A NORTHERN EXTENSION OF THE MAGDALENA MINING DISTRICT
SOCORRO COUNTY, NEW MEXICO

by

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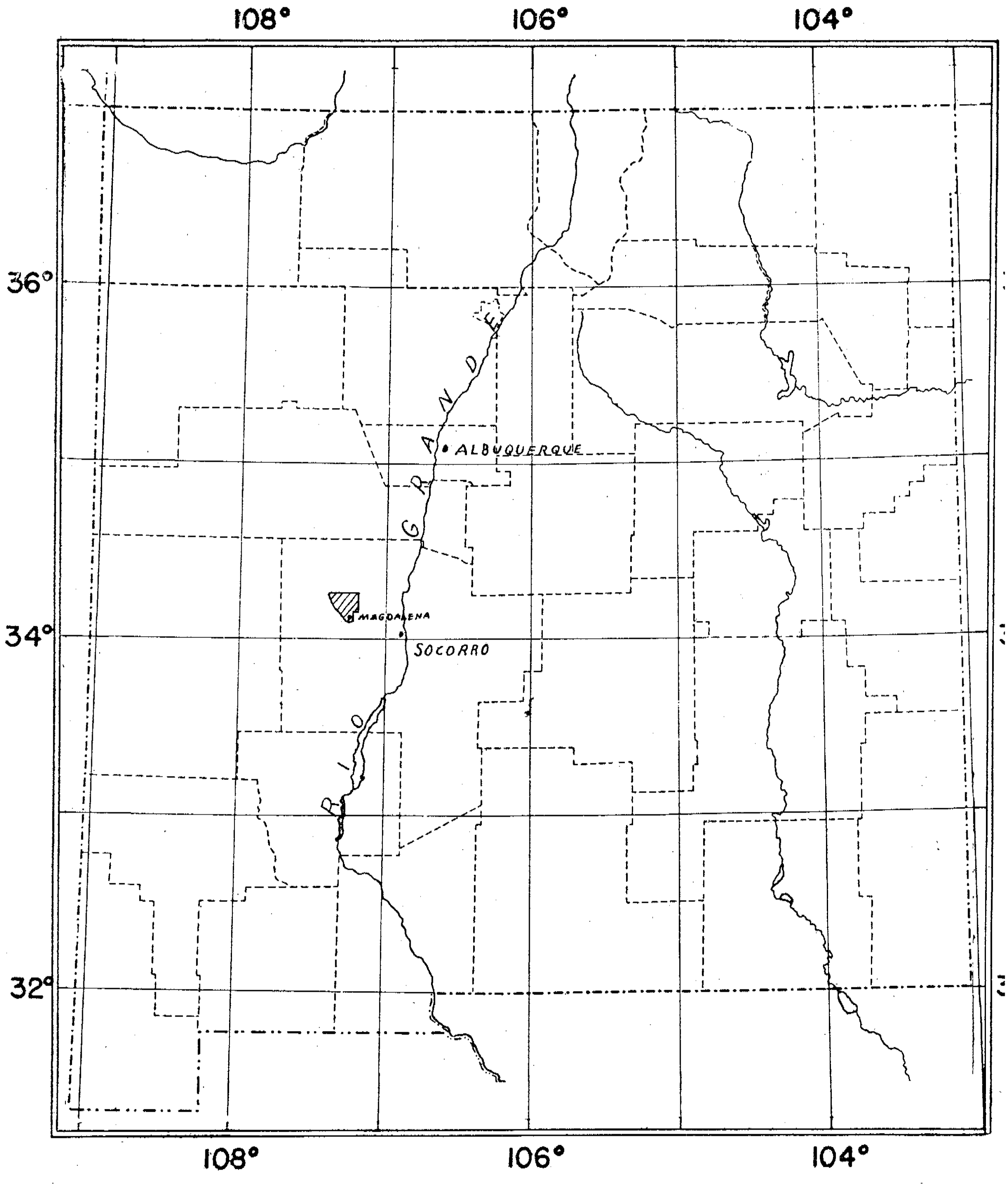
CONTENTS

CONTENTS

Illustrations

Fig. 1



Index map showing location of the North Magdalena area.

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Abstract

The area of this report includes the town of Magdalena, New Mexico, the northern end of the Magdalena Mountains and the southern end of the Bear Mountains.

A three thousand foot sequence of Tertiary rhyolite, latite, andesite and basalt is presumably underlain by sediments ranging in age from Carboniferous to Cretaceous. Surface exposures of sedimentary rocks consist almost entirely of unconsolidated alluvial material of Quaternary and Recent age.

The dominant structural development is block faulting typical of the Sonoran-Chihuahua system and similar to that of the Basin and Range system. Faulting, which apparently began in Laramide time and continued to the present, is believed to be the result of stresses caused by the uplift of the neighboring Colorado plateau.

Introduction

Location and Accessibility

The area covered in this report lies partly within the boundaries of the Magdalena division of the Cibola National Forest and includes parts of three townships: T1S R4W, T1S R5W, and T2S R4W New Mexico Prime Meridian and Base. The town of Magdalena, and U. S. Highway 60, mark the southern limit of the area. The western boundary is along New Mexico state road 52. On the north the area joins the Puertecito quadrangle; and on the east it is bordered by the Snake Ranch Flats. The south-eastern corner joins the Magdalena District Geologic Map (Loughlin and Koschmann, 1942) at Granite Mountain. The area mapped is roughly triangular in shape and includes approximately fifty square miles.

U. S. Highway 60 is a hard-surfaced, all weather road which carries a large volume of East-West traffic throughout the year. New Mexico state road 52, an unsurfaced but well maintained road, forms the western boundary of the area. There are two other unpaved roads into the area. Unlike state 52 these are poorly maintained and frequently impassable by automobile. One of these is the road which goes northward from Magdalena along the eastern edge of the area mapped to the town of Riley; the other connects the Three Mile and Bear Springs ranches in the northern part of the area with state road 52.

Magdalena is the western terminus of a twenty-eight mile Atchison, Topeka and Santa Fe Railroad branch line which originates at Socorro. The branch line was built during the active days of the Magdalena mining district for the purpose of transporting ore to smelters in Socorro or more distant points. Since the cessation of mining activity, Magdalena has survived primarily as a shipping point and supply center for a large cattle grazing area extending nearly 100 miles westward from the town. At present there are two sawmills located in Magdalena which handle timber cut from the mountains to the west. The growing lumber industry ranks second economically to cattle raising, the leading industry of the region.

Purpose and Scope

The geologic investigation of the area included in A Northern Extension of the Magdalena Mining District was conducted with a dual objective in mind. Firstly it was desired to attempt a correlation between the Tertiary volcanic sequence of the Magdalena mining district and the Tertiary volcanic sequence of the Datil Mountains to the northwest. Secondly it was believed that a detailed investigation of the geology might cast some light on the possibilities of further discoveries of ore bodies adjacent to the mining district.

Field work was begun in the spring of 1954 and continued intermittently through the following summer and fall with the greater portion of the work being done during the summer. Field measurements were made with a Brunton Pocket Transit and the field data plotted on vertical aerial photographs having a scale of approximately two miles to the inch. These photographs were taken several years ago for the use of the Soil Conservation Service and are of rather poor quality. Many pictures give the appearance of having been taken after a heavy snow fall. An unpublished planimetric sheet, also a product of the Soil Conservation Service, was used as a base map. Information was transferred from the photographs to the base map with the aid of a Vertical Sketchmaster.

Topography and Drainage

Topography throughout the area is rugged and picturesque. Elevations range from 6200 feet along La Jense Creek to maximum elevations of 7200 - 7300 feet at Granite Mountain and in the southern end of the Bear Mountains. Maximum topographic relief is approximately 1000 feet and the average relief is approximately half as great. The topography strongly reflects the structure of the area which is of the Basin and Range type consisting of block-faulted and tilted parallel mountains separated by alluvium filled valleys. Slopes of thirty degrees and more are common both on the faulted sides and the dip slope sides of the mountains. Granite Mountain and the other features are separated from the main Magdalena range by the northeast trending valley which connects the

Plains of San Augustin with the Snake Ranch Flats.

The present surface shows evidence of at least four periods of uplift and erosion. The earliest erosion surface is represented only by scattered remnants which include the tops of Granite Mountain and the Bear Mountains. A second uplift is indicated by the surface outlined by the tops of the hills which form the eastern border of the area and terrace remnants on the mountain slopes. A third erosional surface is formed by the pediments and alluvium around Granite Mountain and throughout the area. The most recent uplift is represented by arroyos cut in the alluvium. A more detailed study of the topography and physiography might reveal the presence of additional erosion surfaces.

The erosion surfaces described above were recognized and studied in considerable detail by Loughlin and Koschmann (1942). It is possible that these surfaces were produced by local lowering of base level and climatic changes rather than by actual uplift.

There are no perennial streams in the area. Wells and tanks which collect runoff from snow and rain are the only sources of water. The area is drained by La Jenze Creek, which originates in the Gallina Mountains some fifteen miles northwest of Magdalena; La Jenze Creek flows across the area in an easternly direction, passing to the north of Granite Mountain and turns northeastward across the Snake Ranch Flats to join the Rio Salado, which in turn drains into the Rio Grande a few miles north of Socorro. Tributaries of La Jenze Creek may be divided into three general types. First are the arroyos in the alluvium which have no apparent structural control. Second are the generally north-south trending drains which occupy fault valleys or troughs. The third type are remnants of an older pre-uplift drainage pattern which have become entrenched and have a cross-cutting relation to the present structure. Drains of the latter type trend east-west and are most prominent along the eastern edge of the area where they have cut several watergaps through the hills which separate the area from the Snake Ranch Flats; if the term watergap can be properly applied to features carved by streams which so seldom contain water.

Flora and Fauna

The north Magdalena area is located in the Upper Sonoran life zone. The alluvium covered flats are characterized by prickly pear and Cholla cactus and the Yucca plant or Spanish Bayonet along with smaller desert type plants. The largest trees in the area are the pinyon or nut pine and juniper, both of which seldom exceed fifteen feet in height. Although the trees are not large enough to be of interest to the lumbering industry they are of local importance as a source of firewood and fence posts. Scattered patches of grass, including the short bluestem or buffalo grass, provide grazing for a limited quantity of livestock.

That part of the area which is included in the Cibola National Forest is also a state game preserve, well populated by a variety of wildlife. Deer are numerous and smaller game animals including jackrabbits and cottontail rabbits are abundant throughout the area. Ground squirrels and other small burrowing mammals, all known collectively in the southwest as gophers, are very common. The abundance of small mammalian life has attracted a varied and interesting assembly of predatory bird life. Redtailed and golden hawks are conspicuous by their brillant plumage. Monkey-faced owls are especially numerous just west of Granite Mountain where they inhabit the abandoned mine workings and deep prospect pits; and a few Mexican eagles are to be found in the extreme elevations of the area where they nest on the most inaccessible ledges.

Climate

The climate of the area is famous for its mildness and extreme temperatures are encountered only in mid-summer and mid-winter. During mid-summer the unpleasant effects of extreme temperature are usually cancelled or greatly relieved by the low humidity and prevalent breezes. Rainfall is concentrated during the months of July and August and at that time daily showers of short duration along with occasional cloud bursts may be expected during the afternoons. Rainfall during the summer of 1954 was unusually heavy and considerably hampered field work by making much of the area inaccessible by automobile.

Previous Work

During their investigation of the Magdalena mining district, G. F. Loughlin and A. H. Koschmann reconnoitered the area of this report and commented in their paper (Loughlin and Koschmann, 1942) that certain units present in the mining district extended to the north and west beyond the district. The area has been extensively prospected, first for silver and again for lead-zinc ores during the active days of the mining district and in recent years for uranium. The rocks of the area have not been previously differentiated and no detailed geology of the area has been published.

The Puertecito quadrangle, which joins the north Magdalena area on the north, was investigated by Tonking (1952), but the results of that investigation have not been published. That part of the Puertecito quadrangle which is located along the Rio Salado was investigated by D. F. Winchester in 1920. His report was published in U. S. Geological Survey Bulletin No. 716; 1932, under the title of "The Geology of the Alamoso Creek Valley". Alamoso Creek is now known as the Rio Salado.

Acknowledgements

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Geology

The geologic formations exposed in the north Magdalena area comprise two main groups - extrusive and intrusive igneous rocks of Tertiary age; and unconsolidated sediments of Quaternary and Recent age. Sediments older than Quaternary have been recognized in only two places -- Cretaceous(?) sandstone on the west side of Granite Mountain and Santa Fe conglomerate in the extreme north-western corner of the area.

Sedimentary Rocks

Cretaceous (?) sandstone

On the west side of Granite Mountain there is an exposure covering approximately eighty acres of medium grained, buff to light brown massive sandstone. The exposure is on the boundary between the area covered by the Magdalena Mining District Map (Loughlin and Koschmann, 1942) and the area of this report. Loughlin and Koschmann considered the sandstone to be of probable Tertiary age. The sandstone outcrop lies between exposures of granite on the east and latite on the west. Although the actual contacts are covered by pediment gravel, the sandstone appears to be one or possibly two float blocks included in the latite. The isolated position and absence of distinguishing features in this outcrop make it impossible to assign it to any definite stratigraphic horizon. The attitude of the sandstone could not be determined.

It can be stated with assurance only that the sandstone is older than the enclosing latite, i.e. Miocene or older. It is, however, lithologically dissimilar to any known Tertiary sediments in the surrounding region and in the opinion of the present writer is not younger than Cretaceous.

In thin section the rock is seen to consist of a mosaic of irregular quartz grains which are uniform in size and approximately 0.5 millimeters in diameter. Originally the rock consisted of well rounded grains, but secondary silica has in most cases grown in optical orientation with the original grains to form the present mosaic texture. The secondary silica is distinguished from the original material by the inclusion of scattered dust sized particles of hematite which increase in frequency outward from the grain centers and are most numerous at the contact between individual grains. To a lesser extent the interstitial spaces have been filled by a very fine mosaic of secondary quartz, in which cases the original texture can be more easily seen.

Santa Fe formation

In the northwest corner of the north Magdalena area beginning in the NW¼ of section T1S R5W and extending approximately two miles northeastward along a tributary of La Jenze Creek there is a sedimentary exposure which is here assigned to Santa Fe formation. The sediments are exposed only in the stream bed where it has eroded beneath the pediment gravel. The vertical extent of the exposure ranges from four to six feet and it is seldom more than ten feet wide. The beds have no measurable dip and are believed to be flat-lying or nearly so. About three miles to the north the Santa Fe formation is exposed over a considerable area of the Puertecito Quadrangle and is believed to underlie most of the pediment west of the Bear Mountains (Tonking, 1952).

The Santa Fe outcrop consists of a conglomerate of pebbles and cobbles up to four inches in diameter in a matrix of poorly sorted sandstone. The pebbles are well rounded and contain a variety of igneous rock types. Interbedded with the conglomerate are irregular thin (1 - 3 feet) lenses of buff colored, fine-grained tuffaceous sandstone. The extreme southern end of the outcrop is composed almost entirely of pumice. There is a lense of grey pumice sandstone composed of about 80 per cent white pumice grains averaging one millimeter in diameter with smaller grains of reddish quartz and small flakes of biotite. Another pumice lens is made up of white angular pumice fragments one half to one inch in diameter cemented together by a matrix of buff colored silty material. The Santa Fe formation in this section of New Mexico is considered to be upper Miocene or Pliocene in age (Tonking, 1952).

Quaternary sediments

The unconsolidated Quaternary and Recent sediments may be separated into four types - - talus; pediment gravel; alluvium and recent stream deposits. Alluvium and pediment gravel deposits are by far the most numerous and the volume of talus and recent stream deposits is by comparison negligible. The primary purpose of this investigation was to differentiate and correlate the volcanic rocks of the area and therefore in the mapping a detailed subdivision of the unconsolidated sediments was not made. Only alluvium and pediment gravel are shown on the map.

The material mapped as pediment gravel is essentially the same as the alluvium. Except in those places where a pediment surface is exposed beneath the gravel it is not possible to distinguish between the two. Deposits of talus are found beneath the steeper slopes and consist of angular fragments which have been moved by gravity from the slopes above. The recent stream deposits consist of sand to boulder size material and are restricted to the bed of La Jenza Creek and its larger tributaries.

Alluvium is found throughout the area at all but the highest elevations. It probably reaches the greatest thickness along U. S. Highway 60 which is in a down-faulted area. The alluvial material ranges in particle size from sand to boulder and represents all degrees of roundness. It contains representatives of all the known rocks of the surrounding area as well as many which have not been recognized in the vicinity. In some places the alluvium is roughly stratified but for the most part it is unsorted. It rests unconformably on the tilted and folded volcanic sequence.

Tertiary Extrusive Rocks

The greatest bulk of the rocks exposed in the north Magdalena area are andesites, latites and rhyolites of Tertiary age which reach a minimum thickness of 2500 to 3000 feet. At no place in the mapped area is the base of the volcanic sequence exposed nor is there a complete exposure of any unit within the sequence. The total thickness therefore probably exceeds the minimum figure by at least several hundred feet. The Tertiary volcanics have been differentiated into four units all but the youngest of which have been correlated with the volcanics of the Magdalena mining district and the unit names proposed by Loughlin and Koschmann (1942) are used in this report.

Of the ten Tertiary extrusive units reported from the mining district (Loughlin and Koschmann, 1942) only three have been recognized in its northern extension. These represent both the older and younger sequence. Loughlin and Koschmann in their investigation of the mining district (1942) found that the youngest sedimentary formation underlying the volcanics is the Abo formation of upper Permian age. No more precise evidence for dating was found and the volcanics were mapped as Tertiary (?) in age. In the north Magdalena area the base of the volcanic sequence is not exposed, neither is it in contact with any sedimentary (other than Quaternary and Recent) formation of known age. In order to establish the age of the volcanics it has been necessary to search for evidence outside the area. The writer has correlated the volcanics of the north Magdalena area with the Datil formation of the Puertecito quadrangle which joins it on the north. In the Puertecito quadrangle the Datil formation has been reported to overlie unconformably the Baca formation of upper Cretaceous(?) to Eocene (?) age which in turn disconformably overlies the upper Cretaceous Mesaverde formation (Tonking, 1952). Tonking also reports inter-tounging between the upper part of the Datil formation (La Jara Peak member) and the Santa Fe formation which is upper Miocene and Pliocene. In light of this evidence the Tertiary age of the volcanics appears to be well established and in the opinion of this writer there is no longer need to affix the (?) previously used in referring to them. Although there are unconformities within the volcanic sequence these are believed to represent tectonic activity of relatively short duration rather than extended periods of erosion and the various units of the sequence are considered therefore to be of approximately the same age.

Upper Latite

The oldest member of the Tertiary volcanic sequence which is exposed in the north Magdalena area is the upper latite.

It outcrops in the low hills north of Magdalena from Granite Mountain on the east to about two miles west of town. North of Granite Mountain it makes up the whole of Nipple Mountain and is present in a narrow discontinuous line of outcrops along the eastern edge of the area into the Puertecito quadrangle.

The base of the latite is not exposed within the area. On the east slope of Granite Mountain, just east of the area mapped, it overlies the lower andesite in conformable contact and on Stendel ridge to the south it lies unconformably on the Pennsylvanian Sandia formation (Loughlin and Koschmann, 1942). In the Puertecito quadrangle the corresponding Spears member of the Datil formation rests unconformably on the Baca formation.

On the east slope of Granite Mountain Loughlin and Koschmann report a thickness of 1200 feet for the upper latite. At Nipple Mountain there is 900 to 1000 feet of agglomeritic latite exposed and calculations on the west slope give a thickness of 1800 feet, although the latter figure may be exaggerated by concealed faulting. The thickness of agglomeritic facies varies tremendously and its thickness cannot be seriously considered in arriving at a figure for the unit as a whole. About two miles north-west of Nipple Mountain the total thickness of the agglomerate is approximately fifteen feet and elsewhere in the area it is present only in isolated lenses of small extent. Calculations based on exposures west of Granite Mountain indicate a thickness of 1000 to 1200 feet; which appears to be reasonably accurate.

Lithologically the upper latite consists of flows, agglomerates and possibly tuff. Agglomerate is used here to describe a rock which consists largely of a fragmentary material enclosed in flow material which is lithologically identical. The exposures suspected of being tuff have been altered to such an extent that the original texture cannot be determined with any degree of assurance. The flow material presents a varied appearance. In general it is aphanitic with scattered phenocrysts of white to pink subhedral feldspar about two millimeters in diameter making up less than ten per cent of the rock. The color ranges from whitish grey to a pale purplish grey. In some places a faint flow banding can be seen. In thin section the rock has a microgranular groundmass which is composed of orthoclase and a plagioclase in approximately equal parts. The phenocrysts are of subhedral orthoclase which is partially resorbed. The plagioclase grains are too small to be positively identified. The most common accessory mineral is pale brown biotite which is present in amounts of from five to ten per cent. Hematite is present as an alteration product of both magnetite and biotite. The common alteration products of the feldspars are sericite and calcite.

The agglomeritic material in the Granite Mountain - - Nipple Mountain area is commonly more prophyritic than the normal flows. Subhedral, resorbed phenocrysts of orthoclase and plagioclase make up as much as 70 per cent of some specimens. The phenocrysts average from 1.5 to three millimeters, although locally they may be as large as seven millimeters, and are enclosed in a microgranular to glassy groundmass. The color ranges from greenish grey to pinkish grey; the former caused by pale green augite and chlorite and the latter by finely disseminated hematite. Chilled fragments of the same material ranging from microscopic size to as much as a foot and a half in diameter are thickly included and in general make up the bulk of the rock. In thin section the material is so highly altered that identification of the original minerals is very difficult. In the least altered specimens the feldspar consists largely of a perthitic intergrowth of orthoclase and albite-oligoclase. In many specimens the feldspar is altered to sericite and calcite with only crystal outlines left to indicate the original material. The most abundant accessory mineral is pale green to colorless augite which is usually the best preserved mineral and is present in amounts up to ten per cent. Fine grained aggregates of hematite and magnetite are present in what appear to be replacements of biotite and hornblende. Unaltered biotite is very rare. Near the contact with the overlying rhyolite porphyry sill the agglomeritic latite becomes increasingly quartzose and less agglomeritic and the distinction between the two cannot be clearly made. This is well illustrated in an exposed contact about two miles northwest of Nipple Mountain where typical agglomeritic upper latite passes gradually into typical rhyolite porphyry over a stratigraphic distance of about fifteen feet.

West of Granite Mountain there is a grey streaked facies of the latite which megascopically resembles a welded tuff. In thin section alteration is so complete that little about the original composition or texture can be determined. Outlines of feldspar phenocrysts 1.5 millimeters in length have been replaced by a fine-grained aggregate of sericite, calcite and quartz. Quartz penetrates the feldspar outlines in such a manner as to suggest that it formed a perthitic intergrowth with the feldspars before they were completely altered. Iron oxide is present in what appears to be psuedomorphs after pyrite but no pyrite as such is present.

Banded Rhyolite

The banded rhyolite is exposed in a narrow, discontinuous northeast trending belt throughout most of the north Magdalena area. Its areal extent is much smaller than that of the upper latite or the upper andesite. Although the full thickness is not exposed, calculations based on the larger exposures give a thickness of slightly over two hundred feet. It is not very likely that the total vertical extent exceeds this figure by more than one hundred feet.

The banded rhyolite is separated from the underlying upper latite by a sill of rhyolite porphyry, which makes it difficult to accurately determine the relationship between them. The confusion is further intensified by the difficulty in obtaining accurate dip and strike measurements in outcrops of this type. In general the attitudes of the two units appear to be conformable and there is no evidence of structural features which do not affect both of them in the same manner. In the southern part of the Magdalena mining district the rhyolite rests on the underlying volcanics in an apparently conformable attitude (Loughlin and Koschmann, 1942). In the Puertecito quadrangle an erosion surface without angular discordance (a disconformity) is reported between the members of the Datil formation which correspond to the banded rhyolite and the upper latite (Tonking, 1952). In the north Magdalena area the two units are not in contact and no evidence has been found to either confirm or deny Tonking's conclusion. Loughlin and Koschmann state that there is an unconformity between the banded rhyolite and the upper latite in the Granite Mountain area. This conclusion is based on the tenative identification of the sandstone west of Granite Mountain as the Baca formation. As stated previously the sandstone is now considered to be a float block of some considerably older sediment and not the product of intervolcanic erosion and deposition during Tertiary time.

The banded rhyolite extends northward into the Puertecito quadrangle where it is designated the Hells Mesa member of the Datil formation (Tonking, 1953). It is also believed to be at least in part, equivalent to the streaked rhyolite of the Water Canyon area (Kalish, 1953).

The appearance of the banded rhyolite varies considerably. The color ranges from grey to reddish brown and the banding is the only consistent feature. The unit consists predominantly of flow material with a little welded tuff which is indistinguishable from the flow except on the weathered surface. In hand specimen the typical rhyolite consists of an aphanitic dark grey to reddish brown matrix containing irregular bands and streaks of lighter colored material. Phenocrysts of pink orthoclase and clear quartz about one millimeter in diameter are scattered throughout in random orientation and make up about ten per cent of the rock. The light colored streaks range from one sixteenth to one quarter of an inch in width and from one to eight inches in length with an average length from two to four inches. Locally, where the banding is poorly developed, the rhyolite is difficult to distinguish from the upper latite. On weathered surfaces the rock tends to separate along the streaks, sometimes producing thin slabs measuring a square foot or more and from one half to one inch thick. Usually the bands or streaks are irregular to roughly straight but locally they are very wavy and contorted.

In thin section the rock consists of scattered phenocrysts of orthoclase of one millimeter diameter and clear quartz about half as large in a micro-granular to glassy groundmass of orthoclase and quartz. The white bands contain more phenocrysts and probably represent crystal aggregates which were elongated during the extrusion. Pale brown to colorless biotite is the major accessory mineral and fine particles of magnetite and hematite are disseminated throughout.

Upper Andesite

The upper andesite is restricted to the northwestern part of the mapped area where it outcrops over an area of approximately twelve square miles. In contrast to the underlying volcanics it is relatively flat lying and undisturbed by the movements which folded and tilted the lower units. Although the contact is not exposed it appears to rest on the banded rhyolite with an unconformity of approximately fifteen degrees. The upper andesite extends northward into the Puertecito quadrangle where it, together with the overlying olivine basalt, has been designated the La Jara Peak member of the Datil formation (Tonking, 1958). Due to the flat-lying attitude of the unit its thickness is difficult to determine. North of the Three Mile ranch house it is exposed over the entire southeastern slope of Bear Mountain which indicates a thickness of at least one thousand feet. Since only the top and not the bottom of this unit is exposed, the total thickness may be considerably greater.

The color of the upper andesite ranges from red to grey but the predominant color is a brick red. It consists primarily of flows with included irregular lenses of tuff and agglomeritic tuff. Although the appearance varies both laterally and vertically, and the unit is composed of several individual flows, it cannot be separated into mappable units.

The flow material typically is brick red or purplish colored and filled with vesicles ranging from microscopic size to three inches in diameter. Many of the vesicles are filled with chalcedony, quartz and calcite. On weathering the chalcedony geodes form a conspicuous part of the surface.

In thin section a typical flow consists of a felty groundmass of andesine-labradorite laths 0.1 millimeter in length with phenocrysts of augite up to one millimeter in diameter. Phenocrysts of an original mineral with the general form of hypersthene are replaced by hematite, calcite, magnetite or specularite and a white clay mineral. Fine particles of iron oxide are scattered throughout the groundmass. The smaller vesicles 1.5 millimeter and less, are usually filled with calcite, and chalcedony is restricted to the larger ones. Sericite, calcite and clay minerals are present as alteration products of the feldspar. Augite and the altered ferromagnesian mineral make up about twenty per cent of the rock.

There is at least one thin flow of dense grey andesite about four feet thick in the lower part of the unit. It is porphyritic in hand specimen with reddish brown phenocrysts one millimeter in diameter making up about fifteen per cent of the rock. In thin section it is distinguished from the vesicular flows by the absence of the vesicles and the smaller size of the augite crystals which average 0.2 to 0.3 millimeters in diameter. The phenocrysts are a fine aggregate of hematite, calcite, clay minerals and quartz, replacing what was probably hypersthene.

The uppermost part of the upper andesite is a dense glassy flow, brick red in color and scoriaceous at the top. In thin section the rock is porphyritic with phenocrysts of augite one millimeter in diameter forming ten per cent of the slide. The groundmass is glassy and isotropic with fine particles of hematite scattered thickly throughout. Feldspar laths 0.1 millimeter long comprise approximately ten per cent of the groundmass. Small subhedral crystals of magnetite which are largely replaced by hematite make up another five per cent and fine grained calcite in veinlets and irregular cavity fillings is present in about the same amount.

The tuff beds in the upper andesite are purplish red to pink colored and in general have the appearance of fine grained ferruginous sandstone. In part they are agglomeritic with about twenty five per cent larger fragments in a fine grained matrix. The larger fragments seldom exceed ten millimeters in diameter. In thin section the matrix consists of angular to subrounded grains of plagioclase, augite, glass and andesite fragments 0.1 to 0.2 millimeters in diameter. Quartz and orthoclase grains comprise about five per cent of the matrix. The interstitial spaces are filled largely with calcite. The larger fragments have the same composition as the andesite flows.

Olivine Basalt

The youngest member of the volcanic sequence in the north

Magdalena area is the olivine basalt which caps the south end of the Bear Mountains in the northwestern part of the area. It overlies the upper andesite in apparent conformity. It is the least extensive of the volcanics and the total areal extent is not more than half a square mile. The present outcrops are merely erosion remnants of a more extensive flow which may have once covered a much larger area. Maximum thickness of the unit is fifteen feet which does not thicken noticably when traced northward outside the area. Although there is no way of knowing how much of the unit has been removed by erosion it does not seem likely that the original thickness exceeded a few tens of feet. The olivine basalt dips to the southwest at an angle of approximately two degrees, but it is not apparent whether the dip is due to tilting or to extrusion on a sloping surface. The olivine basalt extends into the Puertecito quadrangle where it is considered a part of the La Jara Peak member of the Datil formation. It cannot be directly correlated with any unit in the Magdalena mining district but it occupies a stratigraphic position corresponding to that assigned to the pink rhyolite (Loughlin and Koschmann, 1942). The inclusion of unaltered fragments of glassy upper andesite in the basal part of the basalt indicate that it was deposited immediately following the andesite.

Megascopically the olivine basalt is a dark grey, almost black, aphanitic rock which weathers to a greyish brown. Vesicles which have been elongated in the direction of flow and range in size from a fraction of an inch to three inches long and a quarter of an inch wide give it a somewhat banded appearance. In thin section the basalt has a micro-ophitic texture and consists of eighty per cent bytownite-anorthite in lath-like subhedral crystals 0.2 to 0.3 millimeters in length. Olivine, in small grains, 0.2 millimeters and scattered larger grains one millimeter in diameter originally composed fifteen per cent of the rock. Approximately one third of the olivine has been altered to brownish red iddingsite which completely replaces the smaller grains and forms reaction rims around the larger ones. The remaining five per cent of the basalt is composed of scattered magnetite particles 0.1 millimeter or less in diameter.

Tertiary Intrusive Rocks

The Tertiary intrusive rocks in the north Magdalena area may be separated into three groups on the basis of age. The oldest intrusive is the sill of rhyolite porphyry which was intruded between the upper latite and the banded rhyolite. Next oldest is the monzonite. They are not in contact within the area but in the small monzonite stock southwest of Granite Mountain, just outside the area, the monzonite cuts the rhyolite porphyry. The monzonite is cut by dikes of lamprophyre and white rhyolite which are considered the youngest of the intrusives. The latter two have not been found in contact with each other and their relative ages are unknown. The augite andesite is tenatively considered to be of the same age as the monzonite. Within the area it is not in contact with other intrusives but on Granite Mountain just outside the area it is clearly intrusive into the rhyolite porphyry. The names used here are those used by Loughlin and Koschmann in the Magdalena Mining District Report (1942).

Rhyolite Porphyry

The rhyolite porphyry is extensively exposed along the eastern margin of the area from Granite Mountain on the south to at least one mile beyond the northern boundary of the area. It is the most widely distributed of the Tertiary rocks in the Magdalena mining district and identical rock occurs extensively in the Lemitar Mountains about twelve miles to the east (Loughlin and Koschmann, 1942). It is also present in the south end of the Water Canyon area (Kalish, 1953). At Granite Mountain the rhyolite porphyry is about 1400 feet thick although the total thickness is not exposed. The unit appears to thin to the west but limited exposures and uncertainty as to the exact nature of contacts, which are in part faulted, do not permit accurate measurements. The western most exposure, located one and a half miles southeast of Three Mile ranch, is two hundred feet thick but the contacts other than fault contacts are covered by alluvium and talus and the total thickness may be greater.

The outcrops of rhyolite porphyry are interpreted as being parts of a large sill intruded along the contact between the upper latite and the banded rhyolite. The one exposed contact between rhyolite and underlying upper latite is intrusive and alteration in the top part of the latite --- feldspar replaced by calcite and the addition of secondary quartz --- supports this theory of emplacement. In the Magdalena mining district and the Water Canyon area the rhyolite porphyry is considered intrusive (Loughlin and Koschmann, 1942; Kalish, 1953). In the township joining the mapped area on the west, the writer has seen rhyolite porphyry intrusive into sediments tentatively identified as Mesaverde. There is little evidence within the north Magdalena area to indicate the origin of the rhyolite porphyry, but the evidence from surrounding areas leaves the writer no choice but to consider it intrusive.

The attitude of the rhyolite porphyry is the same as that of the banded rhyolite and the latite. The fact that it has been folded and faulted by the same forces which deformed them indicates that it was emplaced sometime after the extrusion of the banded rhyolite and before the overlying upper andesite, which was not affected by those forces. Emplacement of the porphyry, therefore, was probably the last event during the earlier period of vulcanism or the first event following it.

The rhyolite porphyry is characteristically pinkish-grey in color and can be distinguished from all the other volcanics by phenocrysts of clear glassy quartz which are two to three millimeters in diameter --- five millimeters in occasional specimens --- and form about twenty per cent of the rock. Pink orthoclase up to four millimeters in length and occasional flakes of biotite are the only other minerals recognizable megascopically. It contains dense purple fragments up to an inch in diameter believed to be earlier chilled fragments of the same rock. In thin section the groundmass is micro-granular and apparently composed of orthoclase and quartz. Phenocrysts make up fifty per cent of the rock. Of these fifty per cent are orthoclase, thirty per cent quartz, fifteen per cent plagioclase of the albite-oligoclase range, and five per cent pale brown biotite. The phenocrysts are subhedral and partially resorbed; the resorbed portions in part being replaced by a mosaic of quartz or an intergrowth of quartz or albite with orthoclase. The biotite is partially altered to hematite and finely disciminated hematite is scattered throughout the groundmass. Muscovite and pale green chlorite are present in minute quantities. Some of the quartz phenocrysts have been strained and give a biaxial positive interference figure with an axial angle of approximately ten degrees.

Monzonite Stocks

The monzonite is intruded along the eastern boundary of the area in a north trending belt which is a little more than four miles long and contains seven stocks, which may be connected at a shallow depth. The largest stock is located a mile north of La Jenze creek and covers an area of approximately 125 acres. The alignment of the stocks suggests that they have been intruded along a major fault zone and all originated from a common source. They are also in alignment with the monzonite stocks in the mining district which form a belt some two miles long. (Loughlin and Koschmann, 1942). Unlike the stocks of the mining district which contain both monzonite and granite, those of the north Magdalena area contain only monzonite.

Typically the monzonite is fine grained, though some of the material of the two stocks north of La Jenze Creek is medium grained. The color is medium grey but becomes darker as the grain size decreases or the percentage of mafics increases, and is a rusty brown on weathered surface.

In thin section the monzonite is fine grained -- 0.5 to 0.75 millimeters -- and has a hypidiomorphic-granular texture. The chief constituents are orthoclase and plagioclase of the oligoclase-andesine range in approximately equal amounts. Augite in amounts of from five to ten per cent is the principal accessory. The augite is frequently twinned and in grains equal in size to the feldspars. Pale brown biotite and magnetite are next in importance and minute amounts of apatite and zircon are present. The medium grained material north of La Jenze Creek differs from the typical monzonite primarily in the percentage of accessory minerals. It has the same texture with an average grain size of 1.5 to 2.0 millimeters. Augite, twenty per cent, and biotite, five per cent, are the principal accessories.

Augite Andesite

Dikes of augite andesite intrude the upper latite in the Granite Mountain area and dikes and two small stocks intrude the upper andesite in the southern end of the Bear Mountains. It has not been found in contact with the other intrusives within the area, but on the crest of Granite Mountain it is intrusive into the rhyolite porphyry and is therefore younger at least than the earliest of the intrusives. The largest intrusives are two dikes, each about three quarters of a mile long and almost 100 feet wide, on the southeastern slope of the Bear Mountains. The topography suggests that there are more dikes present beneath a cover of talus although these are not exposed.

The augite andesite, a medium brown weathering aphanitic, purplish dark-grey rock has scattered phenocrysts of glassy feldspar one to two millimeters in diameter. In thin section the rock has a microgranular to glassy groundmass apparently composed of plagioclase and augite. Fifteen per cent of the rock is subhedral phenocrysts one millimeter or less in diameter, of which eighty per cent are augite and the remainder oligoclase-andesine. The phenocrysts are arranged in clusters up to two millimeters in diameter which accounts for their deceptively large appearance megascopically. Powdery hematite forms halos around the phenocrysts and is scattered thickly through the rock. The only other recognizable mineral is a small quantity of hornblende.

Lamprophyre dikes

The name lamprophyre is here applied to the numerous dikes of dark-colored rock which occur throughout the area and are usually so fine grained as to defy positive identification even with the petrographic microscope. Lamprophyre dikes cutting the monzonite prove that they are younger than the monzonite, but their age in relation to the augite andesite and the white rhyolite have not been ascertained. In the Granite Mountain area lamprophyre and white rhyolite dikes frequently occur in close proximity, but they are usually parallel and no cross-cutting relationships have been observed. In general the dikes trend in a northerly direction but to a lesser extent they are orientated in random positions with a few approaching an east-west direction. The width of the dikes seldom exceeds six feet and a few are more than a thousand feet in length. West of Granite Mountain there are also a few sills of the lamprophyre, but exposures of these are not large enough to be shown on the geologic map.

Two types of lamprophyre may be distinguished megascopically. One is a black aphanitic rock which weathers to a rusty brown; the other is greenish grey and slightly porphyritic. In thin section all the lamprophyres possess similarities which justify including them in the same classification. They consist of a felty groundmass of plagioclase laths 0.2 millimeters or less in length, with phenocrysts of small size comprising about ten per cent of the rock. One thin section of black lamprophyre consists of unoriented andesine laths 0.2 millimeters long with augite filling the interstitial spaces and in phenocrysts from 0.5 to one millimeter in diameter, and a few phenocrysts of olivine. The accessory minerals are magnetite and pale green chlorite. A small amount of hematite is present, evidently as an alteration product of the pyroxenes. One specimen of the greenish grey lamprophyre contains phenocrysts of orthoclase and plagioclase (oligoclase-andesine) up to three millimeters and augite up to 1.5 millimeters in diameter in a felty groundmass of feldspar laths 0.1 millimeter long with interstitial augite. The specimen of black lamprophyre described above is a lamprophyre of the variety spessartite (2212) in the Johannsen system of classification. The other specimen is a porphyritic diabase. Other thin sections were examined and found to have the same texture but the feldspars in these have been almost completely replaced by calcite and a positive identification could not be made. In both megascopic and microscopic characteristics, the lamprophyres closely resemble those described from neighboring areas (Loughlin and Koschmann, 1942, Kalish, 1953).

White Rhyolite dikes

Dikes of white rhyolite occur in the Granite Mountain area and in a narrow belt extending about four miles northward. They are intrusive into the monzonite, rhyolite porphyry and upper latite. They are at least as young as the lamprophyre dikes and in the mining district are considered the youngest of the intrusives although definite evidence for this has not been found (Loughlin and Koschmann, 1942). The dikes are usually ten to twenty feet wide and a few hundred feet long. The longest continuous exposures found are approximately one thousand feet.

The rhyolite is light grey on fresh surfaces and weathers to greyish white. Weathered fragments on the surface are conspicuous by their color and give a deceptive impression of the width of the dikes. Small (one millimeter) phenocrysts of quartz and orthoclase make up five to ten per cent of the rock. In thin section the rhyolite has a dense groundmass, apparently composed originally of subhedral quartz and orthoclase but now consisting mostly of sericite and calcite. Euhedral orthoclase and anhedral quartz phenocrysts 0.5 to 1.0 millimeters in diameter are present in approximately equal amounts. Some of the smaller quartz grains are of the high temperature variety, tridymite. A few scattered phenocrysts of plagioclase — albite or oligoclase — are present. No mafic minerals are present, but small aggregates of iron oxide suggest altered flakes of biotite.

Rock Alteration

Summary and Conclusions

Rock alteration in the north Magdalena area is widespread but not intense. For the most part it takes the form of replacement of the original minerals by later minerals without changing the texture of the rock, which is a fact of importance in considering the nature of the intrusive phenomena. In view of the similarity of composition of country rock and intrusives, it is not surprising that alteration is not intense. The intrusion, for example, of monzonite into latite cannot logically be expected to cause any profound changes in the latite, unless the intrusive is accompanied by a large quantity of mineralizing solution.

The most common secondary minerals are sericite, calcite and hematite. The proportions are variable; but in general, calcite predominates over sericite in the latite, andesites, lamprophyres and monzonite; and in the rhyolites, sericite is more plentiful than calcite. This distribution lends strong support to the belief that most of the secondary calcite is an alteration product of the plagioclases. Although much of the secondary calcite was undoubtedly formed after solidification of the rock, calcite is also a common late magmatic mineral (Rogers and Kerr, 1942) and it is quite possible that much of the feldspar alteration occured while the material was still in a semi-molten state.

Most of the alteration can be explained by the circulation of ground water through horizons undergoing normal chemical weathering. One factor that argues against hydrothermal alteration at elevated temperature is the complete absence of pyrite. Epidote and serpentine are rare and are confined to the intrusive bodies. These three are common hydrothermal minerals (Rogers and Kerr, 1942) and if hot magmatic emanations were the principal mechanism of alteration they should be relatively abundant. The common alteration product of the mafic minerals is iron oxide, not the common hydrothermal products tremolite and chlorite; although the iron oxide may represent a second stage of alteration. Secondary quartz is widespread and most common near igneous contacts, but in no case does it make up more than a small fraction of the rock. Intense silicification does not occur even where quartz veins are fairly common.

The most highly altered thin section studied was one of the upper latite collected near a dike of white rhyolite. It contains much secondary quartz and iron oxide pseudomorphs after what appears to be pyrite, but could have been a pyroxene. The feldspars are completely replaced by sericite and calcite but outlines of plagioclase and orthoclase phenocrysts can be recognized. The original groundmass texture cannot be determined.

Structure

The Magdalena area is located within the Cretaceous and Cenozoic orogenic belts, which comprise a relatively narrow zone extending from Alaska to the Andes of South America and including the North American cordillera. The Magdalena area is a part of the Sonoran-Chihuahua structural system (Eardley, 1951), in which block faulting similar to the Basin and Range type forms roughly parallel, tilted mountain ranges, bounded on one or both sides by high-angle faults, and separated by alluvium filled valleys. Similar structure has been described by Eardley (1951) from southern and western Arizona, central New Mexico and northern Mexico.

The Sonoran-Chihuahua structural system is usually included in the Basin and Range province by physiographers. Some confusion has resulted by the use of the two terms - - Basin and Range province in physiography and Basin and Range system in tectonics. The two are not synonymous. The structure of the desert ranges of New Mexico and Arizona differs in one important respect from the true basin and range structure as described by Gilbert (1928) from the Great Basin. True basin and range structure is not associated with igneous activity; but in the Magdalena area, which is typical of the Sonoran-Chihuahua system, faulting and tilting was accompanied or closely followed by the extrusion of vast quantities of lava.

Unconformities

In the north Magdalena area the Tertiary volcanic units are separated into an older and a younger sequence by an angular unconformity. The contact between the two sequences is not exposed, but the relationship is clearly indicated by the structural pattern formed by their component units. The lower sequence, consisting of the upper latite and the banded rhyolite, has been folded and tilted so that the outcrops dip at angles of from fifteen to forty degrees. The upper andesite and olivine basalt of the upper sequence have a maximum dip of three degrees and in most exposures are nearly horizontal. There is no evidence of flow crumpling.

The base of the volcanics is not exposed in the north Magdalena area and the nature of its lower contact is not known. In the northern part of the area the upper latite contains scattered fragments 0.5 to 1.0 inch in diameter of fine-grained brownish-red sandstone which are apparently derived from underlying sediments. The sandstone fragments are too small and altered to be positively identified. They resemble several of the sedimentary units found in this section of New Mexico; namely the Abo, Chinle and Mesaverde formations. In the Puertecito quadrangle, Tonking (1952) reported that the volcanic sequence unconformably overlies the Baca formation of Upper Cretaceous (?) to Eocene (?) age, which in turn overlies the Upper Cretaceous Mesaverde formation. In the Granite Mountain area Loughlin and

Koschmann (1942) report that the volcanics unconformably overlie the Madera limestone and going south-westward through the mining district they overlie successively the Sandia formation and the Abo sandstone. There is therefore, sufficient reason to believe that the volcanic sequence in the north Magdalena area rests unconformably on sediments of an older age, even though the identity of those sediments is unknown. It is the opinion of the writer that the southern part of the area is underlain by Carboniferous limestone and that the portion north of Granite Mountain, at least in part, is underlain by Cretaceous sandstones and shales. This opinion is based on the assumption that the pre-Tertiary structural trends observed outside the area extend into it.

Jointing

The banded rhyolite frequently exhibits parting along a vertical plane parallel to the strike of the outcrop and less frequently along a vertical plane perpendicular to the strike. The jointing is not consistent throughout the area. In some outcrops it is well developed and in others is revealed only by a tendency of the rhyolite to weather in rectangular blocks. The jointing is believed to be caused by diastrophic forces and to be directly related to the deformation of the area. There is also a tendency for the rhyolite to part in a direction parallel to the flow banding, but this is apparently a result of the rock texture and not of external stress.

Jointing is not a prominent feature in the other rocks of the area. The upper latite sometimes shows a parting parallel to the direction of flow similar to that found in the banded rhyolite and like the latter apparently unrelated to diastrophism. The rhyolite porphyry has a poorly defined sheeted structure typical of sills. Jointing is restricted to the older volcanic sequence. No preferential directions of parting were observed in the younger sequence.

Folding

Only one fold was found in the mapped area. Faulting has been active to such an extent that it is difficult to recognize fold structure in the outcrop pattern. In the eastern part of the area the upper latite strikes north to north 30 degrees west and dips to the west at angles of from 20 to 30 degrees while the western outcrops strike generally north 40 to north 45 degrees east and have eastward dips averaging 15 degrees. In between, the latite is relatively flat lying with local irregularities. Exposures of banded rhyolite and rhyolite porphyry are conformable in attitude to the latite.

These dip and strike relationships may be the result of faulting alone; in which case the western exposures would represent a local reversal of the regional trend. A more logical explanation, in the opinion of the writer, is that they represent the north end of a syncline which trends approximately north 20 degrees east and plunges to the south at a low angle. Probably the fold was symmetrical originally and the present asymmetrical form was produced by faulting and more intense tilting along the eastern than along the western margin.

Faulting

There are two systems of faults in the mapped area. One set trends north to north 10 degrees east. The observed fault surfaces of this system dip at angles of 75 to 80 degrees westward but some outcrop traces suggest others may have vertical or steep eastward dips. The second fault system trends in a northwestward direction. The exposed fault surfaces belonging to this set strike north 15 degrees west and dip approximately 45 degrees to the east. No cross-cutting relationships between the two systems have been found and it is not known whether they are contemporaneous or of different ages. All of the faults are of the gravity, or normal type; that is the hanging wall has moved downward with respect to the foot wall. There is no evidence of either thrusting or strike-slip movement.

The presence of many faults in addition to those which may be seen in the field is indicated by the outcrop pattern and the topography of the area. On the east the area is bordered by the Snake Ranch Flats, which is a down faulted area (Loughlin and Koschmann, 1942). The boundary is apparently formed by a zone of closely spaced parallel faults rather than a single large fault. Evidence of this is found in the repetition of the upper latite and rhyolite porphyry in narrow north-south outcrop bands. The presence of a major fault zone is further suggested by the north-south alignment of the monzonite intrusives. Many of the individual faults have a stratigraphic throw of more than one thousand feet and the total displacement along the fault zone may be as great as five thousand feet.

West of the Three Mile ranch there is apparently a major fault which forms the eastern edge of Bear Mountain. The straight line character of the escarpment and the alignment of the augite andesite intrusives both point to this conclusion. In one outcrop a stratigraphic displacement of some fifteen feet was noted but no direct evidence of large scale movement was found.

Interpretation of Structure

Structurally the north Magdalena area may be divided into two parts. The south-eastern part of the area including Granite Mountain is a northern extension of the main Magdalena range. The northern and western portions are a part of the Bear Mountains. The boundary between the Magdalena Mountains and the Bear Mountains is roughly along a line connecting Three Mile ranch and Bear Springs ranch. Tonking (1958) interpreted the Bear Mountains structure as an uplifted syncline. The part of the syncline which lies within the north Magdalena area represents a portion of the east limb and its synclinal character is not readily apparent because it has been faulted producing an outcrop pattern indistinguishable from the other block faulted structure of the area.

The origin and nature of the forces which caused the deformation in the north Magdalena area are difficult to determine. The minor folding present in the area can be explained by compressional forces operating in an essentially east-west direction. The block faulting appears to require a tensional component of force acting in the same direction. An explanation of the structure is not to be found within the confines of the area mapped, but by a study of the regional geology, a rational hypothesis may be advanced. The north Magdalena area is located between two large, relatively stable tectonic provinces - - the Colorado Plateau on the west and the Central Stable Region on the east (Eardley, 1951). Isostatic adjustment of the larger areas would produce stresses which could most easily be relieved by deformation in the structurally weak border zone. It is the opinion of the writer that the block faulting in the mapped area was in response to tensional stresses caused by the uplift of the Colorado Plateau.

Loughlin and Koschmann (1942) believed that deformation in the Magdalena mining district began in Laramide time and continued into the present. In the north Magdalena area only post-Laramide rocks are exposed and there is no evidence to date the beginning of faulting. There is however, evidence that orogenic movements have contimued to the present and may still be active. Evidence of continued activity are rejuvenated streams which cut arroyos in the Quaternary alluvium and pediment gravel. Additional evidence is to be found just east of the area where there is a small fault scarp in the alluvium east of Granite Mountain and northeast of the main Magdalena range.

Ore Potential

The north Magdalena area contains scattered mineralization but no important ore bodies have been discovered within it. Lasky (1932) described a number of claims just to the west of the area in the vicinity of Silver Hill. The workings consist of a number of prospect pits, cuts and shallow shafts. The country rock is andesite and latite and the mineralization occurs in fissures and breccia openings. Chalcocite, covellite, argentite, chrysocolla, malachite and galena were reported as ore minerals. Shallow workings and dumps examined by the present writer reveal only chrysocolla. Two drill holes were put down in an attempt to reach the supposedly underlying limestone. One hole penetrated to 825 feet and the other to 1020 feet and both were still in volcanic rock.

Just west of Granite Mountain are other numerous abandoned pits and shallow shafts. The only ore mineral observed by the writer was galena. The country rock is latite and the gangue minerals are barite, quartz and calcite. All of the mineralization discussed here is open space filling. The volcanics are apparently not favorable for replacement and the carbonate rocks which might contain replacement bodies are too deeply buried beneath the volcanics to warrant investigation at the present time.

Recently there has been considerable prospecting for uranium in the area. Many claims have been examined by the writer and no mineralization found. The claims have apparently been staked on the basis of radiometric anomalies produced by a deceptively high back-ground count in some of the volcanic rocks. The back-ground count in these rocks may be as much as four times that of the alluvium and what appears to the prospector to be an increase suggesting mineralization is actually a change in background.

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