Jarilla Mountains, view to southeast from crest of hill in SW¼NE¼, sec. 34, T. 21 S., R. 8 E. Otero Mesa in background.

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The Geology of the Jarilla Mountains, Otero County, New Mexico

By Paul G. Schmidt and Campbell Craddock

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Abstract

The Jarilla Mountains are a small range of hills in southern New Mexico. The oldest exposed rocks are of Desmoinesian (Pennsylvanian) age; they consist of cherty gray limestone with minor sandstone and shale and are correlated with the Bug Scuffle Member of the Gobbler Formation. This unit is incompletely exposed but is 822 feet thick. Rocks of early to middle Wolfcampian (Permian) and probably latest Pennsylvanian age crop out in the northern and eastern parts of the range. This section is also incompletely exposed but consists of 1200 feet of interbedded thin limestone, siltstone, shale, and conglomerate correlated with the Laborcita Formation, and 1000 feet of gray limestone correlated with the Hueco Formation. The Laborcita Formation and possibly the Bug Scuffle Member and the Hueco Formation were deposited in the Orogrande basin, a local subsiding element on the marine shelf of late Pennsylvanian and early Permian time.

Igneous stocks, dikes, and sills of probable Tertiary age were intruded into the Paleozoic rocks. Three main stages of injection are recognized: a massive syenodiorite, followed by monzonite-adamellite of somewhat variable composition, then by adamellite with large orthoclase phenocrysts. The monzonite-adamellite has in places undergone severe hydrothermal alteration. Metasomatism and thermal metamorphism, locally intense, accompanied the intrusions. Beds of shaly siltstone were recrystallized to a scapolite-diopside-garnet rock; the limestones were mainly changed to marble. Adjacent to igneous contacts, however, the limestones were locally converted to andradite-specularite skarns. Gold, silver, copper, lead, and iron mineralization was spottily developed in some of the skarns.

The Jarilla Mountains consist structurally of a dome formed by the forceful injection of the magmas. The sedimentary rocks dip uniformly away from the igneous core and are cut by many small radial faults. Numerous xenoliths, sills, and dikes occur in the southern part of the range, which is interpreted as a roof area of the intrusives.

Mining of the copper, gold, lead, and silver lode ores and placer gold was begun about 1900, and iron mining activity about 1913. Except for brief periods of placer operations, mining activity ceased about 1930. There are no known ground-water reservoirs of potable water near the Jarilla Mountains. Water is piped 36 miles from the Sacramento Mountains.

Introduction

The Jarilla Mountains are a small range of hills in the Tularosa Basin in Otero County, south-central New Mexico (fig. 1). The range is elongate from north to south and is about six miles wide and ten miles long. Rock outcrop covers about 25 square miles. The town of Orogrande lies at the southeastern end of the range on U.S. Highway 54 and the Southern Pacific Railroad.

The exposed rocks consist of upper Paleozoic sedimentary beds intruded by a series of intermediate igneous rocks which caused contact metamorphism and mineralization. A small patch of Recent volcanic basalt lies at the northernmost end of the range.

The purposes of this study were (1) to provide a measured section of the sedimentary rocks, and determine their ages and regional correlations; (2) to describe the intrusive sequence and the related contact metamorphism and mineralization; (3) to describe and interpret the geologic structure; and (4) to summarize the geologic history of the area.

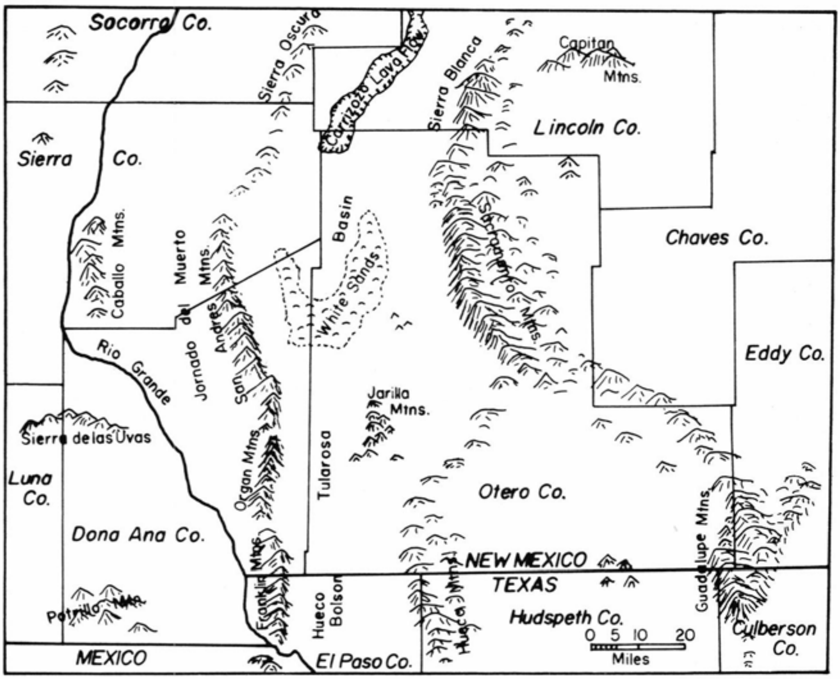


Figure 1. Index map showing location of Jarilla Mountains.

PREVIOUS WORK

Areal studies have been mainly concerned with the mining operations (Lindgren, Graton, and Gordon, 1910; Lasky and Wootton, 1933; Anderson, 1957) and recorded production figures, with only general remarks about the geology. A ground-water report on the Tularosa Basin mentioned the Jarilla Mountains (Meinzer and Hare, 1915) and referred to "Carboniferous limestone" and "granite." Darton (1921) mentioned "Chupadera (Permian) limestone and porphyry" and (1928) mapped the Jarillas on a 1:500,000 scale (Geologic Map of the State of New Mexico), plotting outcrops of Precambrian rocks (at extreme northwest corner of mountains), Pennsylvanian rocks (in sec. 25, T. 22 S., R. 8 E.), and post-Carboniferous intrusives. Needham (1937) collected fusulinids in the limestone hogbacks along U.S. Highway 54, four miles north of Orogrande, and identified the rocks as Wolfcampian in age. Kelley (1949) reported on the iron mining in the Jarilla Mountains. Reynolds and Craddock (1959) published a short account of the geology of the Jarillas.

The surrounding larger mountain ranges flanking the Tularosa Basin have received more intensive study, but little mention is made of the Jarilla Mountains in the published accounts of those areas.

Craddock did about ten days of field work in the Jarilla Mountains with C. B. Reynolds during the summer of 1954 and another ten days of work alone during the following six months. Schmidt spent eight weeks during the summer of 1959 examining the exposed bedrock. Field observations and specimen locations were plotted directly on aerial photographs.

ACKNOWLEDGMENTS

The writers express their sincere thanks to Professor John W. Hall of the University of Minnesota for identification of the fossil wood; to Miss Helen Duncan of the U.S. Geological Survey for identification of two corals; to Grant Steele of the Gulf Oil Company for identification of the fusulinids; to Professor Robert E. Sloan and Olgerts Karklins of the University of Minnesota for help in the identification of other fossils; to Theodora Melone for extensive assistance in the Winchell Library of Geology; to our associates in the Department of Geology and Geophysics at the University of Minnesota for helpful advice and discussion; to Charles B. Reynolds for collaboration in the early field work; and to the friendly people of Orogrande, especially Lewis Taylor, wise in the ways of the desert and prospector, for advice and companionship.

PHYSIOGRAPHY

The Jarilla Mountains lie east of the axis of the Tularosa Basin, a large, partly filled graben with interior drainage in the Sacramento section of the Basin and Range physiographic province (Fenneman, 1931). Ten miles to the east is the southern end of the massive escarpment of the Sacramento Mountains and the west edge of Otero Mesa; twenty miles to the west is the escarpment bordering the Organ and San Andres ranges (fig. 1). To the north the flat floor of the valley stretches beyond the horizon, and to the south it merges with the featureless, structurally continuous, Hueco bolson of west Texas.

The Jarilla Mountains rise abruptly above the flat surface of the valley as scattered hills and subrounded peaks. Maximum relief is about 1200 feet, but most of the range is less than 800 feet above the desert floor. The Tularosa desert surrounding the range has an elevation of about 4100 feet above sea level; the highest peak in the mountains, in section 34, T. 21 S., R. 8 E., has an altitude of 5301 feet.

Drainage of the Jarilla Mountains is almost wholly by surface run-off; little rainfall penetrates into the massive, impermeable bedrock. Numerous dry gullies and arroyos lead out of the hills onto the desert where they branch into distributaries and merge with the flat valley floor.

CLIMATE AND VEGETATION

The climate is that of a true southwestern desert with hot, dry summers and warm, dry winters. The average annual precipitation at El Paso, Texas, fifty miles to the south, is 8.65 inches (Knowles and Kennedy, 1958). Somewhat less rain falls in the Hueco bolson and Tularosa Basin than at El Paso (Sayre and Livingston, 1945). Most moisture comes as short, intense thundershowers during the summer months of July through September. The average annual evaporation is 108 inches, measured by evaporation pans at Ysleta, Texas, near El Paso (Knowles and Kennedy). Summer temperatures range from 65° to 110°F, and winter temperatures from near freezing to 80°F. During the summer, violent thunderstorms sweep across the valley, and numerous dust devils swirl over the heated sandy wastes.

Vegetation consists mainly of rather thinly distributed cactus, yucca, mesquite, creosote bush, and grasses. Patches of tall, thick grass occur in places on the desert floor. The higher parts of the hills are more densely covered with grasses and thorny bushes. Large areas of the surrounding desert consist of semistabilized hummocks of sand. Thick patches of mesquite bushes anchor the sand into knobs three to six feet high; bare blowout surfaces occur between the bushes.

CULTURE

In recent years the Tularosa Basin has become a large military guided-missile and rocket-testing range. The cities of El Paso, fifty miles to the south, and Alamogordo, forty-five miles to the northeast, owe much of their rapid growth of recent years to the military weapons development programs. The residents of Orogrande make their living by working on the firing ranges or supplying gasoline, oil, and meals to travelers.

In the SW1/4 sec. 21, T. 22 S., R. 8 E. are remains of Indian villages that were occupied about the year 1200 A.D., according to Hart Ponder (personal communication, August 1959). The area was visited by the Spanish conquistadores of the seventeenth and eighteenth centuries, but the Jarillas were avoided for the more hospitable Rio Grande Valley to the west of the San Andres and Organ mountains. In the latter part of the nineteenth century, gold and copper deposits were discovered in the mountains. Numerous mineral claims were staked and worked, and cattle ranching was begun in the surrounding desert.

During the early part of the twentieth century there was considerable mining activity in the gold and copper deposits, and some of the skarns were worked for iron. A spur from the railroad was constructed to the mining area, and the towns of Ohaysi in sec. 3 and Brice in sec. 10, T. 22 S., R. 8 E. each had a population of several hundred miners.* In 1921, the mining operations ceased, except for some sporadic placer operations, and the Jarilla Mountains returned to their former tranquil state.

•The Oro Iron Company, which operated several small iron mines in the Jarillas, established a town for its personnel and petitioned the Post Office Department to have the town named O.I.C. for the initials of the mining company. This was denied, so the company settled on the word *Ohaysi* (pronounced oh-HI-see), which is an Apache term meaning "a place far away from anything else." This compromise name suited the town even better than the original, besides being pronounced the same.

Sedimentary Rocks

Sedimentary rocks of Pennsylvanian and Permian age crop out in the Jarilla Mountains. They are mainly gray fossiliferous limestones with minor amounts of sandstone, siltstone, and shale. The small outcrop mapped as Precambrian by Darton (1928) at the northwestern end of the Jarilla Mountains (apparently in sec. 9, T. 21 S., R. 8 E.) is either syenodiorite and monzonite-adamellite or the contact metamorphic rock (skarn, marble) between these igneous intrusives and the Permian limestones.

Other than the identification of some fusulinids, the sedimentary rocks of the Jarilla Mountains had not been studied previously in any detail. Unfortunately, the exposures did not provide so complete a section as was hoped, but the information obtained aids in reconstructing the geologic history for a considerable part of Pennsylvanian and Permian time.

Features of the sedimentary rocks are described as follows: grain size: 0:05 to 0.1 mm, very fine-grained; 0.1 to 0.25 mm, fine-grained; 0.25 to 0.5 mm, medium-grained; 0.5 to 1.0 mm, coarse-grained; 1.0 to 2.0, mm, very coarse-grained; bedding thickness: less than 0.1 foot, very thin-bedded; 0.1 to 0.5 foot, thin-bedded; 0.5 to 1.5 feet, medium-bedded; 1.5 to 5 feet, thick-bedded; 5 feet and greater, massive-bedded. Only the fresh rock color is listed unless otherwise noted.

PENNSYLVANIAN SYSTEM

Pennsylvanian rocks crop out in secs. 9, 10, 11, and 16, T. 22 S., R. 8 E. The best exposed and most complete sequence of these strata occurs in section 11, from the Orogrande reservoir in the SWIG to the NEIL. The beds were intruded by intermediate igneous sills and dikes and were faulted and tilted to the northeast; they are truncated on three sides by the main igneous body. The total thickness of the measured section is 918 feet, including 96 feet of igneous dikes and sills. The exposed Pennsylvanian sedimentary rocks are 822 feet thick, but upper beds are largely covered by rubble slopes.

LITHOLOGY

The Pennsylvanian rocks are mainly marine limestones, light to dark gray or brown in color on fresh surfaces; gray, tan, or brown on weathered surfaces; thin- to massive-bedded; fine- to coarse-grained; and generally fossiliferous. Near the base of the section is a 51-foot unit of interbedded sandstone and shale. There may be other shales and sandstones in the sequence in the covered intervals near the top.

The main rock is a massive, gray, fine- to medium-grained limestone that contains many thinner beds of texturally different material ranging from very fine-grained, laminated, and nearly unfossiliferous limestone to very coarse-grained beds of fossil-shell hash. Chert nodules and masses are abundant throughout the sequence.

The massive limestone contains fossil fragments evenly distributed in a matrix of fine-grained lime mud, whereas the coarser-grained limestones consist of shell fragments minus the finer mud fraction. The latter are calcarenites, show cross-bedding, and contain fragments of crinoids, brachiopods, and fusulinids. The contact between the finer- and coarser-grained layers is sharp, and in places shows flow structures and inclusions of the different types in each other.

Chert nodules usually occur in conspicuous layers, and some form nearly continuous, one-half to two-inch-layers parallel to bedding planes. Other rounded nodules have concentric bands. The chert has sharp contacts with the surrounding limestone, but cuts across structures, beds, and fossils in the limestone.

FOSSILS

The limestones are generally very fossiliferous, although most of the organic material is broken. The most common forms are segments of crinoid stems. Fusulinids were found in thinsections but were inadequate for identification. Poorly preserved bryozoans were found in one bed. Brachiopods and corals furnished evidence of the Pennsylvanian age of this section. The brachiopods *Punctospirifer kentuckiensis* and *Hustedia mormoni* are common Pennsylvanian forms but one coral, *Chaetetes eximius?,* is probably of a more restricted age.

The coral *Chaetetes eximius?* (figs. 2, 3) occurs as silicified nodules a few centimeters thick to masses twenty centimeters in diameter in a prominent marker bed 160 feet above the base of the measured section. The average tube diameter of the coralite is 0.25 mm; the average wall thickness is 0.10 mm. This fossil most closely resembles C. *eximius* (Moore and Jeffords, 1944, p. 191) but is definitely smaller in size. However, this may be a reflection of local ecologic conditions (Robert Dott, Jr., personal communication, 1954). C. *eximius* is found in rocks of Morrowan age in Oklahoma, and Bendian age in Texas. Other species range into the Desmoinesian in Oklahoma (Morgan, 1924). C. *eximius* is in a thin zone with *Profusulinella* (Lower Atokan) in the Great Basin and could be of that age in the Texas, Oklahoma, and New Mexico region (Robert Dott, Jr., personal communication, 1954). *Chaetetes* is abundant throughout limestone strata of Desmoinesian age in the San Andres Mountains (Kottlowski et al., 1956), in the Mud Springs Mountains Desmoinesian rocks (Thompson, 1942), and in the northern Franklin Mountains lower Desmoinesian limestones (Nelson, 1940).

It seems most probable that this *Chaetetes eximius?* is of early Desmoinesian age. The higher parts of the section may range through the Desmoinesian into Missourian or even Virgilian.

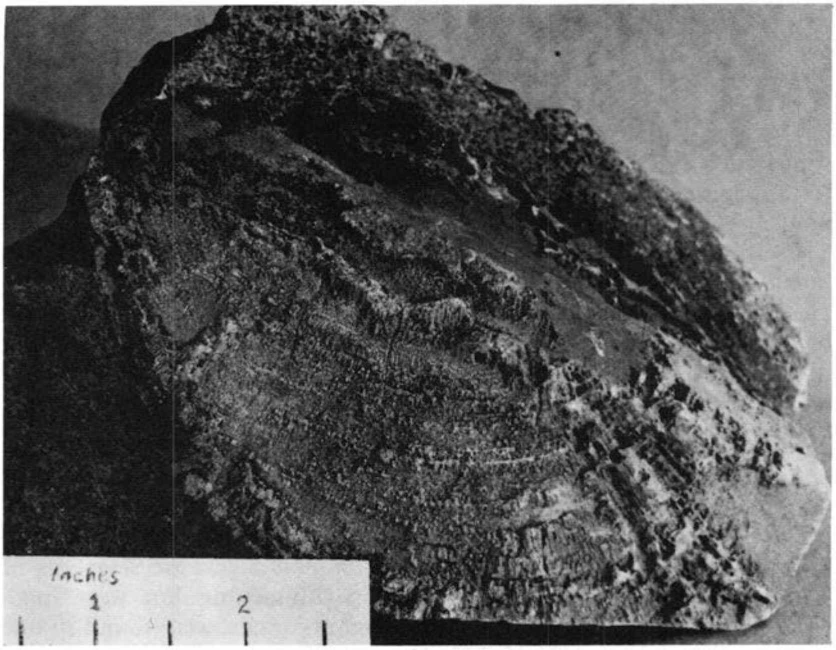


Figure 2. NODULELIKE MASS OF FOSSIL *Chaetetes eximius*?.

CORRELATIONS

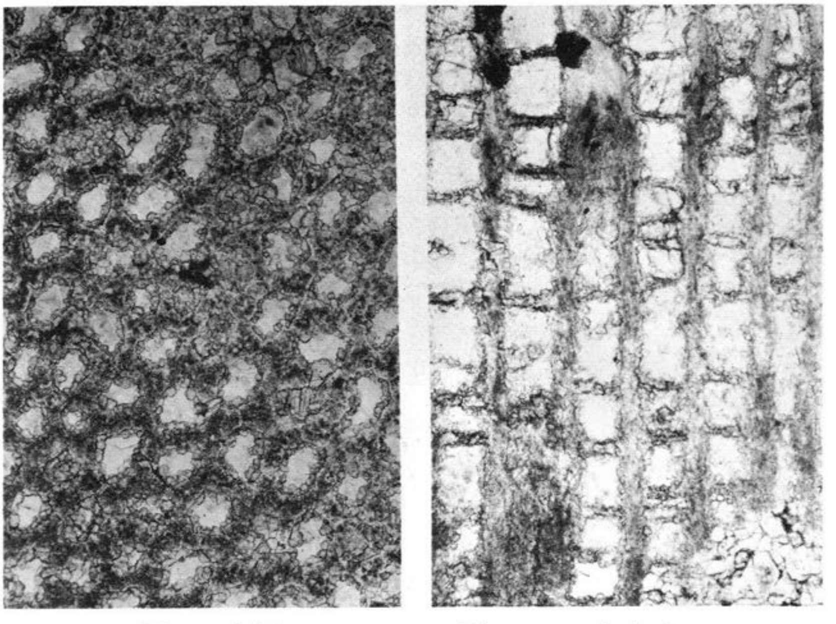
More complete sections of Pennsylvanian rocks crop out along the escarpments of the ranges that border the Tularosa Basin, the Sacramento, San Andres, and Franklin mountains. A few wildcat oil tests have also contributed stratigraphic information.

In the Sacramento Mountains, the Pennsylvanian section is 2000 to 3000 feet thick and has been divided into three formations and one member (Pray, 1961). The lowest is the Gobbler Formation, which contains the Bug Scuffle Limestone Member. The Gobbler Formation rests unconformably on Mississippian rocks and is composed largely of shale, argillaceous limestone, and very coarse-grained quartz sandstone in the lower part. The upper part consists of calcareous sandstone and shale and the Bug Scuffle Limestone Member. This member is a gray, cherty, fine-grained limestone. The Gobbler Formation is of late Morrowan through middle Missourian age.

Overlying the Gobbler Formation is the Beeman Formation of middle to late Missourian age. It consists largely of shale, thin-bedded argillaceous limestone, and feldspathic sandstone. The uppermost Pennsylvanian in the Sacramento Mountains is the Holder Formation of Virgilian age, mainly white limestone interbedded with sandstone, conglomerate, and red and gray shale. The percentage of red beds and conglomerates increases toward the top of the Holder, suggesting the rise of a positive area (Pedernal landmass) to the east (Pray, 1961). The basal part of this formation contains many bioherms of white limestone.

In the San Andres Mountains to the northwest, the rocks of Derryan and Desmoinesian age are considerably thinner than in the Sacramento Mountains, but the rocks of Virgilian age are thicker (Kottlowski et al.). The Desmoinesian rocks there thin from 622 feet in the north to 183 feet in the south at Ash Canyon, 25 miles northwest of the Jarilla Mountains, and are of gray, cherty, bioclastic limestones. The Virgilian rocks are in the Panther Seep Formation and consist of silty shale, argillaceous limestone, silty calcarenite, calcareous sandstone, and biostromal limestone.

Thirty miles to the southwest in the northern Franklin Mountains is a 1600-foot section of Pennsylvanian rocks, and an equal, but unexposed, thickness is inferred overlying this section (Nelson, 1960). The exposed rocks range in age from Bendian through middle Strawnian (Atokan through middle Desmoinesian) and have been assigned to three members of the Magdalena Formation. The lowest unit, the La Tuna Member of Bendian (Atokan) age, is 361 feet thick and consists of limestone, massive and cherty near the base and thinner-bedded near the top. The middle unit, the Berino Member of early Strawnian (early Desmoinesian) age, is thin-bedded limestone, fine-grained, and gray to



A B

Figure 3. Thinsections of *Chaetetes eximius*?.
A. Perpendicular to the tubes. B. Parallel to the tubes. X25

black and brown. The uppermost unit is the Bishops Cap Member, 619 feet of thin-bedded limestones with a few sandstone lenses. It is of middle Desmoinesian age at the top of the exposed section (Nelson, 1960).

A few significant oil tests in the Tularosa Basin have contributed to knowledge of the regional stratigraphy. The Plymouth Oil Company No. 1 Federal oil test, drilled four miles north of the Jarillas, penetrated 3050 feet of Pennsylvanian rocks, of which about 900 feet at the base correlated with the Bug Scuffle Limestone Member of the Sacramento Mountains (Pray, 1959). The Sun Oil Company No. 1 Pearson-Federal oil test, eight miles east of the Jarillas, penetrated 2230 feet of Pennsylvanian rock. According to fusulinid data, about 900 feet of this section are of Desmoinesian age and are correlative with the Bug Scuffle Limestone Member (Kottlowski, 1960b).

Lithologically, the Desmoinesian section of the Jarilla Mountains appears to correlate with the Bug Scuffle Limestone Member of the Gobbler Formation. The basal sandstone and shale beds of the Jarillas may be correlative with the sandstones and shales of the lower part of the Gobbler Formation in the Sacramento Mountains, but as the upper and lower boundaries of the Jarilla Pennsylvanian section are not exposed, this correlation is unproved.

Pennsylvanian strata are thick near the Jarilla Mountains, and these thick marine sections define a closed depositional basin that subsided during most of the Pennsylvanian. This, the Orogrande basin (Pray, 1959), should have a Pennsylvanian section (fig. 4) in excess of 3200 feet in the Jarilla Mountains (Kottlowski, 1960b); unfortunately, the exposed section is incomplete. Subsidence of the Orogrande basin, if any, was slight in Early Pennsylvanian (Atokan, Desmoinesian) time but was accentuated in later Pennsylvanian time (Pray, 1959). The Bug Scuffle Member exposed in the Jarillas was formed on a relatively stable shelf. However, unexposed overlying Pennsylvanian rocks formed from sediments which collected in a subsiding basin adjacent to the Pedernal landmass and are probably of a more heterogeneous nature.

Measured Section of Pennsylvanian Strata

Unit No.	Description	Thickness (feet)
	Bug Scuffle Limestone Member of Gobbler Formation	
27	Limestone, brown-gray, weathers gray, cherty; medium-grained with lower three feet fine-grained; crinoidal shell hash; rubbly slope; top covered	51
26	Limestone, brown-gray, weathers gray, cherty; medium-grained hash of crinoids, brachiopods; rubbly slope	69
25	Limestone, mostly covered; like unit 26; scattered ledges	145½
24	Limestone, gray, weathers brown, cherty, medium- to coarse-grained; rounded ledges	42½
23	Limestone, brown-gray, weathers gray, medium-grained; hash of crinoids and brachiopods; chert nodules in lower part; ledges	47

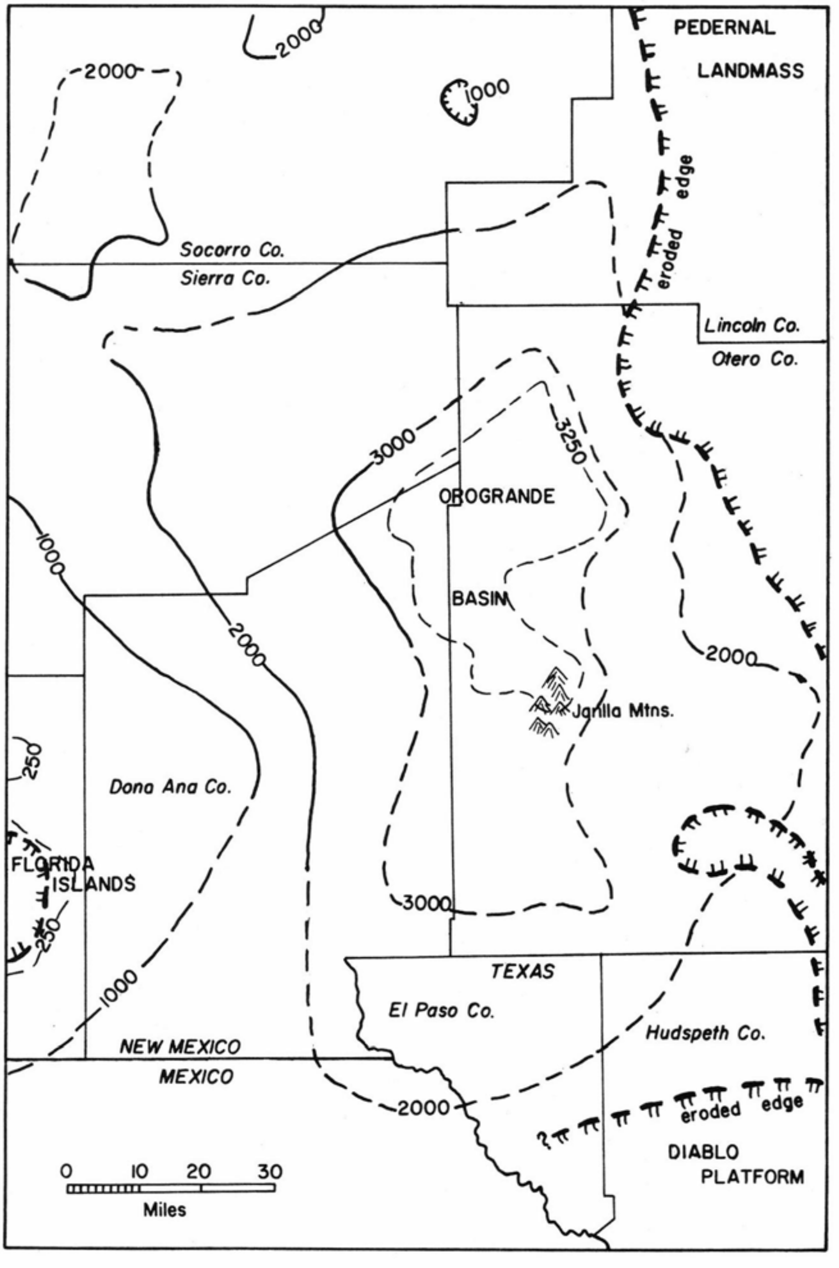


Figure 4. Isopach map for Pennsylvanian of south-central New Mexico (after Kottlowski, 1960a).

Unit No.	Description	Thickness (feet)
22	Igneous sill	33
21	Limestone, brown-gray, weathers gray; upper part cherty, fine-grained; lower part coarse-grained fossil hash; *Fenestrellina*, spirifers, crinoids, cup corals; ledges	34
20	Limestone, black, weathers buff, medium-grained, thin-bedded; chert nodules near base; nodular near top; ledges	42
19	Limestone, gray; clastic shell hash of crinoids, brachiopods, and corals. Lower foot is limestone-pebble conglomerate; *Punctospirifer kentuckiensis*	13
18	Limestone, gray, cherty, fine-grained, fossiliferous, massive	32½
17	Igneous sill	23
16	Limestone, gray, medium-grained; one-foot chert bed at base; ledge	8
15	Igneous sill	12
14	Limestone, brown-gray, weathers gray, fine-grained, massive; contains crinoids, cup corals, brachiopods	16
13	Igneous sill	23
12	Limestone, gray, fine-grained, massive, fossiliferous, ledge	15½
11	Limestone, brown-gray, weathers gray, medium-grained, fossiliferous; contains banded chert nodules; ledge	13
10	Limestone, gray, fine-grained, massive, fossiliferous; crinoids, cup corals, brachiopods; scattered chert nodules; basal three feet are white, thin-bedded, weathers slabby	78
9	Limestone, gray, massive, cherty, medium-grained; basal eight feet are white, medium-grained, massive, hard, dense, quartzose sandstone	47½
8	Limestone, gray, massive, fossiliferous; *Chaetetes eximius?*	12½
7	Limestone, gray to tan, weathers brown, cherty, medium-grained, fossiliferous	18
6	Limestone, gray, massive, fossiliferous; stylolites near top	33
5	Limestone, gray, very cherty, massive, fossiliferous; crinoids, corals, brachiopods; chert in nodules and irregular layers	33
4	Shale, tan-gray, weathers gray, hard, fissile; slope	21½
3	Sandstone, brown; very coarse-grained, cross-bedded, and ferruginous near base; very fine-grained and massive near top; three-foot shaly bed near top	25
2	Shale, brown, fissile, sandy	7
1	Limestone, brown-gray, weathers gray, medium-grained, thin- to medium-bedded; alternating 6-inch to 12-inch beds of gray-weathering and brown-weathering limestone; lower part cherty; underlain by intrusive monzanite-adamellite stock	22½
	Partial thickness of Bug Scuffle Limestone Member of Gobbler Formation (including igneous sills)	918

PERMIAN SYSTEM

Early Permian rocks crop out in the northern and eastern part of the Jarilla Mountains in secs. 2 to 4, 9 to 11, 14, 15, 22, and 23, T. 21 S., R. 9 E.; secs. 25 and 36, T. 21 S., R. 8 E.; secs. 1, 12, and 13, T. 22 S., R. 8 E.; and secs. 6, 7, and 18, T. 22 S., R. 9 E. The most complete section is in the northern end of the area. This 2512-foot section was measured from the SE 1/4 sec. 22, T. 21 S., R. 8 E. to the NWIA sec. 14, T. 21 S., R. 8 E. The sequence is poorly exposed in places and in some areas is considerably assimilated and/or displaced by igneous rock. Numerous faults of 300 feet or less displacement were mapped. Other faults may be hidden by surface debris, especially in the NEV$_{I}$ sec. 22, T. 21 S., R. 8 E. where the measured section crossed several covered intervals (Monte Carlo Pass).

The total thickness of igneous intrusives in this section is 292 feet. Both the base and top of the section are at an igneous contact. The basal part, about 100 feet, is considerably altered by contact metamorphism to hornfels and skarn.

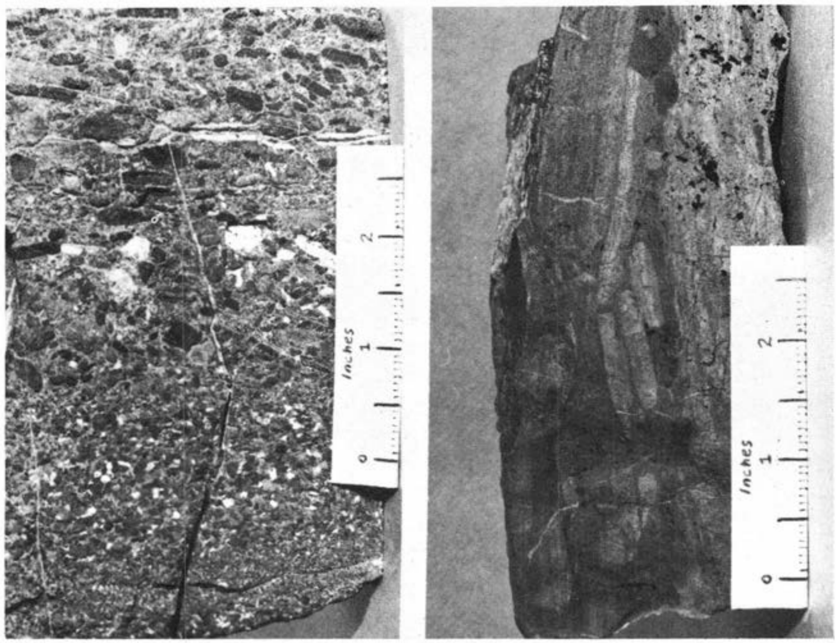
LITHOLOGY

The Permian sequence consists of interbedded limestones and clastic rocks in the lower part but nearly all cherty limestone in the upper beds. Common in the lower half of the section is limestone pebble conglomerate in beds six inches to two feet thick. Beds of coarse-grained, calcareous, cross-bedded brown sandstone composed of quartz and chert grains are also numerous, as are layers of siltstone and laminated shale.

The basal beds of the section are metamorphosed. The limestones have been marbleized, the sandstones changed to quartzite, and the siltstones to a flinty hornfels near the intrusives. The basal 62 feet are mostly brown sandstone, which gives way upward to thin-bedded, silty, argillaceous limestone. A resistant clayey siltstone, baked to flinty hornfels, forms the prominent ridge in the SE1/4 sec. 22, T. 21 S., R. 8 E.

From 257 feet to about 1300 feet above the base of the measured section, the rocks are mainly calcareous sandstones and interbedded laminated argillaceous limestones and siltstones. Limestone pebble conglomerate is common; some of these beds are composed almost entirely of flat limestone fragments in a finer-grained matrix (fig. 5A), but in other finely laminated conglomerates, the fragments seem to be nearly in place (fig. 5B). Others consist of coarse-grained, cross-bedded, rough weathering beds with abundant grains of quartz and angular chert. The conglomerates and sandstones are mostly buff to brown on fresh surfaces, whereas the limestones are generally very fine-grained, thin-bedded and gray to brown. The shales, poorly exposed, are generally thin-bedded, laminated, and gray. Thin layers of fine-grained, laminated limestone occur interbedded in the shales. Soft, silty, buff to whitish soil, probably from weathered siltstone, overlies many of the covered intervals. Thin beds of limestone and sandstone protrude through this silty cover in places.

The upper part of the section, above 1300 feet from the base, is almost exclusively gray, fossiliferous limestone. A few beds of soft siltstone, one 47 feet thick, occur intermittently in the section and form topographic swales. Some of the limestone beds contain many dark chert nodules and stringers and generally form topographic highs. One distinctive, ridge-forming limestone conglomerate, from 1882 to 1892 feet above the base, has a matrix of angular quartz grains and frag-



A B

Figure 5. TYPICAL SPECIMEN OF LIMESTONE PEBBLE INTRAFORMATIONAL CONGLOMERATE.

Bedding is vertical in B. A. Well-broken fragments distributed in fine matrix. B. Fragments nearly in place.

ments of chert and of silicified fossil fragments. Several silicified logs occur interbedded in fossiliferous marine limestones (fig. 6) from about 1620 to 1670 feet above the base of the section. These logs presumably drifted to sea, became waterlogged, sank, and were buried in the lime mud.

FOSSILS

Fusulinids collected at two horizons in this Permian sequence are the basis for the age assignment. The lower half of the section, predominantly clastic rocks, is unfossiliferous except for a three-foot bed of limestone pebble conglomerate at 770 feet which contains fusulinids in the matrix. The upper part of the section is abundantly fossiliferous and contains brachiopods, pelecypods, gastropods, crinoids, corals, scaphopods, echinoids, bryozoans, fusulinids, and silicified wood, all in the gray limestone.

The fossil wood was collected from four silicified logs (SW1/4SW1/4 sec. 14, NE1/4NE1/4 sec. 21, T. 21 S., R. 8 E.; SE1/4SE1/4 sec. 2, SE1/4NE1/4 sec. 12, T. 22 S., R. 8 E.) in gray, cherty, marine limestone from 1620 to 1670 feet above the base of the section. The logs are about one foot in diameter and one to four feet long (fig. 6). John W. Hall (personal communication, 1962) identified the wood as belonging to the genus *Dadoxylon,* a form genus of Paleozoic Araucaria-like plants.

The fossils identified, other than fusulinids, are as follows (footage above base of the section listed in parentheses): corals: *Thysanophyllum* n. sp., *Stylastraea* n. sp. (Helen Duncan, personal communication, 1964) and *Duplophyllum* sp. (1644); brachiopods, *Wellerella osagensis?* (1648), *Linoproductus?* (2158), *Cleiothyridina orbicularis?* (2143); pelecypods: *Myalina* sp., *Volsella* sp., *Astartella* cf. *A. newberryi,* and *Nuculana* sp. (all at 2158); gastropods: *Pharkidonotus pericarinatus, Warthia sp., Cymatospira montfortianus?* (all at 2375), *Orthonema?, Labridens* sp., and *Aclisina bisulcata* (all at 2342); and bryozoan: *Fenestrellina* (2158). These macrofossils are representative Permian forms.

Abundant fusulinids occur in two thin gray limestones at 1635 to 1640 feet and at 1650 to 1670 feet; Needham identified these as *Pseudoschwagerina morsei, Schwagerina emaciata,* and *S. emaciata* var. *jarillaensis.*

Scattered fusulinids were found in a two-foot bed of limestone peb-

Figure 6. Silicified log of *Dadoxylon* in limestone, SW¼SW¼ sec. 14, T. 21 S., R. 8. E.

The log is about 4 feet long, 1½ feet thick.

ble conglomerate at 770 feet; they are complete forms and do not appear to be clastic fusulinids. They were identified by Grant Steele (personal communication, 1960) as *Schwagerina aff. S. emaciata* var. *jarillaensis, Schwagerina* sp. indet., *Triticites ventricosus sacramentoensis, Triticites* cf. *T. gallowayi, Triticites* cf. *T. rhodesi, Triticites* cf. *T. cellemagnus,* and *Triticites* sp. indet. This association of *Triticites* and *Schwagerina* indicates an early Wolfcampian age for these strata; the association of *Schwagerina* and *Pseudoschwagerina* in the beds at 1635 and 1650 feet indicates an age of early Wolfcampian to/or late Wolfcampian.

CORRELATIONS

In the northernmost part of the Sacramento Mountains, the Laborcita Formation occurs between the upper Virgil Holder Formation and middle Wolfcamp Abo red beds (Otte, 1959). The Laborcita formation is about 900 feet thick and was deposited in a transition zone between marine environments to the southwest and nonmarine environments to the northeast. The rocks consist of thin, interbedded argillaceous limestones, cherty limestones, mudstones, shales, sandstones, and arkoses. The Laborcita Formation conformably overlies the Holder Formation in its westernmost outcrop area; to the east it is angularly unconformable on Virgilian strata (Otte). The Laborcita Formation is overlain unconformably by the Abo red beds.

The lower 90 feet of the Laborcita Formation contains a Virgilian fauna, whereas overlying beds bear a Permian *Dunbarinella* and *Schwagerina* fauna, indicating an early Wolfcampian age. The overlying Abo Formation is considered to be middle to late Wolfcampian in age (Otte).

The Bursum Formation, which overlies Pennsylvanian rocks and underlies the Abo red beds in other parts of south-central New Mexico, is probably the continental facies of a part of the Laborcita Formation.

Overlying (probably conformably) the Bursum (Laborcita) Formation in the Sacramento Mountains is the Abo Formation, which consists of 400 to 500 feet of continental red beds in the north, but grades to thicker brackish marine limestones and shales in the south (Pray, 1961). In the northern part of the Sacramento Mountains the Abo red beds overlie the Bursum (Laborcita) strata disconformably (Pray, 1952). Throughout the remainder of the Sacramento escarpment, the Abo rests unconformably on faulted, folded, and eroded Pennsylvanian and pre-Pennsylvanian strata. The Abo Formation intertongues with the Hueco Formation in the southernmost part of the Sacramento Mountains and thus is considered to be of middle to late Wolfcampian age (Pray, 1961).

The San Andres Mountains, northwest of the Jarillas, expose beds tentatively assigned to the Bursum Formation. The maximum thickness is 267 feet of shale, limestone, and limestone pebble conglomerate. These strata unconformably overlie Virgilian rocks, contain a higher percentage of shale and sandstone to the north, and are absent in the southern part of the range (Kottlowski et al.).

Unconformably overlying older strata in the San Andres Mountains is the Hueco Formation, which thickens markedly to the south from 325 feet to 1335 feet in 25 miles. The Hueco Formation is dominantly limestone, calcarenite, and shale, and contains a middle and upper Wolfcampian fauna *(Schwagerina* and *Pseudoschwagerina)*. The amount of shale and red beds decreases to the south. The Hueco is considered to be the southern marine facies of the Abo Formation and intertongues with the Abo Formation, which thins southward from 835 to 325 feet (Kottlowski et al.). The Permian section of the Franklin Mountains southwest of the Jarillas is poorly exposed but consists of 2200 feet of the Hueco Formation (Harbour, 1958), which is similar to the type Hueco of the Hueco Mountains.

The Sun Oil Company No. 1 Pearson oil test, eight miles east of the Jarillas, penetrated 470 feet of Bursum equivalent beds between the Hueco Limestone and strata of Virgilian age. The identification of this early Wolfcampian rock is based on *Triticites* in the lower part, and *Triticites* and *Schwagerina* in the upper part (Kottlowski, 1960b). The Bursum equivalent and the Virgilian strata (Holder Formation) consist of interbedded limestone, siltstone, sandstone, and shale. Some of the Bursum beds contain coal laminae (Kottlowski, 1960b) and apparently accumulated in a transition zone between continental deposition (Pedernal landmass) to the east and marine environments (Orogrande basin) to the west.

To the southeast in the Hueco Mountains, the Hueco Limestone of Wolfcampian age rests with angular unconformity on Pennsylvanian and older strata. The Hueco is 1500 feet thick and consists of upper and lower units that are dominantly thick-bedded, light-gray limestone with a middle unit of thinner-bedded, dark-gray marly limestone. A basal conglomerate and red-bed part is termed the *Powwow Conglomerate Member,* and red shale in the upper division is termed the *Deer Mountain Red Shale Member* (King, King, and Knight, 1945). The lower division is Wolfcampian in age (Thompson, 1954) and the fauna *(Schwagerina, Pseudoschwagerina)* suggests an early Wolfcampian age. The middle division of the Hueco Limestone contains an upper Wolfcampian fauna *(Schwagerina),* and the upper division above the Deer Mountain Red Shale Member has a fauna of advanced Wolfcampian fusulinids *(Pseudofusulina, Schwagerina, Pseudoschwagerina)* (Thompson, 1954).

The Jarilla Mountains section fusulinid beds from 1635 to 1670 feet are correlated with the Hueco Limestone. The fusulinid fauna *(Schwagerina, Pseudoschwagerina)* indicates correlation of the upper part of this section with the lower division of the Hueco Limestone.

Correlation of the siltstone beds from 1700 to 1882 feet with a tongue of the Abo Formation, or the Deer Mountain Member of the Hueco Formation, is possible but proof is lacking. The occurrence of *Triticites* and *Schwagerina* at 770 feet suggests correlation of the lower part of this section with the Laborcita Formation. The unconformity between Hueco equivalents and the Bursum (Laborcita) Formation reported from the Sacramento Mountains was not seen in the Jarilla Mountains. However, much of the interval between the two fusulinid-bearing horizons is poorly exposed. If the measured thicknesses of this section are nearly correct, there are about 1200 feet of sediments lithologically similar to the Laborcita Formation in the Jarilla Mountains. Pray (1952, p. 37) interprets the relative increase in red shale and conglomerate to the east and southeast in the Bursum (Laborcita) of the northern Sacramento Mountains as indicating the existence of a landmass in that direction. In the southern Sacramento Mountains, at the latitude of the Jarillas, the Bursum (Laborcita) Formation is missing, perhaps by postdepositional erosion. The presence of the Bursum (Laborcita) equivalents in the Sun Oil Company No. **1** Pearson well (sec. 35, **T.** 20 S., R. 10 E.) indicates that the Jarilla area was well west of the uplifted area; it probably received marine sedimentation continuously from Virgilian through Wolfcampian time.

During Virgilian time, the Orogrande basin encircling the modern Jarilla Mountains received a thick sequence of sediments (Pray, 1961; Kottlowski, 1960a); it probably continued as a subsiding block into early Permian time (Pray, 1959). The Jarilla Mountains contain a thick section of the Laborcita Formation. Either an unconformity is not present between the Laborcita and the Hueco, and deposition continued from Virgilian into late Wolfcampian time, or only limited erosion took place prior to Abo—Hueco deposition in the central part of the Orogrande basin.

MEASURED SECTION OF LABORCITA AND HUECO FORMATIONS

Unit No.	Description	Thickness (feet)	Cumulative thickness
	Sedimentary section overlain by intruded orthoclase adamellite stock		
	Hueco Formation		
52	Limestone, gray, fine-grained, fossiliferous; gastropods, crinoids, brachiopods, and corals	57	2512
51	Limestone, gray, medium-grained, fossiliferous, massive	24	2455
50	Limestone, gray, fine- to medium-grained, fossiliferous; some beds silicified; *Cymatospira montfortinanum*?, *Pharkidonotus pericarinatus*?, *Warthia* sp.; lower one fourth is tan, soft, silty, massive shale, mostly covered	72	2431
49	Limestone, gray, medium-grained, fossiliferous; *Cleiothyridina orbicularis*?, *Orthorema*?, *Labridens* sp., *Aclisina bisulcata* Chronic	38	2359

Unit No.	Description	Thickness (feet)	Cumulative thickness
48	Shale, brown-buff, soft, silty, massive; slope broken by one-foot bed of limestone, gray, weathers yellow, very fine-grained	8	2321
47	Limestone, gray, fine-grained, massive; some fossiliferous beds, some limestone conglomerate lenses	70	2313
46	Limestone, gray, fine- to medium-grained; beds two feet thick; some lenses of limestone-pebble conglomerate, especially top two feet; fossil shell hash of brachiopods, crinoids, and gastropods	48	2243
45	Limestone, gray; interbedded massive fine-grained dense limestone and medium-grained, thin- to medium-bedded fossil hash limestone; crinoids, gastropods, pelecypods, bryozoan; *Linoproductus*?, *Myalina* sp., *Volsella* sp., *Astartella* cf. *newberryi*, *Nuculana* sp., *Fenestrellina* sp.	44½	2195
44	Limestone, gray, fine-grained; scattered fossils	120½	2150½
43	Limestone, gray, medium-grained, fossiliferous; chert nodules near base and top	40	2030
42	Limestone, gray, massive fossiliferous; lower two feet buff-gray, thin-bedded; five feet above base is fossiliferous, flat-pebble limestone conglomerate	33	1990
41	Shale, whitish, soft, silty; mostly covered	7	1957
40	Limestone; lower nine feet is yellow-gray, silicified, hard; upper part is gray, medium-grained, cherty, massive, fossiliferous	33	1950
39	Limestone, gray, weathers brown-buff; clastic coquina and pebble conglomerate; thin laminated beds at base and top	25½	1917
38	Conglomerate, gray, calcareous; silicified fossil hash; forms ridge, weathers to rough surface	9½	1891½
37	Siltstone, white, weathers tan, friable, silty, calcareous, very thin-bedded, fossiliferous	47	1882
36	Base and top is limestone, buff-gray, weathers yellow-brown, very fine-grained, laminated, siliceous; middle part is whitish tan, soft, thin-bedded, silty shale overlain by brown-buff, coarse-grained, fossiliferous, calcareous sandstone	27	1835
35	Lower part is limestone, gray-tan, weathers yellow-gray, very fine-grained, siliceous, hard; upper part is tan shale, weathers white; soft, massive, silty; poorly exposed	54	1808
34	Basal red shale, soft, silty, poorly exposed; overlain by three feet of limestone conglomerate with flat and rounded pebbles; middle part is gray limestone; fossil shell hash of crinoids, gastropods, corals, and brachiopods; upper limestone is massive and very fine-grained	53½	1754
33	Limestone, gray-black, very fine-grained; lower part massive, cherty, fossiliferous; gastropods, crinoids	26	1700½
32	Limestone, gray, clastic-shell hash; middle massive; *Schwagerina emaciata* Beede, *Pseudoschwagerina morsei* Needham, *Schwagerina emaciata* var. *jarillaensis* Needham, *Dadoxylon*	23½	1674½

Unit No.	Description	Thickness (feet)	Cumulative thickness
31	Limestone, gray, very fine- to medium-grained; limestone pebble conglomerate in middle; very cherty near base; fusulinids and brachiopods in upper third are those of unit 32 and *Wellerella osagensis*? with *Duplophyllum* sp.	42	1651
30	Limestone, purple, weathers gray-black, very fine-grained, very thin- to thin-bedded; weathers to thin slabs	38	1609
29	Limestone, buff-gray, very fine-grained, hard, dense; partly silicified; some small pyrite cubes	24	1571
28	Limestone, gray, medium-grained, fossiliferous, very cherty; forms massive ridge	21	1547
	Partial thickness of Hueco Formation	986	
	Laborcita Formation		
27	Limestone, gray, weathers buff, very fine-grained, laminated, very thin-bedded	59½	1526
26	Partly covered; lower limestone, brown, weathers black, medium-grained, laminated, silty; upper siltstone, white-buff, soft	62	1466½
25	Limestone, gray, weathers buff, fine-grained, silty, thin-bedded; lenses up to one foot thick of limestone-pebble conglomerate	57½	1404½
24	Limestone, buff-gray, very fine-grained, silty, laminated, thin-bedded	33	1347
23	Mostly covered; lower part of siltstone, orange and buff-green, laminated, very thin-bedded; middle limestone, buff-gray, fine-grained, very thin-bedded with arenaceous cross-laminations; in upper slope there is a three-foot limestone ledge, gray, massive, fine-grained	151	1314
22	Limestone, gray, weathers brown, fine-grained, arenaceous, cross-laminated; more arenaceous upward with top calcareous sandstone	35½	1163
21	Sandstone, gray, weathers brown-buff, calcareous, medium- to coarse-grained, thin- to medium-bedded; cross-laminated near base; arenaceous limestone in lower part	31	1127½
20	Sandstone, brown-buff, fine- to coarse-grained, cross-bedded, fine- to medium-bedded; ledges	24	1096½
19	Upper sandstone, gray, weathers buff, fine-grained, calcareous, thin-bedded; lower limestone, brown-gray, weathers gray, fine-grained, massive	19	1072½
18	Shale, partly covered, buff, thin-bedded, soft, silty, sandy; beds two to six feet thick; interbeds of sandstone, gray, weathers buff, very fine- to coarse-grained, thin- to medium-bedded; basal limestone, gray, very fine-grained	97½	1053½
17	Lower two feet is sandstone, buff, fine-grained, calcareous grading upward into limestone, gray, fine-grained; upper part is poorly exposed shale, buff, weathers buff-white, soft, thin-bedded; sandy with one- to four-inch thick lenses of sandstone	52½	956
16	Igneous dike	8½	903½
15	Intercalated limestone, gray, fine-grained, arenaceous; sandstone, gray, fine-grained, calcareous; shale, white, weathers gray, thin-bedded, soft, sandy	19	895

Unit No.	Description	Thickness (feet)	Cumulative thickness
14	Partly covered shale, white, weathers gray-buff, sandy; thin lenses of fine-grained, calcareous sandstone near top	12	876
13	Basal beds are interbedded sandstone, brown-buff, very fine- to very coarse-grained, calcareous; and conglomerate, brown-buff, poorly sorted; matrix medium-grained; chert pebbles, flat limestone pebbles, numerous fusulinids, *Schwagerina* aff. *S. emaciata, S.* sp. indet., *Triticites ventricosus sacramentoensis, T.* cf. *T. gallowayi, T.* cf. *T. cellemagus, T.* cf. *T. rhodesi;* upper sandstone grades upward into limestone, gray, fine-grained, arenaceous; top 70 per cent mostly covered	97	864
12	Covered	80	767
11	Basal limestone, gray, fine-grained, massive; five feet thick; overlain by conglomerate, brown-buff, sandy, cross-bedded, which grades up into sandstone, brown-buff, very fine- to very coarse-grained, thin- to medium-bedded; then poorly exposed shale, gray, very thin-bedded; limestone ledge near top, gray, massive, medium-grained, two feet thick	80	687
10	Mostly covered metamorphosed shale and sandstone, buff-gray, very fine- to fine-grained, very thin- to thin-bedded; rubble slope	33	607
9	Monzonite-adamellite sill	108	574
8	Basal limestone, gray, very fine-grained, massive; six feet thick; upper limestone is similar, two feet thick; mostly poorly exposed sandstone, brownish gray, very fine- to medium-grained, very thin- to medium-bedded	47	466
7	Sandstone, brown-gray, calcareous, very fine- to medium-grained, thin- to medium-bedded; basal six-foot-thick limestone, gray, very fine-grained	18	419
6	Sandstone, brown-gray, calcareous, very fine- to medium-grained, medium-bedded, partly cross-laminated, poorly exposed; basal two-foot-thick limestone, gray, fine-grained, massive	63½	401
5	Poorly exposed sandstone like that of unit 6	52	337½
4	Poorly exposed, intercalated sandstone, brown-gray, medium-grained; shale, gray, laminated, ripple-marked, slightly metamorphosed	28½	285½
3	Metamorphosed sandstone, shale, and limestone; mostly sandstone near base, fine- to coarse-grained, cross-laminated, thin-bedded; hornfels in middle, very thin- to thin-bedded; limestone near top, fine-grained, medium-bedded, hard, dense	62	257
2	Monzonite-adamellite sill	176	195
1	Metamorphosed shale, limestone, and sandstone; altered mostly to hornfels, coarsely crystalline limestone, and quartzite; whitish gray-buff, weathers to brown buff; dense, hard layers, two to twelve inches thick. Base of section is contact with monzonite-adamellite intrusive mass	19	19
	Partial thickness of Laborcita Formation (including sills and dikes)	1526	

Igneous Rocks

Igneous intrusive rocks form the topographically conspicuous parts of the Jarilla Mountains. The great bulk of the intrusive rock is of intermediate composition, diorite, granodiorite, and monzonite. A minimum of three principal stages of intrusive activity was distinguished in three large stocklike bodies. Many small dikes which cut the larger masses may represent other later stages of intrusive activity.

At the extreme northern end of the range is a small patch of extrusive scoriaceous basalt, the youngest consolidated rock in the area.

The igneous rocks are classified according to the scheme of Johannsen (1939) which is based on volume percentages of essential mineralogic constituents identified in thinsection. The textural terminology is the rather standard nomenclature used by Williams, Turner, and Gilbert (1958).

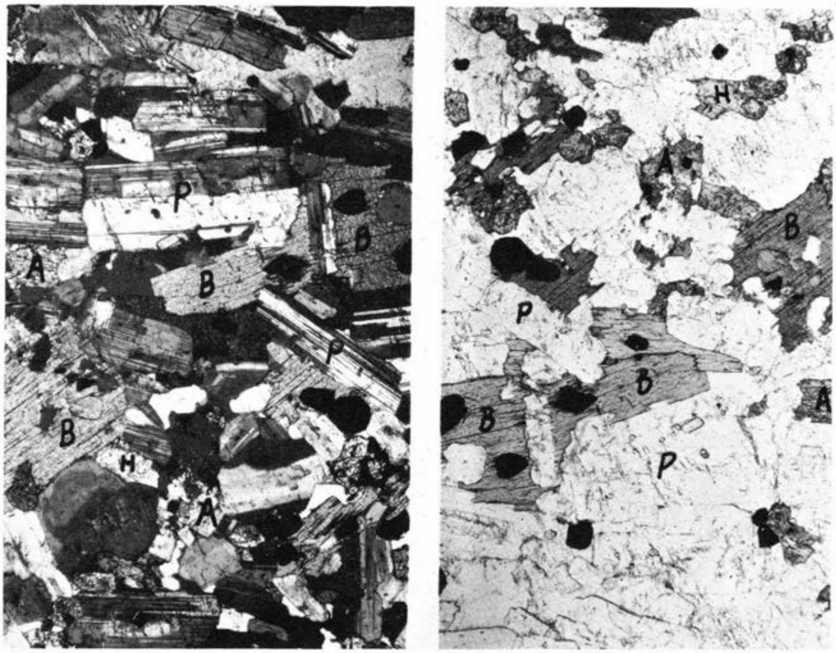
BIOTITE SYENODIORITE

The oldest intrusive occurs in secs. 27, 34, 35, T. 21 S., R. 8 E. It is an irregularly shaped, stocklike mass approximately two thirds of a square mile in area. In secs. 4, 9, 10, 15, T. 21 S., R. 8 E. there are also outcrops of an identical rock, probably part of the same body. This intrusive is a massive, homogeneous, fresh appearing, medium-grained biotite syenodiorite (fig. 7). The minerals from a specimen taken from a prospect pit 20 feet deep in NE1/4 SE1/4 sec. 34, T. 21 S., R. 8 E. are labradorite, 55 per cent; biotite, 15 per cent; microcline, 10 per cent; augite, 8 per cent; hornblende, 8 per cent; magnetite, 2 per cent; and sericite, apatite, and quartz. The feldspars and mafic constituents are usually unaltered. The abundance of small unoriented biotite flakes gives the rock a dark appearance.

The contacts of the syenodiorite with surrounding rocks are well defined, particularly in secs. 34 and 35, T. 21 S., R. 8 E. Later igneous rocks exhibit intrusive relations with the syenodiorite, such as apophyses and chilled borders, and contain numerous inclusions of syenodiorite along the contacts. The syenodiorite is cut by small dikes of monzonite in both main areas of outcrop.

LEUCORHYOLITE

Over widely scattered areas in W 1/2 sec. 2 and E1/2 sec. 3, T. 22 S., R. 8 E. are rubbly outcrops of a white, hard, flinty rock which looks like a very fine-grained felsite porphyry. A single small exposure in NW1/4 NWIA sec. 2 shows that this felsite porphyry was intruded by the monzonite-adamellite. The monzonite-adamellite has a very thin chill zone and flow lineations and contains numerous small inclusions of the felsite, which is slightly brecciated along the contact. In thinsection, the rock has the composition of a leucorhyolite porphyry, with the follow-



A B

Figure 7. THINSECTION OF BIOTITE SYENODIORITE. P, LABRADORITE; B, BIOTITE; A, AUGITE; H, HORNBLENDE.
A. Crossed nicols. B. Ordinary light. X25

ing constituents: sodic plagioclase phenocrysts, 10 per cent; matrix quartz, 20 per cent; matrix potash feldspar, 60 per cent; and minor matrix containing sericite, biotite, calcite, and pyrite, 5 to 10 per cent.

This leucorhyolite may represent a separate intrusive stage, or it may be a chilled border of the monzonite-adamellite. Its occurrence in a rather limited area in the Jarilla Mountains suggests that it was intruded and crystallized before the monzonite-adamellite.

MON Z ON ITE—ADAMELLITE

Succeeding the biotite syenodiorite in the intrusive sequence is a porphyritic rock termed *monzonite-adamellite* because its composition falls in the range of these rock types. The intrusive contact between the two is exposed at places in NW1/4 sec. 35, T. 21 S., R. 8 E. Apophyses of monzonite-adamellite occur in the syenodiorite, and there are many inclusions of the syenodiorite (up to 18 inches long) in the monzonite-adamellite along the contact. The monzonite-adamellite is variable in composition and may have been emplaced in several pulses rather than as a single injection. Considerable differences in mineral and textural composition are locally present within distances of a few hundred or less feet. The distinctive characteristics of the monzonite-adamellite are its gray to tan color; white to flesh-colored oligoclase-andesine phenocrysts; fine-grained potassium feldspar-quartz matrix; presence in some areas of round phenocrysts ("eyes") of clear quartz; the altered (argillized-sericitized) nature of the matrix and plagioclase phenocrysts with complete bleaching in places; and the abundance of sulfides as disseminated grains or in a few places as vein-filling copper mineralization.

This is the most abundant rock in the Jarilla Mountains. Surface exposures include the high central part of the range as well as smaller hills and outliers.

The variation in plagioclase composition, silica (quartz) percentage, composition and proportion of mafic minerals (hornblende, chlorite, epidote), and amount of alteration or bleaching is related to position in the intrusive mass. The most massive and uniform rock is in the central part of the irregular intrusion in secs. 26, 33, 34, and 35, T. 21 S., R. 8 E., and sec. 4, T. 22 S., R. 8 E. This rock is whitish gray with white to tan phenocrysts of andesine and needles of hornblende partly replaced by chlorite or epidote in a blocky matrix of potash feldspar. The quartz "eyes" occur sparingly in this area, and the feldspars are not highly altered. Toward the irregular edges of the intrusive, the rock varies more both in composition and alteration. This is probably due to contamination by xenoliths, the loss of silica and other constituents to the intruded limestones, producing the extensive skarns, alteration by hydrothermal solutions, and the streaming of less consolidated magma through more viscous magma near the edges of the intrusive during injection.

The intrusive rocks in secs. 3, 4, 9, 10, 11, 14, and 15, T. 22 S., R. 8 E. appear to have been the roof and/or edge area of the monzonite-adamellite mass. Large inclusions of metamorphosed limestone (skarn) in structurally concordant positions are great stoped blocks (up to a quarter of a mile in length), metamorphosed and partly assimilated. Avenues of weakness (joints or bedding planes) permitted entry of magma into the country rock in the shape of expanding sills and dikes which coalesced and stoped off large inclusions.

The composition of the monzonite-adamellite (fig. 8) as seen in thin-sections from the central area is about as follows: oligoclase-andesine, 20 to 45 per cent; orthoclase matrix, 25 to 50 per cent; hornblende, 5 to 8 per cent; quartz, 5 to 15 per cent; and accessories (sericite, apatite, sulfides, chlorite, calcite, sphene, zircon, and clays), 5 per cent.

Most of the plagioclase phenocrysts are zoned and contain small blebs of sericite, as well as being argillized (narrow rims to a thoroughly "bleached" appearance).

Potash feldspar forms the groundmass of the porphyritic rock, is very fine-grained with sutured borders, and is generally rather strongly argillized. The hornblende exists as euhedral needles and is largely to

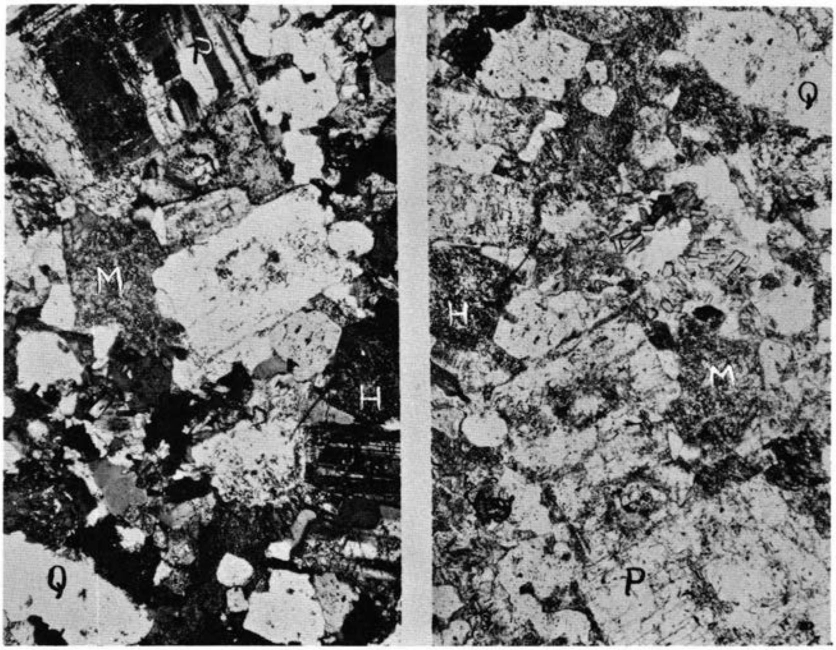


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Figure 8. THINSECTION OF MONZONITE-ADAMELLITE FROM CENTRAL AREA OF THE STOCK.

P, oligoclase-andesine; M, potash-feldsar matrix; Q, quartz; H, hornblende. A, Crossed nicols. B. Ordinary light. X25

wholly altered to epidote. Calcite is locally abundant, forming clear, irregular masses, and commonly replaces epidote and hornblende. The quartz occurs as irregularly rounded, optically continuous "eyes" usually 1 to 5 mm in diameter but locally larger.

The areas of strongest alteration are in the peripheral zone around large inclusions in secs. 3, 10, and 11, T. 22 S., R. 8 E. The rock in the ridge to the west and northwest of the reservoir in SE1/4 sec. 10 is very strongly bleached. The color of the rock varies from bone white to violet, and the feldspar phenocrysts appear as whitened ghosts. Mafic constituents have completely disappeared, and in thinsection the rock is nearly opaque. Sulfide mineralization (pyrite, chalcopyrite) accompanied the hydrothermal alteration and formed scattered grains and thin veins of the sulfide minerals. In NW1/4 NW1/4 sec. 3, on the southern edge of the igneous outcrop, the rock appears strongly argillized and contains many secondary veins of quartz and iron-copper sulfides (which have been largely altered to thin veins of supergene carbonates). Partly digested xenocrysts of garnet and calcite occur abundantly near the contact with a large limestone xenolith where the feldspar and mafic alteration is most severe.

Epidote, pyrite, and, to a lesser extent, hematite are commonly abundant as drusy coatings on joint surfaces throughout the monzonite-adamellite. Actual veins of quartz, epidote, and iron sulfides are confined almost exclusively to the border areas of the intrusive.

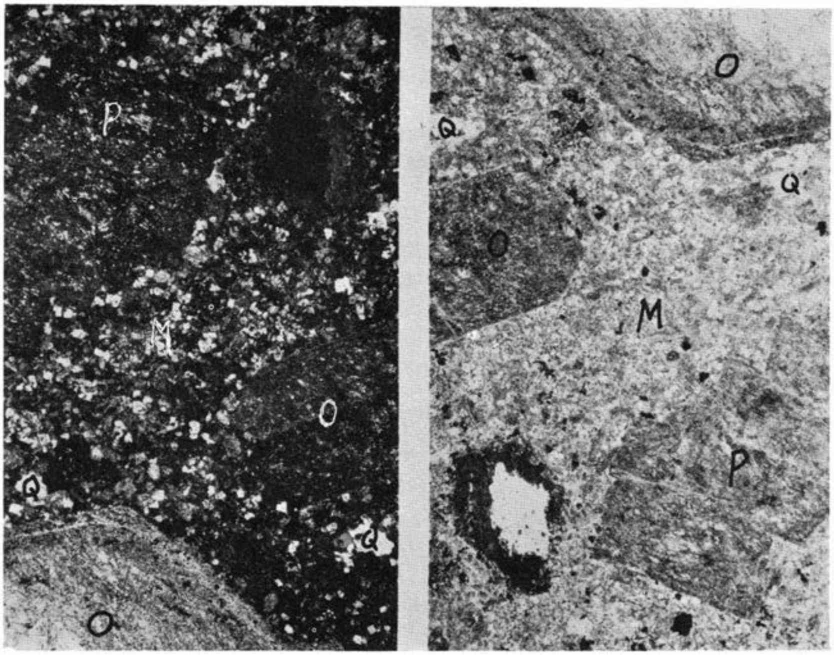
The reaction zones of the monzonite-adamellite with the limestone country rock are more limited than those near the syenodiorite. Also, the distance for which the limestone was strongly recrystallized (marbleized) is considerably less, a maximum of tens of feet along the monzonite-adamellite contacts, compared to hundreds of feet adjacent to the syenodiorite.

ORTHOCLASE ADAMELLITE

The third major unit in the intrusive sequence is a distinctive light-gray porphyritic rock with large, white, euhedral crystals of orthoclase and abundant large, clear, quartz "eyes." This rock, termed *orthoclase adamellite,* crops out in secs. 13, 14, 21, and 35, T. 21 S., R. 8 E.; and SE/ sec. 10, NW/ sec. 14, and secs. 20, 21, 28, and 29, T. 22 S., R. 8 E. The intrusive contact of this rock with the surrounding monzonite-adamellite is well exposed in NW1/4 SW1/4 sec. 35, T. 21 S., R. 8 E., in a wash cut into bedrock on a steep hillside. There the orthoclase adamellite exhibits a chill zone about five feet thick with flow structures and inclusions of the intruded monzonite-adamellite. The intrusive contact of the orthoclase adamellite with the monzonite-adamellite is also exposed in SE1/4 sec. 10, T. 22 S., R. 8 E. The orthoclase adamellite is variable in composition and ranges from sodaclase granite to rhyodacite.

Euhedral, white phenocrysts of orthoclase from one quarter inch to two inches in length that stand out sharply against the gray groundmass of this rock are striking features in the outcrop. Phenocrysts of plagioclase are more abundant but cannot be seen so readily because they blend with the over-all color of the rock. The composition of the rock, based on six thinsections (fig. 9), is as follows: orthoclase phenocrysts, 3 to 10 per cent; plagioclase phenocrysts, 10 to 35 per cent; quartz "eyes," 4 to 10 per cent; hornblende phenocrysts, 8 to 30 per cent; matrix (potash feldspar, quartz), 40 to 60 per cent; biotite, 0 to 5 per cent; calcite, 0 to 7 per cent; and accessories (apatite, zircon, sphene, sericite, clays, and sulfides), 3 to 8 per cent.

The orthoclase adamellite also shows much evidence of deuteric or hydrothermal alteration, as well as several stages in cooling from the molten state. The plagioclase feldspars are complexly zoned, and the orthoclase crystals contain "islands" of untwinned sodic plagioclase with progressively variable extinction angles from edge to center of the "islands" (sodic edge which progresses to a more calcic center). The hornblende, in some cases zoned, is largely altered to chlorite and epidote. At least some of the hornblende apparently recrystallized from



A B

Figure 9. THINSECTION OF ORTHOCLASE ADAMELLITE.
O, orthoclase; H, hornblende; P, albite-oligoclase; M, potash-feldspar matrix; Q, quartz. A. Crossed nicols. B. Ordinary light. X25

pyroxene, because small relict islands of pyroxene are found in a few of the hornblende crystals. The matrix is a uniform, blocky, almost aplitic, fine-grained mixture of potash feldspar and quartz.

The degree of alteration is somewhat variable but nowhere is so severe as in places in the monzonite-adamellite. The feldspar phenocrysts generally show alteration on their edges only as rims of sericite or clays. The matrix varies from slightly cloudy to nearly opaque. There apparently was little or no metallic mineralization accompanying the emplacement and crystallization of the orthoclase adamellite. Reaction with the intruded sedimentary rock was relatively slight and limited to within a few feet of the contact in most places. Thin zones of skarn were developed, succeeded by marble zones rarely more than ten feet wide.

DIKES

Many small dikes as much as thirty feet wide cut all the igneous stocks and the adjacent sedimentary rocks. The dikes vary in composition and were probably formed from the larger intrusives at different stages in their emplacement. Some of the dikes in the sedimentary rocks can be traced directly into larger igneous masses (for instance, NE1/4 sec. 10, T. 22 S., R. 8 E.).

The dikes in the igneous stocks tend to have compositions similar to the bodies which they cut; for example, in the monzonite-adamellite, seven dikes range in composition from diorite to granite but most are intermediate between these extremes. Two dikes in the syenodiorite are of monzonitic and calcimonzonitic composition, and one dike in the orthoclase adamellite is a latite.

The dikes in the sedimentary rocks tend to be more basic in composition. Of four dikes emplaced in limestone, three are trachyandesite, syenogabbro, and basalt, respectively, where one is an adamellite. This is apparently a result of calcic contamination by partly assimilated limestone xenoliths. Calcite and, locally, skarn minerals are abundant in these dikes.

The dikes seem to be confined to border areas of the intrusives, especially of the monzonite-adamellite. No dikes were found in the central interior part of the main monzonite-adamellite stock. Some dikes probably formed during each of the major intrusive stages. The later dikes, those which occur in the marginal zones of the stocks, probably formed mainly as the borders of the stocks cooled and fractured, allowing still molten material from within to be squeezed outward. The youngest dikes are those cutting the orthoclase adamellite. Others which contain orthoclase phenocrysts and which may be related to these dikes occur in areas where no large bodies of orthoclase adamellite crop out.

ORIGIN OF THE INTRUSIVE ROCKS

The assumption is made that the intrusive rocks belong to one magmatic series with the different varieties produced as separate pulses. Evidence for this interpretation is the juxtaposition and similar compositions of the various intrusive rocks.

The general trend in the sequence of three major intrusives is toward alkali and silica enrichment. The syenodiorite is a silica-saturated rock containing a very minor amount of free quartz but 15 per cent biotite. The monzonite-adamellite consists of more sodic plagioclases (An 20-40 per cent) and considerably more free quartz (up to 15 per cent); it generated hydrothermal fluids during its final stages of cooling. The final major intrusive, the orthoclase adamellite, contains large crystals of potash feldspar and more quartz, but less water.

Some trends of magmatic differentiation in rocks of intermediate and granitic composition observed elsewhere include increasing silica, increasing volatiles, increasing Na-Ca ratio, increasing K-Ca ratio, and increasing Na-Fe ratio (Bowen, 1928; Turner and Verhoogen, 1960; Barth, 1952). The Jarilla intrusives show some of these trends. Between the syenodiorite and the monzonite-adamellite, silica increases, Na-Ca ratio increases, K-Ca ratio increases, volatiles increase, and Na-Fe ratio increases, whereas between the monzonite-adamellite and orthoclase adamellite, silica increases, K-Ca ratio increases, volatiles seem to decrease, Na-Ca ratio remains the same, and Na-Fe ratio apparently decreases slightly.

If the Jarilla intrusives originated from the same primary magma, the trend of magmatic differentiation between the syenodiorite and the later rocks is what would be expected if the primary magma had a composition similar to or more basic than the syenodiorite.

Twenty miles to the west in the Organ Mountains, three stages of activity in igneous rocks of similar composition intruding rocks as young as Pennsylvanian were recognized by Dunham (1935). The earliest is a monzonite, characterized by dark color, even texture, and high percentage of ferromagnesian minerals and composed of oligoclase, perthite, pyroxene, hornblende, and biotite. Succeeding this is a quartz monzonite, characterized by a light color, even grain, and low percentage of mafic minerals and composed of strongly sericitized perthite, oligoclase, quartz, and biotite. The final intrusive is a quartz-bearing monzonite, characterized by large phenocrysts of perthite in a coarse-grained matrix of oligoclase, hornblende, biotite, quartz, augite, sphene, magnetite, apatite, and zircon.

The intrusive rocks of the Organ Mountains closely resemble the Jarilla intrusives. The earliest of the Organ intrusives is more sodic in composition, but its holocrystalline texture resembles the syenodiorite of the Jarillas. The succeeding rocks also resemble their Jarilla counterparts, especially the final stage with the large alkali feldspar phenocrysts. These intrusives may be genetically related, but 15 miles of alluvial deposits separates the closest outcrops of the two districts. Magmatic evolution of a common magma or similar parental magmas could account for the resemblances; regional tectonic disturbances probably caused intrusion at about the same time.

EXTRUSIVE IGNEOUS ROCKS

Half a mile north of the northern end of the main Jarilla Mountains is a small outcrop of basalt, with a total area of about one fifth of a square mile. The ground surface is covered by scoriaceous ash, lapilli, small bombs, and extruded driblets. The main vent may have been in the highest area in the south-central part of the outcrop. At the peak of this low rounded hill is a small outcrop of porphyrytic basalt. Other small outcrops of basalt occur at various places in the area, mostly around the edges, and show surface pahoehoe flow structure. Apparently the eruptive episode originated in a small vent or fissure from which basaltic lava was extruded as small flows; volcanic activity culminated with explosive eruption of pyroclastic material.

The surface of the ash area is an oxidized red brown, which changes gradually to black at a depth of about two feet. The formerly loose ejecta are now partly cemented by caliche. The entire basaltic sequence has the appearance of being quite recent, perhaps on the order of several hundred years old, but more probably a few thousand years old.

The composition of basalt collected from the highest outcrop is labradorite (An 68 per cent), 40 per cent; augite, 30 per cent; olivine (forsterite), 15 per cent; magnetite, 15 per cent; and minor iddingsite. The olivine occurs as large phenocrysts in a fine-grained matrix of the other constituents. The rock is a melabasalt.

Metamorphic Rocks

The intruding igneous masses caused contact metamorphism of the adjacent sedimentary rocks. The best exposures of these phenomena occur in the northernmost and southernmost thirds of the Jarilla Mountains.

NORTHERN AREA

The metamorphosed sedimentary rocks are mainly gray cherty limestone as well as a few beds of calcareous argillaceous siltstone. In the northernmost Jarillas, in secs. 9 and 10, T. 21 S., R. 8 E., thermal effects are visible for half a mile from the syenodiorite contact. However, in the southern Jarillas, in secs. 3, 4, 9, 10, and 11, T. 22 S., R. 8 E., the heating effects occur over much shorter distances from the igneous contacts. In addition to recrystallization caused by heating, silicate skarns were formed in both areas near the contacts.

The syenodiorite caused considerable thermal metamorphism of the sedimentary rocks in secs. 9 and 10, T. 21 S., R. 8 E. The siltstone shows topographic reversal along the outcrop from a normal, soft, easily eroded, valley-forming unit to a hard, massive, ridge-forming hornfels. The limestone recrystallized from a thin- to medium-bedded, dark-gray, well-jointed rock to a massive, lighter gray, saccharoidal marble.

The unaltered siltstone is a very fine-grained mixture of fossil shell fragments, small quartz grains, and a few small rhombs of dolomite in a clouded clayey matrix. A specimen collected from this bed in NE1/4 NW1/4 sec. 10 is somewhat hardened, although the closest large igneous body is 2400 feet to the southwest. The specimen is a very fine-grained, murky mixture of scapolite, calcite, diopside?, and small, relatively unaltered quartz grains. The bedding is preserved as thinly layered units of cloudier material.

A specimen taken from the same stratigraphic horizon to the southwest in SW1/4NW1/4 sec. 10, about 1600 feet from the igneous contact, shows more intense reaction. The bed crops out as a resistant ledge of hard, dense, light-green hornfels. Microscopically, it is about 50 per cent scapolite and 40 per cent diopside with minor amounts of calcite and garnet. The scapolite is the most conspicuous constituent, making up large and continuous masses. The diopside occurs as small, irregular masses in the scapolite; a few small, irregular garnets are developed in diopside-rich areas. Calcite remains as scattered, relatively large, relict masses. The bedding is visible as diopside-rich and diopside-poor bands.

A specimen collected from the same bed in SW1/4 NW1/4 sec. 10, about 790 feet horizontally from the igneous contacts, is a massive, light-green, very hard, dense hornfels composed of scapolite, 40 per cent; diopside, 40 per cent; garnet, 15 per cent; calcite, 5 per cent; and minor pyrite and epidote. The garnet occurs as small, individual crystals and somewhat larger irregular masses. Diopside occurs as small, irregular blebs and aggregates in a moderately coarse-grained, sutured matrix of scapolite. The first mineral to crystallize in this bed appears to be scapolite, closely followed by diopside, with garnet forming at the expense of scapolite and calcite, and epidote as the latest mineral. Diopside remains about constant in abundance but increases somewhat in crystal size nearer the intrusive contact. The epidote may be a result of metasomatic addition of iron and water from the magma or of reconstitution of the scapolite in the formation of garnet.

A complementary suite of specimens was collected from a limestone bed about 200 feet below the siltstone. This unaltered rock is dark gray, very fine-grained, medium-bedded, and rich in fusulinids.

The limestone collected about 2400 feet from the igneous contact shows little or no effect of the heating (fig. 10). The fusulinids are intact, have well-defined internal structures, and show no alteration or recrystallization. The very fine-grained matrix between the fossil shells reveals very delicate layering and 'swirling' about the fragments. The few small detrital grains of quartz present show no reaction with the calcite.

The specimen collected 1600 feet from the igneous contact shows moderate effects of recrystallization. The fusulinids are not identifiable

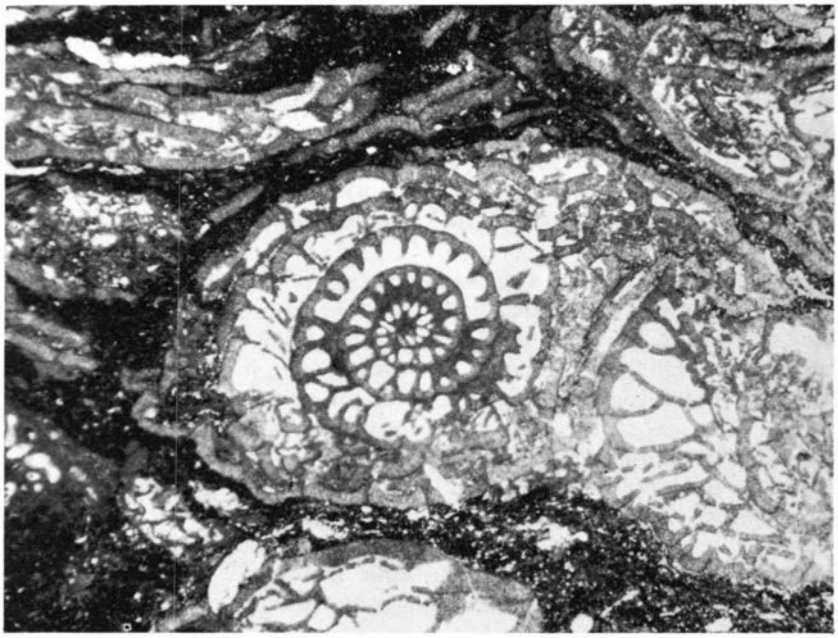


Figure 10. THINSECTION OF UNMETAMORPHOSED FUSULINID LIMESTONE COLLECTED 2400 FEET FROM THE IGNEOUS CONTACT. X25

as such in hand specimen and appear as rounded, white, saccharoidal lumps of calcite in a fine-grained gray marble. Under the petrographic microscope, the former fusulinids are ovoid, coarsely crystalline masses of calcite with only faint remains of internal structures in a medium-grained matrix of sutured calcite.

The specimen collected 790 feet from the igneous contact is a medium-grained, mottled white and gray saccharoidal marble. The original fusulinids are very coarse-grained, irregularly rounded masses of calcite in a medium-grained matrix of subidioblastic calcite (fig. 11). About five per cent of the rock consists of small scattered blebs of diopside and somewhat larger, irregular masses of wollastonite which probably resulted from reaction between sedimentary silicates and the calcite.

A specimen collected a few feet away in a chert nodule bed of the limestone shows a reaction rim of wollastonite and diopside about the chert (fig. 12). In a few of the larger nodules, four inches to six inches diameter, a small remnant of chert was observed in the center of the reaction aureole. Most of the nodules were converted to ovoid masses of fibrous, bladed wollastonite, generally radiating outward from the center. Minor amounts, not more than 5 per cent, of small, very fine-grained patches and veinlike masses of diopside occur within the wollas-

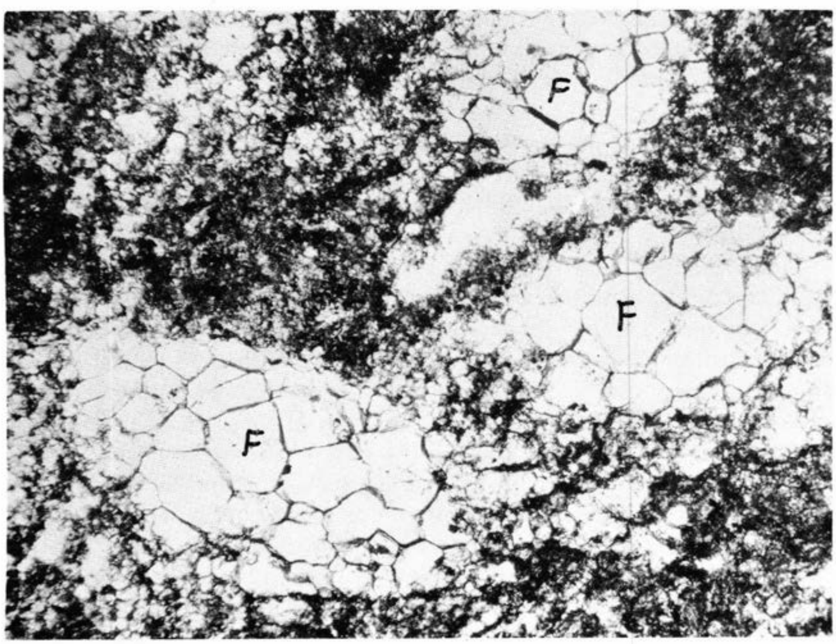


Figure 11. Thinsection of metamorphosed fusulinid limestone collected 790 feet from the igneous contact.
F, former fusulinid. X25

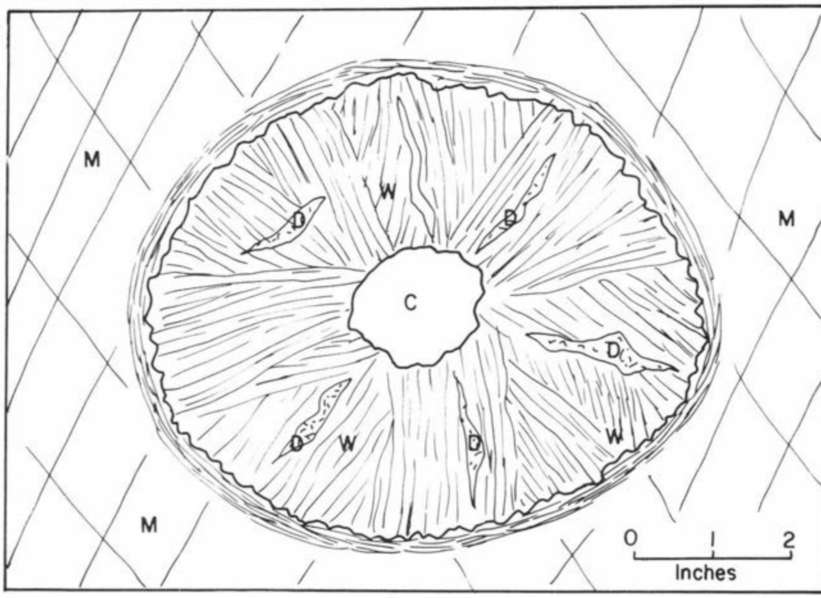


Figure 12. SKETCH OF REACTION ZONE OF CHERT NODULE WITH MARBLEIZED LIMESTONE COLLECTED 790 FEET FROM THE IGNEOUS CONTACT. W, wollastonite; C, chert nodule, M, marble; D, diopside.

tonite. The calcite marble surrounding the nodules has a somewhat schistose structure parallel to the border of the nodules, as if they had expanded slightly during the formation of wollastonite from quartz and calcite.

A specimen collected from the fusulinid-bearing limestone fifty feet from the contact with the syenodiorite in SW1/4SW1/4 sec. 10 shows profound changes. The original character of the rock (fusulinids, bedding, and mineralogy) has been completely altered. Within 75 to 100 feet of the syenodiorite, the marble has been changed to a green, dense, hard, coarsely crystalline skarn. About 80 per cent of the rock is a mosaic of idioblastic masses of zoned, locally anisotropic andradite garnet. Diopside, 15 per cent, occurs as small irregular blebs and masses in the garnet. Calcite and scapolite are present as small isolated remnants and total less than 5 per cent. Epidote and chlorite occur as small crystals alongside and in calcite. This complete change in the mineralogic composition reflects additions of iron, alumina, and silica from the magma. There are no vugs or pore spaces in the skarn, and the increased density apparently resulted from addition of material rather than by reduction of the original bulk volume.

SOUTHERN AREA

The adamellite-monzonite caused similar changes in the intruded limestones in the southern Jarillas. The significant differences were the lower temperature and the presence of more volatile constituents in the more siliceous, alkaline magma.

In W1/2 sec. 3, NE1/4 sec. 4, and W1/2 sec. 10, T. 22 S., R. 8 E., numerous rather small islands of the gray cherty limestone occur in the igneous rock. Some of these are definitely xenoliths, but others may be roof pendants or partly surrounded marginal areas. The true xenoliths have recrystallized to medium-grained marbles and developed definite marginal skarn zones. The limestone bodies only partly stoped by magma have marbleized zones generally about forty to sixty feet wide and skarn zones from one foot to ten feet thick. At many places near the contacts, as in SE1/4NE1/4 sec. 10, and NW1/4 and SE1/4 sec. 11, apparently unmetamorphosed limestone crops out within 20 feet of igneous rock, with skarn zones only a foot or so thick. Examination of skarn zones throughout secs. 3, 4, 9, and 10, T. 22 S., R. 8 E., revealed an irregular and patchy development.

A series of specimens collected in a marbleized cherty xenolith at the haulage entrance to the Lucky Mine, NWIANE1/4 sec. 10, showed that at a distance of thirty feet from the contact, the chert nodules had reacted with the calcite to form wollastonite aureoles one to three inches wide. At a distance of nine feet, only small islands of chert remained unaltered in the fibrous, blady, masses of wollastonite. The zone of metasomatic alteration at this locality is about three feet wide. A specimen taken one foot from the contact is composed of massive, locally zoned andradite garnet (85 per cent), islands of coarsely crystalline calcite and quartz in the garnet, and numerous flakes and radiating bladed masses of specularite. The Lucky Mine itself, now mined out, appears to have been developed in a considerably larger skarn that had a much higher percentage of hematite and was enriched in sulfides.

An xenolith in SW1/4SW1/4 sec. 3, about 35 feet thick, has a core of unaltered fossiliferous gray limestone 12 feet thick. Adjacent to the igneous rock, the limestone is nearly completely altered to andradite garnet in a zone about ten feet thick. This garnet zone dies out gradually in marble. The garnet first appears as small, disseminated euhedral grains in the marble, which grow larger and more numerous toward the contact until the rock is 70 to 80 per cent garnet. The garnet crystals commonly contain small inclusions of specularite. The skarn near the igneous rock contains clear, optically continuous masses of interstitial calcite up to two inches long; bordering these calcite masses, the garnet is usually strongly zoned and somewhat anisotropic. Within about two feet of the contact, the specularite content increases in the interstitial areas of the garnet, in places forming large masses and veins of nearly pure bladed specularite up to six inches across. The zoned garnets increase in iron content (andradite) outward in individual crystals.

Several of the limestone xenoliths in W1/2 sec. 4 and E1/2 sec. 3 have been so markedly enriched in hematite and magnetite as to constitute iron ore. The inclusion in SWIANW1/4 sec. 4 at the Cinco de Mayo iron mine is about 150 feet thick, several hundred feet wide and long, and dips moderately to the north. Apparently it originally was cherty limestone with a few thin beds of calcareous shale and siltstone. The silty argillaceous beds persist as dense seams of light gray-tan, thinly banded hornfels composed of small, subrounded detrital quartz grains in a fine-grained matrix of interlocking epidote, calcite, and scapolite. The upper twenty to fifty feet of the xenolith is largely garnet-calcite-magnetite skarn. The percentage of magnetite increases inward in the xenolith and appears to have formed in place of calcite rather than garnet. The lower 100 feet of the xenolith is a massive layered sequence of alternating beds of nearly pure hematite-magnetite and hornfels. The massive iron-rich layers range from one foot to ten feet in thickness, and the hornfels from a few inches to two feet. The iron-rich rock is composed largely of magnetite, with hematite interstitial to magnetite masses. The magnetite occurs as streaks and irregular masses, with the borders of these areas generally lined with tetrahedra that project into areas of earthy hematite. Numerous small vugs and cavities are common in the rock, and in many of these, hematite forms a botryoidal, layered coating on the cavity wall.

Textural relationships suggest that the original rock was a coarse-grained marble which was partly replaced by magnetite. The calcite which remained was then replaced more or less completely by hematite. The botryoidal surface on the cavity walls suggests that at least some of the calcite was removed completely before the deposition of the hematite. Locally, some of the iron-rich beds are also rich in pyrite. Chert nodules are well preserved and define the original bedding clearly. Apparently the xenolith first developed a rim of garnet skarn several feet thick. The calcite interstitial to the garnet and in the interior of the xenolith was then largely replaced by magnetite, and finally the remaining calcite was replaced by hematite.

A peculiar rock crops out in NW1/4NW1/4 sec. 15, T. 22 S., R. 8 E. It is a bright-green, massive inclusion in monzonite porphyry, and it contains in turn many angular inclusions of the monzonite (fig. 13). The outcrop is about fifty feet in diameter and appears to be a recrystallized inclusion. The green matrix consists of large sutured crystals of calcite (70 per cent) up to two inches in diameter, shot through with a mosaic of euhedral epidote (10 per cent) and fibrous and prismatic actinolite (10 per cent). Quartz, apatite, pyrite, and small fragments of garnet are also present. The 'intrusive skarn' may have been plastic or liquid at one time, since fragments of the monzonite occur randomly throughout the mass. Its appearance even suggests that it may have in-

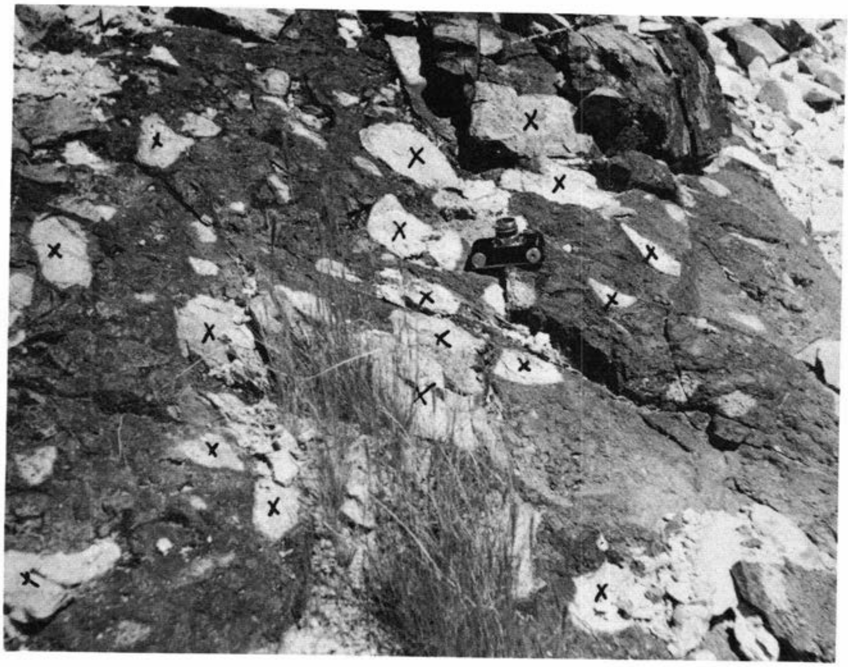


Figure 13. 'INTRUSIVE SKARN'.
X, xenoliths of monzonite-adamellite in the matrix of calcite, epidote, and actinolite.

truded the monzonite and brecciated it. Alongside several other skarns are small green veins, veinlets, and stringers of epidote and calcite which represent a recrystallized fraction of the skarn that seems to have invaded the igneous rock. Only this one example was found, however, where the strongly deformed, recrystallized inclusion reached great size.

Structural Geology

The intrusion of the igneous rocks caused considerable structural readjustment of the sedimentary rocks. The general structure of the Jarilla Mountains is that of a somewhat faulted dome with the sedimentary beds mainly dipping away from the intrusive bodies at gentle to moderate angles. The southernmost third of the range appears to be a roof area of the monzonite-adamellite intrusive. The central part of the range consists of exposures of the interior portion of the igneous plutons, while the northern third is mainly sedimentary rocks intruded by some disconnected igneous bodies. Along the eastern side of the range is a narrow line of hogbacks that also dip away from the central part of the range.

EMPLACEMENT OF IGNEOUS ROCKS

Structural features directly related to the emplacement of the igneous rocks include contact areas between adjacent igneous bodies, contact areas between igneous and sedimentary rocks, and numerous small dikes.

The earliest of the intrusives, the syenodiorite, crops out in two areas: secs. 4, 9, 10, and 15, T. 21 S., R. 8 E. and secs. 27, 34, and 35, **T.** 21 S., R. 8 E. Some of the small, irregularly shaped northern outcrops are bordered by Permian sedimentary rocks. This appears to be a roof area, and the syenodiorite bodies may be cupolas or apophyses into the limestone. The hill of syenodiorite in NW1/4 sec. 9 contains two metamorphosed limestone remnants which appear to be xenoliths or roof pendants. The limestone hills in secs. 3, 4, 10, and 11, T. 21 S., R. 8 E. may be arched over a large underlying mass of syenodiorite.

The second major intrusive, the monzonite-adamellite, forms a major part of the Jarillas. In the center of the range, this rock is homogeneous and massive. Its northernmost main outcrops are several rather thick sills (100 05 200 feet thick) in secs. 22, 23, and 27, T. 21 S., R. 8 E. intruded into Permian strata. The dip of these sills is 17 to 24 degrees to the north. The monzonite-adamellite has nearly surrounded the syenodiorite in secs. 27, 34, and 35, T. 21 S., R. 8 E. Apophyses of monzonite-adamellite extend into the syenodiorite, and along border areas, inclusions of the latter appear in the former. The contact itself is transitional through a two- to three-foot-thick zone.

The southern half of the main body of monzonite-adamellite appears to be a rather complex "roof" area. Many irregular bodies of metamorphosed sedimentary rocks occur throughout the igneous exposures; eight that appear to be definite inclusions are in SD/$_4$ SE1/4 sec. 33; SW1/4SW1/4 sec. 34, T. 21 S., R. 8 E.; SW1/4NE1/4 sec. 4; NE1/4NE1/4 sec. 4; SE1/4NE1/4 sec. 4; NE1/4SE1/4 sec. 4; NE1/4SW1/4 sec. **10; and**

SE1/4SW1/4 sec. 10, T. 22 S., R. 8 E. The best exposed is the large inclusion (about 150 feet thick, a quarter of a mile long, several hundred feet wide) in which the Iron Duke and Cinco de Mayo mines were developed. In the mining cuts, igneous rock overlies the metamorphosed limestone block and surrounds it on three sides. The bottom of the inclusion is not exposed, but it is probably underlain by monzonite-adamellite. This inclusion is tilted to the north at about 25 degrees in the mine cut. A few hundred feet to the south and higher on the hill are other inclusions with discordant attitudes. The large block in SE 1/4NE1/4 sec. 4 and SW1/4 NW1/4 sec. 3, T. 22 S., R. 8 E. is considered a xenolith; the numerous changes in bedding attitude suggest that it was flexed slightly as it was stoped by the upwelling magma. Many apophyses extend into this xenolith, and many small inclusions of skarn occur around it.

In SW1/84 sec. 4, E1/2 sec. 9, NW1/4SW1/4 sec. 10, SW1/4 SW1/4 sec. 10, and N1/2 sec. 15, T. 22 S., R. 8 E., the limestone appears to have consistent orientation, the strikes and dips being mainly uniform throughout the area. This is interpreted as indicating that the sedimentary bodies are roof pendants. The limestone occurring in E1/2 sec. 10 and in sec. 11, T. 22 S., R. 8 E. also appears to be in the border zone. Apophyses of monzonite-adamellite extend into the sedimentary rocks along the contact; at varying distances, up to half a mile, there are numerous small sills.

The felsite which occurs in SE1/4 sec. 3 and W1/2 sec. 2, T. 22 S., R. 8 E. is believed to be a fine-grained local phase of the monzonite-adamellite or of some other earlier intrusive. It occurs as irregular patches, generally on hilltops, and was intruded by the main monzonite-adamellite. A single outcrop in SE1/4NE1/4 sec. 3 exposes the contact between the two rocks. Its uniform composition of quartz and feldspar with small sodic plagioclase phenocrysts and its lack of banding, bedding, or other primary sedimentary structures indicate an igneous rather than metamorphic origin. Kelley (1949) suggested that there are porcelanized shales of Devonian age (Percha Shale) on the Chief and Hamlet claims, but these claims are not shown on his map. The leucorhyolite was the only rock resembling hornfels found by the present writers, other than the thin beds of hornfels found locally in contact areas of Pennsylvanian and Permian rocks.

The latest major intrusive, the orthoclase adamellite, shows intrusive relations with the monzonite-adamellite and syenodiorite in only one area, the SW1/4 sec. 35, T. 21 S., R. 8 E. Other outcrops of this rock are assumed to represent the same mass; hence, there must be considerably more of this rock at depth. Its outcrops are scattered in the central and southern parts of the range. The largest mass of this rock occurs in W1/2 sec. 13 and E1/2 sec. 14, T. 21 S., R. 8 E.

The three main intrusives (syenodiorite, monzonite-adamellite, and orthoclase adamellite) are considered to be stocks, although some exposures are less than one square mile in area. The complete extent of all the intrusives is unknown; desert alluvium covers much of the border and contact zones.

DIKES

Numerous small dikes, generally 2 to 8 feet wide but locally up to 30 feet, occur throughout the range. These dikes are more numerous in border and roof areas and evidently were intruded along fractures as the igneous masses cooled from their margins inward. The monzonite-adamellite is nearly free of dikes in secs. 33 and 34, T. 21 S., R. 8 E., and this area is interpreted as an interior part of this pluton.

In SE 1/4NW1/4 sec. 10, T. 21 S., R. 8 E., a small vertical dike of trachyandesite porphyry 15 feet wide is exposed on the hillside; at the crest of the hill it passes into a small sill about 12 feet thick.

FOLDS AND FAULTS IN SEDIMENTARY ROCKS

The sedimentary rocks are tilted radially away from the igneous core of the mountains. Near the igneous plutons, the dips range from 15 to 35 degrees, with most beds between 15 and 25 degrees. The only exception is in sec. 14, T. 21 S., R. 8 E., where Permian limestone dips into the orthoclase adamellite. However, the attitude of the limestone in this area had been determined by intrusion of the earlier monzonite-adamellite and was little affected by emplacement of the orthoclase adamellite.

In the northernmost part of the range in secs. 2, 3, 4, 10, and 11, T. 21 S., R. 8 E., the Permian strata appear to arch over the syenodiorite. Close to the igneous contact the dip is very gentle, 3 to 6 degrees toward the north and northeast. At greater distance from the contact the dips increase, and at the furthest outcrops, the sedimentary rocks plunge under the alluvial cover at 15 to 20 degrees. These relations suggest that the syenodiorite is under the hill where the dips are gentle. Further evidence is the strongly marbleized nature of the limestone for distances up to half a mile from the exposed contact.

The series of isolated hogbacks along both sides of U.S. Highway 54 on the eastern border of the range are structurally complex. This chain of outcrops includes a convenient key bed, the fusulinid zone between 1635 and 1670 feet in the measured section. In SE1/4 sec. 12 and SW1/4 sec. 7, T. 22 S., R. 9 E., the dip of the fusulinid zone (mapped as a dotted line on pl. 1) is 45 to 47 degrees toward the east. This flattens down dip to 12 and 15 degrees at the eastern limits of the outcrop. Northward in section 1 and section 6, the dips decrease to 23 to 30 degrees and flatten toward the east. Farther north in SE1/4 sec. 36, the fusulinid zone dips 32 degrees east; to the east in E1/2 sec. 31, a large outcrop of limestone has a dip of only 2 degrees to the southeast. In

SE1/4 sec. 25, T. 21 S., R. 8 E. and SW1/4 sec. 30, T. 21 S., R. 9 E., the dip ranges from 80 degrees east at the southern end of the outcrop to 79 degrees overturned to the west at the north end of the outcrop. In addition to the comparatively steep dips, these hogbacks also are offset by small vertical faults with separations of ten to thirty feet. These dip faults strike east and east-northeast, normal to the trend of the ridges.

Either a rather sharp flexure on the edge of the Jarilla uplift or local disturbance due to igneous activity at depth is responsible for the steep dips and small faults along this line of hills. The absence of exposed plutonic rocks just to the west and the lack of metamorphism of the limestone suggest that the structure is the result of a flexure. This structure is continuous for at least five miles roughly parallel to the igneous-sedimentary contact. This feature, therefore, is interpreted as due to sharp flexing of the sedimentary rocks as the intrusives to the west rose and arched the sedimentary roof.

Other faults occur in the Jarilla Mountains in the southernmost and northernmost parts. Tracing of fossil zones (fusulinids in the Permian rocks and *Chaetetes* in the Pennsylvanian rocks) resulted in discovery of the faults. The largest of these vertical faults trends N. 15° E. in W1/2 sec. 11, T. 22 S., R. 8 E. and has a stratigraphic displacement of 370 feet, with the western side displaced relatively upward. In the northern part of the Jarillas, several other vertical faults with displacements of mainly 30 to 80 feet were mapped. The largest of these is exposed in SE1/4 sec. 15 and SW1/4 sec. 14, T. 21 S., R. 8 E.; it has a stratigraphic displacement of about 340 feet.

Several small faults occur in SW1/4 sec. 14 and NW1/4 sec. 23, T. 21 S., R. 8 E. Stratigraphic displacement on these varies from 6 to 20 feet. Two small dikes occur parallel to these faults and may have been intruded along similar faults. Two small faults occur in sec. 10, T. 21 S., R. 8 E. The western has 30 feet of displacement, the eastern, 50 feet; the apparent movement of the northwestern block is relatively upward in each instance.

The mapped faults are consistent in their orientation; in almost every instance they are about normal to the nearest contact zone. This radial orientation of the faults can be explained by extension of the sedimentary rocks about the intrusive periphery as these strata were domed upward.

MECHANICS OF DEFORMATION

Interpretation of these structural data helps explain the emplacement of the various igneous bodies. The syenodiorite, monzonite-adamellite, and orthoclase adamellite are considered to be stocks rather than batholiths, even allowing for their continuation under the alluvial fill of the Tularosa Basin. The syenodiorite appears to have deformed the sedimentary rocks moderately in the northernmost Jarilla Mountains, gently arching the limestones and stoping xenoliths along the contact. The monzonite-adamellite, which is much better exposed, apparently caused the major structural features of the range. As the monzonite-adamellite rose toward the surface, it domed the sedimentary rocks upward, locally rather sharply. In the contact zone the magma invaded the sedimentary rocks along bedding planes, fractures, and faults that formed as this shell of sedimentary rocks was stretched and broken. Many dikes and sills coalesced and caused stoping of large blocks along the contact zone; hence, the margin of the monzonite-adamellite is irregular, with numerous xenoliths and roof pendants.

The orthoclase adamellite is exposed in more limited areas and appears to have been emplaced as small stocks over much of the range. These masses may be the expression of a larger body at depth, which worked its way upward through the denser, massive, earlier igneous rocks.

The numerous small dikes may have been formed from the orthoclase adamellite or the monzonite-adamellite. The lack of these dikes in the central part of the monzonite-adamellite suggests that they are largely a result of injection from the interior of that stock along fractures in its solidifying periphery.

Geomorphology

Geomorphically, the Jarilla Mountains are hills in the midst of a large, elongate physiographic basin with interior drainage that is slowly being filled. The Jarillas are contributing erosional debris to the valley fill, which is mainly composed of material derived from the higher mountains enclosing the Tularosa Basin.

The hills resemble the inselbergs or bornhardts of arid regions (Thornbury, 1954). Long smooth slopes extend from the hills into the encircling desert plain and merge indistinctly with the gently undulating floor of the Tularosa Basin. These slopes may be pediment surfaces. They have a veneer of gravel, clay, and sand that varies from one to six feet in thickness. A few gullies incising these surfaces expose bedrock locally for distances to one mile from the hills. These gullies branch into distributaries where the channel reaches the level of the basin fill. The drainage pattern of the Jarilla Mountains is radial.

Economic Geology

The closing stages of the consolidation of the monzonite-adamellite produced mineralizing fluids which formed deposits of valuable metallic ores in the igneous rock and adjacent metamorphosed sedimentary rocks. Prospecting of these areas began in 1879 (Lasky and Wootton). Three principal types of deposits have been discovered; pyrometasomatic iron deposits, copper-gold-silver-lead lodes, and placer gold. Mining of the nonferrous metals began about 1900, and a railroad spur was constructed from Orogrande to Brice (E1/2 sec. 10, T. 22 S., R. 8 E.). In 1907, a copper-matte smelter was constructed at Orogrande by the Southwest Smelting and Refining Company. This company consolidated a number of the lode claims in the Jarilla Mountains and did some development work on them, but construction of the smelter did not appear justified at the time to Graton (Lindgren, Graton, and Gordon). A meager amount of ore from the Jicarilla Mountains, 100 miles to the north, was smelted, but in 1909 the reduction facility was dismantled.

The majority of the production of the Jarilla Mountains was processed by the Consolidated Kansas City Smelting and Refining Company at El Paso, Texas. The copper recovered by the smelter averaged 40 to 50 pounds a ton, and the gold and silver recovered ranged from no value to $10,000 a carload (38 to 40 tons). Smelter returns of some carloads did not meet their mining and extraction costs, as indicated by some old shipping records owned by Mrs. Bess Voorhees of Orogrande (oral communication, September 1959). The lode ores were mined until about 1930; since then, these properties have been inactive. The value of nonferrous metals produced up to 1930 was $1,900,000 (Lasky and Wootton). Of this total, about $24,000 was from placer gold, about $375,000 from lode gold, and the remainder from copper, lead, and silver. From 1904 to 1930, production included 241 ounces of silver, 6,436,622 pounds of copper, and 1,360,977 pounds of lead; this represents about 95 per cent of the total nonferrous metal production. There are no estimates of production value since 1930, but it has probably been very little.

Mining of the iron ores began in 1913. The railroad spur was extended through Ohaysi in NW1/4 sec. 3, T. 22 S., R. 8 E. to the Cinco de Mayo mine in NE1/4 sec. 4, T. 22 S., R. 8 E. Mining of several iron ore bodies continued until 1921. Some 258,000 tons of ore worth approximately $500,000 were produced (Kelley, 1949).

The placer gold operations were centered in N1/4 sec. 14 and NE1/4 sec. 15, T. 22 S., R. 8 E. They were active in the early part of the century, declined somewhat in the 1920's, but were revived during the depression years by unemployed individuals who dug many small holes and tunnels and "gophered" about in the caliche-cemented gravel following pay streaks. A brief two-year spurt of activity on the Little Joe Claim in the NE1/4NW1/4 sec. 14, T. 22 S., R. 8 E., in the early 1950's was the most recent mining venture in the Jarilla Mountains.

Collection of samples of the lode ores is difficult. The small dumps and waste piles near the mines were carefully hand-sorted for ore during the mining operations, and since then they have been picked over by other prospectors and collectors. The writers worked alone in much of this study of the area and were reluctant to explore the abandoned underground workings.

Numerous showings of malachite, chrysocolla, and turquoise are present in the Jarilla Mountains and can be seen in many of the mine cuts. Production was mainly from small, podlike enriched masses and small veins and shoots in the contact zone. The copper ore minerals included tenorite, malachite, turquoise, chrysocolla, chalcopyrite (Kelley, 1949) and probably cuprite. The orebodies, which occur near the surface, are considerably oxidized in most of the mines.

NONFERROUS METALS, LODE MINES

The greatest portion of the nonferrous production came from the Nannie Baird, Lucky, Garnet, Three Bears, and I mines (Kelley, 1949). The location of the Three Bears mine is unknown to the writers.

The Nannie Baird mine, SW1/41s1W1/4 sec. 11, T. 22 S., R. 8 E., was developed in Pennsylvanian limestone. It consists of three deep (200 feet plus) shafts that apparently mined lode ore in a contact zone. The mine dumps, however, are composed entirely of unaltered limestone. The limestone-monzonite contact is exposed a few hundred feet west and southwest of the mine, and it dips moderately toward the mine. A skarn zone several feet thick is present, and apparently the mine exploited this zone farther down dip. At the crest of the hill in NE1/4 SE1/4 sec. 10 and SW1/4NW1/4 sec. 11 above the reservoir are several large veins (three to ten feet wide) of banded carbonate with scattered grains of pyrite and some malachite staining. The I mine was developed here and followed the contact zone down dip to the northeast (Lindgren, Graton, and Gordon). The monzonite-adamellite in this vicinity is rather strongly bleached and contains many small veins of quartz, calcite, pyrite, and malachite. The general trend of these veins and the larger ones in the limestone above the contact is northeastward.

The Lucky mine, in NWIA NEN sec. 10, T. 22 S., R. 8 E., was apparently developed in a small xenolith of limestone on the crest of the hill. The ore body was about fifty feet in diameter and is exposed at the top of the hill as a sort of glory hole with overhanging edges. An adit driven horizontally beneath the ore body apparently served as the haulageway. The excavation has many niches and pockets from "gophering" by the miners as they grubbed out the rather small ore shoots. The tailings from this mine consist mainly of garnetized marble with a considerable amount of pyrite and earthy limonitic gossan. Joint faces stained green by malachite are common in the monzonite-adamellite around the mine, and in another small area about 300 yards to the northeast. Around the entrance to the adit and on the east side of the hill are abundant, large patches of green paint that closely resemble the malachite stains. It took close examination by the writers, who attempted to sample one thinking it was malachite, to reveal its true composition.

The Garnet mine, in SD1/4 SE1/4 sec. 34, T. 21 S., R. 8 E., is a vertical shaft in a limestone-skarn xenolith. The dumps here are mainly garnet with much pyrite. No ore minerals could be found here, as was the case with the other lode mines.

A glory hole about 100 feet wide and 15 to 30 feet deep in NWIA-NW1/4 sec. 3, T. 22 S., R. 8 E., is one of the better-looking prospects in the Jarilla Mountains and may be the disseminated copper referred to by Kelley (1949). It was developed on the edge of a limestone-skarn xenolith in monzonite-adamellite. The xenolith was mined out, and the excavation was continued into the surrounding igneous rock. The monzonite-adamellite at this locality is severely altered to a relatively soft, bleached rock. Feldspar crystals can be seen only as ghosts; there is no trace of the mafic constituents. Malachite and chrysocolla are abundant as veins and fracture fillings on joint faces. In the mid-1940's, the Anaconda Copper Company reportedly put down two diamond drill holes here with considerable difficulty, and later abandoned the property (Lewis Taylor, oral communication, August 1959). Evidently the mineralization is confined to near the xenolith and does not persist at depth.

IRON MINES

The iron mines are concentrated in W1 sec. 3 and E1/2 sec. 4, T. 22 S., R. 8 E. The largest, the Cinco de Mayo and Iron Duke mines, exploited a mineralized xenolith about 150 feet thick, a quarter of a mile long, and several hundred feet wide in SW1/4NE1/4 sec. 4. The Cinco de Mayo mine was the largest producer of iron ore in the Jarillas and was operated by the Oro Iron Company from 1916 to 1921. The total production of ore from the Cinco de Mayo and Iron Duke mines was about 150,000 tons. The average composition of the ore from the Cinco de Mayo, Iron Duke, Iron King, and Iron Queen mines (six-year weighted average) (Kelley, 1949) is as follows: iron, 54.35 per cent; phosphorous, 0.056 per cent; silica, 10.55 per cent; manganese, 0.31 per cent; alumina, 0.66 per cent; lime, 4.51 per cent; magnesia, 0.58 per cent; sulfur, 1.08 per cent; and copper, 0.11 per cent. The Iron Duke mine consists of an open cut about 200 feet long, 75 feet wide, and 20 to 50 feet high on the southeastern side of the hill. The Cinco de Mayo open cut is about 500 feet long, 100 feet wide, and 100 feet high on the northern and western sides of the hill. At its western end, some underground room-and-pillar stoping was done in some of the thicker (10 to 12 feet) ore zones. A narrow cut connects the two mines. The xenolith is surrounded by monzonite-adamellite on all sides, including the top, except where the open cuts exist. The ore occurs in massive magnetite-hematite beds that vary from six inches to twelve feet in thickness; these are separated by beds of hornfels, pyritic and cherty streaks, and garnetiferous areas. The best ore occurs in the lower half of the xenolith. Kelley (1949) estimated the ore-waste ratio at 43:57. The ore was mined in as large blocks as possible, which were loaded into small cars and trammed down the hill to the rail head. Kelley (1949) estimated that 180,000 tons of indicated ore remains, which would have to be mined by room-and-pillar stoping because of the thick roof of igneous rock.

The Iron King mine, in SW1/4SW1/4 sec. 34, T. 21 S., R. 8 E., consists of two small, narrow cuts about 300 feet apart along the north edge of another large limestone xenolith. The ore zone is five to ten feet wide in the skarn immediately adjacent to the igneous rock. Kelley (1949) estimated that no more than 5000 tons was mined, but there remains an estimated several thousand tons of inferred ore.

The Iron Queen claim contains three small deposits on the edges of two xenoliths in NE1/4NE1/4 sec. 4, T. 22 S., R. 8 E. The mines consist of small trenches, 50 to 100 feet long and maximum of 20 feet deep. The ore zones are narrow, five to ten feet wide, and consist of fine-grained, dense magnetite and hematite adjacent to the contact with monzonite-adamellite. Kelley (1949) estimated that a maximum total of 4600 tons was taken from the three cuts, and inferred reserves amount to no more than a few thousand tons.

The Iron Mask and Laura mines, in NE1/4SW1/4 sec. 3, T. 22 S.,

R. 8 E., consist of numerous small trenches and pits in the hillside. The ore was mostly colluvial boulders of magnetite-hematite, and the mining operation consisted of a pick, shovel, and screening process. The ore was somewhat cemented by caliche, and the shipments looked like carloads of limestone, although the iron content averaged sixty per cent. A total of 54,170 tons of this ore was mined, with a few thousand tons still remaining as scattered patches (Kelley, 1949).

The Lincoln mine, in SE1/4SW1/4 sec. 3, T. 22 S., R. 8 E., is a glory hole about 100 feet wide and 30 feet deep, mined in three steps. The ore was irregularly enriched in stringers and pods and contained considerable sulfide and some copper. Apparently there was much waste, for the dump is rather large. The ore averaged 55 per cent iron, and a total of 31,350 tons was mined (Kelley, 1949). Inferred reserves are on the order of a few tens of thousands of tons.

Approximately 1000 tons of iron ore was taken from several very small cuts on the Cinnamon Bear claim in NE1/4NE1/4 sec. 15, T. 22 S., R. 8 E. This ore was mainly gossan and was probably originally pyritic (Kelley, 1949).

PLACER OPERATIONS

The placer gold operations furnished only a minor part of the total gold production prior to 1930. Since 1930, these deposits are the only ones in the Jarilla Mountains that have been actively worked; these operations have been small and sporadic, mostly during the 1930's when many individuals turned to panning gold as a means of making a living. During the 1940's, there was no mining activity in the Jarilla Mountains, according to Lewis N. Taylor (oral communications, August-September 1959).

In the early 1950's, the Colorado Dry Screen Mining Company of Denver, Colorado, conducted dry-screen operations on the Little Joe and Cottontop claims in NW1/4 NW1/4 sec. 14, T. 22 S., R. 8 E. The ore was dug by a bulldozer and put through a portable dry-screen processing machine. The venture was nearly a financial failure and reportedly lost money for nearly two years until a small pocket of slightly richer ore enabled the undertaking to break even. The owners then ceased operations (Lewis N. Taylor and Bob Day, oral communications, August-September 1959). Several semicontinuous pits about 100 feet long and 50 to 100 feet wide in an area 500 to 600 feet long mark the site of their efforts. The pits range from three to twelve feet deep, averaging about five feet; bedrock was reached in several places.

Sampling of the caliche-cemented gravel wall of one pit by Schmidt revealed that the gold is confined almost entirely to the six to eight inches of gravel (mostly monzonite-adamellite, with some skarn, hematite, and gossan) immediately above bedrock. Gold in the gravel above this bottom layer is very fine-grained and very scarce. Approximately

300 pounds of gravel was panned for gold, including about 150 pounds taken from the enriched layer just above bedrock. The gold was recovered by wet panning in a washtub and totaled 0.00995 ounce, worth 34.8 cents, or 32.7 cents if it is assumed to be 940 fine, at $35.00 an ounce. Jarilla placer gold has been reported to be 940 fine and to average about $1.00 a cubic yard (Lasky and Wootton, p. 86).

OTHER ORES

Lasky and Wootton mentioned that the Orogrande (Jarilla, Silver Hill) district has produced a little tungsten ore, but they do not give any details as to location, mineralogy, or quantity. Presumably, the ore was scheelite or wolframite in a contact pyrometasomatic zone and probably consisted of a few hand samples. The writers did not find any tungsten minerals.

FUTURE OF MINING

The future of mining in the Jarilla Mountains is clouded by three factors: (1) lack of marketable ore in quantity large enough to justify investment, (2) lack of water, and (3) proximity to the White Sands Missile Range, which presently includes the western half of the Jarilla Mountains.

The lack of proved copper-lead-silver-gold ore reserves discourages serious exploration for these metals. The numerous small outcrops or near-surface occurrences of these ores have probably all been found and exploited. To search for other deposits would necessarily involve costly drilling or tunneling. Geophysical exploration might be effective, particularly in the covered desert areas immediately adjacent to the monzonite-adamellite exposures on the eastern, western, and southern sides of the range. Detailed magnetometer surveying might outline contact zones and xenoliths mineralized in magnetite and hematite. Confirmation of any discoveries, however, would require drilling.

Geochemical surveying might also be helpful in this area. The drainage is radially away from the range, and the abundance of scattered mineralized areas has probably created a general dispersion halo around the mountains. A large enriched area, however, might be detectable with this method provided it was not buried too deeply by alluvium from adjacent outcrops. An area of five miles radius from the center of sec. 5, T. 22 S., R. 8 E. would be the most favorable for prospecting. If a program were undertaken, however, localities in the northern part of the range should also be included, although there are few favorable showings.

Exploring for a rich pocket of placer gold would be relatively easy with a mechanical auger, but the number of holes required may be prohibitive because of the necessity for drilling on a closely spaced grid.

Secs. 2, 3, 5, 9, 11, 14, and 15, T. 22 S., R. 8 E. would be the most favorable areas because many mineralized xenoliths and contact zones have been weathered and eroded and their detritus swept into adjacent areas of alluviation.

The remaining magnetite-hematite bodies are probably doomed to abandonment because the high sulfur content (0.4 to more than 1.2 per cent) makes the ore undesirable for most steel furnaces and the known reserves are low. Kelley (1949) estimated the total indicated and inferred reserves at 332,000 tons, 75 per cent of which is in the Cinco de Mayo deposit and would have to be mined by underground methods. The best and most accessible ore has already been mined.

GROUND WATER

The residents of Orogrande use water piped 36 miles southwestward from the Sacramento River to the reservoir in SW1/4SW1/4 sec. 11, T. 22 S., R. 8. E. A local pipeline carries the water to the settlement. The U.S. Army Orogrande Range Camp in sec. 8, T. 22 S., R. 8 E. uses water trucked from Orogrande. Test drilling by the U.S. Geological Survey in the Hueco bolson to the south found lenses containing fresh water in the basin fill adjacent to the Franklin and Organ mountains, but these do not extend into the basin more than six to eight miles. These fresh-water lenses are recharged by runoff from the mountains. However, ground water in deeper formations is too highly charged with dissolved mineral matter to be potable. The fresh water in these lenses also grades laterally into mineralized water in the central part of the basin (Knowles and Kennedy). The elevation of the static water level ranges from 300 to 600 feet below the land surface in the Hueco bolson area. The limited runoff from the relatively small Jarilla Mountains, situated as they are in the center of the Tularosa Basin, probably does not develop any significant fresh-water lenses in underground reservoirs.

Attempts to obtain satisfactory ground water around Orogrande and Orogrande Range Camp have not been successful. A well drilled at the Orogrande railroad 'station (SW1/4 sec. 24, T. 22 S., R. 9 E.) in 1902 passed through 80 feet of alluvium (red sand, gypsum and limestone, soft brown sandstone, gypsum, and clay), 500 feet of "granite" (probably a sill), and about 400 feet of massive limestone. Saline water was encountered at 480 feet in the "granite," at 605 feet in limestone, and at 840 feet in limestone (Meinzer and Hare). Another well in south-central sec. 3, T. 22 S., R. 8 E. (in the shaft of the Lucky Flat mine) passed through 235 feet of limestone and shale and 175 feet of "granite." Mineralized water was struck a few feet above the "granite" and stood at a level 150 feet below the surface in the mine shaft. Considerable pumping was required (175,000 gallons a day) when the mine was in operation (Meinzer and Hare).

Apparently these wells were unacceptable as water sources, for in 1906 the Southwest Smelting and Refining Company constructed, at a cost of $180,000, the 36-mile pipeline system from the Sacramento Mountains (Meinzer and Hare). This pipeline is still in use and is now the only source of water in the vicinity of the Jarilla Mountains.

Geologic History

The exposed rocks of the Jarilla Mountains represent only a small part of the time since the late Precambrian. Hence, the geologic history of this range must be inferred in part from the rocks of the surrounding region. The ranges which bound the Tularosa Basin (Sacramento, San Andres, Organ, Franklin, and Hueco mountains) provide a more complete geologic history.

PRECAMBRIAN

The Precambrian of southern New Mexico consists mainly of igneous and metamorphic rocks, such as metavolcanics, quartzite, schist, and gneiss, locally intruded by granite and diorite. In places there is a thin layer of quartzite unconformably overlying the igneous and metamorphic basement (Foster, 1959). Ancient sedimentary rocks of unknown age were deeply buried, metamorphosed to quartzite, schist, and gneiss, and intruded by the igneous rocks. Erosion exposed these old rocks to a very deep level, and the quartzite was deposited as sandstone on this irregular surface. About 80 feet of slightly metamorphosed shale, silt-stone, and sandstone unconformably underlies the basal Paleozoic in the Sacramento Mountains. This is assumed to be of late Precambrian age (Pray, 1959) although definitive age evidence is lacking.

EARLY PALEOZOIC

Southern New Mexico from late Cambrian to early Pennsylvanian time was mainly a stable marine shelf; sedimentation was interrupted by brief periods of nondeposition or slight erosion.

The lowest Paleozbic strata are of late Cambrian to late Ordovician age and consist of the Bliss Sandstone, El Paso Formation, Montoya Dolomite, and the Valmont Dolomite (Pray, 1961). The Fusselman Dolomite was deposited disconformably over the Valmont Dolomite during middle Silurian time, indicating a withdrawal and return of the shallow sea.

Overlying the Fusselman disconformably are beds of Devonian age, which were deposited unevenly across southern New Mexico. Local disconformities and facies changes make correlation and interpretation difficult (Flower, 1959). The Devonian rocks are mainly shaly and thin-bedded. Mississippian rocks disconformably overlie the Devonian and include the Caballero Formation (interbedded limestone and shale), the Lake Valley Formation (crinoidal and biohermal limestones), Rancheria Limestone, and Helms Formation.

LATE PALEOZOIC

The area of the Jarilla Mountains in early Pennsylvanian time was the site of marine sedimentation on a stable shelf. The Pennsylvanian rocks of the surrounding region rest unconformably on Silurian to Mississippian strata. Comparison with published sections of nearby ranges (Organ, Sacramento) and nearby oil tests suggests that the Jarilla Pennsylvanian rocks rest on Mississippian beds (Dunham; Pray, 1961). The Pennsylvanian section exposed in the Jarillas has been correlated with the Bug Scuffle Member (limestone) of the Gobbler Formation and was formed in quiet, shallow marine waters. In Virgilian time, tectonic disturbances changed the sedimentation pattern. To the east, upwarping developed the Pedernal landmass (Thompson, 1942, p. 12), and to the west and southeast other positive areas, the Florida islands and Diablo platform (Kottlowski, 1960b), appeared at greater distances. The area of the Jarillas was in the Orogrande basin and received a relatively thick sequence of late Pennsylvanian and early Permian sediments. The Pedernal landmass supplied the detritus of the clastic facies of the upper Pennsylvanian and lower Permian rocks now exposed in the Sacramento Mountains (Pray, 1961). The Orogrande basin received some of this deluge of land-derived debris which was deposited as the sandstones, siltstones, and intraformational conglomerates of the Laborcita Formation. Subsequently, while the Pedernal landmass was being buried under the Abo red beds, the limestones of the Hueco Formation were deposited offshore on the site of the present Jarilla Mountains.

Later Permian events are not recorded in the rocks of the Jarilla Mountains and must be inferred from other areas. The Yeso Formation (limestone, shale, and gypsum) probably covered the area at one time; it was formed in a lagoonal back reef environment behind the Vittorio Peak reef to the southeast (Pray, 1952). The landmass at that time (Leonardian) lay much farther to the north, and the Yeso beds are more continental in character in that direction. The gradation from AboHueco to Yeso is conformable. Conformably overlying the Yeso formation is the Glorieta Sandstone and San Andres Limestone. These rocks mark the return of quiet marine shelf deposition in the area (Pray, 1961).

MESOZOIC

Mesozoic rocks are absent in the Jarilla Mountains. Remnant sections of marine Cretaceous rocks crop out in distant surrounding areas; they were probably continuous at one time over the entire region. The last marine seas in the area withdrew near the close of the Cretaceous period.

CENOZOIC

The intrusive rocks of the Jarilla Mountains were probably emplaced in early or middle Tertiary time by analogy with rocks of similar composition and origin which occur to the northeast at Sierra Blanca and the Capitan Mountains. The Jarilla intrusives were injected in three main pulses, the syenodiorite first, then the monzonite-adamellite, followed by the orthoclase adamellite. The total thickness of the sedimentary overburden is not known, but it was probably several thousands of feet. The abundance of biotite in some of the Jarilla plutonic rocks indicates moderate to high water pressures (Turner and Verhoogen), and the intrusives must have been emplaced at considerable depth.

The Sacramento, Organ, and San Andres mountains are tilted fault blocks (Pray, 1961; Kottlowski et al.; Dunham) and the sedimentary rocks in these ranges now dip generally away from the Tularosa Basin. The Tularosa Basin, situated between these fault-block ranges, is a complex graben. The Jarilla Mountains are east of the center of a basin of interior drainage, in which Cenozoic sediments have accumulated to thicknesses of as much as 5000 feet. The Tularosa Basin crustal block must formerly have been elevated relative to the surrounding mountains, and the present bedrock surface was probably established mainly prior to subsidence. The grabens to the west (Rio Grande trough and others) were probably formed in Miocene and Pliocene time (Kelley, 1955), and the Sacramento Mountains are believed to have been uplifted in late Tertiary time (Mott, 1959). The Tularosa Basin probably formed contemporaneously with its structural counterparts in the surrounding region in late Tertiary time. Since then, most of the Tularosa Basin has been accumulating sediments washed in from the surrounding mountains.

During the late Pleistocene or Recent, the small lava flows and the pyroclastics at the north end of the Jarillas were formed during a minor eruption. During some of the Pleistocene, lakes were present in the Tularosa Basin. Lake Otero, which occupied the area of the present White Sands National Monument, may have reached as far as the Jarilla Mountains (Herrick, 1904; Jicha, 1959).

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EXPLANATION

Unmapped areas consist of recent alluvium and sand dunes.

RECENT
- Rb — Basalt Lava Flow

TERTIARY IGNEOUS INTRUSIVES
- Tid — Igneous Dikes, Undifferentiated
- Tio — Orthoclase Adamellite
- Tim — Monzonite Adamellite
- Til — Leucorhyolite
- Tis — Syenodiorite

- M — Metamorphic & Sedimentary Rocks, Undifferentiated

PERMAIN — Wolfcampian
- Ph — Hueco Formation
- Pl — Laborcita Formation

PENNSYLVANIAN — Desmoinesian
- Pg — Gobbler Formation, Bug Scuffle Member

⊢25 STRIKE & DIP OF SEDIMENTARY BED

GEOLOGIC CONTACT

U/D FAULT

MINE

MARKER BED (FUSULINID ZONE IN HUECO FM. 1635 TO 1670 FT., CHAETETES ZONE IN GOBBLER FM. 160 TO 178 FT.)

0 — 1/2 — 1 MILE

0 1000 2000 3000 4000 5000 FEET

SCALE 1:24,000

GEOLOGIC MAP OF THE JARILLA MOUNTAINS OTERO COUNTY, NEW MEXICO

BY
PAUL GERHARD SCHMIDT
1962

PLATE 2
Schmidt 1962

TABULATION OF IGNEOUS AND METAMORPHIC THIN SECTION DATA

Mineral constituents are listed by estimated percentage (X indicates present but 2% or less)

Specimen	Location	Occurrence	Rock type	Intrusive	Texture	Remarks	Plagioclase	Orthoclase	Quartz	Olivine	Magnetite	Augite	Calcite	Hornblende	Sulfide	Apatite	Zircon	Biotite	Fe-oxide	Sphene	Epidote	Clino-zoisite	Chlorite	Actino-lite	Andradite	Diopside	Scapolite	Specu-larite	Wollas-tonite
C-1	4 mi. west of Carrizozo, N.M.	Lava flow	Basalt	—	Hypocrystalline hiatal	Glassy matrix	25 An 50%			10																			
V-2	NENW sec 2 T21S R8E	Lava flow	Melabasalt	—	hiatal	Very fine gr. matrix iddingsite rim on olivine	40 An 68%			15	15	30																	
V-5	NENW sec 2 T21S R8E	Scoria clinker	Melabasalt	—	Hypocrystalline hiatal	Glassy matrix	20 An 58%			10	10																		
M-1	NWNW sec 14 T22S R8E	Stock	Monzonite porphyry	Orthoclase adamellite	Hiatal	Hydrothermally altered	30 An 36%	35	X					30	5	X	X												
M-2	NWNW sec 14 T22S R8E	Stock	Adamellite porphyry	Monzonite-adamellite	Hiatal	Hydrothermally altered	25 An 20%	45	15			X		10	X	X		X	X										
M-3	NWNW sec 14 T22S R8E	Stock	Adamellite porphyry	Orthoclase adamellite	Hiatal	Two varieties of hornblende hydrothermally altered	30 An 43%	35	7				5	8	X	X		X	X	X	X								
M-6	SESW sec 15 T22S R8E	Stock	Adamellite porphyry	Orthoclase adamellite	Hiatal	Hydrothermally altered	25 An 38%	40	18				5	X	X	X			X			X	5						
M-8	SENW sec 11 T22S R8E	Dike in limestone	Adamellite porphyry	—	Hiatal	Hydrothermally altered	25 An 33%	40	12				10	X	X	X	X	5					6						
M-11A	NESE sec 10 T22S R8E	Stock	Leucoadamellite porphyry	Monzonite-adamellite	Hiatal	Strongly altered	25 An 36%	50	15				5		5														
M-11B	NESE sec 10 T22S R8E	Dike in monz.-ada.	Monzonite	—	Aphanite	Hydrothermally altered	30 ?	40	5				10		5	X							7						
M-19	NWNW sec 15 T22S R8E	Inclusion?	Skarn	—	Phanerite	"Intrusive skarn"			5				70		X	X			X		10			10	X				
M-20A	SWNE sec 10 T22S R8E	Dike in monz.-ada.	Diorite porphyry	—	Hiatal	Dark dike	60 An 34%					5	10	10	5	X		X				10							
M-20B	SWNE sec 10 T22S R8E	Dike in dike M-20A	Adamellite porphyry	—	Hiatal	Contains small inclusion of garnet skarn	25 An 31%	35	17				10	4	X	X							4						
M-21A	NENE sec 10 T22S R8E	Dike in monz.-ada.	Adamellite porphyry	—	Hiatal	Hydrothermally altered	35 An 41%	30	15			5		5	X	X		X					5						
M-21B	NENE sec 10 T22S R8E	Dike in dike M-21A	Granite porphyry	—	Hiatal	Strongly altered	20 An 40%	55	12				10		X	X			X				10						
M-22	SE sec 3 T22S R8E	Stock	Monzonite porphyry	Monzonite-adamellite	Hiatal	Orthoclase in matrix	30 An 31%	45	5					5		X					10								
M-23	SE sec 3 T22S R8E	Inclusion in stock	Leucorhyolite porphyry	—	Hiatal	Very fine gr. matrix	10 An 31%	65	20						X			X											
M-24A	SESW sec 3 T22S R8E	Dike in monz.-ada.	Trochyte porphyry	—	Hiatal	Hydrothermally altered	20 An 28%	55	5					X	X	X				X	X			10					
M-24B	SESW sec 3 T22S R8E	Stock	Adamellite	Monzonite-adamellite	Hypidiomorphic granular	Unaltered, no matrix	45 An 12%	25	15				X	8		X	X			X			X						
M-26	SWNW sec 9 T22S R8E	Dike in monz.-ada.	Trachyte porphyry	—	Hiatal	Hydrothermally altered	20 An 33%	50	5				5	X	5	X							10						
M-28	NWSW sec 4 T22S R8E	Inclusion monz.-ada.	Monzonite	—	Hypidiomorphic granular	Small 3 inches dark inclusion	40 An 30%	30	X					30	X	X					X								
M-34	NWSW sec 35 T21S R8E	Stock	Adamellite porphyry	Monzonite-adamellite	Hiatal	Round "eyes" of quartz	30 An 37%	50	15				X	5	X	X							X						
M-37	SWNW sec 35 T21S R8E	Inclusion in syenodiorite	Mela-monzonite	—	Hypidiomorphic	4 inch inclusion in syenodiorite	30 An 25%	10	X			10		30	X	X		15											
M-44A	SESE sec 14 T21S R8E	Dike in stock	Latite porphyry	—	Hiatal	In orthoclase adamellite	40 An 48%	30				5	X			X							20						
M-44B	SW sec 13 T21S R8E	Stock	Adamellite porphyry	Orthoclase adamellite	Hiatal	Plagioclase An 38 in center of large phenocrysts	35 An 12%	35	15				X	5	X	X							5						
M-46	SWNE sec 15 T21S R8E	Dike in limestone	Basalt porphyry	—	Hiatal	Some zoned plagioclase more calcic on outside	50 An 61%	X	X				30	X	X	X		10			X		7						
M-47A	NW sec 9 T21S R8E	Dike in syenodiorite	Calcimonzonite porphyry	—	Hiatal	Dark grey	35 An 51%	30	X					25	X	6				X									
M-47B	NE sec 9 T21S R8E	Dike in syenodiorite	Monzonite porphyry	—	Hiatal	Also cuts dike M-47A	40 An 34%	40	5				X	X	5	X		X					5						
M-48	NW sec 10 T21S R8E	Dike in limestone	Syenogabbro porphyry	—	Hiatal	Fresh, contains inclusions of limestone	30 An 54 to 68%	5					20			X				X						40			
M-52	NW sec 25 T22S R8E	Stock	Granite porphyry	Orthoclase adamellite	Hiatal	Hydrothermally altered zoned hornblende	10 An 8%	55	10					20	X	X	X	5		X									
M-62	NWSW sec 21 T21S R8E	Stock	Monzonite porphyry	Orthoclase adamellite	Hiatal	Hydrothermally altered	30 An 25%	50	5					X	X	X	X						10						
M-80	SENW sec 10 T21S R8E	Dike in limestone	Trachyandesite porphyry	—	Hiatal	Two varieties hornblende, earliest has magnetite rim	50 An 30 to 40%	5			5		X	25		X		X		X	X					X	10		
M-84	SESE sec 10 T22S R8E	Dike in monz.-ada.	Rhyodacite porphyry	—	Hiatal	Contains inclusions of limestone and garnet	50 An 32%	10	5				20		X	X		5				X	X		5				
M-85	NESE sec 34 T21S R8E	Stock	Syenodiorite	Syenodiorite	Hypidiomorphic granular	Clear, unaltered	55 An 50%	10	X		X	8		8		X		15											
S-2-1	NESE sec 22 T21S R8E	Hornfels	Hornfels	—	Xenoblastic	Banded, sedimentary bedding			40				20		X				X		30		X		X		10		
M-66-1	NWNE sec 10 T22S R8E	Skarn zone	Skarn	—	Idioblastic xenoblastic	One ft. from igneous contact			X				5												85		X	5	
M-66-2	NWNE sec 10 T22S R8E	Skarn zone	Skarn	—	Idioblastic xenoblastic	Cherty horizon one foot from igneous contact			5				5		X										85		5		
M-66-3	NWNE sec 10 T22S R8E	Skarn zone	Skarn		Xenoblastic	Cherty horizon 10 feet from igneous contact			5				15																80
M-66-4	NWNE sec 10 T22S R8E	Skarn zone	Skarn-marble	—	Xenoblastic	Cherty horizon 30 feet from igneous contact			20				60																20
M-75-1	SWNW sec 4 T22S R8E	Skarn zone	Skarn		Idioblastic xenoblastic	Skarn rim of xenolith Cinco de Mayo mine			X				10						5 magnetite				5		75			X	
M-75-2	SWNW sec 4 T22S R8E	Hornfels bed	Hornfels		Xenoblastic	Hornfels bed in xenolith Cinco de Mayo mine			50				10		X				X		30						10		
M-67S	NENW sec 10 T21S R8E	Hornfels bed	Hornfels	—	Xenoblastic	Very fine grained, murky mixture			Major constituent				Major constituent		X											Minor constituent	Major constituent		
M-67M	NENW sec 10 T21S R8E	Fossiliferous limestone	Fossiliferous limestone	—	Xenoblastic	Unmetamorphosed							100																
M-68S	SWNW sec 10 T21S R8E	Hornfels bed	Hornfels	—	Xenoblastic	Scapolite matrix							5												5	40	50		
M-68M	SWNW sec 10 T21S R8E	Marble bed	Marble	—	Xenoblastic	Fine grained marble							100																
M-69S	SWNW sec 10 T21S R8E	Hornfels bed	Hornfels	—	Xenoblastic	Scapolite matrix							5		X						X				15	40	40		
M-69M	SWNW sec 10 T21S R8E	Marble bed	Marble	—	Xenoblastic	Med. grained marble							95													X			X
M-70	SWNW sec 10 T21S R8E	Chert nodule in marble	Skarn		Xenoblastic, fibrous	Radiating wollastonite around chert							20													5			75
M-71	SWNW sec 10 T21S R8E	Skarn zone	Skarn		Xenoblastic, idioblastic	Massive garnet skarn							5								X		X		80	15	X		