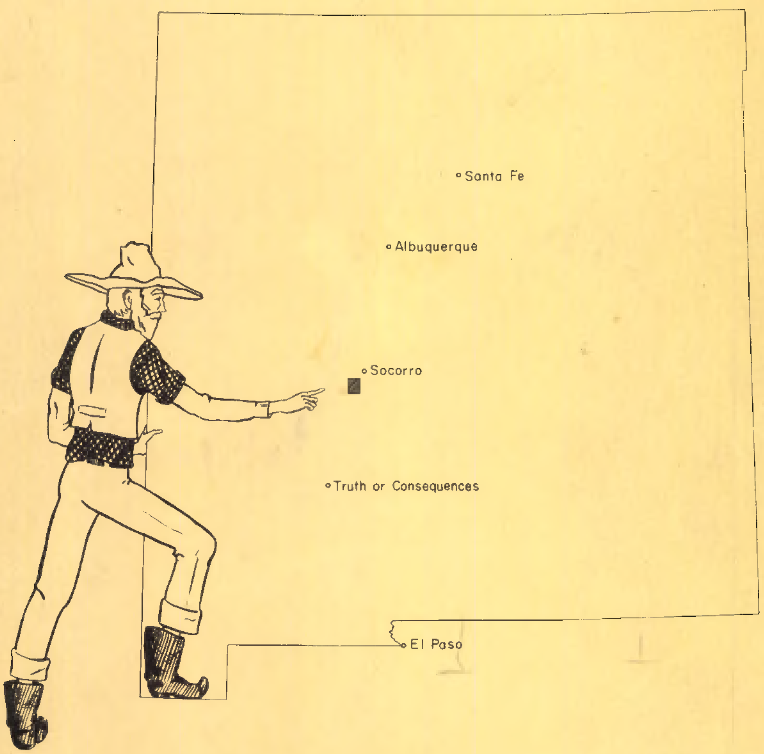
CIRCULAR 38

GEOLOGY OF THE LUIS LOPEZ MANGANESE DISTRICT SOCORRO COUNTY NEW MEXICO

by

Alfred T. Miesch



NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

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SOCORRO, NEW MEXICO

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ABSTRACT

The Luis Lopez manganese district is located in the Chupadera Mountains, a north-south trending range which lies a few miles southwest of Socorro, in central New Mexico. The Chupadera Mountains are made up almost wholly of volcanic rocks, ranging in composition from basalt to rhyolite, but consisting chiefly of rhyolite, tuff, and welded tuff of rhyolitic composition.

The core of the range is massive rhyolite, over 1,000 feet thick, covering an area of about 10 square miles. The other volcanic units are restricted mainly to the northern and southern parts of the range. Though similar, the rocks cannot be correlated directly from north to south; accordingly, they are divided into two sequences. The northern sequence is made up chiefly of tuff, rhyolite, and volcanic breccia with interlayered rhyolite and andesite flows. The southern sequence is welded tuff, rhyolite, and andesite. All these units are older than the massive rhyolite, which is intruded by a plug and dikes of rhyolite in the north and by latite dikes in the south.

The Chupadera Mountains are surrounded by fanglomerates of presumed Santa Fe age. These sediments are semiconsolidated to consolidated sand, gravel, and some clay. They are intruded by basalt sills, dikes, and plugs and are capped by basalt flows at many localities.

Semiquantitative spectrographic analyses of seven volcanic rocks and a complete chemical analysis of the massive rhyolite are presented.

Within the Chupadera Mountains, faulting and tilting of the older volcanic rocks resulted from the intrusion of the massive rhyolite. Later faulting, associated with the formation of the Rio Grande trough, is marked on the eastern front of the mountains by a north-south trending en echelon fault system.

Small manganese deposits are present throughout the area, but the major manganese deposits discovered so far occur in breccia zones or steeply dipping fault zones in the massive rhyolite. Manganese oxide minerals, chiefly psilomelane, occur as banded botryoidal vein fillings or as stockworks of veinlets cementing breccia. The ores are considered to be of hydrothermal (epithermal) origin.

INTRODUCTION

The Luis Lopez mining district provides one of the best illustrations in New Mexico of deposits of manganese oxides in breccias and in veins of rhyolite. In 1955, it was one of the most productive districts in the United States. The purpose of this study is to provide the geologic background for the occurrence of the manganese minerals. The volcanic rocks of the district were studied in detail in order to contribute to the general knowledge of these rocks. The field work by the writer in 1951 and 1952 was done prior to the marked expansion of exploration and mining in 1954 and 1955. In 1955, E. C. Anderson and H. L. Jicha, Jr., of the staff of the New Mexico Bureau of Mines and Mineral Resources, began a detailed study of the manganese mines and prospects and have added to the map the locations of new openings and access roads. Some revisions in the text also have been made to bring the material up to date.

The Luis Lopez district lies southwest of Socorro in the first range of hills west of the Rio Grande, about 5 miles west of the villages of Luis Lopez and San Antonio on the Atchison, Topeka and Santa Fe Railway. A branch line of the latter, extending from Socorro to Magdalena, crosses the north end of the area, as does U. S. Highway 60. The El Paso line of the same railroad and U. S. Highway 85 follow the west bank of the Rio Grande, 5 miles to the east. Roads leading to the principal mines and prospects provide ready access to the area.

There are only two ranch headquarters in the district. Stock wells supply minimum requirements of water, no springs or permanent streams being found in the area. Adequate water for the manganese mills is obtained from wells in the valley fill just off the east edge of the mapped area. Manganese mining is the only notably remunerative activity in the area.

This report is based on a thesis submitted for the Master of Science degree at Indiana University. The field and laboratory work were performed under the guidance of Professor Charles J. Vitaliano, of that institution. Work in the field was done on weekends while the writer was temporarily on the staff of the State Bureau of Mines, in Socorro.

The topographic map of San Antonio quadrangle was not available when the writer undertook this study.

ACKNOWLEDGMENTS

The author is grateful to Dr. Eugene Callaghan, director of the New Mexico Bureau of Mines and Mineral Resources, for facilities and equipment used in this study. Special thanks are also due Dr. R. H. Weber, of the Bureau, for many suggestions and assistance, particularly in conducting the profile surveys required for the preparation of the geologic sections.

GEOLOGY

Geologic Setting

The Luis Lopez district occupies part of a narrow range of hills extending southward 7 miles from Socorro Canyon and U. S. Highway 60 to Nogal Canyon (see pl 1) The range is designated Chupadera Mountains on the San Antonio topographic map and is a continuation of the chain of mountains on the west side of the Rio Grande valley, which includes the Lemitar Mountains and the Socorro Mountains to the north and unnamed hills south of Nogal Canyon. The range ends against a westward curve of the Rio Grande valley 8 miles south of Nogal Canyon. The Chupadera Mountains in the Luis Lopez district are 2-1/2 miles wide, having a local relief of 1,000 ft and a maximum altitude of 6,300 ft. On the west is the high Snake Ranch Valley trough underlain by fanglomerate and deeply dissected by stream courses originating in the Magdalena Range farther to the west. These streams flow eastward directly through the Chupadera Mountains and cross the much lower dissected fans and alluvial fill between the Chupadera Mountains and the floodplain of the Rio Grande (altitude 4,550 ft).

The Chupadera Mountains are made up almost wholly of volcanic rocks ranging from basalt to rhyolite but consisting chiefly of rhyolite or tuff or welded tuff of rhyolitic composition. The underlying rocks are not exposed but might be expected to be Paleozoic or Precambrian. Rocks of these ages occur in the Magdalena Range to the west, in Socorro Mountain to the north and in the unnamed hills to the south. Massive rhyolite makes up most of the core of the mountain range north of Nogal Canyon. For the most part, the volcanic units dip steeply eastward in contrast to the westward dip of similar units in the Socorro Mountains north of the district. The range is believed to be bounded on both east and west sides by faults or fault zones, so that structurally the range is a horst uplifted between relatively depressed areas now covered by fanglomerates (pl 1).

Sequence of Rock Units

Rhyolite Tuff (Tt)

The lowermost unit mapped is a rhyolite-latite tuff (Tt) which occurs in a number of small outcrops covering about one-quarter square mile between U. S. Highway 60 and Black Canyon. This tuff rests on massive rhyolite (Tmr) in two localities in Black Canyon, but the massive rhyolite is interpreted as being intrusive and therefore younger than the tuff. In Black Canyon, the tuff underlies dark rhyolite (Tdr) and along U. S. Highway 60 it is overlain by massive volcanic breccia (Tvb). One-half mile southeast of Box Canyon, a large block of the tuff, over 500 ft thick, dips northward about 25 degrees and is faulted against volcanic breccia. At the northeast end of Box Canyon, the tuff has been intruded by a dark rhyolite dike.

The tuff is very fine grained and is crudely layered, so that the attitude of the beds is determined easily. On highly weathered surfaces, it is dark brown to black, but on fresh surfaces it is light pink to gray. Xenolithic fragments are abundant and usually range from microscopic size to several inches across, though fragments up to several feet across are present. Although the composition of the foreign material varies widely, the most prominent fragments are of a porphyritic rhyolite with a red, glassy groundmass. Numerous angular cavities, up to one-half inch across, have claylike fillings and coatings which turn blue when benzidine reagent is applied, an indication of the presence of montmorillonite (Mielenz et al, 1950), which probably formed as an alteration product of glass fragments.

Thinsections show the matrix of the tuff to be composed chiefly of sharply angular quartz and potash feldspar crystal fragments in a groundmass of almost completely devitrified glass. The potash feldspar fragments, sanidine and orthoclase, are up to 2 mm across and form about 30 percent of the matrix. Both these minerals have been kaolinized and sericitized. Less than 10-20 percent of the glass is now vitric; the remainder has changed to a cryptocrystalline aggregate containing scattered spherulitic structures. Numerous minute laths of biotite are present; many are rimmed or almost completely replaced by magnetite. Many of the fresher grains show wavy extinction as a result of strain. Irregularly distributed magnetite is also present. Small epidote grains are sparingly present.

Dark Rhyolite (Tdr)

Dark rhyolite overlies the tuff (Tt) and occupies an outcrop area of slightly less than 1 sq mile. The writer believes that this rhyolite was much more extensive. The dark rhyolite forms the greater part of the walls of Box Canyon, where it is over 200 ft thick; it also forms a dike about 50 ft wide in tuff (TO at the northeast end of the canyon. It underlies layered volcanic breccia (Tvb) at Blue Canyon, and at Black Canyon a silicified phase dips steeply eastward off the massive rhyolite (Tmr). The dark rhyolite is found in small patchy outcrops at the west end of Nogal Canyon and along the southwest margin of the massive rhyolite (Tmr).

This rhyolite is dark blue to lavender and is locally porphyritic, with phenocrysts of feldspar that appear as irregular white splotches about 2 mm across. The groundmass is aphanitic. The rock is mostly massive, though thin flow layering appears in some places.

The dark rhyolite occurs as numerous inliers in the massive rhyolite at the west end of Red Canyon. Some of the inliers may be former topographic highs of the dark rhyolite surface on which the massive rhyolite rests, but others certainly are large xenoliths. Inliers, up to 700 ft across, in the massive rhyolite in the lower parts of the gulches may be interpreted as former topographic highs. Equally large xenoliths were observed to be clearly enclosed by the massive rhyolite. Both the xenoliths and inliers have been penetrated by stringers and dikes of massive rhyolite.

One of the inlier contacts is of special interest. In the southern part of sec. 18, T. 4 S., R. 1 W., very fine-grained massive rhyolite is separated from the dark rhyolite by a zone or crust of very coarse-grained massive rhyolite about 10 ft thick. The fine-grained rhyolite has intruded both the coarse-grained crust and the dark rhyolite with numerous dikes, usually 6-8 in. thick, but ranging up to 2 ft thick. The textural variations in the massive rhyolite are distinct and well defined, with no obvious gradational zone. Both extremes of crystal size are distinctly different from the normal texture of the rock. It appears that the coarse-grained crust of massive rhyolite formed along the border of the dark rhyolite prior to the solidification of the fine-grained phase. A border of the dark rhyolite about 1 ft thick has been altered, with the formation of abundant epidote and calcite, but the coarse-grained massive rhyolite crust has not been affected visibly.

Thinsections show the dark rhyolite to be a porphyritic to microporphyritic rock, consisting chiefly of orthoclase and plagioclase phenocrysts in a groundmass composed of small interlocking feldspar laths. Some interstitial glass is present locally. Euhedral and subhedral orthoclase up to 2 mm across is the dominant feldspar. Plagioclase occurs in much smaller lath-shaped forms in the groundmass. Biotite occurs prominently as laths up to 1.5 mm in length. Most of the biotite has been bleached and has magnetite rims, or has been replaced almost completely by magnetite. A few magnetite pseudomorphs after hornblende were observed. Biotite and magnetite form about 5 percent of the rock.

The refractive index of glass produced by the fusion of a powder of this rock indicates a silica content of 64-69 percent (Matthews, 1951; Miesch, 1952). Normative quartz and feldspar contents were calculated by using this estimation of silica as well as by semiquantitative spectrographic determination of potassium, sodium, calcium, magnesium, and iron expressed as oxides (see table 2). Although the spectrographic analyses are described in a later section, it is necessary to point out here that the oxidation state of the iron is not reported. Therefore, the upper range of the normative quartz percent was calculated with 69 percent silica, 6.8 percent Fe_2O_3, and 0 percent FeO. The lower quartz range was derived by using 64 percent silica, 0 percent Fe_2O3, and' 6.8 percent FeO. The probable normative quartz content was derived by using 66.5 percent silica (midpoint of the estimated range), 2.7 percent Fe_2O_3, and 4.1 percent FeO (the proportions suggested by modal minerals).

Normative Minerals

quartz	18-12 percent (16 percent probable)
orthoclase	48 percent
albite	17 percent
anorthite	10 percent

Small anhedral grains of interstitial quartz are sparingly present, but at several localities abundant secondary quartz has been introduced into the rock. The dark rhyolite in Black Canyon contains small anhedral grains of quartz scattered evenly throughout the rock. These grains, mostly less than 0.2 mm across, show wavy extinction and, rarely, biaxial interference figures. Some clusters of quartz are present as vesicle fillings. A dark rhyolite xenolith in volcanic breccia (Tvb) about 500 ft west of the sandstone outcrop north of Black Canyon has been penetrated along its margin by numerous silica veinlets, which are about 0.3 mm wide and irregular in length and direction.

Chlorite is abundant in the dark rhyolite in a small area near the contact with volcanic breccia, 300 yd north of Black Canyon. The chlorite, along with chalcedony occurs as a vesicle filling and lining. The chalcedony often forms the core of the filling. In hand specimen, the chlorite appears as irregular agatelike banded patches up to 3 mm across. Its green color is very similar to that of malachite; for this reason a tunnel, 30 ft long, has been driven into the altered rock. Semiquantitative spectrographic analysis indicates no unusual quantity of copper.

Volcanic Breccia (Tvb)

Volcanic breccia (Tvb), together with interlayered rhyolite (Tbr), porphyritic andesite (Tba), and spherulitic rhyolite (Tbsr), has an aggregate outcrop area of nearly 3 sq miles in the northern and northwestern part of the area. The matrix of the breccia is mainly dark red and aphanitic, the fragments ranging in size from small particles to blocks several hundred feet across. Although the fragments range considerably in color, grain size, and composition, nearly all are of volcanic origin.

The volcanic breccia is over 400 ft thick and occurs in two strikingly different phases. The upper part of the unit is very massive, containing practically no flow structure; the lower 50 ft or more has very well-developed flow layers averaging about 1 ft thick. Typical massive volcanic breccia crops out in the vicinity of Box Canyon, the layered phase being best represented by the breccia in the west-central part of the area. The gradation between the two phases may be seen 1 mile south of Box Canyon and at Blue Canyon.

Massive, highly silicified breccia occurs in Black Canyon and near the west end of Blue Canyon. Layered volcanic breccia directly overlies dark rhyolite (Tdr); along U. S. Highway 60, the upper massive phase rests on tuff (Tt). Sandstone (Ts) and rhyolite (Tr) overlie the massive breccia south of Box Canyon.

The matrix of the volcanic breccia forms about 50 percent of the rock and is composed of angular particles of quartz, orthoclase, and plagioclase in an aphanitic groundmass that is colored deep red by iron oxide. Biotite and magnetite are present in the matrix in small amounts. The crystal fragments in the matrix are mainly from 0.5 to

1.0 mm across. The groundmass of the matrix varies in crystallinity from aphanitic to glassy and is partly spherulitic. A fusion test indicates a silica content of 62± 2 percent (Matthews, 1951; Miesch, 1952). The rock is probably a latite or quartz latite. The composition of many of the lithic fragments in the breccia differs greatly from that of the matrix, but the fragments show no appreciable reaction with the matrix.

Usually, the breccia is only slightly altered. Kaolinite and sericite have formed from orthoclase, and magnetite has replaced biotite. Notable exceptions, however, are the intensely silicified zones in the massive phase of the breccia. These zones are indicated on the geologic map (pl 1). The silicification has affected all parts of the rock except crystals and fragments of quartz.

Rhyolite (Tbr)

Of the three units interlayered with the volcanic breccia (Tvb), porphyritic red and gray rhyolite (Tbr) is the oldest and most widely exposed. This rhyolite has been intruded and uplifted by massive rhyolite (Tmr) near the west end of Black Canyon. A small exposure of underlying layered volcanic breccia (Tvb) is present in the bottom of the canyon. At the west end of the canyon, layered breccia overlies the rhyolite; several hundred yards to the northwest, breccia appears to dip under it.

This rhyolite is porphyritic, with a red and gray groundmass and phenocrysts of quartz, feldspar, and biotite. Biotite is especially prominent, occurring as small dark laths and bronze-colored plates scattered throughout the rock. Much of the rhyolite has a layered structure, but immediately north of Black Canyon, it is almost entirely massive and contains abundant veinlets of opal.

Thinsections show the rock to be composed chiefly of orthoclase, quartz, and biotite phenocrysts in a devitrified spherulitic groundmass. The orthoclase phenocrysts are subhedral to euhedral and range up to 4 mm across. Much of the orthoclase has been altered to kaolinite and sericite. Quartz crystals, up to 1 mm across, are common and, for the most part, are deeply embayed by the groundmass. Fresh biotite laths, up to 1 mm in length, are abundant. Stringers and clusters of anhedral quartz are prominent in the rock.

Porphyritic Andesite (Tba)

Porphyritic andesite occurs only in the northern part of the area within the breccia (Tvb). East of Box Canyon, it rests on massive volcanic breccia (Tvb), nearby breccia outcrops containing small andesite fragments. One mile east of Box Canyon, a ridge of the andesite appears to dip under spherulitic rhyolite (Tbsr). The underlying rock is not exposed, but the presence of layered breccia (Tvb) can be inferred from field relations.

The most striking feature of the rock is its pitted weathered surface. The pits are from about one-fourth of an inch to 1 in. across and have been formed by the weathering out of large plagioclase phenocrysts. The aphanitic groundmass is brown on weathered surfaces and light brown to lavender on fresh breaks. In fact, it is very difficult to obtain a specimen in which the plagioclase phenocrysts are not completely weathered out.

The andesite is composed of andesine phenocrysts up to 10 mm in length in a partly crystalline groundmass with a well-developed trachytic texture. The groundmass consists chiefly of felted plagioclase and a very small amount of orthoclase. Biotite is abundant, usually bleached, and at least partly replaced by magnetite. A few hornblende crystals, largely replaced by calcite and epidote, are scattered throughout the rock. The refractive index of a glass produced by the fusion of this rock indicates a silica content of 63-67 percent (Matthews, 1951; Miesch, 1952).

Spherulitic Rhyolite (Tbsr)

The uppermost flow interlayered with the volcanic breccia is a well-layered spherulitic rhyolite at least 50 ft thick, which is exposed along U. S. Highway 60 and a few hundred yards to the south of the highway. Along the highway, the rhyolite dips
to the west and probably overlies the porphyritic andesite (Tba). South of the highway, it dips westward and overlies layered volcanic breccia.

Layering in this rhyolite is particularly striking and locally yields a thin platy structure. Where the unit is not platy, it is massive, dense, and light gray. The platy zones consist of light-gray layers about one-fourth of an inch thick that are separated by thinner pink bands. The layers are extremely wavy and contorted.

Thinsections reveal about 85 percent of the rock as denitrified glass. Spherulites, about 0.2 mm across, are scattered evenly throughout the sections and appear as small crosses between crossed nicols. Many vesicles, up to 5 mm across, are partly filled with small anhedral grains of quartz. Originally abundant biotite has been replaced by magnetite.

Tuff (Tts)

In the southeastern part of the Chupadera Mountains, in the vicinity of Nogal Canyon, the massive rhyolite (Tmr) is overlain by tuff (Its), augite andesite (Tas), and rhyolite (Trs). None of these rocks seems to be exactly comparable with rocks in the northern part of the area. The tuff may be overlain by either the andesite or the rhyolite. Though this tuff (Tts) is similar in texture and structure to the earlier tuff (Tt), it contains abundant plagioclase. In contrast, the earlier tuff contains very little plagioclase.

The later tuff (Tts) is definitely younger than the dark rhyolite (Ur), whereas the earlier tuff (It) is older. South of Nogal Canyon, sediments at the base of the later tuff (Tts) lie on dark rhyolite.

The tuff (Tts) is light gray to pink and in most outcrops is welded. The matrix is composed of about 80 percent denitrified glass. Only in a few localized places can crystals of feldspar and hornblende be detected megascopically. Xenolithic fragments, up to 1 in. across, are abundant, and larger xenoliths are common. At Nogal Canyon, a layer of black perlite about 2 ft thick is interlayered with the lower part of the tuff.

East of the Bianchi ranch in Nogal Canyon, the welded tuff is underlain by pink and creamy-gray water-laid tuffs and tuffaceous sediments, including conglomerates, sandstones, and clays. Basaltic andesite flows and associated breccia occur just below the tuffs at the top of the water-laid section. The lower part of this sequence is exposed farther to the southwest, outside of the mapped area. At Nogal Canyon, the sedimentary beds are cut off by a northward trending fault and by the massive rhyolite (Tmr). The water-laid material is included with the welded tuffs on the map (pl 1).

Augite Andesite (Tas)

An andesite flow having an outcrop area of three-eighths of a square mile rests directly on massive rhyolite (Tmr) and on the tuff (Its). The flow is about 100 ft thick and, in most parts, has a layered or platy structure. The rock is slightly porphyritic, with a dark aphanitic groundmass and small phenocrysts of feldspar. A coarser grained variety of andesite forms a dike in the underlying tuff. This dike has augite crystals up to 2 mm across and fractures lined with thin layers of opaline silica.

The flow andesite is a distinctly trachytic aphanitic rock composed of minute crystals of plagioclase and microphenocrysts of augite. Plagioclase and interstitial glass form about 85 percent of the rock. Small dark red-brown laths of biotite are present but, more commonly, the biotite is very intensely bleached and replaced by magnetite. Other magnetite is scattered throughout the rock. Minute veinlets of introduced silica are common. Although the andesite overlies massive rhyolite (Tmr), the andesite is probably the older of the two rocks, as andesite occurs as xenoliths in the rhyolite. The writer believes that the rhyolite (Tmr) intruded the andesite, pushing it upward and outward. Dips range up to as much as 30-60 degrees.

Sandstone (Ts)

Though one-third of the Tertiary section at Socorro Peak is estimated to consist of sedimentary rocks (Lasky, 1932, p 120), the only Tertiary intravolcanic sediment found in the Chupadera Mountains, a few miles to the south, is a dark-red to orange quartz sandstone, which rests on the massive phase of the volcanic breccia (Tvb) and is overlain by rhyolite (Tr). This sandstone, which has a thickness of about 75 ft, occurs at only two places north of Black Canyon; its total outcrop extent is less than 40 acres. The sandstone is medium to fine grained, fairly well sorted, and moderately well bedded. Most of the grains are subround, but near the intrusive contact with the massive rhyolite (Tmr) many of the grains have been shattered. The sandstone is made up chiefly of quartz, with a few grains of orthoclase, some biotite laths, and grains of magnetite, largely altered to hematite, all cemented by clay materials. Lithic fragments, especially spherulitic fragments, are common.

The lithic fragments in the sandstone clearly indicate that the rock is later than come volcanics, but it is not clear whether the rock is older or younger than the volcanic breccia on which it rests. Two sandstone blocks may have been floated on the lava and brought to the surface from below with the eruption of the volcanic breccia. The author believes, however, that the sandstone was deposited on top of the breccia, as there is no evidence to corroborate the hypothesis that the outcrops are those of floated blocks.

Rhyolite (Tr)

In the northern part of the area, the extrusion of the volcanic breccia sequence (Tvb) and the deposition of the sandstone (Ts) was followed by the extrusion of a rhyolite flow (Tr) having an outcrop area of about one-eighth of a square mile. In the two exposures of the rhyolite (Tr), four rock types are present. A basal layer of tuff, several feet thick, is overlain by a dark-red aphanitic rhyolite that is characterized by numerous gray streaks and lenticles commonly less than 1 in. in length. The uppermost unit is a dark-red vitrophyre. The entire unit is less than 150 ft thick.

All the units consist essentially of glass, quartz, and potash feldspar in varying proportions. The vitrophyre is approximately 60 percent glass, with some small spher-ulites. Fragments and subhedral grains of quartz are a little more abundant than the potash feldspars, sanidine and orthoclase. No plagioclase is present. Biotite, altered to chlorite and magnetite, forms about 5 percent of the rock.

The two rhyolites below the vitrophyre are similar in composition and texture except for the presence of the gray streaks and lenses mentioned above in the younger of the two units. The gray areas in thinsections are clearly more crystalline than the red areas and appear to be a primary feature of the rock. No alteration is associated with them. The textures range from cryptocrystalline in the red areas to microcrystal line in the gray areas. The lower gray or orange rhyolite is entirely cryptocrystalline, with a few small phenocrysts and fragments of quartz and orthoclase.

Rhyolite (Trs)

In an outcrop area of about 1 sq mile in the southeastern part of the area, volcanic tuff (Tts) is overlain by about 100 feet of mottled red and gray rhyolite (Trs). The upper part of this unit is a red vitrophyre. The similarity of this unit to the rhyolite (Tr) in the northern part of the Chupadera Mountains is striking. The red and gray colors show the same textural variations, and the units are overlain by dark-red vitrophyre. The glasses of the vitrophyres are identical in color, and both have small lenses of cryptocrystalline material. The phenocrysts of the two vitrophyres are equal in amount and size.

The mineral composition of the rhyolite sequence in the north, however, is not identical to that in the southeast. The southeastern sequence has well-developed phenocrysts of oligoclase in contrast to the total absence of observable plagioclase in the northern sequence. The northern sequence is far more abundant in potash feldspars. Both sequences are rich in quartz, and both contain nearly equal amounts of biotite. Although the color and textural variations of the two sequences suggest a genetic relationship, field evidence of such a relationship is absent.

Massive Rhyolite (Tmr)

The most extensive formation (10 sq miles) and one of the most important economically, containing over 90 percent of the manganese ore thus far discovered, is the massive rhyolite (Tmr). This unit occupies the central core of the Chupadera Mountains, ending just south of Nogal Canyon. The exposed thickness in canyon walls exceeds 1,000 ft; the base, however, is not exposed, and the top has been eroded.

The massive rhyolite changes very little in appearance throughout its extent. It is, for the most part, highly porphyritic, with phenocrysts of sanidine, quartz, and some biotite in an aphanitic groundmass that is light gray to blue or reddish. Locally, it is only slightly porphyritic, as for example, near its eastern and northern margins. It typically weathers pale reddish brown. Flow structures are almost entirely absent, and the rock is generally nonvesicular. Prominent joints, especially well developed in the Red Canyon area, cut the massive rhyolite in several directions. Locally, the joint surfaces are covered by films of manganese minerals. Concentrations of xenoliths in zones that may be as much as 1,000 ft wide give the rock the appearance of a volcanic breccia. The xenoliths are mainly fragments of older volcanic rocks. In small areas, the fragments include pieces of granites, schists, and gneisses of probable Precambrian age. The xenolithic fragments in these zones range from microscopic to several feet across: In some areas, large xenoliths of rocks other than those mentioned above have been penetrated by stringers and dikes of massive rhyolite. The biggest of these are the dark rhyolite xenoliths discussed in the section on dark rhyolite (Tdr). North of Red Canyon, there is a xenolith of black vitrophyre 20 ft across. Coarse-grained granitic rocks and some highly schistose rocks form xenoliths up to 5 ft in diameter in the western part of sec. 31, T. 4 S., R. 1 W.

In thinsection, the massive rhyolite is highly porphyritic, being composed largely of sharply angular phenocrysts of quartz and sanidine, up to 3 mm across, in a partly crystalline groundmass that is partially spherulitic. Magnetite and small distorted laths of biotite are present in the groundmass. Epidote and muscovite are sparse.

Oligoclase, much of which has been altered, is irregularly distributed through the rock. Some of the oligoclase laths are twinned according to the carlsbad and albite laws, with very thin lamellae; others are zoned. Oligoclase is the only mineral in the massive rhyolite that has been highly altered. Deuteric solutions are believed to be responsible for the alteration of some oligoclase to quartz and orthoclase, or to calcite.

Quartz phenocrysts are deeply embayed by the groundmass, and sanidine has been slightly kaolinized along its nearly invisible cleavage planes. Biotite frequently has inclusions and rims of magnetite. The chemical analysis, norm, and mode for this rock are presented in Table 1.

Abundant silica must have been associated with the final stages of solidification of the massive rhyolite. Nearly all the older volcanics that were disturbed by its eruption, but chiefly the rhyolite (Tbr), dark rhyolite (Tdr), volcanic breccia (Tvb), and andesite (Tas), have been at least partly silicified. In addition, two large masses of white, almost pure, microcrystalline silica, each about 50 ft across, occur in the massive rhyolite.

The eruptive source of the massive rhyolite is, with little doubt, at Black Canyon, where the rock is dense, mildly porphyritic, and somewhat layered parallel to its contact with older rocks. In the southern part of sec. 6, T. 4 S., R. 1 W., sandstone (Ts), volcanic breccia (Tvb), and rhyolite flows (Tr) strike into and are cut off by the massive rhyolite. Their contact with the rhyolite is highly irregular in both plan and cross-section. In SE¼ sec. 6, the older rhyolite tuff (Tt), dark rhyolite (Tdr), and volcanic breccia dip off the massive rhyolite at angles up to 51 degrees. One mile to the west, the massive rhyolite is overlain by older rhyolite (Tbr), and in the central part of sec. 6 volcanic breccia rests directly on massive rhyolite.

Farther south, the massive rhyolite appears to have flowed over volcanic breccia (Tvb), tuff (Tt), and dark rhyolite (Tdr). The direction of flow may have been controlled by a structural and topographic depression, now marked only by the inward dipping volcanic breccia on the west border of the flow. In the southeast part of the area, the flow reached an obstruction of andesite (Tas) and tore some of it away to form xenoliths. At places, massive rhyolite also intruded and uplifted the andesite flow. Toward Nogal Canyon, the flow tongued out, only a few small outcrops occurring south of the canyon.

The fragmental nature of the phenocrysts in the massive rhyolite and the absence of flow structures suggest the possibility of a pyroclastic origin. The groundmass, however, is not at all fragmental; rather, it is cryptocrystalline to glassy and spherulitic. This fact, considered with the field relationships described above, tends to confirm that the rock is not a pyroclastic. Indeed, it appears that the massive rhyolite was intruded at Black Canyon, doming the older rocks. South of Black Canyon, the intrusive dome was punctured, and the massive rhyolite poured out and flowed southward. North of the canyon, the massive rhyolite spread out under the domed older rocks to produce intrusive forms that may be laccolithic. The fragmental phenocrysts might be explained by the high viscosity expected in a lava containing 71 percent silica (table 1). The absence of flow structures is probably a result of turbulent, rather than laminar movement of the lava.

The economic significance of the massive rhyolite lies in the fact that over 90 percent of the manganese deposits occur in this formation. It appears that the massive rhyolite was most susceptible to fracturing in a manner which produces breccia zones (in the tectonic sense). These breccia zones are of extreme importance in the localization of manganese minerals, as they provide openings for the access of ore-bearing solutions and for the deposition of the manganese oxides. Some mineralization has occurred also along open joint planes in the rhyolite.

Late Rhyolite (Tlr)

Highly brecciated, dense, light-gray, intrusive rhyolite (Tlr) forms a small plug and several northeast trending dikes, as much as 100 ft wide, in the massive rhyolite (Tmr). With one exception, all these intrusives occur in the area between Black Canyon and Red Canyon. The plug located in the western part of sec. 18, T. 4 S., R. 1 W., is subcircular in plan and covers an area of about one-eighth of a square mile. A 10-ft-wide rhyolite dike extends about 100 yd from the northern edge of the plug. One particularly interesting dike in NW¼ sec. 7, T. 4 S., R. 1 W., covers a large area, but is less than 100 ft thick. The northwest contact of this steeply dipping dike is exposed for several hundred feet downdip. The dike is lying against a steep hill of massive rhyolite, the massive rhyolite once present on the hanging wall side of the dike having apparently been removed.

The late rhyolite is a microporphyritic rock composed of anhedral to subhedral quartz and potash feldspar phenocrysts up to 0.5 mm across in a partly crystalline groundmass. Many of the quartz crystals have been deeply embayed by the groundmass. Both orthoclase and sanidine are present, but no plagioclase feldspar was observed. A striking feature of the rock is the presence of biotite crystals up to 3 mm across. Some smaller biotite flakes have been altered almost completely to magnetite. One small crystal (0.2 mm) of garnet was seen.

TABLE I. COMPOSITION OF THE MASSIVE RHYOLITE (Tmr)

Chemical Analysis

(By H. B. Wiik, Helsinki, Finland. August 31, 1952)

SiO_2	71.09	CaO	0.88
TiO_2	0.25	Na_2O	1.89
Al_2O_3	14.07	K_2O	6 19
Fe_2O_3	1.73	P_2O_5	0 09
FeO	0.32	H_2O+	2 20
MnO	0.08	H_2O-	0 95
MgO	0.71	CO_2	0 00
			100.45%

Norm

Quartz	33.5	Magnetite	0.5
Orthoclase	36.7	Hematite	1.4
Albite	16.2	Ilmenite	0.5
Anorthite	3.6	Apatite.	0.3
			97.4
Corundum.	2.9	H_2O+	2.2
Enstatite	1.8	H_2O-	1.0
			100.6%

Mode

Aphanitic groundmass	63.3	Oligoclase	6.1
Quartz	5.1	Biotite	1.6
Potash feldspar	23.9		
			100.0%

Latite (Tls)

Dikes of highly porphyritic, pinkish-gray latite intrude the massive rhyolite at the west end of Red Canyon. The largest of these dikes occurs just south of the canyon. It trends east-west for a distance of more than three-quarters of a mile and is about 25 ft thick. The total outcrop area of the latite dikes is about one-eighth of a square mile.

The latite is highly prophyritic and contains many large phenocrysts of glassy sanidine, commonly up to one-half inch across. Smaller crystals of plagioclase feldspar are also abundant. Quartz forms less than 5 percent of the rock. Laths of biotite, commonly up to one-fourth of an inch across, are scattered through the rock.

In thinsection, the light-pink groundmass of the latite appears as a micro-crystalline mass of plagioclase and potash feldspar crystals. The feldspars are in fairly equant grains and intimately intergrown. Some devitrified glass is present.

Tertiary and Quaternary Fanglomerate (TQf)

The consolidated sand, gravel, and clay, which forms broad, dissected alluvial fans in the Rio Grande Valley and fill in some of the higher intermontane valleys in New Mexico, has been referred commonly to the Santa Fe formation of late Miocene and early Pliocene age. Waldron (in preparation) reports the discovery of a tooth in these gravels, which was identified by V. L. Vanderhoof, formerly of Stanford University, as belonging to the genus Gigantocamelis, of upper Pliocene and Lower Pleistocene age. Waldron also reports that rhyolite is interlayered with the base of the Santa Fe formation in at least one nearby area.

Along U. S. Highway 60, the Santa Fe (?) consists predominantly of clay and appears to rest on rhyolite (Tbsr) and volcanic breccia (Tvb). North of the highway, the clay forms a mesa 600 ft high, which is capped by a basalt flow. On the east and west flanks of the Chupadera Mountains, the Santa Fe (?) fanglomerates are mostly covered by a veneer of younger sand and gravel. The Santa Fe (?) is exposed only at the east end of Nogal Canyon, where it is faulted down against older volcanics, and in the southwest part of the area, where it forms a mesa capped by a basalt flow. At both of these localities, it is composed of consolidated to semiconsolidated, well-stratified sand and gravel. The younger gravels that cover the Santa Fe (?) formation have been mapped with it, using the symbol TQf.

It seems evident that the Santa Fe (?) sediments covered the Chupadera Mountains almost completely at one time, because where remnants of the erosional-depositional surface formed on these gravels have been preserved by cappings of basalt, the surface is higher than nearly all the volcanic peaks. During Quaternary time, streams from the Magdalena Range flowed eastward over, these sediments, traversing the buried mountains on their way to the Rio Grande. Later, as the streams began degrading, they were superposed on the exhumed Chupadera Mountains. The steep-sided canyons in the resistant volcanic rocks were cut by these superposed streams.

Quaternary Basalt (Qb)

Quaternary basalt, clearly younger than at least part of the Tertiary-Quaternary fanglomerates, covers over 2 sq miles in the area. North of U. S. Highway 60, a basalt flow rests on clays of the Santa Fe (?) formation. These clays extend southward into the northern part of the Luis Lopez district, where they have been intruded by numerous basalt dikes. The dikes form prominent long, dark ridges. At the east end of Nogal Canyon, basalt forms a sill over 50 ft thick in sand and gravel of the Santa Fe (?) formation. In the southwest part of the area, a basalt flow caps fanglomerates, forming a mesa that is nearly equal in altitude to the highest peak of massive rhyolite (Tmr). A plug of basalt, 1 mile southwest of Box Canyon, has intruded the Santa Fe (?) formation and the older volcanics.

The basalt is a dark-black holocrystalline granular rock composed almost entirely of plagioclase, diopside, and olivine in nearly equant grains. The plagioclase (labradorite) occurs as laths up to 1 mm long and is frequently embedded **in** diopside, forming a diabasic texture. Most of the plagioclase and olivine grains are euhedral, whereas the diopside is subhedral to anhedral. Nearly all the olivine crystals have rims of iddingsite, some grains showing secondary formation of olivine around the iddingsite rim. Magnetite is abundant.

Alluvium (Qal)

The term alluvium is applied to Recent sand and gravel deposited in stream channels and to talus accumulations of Recent age.

STRUCTURE

The principal structural influences on the Chupadera Mountains have been (1) the emplacement of the massive rhyolite (Tmr) and (2) the faulting associated with the formation of the Rio Grande trough and the adjacent positive areas.

Within the Chupadera Mountains, much faulting and tilting of older volcanic rocks resulted from the intrusion of the massive rhyolite. Several faults extend radially from the area in Black Canyon believed to be the intrusive center for this unit, and there is a general outward tilt of the older volcanics away from this intrusive center, which is seen best in the northern part of the mapped area.

Later faulting, associated with the formation of the Rio Grande trough, is marked on the eastern front of the Chupadera Mountains by a north-south trending en echelon fault system. The faulting is well exposed at Nogal Canyon, where rhyolite (Trs) has been faulted against the Santa Fe (?) formation. In the northern part of the area, the eastern range-front faults are marked by scarps and a parallel fracture system in the massive rhyolite. It is believed that some faulting also took place on the west side of the Chupadera Mountains, but no direct evidence of such faulting has been found. However, these inferred faults may be covered by the gravels which fill the southern part of the Snake Ranch Valley trough (Big Basin). In the northern part of the range, additional movement probably took place along the fault lines that were formed during the intrusion of the massive rhyolite.

Faulting appears to have controlled in part the localization of the mineral deposits of the area. The movements probably caused the formation of the breccia zones in the massive rhyolite.

COMPOSITION OF THE VOLCANIC ROCKS

Although only one chemical analysis was obtained, that of the massive rhyolite (Tmr), it was possible, through the courtesy of the Raw Materials Laboratories of the U. S. Geological Survey, in Denver, Colorado, to obtain semiquantitative spectrographic analyses and radiometric analyses of a total of seven rock types occurring in the area. All the analyses are of nonfragmental rocks. Using these spectrographic analyses, it was possible to calculate the approximate normative composition of the rocks.

It may be helpful to explain the basis on which these analyses are reported. The percentages of metal oxides determined by spectrographic analyses are reported in logarithmic ranges. The range is indicated by an "x" placed at the decimal positior of the first significant figure. Thus, o.00x indicates that the exact figure is in the range 0.001 to 0.010 percent. Similarly, x.o indicates a range of 1.0 to 10.0 percent. Plus or minus signs are used to indicate logarithmic subranges (see table 3). A plus indicates that the value is in the upper part of the logarithmic range (e.g., o.ox+ indicates a value between 0.046 and 0.100). Similarly, minus signs indicate values in the lower part of the logarithmic range (e.g., o.ox- indicates a value of 0.010 to 0.022). When neither a plus nor a minus sign is added, the value is near the midpoint of the logarithmic range (e.g., o.ox indicates a value of 0.022 to 0.046). By this method, the results still are given in ranges, rather than specific values, but the probable values are defined more clearly. The subranges are small enough to make their midpoints useful for statistical treatment.

The validity of subrange assignments was tested by the spectrographers of the U. S. Geological Survey on a large number of samples. These tests indicate that subranges can be assigned correctly in two out of three cases. This average is for all 58 elements measured. However, for any given element, the accuracy of subrange assignments ranges from 50 to 100 percent.

The equivalent uranium values given are based on measurements of the radioactivity of the rock samples. The values are determined by assuming that all the radioactivity of the sample results from the decomposition of uranium and its disintegration products, and that no members of the thorium series or other radioactive elements are present. In addition, it is assumed that uranium and all its disintegration products are in radioactive equilibrium, i.e., each member of the uranium series disintegrating at exactly the same rate as it is being formed. Thus, these values are not actual measures of the uranium content of the rock, but rather a method of expressing the radioactivity of the rock in finite terms. No significant amounts of radioactivity were found in any of the rock samples tested.

Interpretation of the Analyses

Normative orthoclase, albite, and anorthite were calculated for each of the seven rock types analyzed spectrographically, using the midpoints of the subrange values reported for potash, soda, and lime, and making the assumption that the rocks are saturated with silica and alumina. This assumption is reasonable, especially since it was found to be true in the case of the one rock for which a complete chemical analysis is available. The normative values determined for the three minerals were plotted on a three-point diagram (fig 1).

TABLE 2. SEMIQUANTITATIVE SPECTROGRAPHIC AND RADIOMETRIC (eU) ANALYSES OF SEVEN VOLCANIC ROCKS FROM THE LUIS LOPEZ MANGANESE DISTRICT, SOCORRO COUNTY; NEW MEXICO*

"x" denotes decimal position of first significant figure in percent concentration.

	SAMPLES						
ELEMENT (1)	297-B-47 Tertiary (?) dark rhyolite (Tdr)	297-B-250 Tertiary (?) augite andesite (Tas)	297-B-229 Tertiary (?) rhyolite (Tr)	297-B-327 Tertiary (?) rhyolite (Trs)	297-B-82 Tertiary (?) massive rhyolite (Tmr)	297-B-138 Tertiary (?) late rhyolite (Tlr)	297-B-320B Quaternary basalt (Qb)
Fe	x.+	x.+	x.-	x.-	x.	x.-	x.+
Ti	o.x+	o.x+	o.x-	o.x-	o.x-	o.x-	o.x+
Mn	.ox	.ox+	.x-	.ox+	.ox	.ox	.x-
Ca	x.-	x.	.x-	.x+	.x+	.x-	x.+
Mg	.x	x.	.ox+	.x	.x	.ox+	x.+
Na	x.-	x.	x.-	x.-	x.-	x.-	x.-
K	x.+	x.-	x.+	x.	x.+	x.+	x.-
Ba	.x-	.ox+	.ox+	.ox+	.x-	.ox+	.ox+
Be	Tr. (2)	.ooox	.ooox	.ooox	.ooox	.ooox	0 (3)
Ce	.ox-	0	0	0	0	0	0
Co	.oox-	.oox-	.ooox	.ooox+	.ooox+	.ooox+	.oox
Cr	.oox+	.oox+	.ooox+	.ooox+	.ooox+	.ooox+	.ox-
Cu	.ox-	.oox+	.oox+	.oox+	.oox+	.oox+	.ox-
Ga	.oox-	.oox-	.oox-	.oox-	.oox-	.ooox+	.oox-
La	.oox+	.oox	.oox	.oox	.oox	.oox	0
Mo	.ooox+	.oox-	.oox-	.ooox+	.oox-	.oox-	0
Nd	.oox+	0	0	0	0	0	0
Ni	.oox	.oox+	.oox	.oox	.oox	.oox	.ox-
Pb	.oox+	.oox	.ox	.oox	.oox-	.oox	0
Sc	o.oox-	o.oox-	0	0	0	0	o.oox
Sr	.ox	.ox+	.oox	.ox-	.ox-	.oox+	.ox+
V	.ox-	.ox-	.oox	.oox	.oox+	.oox	.ox-
Y	.oox	.oox-	.oox+	.oox-	.oox-	.oox-	.oox-
Yb	.ooox	.ooox-	.ooox+	.ooox-	.ooox	.ooox-	.ooox-
Zr	.ox	.ox-	.ox-	.ox-	.ox-	.ox-	.ox-
eU(4)	0.005	0.001	0.003	0.004	0.004	0.004	0.001

Looked for but not detected: P, Ag, As, Au, B, Bi, Cd, Dy, Er, Gd, Ge, Hf, Hg, In, Ir, Li, Nb, Os, Pd, Pt, Re, Rh, Ru, Sb, Sn, Sm, Ta, Th, Tl, Te, U, W, and Zn.

(1) Elements are expressed as oxides
(2) Tr = near threshold amount of element
(3) 0 = looked for but not detected
(4) eU = radiometric, equivalent uranium percent

* Radiometric analyses by J. Fennelly; spectrographic analyses by R. G. Havens, U. S. Geological Survey.

Analyses made on behalf of the Division of Raw Materials of the Atomic Energy Commission.

TABLE 3. EXPLANATION OF SEMIQUANTITATIVE SPECTROGRAPHIC REPORTS IN TABLE 2, SHOWING RANGES WITH APPROXIMATE SUBRANGES AND MIDPOINTS

(U. S. Geological Survey, Raw Materials Laboratory, Denver, Colorado)

Semiquant. spectrographic report (%)	Range (percent)	Subrange (percent)	Midpoint of subrange (%)
xx.+	100	100 - 46	68.
xx.	to	46 - 22	32.
xx.-	10	22 - 10	15.
x.+	10	10 - 4.6	6.8
x.	to	4.6 - 2.2	3.2
x.-	1	2.2 - 1.0	1.5
.x+	1	1.0 - .46	.68
.x	to	.46 - .22	.32
.x-	.1	.22 - .10	.15
.ox+	.1	.10 - .046	.068
.ox	to	.046 - .022	.032
.ox-	.01	.022 - .010	.015
.oox+	.01	.010 - .0046	.0068
.oox	to	.0046 - .0022	.0032
.oox-	.001	.0022 - .0010	.0015
.ooox+	.001	.0010 - .00046	.00068
.ooox	to	.00046 - .00022	.00032
.ooox-	.0001	.00022 - .00010	.00015

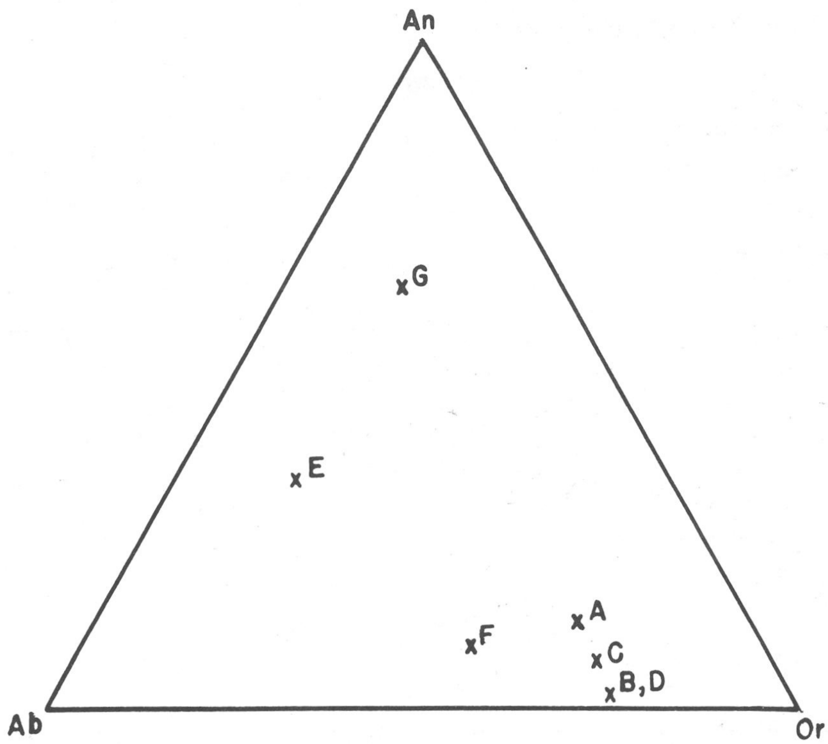


Figure 1.

Normative orthoclase - albite - anorthite diagram for volcanic rocks of the Chupadera Mountains

SAMPLES

A Dark rhyolite (Tdr)

B Rhyolite (Tr)

C Massive rhyolite (Tmr)

D Late rhyolite (Tlr)

E Augite andesite (Tas)

F Rhyolite (Trs)

G Basalt (Qb)

MANGANESE DEPOSITS

Location

Small manganese deposits are present throughout the area examined, but the largest deposits occur in the area underlain by the massive rhyolite (Tmr). Some deposits of commercial importance occur at Red Hill and in SE¼ and NE¼ sec. 12, T. 4 S., R. 2 W. The deposits at Red Hill are being mined by the Manganese Corporation of Arizona. The Gianera mine is located in SE¼ sec. 12, where a vein of psilomelane occurs. The vein averages about 11 ft thick and 400-600 ft in length, with a proven stopping depth of about 80 ft. The Tower Mining Company is mining in NE¼ sec. 12, in an extensive zone of mineralized brecciated massive rhyolite. Most, if not all, of the other properties in the area have not passed beyond the prospecting or early development stage.

History and Production

Occurrences of manganese in the Luis Lopez manganese district have been known for a considerable time (Wells, 1918, pp 79-91). The first recorded production took place during World War I, when about 100 tons of sorted ore containing 35 percent manganese was produced from the area covered by the present Red Hill and Red Hill Extension claims (Neuschel, 1943). Most of this ore came from a now inaccessible incline on the Red Hill Extension No. 4 claim.

Major production from the Red Hill claims began in 1944, when the United Mining and Milling Company constructed a 300-ton mill on the property. Later, the mine and mill were sold to the Socorro Corporation, and subsequently to Southwest Minerals Industries. Late in 1950, after a short period of operation by the latter company, the mill was badly damaged by fire, and the mine was closed down. In 1954, the mine was leased to the Manganese Corporation of Arizona. Mining was recommenced, and a new, large capacity mill was erected. This company purchased the property in August 1955.

Complete production figures for the Red Hill area are not available, but Benjovsky (1946, p 4) quoted the following for the operations of the United Mining and Milling Company up to November 19, 1946:

1944 .... 180 tons of concentrates with 44% Mn
1945 .... 3,500 tons of concentrates with 44-45% Mn
1946 .... 1,046 tons of concentrates with 45% Mn

Current production is variable. It is reported that more than 2,000 tons of ore per day is treated to yield a high-grade concentrate.

Development of other areas in the Luis Lopez manganese district was stepped up with the advent of the government purchasing program, in which premium prices are offered for manganese ores. Many new prospects were uncovered, and attempts were made to develop them; some of the older prospects were placed again in operation. The Tower and Gianera properties were developed under this program. The Tower mine is currently producing about 1,000 tons of low-grade (milling) ore per day. The Gianera mine is producing a small tonnage of high-grade ore per day. Previously, the only large-scale mining and milling operation in the area was the work on the Red Hill claims. Other deposits were being worked on a small scale with the object of recovering a product that easily could be handsorted into high-grade manganese ore. Although this type of mining is still going on, the Tower Mining Company and the Manganese Corporation of Arizona, the two largest producers in the area, are mining low-grade ores that are milled to yield a high-grade concentrate.

With the veto of the bill that would have extended the stockpiling program in August 1955, much of the prospecting in the area ceased. Only a few properties other than the producing mines mentioned are currently active.

Type of Deposits

All of the major manganese deposits discovered so far occur in breccia zones or steeply dipping fault zones in the massive rhyolite (Tmr) member of the volcanic sequence. Most of the faults and breccia zones have a general north to northwest trend, though some strike northeastward. The amount and direction of fault movement is generally indeterminate. The fault zones on the east side of the volcanic mass are normal faults that are downthrown on the east, following the general pattern of the faults bordering the Rio Grande depression. At many places, the amount of movement that caused the brecciation is not defined, though it is clearly not of great magnitude in some areas. Large quantities of commercial-grade (i.e., milling-grade or better) manganese ore are, in most cases, confined to fault-bounded blocks of brecciated rhyolite, with only very low-grade material outside these blocks.

Many small deposits containing manganese minerals in joints and small brecciated zones are located throughout the massive rhyolite and in the late rhyolite (Tlr) plug in the northwestern part of the area. One deposit, located along the contact between massive rhyolite and earlier rhyolite (Tbr) in the southeastern part of sec. 1, T. 4 S., R. 2 W., consists of a vein approximately 2 ft wide exposed vertically for a distance of 20 ft.

Reserves

Reserves of low-grade (milling) ore at the Tower and Manganese Corporation of Arizona properties probably are quite large, but no data for accurate estimates were available.

No estimate of the reserves of the Gianera property was made. Reserves of most other prospects are confined to such ore as may be in sight, as exploration has not progressed to the extent that reliable estimates can be made.

Mineralogy

The only prominent ore mineral in the Luis Lopez manganese district is a hard black manganese oxide identified as psilomelane from an X-ray powder diagram made by Dr. Ming-Shan Sun, of the New Mexico Bureau of Mines and Mineral Resources. The mineral occurs in massive or colloform layers or coatings on fragments of massive rhyolite in the brecciated zones. The layers may be as much as several inches thick, but more often the mineral is present only as a thin, paintlike film on the rhyolite fragments. Where the breccia fragments are closely spaced, several of the col loform layers may come together to yield a rather large mass of fairly pure manganese mineral. In most cases, the mineral has been deposited in open spaces. The manganese minerals apparently do not replace the country rock.

At some places, a felty black material is present on the surface of the hard black psilomelane. X-ray analysis of the felty material indicates that it also is composed chiefly of psilomelane, in spite of its marked resemblance to pyrolusite.

Black calcite is commonly present, but at most places is not nearly so abundant as the psilomelane. The vein in the southeastern part of sec. 1, T. 4 S., R. 2 W., however, is made up almost entirely of black calcite. In every case where the paragenetic relationships of the two minerals could be determined, the black calcite was younger. The calcite occurs in masses of crystals that are as much as one-half inch across and intimately intergrown. Dr. Brian Mason, formerly of Indiana University, made an X-ray analysis of the black residue obtained by leaching the black calcite with acetic acid. The residue is chiefly psilomelane.

Small irregularly shaped masses of a light-gray mineral with distinctive internal reflection were observed in polished sections of the black calcite. Although the masses were too small to be identified by etch tests, some were isolated and tested by microchemical methods. The potassium mercuric thiocyanate test described by Short (1940, p 187) showed the presence of zinc in repeated applications. Spectrographic analysis showed small amounts of zinc to be present in the residue obtained by leaching with acetic acid. It is thought that zinc-containing mineral is a carbonate, because of the fact that after the acetic acid leach it is present in the residue only in small amounts.

White, coarsely crystalline calcite is a prominent mineral in the manganese deposits. It is present commonly as massive crystal growths on masses of black calcite and as veinlets cutting masses of black calcite. From these relations, it is inferred that the white calcite is younger than the black calcite and, therefore, also younger than the psilomelane.

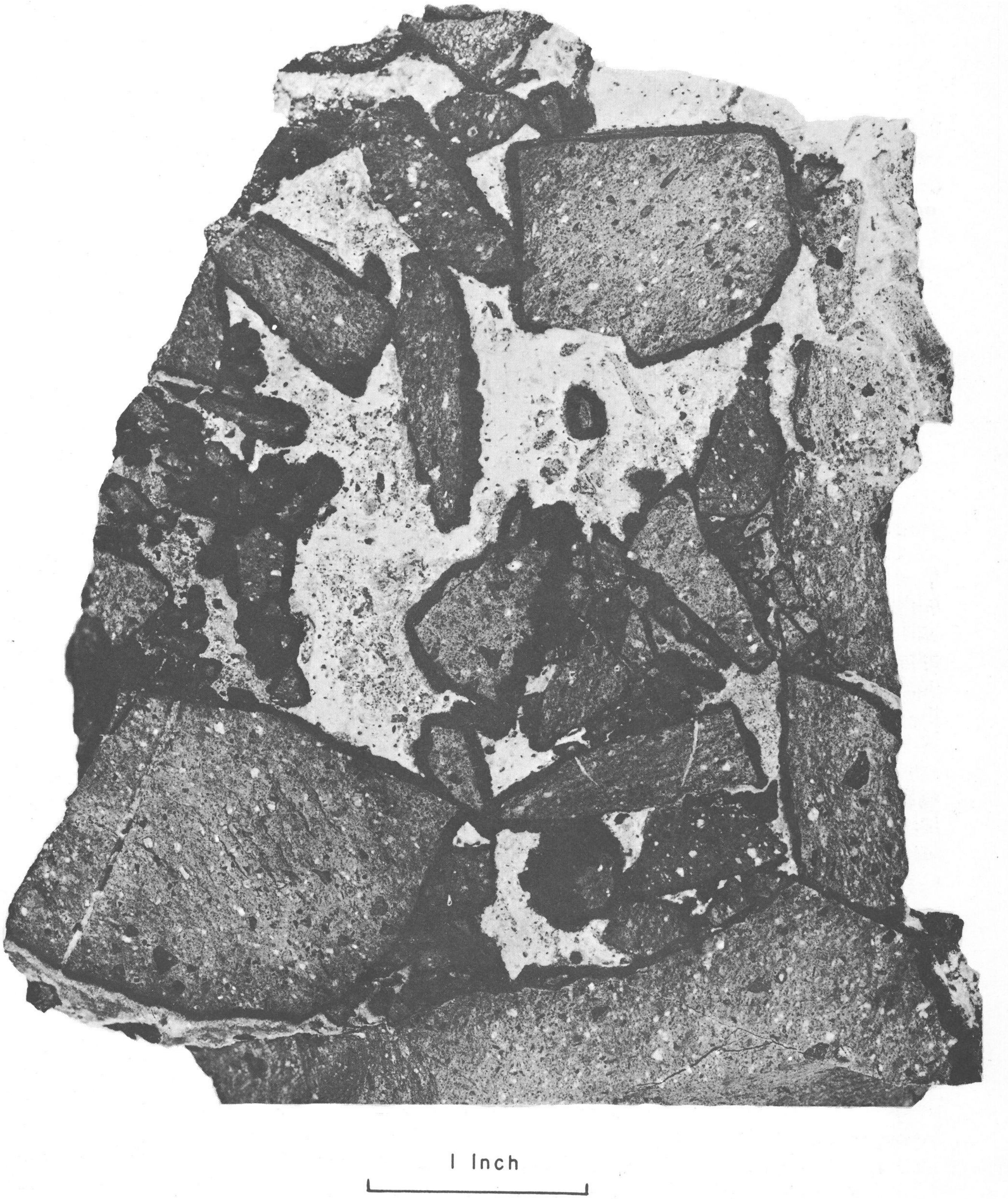


Plate 2

Manganese-bearing breccia from a point just east of the MCA mine. Thin, black coatings of manganese oxides surround the breccia fragments. At lower left, later calcite covers the manganese oxides. The gray cement is calcite and some silica, with scattered small fragments of ground-up rhyolite. At places in the breccia ore, the manganese coatings are as much as 4 in. thick.

Finely crystalline to microcrystalline milky-colored quartz occurs in the manganese deposits and is younger than the manganese minerals. Its relationship to the calcites could not be determined. The quartz is present as fillings of open spaces between fragments of massive rhyolite breccia and as a cement binding fragmental psilomelane and massive rhyolite. It is evident that some brecciation of the ores took place after the deposition of the manganese minerals and before the introduction of the quartz.

Barite also has been observed in the deposits. It is younger than psilomelane, but its relation to other minerals was not determined.

Origin of the Ores

The ores of the Luis Lopez manganese district are thought to be hydrothermal in origin. The mineralization does not appear to die out at shallow depth (some mining has been carried on as much as 200 ft below the outcrop), and ore occurs at various topographic levels. No systematic relation to the present topography is apparent. There is no known source from which descending solutions might have derived the manganese necessary for the formation of these deposits. It is possible that the ore-bearing solutions may have been warm emanations associated with the last stages of eruptive activity. The occurrences of psilomelane deposits in a brecciated plug of late rhyolite and a dike of late rhyolite are considered to be suggestive evidence in favor of the association of the hydrothermal solutions with a later eruptive epoch. The fact that some manganese mineralization occurs in the gravels of prebasalt and postlate rhyolite age also points to such a conclusion. It is possible that the ore-bearing solutions may have been associated with the eruption of the Quaternary basalt, but may not have been related to any specific eruptive event.

The brecciation and faulting associated with the ore deposits controlled the localization of the ore minerals. This brecciation and faulting must have taken place after the emplacement of the massive rhyolite, and probably also after the late rhyolite, though some of it may have been associated with The of the latter. Minor brecciation and fracturing of the ores indicates that movements continued in some areas after the mineralization took place.

Psilomelane is generally regarded as a supergene mineral (Palache, Berman, and Frondel, 1944). However, it is believed that the psilomelane deposits in the Luis Lopez manganese district are hypogene in origin. Both the psilomelane and the host rock are unleached and unweathered in most cases. There is no evidence that the psilomelane replaces any other mineral. On the contrary, psilomelane is the earliest deposited mineral in the deposits examined. One concludes, therefore, that although psilomelane often occurs as a supergene mineral, in these deposits it is hypogene.

The deposition of manganese from hot waters of a thermal spring near Delta, Utah, has been described by Callaghan (1939), who also cites other examples of manganese in thermal springs. Callaghan does not regard the spring as necessarily having an igneous source, but writes that such a source of manganese and barium cannot be eliminated.

The manganese deposits of the Talamantes district near Parral, Chihuahua, Mexico (Wilson and Rocha, 1948), bear a striking resemblance to the deposits in the Luis Lopez manganese district. There, manganese oxides, including psilomelane, cryptomelane, hollandite-cryptomelane, and coronadoite occur in brecciated zones along faults. Trask and Cabo (1948, pp 218-221) indicate that many deposits in Chihuahua and Sonora follow the same general structural and mineralization pattern. The mode of occurrence in the Talamantes district is described as follows (Wilson and Rocha, 1948, p 193):

> "Most of the manganese deposits of the Talamantes district occur in brecciated zones along faults. Manganese oxides occur as veinlets, irregular nodular bodies, and irregular masses surrounding rhyolite fragments of the breccia. About half of the volume of the breccia zones is composed of fragments of wall rock. The manganese oxides have filled open spaces and probably replaced the matrix of the breccia, but the rhyolite fragments show very little evidence of replacement. In many places narrow stringers of manganese oxide extend from the brecciated zones into the bordering wall rock. In some places fairly well defined veins of manganese oxide having definite walls occur along fissures not accompanied by breccia zones. These veins are much thinner, however, than the breccia deposits. . . .
>
> The faults along which the veins occur have dips ranging from vertical to 60° E. or W. The average strike is a few degrees west of north, but the strike ranges to slightly east of north."

The evidence, according to these writers (ibid., p 200), suggests that the deposits may be hypogene, but is insufficient to justify definite conclusions.

A situation in which manganese minerals are thought to have been deposited directly as oxides has been described by Park and Cox (1944, pp 316-317) in the Sierra Maestra region in Cuba:

> "The manganese is thought to have been carried in warm waters emitted during the dying stages of the Sierra Maestro volcanism. . . .

> Manganese-bearing solutions rose in channels through the porous volcanic rocks and deposited their mineral loads where structural and chemical conditions were favorable. . . . Manganese minerals were also deposited among permeable conduits, such as fault zones and fissures. . . . It is likely also, that enough oxygen, and locally enough silica, were present to form oxides or silicates of manganese. Oxygen might well be abundant or at least readily available under.. . near surface conditions of deposition, such as are postulated for the formation of the ores. . . . It is concluded that manganese oxides and silicates were deposited directly from warm waters. . . ."

The mineralogy and volcanic conditions at the Sierra Maestra deposits are similar to the mineralogy and volcanic conditions in the Luis Lopez manganese district.

The manganese deposits of the Luis Lopez manganese district are thought to have originated through the agency of fairly cool thermal solutions associated with the last part of the volcanism in the Chupadera Mountains. It is believed that the manganese minerals were deposited directly as oxides, in association with calcite, some silica, and barite.

BIBLIOGRAPHY

Benjovsky, T. D. (1946) A report of the United Mining and Milling Company manganese mine, Red Hill district, Socorro County, New Mexico, unpubl. rpt., New Mexico Bur. Mines and Min. Res., 6 pp.

Callaghan, E. C. (1939) Manganese in a thermal spring in west-central Utah, Econ. Geology, v 34, 905-920.

Lasky, S. G. (1932) The ore deposits of Socorro County, New Mexico, N. Mex. School of Mines, State Bur. Mines and Min. Res., Bull. 8, 118-133.

Mathews, W. H. (1951) A useful method for determining approximate composition of fine grained igneous rocks, Am. Mineralogist, v 36, 92-101.

Mielenz, R. C., King, M. E., and Schieltz, N. C. (1950) "Staining tests," in analytical data on reference clay minerals, Am. Petroleum Inst., Project 49, Prel. Rpt. n 7, 138.

Miesch, A. T. (1952) Application of method suggested by W. H. Mathews for determining approximate composition of fine-grained igneous rocks to rocks of the Datil volcanic area, New Mexico, unpubl. rpt., N. Mex. Bur. Mines and Min. Res.

Neuschel, S. K. (1943) Four manganese claim groups near Socorro, New Mexico, unpubl. rpt., U. S. Geological Survey, 6 pp.

Palache, C., Berman, H., and Fronde!, C. (1944) Dana's system of mineralogy, v 1, 669, New York, John Wiley & Sons, Inc.

Park, C. F., Jr., and Cox, M. W. (1944) Manganese deposits in part of the Sierra Maestra, Cuba, U. S. Geol. Survey Bull. 935-F, 315-317.

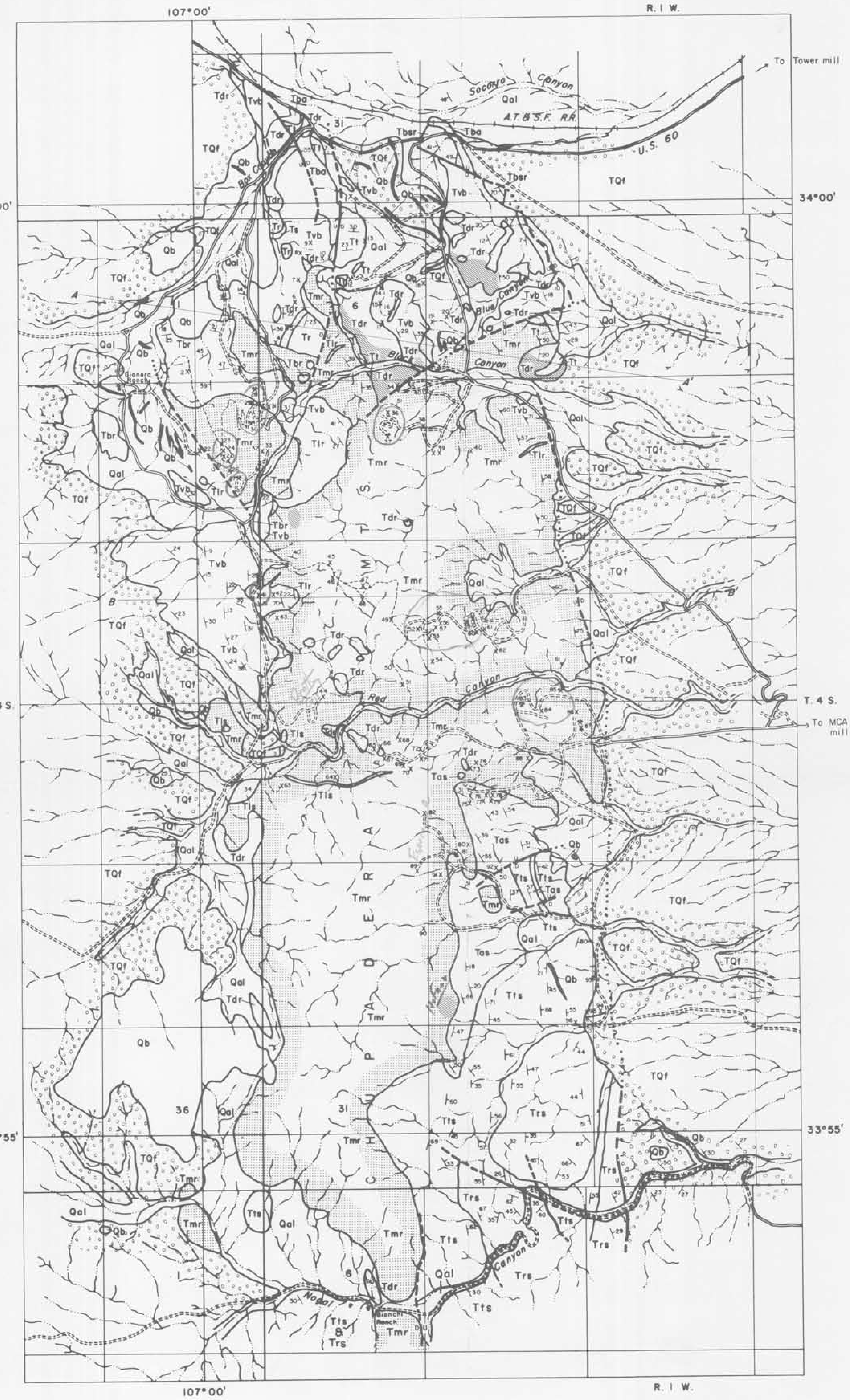
Short, M. N. (1940) Microscopic determination of the ore minerals, U. S. Geological Survey Bull. 914, 2nd ed., 311 pp.

Trask, P. D., and Cabo, J. R., Jr. (1948) Manganese deposits of Mexico, U. S. Geol. Survey Bull. 954-F, 209-315.

Waldron, J. F. (in preparation) Geology and ground-water resources of a part of Socorro County, N. Mex. Bur. Mines and Min. Res.

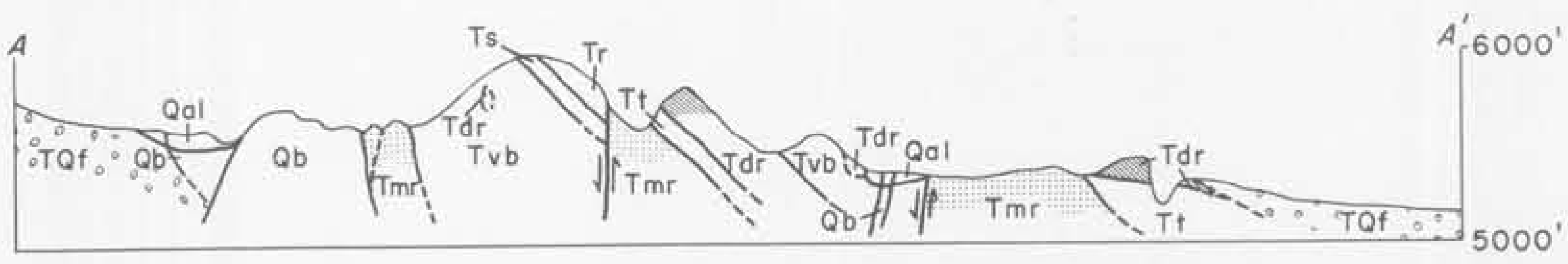
Wells, E. H. (1918) Manganese in New Mexico, N. Mex. School of Mines, Mineral Res. Survey Bull. 2, 85 pp.

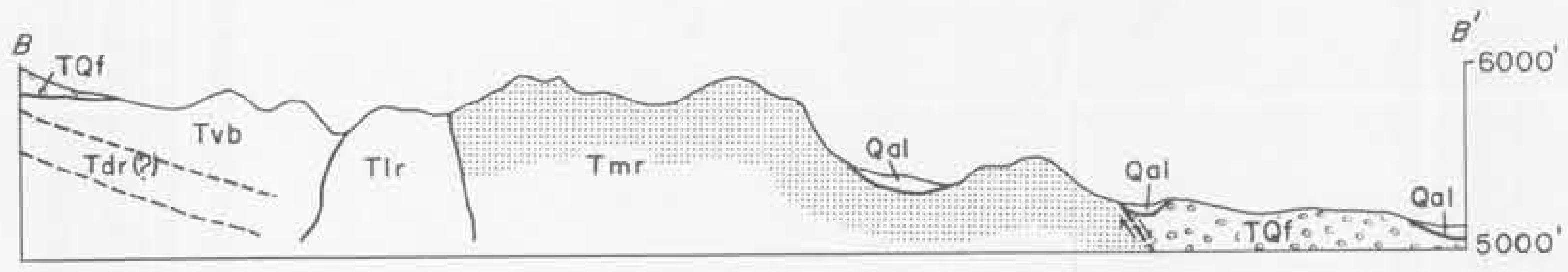
Wilson, I. F., and Rocha, V. S. (1948) Manganese deposits of the Talamantes district near Parral, Chihuahua, Mexico, U. S. Geol. Survey Bull. 954-E, 181-208.



Base map from U.S. Soil Conservation Service sheets 296 and 297.

Geology by A.T. Miesch, Indiana University, 1952.





Index Map showing location of area mapped.

EXPLANATION

QUATERNARY

- Qal — Alluvium
- Qb — Basalt (plugs, dikes, sills)
- TQf — Fanglomerate

TERTIARY

- Tlr — Late rhyolite (plugs, dikes)
- Tmr — Massive rhyolite
- Tr — Rhyolite
- Ts — Sandstone
- Tbsr, Tvb, Tba, Tbr — Volcanic breccia (Tvb), with interlayered units of spherulitic rhyolite (Tbsr), porphyritic andesite (Tba), and rhyolite (Tbr)
- Tdr — Dark rhyolite (flows, dike)
- Tt — Tuff

Southern part of area

- Tls — Latite (dikes)
- Trs — Rhyolite
- Tas — Augite andesite (flow, dike)
- Tts — Tuff

Strike and dip of beds (33)

Strike and dip of joints (50)

Geologic contact

Fault (showing dip) (dashed where inferred) (dotted where concealed)

Manganese mine (21)

Manganese prospect (x 60)

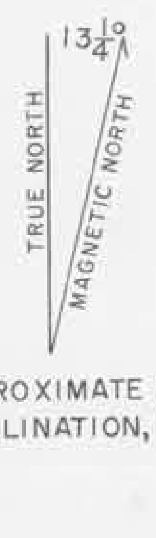
Silicified rock

Paved road

Improved dirt road

Unimproved dirt road

Trail



APPROXIMATE MEAN DECLINATION, 1952

PROSPECT AND MINE NUMBERS

1-2	Prospect pits
3	Old mine tunnels
4-11	Prospect pits
12	Development pit
13-22	Prospect pits
23	Development pit, some ore mined.
24-26	Prospect pits
27	Gianero mine
28	Barrett mines
29	Old mine tunnel
30	Tower mine (open pit)
31	Development pit
32	Bulldozer cut
33	Old mine tunnel
34	Bulldozer cut
35	Prospect pit
36-37	Bursum mine
38-40	Prospect pits
41	Torres mine
42-43	Prospect pits
44	Development cuts
45-51	Prospect pits
52	Development cut
53-56	Prospect pits
57	Development cut
58-59	Prospect pits, some ore mined
60	Development cut
61	Prospect pit
62	Development cut
63-68	Prospect pits
69	Development pit some ore mined
70-71	Prospect pits
72	Development pit, some ore mined
73-75	Prospect pits
76	Development pit
77	Prospect pit
78	Development pit, some ore mined
79-82	Prospect pits
83-85	Open pit mines
86-87	MCA mine (open pits)
88-89	Prospect pits
90	Development shaft
91-96	Prospect pits

Note: Prospect pits may be drilled and blasted or simply bulldozed pits. Nearly all are small. At development pits considerable effort has been expended to find mineable ore. Mines are areas where active ore removal and sale has taken or is taking place.

Scale: 1/31,680

½ 0 1 MILE

GEOLOGIC MAP AND SECTIONS OF THE LUIS LOPEZ MANGANESE DISTRICT, SOCORRO COUNTY, NEW MEXICO