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THE TORTILLA MOUNTAINS OF
ARIZONA

BY
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INTRODUCTION

The field work in the Tortilla Mountains was started by John F. White and myself. Later Vern Thompkins and George Pappas joined us.

John White and Vern Thompkins have mapped the geology of the Riverside Mine district since I started this report and have undoubtedly uncovered additional information relative to faulting, age relationships, and rock types.

Three U.S.G.S. quadrangles cover the area of the Tortilla Mountains. They are the Ray, Florence, and Winkleman quadrangles. Ransome has mapped the geology on the Ray quadrangle.

Murray Rex Arrowsmith

THE TORTILLA MOUNTAINS

Location, Culture, and Transportation

The Tortilla Mountain area is in northeastern Pinal County, Arizona. Part of this short range lying west of Kelvin has been mapped by Ransome, who has determined the structure as is shown in section (1).

The Tortilla Mountains are relatively low, narrow, serrated, and steep, with sharply angular profiles. They are about 28 miles long and 12 miles wide at the widest spot. The highest peak is some 4276 feet above sea level, and the maximum local relief amounts to about 2476 feet.

These mountains are located in the basin and range province. In the basin and range province the mountain ranges and their intervening valleys or plains are largely of structural origin. Few of them appear to have been formed by erosion alone, and most of them reveal the structural or physiographic characteristics of mid-Tertiary and later tectonic masses which have been more or less modified by semiarid erosion. The topographic forms are due partly to the kind and structure of the rock masses and partly to the arid climate.

The mountain ranges are believed to represent blocks of the earth's crust which were elevated relative to the blocks that underlie the plains.

The Tortilla Range is generally lower and more irregular in plan than the Mescal and Dripping Springs Mountains. Distant views indicate that as a definite range it loses its identity a short distance south of the Ray Quadrangle, being separated by irregularly hilly but comparatively low ground from the Santa Catalina Mountains.

The part of the Tortilla Range within the Ray Quadrangle is in the main a ridge of pre-Cambrian granite cut by various intrusive rocks. At its north end near Ray, where it coalesces with the Dripping Springs

Range, it is domposed largely of Pinal Schist. In the southerm part of the Ray Quadrangle the granite is flanked on the east by the same Paleozoic beds that are found in the Dripping Springs and Mescal Ranges, but in the Tortilla Range these beds have dips of 80° to 90° and consequently appear on the geologic map as inconspicuous narrow bands. These steeply upturned beds are considerably faulted, and at least a part of the faulting appears to have taken place after the deposition of the Gila conglomerate. The conglomerate itsself is sharply upturned along the mountain flank, with dips as high as 60°.

There is little to indicate the structural relation of this mass to the adjacent valleys. The nearly vertical attitude of the Paleozoic beds in the southwest corner of the Quadrangle, the known presence of considerable faulting in the same locality, and the steep upturning of the Gila conglomerate along the eastern flanks of the ridges, are all suggestive of faulting rather than folding as the kind of deformation that brought the range into existence.

Kelvin, which lies seven miles south of Ray and on the Gila River, is served by the Arizona Eastern Railroad. This is a branch line running from Phoenix to Florence and thence to Kelvin, Hayden, and Winkleman. Spurs go off of this line to Ray and Christmas. A graveled state highway extends from Superior to Florence through Ray and Kelvin. Another gra-veled road connects Kelvin with Hayden, Winkleman, Mammoth, Oracle, and Tucson. Various secondary roads lead to ranches and mines.

The annual rainfall, probably 10 to 13 inches, occurs mainly in two periods, one in July and August, and the other during the winter months. Very little snow falls in the area.

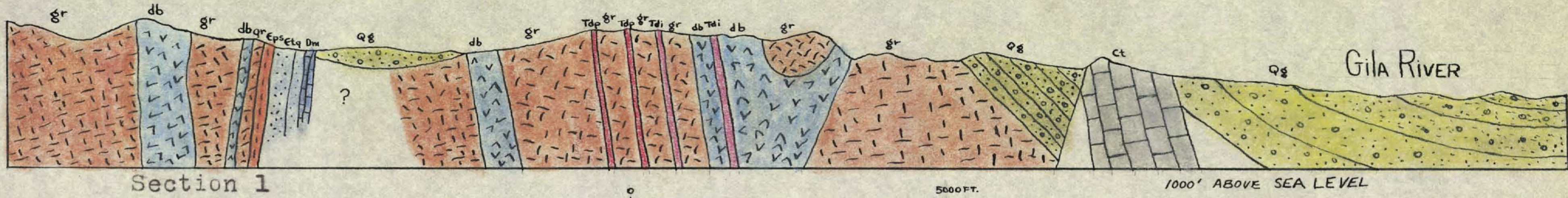
The vegetation is typical of the semiarid portions of southeastern Arizona .

VEGETATION

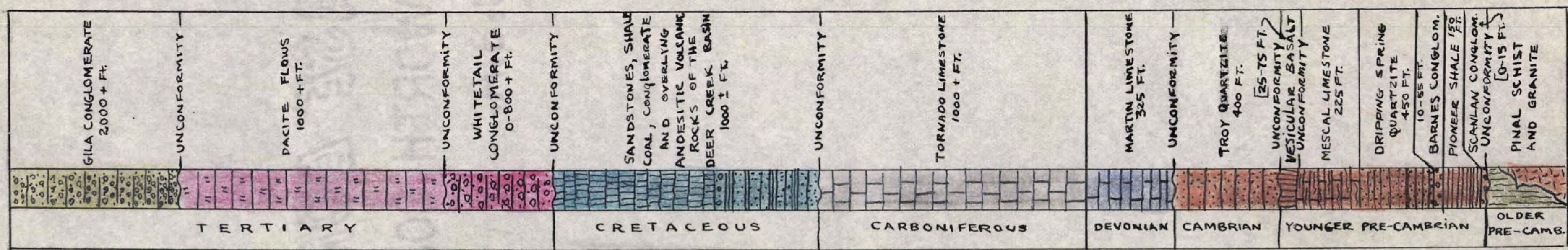
" Scrubby, bushlike oaks, the alligator juniper (Juniperus Occidentalis manosperma Engelmann), the sotol (Dasylirion wheeleri S. Watson), the datil (Yucca baccata Torrey) and probably other yuccas, the century plant or maguey (probably Agave parrye Engelmann), a leafless broomlike shrub (Canotia holacantha Torrey), and the deer nut (Simondsia Californica Nuttall) are among the common larger plants on the higher hills. On lower slopes and on the gravelly mesas of Gila conglomerate are found the green-barked palo verde (Parkinsonia microphylla), the ocotillo (Fouquieria splendens Engelmann), a notable plant at any time and when decked with its scarlet blossoms well deserving its specific designation, the imposing giant cactus or sahuaro (Cargegiea gigantea), suggestive of huge candelabra, the barrel cactus or bisnaga (Echinocactus wizlizena Engelmann), the prickly pear (opuntia, several species), the formidable cholla (opuntia mammillata), amid whose keen, glistening thickset spines the little cactus when nests in security, the cane cactus (Opuntia arborescens Engelmann), and many smaller members of the cactus family.

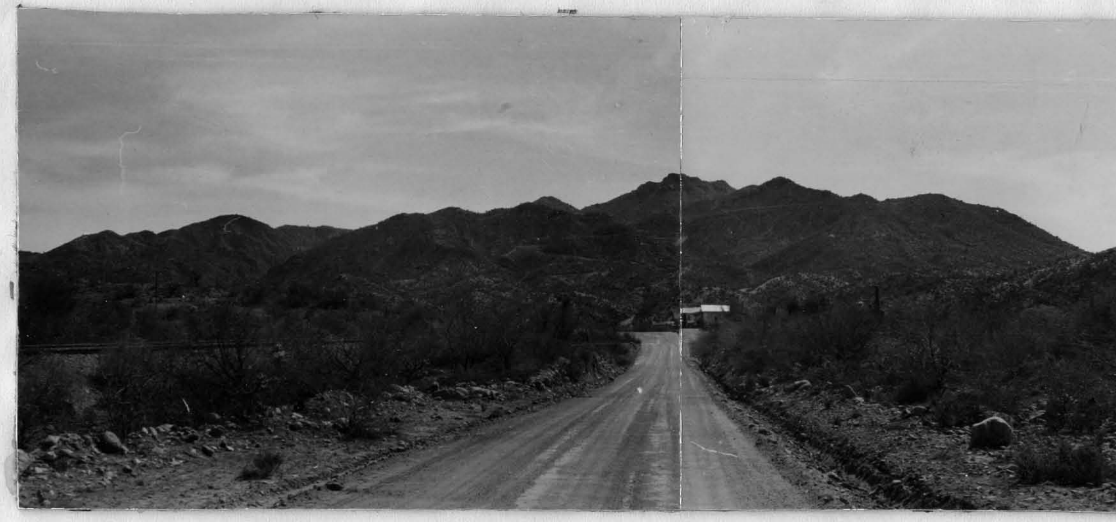
"Mesquite (Prosopis glandulosa Torrey), the catclaw (Acacia greggii A. Gray), which makes amends for the sharpness of its curved spines by the delicious perfume of its small yellow blossoms, and the palma (Yucca macrocarpa (Torrey) Engelmann)) are common along some of the dry bottom lands."[1]

1 Ransome, F.L., Ray Folio, Arizona, U.S. Geological Survey Folio No. 217, pp. 1, 1923.



Section from the Tortilla Range in the southwest corner of the Ray Quadrangle.
(From Ransome)





View of Riverside from the north.

View of Riverside from the West.

GEOLOGY OF THE TORTILLA MOUNTAINS

PRE*CAMBRIAN ROCKS

Pinal Shhist

Granitic Intrusive Rocks

Pre-Cambrian Granite
Quartz mica diorite

PALEOZOIC ROCKS
Cambrian System
Apache Group

Pioneer Shale
Barnes Conglomerate
Dripping Spring Quartzite.
Mescal Limestone
Troy Quartzite

Devonian System

Martin Limestone

Carboniferous System

Tornado Limestone

POST-PALEOZOIC ROCKS
General character and sequence

Diabase
Quartz diorite
Quabtz monzonite porphyry
Granodiorite
Quartz diorite porphyry
Ryolite porphyry (None in the Tortillas)
Dacite (None in the Tortillas)

Gila Conglomerate (Pleistocene)

Recent Deposits

PINAL SCHIST

In the Tortilla Range the only place that the Pinal Schist outcrops is in a small area south of Ray.

In general the Pinal Schist is light gray to blue-gray, with a more or less satiny luster on cleavage surfaces. In texture the varieties range from very fine grained slate sericitic schist to imperfectly cleavable, coarsely crystalline quartz-muscovite schist carrying locally andalusite or sillimanite.

Miscroscopic sections show that the principal constituent minerals of the typical fine-grained fissile schist are quartz and sericite. The quartz occurs in part as grains or irregular outline as much as 0.5 millimeter in diameter in a finely granular groundmass of quartz and sericite with many dust-like particles of magnetite. Small, short prisms of tourmaline are fairly abundant, and minute rounded crystals of zircon are sparsely disseminated through the rock. The fissility of the schist is determined by the general parallel arrangement of the sericite flakes and by a tendency of this mineral to form thin layers separated by correspondingly thin layers of quartz granules.

Southwest of Ray, in the vicinity of the intrusive quartz monzonite p-orphyry of Granite Mountain, the Pinal schists have been clearly modified by the igneous rock, as shown near the contact by an increase in crystallinity, by a pronounced tendency of the mica to segregate so as to give the schists a spotted appearance, and by the development of andalusite. Although this metamorphism was imposed upon rocks long previously rendered schistose the two epochs of alteration are not sharply distinguishable in their results.

The general metamorphism of the Pinal schist was probably connected directly with the extensive batholithic invasions of granitoid rocks in pre-Cambrian time. The fact that some of the pre-Cambrian intrusive masses are themselves in places more or less gneissoid shows that metamorphism continued after solidification of their now visible parts. Moreover, the intrusion of the Schultze granite and of the granite porphyries near Ray locally intensified the metamorphism of the Pinal schist. This may be well seen on Granite Mountain, southwest of Ray, where the schist near the granite porphyry is generally more coarsely crystalline than elsewhere a-nd in pla-ces carries porphritic crystals of andalusite. Other varieties are conspicuously spotted by the segregation of chlorite or mica about numerous centers of crystallization.

BIOTITE GRANITE

The biotite granite is the principal rock of the Tortilla Range from the vicinity of Ray southward past Kelvin and beyond the southern a nd western limits of the area here described.

In all ordinary exposures the granite is weathered and in various stages of disintegration, so that collection of fresh material is rarely possible. This is especially true in the vicinity of the lower P-aleozoic sediments, where the granite is generally reddened by pre-Cambrian oxidation.

It consists as a rule of large shapeless phenocrysts of flesh-colored potassium feldspar from 2 to 5 centimeters in length in a groundmass of coarsely crystalline anhedral pla-gioclase and quartz with a moderate proportion of biotite. The microscope shows that the phenocrysts are, in the main slightly microperthitic orthoclase, although in parts of each crystal there are obscure suggestions of microcline twinning. These crystals are traversed by microscopic quartz-filled cracks, and the rock as a whole shows evidence of deformation in the zone of fracture, the plagioclase is a sodic variety, probably oligoclase, but it is too decomposed for satisfactory identification. Much of the biotite is altered to chlorite.

Owing to its prevalent decomposition no detailed petrographic or chemical study has been made of this rock, which, although it is accompanied by some finer-grained facies, is fairly representative of the coarse, more or less reddish porphritic granites that are characteristic of the pre-Cambrian generally in Arizona. Its relations to the Madera diorite are not discoverable in this region.

The Ruin granite of the northern part of the Globe Quadrangle including the mass of Porphyry Mountain is virtually identical with the granite of the Tortilla Mountains.

QUARTZ DIORITE (MICA)

The quartz-mica diorite is also known as the Madera diorite. In the Globe report it was described as generally a gray rock of granite texture and habit, consisting essentially of plagioclase feldspar (chiefly andesine) with quartz and black mica (biotite). Orthoclase and microcline occur in some varieties that approach granodiorite in composition; in others the occurrence of hornblende indicates gradation toward tonalite. A tendency toward gneissic foliation was noted in some localities.

The rock is not altogether uniform in texture or composition, and it is probable that were the surface scoured clean by glaciation, detailed work would afford data for the discrimination of two or more varieties. But disintegration, in part as a result of pre-Cambrian weathering, is deep and general, so that it is impracticable to treat the rock mass other than as a unit.

The closest quartz mica diorite to the Tortilla Range is the area just east of P-ioneer Mountain.

PIONEER SHALE

The name Pioneer shale has been given to a series of shaly beds that overlie the Scanlan conglomerate and underlie the Barnes conglomerate. In the Tortilla mountain area it may be seen at Hackberry Spring. In general the Pioneer shale consists of dark reddish-brown more or less arenaceous shales composed largely of fine arkosic detritus with little or no calcareous material. In some beds fragments of pink feldspar are easily recognizable by the unaided eye, and as a rule the shales toward their base grade into arkosic grits.

In the ravine west of Hackberry Spring, in the southwestern part of the Ray Quadrangle, the shale is 100 feet thick.

This shale is believed to be marine and to have been deposited in shallow water.

BARNES CONGLOMERATE

In the Tortilla Range it is upturned into a nearly vertical attitude in the vicinity of Hackberry spring and the Ripsey Mine. In the Tortilla Range, south of Kelvin, the conglomerate is about 55 feet thick and carries abundant characteristic pebbles as much as 8 inches in diameter.

DRIPPING SPRINGS QUARTZITE

The Dripping Springs quartzite lies conformably above the Barnes conglomerate and under the Mescal dolomite.

Approximately the lower third of the formation consists of hard fine-grained arkosic quartzites, which, as seen in natural sections, show no very definite division into distinct beds but do exhibit a pronounced striping, due to the alternation of dull-red and dark-gray or nearly black bands parallel with the planes of stratification. These bands as a rule are less than 1 foot wide and give a generally thin-bedded aspect to this portion of the formation. About midway between the top and bottom of the formation the striped beds are succeeded by fairly massive beds, as much as 6 feet thick, of even-grained buff or pinkish quartzite associated with glassy variegated red, brown, and gray beds and with some layers of gray and reddish shales suggestive of the Pioneer shale. In the upper part of the formation the beds become thin, flaggy, and rusty and show a tendency to grade into the Mescal limestone.

This formation was deposited in shallow water, and the sand was at times exposed to the air, as may be seen from the ripple marks, sun cracks, and fossil worm casts visible on the surface of the beds.

Where almost vertically upturned in the Tortilla Range the Dripping Springs quartzite is approximately 500 feet thick, but the presence of intrusive diabase detracts a little from the reliability of this measurement, as movements during the intrusion may have increased the apparent thickness.

MESCAL LIMESTONE

The Mescal limestone and the diabase are closely associated. Lying between the two heavy quartzitic formations, the thin-bedded dolomitic limestone proved an easy path for the invading diabase magma and retains little of its former continuity. In the development of the topography the diabase tends to wear down into swales and hollows, and an extended view over one of the depressions shows the generally olive-tinted surface characteristic of diabase areas varied by blotches of white. These light a-reas represent included blocks of the Mescal limestone, some of which are nearly a quarter of a mile in area.

In the narrow gorge just west of Hackberry Spring, the Mescal limestone stands almost vertical and has a thickness of 225 feet.

TROY QUARTZITE

In the Tortilla Range, in consequence of its nearly vertical attitude it occupies a very small area. In the gorge west of Hackberry Spring a measurement across the edges of the nearly vertical beds gave 300 feet, but there are beds missing from the top of the formation here.

MARTIN LIMESTONE

The Martin limestone occupies conformably the stratigraphic interval between the underlying quartzite and the overlying Tornado limestone, and with the possible exception of some of its unfossiliferous lower beds is of Devonian age.

As a whole the Martin limestone is comparitively thin-bedded and weathers into slopes, broken here and there by a low scarp that marks the outcrop of some bed a little harder or thicker than the rest. It reaches a thickness of around 325 feet.

TORNADO LIMESTONE

In the Tortilla Range the faulted upturned strips of Tornado limestone form sharp, narrow, rugged ridges that project conspicuously above the Gila conglomerate. Along the eastern flank of the Tortilla Range the limestone at present must be fully 1000 feet in thickness, and it may at one time have greatly exceeded this thickness.

DIABASE

In the Tortilla mountains the diabase cuts all rocks up to and including the Tornado limestone. Some of the intrusions in the granite are curiously irregular, as may be seen in the vicinity of Kelvin. Although in some parts of the area diabase to the thickness of several hundred feet has been injected at the horizon of the Mescal limestone, the same limestone where upturned in the gorge west of Hackberry Spring has been only slightly invaded by the ingeous rock in the form of thin sills and small dikes.

Petrography---When fresh, the diabase typical of all the larger areas in the region is a tough, heavy dark gray holo-crystalline rock of medium grain as a whole but grading here and there into fine-grained (aphanitic) varieties or into coarser, exceedingly tough facies with large tabular plagioclase crystals and abundant magnetite. Some of the finer-grained varieties are younger than the mass of the diabase, which they cut as dikes. The minerals readily visible to the unaided eye are plagioclase, a-ugite, and magnetite.

Age---Intrusive relations show very clearly that the diabase is younger than the Troy quartzite. The Mescal and Tornado limestones have been cut only here and there by small bodies of diabase, but these may represent parts of the same magma that solidified in the larger masses. If so the diabase is younger than the P-ennsylvanian epoch of the Carboniferous.

QUARTZ DIORITE

The quartz diorite forms small irregular intrusive masses and a few dikes of considerable size. An irregular mass about one-fourth of a square mile in area cuts granite, diabase, and the Paleozoic formations up to the Mescal limestone just west of Hackberry Spring. Three dikes and a small intrusive body of the same rock cut granite and diabase north east of Ripsey Spring.

Petrography---The obvious characteristics of the typical quartz diorite are light to dark gray color, even fine-grained texture, and general freshness as compared with most of the dioritic porphyries. The constituent minerals are generally not more than 3 millimeters across, and phenocrysts as a rule are very sparsely disseminated or lacking. On fresh fracture the rock sparkles with small crystals of hornblende, augite, or biotite; all three minerals are present in some varieties.

Although the foregoing discription applies to the prevalent variety, the rock is not wholly uniform in general appearance. In certain local facies the crystals of hornblende may be 2 centimeters or more in length, with the feldspars of proportional size. The general composition of the rock is also somewhat variable.

QUARTZ MONZONITE PORPHYRY

The quartz monzonite porphyry of the Tortilla Mountain area is confined to the area around Ray, and for the most part occurs west of that town. Two varieties are recognized. One designated the Granite Mountain Porphyry, is intrusive into the Pinal schist southwest of Ray as a number of irregular masses, of which the largest forms part of Granite Mountain. Most of the altered porphyry in the copper-bearing area west of Ray appears to belong to this variety.

The quartz monzonite porphyry west of Ray is a light-gray, nearly white rock, which on slightly weathered surfaces has generally a faint yellow tint and closely resembles some of the Schultze granite. This lightness of hue is due to the preponderance of feldspar and quartz, the only dark constituent being black mica in small and sparsely diss-eminated scales.

The texture of the larger masses, such as that intrusive into the schist of Granite Mountain, resembles on casual inspection that of a porphyritic granite of medium grain, with phenocrysts of orthoclase and quartz not, a-s a rule, sharply differentiated from the groundmass.

QUARTZ DIORITE PORPHYRY

About a mile west of Kelvin in diabase may be found dikes of quartz diorite porphyry. These dikes are characterized by abundant phenocrysts of dull, slightly pinkish feldspar and of rounded quartz, the largest 1 centimeter in diameter, with inconspicuous phenocrysts of hornblende and biotite, in a dark greenish-gray aphanitic groundmass. The microscope shows that the pink feldspar is not, as its appearance first suggests, orthoclase but is plagioclase, probably andesine, largely altered to kaolinite, calcite, and sericite. Hornblende, rather more abundant in the groundmass than in the typical quartz diorite porphyry, has been for the most part changed to epidote and chlorite. Biotite, in this facies less abundant than in the typical variety, has been altered to the usual secondary products.

GILA CONGLOMERATE

Southwest of the Gila River in the Tortilla Mountains the Gila formation shows a greater thickness of distinctly bedded strata than in any other part of the Ray Quadrangle.

The general dip is to the east-northeast at about 30°, but along the east side of the older rocks of the Tortilla Range the dip is in places fully 75°.

The beds are of varied composition. Probably the most abundant material is a brownish-gray conglomerate in rather thin beds in which the coarse constituents are angular fragments of andesite, andesitic porphyries, and limestone. Many of these fragments are 2 feet or more in diameter, and some of the masses were observed to lie partly in one bed and partly in another, as if they had been thrown independently into the accumulating material. The matrix of these blocks and imperfectly rounded boulders is a poorly washed brown-gray sand in which grains of minute size are mingled with larger particles and fragments of all sizes up to the blocks mentioned. The material of the sand is partly granitic and partly andesitic. The granitic material probably came from the west or south and the andesitic material from the east of the southeast.

Near Hackberry Spring the Gila formation consists of well-bedded coarse sandstone, composed almost entirely of partly rounded granitic crumbs derived from the coarse pre-Cambrian granite of the Tortilla Range. Along the upper, north-south portion of Hackberry Wash the Gila is prevailingly reddish and sandy and occurs in beds for the most part about a foot thick. These beds consist largely of andesitic detritus and contain some fragments of andesite as much as 2 feet across. Stratigraphically under them and lapping up against the Paleozoic rocks to the west is fully 100 feet of soft, crumbling brownish-gray sandstone and sandy shale. There is much faulting in this vicinity, and the silty material is probably faulted against the older rocks and is not the real base of the Gila formation. Where the basal part of the formation is exposed, as farther north along the east side of the Tortilla Range, it consists of coarse fragments of obviously local derivation. The brown sand and shale are made up principally of mineral particles derived from the granite of the range.

Just west of the Tortilla Range is a synclinal basin of Gila conglomerate surrounded for the most part by hills of pre-Cambrian granite. This basin is drained by the intermittent Ripsey Wash, near the mouth of which, about 3 miles west of Kelvin, the Gila formation may be seen resting on the granite. Here the formation consists of light pinkish-gray tuffaceous-looking beds carrying fragments of granite in a matrix composed largely of volcanic material, apparently dacitic. The beds vary in thickness, ranging from shaly seams to strata measuring over 6 feet. Other facies occur farther south. Much of the material is a coarse breccia, the beds of which are thick and rather vaguely laminated. Blocks of granite 3 feet in greatest length are embedded in coarse granitic sand or in a matrix of granitic and dacitic debris. In places beds of soft sandstone and fine silt separate the coarser layers.

These beds of Gila conglomerate in the Ripsey Wash basin are in part so different from the others in the area and are as a whole so much better stratified as to suggest, on first examination, that they may be an older formation, probably having an unconformable relation to the Gila. No evidence of unconformity, however, could be detected, and the well-bedded material a-ppears to grade upward and laterally into Gila conglomerate of the common variety. Evidently the basin in which deposition took place was exceptionally deep, and rapidly accumulated coarse fluviatile material graded at times into finer sediments laid down in comparatively still water.

The accumulation of the Gila conglomerate is clearly indicative of intensely active erosion consequent upon the period of vigerous deform-a-tion that outlined the present mountains and valleys of the region. As a result of the block faulting and earth movements that followed the eruption of the dacite, the mountain ranges were much higher than at the present and the larger or structural valleys much deeper. Consequently the stream grades were steep and the erosive and transporting powers of the running water were far greater than they are now in the same region. Possibly the greater precipitation than at the present, but the general character of the deposit points to a decided preponderance of mechanical disintegration over rock decay and to an arid rather than a humid climate.

The average thickness of the Gila conglomerate in the area of the Tortilla Range is probably around 8000 feet.

ALLUVIUM

Detrital accumulations younger than the Gila conglomerate and probably referable to the later part of Quaternary time include certain sheets of unconsolidated or only partly consolidated rock waste that have been considerably dissected by the present intermittent streams and now form sloping terraces or low flat-topped ridges. The material forming the tops of these terraces has been derived from the adjacent hill slopes and merges with the ordinary stony detritus of those slopes. It represents a series of low-angle confluent alluvial fans formed during a halt in the dissection of the Gila conglomerate.

Lower and younger than the terraces are the flood-plain deposits of the Gila and its principal tributaries.

In connection with recent deposits mention may be made of local conglomerates cemented by copper silicate and carbonates that occur along some of the streamways where they pass through areas of copper-bearing rocks. These occur at various elevations up to 50 feet or perhaps more above the present arroyo bottoms. They are stream gravels cemented by the action of cupiferous water that seeps slowly from the adjacent rock, and the process has probably been continued up to the present time. These copper-bearing conglomerates may be seen in Copper Canyon, which is just west of Ray, and in Copper Canyon just south of Kelvin.

GEOLOGICAL HISTORY

The oldest rock in the area is the Pinal schist, which consists mainly of metamorphosed siliceous sediments and various granitic intrusive rocks. A ll of these rocks are of older pre-Cambrian age. Resting on the eroded surface of the old crystalline rocks are Apache group beds aggregating from 1,200 to 1,300 feet in thickness, apparently in conformable sequence and supposed to be younger pre-Cambrian. More than two thirds of this thickness is represented by two quartzite formations; the remaining beds include shale, dolomitic limestone, and conglomerate. Great masses of diabase of uncertain age intrude the Apache and older rocks. Overlying the Apache group, without any recognizable unconformity to explain the apparent absence of the Ordovician and Silurian, is 325 feet of limestone, supposed to be Devonian. Conformably above the Devonian limestone is the light gray Carboniferous limestone, at least 1,000 feet thick.

After the deposition of the Carboniferous limestone, the region was uplifted and eroded.

Cretaceous sediments were probably deposited, although no remnant of these is present in the region here particularly described. Their nearest known representatives are in the Deer Creek coal field, south of Gila River. The deposition of the supposedly Cretaceous beds was succeeded by andesitic eruptions, of which some of the products remain in the southern part of the Ray Quadrangle.

The andesitic eruptions were followed by the successive intrusion of (1) quatrtz diorite, in small irregular masses and a few fairly large dikes; (2) granite, quartz monzonite porphyry, and granodiorite in masses, some of which, as the Schultze granite, are several miles in diameter; and (3) qua rtz diorite porphyry in dikes, sills, and small rotund bodies. The intrusion of the rocks of the second group was the cause of the original or hypogene metallization that, followed some time later by downward or supergene enrichment, gave rise to the disseminated copper ores of Ray and Miami. The time of the intrusion of the rocks in these three groups is not known but is thought to have been Laramide.

A period of active erosion, during which the coarse clastic material of the Whitetail conglomerate was washed by streams into local basins, followed the granitic intrusions, and this formation in turn was buried under a flow of dacite, probably in late Tertiary time. This deposit has since been deformed by faulting and has been much dissected by the intermittent streams of the present drainage system.

OUTLINE OF GEOLOGICAL HISTORY

1. In pre-Cambrian times fine grits and silts were accumulating. They were derived from granitic rocks.

2. Sedimentation ceased. The beds were folded and compressed by forces acting in a generally northwest-southeast direction.

3. Intrusion of beds by quartz-mica diorite.

4. Crystalline metamorphism into Pinal schist.

5. Intrusions of granitic rocks.

6. At the end of the intrusions the region had risen above the sea and was mountainous.

7. Erosion attacted the mountains and wore them down to a peneplain.

8. At the beginning of Cambrian time there was a subsidence of the land and a fresh advance of the sea. The climate was not conducive to soil formation or to abundant vegetation.

9. Materials were reworked by waves into the Scanlan conglomerate.

10. Sandy silts were accumulated in the shallow water to form the Pioneer shale.

11. Without any apparent unconformity, the fine silt deposited in quiet waters was succeeded by coarse material that must have been laid down under very different conditions of erosion and deposition. This material formed the Barnes conglomerate. The evidence suggests that the Barnes conglomerate is a delta deposit, the work of streams rather than waves.

12. Accumulation of quartzose sands to form the Dripping Springs Quartzite.

13. There was a decided change in sedimentation and deposition. The Mescal limestone, a shallow water marine deposit, was formed.

14. Eruption of a flow of basalt.

15. Sandy and pebbly sediments now consolidated as the Troy quartzite began to accumulate. Up to the beginning of the deposition of the Martin limestone the Paleozoic era had been marked by the preponderance of

siliceous sediments indicative on the whole of shallow water or alternating land and water. From that point on marine conditions, with apparently increasing depth of water prevailed.

16. From Devonian time well into the upper Carboniferous (Pennsylvanian) the region was covered by a sea abounding in animal life and depositing abundant limestone. No unconformity has been found in the Toronado limestone, which carries Mississippian and Pennsylvanian fossils.

17. The Pennsylvanian limestone is the latest Paleozoic deposit of which the region preserves any record.

18. Intrusion of diabase with its associated faulting occurred after the accumulation of the Tornado limestone.

19. At the end of the Carboniferous the area was elevated above the sea level and subjected to erosion.

20. The region was extensively dissected, probably in Mesozoic time, by numerous faults, which appear to have been normal in character, to have been usually of moderate throw, and to have generally had northwest and northeast trends.

21. Intrusion of an enormous quantity of molten diabase magma into rocks of the region, particularly into those most cut by the faults.

The diabase not only forced its way between the beds as sills of varying thickness but found in the faulted rocks the most favorable opportunity for expansion. It occupied the fault fissures and shoved the detached masses of ruptured strata bodily aside, separating them so that they became in many places mere inclusions in a great mass of eruptive rock. These events took place comparitively near the surface.

The contact metamorphism effected by the diabase is generally slight, and aphanitic facies of the intrusive rock are common near original contacts. The manner in which the blocks of strata were displaced indicates that they were under no great load, and the large increase of volume resulting from the intrusion of the diabase must have produced considerable actual elevation of the surface over the Globe-Ray region.

22. After the intrusion of the diabase the region, having probably gained in elevation, was eroded.

23. Andesitic valcanic outbursts prededed or followed the intrusion of the diabase??

24. During late Mesozoic and early Tertiary time apparently belongs the irruption of the quartz diorite, the Schultze granite of the Globe quadrangle, the granodiorite at Troy, the quartz monzonite porphyry of the Ray district, and the related granitic monzonite and dioritic porphyries of the region. The intrusion of these rocks was propably accompanied and followed by faulting and was the immediate cause of ore deposition.

25. Cessation of igneous intrusions. The land was now dry and was undergoing erosion.

26. Coarse, rather angular detritus was washed down the slopes and deposited in the open valleys and gulches as the Whitetail conglomerate. The enrichment of the Ray and Miami copper deposits took place at this time.

27. Dacite flow.

28. Following closely after the dacite eruption, and possibly as a consequence of it, came the great faulting to which are chiefly due the present structure and less directly the topography of the region. This marked the end of the Tertiary.

29. The Quaternary was begun by a vigerous erosion of the complex lithologic mosaic resulting from the superposition of the postdacite shattering upon an earlier structure that was already complex.

The character of the Gila conglomerate indicates that the climatic conditions of the early Quaternary were not very unlike those of to-day. Prevailing aridity and dominance of mechanical disintegration over rock decay were prominent features, and the precipitation apparently occurred in violent downpours of short duration.

There has been at least one eruption of basalt during the Quaternary period.

More or less faulting has continued throughout the Quaternary, and these later dislocations have had a recognizable effect upon the structure, as shown by the shapes and distribution of the areas of Gila conglomerate.

In late Quaternary time erosion has been active over the whole region, reducing the mountains and dissecting the Gila conglomerate.

ORIGIN OF THE COPPER DEPOSITS

Copper ores generally similar to those of the Ray and Miami deposits are closely associated with monzonite porphyry or with porphyry intermediate in character between monzonite porphyry and granite porphyry. Some copper ores though may occur in localities where there is nothing to suggest any connection between them and igneous activity. Taken collectively though, the disseminated copper deposits of the southwestern United States present convincing evidence that the monzonitic porphyries, by which they are invariably accompanied, had something to do with their origin.

The now visible parts of these porphyry bodies probably contributed little to the ore deposition. They, like the neighboring schist, have themselves been altered by the ore-bearing solutions,and, where favorably situated, have been changed into protore just as the schist was changed under similar circumstances. Their significance lies in their evidence to the probable presence of much larger masses of similar igneous material below any depths likely to be reached in mining. It is from these larger and deeper masses, which must have taken far longer to solidify and cool than the bodies now exposed, that most of the energy and at least a part of the materials were derived to form the protore.

Fairly general acceptance is given to the view that deposits such as the protore of Ray and Miami are the work of thermal sulphide waters probably carrying some carbon dioxide.

On the whole the hypogene solutions appear to have been of rather feeble chemical activity, and although the quantity of copper which they transported was large in the aggregate, it was small when measured in percentage of the metallized rock mass.

No clear relation has been made out between primary metallization and rock structure. Typical protore may be found more than 1,000 feet from any known porphyry mass of considerable size.

Permeability was due in a large measure to minute irregular fissuring. This fissuring perhaps accompanied the formation of larger fissures along which faulting took place.

Permeability, it is believed was favored also by irregularity of the intrusive contact and by the presence of little tongues and dikes of porphyry extending out into the schist. The act of intrusion must have caused some disturbance of the schist, and the presence of such tongues and dikes, by introducing heterogeneity into the rock mass, probably made for further fissuring and to that extent provided communicating channels between the deep-lying igneous material and the zone of sulphide deposition.

The quantity of mineralizing solutions available at any place in the contact zone probably depended to a large extent on the shape of the deep-seated mass of magma from which they rose.

There appears to be no regular or significant difference between schist protore and porphyry protore as regards tenor in copper. Chalcopyrite, however, if not more abundant, is in places a more conspicious constituent of the porphyry protore than the schist protore. Molybdenite also seems to be more abundant in porphyry than in schist.

It is probable that at the time the protore was deposited at least 500 feet of rock lay above the present surface, and it is not at all unlikely that the thickness was several times the figure mentioned. The crystallinity of the granite porphyry and the character of the metamorphism that accompanied or followed the intrusion are both indicative of the solidification of the magma under a fairly thick cover.

The deposition of the protore probably followed closely the intrusion of the granite porphyry, but no facts are known that might serve to fix this event definitely in geologic time. The granite porphyry is younger than the diabase, whose intrusion, is supposed to have taken place at the end of the Mesozoic era.

It appears reasonable to regard the intrusion of the granitic porphyries as an early Tertiary event, but it must be admitted that it is little more than conjecture. The deposition of the protore certainly took place after the laying down of the Toronado (Mississippian and Pennsylvanian) limestone and before the eruption of the dacite.

KELVIN-SULTANA MINE

The Kelvin-Sultana Mine is on the south side of the Gila River, nearly opposite Ray Junction. The main shaft is 550 feet deep, and the total underground workings are approximately 10,000 feet in length.

The shaft is sunk in an irregular mass of diabase that is intrusive into pre-Cambrian granite and is itself cut by a quartz diorite porphyry dike and by five or six fissure zones that trend nearly east and west. These fissure zones are vertical or dip south at high angles. Most of them show a little oxidized copper ore near the surface, and some small shipments, amounting to about 500 tons were made from one of these zones on the William J. Bryan No. 2 claim from old workings, now abandoned, 200 feet deep. In 1918, the main shaft was about 800 feet north of these old workings.

When Ransome visited the mine in December of 1914, it was idle, although it was being kept free from water by pumping about 1,000 gallons a day. A 200-ton concentrator had been built, and a wire-rope tramway had been constructed across the river. A power plant had also been erected on the north side of the river.

The production of the mine from 1900-1909 was 50,000 lbs. of copper.

RIPSEY MINE

The Ripsey Mine is in the southwest corner of the Ray Quadrangle and at the time of Ransome's visit in 1911 had evidently been long idle. The Ripsey vein strikes N 70° E and dips 45°-50° S. The granite in the vicinity of the shaft--an incline on the vein--is cut by many intrusive masses of diabase, some of which rock appears in the hanging wall of the vein at the collar of the shaft. Nothing could be learned of the character or extent of the now inaccessible underground workings. Fragments of ore picked up on the dump show chalcopyrite, pyrite, sphalerite, and galena in a matrix consisting of a finely crystalline aggregate of quartz and calcite. This vein material may be a much altered dike rock.

Although this ore might be successfully concentrated if a large quantity of it were available, it is apparently too low in grade to be worked on a small scale, and presumably the past operation of the mine was based on the former presence of material near the surface which had a larger content of gold and silver than is apparently present in the ore examined.

The mine was working as late as 1939 as several assay sheets were found there bearing that date. Below are some of the assay figures as copied from the slips:

		Oz. Au	Oz. Ag
August 22, 1938	200 E #1 stope general	2.58	4.32
	200 E #2 stope general	.16	10.48
August 24, 1938	200 E #1 stope general	.98	36.00
	200 E #2 stope general	.14	smeared
Sept. 14, 1938	200 E #1 stope general	.26	4.45
	200 E #2 stope general	.02	5.48
	200 E #3 stope general	.12	2.86
Sept. 17, 1938	200 E #1 stope general	.20	4.68
	200 E #2 stope general	.26	5.66
Oct. 2, 1938	200 E #3 stope	.14	3.02
	300 W stope	.30	6.71
Oct. 16, 1938	200 E #1 stope	.38	8.60
	300 W stope	.14	3.16
Nov. 7, 1938	200 E #1 stope general	.38	8.64
	200 E #1 stope general grab	.18	4.14
	250 E	.26	5.76
	250 W	.12	2.82
Nov. 11, 1938	200 E #1 stope special	Trace	.28
	200 E #1 stope E section	.08	1.86
	200 E #1 stope W section	.26	5.44
	300 W stope E end	Trace	.32
July 31, 1939	Mill heads	.18	4.00
	Table heads	.03	1.52
	Mill tails	.01	1.09
	Flot. Conc.	.88	18.00
	Table Conc.	.68	14.56
	Cell Recovery	83%	62%
	Table Recovery	67%	28%
	Mill Recovery	94%	73%

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Panoramic view of Riverside drill sites from flag "E" which is on the west side of Copper Canyon. Mineral Creek and Kelvin are at the left side of the picture.