DESCRIPTION OF THE RAY QUADRANGLE.

By F. L. Kansome.

INTRODUCTION.

The Ray quadrangle (see Figs. 1 and 2) is in southwest-central Arizona, in the belt of generally linear range and valleys that, except for a stretch of about 75 miles in the northeastern part of the State, separates the Flats and Province (Colorado Plateau) on the northwest from the Plains Region (Sonoran Desert) on the southeast and that from its present diversified relief has been called the Mountain Region (Mexico-Canadian Highlands). The Mountain Region and the Plains Region are here regarded as divisions of the Basin and Range Province, which extends from Arizona into Nevada, California, and Mexico. The quadrangle lies between meridians 110° 45' and 111° and parallels 33° and 33° 15'. Its area, which is 725 square miles, is, less conventionally, by stage from Tuscon by way of Mammoth and down San Pedro River to its confluence with the Gila near Winklesun, just south of the quadrangle. The distance from Tuscon to Winklesun by this route is about 71 miles.

SITUATION AND ACCESS.

The principal industries in the Ray quadrangle are the mining, milling, and smelting of copper ore, particularly that from the mines in the vicinity of Ray. This town and the adjacent settlements, including the large Mexican village of Sonora, probably contain about 7,300 people. A survey of the town was built up near the concentrating mill of the Ray Consolidated Copper Co., and the smaller of the American Smelting & Refining Co., had a population of 2,508 in 1920. Winklesun, a smaller and older settlement a few miles south of Hayden, on the old, opposite the mouth of the San Pedro, is in the Winklesun quadrangle, which adjoins the Ray quadrangle on the north. The climate and topography of the quadrangle of that name, about half a mile east of the Ray quadrangle, nearly in the latitude of Tomato Creek. A town of the company the population dwindled, and in 1920 it was only 300. As a consequence of the construction of the concentrating mill of the Ray Hercules Copper Co. near Kelvin, that place may regain some of its former prosperity, although a new settlement, known as Boll ravine, appears to have been established still nearer to the mill.

Outside of the settlements mentioned, the quadrangle is inhabited only by a few prospectors and ranchmen. Much of it is a wild desert, whose only useful usefulness is man is to supply scanty grass at certain seasons to wide-ranging cattle. There is some arable land along the Gila and a few small patches along Mineral Creek. A large part of the best land near the river, however, has been turned into dumping ground for the millings from the concentrating mill.

CLIMATE AND VEGETATION.

The climate of the Ray quadrangle closely resembles that of the adjoining Globe quadrangle, to the north, but as the region here described is generally lower than that adjoining to Globe the mean annual temperature is higher. The town of Ray, homestead in by hills, is decidedly hotter in summer than Globe or Miami. So far as known, continuous weather records have been kept within the Ray quadrangle, but the conditions at the Hayden Bureau station 8 miles south of Dudleyville, on the Gila, and at the San Pedro, are fairly representative of those at Hayden, Ray, and Kelvin. According to records between 1891 and 1905 the annual mean temperature is 77.5° F. The absolute maximum 112° F. and the absolute minimum 14° F. January is usually the hottest month. The mean annual precipitation is 12 inches. The precipitation in the driest year within the period of record was 8.4 inches and of the wettest year 12.8 inches.

May and June are the driest months and are followed by the principal rainy season, in July and August, but part of the rain comes in winter. Much of the rain falls in violent local showers, which in a few minutes change dry areas into torrents.

In consequence of the dryness of the air and the rapidity of evaporation the great heat of summer is less oppressive than much lower temperatures in the Eastern States, especially if some protection can be had from the direct rays of the sun, and in winter the clear skies and cool nights are thoroughly delightful, although a change in temperature of 30° or 40° may take place between midnight and noon.

The vegetation is that which is generally found in a climate like that just described throughout this part of the arid Southwest. The higher, for the most part of the Final Range lies almost entirely in the Globe quadrangle, and the area here described is generally crooked. A few pines grow, however, on the steep north slope of El Capitan, in the Mason Range, and eucalyptus, cottonwoods, and walnuts grow along the larger streams and about some of the springs. Scrubby, bushlike sage, the alligator juniper (Juniperus deppeana var. mojunensis), the dwarf (Picea brevita Torrey) and probably some others, the century plant or agave (probably Agave parryi Engelmans), a leafless woodylike shrub (Cotetjum rhodaneseum Torrey), and the deer nut (Bousia californica Nuttall) are among the common larger plants on the higher hills. On lower slopes and on the gravelly slopes of Gila conglomerates are found the great-leafed palo verde (Parkinsonia aculeata), the ocotillo (Fouquieria splendens Engelmans), a noble plant at any time and when decked with its scarlet blossoms well deserving its specific designation, the imposing giant cactus or arborescent cereus (Cereus giganteus), suggestive of huge candelabras, the barrel cactus or bismara (Echinocereus meloecus Engelmans), the prickly pear (Opuntia, several species), the formidable cholla (Opuntia molles), and the ocotillo. Many smaller members of the cactus family. Mesquite (Prosopis glandulosa Torrey), the ocotillo (Acacia greggii), Gila, and any member for the sharpness of its curved spines by the delicious perfume of its small yellow blossoms, and the palms (Ficus anearhoecora Torrey) Engelmans) are common along some of the dry bottom lands, as in Dripping Spring Valley.

Although the vegetation of the desert type has a distinctive beauty that is no less real because it is totally different from that of the more humid regions in which most of us live. Grasses spring up after the rains, and in the spring nearly all the cactuses bear flowers of clear and brilliant color. Many of the shrubs also are flowering, and in bloom brighten the landscape with their named colors and exhibit their delicate perfumes into the desert air.

SURFACE FORMS AND DRAINAGE.

The most prominent features of the surface of the Ray quadrangle are three mountain ranges that trend generally southward and two intervening broad, gravel-filled valleys. These features, enumerated from the Hayden to southeast, are (1) the Ventana Range; (2) the Dripping (or Disappearing) Valley; (3) the Dripping Spring Range; (4) the valley of the Gila, and (5) the Tortillas Range. The valleys are similar in their topography and in the general character of their filling, which consists of the Gila conglomerates. Though all three mountain ranges are carved from materials that are in large part identical, each displays distinctive features of structure and topography.

The elevation of the quadrangle ranges from 1,750 feet in the gorge of the Gila west of Ray Junction to 5,640 feet on the summit of El Capitan, in the Mason Range. The bottom lands along the Gila attain an elevation of 1,900 feet above sea level in the southeastern corner of the quadrangle, and those in Dripping Spring Valley reach about 3,000 feet between Troy and Walnut Spring. The mountains range rise in general from 1,400 to 2,000 feet above the bottoms of the main valleys. As a whole the surface of the quadrangle slopes from northeast to southwest.

The Mason Range, which occupies the northeast corner of the quadrangle, in spite of having a local name of its own, is a broad topographic mass nearly the southeastern continuation of the Final Range, which is the principal escarpment feature of the Globe quadrangle. There are, however, both topographic and geologic reasons for a distinction, inasmuch as the latter part of the range, to which the name Final is usually applied, consists chiefly of pre-Cambrian crystalline rocks from which the Paleozoic sediments have been stripped.
back by erosion, whereas the Mesol Range is composed principally of these Paleozoic beds and intruded diabase. In structure and in topography the division the Final and Mesol ranges are decided in contrast.

The two ranges overlap and merge along the northern border of the quadrangle, the ridges of ordinary rock, the ridges of sedimentary rock, the eastern part of the Final Range, and its side at first gently toward the neighboring arroyos but steepen rather abruptly downward and finally turn into nearly vertical cliffs. In some places, particularly in the part of the valley southeast of Dripping Spring ranch, where the Gills formation is covered by the Final schist, the topography is of the typical badland type. The arroyos, which carry no water except for a short time after rain, are floored with sand and gravel and maintain a regular grade from the middle of the valley into the mountains. Progress along the main arroyos or streamways presents no difficulties, but attempts to treed in directions across their trend are likely to be regretted, and a horseman who enters one of the narrow, steep-walled streamways must have to follow it for miles before he can find a place of escape.

The Dripping Spring Range, which stretches diagonally across the quadrant from the southwest to the northeast corner, varies in width in this part of its course from 3 to 4 miles, being definitely bounded on the northeast by the Gills conglomerate of Dripping Spring Valley and along most of its southwest flank by the similar material that fills the valley of the Gills. On the south it extends to Mineral Creek, less than a mile beyond the boundary of the Ray quadrangle.

Notwithstanding the uniform width and the rectilinear trend of this range there is a well-marked system and it shows some of that obvious relation to geologic structure that is so evident in the Mescal Range. Nevertheless, a general view of the trend of the range shows that the quartzite cliffs of El Capitan, and other peaks of the Mescal Range all seem to have been upturned into an almost vertical attitude.

The only perceptible stratigraphic changes in the quadrangle in the San Pedro Valley are those of an angular unconformity.

The most prominent and interesting feature of the bedrock is the remarkable degree of badland and arroyo development which is characteristic of the quadrangle. This is particularly evident in the area of the quadrangle near the southern border.

The post-Cambrian rocks and have cut deep and very narrow gorges through the Paleozoic beds. In summer the gravelly reaches of these streams in the southern part of the quadrangle are floored with sand and gravel and maintain a regular grade from the middle of the valley into the mountains.

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PRE-CAMBRIAN ROCKS.

Figures 1 to 3 are generalized columnar sections of the rocks that crop out in the Bay quadrangle. Figures 1 and 2 show the distribution of the pre-Cambrian rocks in the area. Figure 3 shows the distribution of the Quaternary rocks in the area.

Figures 4 to 5 are generalized columnar sections of the rocks that crop out in the Globe and Yuma quadrangles.

Figures 6 to 8 are generalized columnar sections of the rocks that crop out in the San Francisco and Sonora quadrangles.

Figures 9 to 11 are generalized columnar sections of the rocks that crop out in the Caliente and Mesquite quadrangles.
silvery-gray rock of imperfect cleavage and on surfaces of fresh
both in comparatively large plates, many of which inclose
very irregularly bounded crystal grains. The muscovite occurs
schist is, in the main, a series of metamorphosed sediments.
given anticipatory suggestions of the conclusion that the Final
have been clearly modified by the igneous rock, as shown near
inonzonite porphyry of Granite Mountain, the Final schists
of granulation with more or less recrystallization under
of quartz and sericite. The large quartz grains show the effects
of the schist exhibit even more decidedly than those with which
sideritized by the stresses accompanying metamorphism.
ment under the stresses accompanying metamorphism.
pressure.
In general the mineral composition of the prevalent kinds of
range of the region but in the largest area of exposure runs
ally more than the typical Madera diorite and as consisting of
grains and green muscovite. The birefringence of the muscovite is
so pronounced near the contacts and decrease so gradually outward to be
crystallographic units but show by their shadowy
coarse grains of quartz and biotite, with accessory magnetite and
birefringence of the muscovite entirely clear. The effects of the intra-
formation was noted in some localities.
was accompanied by batholithic granitic masses dur-
and so intricately intruded by batholithic granitic masses dur-
the more general metamorphism.
Given to the opinion that the general metamorphism of the
ponderance of magnesia over lime, and to a like preponderance
schistosity is roughly parallel with whatever larger banding
ranges of the region but in the largest area of exposure runs
early at right angles to them.
were not large and in a rule are not so bearing, but they are so related to the odes as to deserve careful study.
A detailed analysis in another publication.1,2
With respect to the fairly high alkalis, to an excess of over 10
percent of chlorite above the quantity required to combine with the K2O, MgO, and CaO molecules in a 1:1 ratio, to a pre-
features of metamorphism.
Old Baldy is a slightly foliated porphyritic gneiss containing
optical character of orthoclase and in part that of microcline,
more nearly typical variety in the Globe quadrangle.

| 1. Final schist (My 69). Bartlett flat, a mile southwest of Vizela, close to the edge with granitic porphyry maxima of Sierra, Ray district. | 60.0 | 100.31 | 110.58 | 105.86 |
| 2. Final schist (Ry 69). South end of Red Hills, Ray district. George Steiger, analyst. | 60.0 | 100.31 | 110.58 | 105.86 |
| 3. Final schist (My 59). Trace of porphyritic schist 1,000 feet west of sector of the Warrior quadrangle, Globe district. George Steiger, analyst. | 60.0 | 100.31 | 110.58 | 105.86 |

The evidence in support of this view, part of which was
western is accompanied by schistosity; in others the occurrence of hornblende indicates
change been detected in the general character of the prevailing
mass of the rock represented by analysis 1, above. The feld-
with quartz and biotite. Orthoclase and micro-
composition; in others the occurrence of hornblende indicates
progressive steps whereby the pre-Cambrian sediments
latter as a rather dark-gray color as compared with ordinary granite,

groundmass that consists chiefly
where the porphyritic crystals
in part the optical character of orthoclase and in part that of microcline,
percent of chlorite above the quantity required to combine with K2O,
the schistosity is roughly parallel with whatever larger banding
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the schistosity is roughly parallel with whatever larger banding
are commonly regarded as microcline in composition; in others the occurrence of hornblende indicates
change been detected in the general character of the prevailing

Southwest of Bay, in the vicinity of the intrusive quartz
granitoid rocks in pre-Cambrian time. The fact that the
of pre-Cambrian quartz diorite and granite of the

Although andalusite appears to be confined to the immediate
coarser than the typical Madera diorite and as consisting of
the probable equivalent Yavapai schist of the Bradshaw
F. ______ -________-_____-__- _ -   - _-

5. West slope of Final Range, 3 miles south of Mount Madera.
6. At no place southeast of the stage road has any marked change been detected in the general character of the prevailing
for the discrimination of two or more varieties. But distinction, in part as a result of pre-Cambrian weathering, is deep and general, so that

1. Globie Kevloll stage road, 3 miles north of Peak Pic or 14 mile southeast of Pioneer Mountain.
2. West slope of Final Range, 5 miles southwest of Mount Madera.
considerably different from that given in column 1 of the table on page 4. Such facts show that granite, for example, is characterized by abundant quartz phenocrysts and is generally red by pre-Cambrian incrustation.

Granite (biotite granite).—In all ordinary exposures the granite is weathered and in various stages of disintegration, so that it is a mixture of fresh and altered crystals. The greenish color is due to the presence of tiny patches of chlorite. Considerable numbers of pre-Cambrian crystals are in the granite. In the Globe quadrangle the granite is generally reddened by pre-Cambrian incrustation.

Conformable. Distribution.—In the northeastern part of the Ray quadrangle the Scanlan conglomerate is exposed on El Capitan Mountain, Old Baldy, and at many other places along the contact of the sedimentary series with the Modern diorite. In all ordinary exposures the granite is a massive red rock, and in the Globe report was erroneously classed with the Schultze granite, which is virtually identical with the granite of the Tortilla Mountains.

The Ruin granite of the northern part of the Globe quadrangle is red and is distinguished from the Modern diorite and Modern granite. In the Ruin granite report was erroneously classed with the Schultze granite, which is virtually identical with the granite of the Tortilla Mountains.

PALEOZOIC ROCKS. STRATIGRAPHIC TERMS AND SEQUENCE. The names, thickness, and succession of the Paleozoic rocks that in the Ray quadrangle are not in accordance with the Paleozoic formations of the Carboniferous limestone, to which the name was intended to apply, and in thickness. It was evidently formed with little transgression from the material of the beds of the advancing sea found lying on a well-worn ancient surface of low relief. Areas of schist were litten with fragments of white vein quartz, and the upper parts of the beds were deeply disintegrated. Tiny to medium-sized pebbles, the conglomerates, where it rests on the bed, is composed of thin beds of small particles of schist, granite, quartz, and flint; in some cases on the upturned bed of liassic schist whitish massive rock or grade upward into the arkose and in the sequence of the conglomerates, are connected by transition facies. The thickness of the formation varies widely from place to place. In some localities the base of the Pioneer shale may be marked by a few partly dissected pebbles or the conglomerate cannot be recognized at all. In other places, as far as the Pioneer Mountain and Old Baldy, the conglomerates attain at least a thickness of 15 feet and are not distinguished from the underlying massive rock or grade upward into the arkose and in thickness. The thickness of the formation varies widely from place to place. In some localities the base of the Pioneer shale may be marked by a few partly dissected pebbles or the conglomerate cannot be recognized at all. In other places, as far as the Pioneer Mountain and Old Baldy, the conglomerates attain at least a thickness of 15 feet and are not distinguished from the underlying massive rock or grade upward into the arkose and in thickness. The thickness of the formation varies widely from place to place. 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and to examine in great detail their lithologic features. In the Driggs Spring Range, exposed from the vicinity of Tam o' Shanter Peak to the point where the Paleozoic rocks disappear under younger formations along Mineral Creek in the southeast corner of the Globe quadrangle, in this range the formation is divided by faulting into inaccessible small deposits. In the upper northwest part of the formation lies the Dripping Spring quartzite prominent in surface exposures. In the Tor­

The Dripping Spring quartzite was deposited in shallow water, and the sand was at times exposed to the air, as may be seen from the ripple marks and fossil worm casts in the middle part of the formation. The sand on the Dripping Spring quartzite is generally similar to the material of the overlying Dripping Spring quartzite, although perhaps a little coarser. It varies in hardness, but as a rule all constituents of the conglomerate are cemented together and can be broken up into a hand and durable rock in which fractures traverse pebbles and matrix splits. A very characteristic feature of the Barnes conglomerate throughout the region described is the presence of large fragments of terrigeneous red clay and sand and of sandstone, of which there are nearly 3 feet thick, but the presence of intrusive diabase detests a little from the reliability of this measurement, as movements during the intrusion may have increased the apparent thickness. Southwest of Pioneer Mountain, where apparently the whole of the tholeiitic dolerite is exposed without noticeable faulting, the thickness, obtained by calculation from the width of the outcrop as mapped, the average dip of the beds, and the general angle of topographic slopes, is about 400 and 500 feet. At Barnes Peak, in the Globe quadrangle, the thickness was estimated at 450 feet. The least thickness in the Ray quadrangle is closely associated with intrusive masses of diabase, usually in the form of sheets. Some of the charac­

The usual appearance of the Mescal on outcropping edges is the rough, gnarled banding that is its most characteristic feature. Under the microscope the basalt is seen to retain much of its basic structure, and in the earlier work in the Globe quadrangle the basalt at one locality on Pioneer Creek, half a mile northwest of Tarn o' Shanter Peak to the point where the Paleo­

Mescal limestone.

Preparation. The Mescal limestone was first recognized as a distinct formation in the course of mapping the Ray quadrangle. It is named from the Mescal Mountains, where it is well exposed. Stratigraphically it is limited by the Dripping Spring quartzite and above by the Troy quartzite. Some frag­

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The relation of the Barnes conglomerate to the Pioneer shale is very constant in character and has a uniform thickness. The formation in most localities in the vicinity of Tarn o' Shanter Peak to the point where the Paleo­

The Mescal limestone is composed of thin beds that have a varied range of color but are predominantly brown. The limestone is recognized by its uniform structure, its cellular layers parallel with the bedding planes, and on weathered surfaces these layers stand out in relief and give to the limestone the rough, gneded bending that is its most characteristic feature. The usual appearance of the Mescal on outcropping edges is shown in Plate IV. The general hue of the formation is gray or white, but some beds are yellow, buff, brown, or gray. In some localities the rough, gneded surfaces are accompanied by others in which there are thin, rrep and gray layers.

The Mescal limestone has been recognized in the Sierra Nevada and in the High Sierras. It is in part lithologically identical with and possibly the stratigraphic equivalent of the Abrego limestone of Blythe and Tomberling, which contains the same diabase fossils. This correlation, however, is not regarded as sufficiently well established to justify definite application of the names.

Lithologic characteristic. — The Mescal limestone is composed of thin beds that have a varied range of color but are predominantly brown. The limestone is recognized by its uniform structure, its cellular layers parallel with the bedding planes, and on weathered surfaces these layers stand out in relief and give to the limestone the rough, gneded bending that is its most characteristic feature. The usual appearance of the Mescal on outcropping edges is shown in Plate IV. The general hue of the formation is gray or white, but some beds are yellow, buff, brown, or gray. In some localities the rough, gneded surfaces are accompanied by others in which there are thin, rrep and gray layers.

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sections that show the two quartzites separated by the intervening bed of Mescal limestone, and such brief papers on the geology of the area where it is overlapped by the Gila conglomerate. North­west of El Capitan it outcrops almost continuously for 7 miles to the area which is overlapped by the Gila conglomerate. In the Dripping Spring Range the quartzite, dipping at angles near 20°, appears near the lower limit of the Tamarisk Range and is the most extensively exposed rock in the range between Tum o’ Shanter Peak and Scott Mountain, forming most of the prominent summits in this stretch of about 11 miles. In the Toltilla Range, in the southeast corner of the quadrangle, is composed of its nearly vertical attitude it occupies a very small area.

Lithologic character—The beds of the Troy quartzite differ greatly in thickness ranging from thin flaky beds to coarse-beded pebbly beds from 25 to 50 ft thick. On the whole the thinner beds are characteristic of the lower and middle parts of the formation. The upper part is invariably composed of thin, generally yellowish or rusty wavy-marked shaly quartzite, which is well developed in sedimentation that preceded the deposition of the Devonian limestone. The most charac­
teristic material of these upper beds consists of layers of fusiform and oval calcareous nodules, pink and green quartzite, an inch or two thick, separated by films of olive-green shale whose weathering surfaces are ridged and knotted with numerous worm holes. This quartzite layer varies almost color and texture, but the microscope shows them to consist chiefly of finely fitting quartz grains with specks of Strobein lime­
stone and little nests of a green chlorite mica. The most noto­worthy features of the thicker beds are their conspicuous cross-bedding and their generally pebbly character, which is a useful means of distinguishing isolated exposures of the Troy quartzite from the pebble-free Dripping Spring quartzite. Both of these characteristics are illustrated in Plate V. The Troy limestone is a comparatively thin-beded formation, which weathers into slopes, broken here and there by a low spurs that marks the outcrop of some bed a little harder or thicker than the rest. A typical natural section of the formation is shown in Plate XI. Distinct views of each slope shows that the formation is divisible on the basis of color into two nearly equal parts. The prevailing hue of the lower division is light yellowish gray; the upper division in tint, dis­
plays alternations of deeper yellow and darker gray. Detailed examination proves the lower division to consist mainly of very compact, hard quartzite in beds rarely more than 2 ft thick and, at the base, a bed of impure yellow limestone containing abundant grains of quartz. This lowest bed, which in places is cross-beded and contains so much detrital ma­
terial that it might be classed as a calcareous grit, weathers to a rough sandy surface, but the overlying gray beds are charac­
terized by solution surfaces that although uneven in general are smooth in detail. A characteristic feature of these compact lower limestone is the presence of little spherical, oval, or irregular concretions of dark chert, which as a rule are about the size of peas. No identifiable fossils have been found in the lower division, whereas they are numerous in the upper division as shown in Plate XI. The upper division is generally fossiliferous, some of the shaly partings particularly being crowded with Argopecten regulus and other small Devonian brachiopods. Although the relationship between the Devonian fauna of the Ray quadrangle and that in the Martin limestone of the Bisbee quadrangle and in the lower part of the "Globe limestone" of the Gila quadrangle is sufficiently strong to justify their correlation, there are some interesting contrasts indi­
cated by the fossils that have been collected. Argopecten whelks, which is one of the most abundant species in the fauna of the Gila quadrangle, as it is in the Iowa fauna, is absent from the collection from the Ray quadrangle. Ovula are also almost entirely wanting in this collection, whereas they are conspicuous in the Bisbee collection. One of the species which occurs in the fauna of the Ray quadrangle but which is absent from the known Martin fauna of Globe and Bisbee is Perspecta cf. P. elliptica.

The Devonian formation of the Ray quadrangle to its proper place in the time scale involves the consideration of the very closely related fossils of the Martin limestone in Arizona and the Lower Devonian fauna of Iowa. The Devonian fauna of Russia, which is very closely allied to the Arizona fauna, is the equivalent of the Strobein fauna of eastern Russia, which is generally considered to be of Middle Devonian age. The points of resemblance between the Arizona, Russian, and European faunas are of interest. The Russian fauna is in the writer that more dependable evidence for determining the relative age of the fauna is available without going so far afield. The Lower Devonian fauna of Iowa, with which the Arizona fauna is correlated, contains species of ostracoda common to the Upper Devonian fauna of New York and has been generally considered to be of Upper Devonian age. In Arizona Linnarssøn has found evidence of a

### Distribution of species of Devonian fossils in the Ray quadrangle.

<table>
<thead>
<tr>
<th>Species</th>
<th>Distribution</th>
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<tbody>
<tr>
<td>A. elliptica</td>
<td>X</td>
</tr>
<tr>
<td>B. globulosa</td>
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</tr>
<tr>
<td>C. ovalis</td>
<td>X</td>
</tr>
<tr>
<td>D. lancioides</td>
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<tr>
<td>E. strophoideum</td>
<td>X</td>
</tr>
<tr>
<td>F. carinatum</td>
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<tr>
<td>G. crassum</td>
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<td>H. truncatum</td>
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<tr>
<td>I. elongatum</td>
<td>X</td>
</tr>
<tr>
<td>J. angustatum</td>
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**Distribution of species of Devonian fossils in the Ray quadrangle.**
stratigraphic break between the Devonian limestone and the Carboniferous region of a fauna of Mississippian age. On the ground of its
iferous limestone. The evidence of the Arizona sections indicates
It is of course possible that the time range of this fauna in Arizona
occurring in the lower part of the "Globe limestone," has been
indicate that there is no fauna in the Eocky Mountain region which
small lots, which are designated A, B, C, etc., and labeled as follows:
represent both the Ithaca and the Chemung faunas of New York.
with what is now named the Martin limestone, fossils collected
1901, and March 17, 1902, for report upon the age of the horizon
rule poorly preserved and extremely difficult to collect. About
part. Fossils collected from this bed and those just above it
poorly preserved shells near its base and corals in its upper
Fossils collected from this bed and those just above it were
Kindele, who has identified the follow­ing
species:
1. Pugnax pugnus
2. Cyrtia cyrtiniformis (Hall and Whitfield)
3. Spirifer whitneyi var. animasensis (Girty).
4. Atrypa spinosa Hall.
5. Schizophoria striatula var. australis Kindle.
Mr. Kirk remarks that this fauna can be correlated with that of the Martin limestone of Bisbee and that of the lower or Devonian part of the Omine limestone of Colorado. He states that there can be no doubt as to the Devonian age of the material.
At Jerome, 125 miles northwest of Ray and about 100 miles
forms of sufficient fossils to confirm a lithologic and indecisive pale­
ness with which their structural features are displayed, and
of geologists and bibliographers.
11. Pugnax pugnus
12. Cyrtia cyrtiniformis (Hall and Whitfield)
13. Spirifer whitneyi var. animasensis (Girty).
14. Atrypa spinosa Hall.
15. Schizophoria striatula var. australis Kindle.
16. Cyrtia cyrtiniformis (Hall and Whitfield)
17. Spirifer whitneyi var. animasensis (Girty).
With the exception of the fauna II, the several faunas are presented so as to be more geologically informative, as indicated by the presence of the fishes and other forms which are associated with the limestone fauna which is present in the lower part of the "Globe limestone." On the ground of the classification to an Upper Devonian fauna of Iowa and its stratigraphic position, the fauna in the lower part of the "Globe limestone" would place the fauna of the Martin limestone and its equivalent, the Devonian fauna of Kentucky, in the Upper Devonian. It is of course possible that the time range of this fauna in Arizona may include Middle as well as Upper Devonian, but that it includes the Upper Devonian is very strongly established by the available evidence.
A fauna similar to the Devonian fauna of the Ray quadrangle, occurring in the lower part of the "Globe limestone," has been reported by Prof. H. H. Williams II in the Ithaca fauna of New York. There is no question that the Ithaca or Papuse papuse fauna is the equivalent of a portion of the fauna found in the Martin, or Devonian, fauna of Kentucky. The description of the fauna, as given by Dr. F. L. E. Ramsey in the Globe quadrangle, Arizona, was submitted to the writer November 14, 1901, and March 17, 1902, for report upon the age of the horizon immediately preceding the "Globe limestone." The fauna is preserved in a great variety of small lots, which are designated A, B, C, etc., and labeled as follows:
A. *Bull. 225, p. 243, 1904.*
B. *Unpublished manuscript of Tucson folio.*
C. **U. S. Geol. Survey Prof. Paper 21, pp. 33-42, 1904.**
D. **U. S. Geol. Survey Prof. Paper 43, pp. 66-69, 1905.**
E. **E. S. Geol. Survey Prof. Paper 88, A 1-92, 1922.**

Kindele writes: "These species represent an Upper Devonian fauna of the same general area as that previously collected by you at various points in Arizona." In other words, it is the fauna of the Martin limestone. The total thickness of the beds previously assigned to the Devonian at Jerome is about 500 feet. Of course there is a possibility that the lower compact limestone, from which no fossils were obtained, may be older than Devonian.
In the Grand Canyon the Devonian Temple Butte limestone, 110 feet in maximum thickness, is in many places absent. Recent work of L. F. Nibley 11 supplies many details of its occurrence and of the correlation between it and the over­
lying Redwall limestone and the Mississippian Middle Creek limestone.

Carnovermen System.

TORSO LIGNITE.

Definition.—The Torso lignite, named from Torso Creek, in the southeast portion of the Ray quadrangle, where it is extremely exposed, overlies with apparent conformity the Martin limestone and is equivalent to the Carnovermen portion of the "Globe lignite" as originally mapped in the Globe quadrangle. Its base appears to be a surface of erosion which in general rests the Quarternary Gila conglomerate, and its upper margin forms part of the Ray quadrangle, and is an interesting erosional formation, probably of Messinian age.

Distribution.—In consequence of the thick and resistant character of the beds the Torso lignite is nearly or quite as prominent a member of the sedimentary series as the Toy quartzite.
In the Meesel range it forms the base of the Gila conglomerate in smooth slopes that correspond nearly to the dip of the beds and sweep up in a series of bold crests which separate the Gila from the to the east.
Beginning inconspicuously at the northwest end of the range, these crests increase in size toward the southeast and become imposing in rounded forms where they approach in the vicinity of the Gila gorge, east of the Ray quadrangle. From any
influence may be given to the cliffs or erosion of the so-called "flat
crests" in flowing concentric curves.
In the Toottilla Range the faulted and eroded Tormo limestone forms steep, narrow, rugged ridges that project conspicuously above the Gila conglomerate.
Lithologic character.—The Torso limestone is generally light-weathering in color and is divisible with respect to thickness and character of bedding into at least three members.
The basal division, directly overlying the Devonian, is about 25 feet thick and forms the lower part of the section that so prevalent a feature of the Carboniferous outcrops in central and southern Arizona. Under the action of erosion this division behaves as a single massive bed, but in reality it is made up of a series of horizontal lenticular beds.
This division, with a few normal stratigraphic thickness at its top, is succeeded by a very massive member, fully 100 feet thick, within which, as exposed in cliff faces, there are, a small rift near the horizon of the dip of the beds and sweep up in a series of bold crests which separate the Gila from the to the east.
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from Plate VI, is of lighter and more uniform color than the basal member. The two together constitute the principal dill
forming the Carboniferous lime
The Torpedo limestone consists essentially of calcium carbonate and dolomite, with a small admixture of shells. The third

development of the Gila conglomerate. In the vicinity of Tornado Peak and

the Gila conglomerate. In the vicinity of Tornado Peak and is unknown, for the formation was extensively eroded before the

Thin layers of calcareous shale separate some of the beds, but these are a very subordinate part of the formation.

The two lower divisions contain abundant fragments of crinoid stems and few numerous pebbles with long-winged spindles and

Rhipidophragmus, and to Mellor, show similar relations to underlying shales. The

deposits. The evidence as to marine or fluvial deposition is insufficient.

The Sceian conglomerate, with its pebbles of local origin, appears to be most reasonably accounted for as a basal marine conglomerate, although this interpretation has little definite evidence in its favor. The succeeding Pioneer shale gives no clear indication whether it is of marine or fluviatile origin. It contains no fossil remains or mud cracks, so far as known. The most puzzling feature of the succeeding Barnes conglomerate is its relation to the Pioneer shale. A course conglomerate with well-rounded pebbles, indicative of vigorous abrasion and powerful currents, rests on material that when the pebbles accessible to the bedload. This pebble

Diatomaceous earth, deriving its character from the characteristic fossil organisms

The unfossiliferous Dripping Spring quartzite contains some

The deposition of the impure dolomitic Mescal limestone marks a change of conditions of sedimentation—apparently a

The formation is tentatively regarded as deltaic origin.

The evidence of erosion of the shale found by him in South Africa is looking, as far as known, in Arizona. Mellor's conclusion, that the Mescal limestone in the Martin show that that formation was laid down in shelf

A similar relation appears to hold between the conglomerates of the Eastern Band, South Africa, and the underlying forma-

Several conglomerates in the Witwatersrand series, according to Mellor, show similarities to underlying shales. The

The formation is tentatively regarded as deltaic origin. The

As has been shown in the preceding pages, there is little
difficulty in correlating the Devonian and Carboniferous forma-

1. Northeast corner of Ray quadrangle.
2. South end of Chiricahua Mountains.
3. Hills 3 miles west of south from the triangulation cairn on El Capitan Mountain.
4. 1 mile south of summit of Mount Tamolitch.
5. One mile northeast of London-Arizona mine.
6. One mile northeast of London-Arizona mine.
7. One mile south of triangle northeast of London-Arizona mine.
8. Two and three-quarter miles southwest of summit of Torpedo Peak, near contact with overlying shales.

According to Mr. Girty the older of these two flaxes is early Mississippian and the other is early Pennsylvanian. He notes that the conditions exhibited by the Ray quadrangle are appar-

Thin-bedded gray limestone with some pink limestone alternating. The

The Torpedo limestone and the Martin limestone, as shown by their fossils, are unquestionably marine. Ten or fifteen years ago most of the localities had no location in cleaning the sediments of the Apache group also as marine deposits, although no marine fossils have been found in them. They were, as considered in the Globe report, written in 1905, and in the Globe folio, prepared about the same time. Recent studies, however, upon a thorough review of Recent studies, however, upon a thorough review of the fauna of the Dripping Spring quartzite, in the vicinity of Tornado Peak and along the eastern flank of the Texas Range the limestone at present must be fully 1,000 feet thick, and it nay at one time have greatly exceeded this thickness.

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The foregoing section is entirely different from the Paleozoic section of the Ray-Miami region, and although the section as a whole probably can not yet be fully correlated with the Grand Canyon section, the basal sandstone is without doubt a Tepaste sandstone of the Tonto series. At a short distance from the Place in the Bay cressin point to which this sandstone has been traced is a ridge just south of Payson, where it rests on a gray sandstone similar to the Tonto sandstone. To the north, along the Mogollon escarpment, the beds just described pass under other limestones, probably including the Breccia, and chief thick slices of red beds that are probably Spilus, overlies the Cocomino sandstone.

At Jerome, 65 miles northeast of Payson, the same basal sandstone, 75 to 80 feet thick, rests on pre-Cambrian schist. It is overlain by limestone which attains about 550 feet above the top of the sandstone called Devonian fossils.

In another publication the correlation of the Paleozoic strata in Arizonia has been more fully worked out, and although the section as a whole probably can not yet be fully correlated with the Grand Canyon section, the basal sandstone is without doubt a Tepaste sandstone of the Tonto series. At a short distance from the Place in the Bay cressin point to which this sandstone has been traced is a ridge just south of Payson, where it rests on a gray sandstone similar to the Tonto sandstone. To the north, along the Mogollon escarpment, the beds just described pass under other limestones, probably including the Breccia, and chief thick slices of red beds that are probably Spilus, overlies the Cocomino sandstone.

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II

that subsided in the larger masses. If so the diastase is younger than the Pennsylvanian epoch of the Carboniferous. The relation of the diastase to the andesite in the vicinity of Tornado Peak is not definitely determined; if it is present; however, it is thought to be considerably older than the andesite breccia southeast of Tornado Peak. Most of the rock near Ray is said to be a porphyritic granite of medium grain, with pheno-

TEXT CONTINUES...

In certain localities the andesite breccia may be 2-3 centimeters or more in length, with the feldspars of proportionally smaller size. The minor component of the rock is also somewhat variable.

In a few places the quartz diorite grades into local coarsely crystalline felsite, some of which are highly hornblende.

Contact metamorphism.—Quartz diorite which crops out in a small triangular area about a mile north of Tornado Peak has an included block of Massive limestones. This has been strongly metamorphosed, and the igneous rock near the limestones is more or less slightly crystalline and more conspicuously hornblende than elsewhere. The principal minerals developed by metag-

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on this rock under the microscope and its chemical analysis are shown in U. S. Geol. Survey Paper 133 p. 39, 1909.

To obtain, and the material as a whole has undergone considerable

marble and sericite and the biotite to chlorite and epidote. In a few places the quartz diorite grades into local coarsely

pseudomorphs of plagioclase being embedded in a felsi-

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The text of the larger masses, such as that intrusive into the Huge Mountain limestone, resembles in caseul inspection that of a porphyritic granite of medium grain, with pheno-

the obvious characteristics of the typical quartz diorite are light to dark gray color, even-fine-grained textures, and granular to porphyry structures. This mineral, which is characteristic of the andesite porphyries, is locally present in the quartz diorite. The constituent minerals are generally not more than 3 millimeters across, and the structure of the rock is commonly porphyritic, with a porphyry texture and a foliated or schistose structure. The small feldspars are commonly aligned in parallel fibers, and the rock is often described as a foliated porphyry.

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mation of the Masonic or late Paleozoic.

occurrence and distribution.—The quartz monzonite porphy-

Occurrence and distribution.—In their reports on the Deere Creek coal field both Wolcott 44 and Campbell 46 refer briefly to the occurrence of quartz monzonite porphyry in the southeastern part of the quadrangle, east of Tornado Peak, and but is itself cut by dikes of quartz diorite porphyry similar to the rock of some of the dikes near Troy. Another mass south-

of massive limestones is in the andesite breccia southeast of Tornado Peak. Most of these dikes are east of the Ray quadrangle.

The relation of the diabase to the andesite in the vicinity of

The obvious characteristics of the rock are black color, fine feldspar, and light-green and gray hornblende with a slightly weathered surface. The rock is mostly altered to a light gray felsite with a faint yellow tint and closely resembles some of the Schultze granites. This lightness of hue is due to the presence of feldspar and quartz, the only dark constituent being black mica in small and sparsely disseminated flakes.

The texture of the latter rock, which is a number of irregular masses, of which the largest forms part of Granite Mountain, is that of a porphyritic granite of medium grain, with pheno-

of the Ray quadrangle, there are many dikes and one irregular mass of considerable size exposed on the flanks of Granite Mountain, a prominent landmark northwest of Ray. Granite Mountain porphyry.—The quartz monzonite por-

As bearing on the age of the quartz diorite intrusions, the fact should be noted that dikes of this rock are fairly abundant in the andesite breccia southeast of Tornado Peak. Most of these dikes are east of the Ray quadrangle.

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The granodiorite area. Here magnetite, chlorapatite, and pyrite occur as irregular crystals in a felspar-gray or brown rock, with minute phenocrysts of hornblendes in an amphibolite groundmass. Some varieties show also small pyroxene of the diopside variety. The rock has been invasively cross-cut by a fine-grained pegmatite, rough cleavage parallel with the sides of the dike and has acquired by weathering a pronounced play of structure. Under the cleavage, the marginal rocks are often decomposed and contain abundant calcite, chlorite, and other secondary minerals, but there appear to have been originally small phenocrysts of plagioclase and hornblende in a groundmass consisting chiefly of fine tesselated laths of plagioclase. As it is, however, little more can be done than to call attention to the marked difference in general character between the medial portions and sides of the dikes and to point out that the marginal facies are more hornblende and less quartz than the typical quartz diorite.

Among the quartz diorite porphyry dikes near Cane Spring are a few thin, shiny, dark-green-gneissic epidote schists. As their importance scarcely warrants an individual color and as they were perhaps intruded at the same time as the other dike, they are mapped as quartz diorite porphyry.

**Contact metamorphism.**—Notable contact metamorphism has been produced by the intrusion of quartz diorite porphyry in the vicinity of the London-Arizona mines, in the southern part of the Ray quadrangle, and at Christmas, just east of the quadrangle. Near the London-Arizona mines the dike close to the porphyry has the glittering appearance that denotes the development of secondary biotite and in places has become a dark biotite schist. The alteration is as one in kind but more intense than that near Troy described above. Here and there in the Oxchuck Range, it is not everywhere in actual contact with the porphyry but in all probability a consequence of its intrusion, are masses of gray rock. About a mile southeast of the London-Arizona mines, on the left of the dam formed by the London Range shaft, in Torreon limestone, shows considerable talcose, the pink manganous epidote, associated with some common epidote. This occurrence is probably due to the intrusion of the quartz diorite porphyry, although none of that rock is visible at the surface at this place.

At Christmas the corner deposits of contact-metamorphic origin, occurring in the Torreon limestone in close association with quartz diorite porphyry, the principal silicates are pyrite, chlorapatite, and chlorite associated with magnetite, serpentine, dolomite in granular and in part radiating micrographic aggregate of calcite. It is likely that other minerals are also present, as the mineralogy of the deposits has not been fully studied. A little hornblende and chlorite were noted, the latter closely resembling greenish epidote.

**Comparison of the granitic rocks.**

The accompanying table of chemical analyses shows the close relationship existing between the post-Paleozoic granitic rocks and porphyries, which the Lost Dutchman is lower in alumina than the others and differs from them in also containing more potash than soda. This tends to support the suggestion made elsewhere that the post-Paleozoic granitic rocks and related porphyries may be older than the other post-Paleozoic granitic rocks of the region.

**Chemical analyses of post-Paleozoic granitic rocks and related porphyries.**

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<tr>
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<td>0.13</td>
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**Gneissic granite.**

Gneissic granite, 1 mile west of Schultze ranch, Globe quadrangle. E. T. Alien, analyst.

**Granite tourmaline porphyry.** (216) Granite tourmaline porphyry, 1 mile east of Schultze ranch, Globe quadrangle. E. T. Alien, analyst.
fragments. The fragments are as much as a foot in diameter
but are generally more or less decomposed.

The formation is the record of the operation, prior to the
dacite eruptions, of forces and processes similar to those
that afterward turned the material is in place on the
rugged desolation for many miles to the northwest. Into this
a thick and extensive flow whose surface may be seen from
the steep slopes of Teapot Mountain near Ray (PL VIII) and
showing small crystals or fragments of feldspar, quartz, and
biotite and minute microlites of feldspar.

Under the microscope this glassy dacite is seen to differ from
the pink facies chiefly in the groundmass, which, being less
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Loss of the few specimens representative of these dikes has
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This is an angular, and the formation might in places be termed a sedi­
mentary breccia. Although the Gila conglomerate has in
places been subject to considerable deformation and erosion,
it is obviously in the main a deposit laid down in the existing
valleys and extends in characteristic long directed slopes up the
flanks of the ranges from which its materials were derived.

In the Ray quadrangle the Gila conglomerate is well devel­
oped and plays a more conspicuous part in the landscape than
in the Globe quadrangle. Diastatic slopes of the conglomerate
in Dripping Spring Valley are shown in Plate I, and a nearer
view of the material in Plate VII. In the middle part of this
valley course of the Gila is in large part covered by dacite
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of the granitic, monzonitic, and dioritic rocks of the
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Some of the tuff that occurs locally at the base of the mas­
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Dacite eruptions, of forces and processes similar to those
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The variety of the conglomerate described is not very different, so as to merit consideration, from that east of Gills River in the vicinity of Hayden. The conglomerates there also contain much undeformed material but is not as well developed as that between Brannan station and Hackberry Spring. To the north of the area here especially considered it is quite possible that some of the beds are of slight aerial extent, but any considerable duplication could hardly have escaped by one observer. The character does not take account of the 3-mile belt of Gills conglomerate between Brannan station and the Dripping Spring range to the northeast. In the latter region it is not more than several hundred feet of the conglomerate that is stratigraphically higher than the beds southward of the river. The total thickness of these upper deposits and the extent to which they are underlain by the more regularly bedded material exposed southeast of them could be determined by sagging on the cliffs probably suggested by the name of that ravine.

**STRUCTURE.**

Some mountains, such as the Appalachians, stand in relief because the neighboring valleys, with which they are in contact, have been eroded below a surface once broadly coincident with the present ridge crests. Such is the case in those southwestern Idaho and southeastern Oregon, which Russell has described, owe their prominence to direct uplift over a flat-topped basin, and is indicative of the resultant structure depends upon the relative ages of the phases of its formation. In 1906 Dr. T. Shields Collins of Globe forwarded to the Survey a fossil bone said to have come from the Gills conglomerate, which was ascertained at this place to be underlain by quartzitic (Malad series) deposits. (See p. 15.)

**Formations.**

The deformation of these beds is considered below under "Structure.

The accumulation of the Gills conglomerate is clearly indicative of deposition very different in kind from those of to-day. The thickness of the Gills conglomerate differs...
faulting will be here used as recommended or defined by the committee on the nomenclature of faults of the Geological Society of America.\textsuperscript{54} The application of some of the more important of these terms is illustrated in Figure 4.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{Diagrams of a faulted block illustrating terms used in describing the structure of each range.}
\end{figure}

Evidence of faulting.—In many regions the presence of faults is indicated by the most reasonable way of explaining certain observed structural relations. In the Ray quadrangle the evidence is as a rule of a more direct character. The very topography of the Dripping Spring Range, for example, as stated on page 2, is indicative of intrusive faulting. A distinct view of the range suggests neither the simplicity of a single homoclinal block nor the linear elements of form that we have learned to associate with mountains of folded strata. A view from any high point over parts of this range shows a complex configuration of the various blocks, as indicated by their respective and characteristic lines in the landscape. Here and there patches of limonitic gravel, a feature of much the same trend as that of the scattered working of the several blocks, may be followed over the entire country for miles. Probably few equal areas of the earth’s surface have been so thoroughly dissected by an irregular network of normal faults and at the same time exhibited so clearly the details of the fracturing of the blocks.

When the forunging was written the Dripping Spring Range in the Ray quadrangle had not been geologically mapped and studied. It displays perhaps still better than any equally large area in the Globe quadrangle the faulted terrain faultism another is of no apparent movement.

Indurated, boldly outcropping fault breccias mark the contacts of many faults, particularly those that traverse quartzite or other resistant rock in one well. This brittle weathering resistant rock is the great breccia maker. Even where faults that, at the surface, pass through other rocks than quartzite, may have quartzite breccias, the fragments having been derived from some place along the break where the fissure passes through or lies on resistant rock. A number of illustrations of fault breccias were published in the Globe report.

Diaboliad.—The faults are not evenly distributed over the region here described, and are conspicuous rather than inconspicuous in the main mass of the Final Range and in the Mescal Range. Those differences will be more fully brought out in describing the structure of each range.

Directions of faulting.—The geologist after mapping the faults in a region studies their directions and tries to determine whether they can be classified into groups, each group characterized by a certain trend or strike. By this means he hopes to get some clue to the relative ages of the faults and to the character of the stresses that produced them. Without regard to any possible major fault that may be concealed by the Gila conglomerate, there apparently is no significant preponderance of faults having one direction of trend over those running in other directions. Here and there in the Ray quadrangle some faults may have a direction of trend parallel to that of another locality different from that in another part. For example, in the vicinity of Tornado and Tom o’ Shanter peaks, in the Dripping Spring Range, the more plentiful faults strike about N. 52° W., but at the north end of the range the locally prominent faults strike nearly N. 30° E.

 Apparently no general and significant grouping of the faults on the Ray quadrangle is seen in parallel trends, but it follows that if the faults are of distinctly different ages, discrimination must be based on other criteria than the differences in strike.

Dip.—Of the many faults that have been mapped in the course of the detailed geologic work on the Globe and Ray

Another reverse fault is recognizable on the west bank of Mineral Creek, about a mile below the mouth of the Ray. The final seis in the west has been thrust up over the smooth football of Dripping Spring quartzite on the east. The dip of this foothill fault must be at least 150 feet, for the Pioneer shale has been cut out. In Eldar Gulch, 3 miles northeast of Kelvin, the Tornado conglomerate rests on pre-Cambrian granite, and the contact dips at 10° or less. The Tornado limestone is disturbed and thrown. Although the small area of the older, it does not appear probable that normal slipping could take place on so low a slope, and the dislocation is supposedly due to stress exerted and part of one block may be shoved over another. The very evidence as a rule is of a more direct character. The very topography of the Dripping Spring Range, for example, as stated on page 2, is indicative of intrusive faulting. A distinct view of the range suggests neither the simplicity of a single homoclinal block nor the linear elements of form that we have learned to associate with mountains of folded strata. Here and there patches of limonitic gravel, a feature of much the same trend as that of the scattered working of the several blocks, may be followed over the entire country for miles. Probably few equal areas of the earth’s surface have been so thoroughly dissected by an irregular network of normal faults and at the same time exhibited so clearly the details of the fracturing of the blocks.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5.png}
\caption{Diagrammatic section illustrating the thrust of Modern diorite (pre-Cambrian) over the Tertiary Tertiary near the Old Dominion mine.}
\end{figure}

Relative ages.—The faults clearly are not all of one age. Many of them, so far as can be determined, do not displace the Gila conglomerate. This appears to be generally true of the faults in the Dripping Spring Range. On the other hand, certain fault breccias north of Bay do cut the conglomerate, and some faults in the Tortilla Range southwest of Gila River also appear to displace it. Many faults dislocate the breccias, and from the west side of this fault it appears probable that a large part of the faulting in the region is post-Pliocene. In a few places, however, fault scarps along which, in the older rocks, there has been considerable movement, may have been thrust from the southwest over diorite against any disturbances of that rock. Such places, however, are not common.

Faulting as an erosional factor.—To what extent faulting actually preceded the intrusion of dike in Mesozoic beds and preserved the original surface of the rock layers in the liquid magmas is unknown. The character of the contact of the dike with the other rocks suggests, however, that the intrusion was facilitated to an extent by previous faulting. Be that as it may, it is certain that at the time of the intrusion the beds, particularly those beneath the Tertiary quartzite, were broken in rather extensive and abnormal fashion into irregular blocks, and that these, after more or less movement in the magma, became fixed as huge inclusions in the solidified dike, as may be well seen in the Mescal Range, in the southeast corner of the Ray quadrangle.

At a number of places dike of diorite porphyry has been injected against fault scarps. This is most clearly shown southeast of Ray, where the dike in part fault breccias and in part fault breccia is of no apparent movement.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure6.png}
\caption{Diagrammatic section illustrating the thrust of Modern diorite (pre-Cambrian) over the Tertiary Tertiary near the Old Dominion mine.}
\end{figure}

Expression in topography.—None of the faults, as far as known, fault superficial—expression as a simple unmodified fault scarps. Minor scarps exist here and there, but these are due to the erosion of the softer rock on one side of the fault. The rock which has undergone the greater erosion may or may not be on the downslope side.

That the steeper faces of some of the ranges may be supposedly modified and in part composed fault scarps is probable. The extent to which this may be true will be discussed below.

Over minor drainage lines the scarps appear to have exercised no direct control, and the ravines do not as a rule coincide with the courses of the streams. Major scarps exist here and there, and these have dislocated the Gila conglomerate. The rocks on one side of the scarps have been more or less movement in the magma, became fixed as huge inclusions in the solidified dike, as may be well seen in the Mescal Range, in the southeast corner of the Ray quadrangle.

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origin is a broad regional problem. Faulting of the kind described appears to be the result of collapse—of a widespread inability of the deeper rocks of the earth's crust to support the overlying sediments. This is especially true in the case of the Madera diorite (quartz-mica diorite) and other dikes traversed by Pinal Creek, is divisible into three portions that, superficially at least, present different tectonic features.

Pre-Cambrian granite at the base to the Tornado limestone at the top. In the Pinal Range the strata on the southwest side of the range were once continuous with those that are now exposed. Part of the lowland which this peak overlooks to the north. The range never had any such altitude as the diagram shows the same stratigraphic descent from the Tornado limestone to the north, the Pinal Range, it is composed largely of pre-Cambrian rocks. In the spring range is a remarkable example of a fault mosaic. The fault shows the same stratigraphic descent from the Tornado limestone to the north.

The range is a homoclinal block with a general dip to the south. A thickness name the Mescal Range. This range, as may readily be seen from the geologic cross sections, is a homoclinal block with a slight south dip. As it has been intruded by pre-Cambrian granite to Tertiary dacite, are brought into juxtaposition in different blocks. The result is a fine-textured mosaic rock such as is very characteristic of the region and is especially well illustrated in the Dripping Spring Range, presently to be described.

Overlapping the middle massive section of the Pinal Range on the southwest and extending southeastward Gils River is the middle division of section A-A' on the structure-section sheet, is a homoclinal block. The Pinal Range is a remarkable example of a fault mosaic. The fault shows the same stratigraphic descent from the Tornado limestone to the north, the Pinal Range, it is composed largely of pre-Cambrian rocks. In the spring range is a remarkable example of a fault mosaic. The fault shows the same stratigraphic descent from the Tornado limestone to the north.

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then it is a remarkable exception to the general structure of the region. It might be urged that the intrusive filling so characteristic of the Globe and Ray quadrangles is the result of the collapse of just such folds as the one here suggested. If so, the unconformable crystalline rocks of the Pinal Range should have been faulted and dislocated by some such movement, whether the movement was that of a simple fault or, as seems possible, a more complex one, as in the case of the Gila-Luna region, but of a more extensive area of which the two quadrangles mentioned are merely a part. It may well be doubted, however, whether this dislocation was effected by a single great fault such as is indicated in the diagram of Figure 6. In all probability an area of complex faulting underlies the Gila conglomerate of the valley adjacent to Globe, and the greatly tectonic displacement, a throw of over 5 miles, was accomplished by slipping along many fractures distributed over a considerable period of time during which erosion actively attacked the base on the upthrown side of the fault zone.

Similar reasoning also holds true between the beds in the Mesial Range and the continuations of those same beds in the Dripping Spring Range. The southeastward of the Mesial Range is virtually a dip slope, the Tumaco limestone disappearing under the Gila conglomerate with a dip of about 3 degrees. The Dravos Spring Valley, a typical Spring Valley, is thrusting Dravos Spring Range should be an anticlinal ridge. The range does not have that character but, as has been described (page 16), it is a relict of the old range, the rocks, if they were not so thoroughly faulted, would have a similar attitude to those in the Mesial homocline. The part of the Tumaco valley of the quadrant is composed chiefly of pro-Cambrian granite, and there is little to indicate the structure of the formation of this of the adjacent valley. The dip of the vertical attitude of the Paleozoic beds in the southern corner of the quadrant, the known presence of conglomerate in the Tumaco valley, the characteristic relation 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 about the range into existence.

In order to establish the truth of the supposition that the mountain ranges and principal valleys are tectonic features it is necessary to show that the floor on which the Cambrian sediments were deposited was in the main due to subaerial erosion. The course of the Cambrian sediments and the beds were folded and composed by fissure in a generally north-south direction, with the exception of the few beds of quartzite (the Martin quartzite) and brown and crystalline dolomite (the Martin dolomite). Later intercalations of sandstone and shale, brown and crystalline dolomite, make the structure somewhat complex. The division of the Gila conglomerate along the eastern flanks of the ridges is a delta deposit.

The valleys are now occupied by the Gila conglomerate. These valleys, being tectonic, would have no regular drainage in the form of streams or arroyos. The streams or arroyos are not in evidence as they have been washed away by the stream of debris. The absence of streams or arroyos is consistent with the general structure of the region. The streams or arroyos may have been formed before the conglomerate was deposited and have been cut out by the stream of debris. The absence of streams or arroyos is consistent with the general structure of the region.

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sage from shallow water in which terrigenous sediments could accumulate to deeper water in which limestones were deposited. From Devonian time well into the upper Carboniferous (Pennsylvania), the region was covered by an abundance of animal life and depositing abundant limestones. No noticeable has been found in the Tornado limestone, which carries Mississippian and Pennsylvanian fossils. From Pennsylvanian time through the middle part of the Tertiary, the region, characterized by a diversified type of land and under growing. Although the surface was probably less rugged, the general conditions as regards climate and erosional activity appear to have been not greatly different from those of the present day. As shown by the accumulation of the Whistle formation, coarse, rather angular debris was washed down the slopes and deposited in the more open valleys and gullies. It was during this period of erosion and accumulation of waste that most of the entrenchment of the Bay and Miami copper deposits is believed to have taken place.

Over this uneven surface, with its hollows partly filled with the Whitmore conglomerate, was poured, probably in early or middle Tertiary time, an excessive flow of detritus. The greater part of the region of which the over formation has been preserved is the resulting intricate lithologic mosaic.

There are no available means of determining whether or not the region became land and was eroded before the intrusion of the diabase. The diabase cut across the stratified rocks and would probably have been preserved in the resulting intricate lithologic mosaic.

Following closely after the diabase eruption, and possibly as a consequence of the cooling of the lava, which is chiefly due to the present surface and less directly the topography of the region. The history and character of the basaltic eruptions in the region, particularly as they appear to have been not greatly different from those of the present day. As shown by the accumulation of the Whistle formation, coarse, rather angular debris was washed down the slopes and deposited in the more open valleys and gullies. It was during this period of erosion and accumulation of waste that most of the entrenchment of the Bay and Miami copper deposits is believed to have taken place.

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The Pennsylvanian limestone is the latest Paleozoic deposit of which the region preserves any record. If marine conditions continued to the Permian, the production of such concretionary nodules as those in the Piney and other carbonaceous limestones, which probably would have been preserved in the resulting intricate lithologic mosaic.

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The American Hercules Copper Co., whose on-beamground is almost enclosed by the claims of the Bay Consolidated Copper Co. and contains the extension of the Gila formation, is given elsewhere.
The ground of this company in 1916 was operated by the Ray Hercules Consolidated Copper Co. Its shares of $15 par value. It owns about 207 acres of mining claims and a mill site; the most valuable part of the mining ground is claimed by the owners of the Ray Consolidated Copper Co. which, after acquiring the property of the Gila Copper Co. in 1910, absorbed the Ray Central Copper Mining Co., as an important outside factor in the development of the disseminated deposits.

By far the strongest and most active company in the Ray district and the one with the largest holdings is the Ray Consolidated Copper Co, which, after acquiring the property of the Gila Copper Co. in 1910, absorbed the Ray Central Copper Mining Co., leaving only the Arizona Hercules Copper Mining Co. as an important outside factor in the development of the disseminated deposits.

The Ray Consolidated Copper Co. is organized under the laws of Maine with an authorized capital of $14,000,000 in shares of $10 par value. It controls also the Ray & Gila Valley Railroad Co., capitalized at $2,500,000. The land holdings of the Ray Consolidated Copper Co. are large, comprising nearly 2,000 acres in the Ray district, considerable ground in the vicinity of Kelvin, and a tract of 3,750 acres in the vicinity of Hayden, where the concentrator and smelter are situated. (See Fig. 7.)

The Ray Hercules Min. (Inc.) is capitalized at $16,000,000, with shares of $15 par value. It owns about 200 acres of mining claims and a mill site; the most valuable part of the mining ground is claimed by the owners of the Ray Consolidated Copper Co. The Ray Hercules Min. (Inc.) was reported in 1921 to have developed nearly 4,000,000 tons of 2.44 per cent ore. The company has carried out extensive underground work and has equipped the mines for production on a large scale. Al Bèlgativa, a settlement just north of Ray Junction and about 6 miles from the mine, there is a concentrating mill with a capacity of 1,800 tons a day. Production began in 1918.

The general plan of development of the Ray Consolidated Copper Co.'s mines is indicated in Figure 8. This map, however, shows only the main haulage levels and therefore represents but a small part of the actual workings. Those at the end of the year 1910 had a total length of about 100 miles, of which about 54 miles had been destroyed by stopping operations. The underground workings driven in 1915 amounted to 68,665 feet. There are three mines, known as No. 1, No. 2, and No. 3.

The plan of the ore body (Fig. 8) shows the marked contraction about 700 feet north of the Pearl Handle shaft, which practically divides the ore body into two parts. No. 1 and No. 3 mines are laid out to work the part of the ore body east of the boundary line. No. 1 shaft and adit are close to Mineral Creek, at the mouth of the No. 3 mine. No. 1 shaft and adit are close to Mineral Creek, and No. 3 is worked through the No. 1 mine. The No. 2 shaft and adit are close to Mineral Creek, and the No. 3 shaft and adit are close to Mineral Creek at the southeast of the No. 1 shaft. This shaft, 300 feet deep, is used solely for hoisting ore. It is equipped with 12-ton skips, run in balance by an electric hoist at a speed of 300 feet a minute. The No. 2 vertical shaft and incline of the Ray Consolidated Copper Co. are three-fourths of a mile nearly northwest of the No. 1 shaft, on the west side of Mineral Creek, just south of the mouth of Sharkey Gulch, and are similar in size, arrangement, and equipment to those of the No. 1 mine.

The general system of stoping adopted in the No. 1 and No. 2 mines at Ray is that commonly known as the shrinkage-stope mining system and has been fully described by Blackner.

Electric locomotives draw the ore in trains of 5-ton cars to the main shafts, where the cars are dumped in tipple. At the surface self-dumping skips deliver the ore to crushers and coarse rolls, from which it is conveyed into capacious steel bins, capable of holding about a week's supply. From these bins are loaded the regular ore trains of thirty-two 60-ton steel cars, for the concentrator at Hayden. The No. 3 mine is worked by square-set stoping, this relatively expensive method, costing about four times as much as shrinkage stoping, being warranted by the character of the ore.

TREATMENT OF ORE

At Hayden, 20 miles from Ray (see Fig. 19), the ore is concentrated in a mill designed in accordance with the practice at Gufford, Utah. There are eight sections, each with an originally designed capacity of 1,000 tons. The actual capacity of this mill in 1916, however, was 9,475 tons, and changes were in progress to increase the output further. At first concentration was effected wholly by running water, but later on a flotation section was added.

In addition to the ore milled the company shipped directly to the smelter ore containing the following quantities of copper:

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of Ore shipped to the smelter, tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1915</td>
<td>6,871</td>
</tr>
<tr>
<td>1916</td>
<td>10,093</td>
</tr>
<tr>
<td>1917</td>
<td>13,108</td>
</tr>
<tr>
<td>1918</td>
<td>17,135</td>
</tr>
</tbody>
</table>

The concentrates so milled contain from 18 to 23 per cent of copper. Alongside of the concentrator is a small built and owned by the American Smelting & Refining Co. on ground leased from the Ray Consolidated Copper Co. This has been described by Vail. It was completed in May, 1912, and has treated all the concentrates from the Ray mill. Since July, 1913, it has smelted also concentrates from other mills.

At Hayden also is a power plant, capable of developing 15,000 kilowatts, which, in addition to operating the concentrator and smelter, supplies the mines at Ray.

Those who desire more information about the substantial and modern equipment of the Ray Consolidated Copper Co. may find many technical details in the annual reports of the company and elsewhere.

Some idea of the magnitude of the task of preparing for mining and treating from $8,000 to 10,000 tons of ore a day may be gained from the statement that the net expenditures of the Ray Consolidated Mining Co. for property and development to December 31, 1911, amounts to $6,525,113.81.

ORE AVAILABLE.

Estimates of the quantity of ore available in the mines of the district vary with the data used in computation. As the ore in most places not definitely established, the quantity available tonnage depends very largely upon the fixing of an arbitrary line between those that correspond to ore and those that do not. If everything above 1.5 per cent be classed as ore the tonnage, for example, will be much greater than if 2 per cent be taken as the lower limiting tenor. Moreover, material that on any give it to 4 per cent of copper may be of less value or even of no value as ore if the copper is in one of the oxidized forms that can not readily be concentrated with the sulfides. In general the lower limit of ore is taken to be from 1 to 1.5 per cent.

It is believed that the engineers of the different companies have been careful in their estimate of the available quantity of ore as for their respective mines and that, as a whole, there has been no attempt at exaggeration. It is to be remembered, however, that the results are estimates—not exact measurements.

The known reserves of the Ray Consolidated Copper Co. at the end of 1916 are given in the company's report for that year, 105,753,200 tons, averaging 2.00 per cent of copper. There had been added at this date 15,289,354 tons. Consequently the original are body, according to the latest estimate available, amounts to 121,042,554 tons. This includes about 200,000 tons of ore averaging between 5 and 6 per cent, originally present in the ground formerly owned by the Ray Consolidated Copper Co.

The Ray Hercules Mines (Inc.) estimated in 1921 that in its property there was 9,016,000 tons of 2.42 per cent ore.

The total quantity of known ore originally present in the Ray district and averaging between 2 and 2.5 per cent may be taken as between 110,000,000 and 115,000,000 tons. There probably remains a considerable quantity yet to be developed.

TOPOGRAPHY.

For the first 10 miles of its generally southward course, Mineral Creek traverses a succession of gorges cut in a thick, faulted flow of quartz monzonite. About 9 miles north of its mouth, however, the creek emerges from its narrow confines into a wide open valley, which is traversed from north to south by a small hilly basin, traversed from north to south by pinnacles, which are sufficiently imposing near at hand, to who approaches the district in the usual way, up the channel from the valley immediately north of Kelvin. This separation rises precipitously to a height of about 450 feet above Mineral Creek. Indurated Gila conglomerate, of which the largest, Big Dome, contains very little level ground. The district itself is perhaps 50 miles in length and, in some places, precipitous slopes of the Dripping Spring Range.

FIGURE 10. Plan and section of the ore bodies as developed by underground operations in the Ray district.

The body of disseminated ore in the Ray district may be characterized in general terms as an undulating, festooning mass of irregular horizontal outlines and of variable thickness. (See Figs. 10, 11). As a rule the mass lacks definite boundaries. No readily recognizable division in color, texture, or general appearance marks it off sharply from the enclosing rock, and closely opened sampling and always proves that the passage from ore to country rock is in most places gradual. Consequently, to a greater degree than in most ore deposits of the same general type, the size and shape of the mineral body depends upon the local and current definition of ore.

SHAPE AND GEOLOGIC RELATIONS OF THE ORE BODIES.

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FIGURE 11. Disseminated ore body west of the Ray ore body. One side of the body is faulted. The ore body extends to the right. The ore body is overprinted by the Dripping Spring Range.

In those places where there is an abrupt change from thoroughly leached, oxidized rock containing scarcely a trace of copper to ore, the boundary between the two is likely to be a gouge-filled fissure. Some of these fissures are plainly of later origin than the enrichment, and some were probably formed before enrichment. Of the fissures formed after the
some calculations of tonnage being based on 1.5 per cent as the lower limit of ore. It also shifts with changes in the price of copper when these exceed the ordinary fluctuations and maintains their departure from the normal over any considerable time.

The choice of the word "capping" to designate the leached, practically barren zone of mineralized rock is arbitrary.

RELATIONS OF SUBSURFACE TO SURFACE.

In the Ray district the hypogene metallization does not appear to have followed regular or systematic masses of weathering. Some general disturbance and fracturing of the whole rock mass there undoubtedly was, and many small irregular fractures that resulted were observed. But with pyrites and pyrrhotite, and in much smaller quantity, chalcopyrite and molybdenite. These fillings, however, are what are commonly referred to as stringers rather than veins and have little individual persistence.

GEOLOGY OF PROTORE.

The average copper content of the wholly unmetallized ore is susceptible only of a rough determination from the data available. An examination of all the Ray Consolidated Co.'s drill records leads to the conclusion that where the copper shows any progressive decrease, and presumably therefore below any natural or artificial enrichment, the percentage average from 0.4 to 0.5 per cent of copper. Unmetallized base of Ray generally contains considerable visible chalcopyrite and appears to be on the whole richer in copper than the shaly protore.

METALLIC PROTORE.

The metallized shaly protore does not differ conspicuously in appearance from the normal final shaly protore. On the whole it is perhaps a little lighter in color, and none of it has the bluish tint that is characteristic of this rock at a distance from the ore bodies. The features that especially distinguish it are the immemorial veins, carrying quartz and pyrites, that invade the rock in all directions, the presence of pyrite disseminated rather generally through the mass of the shaly protore, and consequently a prevalent rusty hue on weathered surfaces. A few of these pyrite-pyrrhotite stringers attain a width of 6 inches or more, but as a rule they are smaller and range from more thin veins, scarcely visible, to a few filled with quartz and veining a quarter of an inch wide. These veins have no regularity of arrangement but run in all directions with little or no regard to the plane of the fissure or cleavage.

Pyrites is by far the most abundant and widespread sulphide of the protore but is generally accompanied by a little chalcopyrite and in some places by molybdenite. In many specimens microscopic examination of the concentrate passed from the crushed material shows more or less chalcocite, usually in very thin dark films on the pyrites. The chalcopyrite is important, for from the destruction of this mineralization in the present ore bodies, although doubtless some was derived from apparently homogeneous pyrite. As a rule, however, chalcopyrite in the protore is present in surprisingly small quantity, and in much of the protore chalcopyrite is the only cupriferous mineral recognizable. It becomes necessary to conclude that much of the protore, before any enrichment whatever took place, contained exceedingly little copper, certainly less than has been sometimes supposed. The molybdenite is easily visible in the shaly protore, but has been identified at a few places and is probably distributed thinly through it in small quantity. It is more abundant in the protore protore.

The pyrites, chalcopyrite, and molybdenite have been deposited mainly with the quartz in the small felsauna, but there is considerable pyrite, generally in very small crystals, distributed through the substance of the shaly. On the whole, however, the commonly applied name "disseminated ore" is likely to be a little misleading unless it is understood that the dissemination is due to the minute and dispersive character of the fissions and veining much more than to the development of sulphides in isolated grains throughout the rock mass.

PIGMENTED PROTORE.

Like the shaly variety, the pyrophyte protore is traversed by countless small irregular veins running in all directions and intersecting at all angles. The walls of these strings, therefore, may be fairly analyzed, but in the near absence of any good surface, the proportions of the ore can be only very roughly approximated. The fact that ore bodies, although doubtless some was derived from apparently homogeneous pyrite. As a rule, however, chalcopyrite in the protore is present in surprisingly small quantity, and in much of the protore chalcopyrite is the only cupriferous mineral recognizable. It becomes necessary to conclude that much of the protore, before any enrichment whatever took place, contained exceedingly little copper, certainly less than has been sometimes supposed. The molybdenite is easily visible in the shaly protore, but has been identified at a few places and is probably distributed thinly through it in small quantity. It is more abundant in the protore protore.

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OXIDIZED AND LEACHED ROCK.

From the complete oxidation of the protore and one or two general kinds of material result. One is a rock brilliantly reddish-brown in color, malleable and chrysolithous containing, in the main, as much copper as the ore but in a form not susceptible of satisfactory concentration by the processes applied to the sulfides. In a few places it has been rich enough to mine in a small way and ship to the smelters.

Such chrysolithous rock, traversed generally by many small veins of chrysolithos, is more abundant in the Miami district than in the Bay district.

The other class of material consists of the leached rock or capping. This in its typical development is in strong contrast with the copper-bearing rock just described, although the outline of the two kinds grade into each other. Its prevalent characteristic are a more or less looseness of tint and a peculiar absence of copper. It contains enough iron oxides to give a reddish color to churn-drill sludge, whereas the unoxided chrysolith and ore give a gray sludge and the material containing much chrysolith is a light gray sludge.

If it were possible to recongnize with certainty a particular variety of any rock as indicative of ore beneath it, much easier and at least a part of the materials were derived to solidify and cool than the bodies now exposed, that most of one only of the two districts here described, the observer might of satisfactory concentration by the processes applied to the much larger masses of similar igneous material below any of satisfactory concentration by the processes applied to the much larger masses of similar igneous material below any.

PERMORALILITY.

The conditions that determined the present of metamorphic solutions at any particular place were doubling complex. Essential ore must have been permeability of the rocks affected and an abundant supply of the active solutions.

Permissibility, as shown by a study of the ores, was due in large measure to minute irregular fissuring. This permissibility was probably accompanied by the permeability or interconnections between the deep-lying igneous material and the zone of sulphide deposition. Some probability is given to this suggestion by the fact that the more homogeneous solutions of solutions of the ore are abundant in the metamized ground. This is particularly noticeable about Homestead Hill, where the ore body attains its greatest thickness. That thickness, however, it should be remembered, is probably due more to enlargement than to processes of the same character as the ore was reduced in a small furnace and a little oxidized copper ore near the surface and alongside of the branch of the same porphyry dike complex on which is the ore tenor of typical leached capping is extremely low. This is possibly owing to the fact that the more permeable portions of the capping are not as much in contact with the ore bodies as those rock east of Mineral Creek.

The deposition of the protore probably followed closely the intrusion of the granitic porphyry, but no facts are known that might serve to fix this event definitely in geologic time. The granitic porphyry is a variety of granite, whose intrusion, on general grounds rather than from any definite evidence, is supposed to have taken place at the end of the Mesozoic era. It appears reasonable to regard the intrusion of the granitic porphyry as an early Tertiary event, but it must be admitted that it is not impossible that it occurred earlier.

The deposition of the protore certainly took place after the laying down of the Tornado (Mississippian and Pennsylvanian) limestone and before the eruption of the dacite.

TROY DISTRICT.

The intrusion of the granodiorite of the Troy Basin was followed by pronounced contact metamorphism and by considerable alteration. The granodiorite is closely related to the Schuttite granite and the Granite Mountain and Tepoat Mountain porphyries and was intruded at about the same time as those rocks. It is associated with many dikes and is sur- rounded by much fanned rocks, including limestones, which differ in no essential respect from rocks elsewhere in the same general region. In short, Troy would seem to be a decidedly favorable place for ore deposition. Yet those who have acted on this apparently reasonable assumption have thus far been disappointed. There has been extensive prospecting, and some ore has been found, but the returns have not equaled the outlay.

The principal development has been on the Butte claim, 1 mile or a little south of Troy, on the '91, Burpee, and Alice claims, one-half, three-fourths, and three miles southwest, respectively, of the now practically abandoned settlement. When the visits were made in 1900 and 1904 the underground workings were only in small part accessible.

The workings of the Buttle mine comprise the Simon shaft, which is about 60' of 60' to the southwest and 300 feet in depth, and a shaft connected with three levels, the first of which is 30' adit. The levels rise nearly west-southwest and are open on a section of ground of about 700 feet. A second shaft, east of the Simon, extends only about 50 feet below the adit level. There is a third level and a portion of another level, which follow more or less closely the bedding of the Metalline limestone in which it occurs. The limestones at the Buttle mine is an indication of the original igneous contact being modified in some places by faulting. Granodiorite is not seen in the workings, but it is shown on the geologic map it is not far a way and has effected considerable contact metamorphism in the dikes, which sparkle with secondary biotite. The ore zone dips 20' N. 35' W. and from a point in the main tunnel about 100 feet in has been followed in an inclined adit for about 95 feet to a point where it appears to be cut off by a rather massive shale. There is apparently no large quantity of ore available. The Simon shaft appears to be entirely in dikes below the first level.

The ore of the Buttle mine is a darkly fine-grained aggregate of magnetite and chalcopyrite with varying quantities of silicate minerals derived by metamorphism from the including limestones. With increasing proportions of these the ore grades into the metamorphosed limestones. Analyses of the ore recorded in the books of the Troy Arizona Copper Co. and its predecessors show from 3 to 3.7 per cent of copper, a maximum of 0.04 ounce of gold and 0.17 per cent of silver. The proportion of iron, about 1 per cent of calcium oxide, and 20 per cent of silica. Very little could be seen of the '91 mine, as the shaft had caved in. It apparently is about 150 feet deep, and the mape show three short levels. The limonite copper ore that was found in this mine appears to have occurred, as at the Buttle, as small leaflike bunches in the Metalline limestone. The schistosity in the '91 mine is not pronounced, of which was at one monozone porphyry, by which it is invariably accompanied. It occurs in joints in fractured Dripping Spring quartzes.

The Buckeye mine is situated on a nearly east and west branch of the same porphyry dike complex on which is the Alice mine, at a point where the dike complex runs through Dripping Spring quartzes, Metalline limestone, and Troy quartzites. These stratified rocks appear to be underlain and overlain by intrusive sheets of diabase. The dip of the shaft, which is apparently about 150 feet deep, with three levels, is shably south. These levels trend generally west-northwest. The first level has a length of about 1,000 feet, but each of the other two is less than 300 feet. The Buckeye mine has a little oxidized copper ore near the surface and alongside of the porphyry dike. This ore was reduced in a small furnance at the mine.

The Alice mine was worked through a shaft inclined at 45° with three levels, the lowest of which is about 200 feet vertically below the collar. As shown by the mine map the general trend of the levels is northeast and the length of the block of ground explored by them about 350 feet. The shaft is sunk in quartzite. The workings of the mine have been to a depth of about 750 feet below the surface. A few small branches of ore were found in limestones near the mine, and the mine was not developed further. It could not be entered when the geologic field work on which this folio is

22
buildings, is diabase, apparently in a sheet several hundred feet thick. Since the last visit the Troy Arizona Copper Co. has done additional prospecting and in places has exposed reefs on the south side and schist on the Claxton claim, about three-quarters of a mile southwest of Troy, and in 1917 ore was being shipped.

The Kinder group of 47 claims, which lie southeast of Troy, considerable ore was visible in 1912 in the lower part of the Martin limestone at a point near the crest of a steep spur where the limestone outcrops in an area 50 feet wide. In 1913 these zones on the William J. Bryan No. 2 claim from old workings, now abandoned, 200 feet deep. The present main shaft is about 900 feet north of those old workings. At the time of the first visit, in April, 1912, the 200-foot level was about 150 feet below the bottom level of the mine, which was a continuation of a cross-cut from the shaft to the south perhaps 500 feet in length. This working cut the porphyry dike and three or more of the east and west fissure material. At the second visit, in December, 1914, the mine was idle, although it was being kept free of water by pumping about 4,000 gallons per day. A 2,000-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 mine has since produced a little ore but apparently has not been in continuous operation.

LONDON-ARIZONA MINES.--The London-Arizona mine is in the southeastern part of the quadrangle, about 4 miles north of Hayden, on the north side of the Tornado ravine. The lowest rock exposed in the canyon, in which are the mine buildings, is diabase, apparently in a sheet about 300 feet thick, which was intruded at approximately the horizon of the Mesai limestone. Overlying the diabase in succession are the Troy quartzite and Martin limestone of the crest of the ridge. The main tunnel is stated to be 1,000 feet long and to connect with about 2,000 feet of underground workings with a maximum depth of 900 feet.

OTHER COPPER DEPOSITS.

London-Arizona mines.--The London-Arizona mine is in the southeastern part of the quadrangle, about 4 miles north of Hayden, on the north side of the Tornado ravine. The lowest rock exposed in the canyon, in which are the mine buildings, is diabase, apparently in a sheet about 300 feet thick, which was intruded at approximately the horizon of the Mesai limestone. Overlying the diabase in succession are the Troy quartzite and Martin limestone of the crest of the ridge. The main tunnel is stated to be 1,000 feet long and to connect with about 2,000 feet of underground workings with a maximum depth of 900 feet.

GOLD AND SILVER DEPOSITS.

Pioneer mines.--In the northern part of the quadrangle, near the south base of Pioneer Mountain and close to the stage road fromTucson to Ray, there is a considerable body of material in thin lenses in the limestone. The main shaft is about 180 feet deep and was abandoned in 1893. The mine was re-opened about 1910 and was a continuation of a cross-cut from the shaft to the north about 500 feet in length. At that time it was 300 feet deep and had relatively little development. At the time of the first visit, in April, 1912, the 200-foot level was about 150 feet below the bottom level of the mine, which was a continuation of a cross-cut from the shaft to the south perhaps 500 feet in length.

The vein was worked in a number of levels, two of which were 400 and 600 feet deep. Ore from the lower level was sent to a stamp mill.

On the lower level there is an extension of diabase and quartzite on the north side. The ore, which is all chalcopyrite, contains 3 to 5 per cent copper, 0.3 to 0.5 per cent silver, and 0.5 to 1.0 per cent lead. The ore body is about 100 feet in length and 10 to 20 feet wide, and is associated with a vein-like body of diabase and quartzite. The occurrence of the ore is in the form of a vein about 15 feet wide, which is discordant to the bedding of the limestone.

The vein was followed by underground work for a distance of 1,800 feet, and about 200 feet farther. The ore, which is chalcopyrite, contains 1 to 3 per cent copper, 0.1 to 0.3 per cent silver, and 0.05 to 0.1 per cent lead. The ore body is about 100 feet in length and 10 to 20 feet wide, and is associated with a vein-like body of diabase and quartzite. The occurrence of the ore is in the form of a vein about 15 feet wide, which is discordant to the bedding of the limestone.

The vein was followed by underground work for a distance of 1,800 feet, and about 200 feet farther. The ore, which is chalcopyrite, contains 1 to 3 per cent copper, 0.1 to 0.3 per cent silver, and 0.05 to 0.1 per cent lead. The ore body is about 100 feet in length and 10 to 20 feet wide, and is associated with a vein-like body of diabase and quartzite. The occurrence of the ore is in the form of a vein about 15 feet wide, which is discordant to the bedding of the limestone.
clay. It is reported\textsuperscript{13} that production began in 1917 and that in the middle of 1918 shipments were averaging about 700 tons a month. The ore was brought down to Ray by pack burros and at that time was shipped to the Empire Smelting & Refining Co., at Deming, N. Mex. This miner is understood to be no longer in operation.

A short distance east of the cabin on the San Francisco claim a tunnel about 200 feet long has been run on a strong fissure that strikes N. 70° W. and dips 60° S. The tunnel is mostly in the Martin limestone, but the fissure for a part of its course follows a decomposed diorite porphyry dike. A seam of iron oxides, chiefly hematite, lies along the hanging wall, and in places some sandy cerussite lies under the hematite. No galena was seen. The hematite is not confined to the fissure but occurs in rather bunched masses along a bed from 15 to 20 feet above the base of the Martin limestone, especially where the limestone has been fissured.

The Crown Point claim on the west slope of the main ridge, about three-quarters of a mile west of the cabin, is located on a fissure that strikes nearly east and dips about 72° N. The country rock is Devoian limestone. A shaft, 150 feet deep in March, 1912, had been sunk on this fissure and showed gouge, abundant oxide of iron, and a little cerussite. The zone of soft oxidized material is in places 5 feet wide. The main fissure appeared to be that of a normal fault with a throw of 50 to 100 feet. There are at least two nearly parallel fissures north of the one explored by the shaft.

\textit{Miscellaneous Mineral Resources.}

\textit{Fossils.}—The vanadium prospects of Mr. J. J. Sullivan, afterward taken over by the United States Vanadium Development Co., are 4 miles in a straight line east-northeast of Kelvin and about 2 miles north-northwest of Troy. The principal development in 1912 was on the south side of a narrow steep-walled ravine in diabase. Here a small mass of Mescal limestone, shown on the geologic map, is included in the diabase and is cut by a fissure that strikes N. 80° E. and dips 80°-85° S. A shaft 40 feet deep had been sunk on the fissure, which had also been explored by a few short tunnels. The ore occurred in the fissure and also extended out from the fissure for short distances along some of the bedding planes of the limestone. It consisted of vanadinite (lead chlorovanadate, \(3Pb\,V_2\,O_8\).\(PbCl_2\)) and descloizite (basic vanadate of lead, zinc, etc., \((Pb, Zn),\,(OH)\,(VO_4)\)), associated with galena, cerussite, wulfenite, and quartz. The vanadates are younger than the galena, as in places they occur as veinlets in that mineral. They are older, however, than some of the quartz.

About 600 feet south of the main workings a small open cut on a fissure in diabase exposed a little vanadinite in 1912. On the north side of the ravine and northeast of the main workings a strong fissure between diabase and Mescal limestone also contains a little vanadinite, and small quantities of the mineral were observed in other shallow prospecting cuts in the vicinity. Although it is understood that a mill was built subsequently to the time of visit, there has been no recorded production of vanadium concentrates from this locality.

\textit{Limestone.—}The Ray quadrangle contains abundant limestone, and a plentiful supply for the manufacture of lime or cement might be quarried from nearly every one of the numerous areas of Tornado limestone.

\textit{Building stone.—}Some of the tuffaceous beds that constitute the lower part of the Gila formation north of Ray are easily quarried and dressed and furnish a soft but fairly durable building stone that has been used in some of the buildings in Ray and vicinity.

\textit{Concrete materials and road metal.—}Crushed stone suitable for concrete or for macadam could be obtained near at hand in almost any part of the quadrangle. The hardest and toughest rock could probably be had from the diabase, although the quartzites, limestones, granite rocks, and intrusive porphyries would yield excellent material for certain purposes. Sand and gravel can be obtained in abundance along the lower courses of the arroyos in the areas within which the Gila formation is the surface rock.

\textit{Water.}—Abundant water may be obtained anywhere along the alluvial valley bottom of the Gila from wells below the surface of the river, and somewhat deeper wells in the Dripping Spring Valley would probably also tap an underground flow near the base of the alluvium. Mineral Creek carries surface water along parts of its course throughout the year, and a large part of the water used in the vicinity of Ray comes from a reservoir formed by a dam on this stream, above Ray, although the drinking water for that settlement is obtained from springs in the Dripping Spring Range. Small springs of good water are fairly abundant in this range and in the Mescal Range.

September, 1923.