The Geological Survey is making a topographic and a geologic atlas of the United States. The topographic atlas will consist of maps called Color Atlas, and the geologic atlas will consist of pure geologic forms. Each form includes topographic and geologic maps of a certain four-sided area, called a quadrangle, or of more than one such area, and a text describing its topographic and geologic characteristics. Each quadrangle is a terminal subdivision within it, and at the sides and corners of each map are printed the names of adjacent quadrangles.

SPECIAL FEATURES OF THE MAPS.

On a scale shown to the scale of 1 inch to the mile linear miles on the ground would be represented by a linear inch on the map, and each square mile of the ground would be represented by a square inch of the map. The scale may be expressed also by a fraction, of which the numerator represents a unit of linear measure on the map and the denominator the corresponding number of such units on the ground. Thus, if there are 63,360 inches in a mile, the scale 1 inch to the mile is expressed by the fraction \(\frac{1}{63360}\), or the ratio 1:63,360.

The three scales used on the standard maps of the Geological Survey are 1:62,500, 1:125,000, and 1:250,000, all of which are used on 1:250,000, and 1:125,000, all of which are used on the maps corresponding approximately to 1 mile, 2 miles, and 4 miles on the ground. On the scale of 1:62,500 a square inch of map surface represents about 1 square mile of earth surface; on the scale of 1:125,000, about 4 square miles; and on the scale of 1:250,000, about 16 square miles. In general a standard map on the scale of 1:250,000 represents a "square degree"—that is, an area measuring 1 degree of latitude by 1 degree of longitude; one on the scale of 1:125,000 represents one-sixteenth of a "square degree"; and one on the scale of 1:62,500 represents one-sixteenth of a "square degree". The areas of the corresponding quadrangles are about 4,000, 1,000, and 250 square miles, though they vary with the latitude, a "square degree" in the latitude of Boston, for example, being only 5,525 square miles, and one in the latitude of Galveston being 4,150 square miles.

GENERAL FEATURES SHOWN ON THE MAPS.

The general features represented on the maps are of three distinct kinds: (1) inequalities of surface, called relief, such as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called drainage, such as streams, lakes, and swamps; (3) the works of man, called culture, such as roads, railroads, villages, and cities.

RELIEF.—All altitudes are measured from sea level. The heights of many points have been accurately determined, and those of some are given on the map by figures. It is desirable, however, to show the altitude of all parts of the area mapped, the map of the surface, and the grade of all slopes. This is done by contour lines, printed in brown, each representing a certain height above sea level. A contour on the ground passes through points that have the same altitude. One who follows a contour will go neither uphill nor downhill but on a level. The manner in which contour lines express altitude, form, and slope is shown in figure 1.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as igneous. Molten material has been from time to time forced upward in fissures or channels of various shapes and sizes through rocks of all ages or newly to the surface and formed by the consolidation of molten material, or igneous within these channels—that is, below the surface—are called intrusive. An igneous mass that becomes a new rock by cooling relatively rapidly is called a dike; one that fills a large and irregular chamber is termed a pluton. Molten material that traverses stratified rocks may be intruded along bedding planes, forming masses called sills or sheets if they are relatively thin and broad or if they are large leucodomes. Molten material that is forced out through channels as a lava is termed extrusive and may form volcanoes. Lava that has cooled and solidified on the surface is called basalt. Lava may build up volcanic mountains. Igneous rocks that have solidified at the surface are called extrusives or outflow. Extrusives generally contain more fine-grained crystals because the pressure of the gases in the magma. Explosions due to these gases may accompany igneous activity, creating the escape of dust, ash, and lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of grains of sand, mud, and clay, or of material deposited in bodies of water by chemical precipitation or by organic action are termed sedimentary.

The chief agency of the transportation of such débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried in solid particles and are called mechanical. Such deposits are gravel, sand, and clay, which are later consolidated into conglomerates, sandstones, and shales. Some of the material is sorted in solution, and the mixtures thus produced are lime, calcium, and carbonates. Some of these materials are called organic if formed with the aid of life or chemical if formed without the aid of life. The more common rocks of chemical and organic origin, such as limestones, chalk, gypsum, salt, iron ore, pest, lignite, and coal, are called sedimentary.

Most sedimentary rocks are made up of layers or beds that can be easily separated. These layers are called strata, and rocks deposited in such layers are said to be stratified.

The surface of the earth is not immoveable; it varies in shape and volume of water varies in shape and volume of water over wide regions, it is very slow, or only slightly, and involves the sea, and above these areas are the continents. Marine sedimentary rocks may become a part of the land, and most of our land surfaces is in fact composed of rocks that were originally deposited in water. Rocks exposed on the surface of the earth are subject to weathering by the action of wind, and to the processes of erosion, which are largely determined by the cover of water at the surface of the water. Usually it is not continuous, but is interrupted by small bodies of water. Water washes this material down the slopes of hills and by rivers to the ocean or other bodies of water. Usually it is not continuous, but is interrupted by small bodies of water. Water washes this material down the slopes of hills and by rivers to the ocean or other bodies of water. Usually it is not continuous, but is interrupted by small bodies of water. Water washes this material down the slopes of hills and by rivers to the ocean or other bodies of water. Usually it is not continuous, but is interrupted by small bodies of water.
INTRODUCTION.

LOCATION AND AREA.

The Ray quadrangle (see Figs. 1 and 2) is in southeastern Arizona, in the belt of generally linear ranges and valleys that extend, except for a stretch of about 75 miles in the northeastern part of the State, separates the Plateau Province (Caloosahatchee Pluton) on the northwest from the Plains Region (Sonoran Desert) on the southwest and that from its present

This branch forms the main Ene at Tempe, 8 miles southeast of Phoenix, runs southeastward to Florence across the plain that here separates Salt and Gila rivers, and then follows the Gila up to Ray Junction on the hill, in the western part of the quadrangle. The distance from Tempe to Ray Junction is 72.8 miles. From Ray Junction the railroad continues up the Gila for 62 miles to its present terminus at Florence. Ultimately this road will probably be continued eastward to connect at Sun Corral with the Bowie-Globe-Miami branch of the Arizona Eastern Railroad. From Florence the railroad of the Ray Consolidated Copper Co. provides communication with the mines near Ray, about 7 miles north of the Gila.

The quadrangle may also be entered from the north by stage from Globe to the final range by way of Florence, a distance of about 55 miles, or, less conveniently, by stage from Tucson by way of Mammoth and down Santa Fe River in its confluence with the Gila near Winkelman, just south of the quadrangle. The distance from Tucson to Winkelman by this route is about 71 miles.

SETTLEMENT AND INDUSTRIES.

The principal industries in the Ray quadrangle are the mining, smelting, 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 Somera, probably contain about 2,700 people. Hayden, a town built up near the confluence of the Salt and Superstition and the San Pedro rivers, has a population of about 7,000 people. Winkelman, a smaller and less settled a small settlement, is almost a half mile east of the Ray quadrangle, nearly in the latitude of Toronto Peak. Winkelman, located on the Ray Copper Mine Co., is an English company, at the confluence of Mineral Creek and the Gila, has a place of some importance in 1900, but after the failure of the company the population dwindled, and in 1920 it was only 300. As a consequence of the construction of the concretizing mill of the Ray Copper Mine Co. near Winkelman, that place may regain some of its former prosperity, although a new settlement, known as Beavers, appears to have been established still nearer to the mill.

Outside of the settlements mentioned, the quadrangle is inhabited only by a few proprietors and machines. Much of it is a lovely wilderness, whose only useful usefulness is man to supply scenic beauty at certain seasons to wide-ranging cattle. There is some suitable 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 Hayden concentrator.

CLIMATE AND VEGETATION.

The climate of the Ray quadrangle closely resembles that of the adjoining Globe quadrangle, to the north, and as the region here described is generally lower than that adjacent to Globe the mean annual temperature is higher. The town of Ray, however, being in hilly lands, is decidedly hotter in summer than Globe or Miami.

So for a known, continuous weather records have been kept within the Ray quadrangle, but the conditions at the Weather Bureau station 8 miles south of Dudleyville, on the San Pedro, are fairly representative of those at Hayden, Kelvin, and Ray. According to records, between 1890 and 1901 the annual mean temperature at Dudleyville is 57°F, the absolute maximum 114°, and the absolute minimum 14°. June is usually the hottest month. The annual mean precipitation is 12 inches. The precipitation in the driest year within the period of record was 8.4 inches and of the wettest year, 15.9 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

F. L. HANSON.
The Tortilla Range is generally lower and more irregular in plan than the Mescal and Dripping Spring ranges. Distant views indicate that as a definite range it loses its identity a short distance to the east of the Ray quadrangle, being separated by irregularly hilly but comparatively low ground from the Santa Catalina Mountains, which continue southeast past Tucson to the southern line of the Pacific Southern Railroad. North to the north the Tortilla and Dripping Spring ranges come together in the vicinity of Ray and continue northward to Sulfur Spring as an irregular mountain complex that includes the Supersition Mountains, a range of intricate geomorphic structure. North of Sulfur Spring a well defined range, the Mutilant, between Sonoita and Vorsok, presents the general line of upland to the edge of the Colorado Plateau. The rectilinear chain make up of the Mutilant, Dripping Spring, Mescal, Calcite, Dragon, and Male ranges has a length of about 250 miles and is one of the most notable features in the physiography of Arizona. Nearly parallel with this chain is the line of the Chiricahua, and Finalno range, which, in the vicinity of the Gila either dies out or may perhaps be regarded as a branch from the Final-Mescal member of the more continuous uplift.

The part of the Tortilla Range that is included in the Ray quadrangle is chiefly a ridge of pre-Cambrian granite. East of this granite ridge, in the southern part of the quadrangle, there is a series of sharp, narrow strike ridges composed of the Paleozoic sedimentary beds that are here upturned into an almost vertical attitude.

The only tolerable pedestrian trails in the quadrangle are Gila River and Mineral Creek. The discharge of the Gila has been measured at San Carlos, 25 miles above the point where it entered the Ray quadrangle, and the level known as “The Buttes,” about 12 miles west of Ray Junction. The results are shown in the following table:2

Lippincott3 has concluded that the mean annual discharge at San Carlos is 422,184 acre-feet and at The Buttes 449,009 acre-feet, the difference being due chiefly to the contribution of the San Pedro near Winkelman, just south of the quadrangle, although Mineral Creek at certain seasons is also a considerable effluent. An annual discharge of 449,003 acre-feet is equivalent to an average flow of approximately 4,500 gallons per second.

The river where it crosses obliquely the valley between Dripping Spring and Tortilla ranges is bordered by an irregular series of ridges and valleys. Some of this land is under cultivation, but the river, which in midsummer is a shallow stream, easily fordable, is subject to violent flash floods in January and February, which may make the tenure of the cultivators more or less precarious. Even at low water the Gila carries much fine silt and is of course much more heavily laden in winter than in summer. The Sun Pedro carries little visible water and the bed of Mineral Creek near its mouth is normally dry.

GENERAL GEOLOGY

INTRODUCTORY OUTLINE

The sequence and the thickness of the geologic formations in the Ray quadrangle are shown in Figure 8. This figure, however, does not represent the full history of deposition in this region. Between certain divisions are unerosive gaps showing that at times the accumulation of sediments on a sea bottom or near sea level was interrupted by uplift and erosion. Inasmuch as few of the well known regional boundaries are recognizable, it is possible that there are possibly others in the rocks below the Devonian, although all the beds provisionally included in the Cambrian appear to have been laid down without any break in sequence. The fundamental rocks of the region are those designated the Final schist, commonly a thinly laminated micaceous variety of greenstone, and are prominent in the vicinity of the Ray quadrangle. The ray are con-

The Rock-formation is overlying the Rannock conglomerate. As a rule this formation consists of dark red-brown, more or less argillaceous slate composed largely of fine grained detritus with little or no coarser material. At many places the slate grades down into zeolitic sandstone. Abundant round or elliptical spots of light-buff or greenish color are highly characteristic of the slate.

Next above in the stratigraphic series is the Rannock conglomerate, which in its typical development consists of smooth pebbles of white quartz and of hard vitreous quartzite in a micaeous matrix. The pebbles are generally less than 6 inches in diameter. Small fragments or pebbles of bright-red Jasper, although nowhere abundant, are a very characteristic and constant feature of this conglomerate, which in the Bay quadrangle is from 10 to 40 feet thick.

**Figure 4** - Generalized section of the rocks that overlie in the Bay quadrangle.

Conformably overlying the Rannock conglomerate is a formation of quartzite and quartzitic sandstone from 400 to 500 feet thick, the Dipping Spring quartzite. In most localities in the Globe, Ray, Florence, and Roosevelt quadrangles this formation is closely associated with thick intrusive masses of diabase. The diabase occurs chiefly as sills following the bedding planes but also as crossing structures connected with the sheets. The Mescal limestone conformably overlies the Dipping Spring quartzite. It is composed of thin beds that have a varied range of color but are essentially siltstone. The siliceous segregations as a rule form irregular layers paralleled with the bedding planes, and on weathered surfaces these layers stand out in relief. The Mescal limestone is the rough, ground hanging that is its most characteristic feature. The average thickness of the Mescal limestone in the Bay quadrangle is about 225 feet. At the time of the diabase intrusions the Mescal offered less resistance to the advance of the magma than the other formations, and it has been much broken and eroded by the force of the igneous action. In places it is represented only by fragments included in the diabase. Between the limestone and the overlying formation is a layer of the Mescal conglomerate, which is composed of relictic material, and in some places the thickness is from 75 to 100 feet. Although the basalt in places is much thicker than this, the flow was apparently continuous with the Mescal limestone throughout the Ray and Globe quadrangles and has been recognized as far north as Roosevelt. This basalt, owing to its small thickness, has been mapped with the Mescal limestone in the Ray quadrangle, although it is not included in the definition of that formation.

The succeeding formation is the Troy quartzite, about 400 feet thick, which is conformable with the Mescal limestone by the basalt flow, and this may possibly indicate some unconformity. No evidence of erosion, however, has been detected except for a slight one for the above, which may have flowed over the sea bottom.

The beds thus far described as above the great unconformity of the Mescal limestone have been of the Apachian group and, although no fossils have been found in them, are believed, for reasons presented on pages 90-100, to be of Cretaceous age. The uppermost part of the bed near the top of the group may represent Orensean and Shrinian time, but there is no fossil evidence for this nor has any unconformity been detected to account for the apparent lack of representation of these two great periods.

Conformably above the Troy quartzite is the Martin limestone, which is about 325 feet thick in the Ray quadrangle. This formation is divisible into upper and lower portions of nearly equal thickness. The upper portion carries characteristic Devonian fossils, but no identifiable fossils have been found in the lower portion, which consequently can not be regarded as enpocynvally Devonian.

The Martin limestone is conformably overlain by a thick-bedded high-grey limestone that is nearly everywhere a prominent cliff maker. This is the Tornado limestone. As exposed in the Ray quadrangle it has a maximum thickness of at least 1,000 feet. At its upper limit it is a surface deposit in part from early Mississippian time, the limestone was probably once much thicker. It is of Carboniferous age.

After the deposition of the Tornado limestone the region was uplifted above sea level and underwent erosion, probably until Cretaceous sedimentation began. The diabase is thought to have been intruded when this uplift occurred, thus Paleozoic or early Mesozoic time. Intrusive relations show very clearly that the diabase is younger than the Troy quartzite. The Martin and Tornado limestones have been eroded here and there by small bodies of diabase that are supposed to represent parts of the same magma that solidified in larger bodies at lower stratigraphic levels.

In the southern part of the Ray quadrangle and stretching southward across the Globe is a broad belt of undoubted tuff and breccia associated with the diabase. The lower, or sheeted, portion of the diabase or volcanic series. Walcott and Campbell both refer to the undoubted as overlying Cretaceous sediments and connected with them by the intercalation of sedimentary layers containing a little coal. Presumably, therefore, the undoubted, like the coal, is Cretaceous.

The eruption of the undoubted rocks was followed by the intrusion, in series, of (1) quartz diorite in small irregular masses and a few dikelets of considerable size; (2) granite, quartz monzonite porphyry, and granite-diorite in numerous dikes and irregular masses, several miles in diameter; and (3) quartz porphyry diorite in dikes, silts, and small rounded masses. The rocks of the second group are the products of the cooling of the magma and are characteristic of most of the exposures in the Ray quadrangle.

In the near vicinity of the town of Ray northwesterly to the south, the Schuylkill and Globe quarries the prevalent variety is an almost slate-blue gray rock that disintegrates readily so that on slopes the schist presents a characteristic blue-gray surface deposit. A distance of 100 feet from the diorite into which other formations break down by weathering. Small, ill-defined dark spots, due to the local segregation of some of the darker-colored constituents especially biotite or chlorite, are common in certain heads, and some rather conspicuously spotted schist occurs in the contact zone of the granular porphyry on Granite Mountain, near Ray.

Microscopic sections show that the principal constituent minerals of the typical fine-grained schist are quartz and sericite. The quartz occurs in patches of grainless outline as much as 0.5 millimeter in diameter in a finely granular groundmass of quartz and sericite with many mafic crystal of chlorite. Small, short plates of tourmaline are fairly abundant, and minute rounded crystals of sillimanite are sparsely disseminated through the rock. The facility of the schist is determined by the general parallel arrangement of the sericite flakes and a tendency of this mineral to form thin layers separated by correspondingly thin layers of quartz grains.

**Figure 4** - Generalized section of the rocks that overlie in the Ray quadrangle.
slivery-grey rock of imperfect cleavage and on surfaces of fresh fracture flakes with irregular plates of white mica, generally about half a centimeter thick. The principal constituents are seen to be quartz and muscovite in very irregularly bounded crystal grains. The muscovite occurs both in comparatively large flakes, many of which include grains of quartz, and as the small-blaaded variety known as sericite. The subordinale minerals are micaous, plagioclase, sillimanite, rutil, and cordierite. Similarities of the schist near the quartz diorite contain abundant undulose albite.

**Chemical composition of final schist and ordinary rocks.**

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<th>Y</th>
<th>Ga</th>
<th>FeO</th>
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<tr>
<td>MgO</td>
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In the vicinity of Ray and west of that town a considerable part of the schist is a grey, fine-granular, moderately foliated rock with the unmistakable aspect of a squelched and metasomatized sandstone. This section of the variety under the microscope shows but indistinct outlines of grains up to 3 millimeters in diameter that consist chiefly of quartz and sericite. The large quartz grains show the effects of granulation with more or less recrystallization under pressure. Some consist of many small interlocking crystal grains; others are crystallographic units but show by their shadowy extinction that the quartz has undergone molecular reorientation under the stress accompanying metamorphism. Any variety, not very different from the foregoing in general appearance, contains a little phlogopite and a small amount of blackish amphibole associated with the grains. These are probably metamorphosed feldspathic schist or graywackes.

Southwest of Ray, in the vicinity of the apparent quartz monzonite porphyry of Granite Mountain, the Final schists have been clearly modified by the igneous rock, as shown near the contact in slightly altered, by a pronounced tendency of the micas to segregate so as to give the schist a spotted appearance, and by the development of andalusite. Although this metamorphism was imposed upon rocks long previously rendered schistose the two epochs of alteration are not sharply distinguishable in their results.

Ophitic and phyllomorph—The foregoing description has given anticipatory suggestions of the conclusion that the Final schist is not, in the main, a series of metasomatized sediments. The evidence in support of this view, part of which was achieved in 1903, is now may be seen a little more closely.

In general the mineral composition of the prevalent kind of schist, their regular banding where not locally disturbed, and the finely fibrous character of most of the rocks is indicative of sedimentary origin. That at least a part of the formation was originally sedimentary is evidenced by the presence of the characteristic graywacke and sandstone near the upper part of the sediments. Under no circumstances is the locality of some in small quartz pebbles is still recognizable. Moreover, as noted above, in the vicinity of Ray and west of that town much of the schist presents the unmistakable aspect of a squelched and metasomatized sandstone, accompanied by thin, finely-grained varieties that were evidently at one time in a place of the original bed is plainly apparent. Thin sections of this variety, seen under the microscope, show both red and green varieties, in the latter case believed to be post-Cambrian and two other, the Willow Spring granite and the Lost Gulch micaschist, are possibly also post-Cambrian. Another, the Swiss Bacon, is only a small area about 3 miles southeast of Globe and need not be further considered here. The Granitoid granite of the region is divided into four important types—quartz-mica diorite (Mossanite diorite) and biotite granite (including the Rain granite of the plain south of the Franklin Range). The quartz-mica diorite is most abundant in the Franklin Range, where it is intruded into the schist. The micaous granite is the principal rock of the Franklin Range, and three of the more prominent are the schists from the vicinity of Ray southward past Kebut and beyond the southern and eastern limits of the area here described.

Quartz-mica diorite (Mossanite diorite)—The granite of Mount Mossanite, from Mount Mossanite, in the Franklin Range, was first applied in the Globe region, in which the diorite was described as generally a gray rock of granitic texture and habit consisting essentially of plagioclase feldspar (chiefly andesine) with quartz and black mica (biotite). Orthoclase and microcline occur in minor varieties that approach granodiorite in composition; in others the occurrence of hornblende indicates gradation toward tonalite. A tendency toward gneiss foliation was noted in some localities.

The rock is not altogether uniform in texture or composition, and it is probable that were the surface uncased clay by erosion, detailed work would afford data for the discrimination of two or more varieties. But disintegration, in part as a result of pre-Cambrian weathering, is deep and general, so that it is impracticable to treat the rock mass other than as a unit. In the Globes folos the faces exposed along the stage road northeast of Pioneer Mountain was described as being rather coarser than the granite and Mossanite diorite consisting of plagioclase (Ab31An20), quartz, biotite, microcline, and a little muscovite, with accessory titanite, apatite, magnetite, and zircon. Biotite is so abundant as to give the rock a more or less dark-gray color as compared with ordinary granite, and there is a suggestion of gneissic foliation in the arrangement of the minerals. The specimen appears to be fairly representative of the Mossanite diorite east of Pioneer Mountain, along the northern edge of the Ray quadrangle. A chemical analysis of this rock, taken from the Globe report, is given below, together with an analysis of what was regarded as the more nearly typical variety in the Globe quadrangle.

**Chemical analysis of quartz-mica diorite from the Globe quadrangle.**

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1. Globes folos stage road, 5 miles southeast of Globe Peak by 3 miles east of Globe Peak. 2. West slope of Franklin Range, 5 miles southeast of Mount Mounts. At no place southeast of the stage road has any marked change been detected in the general character of the prevailing rock, yet examination of successive exposures in that direction shows a notable increase in pink potassium feldspar in the form of phenocrysts. A specimen collected in a mile southeast of Mounts is pinkish feldspar containing a light-colored quartz phenocryst of potassium feldspar 4 centimeters or less in length in a groundmass closely similar to the general pink and light-colored groundmass of the rock 1, above. The feldspar phenocryst as seen in thin section shows in part the optical character of orthoclase and in part that of microcline, suggesting the possibility of a gradation between the two forms. The characteristic microcline twinning is as a rule not conspicuously developed, and, as is well known to those familiar with the formation, a typical example is the way in which the twinning lamellae are subsound. The relative abundance of phenocrysts and groundmass differs from place to place, and when the phenocrystals are numerous the composition of the mass as a whole must be...
considerably different from that given in column 1 of the table on page 4. Such facts probably should be classified as "pinkish" in general, and not as "pinkish" in particular, as is no colorless material, however, it did not appear that decision on the exact place in classification of these variable varpory-
phosphatic grits is to wait for analyses of the matrix.

characteristics of the lower Paleomorphs, where the granite is generally redolent by pre-Cambrian oxidation.

It consists of a large shapeless phenocrysts of fuch-

din the granite is weathered and in various stages of diagenesis, so that collection of fresh material is rarely possible. This is especially true of the lower Paleomorphs, where the granite is generally reddened by pre-Cambrian oxidation.

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more abundant as the conglomerate is followed southward, although the gravels are probably not wholly marine. There are some pebbles of basalt, but none of large size. The lower limit of pebbles of basalt is at 50 feet, and the thickness of the conglomerate is from 10 to 15 feet. In the vicinity of El Capitan Creek only small pebbles of basalt are known to occur; in other parts of the basin it is much more abundant than at Barnes Peak, and the thickness of the Formation is from 50 to 100 feet, but at no point is the thickness greater than 200 feet.

The conglomerate is very coarse in character, and is composed of well-rounded pebbles of basalt, with a considerable amount of sand. The pebbles are of various sizes, the largest being about 6 inches in diameter. The sand is fine-grained, and is composed of quartz and feldspar.

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sections that show the two quadrants separated by the intervening Mosel meander, and such brief shears on the northern edge of the range as have appeared since the Globe report have published have dealt only with the immediate surroundings of the upper course of the river. The exposure of the underlying Depressions nappe, the northern side of the valley, is less clearly displayed than elsewhere in the quadrangle. The name of the formation is derived from Tovy Mountain, and Stocca Mountain, forming most of the prominent summits in this stretch of about 11 miles. In the Terrida Range, in the southwest corner of the quadrangle, the consequence of its nearly vertical attitude it occupies a very small area.

Lithologic character.—The beds of the Tovy quadrant differ greatly in thickness, and many sections from thin, shaly or shaly layers to cross-beded pebbly beds from 25 to 50 feet thick. On the whole the thicker beds are characteristic of the lower and middle part of the formation. The upper part is inversely composed of thin, generally yellowish or grey, well-marked sandy limestones, characterized by a change in sedimentation that preceded the deposition of the Devonian limestone. The most characteristic material of these upper beds consists of layers of finely-grained, unevenly colored brown, pink, and green grits. In an inch or two thick, is characterized by a cross-bedded, often yellowish-gray sand whose cleavage surfaces are ridged and knotted with numerous worm casts. The quartz layers appear almost dolomitic in color and texture, but they are not to consist chiefly of finely fitting quartz grains with specks of disseminated lime and little nests of a green chlorite minerals. The most noteworthy feature of the thickest beds is their conspicuous cross-bedding and generally pebbly character, which is a useful means of distinguishing isolated exposures of the Tovy quadrants from those of the neighboring Dipping Spring quadrants. Both of these characteristics are illustrated in Plate V. The Dipping Spring quadrants is nearly all arkose, but the Tovy quadrants shows little or no ripple.

A section of the Tovy quadrants as exposed in nearly horizontal attitude 11 miles southwest of Tam’s Shatter Peak, in the Dipping Spring Range, not quite complete, as in follows:

A section of Devonian conglomerate in Dipping Spring Range.

By far, the most significant feature of the Tovy quadrants is the presence of Devonian conglomerate in the Dipping Spring Range. This conglomerate is composed of angular fragments of Devonian and Carboniferous sandstone, shale, and siltstone, ranging in size from a few inches to several feet. The conglomerate is most abundant in the northeastern part of the quadrangle, where it forms a thick lens in the overlying Cretaceous beds. The conglomerate is believed to have been deposited in a fluvial environment, possibly a braided river system, and it serves as a significant marker horizon in the Tovy quadrants.

Although much of the Tovy quadrants is light gray or white on fresh fracture, the weathered exposures are generally buff, brown, rusty, or maroon. In the canyon northwest of Tam’s Shatter Peak, the weathered exposures of this formation are nearly pure white, with a thin, light-colored, dull-red tint, but the different parts of the formation vary in color from white or pale buff to dull red.

Thicknness.—Measurements and estimates of the thickness of the Devonian limestones in different parts of the region range from 200 to 325 feet. The average thickness is considered to be 225 feet.

In contrast with the older formations, which have yielded no discernable organic remains, the Devonian limestone contains fossils at many horizons in the upper division, from around 500 feet to the surface, at its contact with the underlying layers of the yellow shale. In 70 feet of fossils were collected and were referred to H. W. Williams and R. H. Smith who kindly prepared the following notes.

The identification of the fossils were indicated by the collections examined are given in the following table:

<table>
<thead>
<tr>
<th>Species</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Silurian</td>
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<tr>
<td>Trilobites</td>
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<tr>
<td>Stenothoeus sp.</td>
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<tr>
<td>Plectronothoeus</td>
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<tr>
<td>Schizoneura serrata</td>
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<td>Schizoneura serrata</td>
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<tr>
<td>Schizoneura serrata</td>
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<tr>
<td>Strophomenus sp.</td>
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<td>Strophomenus sp.</td>
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</tr>
</tbody>
</table>

Distribution of species of Devonian fossils in the Tovy quadrants.
strangely close break between the Devonian limestone and the Carboniferous. The evidence of the Aragonite sections indicates that the fauna under consideration is the immediate predecessor in that region of a fauna of the lower Carboniferous, and the close resemblance of the Upper Devonian fauna of Iowa and its stratigraphical relations to the Carboniferous fauna of the Arizona section would place the fauna of the limestone of the Martin limestone in the Lower Pennsylvanian, or the Devonian fauna of the Bay quadrangle, in the Upper Devonian. It is of course possible that this fauna might be found in Aragonite sections in Arizona may include Middle as well as Upper Devonian, but that it includes the Upper Devonian in any event seems well established by the available evidence.

A fauna identical with the Devonian fauna of the Bay quadrangle, occurring in the lower part of the "Globe" member of the Gila formation is correlated by Prof. E. R. Williams with the limestones of New Mexico. In that section the Gila is Potsdamian in age and it is quite possible that the fauna in the Lower Devonian of New Mexico may include Middle as well as Upper Devonian, but that it includes the Upper Devonian in any event seems well established by the available evidence.

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from Plate VI. It is of lighter and more uniform tint than the usual. The two together constitute the principal diff-
ferent part of the Carboniferous limestones. The third divi-
sion consists of beds generally thinner than those in the other
two divisions but not separable from them by any marked
lithologic distinction.

The Torrens limestone consists essentially of calcareous
carbonate and effervescence freely in dilute acid. A partial analysis
of a typical sample is as follows:

<table>
<thead>
<tr>
<th>Anal.</th>
<th>CaCO₃</th>
<th>MgCO₃</th>
<th>Loss on Ignition</th>
</tr>
</thead>
<tbody>
<tr>
<td>85.0</td>
<td>1.5</td>
<td>2.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>

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

**Fossils and correlation.**—Nearly all the Carboniferous lime-
stones contain fossil remains, but there are few localities where
full and satisfactory collections can be made. The beds of the
two lower divisions carry abundant fragments of crinoid stems
and less numerous rugose corals with long-armed spiculae and
Rhipidopora. These appear in slitted form on weathered
surfaces of the rock, but they can not readily be separated from
their matrix. In the upper division appear different species of
*Productus* and *Sphenopora*, *Bryozoan crura*, *Composita orbiculata*,
and *Pteriodex*.

The eight collections that were made were submitted to G. H.
Girty for determination. The following table shows the iden-
tification and distribution of the fossils collected:

<table>
<thead>
<tr>
<th>Location</th>
<th>Fossil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torrens</td>
<td><em>Prodoptus</em></td>
</tr>
<tr>
<td></td>
<td><em>Sphenopora</em></td>
</tr>
</tbody>
</table>

The Torrens limestone and the Martín limestones are not
more closely correlated than those of the upper Carboniferous
age. The apparent similarity in the fossil remains found in the
three groups of limestone is sufficient to hold the limestone
of the lower division in the upper Carboniferous series.

**Conditions of deposition.**

The Torrens limestone and the Martín limestones, as shown by
their fossil and sedimentary character, are of pre-Devonian age.
Ten or fifteen years ago most geologists would probably have had no
hesitation in classing the sediments of the Apache group also as
Devonian deposits, although no marine fossils have been found in
them. They were so considered in the Globe report, written in
1900, and in the Globe files, prepared about the same time.

Recent studies, however, particularly those of Burrell, have
shown the necessity of taking into account continental and
especially fluvial deposition.

That the beds of the Torrens group were laid down in water
there can be no question. They have none of the character-
istics of soda deposits. The evidence to marine or fluvii-
ous deposition, however, is in favor of the latter.

The Stensan conglomerates, with their pebbles of local origin,
support the most reasonable account for a local marine con-
glomerate; although this interpretation has little definitive
evidence in its favor. The succeeding Piercean shale gives no
clue as to weather it is of marine, lacustrine, or fluvial
origin. It contains no fossil fragments or mud cracks, so far as
is known. The most puzzling feature of the succeeding Barnes
conglomerate is its relation to the Piercean shale. A coarse
spray deposit of the size of the pebbles and boulders, indicative of
vigorous streams, abundant vegetation, and powerfust currents,
rests on material that the pebbles accumulated would presumably
a sandy mud. The pebbles evidently could not have been washed
near their present resting place but must have come from a distance.
The surface of contact between conglomerate and shale, in the
very few places where it is well exposed, is subhorizontal, but the
shale layers, instead of being cut by the uneven surface, con-
form to it, as if the conglomerate had been deposited on a soft,
yielding substratum.

A similar relation appears to hold between the conglomerates
of the Eocene and North America, and the underlying forma-

Mollusca are common in the Stensan Pebbles. One of the most
noticeable features of the principal conglomerate bed at the
Eocene base is that it is laid down over many hundreds of
acres upon a wide sheet of muddy and very clayey material,
which over the whole of that area formed the uppermost
portion of a sequence of similar strata some hundreds of feet
in thickness. It is probable that this change in the character of the
sedimentation was brought about simultaneously throughout
the whole area to be extended beyond the immediate vicinity
already alluded to. Among further indications may be mentioned the fact
that thousands of the larger shell fragments of types of shells
underlying muddy deposits which might be found for the gradual exter-
ing of pebbly deposits over them. On the other hand, we do find
evidence of such occurrences as might be expected to occur with the
rapid sweeping of the pebbly deposits over a previously existing
deposit of similar shell fragments. On the other hand, it is possible
I have found numerous examples of the inclusion of fragments of the foot-
steps in the underlying conglomerate, particularly its lower portion.

One of these fragments was a foot in length and about 2 inches in
thickness and of irregular tabular form, with several edges. It appears
among other small pieces of partly consolidated sandstone
which had been torn from the underlying muddy material and
immediately included in the pebbly deposit to be deposited.

Other conglomerates in the Streets of the world, series, according
to Burrell, show similar relations to underlying shales. The
evidence of erosion of the shale found by him in South Africa
is lacking for the moment, in Arizona. Mellor's conclusion, that
the Streets of the world series is a delta deposit, accords with an
earlier suggestion by Dr. LeRoy.11

On the whole such evidence as is obtainable appears to indicate
that the Barnes conglomerate represents a submarine action
rather than more (littoral) or marine action.

The unclassified Dripping Spring quartzite contains some
sand and gravel in its thin upper beds, showing that these beds
must have been exposed to the air during the period of depo-
sition. The formation is tentatively regarded as of delta origin.

The deposition of the impure dolomitic Muscat limestones
marks a change of conditions of sedimentation—apparently
a subsidence of the land and the introduction of shallow saline
waters. On the other hand, the very fine grained fossil
beads appear to have been exposed to the air before it was
covered by the sands that make up the Dripping Spring quartzite.

The pyritic quartzite with its abundant pebbly layers and
considerable cross-bedding is suggestive of fluvial or deltaic
deposition. The upper part of this formation shows gradation
into the unidirectional marine deposition of the Deacon
Martín limestones, although the grit beds and flint limestones

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11 Burrell, Joseph. "Polygenetic geographical importance of sedimental, litholo-

12 Burrell, Joseph. "Polygenetic geographical importance of sedimental, litholo-

13 Burrell, Joseph. "Polygenetic geographical importance of sedimental, litholo-
The disease is intrusive, and although it is highly probable, in view of the situation, that the occurrence of the disease is due to the intrusion of a new species of fungus, it is not yet certain. The disease has been observed in the southwestern part of the state, near the border with Mexico, where it has caused extensive damage to the crops. The disease is characterized by black spots on the leaves and stems, and by the formation of small, dark, circular lesions on the fruit. The disease is transmitted from plant to plant by the wind and by the movement of infected soil particles. The disease is most severe in the late summer and early fall, when the temperature is warm and humid.

A chemical analysis of the disease is given elsewhere. A study of the disease has been conducted by the Department of Agriculture, and the results have been published in several reports. The disease is also being studied by the State University, and the results of the study will be published in the near future.

The disease is a serious problem for the farmers in the southwestern part of the state, and efforts are being made to control it. The state government has provided funds for research and for the development of new methods of control. The farmers are also being advised to take precautions to prevent the spread of the disease. They are advised to destroy infected plants and to plant new crops in the affected areas. In addition, the state government is providing advice on the use of pesticides and other chemicals to control the disease.

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that solidified in the larger masses. If so, the disease is younger than the Pennsylvanian epoch of the Carboniferous. The relation of the disease to the anastomosis in the vicinity of Tornado Creek is not definitely determinable within the data studied, but the disease is thought to be probably older rock. Campbell's reconnaissance of the Deer Creek coal field, etc. showed that the anastomosis is probably Carboniferous, which would make the disease assignable to the early Mississippian or late Pennsylvanian.

CRETACEOUS SEDIMENTARY ROCKS.

The Tornado limestone constitutes the latest record of marine sedimentation preserved in the Glove-Region. The Deer Creek coal field, etc. which lies about 12 miles of the Ray quadrangle, contains several hundred feet of coal-bearing sandstone and shale from which were collected plant remains, according to F. H. Knowlton, suggestive of Upper Cretaceous age, and at a lower horizon in the same beds were obtained imperfect specimens of Osteus and Elycosaur, which, according to T. W. Stannett, are also indicative of Cretaceous time. Campbell described the major portion of the sediments as overlain by a thick mass of anastomosing volcanic rocks which within are interstratified some sedimentary layers. According to him, the main body of coal-bearing sediments extends under the anastomosis thins rapidly to the west. These beds are not represented in the Ray quadrangle, although the anastomosis formation, presumably also of Cretaceous age, extends into the southeastern part of the quadrangle, east of Tornado Park, and will be dealt with elsewhere.

ANASTOMOSING TUBES AND REMNANTS.

Occurrence and distribution.—In their reports on the Deer Creek coal field, etc. Campbell and Bell refer briefly to the occurrence of large masses of anastomosing the Cretaceous sediments and connected with them the intercalation of sedimentary layers containing a little coal. Southeast of Tornado Park and stretching as a broad belt that direction across Gila River lies an area of smaller-beded hills composed of anastomosing tuff. This material is undoubtedly the anastomosis referred to in the Deer Creek reports, although in the Ray quadrangle it rests on the Cretaceous beds partly on the Pennsylvania limestone. In part the material may consist of lava flows, and certainly it is traversed by many porphyry dikes. Similar anastomosing tuff or diorite occurs in many areas in the vicinity of the Ray quadrangle. Finally, the porphyry occurs as a group of dikes that lie generally east of Tom's Slower Park and cut both the anastomosis and the older rocks. Age.—Beyond the fact that the anastomosis rocks rest on an erosion surface of the Porphyry Field, the Ray quadrangle supplies no clue to their age. The work of Campbell in the Deer Creek coal field, however, shows that they are his Cretaceous rocks. Thirteen miles southwest of the quadrangle is a locality of the Mesozoic rocks near the town of Pine and a rich outcrop of Carboniferous rocks at the southern end of the town. These rocks are cut by dikes of quartz porphyry and probably also by the Granite Mountain porphyry. Two smaller bodies on the north side of the town, Suhler Gulch have invaded the Dripping Spring quartzite.

Three miles northeast of Kelvin, near the head of Elder Gulch, a group of small bodies of the Granite Mountain quadrangle. These formations within which it has effected some local metamorphism. Other small bodies of the same igneous rock lie north and east of Ray Mountain. An extremely abrupt about one-fourth of a square mile in area cuts granite, diabase, and the Paleozoic formations up to the Mesozoic limestone just west of Hackberry Spring, in the southeastern part of the Ray quadrangle. These dikes and a small intrusive body of the same rock cut granite and diabase northeast of Roper Spring. Finally, a small body of the quartz dikes in known as Pike Creek in the Mesozoic Region. As bearing on the age of the quartz dikes intrusions, the fact should be noted that these rocks are fairly abundant in the anastomosis southeast of Tornado Park. Most of these dikes are east of the Ray quadrangle.

Petrography.—The porphyric part of the typical quartz dikes are light to dark gray, color, fine-grained texture, and general freshness as compared with most of the diorite porphyry. The rocks are generally not more than 3 millimeters across, and phenocrysts as a rule are very slightly disseminated in the groundmass. On fresh fractures, the rock consists of white feldspar, hornblende, augite, or biotite; all three minerals are present in some varieties. Although the foregoing description applies to the prevalent variety, there are other varieties of the same appearance. In certain localities the crystals of hornblende may be 2 centimeters or more in length, with the feldspars of proportionate size. The general composition of the rock is also somewhat variable.11


In a few places the quartz dikes grade into low colorless crystalline feldspar, some of which are highly hornblende.

Contact metamorphism.—Quartz dikes which crop out in a small triangular area about a mile north-east of Troy contain an inclusion of large, well-formed crystals of mica. This has been strongly metamorphosed, and the igneous rock near the limstone is more corundum crystalline and more conspicuously hornblende than elsewhere. The principal factor of development by metamorphism is the limstone of sevemniite, clinohlore, diopside, epidote, hornblende, and garnet. The vermiculite is in form, nearly milky-white crystals which, according to T. W. Schaller, who verified the determination of the mineral, present no unusual faces. The garnet is a yellow-brown variety of crystals as small as a grain of rice in diameter.

Similiar metamorphism has been undergone by a block of limestone included in quartz dikes 2 miles west of Troy. Here the limstone shows no crystal faces and is full of inclusions of diopside. The rock in places is a fine-grained aggregate of colorless ameboloid diopside.

Another locality where limestone, in this place the Tornado limestone, has been metamorphosed by the quartz dikes is in Elder Gulch, 3 miles northeast of Kelvin. At the contact woldstone has been developed in coarse-crystalline masses and occurs also associated with diopside, vesuvianite, and garnet.

QUARTZ MONOMORPHIC PORPHYRY.

Occurrence and distribution.—The quartz monomorph porphyry of the Ray quadrangle is confined to the vicinity of Ray quadrangle and occurs for the most part west of that town. Two varieties are recognized. One, designated the Granite Mountain porphyry, is intrusive in the Pinion and is northeast of Ray as a number of irregular masses, of which the largest forms part of Granite Mountain. (See the geologic map of the Ray quadrangle.) There are also a small number of bodies of this rock east of Ray. Most of the altered porphyry in the copper-bearing area west of Ray appears to belong to this variety, although owing to alteration, close identification is not everywhere possible.

The other variety, distinguished as the Topton Mountain porphyry, occupies chiefly the north and north-east of Ray and north-west of Tornado Park, the recognized copper-bearing area. One small mass only, that about a mile northwest of Ray, is represented on the geologic map of the Ray quadrangle. But as shown by the geologic map of the Ray quadrangle, which covers an area extending west of the Ray quadrangle, there are many dike and one irregular mass of considerable size exposed on the flanks of Topton Mountain, a prominent landmark northwest of Ray.

Granite Mountain porphyry.—The quartz monomorph porphyry of this locality is a light gray rock, which, on slightly weathered surfaces has generally a faint yellow tint and closely resembles some of the Schnebly granites. This lightness of hue is due to the preponderance of feldspar and quartz, the only dark constituent being black mica in small and sparsely disseminated scales. The texture of the larger masses, such as that intrusive into the schist of Granite Mountain, resembles on casual inspection that of a porphyryic granite of medium grain, with phenocrysts of orthoclase and quartz, none as, a rule, sharply differentiated from the groundmass.

Topton Mountain porphyry.—Close association with the Granite Mountain porphyry, north of Ray, gives rise to a slightly different variety of quartz monomorph porphyry, which occurs for the most part north and west of the copper-bearing area, on the northeastern slope of Tornado Mountain, as dikes and irregular masses in the final schist.

The rock is, as a rule, a little darker in color than the Granite Mountain porphyry and is more obviously porphyritic. The general color of the fresh rock is gray, but surface exposures are generally light yellowish brown from decomposi- tion. Contrasting sharply with the gray groundmass are phenocrysts of pink orthoclase as much as 3 centimeters in length. These are associated with smaller phenocrysts of quartz and evidently of many kinds.

Under the microscope the variety in which the large orthoclase crystals, take itself shows phenocrysts of plagioclase, orthoclase, quartz, and biotite in a very fine-grained granitoid groundmass that is probably chiefly quartz and orthoclase. A single terminal crystal of albite about 0.8 millimeter long was noted in one thin section. Although this porphyry is younger than the Granite Mountain porphyry, it is more restricted in distribution than the latter, and more distinctly represents an altered salientady term for petrographic and chemical study. The feldspars are largely changed to calcite and sericite and the biotite to chlorite.

Contact metamorphism.—The contact action of the quartz monomorph porphyry near Ray is most apparent on the dike, which, near the porphyry, glitters with abundant secondary biotite. This alteration is of the same sort that produced by quartz diorite porphyry in dikes near the London- Arians mines, and is described on page 12. Altered dike of this kind referred to may be seen on the stump of the Blue Bell shaft, southeast of the town of Ray.
Occurrence and distribution.—The little settlement of Troy, in the Dripping Springs Range, is situated in a small upland basin flanked by granodiorite and included by basaltic and Paleozoic sediments, into which the granodiorite is intrusive. The principal area of this granodiorite-like rock is roughly penecontemporaneous, with the point to point to point 1 mile in width and 0.5 miles in greatest width nearly 1 mile. A small outlying area is half a mile northwest of Troy, although included in the surface by Pioche shale, is probably part of the main Troy mass.

 Petrography.—The granodiorite of Troy is a light-gray, evenly-grained rock whose principal constituents are locally recognized as plagioclase, quartz, and black mica, average about 3.8 millimeters in diameter. Although over much of the surface of the basalt the rock is disintegrated, its appearance in some parts is not so coarse as to procure material that is fresh or that shows under the microscope only slight development of euhedral and of the clinoblastic in the biotite of and can refer to the foliae. The change in rocks of this class and for no detailed description. The orthoclase and black mica are held together very tightly, being fairly abundant in some areas and comparatively less abundant in others. They are scarce, however, either as aphanitic constituents or as anorthoclase.

A chemical analysis of a typical specimen of the granodiorite from a point half a mile northeast of the town is:

| Chemical Analysis of Granodiorite | 
|----------------------------------|---|
| SiO₂ | 71.84 |
| Al₂O₃ | 18.16 |
| Fe₂O₃ | 1.80 |
| FeO | 0.85 |
| MgO | 0.11 |
| CaO | 4.04 |
| K₂O | 1.11 |
| Na₂O | 2.88 |
| Total | 99.85 |

The name in the norm system for a rock of the above composition is plagioclase.

The rock of the little area half a mile northeast of Troy resembles that of the main mass, although it is slightly finer grained and, as the microscopist observes, approaches granodiorite porphyry in texture.

Contact metamorphism.—The most noticeable metamorphism near the granodiorite of Troy is on the northwest side of the intrusive area, where the igneous rock is in contact with the coarse-grained gray gneiss. This schist is not unlike some of the felsic-grained varieties of the Final schist, but its geologic relations at this place show that it is largely metasomatized Pioche shale. The schistosity conforms to the bedding of the lower shale, dipping about 15° SW.

One specimen of the schist, examined in this section, proved to consist of quartz, biotite, and muscovite with andalusite in long rung prisms and rather abundant corundum in grains, granular aggregates, and larger individuals without external crystal form. Other specimens from the same small area of schist showed neither andesine nor corundum, although all contain a little dark tourmaline as a microscopie constituent.

The schist is overlain by the Hermit conglomerate, which is so metamorphosed as to be nearly unrecognizable. It looks at first glance like a nearly homogeneous white quartzite, and close examination is required to distinguish the schistosity lines of the original package.

The dike near the granodiorite in place shows noticeable alteration. It is more than 50 feet wide, and the normal dike and evidently contains abundant biotite. The microscopist notes that this rock, while retaining the general texture of the dike, has undergone extensive recrystallization. The original feldspar has a reddish turbidity and are full of minute inclusions. The augite and olivine that have thoroughly disappeared and are replaced by abundant biotite and biotite. There is considerable close secondary feldspar, generated by the optical continuity with the original feldspar and containing flakes of biotite, and needles of muscovite. The rock is perfectly fresh, and it is clear that the change was produced by a more active agency than those which affect the ordinary crystallizations of porphyritic rocks.

Certain of the ore deposits near Troy are to be interpreted as the results of contact metamorphism by the granodiorite magma. Such are the deposits of the Halls Creek or Halls Creek Mine, 2 miles northwest of Troy, on the north side of the town.
Gills conglobulare (persoon).

Character and distribution.—The Gills conglobulare as it occurs in the Gobe quadrangle has been fully described in publications on that area. It is a hyaline deposit consisting of coarse, imperfectly rounded or angular rock detritus near the moutains but grading into gysiferous silts in the central portions of the larger valleys.

The general character of the Gills formation as it occurs within the Gobe quadrangle is that of a firm but not hard material, in places pedogenetic, which ranges in coarse- field to ordinary rhyolite porphyries. These dolos out the quartz diorite porphyry.

Whitehite conglomerate (late tertiary?).

In the reports on the Gobe quadrangle the Whitetite form- mation was described as a deposit of rather coarse sand and in many places somewhat angular stone detritus that lay in the hollows of a former land surface and together with that surface was covered by ducite lava. The material is generally of local origin and varies with the underlying rock. It appears to have accumulated particularly on areas of diabase and in such situations is made up of angular or very imperfectly rounded fragments of that rock with a minor proportion of limonite fragments. The fragments are as much as a foot in diameter and are generally more or less decomposed.

The formation is the record of the operation, prior to the ductae emplacements, of forces and processes similar to those that affected the larger scale, and the Whitetite conglomerate, in which some of the places is almost identical with the Whitetite. Apparently there are now areas of diabase tended to become lowlands and the Whitetite formed on the more abundant and particularly by tran- sient streams.

Detrital fans at the mouths of shallow gulches, merging downward to the stream of sand, water, and the debris carried by the tuff and lava of the ductae emplacements and as preserved.

In the absence of forms a rough approximation to the age of the Whitetite conglomerate, deduced from the general history of the region, is all that is possible. As it lay on the surface over which the probably only tertiary ductae lavas were erupted, it is also referred to the same period.

Excellent places to observe the Whitetite conglomerates are the steep slopes of Teton Mountain near Bay (Pl. VIII) and near the pine mine, in the northwestern part of the Gobe quadrangle.

Ductae.

Definition.—The ductae are porphyritic effusive rocks in which crystals of plagioclase, quartz, and hornblende or biotite, as the common essential minerals, are embedded in a more or less glassy groundmass. The biotite ductae are closely related to the rhyolites, which they commonly resemble. The relation of the ductae to the rhyolites and andesites among the volcanic series is similar to that of the quartz diorite to the andesites and diorites among the plutonic rocks.

Occurrence and distribution.—Ductae occur in large areas and are widely distributed in the Gobe quadrangle but in the Bay quadrangle it occurs only at the north and of the Dripping Spring Range. In the Minerva Range through- out its gorge north of Bay is nearly the western extension of a thick and extensive flow whose surface may be seen from any of the summits north of Scott Mountains in rugged depression for many miles to the northwest. Into this thick mass of lava Mineral Creek and its tributary Devils Creek have incised deep, narrow canyons of picturesque character. The main portion of this flow is flanked down against the older rocks of the Dripping Spring Range, but outlying remnants rest here and there on the higher parts of this range north of Scott Mountains, and a considerable area of ductae, partly covered by the Gills conglomerate, extends south- ward to the vicinity of Bay.

Originally this flow probably covered most of the Gobe quadrangle and much of the Bay quadrangle, but its conti- nuity has been greatly reduced by faulting. The maximum thickness is unknown, but existing remnants show that it must have exceeded 1,000 feet. In spite of vigorous post- ductae deformation of the region, it is clear that the ductae has been broken down into a very minute aggregate of ind Resources and materials in the Gills quadrangle are interbedded with the coarser plutonic material. The tuffaceous beds, considered by themselves, might be taken as indicative of a contiguity of ductae and andesite, alternations during the accumulation of the Gills conglomerate, but it is more accurate with the history of deformation in the region to conclude that those eruptions had ceased and that the products of geyseric activity were reduced to the solidi- fied lavas and swept by streams into depressions where they accumulated, probably in part in short-lived lakes.

The cement material which makes the Gills conglomerate is on the east fork of Mineral Creek, near the northern border of the Bay quadrangle. Here one partly rounded mass of granite rock from the Pinion Range measured about 30 by 25 feet and was estimated to weigh 700 tons. As a rule, the higher the surrounding mountains and the more massive and resistant their rocks the larger the fragments in the Gills conglomerate.

In the southwestern part of the Bay quadrangle, southwest of Gills River, the Gills formation shows a greater thickness of distinctly bedded strata than in any other locality studied.

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

The beds are of varied composition. Probably the most abundant material is a brownish-gray conglomerate in rather thin beds while the coarse sand and units are angular fragments of andesite, and tuffaceous rocks. Many of these fragments are 2 feet or more in diameter, and some of the materials are visible to the naked eye. The fragments in the conglomerate have been broken down into angular and the andesite material from the east or southeast.

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14 See E. E. Gilby, Survey Dept. Paper 61, pp. 68-74, for petrographic details and a chemical analysis.
The variety of the conglomerates described is not very different, so far as mineral composition is concerned, from that of Elas River in the vicinity of Hayden. The conglomerates contain much sandstone material but is not so well bedded as that between Brunnaum station and Hackberry Spring. Associated with the pebbles and a small variety of sedimentary mate-

**Structure.**

**General features.** Some mountains, such as the Appalachians, stand in relief because the neighboring valleys, with which they are in contact, have been eroded below surface once broadly coincident with the present ridge crests. Others, such as those in southeastern Idaho and southeastern Oregon, which Russell**1** has described, owe their prominence to direct uplift relative to the valley floors, and their forms have been modified only very slightly by running water. Still others, like Mount Shasta, California, are mountains of volcanic origin, and their relatively high summit levels above an older surface. In actuality few if any moun-
tains belong exclusively to one of the three ideal types. Most resemble intermediate types, and many of them is difficult or impossible to decide whether deformation or erosion has had the larger share in their development.

The Hackberry Spring area is characterized by ranges trending nearly northwest, separated by destitute-interior valleys. This larger differentiation of the surface into ridges and troughs or moun-
tains and valleys is a result of such etchings. The ranges are essentially tectonic features. Erosion, however, has greatly modified their outline and, at the same time, has removed much of the mountains belonging exclusively to one of the three ideal types. The fluvial erosion has been most active in the northern part of the region, and along the eastern part of the range where the mountains tend to be highest.

**Recent deposits.**

Detrital accumulations younger than the Gila conglomerate and probably related to it at the lowermost bed of the Yuma Group are thin and almost impossible to trace. The well-rounded pebbles are generally well-sorted and are generally found in pebbly sandstone or in gravelly sandstone. The gravel beds are generally thin and irregularly distributed, and the pebbles are generally well-rounded and well-sorted. The well-rounded pebbles are generally well-sorted and are generally found in pebbly sandstone or in gravelly sandstone. The gravel beds are generally thin and irregularly distributed, and the pebbles are generally well-rounded and well-sorted.

faulting will be here used as recommended or defined by the committee on the nomenclature of faults of the Geological Society of America. The application of some of the more important of these terms is illustrated in Figure 4.

In Figure 4—Diagram of a faulted block illustrating terms used in describing faults.

The upper left surface of the block is horizontal, the rock layers are vertical, and all make angles to the fault which, in this example, is vertical, as in Figure 4, a, and 4, b, and 4, c. A fault is said to dip (a) to the right (4, a); to dip to the left (4, c); or to be vertical (4, b). The faults may be plane faults (straight line), right-angle faults (4, a, 4, b, and 4, c), or fault splays (4, d). The term "offset" is given to the gap in the block due to the faulting. The term "juxtaposition" is used to express a fault which has nearly the same strike as the faulted surface, but in which the faulted surface is actually offset by a shorter distance than in the previous diagrams. The term "chieff" is used to express the situation in which the faulted block is actually offset by a shorter distance than in the previous diagrams.

Evidences of faulting.—In many regions the presence of a fault is inferred as the most reasonable way of explaining certain observed structural relations. In the Bay quadrangle the evidence is that of a more direct character. The very topography of the Dripping Spring Range, for example, as stated on page 5, is indicative of intricate 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 been shown to associate with mountains of folded strata. A view from any high point over parts of this range or over much of the Grande plateaux is equally suggestive of deformation. The Drip攻略 report 18 contains the following paragraph:

If one will stand upon the top of Wotak Mountain and look northeast as one passes over the recently actively eroded flat spot below him, he will be struck with the apparently chaotic distribution of the various units, as indicated by their respective and characteristic trends in the landscape. Here and there patches of limestone white with the thin screen of unweathered vegetation, while segments of quartzite are indicated by a reddish color and masses of diabase by a dull olive tinge. The beds show no trace of faulting, and the eye seeks in vain for any persistent or regular structure that may account for this rocky patchwork. 18

In traversing this faulted region one steps with bewildering frequency from quartzite to sandstone, or from sandstone to quartzite, or diabase, the line of separation clearly defined by a fault breccia, forming a fault block that may be followed over thousands of miles. Probably few equal areas of the earth's surface have been so thoroughly dissected by so irregular network of normal faults and at the same time exhibit so clearly the details of the faulting. When the foregoing was written the Dripping Spring Range in the Bay quadrangle had not been geologically mapped and studied. It does indeed still better than any equally large area in the Grande quadrangle the fine-textured fault blocks characteristic of the region.

Indicated, boldly outcropping fault breccia mark the courses of many faults, particularly those that traverse quartzite or have quartzite in one wall. This brittle but weather-resistant rock is the great breccia maker. Even those faults that, at the surface, pass through other rocks than quartzite, may have been modified by the brecciation having been derived from some place along the break where the fissures pass through or beside that rock. A number of illustrations of fault breccia found in the Dripping Spring Range and in the Grande quadrangle are 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 soil cover or the structures that run parallel to it. The characteristics of the structure cut by the surface fault are shown as a rule coincides with lines of faulting. Yet the faulting, by bringing into juxtaposition rocks of diverse behavior under erosion, has in an indirect and irregular way conditioned much of the topographic detail. The minute and unsymmetric character of the fault is reflected by a correspondingly irregular and intricate topography. The distance and the granite rocks are on the whole more readily eroded than the sedimentary rocks, and had the faulting been of such a character as to bring to the surface long belts of these rocks, the drainage would undoubtedly show some tendency to conform to their distribution. The existing fault pattern, however, is too patchy, too lacking in long belts and too the many intricate terraces present an indication to influence appreciably or persistently the direction of stream erosion. Beyond the fact that a majority of the fault streams cross prominent ridges and divide the Grande quadrangle into two unequal sections, topography alone gives little clue to the course of a fault.

Cause of the faulting.—Whatever the cause that led to the extraordinary deformation of the Grande quadrangle region, they were probably not local and not are likely to be clearly understood until we know the help of the geology of Arizona is much more comprehensive and much less disturbed, the context between the broad, monotonous structural features of the Arizona Plateau and the jumble of fault blocks in the country here described north of the Sierra Nevada. The faulting is unquestionably connected with the forces and movements that differentiated the Colorado Plateau province from the Basin and Range province and the question of its
origin is a broad regional problem. Foulshad of the kind described appears to be the result of collapse—of a widespread inability of the drainage basins of the earth's crust to respond to their load. As a whole, however, the mountain region of Arizona does not appear to have subsided generally, in comparison with the plateau. Had it done so its minor structural expression might be expected to contain a larger proportion of rocks younger than those exposed in the plateau areas; and the faults would resemble somewhat those near El Paso, Tex., where the precipitous Franklin Mountains, composed of Paleozoic and pre-Cambrian rocks, the eye range may for hundreds of miles into Mexico, where the only rocks visible on the south are Mesozoic or younger. On the contrary, the rocks making up the ranges of the Arizona region, exclusive of the Coconino and Tertiary igneous rocks are in a large extent older than those in the bounding cliffs of the plateau. North of Payson and about 75 miles north-northwest of Minter, for example, the plateau surface is formed on the Coconino sandstone and has an elevation, near the brink, of about 8,000 feet. The Mesa Range attains nearly as great an elevation, but its crest is composed of pre-Cambrian rocks. In the ranges of the plateau in the pre-Cambrian rocks therefore appear to have been elevated with respect to the same rocks in the plateau. Of course, 75 miles is a long distance, even in Arizona, and it might not be safe to base a conclusion on this one comparison. The inference is in accord, however, with what has been observed elsewhere and at places much nearer the plateau edge, as in the Mantiial Range and in the Sierra Ancha. In fact, the general impression gained from the fairly extensive reconnaissance in this part of Arizona is that the pre-Cambrian rocks in this range region stand on the whole rather higher than in the plateau and in places considerably higher. If this impression is correct, then it follows that the structural collapse of the range region must have been preceded by an uplift in which the fundamental monocline trends were raised above the general level of the corresponding rocks under the plateau.

Notwithstanding the irregular character of the diabase intrusions, the prevalence of fairly substantial forms and the general parallelism of intrusive diabase sheets in pre-Cambrian granite with those in the prevailing Paleozoic sedimentary rocks are approaches to regularity which would not be expected if the diabases at the time of intrusion were greatly faulted and if the sedimentary beds had their present dip. Along the northeastern base of the Mesa Range, however, there is a fairly regular sheet of diabase in pre-Cambrian granite. This sheet dips southwest at about 30°, or approximately at the same angle as the dip of the stratiﬁed rocks on El Capitan. If these beds were nearly horizontal when the diabase magmas were injected, conditions of equal load might have caused the diabase in the granite to follow in places an approximately horizontal plane of intrusion. If, on the other hand, the beds were then inclined 20° it is difﬁcult to see what conditions could have induced the diabase to cut the structural granite at so nearly the same angle. There appears to be a suggestion here that at the time the diabase was injected the beds of the Ray quadrangle were nearly horizontal and that the region itself was structurally a part of what is now the plateau.

Presumably the extensive faulting that followed the emplacement of the diabase in this manner is coincident with part of the structural separation between the plateau and the range region. Whether it initiated this differentiation or merely accentuated a distinction that had already appeared is not known.

**The Mountain Range.**

Area discussed.—In the following discussion of the structure of the mountain ranges no attempt has been made to confine the attention strictly to the Ray quadrangle. The structure of that area can best be understood by considering it in relation to structural features of the Globe quadrangle and of the immediately adjacent region.

**Apache Mountains.**—About 4 miles northwest of the Globe quadrangle are the Apache Mountains. These have the usual northwesterly trend of the ranges of the region, and their line is continued northwest of Salt River by the Sierra Ancha. Both ranges are structurally homogeneous, with dip to the northwest, and are composed chiefly of Cambrian rocks with intrusive sheets of diabase and diorite porphyry. Between the Apache Mountains and Globe quadrangle, the relatively low Globe Hills, which consist of Paleozoic and pre-Cambrian rocks ranging from coarse Arkose granite at the base to the Tonto limestone at the top. The sedimentary rocks have been invaded by two large irregular sill of diabase, and all the rocks, including some overlying diorite, have been displaced by numerous faults.

**Faulkner Range.**—The Faulkner Range, in the west-southwest of the Globe Hills and separated from them by the area of Gila conglomerate increased by Peavine Creek, is divisible into three portions, that superiority, present different features. The high middle portion of the range and some of the lower ground to the northwest consist of the Pearl schist intruded on the older Gila schists (quartz-mica diorite) and granitic rocks. The quartz diorite in some localities is covered with inclusions of schist, and the schist in places is cut by countless small ophiolites from the main intrusive mass. This pre-Cambrian complex, within the area over which it is exposed, is essentially the same as the Superior Granite of the Salt River area. The Peavine Creek diorite appears to be a lower member of the same complex and is cut by the Tonto limestone, which lie in a fault relationship.

The Pearl schist, which forms the low ground between the range and the lake, is a Lower Cretaceous formation, and the Schuller schist and Willow Spruce granite, and Los Altos conglomerates, appears to have been subjected substantially as a unit in the post-Cambrian erosion of the Pearl belt. The Pearl schist, because of its beauty, is largely exposed in the fault scarps of the range. North of this division is a fault of the range that is thoroughly dissected by faults, so that rocks of very different ages form one formation; in the section of the range north of Capitan the faulted mass has brought into juxtaposition in different blocks. The result is a fine-textured fault zone such as is very characteristic of the region and is represented in the Dripping Spring Range, probably to be described.

Overlapping the massive massive section of the Pearl Range on the west and the Capitan Range on the east there is a fairly dismembered section of the range that is commonly dissected by faults, so that rocks of very different ages, from the Pearl belt to the Capitan Range, are broken into blocks by the faulted mass. The result is a fine-textured fault zone such as is very characteristic of the region and is represented in the Dripping Spring Range, probably to be described.

From Blackberry Gulch, 2 miles southeast of Troy, two conspicuous faults diverge northward. One is the fault already referred to in the vicinity of Ray Mountain. The other runs northward, passing about three-quarters of a mile east of Ray. Between these faults and stretching beyond their known extent the Pearl complex rocks lie as a mass above the Tonto limestone at its southern tip. If the Pearl schist and Gila schists, east of Capitan, are to be assigned to the Pearl belt, however, the introduction of diabase and the minor fossiliferous units have introduced much structural irregularity.

West of the block just described is a comparatively small section of the range in the vicinity of Ray which has been uplifted relatively in the black east of it to 500 to 1,000 feet. About 4 miles northwest of Ray a more uniform drop falls the diabase on the northwest against the older rocks on the southeast. If a simple homoclinal range, tilted like the Mesa Range, to the southeast, were cut into sections by north-south faults, each section being displaced so as to be from 500 to 1,000 feet lower than its neighbor to the southeast, and if, further, each section were cut by numerous minor faults into a correspondingly numerous number of small blocks which underwent considerable faulting and movement before they came to rest, the resulting structure would be approximately that of the Dripping Spring Range. Whether the movements took place in the order given is not known and perhaps can never be ascertained.

**Tortilla Range.**—That part of the Tortilla Range within the Ray quadrangle is a small, north-south fault zone where the schist is approximately planar and the schist and Pearl schist are against each other. This range is a striking example of a fault mass. The fault fissures interest in all directions and form an intricate network. Although in some parts of the range it is possible to recognize the predominance of faults trending in some one general direction, the fault net as a whole does not appear to be susceptible of analysis into groups of fissures classified on the basis of direction or age.

**Dripping Spring Range.**—Southwest of the Pearl and Mesa ranges and separated from them by Dripping Spring or Disappointment Valley is the Dripping Spring Range. This range is a remarkable example of a fault mass. The fissure interest in all directions and form an intricate network. Although in some parts of the range it is possible to recognize the predominance of faults trending in some one general direction, the fault net as a whole does not appear to be susceptible of analysis into groups of fissures classified on the basis of direction or age.

**El Capitan.**—Examination of the Pearl Range shows that the Pearl belt is simply a range of Pearl belt rocks cut by Pearl belt faults. The Pearl Belt has masses of Pearl Belt schist cut by Pearl Belt faults. The Pearl Belt has masses of Pearl Belt schist cut by Pearl Belt faults.
then it is a remarkable exception to the general structure of the region. It still leaves the reader with the impression that the beautiful figures of the coast are the result of the collapse of just such folds as the one here suggested. If so, the unevenness of the surface would be evident, and it would show a multitude of intersecting fault lines, whereas in fact they appear to be unusually free from them.

The second hypothesis is that the present structural relation between the sides of opposite sides of the final Ring is the result of faulting, appearing to be more in accord with what is known of the structure of the region, namely of the flats of the basin of the region, but of a more extensive area of which the two quadrangles mentioned are merely a part. It may well be doubted, however, whether the few thousand feet of the great fault such as is indicated in the diagram of Figure 6. In all probability an area of complex faulting underlies the Gulf of California, and the apparent slope of the Flats from valley was suddenly or took place by successive small slips, the result must have been a pronounced steepening of stream grade, which is also a characteristic of the more definite condition of the Flats, being tectonic, would have no regular relationship from basin to basin, but all basins being closed in extent in which the sediments-being storm waters from the mountains would evaporate, or, possibly, in some places, from a lake having an outlet over some low pass in the valley. Under such circumstances the Gila formation may have accumulated under climatic conditions very different from those of today.

GEOLoGY.

Long before Cambrian time the Gulf-Bay region was part of a sea basin upon which were accumulating fine grists and soils, probably derived from granitic rocks. The source of these rocks is that ancient rocky floor upon which they were laid down is now invisible. In the course of time sedimentation ceased, and the beds were folded and thrown into the form of the Gulf and basin of the northwest direction; the boundaries of the granitic to the adjacent country. The new vertical attitude of the Paleozoic beds in the southeast corner of the quadrangle, the known presence of considerable faulting in the same locality, suggests that the unroofing of the Gila conglomerates along the eastern flanks of the ridge, are all suggestive of faulting rather than folding as the kind of deformation that brought the range into existence. In order to establish the truth of the statement that the mountain ranges and principal valleys are tectonic features it is necessary, of course, to prove not only the existence of these structural features mainly to faulting but that the general effect of dislocation has been the elevation of the mountain ranges relatively to the principal valley trends. This to some extent has been shown and is probably true for the final Ring. There remains for consideration, however, the question, How can the valleys be accounted for by erosion on the supposition that they are not due to deformation? In other words, Can the tectonic hypothesis be established by the elimination of its only alternative?

If the region was affected by the last general deformation the land in the area now corresponding to the valleys was as high or as higher than the adjacent mountains and if the valleys had been cut by erosion, then obviously the valleys should show an intimate and characteristic relation either to the present drainage plan or to some older drainage. If it is not so, it is not enough that they should be accepted by streams or by intermittent watercourses. That would follow, nor matter what the original relation of the streams. But, with all regard for differences in the resistance of different rocks to erosion, the valleys, if they were the work of running water, should be roughly proportional in size to the occupying strata and should show the adjustment of shape, width, and depth to the different sections of the stream that is characteristic of a fluvial valley. To pursue this branch of inquiry thoroughly would require the study of a much larger area than that now under consideration, but observation, for so it has gone, shows that the stream courses are not in close adjustment to the valleys. The Gila, for example, is shown on page 2, breaks across the ranges from one valley to another. Its present course must have been determined when the valleys were in existence but were more deeply filled with detritus than they are now. The valley in which stands the town of Globe appears much too large to be worked by one of the principal streams of the region and its tributaries and has not the shape that might be expected were it of erosional origin. Dripping Spring Valley also appears too large for the intermittent streams by which it is defined. The valleys are now occupied by the Gila conglomerates and must therefore have been formed before the conglomerates were deposited. The speculation, on the condition that the valleys erosional features, would require a period of intense denudation in pre-Gila time, during which not one of the valleys occupied by the neighboring mountains were corre- spondingly worn down. Moreover, the detritus resulting from this erosion must have been swept completely out of the region, for, excepting the few of the Flats and the close to the Gila, which was probably derived from an ancient land mass, composed largely of granitic rocks; the detritus with which the present Gila sediments were deposited. Although there is no direct proof that the rocks of these sediments are part of the basin and probably derived from an ancient land mass, composed largely of granitic rocks; the detritus with which the present Gila sediments were deposited. Although there is no direct proof that the rocks of these sediments are part of the basin and probably derived from an ancient land mass, composed largely of granitic rocks; the detritus with which the present Gila sediments were deposited.

The Pima sands, overlying the Scollum conglomerate and the lower quartzes of the Apache Mountains, record the accumulation of sand and gravel in shallow water. The material of these sediments was part of the basin and probably derived from an ancient land mass, composed largely of granitic rocks, situated to the west and north of the Basin sands, elsewhere occupied by 1 to 6 feet of Scollum conglomerate, is filled by about 200 feet, of hard and very quickly weathering quartzites.

The Phoenix sands, overlying the Scollum conglomerate, and the lower quartzes of the Apache Mountains, record the accumulation of sand and gravel in shallow water. The material of these sediments was part of the basin and probably derived from an ancient land mass, composed largely of granitic rocks, situated to the west and north of the Basin.
ECONOMIC GEOLOGY. GENERAL CHARACTER OF RESOURCES.

The rough and generally rocky or stony surface of the Bay quadrangle consists of a deposit formed by the siltation of the bay, the deposition of which has been influenced by the currents and tides of the bay. The bay is a large body of water, extending in all directions, and the sediments are composed of fine silts, clays, and sands. The bay is about 60 miles long and 15 miles wide, with an average depth of 60 feet. The greatest depth is about 300 feet. The sediments are deposited in a series of layers, with the oldest at the bottom and the youngest at the top. The sediments are composed of sand, silt, and clay, with the sand forming the uppermost layer. The sediments were deposited under water, and the water level has changed over time, resulting in the formation of the present bay. The sediments are impervious to water, and the bay is a saltwater body. The sediments are used for various purposes, including the production of sand and gravel, and the bay is a valuable resource for the region. The sediments are also used for the production of oil and gas, and the bay is a significant source of these resources.
COPPER DEPOSITS.
RAY DISTRICT.**
MINING COMPANIES AND CLAIM GROUPS.

By far the strongest and most active company in the Ray district is the one with the largest holdings in the Ray Consolidated Copper Co., which, after acquiring the property of the Gils 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 $1,400,000 in shares of $10 par value. It controls also the Ray & Gils Valley Railroad Co., capitalized at $2,000,000.

The land holdings of the Ray Consolidated Copper Co. are large, embracing nearly 2,000 acres in the Ray district, considered as 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 Mines (Inc.) is capitalized at $16,000,000, with shares of $10 par value. It owns about 207 acres of mining claims and a mill site, the most valuable part of the mining ground is included by the claims of the Ray Consolidated Copper Co.

The Ray Hercules Mines (Inc.) was reported in 1921 to have developed nearly 4,000,000 tons of 2.42 per cent ore. The company has carried out extensive underground work and has equipped the mine for production on a large scale. At Belgradia, a settlement just north of Bay 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 1921.

UNDEVELOPED DEVELOPMENT.

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. These at the end of the year 1926 had a total length of about 167 miles, of which about 54 miles had been destroyed by stoping operations. The underground workings (driven in 1915 amounted to 66,862 feet. There are three mines, known as No. 1, No. 2, and No. 3.

The plan of the ore body (Fig. 8) shows a marked constriction about 700 feet north of the Paddle Hand shaft, which practically divides the ore body into two parts. No. 1 and No. 3 mines are laid out in part to work the part of the ore body east and south of this constriction, and No. 2 mine the part west of it. The greater part of the southeast lobe of the ore body, including the ore in the western part of what formerly was the Ray Central ground, is being worked through the No. 1 mine.

No. 1 shaft and adit are close to Mineral Creek, at the northeastern slope of Ray Hill. 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. North and east of No. 1 mine is the No. 3 mine, which includes what was formerly the eastern part of the Ray Central mines.

The No. 2 vertical shaft and incline of the Ray Consolidated Copper Co. are three-fourths of a mile nearly northeast of the No. 1 shaft, on the west side of Mineral Creek, just south of the mouth of Sharyck Gulch, and are similar in size, arrangement, and equipment to those of the No. 1 mine.

STOPOING.

The general plan of stoping adopted in the No. 1 and No. 2 mines at Ray is that commonly known as the drift-dip-stope caving system and has been fully described by Blackmer.** Electric locomotives draw the ore in trains of 5-ton cars to the main shafts, where the cars are dumped in tippleges. At the surface self-dumping skips deliver the cars to crushers and course rolls, from which it is conveyed to a camp of heavy equipment, 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 ore at Hayden is worked by squad stopeing, this relatively expensive method, costing about four times as much as drift-dip stoping, being warranted by the character of the ore.

TREATMENT OF ORE.

At Hayden, 30 miles from Ray (see Fig. 9), the ore is concentrated in a mill designed in accordance with the practice at Garfield, Utah. There are eight sections, each with an originally designed capacity of 1,000 tons. The actual capacity of this mill in 1926, however, was 5,475 tons, and changes were in progress to increase the output still further. At first concentration was effected wholly by running water, but later 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>Tons of Ore Concentrated</th>
<th>Tons of Copper Concentrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1926</td>
<td>5,475</td>
<td>714</td>
</tr>
</tbody>
</table>

The concentrate as a rule contains from 18 to 25 per cent of copper. Alongside of the concentrator is a smaller 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.

FIGURE 8—Plan showing general plan of development of the Ray Consolidated Copper Co.'s mines on January 1, 1927.

FIGURE 9—Outline map showing the relative positions of the Ray Consolidated Copper Co.'s mines and mills.

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 width of the tracks of the Bay Consolidated Mining Co., for property and development to December 31, 1911, amounted to $4,655,314.81.

ORE AVAILABLE.

Estimates of the quantity of ore available in the mines of the Bay district vary with the data used in computation. As the ore is in most places not definitely bounded, the calculated available tonnage depends very largely upon the fixing of an arbitrary line between above and below the reserve. Moreover, material that on any given time is to 4 to 5 per cent of copper may be of low value or even of no value as ore if the copper is in ore in one of the oxidized zones that can not readily be concentrated with the sulphides. 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 estimates of the available quantity of ore for their respective mines and that 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 Bay Consolidated Copper Co., at the end of 1911 were, according to the company’s report for that year, 33,732,325 tons, averaging 2.02 per cent of copper. There had been mined at this date 12,285,845 tons. Consequently, the original reserve body, according to the latest report, had been, as calculated, 50,000,040 tons. This includes about 50,000,000 tons of ore averaging between 2 and 6 per cent, originally present in the ground formerly owned by the Bay Central Co.

The Bay Hercules Mines (Inc.) estimated in 1921 that in its property there was 3,500,000 tons of 2.45 per cent of copper, as the ore had been taken to a depth of 1,000 feet.

The total quantity of known ore originally present in the Bay district and averaging between 2 and 2.5 per cent may be taken as between 110,000,000 and 150,000,000 tons. There probably remains a considerable quantity yet to be developed.

TOPOGRAPHY.

For the first 10 miles of its generally southeast course, Mineral Creek traverses a succession of gorges cut in a thick, faulted flange of domal schist. About 8 miles north of its mouth, however, the creek emerges from its narrow confines into a more open valley, which continues southwest to Gills River. The Bay district, as the name is used in this folio, is situated at the head of this valley, which, although broadly open, contains very little level ground. The district itself is perhaps best characterized as a confusingly knobby area in which the various eminences are distributed without any recognizable plan or structure. It is overlooked from the east by the steep and, in some places, precipitous slopes of the Dipping Spring Range, which culminates locally in Scott Mountain, 5,151 feet in elevation, or about 3,000 feet above Bay. On the west, the district is so short that it is more correctly termed the Dipping Spring Range. The lower grade of this slope is due partly to the fact that Copper Creek is tributary to Mineral Creek on the west side and brings into the main stream of the valley by various side channels or affluent streams. This summit, with the characteristic outline which gave the mountain its name, is a prominent feature from nearly all parts of the district. Tongue Mountain is capped with domes and is the southern point of a deeply dissected lava plateau which partially incloses the district on the north and stretches for many miles in that direction.

On the south a group of curious pinacles carved from indurated Gills conglomerate, of which the largest, Big Dome, rises precipitously in a height of about 450 feet above Mineral Creek, suggest a topographic separation of the Bay district from the valley immediately north of Kelvin. This separation, however, is not as real as it appears to the traveler who approaches the district along the valley, the channel of Mineral Creek. A broader outlook over the country, such as may be had from the adjacent mountains, reduces these pinacles, which are sufficiently imposing near at hand, to their true proportions in the general landscape and shows that there is no constriction of the valley proper.

It thus appears that the Bay district has the aspect of a small knobby basin, thrown from north to south by Mineral Creek and very imperfectly closed on the south. As seen from a moderate distance, the central part of this basin bristles with a hooded assemblage of little rusty sharp-topped hills, of which Humboldt Hill is a type. Most of these hills stand from 300 to 500 feet above the deepest salt in their part, or probably from 100 to 300 feet above what may be considered the general level of the district. The area characterized partly by this topography of elongated eroded line is a long little north of west, and the concave side of the area lies to the south. Its length is about 2 miles, and its greatest width is about threequarters of a mile. This partly contains a part of the mining district south of it, broad, low, gently sloping slopes, which have evidently been formed by the erosion of superfluous layers of strongly or gravely denuded country. There is a general smoothness which is in marked contrast with the crenated topography of the central area.

GEOL OGY.

In the area immediately adjacent to the principal copper mines, the rocks are almost entirely of a metamorphosed schist with a little granite and quartz of mica-diorite, mostly of inferior quality or were concealed under superficial deposits of much later age.

Of the Paleozoic section only the lower part is represented, mainly on the east side of Mineral Creek, where horizontal conglomerates, fossil shale, and Dipping Spring quartzite are exposed in numerous small fault blocks. The Merril, Martin, and Tornado fissures, although prominent in the mountain front east of Bay, do not occur near the mines. Intrusive rocks of post-Paleozoic but probably pre-Tertiary age are represented by diabase, quartz diorite, and two varieties of quartz monzonite porphyry, distinguished as the Tonnant Mountain and Granite Mountain porphyry, and by dike, chiefly of quartz-nickel diorite porphyry. The variable Whitehill conglomerate and the overlying flow of dike that generally accompanies it are both present, and the erosion of the dike was followed by the deposition of the Gills conglomerate, probably not later than Triassic time. A considerable time has presumably represented by the unconsolidated terne deposits, which appear to be better developed in the Bay district than elsewhere in the region.

Structurally the Bay district is divisible into two parts, separated by a line nearly coincident with Mineral Creek. The general differences in the structure as reflected in the distribution and relations of the rock formations on the two sides of the creek is evident from a glance at the geologic map. On the east side the structure is characterized by the Dipping Spring Range as a whole—a fault mass. The Paleozoic and older rocks have been intruded by diabase and cut by faulted into polygonal blocks, for the most part less than one-fourth of a square mile in area. This displacement of those faults is in general normal. On the west side the creek is a large area of Planar schist, bounded irregularly by various intrusive rocks and covered extensively by termite deposits. This schist is not wholly unaffected by faulting and is doubtless traversed by some faults that, owing to the fact that the same schist occurs on both sides of the fracture, have escaped recognition. On the whole, however, underground work and the mapping of the intrusive masses and the body of schistic schist south of Copper Canyon have brought out little evidence of displacement, and it may safely be concluded that the country west of the creek has been less dissected by faults than the country east of it.

The faults east of Mineral Creek are not of all the same age. Much of the development in the district has undoubtedly occurred when the dike was intruded, but little or none of that displacement is now recognizable as faulting, for most of the present outer limits of the district are occupied by dishes mangan, and the blocks of strata were forced apart by the molten material. Most of the faulting appears to have followed the erosion of the district, and it was later than the deposition of the Gills conglomerate.

Although Mineral Creek in a rough way marks the division between a much faulted region on the east and a less faulted region on the west, and although there is undoubtedly faulting along the general course of the creek, yet there is no profound fault coincident with this line of division. The boundary between the two structural divisions of the district is marked by the topographic differences in general by intersecting faults of moderate displacement and of the same general character as those abundant in the Dipping Spring Range.

The present surface in the Bay district, while it undoubtedly shows topographic expression to Quaternary erosion, has not so an area is very greatly reduced below a surface that existed in Tertiary time. A view over the central part of the district, for example, of Tongue Mountain, such as that shown in Plate VIII, indicates clearly that the Whitfield formation exposed on the steep slopes of the mountain once covered the copper-bearing area. The Whitehill in turn was covered by the dike, which was only after the removal of these rocks that erosion of the schist could again proceed. What the dike had been uncovered for a time by wind erosion of the Gills conglomerate and how far that conglomerate extended over the present schist area can not be determined. The terne deposits, more conspicuously developed in the Bay district than elsewhere in the region, suggest that the area was suddenly lowered when the streams were locally overloaded. Whether this was due to an increase in the quantity of sediments to be eroded, a change in climate, or a combination of such elements is not known. Recent erosion has dissected the termite deposits and echoed out the rough ravines through which storm waters now escape to Mineral Creek.

Although it happens that most of the mining by the Bay Consolidated Copper Co. has been done under two hills, Hay Hill and Humboldt Hill, there apparently is no constant or significant relation between the topographic details of the present surface and the occurrence of ore. The ore is thick under Humboldt Hill, but it is both thick and of comparatively high grade under the lower part of Copper Gulch. In certain details of erosional sculpturing the fact that the rocks contained disseminated pyrite, with its tracts of chemical consequence, appears to have left its mark. It has not, however, proved possible to determine from the work of erosion at any one place the result of the physical and chemical processes of enrichment directly known.

Owing apparently to variation in hardness or inclination from place to place, the Gills conglomerate in some localities has been shaped into eroded forms having little in common with the even-crusted branching spurs that flank the Flat Range. Such exceptional products of erosion are the curious rounded towers that are conspicuous features along Mineral Creek a few miles below Bay. These are residual of assistant portions of the conglomerate left behind in the general reces- sion of the conglomerate bluffs along the creek.

Shape and structural relations of the ore bodies.

The body of disseminated ore in the Bay district may be characterized in general terms as an undulating, flat-lying mass of the momentary outline and of variable thickness. (See Figs. 10, 11.) As a rule the mass lacks definite boundaries. No readily recognizable distinction in color, texture, or general appearance marks its off sharply from the underlying rock, and closely spaced sampling and assays prove that the passage from ore to country rock is in most places gradual. Consequently, to a greater degree than in most ore deposits of other types, the size and shape of the Bay bodies depend upon the local and current definition of ore.

Like most condensed general characterizations, the preceding paragraph requires considerable qualification to make it an accurate statement; for in a preliminary surveying view many details essential to the completeness of the picture are necessarily overlooked. The momentary outline, for example, that the passage from ore to country rock is gradual, though true in a broad way, is subject to many exceptions. As a rule the ore has been mined in a manner that permits the ore to be mined and far more distinct than the transition from ore to the comparatively barren strata below.
some calculations of tonnage being based on 1.5 per cent of the lower limit of 0.75 per cent. In the case of copper when these exceed the ordinary fluctuations and maintain their departure from the normal over any considerable time.

The choice of the word "capping" to designate the leached, practically barren overburden is simply an adoption of local usage. The term "capping" is a familiar one to miners or geologists to designate any objective thing as making the coating of a new word necessary or desirable.

RELATION OF THE ORE BODY TO THE SURFACE.

The depth to ore, or the thickness of the overburden, differ widely from place to place; the average thickness of the overburden on the ground of the Ray Consolidated Copper Co. lies between 200 and 300 feet. The thickest portions, as seen in Figs. 10 and 11, may be 350 feet, and there are in some places only about 25 feet. The thinnest portions, as shown in the average thickness of ore in places where the ground is not elevated may be as little as 5 feet, although in some places they are as much as 150 feet or more. In the ore bodies of the Ray Consolidated Copper Co. there are often narrow zones, sometimes only a few feet wide, where the ore is over 150 feet thick.

LAYER OF OXYDATION.

In the Ray district it is exceedingly difficult and perhaps impossible to get from the available data any definite conception of the ground-water surface when mining began; but apparently it appears to have advanced less than coincides with the bottom of the oxidized zone. It has also been shown that the general trend of oxidized material above the ore is from 400 to 500 feet to the east of the ore body. The average thickness of oxidized material in the eastern end of the ore body is 250 feet. The general trend of the oxidized zone is a fairly definite but uneven and undulated surface. If at any time in the history of the deposits this surface was coincident with a ground-water surface which stopped its gradual relation, then the coincidence is no longer evident. Oxidation appears to have been limited both by the gradual exhaustion of oxygen from air and the gradual destruction of the oxidized material by the effects of the rocks. In being the case, oxidation would extend deeper along certain favorable channels than along the mass of the rock, and in such cases of greater penetration would rarely be vertical, there is little difficulty in accounting for this way for the occasional occurrence of oxidized material directly beneath the oxidized material.

RELATION OF ORM BODY TO SOIL COVER.

The rocks intimately associated with the disseminated ores in the Ray district are the Permian shale, the Granite Mountains, and the quartz monzonite porphyry of the district, and diabase. The last-named is the only material which is used for the disseminated ore bodies, a small part is metalized quartz monzonite porphyry, and a very much smaller part appears from drill holes to be in the interior of the ore body.

THE PROCESS OF NATURAL ENRICHMENT.

The process of natural enrichment, whereby the ores were changed to ore by generalized solutions, is described in another publication. 10

FIGURES, TABLES, AND CAPTIONS.

DEFINITION.

That the ore bodies of the Ray district were formed by a process of enrichment acting upon material that originally contained but very little copper is generally recognized. This is the principal ore body in the district, and it is not at all in the true sense of that word, nor is most likely to become ore by any improvements in mining and milling which can at present be foreseen. To designate this primitive ore body accurately and consistently, without using "ore" in an indeterminate loose sense, apparently requires a new term, and the word "ores" (first or primary ores) has been suggested 11 as likely to be a serviceable substitute for the unnecessary and periphrastic expressions that have hitherto been current.

In practice it will be sufficiently accurate under present economic conditions to refer to rock carrying less than 1.5 percent of copper as ore, while that containing 1.5 percent or more of copper will be called ore. Such usage will clas with the primitive ore bodies as containing enriched material, but this will be a small quantity compared to the total volume of the ore body.

The limit here set is in accordance with the fact that some material of lower grade goes to the mills, for in mining by a saving system ore is to an extent mixed with waste. The limit, moreover, is not the same in all mines.

RAY CONSOLIDATED COPPER CO. THIRD ANNU. REP., for the year ending Dec. 31, 1891, p. 10.


FIGURE II-Typical pyrite kernels in chalcosite. Schist ore, 200 level of the No. 3 mine, Ray district.
OXIDIZED AND LEACHED ROCK.

The complete oxidation of the protore and ore two general kinds of material result. One is a rock brilliantly colored with malachite and chrysocolla containing metallic copper 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 copper-stained rock, traversed generally by many little veins of chrysocolla, is more abundant in the Miami district than in the Bay district.

The other class of material consists of the leached rock or cuprite. This is in large part a typical development in strong contrast with the copper-beehive rock just described, although the mate- rials of the two kinds grade into each other. Their prevalent characteristics are a much leaching of iron and a total absence of copper. It contains enough iron oxide to give a reddish color to charn-cull sludge, whereas the unoxidized chalcocite and one give a gray sludge and the material containing much chrysocolla and malachite a greenish-gray sludge. If it were possible to recognize with certainty a particular variety of cuprock as indicative of one beneath it, much expensive drilling might be dispensed with, but at present no great reliance can be placed upon visible surface criteria. It may be said, however, that a deep and continuous reddish tint of the surface is a less probable than a reddish tint of russet color. The excessive reddishness generally indicates that the chalcopyrite zone is thin and that the ore porphyry will be reached comparatively near the surface. On the other hand, abundant chrysocolla near the surface suggests that erosion may have overtaken the chalcopyrite zone in its downward progression and has left some of the ore body. As a rule, the cup rock above an ore body contains abundant small quartz stringers which show, by minute analyses, the former presence of iron oxide.

The copper tenor of typical leached cupping is extremely low, and such material rarely shows any visible trace of the presence of copper-bearing minerals. Assays of cupping usually range from a mere trace to about 0.2 per cent of copper, higher results generally being indicative of the presence of a little visible silicate or carbonate of copper—rarely, however, of material intermediate between typical leached cupping and oxidized but untested ore.

ORIGIN OF THE COPPER DEPOSITS.

DEPOSITION OF MINERALIZED SOLUTIONS.

The principal development has been on the Rattler claim, 1 mile in a direction a little south of east of Troy, and on the '91, Beckey, and Alice claims, one-half, three-fourths, and 1 1/2 miles southwest, respectively, of the now practically abandoned settlement. When the work was in progress there were in 1891 and 1892 the underground workings were only in small part accessible.

The workings of the Bartle mine comprise the main shaft, while the lead in the area of 200 feet long, connected with three levels, the first of which is an adit. The levels run nearly east-northeast and west-southwest and open a series of veins of about 200 feet long, spaced about 75 feet apart. The main shaft, east of the Sincock, extends only about 50 feet below the level adit. There is no vein, the ore occurring as lenses and lodes that follow closely the bedding of the ore. The main mine has been operated with the working, but it is not far away and has affected considerable contact metamorphism in the district, which veins with secondary chlorite. The ore zone dips 20° S. 15° W. and from a point in the main tunnel about 100 feet in has been followed in an inclined tunnel for about 50 feet to a point where it appears to be cut off by an otherwise useful fault. There is apparently no large quantity of ore available. The Sincock shaft appears to be entirely in dis- ease below the first level.

The ore of the Bartle mine is chiefly a dark fine-grained aggregate of malachite and chalcopyrite with varying quantities of alluvial minerals derived by metamorphism from the enclosing limestone. With increasing proportions of those alluvial the ore grades into the metamorphosed limestones. Analyses show the ore to be almost pure copper. Copper and its alloys have been mined in the Troy-Arizona Copper Co. and its predecessors from 3 to 3.7 per cent of copper, a maximum of 0.04 ounce of gold and 0.02 ounce of silver per ton. The copper is about the same proportion of iron, about 1 per cent of calcium oxide, and 20 per cent of magnesium oxide.

A cuprock body was seen of the '91 mine, as the shaft had caved in. It appears about 150 feet deep, and the shaft stopped to a depth of 175 feet and an inclined tunnel for about 250 feet to a point where it appears to be cut off by a perhaps obscure fault. There is apparently no large quantity of ore available. The Sincock shaft appears to be entirely in dis- ease below the first level.

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based was in progress. The mine maps show that connection was made with the Pratt tunnel by an inclined raise of about 200 feet vertical height.

Since the last visit the Troy Arizona Copper Co. has done additional prospecting and is reported to have sunk a 500-foot shaft on the Climax claim, about three-quarters of a mile southeast of Troy, and in 1917 some ore was being shipped.

On the Renfrew group of 47 claims, about 14 miles southeast of Troy, considerable ore was visible in 1912 in the lower half of Martin limestone at a point near the crest of a steep spur where the limestone beds, which dip at a low angle to the east, are stepped around the top of a small fault below the slope of which is apparently nowhere over 40 to 50 feet. The ore, mostly chalcocite and carbonates, occurs as irregular lenses 6 to 8 feet in length, which lie parallel with the bedding of the limestone and occur as small replacement masses near the surface. From the ravine to the base of the exposures of ore on the ridge, and about 400 feet below them, a tunnel 900 feet in length had been driven in 1912 entirely in diabase, which underlies the Troy quartzite and Martin limestones of the rest of the ridge. The tunnel follows a nearly vertical fissure and runs southeast. No ore had been found in this tunnel in 1912. Since that year the ground has been worked by the Pinal Development Co., which began production in 1917. The ore shipped is oxidized and presumably comes from the replacement deposits in limestones previously mentioned. The main tunnel is stated 1 to be 1,690 feet long and to connect with about 2,500 feet of underground workings with a maximum depth of 900 feet.

**OTHER COPPER DEPOSITS.**

**London-Arizona mine.**—The London-Arizona mine is in the southeastern part of the quadrangle, about 4 miles north of Hayden, on the north side of Tornado Peak.

Theコース is located in the country, in which the mine is located, is diabase, apparently in a series of several hundred feet thick, which was intruded at approximately the bottom of the Mission limestones. Overlying the diabase is a succession of the Troy quartzite, the Martin limestone, and the Tornado limestone. All these rocks are cut by dikes and small intrusive masses of quartz diorite porphyry. The dike and stock intrusive of the mine buildings is compositionally metamorphosed by the porphyry and in place is a sparkly dark biotite schist, generally containing from 5 to 20 feet of additional pyritiferous quartz diorite porphyry. On the south side of the ravine the lower part of the Detwiler Martin limestone, as at other places in the quadrangle, shows alternation of diabase, in which the mine is located, by pyrite-bearing, brecciated, and other diorite porphyry, and since the time of visit considerable oxidized copper ore has been shipped to the Hayden smelter from the dike in diabase. The main body of ore, which consists of chalcopyrite generally rather finely disseminated through altered limestone and associated with yellow-brown garnet, magnetite, and sphalerite, occurs as a group of inclined tabular or lens-shaped replacement masses in certain beds of the limestone near quartz diorite porphyry dikes. Their occurrence is illustrated by the north and south section through the No. 1 shaft of the Climax mine, based on the work of C. H. Sherman, who in 1910 worked for the Gila Copper Syndicate Co., the owner of the deposit. The mine is apparently not in the company's hands, but the ore consists of chalcopyrite generally rather finely disseminated through altered limestone and associated with yellow-brown garnet, magnetite, and sphalerite, occurs as a group of inclined tabular or lens-shaped replacement masses in certain beds of the limestone near quartz diorite porphyry dikes.

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**Miller & Nissen mine.**—The Miller & Nissen group of claims is at Cove Spring, on the road from Kelvin to Troy. At this point is a rather wide and west-dipping quartz diorite porphyry cut by diabase and Dripping Spring quartzite. At the mine the dike is about 15 feet wide, with diabase on the south side and diabase and quartzite on the north side. The ore, which is all oxidized, occurs along the north side of the dike and consists of free gold in a rusty matrix of vein quartz and crushed quartz. Little vein on the periphery of quartz diorite. Some of the gold is associated with pyrite and galena; some is free gold, and some is free on the surface. The ore occurs as thin lenses along bedding planes, apparently in Martin limestone, and near quartz diorite dikes.14 Shipments to the middle of 1914 are given as 265 tons of ore, valued at $18,004.

Although many gold the ore also carries silver, copper, and lead.

**Cow Boy mine.**—The Cow Boy mine is nearly 14 miles southeast-south of Dripping Spring Ranch, in the Dripping Spring Range, on a nearly eastward-dipping porphyry dike, which has a maximum width of 50 feet and which cuts diabase and Mission limestone. The mine is tile at the time of visit and was not examined in detail. The workings consist of two shafts, apparently about 20 and 75 feet deep, with a 130-foot tunnel and unattractive shallow pits and burrows. The vein material is narrow quartz stringers with patches of mica and muscovite and showing a little carbonate of copper. The quartz is banded and apparently occurs partly in the Mission limestone and partly in the porphyry dike, with the value of $2,000 being reported to have been taken from small bunches of ore near the surface. Since the time of visit the mine has been operated in a small way and has yielded a maximum of about $3,000 in gold annually. According to Mr. C. W. Magee, the owner and operator, much of the gold is in coarse wire form and occurs erraticly in pockets, particularly where the vein is in limestone. A sample of concentrate sent by Mr. Magee to the Colorado School of Mines shows the presence of a lead vasuret and probably probably practicable. The total output of the Cow Boy mine to the end of 1914 is estimated at about $25,000 in gold, with a little silver being present in the ore examined.

**Ripsey mine.**—The Ripsey mine is in the southwestern corner of the quadrangle and at the time of the writer's visit in 1911 had evidently been long idle. The Ripsey vein strikes N. 70° E. and dips 45°-50° S. The granite in the vicinity of the shaft—inclined on the vein—is cut by many intrusive masses of diabase, some of which appear to be quite barren and lead. Although this mine might be successfully concentrated if a large quantity of it were available, it is apparently too low in grade to work on a small scale. The present operation of the mine was based on the former presence of material near the surface which had a larger content of gold and silver than is apparently present in the ore examined.

**LEAD-SILVER DEPOSITS.**

In the vicinity of Haley's cabin, about 3 miles east of Bay and 2,225 feet higher than that town, occur deposits of lead ore from which small shipments had been made from time to time prior to 1912, the ore being brought down to Bay on burros. The country rock of this ore, so far as could be seen from openings accessible in 1912, is the Devonian Martin limestone.

The principal work at this time had been done on the Cluthanool mine, a short distance northwest of the cabin. Here the sheet of diorite porphyry in Devonian limestone is cut by fissures that strike nearly east and west. The ore, chiefly chalcopyrite, is quite abundant and has been mined at the ECF mine, and also at the North Star mine. The ore mined at the ECF mine is reported to have been oxidized and to have been shipped to the Hayden smelter.

**Bibliography.**—The London-Arizona mine is described from the information submitted by the American Smelting & Refining Co., the ore going to that company's Hayden smelter. The ore is mined prior to 1911 generally contains from 5 to 20 feet of quartz diorite porphyry, with an average of 40 per cent of silver, 5 to 20 per cent of lead, and a maximum of 30 per cent of sulphur. Much of the ore mined was oxidized and contained 5 to 20 per cent of sulphur, 5 to 10 per cent of silver, 5 to 10 per cent of lead, and a maximum of 30 per cent of sulphur. Much of the ore mined was oxidized and contained 5 to 20 per cent of sulphur, 5 to 10 per cent of silver, 5 to 10 per cent of lead, and a maximum of 30 per cent of sulphur.

An average of the analyses of eight samples of ore from the Las Norias mine, taken above the 2,000-foot level, is as follows:

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<tr>
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claim. It is reported, however, that production began in 1917 and that in the middle of 1918 shipments were averaging about 750 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 Bisbee, N. Mex. This number 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 oxide, 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 branchy 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 Deseran limestone. A shaft, 150 feet deep in March, 1912, had been sunk on this fissure and showed ganges, abundant oxide of iron, and a little cerussite. The zone of soft oxidized material is in place 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.

**Miscellaneous Mineral Resources.**

**Vanadium.**—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 Kellogg and about 2 miles nearly due south of Troy. The principal development in 1912 was on the south side of a narrow steep-walled ravine inishere. Here a small mass of Mesial limestone, shown on the geologic map, is included in the dike 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, 3PbVO₄·P₂O₇) and cervantite (basic vanadate of lead, iron, etc., [Pb, Zn(OH)₂VO₄]) associated with galena, cerusite, wulfenite, and quartz. The vanadines are younger than the galena, as in places they occur as veinslet in that mineral. They are odor, however, than some of the quartz.

About 100 feet south of the main workings a small open cut on a fissure in dike exposed a little vanadinito in 1912. On the north side of the ravine and northeast of the main workings a strong fissure between dike and Mesial 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 vanadinite concentrate from this locality.

**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 Tertiary limestone.

**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.

A harder stone that can be dressed into rough-surfaced blocks may be obtained from certain beds of the dolomitic Mesial limestone. This material has not been utilized, so far as known, within the Ray quadrangle, although it was employed in the masonry of the Roosevelt dam.

A tough, dark, hard stone in small blocks might be quarried in many places from the areas of dike, and the granodiorite of the Troy basin would perhaps yield building stone of good quality, although probably not in large blocks.

**Concrete materials and road material.**—Crushed stones suitable for concrete or for macadam would be obtained near at hand in almost any part of the quadrangle. The hardest and toughest rock could probably be had from the dike, although the quartzite, limestones, granite rocks, and intrusive porphyry 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.

**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 part 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 Mesial Range.

September, 1923.
PLATE I.—VIEW LOOKING NORTH-EASTWARD ACROSS DRIPPING SPRING VALLEY TO THE MESCAL RANGE.

PLATE II.—BAINS CONGLOMERATE ON EL CAPITAN CREEK, MESCAL RANGE.

PLATE III.—VIEW LOOKING NORTH-WESTWARD TOWARD PIONEER CREEK, MESCAL RANGE, SHOWING DIP SLOPE ON DRIPPING SPRING QUARTZITE TO RIGHT.

PLATE IV.—TYPICAL HILLSIDE EXPOSURE OF THE CHESTY MESCAL LIMESTONE IN THE DRIPPING SPRING RANGE, 2 MILES SOUTH OF DRIPPING SPRING RANCH.

PLATE V.—CROSS-BEDDED PEBBLY TROY QUARTZITE, DRIPPING SPRING RANGE.

PLATE VI.—TYPICAL HILLSIDE EXPOSURE OF THE DEVONIAN ON EL CAPITAN CREEK, MESCAL RANGE. The Devonian limestone forms the smooth slope between the rock at the center of the middle distance and the drift of Tonto sandstone above.

PLATE VII.—TYPICAL EXPOSURE OF THE GILA CONGLOMERATE, SHOWING CHARACTERISTIC EROSION. Almost 3 miles southeast of Drifting Spring Ranch.

PLATE VIII.—GENERAL VIEW OF THE RAY DISTRICT LOOKING NORTH-WESTWARD FROM THE EAST SIDE OF MINERAL CREEK.

On the left, across the creek, is the No. 1 mine of the Ray Consolidated Copper Co. To the right are the head frame, crusher house, and one bin of the No. 3 mine, and still farther to the right, nearly in line with the head frame, are the corresponding structures of the No. 5 mine. The prominent peak near the middle of the view is Tepidita Mountain. The lighter-colored, indurately stratified rock under the dark cliff capping the mountain is the Whetstone conglomerate.
Geologic time.—The larger divisions of geologic time are called eras. Smaller divisions are called periods. A smaller unit, or a group of smaller units, is called a epoch. The time divisions of geologic time are grouped together into cycles. The aggregate of formations that form a cycle is called a series. A great aggregate of formations that is divided into a series is called a system.

As sedimentary deposits accumulate, successively, the younger rest on the older, and their relative ages may be determined by observing their stratigraphic relations in sections of strata. However, the beds have been overturned by folding or their relative positions to adjacent beds have been changed by faulting, so that it may be difficult to determine their relative ages from their present positions at the surface.

Many strata consist of layers of plants and animals, or the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them or were buried in the bottom mud. Such strata are said to be fossiliferous. A study of these fossils has shown that the forms of life at each period of the earth's history were a great extent different from the forms at other periods. Only the simplest kinds of marine plants and animals lived when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period these lived forms that did not exist in earlier times and have not existed since then are characteristic of the time from the oldest fossiliferous rocks to the present. If two sedimentary formations are geographically so far apart that it is impossible to determine the relative position of the characteristic fossils found in them may determine which was deposited first. Fossils are also of value in determining the age of formations. Characteristic fossils found in strata at different areas, provinces, and continents afford the most effective means of combining fossil data.

It is in many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can be determined by observing whether an associated sedimentary formation of known age is cut by the igneous mass or lies upon it. Similarly, the time at which metamorphic rocks have been derived from the original mass may be determined by the relations to adjacent formations of known age; but the age recorded in the map is that of the original masses and not that of the land.

Symbols, colors, and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern and is labeled by a special letter symbol. Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and volcanic formations. Patterns of triangles and rhombus are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combinations of patterns are used for metamorphic formations that are known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. The color in which the pattern of parallel lines is used is an arbitrary choice, a particular color being assigned to each system. Each symbol consists of two or more letters. The symbol for a formation is shown in figure 1 as an illustration. To this class belong beeches, alluvial plains, low streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion. The sea cliff is on illustration; it may be eroded from any rock. To this class belong abandoned stream channels, alluvial plains, and peatlands. In the making of a stream terrace an alluvial plain is built up and afterward partly eroded away. The shaping of a plateau is done by the wearing away of the intermediate valleys by erosion and valleys filled up (aggraded). All parts of the land surface are exposed to the action of air, water, and ice, which slowly wears them down, producing material that is carried by streams toward the sea. As this wearing down depends on the flow of water to the sea it cannot be carried out, and this is why the map is called the base-level of erosion. Lakes or large rivers may determine base-levels for certain regions. A large tract that is long unmodified by uplift or subsidence is worn down nearly to base-level, and the clearly even surface thus produced is called a peneplain. If the tract is afterward uplifted it becomes a record of its former close relation to base-level.

The GEOLOGIC MAPS AND SHEETS IN THE FOLIO. AREAL-geology maps.—The map showing the surface area occupied by the several formations is called an areal-geology map. On the margin is an explanation, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the explanation, where he will find the name and description of the formation. If he desires to find any particular formation he should examine the explanation and find the uncolored and then trace out the areas on the map corresponding in color and pattern. The explanation shows also parts of the geologic history. The names and colors of the several formations are grouped, primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and these within each group are placed in the order of the youngest at the top. ECONOMIC-geology maps.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed an economic-geology map. Most of the formations indicated on the areal-geology map are shown on the economic-geology map by patterns in faceted colors, but the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of mine or quarry and is surrounded by the name of the producing minerals and method of mining or quarried. If there are important mining industries or mineral bases in the area the folio includes special maps showing these.

Structure-section sheet.—The relations of different beds to one another may be seen in clays, cements, shales, and other natural minerals by examining sections drawn on paper representing the probable structure to a considerable depth. Such a section is illustrated in figure 2.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, made up of sandstone, which forms the cliffs, and shale, which forms the slopes. The broad plateau of lower land is traversed by several ridges, which are shown in the section, correspond to the outcrops of a folded bed of sandstone that rises to the surface. The upturned edges of the folds of bed or form of the intermediate valleys follow the outcrops of limestone and calcareous shale. Where the edges of the beds appear at the surface their thicknesses are shown, and the points at which they dip below the surface can be observed, and in other positions their positions under the surface are inferred. The direction of the intersection of the surface of a dipping bed with a horizontal plane is called its strike. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called its dip. In many regions the beds are bent into troughs and arches, such as are seen in figure 3. These are called anticlines and the troughs synclines. As the materials that formed the sandstone, shales, and limestone were deposited beneath the sea in nearly flat layers the facies are not bent and folded should form from time to time cause the earth's crust to wrinkle along certain zones. In places the beds are broken across and the parts have slipped past each other. Such breaks are termed faults. Two kinds of faults are shown in figure 4.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted, and the form or arrangement of their massive underwater can not be inferred. Hence the positions shown above only what is probable, not what is known by observation. The section also shows three beds of formations, distinguished by their underwater relations. The bed on the left, is made up of beds of sandstone and shales, which lie in a horizontal position. These beds were laid down under water and are now high above the sea, forming a plateau, and their change of altitude shows that part of the earth's surface has been uplifted. The bed of this set is conformable—that is, they are in perfect agreement, and the surface of contact shows no break in sedimentation.

The lower set of formations consists of beds that are folded into arches and troughs. The beds were once continuous, but the crests of the arches have been removed by erosion. Thus, one, like some of the upper set, are conformable.

The horizontal beds of the plateau rest upon the upturned, creased edges of the beds of the middle set, as shown at the left of the section. The beds of the upper set are evidently younger than those of the middle set, which must have been folded and eroded between the time of their deposition and that of the deposition of the upper beds. The upper beds are nonconformable to the middle beds, and the surface of contact on the unconfornability.

The lowest layer of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plucked by pressure and intruded by masses of granite. The overlying beds of the middle set have not been intruded by these intrusive rocks nor have they been affected by the pressure of the intrusion. It is evident that considerable time elapsed between the formation of the schists and the beginning of the deposition of the beds of the middle set, and during this time the schists were metamorphosed, disturbed by the intrusion of igneous masses, and deeply eroded. The contact between the middle and lowest sets is another unconformity; it marks a period of erosion between two periods of deposition.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps in much the same way that the section in the figure is related to the landscape. The profile of the surface in each structure section corresponds to the actual slope of the ground in the section line, and the depth to any mines or producing or water-bearing beds shown may be measured by using the scale given on the map. COLONIAL-geology maps.—Many folios include a colonial section, which contains brief descriptions of the sedimentary formations in the quadrangle. It shows the character of the rocks as well as the thickness of the formations and the order of their accumulation, the oldest at the bottom, the youngest at the top. It also indicates intervals of time that correspond to events of uplift and depression and constitute important dates of deposition.

The text of the folio states briefly the relation of the area mapped to the general region in which it is situated; points out the salient natural features of the geography of the area and indicates the significance of its history; considers the cities, towns, roads, railroads, and other human features; describes the geology and the geologic history; and shows the chasm and the location of the visible minerals deposited.

George O. Smith,
Director.

January, 1922.
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