BULLETIN 57

Geology of the Central Peloncillo Mountains, Hidalgo County, New Mexico, and Cochise County, Arizona

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1958

STATE BUREAU OF MINES AND MINERAL RESOURCES
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY
CAMPUS STATION SOCORRO, NEW MEXICO

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The central Peloncillo Mountains consist mostly of late Cretaceous and late Tertiary volcanic rocks; in addition, Cretaceous and Paleozoic marine sedimentary rocks and Precambrian granite are exposed in fault blocks bounded by northwest-trending steeply dipping faults. Dikes and sills of Tertiary and probable Cretaceous age intrude the layered rocks. The central part of the mapped area is structurally high with reference to the northern and southern parts, because it occupies the crest of the northwest trending Peloncillo arch, which, with its associated northwest trending faults, probably took shape in the Tertiary period. A horst of Precambrian granite bounded by faults trending east-northeast lies transversely across the middle of the range in the vicinity of Granite Gap.

The volcanic rocks include an "earlier" sequence of much altered andesite flow rock and breccia, which are characterized by abundant epidote, and a younger sequence of mostly rhyolitic rock, the extrusion of which was probably accompanied by explosions, for pyroclastic debris is common. Nuees ardentes eruptions resulted in the thick sequence of ignimbrite which covers much of the southern part of the area.

A few small copper, lead, zinc, and silver deposits, several of which are contact metasomatic deposits, are associated with late-Cretaceous or early-Tertiary quartz monzonite porphyry.

Introduction

SCOPE AND PURPOSE

In recent years a great impetus has been given to the study of the stratigraphy and igneous geology of southwestern New Mexico. The ever-increasing search for mineral and petroleum deposits has made necessary a reevaluation of the geology of the region. Areas have been restudied, and areas which previously had been geologically bypassed have been investigated. As part of this "new look" the geologic map of New Mexico is being revised, and the New Mexico Bureau of Mines and Mineral Resources is engaged presently in completing the geologic reconnaissance mapping of southwestern New Mexico for the new map. This report is one of a series representing detailed studies of areas regarded as critical both with respect to geologic information and to knowledge of mineral deposits.

The central Peloncillo Mountains, situated as they are on the New Mexico-Arizona boundary, are critical in a comparison and correlation of the geology of these two States. The mountains contain a relatively complete sequence of lower Paleozoic strata, similar to strata in portions of New Mexico farther east, but the older rocks of the sequence closely resemble rocks in Arizona. The upper Paleozoic strata are similar to rocks of southeastern Arizona and indicate a closer relationship with western areas. The Cretaceous rocks are closely allied to rocks to the south, in Mexico, and represent the northernmost exposures of the thick Lower Cretaceous sequence of southeastern Arizona, southwestern New Mexico, Sonora, and Chihuahua, with its included volcanic rocks.

The long volcanic history of the region is well represented in the area. Lower Cretaceous, Upper Cretaceous or lower Tertiary, middle and upper Tertiary, and Quaternary volcanic rocks are exposed. The distinction between the different periods of volcanic activity is particularly important in the search for mineral deposits, because no important base-metal deposits have been found in southwestern New Mexico in the younger volcanic rocks.

METHODS

Mapping was done on aerial photographs at a scale of 1:20,000; later the data were compiled on a topographic base map at a scale of 1:31,680, with a contour interval of 100 feet. This base map was compiled for the New Mexico Bureau of Mines and Mineral Resources by the Topographic Division of the U. S. Geological Survey, partly from the published Vanar quadrangle topographic sheet, and partly as a *new* compilation.

Stratigraphic sections were measured by compass and pace, and by the use of the Jacob's staff.

GEOGRAPHY

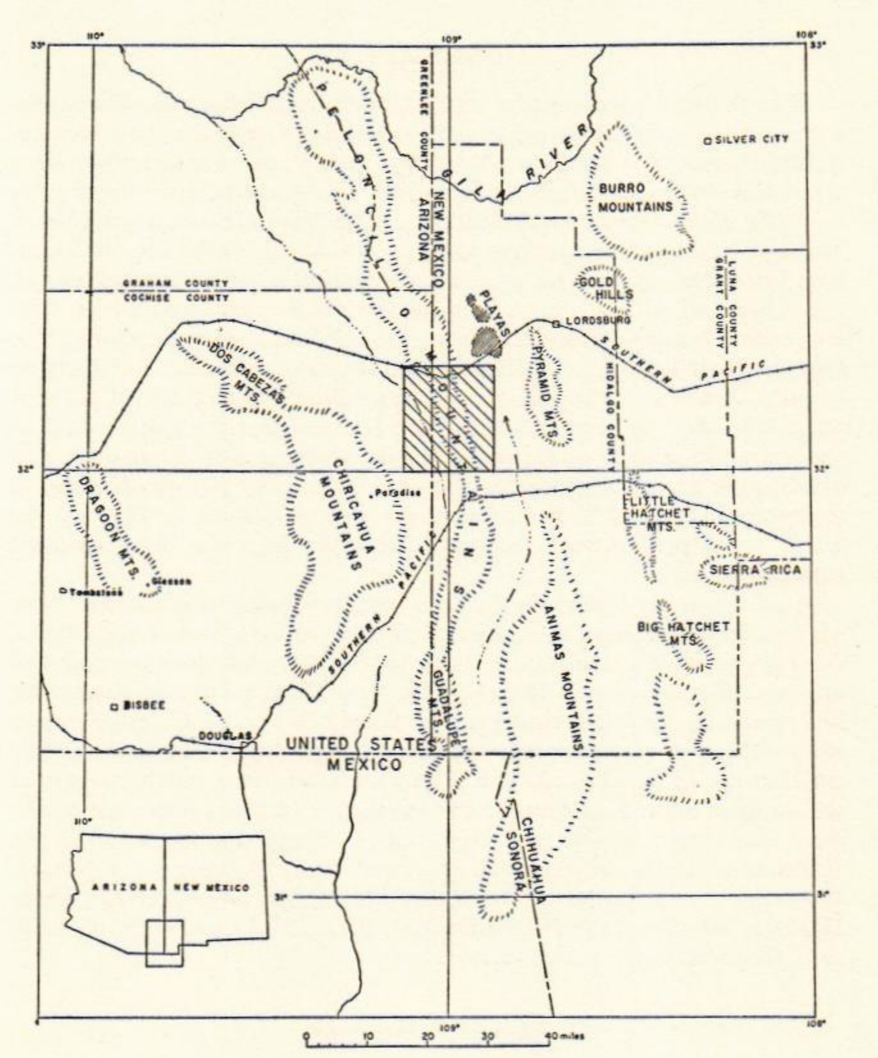
The Peloncillo Mountains extend northward from near the southwest corner of New Mexico (lat. 30°20' N.), just east of the New Mexico-Arizona boundary line, to about lat. 30°20' N. Thence they turn northwestward, cross the State boundary into Arizona, and continue to the Gila River (about lat. 32°50' N.). The New Mexico portion is in Hidalgo County; the Arizona portion in Cochise, Greenlee, and Graham Counties (fig. 1). This report is concerned with the central part of the range and with adjacent parts of the Animas and San Simon Valleys, which border the mountains on the east and west respectively. The area mapped lies within Hidalgo County, New Mexico, and Cochise County, Arizona. Its boundaries are lat. 32°00' N. and 32°15' N., and long. 108°521/2' W. and 109°071/2' W. It comprises the eastern half of the Vanar 15-minute quadrangle and the western half of an unnamed quadrangle temporarily called Pyramid III, or Steins, quadrangle. A topographic map of Vanar quadrangle was published in 1951 by the U. S. Geological Survey. Steins quadrangle has not been mapped topographically.

U. S. Highway 80 crosses the area from northeast to southwest. New Mexico State Highway 14 and its extension, Arizona State Highway 86, extend westward across the northern part of the area from the point of origin at Road Forks on Highway 80. New Mexico State Highway 338 lies along the eastern boundary. The Southern Pacific Railroad crosses the northern part of the area, paralleling Highways 80, 14, and 86. The small towns of Road Forks and Steins are within the northern part of the mapped area. Lordsburg, New Mexico, is 12 miles northeast of the northeast corner of the area. Steins Pass, where the Southern Pacific Railroad and State Highway 14 cross the Peloncillo range, is a historic landmark on the route of the Butterfield Stage. Granite Gap, where Highway 80 crosses the Peloncillo Mountains, and Cowboy Pass, south of Highway 80, are less well known.

PHYSIOGRAPHY

Physiographically the area is divisible into three distinct units: The Animas Valley on the east, the Peloncillo Mountains, and the San Simon Valley on the west. Each of these areas will be discussed separately.

The Animas Valley is a broad, flat, northward sloping interior basin, with no definite drainage lines. Flood waters discharged by the gullies heading in the mountains bordering the valley spread in thin sheets across the valley floor and eventually find their way via broad, ill-



INDEX MAP SHOWING LOCATION OF THE CENTRAL PART OF THE PELONCILLO MOUNTAINS

Figure 1

defined, shallow draws to playas that occupy the lowest parts of the valley. Two playas, North Alkali Flat and South Alkali Flat, lie just north of the mapped area. South Alkali Flat, the larger, occupies the lowest part of the valley. Throughout most of the year the playas are dry, but during the wet season they sometimes contain shallow, but extensive, lakes. The lowest part of Animas Valley within the mapped area is in the northwest corner, at an altitude of about 4,150 feet. This point is about 1½ miles south of the edge of South Alkali Flat and about 8 feet higher.

The San Simon Valley is also a broad flat valley, through which San Simon Creek flows northwestward to the Gila River. The valley is lower than Animas Valley; within the mapped area the altitude of the valley bottom ranges from 3,685 to 3,980 feet. The lowest point in the area is where San Simon Creek crosses the western boundary of the map, south of Arizona State Highway 86.

The Peloncillo Mountains are a narrow range of relatively low hills which rise 1,000 to 1,500 feet above the Animas and San Simon Valleys. The highest point is Blue Mountain (alt. about 5,750 feet). The summit of Cienega Peak, a particularly prominent landmark on the western side of the range, is 5,743 feet above sea level. Low passes in the range are Steins Pass (alt. 4,350 feet), Granite Gap (alt. 4,460 feet), and Cowboy Pass. Although the general relief of the range is not great, the slopes, particularly in the central part of the area, are steep and give an exaggerated effect of loftiness.

The Peloncillo range can be divided into several topographically distinct parts. In the southern and northern parts the hills are lower, have gentler slopes, and are more rounded than in the central part. The range is broad in these areas, averaging 3 to 4 miles across; no linear ridge elements are present. The central part is characterized by one to three parallel ridges alined en echelon oblique to the trend of the range. The individual ridges are a mile or less across; where only one ridge is present, that is the width of the range. The topography is bolder than in the areas to the north or south.

CLIMATE AND VEGETATION

The Peloncillo Mountains and adjacent valleys lie within the semidesert region of southwestern New Mexico and adjacent States. The vegetation is typical of the lower Sonoran life zone. Desert-type grasses and herbaceous plants are common in the valleys and, together with low shrubs, are scattered over the generally bare slopes of the mountains. Trees are scarce, but a few scrub oaks and junipers grow in the mountains.

The climate is mild and dry; winters are not severe. U. S. Weather Bureau records of precipitation from stations within 15 miles of the area, and at altitudes comparable to those of the lower slopes of the Peloncillo Mountains, are listed below:

Station	*Period of record*	*Av. prec.*	*Av. temp.*
Lordsburg, N. Mex.	49 years	9.54 in.	60.8°F
San Simon, Ariz.	55 years	7.93 in.	60.0°F
Rodeo, N. Mex.	21 years	11.29 in.	

Similar conditions of temperature and precipitation exist within the mapped area, although the precipitation may be slightly higher in the mountains. Temperatures above 100°F are common between May and September, and the average for these months is about 75°-80°F. Almost 50 percent of the precipitation occurs during sudden thunderstorms in July, August, and September. Snowfalls are infrequent, and the snow rarely remains on the ground more than a day.

PREVIOUS WORK

Previous geologic work in the area consists of a few general observations on the geology of the Peloncillo Mountains, and detailed studies of the geology of the San Simon and Animas Valleys, which emphasize the ground-water resources.

Antisell (1857, p. 152) recognized the extrusive character of the rocks along the proposed route of the Pacific Railroad in the vicinity of Steins Pass and divided the rocks into trachyte amygdaloids, basalts, and porphyries. He stated that the porphyries were intrusive into, and thus later than, the trachyte amygdaloids, and that the basalts were later than the porphyries. He also observed conglomerate and metamorphosed sandstone and mentioned that the igneous rocks overlie the sandstone and Carboniferous limestone.

Gilbert (1875, p. 513) also mentioned the volcanic rocks at Peloncillo Peak (now Steins Mountain), as well as the sedimentary rocks and granite at Gavilon (now Cienega) Peak. He rightly identified the sandstone and limestone strata of Gavilon Peak as Paleozoic and stated that they dip at high angles and are marbleized at the contact with the granite. He called the granite making up the peak "eruptive" and noted that it is traversed by a "quartz porphyry" dike.

Lindgren, Graton, and Gordon (1903, p. 328) briefly described the geology at Granite Gap and recognized the fault contact between the block of granite exposed at this locality and the limestone to the south. They stated that the age of the granite may be Precambrian or post-Carboniferous. The mineral deposits at Granite Gap, and also those on the west side of the range between Granite Gap and Steins, are described in detail.

Jones (1904, p. 66) mentioned the mines at Granite Gap and elsewhere in the Peloncillo Mountains, but said nothing of the geology of the area.

Schwennesen (1917, 1918) described in detail the geology and water resources of the San Simon and Animas Valleys in two reports. The one on the Animas Valley (1918) is more pertinent to the present study. It contains information relative to the Quaternary lake and beach deposits and to the Quaternary basalt in the valley.

Darton (1928-a, p. 348; 1933, p. 145, 169) briefly described the geology of the mountains, drawing a cross-section eastward from Gavilon (now Cienega) Peak. He recognized the presence of Carboniferous and lower Paleozoic rocks, and granite. He identified the igneous rock of Gavilon Peak as a porphyry and presumably recognized its intrusive nature. He made no mention of Cretaceous rock in the mountains. On the geologic map of New Mexico (Darton, 1928-b) the range is shown to consist dominantly of extrusive rock and Carboniferous limestone. Small intrusive masses and the small area of lower Paleozoic rock north of Granite Gap are shown, but Cretaceous rocks are not shown.

A guidebook published by the New Mexico Geological Society in 1953 includes a map of the northern part of the area and a brief discussion of rocks observed along the route traversed by the field trip (U. S. Highway 80, east of Road Forks, and New Mexico State Highway 14 and Arizona State Highway 86). Most of the geologic information is taken from reports by Darton and by Lindgren and Graton, but on the map the igneous rocks are divided into 3 units: Rhyolite flow rock and tuff, intrusive rock, and andesite and basalt. The existence of Cretaceous sedimentary rock in the area between Steins and Granite Gap is recorded for the first time. The information in this publication on the geology of the Lower Animas Valley is taken from Schwennesen's report (1918).

Unpublished Master's theses on the geology of the area north of Granite Gap (Quaide, 1953) and on the Paradise formation (Packard, 1955) have been completed recently. Additional studies of the groundwater resources of the Lower Animas Valley are part of a current project being carried on by the State Engineer's Office of New Mexico and the Ground Water Branch of the U. S. Geological Survey. Reconnaissance geologic mapping by some of the major oil companies has been done in the area since 1952.

ACKNOWLEDGMENTS

Appreciation has been expressed to many of the persons who have been of assistance in this work, and the writer takes this opportunity to thank the many others whom it has not been possible to reach otherwise. Particular thanks are given to Dr. Eugene Callaghan, formerly director of the New Mexico Bureau of Mines and Mineral Resources, for the financial assistance of the Bureau, and for his helpful suggestions in the field and in the office. Grateful acknowledgment also is made to other members of the staff of the Bureau for their cooperation and assistance.

I am indebted to Prof. R. K. DeFord, of the University of Texas, for his encouragement during the course of the work and for his critical reading of the manuscript. Thanks are due also to Prof. Keith P. Young for his help in the identification of the ammonites, to Prof. W. C. Bell for his critical reading of the manuscript and helpful suggestions, and to the entire staff of the geology department of the University of Texas, whose help and cooperation were greatly appreciated.

The Upper Paleozoic brachiopods were identified by Dr. Frank Stehli, of the California Institute of Technology, and the fusulinids by Mr. Garner Wilde, of the Humble Oil and Refining Co., Midland, Texas. The ammonites and other Cretaceous fossils were examined by Dr. A. A. Stoyanow, of the University of California (Los Angeles). Dr. Harland Johnson examined some algae remains. Richard V. McGehee assisted in the field in the summer of 1955. The help of all these persons is gratefully acknowledged.

I am deeply indebted to Mr. Donald McGhee and Mr. C. G. Perry, of Lordsburg, New Mexico, for making available old mining records and for their cooperation in furnishing other assistance and information.

Geology

Throughout much of the length of the Peloncillo Mountains the surface is blanketed by Tertiary volcanic rock of rhyolitic or quartz-latitic composition. The rhyolite ignimbrite exposed in the southern part of the mapped area and the acidic flow rock and pyroclastic rocks in the northern part of the area are typical representatives. Within the area studied, orogenic movements in the late Tertiary and Quaternary produced two results: The upbowing of the central part of the range into the Peloncillo Arch, and the uplifting of the range as a unit relative to the valleys to the east and west. The first of these movements resulted in the eventual exposure, in the central part of the range, of Precambrian, Paleozoic, Mesozoic, and early Tertiary rocks which underlay the later Tertiary and Quaternary volcanic rocks. Numerous northwest trending faults cut these older sedimentary and igneous rocks and bound a number of differently tilted fault blocks trending diagonally across the range. A pair of east-northeast trending faults bound a horst of Precambrian granite that lies normal to the strike of the range and separates the area of sedimentary rocks into two parts. Small intrusions cut the sedimentary strata, and a few economic concentrations of lead, zinc, silver, copper, and tungsten are associated with these intrusions.

The rocks in the mountains and adjoining valleys are summarized in Table 1.

INTRUSIVE IGNEOUS ROCKS

GRANITE GAP GRANITE

The Granite Gap granite, named from the exposures at Granite Gap, where Highway 80 crosses the Peloncillo Range, is probably Precambrian in age. It unconformably underlies Bolsa quartzite and is typical of Precambrian granite elsewhere in southwestern New Mexico.

The granite crops out in two distinct geologic settings. In the vicinity of Granite Gap it constitutes the greater part of an upfaulted block, oriented east-west, which lies across the axis of the range and the strike of the sedimentary rocks. It is bounded on the north and south by high-angle southward dipping faults, and dips beneath Quaternary gravel to the east and west. The exposures occupy an area of 1½ miles square.

The granite also crops out in a northwest trending band between the main ridge of the Peloncillo Mountains and the smaller ridge north of Preacher Mountain. The zone is only a few hundred feet wide at its southern extremity, where it abuts against the Granite Gap fault block, but widens to half a mile at the point where it dips beneath the gravel of San Simon Valley. It is bounded on the northeast by a high-angle reverse fault, but along the southwest side it is unconformably overlain by Bolsa quartzite of Cambrian age. Small exposures of Granite Gap granite also occur beneath Bolsa quartzite in the low hills immediately south of the Granite Gap fault block and on an isolated hill east of Cowboy Pass.

The topographic expression and the weathering of the Granite Gap granite reflect the geologic setting. Where it underlies the Bolsa quartzite in the northwest trending zone, it is soft and easily erodible, and crops out in the valley bottoms and on the lowermost slopes of the ridges. Wide areas consist of gently rolling hills of the unconsolidated products of the disintegrating granite, with scattered exposures of the underlying rock. As the surface of the granite now exposed in this area is close to the surface upon which the Paleozoic sediments were deposited, it has long been within or near the zone of active weathering. Consequently the much altered limonite-stained rock is soft and crumbly.

Within the Granite Gap fault block, the granite is much harder and more resistant to weathering and erosion. Joints are prominent, and weathering along the joints has produced the rounded massive monolithic forms so typical of many areas of plutonic rocks (p1. 4). The granite occupies some of the higher hills, as well as low areas. Exposures are prominent, and only in small scattered areas is the bare granite covered by the products of weathering. The ferromagnesian minerals are unaltered, and no limonite stains were observed. In this area the granite was brought to the surface by faulting in post-Cretaceous time and has not been subjected to protracted weathering. The surface now exposed is carved on a portion of the granite that was deeply buried and not within the zone of weathering in Precambrian and Cambrian times.

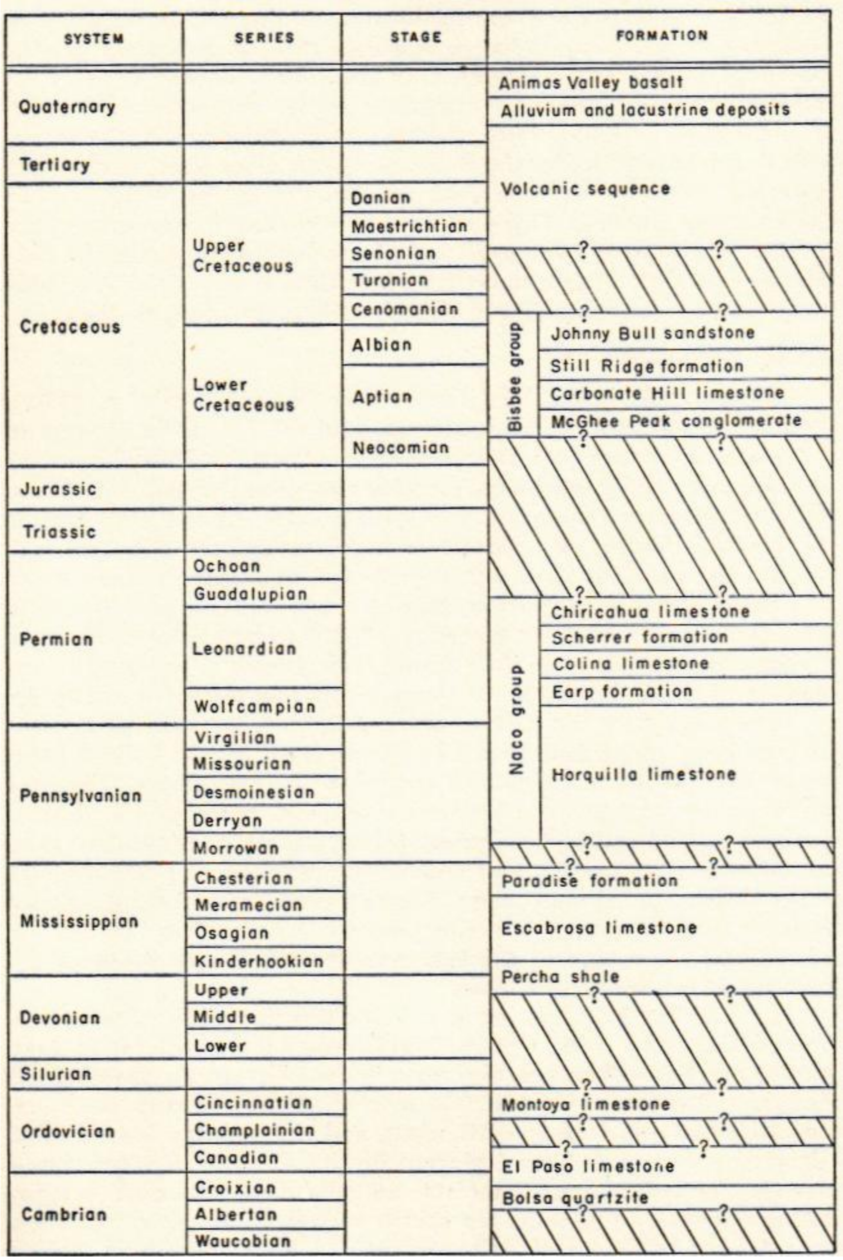
Where fresh and unaltered, the Granite Gap granite is a holocrystalline equigranular medium-grained light-pink to gray rock with a hypidiomorphic texture. It is composed dominantly of anhedral quartz and subhedral orthoclase, which together constitute at least 75 percent of the rock. The orthoclase is slightly in excess of the quartz. About 5 percent albite (An_7), 10 percent microcline, and 5-10 percent microperthite are present. Small biotite flakes are scattered through the rock and constitute 1-2 percent of the total mass. Magnetite is present but not common, and sphene occurs in small wedge-shaped crystals. Locally the granite is coarse grained, with some of the feldspar crystals as much as 2 cm in diameter.

Weathering produces muscovite and magnetite from the biotite. The magnetite then alters to limonite, which stains the rock brown and yellow. The feldspars alter to kaolinite. The weathered rock is soft and crumbly, and a few flakes of silvery muscovite are set in a mass of cloudy altered feldspar and milky quartz grains.

TABLE 1. ROCKS OF THE CENTRAL PELONCILLO MOUNTAINS

Intrusive rocks	Age	Sedimentary and extrusive rocks (layered rocks)		
		Rock unit	Lithology	Thickness (feet)
	Quaternary	Animas Valley basalt	Dark-gray to black fine-grained vesicular olivine basalt	0-60
Rhyolite dikes		Alluvial and lacustrine deposits	Includes older alluvial deposits of poorly sorted coarse gravel upon which a hilly topography is developed; lake beds of interbedded fine sand and clay estimated to be 10-20 feet thick; and younger alluvial deposits of unsorted and unconsolidated sand and gravel on the lower slopes of the mountains and in parts of Animas and San Simon Valleys	
Quartz latite dikes and plug	Tertiary	Weatherby Canyon ignimbrite	Rhyolite and some trachyte ignimbrite and thin interbeds of nonwelded tuff. Most of the ignimbrite is a light-gray to red, hard, compact, aphanitic-porphyritic rhyolite, with phenocrysts of quartz, sanidine, and orthoclase in a devitrified matrix of shards and glass shreds. Numerous elongated lenticular cavities impart a eutaxitic structure to the ignimbrite. Microscopic examination shows that the finer particles are also alined parallel to the bedding. The ignimbrite is confined to the area south of Cowboy Pass	3,000+
Latite porphyry sills and dikes		Vanar Hills volcanic rocks	Flows, vitric tuffs, crystal tuffs, and pitchstone; pinkish-gray latitic rocks, with phenocrysts of feldspar and biotite in a hypocrystalline groundmass. Similar to the intrusive latite porphyry	
Rhyolite, latite, and monzonite porphyry dikes, sills, and plugs		Steins Mountain quartz latite porphyry	Columnar jointed flows and devitrified tuffs which form the upper part of Steins Mountain and adjacent hills. The rock is pinkish-gray porphyritic-aphanitic, with quartz and feldspar phenocrysts and numerous lithic and vitric fragments, many of which are flattened and elongated, imparting a eutaxitic structure to the rock	
		Basalt	Dark-gray to black, fine-grained, holocrystalline, nonporphyritic; consisting wholly of andesine and magnetite. Occurs north of Steins	
		Quarry Peak rhyolite complex	Flows, breccias, and tuffs of rhyolite composition. In general the rock is light gray to white, with a few small inconspicuous quartz or feldspar megacrystals. Many of the breccias and tuffs are well bedded. Occurs north of the Southern Pacific Railroad and forms prominent Quarry Peak	1,000±
Quartz monzonite porphyry dikes and sills	?	Andesite	Dark-gray, red, and grayish-purple flows and breccias, most of which are fine grained, with small phenocrysts of epidotized feldspar and pyroxene. Epidote is very abundant in the rock. Some dacite and basalt are included in the sequence	5,000+
		Bobcat Hill conglomerate	Interbedded impure volcanic arkose sandstone and conglomerate. The conglomerate is characterized by the presence of fragments of limestone and volcanic rocks. A 1-foot bed of limestone, which in places consists entirely of algal remains, occurs near the base of the formation in the eastern part of the outcrop area	720-1,140
		Quartz latite	A holocrystalline equigranular fine-grained to aphanitic gray to brown rock, with small phenocrysts of quartz, feldspar, and biotite, and lithic fragments. Flow structures are present in the upper part	
Cienega Peak granite	Cretaceous	Johnny Bull sandstone	Interbedded light-colored fine-grained well-sorted well-cemented orthoquartzite, dark grayish-brown fine-grained well-cemented subgraywacke, and brown shale	1,047+
		Still Ridge formation	Silty and sandy limestone, sandstone, calcareous sandstone, and limestone pebble conglomerate. The limestone pebble conglomerate, which is prominent in the sequence, consists of black limestone pebbles which weather light gray, in a dark-gray to black limestone matrix which weathers brown. Interbedded volcanic rocks	575-650
		Carbonate Hill limestone	Medium-gray thin-bedded sandy calcarenite with prominent beds, 8-10 feet thick, consisting almost wholly of pelecypod shells. Pelecypods, gastropods, and ammonites are common	200+
		McGhee Peak formation	Alternating beds of conglomerate, shale, sandstone, and limestone. The conglomerate contains limestone fragments but no volcanic rock fragments	470-600
	Permian	Chiricahua limestone	Thick-bedded light-gray medium-grained limestone containing abundant irregularly shaped grayish-pink nodules of chert. Very fossiliferous	800+
		Scherrer formation	Thick-bedded well-cemented dusky-red siltstone	0-50(?)
		Colina limestone	Mostly dark-gray to black very fine-grained limestone with calcite segregations which are probably recrystallized fossils. No chert. Large gastropods and scaphopods are characteristic. A few siltstone beds	500+
		Earp formation	The lower part consists of alternating beds of limestone, siltstone, and sandstone, with some shale. The upper part is dominantly limestone, with some beds of dolomite near the top. Fusulinids are abundant	831+
	Pennsylvanian	*Horquilla limestone*	Thin- and thick-bedded dark- and light-gray limestone with abundant fusulinids, except in the lowermost part. Pinkish-gray and black chert are common.	1,350-1,500
	Mississippian	Paradise formation	Alternating beds of black, gray, and brown limestone, oolitic limestone and calcarenite, calcareous sandstone, and conglomerate. Fossils are abundant	217
		Escabrosa limestone	Lower member mostly thin-bedded to medium-bedded light-gray limestone, with some thin shale interbeds and some beds of dark-gray limestone, about 100 feet thick. Middle member consists of dark-gray to black fine-grained limestone, with abundant black chert in nodules and layers. Crinoidal remains are abundant. This member about 250 feet thick. Upper member is light-gray crinoidal limestone, 113 feet thick, with gray and pinkish chert	460±
	Devonian	Percha shale	Black fissile shale near the base overlain by interbedded calcareous gray shale and thin-bedded limestone. Limestone content increases upward. In much of the area the calcareous shales and limestones are metamorphosed to light-gray siliceous hornfels	235±
	Ordovician	Montoya limestone	Medium- to dark-gray dolomite, with about 30 feet of alternating dolomite and black chert in beds 2-6 in. thick	0-100±
	Cambrian	El Paso limestone	Lower part consists of medium-bedded light-gray dolomite, with pink and black chert. The upper part consists of about 130 feet of very thin-bedded gray limestone and thin irregular interbeds of black chert, a fraction of an inch thick. The laminated beds have a wavy or crinkly appearance	550±
		Bolsa quartzite	Arkosic and orthoquartzitic sandstone and conglomerate containing some glauconite and thin shale beds in the middle part of the unit	60-400
Granite Gap granite	Precambrian			

TABLE 2. CORRELATION CHART



SYSTEM	SERIES	STAGE		FORMATION
Quaternary				Animas Valley basalt
				Alluvium and lacustrine deposits
Tertiary				Volcanic sequence
Cretaceous	Upper Cretaceous	Danian		
		Maestrichtian		
		Senonian		▨
		Turonian		▨
		Cenomanian		▨
	Lower Cretaceous	Albian	Bisbee group	Johnny Bull sandstone
				Still Ridge formation
		Aptian		Carbonate Hill limestone
				McGhee Peak conglomerate
		Neocomian		▨
Jurassic				▨
Triassic				▨
Permian	Ochoan			▨
	Guadalupian		Naco group	Chiricahua limestone
	Leonardian			Scherrer formation
				Colina limestone
				Earp formation
	Wolfcampian			Horquilla limestone
Pennsylvanian	Virgilian			
	Missourian			
	Desmoinesian			
	Derryan			
	Morrowan			▨
Mississippian	Chesterian			Paradise formation
	Meramecian			Escabrosa limestone
	Osagian			
	Kinderhookian			Percha shale
Devonian	Upper			▨
	Middle			▨
	Lower			▨
Silurian				▨
Ordovician	Cincinnatian			Montoya limestone
	Champlainian			▨
	Canadian			El Paso limestone
Cambrian	Croixian			Bolsa quartzite
	Albertan			▨
	Waucobian			▨

The age of the Granite Gap granite is presumed to be Precambrian because of its position beneath Cambrian strata, and because of its similarity to granite elsewhere in the surrounding region described as Precambrian (Darton, 1928-a, p. 3; Paige, 1916, p. 3). As the granite that crops out within the Granite Gap fault block is not in sedimentary contact with lower Paleozoic formations, its age and correlation might be questioned. Lithologically and texturally, however, it is identical with that which underlies the Bolsa, and both differ lithologically and texturally from the Cienega Peak granite, the age of which is early Cretaceous or younger. This does not imply that all Precambrian granite was the result of a single period of intrusive activity, for the field relations elsewhere in southwestern New Mexico indicate that a more complicated history is highly probable (Gillerman, 1953, p. 265).

CIENEGA PEAK GRANITE

Cienega Peak, called Pico Gavilon by Darton (1928-a, p. 349), a prominent landmark on the western side of the Peloncillo Mountains just north of Granite Gap, is formed by an almost vertical sill or laccolith of fine-grained granite which intrudes late Permian and early Cretaceous sedimentary rocks, and the Precambrian Granite Gap granite (pl. 3). This fine-grained granite is herein called the Cienega Peak granite. Darton (1928-a, p. 349) described it as porphyry, and on the New Mexico state map (Darton, 1928-b) it is mapped as porphyry. Gilbert (1875, p. 513), however, correctly referred to it as granite. The rock is markedly different from the Granite Gap granite in topographic expression, texture, mineralogical composition, and degree of alteration.

Topographically the Cienega Peak granite is resistant to erosion. Cienega Peak, which rises to 5,742 feet and is the second highest point in the area mapped, is high and rugged, with steep slopes. The area underlain by the granite northwest, west, and south of the peak is similarly rugged and high standing. Jointing is not so prominent as in the Granite Gap granite, and erosion has resulted in sharp angular rather than rounded land forms. Angular blocks rather than rounded boulders are the typical weathering products. The contrast between the topographic expression of the two granites is well seen south of the peak, where the two are in contact.

The Cienega Peak granite is a holocrystalline equigranular fine-grained light-pink rock with a hypidiomorphic texture. It is even grained and looks like a coarse-grained aplite. Microscopic examination shows that it consists of about 20-30 percent anhedral quartz, 60-70 percent subhedral and anhedral orthoclase, and 10 percent or less anhedral oligoclase (An_n). Less than 1 percent biotite, altering to magnetite, is present. The lack of any appreciable amount of dark minerals justifies calling this rock an alaskite. No apatite or sphene was detected, but a few grains of primary magnetite are present. The rock is only slightly altered. The feldspar shows flecks of kaolinite in thinsection, but megascopically appears glassy and unaltered. The biotite is altered to magnetite and partly sericitized. Epidote is sparingly present in a few localities.

The granite intrudes Chiricahua limestone of Permian age and the basal conglomerate and sandstone of the McGhee Peak formation of Lower Cretaceous age. It is probably intrusive into the Granite Gap granite in the area south of the Preacher Mountain fault, but the actual contact was not observed. No fine-grained border phase of the granite was seen, although the intruded formations are altered and metamorphosed. The intrusion is a sill or laccolith, which lenses out north of Cienega Peak. South of the peak it is offset to the west by the Preacher Mountain fault, and south of the fault its southern extremity is covered by the Quaternary gravel of the San Simon Valley. The granite probably was intruded before the strata were tilted to the high angles that exist today, but some of the tilting may have accompanied the intrusion. The strata are steeper both immediately above and below the intrusion than they are at a distance from it.

The age of the granite is presumed to be Cretaceous but may be Tertiary. It is intruded by a quartz monzonite porphyry dike of probable late Cretaceous or early Tertiary age and intrudes Lower Cretaceous formations. No granite of comparable age is known from the surrounding region of New Mexico or Arizona, although rhyolitic intrusions of possible early Cretaceous age are present in the Lordsburg area (Lasky, 1938, p. 14) and in the Burro Mountains.

QUARTZ MONZONITE PORPHYRY

Numerous sills, dikes, and irregular masses of quartz monzonite porphyry intrude the granite and the Paleozoic and Cretaceous sedimentary rocks in the central part of the Peloncillo Mountains. The exposures form prominent cliffs and ledges that weather light brown. They are readily discernible because of the distinctive color and weathering.

The largest and most prominent of the intrusions is the sill exposed at the Silver Hill mine. At the mine it is 300 feet thick and dips at an angle slightly greater than that of the Permian limestone it intrudes. It thus cuts slightly across the strata; this slight discordance is characteristic of many of the sills in the area. The strata are believed merely to have been dilated, with perhaps some slippage along the plane of intrusion but no assimilation or stoping of the beds. This sill can be traced for almost a mile northward, to beyond Frye Peak and for about 2 miles southward. It thins toward the south. Frye Peak is formed by a horizontal dikelike mass, probably a feeder to the sill, which lies across the upturned McGhee Peak conglomerate.

Another prominent sill caps the western slope of an isolated hill in sec. 24, T. 25 S., R. 21 W., just north of Highway 80. A thin, but persistent sill, exposed in the low hills west of this peak, crops out on the west side of Blue Mountain, and crosses the main ridge of the Peloncillo range about 1,000 feet north of the tip of Blue Mountain. It can be traced northward from the ridge crest along the upper slopes of the eastern side of the ridge for slightly more than a mile. A large irregular dike or sill extends southwestward more than 2 miles from a point about half a mile south of the Silver Hill mine. This intrusive mass crosscuts the sedimentary rocks in places, but elsewhere it is essentially concordant. The outcrop is more than 1,000 feet wide at its northern extremity, but it narrows to the southwest.

A dike extends partly along the fault marking the northern boundary of the Granite Gap fault block, and then cuts southwest through the Cienega Peak granite, before being covered by the gravel of the San Simon Valley.

Other dikes, sills, and irregular intrusive masses of the quartz monzonite porphyry occur elsewhere in the central part of the mapped area. They are confined to the outcrop areas of the granites and sedimentary rocks.

Typically the quartz monzonite porphyry is a holocrystalline porphyritic light-pink to gray rock, with abundant phenocrysts of quartz and feldspar set in an aphanitic groundmass. The phenocrysts comprise 50-60 percent of the rock. Near the borders of some of the intrusive bodies the rock is finer grained and contains fewer phenocrysts, and would more properly be classified as a quartz latite porphyry.

Crystals of quartz comprise 30-35 percent of the total phenocrysts. They are clear euhedral equidimensional crystals which have dihexagonal bipyramidal crystal faces well developed, essentially to the exclusion of the prism faces. Single crystals up to 1 cm in diameter were observed, but most are smaller. Clusters of crystals are common and falsely appear as single large crystals. Most of the quartz crystals are corroded, embayed, and surrounded by thin reaction zones.

Feldspar phenocrysts comprise the remaining 65-70 percent of the phenocrysts except for a few biotite flakes. Glassy and dull-pink euhedral orthoclase and dull-white euhedral andesine (An_{33}) crystals are present. The orthoclase crystals are up to 1 cm long and constitute about 70 percent of the total feldspar crystals. The andesine crystals are smaller. Microscopic examination shows that many of the orthoclase crystals are only slightly altered, but others are highly kaolinized. The andesine is all highly kaolinized except for a few relatively unaltered crystals. Some zoned plagioclase crystals are present.

The biotite occurs as small scattered hexagonal flakes and comprises about 1 percent of the rock mass. Small grains and euhedral masses of magnetite are present, and euhedral apatite crystals are present, though rare. Honey-yellow sphene crystals are common. Some attain a diameter of 3 mm and are apparent to the unaided eye.

The matrix consists of microgranular quartz and intensely kaolinized feldspar.

In addition to the abundant kaolinite, chlorite and epidote can be observed in most thinsections and are a result of the alteration of biotite and calcic plagioclase. Some magnetite also results from the alteration of the biotite. The epidote is abundant locally and in many areas can be detected in hand specimens in the field.

The quartz monzonite porphyry has intruded the Lower Cretaceous sedimentary rocks and also the Cienega Peak granite. It is not found in contact with any sedimentary rock younger than the Still Ridge formation, and it is not in contact with any of the intrusive rocks of the area except at one locality south of the Silver Hill mine, in sec. 10, T. 25 S., R. 21 W., where the quartz monzonite porphyry traverses and probably has intruded a body of andesite. The age of this andesite is unknown but is believed to be either Cretaceous or very early Tertiary. In the Peloncillo Mountains, therefore, the quartz monzonite porphyry can be dated only as early Cretaceous or younger.

Elsewhere in southwestern New Mexico and southeastern Arizona, stocks, dikes, and other intrusive bodies of quartz monzonite porphyry are composed of rock identical in appearance and in mineralogical composition with the rock in the Peloncillo Mountains. These bodies intrude Upper Cretaceous rocks and are overlain by middle Tertiary volcanic rocks. The major ore deposits of southwestern New Mexico are associated with them, and they have been dated as late Cretaceous or early Tertiary in the Lordsburg area (Lasky, 1938, p. 14), Little Hatchet Mountains (Lasky, 1947, p. 28), Silver City region (Paige, 1916, p. 7; Hernon et al., 1953, p. 117), Black Hawk district (Gillerman, 1956, p. 291), and elsewhere. They are believed to represent a phase of the Laramide orogeny. The quartz monzonite porphyry in the Peloncillo Mountains is considered part of this regional suite of rocks.

LATITE PORPHYRY

Numerous dikes and sills of a distinctive latite porphyry traverse the Peloncillo Mountains. On the west side of the range, between Cowboy Pass and Granite Gap, the same rock forms a large intrusive body which is separated into two areally distinct parts by a mass of rhyolite. The outcrop pattern of this intrusion suggests a plug. The writer believes, however, that the contact relations with the Paradise formation on the east indicate that it is a thick sill.

The most prominent of the latite porphyry intrusions is a dike, or more correctly a series of dikes, occupying a fracture zone which extends northwestward for at least 6 miles from near the Carbonate Hill mine to beyond the northern limits of the mapped area. The individual dikes within the zone range from 5 to 60 feet wide, and from 1 to 3 dikes may be present through a zone 200 feet wide. The dikes coalesce and split repeatedly along the strike. They are more resistant to erosion than are the volcanic rocks which they intrude and stand up as wall-like masses above the surrounding rocks.

This resistance to erosion, combined with a pronounced color difference, results in a prominent and noticeable topographic expression, particularly along the eastern front of the range south of State Highway 14, and is in marked contrast to that of other dikes and sills of the latite porphyry. Elsewhere the latite porphyry intrudes sedimentary rocks or granite and is less resistant than its host rocks; where the intrusions cross the ridge crests, benches and low saddles are the typical topographic expressions.

Numerous smaller and less persistent dikes and sills are present, particularly in the area between Cowboy Pass and the southern edge of the main mass of andesitic volcanic rocks. They range from a few feet thick to sills more than 50 feet thick, and some can be traced for over a mile. Many occur along faults.

The latite porphyry is a holocrystalline porphyritic-aphanitic rock consisting, where fresh and unaltered, of large, conspicuous euhedral crystals of pink feldspar and bright glistening flakes of dark-brown biotite set in a grayish-pink aphanitic groundmass. The rock weathers a soft light pinkish gray, with white and light-gray spots and numerous voids. In some areas limonitic stains impart a yellow-brown color to the rock. Phenocrysts typically comprise 20-25 percent of the rock but are smaller and less abundant in the border zones of the thicker dikes and sills and in the narrower intrusive bodies. Feldspar crystals constitute at least 90 percent of the total phenocrysts and range up to 20 mm in diameter, although most of them are less than 10 mm in diameter. The biotite flakes are 1-3 mm in diameter.

The appearance of the rock is distinctive, and even where greatly altered, it can be recognized readily.

Microscopic examination shows that the large feldspar crystals are predominantly labradorite (An_{50}). Some of the crystals have overgrowths of orthoclase, and a few large orthoclase crystals are present. Most of the feldspar crystals are only slightly altered, but others have an altered core of kaolinite and calcite. This is observable megascopically, and it is the removal of this soft core that produces the voids in the weathered rock. There appears to be little distinction in the degree of alteration between the orthoclase and the labradorite.

The biotite is fresh and unaltered in most places, but locally is altered to chlorite and magnetite. Magnetite rims around the chloritized biotite crystals are extremely common in the intrusive mass south of Cowboy Pass. Megascopically the biotite in this area is dull brownish green, quite distinct from the glistening flakes elsewhere.

Primary magnetite is abundant as an accessory mineral; apatite crystals occur in the matrix and also are enclosed in the biotite crystals. A few corroded euhedral quartz crystals are present.

The matrix is a microcrystalline mixture of feldspar and magnetite. The fineness of grain precludes the determination of the type of feldspar present, but orthoclase is believed to be a prominent constituent.

The large intrusive mass south of Granite Gap differs from the remaining latite porphyry chiefly in the color of the rock and the dull and altered appearance of the biotite. Topographically it forms rounded hills, the slopes of which are covered by large rounded boulders. The writer interprets this as a sill, resting with possible slight discordance upon the Paradise and Horquilla formations. The upper contact is buried by Quaternary gravel of the San Simon Valley, but a minimum thickness of 1,200 feet is estimated.

The latite porphyry intrudes the other major intrusive rock types, the sedimentary rocks, the andesitic volcanic sequence, and the Quarry Peak rhyolite complex. South of Cowboy Pass, in the area underlain by the Weatherby Canyon ignimbrite, it was not seen. Nor was it observed in contact with the Steins Mountain quartz latite porphyry. Its relationship with these rocks is unknown. It is undoubtedly the latest of the intrusive rocks in the area, and is probably late Tertiary in age.

MINOR INTRUSIVE ROCKS

Small dikes and sills of other rocks are present in the Peloncillo Mountains. Some of these may be related genetically to the Cienega Peak granite, quartz monzonite porphyry, or latite porphyry, or to some of the extrusive rocks. Others may have no genetic relationship to the major igneous rock types. The areal extent of all these intrusions is small, and many are not shown on the map. Quartz lathe porphyry, monzonite porphyry, latite, and rhyolite are the rock types represented.

A dike of dark-red quartz lathe porphyry occurs on the north side of Cowboy Pass, and a small pluglike mass of the same rock is present about half a mile north. Small phenocrysts, rarely over 2 mm in diameter, of quartz and feldspar constitute 40-50 percent of the rock. A few biotite flakes are present. Microscopic studies indicate that the dense aphanitic matrix was once glassy. Flowage around the phenocrysts and radiating spherulitic structures are common. The blue-gray quartz crystals which constitute about 40 percent of the phenocrysts were once euhedral, but now many of them are rounded and embayed, owing to resorption. Two types of feldspar are present. Clear, glassy crystals of subhedral sanidine are essentially unaltered and constitute 60-65 percent of the feldspar. The remaining feldspar consists of somewhat larger dull-white crystals of albite (An_6), slightly kaolinized. Brown biotite occurs in thin books up to 5 mm in diameter and is slightly chloritized. Lithic fragments are common. The rock is intrusive into rhyolite and possibly into the latite porphyry. It is intruded by a dike which resembles the trachyte of the Weatherby Canyon ignimbrite.

A very fine-grained monzonite porphyry dike, trending east, crops out 1 mile northeast of the Carbonate Hill mine. A similar dike crops out half a mile northwest, in the vicinity of the North Star mines. These may be faulted segments of the same dike. The yellowish-gray holocrystalline porphyritic-aphanitic rock contains feldspar and biotite phenotrysts in a microcrystalline matrix. The phenocrysts comprise about 50 percent of the rock mass and consist of about 35-40 percent orthoclase, 60 percent andesine (An_{40}), and 2-5 percent biotite. Apatite is present, though rare. The feldspars are kaolinized, and the biotite is altered to chlorite, muscovite, and magnetite. Epidote is abundant in the dike near the North Star mines and replaces the andesine and the biotite. The groundmass is an indistinguishable mass of altered feldspar. These dikes intrude the Bobcat Hill conglomerate and the andesitic volcanic rocks. They are cut by the latite porphyry.

Light-colored rhyolite dikes and pluglike masses intrude the andesite volcanic rocks in the vicinity of Steins. The rhyolite is a light-gray to white holocrystalline to hypocrystalline aphanitic rock, which contains a few small orthoclase and quartz phenocrysts. Small limonitic pyrite cubes are common. Microscopic examination shows an interlocking texture between the quartz and the feldspar of the matrix, typical of many rhyolites. Some of the dikes are sheeted parallel to the walls of the dike, and the small circular pluglike mass north of Steins exhibits inward dipping planar structures on all sides. This plug may have been a vent and the source of some of the rhyolite extrusive rocks constituting the Quarry Peak rhyolite complex.

Rhyolite dikes similar in appearance to those mentioned above intrude the rocks elsewhere in the Peloncillo Mountains. No attempt was made to correlate these dikes. One, in sec. 31, T. 26 S., R. 20 W., intrudes the Weatherby Canyon ignimbrite and probably represents a very late period of intrusive activity. It differs slightly from the other dikes in the higher percentage of phenocrysts.

LAYERED ROCKS

BOLSA QUARTZITE

The Bolsa quartzite was first described by Ransome (1904, p. 20) from exposures near Bisbee, Arizona. In the Peloncillo Mountains the Bolsa crops out in an almost continuous northwest trending band in the broad valley west of the main ridge of the range, north of Highway 80. South of Highway 80 it occurs in the isolated hills east of Granite Gap and Cowboy Pass. North and immediately south of Highway 80 it forms the lower slopes of the ridges. In these areas a slight steepening of slope distinguishes the lower part of the Bolsa quartzite from the underlying granite. The uppermost part is cliff-forming and forms small but distinct topographic prominences on the minor ridges. A low saddle or bench marks the top of the formation. Elsewhere the Bolsa quartzite extends to the crest of the low hills, with no distinctive topographic expression.

North of Highway 80 a threefold division of the Bolsa quartzite is characteristic. The lower part of the formation consists of alternating white and green medium-bedded fine-grained well-cemented orthoquartzite. Near the base of the sequence irregular thin beds and lenses contain particles of coarse sand, granule and pebble size, composed of quartz, feldspar, and quartzite, but no continuous conglomerate bed is present. Crossbedding is common in this lower part of the formation and is shown particularly well on weathered surfaces.

The central part of the formation consists mostly of dominantly fine-grained dark-green arkosic and glauconitic sandstone. Lenses and irregular beds of coarse sand and granule-size fragments occur in some places. Soft, easily erodible, thin-bedded strata at the base of this part of the formation grade upward into thin alternating beds of sandstone and gray to black sandy unfossiliferous shale. At the top, 3 feet of black shale is present. The black shale splits readily along slickenside surfaces, which are coated with graphite and small micaceous flakes. The entire central part of the formation is topographically distinct from the upper and lower parts; it forms a bench between these more resistant members. Its color also is distinctive, the darker sandstone and shale standing in contrast to the lighter beds above and below.

The upper part of the formation consists of thick-bedded fine- to medium-grained well-sorted and well-cemented white to light-gray orthoquartzite. Well-rounded quartz grains constitute about 98 percent of the orthoquartzite, the remainder being feldspar and granite fragments. Quartz overgrowths are common on the quartz grains. Cross-bedding is prominent locally. Toward the top of the sequence the sandstone becomes thinner bedded and finer grained, and the top bed is a very white very fine-grained sandstone or siltstone.

Immediately south of Highway 80, in the area east of Granite Gap, this threefold division of the Bolsa quartzite is not apparent. Here the formation consists of alternating dark-greenish sandstone and conglomerate, with abundant granite and feldspar pebbles, up to 50 mm in diameter, in lenses and discrete beds. The fragments are subangular and show no variation either in size or abundance within the 60-70 feet of strata which comprises the formation at this locality. About 2 miles southeast the Bolsa quartzite is exposed on an isolated hill east of Cowboy Pass. At this locality well-rounded pebbles and boulders of white quartzite up to 300 mm in diameter occur at the base of the formation. This conglomerate bed is overlain by white coarse-grained well-sorted thick-bedded orthoquartzite.

Where measured north of Highway 80 (MS 1), the Bolsa quartzite is 396 feet thick. Immediately south of the highway only 61 feet of strata is present. This variation in thickness reflects the uneven surface upon which the Bolsa quartzite was deposited, the formation thinning where it was deposited over hills on the pre-Bolsa terrain. Nowhere, however, was the Bolsa quartzite absent between the granite and the overlying sedimentary rocks.

The abundance of subangular fragments of granite throughout the sandstone sequence in the area just south of Highway 80 suggests that isolated knobs of granite may have stood as islands above the sea in which the Bolsa was deposited. The thinness of the Bolsa in this locality may be the result of deposition upon the flanks of one of these knobs. Similar knobs of Precambrian granite, on the flanks of which angular fragments of granite are incorporated in the basal Cambrian sandstone, are known from the Central mineral region of Texas and the Ozark region of Missouri.

The average thickness of the Bolsa quartzite in the Peloncillo Mountains is about 400 feet. This compares with thicknesses of 460-600 feet in the Chiricahua Mountains (Sabins, 1955, p. 20), 430 feet at Bisbee (Ransome, 1904, p. 29), and 720 feet in the Picacha de Calera Hills, 25 miles west of Tucson (Stoyanow, 1936, p. 466). Kelley and Silver (1952, p. 38) state that the Bliss sandstone (the homotaxial equivalent of the Bolsa quartzite) thickens southward from a thin edge, in the northern Fra Cristobal and southern Oscura Mountains of Central New Mexico, to about 400 feet, in the southwestern part of New Mexico.

The Bolsa quartzite rests unconformably upon the underlying granite and is overlain conformably by the El Paso limestone. The upper contact, where observed, is gradational, with an alternation of sandstone and sandy dolomite beds. At the top of the measured section, however, a covered interval is present between exposures of the two formations. Elsewhere in Arizona and New Mexico, the contact between the Bolsa quartzite and the Abrigo limestone, the Bolsa and the El Paso limestone, and the Bliss sandstone and El Paso limestone, has been regarded as conformable (Ransome, 1904, p. 29; Richardson, 1909, p. 24; Darton, 1928-a, p. 10; Sabins, 1955, p. 26) and as exhibiting a slight unconformity (Kelley and Silver, 1952, p. 37).

The beds herein called Bolsa quartzite are similar in their composition and stratigraphic position to the Bolsa quartzite of the type locality near Bisbee (Ransome, 1904, p. 20). They were undoubtedly once part of a single continuous body of rock which included the stratigraphic unit mapped as Bolsa quartzite by Sabins (1955, p. 26) in the Chiricahua Mountains, just across the San Simon Valley to the west. They are homotaxially equivalent to the Bliss sandstone of New Mexico and west Texas (Richardson, 1904, p. 34; Paige, 1916, p. 3; Spencer and Paige, 1935, p. 12-14; Kelley and Silver, 1952, p. 33-39) but are different in appearance and composition from exposures of the Bliss examined by the writer in the Silver City area, which are the closest geographically (Paige, 1916, p. 3-4; Spencer and Paige, 1935, p. 12-14).

As no fossils were found in the Bolsa quartzite in the Peloncillo Mountains, the age is unknown. C. L. Balk (1956, written communication from Eugene Callaghan, March 16, 1956) has stated that this basal sandstone of the Cambrian sequence of Arizona is a transgressive formation which rises in the section to the north and east. At Bisbee the age of the Bolsa quartzite is considered to be Middle Cambrian (Ran-some, 1904, p. 30; Stoyanow, 1936, p. 480). In the Dos Cabezas Mountains, across the San Simon Valley from the Peloncillo Mountains, Sabins collected trilobites from near the top of the formation which are characteristic of the *Aphelaspis* zone of the upper Dresbachian Stage of the Upper Cambrian Series. East of the Peloncillo Mountains Flower (1953-a, p. 2,055; 1953-b, p. 106) found fossils in the Bliss sandstone in the Rio Grande Valley area that indicate a late Cambrian (Franconian) and an early Ordovician (Gasconadian) age.

The writer believes that in the Peloncillo Mountains the Bolsa quartzite contains beds of early Upper Cambrian (Dresbachian) and Middle Cambrian age, and that the Bolsa quartzite-Bliss sandstone lithostratigraphic unit is older (Middle Cambrian) to the west, in south-central Arizona, and becomes progressively younger to the east and north, including beds of early Ordovician age in central New Mexico and west Texas. Only when diagnostic fossils are found, can a more precise age be determined, and then only for the locality and for the beds that yield the fossils.

EL PASO LIMESTONE

The El Paso limestone was first described by Richardson (1904, p. 29) from exposures in the Franklin Mountains, near El Paso, Texas. Kelley and Silver (1952, p. 40) raised the El Paso to group rank, dividing it into two formations, the Sierrite limestone and the Bat Cave formation. They stated that this twofold division can be recognized in many areas in south-central and southwest New Mexico. Both formations have their type localities in the Caballo Mountains of central New Mexico.

In the Peloncillo Mountains no attempt was made to map these two units separately. A part of the formation resembles the Sierrite limestone, but beds lithologically like the Bat Cave are not so distinctive; therefore, no division was made. With the exception of the beds questionably referred to the Montoya formation, the entire sequence of carbonate rocks lying between the dominantly arenaceous Bolsa quartzite and the dominantly argillaceous Percha shale is referred to as the El Paso limestone.

The outcroppings of El Paso limestone closely follow those of the Bolsa quartzite, but in addition they occur west of a large fault in the NE¼ sec. 24, T. 25 S., R. 21 W. The outcrops typically form low, rounded hills, but the middle cherty part of the formation, which is more resistant, forms rocky crests on the ridges.

In the area northwest of Preacher Mountain the formation is divisible into a lower cherty dolomite member, a middle cherty limestone member, and an upper noncherty dolomite member. The lower member is mostly medium-bedded medium- to fine-grained gray and pinkish-gray dolomite, which is slightly arenaceous toward the base. Many of the beds weather brown, with a sandy surface consisting of dolomite rhombs and some quartz grains. Lenses and nodules of black and pink chert are present.

The middle member consists of about 130 feet of thin-bedded gray limestone and interbedded brown-weathering black chert. The limestone beds are 1-3 inches thick. The chert laminations are less than 1 inch thick and occur as thin discontinuous irregular beds or lenses. Weathering results in a raised reticulated pattern of brown chert on thin slabs of limestone. This was early recorded as distinctive of the El Paso limestone (Paige, 1916, p. 4; Darton, 1928-a, p. 10, 28), as well as of the Abrigo limestone (Ransome, 1904, p. 31). The brown chert markings were called fucoidal markings and fossil seaweed, but Kelley and Silver (1952, p. 43) believed them to be mere concretionary growths within the chert laminations. The irregular chert laminations, the crinkly or undulating bedding planes, and the color differentiation of the chert and limestone on the weathered surface give these beds a distinctive banded or laminated appearance, which is extremely helpful in recognizing the El Paso limestone in isolated outcrops. These are the beds which comprise the Sierrite limestone (Kelley and Silver, 1952, p. 43) and which characterize the Abrigo limestone (Ransome, 1904, p. 31). Detrital limestone that contains crinoid stems, gastropods, and endoceroid siphuncles is present in the upper part of this sequence in the Peloncillo Mountains. These fossils are silicified and stand out on the weathered surface.

The upper member consists of nearly 200 feet of thick-bedded fine-grained noncherty light-gray dolomite which closely resembles the dolomite of the lower member.

The measured thickness of the El Paso limestone about 1 mile northwest of Preacher Mountain is 553 feet (MS 2). This may be slightly excessive, as faulting may have caused some repetition of strata. No complete section was observed anywhere else in the Peloncillo Mountains. The thickness of the El Paso is not constant, and in some areas the upper part is absent. This is due largely to the period of erosion which was associated with the upwarping of much of southern New Mexico and Arizona late in the Silurian or early in the Devonian. It may be due in part, however, to the pre-Montoya post-Canadian period of erosion described by Jicha (1954, p. 8), which resulted in the removal of part of the upper El Paso in the Lake Valley region and perhaps elsewhere in New Mexico.

The El Paso limestone is probably conformable upon the Bolsa quartzite in the Peloncillo Mountains. It is overlain by the Montoya limestone and Percha shale, although nowhere in the area was the upper contact observed.

Fossils are rare; a few fragmentary endoceroid siphuncles and some gastropods were collected about half a mile north of the Ward tungsten mine from the detrital limestone near the top of the middle unit of the formation. Flower (letter from Eugene Callaghan, March 16, 1956) identified the fossils as lowermost Middle Canadian, with gastropods characteristic of his first endoceroid zone of the standard section of the El Paso limestone in central New Mexico. This zone is at the very base of the Bat Cave formation (Flower, 1953-b, p. 109) in central New Mexico.

The El Paso limestone in the Peloncillo Mountains is only in part homotaxially correlative and contemporaneous with the El Paso limestone of the Rio Grande Valley. The middle member is similar to the Sierrite limestone, but beds in its upper part contain fossils characteristic of the lowermost faunal zone in the Bat Cave formation. The upper member, although differing lithologically, is probably contemporaneous with the middle and upper part of the Bat Cave formation. The lower member does not resemble any part of the central New Mexico and west Texas section. It occurs below the beds of Sierrite lithology, which are at the base of the formation farther east.

To the west, in Arizona, the beds of Sierrite lithology have their counterpart in the Abrigo formation at its type locality near Bisbee, Arizona (Ransome, 1904, p. 30); they are homotaxially correlative with this formation. They are also similar to the middle part of the El Paso section measured by Sabins (1955, p. 31) at Apache Pass in the Chiricahua Mountains, Arizona. Endoceroid siphuncles and gastropods from these beds in the Chiricahua and Dos Cabezas Mountains are similar to the fossils of the Sierrite-like beds in the Peloncillo Mountains. The lower member in the Peloncillo Mountains corresponds closely to the lower part of the El Paso section in the Chiricahua Mountains, from which Sabins collected *Billingsella,* a fossil diagnostic of late Cambrian (Franconian) age.

The age of the El Paso limestone of the Peloncillo Mountains, based on the fossils collected and the correlation with the Chiricahua section, is late Cambrian and early Ordovician. It thus contains beds which are older than any heretofore included in the El Paso limestone in New Mexico, where this formation has previously been identified as only early Ordovician. In the Chiricahua Mountains, Arizona, the age of the El Paso is also considered late Cambrian and early Ordovician (Sabins, 1955, p. 29).

The full significance of the inclusion of Cambrian strata in the El Paso limestone in the Peloncillo and Chiricahua Mountains is understood when the regional correlation of the Cambrian and Ordovician strata of New Mexico and Arizona is attempted. An excellent analysis of this problem, with particular reference to the Abrigo-El Paso and Bliss-Bolsa problems, is given by Kelley and Silver (1952, p. 54-56). The writer concurs completely with their conclusions. The Abrigo and El Paso limestones are part of a broad carbonate blanket which includes other homotaxial Arizona formations, and which was once continuous across the area. This carbonate unit was deposited in a transgressing sea which spread eastward into New Mexico from the Sonoran embayment. Older parts were deposited in the west, and progressively younger ones toward the east. At Bisbee the whole unit is Cambrian in age, but at El Paso it is early Ordovician. Between, in the Peloncillo, Chiricahua, and possibly Big Hatchet Mountains, both Cambrian and early Ordovician beds are present.

Identical conditions account for the blanket of nonmarine material below the carbonate deposit. This unit represents a shifting lithotope during medial Cambrian, late Cambrian, and early Ordovician time, which resulted in a blanket of terrigenous sediments now included in the Bliss, Bolsa, Troy, Coronado, and other formations. The carbonate sediments were the offshore clear-water equivalents of the nonmarine sediments, deposited contemporaneously in a different lithotope. As the sea spread eastward, the carbonate lithotope successively displaced the sand and mud lithotope, but the relative vertical position of each remained unchanged. The Abrigo limestone is thus contemporaneous with the Bliss sandstone, but in composition and appearance it is similar to the El Paso limestone. A complete picture of the paleogeography of the Cambrian and Ordovician in southern New Mexico and Arizona involves all these formations. Cambrian history cannot be separated from Ordovician history. The presence of both late and medial Cambrian strata within the Bolsa quartzite, and of late Cambrian and early Ordovician strata within the El Paso limestone, in the Peloncillo Mountains reemphasizes some of these basic stratigraphic concepts.

MONTOYA LIMESTONE

The Montoya limestone was first described by Richardson (1909, p. 27) from exposures in the Franklin Mountains, near El Paso, Texas. Entwistle (1944, p. 16) distinguished three members in the Silver City region, and Kelley and Silver (1952, p. 56) raised the Montoya limestone to group rank. They divided the group into four formations, which in ascending order are the Cable Canyon sandstone, the Upham dolomite, the Aleman formation, and the Cutter formation. The latter three units correspond to Entwistle's divisions.

In the Peloncillo Mountains, dolomite and chert beds lying above undoubted El Paso limestone, and below the Percha shale, in secs. 22 and 24, T. 25 S., R. 21 W., are referred doubtfully to the Montoya limestone. No attempt is made to subdivide the formation, although the beds present most closely resemble the lower and middle members as recognized in the Silver City region.

The Montoya outcrop in sec. 24 is a medium-bedded dolomite that weathers dark gray. It is a distinctive formation in the field, and on aerial photographs it shows as a darker unit between the bounding formations. Part of the sequence consists of about 30-35 feet of alternating brown and black cherts and gray dolomite in beds 2-6 inches thick (pl. 5A). These striking beds closely resemble the middle member in the Silver City region and the Aleman formation of Kelley and Silver. No complete section of the Montoya limestone is exposed in the Peloncillo Mountains, and no section was measured. A thickness of about 100 feet is estimated.

In sec. 22 a single exposure of alternating chert and dolomite beds similar to the exposures in sec. 24 was observed in a small draw, but the unit could not be followed along the strike. It occurs above El Paso dolomite and below Percha shale. It probably represents a remnant of the Montoya limestone remaining after removal of most of the formation during a pre-Percha erosion interval. Removal by erosion prior to the deposition of the Percha shale also accounts for the absence of the formation elsewhere in the area.

The chert and dolomite beds herein described are identified as Montoya limestone because of composition, appearance, and stratigraphic position. They could, just as arbitrarily, be identified as Fusselman limestone. The alternating chert and dolomite beds, however, are more characteristic of the Montoya formation and tip the balance in favor of this formation. No fossils were collected from the formation in the Peloncillo Mountains. Throughout New Mexico and Texas the Montoya limestone contains strata of possible medial and of late Ordovician age. In the Silver City region the beds lying immediately above the Aleman chert beds carry a Richmond fauna.

PERCHA SHALE

Early workers in New Mexico, such as Gordon and Graton (1906-a, p. 590; 1906-b, p. 394; 1907, p. 91), Darton (1928-a, p. 15), Paige (1916, p. 5), used the term "Percha shale" for all beds believed to be of Devonian age. Later work by Stainbrook (1935, 1945), Stevenson (1941, 1945), Nelson (1940), and others resulted in the division of the Devonian rocks within New Mexico into numerous formations and members, and suggestions that perhaps the original Percha shale was in whole or in part Mississippian in age. Attempts at correlation and dating of the various units have been made by Laudon and Bowsher (1949, p. 11, 23, 59, 75), Kelley and Silver (1952, p. 71), Stevenson (1945, fig. 10), Stainbrook (1945, p. 779) and others, with no real agreement. Kelley and Silver (1952, p. 68-78) have given an excellent review of the history of Devonian formational names and attempts at correlation. They concluded that the Percha shale is a distinct lithologic and topographic unit within New Mexico; that it probably includes beds of Devonian and Mississippian age; and that the several stratigraphic units proposed are not litho-logically distinct and probably are only faunal zones. Consequently, they recommended that the term Percha shale be retained as a term applicable to the entire sequence.

Within the Peloncillo Mountains the predominantly shaly strata between the lower Paleozoic carbonate rock and the cliff-making thick-bedded Escabrosa limestone are referred to as the Percha shale. It is a distinct lithologic and topographic unit and corresponds closely to the strata in Grant and Sierra Counties upon which the name Percha was based. It is sharply separated lithologically from the underlying Montoya and El Paso limestone, although the contact was nowhere observed. The upper boundary is conformable with the Escabrosa, in the measured sections (MS 3 and MS 4), and there appears to be no break in sedimentation. The boundary between the two formations was placed at the lower limit of the crinoidal limestone, which corresponded to the upper limit of the dominantly shale sequence and also to the upper limit of the nodular limestone. Some shale occurs above the contact, but it is not abundant.

In the Peloncillo Mountains the Percha shale is easily recognized despite extensive metamorphism which has resulted in a distinct change in the lithologic and topographic aspects of the formation. It crops out below the cliff-forming Escabrosa limestone on the east side of the ridge extending northwest from Preacher Mountain, on the east side of the ridge extending northwest from the Crystal mine, and to the east and northeast of Blue Mountain. It also occurs along the east front of the ridge between Granite Gap and Cowboy Pass and on some isolated hills east of Cowboy Pass.

Where the formation is unmetamorphosed, between Cowboy Pass and Granite Gap and for a short distance northwest of Preacher Mountain, it forms a characteristic slope between the cliff-forming Escabrosa limestone and the rocky Montoya or El Paso dolomite. The slope is steep but is devoid of rock outcrops and is furrowed by gullies. It is distinctive and recognizable from a distance. Low saddles and benches are prominent where the formation crosses the ridges.

Where the formation is metamorphosed it is more resistant. It forms prominent rocky outcrops where it crosses the ridges and at places forms the crests of ridges.

No complete, unmetamorphosed sections of the Percha shale were found in the Peloncillo Mountains. Most of the formation is well exposed in a few outcrops in gullies northwest of Preacher Mountain. There the formation is easily divisible into five units in descending order as follows:

E. the uppermost unit, consisting of 40 feet of alternating thin-bedded green-weathering black silty shale and thin-bedded black limestone which comprises 30-35 percent of the lower part of the unit and increases in amount upward;

D. a partly covered interval, probably consisting of alternating soft easily weathered greenish-gray shale and 2- to 4-inch beds of black nodular limestone, 72 feet thick;

C. greenish-black thin-bedded shale with alternating 1- to 2-inch beds of slightly calcareous nodular black limestone, 45 feet thick;

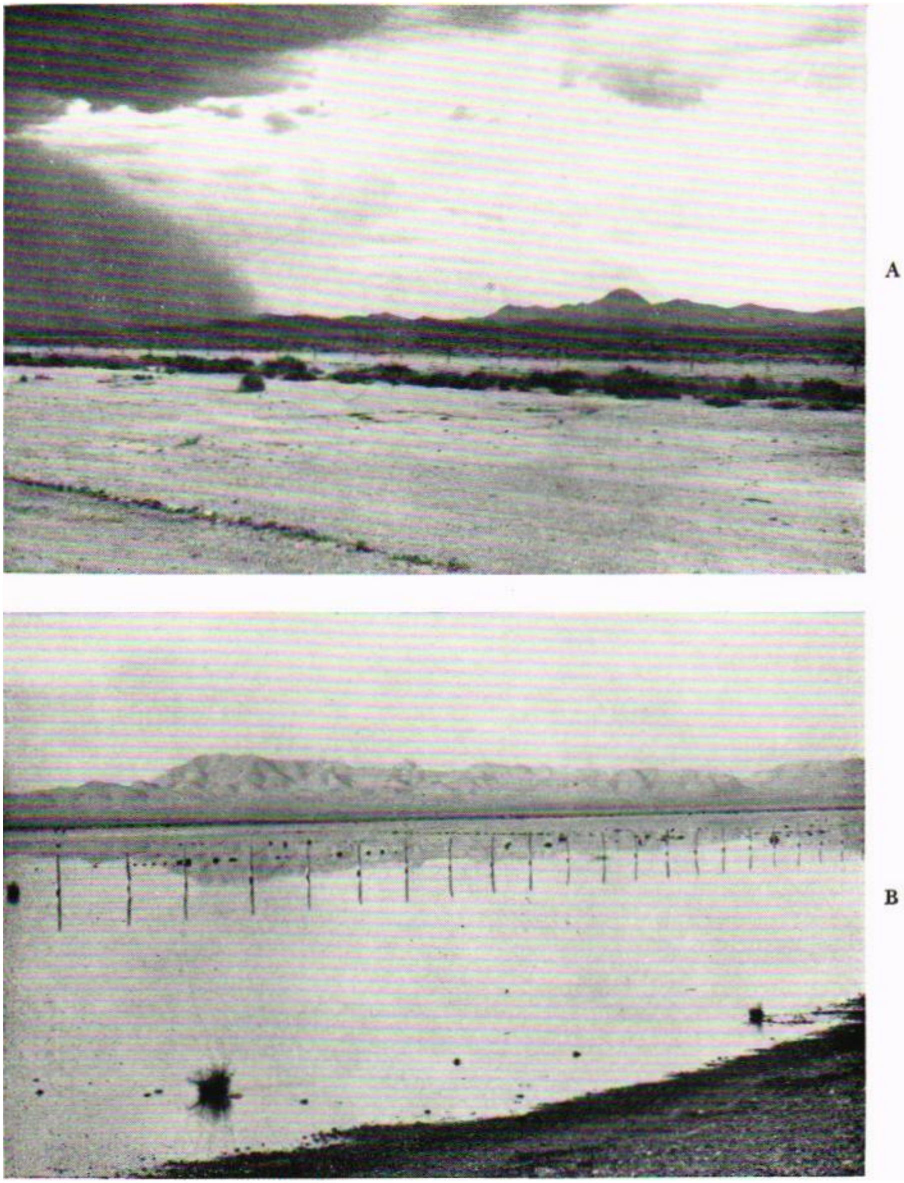


Plate 2

SOUTH ALKALI FLAT

A. View of area when dry; facing southeast.

B. View of same area after a few heavy rains; facing southwest. Peloncillo Range in the background, with Blue Mountain, the high point at the south (left) end of the range. Granite Gap at the extreme left. Both pictures taken from about the same spot on Highway 80, a few miles east of Road Forks.

Plate 3

PALEOZOIC STRATA AND THE CIENEGA PEAK LACCOLITH

View westward from the crest of the main ridge of the Peloncillo Mountains, north of Blue Mountain. The Wood Canyon fault extends down the valley. The dark lower part of the spurs is underlain by Precambrian Granite Gap granite and the overlying Bolsa quartzite. Above this is the El Paso limestone, which forms the crests of the ridge in the central part of the picture. The gullied and furrowed slopes on the left (south) are unmetamorphosed Percha shale, with the dark black member of the Escabrosa limestone forming the ridge crests above the shale slopes. On the three spurs at the extreme right, the dark band crossing the spurs is the black member of the Escabrosa. Overlying this is the upper gray member, the Paradise formation (forming the saddle), and the Horquilla limestone (forming the second crest). The narrow, indistinct dark band below the black member of the Escabrosa on these spurs is metamorphosed Percha shale. The lower part of the spurs is El Paso. A crossfault extends down the side valley to the left (south) of the third major spur from the right edge of the picture. A fault and another large valley lie between the ridge pictured and Cienega Peak in the background. The San Simon Valley and the Chiricahua Mountains are in the far background.

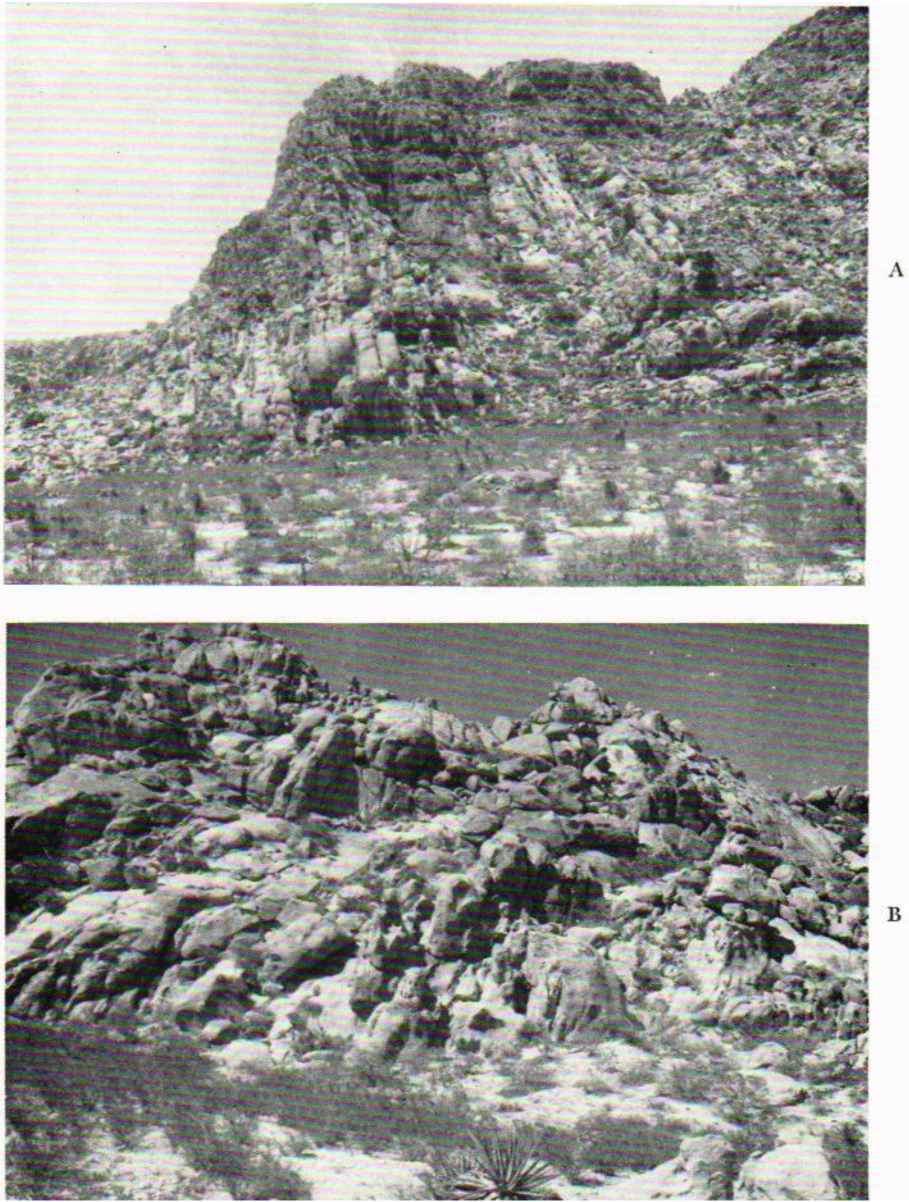


Plate 4

GRANITE GAP GRANITE

Characteristic exposures within the Granite Gap fault block.

A. View north from Highway 80 at Granite Gap, showing the parallel jointing.
R. View east from a point about I mile west-southwest of Preacher Mountain windmill, showing the rounded monolithic blocks produced by weathering along the joints.

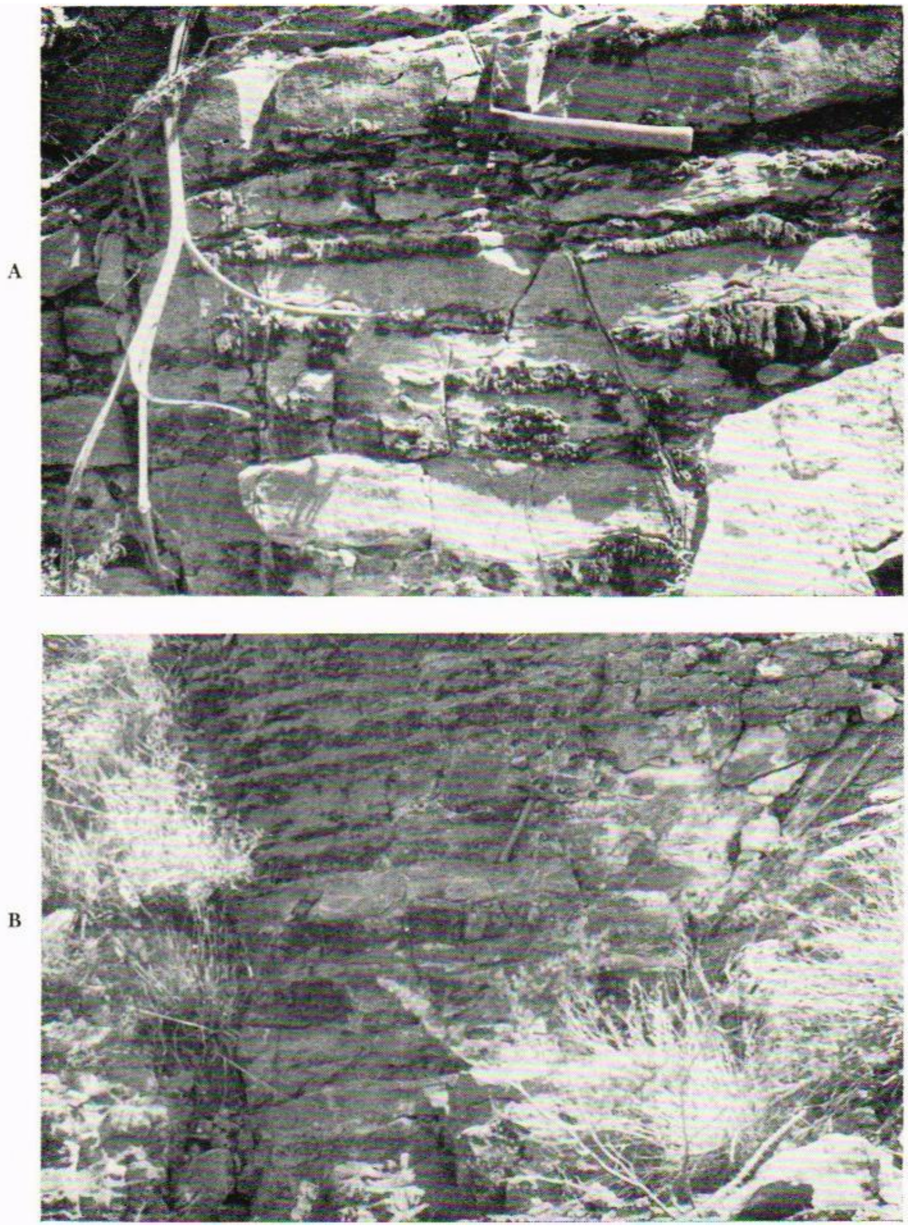


Plate 5

LIMESTONE BANDING

A. Rhythmic banking of limestone and black chert of the Montoya formation exposed in a small gully 2.000 feet west-northwest of the shaft of the Crystal mine.

B. Rhythmic banking of gray limestone and black chert characteristic of the black member of the Escabrosa limestone.

Plate 6

FOSSILIFEROUS LIMESTONE

A. Shell beds of the Carbonate Hill limestone near the Carbonate Hill mine. Most of the fossils are pelecypods.

B. Algal limestone, which forms a bed 1 foot thick in the lower part of the Bobcat Hill conglomerate. The exposure is about 3,000 feet west of Bobcat Hill.

Plate 7

CONGLOMERATE

A. An exposure of the upper part of the Bobcat Hill conglomerate near the North Star mines, showing the lensing character of the deposition of the sandstone and conglomeratic layers. The rock fragments in the conglomerate are almost all andesite, although the light-colored fragments to the left of the compass are limestone. The sandstone and conglomerate are grayish red purple.

B. Fragments of metamorphic rock included in the conglomerate that is interbedded with the quartz latite, about half a mile north of the Carbonate Hill mine and I mile west of Bobcat Hill.

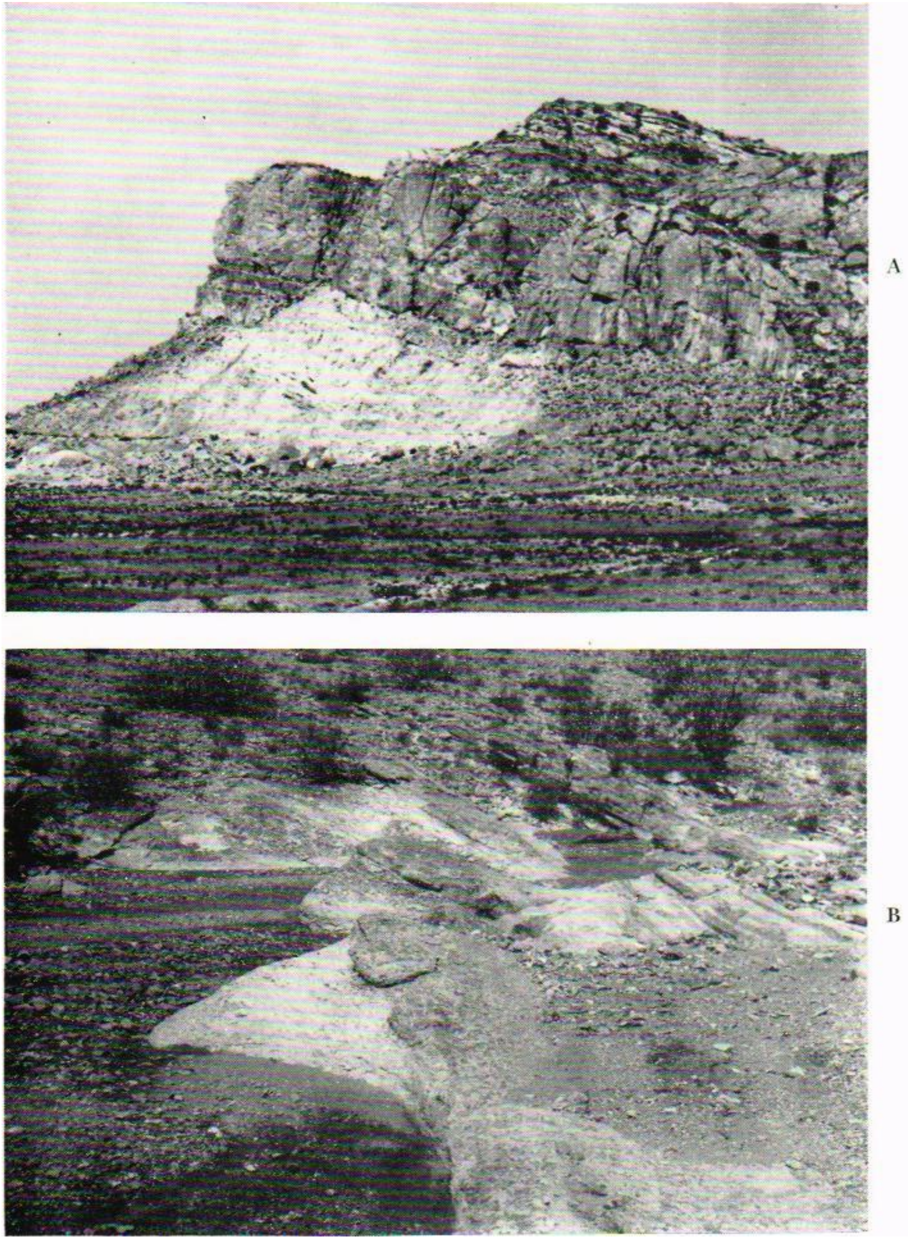


Plate 8

QUARRY PEAK RHYOLITE

A. Quarry Peak rhyolite complex on Quarry Peak. View is northward from State Highway 14. The low hills in the foreground are andesite.
B. Well-bedded impure volcanic arkose sandstone and conglomerate of the Quarry Peak rhyolite complex exposed in a small stream bed about half a mile north of Steins. The excellent bedding and sorting indicate deposition in an aqueous medium, probably a lake.

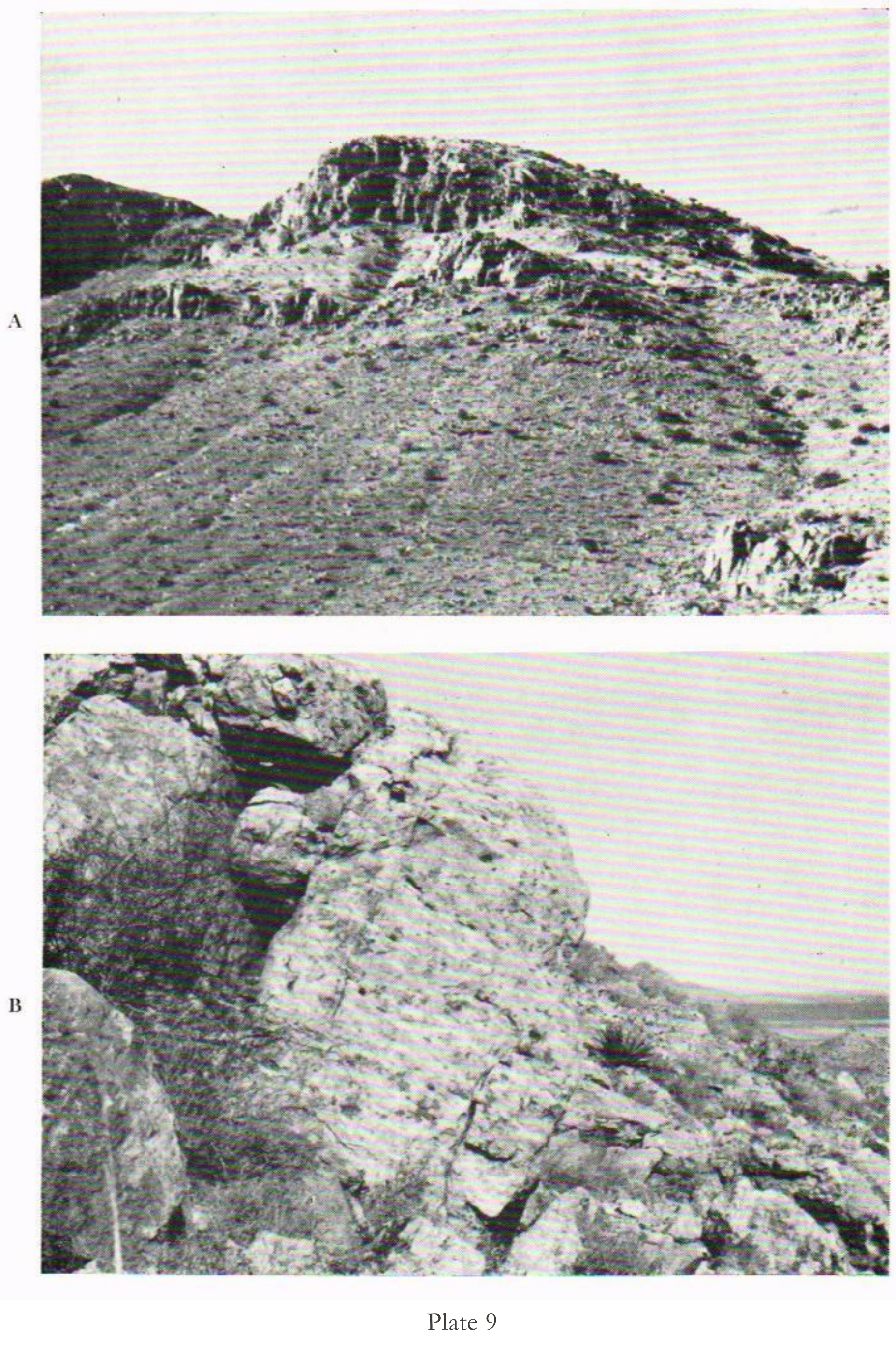


Plate 9

IGNIMBRITES

A. Weatherby Canyon ignimbrite on the northeast side of 1117 Peak.

B. Eutaxitic structure of the Weatherby Canyon ignimbrite at an exposure on the northeast side of 1117 Peak. The structure is due to the elongation and flattening of rock fragments, volcanic *ejecta,* and voids, owing to compaction of the overlying material while the rock mass was still hot and the fragmental material plastic. Some of the cavities are partly filled with secondary minerals.

Plate 10

CARBONATE HILL MINE

The main shaft is indicated by the headframe. The mill is in front of, and to the left of, the headframe. The adit in sec. 3 is near the head of the large gully and just below the crest of the ridge, above the headframe and mill. The high point along the skyline is McGhee Peak. The view is westward.

Plate 11

SILVER HILL MINE

The mine is situated immediately beneath the quartz monzonite porphyry sill which intrudes the Horquilla limestone. The Earp formation is exposed on the upper half of the hillside, the contact between the two formations being about 100 feet above the sill. The sill is 300 feet thick at this locality. The strata dip 20-30 degrees into the hillside. The high point (left) on the ridge crest is McGhee Peak. The view is eastward.

Plate 12

GRANITE GAP MINES

Numerous shafts, adits, and tunnels on Granite Gap Mountain, constituting the Granite Gap mines on the Granite Gap and Bob Montgomery groups of claims.

Plate 13

CHARLES MINE

B. black fissile noncalcareous shale, 45 feet thick;
A. the lowermost sequence of alternating thin-bedded fine-grained black limestone and thin gray shale, 30 feet thick.

Within units C, D, and E the amount of limestone increases gradually upward from a minimum of 0 at the base of unit C to a maximum of 50-60 percent at the top of unit E. Unit E is unit 13 of MS 3; unit D comprises units 4-12 of MS 3; unit C is unit 3 of MS 3; unit B is unit 2 of MS 3; and unit A is not exposed in MS 3 but was measured in a small gully in the SE¼ sec. 16, T. 25 S., R. 21 W.

This section corresponds remarkably well to the section measured by Sabins (1955, p. 34) at Blue Mountain in the Chiricahua Mountains, Arizona, except that he included in unit 1 an additional 100 feet of strata. Sabins' section is as follows:

upper member — 144 feet of very thin-bedded silty limestone, with alternating beds of calcareous shale;
middle member — 52 feet of black fissile siliceous shale;
lowest member — 130 feet of alternating very thin beds of calcareous shale, and shaly and silty limestones.

It also corresponds to the Percha shale as observed by the writer in the Silver City area, Grant County, New Mexico, although there the formation is nearly 500 feet thick.

Metamorphism has strongly altered the Percha shale, particularly in sea. 13, 14, 15, 16, and 24, T. 25 S., R. 21 W., and sec. 1, T. 26 S., R. 21 W. The black shale is only slightly altered, but the overlying interbedded calcareous shale and nodular limestone are changed to hornfels. These beds are particularly well exposed on an isolated hill in the SW ¼ sec. 1, northeast of the Robinson ranch. The hornfels is a dark-weathering light-gray to light bluish-gray thin-bedded extremely hard flinty rock, some beds of which contain numerous cavities 3-4 inches in diameter. These cavities resulted from the removal by solution of the limestone nodules in the original sedimentary rock. Remnants of some of the limestone nodules are still present. A fuller description of the metamorphic effects on the sedimentary rocks is included in the section on metamorphism. The beds are resistant to weathering and form prominent outcrops. They break easily into tabular fragments which litter the outcrop area and occur as float covering the underlying black shale.

No megafossils were found in the Percha shale in the Peloncillo Mountains. The metamorphism affecting much of the formation would effectively destroy any fossils that may have once been present, and exposures of unmetamorphosed Percha shale are rare. Samples of the unmetamorphosed shale from two localities were also examined for microfossils but none were found. The age of the formation elsewhere in New Mexico is late Devonian and possibly early Mississippian.

ESCABROSA LIMESTONE

The thick-bedded cliff-making sequence of limestone, which overlies the Percha shale in the Peloncillo Mountains, resembles the Escabrosa limestone of the Bisbee area, Arizona, (Ransome, 1904, p. 42) much more closely than it does the Lake Valley limestone of approximate equivalent stratigraphic position in central and southwestern New Mexico. Therefore, the term Escabrosa limestone is preferred for this unit in the Peloncillo Mountains, even though it be at variance with the nomenclature used throughout the rest of New Mexico.

The Escabrosa limestone crops out along the crest of the ridge extending from Cowboy Pass to Granite Gap and along the crest of the ridge extending northwest from Preacher Mountain. It also constitutes most of the prominent hill just north of Highway 80 and west of the Crystal mine, and extends northwest from this locality for about 1½ miles along the eastern side of the main ridge of the Peloncillo Mountains. The formation is resistant to erosion, forming cliffs and the crests of ridges in most areas. Together with the lithologically similar Horquilla formation of Pennsylvanian and Permian age, it forms the higher parts of the ridges in the central part of the area, where the sedimentary rocks predominate.

In the central Peloncillo Mountains the Escabrosa limestone is easily divisible into three members: The lower gray member, the black member, and the upper gray member. These are excellently exposed on the isolated hill north of Highway 80 in sec. 24, **T.** 25 S., R. 21 W., and along the ridge northwest of Preacher Mountain (pl. 3). They are distinguishable on aerial photographs as well as upon the ground, and are good mappable units, but are not shown separately on the map included with this report.

The lower gray member, 67-99 feet thick, overlies the Percha shale conformably. It consists mainly of medium-bedded medium-grained gray limestone, with a few thin interbeds of gray calcareous shale in the lower part. Thin beds and lenses up to 6 inches thick are composed of crinoid fragments. Weathering brings out the coarse texture of these lenses and produces a rough granular surface. The limestone weathers light gray.

The black member, 247 feet thick, consists predominantly of massive thick-bedded cliff-forming fine-grained dark-gray and black limestone which weathers to a smooth surface. Crinoid remains are abundant and silicified corals, brachiopods, crinoids, and other fossils stand in relief on the weathered surfaces. Current bedding is common; fossil fragments are alined along the crossbedding laminations. Black chert is prevalent throughout.

Thirty-five feet of alternating beds of black limestone and thin beds and lenses of brown-weathering black chert occurs 52 feet above the base of the member (pl. 5B). The limestone beds are 3-12 inches thick. The chert beds may be as much as 4 inches thick. Where the chert beds pinch out their place is taken by layers of nodules and lenses of various thicknesses alined along the bedding planes. Laminations in the limestones go around the chert nodules. Some of the chert nodules have centers of coarse calcite crystals which may represent remnants of fossils. The chert beds and lenses, as well as the nodules, are believed to be syngenetic deposits of silica on the sea bottom. Boundaries of the chert and the limestone are sharp.

Above this sequence of interbedded chert and limestone, chert is not so abundant. It occurs in beds, lenses, and nodules, but the chert layers are separated by greater thicknesses of limestone than in the lower part of the member. Many of the limestone beds are coarse calcarenite composed almost wholly of crinoid fragments. Current bedding swirls are common. This upper part is neither so massive nor so cliff-forming as the lower part of the member.

The upper gray member is 113 feet thick. It consists of thick-bedded massive coarse- to medium-grained light-gray calcarenite composed almost wholly of crinoid fragments. Chert occurs in nodules rather than in discrete beds; it is not abundant and is pink to light gray in contrast to the underlying black chert. The calcarenite weathers to a rough surface, upon which are exposed numerous crinoid stems up to three-quarters of an inch in diameter and several inches long.

Fossils are abundant throughout the Escabrosa limestone, but they are mostly fragmental and difficult to collect. In many places they are silicified and show as brown chert standing in relief on the weathered surface. Corals, brachiopods, bryozoa, and one cephalopod were collected from the black limestone member. Most of these were undiagnostic, but from a locality in the E1/2 sec. 3, T. 26 S., R. 21 W., Mississippian spirifiroids, "a *Triboloceras*" and "an unquestionable *Lithostrotion*" of probable late middle- or late-Mississippian age were identified (R. Flower, letter of February 24, 1956).

PARADISE FORMATION

The Paradise formation was named by Stoyanow (1926, p. 318) from exposures near the old mining town of Paradise, in the Chiricahua Mountains, Arizona, only a few miles southwest of the mapped area. It was not known to occur in New Mexico until field mapping in 1953 and 1954 revealed its presence in the mountainous ranges in the extreme southwestern part of the state. A detailed study of the formation in the Chiricahua Mountains, Arizona, and the Peloncillo Mountains, Animas Mountains, and Big Hatchet Mountains, New Mexico, was completed recently by Packard (1955).

In the Peloncillo Mountains the Paradise formation is a soft nonresistant formation which crops out west of most of the exposures of Escabrosa limestone. It was not recognized in some places on the east slope of the main ridge of the Peloncillo Mountains. Faulting, igneous intrusion, or erosion may have removed the formation. The easily erodible beds form shaly slopes, benches, and saddles between the more resistant, massive Escabrosa and Horquilla limestone (pl. 3, 5B). The distinctive topographic expression and color of the formation aid in its recognition.

The easily erodible soft shale beds at the base of the Paradise effectively obscured the contact with the underlying Escabrosa. The change in the lithic character of the rocks on either side of the boundary is sharp, however, and the contact can be accurately located. The two formations appeared to be conformable wherever they were observed. Packard came to the same conclusion regarding a section he studied in detail (MS 6).

The Paradise formation consists of alternating beds of fine-grained black, brown, and gray limestone; black calcareous siltstone; brown oolitic limestone; calcarenite; gray and green calcareous shale; quartzitic sandstone; and conglomerate. The thin-bedded sandstone occurs in the basal part of the formation. The conglomerate beds are near the top. The composition varies laterally so rapidly that no two stratigraphic sections are identical. The black calcareous siltstone, fine-grained limestone, greenish shale, and brown oolitic limestone are characteristic of the formation, not only in the Peloncillo Mountains but also throughout its known areal extent. The abundance of fossils is a prominent feature; some beds of gray and brown limestone are actually coquina. Brachiopods, crinoids, blastoids, and bryozoan fragments are especially common. Many of the limestone and shale beds weather yellow brown, imparting a distinctive color to the exposures. Two stratigraphic sections, one measured by Packard in the SE¼ SE¼ sec. 16, T. 25 S., R. 21 W., are reproduced in the appendix. The thinness of the individual beds and the great vertical variations in composition are apparent.

In the Big Hatchet Mountains and in the Chiricahua Mountains the upper part of the formation consists of continental deposits (Packard, 1955), but in the Peloncillo Mountains no evidence of continental beds was observed.

Fossils are extremely abundant in the formation throughout its known extent, but in the Peloncillo Mountains preservation is very poor and the fossils are difficult to extract. Packard (1955) identified *Spirifer* sp., *Spirifer bifurcatus?, Spiriferina sp., Orthotetes kaskaskiensis?,* and *Archimedes* sp., from a zone about 130 feet above the base of the formation in the Peloncillo Mountains; and *Spirifer sp., Composita sp., Eumetria* sp. ?, *and Agassizocrinus* sp., from a zone 70 feet above the base. A rich fauna is described by Hernon (1935) from near Blue Mountain in the Chiricahua Mountains. Blastoids and *Archimedes* are characteristic, the latter with the fronds still intact. The fossils indicate a Chester age for most of the formation, although the age of the basal part may be late Meremac. Faunally it is probably correlative with the Helms formation of the El Paso area.

NACO GROUP

Ransome (1904, p. 44) defined the Naco limestone as comprising the limestones of Pennsylvanian age in the Bisbee district, Arizona, which lie above the Escabrosa limestone. The thickness was estimated at 3,000 feet. Gilluly, Cooper, and Williams (1954, p. 15) in their studies in central Cochise County, Arizona, just north of the Bisbee district, subdivided the Naco limestone into a number of distinct lithostratigraphic units; these were defined as formations, and Naco was retained as a group name. They stated that these formations, valid in central Cochise County, might not prove useful over a wide area. Formations which correspond closely to those defined in central Cochise County, however, were identified by the writer in the Peloncillo Mountains, and therefore, for reasons to be explained subsequently, the same formational names have been used, except for the substitution of *Chiricahua limestone* for *Concha limestone.* In the Chiricahua Mountains, between the Peloncillo Mountains and central Cochise County, Sabins (1955, p. 5195) mapped these same formations. In the Big Hatchet Mountains, to the southeast, Zeller (1956, letter dated May 4, 1956) recognized similar units but did not distinguish them because they are not so clearly indicated there.

Gilluly, Cooper, and Williams (1954, p. 16) divided the Naco group into six formations. In ascending order these are the Horquilla limestone, Earp formation, Colina formation, Epitaph dolomite, Scherrer formation, and Concha limestone. Of these only the Epitaph dolomite was not recognized in the Peloncillo Mountains.

Horquilla Limestone

The Horquilla limestone was named by Gilluly, Cooper, and Williams (1954, p. 16) from Horquilla Peak in the Tombstone Hills, Arizona. They described it as consisting mostly of a series of thin-bedded blue-gray limestone beds which have a pinkish-gray tinge on the fresh-fractured surface. It contains some coarse-grained limestone consisting largely of crinoidal remains. The thickness ranged from about 1,200 feet to 1,600 feet.

In the Peloncillo Mountains the Horquilla limestone is the most widespread of the Paleozoic formations. It forms the upper part of Blue Mountain and crops out along the crest and upper slopes of the ridge extending northwest from Blue Mountain. It also forms the upper part of the ridge east of Cienega Peak, crops out on Granite Gap Mountain and in the vicinity of Cowboy Pass. It forms the lower slopes of the ridge in the vicinity of the Silver Hill mine.

The lower part of the Horquilla limestone, where it rests on the Paradise formation east of Cienega Peak, is a resistant cliff-forming craggy-weathering unit, similar to the Escabrosa limestone. It forms a secondary cuesta west of the main ridge held up by the Escabrosa limestone, and is separated from the latter formation by a saddle or break in slope occupied by the Paradise formation. The less resistant and thinner bedded portions of the formation above the basal part crop out on the back slope of the ridge. On Blue Mountain and the main ridge of the Peloncillo Mountains it forms either the major cuesta or a secondary cuesta. There, too, the upper part, being thinner bedded and less resistant, forms a steep back-slope interrupted by small cliffs and ledges made by the thicker beds.

The formation consists almost wholly of limestone, but a 14-foot argillaceous-sandstone layer is present about 250 feet above the base in the area north of Preacher Mountain. Two distinct types of limestone are well exemplified in the vicinity of the Silver Hill mine, where they alternate as units 10-40 feet thick: A medium-grained dark-gray calcarenite which consists largely of crinoid fragments and contains black chert nodules; and a coarse-grained light-gray to pinkish-gray crinoidal limestone which contains nodules of pink chert. In some places the latter type consists wholly of crinoid fragments and greatly resembles the upper gray member of the Escabrosa limestone. It is distinguished from the Escabrosa with certainty only by the presence of fusulinids in interspersed beds. Almost everywhere in the formation the amount of chert is less than 5 percent, but one 15-foot unit in the lower part of the measured section near the Silver Hill mine contains 30-40 percent of black chert nodules and thin beds. Elsewhere 2- to 3-foot beds in which the chert exceeds 20 percent were observed. The light gray crinoidal limestone is probably more prevalent in the Peloncillo Mountains than the darker limestone.

Fossils are abundant; brachiopods, bryozoa, corals, gastropods, and fusulinids are the most prominent. Large solitary and colonial corals are common. Fusilinids are abundant, constituting the greater part of many beds. They characterize the formation and are extremely valuable in its recognition. Crinoid fragments occur with the fusulinids. Some of the larger fusulinids are silicified and stand in relief on the weathered surface of the limestone. None were found in the basal part of the formation. In the Peloncillo Mountains fusulinids occur elsewhere only in the overlying Earp formation.

Nowhere in the area was a complete section of the Horquilla limestone observed. Partial sections were measured just south of the Silver Hill mine and northwest of Preacher Mountain. Near the Silver Hill mine the base of the formation is not exposed, and an unknown thickness of strata may have been faulted out within the upper part along a quartz monzonite porphyry sill. Near Preacher Mountain only the basal few hundred feet and the uppermost part of the formation are present; the two are separated by a fault. Elsewhere in the mapped area, sections are similarly incomplete, principally because of faulting.

The thickness of the formation is not known. At the Silver Hill mine 819 feet of section were measured, but the total is much greater. An unknown thickness of strata may be missing where the sill intrudes the formation, but the writer does not believe this to exceed 200 feet. The basal part of the section, also missing at this locality, is much thicker elsewhere. Although an exact correlation of that part of the formation near the Silver Hill mine with that part of the section measured near Preacher Mountain was not achieved, tentative correlation between those beds lying above and north of the section measured near Preacher Mountain and the lower part of the Silver Hill section indicates that between 400 and 500 feet of strata are missing below the exposed section near the Silver Hill mine. A total thickness for the formation of 1,350-1,500 feet is believed to be a reasonable estimate.

The lower contact of the Horquilla limestone is sharply defined, but in most parts of the mountains the actual contact is so obscured by soil and debris that it cannot be located within less than a few feet. Consequently, the exact relationships of the Horquilla limestone and the underlying Paradise formation are largely undetermined. Where studied in detail in sec. 22, T. 22 S., R. 21 W., (MS 7 and MS 8), about one foot of local relief is present at the lower boundary of the outcropping Horquilla limestone, but whether this observed lower boundary is the base of the formation is unknown. If so, a disconformity may be present. Where the Paradise formation does not intervene between the Horquilla limestone and the Escabrosa limestone, because of faulting or igneous intrusion, it is difficult to recognize a formational boundary.

The upper contact with the overlying Earp formation is less dearly defined. The change from carbonate rock to a dominantly sandstone, siltstone, and shale sequence is not sharp. A few thin beds of siltstone, a foot or two thick, are interbedded with the limestone near the top of the dominantly carbonate sequence. Arbitrarily, the contact is placed where the siltstone and sandstone beds become dominant over the limestone. This is in conformity with the usage by Gilluly, Cooper, and Williams (1954, p. 17).

In central Cochise County the age of the Horquilla, as determined by fossils, ranges from "post-Morrow Pennsylvanian to middle late Pennsylvanian" (Gilluly, Cooper, and Williams, 1954, p. 34). Beds of Morrow age may be present, but more probably the age of the oldest part of the Horquilla is either Lampasas or Des Moines.

In the Chiricahua Mountains, according to Sabins (1955, p. 56), the fusulinids indicate that the formation ranges in age from Morrow up through the Missouri; there the lowest fusulinids are 150 *feet* above the base of the Horquilla limestone.

The age of the fusulinids collected from the lower 163 feet of the section measured near the Silver Hill mine is Des Moines; they include *Fusulina rockymontana* Roth and Skinner, *Fusulina* cf. *rockymontana* Roth and Skinner, *Fusulina distenta* (Roth and Skinner), *Wedekinella euthysepta* (Henbest), and *Staffela* spp. No fusulinids were collected between 163 feet and the base of the sill, 650 feet above the base of the exposed section. Mega-fossils collected from this interval are long-range forms of no value in determining precise *age. Triticites* sp., and *Schwagerina* sp. occur 651 feet above the base of the exposed section and one foot above the sill. Between this point and the top of the formation, *Triticites aff. creekensis* and *T. aff. ventricocus* (Meek) were collected. It follows that the age of the beds above the sill is Wolfcamp, and that the age of the formation in this area ranges from Des Moines to Wolf-camp, inclusive. Beds of Missouri and Virgil age may be present, or may have been removed by faulting. The Pennsylvanian-Permian boundary may be within the 487 feet of unfossiliferous beds or it may be in beds removed by faulting.

Elsewhere in the area, fusulinids of Missouri and Virgil age were collected. In the section measured north of Preacher Mountain a sill and a fault occur 287 feet above the base of the formation. No fusulinids were found below the fault. *Triticites* sp. of upper Missouri age is present 11 feet above the fault, and *T. kelleyensis* Needham, of Virgil age, occurs 14 feet above the fault. Wolfcamp forms represented by *Schwagerina* sp. occur 80 feet above *T. kelleyensis* Needham. The interval between the beds containing upper Pennsylvanian forms and the beds containing lower Permian forms is poorly exposed, and no information could be obtained relative to the conformability or unconformability of the rock units. The Permian forms occur in beds which may belong to the Earp formation.

Missouri forms in the Horquilla limestone elsewhere include *Triticites irregularis (Staff), T. nebraskensis* Thompson, *T. submucronatus* Thompson, and *T.* sp., which were collected in the SE¼ sec. 14 and the NE¼ sec. 23, T. 25 S., R. 21 W. Wolfcamp fusulinids collected from isolated blocks of the upper part of the formation include *Triticites ventricosus* (Meek), *T. creekensis, T.* sp., and *Schwagerina?* sp.

A poorly exposed section was measured in the SE¼ sec. 16 and the NE¼ sec. 21, T. 25 S., R. 21 W., where slightly over 500 feet of the lower part of the Horquilla limestone overlies the Paradise formation. *Fusulinella* sp. occurs 389 feet above the base of the formation, and *Fusulina?* sp. occurs 492 feet above the base of the formation. The former is characteristic of the upper Derry; the latter Des Moines. The presence of *Fusulinella* is important because it is the oldest fusulinid found in the area, although it occurs almost 400 feet above the base of the formation.

The study of the fusulinids indicates that in the Peloncillo Mountains the Horquilla limestone ranges from upper Derry and possible pre-Derry age to lower Wolfcamp, and that rocks of all the middle and lower Pennsylvanian series and of the Wolfcamp series of the Permian are present. This age determination is at variance with the age of the formation as determined by Gilluly, Cooper, and Williams in central Cochise County (1954, p. 34), and by Sabins in the Chiricahua Mountains (1955, p. 58). In both these areas the base of the Horquilla limestone may be as old as upper Derry or older, but the youngest beds in the formation are considered to be middle late Pennsylvanian (probably Missouri). Fusulinids of Virgil age in the eastern Arizona sections are confined to the more arenaceous and argillaceous sequence of rocks of the overlying Earp formation. It seems probable that western New Mexico was farther from the shoreline in late Pennsylvanian and early Permian times than was eastern Arizona, and that limestone deposition continued in this area through the late Pennsylvanian and into early Permian. The deposition of sandstone, siltstone, and shale did not begin until well into the early Permian, and thus the contact of the Horquilla limestone and the Earp formation is within lower Permian rocks rather than within upper Pennsylvanian rocks.

Earp Formation

The Earp formation was named by Gilluly, Cooper, and Williams (1954, p. 18) from the exposures on Earp Hill in the Tombstone Hills, Arizona. It is defined by them as containing "a much higher proportion of clastic deposits than either of the adjacent formations." The boundaries are indefinite. According to the original description (p. 19), the

> base of the Earp is arbitrarily taken where the thin shaly limestones and reddish shales become dominant over the more massive limestones characteristic of the Horquilla.

The upper boundary, taken at the top of some beds of orange dolomite in the type area (p. 23),

> places nearly all of the clastic rocks — the sandstone and shale beds — in the Earp formation, although there is a local stray sandstone bed considerably higher in the section (in the lower part of the Colina limestone).

In accordance with this usage the Earp formation in the Peloncillo Mountains includes the dominantly argillaceous and arenaceous section between the interbedded light- and dark-gray Horquilla limestone and the black Colina limestone; the boundaries are set arbitrarily at the upper and lower limit of the dominantly clastic rocks.

The Earp formation crops out in several places: Extensively along much of the west slope of the main ridge of the Peloncillo Mountains from Blue Mountain northward to beyond the Silver Hill mine; on the lower part of the eastern slope of the ridge south of the Carbonate Hill mine and in some of the low isolated hills east of the main ridge in this area; and on the west slope of the ridge extending northwestward from Preacher Mountain. As the Earp formation is soft and less resistant to erosion than the underlying Horquilla limestone, the areas underlain by the Earp are relatively low. Only in the vicinity of McGhee Peak and along the ridge to the south does it crop out on the ridge tops. On these ridge tops the upper, more calcareous part is exposed; on McGhee Peak the Earp formation is overlain by the more resistant Cretaceous rock which forms the ridge crest. Resistant ledges of limestone and sandstone form small cliffs on the slopes.

In much of the area the base of the Earp formation is difficult to observe. The lesser resistance of the formation to erosion and its position between more massive limestones have resulted in shearing and slippage in area of deformation. Thus in many places the Earp formation is in fault contact with the underlying Horquilla limestone.

In the Peloncillo Mountains the Earp formation is easily divisible into a lower dominantly clastic unit overlain by an upper dominantly carbonate section. These are best exposed in the vicinity of the Silver Hill mine (MS 9) and along the ridge to the southeast. The uppermost beds at these localities have been removed by pre-Cretaceous erosion, but in the area south of the Silver Hill mine, beds of orange and brown dolomite and sandy dolomite occur beneath black Colina limestone. They are believed to represent the uppermost part of the Earp formation. Faulting in the vicinity obscures their exact relationships.

As exposed in the section measured near the Silver Hill mine, the lower part of the formation consists of alternating beds of sandstone, siltstone, or shale and medium-grained gray limestone. The thicknesses of the limestone units range from a few feet to 24 feet, except for one 48-foot unit near the middle of the lower part of the formation. The thicker and more massive beds form small cliffs. Fusulinids and crinoid fragments are plentiful; some beds consist almost wholly of these organic remains.

The beds of the lower part of the Earp formation consist of thin-bedded very fine-grained, brown-weathering black calcareous siltstone in the lower part, but about 100 feet above the base of the formation the beds become more argillaceous and arenaceous. Above this point brown shale and fine-grained well-indurated light-brown calcareous sandstone are interbedded with the siltstone. Toward the top of the sequence, the clastic beds consist almost entirely of white and light-brown calcareous shale and thin calcareous sandstone. The thicknesses of these units range from 2 feet to 28 feet; they constitute about 40 percent of the sequence.

One 2-foot bed of siltstone, 46 feet above the base of the formation, contains pebbles of gray limestone which weather more readily than the siltstone matrix and impart a gray and light-brown mottled appearance to the rock unit. Above it, a thin conglomeratic layer forms the base of an 18-foot limestone unit. The conglomerate contains limestone pebbles up to one-half inch in diameter. Another conglomerate layer containing small pebbles of limestone is present within one of the light-brown shale units about 75 feet below the top of the lower part of the Earp formation.

The lower dominantly sandstone, siltstone, and shale portion of the Earp formation in the vicinity of the Silver Hill mine is 399 feet thick.

Above the dominantly clastic strata in the vicinity of the Silver Hill mine are 432 feet of strata consisting almost wholly of medium- to thick-bedded medium-grained gray limestone. Many of the beds are composed almost entirely of crinoid or fusulinid remains. The abundant fossils include corals, brachiopods, and bryozoa, as well as the fusulinid and crinoid fragments. Black chert nodules occur in the lower part. Clastic deposits are represented by a 5-foot shale bed 67 feet above the base of the sequence and a 2-foot shale bed 101 feet above the base of the sequence. A few thin yellow-brown-weathering beds of dolomite and irregular yellow-brown-weathering patches, some of which are dolomitic, are also present in the upper part. The top of the section has been removed by pre-Cretaceous erosion.

On the western slope of Blue Mountain and the ridge to the northwest, and on the western slope of the ridge extending northwest from Preacher Mountain, the clastic portion of the Earp formation consists dominantly of brown-weathering smoky-pink siltstone and sandstone, and some brown shale. These crop out on the hillslopes as dark bands which are more resistant to erosion than the interbedded limestone. The limestone is marbleized in places, and the siltstone, sandstone, and shale appear to have been impregnated secondarily with silica. This condition is most prevalent in the vicinity of faults and igneous intrusions and is due to low-grade contact metamorphism.

West of the Silver Hill mine and in the outlying hills between the main ridge of the Peloncillo Mountains south of the Carbonate Hill mine and Highway 80, sequences of interbedded thin-bedded black and light-brown shale, gray limestone, brown-weathering limestone, and conspicuous yellow-brown limestone and dolomite occur. The total thickness of these beds is in excess of 150 feet; they are especially prominent because of their color and the cyclic repetition of rock types. Inasmuch as they are exposed in isolated fault blocks, their true strati-graphic position is not known. In one area they underlie beds of early Cretaceous age and appear to lie above the Earp formation. They may represent an upper portion of the Earp formation, above the carbonate section exposed near the Silver Hill mine, or they may be a facies of the lower dominantly terrigenous unit. Lithologically they are distinct from the lower unit, and, therefore, the first hypothesis seems more probable.

In the area south of the Silver Hill mine, orange and brown dolomite forms the uppermost part of the Earp formation. The section immediately below the dolomite, poorly exposed on account of faulting and the softness of the beds, may represent the thin-bedded strata described in the preceding paragraph.

Fusulinids were collected from numerous beds in the Earp formation in the section measured near the Silver Hill mine and elsewhere in the Peloncillo Mountains. They indicate an early Permian (Wolfcamp) age for the entire formation. Collections from beds 75 feet above the base of the formation exposed near the Silver Hill mine and from beds 10 feet below the top of this section contain Wolfcamp forms. Fossils collected in secs. 2, 11, and 14, T. 25 S., R. 21 W., are stratigraphically higher than those at the top of the Silver Hill mine section and are also Wolfcamp. A pelecypod faunule collected about one-quarter mile slightly north of west from the Ward tungsten mine, in the S½SE¼ sec. 22, T. 25 S., R. 21 W., included *Pseudorthoceras sp., Aviculopecten* sp., and *Pseudomonotis* sp. According to Flower (1956, letter dated February 24, 1956) this group of specimens is medial Permian in age and duplicates a faunal association found previously only in the Yeso formation of central New Mexico. At the locality in the Peloncillo Mountains, these beds lie 55 feet above beds containing fusulinids which are recrystallized, but which are probably referable to *Schwagerina* sp., and 88 feet below beds which also contain recrystallized fusulinids tentatively identified as *Schwagerina* sp., and *Paraschwagerina* sp. or *Pseudoschwagerina* sp.

In central Cochise County, Arizona, Gilluly, Cooper, and Williams obtained upper Pennsylvanian and lower Permian fossils from the Earp formation (1954, p. 35). In the Chiricahua Mountains, Sabins (1955, p. 68) obtained fusulinids of Pennsylvanian (Virgil) and early Permian (Wolfcamp) age. In the Peloncillo Mountains, as explained above in the section on the Horquilla limestone, the deposition of clastic sediments did not begin until well into the Wolfcamp epoch; the Earp formation in this area, therefore, includes beds of Permian age only. The total thickness of the formation is unknown. At the Silver Hill mine 831 feet of strata was measured from the base upward, but the top of the formation is missing. Beds above this are known elsewhere in the area, but no exact bed-for-bed correlation can be made. Across the San Simon Valley at Portal, in the Chiricahua Mountains, Sabins measured 2,710 feet of Earp formation (1954, p. 67).

Colina Limestone

The Colina limestone, named by Gilluly, Cooper, and Williams (1954, p. 23) from exposures on Colina Ridge in the Tombstone Hills, Arizona, crops out on the western slope of the main ridge of the Peloncillo Mountains south of the Silver Hill mine, and also north and east of Cienega Peak. It is not a resistant formation, but forms gentle slopes on which some of the thicker beds crop out as ledges and small cliffs.

Very fine-grained limestone which is dark gray or black on the fresh-fractured surface is the most characteristic feature. The absence of chert is in contrast to its relative abundance in other dominantly carbonate upper Paleozoic formations in the mountains. Much of the black limestone contains irregularly spherical masses of coarse calcite that range up to 2 inches in diameter, although most of them are less than one-half inch in diameter; in some, the central part consists of pink calcite. They appear to be recrystallized fossils. Large gastropods, especially *Ompha-*

lotrochus, and scaphopods are characteristic of the black limestone. No fusulinids were found in the formation. Fossils other than the mollusks mentioned above are rare or poorly preserved.

No complete section of the Colina limestone was observed in the Peloncillo Mountains. North of Cienega Peak, where the formation is least disturbed, a partial section was measured and studied in detail near the center of sec. 21, T. 25 S., R. 21 W. At this locality 504 feet of strata was mapped as Colina, but the base of the formation is not exposed, and a fault may interrupt the measured section. The lower part consists of the typical medium-bedded, fine- to medium-grained dark-gray and black limestone, but above this the black limestone is interbedded with brown-weathering dark-gray and red siltstone and some sandstone in thin beds. The uppermost 120 feet is mostly lighter colored, gray to pinkish-gray friable calcarenite.

East of Cienega Peak recrystallized friable light-gray limestone alternates with recrystallized black limestone; some of the beds are marbleized. Acicular tremolite or actinolite crystals occur along fractures and bedding planes. Inasmuch as metamorphism has so altered the strata that they are difficult to recognize, some mapped as Colina limestone may belong in the upper part of the Earp formation. If all these beds are Colina limestone, the formation is much thicker than 504 feet, or there has been repetition due to faulting.

The contact of the Colina limestone and the underlying Earp formation was not seen in the area north of Cienega Peak because of a covered interval between exposures of the two formations. East of Cienega Peak, where metamorphism prohibits the exact identification, relationships are unknown. South of the Silver Hill mine the black limestone rests on orange and brown dolomite of the uppermost Earp without discordance or obvious unconformity. There too, however, the actual contact is obscured by soil and debris. In the Chiricahua Mountains to the west the base of the formation is conformable with the underlying Earp formation (Sabins, 1955, p. 78). In sec. 21, T. 25 S., R. 21 W., the upper boundary is conformable.

Lithic characteristics, composition, stratigraphic position, and the presence of the characteristic gastropods and scaphopods all assist in identifying the formation and correlating it with exposures in Arizona. In the Peloncillo Mountains the exact age is unknown, but in Arizona Gilluly, Cooper, and Williams (1954, p. 38-41) and Sabins (1955, p. 81) considered the age to be Wolfcamp and Leonard(?).

Scherrer Formation

The Scherrer formation was named by Gilluly, Cooper, and Williams (1954, p. 27) from Scherrer Ridge in the Gunnison Hills, west of Wilcox, Arizona. The formation in that area consists of alternating beds of sandstone and limestone in thick units, with a distinctive red siltstone 65 feet thick at the base. The entire formation is 687 feet thick at the type locality. Near Dunn Springs, in the Chiricahua Mountains, Sabins (1955, p. 95) reported that the Scherrer formation consists of 47 feet of fine-grained dusky-red calcareous sandstone at the base, overlain by about 100 feet of thick-bedded white quartzitic sandstone.

In the Peloncillo Mountains about 50 feet of thick-bedded well-cemented dusky-red siltstone forms the crest of a long ridge extending north from Cienega Peak. It overlies the Colina limestone and is in turn overlain by the distinctive Chiricahua limestone. The northern extremity of the ridge is capped by a thick ledge of white well-cemented sandstone, but faulting has disturbed the beds, and the relative positions of the white sandstone and the dusky-red siltstone are unknown. The white sandstone is believed to overlie the siltstone. The similarity of the siltstone to the basal part of the Scherrer formation in the Gunnison Hills and in the Chiricahua Mountains, together with its stratigraphic position between undoubted Colina and Chiricahua limestones, warrants the identification of these beds as Scherrer formation. The upper limestone of the type area may be present in the Peloncillo Mountains on the back slope of the ridge, where talus and slope wash effectively cover all the bedrock between the exposures of the siltstone on the crest of the ridge and the exposures of Chiricahua limestone near the base of the western side of the ridge.

South of the Silver Hill mine no thick siltstone or sandstone section was observed between beds mapped as Colina limestone and beds mapped as Chiricahua limestone. A poorly exposed section below the massive cherty Chiricahua limestone in the S1/2 sec. 10 and the N1/2 sec. 15, T. 25 S., R. 21 W., contains some thin sandstone and sandy limestone beds, but these more nearly resemble the strata within the upper Colina limestone and the lower Chiricahua limestone than the strata within the Scherrer formation. These beds may be part of the Scherrer formation, or the Scherrer formation may be absent in this area because of nondeposition or because of removal after deposition. Removal after deposition may have been by faulting or by pre-Chiricahua erosion. As exposures are poor, the exact stratigraphic and structural relations of the rock units were not determined. Faults are present in the vicinity, but none was observed within the Colina-Chiricahua sequence. No evidence of a pre-Chiricahua erosion interval is preserved elsewhere in the Peloncillo Mountains; none has been reported in the areas to the west.

A more probable answer to the absence of the Scherrer formation in this area (if these beds are not Scherrer) is that it was never deposited. The formation thins in an easterly direction. It is 687 feet thick in central Cochise County, 150 feet thick in the Chiricahua Mountains, and 30-50 feet in the western part of the Peloncillo Mountains. The locality in secs. 10 and 15 is only about 2 miles from the locality in sec. 21, T. 25 S., R. 21 W., in the western part of the Peloncillo Mountains, but it is separated from it by two, and possibly three, major faults. In Permian time, when the Scherrer formation was being deposited, the distance between the two areas may have been much greater. The eastern limit of the Scherrer formation may have been between the two areas; if so, the Scherrer formation wedges out west and southwest of secs. 10 and 15. The absence of the formation in the intervening areas precludes a definite conclusion.

About 275 feet of thick-bedded, finely laminated and crossbedded, well-cemented, hard, brownish-weathering, red calcareous siltstone occurs about half a mile west of the Ward tungsten mine in the SE1/4 sec. 22, T. 25 S., R. 21 W. These beds are practically vertical and form rocky prominences along the crest of a ridge. They seem to overlie beds referred to the Earp formation, but the contact may be a fault. They are at least partly in fault contact to the west with other beds mapped as Earp. These latter beds are metamorphosed and may be part of the Colina limestone. The strata are most similar to the dusky-red siltstone of the Scherrer formation in the Peloncillo Mountains. The thickness of the siltstone in sec. 22, however, far exceeds the thickness of the Scherrer measured in sec. 21, slightly more than a mile away. Furthermore, the strata in sec. 22 also resemble some of the siltstone of the Earp formation, but no uninterrupted siltstone sequence greater than 50 feet has been observed within the Earp formation.

Distinctive features of the strata in sec. 22 are their fine laminations and crossbedding, which are excellently shown on the weathered surface, and their distinctive weathering into intersecting ridges and botryoidal surfaces. The reticulated and botryoidal surfaces result from the concentration of silica along the fractures and in small spherical masses. On freshly fractured surfaces, the siliceous concentrations are light gray in contrast to the dusky-red color of the major part of the rock.

These beds probably represent a response to a particular depositional environment; they may be a facies either of the Earp or the Scherrer formation, or perhaps of some other unit. They are shown on the map as Scherrer, merely to set them apart from the Earp in the adjacent areas.

No fossils were found in the Scherrer formation in the Peloncillo Mountains, but its position between Permian beds fixes its age as Permian also.

Chiricahua Limestone

In 1926 Stoyanow (1926, p. 318-319) described a limestone from near Paradise, in the Chiricahua Mountains of southeastern Arizona, stating that it was separated from the underlying Naco limestone by about 100 feet of quartzite and contained a Kaibab fauna. At a later date Stoyanow (1936, p. 532) formally designated the limestone as the Chiricahua limestone. He gave no lithic description of the formation, but stated that it was the youngest Permian formation of southeastern Arizona and contained a fauna which was the same as that found in the Beta member of the Kaibab formation in the Grand Canyon. Presumably the type section was the section described in the 1926 publication.

In 1954 Gilluly, Cooper, and Williams (1954, p. 29) described a new formation from exposures on Concha Ridge in the Gunnison Hills, near Wilcox, Arizona, about 50 miles northwest of Paradise. They called it the Concha limestone. On Concha Ridge the formation overlies the Scherrer quartzite and is the uppermost member of the Naco group. Fossils collected near the type locality are compared by Gilluly, Cooper, and Williams (1954, p. 42) with fossils collected by Williams at two localities near Paradise, from what is presumed to be Stoyanow's Chiricahua limestone. The faunal assemblages are very similar.

Sabins (1955, p. 89), mapping in the Chiricahua Mountains immediately north of Paradise, ignored Stoyanow's earlier designation of Chiricahua limestone and called the limestone overlying the Scherrer quartzite, Concha, following Gilluly, Cooper, and Williams. Undoubtedly his Concha limestone is continuous with the type Chiricahua limestone near Paradise.

The writer believes that the Chiricahua limestone and the Concha limestone are the same stratigraphic unit and that the terms are synonymous. Their stratigraphic position, as the topmost unit of the Naco group above the Scherrer quartzite, is identical. Their lithic and faunal characteristics are very similar, if not the same. In the Chiricahua Mountains both names have been applied in adjacent areas to strata that are undoubtedly the same formation. Their type localities are close enough so that one name would suffice. Because of priority, that name should be the Chiricahua limestone.

In the Peloncillo Mountains the term Chiricahua limestone is used for the cherty limestone overlying the Scherrer quartzite. The name is preferable because of its priority and because the type locality of the Chiricahua limestone is closer to the Peloncillo Mountains than is the type locality of the Concha limestone. Stratigraphically the strata correspond in position to both the Chiricahua and Concha as originally described. In composition and lithic character they are almost identical with the Concha at its type locality and to the beds called Concha by Sabins in the Chiricahua Mountains; the latter are undoubtedly close to Stoyanow's type area of the Chiricahua. Because Stoyanow did not give a lithic description of his type section, no direct comparison with the type Chiricahua can be made.

The Chiricahua limestone occurs in the Peloncillo Mountains in scattered exposures north of Cienega Peak and is particularly prominent on the west slope of the peak. In this area it crops out as large white masses, seemingly plastered against the dark-weathering granite of Cienega Peak. South of the Silver Hill mine it forms the crest and west slope of a prominent hill.

In the Peloncillo Mountains the Chiricahua limestone consists principally of thick-bedded light-gray medium-grained limestone containing abundant irregularly shaped grayish-pink chert nodules. In some beds the chert constitutes almost 50 percent of the rock mass. Some of the beds are friable. The lower part of the formation is thinner bedded and contains less chert than does the upper part. Fossils are abundant, particularly brachiopods and corals, but no fusulinids were found.

No section of the Chiricahua limestone was measured in the Peloncillo Mountains and no thickness was obtained. The thickness varies greatly; in much of the area the formation is missing, having been removed wholly or in part by pre-Cretaceous erosion. A maximum thickness north of Cienega Peak is estimated as 800 feet. Sabins (1955, p. 89) reported a maximum of 730 feet for his Concha limestone in the Chiricahua Mountains.

In the vicinity of Cienega Peak, where the Chiricahua has been intruded by the Cienega Peak granite, the limestone is bleached, recrystallized, and marbleized along the contact. The granite invaded the sedimentary rock as a sill or laccolith. As a result of later tilting, both the sill and the limestone beds stand almost vertical. The near-vertical masses of recrystallized and bleached Chiricahua limestone are conspicuous on the west slope of Cienega Peak.

Fossils listed by Gilluly, Cooper, and Williams (1954, p. 42), from Concha Ridge and from the type area of the Chiricahua limestone near Paradise, contain forms characteristic of the Kaibab fauna of the Grand Canyon area (as restricted by McKee, 1936). These are of Leonard or Guadalupe age. The Chiricahua limestone is therefore Leonard or Guadalupe age.

The Chiricahua limestone of the Peloncillo Mountains is correlative with the Chiricahua limestone and the Concha limestone of Arizona, and probably with part of Stoyanow's Snyder Hill formation (Gilluly, Cooper, and Williams, 1954, p. 43).

BISBEE GROUP

Dumble (1902, p. 706) first applied the term "Bisbee beds" to Lower Cretaceous strata of southeastern Arizona, and divided the sequence into four units. Ransome (1904, p. 56) altered the name to "Bisbee group" and divided it into four formations: The Glance conglomerate at the base, the Morita formation, the Mural limestone, and the Cintura formation. These units, however, are not the exact equivalent of Dumble's subdivisions. In 1949 Stoyanow redefined the Mural limestone, restricting the name to the upper part of the original formation and describing the lower part as the Lowell formation. This new formation is best exposed in the Ninety-one Hills south of Bisbee along the international border. Stoyanow divided it into 7 members which he based principally on fossil faunas.

In the Peloncillo Mountains, strata of certain, probable, and possible early Cretaceous age are assigned to the Bisbee group. The formations distinguished have not been correlated with any of Ransome's or

Stoyanow's formations in southeastern Arizona, nor with any of the formations distinguished by Lasky (1947, p. 12) in the Little Hatchet Mountains, New Mexico. They most closely resemble rocks in the Chiricahua Mountains, Arizona, which Sabins (1955, p. 96) has correlated in a general way with rocks in the Bisbee area. Zeller (1953, p. 142) briefly described the Cretaceous sedimentary rocks from the Big Hatchet Mountains, New Mexico, and divided them into 3 units, "A lower clastic formation, a middle limestone formation, and an upper clastic formation." According to Zeller, the same 3 units can be distinguished in the adjoining Sierra Rica, Apache Hills, and Animas Mountains, and resemble a similar threefold division at Bisbee. He also stated that the Lower Cretaceous rocks in the Little Hatchet Mountains described by Lasky (1947, p. 12) are anomalous with respect to the otherwise simple stratigraphic picture of the Lower Cretaceous rocks of southwestern New Mexico and southeastern Arizona.

For all that, the Lower Cretaceous rocks of the Peloncillo Mountains cannot be fitted into this simple pattern. A lower, dominantly terrigenous unit is overlain by two carbonate units, the uppermost of which contains much terrigenous material, and these are overlain by a sandstone and shale unit. These units, however, only slightly resemble the units in the Big Hatchet Mountains, Little Hatchet Mountains, or the Bisbee area. Thicknesses are much less. Examination of the Lower Cretaceous strata in the Bisbee area, in the Little Hatchet Mountains, and in the Chiricahua Mountains, failed to disclose more than a general agreement of the sedimentary rocks in the several areas. The Lower Cretaceous formations of southeastern Arizona and southwestern New Mexico vary greatly laterally; each exposed section is probably the result of deposition in a semi-isolated basin with its own distinctive succession of lithotopes. Sediments derived largely from local sources were poured into each basin at a rate commensurate with the rate of downwarping. Although in some areas great thicknesses of strata are present, they are characteristically shallow-water, and in some places, the continental deposits and the basins were never very deep. Deposits of limestone are subordinate in the total thickness of the rock. The varying thicknesses of the Lower Cretaceous series in the region reflect the differential rate of sinking of the semi-separate basins. The present location of the Little Hatchet Mountains, in which 20,000 feet of Trinity strata are preserved, was probably close to the center of the geosyncline during the early Cretaceous epoch, whereas the sites of the Peloncillo Mountains, the Chiricahua Mountains, and the Bisbee area, where less than 5,000 feet of rock is present, were nearer the shoreline. Intermediate thicknesses of 8,000-10,000 feet are recorded from the Big Hatchet Mountains (Zeller, 1953, p. 142).

In the Peloncillo Mountains, Big Hatchet Mountains, and Bisbee area, fossils indicate that the lower part of the stratigraphic sequence is Aptian in age. The lowest identifiable beds in the Little Hatchet Mountains are lower Albian. To the south, in Mexico, progressively older beds of the Cretaceous are exposed. The 20,000 feet of strata exposed in the Little Hatchet Mountains may therefore represent only the upper part of the section, and the total thickness of Lower Cretaceous strata present may far exceed this.

Vulcanism during the early Cretaceous epoch is recorded by volcanic rocks interbedded with the shale, sandstone, limestone, and conglomerate of the Bisbee group in the Peloncillo Mountains, in the Little Hatchet Mountains (Lasky, 1947, p. 12), and in the Sahuaripa area, central Sonora, Mexico (King, 1939, p. 1660).

In the Peloncillo Mountains the Bisbee group is divided into four formations. In ascending order these are the McGhee Peak formation, the Carbonate Hill limestone, the Still Ridge formation, and the Johnny Bull sandstone. The McGhee Peak formation probably is the equivalent of the Glance conglomerate. The Carbonate Hill limestone is contemporaneous with part of the Lowell formation. The Still Ridge formation and the Johnny Bull sandstone are not correlated with formations elsewhere.

McGhee Peak Formation

The McGhee Peak formation is named from the exposures on McGhee Peak, which is midway between Granite Gap and Steins on the crest of the main ridge of the Peloncillo Mountains. The formation crops out on the top of the peak and is exposed in a northwest-trending belt on the east side of the main ridge of the Peloncillo Mountains in the vicinity of McGhee Peak. To the west of the peak it is exposed as a narrow but almost continuous band which extends from north of Frye Peak to about 2 miles south of the Silver Hill mine, where it crosses the main ridge of the range and continues southeastward for an additional 3 miles. It is also exposed in the low hills at the eastern base of the range in secs. 11 and 14, T. 25 S., R. 21 W., along the eastern base of the small ridge in T. 25 S., R. 20 and 21 W., and in some nearby isolated hills. Scattered exposures are located northwest of Cienega Peak.

In most areas the formation is soft and easily erodible and forms the lower slopes of the ridges. On McGhee Peak and the ridge to the southeast, however, resistant sandstone beds in the lower part form the crest and eastern slopes of the ridge.

The lithic characteristics of the formation vary greatly vertically, and individual beds can be traced laterally for only short distances. Conglomerate and sandstone are especially abundant, but a few beds of shale and limestone are present in the upper part. In most areas the basal beds are composed of ill-sorted conglomerate consisting of rounded cobbles and pebbles of quartzite, limestone, and chert in a firmly cemented quartz-sand matrix. Many of the limestone fragments contain Upper Paleozoic fossils. North of Cienega Peak angular and subround cobbles and pebbles of granite are present in the conglomerate, and well-rounded weathered cobbles occur in sec. 11, T. 25 S., R. 21 W. Conglomerate similar to that in the basal beds occurs throughout the formation, but the percentage of limestone fragments increases in the higher beds. In some beds most of the fragments are of limestone. The abundance of limestone-pebble conglomerate characterizes the formation.

On McGhee Peak (MS 11) the composition of the formation is slightly atypical. The basal conglomerate is absent, and 75 feet of medium-grained white sandstone forms the basal part of the formation. This is overlain by 31 feet of typical conglomerate. Above this the section is mostly sandstone, some of which is conglomeratic. Two beds of very coarse-grained well-cemented pure white sandstone, which are resistant to weathering, occur 59 and 82 feet respectively above the conglomerate and are peculiar to this locality.

The sandstone of the McGhee Peak formation is predominantly fine grained and well indurated, and much of it has a calcareous cement; it ranges from white to gray and red. Some white siliceous siltstone and some argillaceous sandstone are also present. Red sandstone, siltstone, and shale are particularly prominent in the exposures east of the fault in secs. 12 and 13, T. 25 S., R. 21 W., comprising most of the formation there. Conglomerate and brown sandstone also occur at this locality.

A few thin beds of brown-weathering black limestone and some of gray limestone occur in the upper part of the formation. The limestone is thin to medium bedded, very fine grained, slightly sandy or silty, and in many places weathers nodular. Some of the limestone beds are conglomeratic and consist of pebbles of limestone in a limestone matrix. The distinction between matrix and pebbles is difficult to discern on the freshly fractured surface, but weathering produces a color differentiation. The pebbles weather medium gray and the matrix weathers pale olive. The limestones represent a subordinate part of the formation, but increase in abundance toward the top.

The McGhee Peak formation was deposited on an old erosion surface of considerable relief, and the thickness of the formation reflects this uneven topography. On McGhee Peak the formation is 370 feet thick, but elsewhere thicknesses of 546 and about 600 feet were measured. At still another locality 390 feet was measured, with covered intervals exceeding 100 feet both above and below the exposed beds.

The lower contact is an obvious unconformity, for the McGhee Peak formation overlaps several Permian limestones. On McGhee Peak it rests on the Earp formation. The contact is irregular, with a local relief of about 25 feet. An old soil layer, 4-5 feet thick, developed on the Permian limestone contains chert nodules up to 6 inches in diameter. To the south of McGhee Peak the basal Cretaceous strata rest on beds higher in the Earp; to the north of Cienega Peak they rest on the Chiricahua limestone. At McGhee Peak the Cretaceous and Permian beds are parallel, but in sec. 21, T. 25 S., R. 21 W., northwest of Cienega

Peak, an angular discordance both in dip and strike between the Chiricahua limestone and the McGhee Peak formation is present. Elsewhere structural relations are not so obvious.

The contact of the McGhee Peak formation with the overlying Carbonate Hill limestone is conformable and is defined as the base of the distinctive limestone. There are a few limestone beds in the upper part of McGhee Peak formation, but they are different in appearance and composition from the Carbonate Hill limestone, which moreover does not contain beds of quartzitic sandstone or conglomerate as found in the McGhee Peak formation. There is thus a change in composition of the strata indicative of a change in the environment of deposition and in the source of the sediments, but there is no manifest break in sedimentation.

As no fossils were found in the McGhee Peak formation, the inclusion of the McGhee Peak formation in the Lower Cretaceous series is based solely upon its stratigraphic position and its relationship to beds containing lower Trinity fossils. The character of the formation and its relations with the overlying Carbonate Hill limestone indicate that it is the initial deposit of a sea transgressing over an old landmass in an area where more calcareous sediments were later deposited. The absence of any known marine Jurassic rock in the surrounding areas suggests that it does not belong to that System. It probably is correlative with the Glance conglomerate of Arizona; Sabins (1955, p. 97) has mapped what are probably equivalent beds in the Chiricahua Mountains as Glance conglomerate.

The McGhee Peak formation represents deposition in a fluctuating sea transgressing a surface of moderate relief. Many of the pebbles and cobbles in the conglomerate were derived from local sources and represent rock types in the vicinity. This derivation is particularly true of the rounded fragments of fossiliferous Paleozoic limestone and of the fragments of granite. The roundness of many fragments of chert and quartzite indicates that they may have been transported farther; if so, they originated in more distant areas. The quartzite may have been brought in from areas to the west and north, where either the Bolsa or Precambrian quartzite was the surface rock. The angular chert fragments are local in origin. The marked lateral variations in composition and particle size are indicative of the fluctuating sea and may indicate deposition in innumerable separate basins of an archipelago. The pebbles and cobbles of local origin were derived from highlands that stood above sea level.

Carbonate Hill Limestone

The Carbonate Hill limestone is named from exposures in the vicinity of the Carbonate Hill (McGhee) mine, on the east side of the Peloncillo Range in sec. 34, T. 24 S., R. 21 W. No complete section could be measured at this locality, but numerous exposures are present in and around the mine. A stratigraphic section was studied and measured in detail west of the mine on the upper slopes of McGhee Peak.

In addition to the outcrops in the vicinity of McGhee Peak and the Carbonate Hill mine, the Carbonate Hill limestone is exposed on the east side of the small ridge in T. 25 S., R. 20 and 21 W.; near the north end of this same ridge; on the east slope of the range about midway between the Carbonate Hill mine and Blue Mountain; and on the west side of the range about a mile south of the Silver Hill mine.

The limestone is soft and easily erodible and crops out mostly in low hills. Where the outcrop crosses the ridges, saddles and benches are the characteristic topographic expression.

The Carbonate Hill limestone is 113 feet thick where measured on the northeast side of McGhee Peak, but elsewhere it is close to 200 feet thick. Just north of the Carbonate Hill mine 155 feet of the formation crops out, with the base unexposed. East of the main shaft at least 200 feet of limestone is exposed, although faulting may have caused a repetition of beds. On the ridge in R. 20 and 21 W., T. 25 S., 190 feet of limestone was measured, and just west of the north end of this ridge, approximately 225 feet of limestone was measured. South of the Silver Hill mine the Carbonate Hill limestone is 200 feet thick. It thus appears that 200 feet is a close approximation to the average thickness of the limestone and that the thinness of the formation on McGhee Peak is exceptional. No faults were recognized in the vicinity to account for the thinness. Nevertheless the intrusion nearby of monzonitic sills slightly higher in the section appears to have been accompanied by faulting, and bedding-plane faults in the Carbonate Hill limestone may have escaped notice.

The formation is conformable with both the underlying McGhee Peak formation and the overlying Still Ridge formation.

The Carbonate Hill limestone consists largely of thin-bedded, coarse- to medium-grained, dark-gray, sandy calcarenite which weathers brown or gray. Some of the beds are friable. Thin conglomeratic beds consisting of small subangular pebbles rarely more than an inch in diameter, in a sandy limestone matrix, occur in the lower part of the formation. Most of the pebbles are limestone; a few are chert. In most areas the base of the formation is marked by a prominent bed of brown-weathering limestone containing an abundance of large oyster shells. Similar beds are found throughout the formation. Many of the limestone beds consist almost wholly of fragments of shells in a sandy matrix.

Characteristic of the formation are beds 8 feet to 10 feet thick, which consist almost entirely of pelecypod shells (pl. 6A). Three shell beds, separated by calcarenite, occur on McGhee Peak; two 8-foot beds and three thinner beds are present south of the Silver Hill mine; in the vicinity of the Carbonate Hill mine a number of shell beds crop out, but faulting in the vicinity obscures the exact number. The shell beds occupy an interval of about 50 feet in the lower half of the formation.

In the creek just north of the main shaft of the Carbonate Hill mine, one shell bed is underlain by a 3-foot bed of poorly cemented calcareous sandstone which consists of very fine, clear, subround to subangular, very well-sorted, quartz-sand grains. Pelecypod shells are imbedded in the uppermost part of the sand layer and also constitute the bulk of the overlying 10 feet of limestone. Overlying the pelecypod bed is another bed of sandstone, similar to the bed below the limestone, and overlying it is another, thinner, shell bed. These sand beds appear to be neritic deposits upon which, and within which, the pelecypods lived.

The shell beds are composed dominantly of pelecypods, but gastropods, ammonites, and a few corals also occur. Fossils also are present in other beds of the formation. The large oyster *Exogyra* cf. E. *texana* Roemer is abundant in many beds, but is not associated with other fossils except in sec. 18, T. 25 S., R. 21 W., where a few fragments were identified as *Requienia* sp. Elsewhere gastropods, corals, ammonites, and rudistid and other pelecypods are present. No echinoids or *Orbitolina* were found. Rudistids are uncommon and no reef facies was observed. The pelecypod assemblage in the shell beds indicates warm-water near shore conditions, and the neritic sand, calcarenite, and conglomerate are also indicative of littoral, warm-water environment.

The fossils collected from the Carbonate Hill formation, most of them in the vicinity of the Carbonate Hill mine, are listed below. Preservation of the pelecypods is good, but they are difficult to extract from the rock. When the rock is broken the internal molds pop out, but the shells are difficult to separate from the matrix. Many of the internal molds weather free. Identification is thus largely by means of the internal molds. The same statements are true of the gastropods and ammonites, but not to so great a degree as to the ammonites. Fossils from the Carbonate Hill limestone include:

Acanthohoplites sp. aff. *A. aschiltaensis* Sinzow
Parahoplites sp. aff. *P. campichei* (Sinzow)
Trigonia sp. aff. *T. Stolleyi* Hill
Trigonia sp.
Astarte sp.
Clementta sp.
Pleuromya sp.
Ostrea sp.
Pecten sp.
Cyrena sp.
Lithophaga sp.
Cucullaea sp.
Anatina sp.
Turritella sp.
Actaeonella sp.
Orbicella? sp.
Algae(?)

As most of the fossils collected from the Carbonate Hill limestone are internal molds of pelecypods with no discernible ornamentation or dentition, identification below generic rank is hardly possible. Inasmuch as all the genera are long range, these fossils are of little use stratigraphically.

Among the ammonites collected near the Carbonate Hill mine, however, A. A. Stoyanow identified a form very close to *Parahoplites campichei* (Sinzow) and a fragment which is very close to the genotype of *Acanthohoplites, A. aschiltaensis* Sinzow (letter, June 14, 1956 and June 8, 1956; and letter from R. A. Zeller, May 4, 1956). *Acanthohoplites* and *Parahoplites* are characteristic of the upper part of the Gargasian substage of the Upper Aptian Stage (Humphrey, 1949, p. 106; Neaverson, 1955, p. 494). According to Stoyanow (letter, June 14, 1956) the presence of a large *Trigonia* of the pseudoquadrate group and the absence of lower Gargasian forms (present in the lower members of the Lowell formation) corroborate the age determination. The Carbonate Hill limestone is thus upper Aptian (upper Gargasian). It is older than any beds that have been identified from the Trinity strata of the Little Hatchet Mountains, and is about the same age (Gargasian) as some beds from the Big Hatchet Mountains (Zeller, R. A., letter, May 4, 1956). The strata from the Big Hatchet Mountains and the Carbonate Hill limestone are the only known Aptian outcrops in New Mexico.

In the section from the Ninety-one Hills south of Bisbee, described by Stoyanow, the *Acanthohoplites* zone occurs in the Quajote member of the Lowell formation (Stoyanow, 1949, p. 16-18). A similar fauna, containing *Acanthohoplites* and *Parahoplites* is present in the upper part of the La Pena formation of the Sierra de los Muertos, near Saltillo, Coahuila, Mexico (Humphrey, 1949, p. 103-107). On the basis of the ammonite fauna, the Carbonate Hill limestone is considered equivalent in age to the Quajote member of the Lowell formation and to the upper La Pena, and to strata in the lower part of the Cretaceous sequence in the Big Hatchet Mountains. According to Humphrey (1949, p. 107), the La Pena formation corresponds to the upper Cuchillo formation of northeastern Coahuila; the lower member of the Cuchillo formation of the Acatita-Las Delicias area of southwestern Coahuila; to the 0 tates member of the Tamaulipas limestone of southern Tamaulipas; and to most of the Travis Peak formation of the outcrop area in central Texas.

Still Ridge Formation

The Still Ridge formation is named from exposures on Still Ridge, just north of the Carbonate Hill mine. The formation is excellently exposed on the south side of Still Ridge; likewise on the crest and upper slopes of the small ridge in R. 20 and 21 W., T. 25 S. It is also exposed west of the Carbonate Hill mine and south of the Silver Hill mine. It is resistant and characteristically forms high ridges and steep slopes, on which numerous small cliffs mark the more massive and resistant beds.

The formation consists largely of beds of silty and sandy limestone, but beds of sandstone and calcareous sandstone are prominent in the upper and lower parts. Thin beds of shale, in places metamorphosed to hornfels, occur west and northwest of the Carbonate Hill mine. The upper part of the formation contains two or three beds of conglomerate up to 4 feet thick, which consist of well-rounded limestone pebbles averaging 1 inch in diameter in a matrix of coarse quartz sand.

Most of the strata consist of very fine-grained silty-looking arenaceous brown-weathering black conglomerate limestone and limestone conglomerate. The conglomerate texture is difficult to discern on a freshly fractured surface, for the rock simulates a siltstone or fine-grained limestone. The matrix, however, weathers pale yellowish brown; the pebbles weather medium gray and are more susceptible to solution than is the matrix. The result is a pale yellowish-brown rock with depressed medium-gray blotches or with voids from which the pebbles have been completely removed. In most of the beds the pebbles constitute less than 15 percent of the total rock, and the beds are correctly called conglomeratic limestone. In other beds the pebbles are more abundant, and in some they are the dominant component of the rock. These would be correctly classified as limestone pebble conglomerate. The pebbles are subround and may be detrital material derived from the underlying Carbonate Hill limestone which they resemble.

The conglomerate limestone strata are medium- to thick-bedded and form small cliffs. Mechanical disintegration results in a rubble of angular blocks, which covers the more gentle slopes. In many localities weathering has resulted in a light-colored porous zone a fraction of an inch thick around the limestone rubble blocks from which the calcareous material has been leached.

The sandy limestone is medium-bedded, medium-grained, gray, and friable, with prominent crosslaminations on the weathered surface. The sandstone beds are mostly calcareous, and many are gradational into arenaceous limestone above or below. They are medium-bedded, fine-grained, well indurated, and show crosslaminations on the weathered surface.

Metamorphism of some of the calcareous sandstone, calcareous shale and arenaceous limestone in regions adjacent to igneous activity has resulted in well-indurated and siliceous beds which resemble hornfels. Segregations of epidote and radiating crystals of tremolite are present in these beds.

On the south slope of Still Ridge, 658 feet of strata are included in the Still Ridge formation. On the east side of the ridge, in R. 20 and 21 W., T. 25 S., 575 feet of strata was measured between the underlying Carbonate Hill limestone and the overlying Johnny Bull sandstone. No reason for this discrepancy in thickness is known. No measurement of the thickness of the formation was made in the area south of the Silver Hill mine.

The conformable contact with the underlying Carbonate Hill formation is drawn at the top of the characteristic Carbonate Hill limestone. The upper contact, also conformable, is drawn at the base of the thick-bedded quartzitic sandstone, and corresponds to the upper limit of calcareous sedimentation. Along the eastern part of Still Ridge the formation is overlain by volcanic rocks. Although the contact between these two rock types was not observed, there appears to be a slight discordance of dip and strike between them.

No fossils were found in the Still Ridge formation, except for some indeterminable fragments of silicified wood on the ridge immediately north of the Carbonate Hill mine. The exact age of the formation is thus in doubt, but it is considered to be early Cretaceous in age. No attempt is made to correlate the formation with other formations in the region. It is probably correlative with the upper part of the Bisbee group of Arizona, possibly with the lower part of the Cintura formation, and possibly with part of the section in the Little Hatchet and Big Hatchet Mountains of southwestern New Mexico.

Johnny Bull Sandstone

The Johnny Bull sandstone is named from the Johnny Bull mine, about a mile due east of the central part of the type section. It was measured along the south side of a prominent hill just north of the road to the Silver Hill mine, in the SE¼ sec. 4, T. 25 S., R. 21 W.

The formation crops out in the broad band extending northwest and southeast from the type section; it also occupies the highest point on Still Ridge and the crest of the northern part of the small ridge in R. 20 and 21 W., T. 25 S. It is a resistant formation that forms the crests and higher parts of ridges.

Sandstone and interbedded shale comprise the major part of the Johnny Bull formation. South of the type area thin limestone beds are present in what appears to be the upper part of the formation. As faults in the vicinity obscure the exact relationships, the limestone beds may represent displaced portions of lower stratigraphic units.

The shale beds are poorly exposed at the type locality and are recorded mostly by covered intervals. In the eastern part of the area, where better exposed, they are typically thin bedded and brown.

A conglomerate bed 2-3 feet thick, containing chert and quartzite pebbles, occurs 28 feet above the base of the formation on Still Ridge, and a similar conglomerate bed 2-3 feet thick occurs 25 feet above the base of the formation on the ridge in R. 20 and 21 W., T. 25 S. At the type locality the base of the formation is not exposed.

Sandstone constitutes most of the formation. Many of the beds are well indurated and thick, and form resistant ledges. Others are thin, soft, and argillaceous, and are less resistant to erosion. Colors range from white to gray, pink, and brown. The light-colored sandstone is a medium- to fine-grained well-sorted orthoquartzite. Thinsection study of a typical example showed more than 95 percent of well-rounded clear quartz grains, many with overgrowths, 1-2 percent of sericitized feldspar, and 1-2 percent of clay and metamorphic-rock fragments. The latter includes phyllite and schist. The quartz grains may have been derived from a distant source, but more probably they are reworked Bolsa quartzite. The metamorphic rock fragments were derived from Pre-cambrian metamorphic rocks exposed to the north and west of the Peloncillo Mountains.

The darker-colored sandstone is commonly fine grained and grayish brown; it weathers brown with red streaks. Thinsection study show this to be a subgraywacke. It consists of fine-grained angular and subangular quartz grains in an illite groundmass. About 10 percent of the rocks consists of metamorphic-rock fragments, most of which are mica schist or phyllite. Specks of magnetite and hematite are abundant. The sandstone is poorly sorted, and this characteristic, plus the angularity of the grains and the presence of abundant metamorphic-rock fragments, may indicate deposition in a neritic or, possibly, a fluvial environment. The two distinct types of sandstone alternate in the sequence, indicating an alternation of source and of environmental condition, but the subgraywacke is more abundant in the upper part. A light-gray or pinkish fine-grained well-indurated sandstone is also prominent in the sequence.

No complete section of the Johnny Bull sandstone was observed. At the type locality 1,047 feet of strata was measured, but faults form both the upper and lower limits of the formation there. At the other two exposures only the lower part is present. On Still Ridge, only the lowest 60 feet of the formation is present, and on the ridge in R. 20 and 21 W., T. 25 S., only the lower 500 feet. The lower contact both in this area and on Still Ridge appears to be conformable, with no evidence of an interruption of sedimentation after the deposition of the Still Ridge formation. No information is available about the upper contact of the formation.

No fossils were found in the formation and no determination of its age could be made, although its early Cretaceous age is conjectured. No attempt is made to correlate it with other formations in the region. The Cintura formation in the Bisbee region, the upper "elastic" beds in the Big Hatchet Mountains, and the Corbett sandstone of the Little Hatchet Mountains occupy similar stratigraphic positions.

Volcanic Sequence

Quartz Lathe

The crest and most of the northern slope of Still Ridge is underlain by a holocrystalline equigranular fine-grained to aphanitic gray to greenish-gray and light-brown altered quartz latite. Microscopic examination shows large crystals of quartz, orthoclase, andesine, and biotite in a microcrystalline matrix which consists mostly of feldspar laths. Apatite, sphene, magnetite, and ilmenite are present in minor amounts.

Quartz occurs as corroded and embayed euhedral crystals, many of which are cracked, and comprises 10-15 percent of the rock, excluding the matrix. Orthoclase also occurs as corroded and cracked euhedral crystals, and much of it is sericitized and kaolinized. Andesine, close to An_{40}, constitutes 60-70 percent of the total feldspar. Some of the andesine crystals show concentric growth lines, but there appears to be no difference of composition between the separate zones. The andesine is altered to sericite, epidote, and kaolinite. Biotite crystals are partly altered to muscovite and chlorite, but still show distinct pleochroism. Magnetite and ilmenite, the latter partly altered to leucoxene, occur in euhedral and anhedral grains disseminated through the rock and as alteration rims around some of the biotite crystals and what originally may have been sphene crystals. Apatite and sphene are present, but not abundant. A few intensely altered lithic fragments are present, and near the crest of the ridge, about half a mile north of the Carbonate Hill mine, boulders 2-3 feet in diameter of coarsely crystalline Precambrian granite occur in the basal part of the quartz latite.

Throughout its outcrop area the quartz latite is greatly altered. Chlorite and sericite are both prevalent, but epidote is by far the most abundant of the alteration products. It permeates the rock, occurring throughout the matrix, and replacing feldspar and biotite crystals. Small spherical masses of bright-green acicular crystals are common and small veinlets and streaks of epidote are present locally. The abundance of epidote colors the rock green or produces a green-splotched effect.

Near the top of the quartz latite, flowage produced an alternation of layers of coarse-crystalline and fine-crystalline material. At an excellent exposure in the canyon in the SE¼ sec. 28, T. 24 S., R. 21 W., the coarse material contains crystals up to 1 mm in diameter, and the fine material contains crystals of microscopic size. The layers are only a few centimeters thick and are lenslike and discontinuous. Color differences suggest a mineralogical as well as a textural segregation.

Planar structures within the quartz latite dip 30°-40° in a northerly direction, except for local variations probably due to faulting. The attitude of these planar structures is due to tilting since extrusion.

Conglomerate, differing only slightly from the overlying Bobcat Hill conglomerate, is interbedded with the quartz latite east of Bobcat Hill. It is described below in the section on the Bobcat Hill conglomerate.

The quartz latite rests on Cretaceous sedimentary rocks of the Still Ridge and Johnny Bull formations. On the crest of Still Ridge, it successively overlies, from east to west, younger beds of these formations, although there is little difference in the attitudes of sedimentary and volcanic rocks. In the N½ sec. 35, T. 24 S., R. 21 W., it is separated from the Cretaceous sedimentary rocks by a mass of andesite that appears to be intrusive. This andesite may have been extruded before the outpouring of the quartz latite and the contact between the two rock types may be a nonconformity, or it may have been intruded after the extrusion of the quartz latite and the contact would then be intrusive. The field relations are obscure. If the latter interpretation is correct, the andesite is undoubtedly related to the sequence of andesite volcanic rocks described below.

The quartz latite is overlain unconformably by the Bobcat Hill conglomerate, and boulders of quartz latite up to 3 feet in diameter are present in the basal beds of the conglomerate.

Mineralogically the quartz latite is almost identical with the quartz monzonite porphyry sills and dikes that intrude the Cretaceous sedimentary rocks; it may be the volcanic equivalent of these intrusive rocks. Like the quartz monzonite porphyry, its age is probably late Cretaceous or early Tertiary. The quartz latite underlies the Bobcat Hill conglomerate, which in turn underlies the andesite volcanic rocks; therefore, the latite is older than the andesite. The quartz monzonite porphyry, however, intrudes and thus is later than at least some of the andesite. Two interpretations are possible: (a) The quartz latite may represent an early eruption of a magma of quartz monzonitic composition, prior to the extrusion of the andesite, or (b) the andesite intruded by the quartz monzonite porphyry may be older than the andesite overlying the quartz latite, and the quartz monzonite porphyry and the quartz latite may be part of the same period of eruptive activity. This would necessitate two periods of andesite extrusion separated by a period during which rocks of quartz monzonite composition were erupted. For reasons stated below in the section on the andesite, all the andesite is believed to belong to one period of igneous activity. The first hypothesis is thus preferred.

Bobcat Hill Conglomerate

The Bobcat Hill conglomerate is named from exposures on the north and west sides of Bobcat Hill, near the corner common to secs. 25, 26, 35, and 36, T. 24 S., R. 21 W. It is better exposed in the S½ sec. 27, in the vicinity of the North Star mines, and extends east and west in an almost continuous band across the southern parts of secs. 26, 27, and 28, T. 24 S., R. 21 W. The formation is easily erodible and forms low hills and the lower slopes of ridges capped by more resistant rocks.

Alternating beds of sandstone and conglomerate constitute the formation. Some silty beds are present locally in the upper part, and a thin but areally extensive limestone bed is present near the base. The Bobcat Hill conglomerate is distinguished from the conglomerate of the McGhee Peak formation by the presence of volcanic-rock fragments.

The Bobcat Hill conglomerate was studied in detail and strati-graphic sections were measured at two localities: Near the North Star mines (MS 14), and about a mile west (MS 15). A variation in composition and thickness was observed between the two areas. Less detailed studies of the formation east of the North Star mines showed little variation in thickness and composition between this area and the vicinity of the North Star mines.

The formation thickens from 724 feet in the western part of the area to 1,138 feet near the North Star mines. The percentage of discrete conglomerate beds decreases from 33 percent in the west to 26 percent in the east, but their total aggregate thickness increases from 241 feet to 295 feet. This condition may have little significance, as many of the conglomerate beds are lenses which grade laterally into sandstone, and many sandstone beds contain conglomerate lenses. More important is the lateral variation in lithology of the detrital fragments which compose the conglomerate and sandstone. Volcanic-rock fragments are more abundant in the eastern area, and in the upper part constitute at least 80 percent of the rock fragments larger than sand size. Limestone pebbles and cobbles are also more abundant in the east, and the conglomerate in this area can be best described as a limestone- and volcanic-pebble conglomerate. Additional differences are the presence of a thin limestone bed near the base of the section in the eastern part of the area and its absence farther west, and the presence of siltstone and silty shale in the uppermost beds in the eastern exposures.

In the western area the sandstones are characteristically medium-bedded, fine-grained, light grayish-green to yellowish-gray, slightly calcareous, impure volcanic arkoses. Angular to subangular quartz grains derived from earlier rocks surrounding the basin of deposition comprise about 80 percent of the rock. Other detrital material having a similar origin includes altered orthoclase, microcline, and plagioclase; chert; magnetite; and metamorphic-rock fragments. Fragments of fresh angular plagioclase, fresh euhedral biotite, magnetite, and hematite are derived from volcanic rocks extruded only slightly previous to, or perhaps contemporaneous with, the deposition of the sediments. The conglomerate beds and lenses contain rounded pebbles and cobbles, most of which are composed of quartzite, sandstone, or Paleozoic limestone. Volcanic-rock fragments derived from the subjacent formation are present in the lowest members, and a few andesitic pebbles are present higher in the section. The limestone pebbles are subordinate in amount and are most abundant in the upper part of the formation. Fragments in the lower beds are for the most part less than 3 inches in diameter, but range up to 12 inches in diameter.

In the vicinity of the North Star mines the sandstone in the lower third of the formation closely resembles the sandstone in the western section. In the upper part of the formation, however, the sandstone and the conglomerate is grayish red purple and dark purple, imparting a distinctive appearance to that part of the formation. The color is due to the greater abundance of hematite in the sandstone and in the matrix of the conglomerate, and to the greater abundance of purple andesite fragments in the conglomerate. The sandstone is an impure volcanic arkose consisting mostly of quartz, but with some unaltered angular plagioclase fragments, sand-size volcanic rock fragments, and rounded limestone fragments. In the lowermost beds a clay mineral which may have been derived from tuffaceous material forms the matrix between the sand grains. The sandstone is finer grained toward the top of the formation and the upper 110 feet consists of grayish-red purple and dark medium-gray shale and shaly siltstone.

The conglomerate in the eastern part of the area consists predominantly of pebbles and cobbles of andesite and limestone, the andesite increasing in abundance upward in the section (p1. 7A). In the uppermost conglomerate beds, andesite constitutes 80-90 percent of the fragments. Limestone fragments are not present below the thin limestone bed 145 feet above the base of the formation. The limestone fragments are subround to round and are probably derived entirely from upper Paleozoic limestones. A few fragments of granite were observed in the lower beds.

A single 1-foot bed in the vicinity of the North Star mines is composed of medium light-gray, fine-grained, unfossiliferous limestone containing numerous small ooids which are best observed on the freshly fractured surface. Microscopic sections of the limestone showed no structure which could be identified as organic in origin. The limestone was not present in the western part of the area. East of the North Star mines, in the area just west of Bobcat Hill, a single 1-foot bed of medium light-gray limestone that occurs at approximately the same stratigraphic horizon consists almost wholly of algal remains (pl. 6B). These are rodlike or stemlike bodies ranging up to 3 inches long and one-half inch in diameter. Weathering causes them to stand in relief on the surface of the limestone. Most of the algal remains are oriented so that their long axis is parallel to the bedding plane. As exposures of the formation are not continuous between the outcrop areas the two limestone beds cannot be correlated with certainty.

Conglomerate beds closely resembling the Bobcat Hill conglomerate crop out north and northwest of the Carbonate Hill mine. The beds are beneath or possibly within the volcanic rocks which immediately underlie the Bobcat Hill conglomerate and overlie the Still Ridge formation. The maximum thickness of these conglomerate beds is about 300 feet, and they appear to lens out rapidly along the strike. Their abrupt disappearance, however, may be due to faulting. The conglomerate is characterized by abundant cobbles and pebbles of angular to subround metamorphic rock fragments, chiefly schist and phyllite (pl. 7B), and by fossil logs that range from 1 foot to 4 feet in diameter; logs 15 feet long are present. Fragments are composed not only of metamorphic rocks but also of granite, volcanic rocks, black chert, and limestone. The size and angularity of the metamorphic-rock fragments indicate that they were transported relatively short distances. The closest known area from which such rocks could have been derived is Gold Hill, about 30 miles northeast. Precambrian metamorphic rocks, however, may have been exposed in nearer areas at the time of deposition of the conglomerate.

The Bobcat Hill conglomerate rests with obvious unconformity upon the volcanic rocks. Large boulders of the underlying volcanic rocks are present in the basal beds of the formation, and local variations in the relief of the surface upon which the formation was deposited can be observed. The sandstone and siltstone at the top of the formation appear to be overlain conformably by the andesite.

Andesite

Andesite and associated dacite and basalt are the surficial rocks in most of the area between the North Star and Silver Hill mines and State Highway 14, occupying about 20 square miles. The colors of the andesite and of the soil formed in areas underlain by these surficial rocks are distinctive and different from those in the areas underlain by the sedimentary, intrusive, or acid volcanic rocks. Purple, red, and brown predominate. Andesitic exposures can be recognized in the field by their color and on aerial photographs by their shade. The area underlain by the andesite and associated rocks also has a more subdued topography than is characteristic of the area underlain by the sedimentary rocks or the acid volcanic rocks. The andesite is not uniform in composition, texture, or general appearance, a condition which is reflected in its response to erosion and effect upon the topography. Within the area of andesite rocks, the topography ranges from low rounded hills on the east and west flanks of the range to high steep peaks which form the crest of the range.

The heterogeneity of the andesite, the difficulties of tracing a continuous flow or a sequence of flows laterally, and the later tectonism and alteration which profoundly affected the rocks, has imparted a corresponding difficulty to the mapping, and to the correlation and interpretation of these rocks. Although several varieties are recognized, with few exceptions no fixed boundaries can be placed on their areal extent, nor can a distinct sequence of events be determined. Differences in mineral composition, texture, color, degree of alteration, structural attitude, and topographic expression were observed, but most of these are slight and not of sufficient magnitude definitely to set off some of these rocks from others. No major unconformable contacts were seen between any of the several flows; no major erosion surfaces or buried soil zones were observed. None of the criteria, in other words, that might be of assistance in separating an earlier from a later sequence were recognized. All appear to be a part of a continuous period of volcanic activity during which great amounts of lava, most of which was of andesitic composition, were extruded. The total thickness of the flows exceeded 3,500 feet in the area east of the Duke mines, and was probably greatly in excess of 5,000 feet in the area between the North Star mines and State Highway 14. The presence of what appears to be thin devitrified tuff beds on the south side of Attorney Mountain, and the brecciated character of some of the andesite north and east of Robinson Mountain attest to short periods of explosive activity, but the flow structure, thin-bedded character of much of the volcanic rocks, and the prevalence of flow breccias throughout the area, indicate that most of the activity was relatively quiet.

Two small areas, one on the north slope of Still Ridge, and the other in the valley between Still Ridge and McGhee Peak, are shown on the geologic map as andesite. These are interbedded within the sequence of layered rocks. They may be sills intruded into the Cretaceous strata or may represent lava flows which were extruded about the time of formation of the enclosing rocks.

All the andesite has been mapped as a unit on the geologic map accompanying this report. For ease in description, and in order to emphasize the differences between varieties in separate areas, arbitrarily chosen divisions have been made, and the different types are described separately.

The most abundant and, probably, the most characteristic of the andesite rocks in the Peloncillo Mountains are those which are exposed in the low hills on the east side of the range between the Carbonate Hill mine and State Highway 14. This type extends westward to the base of the high peaks that make up the crest of the range in the area. Similar rocks occur in the area north of State Highway 14 and south of the limits of the Quarry Peak rhyolite complex.

Typically this rock is a holocrystalline or hypocrystalline aphanitic-porphyritic gray to grayish red-purple andesite with a hyalopilitic groundmass. The phenocrysts, which constitute 10-30 percent of the rock, are commonly 1-3 mm long and in many places are parallel in alinement. Andesine (close to An_{46}) constitutes about 75 percent of the phenocrysts. The crystals are euhedral, and some show concentric growth lines, but no change of composition, as indicated by optical orientation, is observed in the concentric zones. In one specimen an overgrowth of potassium feldspar or untwinned albite was observed on some of the andesine crystals. In many of the sections examined, the intensity of the alteration precluded an exact determination of the type of feldspar present, but the feldspar was presumed to be the same as that in those sections in which a determination could be made. Pyroxene is abundant; it constitutes 20-25 percent of the phenocrysts in those sections in which alteration does not mask its original character. It occurs as euhedral crystals slightly larger than the feldspar crystals. Polysynthetic twinning, an extinction angle of about 29 degrees, and a small optic angle indicate that the pyroxene is probably pigeonite. Biotite, in flakes and euhedral crystals, is present in amounts up to about 2-3 percent in most sections examined. A few euhedral crystals of quartz were observed, but the total primary quartz probably does not exceed 1 percent. It occurs also as cavity fillings. Magnetite, as primary euhedral crystals and small grains, and also as an alteration product of the biotite and pyroxene, is abundant. The matrix consists of a microcrystalline mixture of feldspar laths, magnetite grains, and possibly altered volcanic glass.

The rocks are intensely altered. Chlorite and sericite have partly replaced the biotite, and the andesine is sericitized and kaolinized. Magnetite rims around the biotite and pyroxene crystals are common, and in some of the sections the entire crystal is replaced by magnetite. Epidote, however, is the characteristic alteration product. It pervades the rock, replacing the pyroxene and feldspar and occurring throughout the matrix. Concentrations of bright-green radiating crystals of epidote as much as one-half inch in diameter are common and smaller blebs and veinlets are present. The presence of epidote imparts a green tinge to the rock in many places. The epidote replaces the chlorite and the sericite, but the kaolinite is later than the epidote. In many of the feldspar and pyroxene crystals, epidotization has proceeded from the center of the crystal outward, and a core of epidote is surrounded by relatively unaltered andesine or pigeonite.

Similar to the andesite just described, except that euhedral quartz crystals are present in amounts sufficient to warrant calling the rock a dacite, is the rock exposed north of State Highway 14 in secs. 5, 6, and 7, T. 24 S., R. 21 W. The quartz phenocrysts are embayed and corroded and are surrounded by reaction rims of fine-grained kaolinized and epidotized feldspar. Pyroxene comprises only about 5 percent of this rock. A few apatite crystals were also observed.

Some of the exposures of andesite along State Highway 14 are less porphyritic and are darker red than the rock described above as typical of the andesite in this area. Mineralogically this dark-red andesite is similar to the typical andesite, although no quartz, and lesser amounts of pyroxene and biotite are present. The feldspar is the only essential mineral present in large enough crystals to be identified in most of the specimens, but pyroxene and biotite can be observed in others. In the specimens examined, the feldspar approaches labradorite. Epidotization is not so far advanced in this area as it is farther east, and the feldspars are less altered, although chlorite, sericite, and kaolinite are all present. Cavities and voids in the andesite, particularly in secs. 10 and 11, adjacent to State Highway 14, are filled with clear and milky-white opal, but no large masses of opal were observed.

In the vicinity of Mineral Mountain mine, and on the ridges to the west, the andesite is so completely altered that little can be determined of its original character. Shiny black phenocrysts which megascopically appear to be pyroxene or amphibole, are actually magnetite, undoubtedly secondary, which has replaced the primary minerals. The feldspars are completely altered to epidote and to kaolinite, and their original character is indeterminable. Only the form of the original crystal persists, and even this is indistinct in some sections. The matrix consisted originally of microlites of feldspar and small grains of magnetite in a vitric groundmass, but the glass is now devitrified and the feldspar is epidotized. Flow lines around the larger phenocrysts can be observed. Epidote is extremely abundant, and some of the rock appears to consist almost entirely of epidote, calcite, and magnetite or limonite. Where less abundant, it occurs throughout the matrix, fills veinlets, and forms spherical masses as large as 5 mm in diameter. In the spherical masses and veinlets it occurs as clear bright-green acicular crystals. Calcite is associated with the epidote, and in places forms a central core within the epidote concentrations. Dark-brown and black acicular crystals, which may be hematite, are common in some of the sections observed. This entire area is traversed by mineralized fractures, which probably account for the excessive alteration of the andesite.

Between the Mineral Mountain mine and Charles mine a dark-red porphyritic andesite is the surficial rock over large areas. The phenocrysts, many of which are 1 cm long and 0.5 cm wide, are plagioclase, but in the specimens examined they were intensely altered and their composition could not be determined. In places they constitute 10-15 percent of the rock. They show concentric growth lines, which probably do not represent zones of different composition. Smaller phenocrysts of what orginally were probably pyroxene are present. These are altered to magnetite, calcite, and chlorite. Magnetite is abundant, both as primary euhedral crystals and grains, and as secondary rims around the pyroxene crystals. Apatite is abundant, and crystals up to 2 mm long were observed. The matrix consists of kaolinized feldspar laths and magnetite grains with a pilotaxitic texture in which the small laths bend around the phenocrysts. Megascopically the parallel alinement of the large phenocrysts and of numerous small white streaks imparts a distinct flow structure to the rock.

North of the Charles mine some of the andesite contains quartz as small anhedral grains in the matrix in amounts up to about 5 percent. Otherwise these rocks are typical andesites, with altered and unrecognizable plagioclase feldspar and pyroxene with rims of magnetite set in a matrix of feldspar laths with a pilotaxitic texture. Calcite, magnetite, epidote, and kaolinite are alteration minerals. Small cubes of limonite, pseudomorphic after pyrite, are present in some of the rocks, and these are characteristically bleached and stained brown.

At the Charles mine, and to the west on Robinson Mountain, the andesite contains more calcic feldspar, which approaches An_{50} in composition. Magnetite is abundant; it constitutes about 10 percent of the rock. Apatite is present. Epidote occurs as small segregation throughout the rock, but the feldspars are mostly kaolinized. Some of the andesite is dark red and very fine grained and probably has a devitrified matrix. Flowage is pronounced in the matrix and some of the feldspar phenocrysts, which are alined parallel to the flow structure of the matrix, have been fractured and broken into 2 or 3 parts during flowage.

The andesite composing most of Attorney Mountain differs from that first described in that it is darker and redder and less porphyritic. Many of the small feldspar phenocrysts are parallel in alinement, and the matrix is partly glass or devitrified glass. Flow lines are prominent microscopically. The ferromagnesium minerals are less abundant, and the rock, consisting dominantly of andesine approaching labradorite in composition, is similar to that on Robinson Mountain. The rock is less altered and many of the feldspars have a distinctly vitreous luster. Segregations of bright-green epidote crystals, however, are common throughout the rock. Andesite breccia is common in this area and angular and subangular lithic fragments, some of which exceed 3 inches in diameter, are included in the rock. Most of the fragments are similar in composition to the matrix, and all are andesitic. Some, however, are distinct from any rocks in the immediate vicinity. The breccias are believed to be flow breccias, and the included fragments are part of the same flow within which they occur or were derived from previous flows.

The andesite forming Attorney and Robinson Mountains differs in its resistance to erosion from the andesite previously described. It occupies high rugged areas, and weathers to steep slopes and cliffs in contrast to the rounded hills present in areas where andesite is the surface rock. The prevalence of flow breccias may partly account for this difference in topographic expression.

The andesite which occupies the valley between Robinson and Attorney Mountains is silicified, pyritized, bleached, and greatly fractured. Much of the pyrite has altered to limonite, and brown stains, particularly along the fractures, are common. Because the fractured and altered rock has lessened resistance to erosion, a valley has been carved in it.

On the western side of the range, west of the Duke mines, 3,500-4,000 feet of almost vertical standing andesite flows and flow breccias crop out in an apparently uninterrupted sequence. Individual flows are a few feet to a few hundred feet thick. The sequence seems to be conformable upon the Lower Cretaceous McGhee Peak formation on the east, but is probably bounded by a fault on the west. The rocks vary in color, texture, mineral composition, amount of phenocrysts, and degree of alteration. Most are dark gray to grayish red purple, but a few light-gray to white layers occur. These latter are silicified and pyritized, and the result is bleaching of the original rock. Many of the beds are only slightly porphyritic, the phenocrysts constituting less than 10 percent of the total rock mass, but others contain 25-30 percent andesine (close to An_{44}) phenocrysts, most of which are less than 2 mm long. Pyroxene and hornblende crystals of about equal size are less abundant.

Magnetite is scattered abundantly through the matrix. No biotite was observed in any of the sections examined microscopically, but it may be present. Ilmenite commonly is associated with the magnetite and alters to leucoxene. Some of the lighter-colored beds contain a few embayed and corroded euhedral quartz crystals, and locally quartz is so abundant as to characterize one particular bed as a dacite. These same "dacites" contain secondary quartz, resulting from silicification, and limonitic stains and pseudomorphs after pyrite. The rocks are altered, with the production of chlorite, sericite, abundant epidote, calcite, and kaolinite. Some of the flows contain lithic fragments and are more properly flow breccias.

A long narrow fingerlike extension of this area of volcanic rocks extends southeast for more than a mile between exposures of sedimentary rocks, from which it is partly separated by faults. The rock exposed is a homogeneous, holocrystalline, mostly nonporphyritic aphanitic dark-red andesite and andesite breccia. It is similar in texture, composition, and color to the rock exposed in places along State Highway 80, in the vicinity of the Charles mine, and on the hill south of the windmill in the SE% sec. 32, T. 24 S., R. 21 W. The fragments constituting the breccia are difficult to distinguish from the matrix and are undoubtedly the earlier solidified parts of the flows. Microscopic examination shows the fragments to be tightly packed and molded one to another, with a minimum of matrix, as if they were partly plastic when final emplacement occurred. The matrix between the fragments is mostly magnetite grains and feldspar crystals.

The feldspar of the matrix appears to be andesine (close to An_{36}), but feldspar crystals in some of the fragments are more calcic than the feldspar in the matrix and fall within the range of labradorite (close to An_{54}). Solidification of part of the lava before all the plagioclase had crystallized effectively stopped the already crystallized calcic plagioclase from reacting with the remaining liquid; hence relatively high sodium feldspar formed during the final stages of crystallization. Together, the two feldspars represent the composition of the plagioclase portion of the original magma.

Some of the andesite is not brecciated; it contains small relatively unaltered, glassy feldspar phenocrysts about 2 mm long which appear to be close to An_{50} in composition. Other minerals present, with the exception of magnetite, are too altered to be determined, and chlorite and epidote mask their original character.

This mass of andesite is intruded by the quartz monzonite porphyry sill which lies above the Silver Hill mine. East of the Silver Hill mine in the center of sec. 4, T. 24 S., R. 21 W., the andesite is also intruded by a quartz latite dike which may be genetically related to the quartz monzonite porphyry sill, although it contains more quartz and less plagioclase than this latter rock, and may represent a separate period of intrusion. The undoubted intrusion by the quartz monzonite porphyry, however, dates this andesite as earlier than the quartz monzonite porphyry, which is postulated to be late Cretaceous or early Tertiary in age. Because of the general similarity in composition and degree of alteration of all the andesitic rocks, and the even greater similarity of this particular mass of andesite with flows and bodies of andesite scattered both geographically and stratigraphically throughout the area of andesite exposure, all the andesite is considered to antedate the quartz monzonite porphyry. Its age is, therefore, probably Cretaceous or very early Tertiary. Similar rocks from the Silver City region have also been dated as late Cretaceous or early Tertiary.

South of Steins, on Cedar Mountain and in the area to the west, thin-bedded andesitic flows appear to be interbedded with rhyolitic flows. Flow structure is prominent, and microscopic examination of the rock shows that much of the matrix was originally vitric but is now mostly devitrified. Intensely altered pyroxene or hornblende crystals and sericitized biotite flakes are oriented parallel to the layers of anhedral feldspar and quartz resulting from the recrystallization of the vitric matrix. A few spherulites are present and magnetite and epidote are both abundant. On Cedar Mountain these flows are tightly folded into vertical isoclinal folds.

In summary of the discussion of the andesitic rocks, the salient points are the general similarity of composition, texture and alteration, and the lack of any profound unconformity separating the rocks into two or more units. Mineralogically most of the variants consist of pyroxene, probably pigeonite or close to pigeonite in composition, some biotite, and large quantities of magnetite and ilmenite; these total about 20-25 percent of the rock, with the pyroxene comprising at least 75 percent of that total. Feldspar constitutes the greater part of the remainder of the rock but small amounts of quartz are present locally. The feldspar is calcic andesine, though locally labradorite is the dominant feldspar. Chloritization and sericitization are prevalent and the production of magnetite, wholly or partly replacing the biotite and pyroxene, is characteristic. Epidote is all pervasive, completely masking the original minerals in many places and commonly forming megascopic segregations of bright-green acicular crystals. The rocks are commonly slightly porphyritic, but the phenocrysts are mostly small.

The andesitic rocks represent an outpouring of lavas, possibly during the late Cretaceous, from vents in areas undetermined, which resulted in a sequence of flow and flow breccias that may be in places greatly in excess of 5,000 feet thick. They are conformable on and probably are interbedded with the Bobcat Hill conglomerate, and the volcanic fragments and debris contained in the sandstone and conglomerate of that formation are identical with the andesite flows which overlie them. The greater prevalence of volcanic debris in the easternmost exposures of the Bobcat Hill conglomerate indicates that at least during the earlier part of the period of volcanic activity the source of the volcanic material was from the east. The andesite unconformably overlies all rocks earlier than the Bobcat Hill conglomerate, or is in fault contact with these rocks.

Quarry Peak Rhyolite Complex

A series of flows, breccias, and tuffs of rhyolitic composition form the prominent peak west of Steins and north of the Southern Pacific Railroad and State Highway 14 (pl. 8A). An abandoned quarry, formerly operated by the railroad is at the base of the steep south-facing cliff. For convenience, in this report the peak above the quarry is called Quarry Peak. The name has no official status, however, and thus does not appear on the map. The sequence of rhyolitic rocks is called the Quarry Peak rhyolite complex. The Quarry Peak rhyolite complex also crops out west and northwest of Quarry Peak and north of Steins.

The resistance to erosion of the rhyolitic rocks depends largely on the stratification and structure of the different units. North of Steins where the complex is thin-bedded and easily erodible, a broad valley has been carved in the rhyolitic rocks. To the west, on Quarry Peak and the hills west of the peak, the complex is more massive and thick-bedded, and is much more resistant to erosion. In this area the complex forms high rugged peaks dominated by craggy outcrops and steep cliffs. Quarry Peak, with its steep south side, is a landmark that can be recognized at a distance of many miles as marking the north side of Steins Pass, through which the old Butterfield Stage Route and the present day highway and railroad cross the Peloncillo Mountains.

Most of the sequence consists of holocrystalline equigranular aphanitic white or light-gray rhyolite which contains a few small inconspicuous phenocrysts of quartz and feldspar. Microscopic examination shows less than 1 percent brown biotite, altered to chlorite. The feldspar is mostly orthoclase, but a few crystals of albite or oligoclase (close to An_n) are present. All the feldspar is partly kaolinized and imparts a dull chalky-white appearance to parts of the rock. The felsitic matrix is an intimate mixture of kaolinized feldspar and quartz, the former greatly predominating.

Interbedded with the rhyolite flows are beds of breccia. These do not appear to be flow breccias, and no flow structure was observed. The rock consists of angular fragments, most of which are rhyolite, but some of which were probably originally andesite, in a matrix of brown structureless clay. Many of the breccias are well bedded and sorted, and fine and coarse fragments occur in alternate layers a fraction of an inch to a few inches thick (pl. 8B). Crosslaminations were observed within the finer-grained portions of the rock. The breccia and tuff (as the finer-grained beds should be called) were undoubtedly deposited by the settling of detrital fragments of rhyolite and other rocks and of fine volcanic ash or dust in either an eolian or an aqueous medium. Two hypotheses for the origin of these lithic tuffs and breccias are presented.

The rocks could be the product of normal sedimentary processes resulting from the deposition in a lacustrine environment of detritus derived from the erosion of a rhyolitic terrain. The angularity of the fragments indicates short transportation, although the size of the fragments does not. The good bedding but imperfect sorting indicates an aqueous rather than an eolian environment of deposition. The degree of alteration of the fragments, which are now mostly a mass of fine-grained quartz, sericite, and kaolinite indicates a period of intensive weathering prior to transportation and erosion, or since deposition. The conclusion that weathering after deposition is the more probable is based on the assumption that weathering prior to erosion would have resulted in a greater degree of roundness of particles of the sizes present in the deposit. The fine clay matrix was probably derived from a separate source. If this hypothesis is correct, the arkosic breccias and arkosic sandstones, as they should be called, were deposited in a temporary lake and became intergraded laterally with the rhyolite flows.

A second hypothesis is that the rocks are lithic tuffs, not the result of normal erosional, transportational, and depositional processes, but rather of violent volcanic eruptions similar to, but on a smaller scale than, the eruption of Krakatoa. The acidic composition of the magma producing the rhyolite indicates a viscosity which may have resulted in a plug or dome of solidified rock filling the vent of the volcano between eruptions. Such a solid mass would act as a plug to contain the volatile gases, but would be fragmented into innumerable small angular particles when sufficient pressure was built up within the conduit to cause a violent explosion. Fine volcanic dust produced by the explosion would mix with the fragmented rhyolite as it fell. Later alteration of the volcanic dust to clay would produce the present-day clay matrix within which the rhyolite fragments are included. Deposition of the products of the eruption might have occurred either on land or within a shallow lake, or both. The excellent bedding and partial sorting of the material in the area north of Steins suggests that in this area a lacustrine environment was most probable. The rapid removal and transportation of the loose unconsolidated material that was deposited on the terrain surrounding the lake, and its almost immediate deposition in the lake would result in thicker deposits in the lake than on the area immediately surrounding it. This would account for the greater thickness of these beds in this locality. The interbedding of these lithic tuffs and the lavas indicate more than one eruptive cycle of explosion, lava flows, solidification of the plug, and explosion again. Minor unconformities within the sequence also attest to the multiplicity of events and the probability of erosion intervals and periods of quiescence alternating with periods of volcanic activity.

Included within the complex are small localized areas within which are lenses of fine-grained reddish-gray rocks which contain numerous small spherical bodies, most of which are about 5 mm in diameter.

These occur throughout the rock, but are more abundant near the base of the bed where they are in contact with one another, almost to the exclusion of the matrix. The spherical pellets have a concentric structure consisting of a core of fine-grained quartz, feldspar, and clay which grades outward toward very fine clay. Three distinct zones can be distinguished: The central granular core with no concentric structure, which constitutes over 75 percent of the pellet; an intermediate zone with a concentric structure formed by thin layers of clay separated by granular material; and the outer thinnest zone composed of concentric layers of clay packed close together with very little granular material. The rock matrix within which the pellets are included is similar in composition and appearance to the pellets, but is more porous.

These pellets are accretionary lapilli, or chalazoidites, and were formed during volcanic eruptions. Berry (1928, p. 598), in a detailed study attributed the formation of chalazoidites of Scinde Island, New Zealand, to aerial mixing of volcanic dust and moisture, stating that the concentric structure is due to a series of ascents and descents in turbulent masses of air containing various amounts of ash and moisture, and that the genesis of the chalazoidites was similar to that of hailstones. Pratt (1916, p. 450) described some spherical bodies or "mud balls," as he called them, formed at the time of the eruption of Taal Volcano, in southwestern Luzon, Philippine Islands, in February 1911. His description indicates that they are similar, except for the degree of lithification, to those in the Peloncillo Mountains. He believed that

> . . . the formation of mud balls has been rather characteristic of that type of volcanic activity which results in the explosive eruption of great clouds of dust-laden steam, at least where atmospheric conditions similar to those on the island of Luzon prevail.

Pratt (1916, p. 453) also recorded similar bodies from older volcanic deposits, probably of late Miocene age, in the Philippine Islands, which he believed were analogous to these recent mud balls and were formed in the same manner. Hovey (1902, p. 343) described similar drops of mud which fell during the 1902 eruptions on Martinique as the result of the immense amount of liquid mud formed within the eruption cloud through the condensation of moisture. Enlow reported chalazoidites in the tuff beds of the Rhyolite Canyon formation in the Chiricahua Mountains (1955, p. 1227) and they are present in Grant County, New Mexico, about 30 miles northwest of the Peloncillo Mountains. Although sparingly referred to in the literature, chalazoidites are probably common. Their presence in the Quarry Peak rhyolite complex may be further evidence of the explosive character of some of the eruptions.

Also included in the complex are beds of devitrified and spherulitic rhyolite which were undoubtedly originally vitric tuffs and vitric flows.

These beds contain a few euhedral quartz and feldspar crystals and a few small lapilli.

The Quarry Peak rhyolite complex is about 1,000 feet thick. East of Quarry Peak the rhyolite appears to rest with slight angular unconformity on the underlying andesite. North of Steins the overlying basalt appears to have flowed out across the beveled and tilted edges of the rhyolite, but south of Steins Mountain the relations are more nearly concordant. Even so, a discordance of 5-10 degrees in dip may be present in this area. The Quarry Peak rhyolite complex is intruded by the latite porphyry dikes, but is not so intensely altered as is the underlying andesite, and epidote is rare or only sparingly present.

Basalt

A very fine-grained holocrystalline nonporphyritic dark-gray to black rock lies above the Quarry Peak rhyolite complex on the south and west sides of Steins Mountain and on the hills east of Steins Mountain. Microscopic examination of specimens of the rock collected about a mile north of Steins show it to consist entirely of laths of andesine (close to An") and traces of magnetite. The feldspar is mostly in small laths or microlites, but a few larger crystals, slightly over 3 mm long, were observed. The feldspar is intensely altered, with flakes of sericite throughout the crystals, and kaolinite is present in a zone near the outermost edges of the crystals. The laths are all subparallel. The magnetite is in small grains scattered throughout the rock and comprises less than 2 percent of the rock mass.

No other thinsection of this peculiar rock was examined, but hand specimens from west of Steins Mountain are identical in appearance to the hand specimen from which the thinsection was made. The rock appears to be uniform in composition and texture wherever observed.

The essentially monomineralic composition of the rock, and the great contrast in the basic composition of the rock as compared to the more acidic Quarry Peak rhyolite and Steins Mountain quartz latite porphyry immediately below and above it, give it extreme petrographic interest. It is called a basalt in this report, merely to distinguish it from the andesite lower in the section. Petrographically it might more properly be called an andesite, because of the composition of the feldspar. A phaneritic rock of this composition would probably be called an anorthosite, however, and thus be classified with the basalt-gabbro clan; but the feldspar of an anorthosite is commonly labradorite, not andesine. Williams, Turner, and Gilbert (1955, p. 54) state that most of the anorthosites of the Adirondacks, Ontario, and Quebec consist of calcic andesine Ab_{50-55} and are sometimes called andesinite and classed with the lime diorites. The magma from which this rock solidified must have been almost devoid of iron and magnesium and extremely high in calcium and sodium, a very unusual composition.

The basalt rests on the Quarry Peak rhyolite complex with angular unconformity. It is overlain unconformably by the Steins Mountain quartz latite porphyry.

Steins Mountain Quartz Latite Porphyry

The Steins Mountain quartz latite porphyry is confined to the northern part of the mapped area, where it forms the upper part of Steins Mountain and the hills to the east. North and northwest of the area it is extensively exposed. As the rock contrasts sharply in color and topographic expression with the underlying Quarry Peak rhyolite complex, its limits are easily discernible. It is a resistant rock that forms rocky outcrops on Steins Mountain and the small hill about 1 mile north of Steins. Columnar jointing is conspicuous at these localities.

The quartz latite porphyry is a hypocrystalline porphyritic-aphanitic pinkish-gray rock, with numerous phenocrysts of quartz and feldspar less than 2 mm in diameter which constitute 25-30 percent of the rock. Lithic fragments are common, and small vitric fragments, most of which are flattened and lenslike, are oriented in layers, producing eutaxitic structure. Some of the originally vitric fragments have been devitrified and recrystallized to quartz and potassium feldspar, but others are still glassy.

The phenocrysts consist of deeply embayed and corroded euhedral crystals of quartz, large kaolinized euhedral orthoclase crystals, and plagioclase crystals less altered than the orthoclase. A maximum extinction angle of 15° was recorded for the plagioclase, but neither the index of refraction nor the optical sign could be determined. It may therefore be albite (near An_4) or andesine (near An_n). A few biotite flakes, partly altered to magnetite are present. The matrix is a structure-less mass of clay, including some chlorite, with ghosts of glass shreds and shards still visible when examined microscopically. The original glassy nature of the matrix is difficult to discern, but the structureless clay is probably the result of an original tuffaceous matrix. The rock should therefore be classified as a devitrified quartz latite porphyry crystal tuff.

The beds dip slightly northward and, together with the underlying conformable basalt, were laid down across the beds of the previously tilted Quarry Peak rhyolite complex from which they are separated by an angular unconformity. No rock overlies the Steins Mountains quartz latite porphyry in the mapped area, but it is intruded by latite porphyry dikes.

Vanar Hills Volcanic Rocks

The Vanar Hills volcanic rocks are the surficial rocks cropping out in the Vanar Hills, north of Arizona State Highway 68, in the northwest corner of the mapped area. The volcanic rocks are mostly latitic and contain numerous phenocrysts of biotite and feldspar in a pinkish-gray aphanitic hypocrystalline matrix. Small spherulites are abundant. The rock is similar, except for texture, to the latite porphyry dikes and sills which intrude all the rocks in the area except the Weatherby Canyon ignimbrite. They may be the volcanic equivalent of these intrusive masses. A dike of the latite porphyry intrudes the volcanic rocks in the Vanar Hills, but it was difficult to determine its boundaries, and it was not mapped separately. Flows, vitric tuffs, crystal tuffs, and a thin bed of dark-green volcanic glass, probably pitchstone, are all present within the mapped area. The volcanics extend northward for an undetermined distance and no detailed study of the sequence was made.

Assuming that these rocks are related to the latite porphyry dikes, the age of the Vanar Hills volcanic rocks is probably middle or late Tertiary. They are younger than the Steins Mountain quartz latite porphyry, but are believed to be older than the Weatherby Canyon ignimbrite.

Weatherby Canyon Ignimbrite

Tuffs and ignimbrites form the surface rock of most of the Peloncillo Mountains between Cowboy Pass and the south boundary of the area mapped, and extend southward for at least an additional 5 miles. Two distinct rock types, rhyolite and trachyte, are present, although the former greatly predominates. The two types appear to be interbedded in the upper part of the sequence, whereas the lower part consists only of rhyolite. The entire sequence is named the Weatherby Canyon ignimbrite from exposures in Weatherby Canyon, near the southern boundary of the area. The ignimbrite is particularly well exposed on 1117 Peak, south of Weatherby Canyon (pl. 9A). No measurement of the thickness of the sequence, or of the individual deposits or members, was made; but unless there is a repetition of beds, at least 3,000 feet of ignimbrite is present on 1117 Peak and the ridges to the west. In this area the rocks dip uniformly to the east at an angle of about 15 degrees, for a horizontal distance of 3 miles normal to the strike of the beds, with no apparent break in continuity. Within the mapped area the ignimbrite and tuff occupy about 7 square miles, only part of their total areal extent.

The tuff and ignimbrite were formed as the result of a series of volcanic eruptions of the nuée ardente type, similar to those described by Fenner (1923, 1937), Marshall (1938), Gilbert (1938), Enlow (1955), and others. The wide areal extent of the ignimbrite in the Peloncillo Mountains is of interest with reference to Fenner's (1948, p. 882) statement in his description of the welded tuffs in the Arequipa area:

> An especially important feature not prominent in the West Indies because of the conditions there, is the ability of such tuff flows to spread widely over level or gently inclined surfaces . . . the inherent properties of the mixture of solid particles and evolving gases were sufficient to impart a spreading tendency equal to or greater than that of a mobile liquid.

The most prominent and abundant of the ignimbrite is a light-gray to grayish-pink and rose-red hard compact aphanitic-porphyritic rhyolitic rock containing phenocrysts of quartz, clear sanidine, and a cloudy alkali feldspar in a devitrified matrix of shards, glass shreds, and hematite and magnetite particles. The phenocrysts constitute 15-25 percent of the rock and are mostly 1-2 mm in diameter. Numerous fragments of pumice are included in the ignimbrite, and cavities and vesicles, many of which are wholly or partly filled with quartz and alkali feldspar are abundant. The completely filled cavities are commonly the smaller ones, whereas the larger cavities are mostly lined with the later minerals. Most of the cavities, fillings, and pumaceous inclusions are flattened, lenticular, and elongated parallel to the bedding, and impart a eutaxitic structure or pseudobedding to the rock (pl. 9B). Microscopic studies show that the finer fragments of the rock are also flattened and alined parallel to the bedding, producing a microeutaxitic structure which bends around the phenocrysts, inclusions, fillings, and voids.

Quartz constitutes about 50 percent of the phenocrysts, and occurs as embayed and corroded euhedral crystals which characterize the rock and stand out as round glassy dots or blebs. Most of the remaining phenocrysts are clear square glassy light-gray to pinkish crystals of sanidine, some of which are slightly embayed. Cloudy alkali feldspar, most of which is almost completely kaolinized, shows in the hand specimen as dull, milky-white crystals, distinct from the glassy sanidine. Biotite is rare, but may be present. Magnetite grains, partly altered to hematite are abundant.

The matrix of the rock, which megascopically is aphanitic or microcrystalline in structure, is resolved microscopically into a groundmass of devitrified and recrystallized shards and glass shreds, with abundant hematite. A eutaxitic structure caused by the parallelism of the flattened and collapsed shards and the hematite streaks is pronounced in many sections, and is particularly well developed between closely spaced phenocrysts, inclusions, or void fillings. The original glassy character of the fragments has been lost, but the form of the shards has been preserved, although they are flattened and distorted because of collapse. Spherulitic and axiolitic structures are present. Westerveld (1943, p. 211; 1947, p. 34) stated that most ignimbrites show a recrystallization of the glassy groundmass, and that the spherulitic and axiolitic structures developed are composed of orthoclase or albite, and tridymite. He hypothesized that rising gases from the still-hot particles at lower levels within the deposit carry silica and alkalies upward, mineralizing the interstices between the glass and mineral particles as well as replacing the glass metasomatically. This is a pneumatolytic process and occurs immediately after emplacement of the deposit. According to this concept the welding of the shards is aided by cementation. In support Wester-veld states that in New Zealand and in eastern California pneumatolytic alteration of the tuffs is more pronounced in the upper layers.

In the ignimbrites of the Peloncillo Mountains the minerals composing the spherulites and axiolites are quartz and potassium feldspar. Many of the particles are so fine that the determination of whether they are sanidine or orthoclase was difficult, but some of the larger ones appear to be orthoclase and show evidence of alteration to kaolinite. No tridymite was identified.

In those rocks in which the eutaxitic structure is well developed, the shards are flattened and deformed and have molded themselves one to the other, and streaks of hematite are alined parallel to the shards. In some rocks, however, only traces of a eutaxitic structure are present. The shards are collapsed and flattened, but they are not alined; hematite and magnetite grains are scattered throughout the matrix and do not appear to be abundant. Spherulites and axiolites are not prominently developed, and the matrix is microgranular. Megascopically these rocks are not so compact as those with the microeutaxitic structure. Although they contain fewer voids and cavity fillings, they do not exhibit megaeutaxitic structure.

Enlow (1955, p. 1231) stated that in the Chiricahua Mountains some of the members of the Rhyolite Canyon formation show a progressive orientation and flattening of fragments and of vitric material from top to bottom of the beds. With an increase of pressure caused by the greater overburden, loose vitric material is compacted and welded together; the shards and glass shreds are flattened and molded one to the other and around phenocrysts and included fragments; and the iron oxide dust, originally scattered uniformly throughout the mass, is concentrated as the mass collapses with an increase of pigment per unit volume. The iron oxide alines itself parallel to the shards and produces the typical eutaxitic structure. Gilbert (1938, p. 183) also states that the lower parts of the deposits show a more pronounced orientation of fragments and also more vitrification.

A very informative exposure is present in a gulch on the eastern side of the ridge about a mile south of Cowboy Pass in the NW¼ sec. 18, T. 26 S., R. 21 W. Hard, compact rhyolite ignimbrite showing eutaxitic structure grades upward into a less coherent porous ashy-gray tuff containing pumice fragments, lapilli, and a few quartz and sanidine crystals. The tuff shows no eutaxitic structure. The matrix of the tuff is an extremely fine-grained microgranular mixture of what is probably quartz and feldspar, but no definite determinations of the minerals could be made because of the small size of the individual particles. No indications of welding are present, and any shards or glass shreds that may have once been present have been completely destroyed, and no trace is left of their former presence. The matrix is the result of complete recrystallization and devitrification of a very fine deposit of volcanic ash and dust. It was not subjected to compaction as was the underlying material and so shows no eutaxitic structure. Undoubtedly the ashy-gray nonwelded porous tuff is merely the uppermost part of the deposit produced by the nuée ardente. Overlying the porous tuff with a very sharp contact is hard compact trachyte ignimbrite representing a distinctly separate nuée ardente eruption.

On the eastern side of 1117 Peak, and extending northward almost to Cowboy Pass, is a band of trachyte ignimbrite. In general the rock is redder than the rhyolite ignimbrite; it exhibits various shades of red, reddish-gray, and reddish-brown. Phenocrysts are mostly orthoclase and sanidine, but a few flakes of biotite are present. Quartz is rare or absent, in contrast to its abundance in the rhyolite ignimbrite. The phenocrysts are smaller, less abundant, and less prominent than in the rhyolite ignimbrite, but lithic fragments are more prominent. Pumaceous fragments and hollow lapilli are common. In most exposures cavities and cavity fillings are less frequent, and the rock is less porous than the rhyolite. Elsewhere cavities are abundant, but they are not flattened nor elongated as much as in the rhyolite. In places the feldspar phenocrysts are indistinctly alined parallel to the bedding. Megascopically the eutaxitic structure is not very prominent, but microscopically the collapsed shards and glass shreds are parallel in alinement, although hematite is scattered throughout the matrix rather than concentrated in streaks.

The trachyte ignimbrite appears to lie both above and below beds of rhyolite ignimbrite. A fault may form its eastern boundary, however, and thus it may represent the basal part rather than an intermediate part of the rhyolite ignimbrite sequence.

Smaller and less continuous exposures of trachyte ignimbrite are present near the head of Weatherby Canyon and also east of the main zone of trachyte ignimbrite described above. Actual contacts with the rhyolite ignimbrite could not be observed, and whether these boundaries are normal depositional contacts or fault contacts is not known. The former are inferred. This inference necessitates positing an interbedding of rhyolite and trachyte ignimbrite and tuff, and might occur if the different rock types originated from separate vents, or if there were an alternation in mineral composition of the pyroclastic ejecta from a single parent magma. It might also occur if a number of vents had existed in the area during the eruption of the pyroclastic material, and each, during its initial or during its final stages of eruption, ejected trachytic material. Rhyolitic material was ejected during the remainder of its period of activity. The various vents became active or dormant at different times over a long period. The bodies of trachytic rock would thus be interbedded with rhyolitic material from other vents, and this process might readily account for the lenslike shape of the trachytic rocks. This hypothesis offers an explanation of the distribution in time and space of these two rock types.

A fourth possibility is that the actual chemical composition of the trachyte and the rhyolite are identical or nearly so. Excess silica appearing as quartz in the rhyolite may be locked up in the glassy material in the trachyte. Different physical conditions of eruptions may have governed the type of rock produced. No chemical analyses of the rocks were made.

Lying above the trachyte ignimbrite on the east and south sides of 1117 Peak, and also on the eastern side of the ridge north of Weatherby Canyon is a well-bedded fine-grained light-gray to white crystal tuff. Embayed and corroded subhedral crystals of quartz and sanidine constitute about 60-70 percent of the rock. Magnetite altered to hematite is common, and a few euhedral crystals of green hornblende and of brown biotite are present. The microcrystalline matrix is a brown clay, possibly limonite stained montmorillonite resulting from the alteration of the original volcanic ash. A few angular fragments of foreign material are present. The rock is porous and semifriable in contrast to the hard compact ignimbrites. The mineral composition of the tuff is so distinct from the underlying trachyte that the tuff appears to be unrelated to this rock and to represent a separate ash fall, perhaps related to rhyolite ignimbrite deposited at the same time elsewhere in the area. No gradation between the trachyte ignimbrite and the tuff was observed.

Near the head of Weatherby Canyon occurs a less granular and more tuffaceous-appearing rock which contains considerable fragmental material, including pumice, lapilli, and foreign rock fragments. Most of the crystals are sanidine and quartz, but kaolinized alkali feldspar is common and a few biotite flakes occur. This rock is intermediate in porosity and compactness between the tuff described above and the rhyolite ignimbrites. Microscopic examination shows it to be partly welded and recrystallized, with replacement of much of the glass by quartz and orthoclase. An indistinct eutaxitic structure is present. The tuff at this locality is 30-50 feet thick, exhibits excellent bedding, and crops out immediately below trachyte ignimbrite. It is undoubtedly the upper part of a deposit of rhyolite ignimbrite.

Welded tuffs or ignimbrites are undoubtedly much more common than formerly believed, but descriptions of these deposits are few and are confined to publications within the past 25 years. Of the descriptions of ignimbrites, the paper by Enlow (1955) is of particular interest to this study because it describes the ignimbrites and tuffs in the Chiricahua National Monument in the Chiricahua Mountains, Arizona. This locality is about 20 miles due west of the exposures of ignimbrites in the Peloncillo Mountains, across the gravel-filled San Simon Valley. Many of the features described by Enlow as characteristic of some of the members of the Rhyolite Canyon formation can be duplicated in the Weatherby Canyon ignimbrites and tuffs of the Peloncillo Mountains. Differences, of course, are present. A greater thickness of deposits appears to be present in the Peloncillo Mountains and no trachyte is recorded by Enlow. The major features, however, warrant a correlation between the Rhyolite Canyon formation and the Weatherby Canyon ignimbrite, and they are undoubtedly closely related in time, genesis, and method of formation.

The lack of extensive alteration of the Weatherby Canyon ignimbrite, and the probable correlation with the Rhyolite Canyon formation of the Chiricahua Mountains indicate a late Tertiary age for the volcanic rocks. No information is available as to its relationships with any of the volcanic rocks in the northern part of the mapped area. It is undoubtedly later than the andesite, and probably later than the Quarry Peak rhyolite complex and basalt. It may be about the same age as the Steins Mountain quartz latite porphyry or it may be later. Most likely it is later than this unit, and therefore the latest of the Tertiary volcanic deposits in the area. The latite porphyry dikes which cut the Steins Mountain quartz latite porphyry and which are probably the intrusive equivalents of the Vanar Hills volcanic rocks were not found cutting the Weatherby Canyon ignimbrite, although they cut the sedimentary rocks just north of the exposures of the Weatherby Canyon ignimbrite. This may be additional evidence that it is the latest of the Tertiary volcanic deposits.

ALLUVIAL AND LACUSTRINE DEPOSITS

Valley-fill deposits of Quaternary age are the surficial deposits in the Animas and San Simon Valleys, with the exception of the Animas Valley basalt discussed below. They consist of fluvial and lacustrine deposits. The fluvial deposits are divided by Schwennesen (1917, p. 8-9; 1918, p. 30-35) into older stream deposits and younger stream deposits, called in this report older alluvium and younger alluvium. They are separated by the lacustrine deposits which are at or near the surface in the Animas Valley and buried to depths exceeding 150 feet in the San Simon Valley. The age of part of the older alluvium may be Pliocene.

Older Alluvium

A group of low hills south of the Cienega ranch in T. 26 S., R. 21 W., consists of coarse partly sorted gravel, which is lighter in color than the more widespread younger alluvium described below. It constitutes the only exposure of older alluvium in the mapped area. The hilly topography developed on this older alluvium represents a more mature stage of erosion than is developed on the younger deposits and is the best distinguishing character between the two alluvium deposits. It contrasts sharply with the aggradational features developed on the younger alluvium. Similar deposits are found exposed farther northwest in the San Simon Valley (Schwennesen, 1917, p. 8) and probably underlie the lacustrine and younger alluvium in the Animas and San Simon Valleys within the mapped area.

Lake Beds and Beach Deposits

A large lake, Lake Animas, occupied much of the lower Animas Valley in Pleistocene time, and sediment deposited within the lake is present at shallow depths in many of the water wells in the valley. The sediment consists of interbedded homogeneous clay, sand, and fine gravel. The lake beds have not been dissected by erosion and no opportunity is available for study of the beds on the outcrop. A thickness of from 10 to 20 feet for the deposits is suggested by Schwennesen (1918, p. 34). Coarser gravel and beds of mixed clay and boulders lying beneath the fine sand and clay beds are probably fluvial deposits below the lake beds, and may correspond to the older alluvium of the San Simon Valley. Fine clay and sand impregnated with alkali is being deposited at the present time in the playas.

Beaches and beach ridges of gravel and sand are preserved in places along the shore of the ancient lake. These are best seen within the mapped area in the vicinity of Road Forks, but are present also near the southern boundary. Excellent examples are present in many places outside the area studied. A gravel pit about a quarter of a mile east of Road Forks is cut through the deposits, and horizontally bedded, well-sorted gravel and sand is exposed. Similar exposures are present in some of the small streams which cut across the beaches and beach ridges in the same vicinity.

Younger Alluvium

In the Animas Valley younger alluvium forms the surficial rock in the areas between the mountains and the lake beds. The alluvium is principally an alluvial fan type of deposit and consists of unsorted and nonbedded or imperfectly bedded heterogeneous debris carried down from the mountains during torrential floods. Talus and soil creep may have accounted in part for the downward movement of material. A rough zonation in the size of the fragments, from coarse to fine toward the valley floor, is present. At any particular place, however, the material is not homogeneous in size because much of the finer material was deposited with the coarse fragments. Because of the torrential nature of the streams and their increased carrying capacity during flood time, the distance that rock fragments of equal size are carried outward upon the fan before being dropped varies greatly, and a heterogeneity in vertical section results. The overlapping and coalescing of fans built up by streams from adjacent valleys also tends to increase the heterogeneity of the deposits at any particular place because the streams are not uniformly spaced, nor do they drain uniformly sized basins. The amount of debris carried and the resulting size of the deposit built are different for each stream. The coalescing has produced a detrital or alluvial apron or bajada which extends along the eastern front of the Peloncillo Range from the mountain front to the valley bottom occupied by the lake deposits. The alluvial debris is encroaching upon the valley floor, and covers or partly covers the lake deposits and also some of the Animas Valley basalt.

In the San Simon Valley a similar bajada composed of debris from the mountains forms the eastern side of the valley and slopes gradually downward to the valley bottom. The deposits consist of clay, silt, sand, and gravel, and locally may be well sorted. The sediments both here and in the Animas Valley are finer and better stratified toward the center of the valley.

The age of both the alluvial and lacustrine deposits is Pliocene-Recent, and Schwennesen (1917, p. 8; 1918, p. 32) correlated them, in part, with the beds of valley fill along the Gila River and with the Gila conglomerate. The term Gila conglomerate has been very loosely used in geologic literature, but it implies conglomerate and associated sandstone which are at least partly indurated and which are well bedded. It is of Pliocene-Pleistocene age, and may be tilted or folded. Quite possibly such beds exist in the Animas and San Simon Valleys within the mapped area, but if so they are buried and covered by later debris. Therefore, these valley fill deposits which occur at or near the surface and include older stream deposits, lake beds, beach deposits, younger stream deposits, and playa deposits should not be correlated with the Gila conglomerate.

Thicknesses of the valley fill deposits are unknown. In the Animas Valley water wells drilled to 500 feet are still in alluvium. On the west side of the San Simon Valley, an unproductive oil well drilled by the Arizona Oil and Gas Company 2 miles north of Dunn Spring Mountains penetrated 7,560 feet of gravel without reaching bedrock (Sabins, 1955, p. 117).

ANIMAS VALLEY BASALT

The northernmost exposures of a basalt flow which extends down the Animas Valley, crops out in the southeastern part of the mapped area. This malpais rock is a dark-gray to dull-black fine-grained very vesicular olivine basalt. Euhedral olivine crystals, many of which are rimmed by magnetite but otherwise unaltered, occur in a matrix of olivine, pyroxene (probably augite), and labradorite (close to An_n). Small grains of magnetite are scattered through the rock. The rock consists of about 45-50 percent labradorite, 25-30 percent pyroxene, 15-20 percent olivine, and 5-10 percent magnetite. Many of the larger vesicles, some of which range up to half an inch in diameter, are lined with quartz and calcite crystals, and what appears to be a zeolite.

The basalt crops out only over a few square miles within the mapped area, but it extends about 9 miles to the south and has a maximum width of about 3 miles. All exposures are confined to the floor of the western side of Animas Valley. The surface of the lava in places extends 20-40 feet above the surrounding plain. Part of the flow is now covered by valley sediments, and wells drilled a short distance north of the limits of the flow have gone through basalt at shallow depths (Collins, Frank, letter dated September 12, 1955). The original limits of the flow, therefore, are not delineated by its surficial exposures. Thickness of the flow is estimated to be about 60 feet, according to evidence provided by a well drilled about 5 miles south of the mapped area in SW¼ sec. 26, T. 27 S., R. 20 W. (Schwennesen, 1918, p. 36). The thickness undoubtedly is not uniform.

The relation of the lava to the valley fill, and the unaltered and the essentially unweathered character of rock indicate a late Pleistocene or Recent age.

STRUCTURE

The Peloncillo range and the adjoining valleys are part of the Basin and Range province, and as such are characterized by the dominance of faulting and monoclinal tilting of strata. The bounding faults delimiting the range were not observed, as they are covered by debris eroded from the mountains. High-angle faults, numerous within the mountainous uplift, divide the range into a number of differently tilted blocks (pl. 2). No thrust faults were recognized. Folding is represented by a major arch in the central part of the range and by small folds genetically related to the faulting. Joints are prominent in the Precambrian granite (pl. 4) and in the younger Cienega Peak granite, but no detailed study of the joint patterns was made. Fractures and faults were important in the localization of some of the ore bodies. Most of the post-Precambrian igneous intrusions are essentially concordant.

PELONCILLO ARCH, NORTHWEST-TRENDING FAULTS, AND DRAG FOLDS

The Peloncillo Mountains within the area mapped are part of a broken arch, the axial plane of which trends northwest, obliquely crossing the range about 2½ miles north of Granite Gap. Precambrian and Paleozoic rocks are exposed in the central part of the area, and probable Upper Cretaceous and Tertiary volcanic rocks occupy the flanks. Where the Precambrian and Lower Paleozoic rocks are exposed in the central part of the arch, at least 7,000 feet of Upper Paleozoic and Lower Cretaceous strata have been removed by erosion in addition to 5,000-7,000 feet of Cretaceous and Tertiary volcanic rocks which may once have been present in the area. A minimum uplift of 12,000-14,000 feet is postulated for the central part of the arch.

A zone of faulting occupies the axial part of the arch, which may be a result of the adjustment of the crust to the stretching caused by the rising of the arch. The faults are parallel to the supposed axial trend of the arch and strike approximately northwest. They are all high-angle faults. The strata exposed within the separate blocks range in age from Precambrian to Cretaceous and each block is differently tilted. Strati-graphic displacement along the faults ranges up to a maximum of about 7,500 feet in the SE¼ sec. 5, T. 25 S., R. 21 W., where Precambrian granite is in contact with the Johnny Bull sandstone. The stratigraphic displacement varies along any single fault, but in general is of the order of hundreds and thousands of feet.

To the southeast, the zone of faulting dips beneath the Quaternary alluvium except where it is interrupted by the Granite Gap horst. It may reappear, however, across the Animas Valley, east of the mapped area, where faults cutting probable Cretaceous rocks occur in the eastern part of T. 26 S., R. 20 W., and the western part of T. 26 S., R. 19 W. The poorly exposed outcrops are small isolated masses sticking up through a cover of alluvium, undoubtedly parts of fault blocks. The strike of the faults appears to be west-northwest to northwest, but it cannot be measured accurately.

The numerous northwest trending faults are remarkably similar in many of their characteristics. All are apparently steep-angle, as indicated by their relative straight course in plan. They are subparallel to each other, and the pattern developed by the differential movement along the faults is a large graben and horst structure rather than a step-fault structure, although step-faulting occurs in a minor way within the grabens and horsts. The faults are simple and unbranching for the most part, but branching does occur. Exposures of the fault planes are rare. Where seen in the SE¼ sec. 9, and the SE¼ sec. 23, T. 25 S., R. 21 W., along the Wood Canyon fault, and in the SW¼ sec. 3, T. 25 S., R. 21 W., along the Johnny Bull fault, the planes show little brecciation or silicification. Along the plane of the Fluorite fault, however, in the NE¼ sec. 21, T. 25 S., R. 21 W., brecciation, silicification, and fluorite and calcite mineralization occur.

Folding, presumably drag folds associated with the northwest trending faults, is present north and northeast of Blue Mountain in secs. 11, 12, 13, and 14, T. 25 S., R. 21 W., and in the vicinity of Cowboy Pass in secs. 10, 11, 12, 13, and 14, T. 26 S., R. 21 W. (p1. 14). In the northernmost of the two localities, a syncline plunging northwestward, and a parallel anticline plunging southeastward are arranged en echelon within the fault block bounded by the Johnny Bull and Goatcamp faults. Their axes are oriented slightly oblique to the strike of the faults. If the faults are wrench faults, with a large horizontal component of movement, a northward movement along the faults of the eastern sides relative to the western sides would produce an arrangement of syncline and anticline such as is present in this area.

Similarly, the folding east of Cowboy Pass may be due to drag along a major northwest-trending fault. This fault is only approximately located in the area northeast of Cowboy Pass, where is is concealed beneath alluvium, but the conclusion that it is present, necessitated by the repetition of the sedimentary strata, is substantiated by observation in the area of surface exposures of bedrock east of Cowboy Pass and east of Granite Gap. If this fault were also a wrench fault, the northward movement of the east side could have produced the observed drag fold.

Because of the attitude of the drag folds, the northwest-trending faults that occupy the site of the crest of the Peloncillo arch are identified as wrench faults. They also fit other criteria litsed by Moody and Hill (1956, p. 1214) as characterizing wrench faults; they have a straight trace, are high-angle, and possibly vary from high-angle reverse to high-angle normal along the same fault. Because of the tilted attitude of the strata no determination can be made by stratigraphic methods of the relative importance of the horizontal and vertical components of movement; nor were any slickensides or striations observed along fault planes.

By analogy with similar faults elsewhere, the northward movement of the block on the east side of some of the faults is probably indicative of a regional pattern, characteristic of all the faults. Because of the tilted attitude of the beds the vertical displacement of the strata is apparent rather than real; it may be due largely to horizontal movement, for undoubtedly some vertical movement did occur. The horst and graben pattern was developed by different degrees of movement of the separate blocks, one block moving further northward with respect to its neighbors than another.

The present structure could also be explained by presuming that the faults are tension faults associated with a breaking of the crest of the arch, the movement having been mostly vertical. Relative to one another the separate blocks moved downward different distances, with rotation and tilting of the strata in a different direction within each block. The alinement of the drag folds, however, cannot be explained by presuming this type of faulting, and the identification of the faults as wrench faults is preferred.

The arching of the Peloncillo area and the associated northwest-trending faulting antedated the late Tertiary or early Quaternary faulting which accounted for the uplift of the Peloncillo block relative to the Animas and San Simon Valley blocks and produced the present topography. Boundary faults between these major blocks, though not observed, are undoubtedly present, covered by debris and talus derived from the highlands. Within the mapped area the amount of structural relief between the blocks was not determined, but on the west side of the San Simon Valley a well (the Arizona Oil and Gas Company State No. 1, in sec. 36, T. 14 S., R. 30 E., Cochise County, Arizona) was sunk through 7,500 feet of gravel at a point 3 miles east of exposed bedrock. Similar separations between parts of one geologic unit probably exist along the borders of the Peloncillo Range, and those separations probably indicate displacements of adjacent crustal blocks.

GRANITE GAP AND PREACHER MOUNTAIN FAULTS

Two major faults do not fit into the above pattern. The Granite Gap and Preacher Mountain faults, which trend east-northeast in the vicinity of Granite Gap, cut transversely across the strike of the northwest-trending zone of wrench faults and also across the trend of the boundary faults of the range and the trend of the Peloncillo Mountains. The block lying between the two faults, called the Granite Gap fault block, is a horst, with Precambrian Granite Gap granite as the surficial rock, except where it is covered by Quaternary gravel. The Granite Gap fault, which forms the southern boundary of the block, is a high-angle normal fault, dipping steeply to the south. The inclination of the Preacher Mountain fault on the north side of the block is unknown, but northeast of Preacher Mountain in the vicinity of old tungsten properties the fault also seems to dip southward at high angles. If so, the fault is a reverse fault.

The exact relationships of these faults to the boundary faults are unknown. They apparently offset the topographic outline of the basin and range blocks, and thus may be later than the faults which outlined these blocks. They undoubtedly interrupt the northwest-trending faults.

NORTHEAST FAULTS

Numerous crossfaults (not shown on pl. 14) offset the major northwest trending faults and also offset the latite porphyry dikes, which in some places occupy the fault planes of the northwest trending faults. They are later than the arching and the formation of the wrench faults, and may be related to the movements that delineated the Peloncillo, Animas, and San Simon blocks, or they may be the result of adjustments to the horizontal movement of the wrench faults. The former hypothesis is considered more likely. Most of these faults cannot be followed more than a few hundred yards, and the stratigraphic displacement is small compared to that along the larger and more persistent northwest trending faults.

LATE TERTIARY AND QUATERNARY FAULTS

A few faults in the northern part of the mapped area, which cut the younger volcanic rocks, appear to be younger than any of the faults described above. The most prominent is the fault that strikes northeast through the Charles mine, south of Steins. This fault offsets a latite porphyry dike which is younger than most of the volcanic rocks. The age of the dike is presumed to be late Tertiary. The fault is a high-angle fault, but the relative amount of displacement or the direction of movement is unknown.

Southwest of Steins, a hypothetical fault extending northward through a small valley south of State Highway 14 may continue northward along the valley east of Quarry Peak.

Another hypothetical fault is presumed to extend along the very straight northward trending valley west of Quarry Peak. The interruption of the latite porphyry dike near the head of this valley is also evidence of a fault in this area. Additional evidence is the alinement of this valley with another straight northward trending valley just north of the boundary of the mapped area.

These faults may cut the Quarry Peak rhyolite but they probably do not cut the basalt or the Steins Mountain quartz latite porphyry. They appear to be tension faults resulting from the relative upward movement of the Peloncillo Block during the outlining of the present topography, and hence would be related to the boundary faults of the range.

RECENT FAULTS

Recent faults in the area are recognized within the valley blocks and near the boundary of the valley and mountain blocks. They may be the result of a continuation of the movements which elevated the mountain block and produced the present day topography. Where recognizable, the movement along these faults is relatively downward on the valley side of the fault.

In the southwestern part of T. 26 S., R. 20 W., a scarp about 6 feet high trends northwestward and can be followed for at least 2 miles northwestward from the southern boundary of the area, and slightly further southeastward. The northeast side is downthrown. Where small intermittent streams cross the scarp, erosion has not yet had time to smooth the gradient, and a small cliff is present. South of the mapped area, the fault appears to offset lava beds in the Animas Valley, but the relations are indistinct. This fault is near the boundary between the Peloncillo Mountain block and the Animas Valley block.

Other Recent faults are marked by brush lines trending almost due north in the E½ sec. 31, T. 25 S., R. 21 W., about three-quarters of a mile east of San Simon Creek and half a mile east of the New Mexico-Arizona boundary line. No scarps are visible, and the brush lines may merely represent healed earthquake cracks.

About 3 miles east of the mapped area, on the east side of Animas Valley in the E½ T. 24 N., R. 19 W., and in the NW¼ T. 25 S., R. 19 W., a small scarp trends northward for about 8 miles. The west, or valley side, is downthrown. Small drag faults cut diagonally northeastward from the main scarp near the southern end of the exposure, with a horst and graben structure developed between the separate fault blocks. The orientation of the drag faults indicates that the direction of movement along the major faults may be explained as that of a wrench fault, the east side of which moved northward.

FORM OF IGNEOUS INTRUSIVE BODIES

The major intrusive bodies in the Peloncillo Mountains, if the Precambrian rocks are excluded, are sills which cut across the strata at very low angles, but are essentially concordant. Most of them appear to have been intruded into the strata without large amounts of stoping, but some assimilation of the country rock must have occurred. Faults, which dip subparallel to the sills, are present along some of the sills. Missing strata in the vicinity of the sills is due largely to these faults. At other sills there is no evidence of faulting.

Many of the sills are intruded along or near the contact of an incompetent and a competent rock. They occur either above, below, or within the Percha shale, or between the Paradise formation and the Horquilla limestone. Others, including the Silver Hill and the Cienega Peak sills, which are the two largest, are intruded wholly within the competent Horquilla and Chiricahua limestones. The thicknesses of the sills, which range from a few feet to more than 1,200 feet, change rapidly along the strike. The extreme example of this variation, the Cienega Peak intrusive mass, has a maximum thickness of 1,400 feet less than a half mile from where it lenses out.

The sills are composed of three different kinds of rock: granite, quartz monzonite porphyry, and latite porphyry. The early sills, composed of Cienega Peak granite and quartz monzonite porphyry, were intruded at greater depths than most of the sills of the latite porphyry. The earlier rock is coarser grained, except at the contacts, and most of the early sills are thicker. They were intruded into the upper Paleozoic and Lower Cretaceous strata, probably after these had been covered by a thick sequence of Cretaceous or early Tertiary volcanic rocks. A minimum cover of about 2,500 feet of strata is postulated; it may have exceeded 7,500 feet.

The sills of latite porphyry, which were intruded late in the Tertiary Period, are mostly fine grained. The cover of volcanic rocks, which once overlay the sedimentary rocks, had already been eroded, and the total cover above the sills was less than 2,500 feet and in many places less than 1,000 feet. An exception may have been the thick sill just north of Cowboy Pass. The coarser grain of the latite porphyry in this mass may be due to the thicker cover above the sill when it was emplaced, as well as to its greater thickness.

The attitude of many of the sills today is the result of tilting of the strata and the intruded masses after emplacement. No deformation of the strata by the intrusions was recognized except at Cienega Peak. In this area the strata were undoubtedly tilted by the intrusion. The present attitude of the beds adjacent to the sill differs by about 20 degrees from the beds less than 1,000 feet northeast of the contact. This tilting of the surrounding strata and the abrupt lensing of the intrusion northward from the peak (a fault and Quaternary gravel obscure the relations south of the peak) suggest that this intrusion be classified as a laccolith rather than a sill. Its attitude is now nearly vertical.

The sills are confined to the areas where sedimentary rocks are exposed. Dikes are prominent in the granite and in the volcanic rocks, although a few also occur within the sedimentary rocks. Small intrusions of rhyolite in the volcanic rocks may be sills or plugs, and one intrusion just north of Steins is either a plug or a volcanic neck. This may have been a vent through which some of the Quarry Peak rhyolite complex was extruded.

METAMORPHISM

Metamorphism, as currently defined, excludes weathering diagenesis and, according to Turner and Verhoogen (1951, p. 368),

> . . . refers to the mineralogical and structural adjustment of solid rock to physical or chemical conditions which have been imposed at depths below the surface zone of weathering and cementation.

This definition includes autometamorphism or late magmatic and deuteric effects, but many students of metamorphism exclude these. Williams, Turner, and Gilbert (1955, p. 162) considered these to be more closely allied to igneous processes. In discussing metamorphism in the Peloncillo Mountains, the more nearly exact definition is to be preferred, thus all effects of "rock alteration" produced either within the zone of weathering, by diagenesis, or by autometamorphism will be excluded.

In the Peloncillo Mountains, metamorphism was not intense. No high grade metamorphic rocks are present, but metamorphic effects are widespread. For convenience of discussion three types can be distinguished: epidotization and propylitization, chiefly of igneous rocks; contact metamorphism, with the production of skarn rocks and associated ore deposits; and hornfelsification and metamorphism of sedimentary rocks at a distance from the intrusive bodies. According to Williams, Turner, and Gilbert (1955, p. 163) all these are included under the broad definition of contact metamorphism. The ultimate cause of the metamorphism is the same for all three, but the effects differ according to the original rock and the distance from the intrusive body.

Epidotization, with the accompanying production of calcite, quartz, albite, and probably zoisite or clinozoisite, is the principal metamorphic effect in the igneous rocks. It is especially characteristic of the andesite and of the quartz latite, but also occurs in other igneous rocks, which are older than the quartz monzonite porphyry, and in the quartz monzonite porphyry. In rocks younger than the quartz monzonite porphyry epidote is absent or only sparingly present.

Epidote occurs as large and small radiating masses of bright-green acicular crystals or as small grains disseminated through the rock. Locally, large masses of rock are completely altered to epidote, with minor amounts of quartz and calcite. Typically, grains of pyroxene, biotite, labradorite, and andesine are wholly or partly altered and replaced by epidote, the excess iron separating out as magnetite. Where epidotization has been intense, the more sodic feldspars are also altered. Calcite forms a central core of many of the smaller radiating masses of epidote. In extremely metamorphosed rocks, the entire mass is so pervaded with epidote, and perhaps with sericite also that neither the original minerals nor the original structure can be distinguished.

Epidotization is also common in the calcareous siltstone and sandstone of the Bobcat Hill conglomerate, which are closely associated with the volcanic rocks. Epidotization of other calcareous rocks throughout the stratigraphic sequence has also occurred. In fact the great amount of epidote throughout the area, both in igneous and sedimentary rocks, is one of the notable features of the region.

In the area between Attorney and Robinson Mountains the andesite has been metamorphosed to a propylite consisting largely of epidote, chlorite, albite, and quartz, with abundant disseminated pyrite. The rock is dull greenish, soft, with little of the original texture. Similar rocks are present elsewhere.

Contact metamorphism and contact metasomatism refers to the production of talc-silicate minerals adjacent to or in close proximity to the igneous intrusive mass which was the source of the heat and chemically active fluids. Skarn, with or without contact metamorphic ore minerals, is the resulting rock. In the Peloncillo Mountains such deposits are limited to the contacts of the quartz monzonite porphyry dikes and sills, and to positions along faults near such contacts. Most prominent are the skarn rocks developed along the Silver Hill sill, the Preacher Mountain fault, and in the vicinity of the Carbonate Hill mine. Smaller masses are present elsewhere.

The skarn rock is characterized by the presence of garnet as its most abundant constituent. The garnet is red or green, either massive or consisting of discrete euhedral crystals. X-ray diffraction patterns of two separate specimens of green garnet are almost identical and fit perfectly the pattern for andradite garnet. Previously grossularite garnet had been identified from some of the ore deposits in addition to the more common reddish-brown andradite, and some of the green garnet observed may be andradite-grossularite, close to the grossularite end of the isomorphous series; but without further confirmation by X-ray analysis no definitive determination can be made. Wollastonite, tremolite, epidote, coarse calcite, quartz, and an unidentified amphibole, probably actinolite, are present. Lindgren and others (1910, p. 331) report a dull-greenish mineral, probably a pyroxene, from the Johnny Bull mine, but no pyroxene was identified by the writer. Scheelite occurs along the Preacher Mountain fault, and fluorite was found in one small pit. Metallic sulphides have been introduced into the skarn rock in places, particularly along the Silver Hill sill and in the vicinity of the Carbonate Hill mine. Marble and recrystallized limestone commonly occur adjacent to the skarn; in many places they extend outward from the contact more than 50 feet.

X-ray diffraction patterns were made from a fibrous mineral associated with garnet and metallic sulphides at the entrance of the adit in sec. 3, T. 25 S., R. 21 W., and also for a fibrous mineral identified megascopically as wollastonite, which occurs with metallic sulphides, magnetite, and marble in a small pit in the SW1/4 sec. 11, T. 25 S., R. 21 W.

The diffraction patterns of the two specimens are almost identical and correspond closely to the standard diffraction pattern for wollastonite. Slight differences in the intensity of the peaks are evident between these patterns and the standard pattern.

Hornfelsification, principally of the calcareous Percha shale and its interbedded limestone, but also of similar rocks in the Earp and Still Ridge formations, is widespread in the area. Most of the outcrop areas of the Percha shale are so affected. Similarly the silicification of some of the calcareous siltstones of the Pennsylvanian, Permian, and Cretaceous sedimentary sequence produce a hornfels. The hornfels is mostly light gray, fine grained, granoblastic, hard, flintlike, brittle, and resistant to weathering. Porphyroblasts are uncommon. The metamorphism of the calcareous sedimentary rocks is not confined to areas adjacent to or in near proximity to igneous intrusions, but may occur 2-3 miles from any exposed igneous rock. Thin beds, or sequences up to 100 feet thick may be metamorphosed, and the metamorphism extends up to at least 5 miles along the strike of the strata.

Quartz, wollastonite, epidote, tremolite, clinozoisite, muscovite, and perhaps other minerals occur in the hornfels and hornfelsic rocks. In some of the slightly metamorphosed strata, actinolite-tremolite crystals, or small masses of epidote or garnet, line cavities in the limestone or occur along bedding planes or fractures. Wollastonite that has replaced entire beds a few feet thick occurs as small interlocking masses of white radiating acicular crystals. Quaide (1953) reported large poikoblastic crystals of scapolite (Me_{54}) with perfect tetragonal crystal form in limestone interbeds of the Percha shale near the shale contacts. Perfectly formed green garnet crystals in limestones and siltstones can be found east of Cienega Peak.

Many of the hornfelses and silicified siltstones resemble silicified volcanic rocks; where such volcanic rocks are interbedded with the Cretaceous Still Ridge formation, it is difficult to distinguish them from metamorphosed sediments.

Metamorphism in the area can be ascribed to the action of heat and chemically active fluids. Pressure was of only minor importance. Both the high temperatures and the hydrothermal solutions had as their source the magmatic masses which intruded the rocks of the area during late Cretaceous or early Tertiary time as dikes and sills of quartz monzonite.

Adjacent to the contact, within the innermost zone of the contact metamorphic aureole, the heat was intense and metasomatism was at a maximum, with a probable interchange across the contact of calcium, iron, silicon, and aluminum. The invaded limestone may have furnished the calcium for the epidote in the quartz monzonite porphyry adjacent to the contact. Much of the iron, silicon, and aluminum of the talc-silicate minerals may be magmatic in origin. Where calcareous sediments were the host rock the normal suite of calc-silicate minerals of the pyroxene-hornfels facies developed. Where more siliceous rocks were the hosts, no skarn rock was formed, although silicification occurred to varying degrees. The addition of metallic sulfides followed the formation of the contact metamorphic minerals and represented the last phase of the metasomatic process.

Away from the immediate vicinity of the intrusions, under conditions of lower temperature and pressure, metamorphism was of a lower grade. Hydrothermal alteration of the andesitic rocks, with the widespread production of epidote, was due to a veritable "bathing" of these rocks by hot aqueous solutions which permeated through innumerable cracks and fissures. Still lower temperatures were conducive to the propylitization of the andesites and the formation of abundant pyrite by solutions rich in H_2S. Metamorphism was due to temperature primarily, but the presence of hydrothermal solutions carrying substances derived from magmatic sources, and the utilization of these materials of magmatic origin in the production of new suites of minerals, was an integral part of the process.

The hornfelsification of some of the sedimentary rocks also proceeded under conditions of relatively low temperatures on the periphery of the contact aureoles. Again both temperature and hydrothermal fluids were important metamorphic agents, although there is little evidence that any material was added. Some iron, silicon, and possibly water may have been added, but there may also have been sufficient quantities of these materials in the sedimentary rocks to furnish the amounts necessary for the formation of the metamorphic minerals. The presence of scapolite (Me_{50}) might indicate the addition of sodium and chlorine from magmatic sources, but the sodium and chlorine could have been derived from connate water.

Most of the calc-silicate hornfels belong to the amphibolite and albite-epidote-amphibolite facies. The presence of wollastonite in some localities indicates local conditions of higher temperatures and the formation of minerals of the pyroxene-hornfel facies that are similar to the suite in the inner zone of the contact metamorphic aureole. Perhaps these areas are relatively close to buried intrusive masses and are thus part of the inner zone of the aureole.

Pure or almost pure calcareous rocks were little affected by metamorphism in the outer zone of the aureole, although some recrystallization of limestone did occur and tremolite-actinolite crystals line cavities and fractures within the limestone. The calcareous shales and siltstones are most affected; presumably the intimate association of limestone and shale, as exemplified by the alternating thin beds of limestone and calcareous shale in the Percha, was most suspectible to the action of the hot solutions. A recombination of the calcium, aluminum, and silicon with the possible addition of iron, water, and some silicon, resulted in the very fine-grained granoblastic hornfels. The predominantly siliceous character of the rocks appears to indicate the addition of silica, either from magmatic sources or from elsewhere in the stratigraphic sequence.

GEOLOGIC HISTORY

The writer as well as the reader of geologic history should bear in mind that the orderly sequence of events within a small area must conform to the pattern displayed by the larger area of which it is a part. The record preserved is always fragmentary. Only by recording it and synthesizing it with similar fragmentary records from other areas can a degree of continuity be established. No history is to be considered final, for additional information or interpretations may negate, change or substantiate parts of it. It is the writer's hypothesis of what probably occurred, built on a foundation of facts, and it necessarily includes the writer's thoughts, ideas, and suppositions on many of the problems involved. The following statement of the geologic history in the Peloncillo Mountains is based on these premises.

In the Peloncillo Mountains the Precambrian sequence of events is poorly recorded, but it probably differs only slightly from Precambrian history elsewhere in southwestern New Mexico and southeastern Arizona. No Precambrian metamorphic rocks are exposed in the Peloncillo Mountains, but the Pinal schist, which crops out in the Chiricahua Mountains to the west (Sabins, 1955, p. 10) and in the Gold Hills and Burro Mountains to the northeast (Gillerman, 1953, p. 265), was probably the country rock into which the Granite Gap granite was intruded prior to the beginning of the Paleozoic Era. Where exposed, the Pinal schist is intensely deformed and metamorphosed and records a complex orogenic history.

After the intrusion in the Peloncillo Mountains, the metamorphic rocks were stripped off by erosion, exposing the granite. A deeply oxidized zone, characteristic of warm humid areas of low relief, developed on the granite prior to its burial by the Cambrian sediments. In Middle Cambrian time, the sea flooded the area, advancing from the west over a terrain of flat plains and low hills. Sand and gravel, the initial deposits, were followed in the late Cambrian by carbonate sediments. Broad warpings and fluctuations of the shore line resulted in the area being subjected to subaerial erosion in the late Middle Ordovician, but sedimentation continued thereafter through the late Ordovician, the Silurian, and possibly into the Devonian.

A widespread retreat of the sea, after the deposition of Silurian rocks and prior to the late Devonian, was general in Arizona and New Mexico. This retreat was accompanied by a broad warping which tilted the terrain southward in New Mexico (Kelley and Silver, 1952, p. 81, 133) and produced an angular discordance between the late Paleozoic strata and the early Paleozoic and Precambrian rocks in New Mexico and central Arizona (Huddle and Dobrovolny, 1950, p. 76). Beginning in the late Devonian with the deposition of Percha shale, marine sedimentation was renewed, and continued with few interruptions into the late Permian. Late Paleozoic rocks of the Peloncillo Mountains resemble contemporaneous rocks of southeastern Arizona more closely than contemporaneous rocks of central New Mexico, and a more open connection with the sea to the west is postulated.

Indications of a post-Paleozoic period of uplift, deformation, and erosion prior to the deposition of Lower Cretaceous sediments are abundant in southern Arizona, and are present in northern Mexico and in New Mexico. The widespread occurrence of the Glance conglomerate and its homotaxial equivalents at the base of the Cretaceous section in the region, is itself evidence of an elevated terrain at the beginning of the Cretaceous Period. In addition, according to Ransome (1904, p. 62), the Glance conglomerate at Bisbee, Arizona, rests on an erosion surface of considerable relief. Gilluly (1941, p. 1,949) mentioned a post-Paleozoic period of deformation, igneous intrusion, and erosion prior to the deposition of Lower Cretaceous sediments in the Dragoon Mountains, Arizona. McKee (1951, p. 496) recorded numerous areas in southern Arizona where the Glance or other basal Cretaceous conglomerates, consisting of locally derived pebbles and boulders of many older lithic units, rest on surfaces of considerable relief carved on Cambrian and late Paleozoic formations. He stated that

> . . . the region must have been raised sufficiently to permit considerable and rapid erosion, to form valleys and canyons exposing rock of many strata, and to allow the covering of this surface of relief with a widespread mantle of gravel, locally derived.

McKee concluded that there is no evidence of folding during this uplift and presupposed broad warping and block faulting (the high-angle Dividend fault at Bisbee, Arizona cuts the Permian but not the Cretaceous sediments: Ransome, 1904, p. 42). He also stated that it appears likely that the conglomerates are all accountable to one period of uplift, the most probable date of which was early in the Cretaceous, approximately contemporaneous with the Nevadan orogeny. As an alternate hypothesis McKee also stated that the uplift in southern Arizona which furnished the gravel for the Lower Cretaceous conglomerate may have occurred in the Triassic and have been the same uplift that furnished the gravel for the Shinarump formation to the north. He did not believe it likely, however, that the area should have remained high for a long enough period for the Triassic uplift to have influenced Cretaceous sedimentation.

In the Silver City area of New Mexico, the Beartooth quartzite of doubtful early Cretaceous age rests without discordance on an erosion surface carved on Paleozoic rocks (Lasky, 1936, p. 21).

In the Peloncillo Mountains, a discordance of about 20° between the basal Cretaceous conglomerates and the Permian limestone can be observed in sec. 21, T. 25 S., R. 21 W., northwest of Cienega Peak. Elsewhere the contact is a disconformity. Different thicknesses of the basal Cretaceous formation throughout the range reflect the unevenness of the terrain upon which the sediments were deposited. Locally derived fragments of Precambrian granite and Cambrian quartzite and of upper Paleozoic limestone are present, and the conglomerate rests on lower and middle Permian formations. A period of deformation, uplift, and deep erosion must have occurred in the area not long prior to the time of deposition of the conglomerate. McKee's supposition of block faulting contemporaneous with the Nevadan orogeny in late Jurassic or early Cretaceous time is probable. The identification of lower Aptian beds above the Glance conglomerate in the area south of Bisbee (Stoyanow, 1949, p. 36) suggests that the deformation probably occurred in the Jurassic.

Sabins (1955, p. 125) suggested that two periods of post-Permian pre-Cretaceous uplift and erosion are indicated in the Chiricahua Mountains. This suggestion confirms McKee's hypothesis of a Triassic and an early Cretaceous period of uplift.

The Laramide orogeny is represented in the southwestern part of the United States by thrust faulting and igneous activity. In the Peloncillo Mountains no thrust faults were recognized, but igneous activity was important during and immediately following the deposition of the Cretaceous sediments. There appears to have been two more or less distinct periods of volcanism during the Cretaceous Period in southwestern United States and northwestern Mexico (King, 1939, p. 1,678). The earliest, of early Cretaceous age, is represented by volcanic rocks in the Little Hatchet Mountains; the Sahuaripa district, Sonora; and possibly in the Courtland-Gleason district, Arizona. Evidence for the second, of late Cretaceous age, is present in the Cabullona district, Sonora; near Christmas, Arizona; in the Silver City district, New Mexico; and elsewhere.

In the Peloncillo Mountains there was igneous activity during the early Cretaceous, and again in late Cretaceous or early Tertiary time. The early Cretaceous volcanism is recorded by only a few thin flows and tuffaceous sandstones within the McGhee Peak and Still Ridge formations. The late Cretaceous or early Tertiary volcanism was much more extensive; it is recorded by abundant andesite flows and breccias and by the quartz-latite flows. The intrusion of the Cienega Peak granite may have preceded the andesite flows; the quartz monzonite porphyry sills and dikes may antedate some of the andesite volcanic rocks. The igneous activity may have been accompanied by some faulting, but the major deformation in the area is believed to be middle and late Tertiary.

The Quarry Peak rhyolite complex was extruded after the andesite, following an unknown interval of time. It may represent a rhyolitic differentiate of the andesite magma or may have had a separate origin. The abundant epidotization of the andesite and earlier rocks, paragenetically associated with the intrusion of the quartz monzonite porphyry, and the almost complete absence of epidote in the Quarry Peak rhyolite, suggest a relatively long time interval between the extrusion of these widely different rock types.

In the Tertiary, the central part of the mountain range was uplifted, forming the Peloncillo arch, and the crest of the arch was broken by numerous steeply dipping northwestward trending faults. The separate fault blocks were differentially tilted, and minor folding accompanied the faulting on the eastern side of the range in the area north of Granite Gap. Although none of the faults can be recognized within the Quarry Peak rhyolite complex, they may have occurred after the extrusion of these volcanic rocks. The fact that these rhyolites and the younger Steins Mountain quartz latite porphyry are tilted away from the crest of the arch suggest that the arching and associated faulting occurred after the extrusion. These younger rocks are believed to be late Tertiary in age; the deformation may have taken place in the very late Tertiary. The extrusion of the Vanar Hills latite and the associated latite porphyry dikes and sills occurred after the arching, probably after the extrusion of the Steins Mountain quartz latite porphyry, but previous to the extrusion of the Weatherby Canyon ignimbrite.

The uplift of the central part of the range was followed by erosion and the removal of the volcanic rocks exposing the Cretaceous and Paleozoic sedimentary rocks, and the Precambrian granite. Following the arching, a large horst, bounded by two east-northeast faults, the Granite Gap and Preacher Mountain faults, was uplifted in the vicinity of Granite Gap. This horst cuts transversely across the trend of the range and across all earlier structural features and may extend beneath the San Simon and Animas Valleys. Precambrian granite is exposed in the fault block. The age relationship between this period of faulting and the faulting which produced the present topography is unknown.

In late Tertiary time, the outlining of the present-day topography was initiated by the rise of the Peloncillo Mountain fault block as a unit, and the relative depression of the adjacent Animas Valley and San Simon Valley blocks. This was contemporaneous with and a part of the Basin and Range orogeny characteristic of western and southwestern United States. The differential movements of these blocks persists to the present day, as evidenced by tilted late Tertiary Gila conglomerate and underlying Tertiary volcanic rocks in the Burro Mountains, 30 miles northeast of the Peloncillo Mountains (Gillerman, 1951, p. 268), and by recent fault scarps and earthquake cracks within the mapped area and elsewhere in the region. The difference in elevation between the crest of the upfaulted block and the position of bedrock below the gravel of the downthrown blocks is at least 12,000 feet. Concurrent with this great vertical movement, faults developed within the upthrown block, parallel to the boundaries of the block. During the course of the uplift, debris eroded from the rising highland was deposited in the adjacent valleys. This process, which continues at present, has filled the basins with gravel and sand to a maximum depth in excess of the height to which the bordering ranges stand above the valley floor.

During the Pleistocene, a large lake, Lake Animas, occupied all or part of the Animas Valley within the area mapped, and may have extended many miles north of the limits of the area. A similar lake was present in the lower San Simon Valley and probably extended up the valley into the mapped area. These lakes drained to the north into the Gila River. The disappearance of the lake in the Animas Valley is related to the changes in climate and the increasing aridity in late Pleistocene and Recent times. It may also be related to crustal movements associated with the Recent faulting in the area, and a northward tilting of the southern part of the valley with a consequent spilling of the water over the divide which separated the lake from the Gila River. This is suggested by the higher elevation of beach ridges in the southern part of the valley (Schwennesen, 1918, p. 88).

In very late Pleistocene, or more probably in Recent time, basalt that was extruded from a vent on the east flank of the Peloncillo Mountains 10 to 12 miles south of the mapped area, flowed northward down the Animas Valley, following the course of Animas Creek. It displaced the stream eastward, so that the present stream channel lies along the eastern margin of the basalt. Recent debris from the mountains has partly covered the basalt and the lake deposits.

Mineral Deposits

Lead, zinc, copper, and silver are the most abundant ore metals in the Peloncillo Mountains. Minor amounts of gold and tungsten have been produced, and fluorspar occurs in very small quantities. None of the deposits are large, although the value of the lead and silver produced from the Granite Gap mines probably exceeded $750,000, and that from the Carbonate Hill mine $1½ millions. Most of the mining activity in the area was concentrated in the period prior to 1920, and only sporadic mining has been done since that date. In 1954 and 1955, mining operations were being conducted at only two small properties; most of the larger and older properties were wholly or partly inaccessible. Information on some of the older properties was obtained from private reports furnished by C. G. Perry and Donald McGhee and from published data by Lindgren and others (1910, p. 329-332).

Pyrometasomatic and hydrothermal vein deposits are present in the Peloncillo Mountains. Most of the deposits are in limestone, but some are in andesite; no deposits occur in any of the extrusive rocks younger than the andesite, nor in any of the younger intrusive rocks. Replacement and open space filling were important processes in the emplacement of the ore. The base metal deposits are believed to belong to the late Cretaceous or early Tertiary metallogenic epoch, which accounted for most of the base metal deposits of southwestern United States. The fluorite and possibly the tungsten deposits may belong to a later period of mineralization.

The pyrometasomatic deposits are the most abundant and include the base metal deposits at Carbonate Hill, Silver Hill, Johnny Bull, and elsewhere as well as the scheelite deposits. The hydrothermal vein *deposits* include the Granite Gap mines and the deposits south and east of Granite Gap, including the Crystal mine. The Mineral Mountain, Charles, and North Star deposits in the northern part of the area are also hydrothermal vein deposits, and the fluorite vein belongs to the same category.

For purposes of discussion, the pyrometasomatic deposits are divided into those containing base metals and those containing tungsten. The former are characterized by the presence of grossularite and andradite garnet, epidote, wollastonite, and possibly tremolite. They are adjacent to or near dikes or sills of quartz monzonite porphyry. Most of them are in limestone, but some of the smaller deposits south of the Silver Hill property are in the McGhee Peak conglomerate, many of the pebbles of which are limestone. Replacement of the limestone by the calcium silicate minerals is accompanied by the introduction of lead, zinc, copper, and minor amounts of silver. Galena, sphalerite, and dialcopyrite are the chief ore minerals; pyrite and magnetite also occur.

Garnet is the most abundant of the skarn minerals and occurs as coarsely granular masses which consist largely of small dodecahedral crystals, or as compact masses. Well formed dodecahedrons and trapezohedrons line cavities and small fissures. Quartz and calcite are commonly associated with the well-crystallized garnet. Yellow-green, orange-red, and red andradite-grossularite garnet are commonly associated. The red garnet is the most abundant variety.

Wollastonite occurs as masses of white and light-green and gray radiating acicular crystals, and in places is very abundant. Tremolite may be present but has not been definitely identified. Epidote is sparingly present in many of the deposits. Quartz, coarse calcite, and rarely fluorite are the other nonmetallic gangue minerals present.

The galena and sphalerite are intimately mixed in most of the deposits, but in the Silver Hill mine large masses of galena are surrounded by sphalerite. The galena, in places, has a bluish tinge, and the sphalerite is dark gray brown to reddish brown. Chalcopyrite occurs in small masses and is disseminated through the garnet or wollastonite.

The deposits occur adjacent to the intrusive bodies, as at Silver Hill (pl. 10), or some distance from them as at the Johnny Bull or Carbonate Hill mines. Those at a distance are along faults. Fissure filling and replacement deposits both are present, but the larger ore bodies are the result of replacement. The deposition of the contact silicates and of the ore was controlled by small fractures and by the texture of the host rock. Porous limestone was the best host rock, and calcarenites, crinoidal limestone, and the shell beds of the Carbonate Hill limestone were the most amenable strata for the migration of the solutions. Strata replaced are not confined to one geologic formation but include beds within the Escabrosa, Horquilla, and Carbonate Hill limestones.

The tungsten deposits are distinguished from the base metal deposits by a slightly different suite of minerals. Scheelite, which is absent from the base-metal deposits, characterizes the deposits, and no base metals occur. Green andradite garnet is very abundant and constitutes most of the skarn rock. Manganese, possibly as a primary constituent of one of the garnet minerals, is present in one of the deposits. The mutual exclusiveness of scheelite and the base-metal sulfides in pyrometasomatic deposits is not uncommon, but it is not universal.

The hydrothermal vein deposits are of two types: sulfide veins, and a fluorite vein. The latter is small, and of importance only because it indicates that the area probably was mineralized late in the Tertiary Period, which is the date of the fluorspar veins elsewhere in southwestern New Mexico.

The sulfide veins occur in limestone (Granite Gap deposits) and in andesite (Mineral Mountain and Charles deposits). Fissure filling was the dominant process of ore emplacement, but where limestone was the host rock replacement also occurred. The primary ore minerals are galena, sphalerite, chalcopyrite, and probably tetrahedrite. Pyrite is common and quartz and calcite are the gangue minerals. At Granite Gap the oxidation of the primary galena and tetrahedrite resulted in an ore body of cerussite containing appreciable quantities of silver. Small quantities of gold occur in some of the veins.

Aside from the skarn silicates, there is no difference in the mineralization of the pyrometasomatic deposits and the hydrothermal vein deposits. The distinction between them is merely one of proximity to the intrusion which was the source of the ore solutions. The hydrothermal vein deposits were emplaced at distances from the intrusion where the temperatures were lower. Where the country rock was andesite it too may have favored vein development as it is not so amenable to replacement as limestone. Thus, excepting the fluorite and possibly the tungsten deposits, all the ore deposits are related to the quartz monzonite porphyry intrusions. This relationship is undoubtedly true for the pyrometasomatic deposits, and if the supposition that the two types of deposits are part of the same period of mineralization is true, it follows that it is true for the hydrothermal vein deposits. The absence of sulphide deposits in rocks younger than the quartz monzonite porphyry is an additional argument for this hypothesis. In nearby areas, similar deposits have been identified as being genetically associated with a similar rock type of about the same age. (Lasky, 1936, p. 24; 1938, p. 14, 67; 1947, p. 79; Spencer and Paige, 1935, p. 64; Paige, 1916, p. 14; Lindgren, Graton, and Gordon, 1910, p. 36-40).

The tungsten deposits are assigned, with some doubt, to the same period of mineralization, and the doubt is due, for the most part, to the dissimilarity of mineralization.

COPPER, LEAD, ZINC, AND SILVER DEPOSITS

CARBONATE HILL MINE

The Carbonate Hill mine, known also as the McGhee mine, is on a block of 32 unpatented claims in secs. 34 and 35, T. 24 S., R. 21 W., and secs. 3 and 4, T. 25 S., R. 21 W. The main shaft, about 2 miles west of U. S. Highway 80, is accessible by a good all-weather graded road. The claims are owned by Donald McGhee, Lordsburg, New Mexico; in September, 1956, they were under lease to Earl Strong and Ira Mosely, Silver City, New Mexico.

The property was first located in 1894 by a man named Fox. In 1916 it was purchased by the McGhee brothers, father and uncle of the present owner. The original workings were a few hundred feet north of the present mine shaft. The property was operated intermittently by the McGhees from 1916 to 1948, when a fire destroyed part of the main shaft and the mill. The 100-ton flotation mill had been built in

1928. In 1956 the property was leased to Strong and Mosely, the shaft repaired, and mining operations resumed.

The major workings are in the SE¼ sec. 34, a few hundred feet west of the boundary between secs. 34 and 35 (pl. 10). They are accessible by a vertical shaft, about 500 feet deep. Drifts at various levels extend for about 1,000 feet along the vein, both northwest and southeast of the shaft. Most of the mining has been done above the 150-foot level. In favorable areas ore has been mined through a width of 75 feet. A separate ore body, about half a mile southwest of the main shaft, in the SW¼ sec. 3, has been explored by an adit extending southwest into the hillside for about 100 feet. Short drifts extend laterally from the adit at its terminal end. Numerous small shafts, pits, and adits are scattered over the property.

The ore is predominantly lead-zinc, with only small amounts of silver. The copper content is negligible, and no copper has been recovered. Total production through 1955 is in excess of 100,000 tons of ore, assaying about 6 percent Pb, 5 percent Zn, and 2 ounces Ag per ton. Total value of the ore produced is estimated as exceeding $11/2 millions. Ore from the adit in sec. 3 is higher in Ag and lower in Zn than that from the main ore body. In the main ore body the tenor of the ore appears to be about the same, both along the strike of the ore body, and with depth.

The ore at the main ore body consists of galena containing small amounts of silver and sphalerite; the gangue is calcite, quartz, and country rock. The sulphides are intimately mixed, but the proportions vary in different parts of the mine. No contact metamorphic minerals were observed in a cursory examination of the accessible parts of the mine, but garnet was found on the dump of an old shaft that lies a few hundred feet north of the main ore body and probably along the same structure. Garnet was reported by James H. Parker from the main ore body (letter to C. G. Perry, Lordsburg, New Mexico, dated May 7, 1939). Garnet and wollastonite occur with the ore minerals at the adit in sec. 3.

The main ore body occurs along an andesite or latite dike which traverses the Carbonate Hill limestone and the Still Ridge formation. The dike is so completely altered and silicified that the original composition of the rock is difficult to determine. In the vicinity of the main shaft the dike is 20-30 feet wide, but it widens rapidly northward and thins toward the south. Its trend ranges from north to north-northwest, and it is almost vertical. The dike, which was emplaced previous to the deposition of the ore minerals, occupies an old fault zone. Movement along the fault has been complex; some of the movement occurred after the emplacement of the dike, brecciating it, and perhaps displacing it. The major fault, as mapped, is located along the west margin of the dike; it has been traced southeastward three-quarters of a mile, to where debris eroded from the mountains obscures surface exposures, and northwestward about a mile. Small faults branch northward from the major fault on the northeast side. One of these small faults forms the eastern boundary of the dike in the vicinity of the shaft and may be the cause of the diminishing thickness of the dike to the south.

At the mine the upper part of the Still Ridge formation is adjacent to the dike on the southwest side, and the Carbonate Hill limestone is adjacent to it on the east. A displacement along the complex fault system of about 500 feet is estimated, with the eastern side upthrown. Beds of the Still Ridge formation adjacent to the dike strike N. 45°-60° W., and dip 25°-35° NE. The Carbonate Hill strata strike N. 15° W. and dip 10° SW. adjacent to the eastern side of the dike, but a few hundred feet to the east the strike is N. 75° W. and the dip is 10° SW. Still farther to the east the strike is about N. 45° W. and the dip, 20°-30° NE., which corresponds closely to the dip of the Still Ridge formation west of the dike and to the regional dip. The attitude of the beds near the fault is not consistent with a simple vertical upward displacement of the eastern side of the fault zone, and a more complex history is indicated, with probable repeated movements in various directions.

Replacement of the limestone by the ore minerals was the major process involved in the emplacement of the ore, but some fissure filling occurred. As the high porosity and open texture of the calcarenites and shell beds of the Carbonate Hill limestone was particularly conducive to the migration of the ore-bearing solutions outward from the major channels of ingress, these beds are the most favorable host rock for the ore. The shell beds in particular were especially susceptible to replacement; bodies of sulphides in these beds extend outward from the dike in some places for as much as 75 feet. Internal molds and shells of pelecypods and ammonites replaced by galena are striking features of the deposit.

The beds of the Still Ridge formation, west of the dike, were less susceptible to replacement by the mineralizing solutions, but some ore does occur. Most of the ore that has been mined has been from within the Carbonate Hill limestone southeast and east of the dike. In the deeper parts of the ore body the Carbonate Hill limestone should occur west of the dike; good ore has been reported west of the dike at depths.

At the adit in sec. 3, the ore occurs along or near a rhyolite or quartz latite dike which lies along a fault. The fault strikes about N. 70° E. and dips 80° NW. The country rock is Horquilla limestone which strikes about N. 30° *W.* and dips 35° NE. Along the southwest side of the dike and fault, in a zone 20-30 feet wide, the limestone is metamorphosed to a skarn in which the ore minerals occur.

SILVER HILL MINE

The Silver Hill property consists of two adjoining claims, the Silver Hill and the State of Maine, located mostly in the NW¼ sec. 3, T. 25 S., R. 21 *W.,* and owned by C. G. Perry, Lordsburg, New Mexico, and the heirs of the Misses Cora C. and Sarah Estelle Cloudman. The Silver Hill claim was first staked in 1877 by an unknown individual. Somewhat later it was worked by a Mr. Bradford, and became known as the Bradford property. The State of Maine claim was staked in 1918. The two properties have been worked intermittently since 1877 by the various owners and by lessees. Chief among the lessees were the Phelps Dodge Copper Corp., which leased the property in 1928-30, and the Peru Mining Co., which leased it in 1948-53.

The ore consists principally of galena and sphalerite, but small amounts of silver are also present. An average analysis of the ore shipped by the Peru Mining Co. was obtained from 12 randomly selected shipments during the periods of May 1948-May 1949 and of January 1951-February 1952. The ore averaged 11.47 percent Pb, 5.19 percent Zn, and 3.32 ounces of Ag per ton. No figures on the total production are available, but it probably amounted to several thousand tons.

The deposit is explored by a shaft on the Silver Hill claim. The shaft is inclined about 75°-80° S. 85° E. and is 200 feet deep. Levels have been driven 20, 60, 90, 165, and 195 feet below the collar of the shaft. On the upper levels, the drifts extend farther to the southwest than to the northeast, but the reverse is true on the lower levels.

A quartz monzonite porphyry sill, 300 feet thick, intrudes the Horquilla limestone near the shaft (pl. 11). The limestone strikes N. 35° W. and dips 30° NE. The sill also strikes N. 35° W., but appears to dip at a slightly smaller angle than the sedimentary rocks. Adjacent to both the upper and lower surfaces of the sill the limestone has been metamorphosed and recrystallized to a fine-grained sugary white marble. The metamorphism extends for a long way laterally along the sill, but the distance outward from the sill depends upon the composition, texture, and degree of fracturing of the various individual limestone beds. In places, garnet and other contact metamorphic silicate minerals are developed within the marble zone, near or adjacent to the sill. Metallic sulfides, chiefly galena and sphalerite, are associated with the silicates at many localities along the sill. The greatest known concentration of the metallic sulfides is at the Silver Hill mine, but smaller deposits have been worked both northwest and southeast of the mine, on both the upper and under sides of the sill.

At the Silver Hill mine the principal ore minerals are galena and sphalerite. Chalcopyrite is present in the deeper workings, and minor amounts of pyrite, magnetite, and manganese oxide occur. Gangue minerals are grossularite(?) and andradite garnet, tremolite or wollastonite, epidote, and coarsely crystalline calcite. The ore occurs principally along a fissure striking about N. 25° E. and dipping about 75° SW. The fissure steepens to 80°-85° just below the 90-foot level. The ore body plunges northeastward, approaching the sill with depth, but the sill is not exposed in the workings. The fissures or fracture zone varies in width from 2 to 3 feet to more than 6 feet, the ore occurring in ribbons and streaks along the fissure. A single streak may be present, or 3 or 4 branching and anastomosing streaks may occur. Individual ribbons range from 1 to 6 inches in width and 1 to 6 feet in length. Crossfissures are present, and the ore extending out into the marbleized and garnetized wall rock in the vicinity of the crossfissures results in masses of sulfide 6 feet wide and 20-25 feet long. In the lower part of the workings the mineralized part of the fissure is next to the hanging wall, but where the crossfractures are present the sulfides extend into the silicate zone of the footwall. The ore zone appears to flatten and turn northwestward in the drifts on the lowermost level.

Zinc and lead carbonates occurred near the surface, but these were not observed below the 20-foot level. Calcite is also more plentiful in the upper part of the workings.

The ore body plunges in a northerly direction because of the dip of the limestone beds and because of preferential mineralization along a single bed or a series of contiguous beds which are more favorable as host rocks than the beds immediately above or below. Chemically active gases and fluids migrating outward from the sill through fractures in the sedimentary rock, reacted with the limestone where the fissure traversed these more favorable beds, forming contact metamorphic silicates. Later ore solutions followed the same paths and deposited the sulfides in the same environment. The intersection of fractures, resulting in greater porosity and permeability of the limestone favored the formation of wider ore shoots.

JOHNNY BULL MINE

The Johnny Bull and adjacent prospects are on three patented claims, the Johnny Bull, South Virginia, and Sterling Price, mostly in the SW¼ sec. 4, T. 25 S., R. 21 W. In 1955 these were owned by the heirs of Cleveland N. Dodge, formerly vice president of the Phelps Dodge Copper Corp. The mine is now caved and inaccessible and little is known about it. Copper was probably the principal metal produced, but minor amounts of lead and probably some silver were also present in the ore. According to Lindgren, Graton, and Gordon (1910, p. 331) the mine had been in operation prior to 1910, and probably had produced a considerable tonnage of ore. Shipments of copper are recorded for 1915 and intermittently thereafter for a number of years (Henderson, 1915, p. 374; 1916, p. 203; 1917, p. 713; 1918, p. 321; 1919, p. 741; 1920, p. 558). To judge from the size of the dump, the mine must have produced considerable ore; it was probably one of the largest mines in the area when it was in operation.

The deposit contains the typical contact metamorphic suite of silicates and ore minerals; it occurs along the Johnny Bull fault between the Horquilla limestone and the McGhee Peak conglomerate, about 1,000 feet west of the quartz monzonite sill exposed on the Silver Hill property. The ore occurs in the Horquilla limestone. Andesite volcanic rocks, and a latite porphyry dike crop out a few hundred feet southwest of the mine. The Horquilla limestone strikes about N. 65° W. and dips 35° NE. in the vicinity of the mine. At the mine the Johnny Bull fault strikes about N. 65° W., but a minor fracture striking N. 75° E. and dipping 65° SW. occurs within the Horquilla limestone.

According to Lindgren, Graton, and Gordon (1910, p. 331), from whom most of the following information is taken, two inclined shafts, the deeper of which was said to be 150 feet, were present in 1910. These were inaccessible, but the deeper of the shafts was cut at a depth of 40 feet by a short crosscut tunnel which was accessible in 1910. A stope about 40 feet long, 15 feet wide, and 15 feet long on the 40-foot level, followed a garnet zone which appeared to dip about 70°-80° E. The limestone in the mine was marmorized and contained cavities lined with calcite crystals. Garnet and quartz were abundant, but occurred in irregular bodies and patches. Cavities in the garnet contained quartz crystals coated with opal. Epidote was present, and a white mineral, probably wollastonite, was plentiful. A dull-greenish mineral may have been a pyroxene. Pyrite occurred in small masses, and chalcopyrite and a little bornite were scattered through the garnet. Limonite, malachite, and azurite occurred near the surface and chrysocolla, with quartz and opal, was present on the Copper Queen claim adjoining the Johnny Bull on the north.

DUKE AND OTHER CLAIMS

Numerous other prospects and old shafts are present in the area north and west of the Silver Hill and Johnny Bull mines. All are small and, with few exceptions, are caved and inaccessible. Some are along or near the Johnny Bull fault. Others are along or near the quartz monzonite porphyry sill which crosses the Silver Hill property. Others are not associated with either of these features. Copper, zinc, and lead are the principal ore metals, and small amounts of silver and possibly gold are present.

The Duke claims are in the SE% sec. 34, T. 24 S., R. 21 W., and the NE¼ sec. 4, T. 25 S., R. 21 W. They consist of a number of small pits, shallow shafts, and a large open cut in the vicinity of Frye Peak. All are within the Horquilla limestone, adjacent to or very near the quartz monzonite porphyry sill, about half a mile northwest of the Silver Hill mine. Some of the prospects are below the sill; others are above the sill. The mineralogy and structural relations are similar to those at the Silver Hill mine. To judge from the size of the dumps, no appreciable tonnage of ore has been shipped from this property.

A 70-foot vertical shaft on the Stella Maris Number 1 claim immediately north of and adjoining the Johnny Bull claim is within 250 feet of the Johnny Bull fault. In 1955 this claim was owned by Mrs. Cora Simonson of San Simon, Arizona. It is probably the same claim as the old Copper Queen claim, and old pits and shafts are close by the vertical shaft mentioned above. The quarter corner between secs. 3 and 4, T. 25 S., R. 21 W., lies 90 feet S. 28° W. of the shaft. A drift 20 feet below the collar of the shaft extends 25 feet north. In it a fracture which strikes N. 20° E. and dips 75° SE. is exposed. Chalcopyrite, quartz, and a small amount of galena occur in a siliceous limestone through a width of five feet along the fracture. On the surface a latite porphyry dike cuts the Horquilla limestone 10 feet north of the shaft. Epidote and garnet occur on the dump.

GRANITE GAP MINES

The Granite Gap group of claims includes seven patented claims mostly in the N½ sec. 3, T. 26 S., R. 21 W., but partly in SE¼ sec. 34, and the SW¼ sec. 35, T. 25 S., R. 21 W., owned by Vincent Veseley and Frank Veseley, Silver City, New Mexico, and three patented claims mostly in the SE¼ sec. 34 and the SW¼ sec. 35, T. 25 S., R. 21 W., but partly in the N½ sec. 3, T. 26 S., R. 21 W., owned by Raymond H. Custer and Robert A. Custer, Longview, Washington. The first group is called the Granite Gap or World's Fair group, and includes the Granite Gap, the November, the May, the World's Fair, the A. Bird, the Animas, and the Silver Star claims. The second group is called the Bob Montgomery group and includes the A. M., the Outlook, and the Bob Montgomery claims. The claims are all contiguous, and on them are a great number of shafts, tunnels, and adits, all of which are interconnected with a veritable maze of drifts, crosscuts, raises, winzes, and stopes. All the shafts are inaccessible, but a few of the adits can be entered; these were explored for a short distance only. Claim corners were not located on the ground, and it was not feasible to determine which shafts or adits are located on which claims. The geology is identical for all the deposits, and no attempt is made to distinguish or to discuss separately the deposits on the two groups of claims. Most of the shafts and the major portion of the deposits are on the Granite Gap group of claims.

The properties, which occupy most of the large hill on the south side of Highway 80 at Granite Gap (pl. 12), were first explored about 1880. Large scale operations began in about 1897, when many of the properties were consolidated under the control of Corbett and Wyman. Later the United States and Mexico Development Co. obtained control and was operating the mines when they were visited by Lindgren, Graton, and Gordon (1910, p. 330). Still later the Hartford Mining and Development Co., owned and controlled by the Hartford Insurance Co., Hartford, Connecticut, obtained control of the mines. Extensive production stopped about 1915, although small amounts of ore were shipped until at least 1926, and probably much later. Lindgren, Graton, and Gordon (1910, p. 330) state that the total value of shipments up until 1906 was at least $600,000. No estimate of the value of the ore shipped since that date is available, but it probably is also close to that figure. Most of the income came from lead and silver. Shipments were to smelters at El Paso, Texas, Deming, New Mexico, and Douglas, Arizona.

The deposits occur in the highly fractured limestones of the Horquilla and Escabrosa formations. Alteration, fracturing, and brecciation has obscured the stratigraphic relations, and some of the strata may be mistakenly identified. The Paradise formation, which elsewhere separates these two formations, was not traced definitely into the mineralized area, although it is present immediately to the south. If present, it is greatly altered.

Much of the following information is taken from the report by Lindgren, Graton, and Gordon, who examined some of the workings in 1905.

The ore is oxidized almost entirely to cerussite, but kernels of solid, probably recrystallized, galena are present. A little copper, zinc, and arsenic occur. The only gangue observed was coarse aggregates of calcite; the ore also contained limonite and manganese oxide. Very little gold was present, but the ore shipment in 1900 contained from 10 to 15 ounces of silver to the ton and as much as 20 percent lead. The original unoxidized ore may have been composed of galena and tetrahedrite.

Where observed the ore occurred exclusively in the limestone, near or adjacent to dikes of a light-colored fine-grained granite porphyry containing small phenocrysts of quartz and orthoclase. No contact metamorphic effects in the limestone were observed. Most of the ore bodies form small bunches, pockets, or stringers and are characterized by their irregularity of development. This irregularity is reflected in the workings. Some of the best ore occurred not far from the dikes.

None of the dikes mentioned by Lindgren, Graton, and Gordon as occurring in the vicinity of the workings were observed. A highly weathered granite dike, which may be the same rock, is present at the base of the hill west of the major workings. The description of the dikes, however, suggests that they may have been dikes of the quartz monzonite porphyry. Graton, Lindgren, and Gordon suggest that the most interesting genetic facts in relation to these deposits is the lack of contact metamorphism and the intimate relations of the ore and the dikes. To this may be added the extreme brecciation of much of the limestone and the position of the mineralized area adjacent to the Granite Gap fault, one of the major structural features of the range. The fault forms the southern boundary of an upthrown block of Precambrian granite.

DEPOSITS EAST AND SOUTH OF GRANITE GAP

Three caved and inaccessible shafts, some trenches, and small prospect pits lie less than half a mile east of Granite Gap in the NE¼ sec. 35, T. 25 S., R. 21 W. They are about 1 mile northeast of the central part of the Granite Gap group of mines. In the early 1950's the properties were under lease to E. B. Killian, El Paso, Texas.

The workings are along or in close proximity to the Granite Gap fault and are in the lower part of the El Paso limestone, or between this formation and the Bolsa quartzite or the Granite Gap granite. They appear to be simple fissure fillings, with possibly some replacement of the dolomite of the El Paso limestone. The fissures strike N. 60°-75° E. and dip steeply to the southeast. Fragments of galena and pyrite were found on the dumps.

About 2,000 feet south of these workings, a small pit along a fault striking N. 30° W. between El Paso limestone and Granite Gap granite contained marble, garnet, epidote, quartz, fluorite, pyrite, and copper carbonates. A nearby pit contained galena and sphalerite.

Half a mile southwest of the workings mentioned first above, a number of shafts and pits have been excavated along a fault which strikes N. 50°-70° W. and dips nearly vertically. Bolsa quartzite lies on the east side of the fault, and what is probably Percha shale lies on the west side. Abundant magnetite is present on the dumps.

CRYSTAL MINE

The Crystal mine was one of the small properties that was being worked in 1954 and 1955, by Mr. Sweet, Lordsburg, New Mexico. The mine, in the NE¼ sec. 19, T. 25 S., R. 20 W., is developed by a vertical shaft less than 50 feet deep and an adit 200 feet long below the shaft. The adit extends about 150 feet N. 80° W. and then turns north for about 60 feet. From this point stopes extend upward along the vein into the shaft. The ore occurs along a fracture in the Escabrosa limestone within a few hundred feet of an intrusion of quartz monzonite porphyry. The quartz monzonite porphyry may owe its present position to postintrusion faulting. The vein strikes about N. 20° E. and is almost vertical. Galena, sphalerite, chalcopyrite, and pyrite occur with calcite and quartz; galena is the most abundant of the sulfides, and only a few specks of chalcopyrite were observed. Brown cleavable calcite and cream-color fibrous calcite both are present. None of the contact-metamorphic silicate minerals were observed.

MINERAL MOUNTAIN MINE

The Mineral Mountain mine lies near the center of the line between secs. 20 and 17, T. 24 S., R. 21 W. The major shaft is probably in sec. 20. The mine is inaccessible and filled with water, but according to Lindgren, Graton, and Gordon (1910, p. 331) it is developed by an inclined shaft 200 feet deep. The vein strikes N. 80° E. and dips 65° S. The country rock is altered intensely, but is part of the andesite volcanic sequence. The vein contains quartz carrying appreciable percentages of galena, most of it fine grained. In places the ore carried as much as 20 ounces of silver to the ton (Lindgren, Graton, and Gordon, 1910, p. 331). Malachite is scattered on the dumps of nearby prospects.

CHARLES MINE

The Charles mine, a small property in the NE¼ sec. 21, T. 24 S., R. 21 W., was being operated by Mr. Sweet, Lordsburg, New Mexico, in 1954 and 1955 (pl. 13). It consists of a vertical shaft, 100 feet deep along an almost vertical fault striking about N. 45° E., with drifts extending about 50 feet both northeast and southwest of the shaft on the 100-foot level. Old caved and inaccessible shafts filled with water are nearby. The property has been worked intermittently for about 30 years, the first known record of shipment being in 1927 (Henderson, 1927, p. 471). Copper and lead (which has small amounts of silver) are the ore metals present. The ore consists of galena, pyrite, and chalcopyrite in a quartz gangue. The country rock is andesite.

The andesite is not intensely altered near the shaft, but along the extension of the fault to the southwest, in the valley between Attorney and Robinson Mountains, it is greatly fractured and pyritized over a wide area.

OTHER DEPOSITS

Numerous other small prospect pits and shallow shafts are scattered over the hills. Some of these contain hydrothermal vein deposits; others, pyrometasomatic deposits. No attempt was made to study them, for detailed analyses of them would add little to this report.

TUNGSTEN DEPOSITS

Deposits of scheelite in skarn rock of andradite garnet, tremolite or actinolite, quartz, and coarse calcite occur along the Preacher Mountain fault and along subsidiary and intersecting faults. Deposits occur both east and southwest of Cienega Peak, where the rocks on the north side of the fault are limestone. Southwest of Cienega Peak the deposits are in Chiricahua limestone where it abuts against the fault; east of the Peak they are in the Horquilla limestone. A quartz monzonite porphyry dike lies along the fault between the deposit southwest of the Peak and those east of the Peak. No quartz monzonite porphyry occurs along the fault in the vicinity of the deposits.

Southwest of Cienega Peak a small open cut and adit have been driven parallel to the strike of the strata into nearly vertical beds of Chiricahua limestone. The limestone is marbleized, and irregular masses of garnet are present. A greenish fibrous mineral, probably actinolite or tremolite, occurs in small veinlets and radiating masses within the garnet. Limonite and manganese oxide are present. Much of the garnet is red and reddish-brown andradite, similar to the garnet found elsewhere in the area, but some is dark reddish brown or brown, and may be spessatite or a manganesian andradite. Scheelite is present in small grains throughout the skarn rock.

East of Cienega Peak, some old prospect pits are present along the Preacher Mountain fault slightly less than half a mile west of the Preacher Mountain windmill. Red andradite garnet, green andradite garnet, calcite, and quartz occur on the dumps. These pits are reported to be the oldest workings among the tungsten deposits, and ore containing from 3 to 4 percent tungsten is said to have been mined.

A few hundred feet northwest of these old pits a vertical shaft about 25 feet deep has been sunk in Horquilla limestone near a fault which separates the limestone from the Bolsa quartzite. This fault strikes about N. 45° W. and intersects the Preacher Mountain fault near the old pits described above. The fault is not exposed in the shaft. Skarn rock consisting mostly of garnet with disseminated scheelite is present in the shaft. Ore removed from the shaft contained about 1 percent tungsten. A few hundred feet west of the shaft a thin bed of limestone that has been metamorphosed now consists largely of white radiating wollastonite. The bed strikes north at this point and dips 35° W. Small prospects excavated in 1954 and 1955 along the bed produced ore assaying 0.1-0.2 percent tungsten. The property in 1955 was recorded as the Baker-Standard Tungsten mine, controlled by the Standard Tungsten Corp. and Kelly and Co., Benson, Arizona, and New York, New York.

East of the Preacher Mountain windmill, the Preacher Mountain fault appears to break up into a number of parallel fractures. Several pits 8-10 feet deep have been dug on these fractures. The fractures strike N. 75°-80° E., and one of them dips 70° NE.; the dips on the others were not determinable. The Horquilla limestone is metamorphosed and replaced by contact silicates through a zone as much as 20 feet wide along the fractures. Coarsely crystalline massive light-green andradite garnet constitutes most of the skarn rock, but red andradite garnet, coarse calcite, and quartz are also present. Scheelite occurs sparingly throughout the skarn.

FLUORITE DEPOSITS

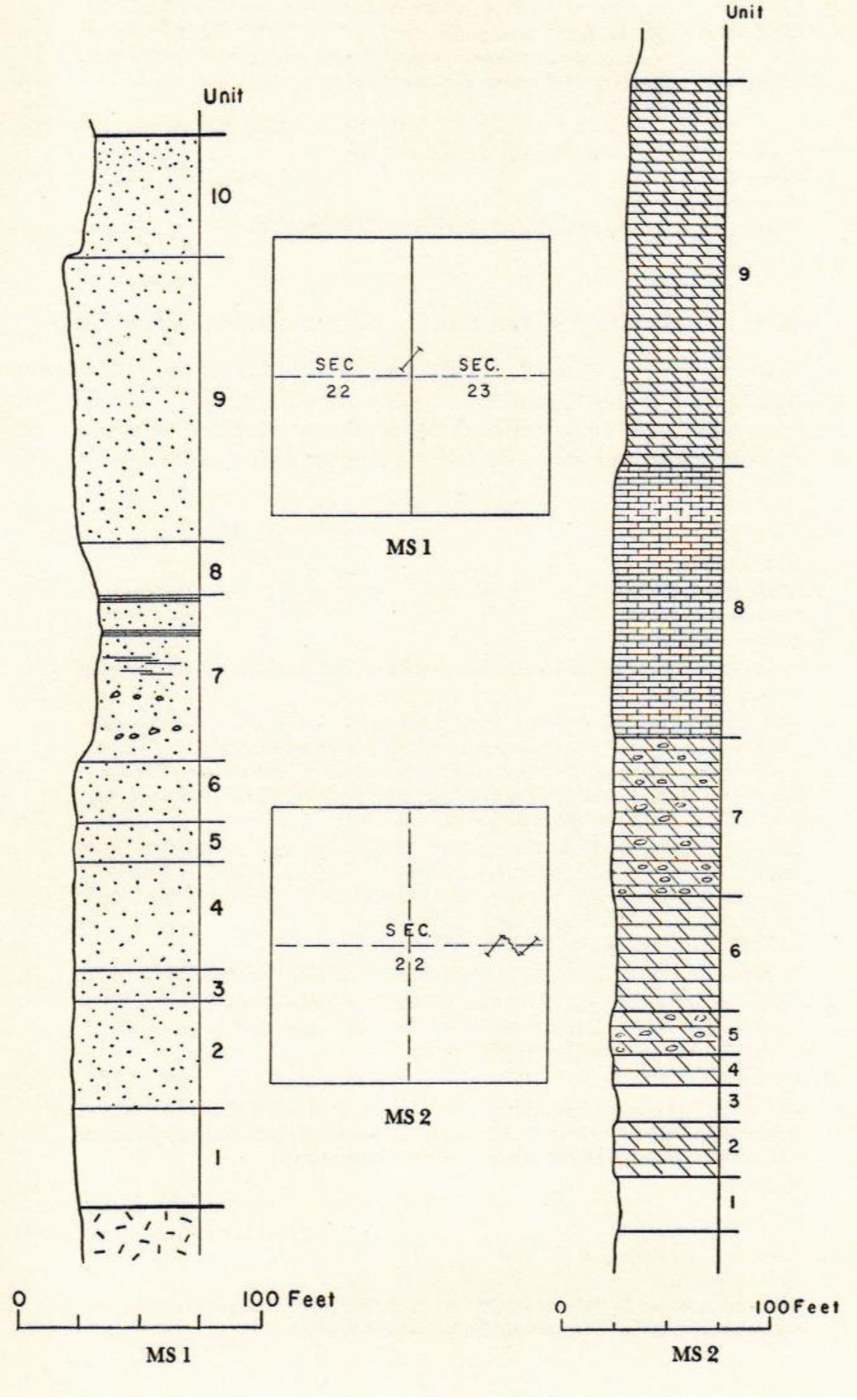
A few small pits containing veins of fluorite with quartz and calcite occur along the large northwestward trending fluorite fault in the N½ sec. 21, T. 25 S., R. 21 W. The coarsely crystalline green fluorite is in stringers and veinlets as much as 1 foot wide, in a breccia zone 2-3 feet wide, in limestone of the Earp formation. Small lenses of the fluorite are present in a number of places along the fault for a distance of about 1 mile.

Measured Sections

MS 1. BOLSA QUARTZITE (Cambrian)

About three-quarters of a mile northwest of Preacher Mountain windmill, in SW¼NW¼ sec. 23 and SE¼NE¼ sec. 22, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Adjoins MS 2. Measured by Elliot Gillerman and R. V. McGehee, August 1955, with Jacob's staff.

UNIT No.	DESCRIPTION	THICKNESS *(feet)*
	El Paso limestone	
	Dolomite, light-gray, fine-grained, medium-bedded, with dolomite rhombs in relief on the weathered surface (unit 2, MS 2).	
	Concealed (unit 1, MS 2).	
	Contact concealed	
	Boise quartzite	
10	Sandstone, white to light-gray, fine- to very fine-grained, thin-bedded, well-sorted; very pure orthoquartzite; quartz grains well rounded; grain size decreases upward, and the uppermost beds are a white siltstone	49
9	Sandstone, light-gray to white, fine- to medium-grained, well-cemented, well-sorted orthoquartzite; quartz grains subround; beds as much as 4-5 ft thick; crosslaminated; small amount of feldspar; resistant and cliff-forming	116
8	Concealed	*22*
7	Sandstone and shale, dark-greenish, fine-grained arkosic and glauconitic sandstone in lower part; quartz and feldspar grains angular to subround; thin conglomeratic beds and lenses of granule-size fragments; upper part is alternating thin-bedded sandstone and dark-gray to black sandy shale; shale has wavy bedding planes, with mica and graphite flakes on bedding surfaces; no fossils observed. This unit weathers to a darker color than does the remainder of the formation	67
6	Sandstone, gray, medium-grained, arkosic sandstone; considerable clay or weathered feldspar between quartz grains; less resistant to weathering than lower beds and forms a topographic saddle	25
5	Sandstone, green, fine-grained, slightly glauconitic orthoquartzite; beds 12-24 in. thick; quartz grains angular to subangular and not so well sorted as in lower beds; feldspar grains uncommon	16
4	Sandstone, light-gray to white, fine-grained orthoquartzite; beds 3-12 in. thick; quartz grains well rounded; well-cemented; a few thin beds and lenses of coarse-grained arkosic sandstone in the upper part. In these beds the feldspar is only slightly altered, and the quartz and feldspar grains are angular to subangular	44
3	Sandstone, green, fine-grained glauconitic orthoquartzite; beds 12-24 in. thick; quartz grains mostly well rounded; lenses of medium- and coarse-grained sandstone and conglomeratic sandstone, with granule- and pebble-size quartz and feldspar fragments; large feldspar fragments are angular	13


Unit
10
9
8
7
6
5
4
3
2
1
0
100 Feet
MS 1
SEC
22
SEC.
23
MS 1
SEC.
22
MS 2
Unit
9
8
7
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5
4
3
2
1
0
100Feet
MS 2

2	Sandstone, light-gray to white, fine-grained, well-cemented orthoquartzite; beds 6-12 in. thick; quartz grains well rounded; thin beds in upper part are coarser grained and contain some feldspar particles of pebble size. Feldspar is unaltered, and grains are subround	44
	Total Bolsa quartzite	396
	Contact concealed, undoubtedly unconformable	
1	Concealed	41
	Granite Gap granite	
	Granite, pink, coarse-grained, much altered. Precambrian.	

MS 2. EL PASO LIMESTONE (Cambrian and Ordovician)

About three-quarters of a mile northwest of Preacher Mountain windmill, in SE¼NE¼ and NE¼SE¼ sec. 22, T. 25 S., R. 21 W., Hidalgo County, New Mexico. A continuation of MS 1. Measured by Elliot Gillerman and R. V. McGehee, August 1955, with Jacob's staff.

UNIT No.	**DESCRIPTION**	**THICKNESS** (feet)
	Percha shale	
	Shale, black, fissile	
	Contact concealed	
	El Paso limestone	
9	Dolomite, light-gray, fine-grained, noncherty; beds 1-3 ft thick; darker gray toward the top	185
8	Limestone, gray, thin-bedded, with wavy or crinkly bedding planes; fine-grained; alternating with very thin-bedded brown-weathering black chert; weathered surfaces and bedding plane surfaces show brown cherty fucoidallike markings in a raised reticulated pattern. Unit weathers in slabs 1-3 in. thick. Some shale interbeds and chert nodules	130
7	Dolomite, moderate-pink, fine-grained, with lenses and nodules of moderate-pink chert; beds 2-3 ft thick; surface weathers rough, with crinoid stems and dolomite rhombs standing in relief on the surface; chert lenses are up to 3 in. thick and 5 ft long	75
6	Dolomite; similar to unit 7 but free of chert	56
5	Dolomite, medium light-gray, fine-grained, with thin lenses of black chert	21
4	Dolomite, medium light-gray, fine- to medium-grained, with crosslaminations and bedding planes showing on the weathered surface as brownish ridges. Weathered surfaces appear sandy	15
3	Concealed	18
2	Dolomite, light-gray, fine-grained, medium-bedded, with dolomite rhombs standing in relief on the weathered surface and giving a sandy appearance to the rock. Weathered surface is pale yellowish brown	26
1	Concealed	27
	Total El Paso limestone	553
	Contact concealed	
	Bolsa quartzite	
	Sandstone, white to light-gray, fine- to very fine-grained, thin-bedded, well-sorted; very pure orthoquartzite. Same as unit 9, MS 1.	

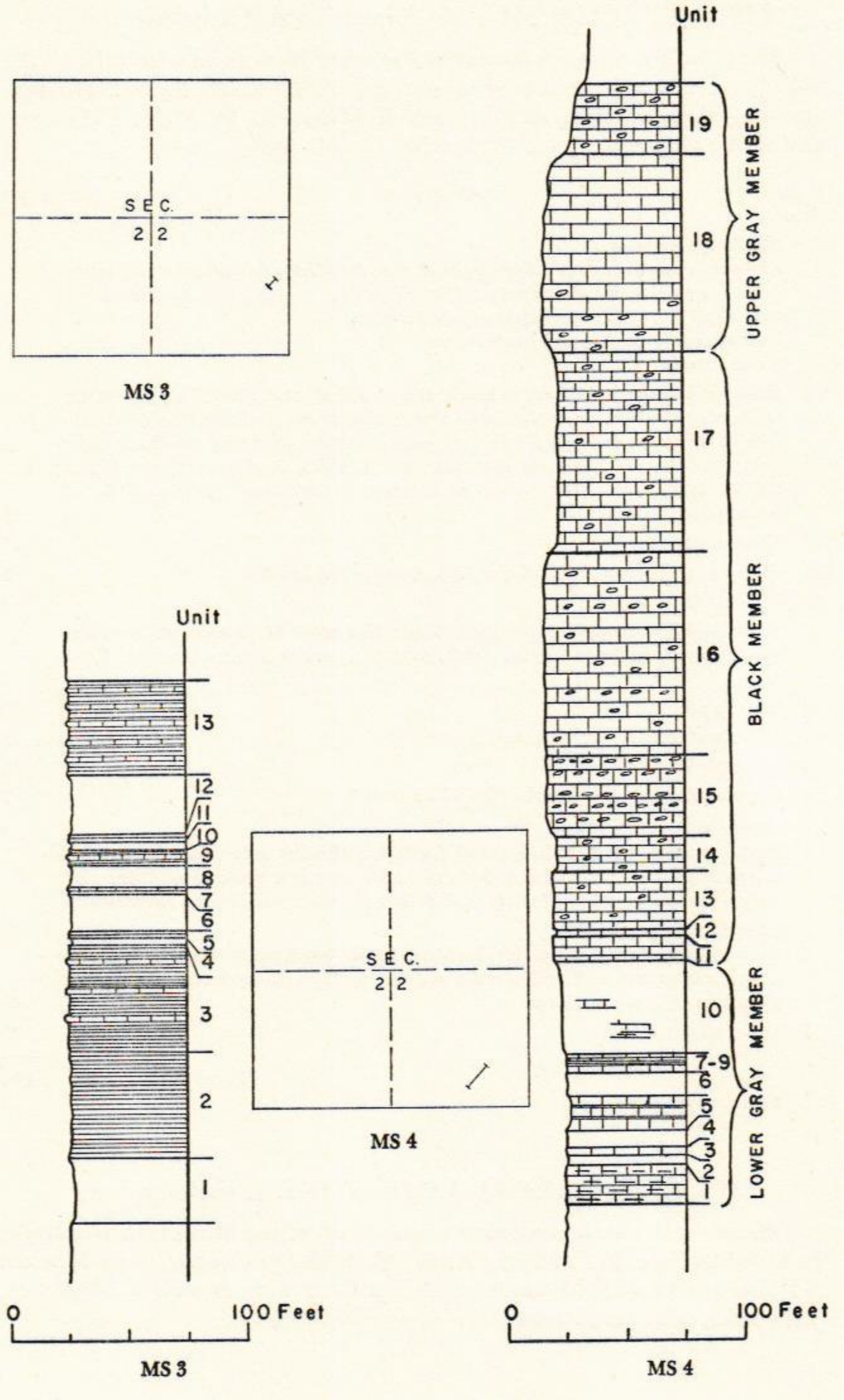
MS 3. PERCHA SHALE (Devonian and Mississippian?)

About half a mile northwest of Preacher Mountain windmill in the SW¼ sec. 23 and the E½SE¼ sec. 22, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Adjoins MS 4. Measured by Elliot Gillerman and R. V. McGehee, June 1955, with Jacob's staff.

UNIT No.	DESCRIPTION	THICKNESS (feet)
	Escabrosa limestone	
	Limestone, medium-gray, fine-grained, thin-bedded, with crinoid and other fossil fragments; weathers pale yellowish brown. Gradational upward from unit 13 of the Percha formation (unit 1, MS 4)	
	Contact conformable and gradational	
	Percha shale	
13	Shale and limestone. Shale is black, thin bedded, and platy, but not fissile as in lower beds; weathers grayish green; calcareous on fresh-fractured surface. Limestone is black, fine grained, nodular; weathers medium light gray; nodules are 1-8 in. in diameter, 2-3 in. thick, and in irregular layers 2-6 in. apart, separated by shale. Limestone comprises 30-50 percent of lower part of unit	40
12	Concealed	25
11	Shale, greenish-gray, soft, fissile, calcareous, thin-bedded	3
10	Concealed	4
9	Shale and limestone interbedded. Shale like unit 11; limestone is black, fine grained, in beds 2-4 in. thick, nodular, and weathers medium light gray	6
8	Concealed	10
7	Shale and limestone; like unit 9	3
6	Concealed	15
5	Shale and limestone interbedded; like unit 9	2
4	Concealed	4
3	Shale, greenish-black, thin-bedded, fissile, weathering pale yellowish brown; alternating with 1-2 in.-thick beds of black very fine-grained nodular and flaggy limestone; some of shale is slightly calcareous; limestone increases in abundance upwards	45
2	Shale, black, fissile, very thin-bedded, hard, blocky-weathering, and not contorted; green and red streaks on the weathered surfaces and brown stains on fracture surfaces	45
1	Concealed	28
	Total Percha shale	230
	Latite porphyry dike	

MS 4. ESCABROSA LIMESTONE (Mississippian)

About half a mile west-northwest of Preacher Mountain windmill, in SE¼SE¼ sec. 22, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Adjoins MS 3 and 5. Measured by Elliot Gillerman and R. V. McGehee, June 1955, with Jacob's staff.


SEC.
22
MS 3
Unit
13
12
11
10
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8
7
6
5
4
3
2
1
0
100 Feet
MS 3
SEC.
22
MS 4
Unit
19
18
17
16
15
14
13
12
11
10
7-9
6
5
4
3
2
1
UPPER GRAY MEMBER
BLACK MEMBER
LOWER GRAY MEMBER
0
100 Feet
MS 4

UNIT No.	**DESCRIPTION**	**THICKNESS** (feet)
	Paradise formation	
	Limestone, brownish-gray to medium-gray, very fine-grained, thin-bedded; weathers gray and brown; same as unit 1, MS 5	
	Contact conformable	
	Escabrosa limestone	
	Upper gray member	
19	Limestone, medium light-gray to light-gray, coarse- to medium-grained calcarenite, consisting largely of crinoidal fragments; thick-bedded; pink and light-gray chert nodules abundant	30
18	Limestone, medium light-gray to light-gray, coarse- to medium-grained calcarenite, consisting largely of crinoidal remains; beds 2-10 ft thick, massive; rough-weathering; a few beds of dark-gray to grayish-black crinoidal limestone, particularly in the lower part; chert lenses present but not common; chert is moderate pink to white; unit forms a steep slope but is not cliff forming, as are the units below; this unit and unit 19 form the crest of the ridge	83
	Black member	
17	Limestone, dark-gray to grayish-black, fine- to medium-grained calcarenite; many of the beds consist wholly of crinoidal remains; crosslaminations and current swirls; dark-gray and grayish-black chert nodules abundant; chert weathers brown; beds 3-12 ft thick; beds of black crinoidal limestone 6-12 in. thick, and several 2-in.-thick beds of black siliceous siltstone near the top. Unit not so cliff forming as units 16 and 15 below	86
16	Limestone and interbedded chert. Limestone like that of unit 17, but thicker bedded. Chert also like that of unit 17, but in beds as well as nodules. Chert more abundant in upper than in lower part of unit. Cross-laminations show on weathered surfaces, with fossil fragments strung out along laminations	85
15	Limestone and interbedded chert. Limestone and chert like those of units 17 and 16. Chert in irregular beds 2-4 in. thick; limestone in beds 3-12 in. thick, which contain chert nodules. Chert beds more persistent where thicker; when thin, they break into nodules. Bedding and laminations in limestone go around chert nodules, not through them. Chert nodules and lenses have sharp boundaries	34
14	Limestone, grayish-black to black, fine-grained, smooth on weathered surface; beds up to 10 ft thick, massive; black chert nodules, weathering dark brown; crinoidal fragments	14
13	Limestone, dark-gray to black, very fine-grained to fine-grained; beds 5-10 ft thick, massive; black chert nodules, which weather brown; abundant fossil fragments standing in relief on weathered surface	25
12	Limestone; like unit 13, but beds are only 6-12 in. thick	3
11	Limestone; like unit 13, but no chert observed; fossil fragments are mostly crinoidal remains	10
	Lower gray member	
10	Concealed; but a few thin beds of gray limestone are poorly exposed	25
9	Limestone, medium-gray, medium-grained, 6-in.-thick beds of calcarenite composed of shell fragments	1
8	Shale, white, soft. calcareous, much weathered	5

7	Limestone, dark-gray, medium-grained calcarenite in beds 3-8 in. thick; calcareous shale interbeds up to 2 in. thick; a few crinoidal and other fossil fragments; weathered surface is rough; abundant veins filled with coarse calcite	2
6	Concealed	10
5	Limestone; like unit 7	15
4	Concealed	8
3	Limestone, dark-gray, fine-grained, thin-bedded, shalt', fossiliferous; weathers pale yellowish brown	3
2	Concealed	4
1	Limestone; like unit 3 but grades into unit below with increasing shale content	17
	Total Escabrosa limestone	460
	Contact conformable and gradational	
	Percha shale	
	Shale and interbedded limestone; unit 13, MS 3	

MS 5. PARADISE FORMATION (Mississippian)

About three-quarters of a mile west-northwest of Preacher Mountain windmill, in SE¼SE¼ sec. 22, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Adjoins MS 4 and MS 7. Measured by Elliot Gillerman and R. V. McGehee, June 1955, with Jacob's staff.

UNIT No.	**DESCRIPTION**	**THICKNESS** (feet)
	Horquilla limestone	
	Limestone, medium light-gray, fine-grained, medium- to thick-bedded, rough-weathering, with some chert nodules; same as unit 1, MS 7	
	Paradise formation	
16	Concealed	10
15	Limestone, medium-gray, which weathers brown, medium-bedded; numerous fossil fragments; pyrite crystals on the weathered surfaces	8
14	Concealed, probably brown, siliceous, oolitic limestone	33
13	Limestone, medium-gray, with brown streaks, thin-bedded, hard, very fossiliferous; contains bryozoa brachiopods and crinoid fragments	2
12	Limestone, medium-gray and brown, medium- to coarse-grained, medium-bedded, oolitic, fossiliferous calcarenite or coquina	1
11	Limestone; like unit 13	6
10	Concealed	6
9	Limestone; like unit 12	6
8	Concealed, but with two thin beds of brown-weathering, medium light-gray, calcareous siltstone, poorly exposed within the interval	6
7	Limestone, medium-gray, fine-grained, hard, medium-bedded; breaks with conchoidal fracture; fine crosslaminations show on weathered surface	5
6	Concealed	5

5	Limestone, black, with red and green streaks, very fine-grained, thin- to medium-bedded; weathered surface is mottled, medium light gray, and light brown; conchoidal fracture; no fossils observed	3
4	Limestone, medium-gray, weathering medium light gray and light brown; medium- to thick-bedded, medium-grained, calcarenite and coquina composed wholly of fossil fragments	24
3	Concealed	6
2	Limestone, light-brown and medium-gray, fine-grained, medium-bedded, hard; weathers to a rough surface, with brown streaks on a gray background	4
1	Limestone, brownish-gray to medium-gray, very fine-grained, thin-bedded; weathers gray and brown; the limestone forms discrete beds between concealed areas, which are probably shale	18
	Total Paradise formation	143

Contact conformable

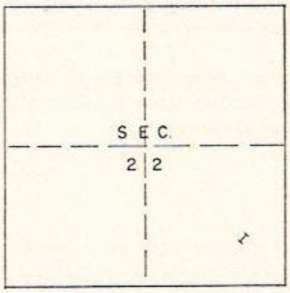
Escabrosa limestone

Limestone, medium light-gray to light-gray, coarse- to medium-grained calcarenite with pink and light-gray chert nodules (unit 19, MS 4)

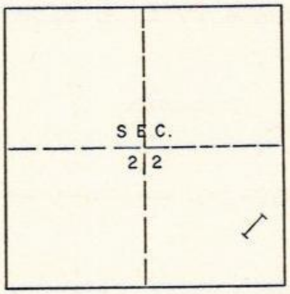
MS 6. PARADISE FORMATION (Mississippian)

About one and one-quarter mile north-northwest of Cienega Peak, in SE¼ sec. 16, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Near top of large gully on east face of north-northwest trending hogback, and on small backslope of slight prominence that forms the southeast side of the gully. Measured by F. A. Packard, August 1954, with Brunton compass and tape.

UNIT No.	**DESCRIPTION**	**THICKNESS** (feet)
	Naco limestone	
	Limestone and chert, light-gray, fossiliferous, medium-grained; chert nodules.	
	Fault contact	
	Paradise formation	
74	Argillite, partially covered, dark-gray, quartzite, fairly hard, pyritic; almost a quartzite in places	2.0
73	Conglomerate, dark-gray, limestone-pebble conglomerate; particles are subangular	1.0
72	Argillite; same as bed 74	8.5
71	Quartzite, mostly covered, gray, weathering brown, pyritic, calcareous, fine-grained	12.5
70	Conglomerate, dark-gray, limestone pebble conglomerate; pebbles are dark-gray fine-grained limestone; matrix is almost same, but somewhat more argillaceous	0.9
69	Argillite, covered, light-green, fairly hard	6.0
68	Limestone, dark-gray, weathering light gray; pyritic, medium-grained	1.0



MS 5



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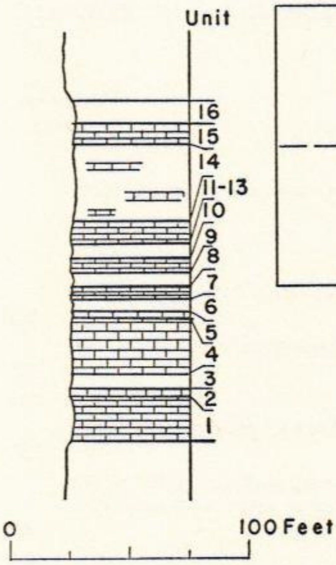

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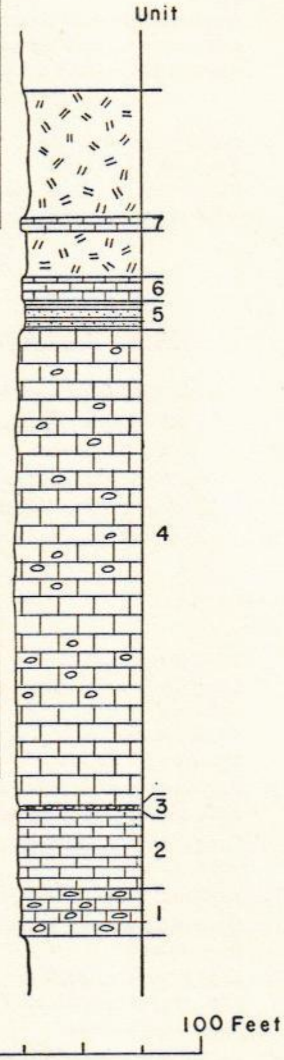


MS 7

67 Limestone, gray, weathering light gray; very oolitic, medium-grained	0.9
66 Argillite, covered, light green-gray with yellow spots	4.1
65 Argillite and limestone, dark-gray and brown mottled, weathering to a rough surface of gray and brown; limestone is gray, fine grained; argillite is spotted, occurs as a matrix around the limestone "nodules"; possibly a nodular limestone	2.8
64 Limestone, apparently finely crosslaminated, dark brown-gray and black, weathering mottled colors of gray, slightly oolitic, finely arenaceous, medium-grained; appears to have small lenses of purer limestone surrounded by more resistant, more arenaceous material	2.6
63 Limestone, partly covered, finely crosslaminated, weathering gray, finely arenaceous, medium-grained	3.2
62 Limestone, gray-brown, weathering brown, slightly fossiliferous, finely arenaceous, medium- to coarse-grained; Bryozoa	2.4
61 Argillite, covered, gray, weathering brown gray, spotted; contains some elongate ferrugenous impressions that may have been plant remains(?)	2.8
60 Limestone, gray, weathering light gray, crinoidal, medium-grained	2.3
59 Argillite, covered, platy, light green-gray, fairly hard and brittle	4.6
58 Limestone, very fractured, probably finely crosslaminated, gray and dark-gray, weathering light gray and brown on a rough surface, fossiliferous, finely arenaceous, medium-grained; has appearance on weathered surface of small lenses of purer limestone surrounded by more resistant, more arenaceous bands	1.9
57 Limestone, finely crosslaminated, gray, weathering light brown and gray mottled, very silty, fine- to medium-grained	1.8
56 Argillite, gray, weathering to brown and gray, hard, pyritic, slightly calcareous	1.4
55 Limestone, gray-brown, weathering brown and gray; fossiliferous, partially granulitic, silty and argillitic in part; thin argillitic portions contain granules of dark-gray limestone; Bryozoa	1.1
54 Argillite, mostly covered, contorted to a slight degree; olive, gray, and reddish-brown, weathering yellow brown and gray, spotted at levels, medium-hard, pyritic, very slightly calcareous at levels; fairly low-grade argillite; contains some mottling by ferrugenous material and some structures that may be ironstone concretions	21.0
53 Limestone, dark olive-gray, weathering brown-gray, very fossiliferous, oolitic, medium-grained; *Spirifer* sp., *Spirifer bifurcatus?, Spiriferina sp., Orthotetes Kaskaskiensis?, Archimedes* sp	1.4
52 Limestone, dark-gray, weathering brown, very fossiliferous, fairly soft, medium-grained; *Archimedes* sp	2.4
Fault (Lower beds were measured near top of main gully 100 yards north of backslope below small prominence where upper beds are exposed.)	
51 Limestone and argillite, thin beds of limestone are separated by argillite laminae, are finely crosslaminated at some levels between the argillite laminae, and are dark gray, weathering brown gray, silty to very silty, fine- to medium-grained; argillite laminae are parallel to subparallel, dark gray, weathering brown, slightly calcareous to noncalcareous, pyritic	15.4
50 Argillite and marble, gray, and gray- and white-mottled, weathering to brown and gray mottled with a rough surface; argillite is gray, spotted, pyritic; marble occurs in the middle of the unit and is white, crumbly, fairly pure; marble is in "pockets" with argillite surrounding it in the manner of a matrix; possibly a nodular limestone	5.4

49	Argillite and marble, dark- and light-gray mottled, weathering brown and light gray; argillite is gray, fairly hard, spotted, pyritic; marble is in pockets, light-gray, possibly a nodular limestone	1.4
48	Limestone, gray, weathering brown gray, medium- to coarse-grained; almost a marble	1.1
47	Argillite, gray- and light-gray mottled, weathering tan, spotted, hard, pyritic	0.1
46	Argillite and limestone, dark- and light-gray mottled, weathering brown and light gray mottled, fossiliferous; argillite is dark gray, hard, pyritic, slightly calcareous; limestone is light gray, medium grained, near a marble; limestone is in thin, small lenses with argillitic material in undulating bands around it; probably a clastic deposit; Bryozoa	1.9
45	Argillite, gray, weathering gray, spotted, pyritic	1.9
44	Limestone and argillite. Limestone is gray, in thin beds between argillite laminae, finely crosslaminated in many of these beds, finely arenaceous, fine- to medium-grained. Argillite is in parallel to subparallel very thin beds and laminae, dark-gray, weathering brown, spotted, hard, pyritic, slightly calcareous	11.5
43	Argillite and limestone. Argillite is dark gray, weathering brown, spotted, hard, calcareous. Limestone occurs in upper foot as small, numerous, thin lenses with argillite material as thin undulating bands around them; probably a clastic deposit	3.7
42	Argillite, brown-gray, weathering brown, spotted, hard, pyritic; contains a few weathered out pockets that may represent nodules(?) of limestone	1.3
41	Argillite, gray and dark-brown semi-banded, weathering chocolate brown, spotted, hard, pyritic, slightly calcareous	0.9
40	Quartzite, gray, weathering brown, hard, pyritic, slightly calcareous, fine-grained	2.3
39	Limestone, laminated, gray, weathering brown, oolitic, slightly finely arenaceous, medium-grained	0.4
38	Quartzite, gray, weathering brown, hard, pyritic, slightly calcareous, fine-grained	2.7
37	Limestone, covered, gray-brown, weathering grayish brown, medium-grained	0.6
36	Argillite, covered, olive-green, spotted, fairly hard	1.7
35	Limestone, gray, weathering light gray, finely arenaceous, soft and rotten, medium-grained; almost a marble	1.5
34	Limestone, finely crosslaminated, gray-brown, oolitic(?), medium-grained	0.6
33	Limestone, gray, weathering light gray, finely arenaceous, soft, rotten, medium-grained	0.9
32	Limestone, gray to olive-brown, weathering to gray, fossiliferous, very oolitic, medium-grained; fossil evidence poor; *Spirifer* sp., *Composita* sp.(?), *Eumetria* sp.(?), *Agassizocrinus* sp	6.0
31	Limestone, finely crosslaminated, dark-gray, weathering brown gray, finely arenaceous, silty, medium-grained; almost a calcareous, fine-grained sandstone	0.9
30	Argillite, platy, dark-gray, weathering brown, hard, brittle	0.6
29	Limestone, light-gray, fossiliferous, soft and rotten, medium-grained	2.8
28	Argillite, laminated, light-tan, weathering tan spotted; still retains some of shale cleavage	0.4
27	Limestone, gray, weathering gray, oolitic, medium-grained	0.3

26	Argillite and limestone, argillite is gray, weathering brown, very hard, pyritic, very slightly calcareous; pyrite is concentrated in very thin layers; lower and upper 0.3 feet has small lenses of limestone, finely crosslaminated, gray, finely arenaceous, medium-grained	1.2
25	Limestone, finely crosslaminated, finely arenaceous, medium-grained	3.0
24	Limestone, light-gray, weathering gray, fairly soft and rotten, medium-grained, very metamorphosed	0.5
23	Argillite, gray, weathering mottled brown and light yellowish brown, very hard, pyritic, calcareous	1.6
22	Argillite, gray, weathering dark slate gray, spotted, very slightly calcareous	3.8
21	Argillite, gray- and light gray-mottled, weathering yellow brown, spotted, very hard, pyritic, calcareous; weathered-out pockets that probably represent nodules of limestone	1.6
20	Limestone, lower part is gray- and light gray-banded, slightly finely arenaceous, medium-grained, very metamorphosed; grades up into tan, weathering a light brown, rotten, crinoidal, medium- to coarse-grained limestone	5.2
19	Limestone, finely crosslaminated, gray and tan, weathering a light gray and brown banded, very finely arenaceous, medium-grained; more arenaceous parts stand out and weather a different color, giving an undulating banded appearance	1.4
18	Limestone, gray, weathering gray, fairly pure, medium-grained	11.4
17	Limestone, light-gray to brownish-gray, weathering light gray and brown, finely arenaceous, medium-grained; contains thin, undulating, very arenaceous layers that weather brown and stand out on weathered surface	2.9
16	Limestone and argillite, limestone is nodular, gray, gray-brown and light-green mottled, weathering gray and brown mottled with a rough surface, fine-grained; argillite is gray, weathering brown, slightly calcareous, and serves as a matrix around nodules of limestone	1.8
15	Argillite, chocolate-brown, weathering light brown, very hard, pyritic	12
14	Limestone and argillite; same as bed 16	1.7
13	Quartzite, chocolate-brown and gray-green mottled, weathering to a brown, very hard, argillitic	2.1
12	Limestone, lower part finely crosslaminated, gray and brown-gray, weathering a light gray, finely arenaceous, medium-grained; grades up into limestone that is much less arenaceous	4.2
11	Limestone and chert, finely crosslaminated, very light gray and light gray-brown, weathering to light brown and gray, finely arenaceous, cherry, medium-grained; chert is very light gray, and occurs as thin lenses	1.5
10	Limestone and chert, green-gray, cherty, medium- to corase-grained; almost a marble; chert is very light gray and contains small calcareous fragments	2.4
9	Argillite, light-gray, slightly micaceous, with fairly good shale cleavage; low-grade argillite	0.6
8	Quartzite, brown-gray, weathering light gray, fine-grained, argillitic	0.7
7	Limestone, brown-gray, weathering light gray, finely arenaceous, medium-grained	3.7
6	Quartzite, grayish-brown, very hard, pyritic, fine-grained	1.7
5	Limestone, light gray-brown, weathering brown, finely arenaceous, fairly hard, medium-grained; almost a calcareous sandstone; more arenaceous parts stand out and weather a darker color in an undulating pattern	1.2

4	Limestone, finely crosslaminated, light-gray, very arenaceous, hard, pyritic, medium-grained; almost a calcareous sandstone or quartzite	3.9
3	Limestone, finely crosslaminated, gray-brown, finely arenaceous, hard, pyritic, medium-grained; almost a fine-grained calcareous quartzite	0.9
2	Quartzite, gray, weathering dark reddish brown, hard, pyritic, very slightly calcareous, fine- to very fine-grained	0.3
1	Limestone, finely crosslaminated, light-gray, weathering to a brownish gray, very arenaceous, medium-grained; almost marble	1.3
	Total Paradise formation	216.7

Conformable contact ?
Top of Escabrosa, marble; pinkish-white, weathering light tan and pink, saccaroidal- to coarse-grained.

MS 7. HORQUILLA LIMESTONE (Pennsylvanian and Permian)

About three-quarters of a mile west-northwest of Preacher Mountain windmill, in the SE¼SE¼ sec. 22, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Measured by Elliot Gillerman and R. V. McGehee, June 1955, with Jacob's staff.

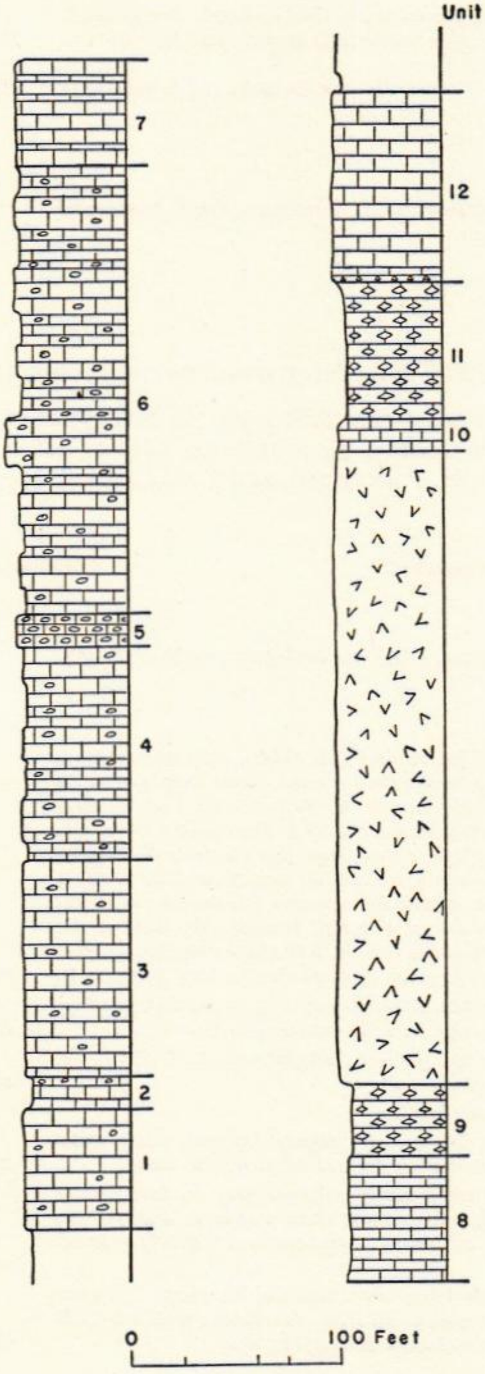
UNIT No.	DESCRIPTION	THICKNESS (feet)
	Horquilla limestone (middle or upper part)	
	Limestone, dark-gray or black, medium-bedded, fine-grained; abundant calcite veins; *Triticites* sp. 11 ft above the base of the unit and *Triticites kellyensis* Needham 14 ft above the base of the unit	
	Fault	
	Latite porphyry dike or sill	53
	Horquilla limestone (basal part)	
7	Limestone, medium-gray, weathering to dark-gray; streaked and spotted, red and light-gray; thin- to medium-bedded	6
	Latite porphyry dike or sill	18
6	Limestone, medium-gray, grayish-red, and light-brown; weathers brown; thick-bedded, hard	10
5	Sandstone and shale, medium- to light-gray with brown streaks; weathers brown; hard; calcareous; blocky weathering	14
4	Limestone, medium-gray, thick-bedded, massive, cliff-forming; fine-grained; fossiliferous beds 50 ft and 73 ft above the base of the unit with brachiopods, bryozoans, corals, and crinoid fragments; abundant gray and pink chert nodules, which weather brown, particularly in the upper part	198
3	Limestone, similar to unit 4, but thinner bedded and with thin beds and nodules of black chert	2
2	Limestone, medium-gray, thick-bedded, massive, medium- to coarse-grained; rough weathering; fossiliferous; calcite veins in upper part	33

1	Limestone, medium light-gray, medium- to thick-bedded, fine-grained, with elongated chert nodules; rough weathering; pyrite incrustations	20
	Total Horquilla limestone (basal part)	283
	Contact covered	
	Paradise formation	
	Concealed (unit 16, MS 5)	
	Limestone, medium-gray, medium-bedded, numerous fossil fragments; brown-weathering. (unit 15, MS 5)	

MS 8. HORQUILLA LIMESTONE (Pennsylvanian and Permian)

About 2,000 feet south of the Silver Hill mine, in NW¼ sec. 3, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Adjoins MS 9. Measured by Elliot Gillerman, H. P. Bushnell, and F. A. Packard, July 1954, with Jacob's staff.

UNIT No.	DESCRIPTION	THICKNESS (feet)
	Earp formation	
	Limestone, silty, very fine-grained, black to dark-gray, weathering tan. Unit 1, MS 9.	
	Contact conformable	
	Horquilla limestone	
12	Limestone, dark-gray, thick-bedded (beds 3-5 ft thick), very fine-grained, cliff-forming; a 3-ft-thick breccia bed at the base, composed largely of small angular and subangular limestone fragments. *Triticites* sp. and *Schwagerina huecoensis* (Dunbar and Skinner) occur 25 ft above the base of the unit and 2 ft above a large *Syringopora* sp. colony; 2 ft above the fusulinids is a 3-ft bed of lighter gray limestone, containing numerous dark blotches which may have originally been corals. *Schwagerina aff. huecoensis* (Dunbar and Skinner) and *Schubertella* sp. occur 37 ft above the base of the unit, and another 3-ft blotchy layer is present 3 ft above these fusulinids. *Schwagerina* sp. and *Triticites* sp. occur 58 ft above the base of the unit	89
11	Limestone, white, medium-bedded, fine-grained, sugary-textured marble, resulting from contact metamorphism; soft; weathers to low slope	65
10	Limestone, dark-gray to black, fine-grained, well-indurated. *Triticites aff. creekensis, 1* ft above the base of the unit	15
	Quartz monzonite porphry sill 300 ft thick	
9	Limestone, light-gray to white, fine-grained, sugary-textured, soft marble-ized limestone with greenish-brown streaks and small quartz lenses	35
8	Limestone, dark gray on weathered surface, lighter gray on freshly-fractured surface; medium-bedded, fine-grained; chert common; many of the beds are very fossiliferous and calcarenites are common. Light-gray lenses are present locally	60
7	Limestone; similar to the underlying unit, but the limestone is darker gray, with beds 3-4 ft thick, forming small cliffs, alternating with 1-ft-thick beds. Chert is not so abundant as in the underlying unit	50



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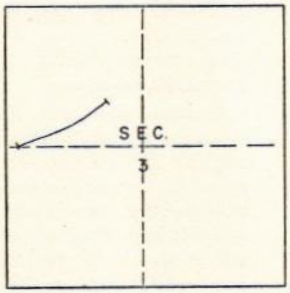


MS 8

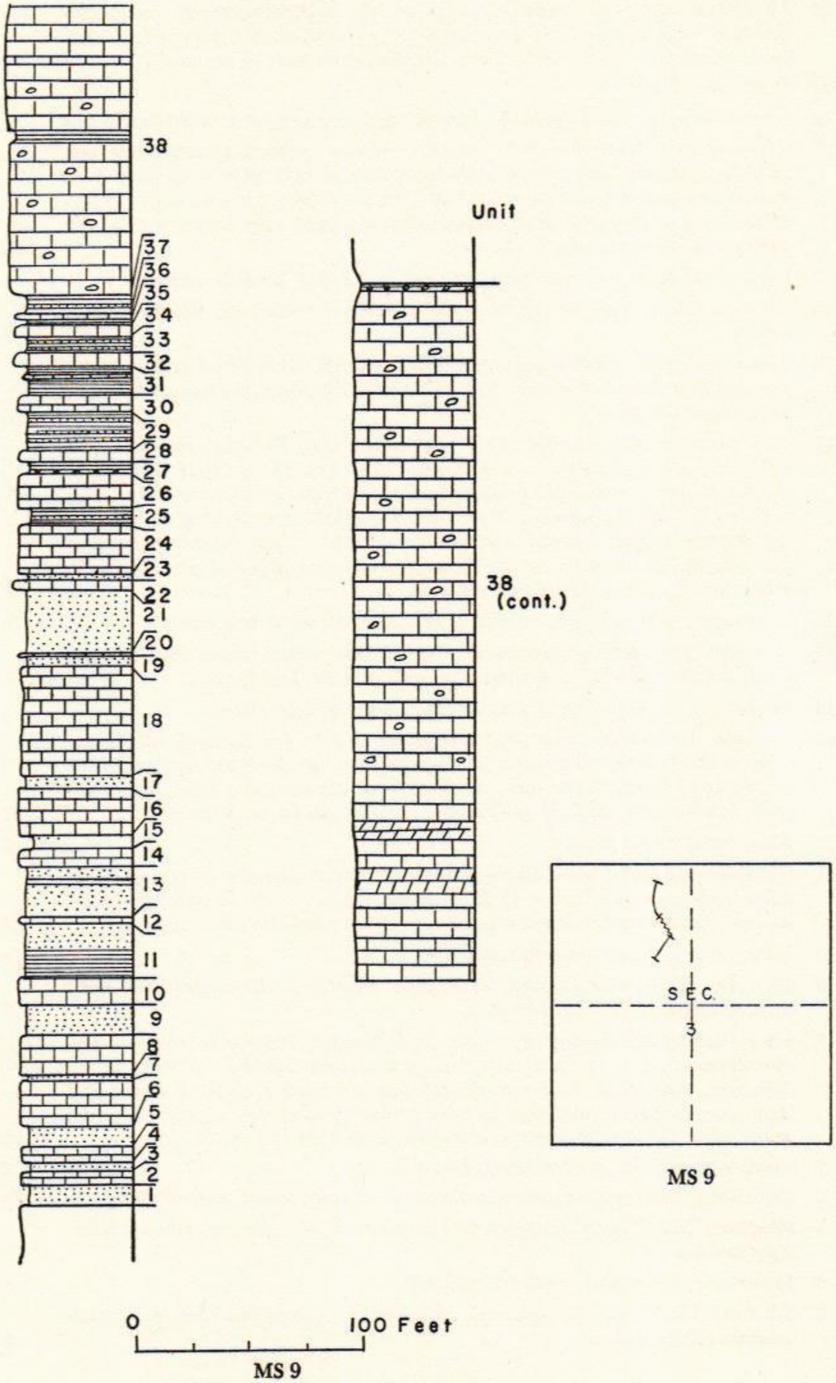
6	Limestone, dark-gray, medium-grained beds of crinoidal calcarenite, containing about 5 percent black chert nodules and abundant coral, brachiopod, and crinoid fragments, alternating with beds of light-gray, crinoidal limestone; the subunits are 10-35 ft thick; between 64 ft and 87 ft above the base, the unit forms rugged cliffs; above these massive beds, chert is more abundant, and crinoidal remains are less conspicuous	212
5	Limestone, dark-gray, medium-bedded, with abundant chert; the chert occurs as irregular beds and as nodules, and constitutes about 30-40 percent of the unit. A 2-ft-thick bed of siliceous limestone is present at the top of the unit	15
4	Limestone, light-gray, coarse-grained beds of crinoidal calcarenite, containing pink chert nodules and abundant remains of brachiopods, crinoids, and corals, alternating with beds of dark-gray to black limestone with black chert. The alternating light-gray and black units are 10-20 ft thick	101
3	Limestone, dark-gray, medium-bedded, medium-grained, crinoidal calcarenite, with black chert nodules; large cup corals up to 2 in. across are abundant; coarse-grained lenses consisting wholly of crinoidal fragments are common in some of the beds. Fusulina *cf. rockymontana* (Roth and Skinner), *Wedekindella euthysepta* (Henbest) and *Composita* sp. occur 11 ft above the base of the unit; *Fusulina distenta* (Roth and Skinner) and *F. rockymontana* (Roth and Skinner), *Aulopora* sp., and brachiopods occur 20 ft above the base of the unit; abundant *Chaetetes* sp. occur 89 ft above the base and *Fusulina* sp., and *Stafella* sp., occur immediately above the Chaetetes	103
2	Limestone, medium light gray to pink and pinkish gray on the fresh-fractured surface; weathers light brown; thin-bedded; silty; brown-weathering, black chert nodules form about 10 percent of the rock mass in the upper part of the unit; the upper beds are transitional to unit 10; corals, brachiopods, and bryozoan are common; the corals are siliceous and weather out, leaving small pits. The triangular bryozoan, *Prismopora triangulata (White)?* is characteristic	16
1	Limestone, dark-gray, medium- to thin-bedded, medium-grained, crinoidal calcarenite, with a few beds of fine-grained limestone; black chert nodules constitute about 5 percent of the rock; crinoidal and other fossil fragments, including large coiled gastropods, are common; Fusulina sp. occurs 35 ft above the base of the formation and small chert nodules and brachiopods occur in the same bed. The limestone has a faint, fetid odor	58
	Section concealed	
	Total Horquilla limestone (excluding sill)	819

MS 9. EARP FORMATION (Permian)

About 2,000 feet east of the Silver Hill mine, in the NW¼ sec. 3, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Adjoins MS 8. Measured by Elliot Gillerman, H. P. Bushnell, and F. A. Packard, July 1955, with Jacob's staff.

UNIT No.	DESCRIPTION	THICKNESS *(feet)*
	McGhee Peak formation (Lower Cretaceous)	
	White, fine-grained sandstone	
	Unconformable contact	
	Earp *formation*	
38	Limestone, about 125 ft of medium-gray, medium- to fine-grained, thick-bedded limestone, containing nodules of black chert and numerous large solitary corals; overlain by about 105 ft of light-gray to white, very fine-grained crinoidal calcarenite; a few thin beds and numerous irregular patches of yellow-brown dolomite in the interval between 160 ft and 230 ft above the base of the unit. The uppermost 200 ft of the unit consists of dark-gray and black crinoidal limestone, with nodules of pink chert. The uppermost 2 ft appears to be a fossil soil zone, and consists of a 6-in. bed of chert pebbles overlain by a dark sandstone; the upper surface of the sandstone is unconformable beneath the overlying Cretaceous sandstone. Fusulinids, corals, brachiopods, and crinoid remains are common through the unit; the fusulinids occur in distinct beds and constitute the greater part of the rock mass of these beds. Fusulinids identified were *Schwagerina vervillei* and *Rugosofusulina* sp., occurring 7 ft above the base, *Triticites aff. creekensis,* occuring 39 ft above the base, *Triticites* sp., and *Schwagerina huecoensis* (Dunbar and Skinner), occurring 87 ft above the base, *Schwagerina aff. huecoensis* (Dunbar and Skinner) and *Schubertella* sp., occurring 144 ft above the base, *Schwagerina* sp., *Triticites* sp., and Schwagerina *longissimoidea* (Beede), occurring 159 ft above the base, *Schwagerina bellula* and *S.* cf. *emaciata (Beede),* occurring 232 ft above the base, and *Schwagerina cf. huecoensis,* occurring 420 ft above the base. A light-colored shaly zone, 5 ft thick, occurs 67 ft above the base and a 2-ft-thick bed of light-brown shale occurs 101 ft above the base	432
37	Shale, white, calcareous, with thin siltstone beds; unit partly covered	8
36	Limestone, medium-gray, medium-grained	3
35	Shale and siltstone; like unit 37	2
34	Limestone, medium-gray, medium-grained	5
33	Shale and siltstone; like unit 37	8
32	Limestone, dark-gray, weathering black; a single bed	5
31	Shale, siltstone, and sandstone, white calcareous shale, with thin siltstone and calcareous sandstone beds; a 2-ft-thick bed of gray limestone 8 ft above the base of the unit, contains *Triticites* sp., *Rugosofusulina?* sp., *Schwagerina* sp., and *Schubertella aff. kingi* (Dunbar and Skinner)	13
30	Limestone, black, weathering dark gray, medium-grained; a single bed	7
29	Shale, light-gray to white, calcareous, with a few thin, gray, silty limestone beds, which weather light brown. Partly covered	17
28	Limestone, dark-gray, weathering black; medium-grained; *Triticites* sp. 1 ft above the base. A single bed	4
27	Shale, light-brown, calcareous; a 1-ft-thick limestone pebble conglomerate in the lower part. *Triticites* sp. and *Schwagerina* sp. 1 ft above the base	6
26	Limestone, pink on fresh-fractured surface, weathering to a medium grayish-pink; fine-grained and thick-bedded	15
25	Shale, light-brown, calcareous; thin beds of light brown-weathering, gray, calcareous siltstone interbedded with the shale. Partly covered	8

24 Limestone, gray to medium grayish-pink, medium-grained, medium-bedded; some of the beds are crinoidal calcarenites. *Triticites* cf. *ventricosus* Meek and *T.* cf. *meeki* occur 1 ft above the base of the unit	21
23 Sandstone, silty	3
22 Limestone, gray, thick-bedded, massive, cliff-forming, with fossil fragments	4
21 Siltstone, sandstone and shale; black, very fine-grained, thin-bedded, calcareous siltstone, which weathers light brown and grades upward into brown fine-grained sandstone. A bed 6-12 in. thick of brown shale occurs at the top of the unit and additional shale beds may occur within the partly concealed portion of the unit	28
20 Limestone, dark-gray, medium-grained, containing fossil fragments	1
19 Siltstone, black, very fine-grained, thin-bedded, calcareous; weathers light brown	4
18 Limestone, gray, medium-grained, thick-bedded, with fossil fragments; a mottled light-brown and gray bed of limestone pebble conglomerate occurs 20 ft above the base	48
17 Limestone pebble conglomerate, pebbles of very fine-grained dark-gray limestone are imbedded in a dark-gray silty limestone. Little distinction can be made between the pebbles and the matrix on the fresh-fractured surface, but on the weathered surface the pebbles are light gray whereas the matrix is light brown. The pebbles weather more readily than does the matrix, and results in the brown-weathering limestone standing in raised relief on the surface of the rock	6
16 Limestone, medium-gray, medium-grained, with fossil fragments	20
15 Hornfels; probably originated as a calcareous shale; white, thin-bedded, hard, siliceous; containing tremolite, wollastonite, and quartz	6
14 Limestone, dark-gray to black, medium-bedded, fossiliferous	8
13 Siltstone, limestone, shale, and sandstone; black, fine-grained silty limestone and siltstone, which weathers light brown; brown shale and sandstone in the upper part of the unit. At the top of the unit is a light brownish-gray, fine-grained, slightly calcareous, well-indurated sandstone	22
12 Limestone, medium-gray	2
11 Siltstone and shale; black fine-grained calcareous siltstone, which weathers light brown, overlies about 12 ft of brown shale. A thin bed of light-gray, siliceous, and silty limestone separates the shale and the black siltstone	24
10 Limestone, gray, medium-grained	12
9 Siltstone, black, fine-grained, calcareous siltstone, which weathers light brown; arenaceous toward the top	13
8 Limestone, gray, medium-grained, thick-bedded limestone with a conglomerate layer at the base, containing limestone pebbles up to 1/2 in. in diameter. The gray limestone grades upward into a mottled dark- and light-gray limestone, and this in turn grades upward into a gray, crinoidal calcarenite. Fusulinids occur in a bed 1 ft below the top of the unit	18
7 Limestone pebble conglomerate; like unit 17	2
6 Limestone, light-gray, medium-bedded, medium-grained, cliff-forming	20
5 Siltstone; black, very fine-grained, calcareous siltstone, which weathers light brown	9
4 Limestone, light-gray, medium-grained	8
3 Siltstone, black, very fine-grained, thin-bedded, calcareous siltstone, which weathers light brown	3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MS 9

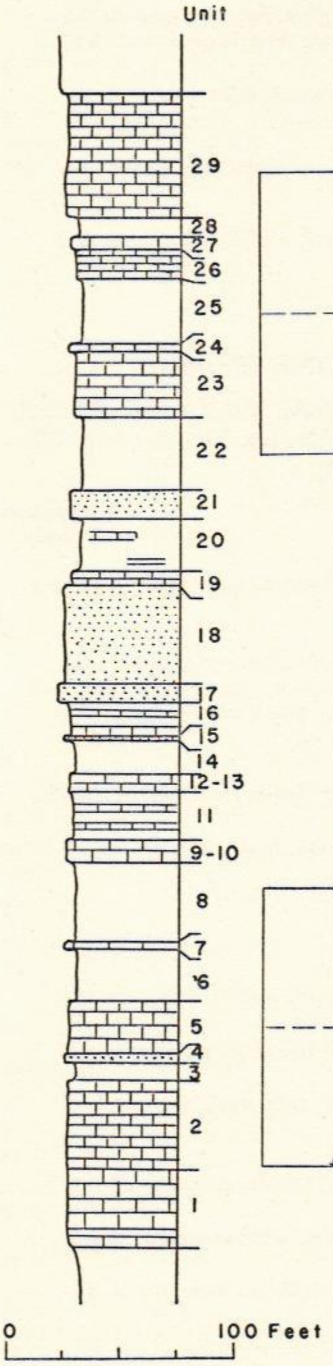
MS 9

2	Limestone, light gray on the fresh-fractured surface, but dark gray on the weathered surface; medium- to very fine-grained, thick-bedded, and cliff-forming; crinoid and brachiopod fragments	7
1	Siltstone and silty limestone, black, very fine-grained, calcareous siltstone, which weathers light brown	9
	Total Earp formation	831
	Contact conformable	
	Horquilla limestone	
	Limestone, dark-gray, thick-bedded, fine-grained, cliff-forming; unit 12, MS 8	

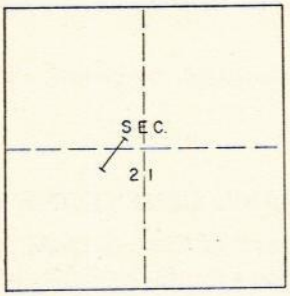
MS 10. COLINA LIMESTONE (Permian)

About one mile northwest of Cienega Peak, in the center of sec. 21, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Measured by Elliot Gillerman, July 1955, with compass and pace.

UNIT No.	**DESCRIPTION**	**THICKNESS** (feet)
	Scherrer formation	
	Sandstone, dusky-red, thick-bedded, hard, well-cemented quartzite.	
	Contact conformable	
	Colina limestone	
29	Limestone, medium pinkish-gray, medium-bedded, medium-grained, soft, very friable calcarenite, which grades upward into a harder, more indurated limestone; a thin bed of dark-gray to black limestone at the top of the unit contains scaphopods and *Euomphalotrochus* sp.	55
28	Concealed	9
27	Limestone, dark-gray to black, medium-bedded, fine-grained; upper part is lighter gray	5
26	Limestone, medium pinkish-gray, fine-grained, soft, friable calcarenite	14
25	Concealed; probably similar to part in unit 26	28
24	Limestone; like unit 26	3
23	Limestone; like unit 27	28
22	Concealed	32
21	Siltstone, grayish-red, thick-bedded, thin-laminated, with laminae showing well on the weathered surface; crumbly weathering	12
20	Concealed, except for a few thin beds of grayish-red siltstone and of black limestone	23
19	Limestone, black, medium-bedded, fine-grained, with small aggregates of calcite present but not abundant	6
18	Siltstone, grayish-red, thin-bedded, siliceous	43
17	Siltstone, grayish red on fresh-fractured surface, brown on weathered surface; thick-bedded, well-cemented	9
16	Limestone, partly concealed; black, thin-bedded, with numerous aggregates of calcite 1/4-1 in. in diameter	14
15	Sandstone, gray, fine-grained, sugary texture, friable, crosslaminated, calcareous; one 2-ft bed	2
14	Concealed	14



MS 10



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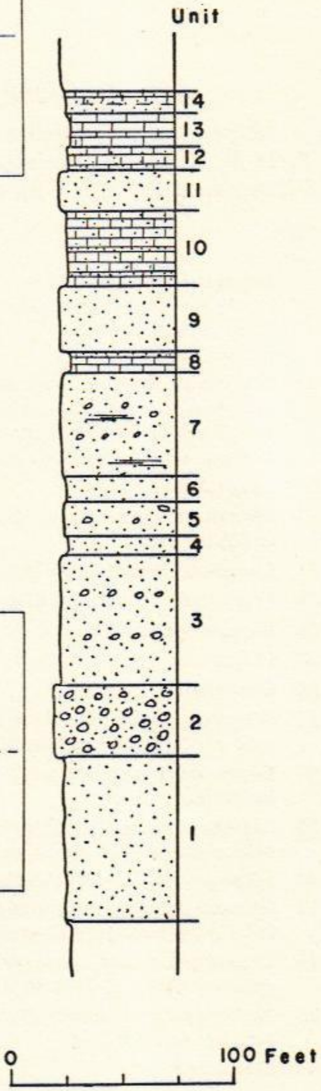
MS 11



MS 11

13	Limestone, black, medium-bedded, fine-grained, with numerous aggregates and small geodes of coarse white calcite, many of which have pink calcite in the center of the aggregate. Scaphopods and other fossils are common	5
12	Limestone, light-gray, thin-bedded, fine-grained, soft	2
11	Limestone; similar to bed 19; partly concealed	22
10	Limestone; like bed 13	2
9	Limestone, light-gray, very fine-grained, hard, siliceous	7
8	Concealed; probably thin-bedded, brown-weathering sandstone	35
7	Limestone; like bed 9; one 3-ft bed	3
6	Concealed; probably thin-bedded, brown-weathering sandstone	23
5	Limestone; like unit 13	23
4	Siltstone, gray, weathering brown, fine-grained, hard, slightly calcareous, siliceous, well-cemented; one 3-ft bed	3
3	Concealed; probably shale and thin-bedded friable sandstone	8
2	Limestone; like unit 13	39
1	Limestone, dark-gray, medium-bedded, medium-grained; lower part of unit partly concealed	35
	Total Colina limestone	504
	Concealed	

MS 11. McGHEE PEAK FORMATION (Cretaceous)

On the north side of McGhee Peak, beginning on the crest of the peak, in SW¼ sec. 34, T. 24 S., R. 21 W., Hidalgo County, New Mexico. Measured by Elliot Gillerman, H. P. Bushnell, and F. A. Packard, July 1954, with Jacob's staff.

UNIT No.	DESCRIPTION	THICKNESS *(feet)*
	Carbonate Hill limestone Limestone, gray, coarse- to medium-grained, thin-bedded, arenaceous calcarenite, with abundant fossil fragments; individual beds consist almost wholly of pelecypod shells. Contact conformable *McGhee Peak formation*	
14	Sandstone and limestone, light-gray, brown-weathering, fine- to medium-grained, calcareous sandstone, containing 5-10 percent angular and sub-angular chert, and quartz pebbles up to ½ in. in diameter. Calcium carbonate becomes more abundant in the upper part of the unit and the top beds consist of light-gray, fine-grained, arenaceous limestone	10
13	Limestone, black, very fine-grained to lithographic, nodular limestone, which weathers to light brown and light gray. The upper part is mottled gray and pale olive on the weathered surface	15
12	Limestone, black, weathering brown, very fine-grained, medium-bedded, slightly silty, with a few grains of sand-size quartz	10

11	Sandstone, white, light gray-weathering, thin-bedded, very fine-grained, well-cemented by silica; blocky-weathering	18
10	Limestone, brown, thin-bedded, medium-grained, slightly arenaceous; slabby and rough-weathering; thin beds of sandstone alternate with the limestone	34
9	Sandstone, white, thin-bedded, medium-grained orthoquartzite, with siliceous cement; grains round to subround	29
8	Limestone, black on fresh-fractured surface, light gray on weathered surface; fine-grained, slightly silty; upper beds are arenaceous, and a brown silty sandstone 1-2 ft thick occurs at the top of the unit	11
7	Sandstone, white, weathering to light brown, very fine-grained orthoquartzite, containing some beds of white conglomerate, with pebbles mostly of quartz or chert; a few white siliceous siltstone beds; orthoquartzite, conglomerate, and siltstone all well indurated; toward the top, the unit is thin bedded and weathering results in a flaggy covered slope. A few thin beds of shale may be present	44
6	Sandstone, white, thin-bedded, coarse-grained, orthoquartzite, with some granule-size fragments of quartz; well-indurated with siliceous cement; cementation probably due to circulating ground waters, and may be a near-surface phonomena	11
5	Sandstone; similar to unit 7; contains vugs from which pebbles have been eroded. Some of quartz fragments are of granule size	15
4	Sandstone, white, very coarse-grained, thick-bedded, massive orthoquartzite; grains subround; a few white quartzite pebbles; a very resistant and prominent unit that forms the crest of McGhee Peak	8
3	Sandstone; similar to unit 7, but not so thin bedded toward the top	59
2	Conglomerate, white, thick-bedded, massive; consists mostly of white-quartzite pebbles and sand-size grains cemented by silica; a few blackchert pebbles and cobbles are present; near the base, the unit contains beds with calcareous cement	31
1	Sandstone, white, medium-bedded, very fine-grained, well-indurated; small green flecks occur throughout the sandstone	75
	Total McGhee Peak formation	370

Contact:
Erosional unconformity; a relief of at least 5 ft locally and more over a wider area. The contact lies just above an old soil layer, which has been removed in places.

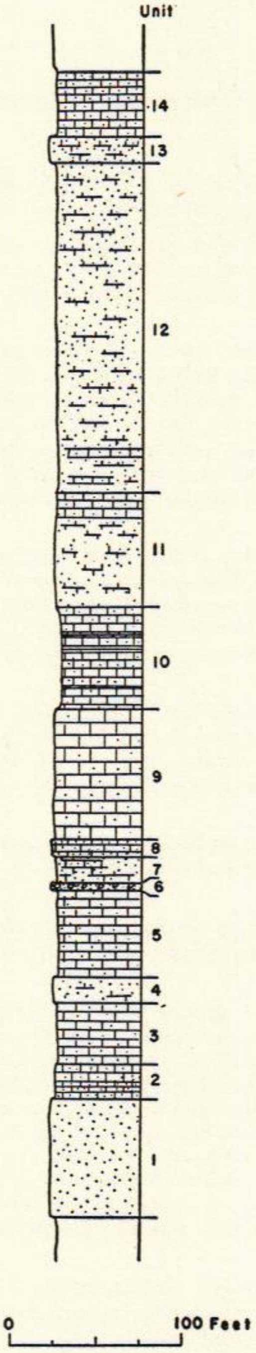
Earp formation

Limestone; unit 38, MS 9

MS 12. STILL RIDGE FORMATION (Cretaceous)

About three-quarters of a mile northwest of the Carbonate Hill mine, in NW¼ sec. 34, T. 24 S., R. 21 W., Hidalgo County, New Mexico. Measured by Elliot Gillerman, H. P. Bushnell, and F. A. Packard, July 1954, with Jacob's staff.

UNIT No.	DESCRIPTION	THICKNESS (feet)
	Johnny Bull sandstone	
	Conglomerate, dark-brown, vuggy, medium-bedded, metamorphosed.	
	Contact conformable	
	Still Ridge formation	
14	Limestone, dark-gray, thick-bedded, massive, arenaceous, with lenses and thin beds of arenaceous conglomerate; vuggy, and metamorphosed locally	38
13	Sandstone, light-gray, thin- to medium-bedded, crossbedded, medium-grained, soft, friable, calcareous; grains round to subround; well sorted mechanically, but not very well sorted chemically; 8-10 percent dark mineral grains; remainder apparently quartz	15
12	Sandstone, light-gray, massive, crossbedded, fine- to medium-grained, hard, well-cemented, calcareous orthoquartzite with a slight greenish tinge in places; grains round to subround; well-sorted; some vuggy limestone lenses near the base; a few thin, white, siliceous siltstone beds within the unit; actinolite neddles in vugs and along the bedding planes of the calcareous sandstones and siltstones. These and the green color, which may be due to epidote, are probably the result of alteration because of igneous activity	190
11	Sandstone and arenaceous limestone. Sandstone is dark gray, thin bedded, fine grained, hard, very calcareous; crossbedding shows on weathered surface; grades upward from underlying unit, but distinguished from that unit by the absence of shale. The top of the unit is an arenaceous limestone; dark-gray, vuggy, massive, and cliff-forming; it grades upward into the overlying unit	67
10	Limestone, dark- and medium-gray, thin-bedded, fine-grained, well-cemented, arenaceous at the base, grading upward into a dark-gray arenaceous limestone; some shale and arenaceous shale beds; a 1-ft bed of limestone pebble conglomerate occurs 13 ft above the base; the unit is more sandy above this bed	58
9	Limestone, dark-gray, weathering brown; thick-bedded, medium-grained, arenaceous; crossbedding in arenaceous beds, but this is not so prominent as in underlying unit; vuggy	75
8	Limestone, gray, weathering gray and brown; medium- to thin-bedded, medium-grained, very sandy; crossbedding shows very well on the weathered surfaces	10
7	Limestone and sandstone; limestone is dark gray to black on the fresh-fractured surface, but weathers pale yellowish brown with medium-gray splotches; the medium-gray splotches are pebbles of an older limestone included in the pale yellowish brown-weathering limestone and are difficult to distinguish on the fresh-fractured surface. The medium-gray pebbles are softer than the matrix, and in places weather out leaving voids; the limestone is fine to medium bedded, medium grained, arenaceous, and in some places is a calcareous sandstone; a light-colored leached zone as much as 1/4 in. thick, devoid of calcium carbonate, is present in places on the weathered surface; the unit weathers to a pale yellowish-brown rubble, which covers the slope	16
6	Limestone pebble conglomerate; small limestone pebbles, mostly 1 in. in diameter, or smaller, and well-rounded, cemented by brown sand; the pebbles constitute at least 75 percent of the unit	4



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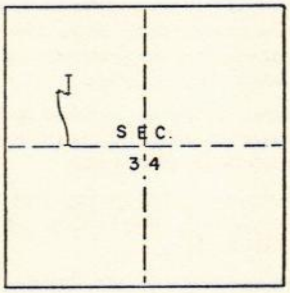


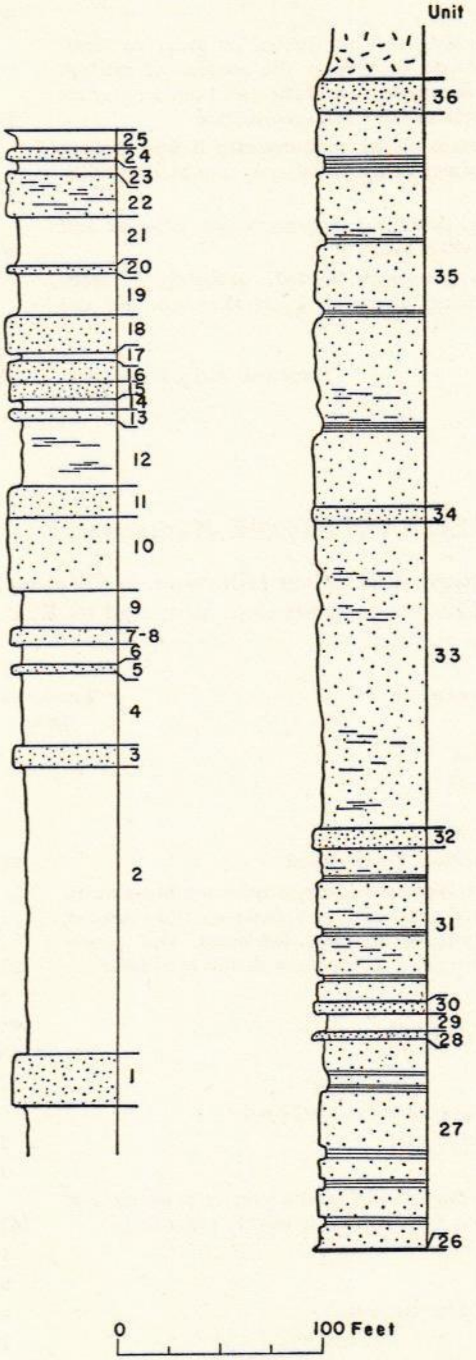
MS 12

5	Limestone; like unit 7	50
4	Sandstone, medium-gray, weathering to light brown or gray; medium-bedded, fine-grained, well-indurated, calcareous; the amount of calcium carbonate increases upward and the upper part of the unit is an arenaceous limestone; crossbedding shows well on the weathered surface	15
3	Limestone; like unit 7, but matrix of the conglomerate is fine grained and silty; some thin beds of shale and thin-bedded, gray and black, bluish-gray sandstone	35
2	Limestone, white and light-gray, thin-bedded, fine-grained, siliceous and arenaceous; probably some thin shale beds	20
1	Sandstone, white to light-gray, medium-bedded, fine-grained, well-cemented with a siliceous cement; hard; dark streaks show on the weathered surface	70
	Total Still Ridge formation	663
	Concealed	

MS 13. JOHNNY BULL SANDSTONE (Cretaceous)

About one mile south-southwest of the Silver Hill mine, in SW¼ sec. 4, T. 25 S., R. 21 W., Hidalgo County, New Mexico. Measured by R. V. McGehee, August 1955, with Jacob's staff.

UNIT No.	**DESCRIPTION**	**THICKNESS** *(feet)*
	Granite Gap granite (Precambrian) Granite, pink to red, coarse-grained Fault contact *Johnny Bull sandstone*	
36	Sandstone, light-gray, medium-bedded, fine-grained	16
35	Sandstone and shale. Sandstone is light olive gray, weathering brown with varicolored surficial stains, mostly red-brown or yellow; medium-bedded, fine-grained subgraywacke; fragments, angular, subround, and poorly sorted; thin beds of reddish-brown shale alternate with the sandstone	191
34	Sandstone; like unit 36	8
33	Sandstone; like unit 35	148
32	Sandstone; like unit 36	10
31	Sandstone; like unit 35	74
30	Sandstone, light-gray to pinkish-gray, fine-grained, hard	6
29	Concealed; probably brown shale in part	9
28	Sandstone; like unit 30	4
27	Sandstone; like unit 35 but very fine grained, and a greater percentage of the unit consists of reddish-brown shale, which is largely concealed	103
26	Sandstone; like unit 30	1
25	Concealed	9
24	Sandstone; like unit 35 but very fine grained	6
23	Concealed	7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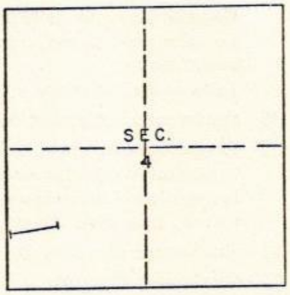
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MS 13

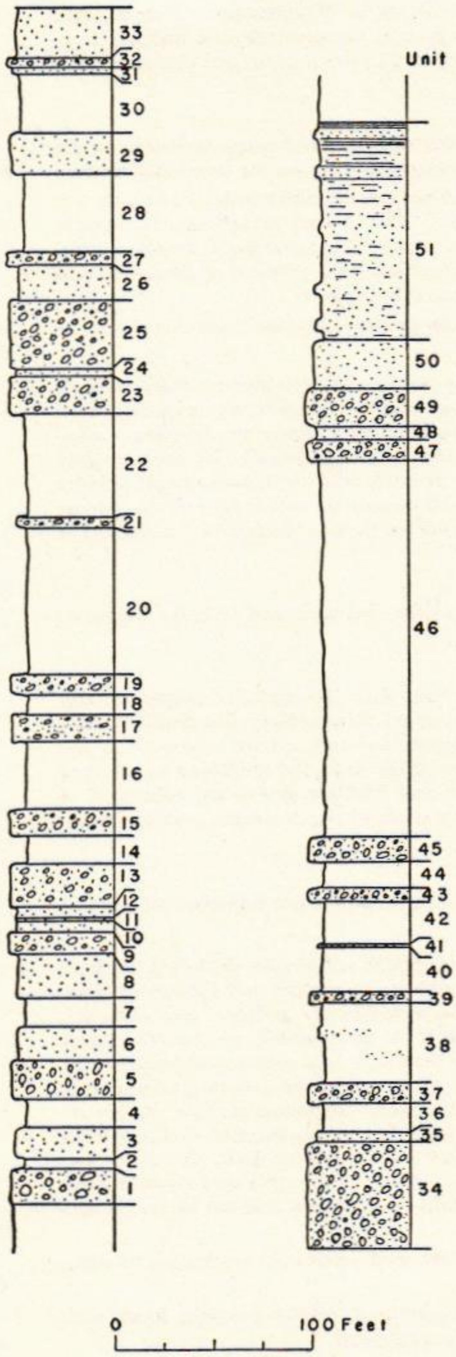
22 Siltstone; similar to unit 35 except for grain size; shale alternates with the siltstone	21
21 Concealed	24
20 Sandstone; like unit 35	4
19 Concealed	20
18 Sandstone, grayish-pink, thin-bedded, very fine- to medium-grained; hard in places; the upper portion of the unit is a breccia of angular sandstone pebbles cemented by grayish-brown silica	18
17 Concealed	4
16 Sandstone; like unit 35 but blocky-weathering	11
15 Sandstone; white to light-green, thick-bedded except for lower portion, which is thin bedded, medium- to coarse-grained; orthoquartzite; grains well rounded; well-cemented	9
14 Concealed	5
13 Sandstone; like unit 35 but thinner bedded; interbedded with thin beds of brown shale	5
12 Concealed; probably brown shale	32
11 Sandstone; like unit 35	15
10 Sandstone, white to light-gray, massive, thick-bedded, fine- to medium-grained orthoquartzite; thinsection examination shows the grains to be well rounded but with quartz overgrowths; well-cemented; over 95 percent of grains are quartz; limonite stains in fractures	35
9 Concealed	19
8 Sandstone, gray, thin-bedded at bottom, medium-bedded at top, fine-grained, very hard	4
7 Sandstone; like unit 10 but not so thick bedded or massive	4
6 Concealed	9
5 Sandstone, light- and dark-brown and black (colors irregular and in streaks), thin-bedded at bottom, medium-bedded at top, very fine-grained, very hard	5
4 Concealed	35
3 Sandstone; like unit 5	11
2 Concealed	140
1 Sandstone, light-gray and pink, very fine-grained, hard; weathers brown; contains spots and small streaks of epidote; partly concealed	25
Total Johnny Bull sandstone	1,047
Concealed	
Fault contact with Permian limestones	

MS 14. BOBCAT HILL CONGLOMERATE
(Cretaceous or Tertiary)

One mile west-northwest of the Carbonate Hill mine, in SE¼ sec. 27, T. 24 S., R. 21 W., Hidalgo County, New Mexico. About one mile east of MS 15. Measured by Elliot Gillerman and R. V. McGehee, July 1955, with Jacob's staff.

UNIT No.	DESCRIPTION	THICKNESS (feet)
	Andesite	
	Contact apparently conformable, but may be erosional.	
	Bobcat Hill conglomerate	
51	Siltstone and shale; dark medium-gray to grayish red-purple, thin-bedded, calcareous, impure volcanic arkose siltstone, and interbedded silty and sandy shale; upper part of unit is a sandy shale, which apparently grades upward into the volcanic rocks of the overlying formation; thin-section examination of the siltstone shows that most of the fragments are very fresh and angular, and consist largely of quartz and feldspar presumably derived from volcanic rocks extruded at about the time of deposition of the sediments or slightly earlier; magnetite and hematite are abundant in the siltstone and shale	110
50	Sandstone, basal part is medium gray to grayish red purple, fine-grained, alternating thick- and thin-bedded, shaly, impure volcanic arkose; upper part of unit is similar to unit 51 and is gradational into it	25
49	Conglomerate, abundant fragments of andesite and of limestone; fragments subangular to subround and as much as 1 ft in diameter; matrix is coarse-grained dark medium-gray to grayish red-purple sandstone; andesite fragments constitute about 80 percent of all gravel-size particles	19
48	Sandstone, medium-gray to grayish red-purple, medium-bedded, fine-grained, well-cemented, calcareous impure volcanic arkose, alternating with thin-bedded argillaceous sandstone of a similar type	7
47	Conglomerate, abundant andesite and limestone fragments as much as 1 ft in diameter; subround to subangular; matrix is coarse-grained dark medium-gray to grayish red-purple sandstone	10
46	Concealed; probably like unit 48	190
45	Conglomerate; like unit 47	13
44	Concealed	13
43	Conglomerate; like unit 47	7
42	Concealed	22
41	Sandstone, thin-bedded, shaly, calcareous; similar to thin-bedded portions of unit 48	1
40	Concealed	23
39	Conglomerate; like unit 47	5
38	Concealed, with a few thin beds of sandstone exposed	4
37	Conglomerate; like unit 47	10
36	Concealed, a few thin beds of sandstone; similar to the sandstone of unit 48, exposed	15
35	Sandstone; like unit 48	5
34	Conglomerate; like unit 47	55
33	Sandstone; like unit 48, but with a few thin conglomeratic beds in the upper part	26
32	Conglomerate; like unit 47, but with a few thin beds and lenses of sandstone	4
31	Sandstone; like unit 48	4
30	Concealed	30
29	Sandstone; like unit 48	20
28	Concealed	40

27	Conglomerate; like unit 47, but the limestone fragments constitute a larger portion of the total gravel-size fragments; the percentage of andesite fragments progressively decreases downward in the section, and the percentage of limestone fragments increases	6
26	Sandstone; like unit 48	18
25	Conglomerate; similar to unit 47, but with lenses of coarse sandstone in the conglomerate; the sandstone shows crossbedding on the weathered surface	35
24	Sandstone, medium-gray to grayish red-purple, thick-bedded (a single 4-ft bed), coarse-grained, well-cemented, hard, round to subangular, impure volcanic arkose; sand-size particles consist of quartz, chert, feldspar, magnetite, and limestone; also a few well-rounded pebbles of limestone and quartzite scattered through the bed; calcareous	4
23	Conglomerate; similar to unit 25; the matrix is like the sandstone of unit 24	18
22	Concealed	53
21	Conglomerate, dark medium-gray to grayish red-purple, thick-bedded; gravel fraction contains pebbles and cobbles of limestone, quartzite, chert, granite, quartz latite, and epiditized andesite; limestone fragments comprise over 50 percent of the rock; the matrix consists of dark medium-gray to grayish red-purple, very coarse-grained sand, with some small pebbles and granules; a bed of hard, well-cemented, coarse-grained sandstone, similar to the matrix of the conglomerate, forms a discrete bed at the top of the unit	5
20	Concealed	75
19	Conglomerate; like unit 21; some of the limestone and andesite fragments are angular	10
18	Concealed	10
17	Conglomerate; similar to unit 21, but with less andesite fragments, and with a 1 ft-thick bed of brownish-gray, thin-bedded, fine-grained, well-cemented, slightly-argillaceous, impure volcanic arkose sandstone at the top of the unit and also at the base of the unit; the sandstone weathers to a soft, shaly material; the quartz and feldspar grains are subround. A similar sandstone probably occupies much of the concealed portions of the middle part of the formation	13
16	Concealed	35
15	Conglomerate; similar to unit 21, but with only a few fragments of andesite	13
14	Concealed	20
13	Conglomerate, dark medium-gray to grayish red-purple, thick-bedded (beds are 6-10 ft thick); gravel fraction consists of pebbles and cobbles of limestone, quartzite, granite, and quartz latite; no andesite was observed; smaller pebbles of granite are angular to subrounded, whereas the larger boulders are rounded; most of the limestone is of cobble and boulder size, and the quartzite is of pebble and granule size; the matrix is coarse sand, granules, and small pebbles; the limestone fragments contain crinoid remains, and are probably derived from Pennsylvanian and Permian limestones; a dark-red sandstone occurs 6 ft above the base. Conglomerates above unit 11 are medium gray to grayish red purple and contain limestone fragments. Those below contain no limestone and are various shades of gray and brown	23
12	Sandstone, medium-gray, fine-grained, well-cemented; weathering to angular blocks	6
11	Limestone, medium light-gray, fine-grained, sublithographic; hard, with small green spots; unfossiliferous; a single bed	1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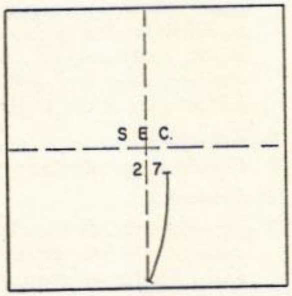
MS 14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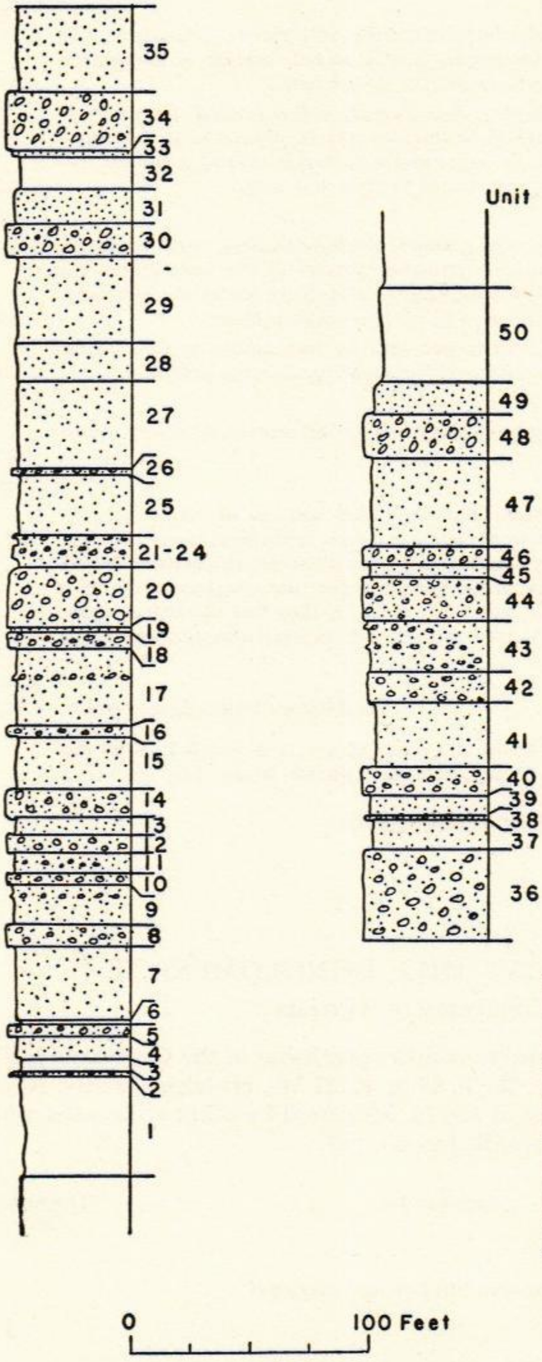
MS 14

10	Sandstone; like unit 12	6
9	Conglomerate, pebbles and cobbles of granite, vein quartz, vein calcite, and quartzite; no limestone fragments; poorly sorted; matrix is feldspathic sand; conglomerate grades laterally into sand lenses	11
8	Sandstone, light yellowish-gray, fine-grained, well-cemented, impure volcanic arkose with subround to subangular quartz, quartzite, and feldspar grains; abundant feldspar, in larger grains than quartz, and relatively unaltered; abundant epidote; numerous cavities and voids	22
7	Concealed	15
6	Sandstone, yellowish-gray, fine-grained, medium-bedded, well-cemented, impure volcanic arkose, greatly resembling many of the beds of MS 15; grains are angular to subrounded; epidote abundant; lenses of conglomerate sandstone, containing close to 25 percent small pebbles	17
5	Conglomerate; similar to unit 9, but with no vein quartz or vein calcite fragments, and with no granite pebbles; some quartz latite pebbles	20
4	Concealed	15
3	Sandstone, dusky yellow-green, fine-grained, *well-cemented,* arkosic; with epidote	16
2	Concealed	5
1	Conglomerate, poorly sorted; gravel fraction consists of round to sub-round fragments up to 2 ft in diameter of quartz latite from the underlying formation; a few quartzite boulders also were observed; the matrix consists of feldspathic sand and small pebbles; laterally, the conglomerate grades into sandstone lenses; beds are 4-6 ft thick. A thin bed of medium-gray, very fine-grained, well-cemented sandstone is present near the top of the unit	18
	Total Bobcat Hill conglomerate	1,148
	Contact concealed, but the dip and strike of unit 1 is parallel to the dip and strike of the beds of the underlying quartz latite. The contact is apparently a disconformity	
	Quartz *latite,* fine-grained, light greenish-gray	

MS 15. BOBCAT HILL CONGLOMERATE
(Cretaceous or Tertiary)

About one and three-quarters miles northwest of the Carbonate Hill mine, in the center of sec. 28, T. 24 S., R. 21 W., Hidalgo County, New Mexico. About 1 mile west of MS 14. Measured by Elliot Gillerman and R. V. McGehee, July 1955, with Jacob's staff.

UNIT No.	**DESCRIPTION**	**THICKNESS** (feet)
	Andesite	
	Contact apparently conformable but probably erosional	
	Bobcat Hill conglomerate	
50	Concealed	40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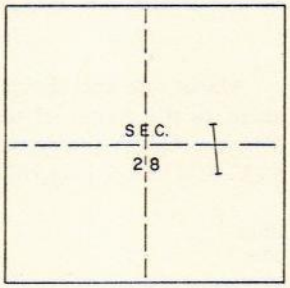
MS 15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MS 15

49	Sandstone, yellowish-gray, thin-bedded, very fine-grained; weathers pinkish brown; contains some epidote	14
48	Conglomerate, dark-gray to black; pebbles of quartz, calcite, and granite, some of which are as large as 12 in. in diameter, but most are smaller	18
47	Sandstone, light grayish-green, thin- to medium-bedded, fine-grained, with a few thin nodular calcareous layers; calcite-filled fractures, quartz geodes, and small segregations of epidote crystals	37
46	Conglomerate; like unit 48, but pebbles are larger	8
45	Sandstone; like unit 47	5
44	Conglomerate, matrix dark yellowish green; pebbles and cobbles are mostly of quartz, but some limestone and calcite pebbles are present; pebbles and cobbles range up to 6 in. in diameter; some thin beds of sandstone present	18
43	Sandstone; like unit 47, but with lenses of conglomerate	22
42	Conglomerate; like unit 44, but with some sandstone lenses	12
41	Sandstone; like unit 47	28
40	Conglomerate; like unit 44	12
39	Sandstone; like unit 47	8
38	Conglomerate; like unit 44	2
37	Sandstone; like unit 47	13
36	Conglomerate; like unit 44, but with more limestone fragments; sandstone beds and lenses interbedded with the conglomerate	38
35	Sandstone; like unit 47	37
34	Conglomerate; like unit 44	24
33	Sandstone, grayish-red, thin-bedded, fine-grained; some of larger quartz grains stained green by epidote; weathers to reddish brown, gray, or green, with ***green*** spots and stains of epidote; weathers nodular	2
32	Concealed	14
31	Sandstone; like unit 33, but weathers blocky instead of nodular	14
30	Conglomerate; like unit 44	14
29	Sandstone; like unit 33, but with some thin beds of green, medium-grained, calcareous sandstone	36
28	Sandstone; light grayish-green, medium-grained, soft, very calcareous, very epidotized sandstone, alternating with grayish red-purple and grayish-green, fine-grained sandstone, similar to unit 33	16
27	Sandstone; like unit 33, but with thin black streaks	37
26	Conglomerate, grayish-green and moderate-green, epidotized pebbles of limestone and calcareous sandstone in a matrix of medium and coarse sand. The matrix constitutes about 75 percent of the rock unit	3
25	Sandstone; like unit 33, but weathers blocky instead of nodular	25
24	Conglomerate, the matrix consists mostly of coarse- to medium-grained subround quartz particles, well-cemented; the gravel fraction consists mostly of subangular and subround pebbles, cobbles, and boulders of quartzite and limestone, many of which are 4-5 in. in diameter; a few andesite cobbles are also present	1
23	Sandstone, fine-grained, poorly cemented, arkosic and epidotized	3
22	Conglomerate; like unit 24	5

21	Sandstone; like unit 23, but with a 2 in. bed of medium dark-gray sandstone, 1 ft above the base	4
20	Conglomerate; like unit 24	25
19	Sandstone; like unit 23	2
18	Conglomerate; like unit 24	7
17	Siltstone and sandstone; siltstone is light grayish green, well cemented, and contains 20-25 percent very fine sand-size material; sandstone is fine grained; a 1-ft bed of conglomerate 2 ft above the base of the unit; epidote and calcite in cavities in siltstone	33
16	Conglomerate; like unit 24, but with less volcanic pebbles	4
15	Sandstone and siltstone; the lower 5 ft of the unit is yellowish-gray, well-cemented siltstone, containing round cavities lined with calcite crystals and rimmed by epidote; above this is 2 ft of dark-gray, fine-grained, slightly-arkosic sandstone; above this is 6 ft of light grayish-green, fine-grained, poorly cemented, arkosic and epidotized sandstone; the upper 10 ft of the unit is a coarse-grained sandstone except for the very topmost foot, which is very fine-grained	23
14	Conglomerate; like unit 24, but with less limestone fragments	11
13	Siltstone; like the lower 5 ft of unit 15	8
12	Conglomerate; like unit 24, but with few limestone fragments; the fragments are mostly 2-3 in. in diameter, but a few range up to 10 in. in diameter	7
11	Sandstone, light-gray to grayish yellow-green, thick-bedded, well-cemented, slightly epidotized, orthoquartzite; grains subround; conglomeratic lenses throughout the unit	8
10	Conglomerate, small subangular to subround pebbles in a matrix of sandstone, similar to the sandstone of unit 11; a gradation between unit 10 and units 11 and 9 with no break in sedimentation, the only difference being in percentage of conglomerate over the sandstone; lenses of sandstone, similar to units 11 and 9 occur in conglomerate. This lensing of conglomerate and sandstone is typical of the units throughout the section; the lateral and vertical gradation of sandstone into conglomerate, and vice-versa, is sharp	6
9	Sandstone, the lower 10 ft are like unit 11; the upper part of the unit contains beds of fine-grained sandstone and of siltstone; the siltstone contains 20-25 percent fine sand-size material; green epidote spots, ¼-¾ in. in diameter, are abundant	16
8	Conglomerate, gray to grayish-yellow, thin-bedded; gravel fraction consists of rounded fragments ranging from 1/2-12 in. in diameter, mostly of quartzite and underlying quartz latite, but with a few large limestone boulders; the matrix is a gray to grayish yellow-green, soft sandstone, similar to the sandstone of the lower part of unit 9; discontinuous beds and lenses of sandstone occur throughout the conglomerate	10
7	Sandstone; similar to the sandstone of unit 11, but slightly cavernous near the top, due to solution, with voids up to 1 in. in diameter	30
6	Concealed	2
5	Conglomerate, gray to yellowish-gray; fragments up to about 10 in. in diameter and constituting a smaller percentage of the rock than in unit 8; poorly sorted; smaller pebbles well rounded; fragments of chert, quartzite, calcareous sandstone, and quartz latite; matrix similar to matrix of bed 8	5

4 Sandstone; like sandstone of unit 5; weathers into angular blocks	10
3 Concealed	5
2 Conglomerate; like unit 45, but fragments smaller; maximum diameter is about 6 in.; matrix is fine-grained arkosic sandstone with subround grains	2
I Concealed	43
Total Bobcat Hill conglomerate	767

Contact concealed, but undoubtedly an erosional
unconformity Quartz latite

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