DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

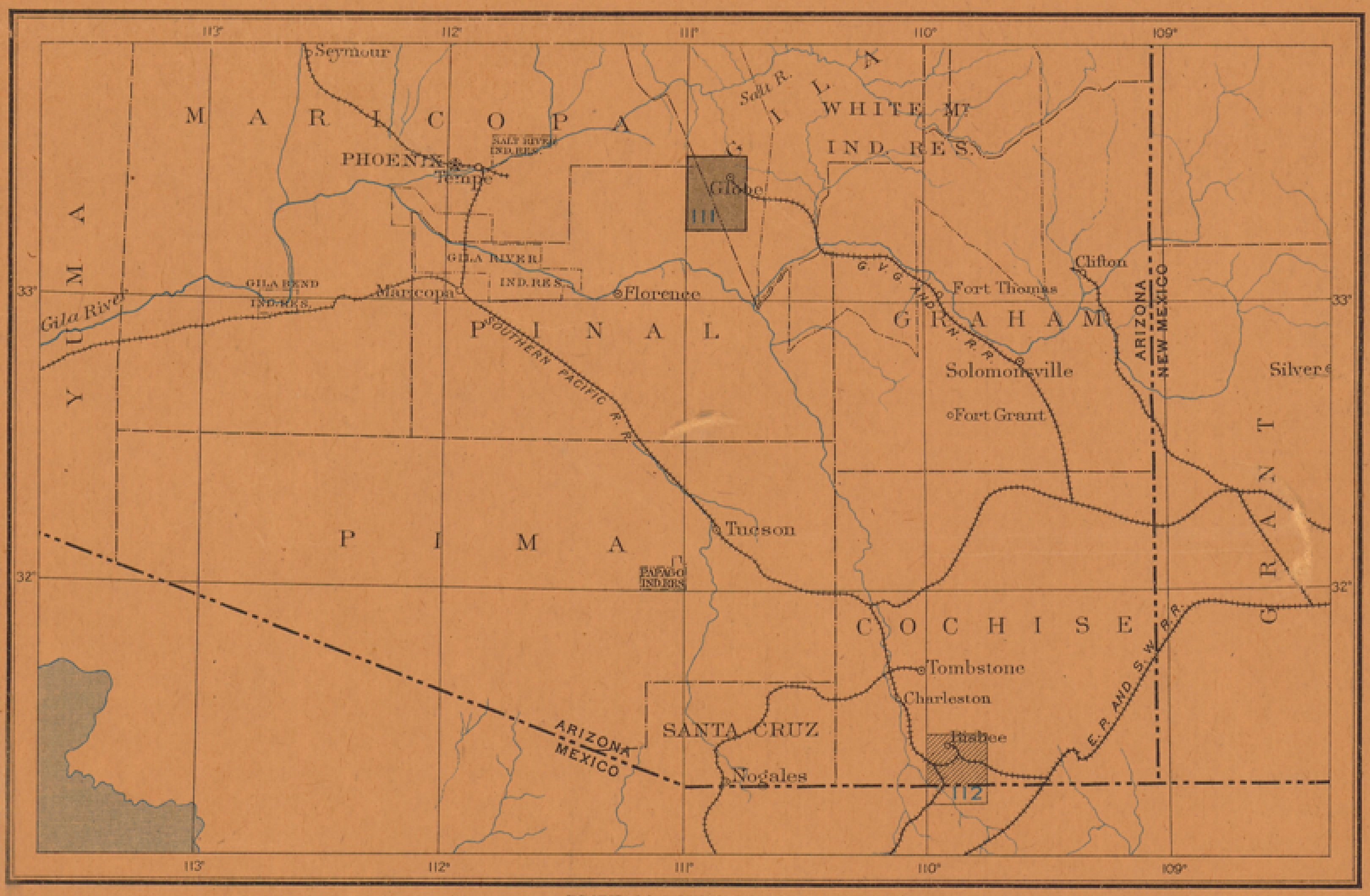
111

GEOLOGIC ATLAS OF THE UNITED STATES

GLOBE FOLIO

ARIZONA

INDEX MAP



SCALE: 40 MILES = 1 INCH

GLOBE FOLIO

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CONTENTS

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GLOBE FOLIO
NO. 111

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GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER
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EOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

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

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the altitudinal interval represented by the space between lines being the same throughout each map. These lines are called *contours*, and the uniform altitudinal space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

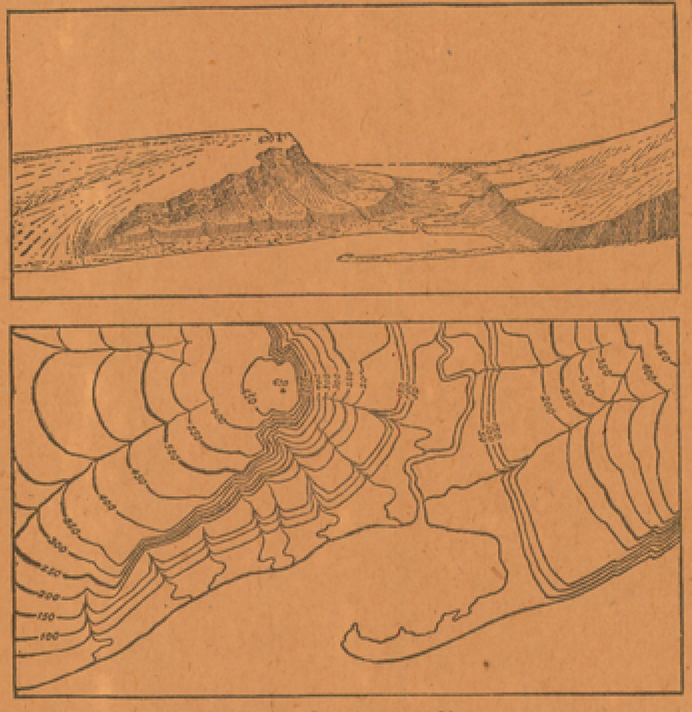


FIG. 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply, forming a precipice. Contrasted with this precipice is the gentle slope from its top toward the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. These relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The altitudinal space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is serviceable for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If a stream flows the entire year the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, are printed in black.

Scales.—The area of the United States (excluding Alaska and island possessions) is about 3,025,000 square miles. A map representing this area, drawn to the scale of 1 mile to the inch, would cover 3,025,000 square inches of paper, and to accommodate the map the paper would need to measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the *scale* of the map. In this case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to an inch" is expressed by $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale $\frac{1}{125,000}$, about 4 square miles; and on the scale $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles in English inches, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree—i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-fourth of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles.

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic map.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land, and the structure sections show their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

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

Igneous rocks.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers produced by the force propelling the magmas upward. Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

Sedimentary rocks.—These rocks are composed of the materials of older rocks which have been broken up and the fragments of which have been carried to a different place and deposited.

The chief agent of transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. In smaller portion the materials are carried in solution, and the deposits are then called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind; and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in layers are said to be stratified.

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

Rocks exposed at the surface of the land are acted upon by air, water, ice, animals, and plants. They are gradually broken into fragments, and the more soluble parts are leached out, leaving the less soluble as a *residual* layer. Water washes residual material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of standing water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it is called *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called *metamorphic*. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be lost, or new substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock mass. Such changes transform sandstone into quartzite, limestone into marble, and modify other rocks in various ways.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, a rapid alternation of shale and limestone. When the passage from one kind of rocks to another is gradual it is sometimes necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation is constituted of one or more bodies either containing the same kind of igneous rock or having the same mode of occurrence. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which the rocks were made is divided into several *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by naming the time interval in which it was formed, when known.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

(Continued on third page of cover.)

DESCRIPTION OF THE GLOBE QUADRANGLE.

By Frederick Leslie Ransome.

INTRODUCTION.

PHYSIOGRAPHIC DIVISIONS OF ARIZONA.

The Territory of Arizona may be divided into three physiographic regions (see fig. 1). The first of these, occupying the northeastern portion of the Territory, is included within the Colorado Plateaus, that wonderful province which the writings of Powell, Gilbert, and Dutton have made classic ground in geology. This division, which within the boundaries of Arizona has an area of about 45,000 square miles, drains northward, through the Colorado Chiquito (Little Colorado), Rio Puerco, and smaller streams, into the Grand Canyon of the Colorado. Its southeastern limit traverses the Territory in a general southeasterly direction from the Grand Wash, near the eastern border of Nevada, to the New Mexico line, a few miles northeast of Clifton. This limit is not everywhere clearly defined. For about 240 miles extending from the mouth of Diamond Creek on Colorado River to the vicinity of Fort Apache the edge of the plateau is marked, according to Gilbert in the Wheeler Survey reports, by the continuous line of the Aubrey Cliffs, which divide the waters of

FIG. 1.—Map showing physiographic regions of Arizona.

the Colorado Chiquito from those of the Gila. These cliffs are well shown at the southwestern edge of the Mogollon Mesa, where they form an abrupt scarp from 1000 to 2000 feet in height, overlooking the Tonto basin and facing the Mazatzal and Ancha ranges. From Fort Apache eastward to the New Mexico line the plateau boundary is less distinct. Vast accumulations of volcanic rock have obscured the plateau surface, and erosion has partly destroyed its continuity. The San Francisco, Mogollon, Blanca (White), and Escudillo mountains are described by Gilbert as volcanic masses resting upon the general plateau surface. Describing this surface Dutton, in his Tertiary History of the Grand Cañon District, says:

> Its strata are very nearly horizontal, and with the exception of Cataract Cañon and some of its tributaries it is not deeply scored. Low mesas gently rolling and usually clad with an ample growth of pine, piñon and cedar; broad and shallow valleys yellow with sand or gray with sage, repeat themselves over the entire area. The altitude is greater than the plateaus north of the chasm except the Kaibab, being on an average not far from 7000 to 7500 feet. From such commanding points as give an overlook of this region one lonely butte is always visible and even conspicuous, by reason of its isolation. It stands about 20 miles south of the Kaibab division of the Grand Cañon and is named the Red Butte. It consists of Permian strata lying like a cameo upon the general platform of the Carboniferous beds. The nearest remnant of similar beds is many miles away. The butte owes its preservation to a mantle of basalt which came to the surface near the center of its summit. It is an important factor in the evidence upon which rest the deductions concerning the great erosion of this country.
>
> Fifty or sixty miles south of the river rise the San Francisco Mountains. They are all volcanoes, and four of them are of large dimensions. The largest, San Francisco Mountain, nearly 13,000 feet high, might be classed among the largest volcanic piles of the West. Around these four masses are scattered many cones, and the lavas which emanated from them have sheeted over a large area. The foundation upon which they are planted is still the same platform of level Carboniferous strata which stretches calmly and evenly from the base of the Vermilion Cliffs for more than 150 miles southward, patched over here and there with the lingering remnants of lower Permian strata and isolated sheets of basalt. South of the San Francisco Mountains the level Carboniferous platform extends for 20 or 30 miles, and at last ends abruptly in the Aubrey Cliffs, which face southward and southwestward, overlooking the sierra country of central Arizona.

It is the rolling, partly timbered surface of this great plateau, surmounted by isolated volcanic mountains, which surrounds the traveler as he journeys across the Territory from New Mexico, by way of Holbrook and Flagstaff, to Ash Fork on the Atchison, Topeka and Santa Fe Railroad.

The second physiographic division, which may be called the Mountain Region, adjoins the Plateau Region on the southwest, and is essentially a broad zone of short, nearly parallel ranges extending diagonally across the Territory from the southeast corner northwesterly to Colorado River. The width of this zone may be taken as from 70 to 150 miles, but, as will be later seen, its southwestern boundary is not capable of precise demarcation. It is characterized by numerous nearly parallel, short ranges, separated by valleys deeply filled with fluviatile and lacustrine deposits. The individual ranges, such as the Dragoon, Chiricahua, Pinalino, Caliuro, Santa Catalina, Tortilla, Pinal, Superstition, Ancha, and Mazatzal mountains, rarely exceed 50 miles in length or 8000 feet in altitude. Their general trend is nearly northwest and southeast, but near the Mexican border it becomes more nearly north and south, and the mountain zone as a whole coalesces with a belt of north-south ranges which extends northward through New Mexico and borders the Plateau Region on the east. The northwesterly belt of Arizona is described by Gilbert as continuous with the Basin Range system of Nevada and Utah, and is considered by him as exhibiting the same prevailing type of orographic structure. He states that his examinations "have demonstrated no anticlinal structures, except as minor features. The usual structure is monoclinal, demonstrably due to faulting in the Chiricahua and Pinal ranges, and presumably so in all the others." With this conclusion the observations embodied in the present folio accord.

As far as can be gathered from existing descriptions the greater number of the ranges consist mainly of Paleozoic sandstones or quartzites, and limestones, resting with marked unconformity upon pre-Cambrian schists and granites. The extent to which this ancient basement composes the mass of a given range is dependent upon the elevation of the latter and the amount of subsequent degradation which it has undergone by erosion. The Paleozoic and pre-Cambrian rocks are cut by various eruptives, and partly covered by flows of volcanic rock.

Adjoining the mountainous zone on the southwest is the third physiographic division, also characterized by numerous short mountain ranges of prevalent northwest-southeast trend. But in this region the ranges are separated by broad desert plains underlain by fluviatile and lacustrine deposits of late geological age, or by undulating granitic lowlands veneered with gravel or partly covered by flows of lava. This may be termed the Desert Region of Arizona. It can not be sharply distinguished, at least without further investigation in the field, from the Mountain Region, but the boundary between the two may provisionally be taken as a curved line extending from Nogales on the Mexican border past Tucson, Florence, and Phoenix, and thence northwesterly to Needles, near the California line. The Mountain Region and the Desert Region are both included in the Basin Range system of Gilbert.

The main drainage of the Mountain and Desert regions is transverse to the trend of the ranges, through the Gila, Salt, and Williams rivers into Colorado River. The minor drainage is by streams, many of them intermittent in character, occupying in general the valleys between the parallel ranges.

LOCATION OF THE GLOBE QUADRANGLE.

The area embraced within the Globe quadrangle lies between the meridians 110° 45′ and 111° 00′ west longitude and the parallels 33° 15′ and 33° 30′ north latitude. It is thus one-sixteenth of a square degree of the earth's surface, and contains about 249 square miles. It is situated in the southeast-central part of the Territory of Arizona, between Gila River on the south and Salt River on the north, and includes portions of Gila and Pinal counties. The town of Globe, with a population of about 1500, lies near the eastern end of the quadrangle, and is the terminus of the Gila Valley, Globe and Northern Railway, a branch line about 130 miles in length, which connects with the Southern Pacific Railroad at Bowie.

The principal drainage of the district is northward, through Pinal and Pinto creeks into Salt River, but a relatively small area along the southern edge of the quadrangle is tributary to Gila River.

TOPOGRAPHY.

The Globe quadrangle lies in the heart of the Mountain Region of Arizona. The Pinal Range (including also under that term an irregular group of hills which form a northwesterly continuation of the Pinal Mountains, as they are locally designated) extends diagonally across the quadrangle from its southeast to its northwest corners, and occupies, with its flanking slopes, about five-sixths of the total area. Five or 6 miles beyond the northeast corner of the quadrangle rise the Apache Mountains, of which only the southwestern foothills appear within the area of the map. This range, like the Pinal Range, has a northwesterly trend, and, lying farther north, it occupies a position en échelon with reference to the latter. Between the two ranges lies a broad valley partly filled by a thick fluviatile deposit (Gila formation) which has been dissected by the present streams into a characteristically hilly topography. Practically all of the valley included within the quadrangle drains northwestward through Pinal Creek into Salt River. But close to the eastern border of the quadrangle the railroad crosses through a low pass (3750 feet above sea) into the drainage basin of San Carlos Creek, a tributary of Gila River.

The main Pinal Mountains form a bold, serrate range culminating in Pinal Peak, 7850 feet above sea and about 4370 feet above the town of Globe, situated on Pinal Creek, in the valley just described. From this peak the Mogollon escarpment, forming the southwestern boundary of the Plateau Region, is clearly visible about 70 miles to the north while to the southwest the eye sweeps over the Dripping Spring and Tortilla ranges, with many subordinate rocky ridges, to where the reservoir at Florence flashes in the afternoon sun, on the border of the Desert Region. The Pinal Range itself has been carved by erosion from a mass of nearly vertical schists invaded by extensive batholithic intrusions of granitic rock, and the resultant forms do not differ from those usually effected by atmospheric disintegration and running water upon such a mass. The erosion has been influenced to some extent by the difference in resistance of the various rocks. Those schists which have undergone contact metamorphism about the peripheries of the granitic intrusives are least readily worn down and consequently form most of the ridge crests and sharp summits. The granitic areas, as a rule, succumb somewhat more readily to erosion, and consequently determine the larger canyons and the basin-like hollows, such as occur in the vicinity of Hog ranch and the Pinal and Schultze ranches. Lowest in the scale of resistance are those schists which have not been indurated by proximity to masses of intrusive rock, and which form low foothills or spurs on the flanks of the range, especially on its southwestern side.

The northeastern slope of the Pinal Range above a line whose average altitude may be roughly placed at 4200 feet is abrupt and deeply scored with steep-walled V-shaped canyons. Its spurs present the rocky and angular character usually associated with youthful and vigorous erosion of a metamorphic and intrusive complex. But below this line the topography, as is evident from a glance at the map, is of an entirely different kind. The general slope, descending to Pinal Creek at the rate of about 290 feet to the mile, is comparatively gentle. The main spurs, although elaborately sculptured, show soft, rounded contours, and are separated by long, branching arroyos of very even grade. This latter topography, as will be more fully shown later, is that characteristic of the thick deposits of fluviatile material which in this region fill the valleys between the mountain ranges and lap up over the latter in long, gentle slopes intricately dissected by the present streams.

Toward the southeast corner of the quadrangle the Pinal Mountains fall off rapidly to an altitude of about 5000 feet, and are succeeded by several smaller ridges whose forms are evidently conditioned by monoclinal structure, with southwesterly dip. South and southwest of Pinal Peak, in the vicinity of the old mining settlement of Pioneer, the ridges (collectively and somewhat vaguely known as the Dripping Spring Range) exhibit a topography which is strikingly controlled by a general monoclinal structure of northwesterly trend and southwesterly dip. These ridges, carved from Paleozoic sediments and intrusive sills of diabase, show prevailingly gentle slopes to the southwest, and a series of steep slopes, benches, and scarps facing the crystalline mass of the main Pinal Range. A view over this region, which, unfortunately for the discussion of the interesting structural problems which it presents, lies just outside of the Globe quadrangle, gives an impression of structural regularity and continuity in the several ridges, which, as will be shown later, closer examination dispels.

Toward the southwest and west the slopes of the main Pinal Range, descending to the Dry Wash of Mineral Creek, show a similar but scarcely so well-marked contrast in topography as the northeastern side of the mountains. The fissile schists upon which the greater part of this slope has been eroded are associated with a rather intricately modeled surface of small spurs and ravines, which passes, with no very noticeable change, into the topography produced by the erosion of the Gila formation along Mineral Creek. On the west side of Mineral Creek and the Dry Wash the older rocks are buried beneath a great flow of dacite, whose surface, while forming in its larger aspect a gentle slope showing only moderate dissection, is so exceedingly rough and rocky as to be generally impassable for horses and traversable on foot only with much difficulty.

Toward the northwest the Pinal Mountains decrease in altitude to the hilly granitic basin inclosing the Schultze ranch. From this ranch northwestward to the bounds of the quadrangle, and between the northward-flowing Pinal and Pinto creeks, is an area of crowded hills showing no apparent regularity of form or arrangement. The highest of these is Webster Mountain, and, like Sleeping Beauty and other prominent knobs in this vicinity, it is capped with dacite. To the presence of the same capping is also due the flat mesa-like character of some of the higher ridges whose tops are usually exceedingly rugged in detail and are often bounded by precipitous slopes, or cliffs due to erosional sapping. As a whole the topography of this portion of the quadrangle is rather minutely and irregularly diversified, and, as will be shown later, this is the direct consequence of deep, erosive etching upon complexly faulted heterogeneous rocks. By this faulting the country has been broken into countless small blocks, and in the subsequent wearing down of the region each block has been to a large extent a unit, influencing by its position and structure the destroying agencies at work upon its exposed portion. This complex of hills is underlain by granite, of which considerable areas are exposed. The characteristic topographic expression of areas where this rock forms the surface is that of an undulating or hilly lowland surrounded by ridges of the other rocks.

In the northeast corner of the quadrangle lies a region of hills, within which may be distinguished two minor topographic divisions. The first of these, in the extreme corner of the district, consists of a series of northwest-southeast ridges composed mainly of quartzite, with a prevailing southwest dip. They are essentially strike ridges, in which the same beds are partly repeated by faulting. Between these ridges and Pinal Creek is a zone, about 3 miles broad, within which the valleys and relative lowlands are carved in diabase, while the ridges and most of the higher hills are composed in their upper portions of quartzite resting with intrusive contact upon the diabase. As in the region north of Schultze ranch, the topography is irregular, and is intimately related to the geological structure, as will be shown on a succeeding page. The hills northeast of Globe may all be regarded as the lower southwestern foothills of the Apache Mountains, and may be conveniently called the Globe Hills.

The topography characteristic of areas underlain by the Gila formation has already been noted in connection with the description of the northeastern flanks of the Pinal Mountains. Its intricate modeling and yet smooth, rounded contours are found, with one or two local exceptions, wherever this formation occurs. They are the notable features in the landscape in the immediate vicinity of Globe, northward along Pinal Creek, about Miami Flat and Russell Gulch, near the head of Webster Gulch, along portions of Pinto Creek, and elsewhere.

No account of the topography can be considered complete without some reference to the stream channels or arroyos. The larger ones, such as Pinal, Pinto, and Mineral creeks, have broad, sandy or gravelly beds of very even grade. This evenness of grade is not, as a rule, confined to open country, but persists even where the streams, such as Pinto Creek, have cut deep canyons through hard rocks. Rock in place is very rarely exposed in the bottoms of these channels, and being dry for the greater part of the year, they form the natural roads of the region. Even in the canyons it is usually found that obstructions to travel are due to fallen masses of rock, rather than to falls or inequalities in the stream bed itself. The tributaries of the main creeks exhibit similar characteristics on a smaller scale, and as a rule it is not until the steeper headwater ramifications of an arroyo are reached that rock in place appears in its bed, and travel becomes more difficult. This regularity of grade and absence of rocky bottom are particularly noticeable in all the important channels which have trenched the conglomeratic beds of the Gila formation.

CLIMATE AND VEGETATION.

The control imposed by climatic conditions upon the geological processes of denudation and degradation, which are immediately concerned in sculpturing the hills and in producing those varied details of form which characterize the scenery of a given district, is nowhere more strikingly shown than in those arid countries of which the Globe region furnishes an example. With the exception of the upper slopes of the Pinal Mountains, which from their elevation enjoy a larger share of moisture and more luxuriant vegetation than falls to the lot of the country stretching away from their flanks, the Globe quadrangle is typically although not extremely arid. Complete meteorological records are not available for any part of the quadrangle. Reports made to the Weather Bureau from Globe for the year 1894 show a mean annual temperature of 64.3 degrees, with an extreme range from 21 degrees in January to 108 degrees in July, and a total precipitation of 12.87 inches. A record of precipitation has been kept for more than ten years at the Pinal ranch, near the western edge of the quadrangle, and shows an average of about 20 inches—probably considerably more than falls in the vicinity of the town of Globe. At San Carlos, about 25 miles southeast of Globe, records for a decade past show a mean annual temperature of about 64 degrees, a maximum temperature of 117 degrees, and a minimum of 1 degree. The average annual precipitation at San Carlos during this period was about 11 inches. At Florence, about 40 miles southwest of Globe, the mean annual temperature is about 68.5 degrees, the winters being apparently somewhat warmer than at San Carlos. As the elevation of Globe is 1000 feet greater than that of San Carlos, its summers are probably somewhat cooler, the maximum at Globe in 1894 being 108 degrees, as against 111 degrees at San Carlos. The hottest weather at Globe is usually during June and July.

Throughout this part of Arizona a considerable proportion of the scanty annual precipitation falls in the form of rain during the sudden and violent downpours which are common in July and August. The effect of these rains is to wash the loose detritus down the hill slopes and to fill the dry stream beds with transient but turbulent torrents. The erosive work done in a brief time by the more violent of these rains, locally termed "cloudbursts," is remarkable, and it is largely through their brief but energetic activity that the process of degradation is carried on.

As a result of the prevailing aridity, the Globe region as a whole supports only the scanty and thorny growth characteristic of dry countries. Numerous species of cactus and yucca, with the maguey, palo verde, "hackberry," "cat-claw," and other thorny shrubs, constitute the common vegetation of the lower slopes. In more favored localities stunted growths of oak and manzanita appear, while larger oaks and sycamores occur along some of the arroyos. In the Pinal Range small oaks and the western juniper form a transition zone between the typically desert plants and the pines and firs which, although much thinned by the sawmills, still flourish in places along the crest and afford striking evidence of the climatic contrasts which in this region accompany any notable range in altitude.

With the exception of the timbered slopes of the Pinal Mountains and of a few alluvial areas along the main arroyos, the surface of the region is almost destitute of soil. The scanty shrubbery and the sparse grass and herbage which spring up with wonderful rapidity after the rains are insufficient to prevent such soil as may form from being washed away by rains. The humus acids which in moister climates and beneath a covering of soil aid in rock decay, have in this region little opportunity to form or to attack the rocks. The latter crumble or flake under the influence of the sharp atmospheric changes characteristic of the climate, and these fragments are rapidly carried into the valleys. The granitic masses crumble into particles of quartz, flakes of mica, and angular fragments or crystals of comparatively fresh feldspar. The rains acting on this disintegrated material soon washed it down to the larger streams, which carry off the quartz and mica. The larger fragments of feldspar often build up alluvial fans at the mouths of the small ravines heading in a granitic area, and such fans are remarkable for the purity and freshness of the feldspathic material which composes them, the numerous cleavage faces flashing brightly in the sun. Excellent examples of these fans were observed along Pinto Creek north of Horrell's west ranch, They are evidently transient phenomena, accumulating until an exceptionally wet season causes Pinto Creek to rise and sweep them away.

Postponing for the present the special subject of the influence of an arid climate on ore deposition, it may be said in general that the dominant geological fact traceable directly to climatic control is the overwhelming preponderance of mechanical disintegration over chemical decay and the consequent freshness of the materials transported by the streams. Furthermore, while there is less water available for erosion than in more humid regions, this deficiency is partly compensated by the greater erosive energy imparted to the water by the conditions under which it acts.

GENERAL GEOLOGY.

PRELIMINARY OUTLINE.

The oldest rocks occurring within the Globe quadrangle are crystalline schists of pre-Cambrian age. These represent ancient sediments which prior to the deposition of the lowest Cambrian rocks known in this region were upturned, compressed, intruded by granitic rocks, and metamorphosed to their present crystalline condition. They will be called the Pinal schist. It is highly probable that at the close of the pre-Cambrian revolution the region was characterized by a mountainous topography. But of this no evidence remains to-day other than can be inferred from the structures and textures of the pre-Cambrian rocks. It is certain that a long period of denudation and degradation reduced this crystalline basement to a fairly even surface, or peneplain, upon which the next younger rocks were deposited.

These latter rocks comprise shales, conglomerates, and quartzites, with a local thickness of from 500 to 800 feet. No fossils have been found in these beds, but they are thought to be probably Cambrian in age, corresponding to the Tonto group of the Grand Canyon section, or they may possibly correspond to the Algonkian Grand Canyon series. This entire assemblage of shales, conglomerates, and quartzites will be referred to as the Apache group.

Overlying the Apache group is a series of limestones with an observed maximum thickness of about 400 feet. These limestones are fossiliferous, and their age is thereby determined as ranging from Devonian to Pennsylvanian. But it was found impracticable to consistently divide and map them as two or more formations, and they will accordingly be treated as a unit and referred to as the Globe limestone.

Although no convincing evidence of unconformity was obtained, even in excellent exposures, it is probable that an erosion interval separates the Globe limestone from the Apache group.

The original top of the limestone section is nowhere preserved within the Globe region. If it was once covered by Mesozoic sediments, all trace of them has been removed. The Globe limestone, so far as the Globe district is concerned, closes the record of marine sedimentation. During the long geological interval between the close of the Pennsylvanian and the extensive effusive eruptions of dacite which are provisionally referred to the early Tertiary occurred the second great deformation of the region, imposing upon it structures to which are in large measure due the features of the present topography. The Paleozoic sediments and their underlying crystalline basement were cut by hundreds of faults. Following or accompanying the faulting large masses of diabase were intruded, chiefly in the form of sills, between the sedimentary beds of the fault blocks. The intrusion of the diabase was followed by long-continued erosion, during which the rocks were further faulted and the original sulphide ores were deposited. After this period of erosion, which reduced much of the region to a very moderate relief, the volcanic energies again manifested themselves through extensive eruptions of dacite, which appears to have covered all of the area except the higher portions of the Pinal Mountains. The vents through which the dacite was erupted have not been identified, but the rock is known to have a distribution far beyond the Globe quadrangle to the north and west. The time of the volcanic eruption may be tentatively referred to the early Tertiary, but the Globe region affords no known facts upon which to base a more precise date.

After the dacite eruption the region was again deformed by extensive normal faulting. The rocks, traversed by numerous faults, were carved into nearly their present topography, and the waste was deposited in the valleys as a variable fluviatile accumulation which has been termed the Gila conglomerate. The age of this conglomerate can not be exactly determined. It is probably early Pleistocene, or possibly late Tertiary. During its deposition there was at least one eruption of basalt.

The Gila conglomerate has also been faulted, and is generally well dissected by the present arroyos or stream channels, as a result of some regional change, either of elevation or of climate.

DESCRIPTION OF THE ROCKS.

Sedimentary Rocks.

PRE-CAMBRIAN CRYSTALLINE METAMORPHIC ROCKS.

PINAL SCHIST.

General character and occurrence.—The Pinal schist, broken by granitic intrusions into very irregular masses, is abundantly present and well exposed in the Pinal Mountains, whence its name is derived.

The largest single body of schistose rocks in the quadrangle is that underlying the greater part of the western slope of the range, stretching out ragged tongues over its crest, and extending down beneath the Gila formation at the northwest foot of the mountains. Another considerable area is found near the southeast corner of the quadrangle, partly bounded to the southeast by a fault.

As a rule the schists are separated by intricate boundaries from the granitic rocks (Madera diorite, Schultze granite, etc.) which have irregularly invaded them. Masses of schist, ranging in size from those measurable in inches to those most conveniently expressed in miles, are often entirely surrounded by the eruptive rock, and in the Madera diorite these inclusions are frequently so small and so numerous that it is impracticable to delineate schist and eruptive separately on a geological map. The practice in such cases has been to map the inclosing granitic rock and to outline only those areas of schists which are of sufficient size and individual importance to appear on a map of the scale used. The great local abundance of schist fragments included in the Madera diorite may be well seen along any of the various roads that ascend the northeastern slope of the mountains. As the schists close to the contact with the Madera diorite are usually highly crystalline, resistant rocks they are less readily degraded than the eruptive rock under similar conditions of erosion, and frequently stand out as ridges and spurs, while the canyons and basins are more commonly excavated in quartz-mica-diorite or granite. This relation is, however, partly due to the fact that the granitic rock as a whole underlies most of the schist, and the exposures of the latter become less extensive as the whole range is degraded.

As might be expected in rocks so intricately intruded by batholithic granitic masses, the Pinal schist shows variable strikes and dips. It is least disturbed or contorted in the broad belt between the Hog ranch and Hutton Peak, and between Lyons Fork and the main branch of Mineral Creek. In this area regularly laminated sericite-schists, containing some bands in which the original character of quartzose grits is distinctly recognizable, predominate, but change to more coarsely crystalline muscovite-schists as the Madera diorite is approached. The prevailing strike of the schistose cleavage in this and in other schist areas of any considerable size is northeasterly and southwesterly. The dip varies from 45 degrees to vertical, and is generally to the northwest. In smaller masses included in the granite and granitic rocks near the contact of the latter the strike and dip are often very variable. As a rule the schistosity is roughly parallel with whatever larger banding, due to differences in composition of the schists, may be discernable. It is noteworthy that the strike of the schistose cleavage runs nearly at right angles to the dominant trend of the present mountain ranges of the region.

The extensive intrusive mass of Schultze granite which stretches from Bloody Tanks Wash southwestward to the Pinal ranch separates the schists of the main Pinal Range from several smaller areas to the north, which together constitute a very irregular and interrupted belt extending from Black Warrior southwestward to Powers Gulch.

The schist of these northern areas is lithologically similar to that of the main Pinal Range. But the folia are much more distorted, and the rock is often so thoroughly shattered as to resemble a fault breccia. With the exception of the area just east of Bloody Tank and that south of Gold Gulch, it is rarely possible to detect any regular strike and dip of the schistosity. Good exposures of this crumpled, shattered schist may be seen along Webster Gulch, particularly near Black Warrior and the Black Copper mine, near the head of Live-oak Canyon, and on Pinto Creek.

The brecciation of the schist probable dates in part from an early period. At that time the schist laminæ were crumpled and broken, apparently under slight superincumbent load, and the open, more or less lenticular spaces formed between the contorted laminæ were filled with quartz. The result was a fragile rock, full of small surfaces of weakness, which was thoroughly shattered by later movements, such as the post-dacitic faulting of the region.

An isolated mass of Pinal schists occurs 4 miles a little east of north from Globe. This area is surrounded by diabase, from which rock it is very probably separated on all sides by faults.

Petrography.—With the exception of occasional bands of greenish amphibolite, later to be described, the Pinal schist is generally rather light gray in color, with frequently a silvery, satiny luster. In texture it ranges from cryptocrystalline, slaty sericite-schists, through finely granular, fissile rocks of somewhat sugary texture, to imperfectly cleavable, highly crystalline muscovite-schists. The sericite-schists, with their regular cleavage and inconspicuous crystallization, are characteristic of the larger schist areas at some distance from the Madera diorite contact. The coarser, more conspicuously crystalline muscovite-schists are found near the contact and in masses of schist inclosed by the granitic rock.

In spite of much variety in coarseness of crystallization, cleavability, and megascopical appearance, the Pinal schist when studied microscopically shows great mineralogical simplicity and uniformity. It consists essentially of aggregates of quartz and muscovite (including the minutely crystalline variety, sericite), with usually a little microcline or plagioclase, and small amounts of magnetite or specularite, zircon, tourmaline, hornblende, biotite, and chlorite. Andalusite and sillimanite are abundant in certain contact facies near the granite, but are not generally present.

As a typical example of the sericite-schist there may be described a specimen collected on the trail to Lyons Fork, 2 miles southwest of the Hog ranch. This rock is bright gray, with a satiny sheen, and is cryptocrystalline in texture. It cleaves readily into thin flakes, and shows small greenish knots, about 2 millimeters in size, dotting the lustrous cleavage surfaces.

Under the microscope it appears as a clear crystalline aggregate of allotriomorphic quartz grains and small scales of muscovite (sericite), the two minerals being present in nearly equal amount. A thin section cut across the schistose cleavage shows that this structure is due to the concentration of the quartz and muscovite in alternating microscopical bands or layers. Small granules of opaque black iron ore (probably magnetite) are scattered rather abundantly through the principal minerals, while little bunches of green, obscure fibrous minerals, either amphibole or chlorite, and occasional minute prisms of tourmaline and rounded crystals of zircon complete the list of mineral constituents. Microcline, sometimes abundant in the more coarsely crystalline schists, is here absent.

Among the sericite-schists on the western slope of the Pinal Range between the Hog ranch and the Dry Wash of Mineral Creek occur certain bands which, while schistose, preserve in great part the original texture of siliceous grits. The small pebbles, principally quartz, still retain their original waterworn outlines, while the finer material of the matrix has recrystallized as quartz and sericite. So far as observed these grit bands have the same strike and dip as the schistose cleavage, showing that the secondary structure is here parallel with the original bedding.

A specimen collected 2 miles northeast of Pinal Creek, a few hundred feet from the granite, may be taken as typical of the coarser mica-schist. This is a silvery-gray rock of imperfect cleavage, which on fresh fracture flashes with irregularly bounded plates of white mica, generally about half a centimeter in diameter. Under the microscope the principal constituents are seen to be quartz and muscovite, with very irregular allotriomorphic boundaries. The muscovite occurs in large plates, often inclosing the grains of quartz (poikilitic structure), and as the fine-leaved microcrystalline variety known as sericite. The remaining minerals of the rocks are subordinate to the quartz and muscovite. They comprise magnetite in scattered granules, plagioclase, in occasional allotriomorphic grains, fibrolite and rutile (?) as acicular or capillary crystals inclosed in quartz, zircon in short, rounded prisms in quartz and muscovite, and chlorite in little interstitial fibrous tufts.

Varieties of the Pinal schist in which biotite predominates over muscovite are not common. Such occur, however, on Pinto Creek, 2 miles southwest of the Schultze ranch.

Tourmaline has already been mentioned as a sparing microscopical constituent of the schist. It is occasionally present, however, in greater abundance, and in vein quartz is common in certain phases of the schist near the granite. This occurrence and that of the characteristic contact minerals andalusite and sillimanite will be again referred to when the contact phenomena of the granitic rocks are described.

Associated with the prevailing silvery-gray muscovite or sericite-schists are occasional bands of green schists of fine, fibrous texture. A specimen of one of these green schists, taken from a mass of Pinal schist surrounded by granite 2 miles northeast of Pinal Peak, shows, on microscopic examination, that its principal mineral constituents are green hornblende, quartz, and epidote, with smaller amounts of biotite, chlorite, and magnetite. The rock is an amphibolite-schist.

Origin.—The preponderance of quartz over all other mineral constituents, the still greater preponderance of quartz and muscovite together, and the general absence of calcic minerals are strongly indicative of the formation of the Pinal schist by metamorphism from quartzose sediments. That at least a part of the schists are so derived is conclusively shown by the occurrence, at some distance from the intruded granitic rocks, of only partly metamorphosed beds of grit of coarse sandstone forming an integral part of the schistose series. The presence of muscovite and microcline in the schists renders it probable that these original sediments were of granitic origin—were arkosic sandstones or grits similar to those of the Apache group. Their original sedimentary character is also strongly suggested by the regular banding observable in the uncontorted schists on Lyons Fork of Mineral Creek, on upper Pinto Creek, and elsewhere.

The occasional bands of amphibole-schist, on the other hand, have a mineralogical composition such as results from the metamorphism of eruptive rocks. Whether this eruptive material was originally in the form of dikes cutting the siliceous sediments, or of intercalated tuff beds, can not now be determined.

It is impossible to retrace all of the vicissitudes through which rocks so ancient as the Pinal schist have passed, or to determine each step in the probably complex history of their metamorphism. There can be little doubt, however, that the extensive intrusions of quartz-mica-diorite had much to do with the transformation from sediments to crystalline schists. The change had been effected at the time of the later intrusion of the Schultze granite (granitite), and this rock seems to have produced little if any further metamorphism of the schists.

Age and correlation.—The Pinal schist has a prevailing nearly vertical schistose structure, probably in the main parallel to original bedding planes. It is intruded by granitic rocks, and both schist and intrusive masses were degraded to a peneplain before the deposition of the Apache group upon the complex basement thus provided. The Pinal schist and the Apache quartzites are thus separated by a profound unconformity, comparable with the break between the Vishnu and Grand Canyon series in the Grand Canyon of the Colorado, as described by Walcott. In the Grand Canyon, as in the Globe district, this unconformity separates crystalline schists intruded by granite from the base of the unmetamorphosed sediments. The Vishnu is doubtfully referred by Walcott to the Algonkian, while the Grand Canyon series above the great unconformity and below the Cambrian Tonto group is more certainly assigned by him to that period.

If, as not improbable, the Pinal schist is the equivalent of the "Vishnu series" of Walcott in the Grand Canyon of the Colorado, it is also much older than the supposed Algonkian rocks represented by the "Chuar and Unkar terranes" which in that great gorge are found to overlie the Vishnu schists with conspicuous unconformity. Furthermore, Powell and Walcott describe the "Grand Cañon schists" or "Vishnu series" as in part metamorphosed sediments, while the Pinal schist of the Globe region was certainly derived from ancient sediments by metamorphism.

If, therefore, the original definition of the Algonkian as including all pre-Cambrian sedimentary rocks be accepted, the Pinal schist belongs in that period, which must then be considered as embracing rocks above and below the most profound unconformity known in Arizona. In view of this fact, it seems best in the absence of definite correlation, to refer to the Pinal schist simply as pre-Cambrian, leaving future investigation to determine whether the Algonkian is to be represented in Arizona by the Grand Canyon series, or by the Vishnu series, or by both of these series separated by an unconformity apparently as profound as any described in geological literature.

CAMBRIAN (?) SYSTEM.

APACHE GROUP.

General character and occurrence.—The name Apache group is here applied to a conformable accumulation of quartzites, arenaceous shales, grits, and conglomerates, which attain within the quadrangle a maximum thickness of from 800 to 1000 feet, and are particularly well exposed on the western face of the Apache Mountains. The group rests unconformably on the pre-Cambrian crystalline complex, and is apparently conformably overlain by the Globe limestone. The original continuity of the beds of the Apache group has been greatly impaired by faulting, by intrusions of eruptive rock, and by erosion, so that at the present time the strata occur in relatively small and often isolated blocks or masses, which in a general way are peripherally disposed about the main crystalline mass of the Pinal Mountains. In the southern half of the quadrangle the Apache group is but scantily represented, strata belonging to it occurring only in the extreme southeast corner and at the northern end of one of the ridges of the Dripping Spring Range, near the Sixty-six ranch. A short distance south of the quadrangle boundary, however, these beds become more prominent, forming numerous short monoclinal ridges and maintaining a general dip of about 20 degrees to the southwest.

In the northern half of the Globe quadrangle the Apache quartzites, shales, and conglomerates occur in numerous small fault blocks and in masses irregularly broken and often inclosed by intrusive bodies of diabase. As a rule, only a part of the whole group is represented in any one block of strata, but the full local section from the bottom of the Globe limestone down to the pre-Cambrian basement is exposed in Barnes Peak.

In the extreme northeast corner of the quadrangle the quartzites of the Apache group form a series of short, generally monoclinal ridges, which are intermediate between the Apache Mountains and the lower elevations of the Globe Hills.

In the following description and discussion of the Apache group it is proposed to divide the only complete section found, that of Barnes Peak which, appears to be representative of the greater part of the quadrangle, into four formations. The beds occurring in the numerous fault blocks of the quadrangle will then be correlated as far as possible with the formations of Barnes Peak. In many cases the identification presents no great difficulty. But in others the proper correlation of the often fragmentary and isolated masses of Apache strata with the type section can not be satisfactorily made. The chief sources of difficulty lie, first, in the considerable lithological variation of the Apache beds within the bounds of the quadrangle, whereby conglomerates and quartzites not always distinguishable from those in the type section appear at unexpected places in the stratigraphical column, and, second, in the remarkable manner in which a combination of geological causes has destroyed the original continuity of the beds, producing an effect of shattering and redisposition that may not inaptly be termed the kaleidoscopic. No fossils have thus far been found in the Apache group, and all correlation consequently rests upon lithological and stratigraphic grounds. It was this group of rocks that Marvin, in his reconnaissance through this region for the Wheeler Survey in the year of 1871, appears to have provisionally correlated with the Tonto group of Gilbert. Much work remains to be done before the history of the Apache group can be fully understood and its formational units receive their final distinction and definition. The field for this investigation, however, lies not within the greatly faulted area of the Globe quadrangle, but without its borders.

Lithology and subdivisions.—In considering the composition of the Apache group in detail, it is necessary to distinguish at the outset the beds lying north of Globe and east of Pinal Creek from those of the rest of the quadrangle. The latter, with a few exceptions which will be discussed later, are represented by the typical section of Barnes Peak, presently to be described. The former, on the other hand, appear to correspond to the Apache Mountain section, which differs from that of Barnes Peak, as will be shown on a later page.

Barnes Peak, 5028 feet in altitude, standing in the northwestern part of the quadrangle, is carved from several fault blocks of nearly horizontal strata which rest upon the eroded surface of the Ruin granite. The eastern slope of the hill is steep and bare, and provides a complete exposure of the Apache beds, from the base of the Globe limestone, a remnant of which is preserved on the top of the hill, down to the granite.

The lowest bed of the group, resting upon the nearly horizontal eroded surface of the granite, is a conglomerate, varying in thickness from 1 to 6 feet. It is composed of imperfectly rounded pebbles of glassy vein quartz with an occasional small flake of schist, held together by an abundant pink matrix consisting of cleavage particles of orthoclase or microcline and quartz. The material of this conglomerate appears to have been of local derivation, and to represent the surficial detritus of the ancient granitic plain, slightly reworked by the waves of an encroaching sea. It may be conveniently referred to as the Scanlan conglomerate, from Scanlan Pass, through which the trail passes just east of Barnes Peak.

Overlying the Scanlan conglomerate are dark reddish-brown arenaceous shales having a thickness of about 200 feet. For a distance of about 25 feet above the Scanlan conglomerate the sandy shales are distinctly arkosic, containing abundant fragments of pink feldspar. Toward the top of the formation the shales become more quartzose, but are probably nowhere quite free from particles of granitic feldspar. Intercalated within these fissile shales are occasional beds of quartzite, rarely over a foot but occasionally a foot and a half in thickness. This formation of sandy shales with its subordinate thin beds of quartzite will be called the Pioneer shale, from the old mining settlement of that name, just south of the quadrangle, where the shales are well exposed.

The Pioneer shale can usually be identified over the western part of the quadrangle by the thinness of its bedding and the dark chocolate or maroon tint of the hill slopes carved upon this formation. Very characteristic of the formation are abundant round or elliptical spots, light buff in color, caused by local removal of the ferruginous coloring matter of the shale.

Conformably overlying the Pioneer shale, and forming a conspicuous stratigraphic girdle about Barnes Peak, is a conglomerate, from 10 to 15 feet in thickness, which may be named the Barnes conglomerate. This bed is composed of well-rounded pebbles of hard, white or pink quartzite, with some reddish jasper and white vein quartz. The average diameter of the pebbles is probably 3 or 4 inches. They are embedded in a matrix of arkosic grit, which varies greatly in abundance from point to point. In some exposures the pebbles are closely crowded from top to bottom of the bed. In others they occur in irregular bands or thinly scattered through the feldspathic quartzite.

Overlying the Barnes conglomerate are beds of quartzite with an aggregate thickness of about 400 feet. In a region singularly lacking in apt names for its topographic features, a thoroughly appropriate designation for this quartzite is not available. Distant views indicate that it is prominently developed in the Sierra Ancha, north of the quadrangle, and if this surmise is correct, a formation name derived from these mountains would perhaps be the most satisfactory that could be chosen. It is safer, however, to adopt provisionally a name less desirable but derived from a locality where the quartzite is known to occur. For the present, therefore, the quartzites lying between the Barnes conglomerate and the Globe limestone will be referred to as the Dripping Spring quartzite, from the Dripping Spring Mountains, a term somewhat vaguely applied, but apparently embracing the monoclinal ridges south of Pioneer which owe their boldly scarped outlines to these quartzites and to the underlying Barnes conglomerate.

At Barnes Peak the lower 175 feet of the Dripping Spring formation consists of massive beds of streaked buff and pink quartzite, the former being the dominant color. The beds are not sharply defined, the more massive quartzite occurring in bands 10 feet or so in thickness, which grade one into the other through rather shaly and laminated varieties. As a rule it is difficult to determine the plane where one bed stops and another begins. These quartzites and the underlying Barnes conglomerate are the most resistant portions of the Apache group, and commonly find prominent topographic expression as cliffs and cuestas.

The upper part of the Dripping Spring quartzite is characterized by thinner-bedded, hard, laminated quartzite, usually streaked with iron oxide and decidedly rusty in general appearance. These beds are apparently conformably overlain at Barnes Peak by the Globe limestone.

A graphic summary of the foregoing description of the type section for this part of the quadrangle is given in Section A of the columnar section sheet. No fossils have yet been found in any part of the Apache group.

It is now possible to compare with the Barnes Peak section the more fragmentary sections of Apache strata in other parts of the quadrangle.

In the greatly shattered district lying north and northwest of Webster Mountain and extending beyond the northern edge of the quadrangle, little departure is observed from the Barnes Peak section, except in the varying number and thickness of the sills of decomposed diorite-porphyry intercalated in the Pioneer shale. As might be inferred from the frequent exposures of the granite basement in this faulted area, the lower beds of the Apache group predominate, although the upper beds are frequently present. The general distribution of the latter is indicated on the geological map by the areas of Globe limestone, which, when not bounded by faults or cut off by intrusions of diabase, overlies the Dripping Spring quartzite. The granite in the northwest corner of the quadrangle appears to have been worn down to an even plain prior to the deposition of the Apache group. At some points the arkosic Pioneer shale is found resting directly upon the old surface, with no intervening Scanlan conglomerate. Usually, however, the latter is represented by a bed, from 1 to 2 feet thick, of quartz pebbles in the usual pink feldspathic matrix. Occasionally thin bands of similar pebbles occur in the shales a foot or more above their base.

On the eastern side of Ruin basin, near the northern edge of the quadrangle, about 200 feet of nearly horizontal Pioneer shale is overlain by the Barnes conglomerate, and the latter by about 50 feet of the Dripping Spring quartzite. A fault separates the shales from the Ruin granite on the west, so that the base of the Apache group has not been exposed.

Between Ruin basin and Gerald's ranch the Apache beds, apparently representing chiefly that portion of the group lying above the Pioneer shale, have been considerably disturbed by irregular sill-like intrusions of diabase and by faults. Beds having the general character of the upper part of the Dripping Spring quartzite are to all appearances conformably overlain by the Globe limestone, a mile and a quarter northwest of Gerald's house, and both north and west of Sleeping Beauty Peak.

West of Black Warrior, in Webster Gulch, the Apache group has but fragmentary representation. Its occurrence here is of interest, however, as affording the only exposure in the quadrangle illustrating the direct relation of the group to the Pinal schists. The Scanlan conglomerate is here represented by a rather striking breccia consisting of more or less angular fragments of white vein quartz embedded in a silvery-gray matrix of schist particles. This change in the material of the conglomerate from point to point shows the very narrowly defined local derivation of its materials.

Half a mile north of the Continental mine thin beds of hard red quartzite and of pink grits containing abundant particles of reddish granitic feldspar rest, with gentle westerly dip, upon an erosion surface of coarse reddish Schultze granite. The aggregate thickness of these beds is about 200 feet. A few inches of Scanlan conglomerate usually separates the quartzite from the granite, but is not always present. These grits and quartzites thus occupy the usual position of the Pioneer shale, and appear to be a gritty and quartzitic facies of that formation. Lithologically, however, they might readily be taken for certain of the higher beds of the Dripping Spring quartzite.

About 2½ miles southwest of the Continental mine, in the gorge of Pinto Creek, are excellent exposures of some of the upper beds of the Apache group and of the overlying Globe limestone, somewhat complicated, however, by the usual faults. The stratigraphical sequence in this locality is shown in the columnar sections D and E. Section D presents the occurrence of the beds in the west wall of the canyon, half a mile upstream from the edge of the quadrangle. Section E corresponds to the east side of the gorge about a quarter of a mile farther downstream. Both sections have at the base thin-bedded, rusty-red quartzites or sandstones, whose weathered surfaces are often dotted with little wart-like excrescenses, probably due here, as elsewhere in the quadrangle, to the presence of minute nests of sericite disseminated through the mass of the rock. Within these beds, on the west side of the canyon, occurs a stratum of hard siliceous conglomerate, 6 feet in thickness, which is lacking or concealed on the east side. In both sections there appears a heavy bed, probably from 30 to 50 feet thick, of a rather coarse, rusty conglomerate. The pebbles of this conglomerate are principally quartzite, and appear to be lithologically identical with the reddish, warty quartzites which underlie them. No visible unconformity could be detected, however, in either section. Overlying the conglomerate are thin-bedded, dark grits, sandstones, and shales, the latter occasionally showing obscure fucoid markings. On the west side of the canyon (Section D) these beds reach a total thickness of about 100 feet, and are overlain by a 6-foot bed of conglomerate containing some well-rounded quartz pebbles, but made up chiefly of rather angular pebbles of quartzite up to 8 inches in diameter. Immediately above the conglomerate is an intrusive sheet or sill of decomposed diorite-porphyry, about 6 feet in thickness. Apparently the same sill appears in the east wall of the canyon, about 70 feet above the thick brown conglomerate. Above the diorite-porphyry, in both sections, appear hard, yellowish, thin-bedded, calcareous grits, containing scattered pebbles or quartz and quartzites, and immediately underlying gray Globe limestones which contain few distinct fossils near their base.

From the preceding description it is clear that the Pinto Creek sections differ radically from the Barnes Peak section, although the two localities are only a little over 5 miles apart. The stratigraphic position of the beds on Pinto Creek immediately beneath the Globe limestone, into which they apparently grade, through some calcareous grits, is that of the upper portion of the Dripping Spring quartzite, although there are present two conglomerates not recognized in the Barnes Peak section. Some of the thick, rusty, lower conglomerate was recognized on Gold Gulch, 1 mile due west of the summit of Porphyry Mountain. But between this point and Barnes Peak the more or less isolated, faulted fragments of the Apache group throw no light upon the lithological relation or gradation between the dissimilar beds underlying the Globe limestone at the two localities.

From the gorge of Pinto Creek southward the Apache group is unrepresented until the southern border of the quadrangle is reached. The small area shown on the map near the Sixty-six ranch is at the northern end of the ridge upon which, some miles to the southwest, is the mining town of Troy. The rocks here are thin-bedded, reddish quartzites and red shales, showing reticulated mud cracks. Their position within the Apache group is as yet unknown, as their study was not carried far beyond the limits of the quadrangle.

In the southeastern corner of the quadrangle apparently the entire Barnes Peak section is represented, although the beds are much disturbed by diabase intrusions and by faults. In a general way the diabase separates the topmost beds of the Dripping Spring quartzite, which immediately underlie the Globe limestone, from the bulk of the Apache group resting upon the Madera diorite.

A generalized columnar section of the Apache group as represented in this part of the district is given in Section C. This section resembles very closely the typical one of Barnes Peak. The Pioneer shale here has a thickness of about 150 feet. In some places the formation rests directly upon the worn and weathered pre-Cambrian surface of the Madera diorite, and in such cases is conspicuously feldspathic, being made up largely of particles of pink feldspar derived from the underlying Madera diorite, the coarser particles of feldspar and quartz frequently forming well-defined grit bands near the base of the shales. At other points the Scanlan conglomerate is well developed, reaching a thickness of 5 feet. This conglomerate, however, does not everywhere rest directly upon the Madera diorite, but is occasionally separated from the latter by a coarse arkose containing fairly fresh feldspar fragments over an inch in length. This material, which is not readily distinguishable from the massive Madera diorite beneath it, reaches a maximum thickness of about 12 feet, and grades insensibly into the matrix of the Scanlan conglomerate. Above the Pioneer shale comes the Barnes conglomerate, about 15 feet in thickness and crowded with well-rounded pebbles of quartz, jasper, and quartzite. The Dripping Spring quartzite overlies the Barnes conglomerate and is similar to that at Barnes Peak, although somewhat thinner bedded.

Section B, represents the succession of the Apache beds 2¾ miles southwest of Pinal Peak, and accordingly just outside of the quadrangle. The correspondence with the Barnes Peak section is close, the most striking difference being the presence of thick sills of yellowish, decomposed diorite-porphyry. The Scanlan conglomerate, moreover, has here a thickness of from 6 to 10 feet, and consists of well-rounded pebbles of quartz and hard, compact quartzite up to 8 inches in diameter. The conglomerate rests, as a rule, upon the ancient reddened surface of the Madera diorite, but is locally separated from the latter by a sill of diorite-porphyry. Immediately above the conglomerate and beneath the characteristic dark-red shales of the Pioneer formation there intervene from 15 to 30 feet of light-colored, highly feldspathic grits, in fairly thick beds. These grits are not developed in the vicinity of Barnes Peak.

It appears from the foregoing descriptions that, with the exception of the portion of the group exposed in the gorge of Pinto Creek, which can not yet be satisfactorily correlated, the Barnes Peak section is fairly representative of the Apache group as the latter occurs in the western and southern halves of the quadrangle.

In the portion of the quadrangle lying north of Globe and east of Pinal Creek the Apache group is very imperfectly represented by fragmentary masses of strata that nowhere afford a complete local section of the whole group. The nearest approach to such a section is found on the western face of the Apache Mountains, and is given in conventional columnar form in Section C. The lowest bed rests, as usual, upon a worn granitic surface, in this case apparently a biotite-granite. The Scanlan conglomerate, however, was not recognized. In its place are beds of hard, pinkish quartzites with an aggregate thickness of nearly 200 feet. The basal bed is a tough, fine-grained, faintly striped, pinkish quartzite, speckled with little greenish nests of chlorite or sericite, and containing much detrital feldspar. This is succeeded by thick beds of similar character, varying somewhat in texture, which attain a total thickness of 75 feet. Above these thick beds lie about 125 feet of thinner beds, which resemble more and more the Pioneer shale, until finally they pass upward, with no well-defined plane of separation, into beds which have all the characteristics of the latter formation. These transition beds resemble so closely some of the upper portions of the Dripping Spring quartzite as exposed in other parts of the quadrangle that no certain lithological criteria for their distinction were discovered.

If the quartzite beds just described as underlying the Pioneer shale in the Apache Mountains be really the equivalent of the Scanlan conglomerate, they may be called the Scanlan quartzite. But too little work has yet been done beyond the bounds of the quadrangle to render it certain that the Scanlan conglomerate is everywhere absent beneath these quartzites, and for the present the latter will be referred to merely as "the lower quartzite."

The Pioneer shale reaches a thickness of about 200 feet in the Apache Mountains, and exhibits the same lithological character as at Barnes Peak. It is overlain by the Barnes conglomerate, which is locally a bed of hard, buff sandstone or quartzite 15 feet thick and containing subordinate bands of well-rounded quartz pebbles. The Dripping Spring quartzite forms the crest of the Apache Range and is represented by thick beds of buff quartzite, of which about 150 feet remain, the higher beds having been removed by erosion.

The striking change in the Apache group through the addition of 200 feet of quartzite below the Pioneer shale, the absence of a continuous section of the upper beds of the Dripping Spring formation, and the great disturbance due to diabasic intrusions and to faulting, combine to render impossible the satisfactory correlation of the various quartzitic masses in the northeastern part of the quadrangle. Near the northern edge of the area the "lower quartzite" is found resting in small remnants upon the Ruin granite. About the Old Dominion mine the Globe limestone is apparently underlain by rather thin-bedded quartzites of the Dripping Spring formation, while the lower, heavier beds of the same formation form most of the strike ridges northeast of Ramboz Peak. In the extreme northeast corner of the quadrangle a little Globe limestone appears to overlie rusty grits containing quartz pebbles up to 5 millimeters in diameter. About 2 miles northeast of Ramboz Peak, which is capped by Barnes (?) conglomerate, are cherty beds alternating with siliceous conglomerates and grits. The stratigraphic position of these cherts, grits, and conglomerate, is not definitely known. It is probable that they either represent the upper part of the Dripping Spring quartzite or are the equivalent of a part of the Globe limestone. Future study of the region east of the Globe quadrangle will probably result in finding more satisfactory sections of the Apache group and the Globe limestone, and thereby throw light upon their subdivision and mutual relationships.

Age and correlation.—As no fossils have been found in the rocks of the Apache group the precise age of these beds can not be determined until their stratigraphy is studied over a much broader field than that of the Globe quadrangle. There are, however, certain general considerations that indicate, although they do not fix, the geological period to which the group belongs.

As the overlying Globe limestone contains Devonian fossils, the Apache group can not be younger, and is probably pre-Devonian. As the quartzites rest unconformably upon the Pinal schist and intrusive rocks of the pre-Cambrian crystalline complex, they are evidently much younger than the latter. So far, therefore, as its stratigraphic position is concerned, the Apache group may be Algonkian, Cambrian, Ordovician, or Silurian. The apparent absence of fossils, however, points to the Cambrian or Algonkian rather than the Ordovician or Silurian, which appear to be well provided with organic remains wherever found in Arizona. At Clifton, about 90 miles easterly from Globe, Mr. Lindgren has obtained a characteristic and abundant Ordovician fauna. As between Cambrian and Algonkian, the former seems to be the more probable. As shown by Powell and later observers, the Algonkian Grand Canyon group is separated from the Cambrian Tonto group by a well-marked angular unconformity, the Tonto in places resting upon the

Vishnu schists and their associated granitic intrusives. As no equivalent unconformity could be detected between the Apache group and the Globe limestone, it is probable that the former corresponds to the Tonto group, rather than to the Grand Canyon group—a conclusion in general agreement with the earlier correlation of Marvine. The Apache group is accordingly placed provisionally in the Cambrian. It may correspond in part to the Dragoon quartzites of Dumble, which are reported as underlying limestones containing Devonian and Carboniferous fossils in the Dragoon Mountains, and to the Bolsa quartzite of the Bisbee quadrangle.

DEVONIAN AND CARBONIFEROUS SYSTEMS.

GLOBE LIMESTONE.

General character and occurrence.—The name Globe limestone is here applied to a formation consisting almost exclusively of limestone, in beds usually ranging from 1 to 6 feet in thickness. The formation rests upon the Apache group, with locally no visible angular unconformity, and attains a maximum thickness of at least 700 feet, as exposed in the canyon of Pinto Creek. Its upper limit, everywhere within the quadrangle, is a surface of erosion, the total original thickness being therefore unknown. Although the Globe limestone apparently rests conformably upon the Dripping Spring quartzite, there are some grounds, such as the absence of recognizable Ordovician and Silurian beds and the occurrence of the basal quartzitic breccia noted on page 4, for suspecting that the two formations are really separated by an interval of erosion. In the Grand Canyon, according to Walcott, the Devonian strata, with a maximum thickness of 100 feet, rest unconformably upon the Tonto beds, but this unconformity can rarely be detected in actual exposures. As far as could be seen in the Globe district, the limestone beds are themselves conformable throughout.

The general distribution of the Globe formation is that of the Apache group, which it overlies. Natural sections, however, are even more fragmentary than in the case of the latter group, and it was found impracticable to carry over the whole area such lithological and paleontological distinctions as might occasionally be made in some of the more continuous sections.

Lithology.—The basal portion of the Globe limestone is lithologically varied in different parts of the quadrangle. In the canyon of Pinto Creek and in the greatly faulted region between Ruin and Granite basins, the base of the formation consists of about 10 feet of calcareous grits, succeeded by gritty, fossiliferous limestones, which in turn are overlain by hard, gray and buff limestones with occasional bands of calcareous shales, grits, and thin-bedded quartzite. In other localities, as at Barnes Peak, north of Sleeping Beauty Peak, and near the Old Dominion mine, the basal grits are absent, and gray limestone, not noticeably fossiliferous, rests directly upon thin-bedded Dripping Spring quartzite. About three-fourths of a mile north of the I. X. L. mine the base of the Globe limestone is separated from the underlying quartzite by a thin bed of siliceous breccia containing angular fragments of quartzite. Wherever thick sections of the Globe linestone are exposed it is found that the alternating buff and gray limestones with subordinate grits are overlain by gray, sometimes slightly pinkish, crinoidal limestones, usually in rather thick beds, but also some cherty beds, and an occasional bed of siliceous conglomerate. As a rule, however, the limestone occurs in such small faulted masses that it is rarely possible to determine the stratigraphic horizon of the beds exposed in a given block.

The least fragmentary sections of the Globe formation found have failed to show any well-defined or recognizable plane of lithological or structural distinction within the limits of this sequence of beds, among which hard gray limestones greatly predominate.

Age and correlation.—Well-preserved fossils were found within the Globe limestone at several points, and their investigation by Prof. Henry S. Williams and Dr. G. H. Girty has shown that they range from the Devonian to the Pennsylvanian. Unfortunately, however, no single section has been found to clearly embrace the whole formation from its base to the highest fossiliferous Carboniferous strata preserved.

Among the Devonian fossils found may be mentioned the following.

Atrypa reticularis Linn.
Productella hallana Walcott.
Stropheodonta calvini Miller.
Cyrtia cyrtiniformis (H. and W.).
Spirifer hungerfordi Hall.
Spirifer orestes (H. and W.).
Spirifer whitneyi Hall.
Reticularia fimbriata (Conrad).
Cyrtina hamiltonensis Hall.
Pugnax pugnus (Martin).
Orthothetes chemungensis (Con.) var.

The Carboniferous forms include the following:

Rhombopora lepidodendroides.
Seminula subtilita.
Productus simireticulatus.
Productus punctatus.
Productus inflatus.
Spirifer rockymontanus.
Spirifer cameratus.
Spirifer boonensis.
Fusulina cylindrica.
Derbya crassa.
Myalina subquadrata.
Squamularia perplexa.
Campophyllum torquium.
Crinoid fragments.

It appears from the Pinto Creek sections that the Globe formation includes in its lower part at least 300 feet of Devonian strata and in its upper part at least 500 feet of Carboniferous beds. No unconformity, however, has been found between the beds belonging to these different periods. While future work in the broader region about the Globe quadrangle may result in the discovery of such an interruption of sedimentation, and in the consequent splitting up of the Globe limestone, it is believed that no such division is at present practicable within the Globe quadrangle.

There is nothing as yet known that precludes the presence of Mississippian beds in the Globe limestone between the known fossiliferous Pennsylvanian and the known fossiliferous Devonian. The absence of any recognizable unconformity within the mass of limestone strata is suggestive of uninterrupted deposition from the Devonian to the Pennsylvanian, and consequently of the presence of some Mississippian sediments.

TERTIARY SYSTEM.

WHITETAIL FORMATION.

General character and occurrence.—The Whitetail formation (so named from Whitetail Gulch and Whitetail Spring) is a deposit of rather coarse and often somewhat angular stony detritus that lay in the hollows of a former land surface and, with the latter, was covered by the dacite eruptions. The deposit varies much, both in thickness and in lithological character, and where its relation to the dacite is not clearly shown, can not always be distinguished from certain facies of the younger post-dacitic Gila conglomerate. It appears to have accumulated particularly upon areas of diabase, and in such situations angular or very imperfectly rounded fragments of the underlying eruptive rock, with occasional pebbles of limestone, make up the bulk of the deposit, which is usually weathered and partly decomposed.

A good idea of the usual appearance of the deposit may be gained from roadside cuttings just southeast of the Continental mine. The fragments range in size from a fraction of an inch to a foot or more in diameter.

Material similar to that described occurs on Pinto Creek, just above the gorge, both north and south of Gold Gulch, and near the head of Whitetail Gulch.

Three-fourths of a mile northwest of Continental Spring excellent exposures of the Whitetail formation may be studied on the south side of a little conical hill capped with dacite. At the lowest point in the section is exposed coarse, unstratified, diabase detritus, containing fragments of the latter rock up to 3 feet in diameter, and an occasional bowlder of limestone in a soft and usually somewhat earthy matrix. About 25 feet higher up in the section the coarse material is mingled with some sandy detritus, and shows rude stratification. Still higher the deposits become finer and more distinctively bedded, and at the top of the 75 feet of the formation here exposed dark sands, largely of diabasic origin, are overlain by a bed of dacite tuff.

The other areas of the Whitetail formation shown on the geological map require no special description. The deposit is nearly always found in close proximity to the dacite, for when the latter is removed by erosion the soft Whitetail formation can not long survive, unless, like the area southeast of the Continental mine, it is protected by being faulted in among more durable rocks. Moreover, with the removal of the dacite the underlying Whitetail formation can not in all cases be certainly distinguished from the Gila conglomerate.

Origin.—The Whitetail formation preserves the record of the operation, prior to the dacite eruptions and on a smaller scale, of forces similar to those which afterwards accumulated the sometimes lithologically indistinguishable Gila conglomerate. Apparently then, as at a later date, areas of diabase tended to become lowlands, and were strewn with stony detritus, locally reworked and partly stratified by transient streams. Detrital fans near the mouths of shallow gulches merging with the loose stony litter of an arid surface were probably all covered by the tuff and lava of the dacitic eruption, and so preserved as the Whitetail formation.

Age.—In the absence of fossils a rough approximation to the age of the Whitetail formation, deduced from the general physical history of the region, is all that can be offered. As it lay upon the surface over which the probably early Tertiary dacitic lavas were erupted, it also is referred to the same period.

QUATERNARY SYSTEM.

GILA CONGLOMERATE.

General character and occurrence. — Gilbert, while studying, in 1873, the region drained by the upper Gila and its tributaries, gave the name Gila conglomerate to certain valley deposits which he described as follows, in the reports of the Wheeler Survey:

> The bowlders of the conglomerate are of local origin, and their derivation from particular mountain flanks is often indicated by the slopes of the beds. Its cement is calcareous. Interbedded with it are layers of slightly coherent sand, and of trass and sheets of basalt; the latter, in some cliffs, predominating over the conglomerate. One thousand feet of the beds are frequently exposed, and the maximum exposure on the Prieto is probably 1500 feet. They have been seen at so many points, by Mr. Howell and myself, that their distribution can be given in general terms. Beginning at the mouth of the Bonito, below which point their distinctive characters are lost, they follow the Gila for more than 100 miles toward its source, being last seen a little above the mouth of the Gilita. On the San Francisco they extend 80 miles; on the Prieto, 10; and on the Bonito, 15. Where the Gila intersects the troughs of the Basin Range system, as it does north of Ralston, the conglomerate is continuous with the gravels which occupy the troughs and floor the desert plains. Below the Bonito it merges insensibly with the detritus of Pueblo Viejo Desert. It is, indeed, one of the "Quaternary gravels" of the desert interior, and is distinguished from its family only by the fact that the watercourses which cross it are sinking themselves into it and destroying it, instead of adding to its depth.

Deposits identical in character and origin, and in part directly continuous, with those noted by Gilbert occur within the Globe quadrangle, and are in this report designated by the same name.

The general character of the Gila formation as it occurs within the Globe quadrangle is that of a firm but not hard conglomerate, the material of which ranges in coarseness from fine sand to bowlders 8 or even 10 feet in diameter. It is nearly always distinctly stratified, but as a rule the individual beds show little persistence, layers of conglomerate passing into sands, or vice versa. The pebbles are sometimes well rounded, most of these having probably been derived from the erosion of Paleozoic conglomerates, but oftener they are subangular or even angular in shape, and the formation might appropriately be termed a breccia. The material composing the deposit varies greatly in different portions of the area, as might be expected from its local derivation. In one locality the deposit may consist almost entirely of dacitic detritus and in another place of granitic fragments or bowlders. Beds of tuff occur as a part of the formation in the Mineral Creek area.

The maximum thickness of the Gila conglomerate within the Globe quadrangle is not known. It is certainly more than 700 feet, and probably considerably over 1000 feet. But the bottom of its thickest portions is nowhere exposed. Pinal Creek has not cut down to it, nor has it been reached by any of the wells sunk in the vicinity of Globe.

The Gila formation is essentially a valley deposit, having usually, in spite of deformation and dissection, a still recognizable relation to the larger features of the existing topography. It lies indifferently upon the eroded surfaces of all the other rocks of the quadrangle, with the exception of basalt, which occurs as an intercalated flow between the conglomeratic beds, and is therefore of contemporaneous age. The conglomerate is frequently found overlying dacite, the latter showing evidence of vigorous erosion prior to the deposition of the former. This relation is well shown on Mineral Creek about 1 mile east of the Sixty-six ranch, the conglomeratic beds here abutting against a crag of dacite.

The largest area of the Gila conglomerate within the bounds of the quadrangle is that which underlies and surrounds the town of Globe, and which may be conveniently referred to as the Pinal Creek area. It occupies the trough between the Apache and Pinal mountains, lapping far up on the flanks of both ranges. On the northeast slopes of the Pinal Mountains the conglomerate attains a maxium elevation of 4750 feet. On the southwest face of the Apache Mountains it reaches a similar altitude, but being here some miles beyond the quadrangle limits, the exact elevation was not ascertained. Near the town of Globe the Gila formation has a width of about 6 miles from southwest to northeast. About 4½ miles northwest of Globe, at the junction of Pinal Creek and Miami Wash, exposures of underlying rock contract the actual width of the conglomerate to less than a mile, but from this point it again broadens northward beyond the bounds of the district here considered.

About 2½ miles southeast of Globe the Gila conglomerate, preserving its width of about 6 miles, occupies the low divide which separates the drainage of the Gila from that of Salt River, and broadening out to the southeast, becomes continuous with the deposits originally described by Gilbert, which form so noticeable a feature of the topography in the basins drained by Alizo, San Carlos, and Sycamore creeks, tributary to the upper Gila.

A much smaller area of Gila conglomerate occurs in the southwest corner of the quadrangle, lying chiefly on the lower slopes of Pinal Range and within the drainage area of Mineral Creek. It will be referred to as the Mineral Creek area. The bulk of this deposit lies in a basin eroded in dacite, but in part it overlaps the Pinal schist up to an elevation of 4150 feet. Near Hutton Peak small outlying patches of the conglomerate, probably originally part of the larger area to the south, attain a maximum altitude of 5400 feet—the highest point within the quadrangle at which the Gila formation has been found.

An interesting area of the conglomerate lies within the drainage basin of upper Pinto Creek, and may be referred to as the Upper Pinto area. It apparently occupies a shallow structural trough or syncline of northwest-southeast trend, the structure being brought out on the geological map by an intercalated flow of basalt.

Another area presenting many features of interest occurs near the head of Webster Gulch, and will be referred to as the Needle Mountain area, from the peak 5050 feet in altitude, which is capped by the Gila formation.

The Gila conglomerate occurs also on lower Pinto Creek, at Horrell's west ranch (Lower Pinto area), in several patches in the northeast corner of the quadrangle, and in numerous isolated remnants in various parts of the Globe district.

Relation to earlier topography.—As pointed out by Gilbert, the Gila formation is essentially a valley deposit. Although its occurrence is not at the present time confined to existing valleys, it is plain that it originally accumulated in depressions or lowlands separating mountain ridges, and never formed a general deposit covering the whole region. Throughout the period of its deposition the Pinal Mountains must have existed as a high range, and the vigorous erosive sculpturing of their slopes contributed a large share of the conglomeratic material.

The conglomerate and tuff of the Mineral Creek area appear to have been laid down in a valley bounded on the east by the main Pinal Range, and on the west by extensive slopes of dacite, which they undoubtedly overlapped to an unknown distance. The occurrence of patches of the conglomerate at an elevation of 5400 feet just east of Hutton Peak indicates that the Mineral Creek deposit was once much more extensive, and that its boundaries could not have been embraced within the limits of the present valley, upon the floor of which the remnant of the formation lies. The conglomerate originally either swept round to the north, past the position of the Pinal ranch, and joined the Upper Pinto area, or else there existed in the vicinity of the ranch a dividing ridge which has since been reduced by erosion. The latter hypothesis is considered most probable and most accordant with what has been observed elsewhere in the district. No evidence has been discovered to indicate that the conglomerates near Hutton Peak owe their relatively high elevation to faulting.

The Apache Mountains, northeast of the quadrangle, must also have existed, although their structure has probably undergone modifications since the conglomerate was deposited. In the valley between the Pinal and Apache mountains was laid down the largest single area of conglomerate within the quadrangle.

Over most of the northern half of the quadrangle, however, the relation of the Gila formation to an older topography is less clearly read. The deposit caps Needle Mountain and there is at present no topographic barrier between the Needle Mountain area and the Upper Pinto area. But the coarse nature of the conglomerate on the peak indicates that it was deposited close to a mountain slope, and the character of its materials points plainly to their derivation from the west or southwest. The occurrence of the deposit on the summit of a peak which dominates the surrounding country within a radius of 3 miles, is alone eloquent of erosion, and taken in connection with the character of the material in the conglomerates of the Needle Mountain and Upper Pinto areas, indicates that the two were formerly separated by a northwest-southeast ridge forming a continuation of the Pinal Range. The Needle Mountain area of conglomerate appears to have been deposited against the thick accumulation of dacite on the north which now culminates in Webster Mountain, and which undoubtedly supplied most of the dacitic detritus to the younger formation.

The Lower Pinto area, while obviously modified in outline by deformation and erosion, was deposited within a valley which in general exists as part of the drainage basin of Pinto Creek.

The presence of several small patches of the Gila conglomerate northeast of Webster Mountain indicates the former existence of a valley in which the gravels were laid down. But subsequent deformation and erosion have obliterated the boundaries of this hollow.

In the northeast corner of the quadrangle the deposits of Gila conglomerate are in general related to the present valleys. They cons'st chiefly of quartzite, and grade, without any discoverable break, into the modern talus from the quartzite ridges.

The relation thus sketched between the Gila formation and an earlier and the present topographies may be summed up in a general statement. An observer standing on a commanding elevation, such as Pinal Peak, will see below him to the northwest the broad basin in which lies the town of Globe, evidently deeply filled with a relatively soft deposit intricately carved by the present system of arroyos. He will observe that the deposit is not horizontal, but slopes gently up to the foot of the range upon which he stands, and up to the Apache Mountains to the northeast. He will also see that it is continuous with much larger areas to the southwest, apparently filling the basin of the Gila and extending up in long terraced slopes to the Pinalena and other ranges. The impression made by such a broad view is that the conglomerate merely fills the existing valleys, and is now being trenched by the streams, as a consequence of simple regional uplift or climatic changes. But detailed study of the district soon modifies this first impression and it becomes evident that both deformation and erosion have locally effected topographic transformations whereby valley bottoms of the time of deposition of the Gila formation have in some cases become mountain tops of today.

Origin.—The rapid variation in character, the coarseness and angularity of the bowlders, the distribution of material with reference to existing mountain ranges, the nature and dip of the stratification, and the frequent abrupt changes observable in both horizontal and vertical sections, all point decisively to the result of fluviatile action. The bulk of the Gila formation as it occurs in the Globe quadrangle was deposited by streams, and resembles the material found in the beds of the prevailingly dry arroyos to-day.

The freshness of the material forming the pebbles and bowlders, taken in connection with their angular shape, indicates that the detritus supplied to these streams came from slopes where mechanical disintegration strongly preponderated over rock decay—a characteristic of the region at the present time. The occurrence of large angular blocks near the mountains, with the rapid gradation into finer materials toward the middle of the depositional tract, points to tumultuous transportations — to torrential rushes of water, by which large quantities of rock waste were transported in a short time from the mountain slopes to the valley, with little of that rounding of individual fragments which characterizes the action of streams having a more constant flow, and in which the materials as a rule travel more leisurely to greater distances before coming to rest. As already pointed out, the present erosion in this arid region shows similar characteristics—turbulent floods of water roaring suddenly down channels whose dry beds have been exposed for months to the burning rays of the sun. While the precipitation may have been somewhat greater during the deposition of the Gila conglomerate, the conditions of erosion appear to have been those peculiar to arid rather than humid regions. The transporting power of the streams which deposited the Gila formation diminished very rapidly after they issued from the mountain canyons, and their load was deposited over the valley floors as a series of coalescent detrital fans.

That the conditions of deposition just outlined were not unfavorable to the occurrence of associated lake deposits in the middle of the larger valleys is certain, and it would not be surprising to find in some of the larger basins outside of the Globe quadrangle fluviatile deposits passing into lacustrine sediments. Such a condition seems to have obtained in the Tonto basin, north of the region here discussed. But even in smaller valleys it is probable that the drainage was at times ponded by the encroachment of alluvial fans, or by deformation resulting from demonstrable faulting. Moreover, many of these valleys were drained by streams engaged in deepening their outlets through masses of extrusive dacite. Such narrow gorges may have been incapable of discharging the sudden floods poured into the valleys, and more or less temporary lacustrine conditions have consequently prevailed. The well-bedded tuffs associated with conglomerates in the Mineral Creek area were probably deposited in lake waters, and it is interesting to note that the present outlet of this valley is a narrow impassable gorge cut through the dacite.

As shown on page 2, the Globe region was extensively faulted after the extrusion of the dacite and prior to the deposition of the bulk of the Gila formation. Unless this faulting was extremely slow it must have modified the drainage, ponding the streams until they could cut new channels through the blocks of rock which arose athwart their courses. Detailed observations must be carried over a much larger area than the Globe quadrangle before the extent to which faulting determined the accumulation of the Gila formation can be ascertained. It is noticeable that considerable deposits of Gila conglomerate occur in valleys whose drainage escapes through narrow gorges cut in tilted fault blocks of dacite or older rocks. This is true of the Mineral Creek, Pinal Creek, and Pinto Creek areas within the quadrangle, and particularly of the Tonto basin to the north. This relation is suggestive, and deserves investigation over a broader field.

Igneous Rocks.

PRELIMINARY STATEMENT.

The igneous rocks of the Globe quadrangle include a number of pre-Cambrian eruptives of general granitic appearance, such as granite, granitite, quartz-mica-diorite, granodiorite, and quartz-monzonite, all of which cut the Pinal schist. With these ancient rocks is placed a small mass of somewhat doubtful origin and relationship which has been designated metadiabase. Of probable Mesozoic age are extensive intrusions of olivine-diabase in the form of sills, dikes, and irregular masses, and much smaller and less important dikes and sills of diorite-porphyry. The post-Mesozoic igneous rocks of the quadrangle comprise a thick and extensive flow of dacite with some associated dacitic tuff, probably of early Tertiary age, and some small flows and intrusive masses of basalt, of Quaternary or late Tertiary age.

PRE-CAMBRIAN.

MADERA DIORITE (QUARTZ-MICA-DIORITE).

Definition.—Quartz-mica-diorite is usually a gray rock of granitic texture and habit, consisting essentially of plagioclase feldspar (usually andesine) with quartz and black mica (biotite). There is sometimes a little orthoclase or microcline present, in which case the rock approaches granodiorite in composition, while by the addition of hornblende it may grade into tonalite. The local name Madera diorite is derived from Mount Madera, one of the peaks of the Pinal Range.

Occurrence.—Under the name quartz-mica-diorite may be included a large part of the granular plutonic rocks intrusive as batholiths into the Pinal schist and locally known as "granite." This rock closely resembles many true granites in its general texture, prevailing gray color, and mode of weathering. Close inspection, however, reveals the fact that the dominant feldspathic constituent is plagioclase, and not, as in granite proper, orthoclase.

As may be seen from the geological map, the Madera diorite, with the exception of a single small mass in schist north of Black Peak, is limited in distribution to the southern half of the quadrangle, where it forms exceedingly irregular bodies, which have extensively invaded the schists, dividing the latter into detached masses of widely - variant shapes and sizes. The relation of the quartz-mica-diorite to the schists is often exceedingly intimate. Irregular tongues of the intrusive rock extend into the schists, and fragments of the latter are often thickly crowded as inclusions in the former.

For convenience of description the Madera diorite may be treated in four areas. The first of these, which will be called the Crest area, is the most northerly. Its name is suggested by the fact that it occupies much of the crest of the Pinal Mountains, from the Ridge road in Russell Canyon northward to the trail between Globe and the Hog ranch. On the west it forms the ear-shaped area extending southward from the above-named ranch across Lyons Fork of Mineral Creek. On the east it is the principal rock of Russell Canyon, up which the Ridge road passes, and extends down beneath the conglomeratic beds of the Gila formation. As far as existing exposures go, the Crest area of quartz-mica-diorite is distinct from other areas of similar rock to the southeast. This isolation, however, is undoubtedly more apparent than real. Connections probably exist beneath the covering of Gila conglomerate and beneath the schist masses at the head of Icehouse Canyon.

The second area lies east of the Crest area, and is of comparatively small extent. It comprises the rock in which Icehouse Canyon is excavated, and extends eastward across Pinal Creek, where it is united, by a narrow ribbon of the diorite between two schist areas, with the much larger and very irregular mass forming the third or Pinal Peak area, so called from the mountain of that name. It is the quartz-mica-diorite of the Pinal Peak area, often thickly crowded with schist inclusions, which is so well exposed along the stage road that crosses the range at the head of Pinal Canyon and connects Globe with Florence.

The fourth and last area lies in the extreme southeast corner of the quadrangle, and may be conveniently referred to as the Southeastern area. It probably connects with the Pinal Peak mass to the northeast, beyond the bounds of the quadrangle.

Although all four areas are extremely irregular in outline, they yet, as may be seen on the geological map, show a tendency to elongation parallel with the general strike of the schist, which is northeasterly and southwesterly.

Petrography.—The characteristic rock of the Crest area is granitic in general aspect, usually massive, but becoming somewhat gneissoidal near the contact with the Pinal schist, particularly east of the Hog ranch. Its usual color is bright gray, with none of the flesh-colored tint commonly associated in this region with rocks containing much orthoclase. Epidote is sometimes locally abundant as greenish-yellow flecks, streaks, and veinlets, particularly near the contact with other rocks. The rock is not porphyritic, but has a uniform granular texture, the average size of the component mineral grains being somewhat less than 5 millimeters. The minerals visible to the unaided eye are milky white feldspar, usually showing albite striations, quartz, and abundant black mica.

The structure as seen under the microscope is typically hypidiomorphic granular, the plagioclase and biotite usually having partial crystallographic outlines. The principal constituents, in order of apparent abundance, are plagioclase, labradorite, quartz, biotite, microcline or orthoclase, and muscovite. The accessory constituents are magnetite apatite, titanite, rutile, and zircon. Epidote and a little sericite and chlorite are always present as secondary minerals. Hornblende is not a constituent of the typical rock of the area, but may occur abundantly in certain contact facies to be presently described.

The Crest area of the Madera diorite is not bordered by any persistent peripheral facies, but a well-marked differentiation into local contact modifications occurs at a few points, particularly in the vicinity of the saddle through which the trail from Globe to the Hog ranch passes, and near the contacts with the inclosed masses of schist on the eastern slope of the Pinal Range. These facies are darker in color than the normal rock, and evidently contain hornblende as well as biotite, while the quartz becomes very inconspicuous. Under the microscope these darker rocks show a hypidiomorphic-granular structure, and consist of plagioclase, quartz, hornblende, and biotite, with accessory iron ore, apatite, titanite, and zircon. The plagioclase is labradorite, somewhat more calcic than in normal varities of the rock. The quartz is wholly allotriomorphic, with a tendency to become interstitial. Potassium feldspars were not noted in the thin sections examined, but probably occur in transitional facies. The hornblende is the common variety, greenish yellow by transmitted light, usually found in dioritic rocks, and the biotite presents no noteworthy features. The secondary minerals are chlorite, largely after biotite, and epidote. The rock is a quartz-hornblende-biotite-diorite, differing from the main rock of the area in the presence of abundant hornblende and in its more calcic feldspars.

The rock of the Icehouse Canyon is gray in tint, of rather evenly granular texture, and generally shows conspicuous foliation. Its structure is thoroughly gneissic. As already noted, on this page, it is often filled with inclusions of schist.

Under the microscope the rock shows a mineralogical composition similar to that of the quartz-mica-diorite of the Crest area. It differs from the latter chiefly in the microscopical evidence of intense squeezing. The original quartz areas, where not completely reduced to aggregates of small granules (cataclastic structure), show undulating extinctions between crossed nicols, and are granulated on their peripheries. The plagioclase, usually labradorite, is also granulated, but to a less extent than the quartz, while the laminæ of the biotite and muscovite are bent or contorted. The potash feldspar is a microperthitic microcline, which varies in abundance in different specimens. The accessory minerals, sparingly present, are iron ore, apatite, zircon, and titanite. Epidote occurs as small granular aggregates in close proximity to the biotite.

The quartz-mica-diorite of the Pinal Peak area is generally more coarsely crystalline than the rocks of the Icehouse or Crest areas, the average size of the grains of quartz and feldspar being about 1 centimeter. The feldspars occasionally show porphyritic development, but as a rule the rock is evenly granular. The minerals visible to the unaided eye are quartz, white striated feldspar, a little orthoclase or microcline, biotite, titanite, and a few specks of chlorite and pyrite. The prevailing tint is gray, but this changes to a decided reddish color near the base of the Apache group, which is found resting upon the Madera diorite just south of the quadrangle boundary. The rock disintegrates rather easily to a crumbling mass, and in the eastern portion of the area fresh specimens are obtained with some difficulty.

Under the microscope the quartz-mica-diorite of the Pinal Peak mass shows a hypidiomorphic-granular aggregate of labradorite, quartz, biotite, microcline, and a little muscovite. The accessory minerals are titanite, which is more abundant than in the other quartz-mica-diorites described, apatite, iron ore, and zircon. In the fresher specimens the secondary minerals are of slight importance, and comprise chlorite, epidote, sericite, calcite, and a little fibrous green hornblende.

The red color of the Madera diorite where it is overlain by the Apache group is the result of the pre-Cambrian weathering of the old surface upon which the sediments were laid down. The immediate cause of the coloration is the decomposition of the feldspars, which the microscope shows to consist of fine kaolinitic aggregates containing minute dust-like particles of iron oxide.

The granitoid rock of the southeastern area is probably continuous eastward beyond the edge of the quadrangle with the quartz-mica-diorite of the Pinal Peak area. It varies in color from gray near the eastern border of the area to red where it underlies the Apache group westward. It crumbles readily when weathered, and exposures of firm, fresh rock are not abundant. Specimens of the latter show a handsome greenish-gray, rather coarsely crystalline rock in which occur scattered and irregular phenocrysts of pink potassium feldspar up to 2 or 3 centimeters in length. The constituents making up the granular groundmass have an average diameter of about 5 millimeters, and comprise a rather oily green plagioclase, quartz, and biotite.

A thin section under the microscope shows a hypidiomorphic-granular aggregate of plagioclase, quartz, microcline, and biotite, named in order of apparent abundance. The plagioclase is principally andesine. The microcline occurs as the porphyritic crystals noticeable in hand specimens and as irregular inclusions in the andesine. The accessory and secondary minerals are those already noted for the Pinal Peak area.

This rock has not been subjected to chemical analysis, but the microscopical examination indicates that although potassium feldspars are scarcely so abundant as the conspicuous phenocrysts might suggest, it is probably more nearly a granodiorite than the quartz-mica-diorites described in the preceding pages. In the absence of chemical investigation, however, and in consideration of its probable continuity with the plutonic mass of Pinal Peak, the rock is provisionally included with the Madera diorite.

SOLITUDE GRANITE (GRANITE AND MUSCOVITE-GRANITE).

Definition.—The term granite, strictly used, without modification, stands for a granular plutonic rock consisting essentially of a potassium feldspar (orthoclase or microcline), quartz, muscovite and biotite. If the black mica is absent entirely the rock is termed muscovite-granite. There is usually present also a subordinate amount of plagioclase—either albite or oligoclase. The local name Solitude granite is derived from Solitude Gulch, near the head of which this rock is well exposed.

Occurrence.—Granite (using the word in its strict petrographic sense) and muscovite-granite are not abundant in the Globe region. Their occurrence is limited, so far as known, to three small areas. One of these lies halfway between Black Warrior and the Continental mine, and may be called the Willow Spring area, from the gulch of that name. It will be described later under the heading "Willow Spring granite." The other two lie southeast of Bloody Tanks, at the head of Solitude Gulch, and together cover about 3 square miles. The latter are masses of very unequal size, separated by a narrow strip of schist. The rocks of these two areas, while in part of similar mineralogical composition, are different in appearance and texture, and will be separately described. They, like the other granitic rocks of the Pinal Range, are intrusive into the Pinal schist. The smaller of the two southerly masses is cut by porphyry dikes sent out from the Schultze granite.

Petrography.—The principal rock of the southern and largest mass is a light-gray, sometimes nearly white, muscovite-granite, passing, with no recognized break, into true granite in the southern portion of the area. It weathers in yellowish tints, resembling in this respect the granitite of the Schultze area, rather than the grayish-weathering quartz-mica-diorites of the southern part of the Pinal Range. It is massive, and usually of evenly granular texture, the average size of the grains being about 5 millimeters. The minerals visible to the naked eye are quartz, porcelain-white feldspar, silvery-white mica (muscovite), and sometimes black mica (biotite).

Under the microscope the rock shows a nearly allotriomorphic aggregate of quartz, microcline, and orthoclase in varying proportions, albite or oligoclase, and muscovite. Although the biotite is often entirely lacking, in some facies it is nearly as abundant as muscovite, and the rock becomes granite proper. On the whole, microcline, quartz, and muscovite are the most constant and important constituents, and dark minerals are notably lacking. The feldspars, although somewhat turbid with dust-like particles, are generally fresh. Intergrowths of the various feldspars are common. The quartz grains as seen in thin section usually consist of several interlocking granules, but this structure is apparently not of cataclastic origin.

Accessory minerals are always very sparingly present. They are titanite, zircon, and tourmaline, the latter in minute prisms. The rock as a whole may be described as a muscovite-granite with true granitic facies.

The rock of the neighboring smaller area is darker and finer grained. In fresh exposures it always shows a peculiar streaky appearance suggestive of imperfect mixing of a heterogeneous magma.

Hand specimens show a uniformly fine-granular texture, the muscovite and biotite (the latter sometimes aggregated to little dots or bunches) being the only minerals easily recognized by the unaided eye.

Under the microscope quartz, muscovite, a little albite or oligoclase, and occasionally andalusite appear as allotriomorphic grains, either intricately interlocking or poikilitically inclosed in a somewhat indistinct matrix or mesostasis, which is principally if not wholy orthoclase. The andalusite is always allotriomorphic, and usually closely associated with the quartz and muscovite. It shows the cleavage, faint green and pink pleochroism, index of refraction, double refraction, and other optical properties characteristic of andalusite, but is free from the black carbonaceous inclusions common in this mineral when a constituent of contact-metamorphic rocks.

Andalusite is not a common mineral in granitic rocks, but has been described by Teall as a constituent of granite in Cornwall, where it is associated with sillimanite and possibly cordierite, and by Cohen in granites of the Black Forest and Vosges Mountains.

The purely accessory minerals of this granite are apatite, titanite, zircon, and magnetite, none of them being abundant. The secondary minerals are a little chlorite and epidote.

SCHULTZE GRANITE (GRANITITE OR BIOTITE-GRANITE).

Definition.—Biotite-granite or granitite is a granular plutonic rock consisting normally of orthoclase, quartz, and biotite, with usually a little oligoclase. The rocks presently to be described depart rather widely from the type, and furnish an interesting illustration of the unsatisfactory and transitory character of the general scheme of rock classification now in use. The local name, Schultze granite, is derived from Schultze ranch, in the vicinity of which this rock is well exposed.

Occurrence.—In contradistinction to the quartz-mica-diorite, which occupies the southern third of the quadrangle, the characteristic granitoid rocks of the northern two-thirds of the region are granitites. In order to bring out certain slight mineralogical differences, possibly indicative of difference in age, these granitites occurring in many separated areas, are mapped and described in two geographical groups, namely, the Schultze granite and the Ruin granite, so called from Ruin basin, which is eroded in the latter rock.

The largest and most interesting mass of Schultze granite forms what may be termed the Bloody Tanks area, which stretches eastward, from the Pinal ranch across Pinto Creek, to Liveoak Canyon. It is this rock which forms the light-colored hills about Schultze's ranch, and the rather conspicuous white peaks east of the Pinal ranch. As a rule its erosion tends toward the development of broad basins and moderate slopes, which, however, are usually often hilly, and may be exceedingly rough in detail. The surfaces of these hills are but poorly screened by scanty vegetation, so that the rounded outcrops of granitic rock and the smoother slopes covered by loose particles of feldspar, quartz, and mica impart a pale-yellow tint to the landscape.

A rather conspicuous jointing is characteristic of the mass, and is particularly well developed along Pinto Creek, where the granitite is regularly divided into great slabs by joints which strike about N. 65° E., and dip southeasterly at about 60 degrees. Joints having this general trend are abundant over most of the Bloody Tanks area, but they are often associated with northwesterly joints, and with still others running in various directions.

That portion of the granitic area lying north of Bloody Tanks and drained through Liveoak Canyon is characterized by a porphyritic facies which has been much fissured and altered and is often conspicuously stained with salts of copper.

The Bloody Tanks mass of biotite-granite is nowhere in contact with the Paleozoic sediments of the region, so that its age relative to these is not directly determinable.

Another mass of granitite, which is correlated with the Schultze granite, lies to the west of the Continental mine, and may be conveniently referred to as the Porphyry Mountain area, since it forms the mass of Porphyry Mountain. North of the mine the granitite, showing the reddish color always associated with the pre-Cambrian erosion surface, is overlain by the basal conglomerate and some of the lower quartzites of the Apache group.

Petrography.—The granitoid rock of the Bloody Tanks area is characterized by a prevalent porphyritic structure and a generally light tint. The usual color of slightly weathered surfaces is pale yellow, but fresh specimens are nearly white, speckled with small flakes of black mica. The constituents visible to the unaided eye are porphyritic crystals of a fresh, nearly white feldspar, often as much as 2 inches in length, showing the brilliant cleavage faces and carlsbad twinning characteristic of orthoclase. These phenocrysts lie in a granular groundmass, whose constituent grains vary from 1 or 2 millimeters up to a centimeter in diameter, and comprise quartz, white feldspar, and biotite. Close inspection of cleavage faces shows that the feldspar of the groundmass is predominantly plagioclase. Such is the rock in which the kettle-like holes are eroded at Bloody Tanks, and which is well exposed around the Schultze ranch, on Pinto Creek, and along the trail from this creek to the Pinal ranch.

Under the microscope thin sections (which as a rule illustrate chiefly the groundmass or granular portion of the rock) show a hypidiomorphic-granular aggregate of oligoclase, quartz, orthoclase, and biotite, with accessory muscovite and a very little iron ore, apatite, and zircon. Small amounts of epidote and chlorite are occasionally present as alteration products of biotite.

The foregoing description applies to what may be termed the typical rock of the Bloody Tanks area—the rock characteristic of the mass as a whole, particularly at some distance from its periphery. Near the latter the typical porphyritic granitoid rock sometimes passes into facies which in the absence of a more appropriate name may be called biotite-granite-porphyry. Such porphyry is characteristic of the area north of Bloody Tanks drained by Liveoak Canyon, and of the southern border of the granitic area near the schist contact south of the Schultze ranch. The lobe-like projection of the biotite-granite extending northward past Needle Mountain toward Jewel Hill shows much textual variation, frequently passing into facies in which very conspicuous orthoclase phenocrysts lie in a medium-granular to fine-granular, rather biotitic groundmass. The orthoclase phenocrysts are occasionally 4 or even 5 inches in length, such large crystals always showing rounded outlines and more or less peripheral poikilitic texture.

A typical specimen of the granitic porphyry near the schist contact 2 miles south of the Schultze ranch shows idiomorphic phenocrysts of orthoclase and quartz in a fine-grained groundmass consisting chiefly of white feldspar, quartz, and biotite. The orthoclase phenocrysts occur in apparently untwinned individuals of the usual orthoclase habit, and have a maximum length of about 2 centimeters. The quartz phenocrysts are of slightly rounded bipyramidal form, and rarely exceed 5 millimeters in length.

Under the microscope the rock shows a typical porphyritic texture. Phenocrysts of orthoclase, quartz, plagioclase (mostly oligoclase), and biotite lie in an extremely fine-granular groundmass, such as is common in quartz-porphyries, but was hardly expected in a facies of so crystalline a plutonic rock as the Bloody Tanks granitite. The quartz phenocrysts too are embayed as is common in rhyolitic effusive rocks. The orthoclase is usually untwinned, idiomorphic, and fairly fresh, although all the feldspars contain some sericite and indeterminable alteration products. The biotite is almost wholly altered to chlorite, epidote, and iron ore.

The porphyry of Liveoak Canyon has been much shattered, and is often extensively stained with salts of copper. In its petrographical character it is similar to that just described, but along the Western Pass road near Bloody Tanks all gradations may be found, from porphyries with microcrystalline groundmass to the typical biotite-granite of the central portion of the batholith.

The texturally variable rock which forms the lobe extending across the Pinto Creek road south of Jewel Hill differs microscopically from the typical rock of the Bloody Tanks area in the presence, with the oligoclase, of a more calcic plagioclase, in part labradorite. Biotite is also a little more abundant, and titanite, never more than a very sparing constituent in the normal rock, is here a conspicuous accessory mineral, not only in idiomorphic microscopic crystals, but as individuals visible in hand specimens. Iron ore and apatite are also somewhat more abundant than in the usual rock of the area.

The small area of granitic rock intrusive in Pinal schist at the forks of the Gold Gulch and Pinto Creek roads is probably merely an off-shoot of the main Bloody Tanks mass, which it petrographically resembles.

The rock of the Porphyry Mountain area, as exposed in the upper part of Gold Gulch and on Porphyry Mountain, is a light-gray porphyry resembling that of Liveoak Canyon, and like the latter, it is much fissured and is somewhat generally impregnated with fine pyrite. North of Porphyry Mountain this porphyry grades into a rather coarsely crystalline, crumbling, porphyritic granitite, which becomes reddish as it passes beneath the quartzites of the Apache group.

Under the microscope the porphyry and porphyritic granitite of the Continental area closely resemble the corresponding rocks of the Bloody Tanks area, and both are probably referable to the same magma and to the same period of intrusion.

Dikes connected with the intrusion of the Schultze granite.—These dikes which may be classed generally as granite-porphyries, are confined to the southern half of the quadrangle, and cut the Madera diorite and the Pinal schist. Some of them, as, for example, the dike shown on the map about a mile and a half east of the Pinal ranch, and the smaller ones shown about 2 miles southeast of the Schultze ranch, are directly connected with the Bloody Tanks granitite mass. Others, such as the irregular dikes extending southwestward from the Hog ranch, and the lone one south of Lyons Fork, have no visible connection with any parent granitic body. The dikes, even when occurring in the quartz-mica-diorite, show a marked tendency to conform in trend with the general strike of the schists.

The rock forming the middle portions of the larger dikes is a granite-porphyry petrographically identical with the marginal facies of the Bloody Tanks mass already described. Near their walls the granite-porphyry dikes often pass into nearly white aphanitic facies in which an occasional minute phenocryst of quartz or feldspar may be detected. Under the microscope this marginal variation shows small phenocrysts of oligoclase and orthoclase in felsitic groundmass which extinguishes in shadowy areas between crossed nicols and is a minutely crystalline aggregate of quartz, orthoclase, and probably other feldspars.

RUIN GRANITE (GRANITE OR BIOTITE-GRANITE).

Occurrence.—Between Pinal and Pinto creeks, near the northern edge of the quadrangle, the exposures of granitite fall into three principal and several smaller areas. It is evident, however, that all are really part of one great mass which forms a continuous basement beneath the faulted remnants of Paleozoic rocks. Thus the Pinto Creek area, in the extreme northwest corner of the quadrangle, is undoubtedly part of the same mass as the granitite forming the broad floor of Granite basin northeast of Webster Mountain; and, although the connection in this case is less obvious, it is highly probable that the granitite of Granite basin is really continuous with the petrographically identical rock of Ruin basin.

The granitite of all these northern areas, shows in an even more marked degree than the Schultze granite, the tendency to form relatively broad basins or valleys of erosion. It is more generally decomposed than the latter rock, and usually somewhat reddish in color, both of which facts are probably due to less extensive erosion below the old pre-Cambrian surface. The surfaces of the larger areas are only moderately rocky, and the generally gentle slopes are often covered with what might be termed granite crumbs—a coarse, angular sand consisting of particles of quartz, crystals and fragments of pinkish feldspar, and flakes of biotite, derived from the crumbling of the rather coarse-grained granitic rock.

A little coarse reddish granitite, correlated with the Ruin granite, is also found about 3 miles east of Gerald's ranch, forming three small areas near the northern edge of the quadrangle.

The Ruin granite is frequently found overlain by the basal conglomerate of the Apache group, resting upon a pre-Cambrian surface of erosion.

Petrography.—The Ruin granite is uniformly of coarse-grained, porphyritic texture, with a tendency to crumble into rounded forms, from which it is almost impossible to secure fresh hand specimens. Rounded pinkish phenocrysts of unstriated feldspar, often 2 inches in length and generally showing carlsbad twinning, are conspicuously scattered through a rather coarsely granular groundmass consisting of preponderating white plagioclase, quartz, black mica, and a little pink feldspar. In general texture this rock closely resembles the much fresher, coarsely crystalline, and somewhat biotitic facies of the Schultze granite exposed on the Pinto Creek road near the head of Webster Gulch. The resemblance is so close as to suggest in the field that the rocks were originally identical, and that the difference in color, largely due to the pinkish tint of the phenocrysts in the rock of the northern areas, is merely due to longer exposure to weathering. Under the microscope, however, the large feldspar phenocrysts are found to be a finely microperthitic microcline, a mineral not known in the Bloody Tanks mass. They are micropoikilitic also with reference to the other constituents, particularly in their pheripheral portions. The groundmass is a hypidiomorphic-granular aggregate of quartz, microcline, oligoclase, and biotite, named in order of apparent abundance, with accessory titanite, apatite, magnetite, and zircon. The microcline is generally fresh, but the oligoclase is more or less altered to turbid aggregates of kaolin and perhaps sericite, while the biotite is partially chloritized.

It appears from the foregoing description that the granitoid rock of the northwestern part of the quadrangle is more nearly a typical biotite-granite than the Bloody Tanks mass of Schultze granite. It differs mineralogically from the latter to a sufficient extent to cast some doubt upon the view held in the field that they represent practically simultaneous eruptions of the same magma, and they have accordingly been separately mapped and described. The small masses of biotite-granite lying near the northern edge of the quadrangle, about $2\frac{1}{2}$ miles east of Gerald's ranch, consist of rather coarsely crystalline, reddish rock composed chiefly of microcline, quartz, oligoclase, and biotite, and not distinguishable under the microscope from the facies just described.

LOST GULCH MONZONITE (ADAMELLITE OR QUARTZ-MONZONITE).

Definition.—As defined by Brögger in his classic paper on the rocks of Monzoni, in the Tyrol, the monzonites are granular plutonic rocks chemically and mineralogically intermediate between the syenites and diorites. They are characterized by the presence of nearly equal amounts of orthoclase and plagioclase, together with hornblende, biotite, or augite. When quartz is present in notable quantities the rock becomes a quartz-monzonite, closely related on the one hand to the granites and on the other to the granodiorites.

Occurrence.—The Lost Gulch monzonite forms a roughly quadrangular area about 4 square miles in extent, which occupies the greater part of Lost Gulch, and stretches northeast toward Horrell's ranch on Pinal Creek. Like the Madera diorite and the Solitude and Schultze granites, the Lost Gulch monzonite is intrusive into the Pinal schist. Its present boundaries, however, save where overlapped on the east by the Gila formation, are determined chiefly by faults, which have dropped the younger rocks so that they abut against the monzonitic fault block.

Petrography.—As it occurs in Lost Gulch the quartz-monzonite is a fine-granular gray rock containing scattered phenocrysts of potassium feldspar with smaller ones of plagioclose. In megascopical appearance it closely resembles the Willow Spring granite. Toward the eastern part of the area the rock becomes more closely crystalline, and the gray medium-granular groundmass is made up of potassium feldspar, plagioclase, quartz, and biotite.

Under the microscope the monzonite shows a hypidiomorphic-granular texture. Quartz is apparently the most abundant constituent, followed by plagioclase, microcline, and biotite. The accessory minerals are magnetite, titanite, apatite, and an occasional crystal of zircon. Both the quartz and the microcline show a tendency toward poikilitic structure The latter mineral is occasionally slightly perthitic. The plagioclase ranges from calcic oligoclase to andesine.

WILLOW SPRING GRANITE (GRANITE).

Occurrence.—This is a small isolated mass lying just north of Webster Gulch and occupying an area of less than a square mile. It is intrusive into the Pinal schist, and, like the Lost Gulch monzonite, is bounded in part by faults.

Petrography.—The Willow Spring granite is gray in color, and unusually fine grained for a rock of granitic composition, the average diameter of the grains being less than a millimeter. Occasional phenocrysts of orthoclase or microcline occur scattered through this, often nearly aphanitic, groundmass.

The microscope reveals a hypidiomorphic-granular aggregate consisting of abundant quartz and microcline, with oligoclase, muscovite, and biotite. The exact nature of the oligoclase is not readily determinable, owing to the general decomposition of this constituent into nearly cryptocrystalline aggregates, apparently consisting principally of kaolin. The accessory minerals are apatite, iron ore, and tourmaline, none of them being abundant. The secondary minerals are kaolinite, epidote, and chlorite.

The exact petrological relationship of the Willow Spring granite remains somewhat in doubt. It is quite possible that it may be more closely connected with the neighboring quartz-monzonite of Lost Gulch than with the Solitude granite.

SEQUENCE OF THE GRANITIC ROCKS.

All of the granitic rocks of the Globe quadrangle are pre-Cambrian, but are younger than the Pinal schist, into which they are intrusive. The extensive development of gneissic structure in the Madera diorite and its absence in the other granitic rocks points to the earlier age of the former. The Madera diorite is certainly older than the Schultze granite, for it is cut by dikes from the latter. The Solitude granite is also cut by similar dikes, and is accordingly older than the Schultze granite, although probably younger than the Madera diorite. The evidence for the latter relation, however, is far from conclusive, and depends chiefly upon the more gneissic structure of the supposedly older rock.

The relative age of the Willow Spring granite and the Lost Gulch monzonite is unknown. It is almost certain that they are younger than the Madera diorite, but whether they are younger or older than the Schultze granite has not yet been determined. The age of the Ruin granite is also somewhat in doubt, but on account of their close petrographical resemblance the Schultze and Ruin granites are thought to be of practically the same age.

CONTACT METAMORPHISM IN CONNECTION WITH THE GRANITIC INTRUSIONS.

Distinct contact metamorphism is found only in connection with the Madera diorite. The other granitic rocks were intruded into already metamorphosed and crystalline schists and have consequently produced no change that can be clearly distinguished from an earlier and more general metamorphism.

While the intrusion of the Madera diorite resulted in undoubted contact phenomena, it is rather difficult to discriminate between these and the broader metamorphism, whereby a series of sedimentary rocks were transformed into crystalline schists. Andalusite and sillimanite, characteristic contact minerals, are frequently present in the coarsely crystalline and rather massive muscovite-schists near the quartz-mica-diorite, but are not found in the laminated sericitic schists at a distance from the eruptive rock. Black tourmaline, while not uncommon as a microscopic constituent of the schists, is particularly abundant near the eruptive contact, associated with quartz in veins and veinlets. But in addition to the development of these minerals, which are characteristic of granitic contact zones, the general crystalline texture of the schists is plainly related to the intrusion of Madera diorite. Near the latter the schists are coarsely crystalline, rather massive, and have lost all traces of original clastic structure.

Away from the diorite they become finely crystalline, fissile, and occasionally retain in part the structure of pebbly grits. It is probable that the metamorphic action of the quartz-mica-diorite was not confined to the production of a well-defined contact zone, but was an important factor in transforming the sedimentary beds as a whole into crystalline schists. That later metamorphic forces have also been effective in imposing its present character upon the pre-Cambrian complex is shown by the considerable development of gneissic structure in the Madera diorite itself.

METADIABASE.

Definition.—By metadiabase is meant a diabase which has undergone mineralogical change, although its original character is not wholly obliterated.

Occurrence.—The name metadiabase might with propriety be applied to certain uralitic facies of the rock described in this report as diabase. For the sake of clearness and convenience, however, it is restricted to a small area of more conspicuously altered rock which lies $1\frac{3}{4}$ miles east of Schultze's ranch, and which is older than the characteristic diabase of the region. Very little of this rock is exposed, and as it passes beneath the Gila formation its actual extent is not known.

Petrography.—The metadiabase is very dark green and rather coarsely crystalline, the feldspar being so dark in color as to superficially resemble amphibole. A striking peculiarity of the rock is the occurrence of numerous inclusions of white quartz—apparently vein quartz. These fragments are conspicuously corroded and embayed, and they are surrounded by reaction rims of amphibole visible to the unaided eye.

The microscope shows that the rock is a rather coarsely crystalline ophitic aggregate in which the usual place of the augite is taken by nests of light-green amphibole with a little biotite, apatite, and iron ore. The feldspar is apparently a calcic labradorite, and although fairly fresh is brown in transmitted light, the color being due to thickly crowded minute rods and dark dust-like particles. The amphibole does not merely occupy the spaces between the feldspars, but prisms of the former mineral often project into the latter. Although the general character of the alteration is similar to ordinary uralitization, yet there is a suggestion that the diabase of this mass, like the andalusite-bearing granite adjoining it, has been subjected to contact metamorphism, which appears to have been a local effect of the intrusion of the granitite of the Bloody Tanks area. The quartz inclusions are granular aggregates having the common microscopical character of vein quartz, and are enveloped in green amphibole, the small prisms of the latter mineral standing generally perpendicular to the surface of the quartz. The source of these inclusions is not known.

Age.—The metadiabase is cut by granite-porphyry dikes from the Bloody Tanks granitite, which is considered as probably of pre-Cambrian age. The metadiabase is therefore pre-Cambrian and much older than the diabase next to be described.

MESOZOIC.

DIABASE.

Definition.—Diabase, or dolerite, is an eruptive rock, usually intrusive, and consists essentially of a crystalline aggregate of calcic plagioclase (which may range from labradorite to anorthite), with pyroxene, frequently a little biotite, and usually olivine. When the latter mineral is present the rock is commonly termed an olivine-diabase. The ordinary accessory constituents are magnetite (usually titaniferous) and apatite. The texture of diabase varies from aphanitic to coarsely crystalline, and as seen under the microscope is ophitic—that is, the pyroxene (usually augite) fills angular spaces between the partly idiomorphic crystals of plagioclase. Diabase is commonly a heavy rock, with dark-gray or greenish color. In the Globe district the diabase, really an olivine-diabase, is usually termed "diorite" by the miners.

Occurrence.—In all the rocks of the Globe region from the pre-Cambrian schists and granitic batholiths up to and including the Globe limestone, diabase is intruded as sills (intrusive sheets) from a fraction of an inch to several hundred feet in thickness, as irregular masses cutting across the invaded strata, and as small dikes.

Owing to the numerous faults which traverse the region, it is impossible to determine the number, thickness, and former continuity of the diabase sills. They appear to have been intruded at different stratigraphic horizons in rocks already much faulted. Thus in one portion of the quadrangle certain beds of the Apache group may be separated by a sill 400 feet thick, while a few miles away the same beds will be found in undisturbed sedimentary contact, with smaller sills above or below in the stratigraphic column.

One or more sheets varying greatly in thickness are usually found cutting the pre-Cambrian schistose and granitic complex about 200 feet below the basal conglomerate of the Apache group and lying roughly parallel to the stratification of the latter. Such a sill appears in the southeast corner of the quadrangle. Another of irregular shape, possibly originally a continuation of the foregoing, is shown near the edge of the map, southwest of Pinal Peak. North of Webster Mountain there is a relatively thin sill, 50 or 75 feet in thickness, occurring less than 50 feet below the base of the Apache group, and in the northwest corner of the quadrangle the granitite is cut by two or more sills at varying distances up to 200 or 300 feet below the old pre-Cambrian erosion surface. These sills are so irregular and have been so faulted as to render their original number, thickness, and position, with reference to the Apache sediments, which formerly overlay them, rather conjectural.

Similar sills occur in the biotite-granite near the edge of the quadrangle north of Globe, and they may generally be found wherever the granitic rocks which underlie the Apache group are extensively exposed.

The diabase masses, however, attain their greatest bulk and importance within the stratified rocks of the Apache group and Globe formation. Their intrusion into these quartzites and limestones was accompanied or preceded by extensive faulting, which divided the strata into numerous blocks. The molten magma not only forced its way as sills between the strata of the individual blocks, but filled the fault fissures and drove the blocks apart. Masses of limestone and quartzite were thus completely enveloped in the invading molten rock, and often shifted bodily to an extent which at first views seems scarcely credible. Although the process can not be exactly paralleled by any familiar simile, it may be partly likened to the break-up and movement of thick ice by a spring flood.

The largest area of diabase within the quadrangle is that extending northward from the Old Dominion mine, and from it may be drawn several illustrations of the general mechanical effect of the intrusion. Scattered over this area, particularly west of Ramboz Peak, are little masses of quartzite belonging to the Apache group and composed of strata dipping generally to the southwest. Some of these masses are bounded in part by faults, but many of them are separated from the diabase by eruptive contacts. They are not merely remnants of an overlying sedimentary cover now largely stripped away from the diabase by erosion, but they are detached, irregular blocks of more or less contorted strata, isolated in the eruptive rock. Most of them are, in fact, inclusions, brought to light by the erosion of the diabase, which formerly completely inclosed them. Such is the mass of quartzite at the Big Johnnie mine, on the northern slope of Black Peak. It is made up of beds dipping gently to the south, underlain and overlain by diabase, from which it is separated by intrusive contacts. The sheet of diabase here lying on top of the quartzite and forming the summit of Black Peak has a thickness of at least 300 feet, while it is not known how much more has been removed by erosion. In the workings of the Grey mine, in Copper Gulch, masses of quartzite and limestone strata were found irregularly distributed in the diabase down to the sixth level, at a depth of about 300 feet. Below this the shaft is in diabase for 400 feet, although blocks of inclosed strata may possibly be encountered when drifting is begun. About half a mile east of the saddle at the head of Copper Gulch (northeast corner of the Globe Special map) a considerable body of limestone strata belonging to the Globe formation is inclosed by the diabase, while just south of the limestone, at an elevation of about 300 feet above it, the same mass of diabase passes with an intrusive upper contact beneath conglomerate, grits, and quartzite of the Apache group. Stratigraphically the limestone belongs above the quartzites, but here it lies enveloped in the diabase at least 500 feet below its normal position. A similar condition exists in the Old Dominion mine, a block of limestone occurring isolated in the diabase that forms the general footwall of the Old Dominion fault. Similar examples of the displacement and isolation of blocks of strata at the time of the diabase intrusion might be cited from other parts of the quadrangle. Some of these are evident from an inspection of the general geological map, but the detailed description of all is not necessary.

So far as its upper contact is preserved the great body of diabase north of Globe has the general character of a thick sill or laccolith. On Buffalo Ridge and elsewhere the intrusive rock passes under the quartzites with a contact which in general follows a bedding plane. But even as regards its upper surface, this irregular mass, which forced itself into and around the blocks of faulted strata, is a sill only in a very general way. Of its lower surface nothing is known. Although in other parts of the region, and in the canyon of Salt River northwest of the quadrangle, the diabase forms distinct sills, none of them are demonstrably so thick as this mass, which, if we disregard the blocks of included strata, is shown by the workings of the Old Dominion and Grey mines to reach a thickness of over 800 feet. Whether it rests upon the lower beds of the Apache group or has followed in general the pre-Cambrian surface upon which the sediments were laid down, or whether it extends downward as a batholith of indefinite depths, are questions which at present can not be answered.

Petrography.—When fresh the diabase typical of the larger areas in the quadrangle is a tough, heavy, dark-gray, holocrystalline rock of medium grain. The minerals readily visible to the unaided eye are plagioclase, augite, and iron ore. The augite is often particularly noticeable on natural surfaces of the rock, as it forms flashing poikilitic blotches, sometimes 2 centimeters in breadth. The weathered rock is usually greenish, and the diabase masses can often be distinguished from a distance by the dark-olive hue of their bare slopes. Hard residual nodules of various sizes and curious nodular surfaces are extremely characteristic of the disintegration of the typical diabase. The rock crumbles to a greenish sandy soil (saprolite), embedded within which are residual kernels of sound rock ranging in size from peas up to a foot or more in diameter. The larger masses have very characteristic lumpy or warty surfaces, and with the further progress of disintegration these lumps separate as small nodules. Close examination of these little bodies shows that their form and their resistance to disintegration are dependent upon the presence of rounded, poikilitic crystals of augite. In addition to the knobs with which exposed surfaces of the diabase are usually studded, there are sometimes present well-marked projection ribs or ridges an inch or two in height. These are due to the development of secondary hornblende along minute fissures in the rock, and the resistance of this mineral to weathering.

Thin sections examined under the microscope show a perfectly fresh ophitic aggregate of calcic labradorite or bytownite, faintly brownish augite, olivine, and a little biotite, magnetite, apatite, and titanite. In many cases, as, for example, the rock on the summit of Black Peak, the diabase is so fresh that the olivine, which occurs in the usual rounded forms more or less inclosed in the augite, shows scarcely a trace of serpentinization. The augite is broadly poikilitic, the apparently isolated angular areas between the partly idiomorphic crystals of plagioclase showing optical continuity over a large part of the microscopic slide.

Although the diabase maintains its general character and appearance far beyond the bounds of the Globe quadrangle, it is subject to certain local variations. In part these are due merely to alteration, the olivine being serpentinized and the augite wholly or partly changed to green uralitic amphibole. Every large mass of the diabase is made up in part of such uralitic facies, and some of the smaller bodies are more or less uralitic throughout.

Near the intrusive contact of the diabase with other rocks the former exhibits well-marked textural variation. It is generally more finely crystalline, and may be nearly aphanitic. Vesicular structure is not infrequent, and is particularly characteristic of intrusive contacts of the diabase with the Globe limestone. Such contacts may be well studied east and southeast of Black Peak, near the Murphy ranch, and in the southeast corner of the quadrangle.

In contact with the quartzites of the Apache group the diabase is usually nearly aphanitic and contains small vesicles filled with chlorite, calcite, quartz, or specularite. This contact modification, which is usually reddish in color, while the typical diabase is dark gray or green, is well exposed south of the saddle at the head of Copper Gulch, a mile and a quarter a little west of south from Barnes Peak, and elsewhere in the quadrangle where the two rocks are in eruptive contact.

The contact facies are, as a rule, much decomposed. The microscope shows that the augite and olivine have been changed to chlorite, serpentine, calcite, and ferric oxide, while the plagioclases have become obscure aggregates of calcite, quartz, kaolin, and other secondary products. These contact rocks were originally vesicular basalts, and some of them appear to have been more or less glassy.

Other local facies of the diabase come from variations in the relative amounts of feldspar and ferromagnesian minerals present. Irregular streaks in which the augite and olivine are less abundant than usual are not uncommon, and such local facies are noticeably light colored and feldspathic as compared with the normal diabase.

The diabase occurring as dikes cutting the pre-Cambrian complex is usually more finely crystalline than that of the larger sills, and may be nearly aphanitic.

Contact metamorphism.—The metamorphic action of the diabase, even when intruded in great masses into quartzites and limestones, is remarkably slight. The only effect discoverable in the Globe limestone is the development of a little coarser crystalline texture, which may extend for only a few inches from the contact. Even this alteration is not always recognizable. The quartzites often show no perceptible alteration at the diabase contact. In one case, however, for a distance of 15 feet or more from the contact the quartzite was observed to be thickly speckled with small greenish spots which the microscope showed to be little nests of chlorite. But as these spots are very similar to the little spherical aggregates of sericite (described on page 3), which are not clearly connected with the intrusion of the diabase, it is by no means certain that they are really the result of contact metamorphism.

Age.—Since the large sills are intrusive into the Globe limestone as well as into the Apache group and older rocks, the main diabasic eruption must have taken place after the close of the Carboniferous. The whole region was afterwards greatly eroded before the eruption of the dacite, the latter event being assigned with some probability to the Tertiary. The great diabase intrusions are accordingly referred provisionally to the Mesozoic, although there are no data available to fix within that era the particular period to which they belong.

The age of the dark-colored, nearly aphanitic dikes and small intrusive masses occurring in the pre-Cambrian complex is not directly determinable. Their geological position leaves it uncertain whether they belong to the intrusive period represented by the diabase sills or to the much later date of the post-dacitic eruption of olivine-basalt described on page 10. The distinction has accordingly been made on petrographic grounds, certain fresh, more or less glassy masses, such as that just north of the Pinal ranch, being correlated with the later eruption and colored on the map as olivine-basalt, while the more coarsely crystalline uralitized dikes are considered as probably contemporaneous with the diabase sills. The magmas of the two eruptions were practically identical.

DIORITE-PORPHYRY.

Definition.—By diorite-porphyry is usually meant a holocrystalline intrusive rock having the chemical and mineralogical composition of diorite, but characterized by porphyritic structure, with a well-defined, fine-grained groundmass. The rocks here described under this head are generally decomposed, and it is not certain that all of them were originally typical diorite-porphyry.

Occurrence.—The diorite-porphyry occurs most characteristically as sills, ranging in thickness from 1 to 50 feet, in the lower, shaly member of the Apache group, and less frequently as dikes and small irregular intrusive masses. Small sills are also occasionally found intruded between the beds of the Globe limestone, and in the granitic rocks just below the base of the sedimentary series. On account of their small size the sills are not shown on the geological map. They are rarely absent, however, from the lower part of the Apache group, and are well exposed in the southeast and northwest corners of the quadrangle.

Just north of the Old Dominion mine a dike of diorite-porphyry (shown on the geological maps) cuts the diabase, and can be traced from the point where it emerges from beneath the dacite flow almost up to the Buffalo mine. A smaller dike of decomposed diorite-porphyry occurs also in diabase near the Ninety-six shaft of the Continental mine.

In the Apache Mountains, outside of the quadrangle, occur considerable masses of post-Cambrian diorite-porphyry which is very much fresher than any of the rock just described. It is not yet known whether the Apache Mountain diorite-porphyry is contemporaneous with or younger than the decomposed sills of the Globe quadrangle.

Petrography.—The rock of these sills and dikes is always more or less decomposed, and its color is usually light yellowish or greenish gray. In the fresher specimens small, dull-white phenocrysts of feldspar, and sometimes minute prisms obviously pseudomorphic after hornblende, are recognizable with the unaided eye. Owing to its ready decomposition the rock easily crumbles, and coherent specimens are obtainable with some difficulty.

Microscopic examination of thin sections shows that the rock is generally too much altered to allow of its precise classification. The plagioclase phenocrysts, apparently for the most part andesine, are partly altered to aggregates of calcite, sericite, and probably kaolin. The original hornblende and possibly some biotite are completely changed to chlorite and other secondary products. Small embayed phenocrysts of quartz, while lacking in some facies, are fairly abundant in others, and it is quite possible that these decomposed, greenish-gray sills and dikes embrace rocks of more than one type and were intruded at different times. The groundmass is usually a finely crystalline aggregate of plagioclase, quartz, and possibly some potassium feldspar, the whole showing the patchy and indistinct extinctions common to many dioritic porphyries when seen between crossed nicols. The dike north of the Old Dominion mine is a quartz-free diorite-porphyry, with some chlorite which is apparently pseudomorphous after biotite.

Age.—As the diorite-porphyry cuts the Globe limestone it is post-Carboniferous. Alongside the county road to Florence, just beyond the southern edge of the quadrangle, dikes of this eruptive, here apparently containing no quartz, cut the diabase and are therefore younger. The same relation obtains in the case of the dikes north of the Old Dominion and near the Continental mine. As a rule, however, the two rocks are rarely found in juxtaposition, and this fact, taken in connection with the general decomposition of the diorite-porphyry and its occurrence as regular and often thin sills in blocks of strata which have been faulted and shifted about at the time of the diabase intrusions, strongly suggests that a part of the porphyry, particularly that which may be provisionally termed quartz-diorite-porphyry, represents a period of eruptive activity anterior to the great invasion of diabase, and consequently that the more or less decomposed intrusives here described as diorite-porphyry are not all of the same age.

TERTIARY.

DACITE.

Definition.—The dacites 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-dacites are closely related to the rhyolites, which they often much resemble. The relation of the dacites to the rhyolites and andesites among the volcanic rocks is similar to that of the quartz-diorites to the granites and diorites among the plutonic rocks.

Occurrence.—Owing to its abundance, peculiar weathering, and often striking topographic expression, dacite is one of the most conspicuous rocks in the region, and is familiarly known to rancher and miner alike as "trachyte." It forms one or more effusive sheets or flows, often locally associated with underlying beds of tuff. The probable original continuity of this flow has been greatly obscured by faulting. The maximum thickness is unknown, but existing remnants show that it must have exceeded 1000 feet. In spite of vigorous post-dacitic deformation of the region, it is clear that the flow was poured out over an irregular surface in whose ravines and valleys the Whitetail formation had previously accumulated.

As it is one of the youngest rocks in the quadrangle and is of fairly resistant nature, the dacite caps many of the hills under 6000 feet in elevation, particularly in the northwestern part of the area. It lies upon various rocks, many of which are soft and easily eroded, and is consequently a frequent cliff-maker, responsible for much of the minor ruggedness of the topography. In natural exposures the dacite varies in color from light-pinkish-gray to nearly black. It has a tendency to weather into large, rounded, bowlder-like masses, forming characteristically rocky surfaces which are difficult to traverse. These loose masses are frequently over 6 feet in diameter, and, owing to differential weathering of glassy and lithoidal portions of the rock, often show curiously pitted exteriors. The origin of the bowlders is traceable to a rather irregular division of the rock into rude cuboidal blocks, by systems of joints which are often not visible until brought out by initial disintegration. Such joints can be well seen in the cliffs along Mineral Creek at the Sixty-six ranch, where various intermediate stages may be observed between angular joint blocks and rounded bowlders. As a rule the weathering of the dacite is a very superficial process, being confined to the disintegration of exposed surfaces. Decomposition has rarely penetrated the rock for more than a fraction of an inch.

By far the most abundant facies is a light-pinkish, inconspicuously porphyritic biotite-dacite, which preserves great uniformity of color and texture over the entire region. This is the rock to which the name "trachyte" is erroneously but unanimously applied by the people of the Globe district. Of far less abundant occurrence is a dark-gray, glassy facies, often showing distinct flow banding, and of typical vitrophyric structure, which is frequently found at the base of the dacite. It is merely the quickly cooled glassy bottom of the lava flow. It is not always present, but when it does occur it invariably intervenes between the pink dacite and the underlying rocks. Beneath this vitrophyre, and not always easily separated from it in the field, are certain local accumulations of bedded dacitic tuffs. These are soft, often plainly detrital rocks, ranging in tint from white to pale lemon-yellow or gray. They were laid down in small local basins, and are often absent, the dacite resting directly upon the older rocks.

The largest mass of dacite occurring in the Globe quadrangle lies in its southwest corner. This is the rock which forms Hutton Peak, and through which Mineral Creek has cut its narrow gorge south of the Sixty-six ranch. It is continuous with the dacite just north of the Pinal ranch, and extends for a considerable distance westward beyond the bounds of the quadrangle.

The entire mass is apparently part of a single flow which has undergone deformation and erosion. It culminates at 5608 feet in Hutton Peak, and slopes gently southward, with the exceedingly rugged surface characteristic of this rock. Near the Pinal ranch the dacite rests on granite, the surface of the latter having been irregularly eroded before the eruptive rock covered it. Southeast of Hutton Peak it rests upon the Pinal schist. The mass of the flow is composed of the pink biotite-dacite, but the darker, more glassy, and highly vitrophyric facies described above is frequently found where the base of the flow is exposed. This variety is usually less than 10 feet in thickness, and is apparently an integral part of the main flow. It is not always present, and pink dacite sometimes rests directly upon the granite or schist.

The quartzites south of Mineral Creek between the Sixty-six ranch and Government Spring, at the northern end of the Dripping Spring Range, appear to have formed an island-like mass around which the dacite flowed and which it possibly formerly covered.

In the northwestern part of the quadrangle the principal body of dacite is that culminating in Webster Mountain. This is evidently a very thick portion of the flow, as shown by the canyons that have been excavated in it without exposing its base. The area is partly inclosed by peripheral faults, whereby this portion of the flow has been relatively dropped with reference to the surrounding older rocks, and its edges in some places brought against the latter. The bounding slopes of this fault block, particularly on the west, north, and east, are often precipitous, and good exposures of the bottom of the flow are rare. The rock is the prevailing pink dacite, but the dark vitrophyric facies which occurs only at the bottom of the flow is exposed on the east slope of Webster Mountain and at the head of Willow Spring Gulch.

Considerable masses of dacite occur along Pinto Creek, forming picturesque cliffs south of Horrell's ranch, and the same rock forms the pinnacles and abrupt western wall which look down into the gorge of Pinto Creek south of the mouth of Gold Gulch.

In the much faulted country between Webster Mountain and Pinal Creek pink biotite-dacite caps most of the higher hills, including Sleeping Beauty Peak. The bluffs overlooking this creek west and south of Horrell's home ranch are, as the map shows, the eroded edge of a much warped and probably faulted fragment of the flow which rests on diabase and forms an apparent synclinal basin, open to the south and filled with Gila conglomerate.

Half a mile southwest of Black Warrior the massive dacite rests upon 40 or 50 feet of tuff containing many fragments of the underlying Pinal schist. The ores of the Geneva, Dadeville, and Montgomery claims occur in this tuff. The area on the south slope of the hill west of Black Warrior, colored on the geological map as dacite, is composed chiefly of this tuff, most of the overlying massive dacite having been eroded away.

North and east of Globe the dacite flow is represented by an irregular and interrupted remnant which overlies quartzite, limestone, and diabase, and dips gently southwestward under the Gila conglomerate. This outcrop attains a maximum width of about three-fourths of a mile north of the Old Dominion mine. It lies upon an uneven surface, and was considerably eroded before the Gila formation was deposited, since the latter rests directly on limestone and quartzite southeast of the mine. A single tiny remnant of the dacite occupying a little saddle in quartzite 5½ miles north of Globe, at an elevation of 4500 feet, is the only vestige of the former extension of the lava flow over the extreme northeastern portion of the district. In the southeast quarter of the quadrangle the dacite does not occur.

Petrography.—The color of the freshly fractured dacite is light gray, usually with a decided pinkish tinge. The rock is rough to the touch, and at first glance appears to be more porous than is actually the case. It is firm and tough, rather than hard and brittle, and is easily quarried and shaped. Owing to the small size of the phenocrysts, which rarely exceed 3 millimeters in length, the porphyritic structure is not conspicuous, and the rock shows a rather uniform texture. Small included fragments of other rocks are often abundant, and in most cases these are of diabase. Such inclusions are particularly numerous and well exposed in a little gorge cut through the eruptive rock 1½ miles northeast of Government Spring; but there are few masses of the dacite which do not contain some of these inclusions.

Close examination of a fresh surface of the dacite shows numerous phenocrysts of feldspar, many of which have the striated cleavage faces of plagioclase, while a few are apparently orthoclase (sanidine). Sparkling hexagonal scales of biotite, rarely over a millimeter or two in diameter, are scattered through the rock, their number varying considerably in different specimens. Phenocrysts of quartz are always present, but are not conspicuous, and occasionally small black phenocrysts of hornblende can be detected. All of the phenocrysts are embedded in a dull, pinkish, semi-lithoidal matrix, which gives the general tint to the rock.

Seen under the microscope the prevalent pinkish variety of the dacite shows vitrophyric structure. The phenocrysts of feldspar, quartz, biotite, and occasionally of hornblende are inclosed in a streaky or ropy, semi-opaque, glassy groundmass, showing the beautiful billowy flowage lines characteristic of this structure in andesitic and rhyolitic rocks.

The feldspars, which are principally plagioclase, are all more or less rounded in outline from magmatic corrosion. They are perfectly fresh and clear, and range from labradorite ($ab_1\ an_1$) to andesine ($ab_5\ an_3$). Zonal structure is common, the outer shells being less calcic that the inner.

The potassic feldspar is much less abundant than the plagioclase, and is the clear vitreous variety of orthoclase commonly known as sanidine. It has been more strongly corroded than the plagioclase, and presents rounded or even enlarged outlines. It shows the usual cleavages, optical orientation, index of refraction, and double refraction of orthoclase, but as far as observed is not twinned. It is more frequently irregularly cracked than the plagioclase, and fragments of the broken crystals have sometimes been displaced by movement of the magma. The ratio of the andesine and labradorite to the orthoclase is probably greater than ten to one.

The quartz presents no features of exceptional interest It is deeply embayed and destitute of all crystal boundaries, as is common in rocks of this type. It is perhaps a little more abundant than the orthoclase, but much subordinate to the plagioclase.

The biotite is the common conspicuously pleochroic variety, with the strong absorption usual in andesitic rocks. It sometimes shows magmatic alteration, which has involved not only the outer surface of the crystal but its whole mass. This altered mica has lost part of its color and strength of pleochroism, the lamellæ have frayed out at the ends and split apart, and the whole is filled with specks of opaque iron ore.

Intergrowths between the different phenocrysts are sometimes met with. Quartz and andesine rarely form micropegmatite, and andesine or labradorite are occasionally intergrown. The accessory constituents are a green hornblende, occurring in small prismatic crystal fragments, apatite, titanite, zircon, and a little magnetite.

The groundmass of the dacite is glassy, and notwithstanding the thickness which the flow must have attained, never exhibits more than incipient crystallization. Globulites, trichites, feldspathic microspherulites, and an indeterminate ferritic dust which renders the groundmass semi-opaque and gives the pink tint to the rock, are common. In some cases the groundmass shows the minutely divided and shadowy double refraction characteristic of the devitrification of siliceous glasses into obscure aggregates of quartz and feldspar. But distinct well-formed crystals of younger growth than the evidently intratelluric phenocrysts do not occur. The rock is a vitrophyric biotite-dacite, and belongs with the hyalo-dacites of Rosenbusch.

It has been noted on this page that there is frequently found at the bottom of the dacite flow a more glassy facies, often showing megascopical flow banding. This rock varies in color from light to dark gray. In many specimens the banding is obviously due to the alternation of streaks of glistening black glass with those of more lithoidal material. Small included rock fragments, particularly of diabase, are perhaps more numerous in this facies than in the more common pink dacite described in the preceding pages. The phenocrysts recognizable by the unaided eye are of the same kind as those of the latter rock.

Under the microscope this glassy dacite differs from the pink facies chiefly in the groundmass, which, being less crowded with incipient crystal growths, is more transparent and is often a pale-brown, slightly globulitic or trichitic glass. Microscopic flow structures are developed in great profusion and beauty, and the rock is typically vitrophyric. The phenocrysts are the same as in the more lithoidal dacite, but green hornblende occurs a little more abundantly in the thin sections examined, and is sometimes nearly as abundant as the biotite.

A single angular fragment of a diopside-like pyroxene was noted in one thin section, but this mineral is apparently not a regular constituent of the dacite.

The other accessory minerals are zircon, apatite, titanite, and magnetite, as in the common lithoidal dacite.

Occasionally there is found associated with the gray vitrophyre just described a yet more glassy facies. This is a gray, brittle, volcanic glass, of greasy luster, in which can be seen small phenocrysts of fresh feldspar, quartz, and biotite. Under the microscope the rock appears as a colorless perlitic glass containing scattered phenocrysts of plagioclase, orthoclase, quartz, and biotite, and minute microlites of feldspar.

The tuffs which have been described as occurring locally at the base of the massive dacite are nearly white rocks, which are sometimes exceedingly troublesome to separate in the field from the overlying massive dacite. The separation is particularly difficult in the case of a white or slightly pinkish tuff which immediately underlies the gray vitrophyric dacite at several points in the northwestern part of the quadrangle. This is a firm rock, showing small crystals of fragments of feldspar, quartz, and biotite in an abundant, uniformly fine-grained base. It might easily be taken for a massive lithoidal rhyolite. Under the microscope fractured or corroded crystals of plagioclase, biotite, hornblende, and quartz lie thinly scattered in a dusty, gray, glassy groundmass, which somewhat indistinctly reveals the reentrant curves and sharp points of minute glass sherds—the characteristic structure of glassy volcanic ash. With nicols crossed it is seen that very little true glass remains, the groundmass having been changed by devitrification into a very minute aggregate of indefinite and shadowy crystal forms. Calcite, unknown in the massive dacite, is here abundant, not only throughout the devitrified glassy base, but as an alteration product of the plagioclase. In this alteration there is none of the general clouding and breaking down of the feldspar, as is often seen in weathered rocks, but the calcite is separated by a sharp boundary from the perfectly clear and fresh plagioclase at the expense of which it is forming.

The tuffs occurring below that just described are usually plainly clastic rocks of light-gray or pale-yellow tints, varying in lithological character from point to point. The microscope shows them to be glassy volcanic ashes, containing fragments of the same minerals that occur as phenocrysts in the dacite, with occasional particles of diabase or other foreign rock, inclosed in a devitrified glassy base. They usually contain abundant calcite.

Age.—There are no available data for fixing the exact date of the dacite eruption. It is known to have occurred long after the supposedly Mesozoic intrusion of diabase, for the latter rock was extensively eroded before being covered by the dacite. On the other hand, it clearly antedated the development of the present topography. The dacite is therefore provisionally considered of Tertiary age. According to an oral communication from Mr. W. Lindgren, a very similar rock occurs at the base of the extensive volcanic series at Clifton, indicating that it may belong to the earlier part of the Tertiary.

QUATERNARY.

BASALT.

Definition.—Basalt is a dark, heavy rock of the same chemical and mineralogical composition as diabase, but usually more finely crystalline and often showing vesicular or glassy facies. This rock is of widespread occurrence in the form of effusive or surface flows and as small dikes.

Occurrence.—The largest mass of basalt within the quadrangle occurs near the western border of the area, as a flow from 50 to 150 feet thick, intercalated in the Gila conglomerate south of Gold Gulch. Other small masses occur between Gold Gulch and Horrell's west ranch. One of the latter is a sheet about 10 feet thick forming a small area on the crest of a dacite ridge about 2 miles northwest of the Continental mine. It rests directly upon the pink dacite, and although darker in color weathers in similar rounded masses. It may possibly represent a local eruption. Other bodies occur at lower elevations southwest of the ridge. The relation of these to the dacite is not clearly shown. They overlie the Whitetail formation, and apparently underlie the dacite, but whether they represent a thin intrusive sheet or a pre-dacitic surface flow could not be determined. Inasmuch as the known occurrences of similar basalt are in this region post-dacitic, these small masses are provisionally regarded as intrusive, and as contemporaneous with the basalt flow south of Gold Gulch. It is not unlikely, however, that future work west of this quadrangle will establish the existence of a pre-dacitic basalt flow. On Manitou Hill, overlooking Pinto Creek, small intrusive masses of the basalt have broken through the granitite and schist and probably mark the vents whence the basaltic flow issued. In the southwestern portion of the quadrangle are two small intrusive masses of basalt which are petrographically somewhat different from the masses above described, and may possibly belong to a different period of eruption. These form the area just north of the Pinal ranch and the tiny body which cuts the granite-porphyry of the Hog ranch dike. It is possible too that some of the smaller aphanitic dikes occurring in the schists and granitic rocks of the main Pinal Range are to be correlated with the basaltic rather than the diabasic eruption.

Petrography.—The flow south of Gold Gulch, the small mass on the dacite ridge to the north, and the intrusive bodies of Manitou Hill are all composed of typical dark-gray olivine-basalt, showing small phenocrysts of feldspar, augite, and olivine, with occasional blebs of dark glass, in a dense, nearly aphanitic groundmass. The olivine phenocrysts are often partly altered to brown pseudomorphs of iddingsite. The basalt of the main flow is often vesicular, many of the vesicles being filled with calcite. The rock of the doubtful masses occurring between the Whitetail formation and the dacite is a somewhat grayish decomposed basalt in which the olivine phenocrysts have been wholly altered to soft, earthy, ferruginous pseudomorphs, which frequently have a bronze luster.

Under the microscope the rock of all the areas except those at the Pinal ranch and southwest of the Hog ranch appears as a perfectly normal olivine-basalt, in which phenocrysts of olivine, anorthite, and augite, in varying proportions, lie in a usually holocrystalline, intersertal groundmass consisting of anorthite laths, augite, and iron ore. All the minerals are fresh except the olivine, which shows various stages of alteration into the usual reddish-brown iddingsite, fibrous green serpentine, and more obscure products.

The rock of the Pinal ranch area is dark gray, nearly aphanitic, and so traversed by rusty, conchoidal fractures as to render the collection of a sound hand specimen very difficult. The microscope shows a few minute lath-shaped phenocrysts of anorthite lying in a hyalopilitic groundmass made up of microlites of plagioclase, grains of augite and iron ore, and glass. Olivine was not recognized.

The basalt of the small mass intrusive in the Hog ranch dike is a little more coarsely crystalline than that near the Pinal ranch, and shows small porphyritic crystals of augite and plagioclase just visible to the unaided eye. Under the microscope the thin sections show small rounded phenocrysts of augite and olivine with laths of anorthite, lying in a very fine holocrystalline groundmass of feldspar microlites with granules of augite, olivine, and iron ore. Of rare sporadic occurrence are phenocrystic grains of corroded quartz surrounded by reaction rims of augite with intersertal brown glass.

Contact metamorphism.—Where the small dike-like mass of basalt breaks through the Pinal schist on Manitou Hill the latter rocks are transformed near the contact into a hard, reddish-brown, partly brecciated material which resembles a baked quartzite rather than the usual schist. Under the microscope the metamorphosed rock is seen to be made up of irregular dark bands consisting of plagioclase and quartz rather obscurely crystallized and crowded with microscopic particles of some dark pigment, alternating with clear bands consisting chiefly of quartz. The quartz grains, however, are rounded and embayed and are held in a web of brownish microlitic glass. This glass is apparently the result of partial fusion, or of the corrosive action of the basaltic magma, acting along the surfaces where the original allotriomorphic quartz grains came in contact with one another. The process has attacked the grains from their peripheries, and has rounded and embayed their outlines. A similar alteration has been effected by the basaltic magma on numerous inclusions of a light-gray, fine-grained, granitic rock. Thin sections show that these inclusions are usually enveloped in a film of pale-brown glass, which has also penetrated the inclusion interstitially for some distance from the actual contact.

Age.—North of Gold Gulch the small mass of basalt on the ridge top rests upon dacite, and is therefore younger. The main flow, between Gold Gulch and Manitou Hill, rests upon lower beds of the Gila conglomerate and is in turn overlain by later portions of the same formation. It is accordingly of the same age as the latter formation, and may be provisionally referred to the early Pleistocene. Flows of basalt are mentioned by Gilbert, in the Wheeler Survey reports, as occurring in similar positions within the Gila conglomerate in the tributary valleys of the upper Gila. The age of the basalt just north of Gold Gulch, at the edge of the quadrangle, is, as previously indicated, somewhat doubtful, but is provisionally considered Quaternary. Fully as uncertain is the age of the mass at Pinal ranch and of the little body cutting the Hog ranch dike of granite-porphyry. These are included with the Quaternary basalt merely on the ground of petrographical similarity. They may, however, be older.

GEOLOGICAL STRUCTURE.

GENERAL CHARACTERIZATION.

The preceding pages have been occupied with a description of the rocks of the Globe district—the rough materials from which the forces of deformation and erosion have fashioned the existing geological structure and the visible configuration of the region. Before passing to a consideration of the historical sequence and structural results of the geological processes which have wrought upon the rocks, it is desirable to devote some attention to the present expression and significance of that particular form of deformation which is preeminently characteristic of the district.

If one stands upon the top of Webster Mountain and looks northward or eastward over the hilly country spread out before him, he is struck with the apparent chaotic distribution of the various rocks, as indicated by their respective and characteristic tints in the landscape. Here and there patches of limestone gleam white through the thin screen of scanty vegetation, while areas of quartzite are indicated by a reddish color, and masses of diabase by a dull-olive tint. The beds show no trace of folding, and one looks in vain for any persistent or regular structure that may account for this rocky patchwork. A similar view is obtained on looking southeast from the steep southeastern slope of the Pinal Mountains over the region just outside of the bounds of the quadrangle. Here, however, the structure has more regularity, and the manifold repetition of beds of white limestone overlying reddish quartzites, all dipping gently to the southwest, is at once suggestive of faulting.

That this suggestion is in fact the clue to the dominant structure of all that part of the quadrangle in which the Apache group and Globe limestone are represented becomes evident upon closer study. In traversing this faulted region one steps with bewildering frequency from quartzite to limestone, granite, or diabase, the line of separation being often clearly defined by a fault breccia forming a bold outcrop that may be followed for miles. Probably few equal areas of the earth's surface have been so thoroughly dislocated by an irregular network of normal faults, and at the same time exhibit so clearly the details of the fracturing. An inadequate conception of the extent of this regional shattering may be had from the geological map. The faults there shown, however, are merely those which attain some structural importance, and the numerous little fault blocks that they bound are themselves cut by faults far too many and too closely spaced for representation. For a considerable part of the northwestern portion of the quadrangle the term regional brecciation perhaps most aptly expresses the actual conditions there found.

Probably the majority of the faults have throws of less than a hundred feet, and their marked influence upon the general structure of the region is dependent, as a rule, rather upon their enormous number than upon great individual displacement. In spite of much variety in strike and dip, the general result of the faulting has been to drop, by successive steps toward the northeast, beds having a general southwesterly dip, the throws of the faults being such as to offset in the main the effect of the dip, which would otherwise rapidly carry the strata above or below the present erosion surface of the quadrangle. It is due to these faults of generally moderate displacement that the Globe limestone, for example, retaining in most cases a southwesterly dip of from 20 to 40 degrees, is scattered broadcast in small areas over the quadrangle.

Much of the structure of the region is partly dependent upon faults which no longer appear as distinct dislocations and are not represented by fault lines on the geological maps. These are the generally northwesterly or northeasterly fractures which immediately preceded or accompanied the great diabase intrusion and which, from their close connection with this event, may be conveniently distinguished as intrusion faults. They became, at the time of eruption, channels for dike-like connections between the sills, and were important factors in determining the form of the molten mesh in which the blocks of strata were inclosed. Most of the surfaces of dislocation were transformed to eruptive contacts, with which, however, planes of later faulting frequently in part coincide, as in the case of the Old Dominion fissure.

In most regions of diversified topography underlain by stratified rocks the dominant structures are due to folding modified to a greater or less degree by faulting. In the Globe district on the other hand, the structure, where not traceable directly to the effect of igneous intrusions, is the result of faulting, while folds are either entirely absent or are represented by an occasional gentle and structurally unimportant buckling of the strata in some fault block.

FAULTS.

Evidence of faulting.—With probably not more than a dozen exceptions, the several hundred faults shown on the map were actually traced on the surface, usually by the aid of a fault breccia. Such a breccia is invariably present where Apache quartzite forms one or both walls of the fissure. It is commonly made up of angular fragments of quartzite, with occasionally rounded pebbles dragged in from some conglomerate bed dislocated by the fault, the whole being embedded in a more or less rusty matrix of siliceous detritus, and often cemented by oxide of iron. Sometimes fragments of diabase, schist, or other rocks traversed by the fault are mingled with the quartzite, and in a few cases, where faults cut Pinal schist, the breccias are composed entirely of fragments of the latter rock. But by far the greater number of the fault breccias in the region consist chiefly of crushed quartzite.

These quartzitic breccias are frequently so indurated as to be more resistant than the rocks on either side, and they then outcrop boldly as ragged walls stretching across the country. Examples of such indurated breccias are abundant over the northern half of the quadrangle. One forms a conspicuous crag by the roadside about 4 miles northwest of Globe. Another separates limestone from diabase on the northwest side of Big Johnnie Gulch (see the Globe Special map). Still others stand out prominently south of the trail from Granite basin to Horrell's west ranch, and notable breccias of schist fragments, showing considerable alteration and mineralization, occur on Pinto Creek near the mouth of Cottonwood Gulch.

Frequently the faults bring into juxtaposition rocks unequal in resistance to disintegration, and a scarp of more or less topographic prominence results from differential erosion. The region affords many examples of such scarps, where hard Apache quartzites are normally faulted against crumbling Ruin granite. Such scarps are of purely erosional origin, depending upon the relative hardness of the rocks and not upon the throw of the fault.

Where pronounced topographic expression fails, there is still usually no great difficulty in actually tracing the course of a given fault over a country where the character and attitude of the rock underfoot is rarely in doubt, and where the outcrop of the fault plane is confined within the limits of the single step that usually suffices to pass from one rock to another. Without such clear exposures it would be impossible to express the complex structure other than by the crudest and most inaccurate generalizations. As a rule, the chief embarrassment lies not in finding the evidence of dislocation, but in determining which one of many faults shall be mapped as structurally the most significant where it is impossible to show them all, and, amid the general shattering, identifying throughout its course, the particular fault originally selected.

Faults wholly in diabase or limestone are usually not conspicuous. Their courses in the former rock are often marked by zones of brecciation which are commonly stained black by oxide of manganese and sometimes mineralized with salts of copper. The passage of a fault through limestone may produce considerable brecciation, which, however, is likely to be so healed by recrystallization of the calcite as to be detected with some difficulty, as in the case of the Old Dominion lode north of the Hoosier shaft.

While only a very small proportion of the faults are perceptibly mineralized, many of them have been superficially prospected, and the study of some of the more obscure dislocations of the region has been facilitated by that remarkable instinct which guides the impartial pick of the prospector to the discovery of fissures, irrespective of the wealth or poverty of their mineralization.

The evidence of the existence of intrusion faults associated with the diabase eruption is of a more general character than that of the later faults directly traceable on the surface. In a few instances the diabase can be observed in undisturbed eruptive contact against a regular surface of dislocation cutting across the bedding. But in other cases later movement has taken place along this contact, and the original character of the latter is inferred from the petrography of the diabase near the fissure and from the demonstrable inadequacy of the later faulting to account for all of the contiguous structures. In the Old Dominion fault, for example, the diabase of the footwall exhibits the texture characteristic of this rock near its original intrusive contacts. Furthermore, the existence of an included block of limestone in the diabase of the footwall is unexplainable if the relation of the diabase footwall to the limestone and quartzite hanging wall be supposed wholly due to faulting of later date than the solidification of the eruptive rock. Lastly, even if the limestone in the footwall be disregarded, the general geological evidence indicates that the faulting subsequent to the diabase intrusion has been of too moderate displacement to wholly account for the relative position of diabase footwall and limestone hanging wall. Thus the dacite in the upper workings of the Old Dominion mine shows a throw of less than 100 feet, a displacement wholly insufficient to explain the juxtaposition of diabase and limestone observed in the lower levels.

Still further evidence of the existence of these intrusion faults is afforded by the general structure of the region as expressed in the geological maps. It is apparent from these that extensive dislocation of the beds must have preceded or accompanied the diabase intrusion and prepared the blocks of strata for their erratic dispersal and rearrangement by the mass of molten magma forced into the shattered fabric.

Distribution of the faults.—The geological map shows that the faults are very much more numerous in the northern than in the southern half of the quadrangle. It is further apparent that the crystalline, schistose, and granitic complex forming the mass of the Pinal Mountains is nearly free from dislocations, while the latter are particularly abundant wherever the Apache group, Globe limestone, and diabase are the prevailing rocks. To some slight degree this difference is probably exaggerated, as faults in the granitic and schistose terranes are structurally inconspicuous, and may be overlooked in mapping, while even small faults may effect striking results in traversing beds of quartzite and limestone. Such slight exaggerations, however, can hardly detract from the great actual contrast presented on the one hand by the relatively simple structure of the Pinal Mountains, with their batholithic granitic masses irregularly invading the schists, and on the other by the complex dislocation of the northern half of the quadrangle.

No faults are shown within the large areas of Gila conglomerate, such as the Pinal and Mineral Creek areas. This is chiefly due to the fact that the more important faults antedate the deposition of this formation. It is undoubtedly cut, however, by faults of later age, but it is impossible to trace these for any considerable distance in material of this character. It is almost equally impracticable to detect or follow faults on the surface when dacite forms both walls of the fissure, and this fact is probably in part responsible for the paucity of the faults mapped within dacite areas.

Directions and character of the faulting.—The dominant faults of the Globe quadrangle fall into two groups, (1) those having a generally northeast-southwest trend, and (2) those striking approximately northwest and southeast. The dislocations of the first group dominate the structure of that portion of the Globe Hills lying just north of Globe and partly included within the area of the Globe Special map, and are conspicuous in the vicinity of Black Warrior and Lost Gulch. These faults have dips ranging from 55 to 90 degrees, the greater number being inclined about 75 degrees to the horizon. Northwesterly dips are about as frequent as southeasterly, and as the throw of the faults is apparently always normal, these dislocations have resulted in dropping downward-pointing wedges of geologically higher rocks between upward-pointing wedges of lower rocks (trough faulting). Thus on the south slope of Buffalo Ridge little areas of Globe limestone are inlaid in the quartzites of the Apache group, between the two branches of the Buffalo fissure. The Lost Gulch monzonite is a fault block separated on the northwest and southeast from geologically higher rocks that have been dropped against it by faults of this group.

The fissures of the second group dominate the structure in the area northwest of a line passing through Sleeping Beauty Peak and the Continental mine, and also in the extreme northeast corner of the quadrangle. The usual dip of these faults is about 75 degrees, and may be either to the northeast or to the southwest. West of Pinal Creek the net result of the many displacements has been a general dropping of the beds toward the northeast (step faulting). In the northeast corner of the quadrangle, however, the faulting already begins to partake of the character of that along the western face of the Apache Mountains, resulting in a general elevation of the beds toward the northeast.

Although faults belonging to the two groups just recognized have effected the most conspicuous structural results, they are associated with countless other fissures running in all directions and adding greatly to the complexity of the fault network. It has proved impossible to reduce these generally subordinate fractures to distinct groups or systems, and when it is remembered that for each dislocation shown on the map there are several others unrepresented, the reason for the failure is apparent. The region has not been dissected with mathematical precision along determined lines, but has been shattered by complex geological forces to an extent that is only less difficult of analysis than is a pane of shivered glass.

Among the many hundreds of faults occurring within the quadrangle are a number in which the character of the relative movement is not clearly shown, either because the dip of the fault is unknown or because the original geological horizons of the rocks adjacent to the fissure are in doubt. The majority of the faults, however, are clearly normal, while indubitable cases of reversed or thrust faulting are unknown.

Age of the faults.—The oldest dislocations distinctly recognizable in the structure of the Globe region are the intrusion faults associated with the post-Carboniferous (Mesozoic?) intrusion of diabase. From the close of this period of revolutionary eruptive activity to the probably Tertiary outbursts of dacitic lava, one process only, that of erosion, has left a perfectly legible record. It is believed, however, that important faulting also took place during this interval, and that some of the fissures which do not at present cut the dacite, particularly those showing mineralization, are actually of pre-dacitic age. The evidence for this belief is drawn from observations tending to show that the original sulphide ore of the district is older than the dacite, as will be more fully shown on a later page. The great faulting of the region—that tremendous shattering which finds its best expression in the northwestern portion of the quadrangle—followed the dacitic eruptions and involved their lava in the final structure of the resulting geological mosaic. The date of this fissuring which blocked out the existing structure of the country is not definitely known. As it occurred after the dacite eruptions and before the accumulation of the Gila conglomerate, it may provisionally and tentatively be referred to the latter part of the Tertiary. Its results can not always be clearly distinguished from the earlier faulting that followed the diabase intrusions and preceded the eruption of dacite. Faults once initiated have usually remained planes of weakness, along which there has been a revival of movement with each successive period of dislocation.

Numerous normal faults, usually of small throw, cut the Gila conglomerate and indicate the continuance of faulting into the Quaternary, while the presence of soft gouges and unconsolidated breccias in some of the Tertiary (?) faults shows that displacement is probably even yet in progress.

Although it has been ascertained that the faults of the region are of various ages, it has not been possible to discover that those of any period were distinguished by the possession of peculiar trends.

Geological significance and origin of the faulting.—As the earlier faulting was apparently closely followed by the intrusion of diabase, the circumstances under which the fracturing took place and the forces to which it was due are somewhat obscure. It is clear that rather thick and brittle beds were much fissured, and that the diabase, instead of being confined to regular and persistent sills, filled the fractures and in many cases greatly displaced the severed blocks of strata. The number of the dislocations and the comparatively small size of the fault blocks indicate that the beds did not, at the time of their rupture, lie under great load, and the facility with which the blocks were shifted by the magma is evidence that the intrusion also took place under no great superincumbent mass. The absence from the region of remnants of any rocks that might have overlain the Globe limestone when it and the older rocks underwent such extensive deformation affords additional ground for the conclusion that the faulting and intrusion must have taken place within a very moderate distance of the surface as it was at that time.

The present geological structure is such as to suggest that this earlier faulting was generally normal in character, but whether the original dislocation was due directly to the intrusive force of the diabase or to the earlier and perhaps independent stresses has not been determined.

The post-diabase and pre-dacite faulting, with which was connected the primary mineralization of the district, can not as a rule, be satisfactorily distinguished on structural grounds from the post-dacite faulting, partly because the latter, as in the Old Dominion fault, revived older dislocations.

In an attempt to deduce from the character of the post-dacitic faulting the circumstances under which it took place and the forces to which it was due, the fact that an overwhelming proportion of the faults are demonstrably normal is of prime importance. Normal faulting implies horizontal extensions and is incompatible with regional tangential compression, a conclusion which is strongly reinforced by the absence of folding in the stratified rocks of this district. The fact that beds when normally faulted tend to occupy a greater area than before their dislocation, can not, however, be taken as evidence that tangential tension has been a cause of the fracturing. The occurrence of such a stress is geologically improbable, and even if the stress were set up it would be relieved by the first fracture. The faulting of the Globe region is most satisfactorily accounted for by supposing stresses acting in directions more nearly vertical than horizontal, such as would result from differential elevations or subsidences over the area. The behavior of the rocks may be likened to that of a large and thick sheet of plate glass lying horizontal upon an uneven surface and fissuring under its own weight in consequence of unequal support. The generally rather thick-bedded and brittle rocks of the district are, however, far more easily and thoroughly fissured by geological processes than would be the relatively insignificant mass of glass by the feeble stresses produced in the suggested experiment.

It is certain that the rocks of the quadrangle when broken by the post-dacitic (Tertiary?) faulting were practically free from load other than their own mass. In the light of the geological history of the district it is inconceivable that any considerable thickness of rock should have accumulated in Tertiary time above the dacite and then have been completely removed, leaving no trace of its former presence. When the faulting occurred dacite was probably the surface rock over such considerable portion of the region as did not stand too high to be buried beneath the lava at the time of eruption. It was certainly the youngest rock occurring in any considerable mass within the district. Erosion has undoubtedly reduced the maximum thickness of the dacite since the period of dislocation. But such reduction does not affect the force of the statement that when the post-dacite faulting occurred the rocks involved, with the exception of the Gila conglomerate and the Quaternary basalt, were those now exposed in the region, and that the phenomena observed are those associated with rock fracturing taking place close to the surface and therefore under little or no load.

The results, as described in preceding pages, for the northern half of the quadrangle are such as might be expected under the conditions just outlined—a shattered, brecciated region cut by innumerable small normal faults showing varying local regularity in strike, which is more or less masked by the apparently haphazard trend of the countless smaller fractures. It is not known why the main crystalline massif of the Pinal Mountains escaped the minute dissection of the rest of the area. It is possible that its lithological character and the relation of the batholithic masses of granitic rocks to the schists presented elements of strength lacking in the surrounding areas, where stratified rocks and diabase prevail, and that it consequently moved as a unit in the general readjustment of the region by faulting.

The causes of the post-dacite and post-diabase faultings are deep seated and inscrutable. It is suggestive that here, as in the San Juan region of Colorado, the later fissuring followed or was correlated with an extensive transfer of volcanic material from its subterranean source to the surface. It is probable that there is a more direct connection between such volcanic paroxysms and the subsequent fissuring. The earlier, structurally less conspicuous, but economically more important, post-diabase dislocations were also preceded by great eruptive activity, and it is reasonable to regard this faulting also as a phase of regional readjustment after the widespread disturbances effected by the intrusion of the diabase.

The latest faulting of the Globe district, manifested by slips along earlier fault planes and minor dislocations of the Gila conglomerate, is regarded merely as an indication that the shattered structure of the region is still approaching by slow steps the goal of final equilibrium, which was not fully attained by the vigorous movements of the post-dacitic fissuring.

GEOLOGICAL HISTORY.

Pre-Cambrian time.—Long before Cambrian time that which we now know as the Globe region was part of a sea bottom upon which were accumulating fine grits and silts, probably derived from granitic rocks. The source of these sediments is unknown, and no trace of the ancient rocky floor upon which they were laid down is now visible. In the course of time sedimentation ceased, the beds were folded and compressed by forces acting in a generally northwest-southeast direction, were intruded by great masses of quartz-mica-diorite (the Madera diorite), and underwent crystalline metamorphism into the Pinal schists. Later intrusions of granite, granitite, and monzonite followed, and at the close of this period of plutonic eruptive activity the region had risen above the sea and become mountainous. A new physiographic cycle was thus initiated, which was probably well under way, however, before the constructive processes that have just been outlined were concluded. Before the rocks attained their final elevation erosion was vigorously at work, and upon becoming ascendant began the actual reduction of the mountainous topography, carrying it successively through the various intermediate stages of the geographic cycle to the final one of the nearly featureless, worn-down plain of old age—a peneplain.

So much, in brief, of pre-Cambrian history is decipherable from the character, structure, and texture of the older rocks. The cycle was run, and the initiation of Cambrian time was marked by subsidence and a fresh advance of the sea over what had so long been dry land.

Cambrian time.—The sea as it swept over the peneplain found it littered in part with fragments of quartz weathered out from veins in the schists and granitic rocks, and with smaller particles of feldspar and quartz derived from the disintegration of the granitic masses. The existence of particles of feldspar, which have remained fairly fresh to the present time, appears to afford some indication that the Cambrian climate was not conducive to soil formation or to abundant vegetation. These materials were slightly reworked by the waves into the Scanlan conglomerate of the Apache group, the remnants of which are now found resting usually upon the weathered and reddened surface of the Madera diorite and the granites, sometimes separated from the sound rock by several feet of pre-Cambrian granitic saprolite (disintegrated rock in place). The Scanlan conglomerate or its equivalent covered the Pinal schists as well as the plutonic rocks, but the former relationship is visible only in a few fragmentary exposures west of Black Warrior, where the Scanlan conglomerate is represented by a breccia consisting chiefly of glassy quartz fragments embedded in a matrix composed of smaller particles of schist. It appears that the region was submerged too rapidly to permit any considerable rounding of the pebbles by wave action or to allow much transportation of material by littoral currents, both of which processes are favored by stability of shore line. The lack of such evidence of long-continued shore action shows that the floor upon which the Cambrian sediments were deposited was in the main due to subaerial erosion and not to marine truncation.

Either there were valleys in the old peneplain as much as 200 feet in depth or the region subsided unevenly to an equal extent, for in the Apache Mountains the interval between the pre-Cambrian peneplain and the base of the Pioneer shale, elsewhere occupied by from 1 to 6 feet of Scanlan conglomerate, is filled by about 200 feet of hard and varyingly arkosic quartzite.

The Pioneer shale, overlying the Scanlan conglomerate and the lower quartzites of the Apache Mountains, records the accumulation of sandy silt in waters so shallow that the mud sometimes lay bare and was dried and cracked by the sun. The material of these sediments was in part feldspathic and probably derived from an adjacent land mass, composed largely of granitoid rocks similar to those occurring in the Pinal Mountains. While there is no direct proof that the rocks of these mountains themselves were reduced to the general level of the peneplain and covered by the Cambrian sediments, yet it seems probable that such was the case, and that they owe their present elevation and the stripping of their Paleozoic cover to later movements and to erosion. There is no evidence to show that they constituted a sharp and local exception to the general evenness of what was at one time an extensive peneplain.

The deposition of the Pioneer shale was succeeded by that of the Barnes conglomerate. The origin of this conglomerate, which, with its well-rounded pebbles composed largely of quartzites, succeeds so strikingly the reddish sandy shales and quartzites beneath it, presents questions to which the region investigated returns no answer. Without any apparent unconformity the quiet deposition of fine silt was succeeded by the laying down of fairly coarse conglomerate bearing evidence of continued wave or current action and plainly derived from earlier (Algonkian?) sedimentary deposits of which the Globe district furnishes no knowledge. The matrix of the Barnes conglomerate, however, still shows abundant feldspathic detritus, such as might have been supplied by a neighboring unsubmerged area of the pre-Cambrian granitic rocks.

Succeeding the Barnes conglomerate came the accumulation of quartzose sands now represented by the Dripping Spring quartzite. These appear to have been laid down in somewhat deeper water than the preceding beds, although the occurrence of conglomerates and grits in the upper part of the formation suggests a return of littoral conditions at the close of the Cambrian.

Ordovician and Silurian time.—The geological record of the limited region studied is blank as regards these periods. No strata belonging to these systems have been identified, nor, on the other hand, has any unconformity been certainly detected between the Cambrian and the Devonian to account for their apparent absence. Such field evidence as could be obtained bearing upon this point is inconclusive. Inasmuch as Walcott has shown that an actual unconformity, rarely discernible, exists between the Cambrian and Devonian beds in the Grand Canyon, a similar usually invisible stratigraphic break may be present in the Globe district. If so the region was elevated with little or no deformation of the beds, and remained dry land throughout the Ordovician and the Silurian. It is conceivable, however, that the absence of such strata is not due to emergence of the sea bottom, but to a cutting off of the supply of sedimentary material, either by a depression so great as to carry this part of the sea bottom beyond the reach of land waste or by a reduction to approximate base-level of the area supplying the sediments. In such an event the two systems might be practically unrepresented and yet there would be no real unconformity.

Devonian and Carboniferous time.—Passing to the Devonian, we find some ground for the suggestions last made in the fact that arenaceous deposits are here almost absent and limestones predominate. At the base of the latter are frequently encountered calcareous grits, forming an apparent transition from the underlying quartzites to the nearly pure limestones. It has been found impossible to believe these to be other than actual transitional beds in a conformable sequence. Yet they are not always present, and the occurrence of a little quartzitic breccia observed at a single point at the base of the Globe limestone north of Globe enforces the suggestion of a possible unconformity.

From the Devonian to the Pennsylvanian the region was covered by a sea of some depth abounding in marine life and depositing abundant limestone. Although no characteristic Mississippian fauna was found, rocks of that epoch may be present, and the Globe limestone as a whole contains no visible unconformities. From time to time there were slight incursions of sandy, quartzose sediment, and in a few instances bands of siliceous conglomerate were intercalated within the limestone. The mass of these is unimportant, but they are significant in showing that this part of the Devonian and Carboniferous sea was probably neither very deep nor far distant from a land mass.

The limestone of Pennsylvanian age is the latest Paleozoic deposit of which the region preserves any record. If marine conditions continued into the Permian the deposits of that epoch must have been wholly removed before the strata were broken up and invaded by diabase. Had Permian or later beds been involved in that structural revolution, some traces of them would probably have been preserved in the resulting intricate lithological mosaic.

Mesozoic time.—There are no available means of determining whether or not the region became land and was eroded before the diabase intrusion. We know only that the latter event, with its associated faulting, occurred after the accumulation of the Globe limestone, and has left unmistakable record of its structural importance. The region was presumably elevated above sea level at the close of the Carboniferous, and subjected to erosion. It was extensively dissected, probably in Mesozoic time, by numerous faults which appear to have been normal in character, usually of moderate throw, and to have had generally northwest-southeast and northeast-southwest trends. There is ground for supposing that the crystalline massif of the Pinal Mountains escaped much of the intensity of this faulting, as it did of that of a later period. Following or accompanying the dislocations an enormous quantity of molten diabase magma was intruded into the rocks of the region, particularly into those most cut by the faults. If present exposures can be taken as generally indicative of the original proportion of the diabase to the stratified rocks, it appears that the intruded rock fully equaled if it did not considerably exceed in volume the stratified rocks. As the latter were not fused at any point now exposed to observation, room for this great addition of material was obtained by mechanical displacement. The dominant form of the diabase was that of the intrusive sheet or sill, and had the region not been shattered by faults these sills would probably have been fairly regular, resembling those occurring in the less faulted portions of the country just without the quadrangle, such, for example, as are well exposed in the canyon of Salt River below its junction with Tonto Creek. As it was, however, the diabase not only forced its way between the beds as sills of varying thickness, but found in the region of greatest faulting the most favorable opportunity for expansion. It occupied the fault fissures and shoved the detached masses of ruptured strata bodily aside, separating them so that they became in many cases mere inclusions in a great mass of eruptive rock. All the observed phenomena connected with the faulting and intrusion, as well as the more general geological considerations outlined in preceding pages, indicate that these events took place comparatively near the surface. The contact metamorphism effected by the diabase is of the most insignificant character, while vesicular and aphanitic facies of the intrusive rock are common near original contacts. The manner in which the blocks of strata were displaced indicates that they were under no great load, and the great increase of volume resulting from the intrusion of the diabase must have produced considerable actual elevation of the surface over the Globe region. It would seem that with such active deformation and intrusion in progress at so slight a depth, at least some of the magma must have found its way to the surface and been erupted as basalt. Any such manifestation of volcanic activity as may have existed has, however, since been removed by erosion.

With the close of the diabase intrusion the region, having probably gained in elevation, was subjected to subaerial erosion. It is possible that during the Mesozoic it underwent many unrecorded vicissitudes, and may even have been covered by sediments that were afterwards stripped away.

Tertiary time.—At a time which can not definitely be fixed but which is provisionally considered as coinciding with the earlier part of the Tertiary, the region, characterized by a somewhat diversified topography, was apparently dry land and undergoing erosion. Although the topography was probably less rugged, the general conditions appear not to have been greatly different from those of the present day. As shown by the accumulation of the Whitetail formation, coarse, rather angular detritus was washed down the slopes and deposited in the more open valleys or gulches.

It was this uneven surface that was in greater part buried by the probably early Tertiary eruptions of dacite. As the Whitetail formation occasionally shows rude stratification in its upper part, and the massive dacite is frequently underlain by beds of tuff, it is probable that the region was at this time partly covered by transient bodies of water, possibly due to a disturbance of the drainage by orogenic movements immediately preceding the eruptions. As a result of the latter the whole of the district, with the possible exception of the Pinal Mountains and some of the foothills of the Apache Mountains, was covered with a flow of dacite, which in its greatest thickness probably exceeded a thousand feet.

Following closely after this volcanic activity came the great faulting to which is chiefly due the present structure, and less directly the topography, of the region. The nature of this faulting has already been described. By it the northern half of the district was shattered to an extent but imperfectly shown by the great number of small fault blocks outlined on the geological map. The southern half of the quadrangle, however, shows comparatively little dislocation, and it is evident that the crystalline massif of the Pinal Mountains moved as a unit and forms the largest fault block in the area. On the southeast this block is fairly well defined by a strong northeast-southwest fault that has dropped rocks of the Apache group and Globe formation, with intruded masses of diabase, against the older Pinal schist and Madera diorite lying to the northwest. Toward the south and southeast the Pinal Mountain block apparently extends beyond the bounds of the quadrangle. On the northwest the passage into the region of intense faulting is somewhat indefinite, and no single fault was found marking a simple boundary between the Pinal fault block and the shattered rocks to the northwest of it. On the northeast the Pinal Creek area of the Gila conglomerate effectually conceals the structural boundary separating the Pinal fault block from the minutely dislocated Globe Hills. The strata of these hills dip generally to the southwest beneath the Gila formation.

They reappear again on the back of the Pinal fault block near Pioneer, and here also have a persistent southwesterly dip. If the portion of the beds removed from this block by erosion were restored they would lap up over the southwestern slope of the Pinal Mountains and form a scarp along the crest of that range, overlooking the Globe Valley and the very much lower fragments of the same strata in the Globe Hills, on the far side of the gravel-filled depression. It is not impossible that the Apache and Globe beds and the overlying dacite formed a complex anticline over the crystalline core of the Pinal Mountains and a syncline beneath what is now the Globe Valley. But as there are here no discoverable traces of a structure so wholly lacking in representation in other parts of the region, it is fair to conclude that the observed tectonic relations have resulted either from a single generally northwest-southeast fault of over 6000 feet maximum throw or from a zone of faults of like trend. In either case the thickness of the Gila conglomerate effectually prevents any study of these faults at the surface. The fissure which cuts off the Lost Gulch monzonite on the northeast and apparently passes beneath the Gila conglomerate to the southeast has a throw of the kind required in members of the hypothetical fault zone suggested.

The crystalline massif of the Pinal Mountains is thus regarded as an eroded fault block, uplifted along its northeastern edge and consequently tilted to the southwest. It is possible that the concealed fault or fault zone along the northeastern front of the range, of which the maximum throw can scarcely be less than 6000 feet, is only in part due to post-dacitic dislocation, and that the initial displacement dates from the episode of intrusion faulting connected with the diabase eruption or that of the post-diabase fissuring.

In the absence of any satisfactory evidence for connecting with the recognized geological epochs the events which took place in this district after the close of the Carboniferous, the post-dacitic faulting is rather arbitrarily considered as ending the Tertiary. The provisional nature of this and other post-Carboniferous correlations in this region should not be forgotten. They may be considerably modified when the geological work of the Globe quadrangle is supplemented by the study of a broader area. The divisions recognized appear to be distinct chapters in the local physical history. They may not, however, be correctly inserted in the larger volume of the geological story of the earth.

Quaternary time.—The Quaternary was opened by a vigorous erosion of the complex lithological mosaic resulting from the superposition of the post-dacitic shattering upon earlier structures already complex. Great quantities of coarse, rocky detritus were washed down the slopes and deposited as the Gila formation in valleys partly at least of structural origin. It has already been shown that the conglomerate-filled Globe Valley probably owes its original depression to faulting. The Gila formation of the Mineral Creek area fills a hollow eroded in the dacite. The Upper Pinto area also occupies a small northwest-southeast valley of erosion, but there has been some Quaternary faulting and possibly a very slight synclinal flexure of the deposit along the axis of the trough.

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

There was at least one eruption of basalt during the Quaternary, as shown by the flow intercalated in the Gila formation south of Gold Gulch and the smaller masses in the western part of the district. The basalt apparently issued from more than one small vent, and its present distribution is not entirely understood.

The early Quaternary erosion that supplied the materials for the Gila formation undoubtedly effected pronounced changes in the topography, but it usually is difficult or impossible to distinguish between such changes and those brought about in recent time.

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

In later Quaternary or Recent time erosion has been active over the whole region, reducing the mountains and dissecting the Gila conglomerate. In some parts of the area, as near Hutton Peak and Needle Mountain, this later degradation appears to have been exceptionally active, and has left fragments of the Gila formation, originally a valley deposit, upon the summits of ridges and peaks. Within the large Pinal area of conglomerate, however, the present arroyos have merely effected an intricate dissection and sculpturing, without exposing the base of the formation save near its margins. As is usually the case, this trenching was somewhat intermittent, as is shown by inconspicuous terraces, best seen along Bloody Tanks Wash.

In the present topography of the region three main features are readily distinguishable—the Pinal Mountains carved from the uplifted Pinal fault block, the gravel-filled depression of the Globe Valley, and the hilly country in the northern half of the quadrangle. These features depend primarily upon the geological structure, the development of which has been traced in the preceding pages, and secondarily upon the erosion of the present cycle. The elevation of the Pinal block, while it led to the rapid stripping off of the Paleozoic and younger rocks, exposed to the present erosion the little-fissured and generally resistant foundation of crystalline schists and granitic batholiths. Thus the Pinal Mountains are the result of an original uplift, which subsequent erosion has greatly lowered and sculptured, but, checked by the highly metamorphosed schists, has been unable to degrade to the general level of the surrounding country. The topography of the range is still characterized by the steepness and sharpness of form associated with physiographic youth.

The Globe Valley, on the other hand, probably originated as the downthrown region lying northeast of the Pinal uplift, the result of such downthrow being to form a structural depression floored with shattered Paleozoic sediments, diabase, and dacite. How far erosion was able to modify this floor before it was buried beneath the Gila formation is of course unknown. The existing topography of the valley exhibits a stage of mature dissection of the fluviatile deposits that fill it. As the principal intermittent streams issue from the Pinal Range they tend to retain the axial stream, Pinal Creek, close to the base of the Globe Hills. Near the northern edge of the quadrangle, however, the conditions are reversed, and the influence of the stronger drainage, with its more extensive deposition of detritus, from the Apache Mountains to the northeast of the quadrangle, is seen in the crowding of Pinal Creek over toward the hills west of Gerald's ranch.

The topography of the northern half of the quadrangle is closely related in its irregularity to the rock masses that underlie it. It is such as might be expected from the erosion of a region having planless heterogeneity of structure. The drainage of such a tract records minute adjustments to conditions of great local diversity. Each little fault block, by its materials and position, has influenced the topography. Areas of granite or diabase tend to become valleys or basins, while quartzite and limestone form ridges or peaks.

ECONOMIC GEOLOGY.

INTRODUCTION.

History of mining development.—Prior to the year 1874 the desert isolation of the mountains of central Arizona, and the predatory Apaches who lurked within their rocky fastnesses, appear to have been obstacles from which even the proverbially hardy prospectors shrank. But in that year a temporary subjection of the Indians opened the way to the more adventurous spirits, and a party of prospectors, having crossed the Pinal Mountains from the west, located the Globe claim, now part of what is generally known as the Old Dominion mine. The Silver King mine, lying about 19 miles south-southwest from the present town of Globe, was located by members of this same party as they were returning to Florence. Other discoveries rapidly followed and small settlements sprang up at various points. One of the first of these, known as Ramboz Camp, was founded by Henry Ramboz in 1875. The ruins of this camp and some neglected graves of its pioneers may be seen about 4 miles northeast of Globe, at the foot of Ramboz Peak. It was the base whence active prospecting was carried on in the Globe Hills during the seventies, when some mines, such as the Fame, Centennial, and Rescue, were opened and produced silver ore in commercial quantities. Although the Globe claim, destined afterwards to become the greatest copper producer in the district, was the earliest location, it attracted but little attention for several years, owing to the greater interest aroused by silver ores, and the success which was already attending their exploitation in the Silver King mine.

Other settlements or camps sprang into existence about the same time as that at Ramboz. Among these were Cottonwood Springs, Richmond Basin, Watsonville, and McMillanville. Richmond Basin, situated at the southwest slope of the Apache Mountains, first came into notice through the nuggets of native silver which were found in the superficial wash and decomposed rock forming the floor of the little depression whence the name of the settlement was partly derived. Shafts were sunk, that of the McMorris mine reaching a depth of 800 feet and producing high-grade silver ore up to 1882, when work ceased. Most of this ore was treated in a mill at Wheatfields, on Pinal Creek, somewhat over 12 miles northwest of Globe, although in 1878 some was apparently worked in the old Miami mill, 4 miles from Globe, at the northern end of Miami Flat. The total yield has been variously reported as from \$300,000 to \$647,574.85. The Nugget mine, about 2 miles southwest of Richmond basin, was also a prominent mine of these early days, and had a small stamp mill east of Gerald's ranch and 7 miles due north of Globe.

McMillanville, in the Apache Mountains, about 20 miles from Globe, was a well-known and active camp during the later seventies, owing largely to the operation of the Stonewall Jackson mine. Rich bunches of ore carrying native silver were found in this mine in 1878 and 1879, and a 5-stamp mill was erected at McMillanville in the latter year.

Throughout this period and up to 1884 the Silver King continued productive and reached a depth of over 700 feet. Like several others of the silver mines mentioned in this historical sketch, it lies outside of the bounds of the Globe quadrangle, although within what may be broadly considered as the Globe region.

Some time prior to 1878 the principal settlement of the district was transferred from Ramboz to Globe, the choice of the latter situation being probably determined by the more plentiful water supply afforded by the bed of Pinal Creek, and the better position of the latter place as a general distributing point for the whole region. A newspaper, "The Arizona Silver Belt," was started about this time, and from its files, extending from May 2, 1878, to January, 1902, many of the facts of the present sketch were gleaned.

During 1878 and 1879 the raids of the Apaches under Geronimo and Victorio kept the miners in a state of constant anxiety. But although isolated prospectors sometimes fell victims to the savages, the latter never ventured to attack the settlement of Globe.

In 1880 the Globe region was producing silver from several small mines within and adjacent to the area embraced by the present quadrangle. The most prominent properties at this time appear to have been the McMorris and Stonewall Jackson, the former being credited with a product of \$84,370.58 for six months of the year. The Buffalo and Alice mines were also opened about this time, for silver ore, and the Old Dominion (original)[1] was prospected. In May of this year the Miami, Duryea, Stonewall, and Isabella mills were working in all 27 stamps, and the Nugget, Baldwin, Golden Eagle, Irene, Silver Era, and Townsend mills, with a total of 65 stamps, were in process of construction. Lost Gulch was at this time coming into notice as a promising field for gold prospects. It is probably to this period that the former activity of the abandoned silver mines at Pioneer, 12 miles south-southwest of Globe, is to be referred; but no published record of their operations has been found.

In 1883 there were 12 mills reported in the Globe region working on silver and gold ores and having in all 86 stamps. The Silver King mine had reached a depth of 714 feet on a body of rich silver ore which, however, gave out near this level. From this year on, silver mining declined, and although a little desultory prospecting and mining continued, and the Fame mine was exploited as late as 1889, the mines were one by one shut down, and the production of silver ores appears to have practically ceased by 1887.

The future prominence of copper as the principal product of the Globe district appears to have been at first unsuspected, in spite of the strong surface indications of the presence of copper ore, and these mines which subsequently became the largest copper producers were at one time worked for silver.

The first notices of copper prospecting are in "The Arizona Silver Belt" of July 11, 1878, where reference is made to the abundant copper ore revealed by the very superficial workings on the Globe and Globe Ledge claims. This ore seems, however, to have attracted little serious attention until 1881. About this time the Old Dominion Company erected a small copper furnace on the Western Pass road, about 6 miles nearly due west of Globe and about half a mile northeast of Bloody Tanks. The ore for this furnace was obtained from a vein in the schists near by, but appears to have only been a small pocket, and the mine was soon abandoned. The smelter was moved to Globe and worked for a time on the siliceous copper ore from the Old Dominion (original) mine. But the company soon purchased the Globe mine, and in May, 1884, this was in full operation and produced 490 tons of copper from two 30-ton furnaces. From this time on, the Old Globe mine became generally known as the Old Dominion, while the original mine of that name was practically abandoned.

In 1886 the property of the Old Dominion Company was sold at auction to William Keyser, of Baltimore, the reported price being \$130,000. The product at this time is said to have been about 10 tons per day from one furnace, and the total product from 1882 to September 1, 1886, is given as 22,800,000 pounds. There were in all 6 copper furnaces in the district, and mines other than the Old Dominion are credited with a total product of 1,000,000 pounds for the same period. At the end of this year the low price of copper, combined with the necessarily high operating expenses in a region where supplies were hauled by wagon from Wilcox, 120 miles away, compelled the copper mines to close.

Early in 1888 the Old Dominion Company was reorganized; work was resumed, and the sixth level was opened from the new Interloper shaft. During this and the following year the mine produced 10,515,510 pounds of copper, and is said to have maintained an average annual production of about 8,000,000 pounds up to the close of 1893. The Buffalo mine was producing some copper ore in 1890, but the economic history of these years is largely that of the Old Dominion mine.

In 1892 the United Globe Company was organized and the Buffalo, Hoosier, and numerous other claims were consolidated into one group. Three years later the Old Dominion also changed hands.

The United Globe mines enlarged their plant in 1895, and began active operations in 1896, directed chiefly to the development of the Hoosier claim, which had produced considerable ore from bodies in limestone near the surface. There was a general revival of prospecting at this time in Lost Gulch and Pinto Creek, and development work was in progress at the Black Warrior and Black Copper mines, then owned by the same company. In Lost Gulch the Kasser mill, of 10 stamps, was operating for a time on gold ores.

In April, 1897, the Old Dominion mine, which had been producing steadily, with the exception of brief stoppages due to labor difficulties, shut down to await the arrival of the railroad, which was completed to Globe on December 1, 1898. The mine then resumed operations and has produced copper constantly to the present time. It continues to be the only large and steadily productive mine of the region, although ores in considerable quantity have been shipped from time to time from the United Globe and smaller properties.

Mines.—The only large and productive mine in the Globe quadrangle at the present time is the Old Dominion. The total length of ground explored by the working of this property is about 3600 feet, and the maximum depth about 1000 feet. Active prospecting, however, is in progress in the Grey mine, one of the United Globe properties, and some high-grade copper ore was being shipped in the spring of 1902 from the Josh Billings mine, belonging to the same company. Small quantities of ore were also being produced at that time from the Buckeye and Geneva, both small mines owned by the United Globe Company, and from the Keystone, Summit, and original Old Dominion mines. These shipments were all of copper ore, and, with the exception of the Summit mine, all the mines mentioned were working oxidized ores only.

Production.—In the Globe district the production of copper far exceeds in importance that of any other metal, and more than three-fourths of the whole output has come from a single mine, the Old Dominion (formerly known as the Globe). The total product of this property and the various mines of the United Globe group at the close of the year 1901 was a little over 118,000,000 pounds of copper. If an estimated 2,000,000 pounds additional be added to this to cover unrecorded and irregular shipments from smaller mines, there is obtained a total product of the quadrangle of, in round numbers, 120,000,000 pounds.

Statistics of the output of gold and silver are lacking. The McMorris mine, in Richmond basin, which while not in the Globe quadrangle comes within what is generally known as the Globe region, is credited with a production of nearly \$150,000 in silver during 1880 and 1881. The total product of this mine probably exceeded \$300,000. Silver was also produced in the early eighties from the surface workings in Richmond basin, in the form of nuggets, and from several small mines, such as the Fame, Centennial, Nugget, and others, lying north of Globe; but the total amount was probably not large.

Gold has been mined in small quantities in Lost and Gold gulches, the output from the former being given in the report of the Governor of Arizona for 1896, as \$48,000 in 1896. The production of this metal however, has been intermittent, and the total is probably inconsiderable.

METALLIFEROUS ORES.

GENERAL CLASSIFICATION.

The ores of the Globe district may be classed as (1) free gold ores, (2) native silver or silver-lead ores, and (3) cupriferous ores containing varying amounts of the precious metals. At the present time, however, ores of the first and second classes are mined on so small a scale and so intermittently that it is scarcely necessary to consider them. They play but an insignificant part in the mining industry of the region, and very little of scientific interest is to be gained from the present underground developments connected with their exploitation. It is to the cupriferous ores that the district owes its life, and with them this folio is most concerned.

The copper ores may be divided on genetic as well as practical grounds into (1) oxidized ores and (2) sulphide ores. To the former division belongs nearly all of the ore produced in the district to the year 1901, when some small shipments of sulphide ore were made from the Summit mine. Sulphide ore, on the other hand, if there be excepted occasional bunches of chalcocite found with oxidized ore, as in the Buffalo mine, is of recent discovery, and is a factor of increasing importance in determining the future of mining operations in this district.

As will be shown later, the sulphide ores are theoretically capable of further division into primary ores, or ores of original deposition, and secondary ores derived by subsequent chemical processes from the primary ores. The oxidized ores also may be conveniently distinguished as indigenous and exotic, the former being those produced by the oxidation of sulphides in situ, and the latter those deposited after some migration from the place of sulphide oxidation. It is evident that this distinction can not always be made in practice, and the extent of the migration of the oxidized ores in solution is rarely determinable. Between the two kinds of ore no hard and fast line can be drawn, but the classification recognizes a factor in ore genesis which both observation and theory agree to be real, and which in the Globe district has a practical bearing.

DISTRIBUTION.

The ore bodies which have thus far proved of most importance in the Globe quadrangle occur in the Globe Hills just north of Globe. The copper ores, which have given the district its later prominence, are found in the southern part of these hills, within a radius of 3 or 4 miles from Globe, principally in the properties owned by the Old Dominion and United Globe companies, while the silver ores, which first attracted attention to the region, were formerly mined in the northern portion of the hills and the adjoining quadrangles to the north and east. Such old silver workings as lie within the Globe quadrangle have been idle for years. They are not extensive, and are now of slight importance, and afford, in their present condition, little opportunity for scientific investigation.

Although the same rocks that make up the Globe Hills occur also in the northwestern part of the quadrangle, where they have been fissured in a remarkable manner, no workable ore and very little mineralization has been found north of a line joining Sleeping Beauty Peak and Webster Mountain.

South of this line copper ores occur at the Black Warrior and Black Copper mines, in Webster and Gold gulches, and at the Geneva and Continental mines, while sufficient gold has been found in Lost and Gold gulches, both in small veins and in superficial gravels, to encourage prospecting and intermittent mining on a small scale since the discovery of the district.

In the vicinity of Liveoak Gulch the porphyritic facies of the Schultze granite has been much fissured and shattered, and is often conspicuously stained with carbonates and silicate of copper, while workable deposits of chrysocolla have been exploited on a small scale in the Liveoak and Keystone mines.

On Pinto Creek near the mouth of Cottonwood Gulch the schists are very much brecciated by numerous fissures, and show conspicuous green stains of copper, but no ore bodies have yet been found. In general it may be said that there is more or less mineralization at several points in the Pinal schist close to the contact with the Schultze granite, but ore in workable quantity has not been discovered.

In the diabase of Powers Gulch are a few small veins showing, in croppings and shallow prospects, some galena in rusty copper-stained quartz.

In the southern half of the quadrangle there is comparatively little mineralization, although bodies of ore have been found at the Summit, Cole & Goodwin, and Bobtail mines, in the large irregular area of schist covering much of the western slope of the Pinal Range. Some silver ore has been produced by the mines at Pioneer, but they lie just outside of the southern boundary of the quadrangle. On the northeastern slope of the range a little gold has been obtained from the gravels of Pinal Creek, but no workable gold-quartz veins have yet been found.

MINERALOGY.

General statement.—The mineralogical character of the Globe ores is simple. The primary sulphide ores, and those which in the absence of any evidence of secondary origin may be grouped with them, are composed usually of rather crumbling, granular pyrite, with which is commonly associated some chalcopyrite. Of less frequent occurrence are galena and sphalerite, with occasionally the tungstate hübnerite, as in the Bobtail mine. The gangue is altered country rock, or quartz, the latter being rarely abundant, or sometimes calcite, as in the Cole & Goodwin mine.

As might be expected, the oxidation of sulphides showing so little diversity as those in the Globe district has resulted in mineralogically simple products. Arsenical and antimonial minerals, which in some copper districts accompany the sulphides and give rise, by oxidation, to various mineralogically interesting derivatives, are here unknown. Pyrite, chalcopyrite, and chalcocite have their sulphur replaced by oxygen, carbon dioxide, or silica, usually with accompanying hydration, and become hematite, limonite, cuprite, malachite, or chrysocolla. Azurite rarely occurs save as an occasional incrustation on malachite.

Pyrite.—Loosely coherent pyritic ore, often containing no visible chalcopyrite, is found on the eleventh and twelfth levels of the Old Dominion mine, between the fifth and sixth levels of the Grey mine, and in the Continental mine. It also occurs, with some chalcopyrite, finely disseminated through the granite-porphyry (Schultze granite) near the head of Gold Gulch.

Chalcopyrite.—Chalcopyrite is found abundantly in the Summit mine, where it forms the bulk of the ore, in the Cole & Goodwin mine with pyrite, in the Bobtail mine with sphalerite and galena, and in a quartz vein in Schultze granite at the Yo Tambien, a prospect on the west side of Pinto Creek near the mouth of Cottonwood Gulch.

Galena.—Galena occurs very sparingly in the district, and was seen only at the Bobtail mine, as occasional specks in the Cole & Goodwin ore, and

[1] The original Old Dominion mine is situated about 4 miles north of Globe, on a vein in quartzite. Its owners, the Old Dominion Company, afterwards purchased the old Globe mine, which is now the principal mine of the region, and is popularly known as the Old Dominion mine. To avoid as much as possible the confusion which this duplication of names involves, the first mine, to which the name really belongs, will be referred to as the Old Dominion (original). It at one time afforded handsome specimens of native silver and free gold from its upper levels, but is no longer worked by the company.

in the partly oxidized ore of some prospects in Powers and Gold gulches. It probably occurs to some extent, however, in the argentiferous veins in the diabase of the northern Globe Hills, and was seen with sphalerite in the ores of Pioneer and Richmond basins, which lie outside of the quadrangle.

Sphalerite.—Sphalerite is known only at the Bobtail mine and in minute quantities at the Cole & Goodwin mine.

Chalcocite.—The only secondary sulphide recognized in the district is chalcocite, or copper glance. This occurs as a thin film coating fragments of chalcopyrite in the Summit vein, and is here indubitably of later origin than the chalcopyrite. The hematite associated with it probably represents part of the iron set free from the chalcopyrite in the change to chalcocite. In the Buffalo mine massive chalcocite occurs, altering to malachite. As it is found only in small residual masses and is the only sulphide present, no direct light is thrown on its presumable origin from primary sulphides. In the Old Dominion mine compact, massive chalcocite occurs within the zone of change from oxidized ores to pyritic ore, chiefly on the eleventh and twelfth levels. Some of the chalcocite is free from pyrite, but the latter mineral is often disseminated in small particles through the mass of gray copper sulphide. When the chalcocite is examined closely, particularly with a lens, it shows an indistinct unevenness of texture, suggestive of the obscurer forms of pisolitic structure observed in some bauxites. Critical scrutiny of the inclosed grains of pyrite reveals the facts that their outlines are rounded and that the chalcocite has a more or less distinct, concentric, shelly structure around each grain. These facts at least strongly suggest that the chalcocite has been formed at the expense of the pyrite, and that the minute structure observable in chalcocite now free from pyrite records the former presence of that mineral and its subsequent replacement by the sulphide of copper. This process will be discussed at greater length, however in the section devoted to ore genesis.

Hematite.—The hematite when not combined in an aphanitic earthy mixture with cuprite occurs as specularite, sometimes in the form of a loose powder of greasy feel, but oftener in firm aggregates streaked with chrysocolla or malachite and containing little vugs lined with one of the latter minerals, which in turn are not infrequently covered with drusy quartz. The specularite is found usually in quartzite or limestone, often forming the gangue or matrix of bunches of oxidized ore.

Limonite.—The occurrence of limonite is similar to that of hematite, but it never has the unctuous, pulverulent form often taken by the latter. It is found principally in limestone, as a firm, aphanitic material, more or less cavernous in texture and passing occasionally into yellow, ocherous varieties. It is usually associated with the oxidized ores of copper, either as a "casing" between the ore and the limestone or as a large mass within which the ore, if present, is found in bunches. It also occurs intimately mingled with the cupriferous minerals in the ore itself. Limonite is abundant in the Old Dominion mine, and appears to be in this district a characteristic accompaniment of oxidized copper ores in limestone.

Cuprite.—Cuprite showing crystalline texture was noted only at the Continental and Buffalo mines. Mixed with hematite or limonite, however, it probably makes up a considerable part of the high-grade, aphanitic, brown copper ore found in the Old Dominion and other mines in the Globe Hills.

Malachite.—The green carbonate of copper is very abundant, particularly throughout the Globe Hills, but never, so far as seen, forms large masses. It occurs characteristically as small stringers or veinlets cutting the other oxidized ore minerals or lining small vugs. It is particularly conspicuous in connection with ore bodies in quartzite, as the innumerable minute fissures formed in this brittle rock, many of them of microscopic size, are usually filled with malachite, giving a bright-green tint to the whole. In many cases the malachite has apparently directly replaced the quartzite, as the microscope shows crystals of the carbonate projecting from the microscopical veinlets into the substance of the rock. Associated with chrysocolla it forms a considerable proportion of the ore of the Buffalo, Big Johnnie, Buckeye, and other mines in quartzite. It occurs as veinlets in the chrysocolla of the Keystone mine, and as a conspicuous green stain over much of the granitic porphyry in the vicinity of Liveoak Gulch.

Azurite.—The blue carbonate of copper is rarely seen, and only as small druses or incrustations on malachite.

Chrysocolla.—The hydrous silicate of copper is an abundant and important ore mineral in the Globe district, although its high contents of silica and water make it relatively low grade as compared with ores containing cuprite or malachite. It varies widely in color, from delicate apple-green or turquoise-blue tints to dark green, brown, or black, the darker tints being apparently due in most cases to the presence of oxide of manganese.

The green and blue varieties are common in all the oxidized ores of the Old Dominion, Buffalo, and other mines and prospects in the Globe Hills, often occurring as little bunches and veinlets in the cryptocrystalline, impure cuprite of the high-grade brown ore. A pure, greenish-blue chrysocolla with chalcedony-like banding forms the ore of the Keystone mine, where it occurs as a vein in granitic porphyry, and is common in neighboring prospects north of Bloody Tanks.

The same mineral constitutes the ores of the Black Warrior, Geneva, and Black Copper mines, occurring chiefly as a replacement and mineralization of dacite-tuff. Much of this ore is dark colored, owing to the presence of manganese oxide, and that of the Geneva especially is of very striking appearance. It consists of kernels of black or dark olive-green chrysocolla, of very irregular shape, embedded in lighter-colored varieties of the mineral, ranging in tint from a delicate turquoise-blue to a deep bottle-green, the whole ore having a resinous luster. These paler-tinted varieties are often arranged in fine concentric bands about the dark kernels, and as they do not always completely fill the interstices between the latter the resulting cavities form little vugs, usually lined with pale-blue botryoidal chrysocolla. Field relations show that this ore occurs as a replacement of dacite-tuff, and a study of specimens indicates that the dark kernels, which owe their depth of color to the presence of oxide of manganese, probably represent original glassy particles of dacite and possibly small schist fragments in the tuff. Traces of flow structure and of original partly crystalline texture can occasionally be detected, and residual flakes of biotite, such as occur in the dacite, are not uncommon within the dark chrysocolla. The present boundaries of the kernels are not, however, identical with those of the supposed original clastic particles. The latter have been rounded and embayed in the process of ore deposition, and in part replaced by the banded chrysocolla, which apparently occupies in the main the place of the former fine interstitial material of the tuff.

Native metals.—Native gold, silver, and copper were seen in place only within the zone of oxidation, although the first-named mineral probably occurs to some extent in the district as a primary ore constituent. Gold occurs as thin hackly plates and short wires in the massive impure cuprite of the original Old Dominion mine. More or less native silver has probably been found in many of the oxidized ore deposits in the district, but at the time of visit was seen only in the Continental mine, as minute flakes in calcite accompanying cuprite. Native copper in small hackly particles is abundant in certain parts of the Old Dominion mine, particularly in mineralized, shattered quartzite within the zone of oxidation.

Paragenesis.—By paragenesis is meant the association of the various ore and gangue minerals, with special reference to the order and mode of their formation.

So far as known, the minerals of the primary sulphide ores were contemporaneously formed and exhibit no regular sequence. Thus in the Bobtail mine, chalcopyrite, sphalerite, galena, pyrite, and hübnerite occur together in a quartz gangue, none of the minerals named showing evidence of earlier or later origin than the others.

The secondary sulphide chalcocite was the latest of the sulphides to form, as shown by its coating fracture surfaces of chalcopyrite in the Summit mine and its occurrence near the bottom of the zone of oxidation in the Old Dominion and Grey mines.

The oxidized ores are, of course, of generally later date than the sulphides, although it must be borne in mind that the formation of chalcocite is probably still in progress below the zone of complete oxidation.

Cuprite, native copper, and hematite appear to be characteristic of the lower portion of the oxidized zone, and probably tend, in such a position, to form first from the sulphides. Occasionally, however, as in the Buffalo mine, chalcocite changes directly into malachite. The character of the transformation depends upon the nature of the solutions affecting it, and that in turn upon the depth at which the process takes place and the materials through which the solutions have previously percolated. As a rule chrysocolla is older than malachite when the two minerals occur together. The silicate, other things being equal, seems to form at a greater depth in the zone of oxidation than does the malachite. Azurite, when it occurs, is of later origin than the malachite.

The formation of quartz and calcite is not limited to any single phase or period of ore deposition, but traverses the entire range of mineralization, from the primary sulphides to the latest oxidized ores. These gangue minerals are rarely abundant, however.

Exceptions to the usual sequence of the ore minerals, as just outlined, are by no means difficult to find, and illustrate the variable and complex factors concerned in ore genesis. Thus a specimen from the Old Dominion mine, seen in the mine office, showed chalcocite partly altered to malachite and the malachite covered with druses of quartz upon which were implanted crystals of calcite. Upon the calcite, in turn, were arborescent crystalline aggregates of native copper. Still another specimen showed copper inclosed in quartz.

OCCURRENCE OF THE ORES.

The ore bodies of the Globe quadrangle exhibit various forms, and, as is usual in such cases, these are not sharply distinguishable from one another. For purposes of description, however, they may be classed as (1) lodes, (2) masses in limestone, and (3) irregular mineralizations of shattered or permeable rocks.

The lodes, for the most part simple fissure veins, are mineralized post-diabase fault fissures belonging with those already described on page 12. Of the hundreds of dislocations dissecting the region only a very small proportion contain ore, and these are often structurally unimportant as faults. The cause of the mineralization of certain fissures and its absence from others is unknown. It has been impossible to discover any particular distinction, other than the presence of ore, possessed in common by the mineralized faults and not also found in some of the barren fissures of the region, although the post-dacite faults, as far as known, are unmineralized. The greater number of the lodes have approximately northeast-southwest strikes, and dips ranging from 40 to 90 degrees.

As examples of lode deposits may be cited the Summit, Cole & Goodwin, and Bobtail lodes, carrying sulphide ores in Pinal schist, the Keystone vein of chrysocolla in Schultze granite, the Big Johnnie vein carrying cuprite, chrysocolla, and malachite in quartzite, the Josh Billings, containing oxidized ore in diabase, the veins of oxidized ore in the quartzite of Copper Hill, the oxidized North vein in the diabase in the Old Dominion mine, the pyritic lodes in diabase in the lower levels of the same mine, the vein of the original Old Dominion mine in quartzite, and many others, particularly throughout the Globe Hills. Some of these lodes, such as the original Old Dominion, the Keystone, and the Summit, are nearly typical simple fissure veins. The ore fills a formerly nearly empty fissure, with little or no replacement of the original walls. Others, like the Bobtail and Big Johnnie, are mineralized fault breccias. The ore has filled the interstices between the fragments of the breccia, and has frequently to some extent metasomatically replaced the latter, thus forming a link between the lodes and the other two classes of ore deposits recognized in this region.

Still other lodes, such as the pyritic deposits in the Old Dominion and Grey mines, might be classed as stringer lodes—that is, they consist of several irregular anastomosing fissures filled with ore. Where, as in these cases, the country rock is diabase the mineralization is not confined within the fissures, but has penetrated into the diabase by the process of metasomatic replacement. Such ore possesses no regular vein walls, but grades gradually into altered diabase containing disseminated pyrite. Such a process, while it does not extend to a sufficient lateral distance to destroy the general lode-like form of the deposit, nevertheless tends to connect fissure veins through intermediate forms with the deposits belonging to the other classes. The pyritic lode of the Continental mine, which is in a granite-porphyry facies of the Schultze granite, is also a stringer lode and is accompanied by considerable metasomatic mineralization of the neighboring country rock.

When, as is the case in the I. X. L., Big Johnnie, Buffalo, and Copper Hill mines, lodes pass upward from diabase into overlying quartzite, the latter rock usually shows the greater mineralization. The only known exception to this is the Josh Billings vein, in which the ore occurs principally in the diabase.

Although the lodes often contain excellent ore, it has not yet been found in such abundance as in the large masses in limestone, which have supplied most of the copper from the district for the last twenty years.

All of the important ore bodies thus far discovered in limestone, with the exception of one formerly worked in the Buffalo mine, lie on the southeast side of the Old Dominion fault, and have been worked through the Old Dominion and Hoosier mines. In the former property there is exposed in the hanging wall of the master fissure —the Old Dominion fault—a thickness of from 350 to 550 feet of the Globe limestone resting upon the Apache quartzites. The ore bodies occur rather irregularly throughout this limestone section from the top to the bottom. In general they are rudely lenticular in shape and lie roughly parallel with the nearly horizontal bedding of the limestone. Some of them are directly connected with the Old Dominion fault, the ore forming the hanging wall and extending irregularly for 20 or 30 feet out into the limestone. Others, although never far from the Old Dominion fault, are completely inclosed within this rock, which, however, always shows more or less fissuring, such as may have given access to the ore-bearing solutions. Some of these ore masses have been large, one in the Old Dominion mine having been about 200 feet long, 100 feet wide, and 60 feet thick. This, however, was not wholly within the limestone, but was partly in quartzite, and in reality falls also into the third general class of the ore deposits of the district. Other masses of ore not coming strictly within the definition occur in the Old Dominion mine at the contact of limestone with overlying dacite. The ore, however, apparently occupies space formerly filled with limestone and not with dacite, and the form of such deposits is similar to that of deposits occurring wholly in limestone.

The ore of these masses in the Globe limestone is always oxidized, and often accompanied by large quantities of hematite or limonite. It sometimes rests snugly against the limestone, and is sometimes separated from the latter by a shell of limonite. As a rule the limestone shows very little alteration at a distance of a few inches from the ore or from the iron oxides.

Ore occurring in the form of irregular mineralization of shattered or permeable rocks has contributed largely to the total output of the Globe district. Here belong the masses occurring in brecciated quartzite, always associated with one or more fault fissures but not confined within their walls. Such bodies have supplied much of the ore of the Old Dominion mine, where a mass of the quartzite lying between the Old Dominion and Interloper faults has been extensively mineralized. Similar conditions exist in the Grey and Buffalo mines, and to some extent in the Buckeye mine. Such ore masses are usually very irregular in form and often have no sharp boundaries, as workable ore changes gradually into less broken country rock only slightly stained with malachite or chrysocolla. The ore is usually wholly oxidized, and may consist of chrysocolla, cuprite, malachite, specularite, and native copper, in varying proportions. Some chalcocite, however, occurs as residual unoxidized kernels in the ore of the Buffalo mine. The microscope shows that the shattering of the brittle quartzite is often exceedingly minute, so that it is not always easy to determine whether there has been any actual metasomatic replacement of the quartzite by ore. As a rule, however, the fact of such replacement can be ascertained, although the bulk of the ore has undoubtedly filled mechanically formed spaces.

The conspicuously stained but not hitherto productive schist-breccias so noticeable alongside the road from Webster Gulch as it descends into Pinto Creek, and the green-tinted granitic breccias of Liveoak Canyon, are similar in general character to the more richly mineralized deposits in quartzite just described.

In this class also come the ore bodies of the Black Warrior (Montgomery and Dadeville claims), Geneva, and Black Copper mines. In the first two the ore which is chrysocolla, occurs as a metasomatic replacement of dacite-tuff lying between schists below and massive dacite above. All gradations may be traced, from the solid chrysocolla resulting from practically complete replacement to tuff showing mere traces of mineralization or none at all. In the Black Warrior and Geneva the ore bodies are flat, blanket-like masses passing gradually into tuff on their peripheries. They sometimes rest directly upon the schists, sometimes are separated from the latter by a layer of tuff. They are always associated with fault fissures, which are in part later than the ore. In the Montgomery and Dadeville claims is a strong east-west fault, which was apparently initiated prior to the deposition of the ore.

The ore body of the Black Copper mine, also lying between schist and dacite, is of rather irregular shape, and evidently was formed, at least in part, by replacement of dacite or dacite tuff. It has an easterly dip of about 35 degrees, and it is possible that it occupies a fault fissure opened prior to ore deposition, and might perhaps be classed with the lodes.

ALTERATION OF THE COUNTRY ROCKS.

Owing to the prevalent oxidation and the absence of extensive mine workings in connection with sulphide ores, the Globe region does not at present offer favorable opportunities for the study of metasomatic alteration of the country rock as an accompaniment of original ore deposition. Such alteration as was observed was not conspicuous and was not particularly studied. In very few cases have the developments on sulphide ores gone to such a depth as to entirely eliminate the action of descending surface waters.

GENESIS OF THE ORES.

Sulphide ores.—The little mining development so far accomplished upon the primary sulphide ores has brought to light no evidence against the commonly accepted view that such ores were deposited by ascending solutions of originally meteoric water which had become charged with ore-forming constituents in the course of a slow and devious underground circulation. Their metalliferous contents were probably derived from the deep-seated rocks of the region. The diabase, which was so extensively intruded into the Carboniferous and older rocks, contains abundant augite, olivine, and magnetite, and is obviously a likely source of supply for at least some of the ore constituents. In order to test this hypothesis, 10 grams of fresh diabase, of which a petrographical description is given on page 9, was examined in the Survey laboratory by Dr. E. T. Allen, and the presence of a trace of copper determined. As the specimen came from an unfissured mass exhibiting no signs of mineralization, and is shown by the microscope to be almost ideally fresh, it is probable that the copper is an original constituent of the rock and a source of at least a part of the copper concentrated by natural processes in the ore bodies.

As fissuring accompanied or followed by the original mineralization of the district are the important events recorded in the geological history of the region as succeeding the intrusion of diabase, it is probable that here, as in other mining districts, there is a close genetic relationship between the manifestations of volcanism and the subsequent ore deposition. The intrusive masses not only supplied ore constituents, but were probably partly responsible for the fissuring, and supplied heat and chemical activity to the underground waters.

In spite of the limited amount of mining work done upon the sulphide ore bodies of the district, the evidence for the secondary origin of the chalcocite is satisfactory. In the Summit mine this mineral occurs probably at a depth less than 200 feet, as a thin black film coating fracture surfaces of chalcopyrite, and often associated with hematite. The mineral in this case is obviously formed subsequently to the fracturing of the chalcopyrite, presumably by descending solutions carrying down copper sulphate and oxygen from the zone of oxidation. A reaction capable of producing this result may be written thus:

Chalcopyrite		Culpric sulphate		Atmospheric oxygen		Chalcocite	
$Cu\,FeS_2$	+	$Cu\,SO_4$	+	O_2	=	Cu_2S	+
		Ferrous sulphate		Sulphur dioxide.			
		$Fe\,SO_4$	+	SO_2			

The actual reactions, however, are probably more complex, and further chemical study of the action of various solutions upon natural sulphides is required before every step in the process is known. Apparently a part of the iron formerly combined with copper and sulphur in chalcopyrite has been redeposited as hematite, by further oxidation of the ferrous sulphate.

In the Old Dominion mine the chalcocite, as has been pointed out by Emmons, occurs in the transition zone between the oxidized and pyritic ores. According to the observations of Emmons, chalcocite was first encountered between 400 and 500 feet below the surface, where it must have been accompanied by oxidized ore. It is now known to extend downward to the twelfth level, or about 900 feet below the surface, and is here associated with unoxidized pyrite. Its vertical range is thus considerable. At the time of visit no chalcocite was seen in place above the tenth level.

The occurrence of the chalcocite as a characteristic mineral of the transitional zone from oxidized to sulphide ore is alone suggestive of its secondary character. This, however, is still more strongly brought out by the structure of the ore itself, which, as described on page 15, has formed in concentric shells about small residual grains of pyrite. The cupriferous sulphate solutions descending from the oxidized zone above have percolated through the loosely coherent pyrite and changed it in part to chalcocite. The reaction in this case has involved not only the little chalcopyrite in the pyritic ore, but has apparently transformed pyrite to chalcocite without any intermediate stage. That this is possible is shown by the reaction cited from Van Hise's well-known paper on the deposition of ores.

Cuprous sulphate		Pyrite		Chalcocite		Ferrous sulphate,
$Cu_2\,So_4$	+	FeS	=	Cu_2S	+	$Fe\,SO_4$

The process of sulphide enrichment appears to have worked downward, keeping 200 feet or more in advance of distinct oxidation. Chalcocite thus occurs as residual masses in the oxidized ore, and as bunches in pyrite below the limit of oxidation. Below the twelfth level chalcocite will probably be less abundant, and it is rather doubtful whether it will be found in any quantity on the thirteenth level when that depth is reached.

Oxidized ores.—The oxidized ores are in greater part indigenous—i. e., occupy substantially the places of formerly existent sulphides, the latter having been altered in the usual manner by descending solutions, which, starting at the surface with oxygen and carbon dioxide, constantly gathered new materials and effected manifold chemical changes in the ores in their downward progress. Such apparently are the oxidized ores of the Old Dominion, Hoosier, Buffalo, and other mines in the Globe Hills. But even in these cases there has evidently been some migration of the ores during the general progress of oxidation, although it is difficult to determine how extensive this movement has been. In the Buffalo mine, for example, the occurrence of kernels of chalcocite surrounded by malachite shows that the change has been, on the whole, in situ. But, on the other hand, microscopical study of the oxidized ore indicates that some of the malachite has directly replaced the quartzite and occupies a position not previously filled by a sulphide.

So far as known, no sulphides have been found in the large ore bodies occurring in limestone in the Old Dominion mine, and there is no direct evidence that they were ever present. But, reasoning from analogy with deposits of like form and similar geological surroundings in other districts, it is fair to suppose that these masses were originally deposited as sulphides, although it is not safe to assume that these sulphides were identical in character with the pyritic ores now known in the diabase of the lower levels. It is very probable that they were more cupriferous.

With the oxidation of these ore bodies much of the iron and copper passed into solution as sulphates, carbonates, or silicates, and this change was unavoidably accompanied by migrations of the different ore constituents within the oxidizing mass. That such indeed took place is seen by the structure of the oxidized ore, in which stringers or bunches of one ore mineral occur inclosed within another. Moreover, these ore solutions can scarcely have been confined within the space originally occupied by sulphide ore. They undoubtedly took advantage of such mechanically formed spaces as may have opened since the sulphides were originally deposited, to transport ore into new crevices, and very probably replaced to some extent the inclosing limestone and such of the shattered quartzite as lay within reach of their attack.

In the case of the chrysocolla deposits of the Black Warrior, Geneva, and Black Copper mines, the ores occur as replacements of dacitic tuff, or possibly dacite in the last-named property, and their structure is such as to indicate strongly that they have been deposited directly in the tuff as the hydrous silicate of copper and do not represent the alteration in place of former sulphides. Proof of this hypothesis is perhaps not to be had. But the total absence of sulphides, combined with the lack of iron oxide and the fact that the ore is practically a single mineral rather than a mixture such as results from the oxidation of more or less pyritic ores, is a point in its favor. Furthermore, the structure of the chrysocolla is closely and minutely related to that of the tuff it has replaced, which would probably not be the case did the ore result from the alteration of former bodies of sulphide. For, even if the sulphides preserved some vestiges of the original texture of the tuff, the further change into chrysocolla could scarcely fail to obliterate them entirely. It is therefore concluded that the chrysocolla ores of these mines are probably exotic, although it is admitted that actual proof of this is, from the nature of the case, not at hand.

The source of the solutions that deposited the hydrous silicate of copper is unknown. Although the ore-bodies are always associated with much fissuring, a large part of this is later than the ore, and none of the fissures that have been cut in the underlying schist show such mineralization as would be expected had they served as channels for ore-bearing solutions capable of depositing the over-lying ore bodies. The hypothesis that the ores have reached their present position by direct ascent through these fissures in the schists, while attractive at first glance, has insufficient support as far as present developments go.

A second hypothesis is that they may have come in laterally along the previous beds of tuff, carrying the copper first as carbonate, afterwards to be transformed to silicate by the abundant silica present in the glassy tuff, the ready solubility of which is shown by the frequent occurrence of opal and chalcedony in the tuffaceous and massive dacite. Probably there were scattered over the old surface of shattered schist upon which the tuff was laid down surficial deposits containing carbonate of copper, much as, at the present day, slightly water-worn gravelly detritus cemented by impure malachite may be seen in Webster, Lost, and Gold gulches, usually just above the level of the existing stream channels. Such deposits show that solution and transportation of ore may be effected by the mere passage of meteoric waters over the surface of a generally mineralized region. The covering of such a surface with a permeable mantle of tuff offers exceptional opportunity for the solution and transportation of the scattered, low-grade surficial ore, and its concentration in favorable places at the base of the tuff, through the agency of what are practically surface waters. The deposition of this exotic ore would be particularly favored by a fault, such as that at the Montgomery claim, which should drop the tuff against older, less permeable, and less chemically active rock, thus forming a depositional trough.

It is believed that such an hypothesis best accounts for the chrysocolla ore of the Black Warrior and Geneva mines, and probably also for that of the Black Copper mine. The ore is exotic, and has been derived, not from sulphides in place, but probably from the lateral transport and concentration of scattered surficial deposits of predacitic origin, which were themselves formed by the oxidation and weathering of sulphides.

The genesis of the chrysocolla of the Keystone and neighboring veins in granite-porphyry is not clearly understood. The purity of the chrysocolla, its vein structure, and the absence of evidence of sulphide oxidation from the vein and wall rock are suggestive of an exotic origin of the ore and its deposit in the fissure as hydrous copper silicate. The present depth of the Keystone mine, however, is not sufficient to determine the real genesis of the ore body. The occurrence of some unoxidized pyrite in a stringer near the mouth of the lower tunnel indicates that if the chrysocolla is to give place to sulphides in depth the point of change should not be far off. It is hoped that the mine will be successfully exploited to a sufficient depth to thoroughly expose this interesting deposit.

Owing to the fact that there is only one moderately deep mine in the quadrangle, the Old Dominion, in which the relation of ground-water level to oxidized and sulphide ores can be studied, significant data bearing upon the influence of climate on ore oxidation are meager. Even in the Old Dominion mine the water conditions can not be regarded as typical of the district, since the greater part of the water there encountered comes from the base of the Gila conglomerate and not from the older rocks in which the ores occur. In this mine oxidized ore prevails down to the tenth level, or to a depth of 600 or 700 feet. The change to sulphide ores occurs between the tenth and eleventh levels, and probably marks approximately the lowest natural level of standing water. More extensive mining operations would probably show that the ground water of the Globe quadrangle, as in other districts of similar aridity, lies generally deep and that its surface exhibits less conformity with the topography than is commonly the case in more humid regions. Although in the Globe quadrangle there is no sharp boundary between oxidized and sulphide ores, the precipitation appears to have been sufficient in most cases to effect an oxidation of the deposits by descending surface water practically down to the ground-water level. This alteration has been most thorough in the larger deposits associated with limestone, quartzite, and diabase. It has been least effective in some of the smaller lodes in the Pinal schist.

While it is probable that the precipitation was greater during the deposition of the Gila conglomerate (early Quaternary?), the rather limited number of ore bodies available for study has revealed in them no features clearly ascribable to the climatic change suggested by the present aridity.

AGE OF THE ORES.

As in this district primary sulphide ores are found in fissures cutting diabase, they were evidently deposited after the eruption of that rock. Similar original ores also occur in Pinal schist, in which case there is nothing in their surroundings to show that they are not much older than the ores in diabase. But as they are even less deeply oxidized than the latter, it seems reasonable, in the lack of distinct evidence to the contrary, to refer all of the primary sulphide mineralization to one period, subsequent to the great disturbing and mineralizing event in the geological development of the region—the diabase intrusions.

Although the fact that the primary ores are later than the diabase is readily established, their relation to the dacite is less easily determined. It has been shown that the region was probably faulted after the diabase intrusion and long before the eruption of the dacite. The results of this faulting were, however, greatly obscured by the post-dacite faulting, probably of late Tertiary age. There is some question whether or no this earlier faulting was important, and whether the original mineralization is related to it or to the post-dacite faulting. Owing chiefly to the usual oxidation of the ore, no thoroughly conclusive evidence for the decision of this question could be obtained at any one point. That the former of these alternative hypotheses—namely, that the sulphide ores are older than the dacite—is the true one is, however, strongly indicated by the cumulative weight of several facts, no one of which alone is fully decisive. These may be summarized as follows:

The mineralized fault fissures north of Globe either pass beneath the dacite flow without perceptibly faulting it, as may be seen near the I. X. L. mine, and is indicated on the geological map, or else they dislocate it to an extent incommensurate with their displacement of the older rocks, as in the case of the Old Dominion fault. It is difficult to trace faults when they enter the dacite, but the total disappearance of the outcrops, several strong fissures where this rock forms the surface, and the striking contrast between the faulting of the older underlying rocks and the practical integrity of the dacite flow as it is exposed just north of Globe, admit of but one interpretation. These generally northeast-southwest faults, many of which are more or less mineralized, were originally formed in pre-dacite times. In the northwest corner of the quadrangle, on the other hand, the dacite is conspicuously faulted, but these post-dacite faults preponderate, and are not mineralized, or at least have not been shown to contain sulphide ores. This difference in age of the dominant faults thus probably accounts for the notable lack of mineralization in the northeast corner of the area, in spite of the fact that the same rocks occur there as north of Globe, and are even more thoroughly fissured.

No sulphide ore has yet been found in dacite. In the Old Dominion mine such ore as has been mined near this rock has invariably been oxidized, even on the lower levels, which elsewhere encounter sulphides. The ore bodies never extend irregularly into the dacite, but are separated from it by faults, or else underlie it with every appearance of having been deposited and at least partly oxidized before its eruption. The only bodies of oxidized ore known to occur in dacite or dacite tuff are those of the Black Warrior, Geneva, and Black Copper mines, in which the ore is certainly later than the eruptive rock. But it has been shown that these ores consist of chrysocolla and are exotic. Thus their existence in the tuff at the base of the dacite points to the existence of pre-dacite sulphide ores from which they were originally derived. Their occurrence would be difficult of explanation were it supposed that the original mineralization of the district took place after the eruption of dacite.

It is therefore concluded that the hypothesis which assigns the original deposition of the sulphide ores to a period following the intrusion of the diabase and preceding the eruption of the dacite is in harmony with the observed facts, as well as with the general theoretical considerations suggestive of a genetic connection between the intruded diabase and the deposition of ore. The primary mineralization of the Globe district thus probably took place during the later Mesozoic.

NONMETALLIFEROUS DEPOSITS.

Limestone.—Practically all the limestone areas shown on the geological map may be regarded as potential sources of calcareous flux or of lime. The limestone used for fluxing in the Old Dominion smelter is quarried about 400 feet east of the main (Interloper) shaft, and this rock has been burned to supply lime for the company's needs. The same mass of limestone has also been utilized for the production of lime in a small way in Copper Gulch.

Building stone.—The Globe quadrangle is well provided with good stone of various kinds. The dacite, which occurs in inexhaustible quantity and in a readily accessible position within half a mile of Globe, affords an easily worked and durable material, which has been used for walls and foundations by the Old Dominion and United Globe mining companies. It has not, however, been quarried extensively enough to determine whether blocks of large size could be obtained from this source. In Rocky Gulch, about 1½ miles east of Globe, are exposed some beds of red quartzose sandstone, belonging to the Apache group. These beds are less indurated than the usual quartzites belonging to this group, and have been quarried in a primitive way for building stone. The stone is durable, but it is doubtful whether it could be obtained in large quantity and uniform quality.

The granitic rocks of the Pinal Range, particularly the Madera diorite, the Schultze granite, and the Solitude granite, would afford any desired quantity of high-grade building stone, but at present there is no demand for material of this character.

WATER RESOURCES.

Owing to the small rainfall, water is not abundant in the Globe quadrangle, and the best utilization of the scanty supply constitutes a problem of considerable economic importance. Fortunately for the district, the high, timbered crest of the Pinal Range receives and contains considerable snow during the winter months. This, melting gradually in spring, ameliorates the drought in the lower country, which would otherwise be severe until broken by the summer rains. The storage capacity of the range seems to have been somewhat diminished by the cutting of the timber, but the Pinal Mountains nevertheless continue to be the source of much of the water available in the lower portions of the quadrangle.

Even in the dry months small streams of good water persist near the heads of several of the larger ravines of the Pinal Range, but this water usually sinks into the sand and gravel of the stream beds when the latter enter the Gila conglomerate. In a few of the larger arroyos, such as Pinal, Pinto, and Mineral creeks, some of this water reappears at intervals, often at several miles from the mountains.

To procure water for ordinary domestic purposes in the low-lying portions of the area, is usually not difficult. There are a number of little springs scattered over the quadrangle and a few perennial streamlets. As a rule, wells sunk along any of the principal arroyos encounter permanent water at depths of less than 40 feet. The inhabitants of Globe formerly depended for their water supply upon wells within the town limits. Such wells are, however, from their situation, open to contamination, and to avoid this danger the present town supply is pumped from a well sunk near the bed of Pinal Creek about 1½ miles southeast of town. The settlement of Black Warrior is supplied in a similar manner from a well nearly 3 miles away, at the point where Miami Flat opens on Pinal Creek. In this case it is probable that an adequate supply of good water might have been obtained from a well sunk closer at hand.

The development of the Old Dominion mine has shown that there is abundant water at the base of the Gila conglomerate. The attitude of this formation with reference to the Pinal Range is highly favorable for the existence of artesian conditions. Unfortunately, however, these deposits are so porous and variable as to give little hope that there is any bed sufficiently impervious and persistent to retain the water under considerable hydrostatic head. It appears, therefore, that in the future, as in the past, the main dependence of the district must be upon non-flowing wells. A limited supply might be obtained by damming some of the streams in the Pinal Range, but the flow of any one stream would probably not be sufficient to warrant the cost of the dam and pipe line.

December, 1902.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

TOPOGRAPHY

ARIZONA
GLOBE QUADRANGLE

33°30′ 111°00′ — 55′ — 50′ — 110°45′ 33°30′
33°15′ 111°00′ — 55′ — 50′ — 110°45′ 33°15′

E. M. Douglas, Geographer in charge.
Triangulation by A. H. Thompson.
Topography by W. J. Lloyd.
Surveyed in 1900-1901.

APPROXIMATE MEAN DECLINATION 1900.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

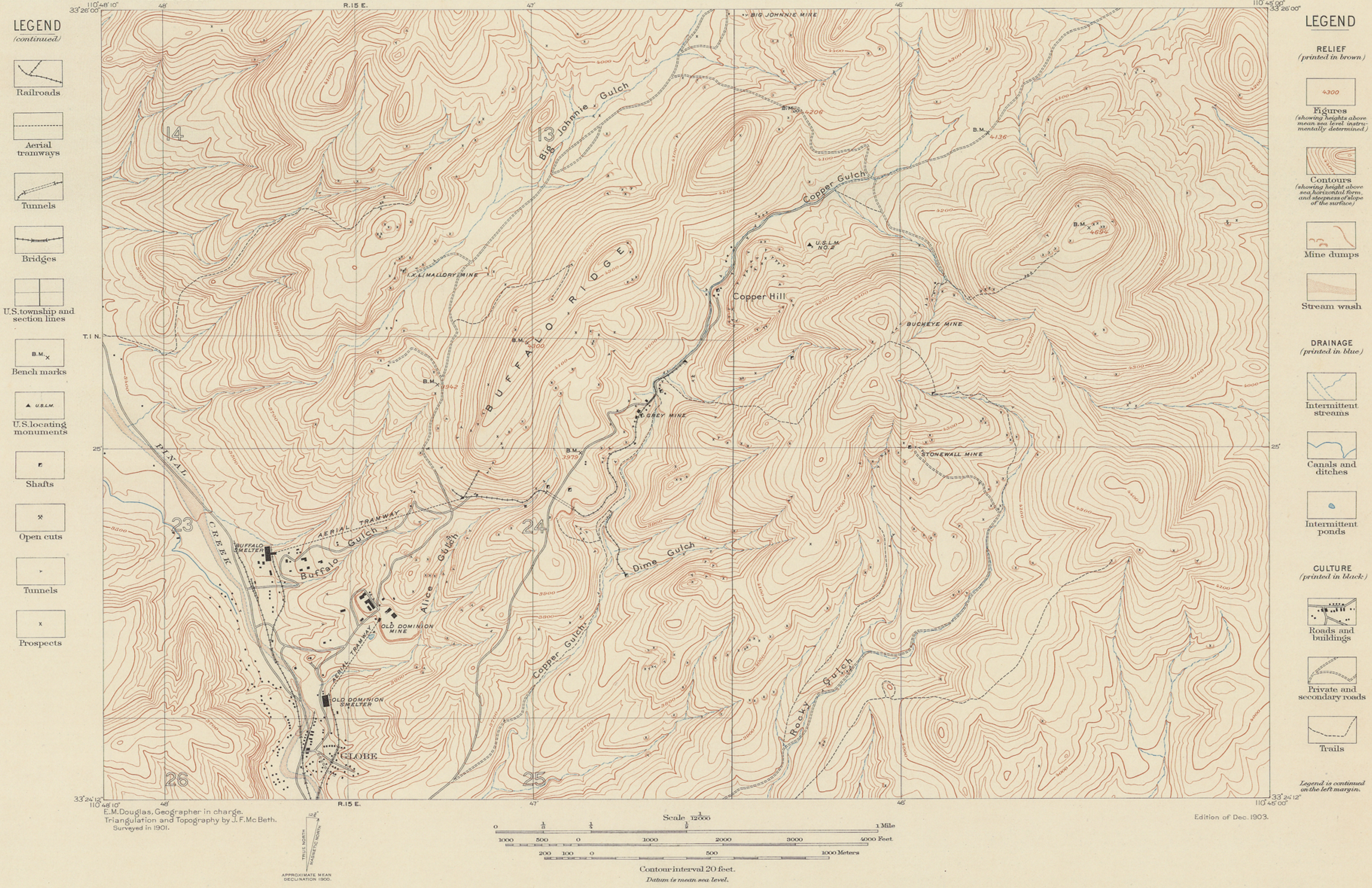
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Edition of Jan. 1904.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT
DIRECTOR

TOPOGRAPHY

ARIZONA
(GILA COUNTY)
GLOBE SPECIAL MAP



E.M. Douglas, Geographer in charge.
Triangulation and Topography by J.F. McBeth.
Surveyed in 1901.

Edition of Dec. 1903.

Scale $\frac{1}{12000}$

Contour interval 20 feet.
Datum is mean sea level.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT DIRECTOR

AREAL GEOLOGY

ARIZONA
GLOBE QUADRANGLE

LEGEND

IGNEOUS ROCKS
(continued)

PRE-CAMBRIAN

rgr — **Ruin granite** *(granitite or biotite-granite; extensive batholithic mass underlying the northern part of the quadrangle)*

sgr — **Schultze granite** *(extensive batholithic mass of granitite or biotite-granite, intrusive in Pinal schist in west-central part of quadrangle, and associated dikes of granite-porphyry)*

stg — **Solitude granite** *(granite and muscovite-granite; intrusive mass in Pinal schist)*

mdi — **Madera diorite** *(quartz-mica-diorite; extensive batholithic mass intrusive in Pinal schist in southern portion of the quadrangle)*

Known faults *(occasionally accompanied by mineralization)*

Concealed faults *(covered by younger deposits)*

Probable faults

Sections

A B C D

Strike and dip of stratified rocks

Horizontal beds

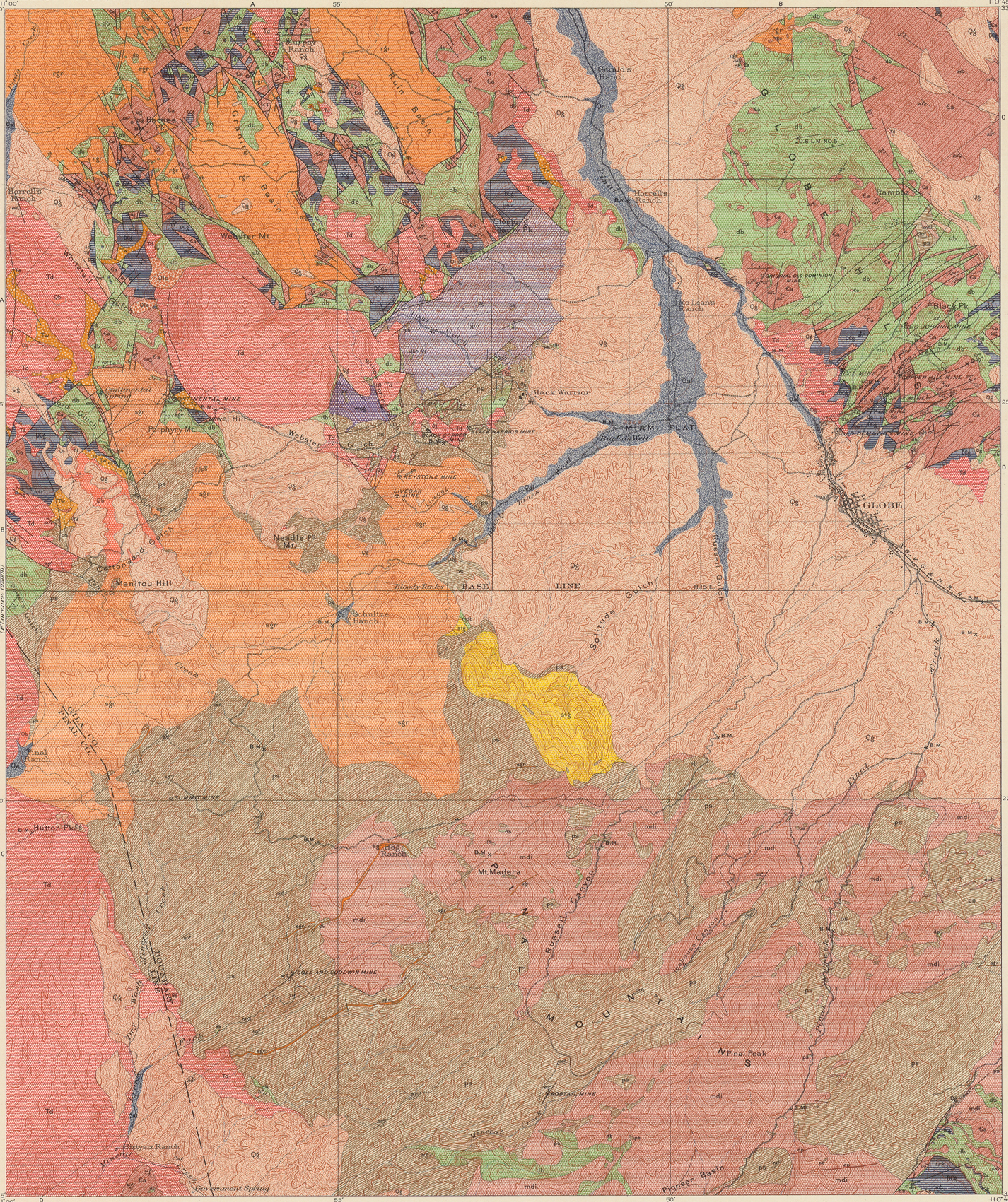
Dip of fault planes

Strike and dip of schistose cleavage

Strike of vertical schistose cleavage

Mines

Prospects



LEGEND

QUATERNARY

Qls — **Landslides** *(composed chiefly of blocks of dacite)*

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines, subaerial deposits by patterns of dots and circles; metamorphism is indicated by hachures)

QUATERNARY

Qal — **Alluvium** *(sands and gravels along present streamways and in small valleys)*

Pleistocene?

Qg — **Gila conglomerate** *(fluviatile deposit of irregularly bedded conglomerates, breccias, grits, and tuffs)*

TERTIARY — *Eocene series?*

Tw — **Whitetail formation** *(fluviatile deposit, usually composed of subangular fragments of diabase and limestone)*

DEVONIAN AND CARBONIFEROUS

DCg — **Globe limestone** *(hard, buff and gray limestone, in beds ranging in thickness from 1 to 6 feet)*

CAMBRIAN ?

Ca — **Apache group** *(chiefly quartzite, with subordinate amounts of shale and conglomerate)*

PRE-CAMBRIAN

ps — **Pinal schist** *(muscovite- or sericite-schist of sedimentary origin with a little amphibolite-schist and some incompletely altered grits. Wavy lines indicate general direction of schistose cleavage)*

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs)

Later than Whitetail formation — *Pleistocene?*

QUATERNARY ?

Qb — **Basalt** *(surface flow, intercalated in Gila conglomerate, and small intrusive masses)*

TERTIARY

Td — **Dacite** *(surface flow and underlying tuff)*

TRIASSIC, JURASSIC, OR CRETACEOUS ?

dp — **Diorite-porphyry** *(small sills and dikes intrusive in Globe limestone, Apache group, Madera diorite, and diabase, many too small to represent on the map)*

db — **Diabase** *(intrusive in Globe limestone and Apache group as thick sills and irregular masses)*

PRE-CAMBRIAN

mdb — **Metadiabase** *(intrusive mass in Pinal schist)*

wsg — **Willow Spring granite** *(intrusive mass of granite in Pinal schist)*

lgm — **Lost Gulch monzonite** *(intrusive mass of adamellite or quartz-monzonite in Pinal schist)*

Legend is continued on the left margin.

E.M. Douglas, Geographer in charge.
Triangulation by A.H. Thompson.
Topography by W.J. Lloyd.
Surveyed in 1900-1901.

TRUE NORTH — MAGNETIC NORTH — 12½°
APPROXIMATE MEAN DECLINATION 1900.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.
Datum is mean sea level.
Edition of Mar. 1904.

DIAGRAM OF TOWNSHIP.

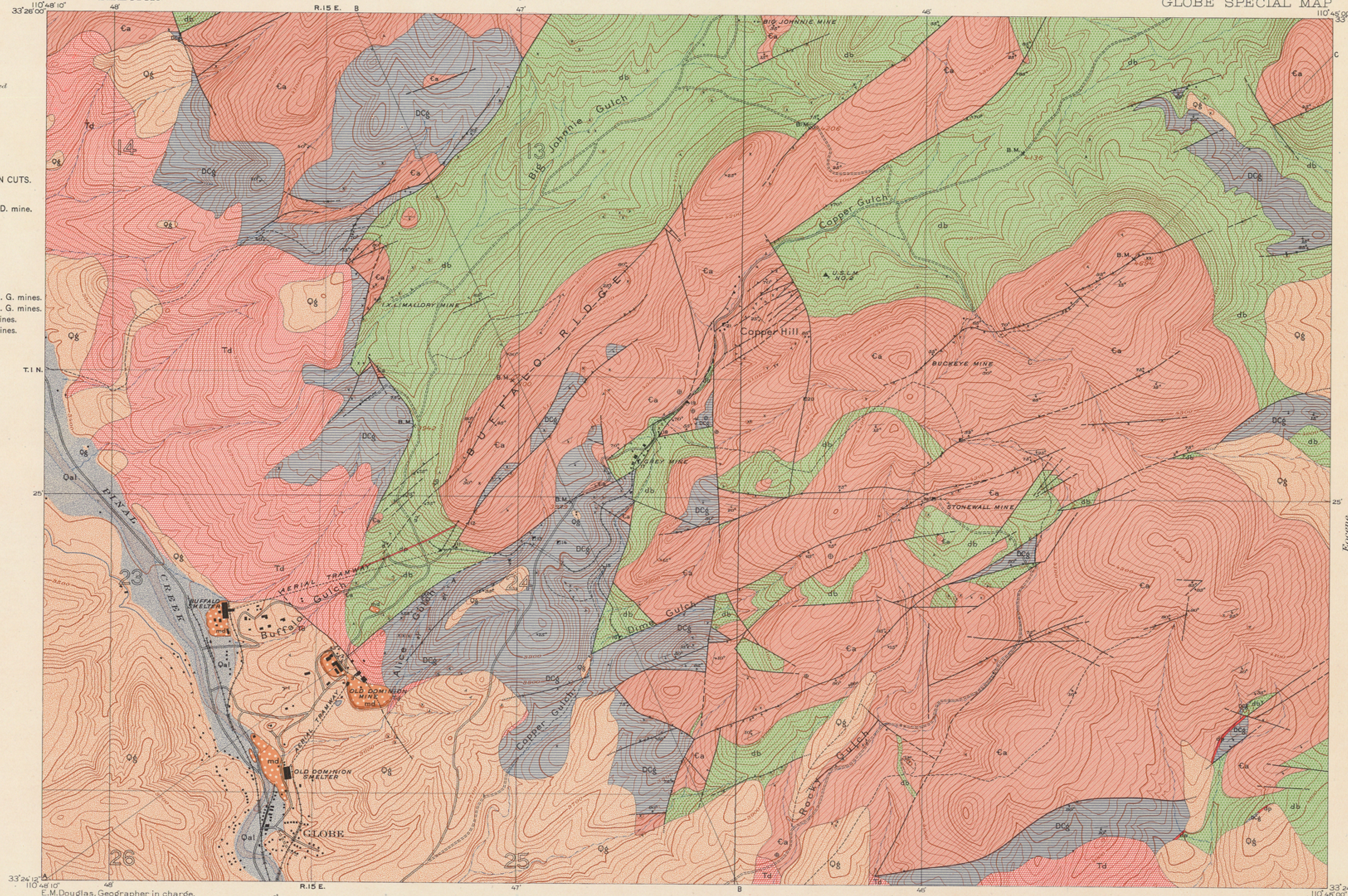
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Geology by F. L. Ransome.
Assisted by J. D. Irving.
Surveyed in 1901 and 1902.

U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT
DIRECTOR.

ECONOMIC GEOLOGY

ARIZONA
(GILA COUNTY)
GLOBE SPECIAL MAP



E. M. Douglas, Geographer in charge.
Triangulation and Topography by J. F. McBeth.
Surveyed in 1901.

APPROXIMATE MEAN DECLINATION 1900.

Scale $\frac{1}{12000}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of Mar. 1904.

Geology by F. L. Ransome.
Surveyed in 1902.

LEGEND

Mine and smelter dumps (md)

SEDIMENTARY ROCKS
(Areas of subaqueous deposits are shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles.)

QUATERNARY

- Qal — Alluvium *(sands and gravels along present streamways)*
- Qg — Gila conglomerate *(fluviatile deposit of irregularly bedded conglomerates)* — *Pleistocene?*

DEVONIAN AND CARBONIFEROUS

- DCg — Globe limestone *(hard, buff and gray limestone with some cherty bands)*

CAMBRIAN ?

- Ca — Apache group *(white and red quartzite with some grits and conglomerates)*

IGNEOUS ROCKS
(Areas of Igneous rocks are shown by patterns of triangles and rhombs.)

TERTIARY

- Td — Dacite *(surface flow.)* — *Eocene series?*

TRIASSIC, JURASSIC, OR CRETACEOUS ?

- dp — Diorite-porphyry *(dikes)*
- db — Diabase *(intrusive in Globe limestone and Apache group as thick sills and irregular masses)*

Known faults *(occasionally accompanied by mineralization)*

Concealed faults *(covered by younger deposits)*

Probable faults

Sections

Legend is continued on the left margin.

LEGEND
(continued)

- *Strike and dip of stratified rocks*
- *Horizontal beds*
- *Dip of fault planes*
- *Shafts*
- *Tunnels*
- *Open cuts*
- *Prospect pits*

SHAFTS, TUNNELS, AND OPEN CUTS.
(Unnamed on the map.)

1. Fourth level drain tunnel, O. D. mine.
2. Mule tunnel, O. D. mine.
3. Interloper shaft, O. D. mine.
4. Alice tunnel, O. D. mine.
5. Open cut, O. D. mine.
6. Alice cross cut, O. D. mine.
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9. Josh Billings, tunnel No. 2, U. G. mines.
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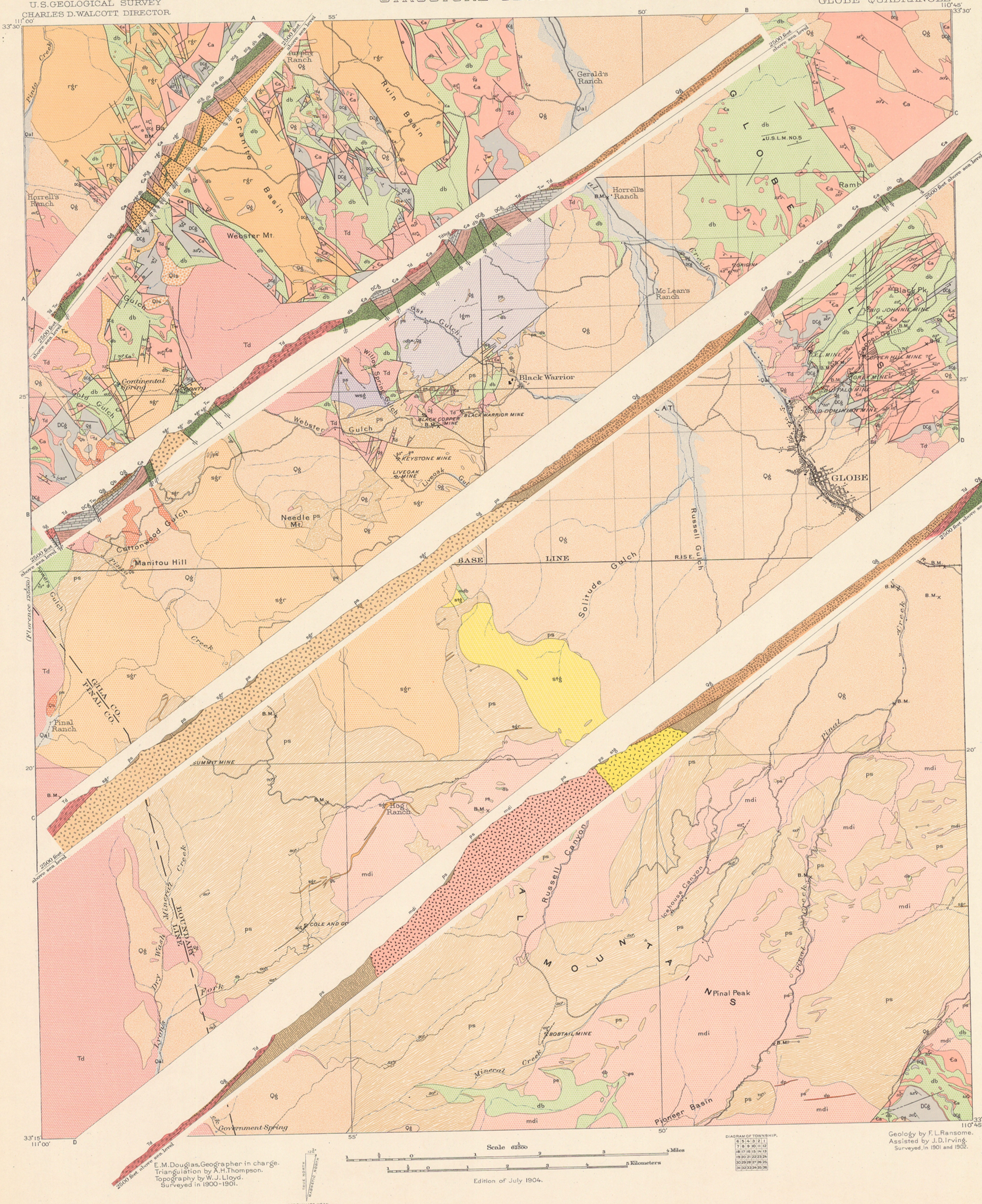
15. Centralia shaft, U. G. mines.
16. Dime shaft, U. G. mines.
17. Grey shaft, U. G. mines.
18. Grey incline, U. G. mines.
19. Cuprite shaft, U. G. mines.
20. Budget shaft, U. G. mines.
21. Copper Hill shaft.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT DIRECTOR

STRUCTURE SECTIONS

ARIZONA
GLOBE QUADRANGLE



E.M. Douglas, Geographer in charge.
Triangulation by A.H. Thompson.
Topography by W.J. Lloyd.
Surveyed in 1900-1901.

Scale $\frac{1}{62500}$

Edition of July 1904.

Geology by F.L. Ransome.
Assisted by J.D. Irving.
Surveyed in 1901 and 1902.

LEGEND

SHEET SYMBOL

Qls — **Landslides** (composed chiefly of blocks of dacite)

SEDIMENTARY ROCKS

QUATERNARY

Qal — **Alluvium** (sands and gravels along present streamways and in small valleys)

Pleistocene? Qg — **Gila conglomerate** (fluviatile deposit of irregularly bedded conglomerates, breccias, grits, and tuffs)

TERTIARY

Eocene? Tw — **Whitetail formation** (fluviatile deposit, usually composed of subangular fragments of diabase and limestone)

DEVONIAN AND CARBONIFEROUS

DCg — **Globe limestone** (hard, buff and gray limestone, in beds ranging in thickness from 1 to 6 feet)

CAMBRIAN?

Ca — **Apache group** (chiefly quartzite, with subordinate amounts of shale and conglomerate)

PRE-CAMBRIAN

ps — **Pinal schist** (muscovite- or sericite-schist of sedimentary origin with a little amphibolite-schist and some incompletely altered grits. Wavy lines indicate general direction of schistose cleavage)

IGNEOUS ROCKS

QUATERNARY?

Qb — **Basalt** (surface flow, intercalated in Gila conglomerate, and small intrusive masses)

TERTIARY

Later than Whitetail formation. Td — **Dacite** (surface flow and underlying tuff)

TRIASSIC, JURASSIC, OR CRETACEOUS?

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PRE-CAMBRIAN

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Known faults (occasionally accompanied by mineralization)

Concealed faults (covered by younger deposits)

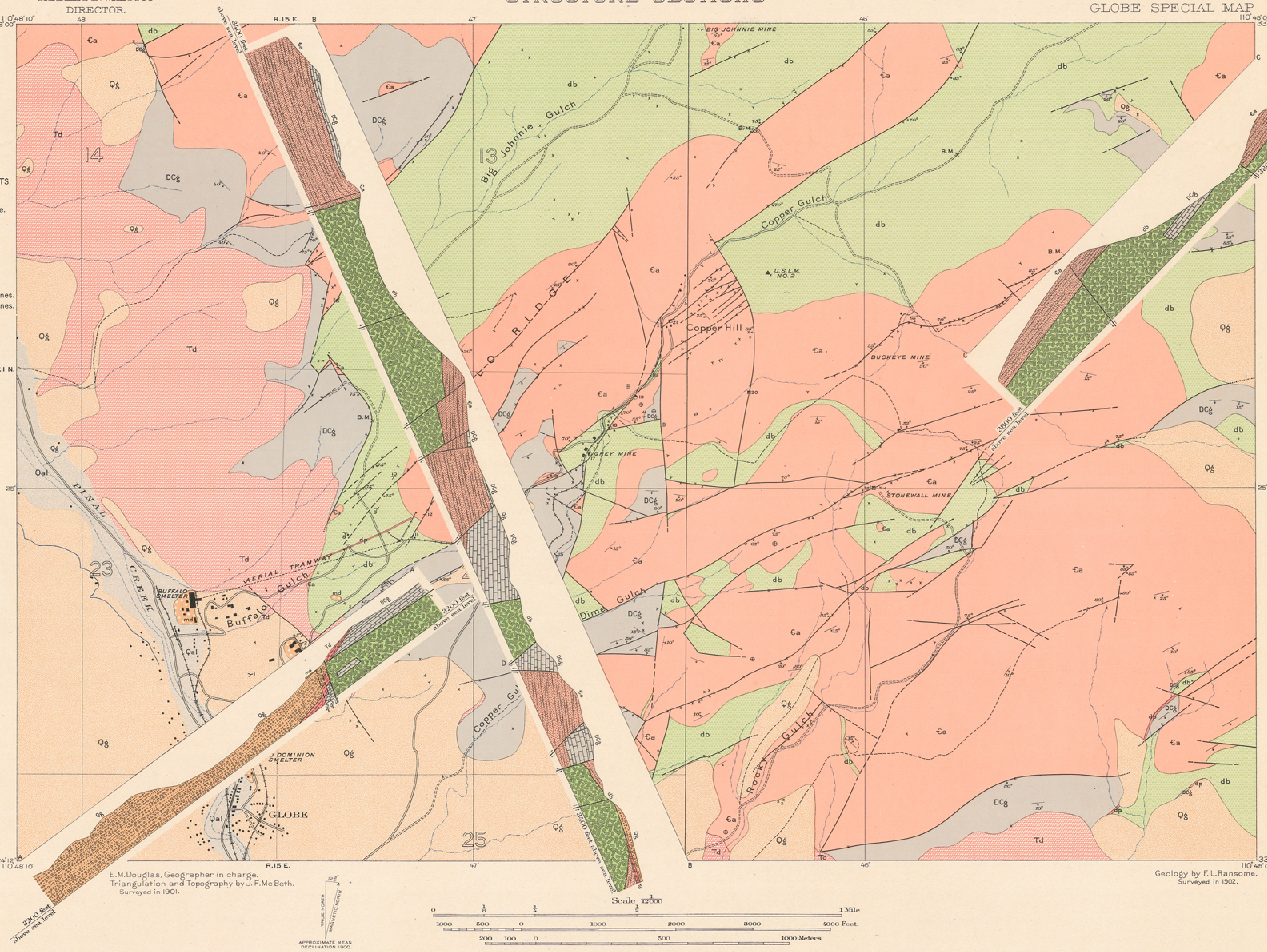
Probable faults

Strike and dip of stratified rocks
Horizontal beds
Dip of fault planes
Strike and dip of schistose cleavage
Strike of vertical schistose cleavage

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT
DIRECTOR.

STRUCTURE SECTIONS

ARIZONA
(GILA COUNTY)
GLOBE SPECIAL MAP



E.M. Douglas, Geographer in charge.
Triangulation and Topography by J.F. McBeth.
Surveyed in 1901.

Geology by F.L. Ransome.
Surveyed in 1902.

Scale 1/12000

0 — 1 Mile

1000 500 0 1000 2000 3000 4000 Feet

200 100 0 500 1000 Meters

APPROXIMATE MEAN DECLINATION 1900.

Edition of Aug. 1904.

LEGEND

Mine and smelter dumps (md)

SEDIMENTARY ROCKS

QUATERNARY
- Alluvium (Qal) (*sands and gravels along present streamways*)
- Pleistocene? Gila conglomerate (Qg) (*fluviatile deposit of irregularly bedded conglomerates*)

DEVONIAN AND CARBONIFEROUS
- Globe limestone (DCg) (*hard, buff and gray limestone, with some cherty bands*)

CAMBRIAN ?
- Apache group (Ca) (*white and red quartzite with some grits and conglomerates*)

IGNEOUS ROCKS

TERTIARY
- Eocene series? Dacite (Td) (*surface flow*)

TRIASSIC, JURASSIC, OR CRETACEOUS ?
- Diorite-porphyry (dp) (*dikes*)
- Diabase (db) (*intrusive in Globe limestone and Apache group as thick sills and irregular masses*)

Known faults (*occasionally accompanied by mineralization*)

Concealed faults (*covered by younger deposits*)

Probable faults

Legend is continued on the left margin.

LEGEND
(*continued*)

- *Strike and dip of stratified rocks*
- *Horizontal beds*
- *Dip of fault planes*
- *Shafts*
- *Tunnels*
- *Open cuts*
- *Prospect pits*

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(Unnamed on the map.)

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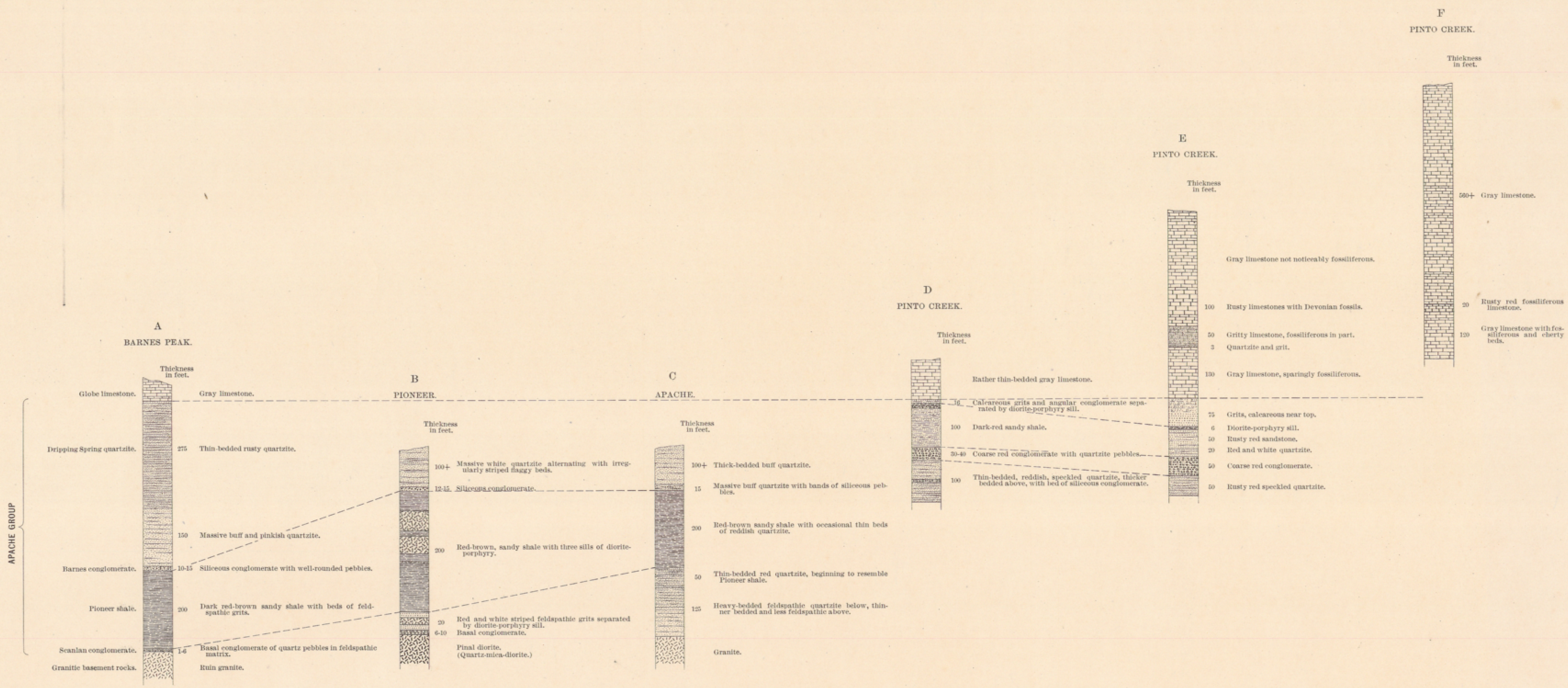
20. Budget shaft, U. G. mines.
21. Copper Hill shaft.

COLUMNAR SECTIONS

GENERALIZED COLUMNAR SECTIONS FOR THE GLOBE QUADRANGLE.

SCALE: 1 INCH=200 FEET.



F. L. RANSOME,
Geologist.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be determined by observing their positions. This relationship holds except in regions of intense disturbance; in such regions sometimes the beds have been reversed, and it is often difficult to determine their relative ages from their positions; then *fossils*, or the remains and imprints of plants and animals, indicate which of two or more formations is the oldest.

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed 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 there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. When two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains found in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it.

Similarly, the time at which metamorphic rocks were formed from the original masses is sometimes shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

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.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary...	Recent........ / Pleistocene....	Q	Brownish-yellow.
	Tertiary......	Pliocene....... / Miocene....... / Oligocene...... / Eocene........	T	Yellow ocher.
Mesozoic	Cretaceous....	....	K	Olive-green.
	Jurassic	....	J	Blue-green.
	Triassic.......	....	Ћ	Peacock-blue.
Paleozoic	Carboniferous.	Permian....... / Pennsylvanian / Mississippian..	C	Blue.
	Devonian.....	....	D	Blue-gray.
	Silurian.......	....	S	Blue-purple.
	Ordovician....	....	O	Red-purple.
	Cambrian.....	Saratogan..... / Acadian....... / Georgian......	€	Brick-red.
	Algonkian	....	A	Brownish-red.
	Archean	....	Æ	Gray-brown.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs 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 combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin.

The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system. The symbols by which formations are labeled consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters. The names of the systems and recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and valleys and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 1, is an illustration. To this class belong beaches, alluvial plains, lava 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, and these are, in origin, independent of the associated material. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterwards partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface, and can draw sections representing the structure of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

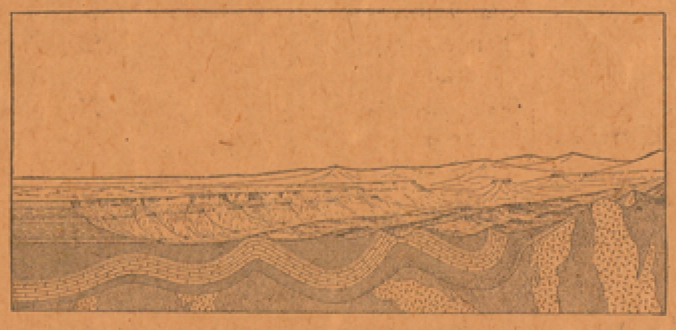


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

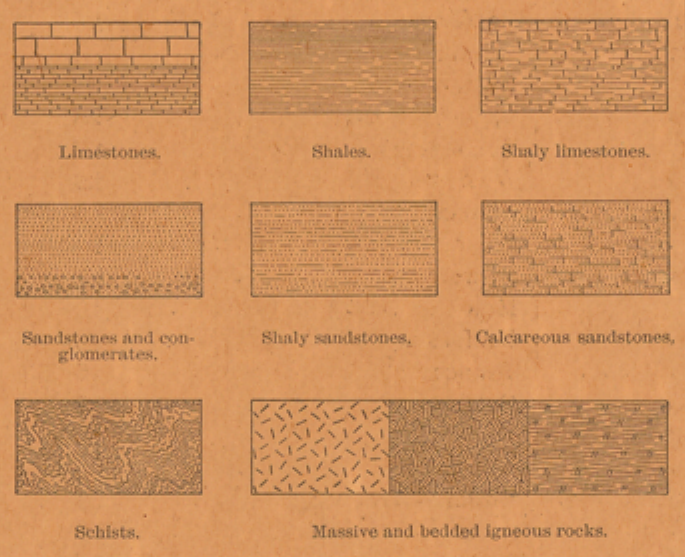


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in fig. 4.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be

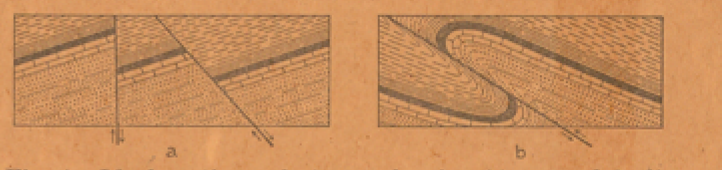


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The uppermost of these, seen at the left of the section, is a set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been raised from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks thus rest upon an eroded surface of older rocks the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum which appears in the section may be measured by using the scale of the map.

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

CHARLES D. WALCOTT,

Director.

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