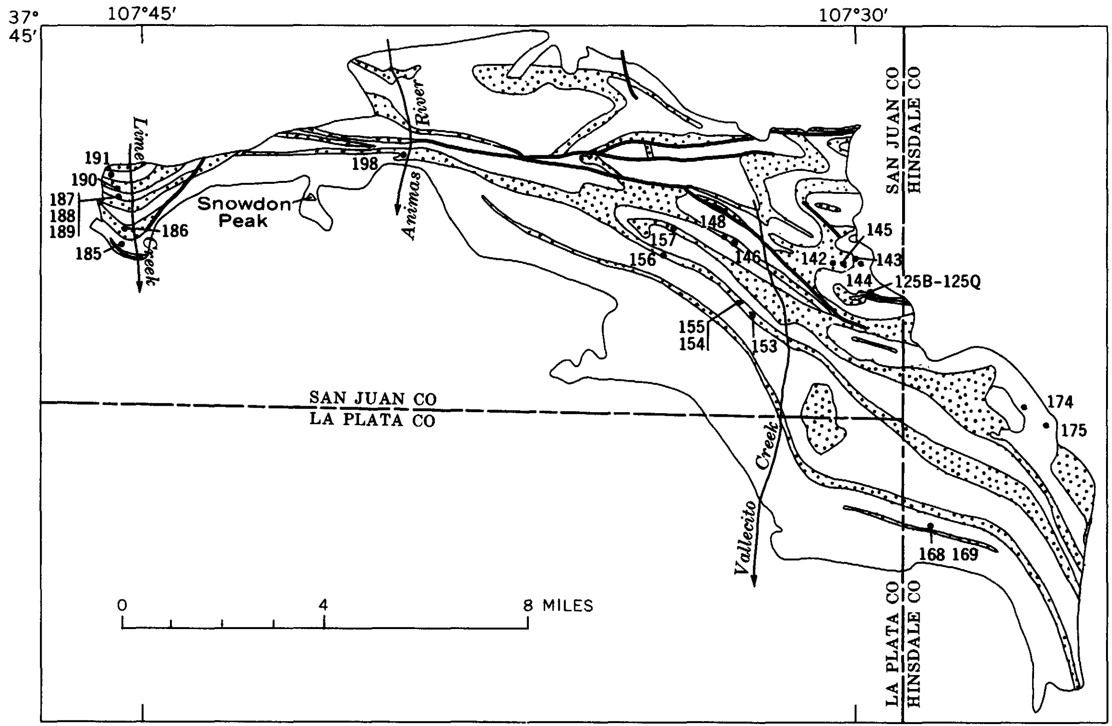


FIGURE 5.—Geologic map of the Uncompahgre Formation, Needle Mountains, Colo., showing sample localities. Slate and schist, stippled; quartzite with pebbly layers, no pattern. Geology from Cross and Howe (1905) and Barker (1969).

TABLE 2.—*Analyses of slates, phyllites,*

[All values are in parts per million except those for Ca, Fe, Mg, and Ti, which are in percent. Numbers in parentheses below element symbols are limits of detection. N, looked for but not detected; n.a. not looked for. Analytical errors, of values given, are +100 percent, −50 percent for spectrographic analyses and ±30

Sample loc. No.[1] (fig. 5)	Semiquantitative spectrographic analyses [2]															
	Ag (0.5)	As (200)	B (10)	Ba (20)	Be (1)	Bi (10)	Ca (0.05)	Cd (20)	Co (5)	Cr (5)	Cu (2)	Fe (0.05)	La (20)	Mg (0.02)	Mo (2)	Mn (20)
125B	N	N	30	700	3	N	0.05	N	50	150	20	15	50	1.5	N	1,500
125D	N	N	150	500	2	N	.05	N	30	150	30	15	30	1.5	N	1,000
125F	N	N	150	1,500	1	N	.15	N	20	150	50	15	N	3	N	500
125G	N	N	200	700	N	N	.07	N	N	30	15	2	30	.7	50	200
125H	1	N	200	500	1	N	.7	N	N	30	50	7	20	2	70	700
125J	.5	N	30	700	N	N	.5	N	10	50	70	5	N	1	30	500
125K	.7	N	150	700	N	N	.3	N	5	30	5	.7	30	.5	30	70
125L	.5	N	100	1,000	1.5	N	1.5	N	N	30	30	2	20	1.5	70	300
125M	.7	N	50	700	N	N	.5	N	N	30	10	1.5	20	1	50	300
125N	.5	N	100	700	N	N	.7	N	N	30	20	3	20	.7	50	150
125Q	N	N	150	700	N	N	.7	N	30	50	150	7	20	1.5	10	500
142	N	N	50	500	1	N	.2	N	N	100	70	5	N	1	N	500
145	N	N	30	200	1	N	.2	N	N	100	50	3	20	1	N	300
146	N	N	150	200	2	N	.05	N	5	70	50	2	50	.5	N	20
148	N	N	150	300	1	N	.05	N	N	50	20	1	N	.5	N	30
153	N	N	100	150	1	N	.05	N	5	70	20	7	30	1	N	150
154	N	N	100	300	1	N	N	N	N	150	10	3	100	.7	N	100
155	N	N	50	200	1	N	N	N	5	150	30	5	30	1	N	500
156	N	N	50	500	1	N	.5	N	N	30	20	1	30	.5	15	50
157	N	N	20	500	1	N	N	N	5	50	50	5	20	1	N	500
186	N	N	70	200	1	N	N	N	50	50	150	7	20	1	N	200
190	N	N	70	200	1	N	.1	N	N	20	30	1.5	20	.7	20	100
198	N	N	50	200	1	N	N	N	N	100	5	5	30	1	N	200

[1] Samples 125B–125Q were collected, by T. A. Steven, in a layer of black slate and siltstone about 145 ft thick; individual samples were collected above the base (north margin of this layer) as follows: 125B, 8 ft; 125D, 21 ft; 125F, 39 ft; 125G, 49 ft; 125H, 55 ft; 125J, 90 ft; 125K, 105 ft; 125L, 120 ft; 125M, 126ft; 125N, 131 ft; and 125Q, 139 ft. Sample 155 was collected 10 ft east of sample 154 locality.

and pyritic compositionally layered dark-gray to black slate, phyllite, and siltstone. None of the samples showed detectable gold by atomic absorption analysis, with 0.02 ppm as the limit of detection. These analytical results indicate that the pelites of the Uncompahgre Formation generally are not metalliferous.

TUSAS MOUNTAINS, N. MEX.

GEOLOGIC RELATIONS

The Tusas Mountains of Rio Arriba County, N. Mex., lie immediately west of the Rio Grande valley, and are a southeastern continuation of the San Juan Mountains of Colorado. Slightly more than 200 square miles of Precambrian rocks are exposed in this area.

The hydrothermal ore deposits of the Tusas Mountains, including the gold placers of Hopewell, were described by Lindgren, Graton, and Gordon (1910), and the geology of the Precambrian rocks was *and siltstones of the Uncompahgre Formation*

percent for atomic absorption analyses. Gold was not detected in any of the samples, by atomic absorption analysis, with 0.02 ppm as the limit of detection]

Semiquantitative spectrographic analyses [2]—Continued													Atomic absorption analyses, by colorimetric methods,[3] (parts per million)			
Nb (10)	Ni (2)	Pb (10)	Sb (100)	Sc (5)	Sn (10)	Sr (50)	Ti (0.002)	V (5)	W (50)	Y (5)	Zn (200)	Zr (10,200)	Cu (10)	Mo (4)	Pb (25)	Zn (20)
20	100	100	N	30	N	N	1	200	N	50	200	200	24	4	40	160
15	150	50	N	20	N	N	1	200	N	70	N	>1,000	59	N	70	89
15	30	70	N	30	N	N	1	500	N	15	N	300	92	N	70	100
10	10	30	N	15	N	N	.3	700	N	20	N	150	18	44	40	67
10	30	50	N	15	N	N	.5	700	N	30	1,000	150	67	60	110	510
15	30	N	N	15	N	N	.3	300	N	10	N	150	22	16	N	340
15	15	N	N	7	N	N	.2	300	N	15	N	100	N	40	N	200
15	150	N	N	7	N	N	.3	500	N	20	N	150	12	60	N	92
15	15	N	N	10	N	N	1	700	N	30	N	70	N	60	N	100
15	50	30	N	7	N	N	.5	500	N	15	N	100	12	56	35	20
15	30	70	N	7	N	N	.3	300	N	15	N	150	100	8	N	180
n.a.	15	15	N	30	N	50	.7	100	N	20	N	700				
n.a.	15	10	N	20	N	50	.7	100	N	20	N	300				
n.a.	30	N	N	20	N	50	1	100	N	20	N	300				
n.a.	N	10	N	15	N	N	.7	200	N	20	N	200				
n.a.	15	N	N	15	N	N	.7	50	N	30	N	500				
n.a.	10	20	N	50	N	N	.5	150	N	30	N	150				
n.a.	15	10	N	30	N	N	.5	100	N	50	N	200				
n.a.	N	10	N	30	N	N	.7	200	N	50	N	200				
n.a.	15	10	N	20	N	N	.3	50	N	15	N	150				
n.a.	50	70	N	20	N	N	.2	50	N	50	N	200				
n.a.	10	N	N	10	N	N	.3	200	N	30	N	200				
n.a.	5	10	N	30	N	50	.5	150	N	30	N	200				

[2] Analysts: samples 125B–125Q, Arnold Farley, Jr.; samples 142–198, K. C. Watts.
[3] Analysts: for Cu, Pb, and Zn, S. L. Noble and Elizabeth Martinez; for Mo, W. L. Campbell and Z. C. Stephenson.

described by Just (1937), Barker (1958), and Bingler (1965). The study by Just was reconnaissance in nature; the stratigraphic sequence (table 3) and structural features were first determined by Barker (1958, p. 10–36).

The rock units pertinent to this investigation are the Ortega Quartzite and the Big Rock Conglomerate and Jawbone Conglomerate Members, and the upper quartzite member of the Kiawa Mountain Formation. The lithology and thickness of each of these is given in table 3, and areal distributions are shown in figure 6. The clasts in the pebbly quartzite and conglomerates of this area are identical with those in the rocks of the Needle Mountains, which suggests a common provenance. Also, there may be a general correlation of these rocks of the Tusas Mountains with the Vallecito Conglomerate and Irving Formation of the Needle Mountains.

The Precambrian rocks of the Tusas Mountains are intensely folded (see Barker, 1958), and the fold axes plunge to the northwest and west-northwest. The major folds are a syncline whose axial surface

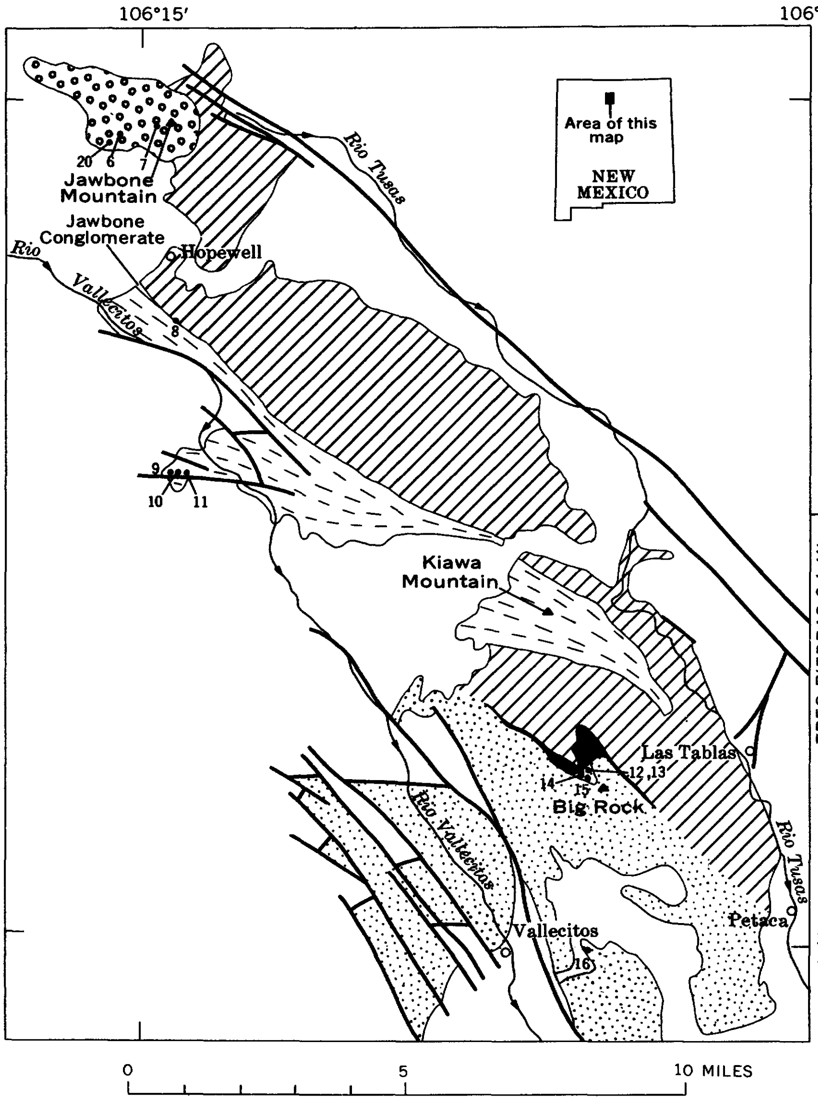
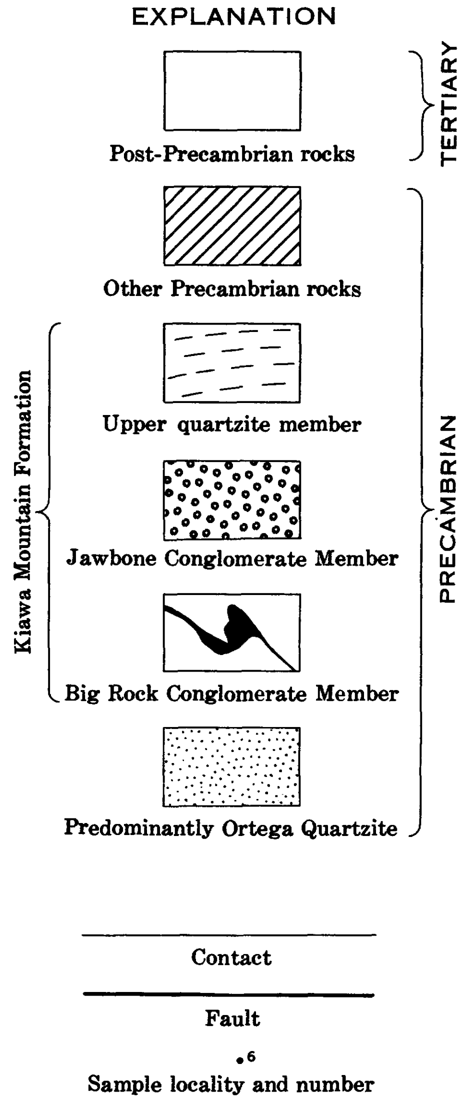


FIGURE 6.—Geologic sketch map of the Tusas Mountains, N. Mex. Geology adapted from Barker (1958) for area north of lat 36°30′ N., and from Bingler (1965) for area south of lat 36°30′ N.

is approximately vertical, called the Kiawa syncline, which passes through Kiawa Mountain and is delineated by the upper quartzite member of the Kiawa Mountain Formation (fig. 6); and an inferred anticline, the Hopewell anticline, whose axial surface lies close to



Hopewell. The Big Rock Conglomerate Member is folded into a minor syncline and anticline, as indicated by the pattern in figure 6.

SAMPLING RESULTS

The Ortega Quartzite in the Tusas Mountains is sparsely pebbly, and only one sample was taken from it. That sample was collected in the SE¼SW¼ sec. 10, T. 26 N., R. 8 E. (La Madera quadrangle),

TABLE 3.—*Stratigraphic column of Precambrian rocks in the Tusas Mountains, N. Mex.*

[In part from Barker (1958, p. 10)]

Formations (from youngest to oldest)	Character	Thickness, in feet
Kiawa Mountain Formation:		
Upper quartzite member.	Quartzite, light-gray to blue, vitreous, massive, with sparse pebbly layers; contains laminae of kyanite and of hematite (commonly both) along bedding planes; cross-laminated.	5,000–10,000; uppermost part not exposed.
Amphibolite member	Amphibolite and quartzite, interlayered. Amphibolite consists largely of hornblende, oligoclase-andesine, chlorite, quartz, and ilmenite; it is basaltic in composition.	35 to about 2,000.
Lower quartzite member.	Quartzite, light-gray to blue, vitreous, massive; contains muscovite in the Petaca pegmatite district.	Several hundred.
Jawbone Conglomerate Member.	Quartzose conglomerate and quartzite, gray, fine-grained, interlayered, vitreous, massive. A few pebbly layers with clasts of quartzite and jasper 6–25 mm in size.	500–2,000(?).
Big Rock Conglomerate Member.	Quartzose conglomerate and pebbly quartzite, interlayered, gray; clasts are of quartzite and jasper, ½–5 in. in size; secondary muscovite is present; cross-laminated.	50–200.
Moppin Metavolcanic Series.	Greenschist and amphibolite, ranging in composition from olivine basaltic to andesitic; minor phyllite, conglomerate, schist, and gneiss.	Several thousand.
Ortega Quartzite	Quartzite, light-gray, pink, or blue, vitreous, massive; with laminae of kyanite and of hematite (commonly both) along bedding planes; cross-lamination is common.	14,000–20,000; lowermost part not exposed.

across a 15-foot thickness of gray schistose muscovitic quartzite containing 3–10 percent by volume of ½- to 3-inch pebbles of quartz and dark-gray jasper. The Big Rock Conglomerate and Jawbone Conglomerate Members, and the upper quarzite member of the Kiawa Mountain Formation were sampled. (See table 1 for localities and descriptions of samples.) None of the rocks collected was found to contain gold, with 0.1 ppm as the limit of detection.

PICURIS RANGE, N. MEX.

GEOLOGIC RELATIONS

The Picuris Range, which is east of the Rio Grande River and southwest of Taos, is underlain largely by Precambrian metasedimentary rocks. Its geology was studied by Just (1937, p. 9–40) and, in much greater detail, by Montgomery (1953). The economic geology of the Copper Hill or Picuris district and of the Glen Woody area, both in the Picuris Range, was discussed by Lindgren, Graton, and Gordon (1910, p. 82, 89–91).

The stratigraphic units of the Precambrian rocks of the Picuris Range are described in table 4. These units are intensely folded and are generally eastward trending.

TABLE 4.—*Stratigraphic column of Precambrian rocks in the Picuris Range, N. Mex.*

[From Montgomery (1953, p. 8)]

Formations (from youngest to oldest)	Character	Thickness, in feet
Vadito Formation:		
Schist member	Quartz-muscovite schist and phyllite, quartz-biotite granulite; lower part quartz-muscovite schist interlayered with plagioclase amphibolite.	2,500.
Conglomerate member.	Quartzose conglomerate and quartzite, both muscovitic; interlayered felsite, meta-dacite, meta-andesite, and amphibolite.	2,000.
Unconformity.		
Ortega Formation:		
Pilar Phyllite Member.	Gray to black carbonaceous quartz-muscovite phyllite	2,300.
Rinconada Schist Member.	Phyllite, quartzite, staurolite schist and gneiss and andalusite-biotite hornfels.	800–1,850.
Lower quartzite member.	Coarse-grained quartzite with minor hematite and ilmenite, including thin beds of sillimanite and (or) kyanite, and sparse lenses of quartz-pebble conglomerate.	2,500; lowermost part not exposed.

SAMPLING RESULTS

In this study the lower quartzite member of the Ortega Quartzite and the conglomerate member of the Vadito Formation of Montgomery (1953) were sampled, as shown in figure 7, and no gold was found. Sample localities and descriptions are given in table 1.

COMPARISON WITH THE CENTRAL RAND GOLDFIELD, SOUTH AFRICA

The quartzites and conglomerates examined in this study may be compared with the auriferous conglomerates of the Central Rand goldfield of South Africa. The gold-bearing conglomerates of the Central Rand are found in the Precambrian Witwatersrand System, which is about 24,000 feet thick and lies on a basement complex of granite, gneiss, and schist. These conglomerates were deposited 2,100–3,000 m.y. ago, and they contain about 8 percent conglomerate beds (Pretorius, 1964, p. 69–86). The economically important deposits are in many thin layers of pebble conglomerate that lie in the upper 9,400 feet of the Witwatersrand System. The pebbles are mostly vein quartz, quartzite, and chert, with lesser amounts of quartz porphyry, shale and schist, jasper, and tourmaline-bearing rock. The matrices are predominantly quartz, pyrite, muscovite, sericite, and pyrophyllite, with minor chlorite, chloritoid, rutile, tourmaline, carbon, zircon, calcite, dolomite, pyrrhotite, galena, sphalerite, chalcopyrite, chromite, gold, uraninite, ilmenite, leucoxene, platinum metals, and other minerals

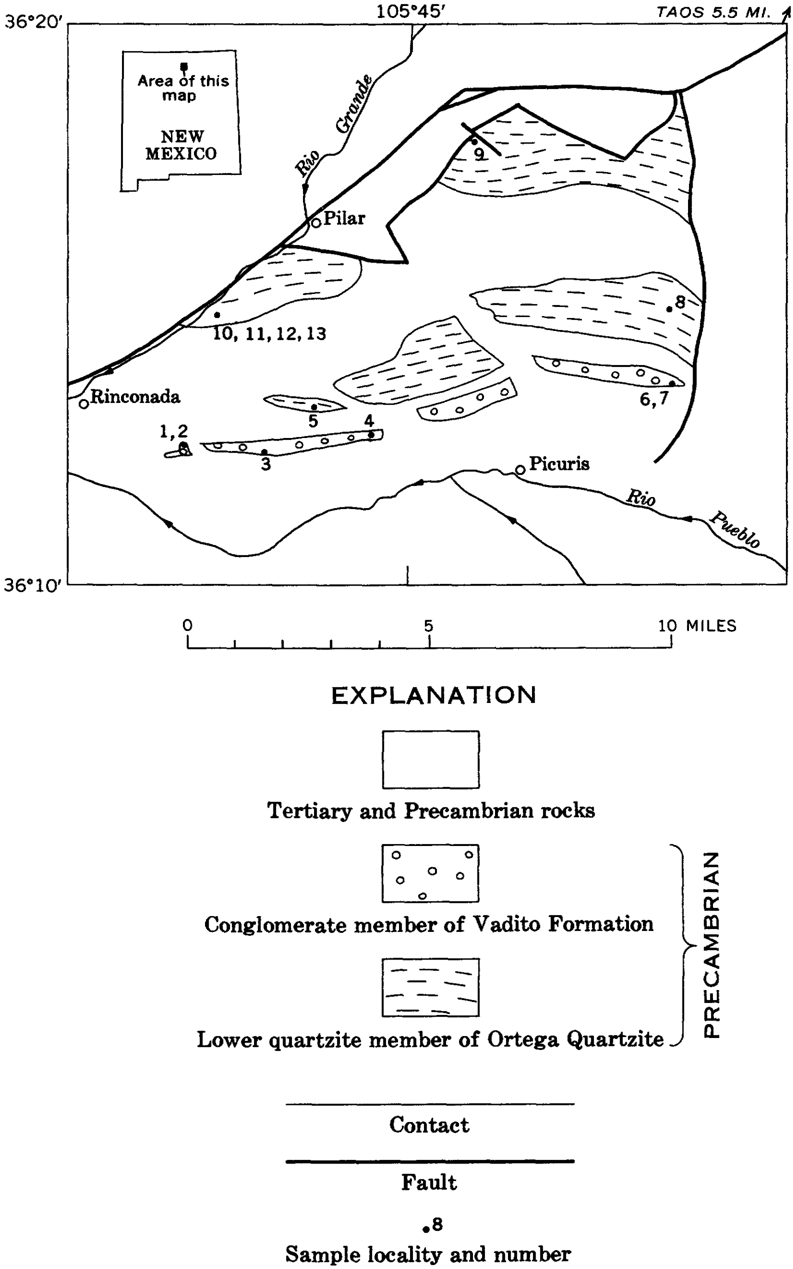


FIGURE 7.—Geologic sketch map of the Picuris Range, N. Mex., showing areas underlain by the lower quartzite member of the Ortega Quartzite and the conglomerate member of the Vadito Formation. (From Montgomery, 1953.)

(Pretorius, 1964, p. 94–95). Average values of ore of the 17 largest mines in the Central Rand have ranged from about 1/3 to 1 ounce of gold per ton (Pretorius, 1964, p. 105). The varied and unusual suite of minerals in these conglomerates partly results from a postdepositional hydrothermal event in which the detrital quartz, feldspars, magnetite, gold, uraninite, platinum, and other minerals were partly recrystallized and were moved short distances or otherwise altered, and in which the mica, pyrophyllite, and sulfides were formed.

In contrast to these rich beds of the upper Witwatersrand System, the quartzites, shales, and minor conglomerates of the lower parts of that system are largely barren. These quartzites are orthoquartzites, whereas the quartzose sedimentary rocks of the upper part of the Witwatersrand System are largely graywackes (Fuller, 1958, p. 27–30). Thus the quartzites of the Ortega, Kiawa Mountain, and Uncompahgre Formations in Colorado and New Mexico, all orthoquartzites, are lithologically similar to the lower, barren quartzites of the Central Rand goldfield.

In summary, the clastic rocks of Colorado and New Mexico discussed in this report differ from the auriferous conglomerates of the Central Rand in their lack of detrital gold, platinum group minerals, and uraninite; in being free of carbon; in having escaped hydrothermal alteration in which pyrite, sphalerite, galena, and other sulfides were formed; and probably in containing much less detrital vein quartz. Also, the American rocks are at least 300 m.y. younger than the African sediments and apparently were derived from a terrane much poorer in granitic and gneissic rocks.

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GEOLOGICAL SURVEY

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