Volcanic Geology in Parts of the Southern Peloncillo Mountains, Arizona and New Mexico

U.S. GEOLOGICAL SURVEY BULLETIN 1671

Volcanic Geology in Parts of the Southern Peloncillo Mountains, Arizona and New Mexico

By D. H. McINTYRE

U.S. GEOLOGICAL SURVEY BULLETIN 1671

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1988

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center, Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

McIntyre, David H.
Volcanic geology in parts of the Southern Peloncillo Mountains, Arizona and New Mexico.

(U.S. Geological Survey bulletin ; 1671
Bibliography: p.
Supt. of Docs. no.: I 19.3:1671
1. Volcanic ash, tuff, etc.—Peloncillo Mountains (Ariz. and N.M.)
2. Volcanism—Peloncillo Mountains (Ariz. and N.M.) 3. Geology—Peloncillo Mountains (Ariz. and N.M.) I. Title. II. Series.
QE5.B9 no. 1671 [QE461] 557.3 s 86-600174
[551.2'1'09789]

CONTENTS

FIGURES

TABLES

Volcanic Geology in Parts of the Southern Peloncillo Mountains, Arizona and New Mexico

By D. H. McIntyre

Abstract

Two small cauldrons are exposed in the southern Peloncillo Mountains, Arizona and New Mexico. The first, the Geronimo Trail cauldron, collapsed during eruption of the rhyolitic tuff of Guadalupe Canyon. Resurgence accompanied eruption of intermediate-composition lavas and breccias and emplacement of intermediate-composition intrusions and domes near the ring-fracture zone and on the resurgent dome. A 5-km^2 area of hydrothermally altered rocks is located on the resurgent dome. Initial collapse of the second cauldron, the Clanton Draw cauldron, appears to have accompanied eruption of the alkali rhyolitic tuff of Skeleton Canyon. The cauldron subsequently was filled to overflowing with tin-bearing alkali rhyolitic lava, the rhyolite of Clanton Draw. Intermediate-composition intrusive masses mark part of the ring-fracture zone, which is concealed by the rhyolite lava.

INTRODUCTION

This report describes the results of a brief study of the volcanic geology of the southern Peloncillo Mountains, Arizona and New Mexico. Field work occupied five weeks in October and November of 1983. Scott Birmingham ably assisted the author for several days during that period.

The most comprehensive previous study (Erb, 1979) that includes the area described in this report (fig. 1) defined the stratigraphic relations in this and nearby areas. Erb (1979) also defined several cauldrons, one of which, the Geronimo Trail cauldron, is located within the study area. Also valuable are a series of reports on the Bunk Robinson Peak and Whitmire Canyon Roadless Areas. The first of these reports, a geologic map by Hayes (1982), draws heavily on the map by Erb (1979) but includes some important additions. A geochemical study by Watts and others (1983) and a mineral resource potential map (Hayes and others, 1983) pointed out, for the first time, the occurrences of tin in stream sediments in part of the area and the presence of a large area underlain by hydrothermally altered rocks.

VOLCANIC STRATIGRAPHY

The principal volcanic rock units, as defined by Erb (1979), include, from oldest to youngest, the tuff of Guadalupe Canyon, the breccia of Hog Canyon and associated rocks, the dacite of Outlaw Mountain and related intrusive rocks and domes, the tuff of Skeleton Canyon, the tuff of Whitmire Canyon, and the rhyolite of Clanton Draw (table 1). Fission-track age determinations on zircon indicate that this sequence, of late Oligocene age, ranges from about 26 to 27 m.y. (Erb, 1979, table 1); part of the sequence could be about 30 m.y. (table 1, this report). A small area mapped near the mouth of Guadalupe Canyon contains a sequence of rocks that could not be readily correlated with rocks exposed elsewhere in the area.

Tuff of Guadalupe Canyon along Cottonwood Creek

During this study, the tuff of Guadalupe Canyon was seen chiefly in exposures along Cottonwood Creek and its tributaries (fig. 2). A stratigraphic section somewhat more than 200 m thick southwest of Outlaw Mountain was examined and sampled (fig. 3). Most of the tuff of Guadalupe Canyon exposed there and in the surrounding area is nonwelded to moderately welded rhyolitic ash-flow tuff (table 2). All the rocks in this unit are altered in the Cottonwood Creek exposures. The principal alteration products are opal and zeolites, which have replaced glass shards and pumice; the phenocrysts have been little affected by alteration. Cementation of the rock by the alteration minerals gives the deceptive impression that the rock is densely welded. The opalized rock, which makes up almost half the stratigraphic thickness exposed southwest of Outlaw Mountain, is white to gray on weathered surfaces. Partial dehydration of the opal commonly has produced fine networks of shrinkage cracks on the weathered surfaces. In exposures along Cottonwood Creek south of Outlaw Mountain, gray, intensely

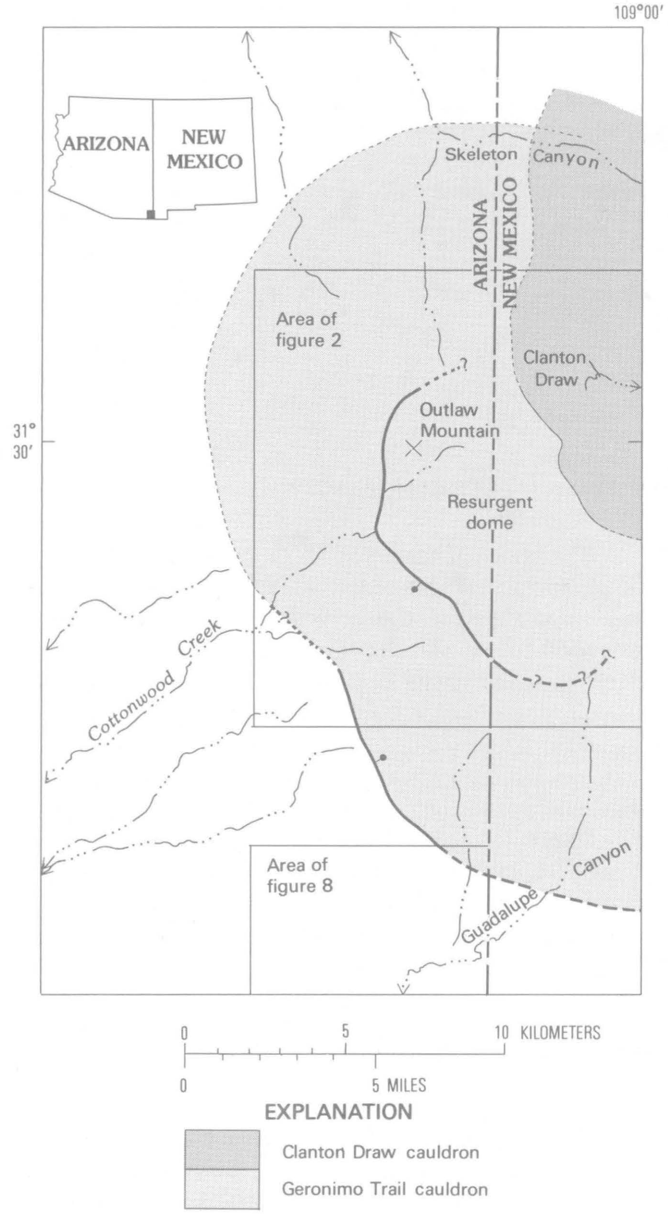


Figure 1. Map showing locations of figure 2 and figure 8 and approximate areas underlain by Geronimo Trail and Clanton Draw cauldrons. Southern boundary of Geronimo Trail cauldron from Erb (1979, fig. 2).

opalized rock locally overlies brown, less altered rock along a sharp contact. Relict masses of the brown, less altered rock within the gray, opalized rock clearly demonstrate that the color differences were caused by alteration and have no stratigraphic significance. Rock containing unweathered olive-green opal is exposed in roadcuts southeast of Outlaw Mountain.

The tuff of Guadalupe Canyon in the Cottonwood Creek area can be divided into two distinct units based on relative proportions of plagioclase, sanidine, and quartz. The lower of the two units consistently contains more plagioclase than sanidine or quartz; the upper unit consistently contains less plagioclase (fig. 3). The break between the two units appears to be abrupt. Biotite is the only mafic mineral present in most samples. Very small amounts of amphibole and (or) pyroxene (less than 1 percent) may have been present in some of the rock prior to alteration.

The tuff of Guadalupe Canyon exposed in Skeleton Canyon east of the Arizona-New Mexico boundary (north of the area shown in figure 2) has phenocryst proportions characteristic of the lower unit.

Magnetic polarities for the tuff of Guadalupe Canyon measured in the field with a fluxgate magnetometer were consistently normal. Some of these measurements were made on outcrops of altered rocks, so the reliability of some determinations is doubtful.

The age of the tuff of Guadalupe Canyon is somewhat uncertain. Erb (1979, table 1) reported a zircon fission-track age of 27.1 ± 1.5 m.y. for a sample collected from the NW¼ SW¼ sec. 27, T. 22 S., R. 32 E. Deal and others (1978) reported a potassium-argon age on sanidine of 24.26 ± 0.52 m.y. on a sample collected from the same area. This potassium-argon age, significantly younger than the fission-track age, also is younger than a fission-track age for the rhyolite of Clanton Draw, several units higher in the local stratigraphic sequence (Erb, 1979).

The sample locality of Deal and others (1978) (lat 31°29′ N., long 109°04′45″ W.) was recovered during the present study. The rock debris left behind during trimming of the sample for age determination was found and sampled. The material is intensely opalized, which casts some doubt on its suitability for age determination.

The imprecise location provided by Erb (1979) prevents recovery of his sample locality. However, if the locality were along the road up Cottonwood Creek, which is permitted by the locality information, his sample possibly was less altered than that of Deal and others (1978). Most exposures along the road in the area in question are less altered than the one sampled by Deal and others (1978) on the slope north of Cottonwood Creek. If this inference about the Erb (1979) sample locality is correct, it would explain why the fission-track age of Erb (1979) is older than the potassium-argon age of Deal and others (1978). It seems reasonable to conclude that the fission-track age of 27.1 ± 1.5 m.y. is the better age estimate for the tuff of Guadalupe Canyon.

Table 1. Fission-track ages on zircon, and magnetic polarities for principal volcanic units in the southern Peloncillo Mountains
[Magnetic polarity determinations made in the field with a portable fluxgate magnetometer]

Unit name	Fission-track age (m.y.)	Magnetic polarity
Rhyolite of Clanton Draw	25.8 ± 1.2	Reversed
Tuff of Whitmire Canyon		Reversed
Tuff of Skeleton Canyon		Normal
Dacite of Outlaw Mountain		Reversed
Breccia of Hog Canyon		Reversed
Tuff of Guadalupe Canyon	27.1 ± 1.5	Normal
Ash-flow tuff vitrophyre at Cowboy Flats	30.6 ± 3.4	

Ash-Flow Tuff Vitrophyre at Cowboy Flats

Cowboy Flats, on upper Sycamore Creek south of Cottonwood Creek, exposes a mass of vitrophyre at least 100 m thick that is overlain by devitrified tuff of Guadalupe Canyon and separated by a fault from tuff of Guadalupe Canyon exposed to the west. The vitrophyre crops out as a series of horizontal ledges as much as 10 m high.

Embedded in the densely welded, shard-rich matrix of the vitrophyre are phenocrysts of quartz, sanidine, plagioclase, and biotite in proportions similar to those in rocks in the lower part of the tuff of Guadalupe Canyon (fig. 4). In addition, the vitrophyre contains nearly 4 percent clinopyroxene and amphibole, not noted in the tuff of Guadalupe Canyon exposed along Cottonwood Creek. The devitrified tuff of Guadalupe Canyon that overlies the vitrophyre has phenocryst proportions (fig. 4) nearly identical to one of the samples collected low in the section southwest of Outlaw Mountain (fig. 3).

Measurements of magnetic polarity on the vitrophyre outcrops revealed both normal and reversed polarity. Lightning strikes on these very exposed ledges may account for the mixed results.

A fission-track determination on zircon from the vitrophyre gave an age of 30.6 ± 3.4 m.y. (W. E. Brooks, written commun., 1984; table 1). This result is apparently older than, but statistically not significantly different from, the 27.1 ± 1.5 m.y. of Erb (1979) from the somewhat altered exposures of the tuff of Guadalupe Canyon along Cottonwood Creek.

The vitrophyre probably should be considered part of the tuff of Guadalupe Canyon.

Intermediate-Composition Volcanic Breccias, Lavas, Domes, and Intrusive Rocks

Intermediate-composition volcanic breccias, lavas, domes, and intrusive rocks, younger than the tuff of Guadalupe Canyon, crop out over a broad area in the southern Peloncillo Mountains. Similarities in mineralogy and composition among those units that crop out in the area of figure 2 indicate that they form a cogenetic sequence. These rocks are the breccia of Hog Canyon and related rocks and the dacite of Outlaw Mountain and related intrusive rocks and domes.

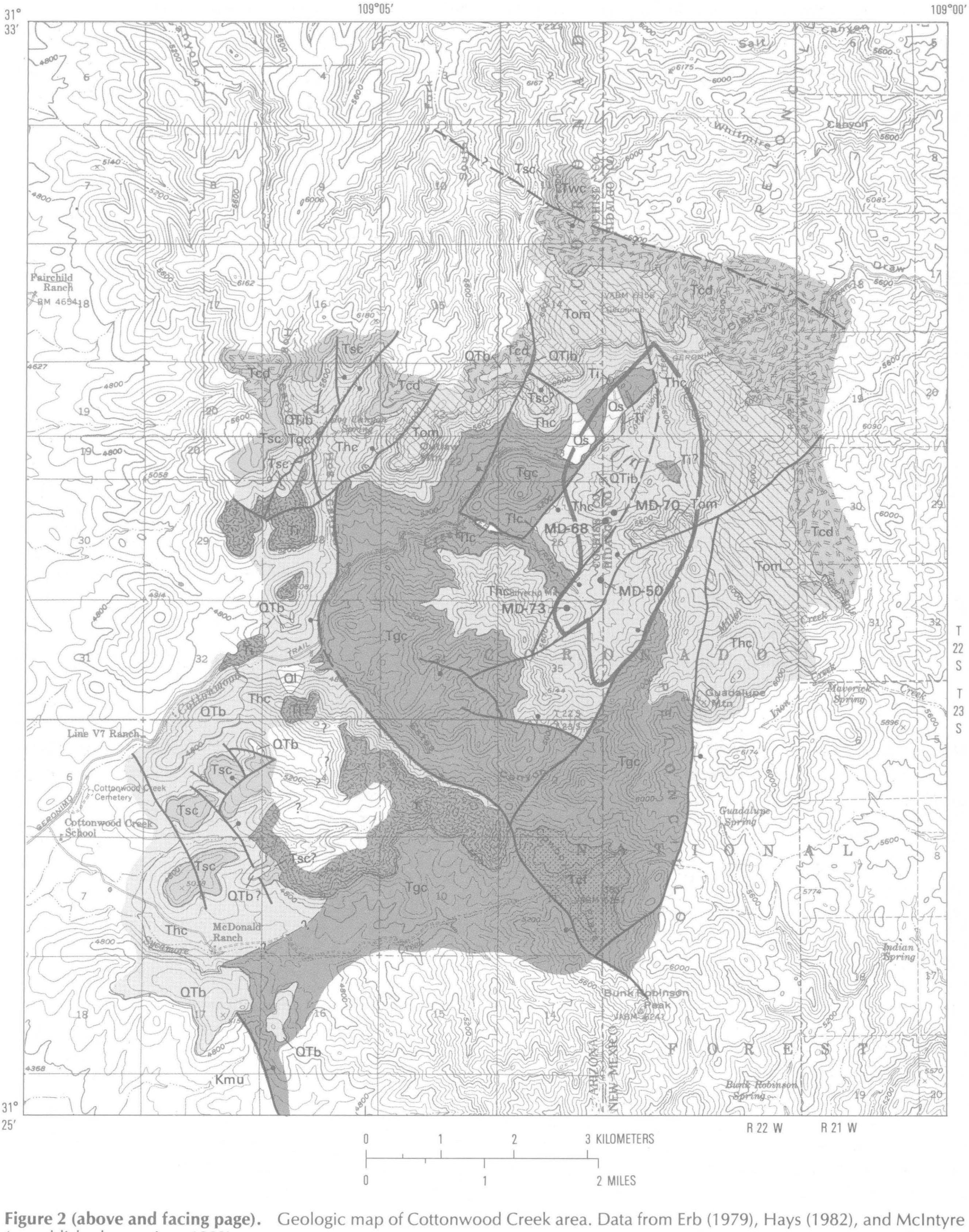
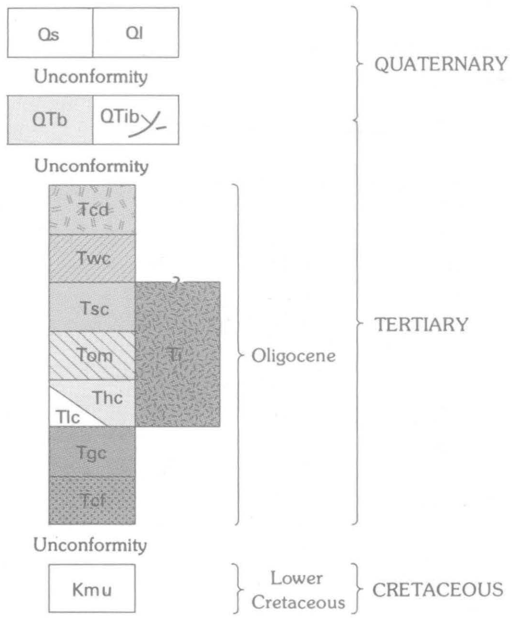


Figure 2 (above and facing page). Geologic map of Cottonwood Creek area. Data from Erb (1979), Hays (1982), and McIntyre (unpublished mapping, 1983).

CORRELATION OF MAP UNITS



LIST OF MAP UNITS

Qs	**Surficial deposits, undivided**
Ql	**Landslide deposit**
QTb	**Basalt**
QTib	**Basalt dike**
Tcd	**Rhyolite of Clanton Draw**
Twc	**Tuff of Whitmire Canyon**
Tsc	**Tuff of Skeleton Canyon**
Ti	**Intermediate-composition intrusive rocks**
Tom	**Dacite of Outlaw Mountain**
Thc	**Breccia of Hog Canyon**
Tlc	**Deposit containing blocks of limestone and limestone conglomerate**
Tgc	**Tuff of Guadalupe Canyon**
Tcf	**Ash-flow tuff vitrophyre at Cowboy Flats**
Kmu	**Mural Limestone**

Contact—Dashed where approximately located

Fault—Dashed where approximately located, queried where uncertain

MD-73 • **Sample locality**—Listed in table 4

Outline of altered area

Breccia of Hog Canyon and Related Rocks

The breccia of Hog Canyon and related rocks overlie the tuff of Guadalupe Canyon. Erb (1979) distinguished several units—the breccia of Hog Canyon, the sedimentary breccia of Cottonwood Creek, and the breccia of Geronimo Pass. All locally are similar in mineralogy and all appear to be genetically related to eruptions from vents marked by nearby intermediate-composition intrusive rocks and domes. Erb's three units are treated as a single unit in this report.

The breccias contain clasts of intermediate-composition volcanic rock. Locally they also contain clasts of rhyolitic ash-flow tuff, especially near the base of the sequence. The tuff clasts resemble the tuff of Guadalupe Canyon. The crystal contents of breccia matrices are surprisingly consistent over a fairly large area (fig. 5). Plagioclase is more abundant than sanidine, which is more abundant than quartz. Biotite, clinopyroxene, and amphibole are present in varied amounts.

The breccias exposed in Hog Canyon clearly are near their source. One unit that forms a continuous cliff about 6 m high contains blocks more than 2 m in diameter. Blocks greater than 1 m are common in many exposures. At one series of exposures in the canyon, the breccia matrix has a strong reversed magnetic polarity, which shows that this material was above the Curie temperature of its magnetic minerals at the time of deposition. The site from which the rocks in the canyon were erupted most probably is now marked by an intrusive mass exposed on the ridge west of the canyon.

Breccia similar to that exposed in Hog Canyon crops out in the area northeast of the Silvertip Mine (fig. 2). Most of these rocks, mapped as tuff of Guadalupe Canyon by Erb (1979), occur within an area of intense hydrothermal alteration, which makes identification difficult. However, exposures of little-altered rocks are present, especially north of the Silvertip Mine (figs. 2 and 5). Rocks there include, in addition to the breccia, densely welded ash-flow tuff that is plagioclase rich and quartz poor, similar to the Hog Canyon rocks. Furthermore, in the area of intense alteration breccia textures are visible in some places, and well-bedded, thin layers of fine tuff can be seen separating more massive units. None of these features of the altered rocks are present in nearby exposures of the tuff of Guadalupe Canyon.

Blocks of limestone or limestone conglomerate locally are present at the contact of the breccia of Hog Canyon and older rocks. They probably represent debris slumped from caldera-wall exposures of pre-Tertiary rocks. The two largest occurrences noted are near the jeep trail leading to the Silvertip Mine (fig. 2). The eastern occurrence is characterized by blocks of limestone conglomerate larger than 1 m in diameter. The conglomerate contains well-rounded gray fossiliferous limestone cobbles and subordinate black chert pebbles in a reddish-orange mud matrix. The western occurrence contains blocks of gray and reddish-purple, highly fractured, recrystallized limestone. Locally present are blocks of conglomerate containing well-rounded clasts of shard-rich, densely welded ash-flow tuff, opaque-oxide-rich lava, and granitic rock. Single crystals of plagioclase,

Table 2. Chemical analyses and CIPW norms for principal units in the southern Peloncillo Mountains

[Analyst: E. E. Erb, using methods described in Erb (1979, p. 6–7). BaO, SrO in original analyses omitted]

	1	2	3	4	5	6
			Chemical composition (wt percent)			
SiO_2	74.83	65.87	63.61	76.74	74.64	74.96
Al_2O_3	12.65	16.31	16.86	12.50	13.83	13.09
Fe_2O_3	1.01	3.27	3.06	0.95	1.23	1.28
FeO	0.12	0.19	1.07	0.08	0.20	0.14
MgO	0.28	0.67	1.37	0.08	0.16	0.12
CaO	0.83	2.72	3.85	0.21	0.42	0.37
Na_2O	2.69	3.58	3.69	3.87	3.33	3.62
K_2O	4.96	4.55	3.33	4.59	5.48	5.21
H_2O^+	1.58	1.23	1.30	0.26	0.58	0.47
H_2O^-	0.62	0.74	0.46	0.00	0.06	0.16
TiO_2	0.16	0.46	0.61	0.16	0.22	0.15
P_2O_5	0.03	0.12	0.18	0.02	0.03	0.02
MnO	0.04	0.04	0.06	0.07	0.04	0.06
SUM	99.80	99.75	99.45	99.53	100.22	99.65
			Normative composition			
Q	39.93	21.67	20.08	36.42	33.38	33.38
C	1.45	0.86	0.63	0.84	1.74	0.88
or	30.03	27.55	20.14	27.32	32.52	31.09
ab	23.32	31.04	31.96	32.99	28.30	30.93
an	4.02	13.02	18.35	0.92	1.90	1.72
hy-en	0.71	1.71	3.49	0.20	0.40	0.30
mt	0.05	0.00	1.92	0.02	0.14	0.21
hm	1.00	3.35	1.81	0.94	1.14	1.14
il	0.31	0.50	1.19	0.31	0.42	0.29
ap	0.07	0.29	0.44	0.05	0.07	0.05

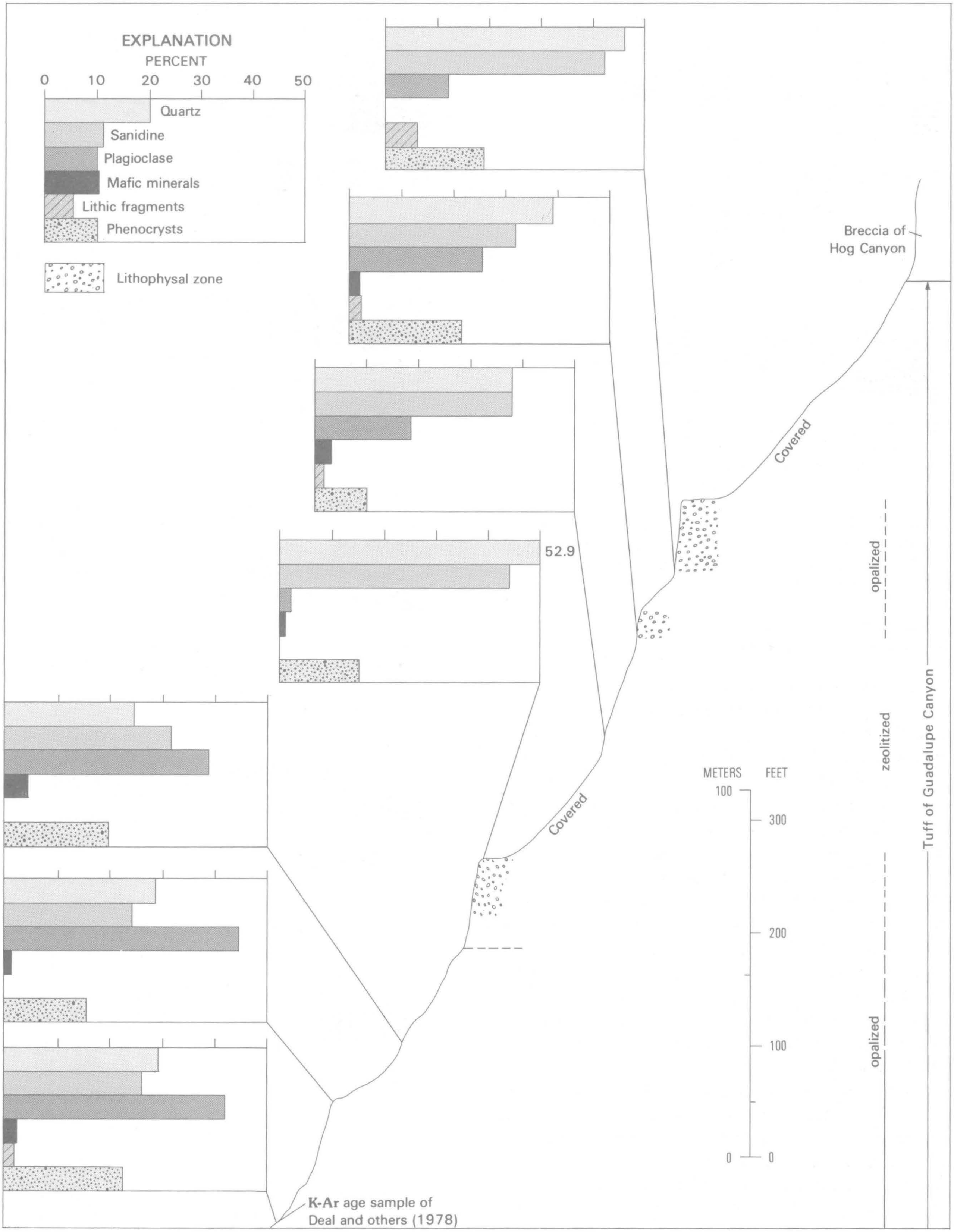
Descriptions

1. Tuff of Guadalupe Canyon (Erb, 1979; average of nos. 2, 3, 4, 5, 6 of table 36).
2. Breccia of Hog Canyon (Erb, 1979; average of nos. 7, 8, 9 of table 36).
3. Rhyodacite; "Dacite of Outlaw Mountain" (Erb, 1979; average of nos. 10 and 11 of table 36).
4. Tuff of Skeleton Canyon (Erb, 1979, table 45).
5. Tuff of Whitmire Canyon (Erb, 1979, table 36, no. 14).
6. Rhyolite of Clanton Draw (Erb, 1979; average of nos. 15 and 16 of table 36).

quartz, sanidine, and microcline occur interstitially. Exposures east of the abundant limestone are of a reddish-brown monolithologic breccia of the breccia of Hog Canyon. The limestone, conglomerate, and breccia of Hog Canyon in the western occurrence probably are in a downdropped fault block.

A third example of limestone-block breccia is located near the center of sec. 33, T. 22 S., R. 32 E., at the breccia of Hog Canyon-tuff of Guadalupe Canyon contact west of the fault. The largest block, of fossiliferous gray limestone, is about 6 m long by 2 m wide. The block contains abundant oyster and gastropod fragments.

Figure 3(facing page). Stratigraphic section in tuff of Guadalupe Canyon southwest of Outlaw Mountain, and histograms showing crystal and lithic fragment content of samples. Values for phenocrysts and lithic fragments are percentages of the whole rock. Values for individual minerals are percentages of total phenocrysts, not percentages of the whole rock. An unlabeled mafic mineral bar means that biotite is the only mafic mineral present. Bar is labeled where hornblende (Hb), clinopyroxene (Cpx), or orthopyroxene (Opx) are present in addition to biotite (B). Where value for a component exceeds 50 percent, the numerical value is shown.


EXPLANATION
PERCENT
0 10 20 30 40 50
Quartz
Sanidine
Plagioclase
Mafic minerals
Lithic fragments
Phenocrysts
Lithophysal zone
52.9
Breccia of Hog Canyon
Covered
Covered
opalized
zeolitized
opalized
Tuff of Guadalupe Canyon
METERS
FEET
100
300
200
100
0
0
K-Ar age sample of Deal and others (1978)

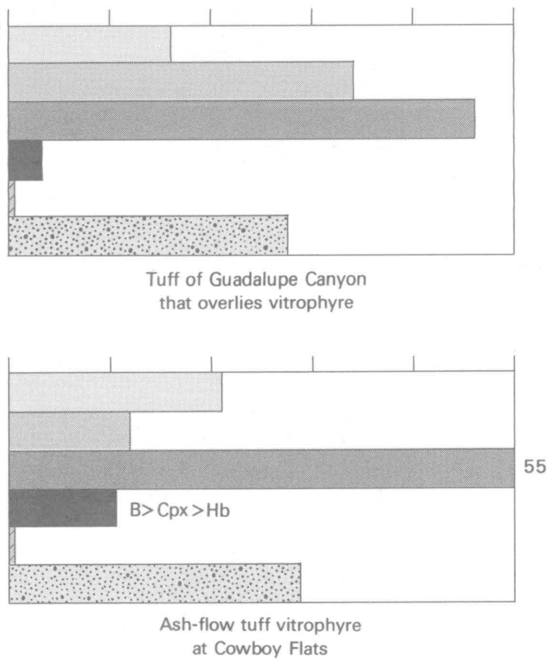


Figure 4. Histograms showing crystal and lithic fragment content of ash-flow tuff vitrophyre at Cowboy Flats and overlying tuff of Guadalupe Canyon. (For explanation of symbols see figure 3.)

Dacite of Outlaw Mountain and Related Domes and Intrusive Rocks

Erb (1979) used the name dacite of Outlaw Mountain for a sequence of intermediate-composition lavas that overlie the breccia of Hog Canyon and related rocks. These lavas and related intrusive rocks and domes commonly are porphyritic and contain phenocrysts of plagioclase, quartz, and mafic minerals. Of the mafic minerals, biotite and amphibole are present everywhere; clinopyroxene and orthopyroxene occur in only a few specimens. Chemical compositions range from rhyodacite for the lavas and most of the intrusive rocks to quartz latite for part of the domical mass exposed north of Sycamore Creek (tables 2 and 3). According to Erb (1979, p. 211) the analyzed sample from Sycamore Creek (table 3, no. 2) contained sanidine phenocrysts. The sample collected by us from the southeast margin of the mass contained no sanidine. This sequence of rocks has reversed magnetic polarity.

In addition to the intrusive rocks and domes exposed in the western part of the area, numerous small intrusive masses occur near the headwaters of Cottonwood Creek. Some of these, too small to be shown on the map, are located in the southwest-trending draw in the NE¼ sec. 26, T. 22 S., R. 32 E. Most are hydrothermally altered.

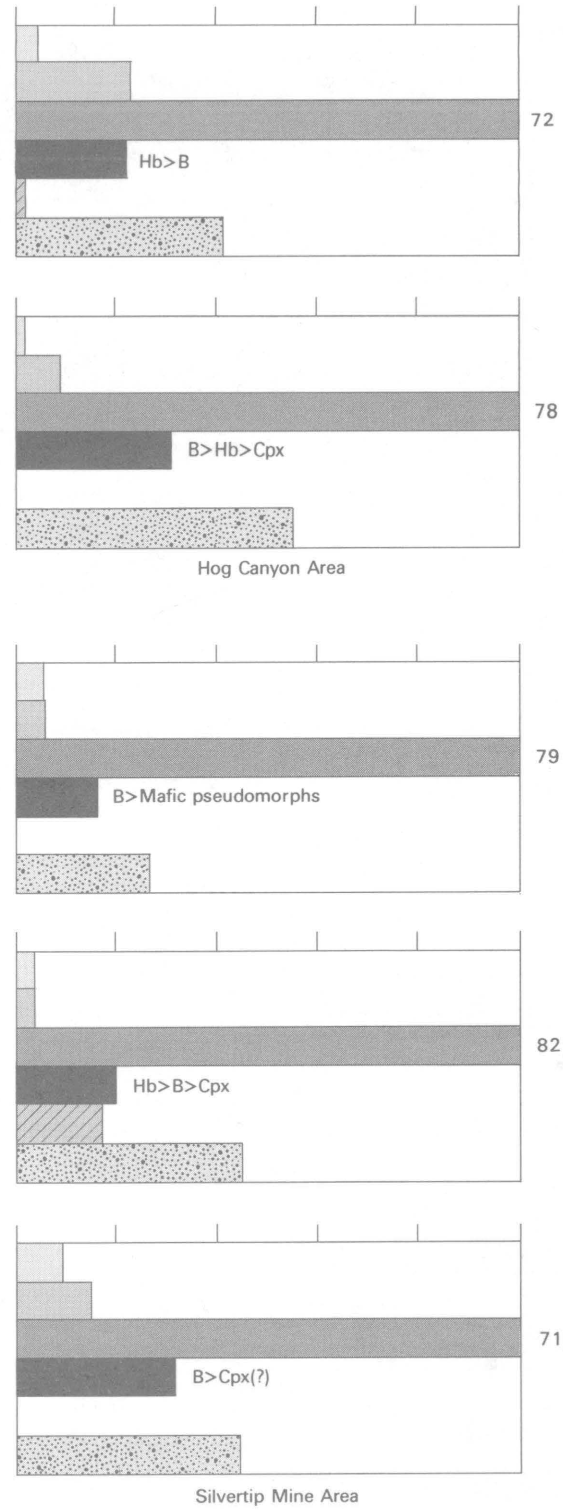


Figure 5. Histograms showing crystal and lithic fragment content in matrix of breccia of Hog Canyon. (For explanation of symbols see figure 3.)

Table 3. Chemical analyses and CIPW norms for intermediate-composition intrusive rocks and basalt, southern Peloncillo Mountains
[Analyst: E. E. Erb, using methods described in Erb (1979, p. 6–7). BaO, SrO in original analyses omitted]

	1	2	3	4
	Chemical composition (wt percent)			
SiO_2	65.90	68.33	46.99	47.78
Al_2O_3	16.02	14.40	16.39	15.70
Fe_2O_3	3.50	1.81	3.58	3.63
FeO	0.23	0.39	7.14	6.81
MgO	1.20	0.82	7.22	8.24
CaO	2.64	1.72	9.47	9.36
Na_2O	4.75	2.62	2.99	3.42
K_2O	2.94	4.90	1.38	0.83
H_2O^+	0.91	3.58	1.71	1.18
H_2O^-	0.54	0.72	0.28	0.16
TiO_2	0.48	0.30	2.32	2.22
P_2O_5	0.17	0.08	0.59	0.45
MnO	0.09	0.06	0.17	0.16
SUM	99.37	99.73	100.23	99.94
	Normative composition			
Q	20.50	31.08	0.00	0.00
C	0.64	1.94	0.00	0.00
or	17.76	30.34	8.30	4.97
ab	41.09	23.23	25.75	29.34
an	12.26	8.39	27.70	25.39
di-wo	0.00	0.00	6.76	7.81
di-en	0.00	0.00	4.56	5.50
di-fs	0.00	0.00	1.68	1.65
hy-en	3.06	2.14	1.37	1.05
hy-fs	0.00	0.00	0.50	0.31
ol-fo	0.00	0.00	8.67	9.99
ol-fa	0.00	0.00	3.53	3.29
mt	0.00	0.61	5.28	5.34
hm	3.58	1.48	0.00	0.00
il	0.69	0.60	4.48	4.28
ap	0.41	0.20	1.42	1.08

Descriptions

1. Rhyodacite of "Spring of Contention member of volcanics of Hog Ranch" of Erb (1979, table 36, no. 12).
2. "Quartz latite of Sycamore Creek" of Erb (1979, table 36, no. 13).
3. "Basalt of the Peloncillo Mountains" of Erb (1979, table 48, no. 1).
4. "Basalt of the Peloncillo Mountains" of Erb (1979, table 48, no. 2).

Tuff of Skeleton Canyon

The tuff of Skeleton Canyon, named by Erb (1979) for exposures within that canyon, is an alkali rhyolitic ash-flow tuff (table 2, no. 4). The densely welded part of the tuff of Skeleton Canyon commonly is grayish purple and contains gray wisps of flattened pumice. Within Skeleton Canyon, the upper part of the zone of dense welding contains a zone of closely spaced lithophysae that give a Swiss cheese-like aspect to the outcrop. The tuff contains phenocrysts of quartz, sanidine, minor plagioclase, and biotite. A few crystals of sphene also are present in most samples. The sphene has an unusually small optic axial angle and is rimmed by opaque oxides. The electron microprobe shows that the sphene has a relatively high iron content and contains detectable yttrium and neodymium. It does not contain detectable tin (R. P. Christian, written commun., 1984). The upper part of the zone of dense welding in Skeleton Canyon is more mafic than the lower, containing much more plagioclase and biotite (fig. 6). The tuff of Skeleton Canyon has normal magnetic polarity.

Tuff of Whitmire Canyon and Associated Rocks

Only the southernmost exposures of the tuff of Whitmire Canyon of Erb (1979) were examined during this study (figs. 2 and 7). The unit is a crystal-poor rhyolitic ash-flow tuff that varies greatly in degree of welding and phenocryst proportions from base to top. Welding increases gradationally upward from a nonwelded base to a densely welded, platy-weathering top. Samples in the lower part of the unit contain abundant sanidine; the sample from the upper, platy part lacks sanidine (fig. 7). The unit has reversed magnetic polarity.

The lower part of the tuff of Whitmire Canyon contains abundant rhyolite blocks and overlies a zone about 1 m thick in which rhyolite blocks, as much as 1 m in diameter, are concentrated. In outcrop, these blocks resemble the tuff of Skeleton Canyon; a sample from one of them, however, contains no plagioclase. A similar block-rich zone occurs still lower in the section (fig. 7). The two block-rich zones are separated by an interval of nonwelded, pumice-rich tuff. This interval probably is related to the tuff of Whitmire Canyon.

Erb (1979, fig. 2) showed the tuff of Whitmire Canyon as overlying the rhyolite of Clanton Draw. The exposures examined during this study show instead that the tuff of Whitmire Canyon overlies the tuff of Skeleton Canyon (fig. 7). Talus shed from the ledge of tuff of Skeleton Canyon obscured the rocks underlying the tuff of Skeleton Canyon at this locality. The tuff of Skeleton Canyon overlies the dacite of Outlaw Mountain in exposures a few kilometers to the southwest.

The exposures examined gave no direct clues concerning how the tuff of Whitmire Canyon is related to the rhyolite of Clanton Draw. The tuff of Whitmire Canyon probably is older than at least part of the rhyolite of Clanton Draw. The tuff of Whitmire Canyon rests on the tuff of Skeleton Canyon, which in nearby exposures directly underlies the rhyolite of Clanton Draw.

Rhyolite of Clanton Draw

The rhyolite of Clanton Draw is a crystal-poor, alkali rhyolite lava (Erb, 1979, table 36). It is a major, widespread unit east and north of the area of figure 2. Reconnaissance examination of most of the area in which these lavas are exposed (mostly east of the area shown in figure 2) showed them to be remarkably uniform. Most exposures are of gray and purplish-gray, flow-laminated rock that contains inconspicuous grains of quartz, sanidine, plagioclase, and biotite. This rock occurs as thick flows and domes. Vitrophyre occurs locally within the sequence and at contacts with older rocks. Intercalated within this sequence of flows and domes are local accumulations of rhyolitic tephra, which probably are located near the vents from which much of the rhyolite was erupted. A sequence of rhythmically bedded rhyolitic tephra that overlies the rhyolite of Clanton Draw crops out east of the area of figure 2, in sec. 17, T. 32 S., R. 21 W. These bedded rocks, indistinguishable from tephra intercalated between flows elsewhere, were mistakenly included by Erb (1979) as part of the unit he termed the conglomerate of Animas Valley.

Zircon from the rhyolite of Clanton Draw gave a fission-track age of 25.8 ± 1.2 m.y. (Erb, 1979; see table 1). The rhyolite of Clanton Draw has reversed magnetic polarity.

Rocks of Uncertain Correlation at the Mouth of Guadalupe Canyon

The hills north of the mouth of Guadalupe Canyon (fig. 8) are underlain by a sequence of volcanic rocks that, on the basis of available information, cannot be firmly correlated with other volcanic units in the region. The problem is not that they are unique; it is, rather, that several of the units resemble in some respects at least two others well known elsewhere. Insufficient information is available to make the necessary choices for all but one of the units. The units are referred to here as follows: Bluff Creek(?) Formation and ash-flow tuff units A, B, and C. Olivine andesite(?) lava locally is intercalated between the Bluff Creek Formation and unit A. Breccia containing clasts of rhyolite and intermediate-composition lava locally overlies unit A.

Bluff Creek(?) Formation

The Bluff Creek(?) Formation of Zeller and Alper (1965) consists chiefly of crystal-poor, nonwelded, pumice- and lithic-rich ash-flow tuff more than 30 m thick. The nonwelded tuff is capped by a zone about 20 m thick that grades from a moderately welded base to a densely welded top. These rocks are characterized by abundant sanidine, no quartz, and little plagioclase (fig. 9). The upper part of the zone of dense welding contains more biotite than the rocks below.

Erb (1979, p. 42 and 195) tentatively correlated the rocks of this unit with the Bluff Creek Formation, which was named for exposures near Bluff Creek on the east flank of the Animas Mountains. The phenocryst

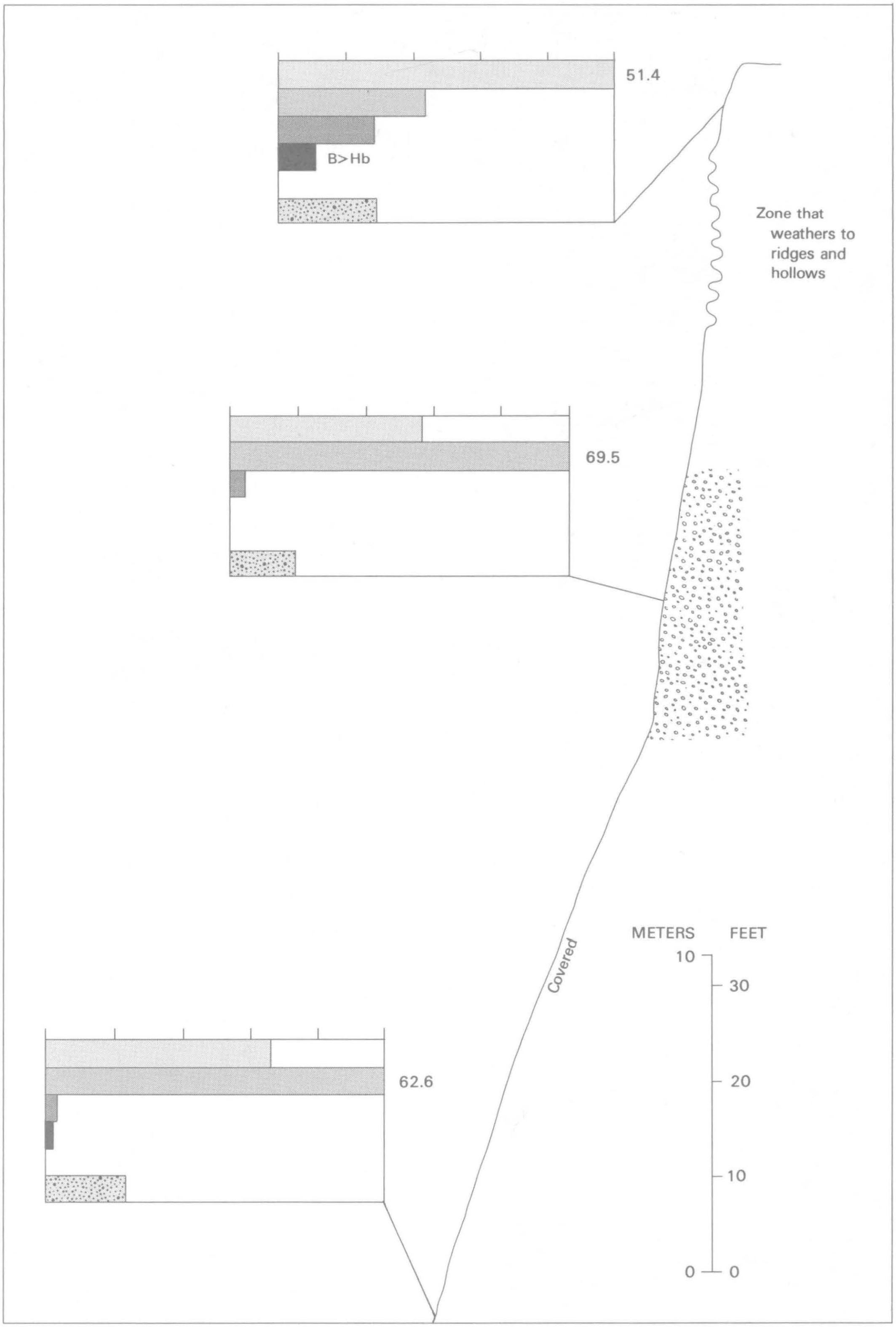


Figure 6. Stratigraphic section of tuff of Skeleton Canyon in Skeleton Canyon and histograms showing crystal content of samples. Section located on north side of canyon in NE 1/4 SW 1/4 sec. 24, T. 31 S., R. 22 W. (For explanation of symbols see figure 3.)

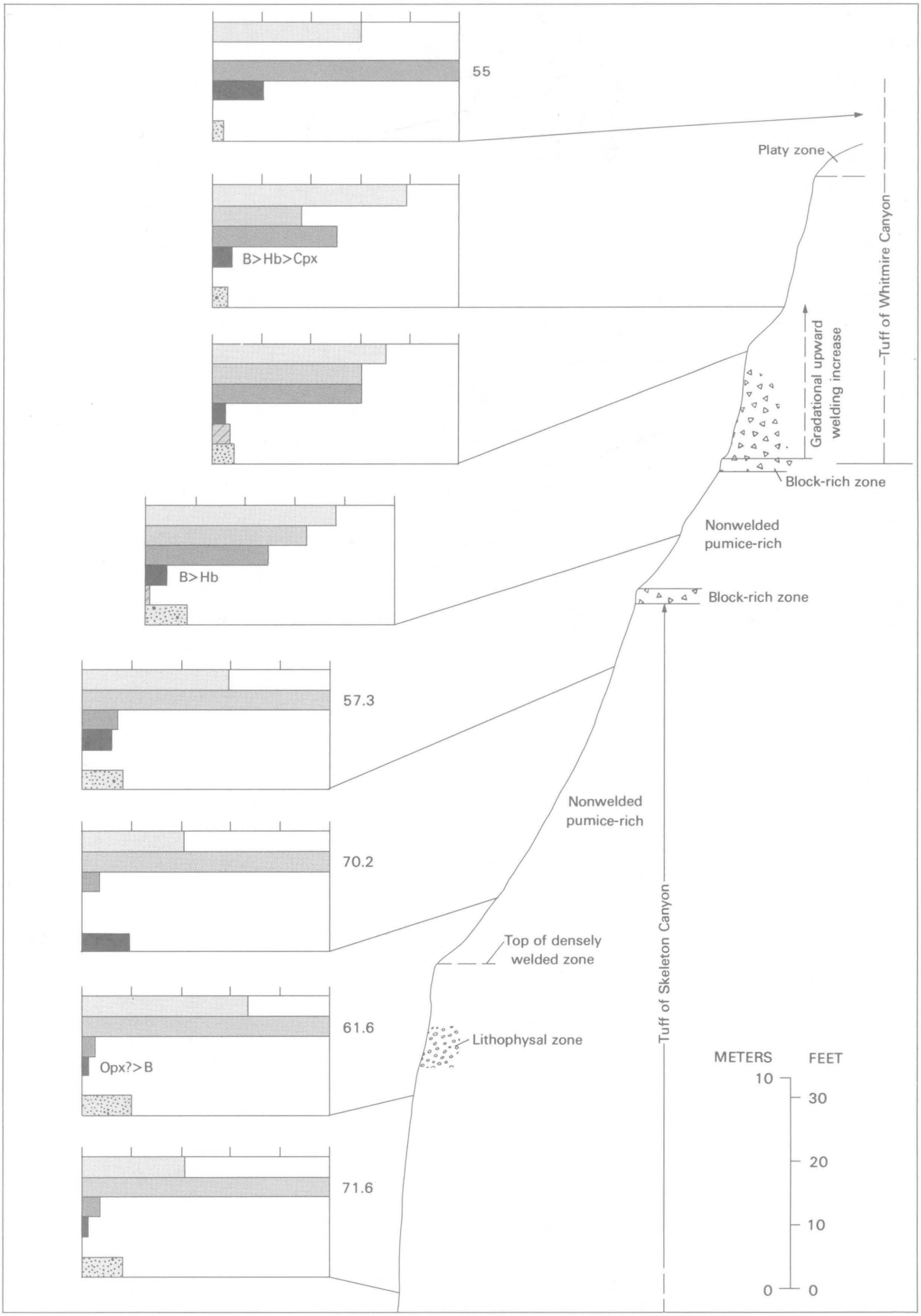
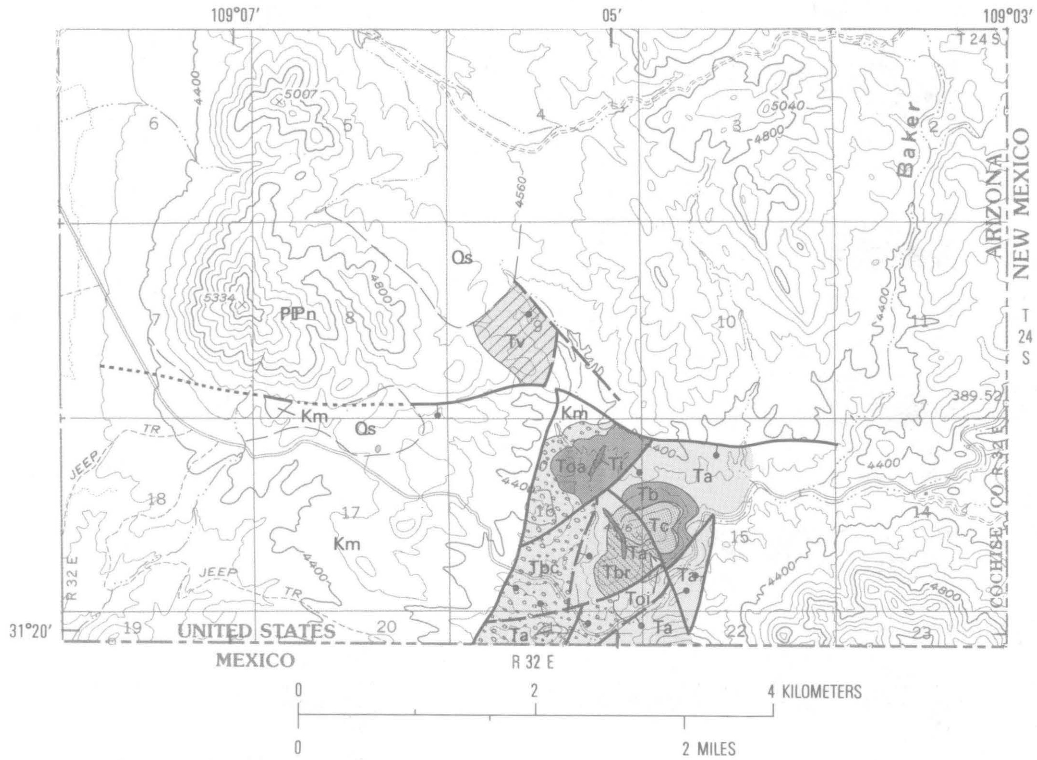
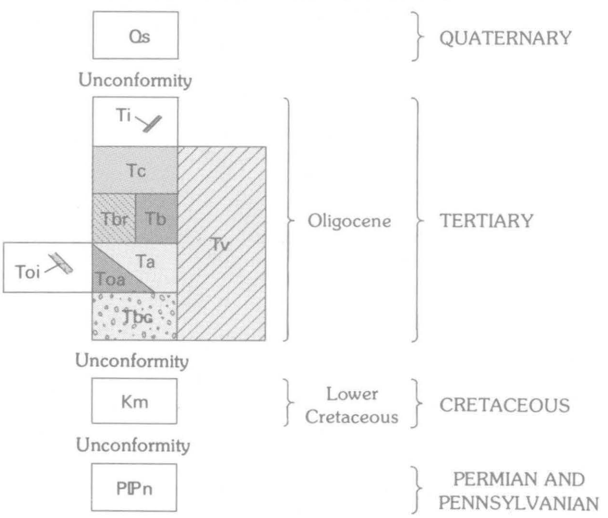


Figure 7. Stratigraphic section of tuff of Whitmire Canyon and tuff of Skeleton Canyon and histograms showing crystal and lithic fragment content of samples. (For explanation of symbols see figure 3.)



CORRELATION OF MAP UNITS



LIST OF MAP UNITS

Qs	**Surficial deposits, undivided**
Ti	**Intermediate-composition dikes**
Tc	**Unit C**
Tb	**Unit B**
Tbr	**Rhyolitic and intermediate-composition breccia**
Toi	**Olivine andesite(?) dike**
Toa	**Olivine andesite(?) lava**
Ta	**Unit A**
Tbc	**Bluff Creek(?) Formation**
Km	**Morita Formation**—Sandstone, siltstone, mudstone, and minor limestone
PPn	**Naco Group**—Limestone and dolomite, with minor siltstone

Contact—Dashed where approximately located

Fault—Dashed where approximately located, dotted where concealed; bar and ball on downthrown side

Figure 8. Geologic map of area near the mouth of Guadalupe Canyon. Geology of western part after Hayes (1982); geology of volcanic rocks in south-central part by D. H. McIntyre (unpublished mapping, 1983).

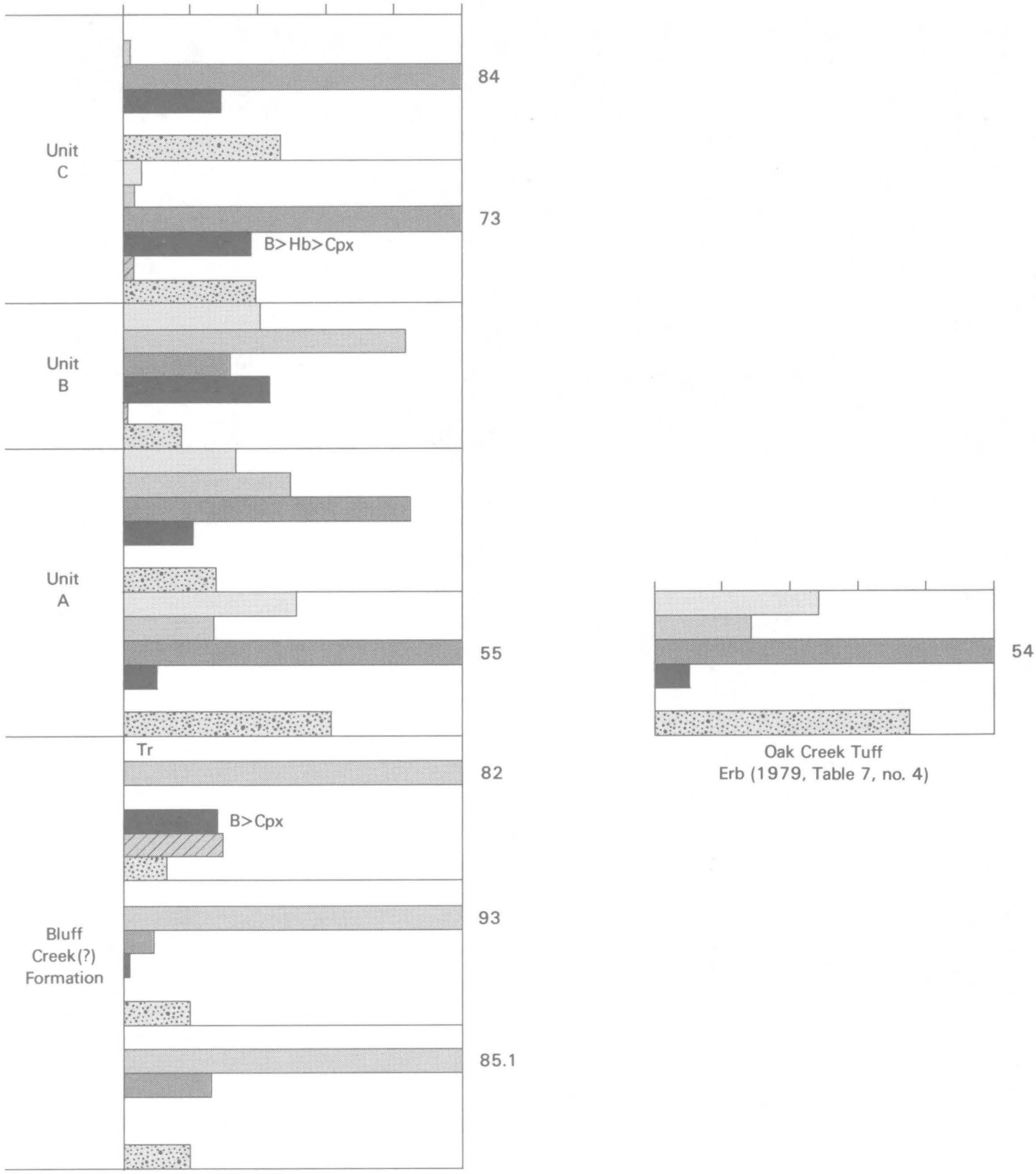


Figure 9. Histograms showing crystal and lithic fragment content of rocks of uncertain correlation at the mouth of Guadalupe Canyon. (For explanation of symbols see figure 3.)

proportions of the rocks near the mouth of Guadalupe Canyon are very close to those in ash-flow tuffs of the lower part of the Bluff Creek exposed to the east (Reiter, 1980, table 5), so this tentative correlation is quite reasonable.

Unit A

Unit A is a moderately to densely welded, crystal-rich, ledge-forming ash-flow tuff. Outcrops along the road up Guadalupe Canyon expose lenses of white collapsed pumice as much as 30 cm long. Phenocryst proportions in unit A (fig. 9) closely resemble both those in the Oak Creek Tuff of the Animas Mountains (Zeller and Alper, 1965; Erb, 1979) and the lower part of the tuff of Guadalupe Canyon as exposed along Cottonwood Creek. If the correlation of the underlying unit with the Bluff Creek Formation is correct, it would be logical for unit A to be Oak Creek Tuff because, in the Animas Mountains, Oak Creek Tuff overlies the Bluff Creek Formation. Unit A, however, could as well be tuff of

Table 4. Trace-element analyses of samples from hydrothermally altered zone south of upper Cottonwood Creek

[Sample locations shown on fig 2. Au, As, Bi, Sb, Te determined by atomic absorption; analyst: T. A. Roemer. Se determined by flameless atomic absorption; analyst: E. P. Welsch. Cu, Mo, Pb, Ag determined by semiquantitative spectrographic analysis; analyst: M. S. Erickson. Detection limits for some elements shown in parentheses. N = not detected at value shown; L = detected, but below limit of determination. All values are in parts per million (ppm)]

Sample No.	Au	As	Bi	Sb	Se	Te	Cu	Mo	Pb	Ag
MD-50-B	L(.05)	L(5)	2	L(2)	0.80	1.4	10	N(5)	10	N(.5)
MD-68	L(.05)	N(5)	4	N(2)	2.20	3.0	15	N(5)	30	N(.5)
MD-70-A	N(.05)	L(5)	1	L(2)	0.65	5.0	15	L(5)	N(10)	N(.5)
MD-70-D	N(.05)	N(5)	2	N(2)	0.20	0.1	30	L(5)	20	N(.5)
MD-73	.05	L(5)	1	N(2)	0.35	20	L(5)	N(5)	N(10)	N(.5)

Sample descriptions

MD-50-B	Quartz vein that contains finely disseminated pyrite.
MD-68	Quartz vein that contains finely disseminated pyrite.
MD-70-A	Spongy vein quartz float that contains finely disseminated pyrite.
MD-70-D	Unweathered, hydrothermally altered breccia impregnated with silica and disseminated pyrite.
MD-73	Quartz vein that contains sparse pyrite and a few grains of an unidentified dark gray metallic mineral.

Guadalupe Canyon unconformably overlying the Bluff Creek(?) Formation. Erb (1979) assigned unit A to the tuff of Guadalupe Canyon. Unit A has normal magnetic polarity.

Unit B

Unit B is massive, moderately welded, and tends to form gray to grayish-purple, rounded bluffs. Much of the unit is concealed by debris shed by the more competent overlying unit C. Biotite is conspicuous in hand specimen. The rock also contains abundant quartz, sanidine, and plagioclase (fig. 9). Phenocryst proportions resemble those in the Basin Creek Tuff (Zeller and Alper, 1965, table 4) and the tuff of Gray Ranch (Erb, 1979, table 15; Reiter, 1980, table 11).

Unit C

Unit C is a densely welded, reddish-brown, bluff-forming ash-flow tuff that caps a hill north of the mouth of Guadalupe Canyon. Unit C is crystal-rich; plagioclase and biotite are abundant, and sanidine and quartz are sparse or absent (fig. 9). Phenocryst proportions resemble those for the tuff of Black Bill Canyon (Erb, 1979, table 11) and the matrix of the breccia of Hog Canyon (fig. 5).

A black vitrophyre occurs at the base of unit C where exposed on the southeast side of the hill. Most of the lower part of the unit above the vitrophyre, however, is best exposed on the north side of the hill. Exposures and float there show well-developed vitroclastic texture. Higher in the unit the texture is smeared by flowage; near the exposed top this texture is wholly obliterated and only fine flow laminae are visible. Erb (1979, p. 210) called these rocks dacite(?) lava, evidently having seen only the flow-laminated rocks in the upper part of the unit. The unit has reversed magnetic polarity.

Olivine Andesite(?) Lava and Dike

A small patch of olivine-bearing lava crops out north of the mouth of Guadalupe Canyon. The lava is a phenocryst-poor rock that contains brown pseudomorphs after olivine that are as much as 2 mm long and sparse plagioclase phenocrysts less than 1 mm long, all set in a trachytic matrix of plagioclase and opaque oxide grains. The lava rests concordantly on east-dipping rocks of the Bluff Creek(?) Formation and is in fault contact with Unit Ta. Local exposure of an oxidized flow top shows that these rocks are a lava rather than a sill. The lava is cut by a small dike that in outcrop resembles the intrusive rocks associated with the dacite of Outlaw Mountain. An olivine phenocryst-bearing dike exposed in Guadalupe Canyon, in the SW¼ sec. 15, T. 23 S., R. 32 E., appears in thin section to be identical to the lava.

Rhyolitic and Intermediate-Composition Breccia

The southwest slopes of the hill capped by unit C are underlain by poor exposures of breccia containing clasts chiefly of rhyolite and intermediatecomposition lava. Locally, rhyolite blocks more than 1 m in diameter litter the slope. One block of gneiss (a few centimeters in diameter) was noted.

Rhyolite clasts, although crystal-poor, contain phenocrysts as much as 2 mm in length of quartz, sanidine, minor plagioclase, and biotite. In thin section, some of the larger rhyolite clasts have been molded around smaller clasts, indicating that the larger clasts were hot and plastic when deposited whereas the smaller ones were cool and rigid.

The intermediate-composition clasts contain phenocrysts of clinopyroxene, plagioclase, and amphibole. The matrix of this breccia contains crystals as much as 1 mm long of plagioclase, sanidine, quartz, and amphibole. Some of the breccia rich in intermediate-composition clasts also contains clasts of siltstone that probably were derived from pre-Tertiary formations.

Basalt

Basalt in the area occurs as lavas that unconformably overlap the older rocks in the southwestern part of figure 2 and as dikes cutting the altered rocks in the hills northeast of the Silvertip Mine. The lavas and dikes are indistinguishable in hand specimen or thin section. Although phenocryst-poor, all contain olivine, clinopyroxene, and minor plagioclase phenocrysts as much as 3 mm in size. The dikes in the altered zone are themselves unaltered. Dike rocks are not altered even immediately adjacent to the only well-exposed contact found.

The basalt is part of an extensive field in the San Bernardino Valley, west of the area of figure 2. The clusters of dikes that occur in the Peloncillo Mountains show that basalt eruptions occurred within the mountains as well as within the adjacent valley.

GERONIMO TRAIL CAULDRON

Erb (1979) recognized a single cauldron in the southern Peloncillo Mountains, which he named the Geronimo Trail cauldron. Evidence for this cauldron is best seen along its southwest margin, where the volcanic rocks within the cauldron are downdropped against pre-Tertiary rocks along an arcuate fault (fig. 1; Erb, 1979; Hayes, 1982). Most domes and intrusive rocks are restricted to a zone a few kilometers wide near this ring-fracture fault (Erb, 1979; fig. 2). Collapse of the cauldron most likely was caused by eruption of the tuff of Guadalupe Canyon.

Erb (1979) recognized that the cauldron collapse was followed by resurgence. The fault-bounded area northeast of Estes Canyon, including the Silvertip Mine area (sec. 26, T. 32 S., R. 32 E.) and Outlaw Mountain, are part of a broad, rather flat resurgent dome. Uplift of the resurgent dome accompanied invasion by dacitic magma of the collapsed block within the cauldron. Much of the dacitic magma leaked to the surface near the ring-fracture zone and formed the domes and intrusive masses north of Sycamore Creek and west of Hog Canyon. Small leaks on the resurgent dome itself resulted in the intrusive bodies near the headwaters of Cottonwood Creek. The breccia of Hog Canyon and related rocks and the dacite of Outlaw Mountain were erupted from vents marked by these intrusive bodies in the ring-fracture zone and on the dome.

Only the southwestern part of the Geronimo Trail cauldron has been preserved. The fault marking the western margin of cauldron passes beneath younger rocks of the valley to the west. The north margin of the cauldron probably is marked by a fault that follows the north rim of Skeleton Canyon; a vastly different suite of rocks occurs north of the fault. The east half of the cauldron, including the ring-fracture zone and part of the resurgent dome, has been obliterated by collapse of a younger cauldron, centered to the northeast, that overlaps the Geronimo Trail cauldron.

CLANTON DRAW CAULDRON

The name Clanton Draw cauldron is here proposed for a structure that truncates the Geronimo Trail cauldron. Available evidence suggests that initial collapse of this cauldron accompanied eruption of the tuff of Skeleton Canyon. The cauldron subsequently was filled to overflowing with the rhyolite of Clanton Draw.

The topographic wall at the southwest margin of the cauldron is exposed near the head of Clanton Draw, where the rhyolite of Clanton Draw and older rocks meet at a steep contact (fig. 2). Erb (1979), impressed by vitrophyre at this contact, believed it to be an intrusive contact. However, vitrophyre is common at the contact of the rhyolite of Clanton Draw with older rocks, whether the contact is steep, as in the example above, or flat and clearly extrusive, as in exposures of the contact northeast of Outlaw Mountain. The moderately to steeply eastward-dipping contact continues southeastward for several kilometers (fig. 2). Toward the northwest, the contact flattens abruptly. Farther west and northwest, the rhyolite rests either quasiconcordantly on the irregular upper surface of the dacite of Outlaw Mountain or concordantly on the tuff of Skeleton Canyon where that tuff is present. The change of contact attitude from steep to flat is interpreted here to mark the spillover point, where the rhyolite filling the Clanton Draw cauldron overtopped the topographic wall. Beyond this point, the rhyolite spread westward as outflow upon the rocks outside the cauldron. No collapse breccia occurs adjacent to the wall because present exposures are high on the wall, in the zone from which such deposits are derived and topographically above where they accumulate.

As noted earlier, accumulations of rhyolitic tephra east of the area of figure 2 mark the vents within the cauldron from which most of the rhyolite lava was erupted. The vents probably are located along part of the ring-fracture zone. The current position of the topographic wall, several kilometers to the west, probably is the result of rapid scarp retreat before or early during the lava eruptions. Collapse breccia formed during the scarp retreat should be widespread beneath the rhyolite.

Eruption of the tuff of Skeleton Canyon is proposed as the event triggering collapse of the Clanton Draw cauldron because (1) it commonly underlies the rhyolite of Clanton Draw, which is the principal unit exposed within the cauldron; (2) it is alkali rhyolitic, similar in composition to the rhyolite of Clanton Draw; and (3) according to Erb (1979, p. 231), it has a minimum thickness of 125 m in Skeleton Canyon—thicker at that place within the proposed cauldron than outside it.

A sequence of events consistent with what currently is known is (1) explosive eruption of a modest volume of volatile-charged alkali rhyolitic magma (tuff of Skeleton Canyon) accompanied by formation of a shallow cauldron and then (2) more quiescent eruption of the remaining available alkali rhyolitic magma, filling the shallow cauldron to overflowing with rhyolite lava.

What role, if any, the tuff of Whitmire Canyon played in development of the Clanton Draw cauldron is unclear. Its chemical composition is virtually identical to that of the rhyolite of Clanton Draw (table 2); it thus may be an explosively erupted, immediate precursor to the rhyolite lava.

Intermediate-composition intrusions into the rhyolite of Clanton Draw and related rocks northeast of the area of figure 2 probably mark part of the ring-fracture zone on the southwest side of the Clanton Draw cauldron. Flooding of the cauldron by the rhyolite lava following collapse has concealed the ring-fracture faults. The intrusive bodies are the analogues of those in the ring-fracture zone of the Geronimo Trail cauldron. The eastern part of the cauldron is concealed by younger deposits in the valley east of the mountain range.

STRUCTURE

The structure within the mapped area (figs. 2 and 8) appears chiefly cauldron related; insufficient area was studied to permit identification of those elements that might clearly be related to regional tectonism. With the possible exception of the fault bounding the southwest margin of the Geronimo Trail cauldron, none of the faults has large displacement. The faults on the resurgent dome in the upper Cottonwood Creek area, which break up the rocks into a mosaic of small blocks, form a pattern much like that found on some other resurgent domes (see, for example, Carr and Quinlivan, 1966). More detailed mapping in this area probably would reveal many more such small faults.

MINERALIZATION

Mineralization in and northeast of the area shown in figure 2 was of two kinds. Products of the first are associated with a 5-km^2 area of hydrothermally altered rocks and quartz veins located primarily east and northeast of the Silvertip Mine. The second mineralization event is indicated by geochemically anomalous tin in sediments of streams draining areas underlain by the rhyolite of Clanton Draw.

Hydrothermal Alteration and Quartz Veins

The area of hydrothermal alteration, outlined on figure 2, contains intensely leached, clay-altered rock that includes several zones of large quartz veins. One exposure of unweathered rock within the area is rich in disseminated pyrite. Much, if not most, of the leaching and clay formation elsewhere in the zone evidently has been by acid waters derived from weathering of disseminated pyrite. Watts and others (1983, table 2) collected acid-sulfate water (pH 3.66) from a seep in upper Cottonwood Creek that contained large amounts of aluminum, iron, manganese, and zinc. This water clearly shows that leaching of the rock in the altered area is going on at the present time. Much of the leachate evidently is leaving the area via the surface drainage rather than being reprecipitated and concentrated at depth.

The intensity of rock alteration varied within the zone. In many parts of the zone, especially near the Silvertip Mine, feldspar phenocrysts in the rock are fresh and glassy, despite leaching of the matrix. In the northwestern part of the zone, alteration was more intense; feldspars commonly have been completely dissolved, leaving empty holes in the rock matrix. The altered biotite is silver-green. Limonitic coatings on joints commonly are heavy and goethite rich, locally with minor hematite.

The quartz veins within the altered zone trend N. 10° W. to N. 15° E., are tens of meters long, essentially vertical, and locally attain widths of 6 m. All contain abundant blocks and slabs of country rock. Most exposures are deeply weathered and strongly stained by goethite and hematite. Fresh vein rock is dark greenish-gray and contains finely disseminated pyrite, which in some veins alternates with stringers of barren white quartz a few centimeters across.

The Silvertip Mine is a S. 40° W.-trending adit, still open at the portal, but not entered during this study. The adit at the portal follows a steep shear zone about 1 m wide that lacks strong silicification. According to Hayes and others (1983), the adit is 240 ft (73 m) long and explores a fracture zone that attains a width of 10 ft (3 m). A shallow shaft also is present. The small dump near the adit contains a few pieces of sulfide-bearing quartz in addition to altered breccia of Hog Canyon. The quartz, unlike that seen in nearby veins, is dark gray and spongy. Quartz phenocrysts recognizable within the spongy matrix suggest that the spongy quartz may have formed, at least in part, by replacement of the volcanic country rock. The quartz contains a few scattered crystals of pyrite and (or) chalcopyrite. One specimen contained a single grain a fraction of a millimeter in diameter of a dark gray, soft mineral with a submetallic luster. Similar, spongy quartz was seen as float at locality MD-70 (fig. 2). The Silvertip Mine has no recorded production.

The age and genetic affinities of the altered zone are not well defined, but field relations permit some limited inferences. Alteration affected rocks as young as the dacite of Outlaw Mountain. Younger rocks, such as the tuff of Skeleton Canyon and the rhyolite of Clanton Draw, are not altered, but they do not occur in or very near the altered area. Another approach to the problem would note that none of the rocks seen during this study anywhere in the Clanton Draw cauldron are hydrothermally altered, but that all of the rocks in the Geronimo Trail cauldron locally are. This would suggest that the alteration was a characteristic of the Geronimo Trail cauldron. As noted earlier, the zone of intense alteration is located on the cauldron's resurgent dome.

Unweathered samples from several of the veins and one sample of unweathered, altered rock did not contain unusual concentrations of any element except that some of the veins contain very small amounts of gold. Analytical results for several elements are shown in table 4. Intense leaching of most rocks exposed at the surface in the altered zone makes evaluation of its metals content very difficult. It is possible that higher metals values may exist in some of the unweathered rock concealed beneath the leached surface capping. The results shown in table 4, however, are not encouraging.

Tin

Anomalous quantities of tin were found during the geochemical survey (Watts and others, 1983) chiefly in sediments from streams draining the area underlain by the rhyolite of Clanton Draw. The tin anomalies are most apparent in the panned heavy-mineral concentrates, in which cassiterite was visually identified (Watts and others, 1983). Other minerals identified in the concentrates that commonly are associated with cassiterite in tin deposits are fluorite and possible pseudobrookite (Watts and others, 1983). Topaz was identified by the author in one of the pan concentrates. No cassiterite was noted in any of the rock samples collected from the rhyolite of Clanton Draw during this study. No hydrothermal alteration was observed in terrain in and around two drainages that provided pan concentrates containing 2,000->2,000 ppm tin southeast of Clanton Draw east of the area of figure 2 (Watts and others, 1983). Fresh glass was common at the margin of several rhyolite bodies exposed there. Although the sources for the tin in the stream sediments were not located, the presence of large hydrothermally altered areas in which the tin might have been concentrated was ruled out. No hydrothermal alteration was noted elsewhere in the outcrop area of the rhyolite of Clanton Draw. The cassiterite evidently was supplied to the stream sediments from small cassiterite-bearing zones within the unaltered rhyolite that were missed during the rock sampling.

REFERENCES CITED

Carr, W. J., and Quinlivan, W. D., 1966, Geologic map of the Timber Mountain quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-503.

Deal, E. G., Elston, W. E., Erb, E. E., Peterson, S. L., Reiter, D. E., Damon, P. E., and Shafiqullah, M., 1978, Cenozoic volcanic geology of the Basin and Range Province in Hidalgo County, southwestern New Mexico: New Mexico Geological Society Guidebook, 29th Field Conference, Land of Cochise, p. 219-229.

Erb, E. E., Jr., 1979, Petrologic and structural evolution of ash-flow tuff cauldrons and noncauldron-related volcanic rocks in the Animas and southern Peloncillo Mountains, Hidalgo County, New Mexico: University of New Mexico Ph.D. thesis, 286 p.

Hayes, P. T., 1982, Geologic map of Bunk Robinson Peak and Whitmire Canyon Roadless Areas, Coronado National Forest, New Mexico and Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1425-A, scale 1:62,500.

Hayes, P. T., Watts, K. C., Hassemer, J. R., and Brown, S. D., 1983, Mineral resource potential map of Bunk Robinson Peak and Whitmire Canyon Roadless Areas, Hidalgo County, New Mexico and Cochise County, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1425-B, scale 1:62,500.

Reiter, D. F., 1980, Geology of the Alamo Hueco and Dog Mountains, Hidalgo County, New Mexico: Albuquerque, University of New Mexico, M.S. thesis, 100 p.

Watts, K. C., Hassemer, J. R., and Day, G. W., 1983, Geochemical maps of Bunk Robinson Peak and Whitmire Canyon Roadless Areas, Hidalgo County, New Mexico and Cochise County, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1425-C, scale 1:62,500.

Zeller, R. A., Jr., and Alper, A. M., 1965, Geology of the Walnut Wells quadrangle, Hidalgo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 84, 105 p.

★ U.S. GPO: 1988 573-047/66,082

McIntyre—VOLCANIC GEOLOGY, SOUTHERN PELONCILLO MOUNTAINS, ARIZONA AND NEW MEXICO—U.S. Geological Survey Bulletin 1671