DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

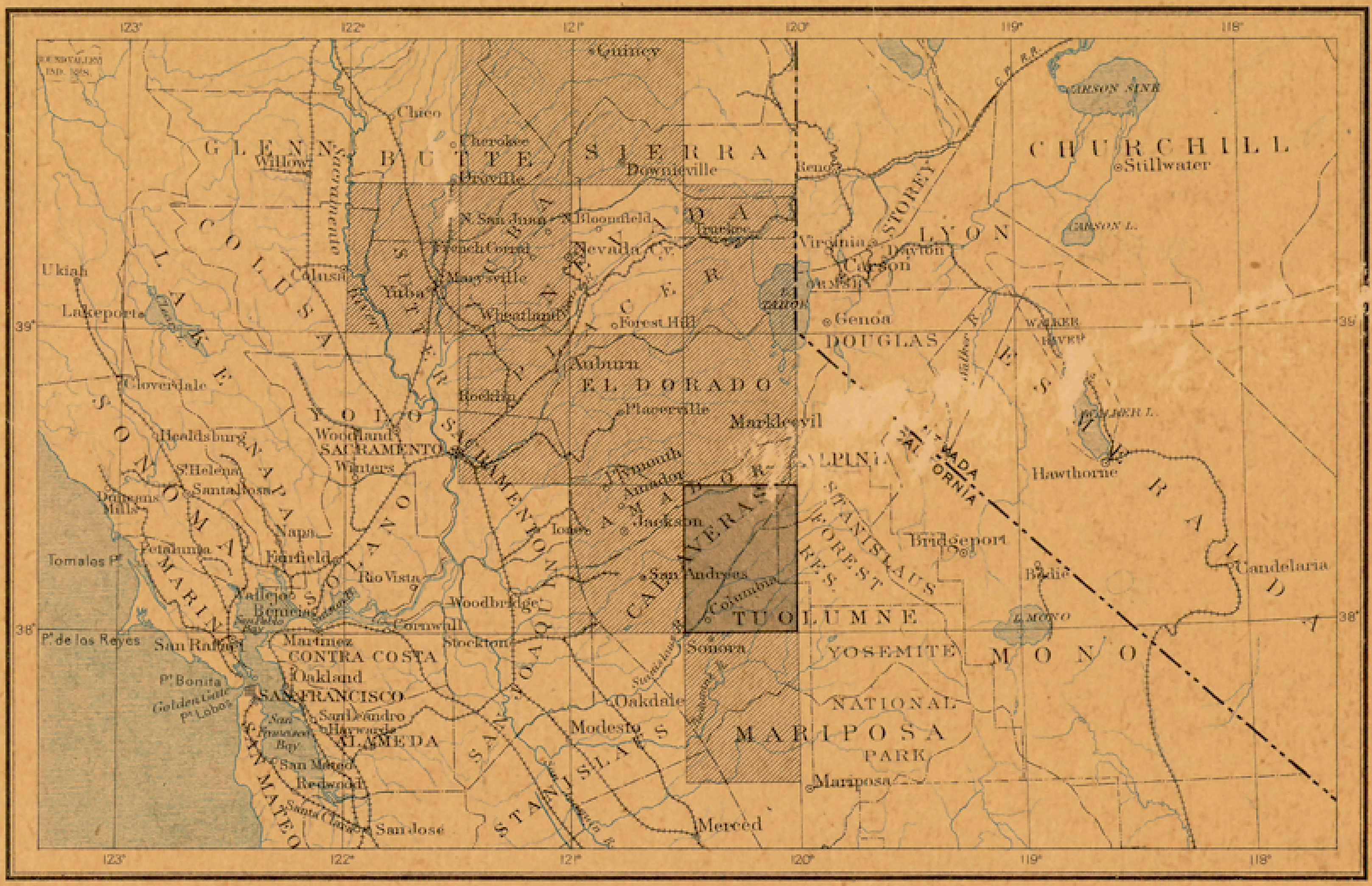
OF THE

UNITED STATES

BIG TREES FOLIO

CALIFORNIA

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE BIG TREES FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION — TOPOGRAPHY — HISTORICAL GEOLOGY — ECONOMIC GEOLOGY — SPECIAL ILLUSTRATIONS

FOLIO 51 — LIBRARY EDITION — BIG TREES

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS. S. J. KUBEL, CHIEF ENGRAVER

1898

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base 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, railroad, 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea-level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical 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:

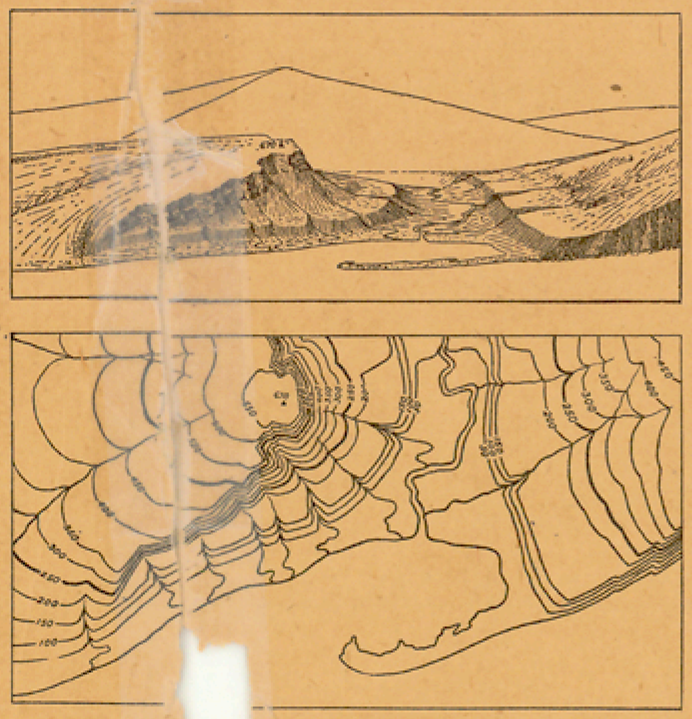


Fig. 1.—Ideal [illegible] and corresponding contour map.

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 in a precipice. Contrasted with this precipice is the gentle descent of the left-hand slope. 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 approximately a certain height above sea-level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea-level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all 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 nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The 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 vertical 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 used 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 the stream flows the year round 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, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be 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 $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

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 and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,000}$, to about 4 square miles; and on the scale $\frac{1}{250,000}$, to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory 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-quarter 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, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or 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 sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known, and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it either consolidates in cracks or fissures crossing the bedding planes, thus forming dikes, or else spreads out between the strata in large bodies, called sills or laccoliths. Such rocks are called *intrusive*. Within their rock enclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock, it is younger than that rock, and when a sedimentary rock is deposited over it, the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in successive 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 over wide expanses, and as it rises or subsides the shore-lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quarzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus

DESCRIPTION OF THE GOLD BELT.*

GEOGRAPHIC RELATIONS.

The principal gold belt of California includes a portion of the Sierra Nevada lying between the parallels of 37° 30′ and 40° north latitude. It is bounded on the west by the Sacramento and San Joaquin valleys, and on the east by a diagonal line extending from about longitude 120° 40′ in the neighborhood of the fortieth parallel to longitude 119° 40′ in the neighborhood of parallel 37° 30′. There are other gold-bearing regions in the State, both to the north and south of this belt, but by far the largest quantity of gold is produced within these limits. The area thus defined contains approximately 9000 square miles. At the northern limit the gold deposits are scattered over nearly the entire width of the range, while to the south the productive region narrows to small dimensions, continuing as a very narrow strip for some distance south of latitude 37° 30′. The whole southern part of the range is comparatively barren. North of the fortieth parallel the range is not without deposits, but the country is flooded with lavas which effectually bury the larger part of them.

GENERAL GEOLOGY.

The rocks of the Sierra Nevada are of many kinds and occur in very complex associations. They have been formed in part by deposition beneath the sea and in part by intrusion as igneous masses, as well as by eruption from volcanoes. All of them except the latest have been more or less metamorphosed.

The northern part of the range, west of longitude 120° 30′, consists prevailingly of clay-slates and of schists, the latter having been produced by the metamorphism of both ancient sediments and igneous rocks. The trend of the bands of altered sediments and of the schistose structure is generally from northwest to southeast, parallel to the trend of the range, but great masses of granite and other igneous rocks have been intruded among these schists, forming irregular bodies which interrupt the regular structure and which are generally bordered each by a zone of greater metamorphism. These slates and schists and their associated igneous masses form the older of two great groups of rocks recognized in the Sierra Nevada. This group is generally called the Bed-rock series.

Along the western base of the Sierra occur beds of sandstone and clay, some of which contain thin coal seams. These are much younger than the mass of the range and have not shared the metamorphism of the older rocks. They dip gently westward beneath later deposits, which were spread in the waters of a shallow bay occupying the Valley of California and portions of which have been buried beneath recent river alluvium.

Streams flowing down the western slope of the Sierra in the past distributed another formation of great importance—the Auriferous gravels. The valleys of these streams served also as channels for the descent of lavas which poured out from volcanoes near the summit. Occupying the valleys, the lavas buried the gold-bearing gravels and forced the streams to seek new channels. These have been worn down below the levels of the old valleys, and the lava beds, with the gravels which they protect, have been isolated on the summits of ridges. Thus the Auriferous gravels are preserved in association with lavas along lines which descend from northeast toward southwest, across the trend of the range. The nearly horizontal strata along the western base, together with the Auriferous gravels and later lavas, constitute the second group of rocks recognized in the Sierra Nevada. Compared with the first group, the Bed-rock series, these may be called the Superjacent series.

BED-ROCK SERIES.

PALEOZOIC ERA.

During the Paleozoic era, which includes the periods from the end of the Algonkian to the end of the Carboniferous, the State of Nevada west of longitude 117° 30′ appears to have been a land area of unknown elevation. This land probably extended westward into the present State of California and included part of the area now occupied by the Sierra Nevada. Its western shore was apparently somewhat west of the present crest, and the sea extending westward received Paleozoic sediments which now constitute a large part of the central portion of the range.

At the close of the Carboniferous the Paleozoic land area of western Nevada subsided, and during the larger part of the Juratrias period it was at least partly covered by the sea. At the close of the Juratrias the Sierra Nevada was upheaved as a great mountain range, the disturbance being accompanied by the intrusion of large amounts of granitic rock.

The Auriferous slate series comprises all of the sedimentary rocks that entered into the composition of this old range of Juratrias time. Formations representing the Algonkian and all of the Paleozoic and Juratrias may therefore form part of the Auriferous slate series.

Fossils of Carboniferous age have been found in a number of places, and the presence of Silurian beds at the northern end of the range, north of the fortieth parallel, has been determined. A conglomerate occurs in the foothills of Amador and Calaveras counties, interbedded with slates containing Carboniferous limestone; this conglomerate is therefore presumably of Carboniferous age. The conglomerate is evidence of a shore, since it contains pebbles of quartzite, hornblende-porphyrite, and other rocks, which have been rounded by the action of waves. The presence of lava pebbles in the conglomerate shows that volcanic eruptions began at a very early date in the formation of the range, for the hornblende-porphyrite pebbles represent lavas similar to the hornblende-andesites of later age.

The great mass of the Paleozoic sediments of the Gold Belt consists of quartzite, mica-schist, sandstone, and clay-slate, with occasional limestone lenses. On the maps of the Gold Belt these sediments are grouped under two formations:

(1) The *Robinson* formation, comprising sediments and trachytic tuffs. This contains fossils showing the age to be upper Carboniferous. The formation is known on the Gold Belt series of maps only in the Downieville quadrangle, a short distance south of the fortieth parallel.

(2) The *Calaveras* formation, comprising by far the largest portion of the Paleozoic sediments of the Gold Belt. Rounded crinoid stems, corals (Lithostrotion and Clisiophyllum), Foraminifera (Fusulina), and bivalves have been found in the limestone lenses, and indicate that a considerable portion at least of this formation belongs to the middle or lower Carboniferous. In extensive areas of the Calaveras formation no fossils have, however, been found, and older rocks may be present in these. It is not likely that post-Carboniferous rocks are present in these non-fossiliferous areas.

POST-CARBONIFEROUS UPHEAVAL.

After the close of the Carboniferous and before the deposition of at least the later Juratrias beds (Sailor Canyon, Mariposa, and Monte de Oro formations), an upheaval took place by which the Carboniferous and older sediments under the then retiring sea were raised above water level, forming part of a mountain range. The beds were folded and compressed and thus rendered schistose. Smaller masses of granite and other igneous rocks were intruded at this time.

JURATRIAS PERIOD.

The areas of land and sea which existed during the earlier part of this period are scarcely known. Fossiliferous strata showing the former presence of the Juratrias sea have been recognized in the southeastern portion of the range, at Mineral King, where the sediments are embedded in intrusive granite; at Sailor Canyon, a tributary of American River; in Plumas County at the north end of the range about Genesee Valley and elsewhere; and in the foothill region from Butte to Mariposa counties in the slates of the Mariposa and Monte de Oro formations.

The land mass that originated with the post-Carboniferous upheaval became by gradual elevation very extensive toward the end of the Juratrias period. This continental mass of late Jurassic time probably reached eastward at least as far as the east base of the Wasatch Mountains. This conclusion is based on the fact that the latest Jurassic beds of California, the Monte de Oro and the Mariposa slates, are found only on the western flank of the Sierra Nevada. During the earlier part of the Juratrias period portions of the Great Basin were under water, as is shown by the fossiliferous beds of that age in Eldorado Canyon south of Virginia City and in the Humboldt Mountains, but nowhere from the foothills of the Sierra Nevada to the east base of the Wasatch, if we except certain beds near Genesee Valley, are any deposits known which are of late Jurassic age.

The following formations have been recognized on the Gold Belt maps:

(1) The *Mariposa* formation, which occurs in narrow bands along the western base of the range. The strata are prevailingly clay-slates, which are locally sandy and contain pebbles of rocks from the Calaveras formation. Tuffs from contemporaneous porphyrite eruptions also occur in them. The fossils of these beds, such as Aucella and Perisphinctes, have their nearest analogues in Russia, and indicate a very late Jurassic age.

(2) The *Monte de Oro* formation, occurring to the northeast of Oroville. This consists of clay-slate and conglomerate containing plant remains of late Jurassic age.

(3) The *Sailor Canyon* formation, which appears well up toward the summit of the range, and consists of clay-slates, altered sandstones, and tuffs. It is separated from the Mariposa formation by a broad belt of the Calaveras formation. The fossils indicate that the period of its deposition covered both the later part of Triassic and the earlier part of Jurassic time.

(4) The *Milton* formation, which has thus far afforded no fossils; it is lithologically similar to a portion of the Sailor Canyon series, and future research may show that it really was deposited at the same time.

THE POST-JURATRIAS UPHEAVAL.

Soon after the Mariposa formation had been deposited the region underwent uplift and compression. The result of uplift was the development of a mountain range along the line of the Sierra Nevada. The Coast Range also was probably raised at this time. The action of the forces was such as to turn the Mariposa strata into a nearly vertical position, and to fold them and other Juratrias beds in with the older Paleozoic strata. The Juratrias clay-shales, in consequence of pressure, now have a slaty structure, which appears to coincide in most cases with the bedding. This epoch was one of intense eruptive activity. The Mariposa and other Juratrias and older beds were injected with granite and other intrusive rocks. There is evidence that igneous rocks were intruded in varying quantities at different times; but that the intrusion of the great mass of the igneous rocks accompanied or immediately followed the upheavals is reasonably certain. Those beds that now form the surface were then deeply buried in the foundations of the range.

The disturbance following the deposition of the Mariposa beds was the last of the movements which compressed and folded the Auriferous slate series. The strata of succeeding epochs, lying nearly horizontal or at low angles, prove that since they were accumulated the rock mass of the Sierra Nevada has not undergone much compression. But the fact that these beds now occur above sea-level is evidence that the range has undergone elevation in more recent time.

THE GOLD-QUARTZ VEINS.

The extent of the gold deposits has been indicated in the introduction to this description. In character they may be classed as *primary*, or deposits formed by chemical agencies, and *secondary*, or those formed from the detritus produced by the erosion of the primary deposits. The primary deposits are chiefly gold-quartz veins,—fissures in the rock formed by mountain-making forces and filled with gold-bearing quartz deposited by circulating waters. The gold-quartz veins of the Sierra Nevada are found in irregular distribution chiefly in the Auriferous slates and associated greenstone-schists and porphyrites, but they also occur abundantly in the granitic rocks that form isolated areas in the slate series. While some gold-quartz veins may antedate the Jurassic period, it is reasonably certain that most of them were formed shortly after the post-Juratrias upheaval, and that their age, therefore, is early Cretaceous.

SUPERJACENT SERIES.

CRETACEOUS PERIOD.

Since no beds of early Cretaceous age are known in the Sierra Nevada, it is presumed that during the early Cretaceous all of the present range was above water.

During the late Cretaceous the range subsided to some extent, allowing the deposition of sediments in the lower foothill region. These deposits are known as the Chico formation, and consist of sandstone with some conglomerate. In the area covered by the Gold Belt maps this formation is exposed only near Folsom on the American River up to an elevation of 400 feet, and in the Chico district at elevations of from 500 to 600 feet. Since their deposition these strata have been but slightly disturbed from their original approximately horizontal position, but the larger part of them has been eroded or covered by later sediments.

Auriferous gravels are found to some extent in the Chico formation—for instance, near Folsom—showing that the gold-quartz veins had already been formed before its deposition.

EOCENE PERIOD.

In consequence of slow changes of level without marked disturbance of the Chico formation, a later deposit formed, differing from it somewhat in extent and character. The formation has been called the Tejon (Tay-hone′). It appears in the Gold Belt region at the Marysville Buttes, in the lower foothills of the Sonora district, and it is extensively developed in the southern and western portion of the Great Valley of California. During the Eocene the Sierra Nevada remained a separate, low mountain range, erosion continuing with moderate rapidity but no great masses of gravels accumulating.

NEOCENE PERIOD.

The Miocene and Pliocene periods, forming the later part of the Tertiary, have in this atlas been united under the name of the Neocene period. During the Neocene a large part of the Great Valley of California seems to have been under water, forming perhaps a gulf connected with the sea by one or more sounds across the Coast Ranges. Along the eastern side of this gulf was deposited during the earlier part of the Neocene period a series of clays and sands to which the name Ione formation has been given. It follows the Tejon, and appears to have been laid down upon it, without an interval of disturbance or erosion. Marine deposits of the age of the Ione formation are known within the Gold Belt only at the Marysville Buttes. Along the eastern shore of the gulf the Sierra Nevada, at least south of the fortieth parallel, during the whole of the Neocene formed a low range drained by numerous rivers. The shore-line at its highest position was several hundred feet above the present level of the sea, but it may have fluctuated somewhat during the Neocene period. The Ione formation appears along this shore-line as a brackish-water deposit of clays and sands, frequently containing beds of lignite.

The Sierra Nevada during this period was a range with comparatively low relief. The drainage system during the Neocene had its sources near the modern crest of the range, but the channels by no means coincided with those of the present time. Erosion gradually declined in intensity and auriferous gravels accumulated in the lower reaches of these Neocene rivers, the gold being derived from the croppings of veins. Such gravels could accumulate only where the slope of the channel and the volume of water were sufficient to remove the silt while allowing the coarser or heavier masses to sink to the bottom with the gold.

During the latter part of the Neocene period volcanic activity, long dormant, began again, and floods of lavas,[1] consisting of rhyolite, andesite, basalt, and plagioclastic glassy rocks chemically allied to trachyte, were ejected from volcanic vents, and these eruptions continued to the end of the Neocene. These lavas occupy

*Jointly prepared by Geo. F. Becker, H. W. Turner, and Waldemar Lindgren, 1894. Revised January, 1897.

[1] The term "lava" is here used to include not only such material as issued from volcanic vents in a nearly anhydrous condition and at a very high temperature, but also tuff-flows and mud-flows, and, in short, all fluid or semifluid effusive volcanic products.

small and scattered areas in the southern part of the Gold Belt, increasing in volume to the north until, north of the fortieth parallel, they cover almost the entire country. They were extruded mainly along the crest of the range, which still is crowned by the remains of the Neocene volcanoes. An addition to the gold deposits of the range, in the form of gold-quartz veins and irregular thermal impregnations, attended this period of volcanic activity.

When the lavas burst out they flowed down the river channels. The earlier flows were not sufficient to fill the streams, and became interbedded with gravels. They are now represented by layers of rhyolite and rhyolite-tuffs, sometimes altered to "pipe-clay." The later andesitic and basaltic eruptions were of great volume, and for the most part completely choked the channels into which they flowed. The rivers were thus obliged to seek new channels — substantially those in which they now flow.

Fossil leaves have been found in the pipe-clay, and in other fine sediments at numerous points. Magnolias, laurels, figs, poplars, and oaks are represented. The general character of the flora is thought to indicate a warm and humid climate, and has been compared with the present flora of the South Atlantic Coast of the United States.

THE NEOCENE UPHEAVAL.

In the latter part of the Neocene period a great dislocation occurred along a zone of faulting at the eastern base of the Sierra Nevada, and the grade of the western slope of the range was increased. These faults are sharply marked from Owens Lake up to Honey Lake. There was also a series of faults formed apparently at the very close of the Neocene within the mass of the range in Plumas County. Near the crest the Sierra Nevada is intersected by a system of fissures, often of striking regularity; it is believed that these fissures originated during the Neocene upheaval.

PLEISTOCENE PERIOD.

During Cretaceous, Eocene, and Neocene times the Sierra Nevada had been reduced by erosion to a range with gentle slopes, and the andesitic eruptions had covered it with a deep mantle of lava flows. The late Neocene upheaval increased the grade of the western slope greatly, and the rivers immediately after this disturbance found new channels and, rejuvenated, began the work of cutting deep and sharply incised canyons in the uplifted crustal block.

A period of considerable duration elapsed between the emission of the lava flows which displaced many of the rivers and the time of maximum glaciation. In this interval most of the deep canyons of the range were formed. Such, for example, are the Yosemite Valley on the Merced River, the great canyon of the Tuolumne, and the canyon of the Mokelumne. The erosion of these gorges may have been facilitated by the fissure system referred to above, for many of the rivers of the range appear to follow one or another set of parallel fissures for a long distance.

At what point the limit between the Neocene and the Pleistocene should be drawn is a somewhat difficult question. On the maps of the Gold Belt the great andesitic flows are supposed to mark the close of the Neocene, and this division is in fact the only one that can be made without creating artificial distinctions. But it is not positively known that this line corresponds exactly to that drawn in other parts of the world between these periods.

The Sierra, from an elevation of about 5000 feet upward, was long buried under ice. The ice widened and extended the canyons of preexisting topography and removed enormous amounts of loose material. It seems otherwise to have protected from erosion the area it covered and to have accentuated the steepness of lower slopes. Small glaciers still exist in the Sierra.

During the earlier part of the Pleistocene period the Great Valley was probably occupied for a time by a lake dammed by the post-Miocene uplift of the Coast Ranges. Later in the Pleistocene this lake evidently was drained and alluvial deposits were spread over the valley. There is no valid reason to believe that the central and southern part of the Sierra has undergone any important dynamic disturbance during the Pleistocene period, but renewed faulting with small throw has taken place along the eastern base of the range in very recent times.

IGNEOUS ROCKS.

Rocks of igneous origin form a considerable part of the Sierra Nevada. The most abundant igneous rocks there found are of granitic character. Rocks of the granitic series are believed to have consolidated under great pressure and to have been largely intruded into overlying formations at the time of great upheavals; they are thus deep-seated rocks, exposed only after great erosion has taken place.

The rocks called diabase and augite-porphyrite on the Gold Belt maps are not usually intrusive, but largely represent surface lavas which have been folded in with the sedimentary rocks and correspond to modern basalt and augite-andesite. In like manner hornblende-porphyrite corresponds to hornblende-andesite, quartz-porphyrite to dacite, and quartz-porphyry to rhyolite. In the Sierra Nevada the diabases and porphyrites are of pre-Eocene age, and contain in most cases secondary mi. rals, such as epidote, zoisite, uralite, and chlorite. The unaltered equivalents of these rocks — basalt, andesite, dacite, and rhyolite — are, in the Sierra Nevada, chiefly of Neocene or later age.

Tuffs are volcanic ashes formed by explosions accompanying the eruptions. Mixed with water, such material forms mud flows; and when volcanic ashes fall into bodies of water they become regularly stratified like sedimentary rocks and may contain fossil shells. Breccias are formed by the shattering of igneous rocks into irregular angular fragments. Tuffaceous breccias contain angular volcanic fragments cemented by a consolidated mud of volcanic ashes.

GLOSSARY OF ROCK NAMES.

The sense in which the names applied to igneous rocks have been employed by geologists has varied and is likely to continue to vary. The sense in which the names are employed in this folio is as follows:

Peridotite.—A granular intrusive rock generally composed principally of olivine and pyroxene, but sometimes of olivine alone.

Serpentine.—A rock composed of the mineral serpentine, and often containing unaltered remains of pyroxene or olivine. Serpentine is usually a decomposition product of rocks of the peridotite and pyroxenite series.

Pyroxenite.—A granular intrusive rock composed principally of pyroxene.

Gabbro.—A granular intrusive rock consisting of soda-lime or lime feldspars and pyroxene, or more rarely hornblende.

Diabase.—An intrusive or effusive rock composed of soda-lime feldspar (often labradorite) and pyroxene (more rarely hornblende). The feldspars are lath-shaped. The pyroxene is often partly or wholly converted into green, fibrous hornblende or uralite. From this change, also frequent in gabbros, rocks result which are referred to as uralite-diabase or uralite-gabbro.

Diorite. A granular intrusive rock consisting principally of soda-lime feldspar (chiefly andesine or oligoclase) and hornblende or pyroxene (sometimes also biotite).

Quartz-diorite.—A granular intrusive rock composed of soda-lime feldspar and quartz, usually with some hornblende and brown mica.

Granodiorite.—A granular intrusive rock having the habitus of granite and carrying feldspar, quartz, biotite, and hornblende. The soda-lime feldspars are usually considerably and to a variable extent in excess of the alkali feldspars. This granitoid rock occupies a position intermediate between a granite and a quartz-diorite, and is in fact closely related to the latter. The large areas occupied by it and the constancy of the type justify the special name.

Granite.—A granular intrusive rock composed of quartz, alkali and soda-lime feldspars, mica, and sometimes hornblende.

Aplite (also called *Granulite*).—A granitoid rock usually occurring as dikes, and consisting principally of quartz and alkali feldspar.

Syenite.—A granular intrusive rock composed chiefly of alkali feldspars, usually with some soda-lime feldspars and hornblende or pyroxene.

Amphibolite, amphibolite-schist.—A massive or schistose rock composed principally of green hornblende, with smaller amounts of quartz, feldspar, epidote, and chlorite, and usually derived by metamorphic processess from augite-porphyrite, diabase, and other basic igneous rocks.

Augite-porphyrite.—An intrusive or effusive porphyritic rock with larger crystals of augite and soda-lime feldspars in a finer groundmass composed of the same constituents.

Hornblende-porphyrite.—An intrusive or effusive porphyritic rock consisting of soda-lime feldspars and brown hornblende in a fine groundmass.

Quartz-porphyrite.—An intrusive or effusive porphyritic rock consisting of quartz and soda-lime feldspar, sometimes with a small amount of hornblende or biotite.

Quartz-porphyry.—An intrusive or effusive porphyritic rock, which differs from quartz-porphyrite in containing alkali feldspars in excess of soda-lime feldspars.

Rhyolite.—An effusive rock of Tertiary or later age. The essential constituents are alkali feldspars and quartz, usually with a small amount of biotite or hornblende in a groundmass, which is often glassy.

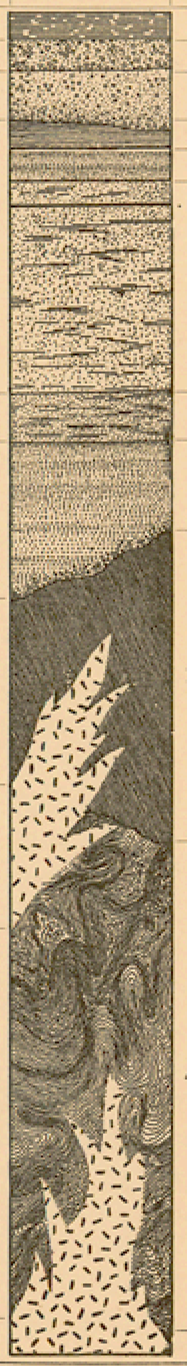
Andesite.—An effusive porphyritic rock of Tertiary or later age. The essential constituents are soda-lime feldspars (chiefly oligoclase and andesine) and ferromagnesian silicates (hornblende, pyroxene, or biotite), in a groundmass of feldspar microlites and magnetite, usually with some glass. The silica is ordinarily above 56 per cent. When quartz is also present the rock is called a dacite.

Basalt.—An effusive rock of Tertiary or later age, containing basic soda-lime feldspars, much pyroxene, and usually olivine. The silica content is usually less than 56 per cent. It is often distinguished from andesite by its structure.

Trachyte.—An effusive rock of Tertiary or later age, composed of alkali and soda-lime feldspars, with biotite, pyroxene, or hornblende.

GENERALIZED SECTION OF THE FORMATIONS OF THE GOLD BELT.

	Period.	Formation Name.	Formation Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
Superjacent Series	Pleistocene	Recent.	Pal		1–100	Soil and gravel.
		River and shore gravels.	Pgv		1–100	Sand, gravel, and conglomerate.
	Neocene	River and shore gravels.	Ng		10–400	Gravel, sandstone, and conglomerate.
		Ione.	Ni		10–100	Shale or clay rock.
					10–100	Sandstone.
					....	..Coal stratum.
					50–800	Clay and sand, with coal seams.
	Eocene	Tejon.	Et		10–300	Sandstone and conglomerate.
	Cretaceous	Chico.	Kc		50–400	Tawny sandstone and conglomerate.
						GREAT UNCONFORMITY
Bed-Rock Series	Juratrias	Monte de Oro. Mariposa. Milton. Sailor Canyon.	Jo Jm Jml Js		1000 or more	Black clay-slate, with interbedded greenstones and some conglomerate.
		Intrusive granitic rocks.	gr grd			UNCONFORMITY
	Carboniferous and Older	Robinson. Calaveras.	Crb Cc		4000 or more	Argillite, limestone, quartzite, chert, and mica-schist, with interbedded greenstones.
		Intrusive granitic rocks.	gr grd			



DESCRIPTION OF THE BIG TREES QUADRANGLE.

GEOGRAPHICAL RELATIONS.

Extent of the quadrangle. The Big Trees quadrangle comprises the territory between the meridians of 120° and 120° 30′ west longitude and the parallels of 38° and 38° 30′ north latitude, being thus a quarter of a square degree of the earth's surface. It is about 34½ miles long and 27¼ miles wide and contains about 938 square miles. It embraces portions of Amador, Alpine, Calaveras, and Tuolumne counties, but more than seven-eighths of the area belongs in the two last named. Other quadrangles immediately adjacent to it are the Pyramid Peak on the north, the Dardanelles on the east, the Sonora on the south, and the Jackson on the west. In contact with its corners are the Markleeville on the northeast, the Yosemite on the southeast, and the Placerville on the northwest. The greater part of the Big Trees district lies within what may be termed the middle region of the western slope of the Sierra Nevada—that is, the well-watered and forested zone lying between the alpine topography of the "high Sierra" and the foothill district in which the gold mines of the Mother Lode are situated. In the extreme northeast corner of the quadrangle the country already begins to assume the characteristics which belong to the higher portions of the range, while the extreme southwest portion, on the other hand, lies in the foothills.

TOPOGRAPHY.

Character of the ridges. *Relief.*—The elevations range from a general altitude of about 1500 feet near Robinson Ferry to over 8600 feet in the extreme northeast corner of the quadrangle, corresponding to an average grade of about 165 feet per mile for this portion of the Sierra slope. Robinson Ferry itself, being in a canyon incised below the general level of the country, has an elevation of only 700 feet above the sea. With the exception of a few mountain meadows, usually near the heads of streams, the area as a whole is practically destitute of alluvial valley bottoms, and is drained by streams of torrential character, flowing in narrow canyons. The dominant features of the topography are long, rather narrow, flat-topped ridges, which usually have a northeasterly-southwesterly trend. These ridges are, as a rule, capped with volcanic breccia made up of fragments of andesitic lava. As their tops are often bare and fairly even, they have come to be natural routes of travel through the region, and are followed by the sheep and cattle herders, who make use of the highest alpine districts for pasturage during the summer months. Keeping upon the crest of one of these ridges, the traveler may ride for hours on a scarcely perceptible grade toward the northeast. The general aspect of the country, as seen from such an elevation, is that of a somewhat uneven, gently sloping plain, below the surface of which the present canyons have been excavated. It is evident that the topography of to-day is compound in character. The streams now rushing through the canyons have been for some time at work cutting and shaping the surface of the region, but they have not been able to efface entirely an older land surface which existed before their present period of activity began. **Old eroded surface.** Before the beginning of the present cycle of erosion an earlier cycle had passed through the successive stages of its history, resulting in a low surface which, after being covered with volcanic material near the close of the Neocene period, was elevated. Thus again exposed to the action of the streams and other erosive agencies, it was carved into the present intricate detail of canyons, ridges, and peaks. The significance of the present topography can be best understood by retracing briefly the steps by which it was produced. If the present canyons were once more filled up with the solid rock which in the course of Pleistocene time has been disintegrated and carried down as sediment to the Great Valley, and if the lava cappings of the ridges were extended so as again to cover the filled-in canyons, there would be reproduced a surface nearly identical with that upon which the existing streams began their work. It would be a great desolate lava plain, sloping gently to the southwest. Its surface, however, would be somewhat uneven, and above it would project several summits, such as Blue Mountain, composed of unusually resistant rocks belonging to the Bed-rock series, and which, on account of the durability of their materials, formed hills too lofty to be buried beneath the lavas. The larger streams have long since cut through this volcanic mantle into the underlying Bed-rock series, and have carved deep canyons. The canyons of the smaller streams are similar in character but not so deep, and break up into head-water ramifications long before reaching the summit region of the Sierra.

As a consequence of the energetic cutting of the streams during Pleistocene and present times, traveling in a northwest-southeast direction, parallel with the crest of the range, is slow and toilsome. It is no longer possible to ride easily along upon a nearly level ridge, but canyon after canyon must be crossed by the tedious process of descending one of its steep sides and climbing laboriously up the other, sometimes a matter of hours.

Consequent streams. *Drainage.*—The greater part of the Big Trees quadrangle is drained by the Stanislaus and Mokelumne rivers. The streams, however, which cross the southern border of the quadrangle to the east of Shaws Flat flow into the Tuolumne River in the Sonora quadrangle, while those crossing the western border between the divide north of Calaveras Valley and the divide south of San Domingo Creek are tributary to the Calaveras River in the Jackson quadrangle. The drainage as a whole is of the consequent type—i. e., the important streams show a well-marked tendency to flow straight down the slope in consequence of the general southwesterly inclination given to the region by orogenic or mountain-making forces, especially at the time of the Neocene upheaval. This parallelism of streams, dependent upon original angle of slope rather than upon the controlling influence of belts of weak rock, is well shown in the southeast corner of the quadrangle; also in the region between the North and Middle forks of the Stanislaus. That all the streams, even under the nearest approach to ideal conditions possible, should flow in strictly parallel lines is not conceivable. Such conditions did not obtain in the Big Trees quadrangle. Inequalities in the resistance of rocks, and structural features, have had an important influence upon the course of the streams. But it is to be observed that where a large stream, such as the Middle Stanislaus, departs from what may be considered its normal consequent direction, as is the case between its mouth and Bakers Crossing, the streams of secondary importance, as a rule, still retain their consequent direction. Thus, in spite of the depth of the Middle Fork of the Stanislaus in this portion of its course, it receives no drainage from the south except the insignificant amount gathered from the canyon wall itself. The streams on its southern side usually head close up to the brink of the canyon and then flow away in the normal direction of slope to the southwest.

Influence of structural features on the course of streams. In the northern portion of the quadrangle the general trend of the forks of the Mokelumne and their main tributaries is westerly, and this is likewise true, as a rule, of the lower parts of the tributaries of the Stanislaus to the south of the Middle Fork. The relatively greater hardness of the quartzite of Blue Mountain ridge seems to be an efficient cause for the northwest deflection of the Middle Fork of the Mokelumne and for the southwest deflection of the South Fork, the general trend of both forks being nearly due west. Rivers can erode channels parallel to bedding planes and planes of schistosity with greater ease than across these planes, unless the rocks are shattered transverse to the bedding. As examples of streams influenced by these structures may be cited Rose Creek from the Star mine westward and the South Fork of the Stanislaus just north of Mount Elizabeth, where canyons are cut in the quartzite parallel to its strike. The westerly course of Fivemile Creek is likewise determined by the same conditions. It will be observed that Twomile Creek, Hull Creek, and the North Tuolumne, after flowing some distance to the southwest, turn sharply to the southeast. It is probable that the southeasterly courses of these streams are due to structural features.

The region as a whole is well watered, most of the streams flowing the year round. The North Fork of the Mokelumne and the Middle and North forks of the Stanislaus are fed in part by melting snow from the crest regions of the Sierra until late in summer, and retain at all ordinary seasons good volumes of water. They are usually fordable on horseback in summer at points where their beds are not too rocky or cumbered with large bowlders.

Trees of the timber belt. *Vegetation and Culture.*—The greater part of the quadrangle falls within the heavily forested zone of the Sierra Nevada locally known as the "timber belt." This belt crosses the quadrangle from northwest to southeast, and lies between the general elevations of 3000 and 6000 feet, although not sharply limited by these altitudes. It is a stretch of magnificent forests which have in great part escaped the saw-mills. In size and number the conifers dominate all other trees. They include the yellow pine (*Pinus ponderosa*), the sugar pine (*Pinus lambertiana*), and the famous "big tree" (*Sequoia gigantea*). All of these species attain great size and beauty (see fig. 5, page of illustrations), particularly in the middle portion of the quadrangle, to which district the Sequoias in the Big Trees quadrangle are restricted. **The "big trees"—Sequoias.** The latter trees occur in two groves, the smaller one in Calaveras County, at the post-office and hotel of Big Trees, and the larger one in Tuolumne County, about 5 miles southeast of the hotel. The fact that these noble trees flourish only in these two places within the quadrangle may be partly due to their exceptionally sheltered locations. They grow in quiet hollows, protected from the winter storms by the partly inclosing ridges and the surrounding forests of pines. All the larger conifers flourish best in sheltered spots, but are likewise found on many of the ridges. The forests are often very beautiful. The conifers, standing some distance apart, are frequently interspersed with black oaks. Undergrowth is usually lacking except near springs or small streams, and the ground is often thickly covered with a low bright-green plant of the rose family (*Chamæbatia foliolosa*), sometimes called by the inhabitants "mountain misery," and a prostrate shrub known as "Indian carpet," thus giving these forests an open, park-like character which is very pleasing.

Foothill region. In the southwest corner of the quadrangle the vegetation assumes the less attractive character associated with the foothill districts. The dark but fresh green of the larger conifers is here replaced by the sad bluish-green hue of the digger pine (*Pinus sabiniana*), with which tree are usually associated scattered oaks (*Quercus douglasii*) of like dusty shades of green. All the trees of this district are smaller and less symmetrical in form than those of the higher slopes, while many of the hills are covered with grass, which dries to a dusty brown in summer, or with thickets of low and stiff shrubs. This portion of the area has not the well-watered aspect of the forest zone. Flowing springs are rare, and the drainage from the upper Sierra slopes has here been concentrated into the larger streams flowing below the general surface of the district.

Alpine region. In the northeast corner of the area the vegetation also changes. The tamarack pine (*Pinus murrayana*) and the silver fir here become abundant, the fir clinging generally to the ridges and higher slopes, while the tamaracks, in company with willows and poplars, prefer the relatively low and damp flats. Some of the rock at this altitude has been swept bare by glaciers, and the trees often struggle for subsistence in the cracks and crevices of the granite. Damp meadows covered with luxuriant grass are abundant, and near them there usually are groves of "quaking aspens."

As a whole the quadrangle is a sparsely settled region. The winter snowfall at elevations above 4500 feet is usually heavy, and few of the inhabitants attempt to pass the winter above that altitude. The herds of cattle and "bands" of sheep which find pasturage on these higher slopes during the summer months are gathered together in the autumn and driven down to the Great Valley or to the lower foothills. In the forest zone timber, chiefly yellow pine, is being cut at several points, while between Murphy and Big Trees the smaller yellow pines, in part a second growth, are being extensively felled to supply the demand for mine timbers created by the large mines at Angels, in the Jackson quadrangle.

Some of the high ridges capped with andesitic breccia are exceedingly dry and support scarcely any shrubs or trees, and when these are present they are often of types that normally occur at lower altitudes, as wild lilac (Ceanothus), digger pine, and manzanita.

Two transmontane highways, once important but now little used, cross the quadrangle. One, the Sonora and Mono toll road, enters the quadrangle at its southern border, near the Phoenix Reservoir, and passes out of it, into the Dardanelles quadrangle, northeast of Parsons. The other, the Big Trees and Carson Valley road, extends from Big Trees northeastward to Silver Valley and thence beyond the bounds of the quadrangle.

GEOLOGY.

BED-ROCK SERIES.

The Bed-rock series consists of sedimentary rocks, which were turned into a nearly vertical position during or before the post-Juratrias deformation, together with the associated igneous rocks.

The sedimentary rocks of this period represent beds of clay, sand, and gravel which have been hardened and metamorphosed. These beds were originally horizontal, but have since been folded and greatly compressed by forces acting chiefly from the NNE. and SSW. They have also been subjected to extensive erosion, so that the upper parts of the folds have disappeared. Intercalated in these sediments are layers of metamorphic lavas and tuffs, showing that volcanic eruptions occurred while the sediments were being deposited. Irregularly intruding the sedimentary rocks with their included volcanic layers are masses and dikes of various granular igneous rocks, such as granite and gabbro.

SEDIMENTARY ROCKS.

Schistosity and bedding. *Calaveras formation.*—Rocks which have been referred to this formation in the Big Trees quadrangle may be divided into two portions differing on the whole in lithological character and in the degree of probability with which they can be assigned definite age. Together they occupy the western and southern portions of the quadrangle, and are separated from the granitic rocks on the east by a very irregular line, extending across the quadrangle in a southeasterly direction from Panther Creek in the northwest corner to near the mouth of Hull Creek in the southeast corner. The great bulk of the formation is composed of slaty or schistose rocks which have plainly been derived from siliceous sediments of varying coarseness. In all cases where such an observation was possible, the schistosity was seen to be approximately parallel with the original bedding. **Igneous schists.** Associated with these sediments are limestones, frequently in lenticular masses, and a smaller amount of schistose rocks which have been derived from igneous material, probably in most cases intruded into the sediments at some early stage of their history, subsequent to their deposition, but also in part of volcanic origin and laid down contemporaneously with the siliceous sediments in the form of tuffs and flows.

Two divisions in the Calaveras. The possibility of dividing this formation into two portions which differ in age is suggested by the fact that one division as a whole is more siliceous than the other and does not contain lenses of limestone. The line of division between the siliceous and the more argillaceous and calcareous series may be considered as passing through Sheep Ranch and running just east of the limestone lenses at

American Camp. Even if the two hypothetical portions of the Calaveras formation are separated by an unconformity, the subsequent folding and compression of the whole has been so intense and so complex that the fact might readily remain undiscovered. On the other hand, it is quite possible that the entire series represents continuous sedimentation with a gradual change of lithologic character from one portion to another. Dikes of diorite-porphyry and other igneous rocks are abundant in all of the rocks of the Calaveras formation except the massive quartzites.

Siliceous terrane.

The rocks belonging to the siliceous division lie to the northeast of the line above indicated as separating the two portions of the Calaveras formation. These rocks are almost without exception quartzites or highly siliceous schists. Occasionally, as south of Sheep Ranch, east of Collierville, and west and south of McCormick's ranch, the quartzites are associated with schistose or gneissic bands which have probably been derived from igneous material. As a rule these bands are too narrow and too intimately associated with the quartzites to be separated on a map of this scale. The quartzites may be in comparatively thick beds, nearly white in color, or in thinner, schistose beds, in which case the color is usually darker and the grain finer. The massive white quartzite makes up the greater part of Blue Mountain and extends southward across San Antonio Creek as a belt of resistant material which has determined some picturesque falls where it crosses that stream. Thence it continues as a high ridge until it is interrupted by the granitic area which extends westward from Avery's ranch. South of the Stanislaus the quartzite masses of Mount Elizabeth, Mount Lewis, and Mount Provo may be correlated with the Blue Mountain quartzite. Under the microscope such quartzite is seen to be composed of interlocking grains of quartz, with some scales of mica. No fossils have been found in the siliceous series in the quadrangle, but it is probable that these rocks are of Paleozoic age.

Argillaceous and calcareous terranes.

Southwest of the siliceous terranes above described the Calaveras rocks are chiefly dark slates, fine-grained siliceous mica-schists, thin-bedded quartzites, and limestone. The most interesting rock of this southwestern division of the Calaveras formation is the limestone, as by it the Carboniferous age of the sediments with which it is immediately associated is determined in a fairly satisfactory manner. The large and fantastically irregular area shown in the neighborhood of Columbia extends for several miles into the Sonora quadrangle and is the largest member of a disconnected but linear chain of limestone lenses extending in a southeast direction across the Sonora quadrangle into the Yosemite district, and in a northwesterly direction into the Jackson quadrangle. At Hites Cove, in the Yosemite quadrangle, fossils (Fusulina) indicating Carboniferous age have been found in one of the lenses of this chain.

Large area of limestone.

The Columbia area of limestone is remarkable not only as being the largest exposure of limestone yet mapped in the Gold Belt, but also for its exceedingly irregular and curious outline. It partly surrounds a considerable mass of granodiorite, toward which the bedding on the inner margin of the limestone area dips, as shown by thin interbedded bands of schist and quartzite. On the outer margin of the area the dip of the bedding and schistosity is usually northeasterly at a high angle or practically vertical. The strike is variable, swinging around near the contact with the Parrott Ferry granodiorite so as to be everywhere approximately parallel with its periphery. Toward the north the limestone is largely concealed beneath the Neocene gravels and lavas, but is exposed over a considerable area at Douglas Flat, again disappearing beneath Neocene deposits to the northwest. Most of the limestone, although retaining a distinct bedded or schistose structure, has become a granular crystalline rock to which the name marble is properly applicable. When polished it is generally nearly white, marked with faint gray veinings, and is rather fine grained. Pure white beds, as well as others of variegated pink and green tints and containing bands of biotite, occur a short distance upstream from Abbott Ferry. The beds of nearly pure limestone are sometimes separated by thin bands of schist of various kinds, while larger masses of mica-schist, siliceous schist, and granodiorite are not uncommon within the limestone area. When of sufficient size these masses are indicated on the map. The limestone is also cut by numerous dikes of diorite-porphyry, altered and decomposed.

Probable cause of the irregular shape of the limestone areas.

The very irregular shape of this limestone area is probably due to a combination of several causes. The fact that the beds, even in the middle of the series, are sometimes separated by thin beds of non-calcareous sediments shows that the deposition of the limestones was an interrupted process. Furthermore, each single bed when deposited was a lens, thickest at the middle and tapering out at the edges; or perhaps, by the admixture of ordinary clastic material, passed gradually into the siliceous sediments which have given rise to the schists and quartzites of the Calaveras formation. Thus, before any folding of the series took place, the limestone deposits consisted of a series of lenses of different shapes, sizes, and thicknesses, lying one above the other. In their middle portions these lenses might be separated by thin layers of ordinary sediments or be continuous one with the other. Toward their peripheries, however, they would become thinner, and thus be separated by increasing thicknesses of other sediments, or they would grade gradually into the latter by admixture of ordinary sedimentary material. With the subsequent intrusion of masses of granitic rocks, and with the intense compression and complex folding of the whole region, the originally flat-lying strata were thrown not only into longitudinal folds but into transverse folds as well. Finally, with the planing off by erosion of all the upper portions of the folds and their truncation down to the level of the present surface, it is not difficult to see how the present shape of the area may have been brought about, although it may not be possible to follow it step by step. The structure and character of the limestone beds are excellently shown where they are cut by the canyon of the Stanislaus, northeast of Abbott Ferry. The limestone area within which the town of Murphy lies is similar to that just described, as indeed are most of the smaller patches shown on the geological map. They are nearly all composed of several beds of limestone separated by layers of other sediments, and illustrate well the lenticular form and lack of horizontal continuity shown by deposits of this character. The area about Murphy is somewhat noted as containing an interesting cave of unknown depth. The cave lies about a mile northwest of the town, and is frequently visited by tourists on their way to Big Trees. The limestone near the cave, when struck by the hammer, emits the fetid odor common to similar rocks.

The argillaceous slates.

The other rocks comprising the southwest division of the Calaveras formation and which are probably of Carboniferous age, present few points of general interest. In the southwest corner, in the vicinity of Robinson Ferry, these consist in good part of normal dark clay slates, sometimes a little micaceous. West of Columbia, between the limestone and the granodiorite, the rocks are highly metamorphosed, and at a point 2 miles west of the town occurs a beautiful mica-schist which the microscope shows to be made up of clear interlocking grains of quartz with abundant biotite and muscovite. This schist weathers to a red soil, recalling that usually produced by the decay of basic igneous rocks. Some little-altered clay slates occur just southeast of Vallecito, and also near the edges of the quadrangle, west of the same town. West of Murphy are siliceous slates, mica-schist, and some streaks of amphibolite-schist and talc-schist. West and south of Sheep Ranch the prevailing rocks are dark siliceous slates, frequently passing into slaty mica-schists.

The prevailing strike of all of these rocks, when not too close to areas of massive igneous rocks, is northwesterly and southeasterly, with a northeasterly dip of from 60° to 70°. Variations in both dip and strike are, however, frequent, even when not close to visible intrusive masses.

IGNEOUS ROCKS.

Granodiorite, quartz-diorite, granite, and gneiss.—About two-thirds of the Big Trees quadrangle is underlain by a great complex of granitic rocks varying in age and in composition. Taken as a whole this complex contains no deposits of economic importance. The exceptions to this consist entirely of those masses which are inclosed, or nearly inclosed, by the sediments of the Calaveras formation. Thus gold-quartz veins are abundant in granodiorite east of Columbia in the south part of the quadrangle, and north of Woodcock in the northwest part. While at many points the members of this complex are intermingled in a very intricate manner, it may be divided into two groups which together form very large areas. These are (1) biotite-granite and gneiss, and (2) granodiorite and quartz-diorite. These two groups of rocks are not discriminated on the geological maps, but are indicated by a single color.

Granite and gneiss complex.

The granite and gneiss series will first be described. The largest area of these rocks forms a zone 4 to 9 miles in width lying immediately east of the rocks of the Calaveras formation.[1] This zone extends from East Panther Creek diagonally across the quadrangle to its southeast corner. The eastern border of the zone, or its contact with the large granodiorite mass of the eastern portion of the quadrangle, is a very irregular one. The irregularity of the western boundary, its contact with the rocks of the Calaveras formation, is less marked.

Biotite-granite.

The coarse biotite-granite, which is the most conspicuous member of the granite and gneiss complex, is a rock usually susceptible of ready recognition in the field. Potash feldspar is an abundant constituent, and by its conspicuous development in relatively large crystals tends to give the rock a porphyritic texture. Other minerals readily seen with the naked eye are quartz and biotite, the former in distinct grains of irregular shape, and the latter in small scales, usually so arranged as to give a suggestion of gneissic or banded texture even in hand specimens. Perfectly fresh specimens are secured with difficulty, as the rock weathers to a considerable depth and becomes somewhat friable.

Under the microscope the porphyritic texture is generally not conspicuous. The component minerals are seen to be microline, orthoclase, oligoclase, abundant quartz, some biotite, and usually a few small zircons. More rarely muscovite, titanite, and apatite are present in small amounts. Thoroughly typical biotite-granite of the kind described occurs in the canyon of the North Mokelumne, in the Calaveras Grove at the Big Trees hotel, in the South Grove, in the canyon of the Middle Stanislaus northeast of Mount Knight, and at various other points.

Biotite-granite-gneiss.

Exposed on steep canyon walls, as northeast of Mount Knight, this gneissoidal granite usually weathers in yellowish tones and in forms suggestive of bedding, whereas typical massive granodiorite weathers in gray tints and in rounded masses with absence of parallel structure except where it has been much jointed. The biotite-granite has been greatly compressed and sheared at many points, so that much of it may be correctly called biotite-granite-gneiss. Although typical facies of the gneissic biotite-granite and of the massive granodiorite are readily distinguished, yet this difference is bridged by various intermediate facies, so that it is often a matter of great difficulty to say just where the dividing line should be drawn. The gneissoidal granite may locally lose its gneissic structure, while the granodiorite may become gneissic or schistose, particularly near contacts.

Intimately associated with the biotite-granite are some fine-grained gneisses,[2] sometimes alternating with the former in bands, but often occurring in irregular patches and occasionally in large areas. These gneisses vary much in composition. The most abundant kinds are diorite-gneiss and quartz-diorite-gneiss.

Diorite-gneisses

The diorite-gneiss is dark green in color and is composed of soda-lime feldspar (chiefly oligoclase-andesine), green amphibole, brown biotite, magnetite, and pyrite. There are two kinds of such gneisses; some are fine grained and even textured, and are quite dark in color; others are coarser grained, with small rounded porphyritic feldspars. The contact between these two rocks is often sharp. The fine-grained diorite-gneiss is sometimes penetrated by white anastomosing dikes of fine-grained granite. It is possible that the dark fine-grained diorite-gneiss represents intrusions in the other gneisses. The diorite-gneiss often occurs in rounded nodules included in granodiorite, as at Highland Creek. Sometimes these nodules are so abundant that the mass resembles a conglomerate. Certain gneisses associated with the amphibole-diorite-gneisses, just described, differ from the latter in containing pyroxene, which is more or less altered to green amphibole, biotite of a reddish-brown color, and pyrrhotite with little or no pyrite. These gneisses may be called pyroxene-diorite-gneisses.

Pyroxene-diorite-gneisses.

All of these diorite-gneisses are probably recrystallized igneous rocks or tuffs. It is not impossible that many of the gneissic diorite nodules found included in the granitic rocks represent an earlier crystallization of the granitic magma; but all of these gneisses present evidence of having undergone recrystallization. Many of the nodules show no banding. In the bed of the North Mokelumne, on Mount Knight, and at other points are found greenish quartzite-like rocks. These differ from ordinary quartzite in containing green pyroxene, epidote, amphibole, titanite, and specular iron ore. They also contain plagioclase, but in no case are all of these minerals contained in any one specimen.

Quartz-pyroxene-gneisses.

Such gneisses have probably resulted from the recrystallization of more or less impure quartzites. Such rocks may be found on the north side of the North Mokelumne about 1 kilometer above the mouth of Blue Creek, and also above the mouth of Bear River.

Lime-silicate gneisses.

In the North Mokelumne Canyon at two points, and at one point on the ridge north of the Middle Mokelumne to the northeast of Blue Mountain, there were found in the gneiss series narrow bands of light-colored gneiss composed chiefly of lime silicates, wollastonite, and garnet, with some titanite and quartz. Such lime-silicate gneisses may be completely metamorphosed impure limestones. All of the above gneisses are found in the series exposed in the canyon of the North Mokelumne.

Pyroxenic alkali-feldspar gneisses.

South of Big Trees are some streaks of pyroxene-gneiss usually containing potash feldspar, and a minor amount of quartz. The original nature of these rocks is uncertain. They would be called pyroxene-granulites by German petrographers.

Quartz-gneiss.

At many points in the gneiss series are found narrow bands composed almost entirely of coarsely granular quartz. It is possible that such quartz-gneisses represent vein quartz which has become thoroughly granulated through crushing and recrystallization.

While some of the gneisses of the Big Trees quadrangle are regarded as recrystallized sediments, in no case can they be considered contact metamorphics. They are, to be sure, associated in a very intricate manner with the biotite-granite-gneiss which is intrusive in them, but they are no more thoroughly recrystallized at one point than at another. Their complete metamorphism and recrystallization is rather to be regarded as a kind of regional metamorphism, they being deeply buried at the time the metamorphism took place. It is probable, however, that the biotite-granite, which was intruded into the gneiss series at an earlier period, formed zones of contact metamorphism at the time of the intrusion. The entire series, both the intrusive granite-gneiss and the other gneisses, was intruded at a later date by the granodiorite and quartz-diorite magma; but the gneisses having already undergone a complete recrystallization, no evidence of further alteration along the contact is to be noted.

While the larger portion of the gneisses is included in the broad band extending across the quadrangle, as previously described, isolated masses are found at many points. Such is the area outlined on the geological map 5 miles east of Murphy, in the canyon of the North Stanislaus. This area is entirely surrounded by the sediments of the Calaveras formation, which also contains at some points narrow streaks of the same gneissic rock. Another isolated mass lies one-quarter mile northeast of Clover Meadow, in the granodiorite.

Garnet-epidote deposit.

On the summit of Garnet Hill, east of the mouth of Moore Creek, is an interesting deposit, which, though of no economic importance, is somewhat remarkable for the size and beauty of the minerals which compose it. It is made up of white quartz, green epidote in prisms 3 inches or more in length, and brownish-red garnets. The latter usually show brilliant crystal faces. This lode lies in a narrow tongue of gneiss which projects from the large area south of Moore Creek. The main mass of Garnet Hill is granodiorite.

Granodiorite and quartz-diorite complex.

The granodiorite and quartz-diorite series is exposed over wide areas in the eastern and northeastern portions of the quadrangle, and in smaller detached areas in the southwestern part. As the rock of these circumscribed areas is, as a rule, less typical and less constant in character than that of the large eastern mass, the latter will be first described. Over most of the region drained by the Stanislaus River northeast of Bakers Crossing the granodiorite shows a fairly uniform character. It is a rather even-textured rock of only moderate coarseness of grain.

Composition of typical granodiorite.

The component minerals recognizable with the naked eye are plagioclase, quartz, orthoclase, biotite, hornblende, and frequently accessory titanite in crystals up to one-eighth of an inch or more in size.

Under the microscope such a rock shows abundant plagioclase, chiefly andesine, which often has idiomorphic outlines, grains of quartz and hornblende, and orthoclase in large areas, acting as a matrix to the other minerals. Titanite, apatite, epidote, and small zircons are generally present as accessory constituents. Microline is sometimes present, as in

[1] On the Pyramid Peak geological map the northern extension of this gneissic area is represented as being composed of contact metamorphic rocks of the Calaveras formation, no attempt having been made in the adjacent portions of the Pyramid Peak quadrangle to separate the gneisses from schists derived from sediments.

[2] The word gneiss is here used as a textural term, and does not define mineral composition. The rocks designated as gneisses, while thoroughly granular, usually have the mineral grains arranged in layers, so that they are roughly schistose. Such rocks are often formed by the recrystallization of other rocks under pressure. The original texture is usually entirely lost in this process of recrystallization, but the chemical composition may be the same in the original rock and the recrystallized gneiss. Some gneisses are igneous rocks which have become schistose by movements while still in a viscous condition.

a facies rich in titanite which occurs near the head of Dry Meadow Creek. The granitic rock near Bloods is, strictly speaking, not a granodiorite, but an amphibole-biotite-granite or quartz-monzonite. Its relations to the normal granodiorite were not determined.

Along the North Fork of the Stanislaus the granodiorite protrudes into the granite and gneiss complex as a long tongue, extending southwestward to a point about 1 mile northeast of Gardner's hotel. On the northern side of this tongue the contact line between the granodiorite and the granite and gneiss complex is largely hidden under andesitic breccia. On the south and west, however, it is concealed only by soil and trees. It has nevertheless proved extremely difficult of satisfactory delineation, even where cut by the canyon of the North Stanislaus. The massive granodiorite becomes gneissic or schistose as the contact is approached, and is intimately mingled with fine-grained biotite-gneisses like those of the granite and gneiss complex. Much of the biotitic gneiss is plainly included in the schistose granodiorite. The contact between the granodiorite and the granite and gneiss complex is shown with more than usual sharpness a little more than a mile southwest of Fennessy's house, in the bed of Griswold Creek. Here the massive granodiorite is succeeded on the west by fine-grained pyroxene-gneisses containing hypersthene, which in turn give place to the coarse gneissic biotite-granite.

Knight Creek quartz-mica-diorite.

Three areas of granodiorite occur in the southwestern portion of the quadrangle, entirely surrounded by rocks of the Calaveras formation. The smallest of these is traversed by Knight and Rose creeks, and is composed of a granodiorite differing but little megascopically from that of the main mass on the eastern border of the quadrangle. The hand specimens, however, do not show any crystals of titanite, and the microscope shows that orthoclase is less abundant than usual. The rock thus tends toward an ordinary quartz-mica-diorite. On the western side of this intrusive mass there is evidence of contact metamorphism induced in the inclosing schistose rocks of the Calaveras formation, the latter being here converted into thoroughly crystalline fine-grained biotite-schists, which at one place carry red garnets of considerable size.

Parrott Ferry and Vallecito granodiorite areas.

The Parrott Ferry area and the one west of Vallecito present the characters usually found in the intrusive masses of granodiorite occurring in or near the foothill belt of the Sierra slope. The rock of such areas is nearly always more basic than that of the broad exposures nearer the summit of the range. Hornblende is more abundant and frequently shows a porphyritic development. Biotite is less conspicuous and often lacking, while plagioclases are generally the only feldspars present. It is usually possible in these areas to find all gradations from quartz-mica-diorite to more basic facies composed chiefly of hornblende with a little interstitial epidote. This is especially the case near their peripheries. Strictly speaking, these rocks are seldom true granodiorites, although they were probably intruded at the same time as the main mass and may represent modifications of the same magma. The area west of Vallecito resembles the Parrott Ferry area very closely, both being probably parts of a single intrusion. It is composed chiefly of a dark medium-grained rock of dioritic aspect. The microscope shows considerable alteration, the large crystals of green hornblende being surrounded by a granular aggregate of epidote, quartz, and a little secondary feldspar. At its northern end the mass passes into a schistose hornblendic facies which the microscope shows to contain epidote and a little pyroxene in addition to the hornblende. The granitic area extending west from the canyon of the North Stanislaus to near Sheep Ranch is regarded as granodiorite. It contains, however, more biotite and orthoclase than does most of the granodiorite of the quadrangle.

Syenite.—Granular rocks composed chiefly of alkali feldspar, with usually some amphibole, pyroxene, or mica, are called syenite. There are but few areas of such rocks in the Big Trees quadrangle. That shown on Mill Creek, in the northwest corner, is an amphibole-syenite; the dike by the road east of Calaveras Valley is a mica-syenite; and the two small areas in the drainage of Rose Creek, a little to the west of the contact of the granodiorite with the schists of the Calaveras formation, are composed chiefly of alkali feldspar without dark constituents. The outlines of the two areas last noted are only approximate.

Amphibole-gabbro.

Gabbro.—Granular rocks made up of basic lime-soda feldspars usually with pyroxene or amphibole are called gabbro. Such rocks occur in the Big Trees quadrangle at a great many points. On the geological map only the larger areas are shown. The most abundant gabbro is a dark-green coarse-grained rock. This is, as a rule, composed almost entirely of amphibole and basic plagioclase with some magnetite. Occasionally grains of pyroxene and olivine are found in the rock, and sometimes pyrite. Such a rock may be called an amphibole-gabbro. A large area of this gabbro occurs in the drainage of Beaver Creek. The area at the tip of the granitic tongue about $2\frac{1}{2}$ miles northeast of Sheep Ranch contains hypersthene. This mass is plainly intrusive in the Calaveras formation and sends dikes into the latter. The largest of these dikes is shown on the map.

Olivine-gabbro.

The gabbro of the area in the northwest corner of the quadrangle contains olivine, pyroxene, and little or no amphibole, and may be called an olivine-gabbro.

Uralite-gabbro.

The mass designated gabbro on the ridge 3 miles due north of Sheep Ranch is in reality heterogeneous in character. These rocks are largely altered, and while a part of the area may be called uralite-gabbro, other portions contain little feldspar, and are largely made up of green amphibole, probably of secondary origin. There is perhaps also some diorite in this area.

Pyroxenite.—Granular rocks composed chiefly of pyroxene are called pyroxenite. There are two areas in the drainage of Jesus Maria Creek which are so called. The larger of these extends northward across Esperanza Creek. Like similar areas in the Jackson quadrangle, the pyroxene is largely altered to amphibole, so that many specimens in the areas designated pyroxenite might more correctly be called massive amphibolite.

Dikes of diorite-porphyry.

Diorite-porphyry.—Fine-grained, dark-green dikes are abundant in some portions of the Calaveras formation in the western part of the quadrangle. They are particularly numerous in the limestone area east of Shaws Flat and north of Columbia, in the schists and limestones east of Collierville, and in the schists, slates, and quartzites between the North Stanislaus and the northwest corner of the quadrangle. They are also common in granodiorite in the northwest corner of the district, and were noted in the gneisses of the North Mokelumne Canyon. These dikes are usually small, and no attempt was made to represent them all on the geological map, a few of the larger and more persistent ones only being shown. Under the microscope such rocks generally show decomposed porphyritic feldspars, prisms of greenish-brown hornblende, and an altered groundmass with abundant epidote, chlorite, calcite, and quartz. Occasionally they lack the porphyritic structure and may be called fine-grained diorite.

Amphibolite.—This rock, in most places a schist, forms small areas in the southwestern portion of the quadrangle. One of these terminates at the Stanislaus at Robinson Ferry, and is important as containing at this locality the gold-quartz veins of the Mother Lode. This same belt of amphibolite-schist extends northwestward into the Jackson quadrangle and there contains the famous mines of Carson Hill and Angels Camp. The schist is light green in color and fine grained. The microscope shows it to be composed of numerous prisms of green amphibole and grains of epidote in a groundmass of quartz, calcite, usually some feldspar, and sometimes biotite. Another small area of amphibole-schist occurs about a mile north of Vallecito, and there is a narrow streak just west of Murphy which is not shown on the map. Still another band extends in an east-west direction in the northwest corner of the quadrangle, to the northeast of Woodcock. This area lies between the Calaveras formation and granodiorite.

A small lens of amphibole-talc-schist occurs in the western portion of the quadrangle west of Murphy. Like the similar lenses in the Jackson quadrangle, this rock is an altered form of dikes of the peridotite-pyroxenite family.

SUPERJACENT SERIES.

The Superjacent series consists of late Cretaceous, Eocene, Neocene, and Pleistocene sediments, lying unconformably on the Bed-rock series, together with igneous rocks of the same periods. During late Cretaceous, Eocene, and Neocene times the Sierra Nevada was a mountain range and the Great Valley of California was under water. During the same time the rivers flowing down the western slopes of the range deposited the auriferous gravels. Volcanoes situated mostly along the crest of the range poured out floods of lava, chiefly in Neocene times. During the Pleistocene, also, portions of the Great Valley were under water, but there were few volcanic eruptions.

NEOCENE.

Neocene eroded surface.

During late Cretaceous and early Neocene time there appear to have been no mountain making movements of importance in this part of the Sierra Nevada. During this long epoch the Big Trees quadrangle was subject to erosion. About the close of the Neocene nearly its entire surface was flooded with lava. In Neocene time the region was a greatly eroded surface. The persistent process of rock decay, combined with the action of frosts, rain, and streams, had succeeded in subduing a once rugged region to one of such gentle slopes that the streams were largely deprived of their cutting power. Certain rocks of the Bed-rock series, such as quartzite, are more resistant than others, and withstand longer the unceasing attack of the erosive agencies. Masses formed of such rocks at every stage of degradation stand higher than the surrounding country, forming what are known as monadnocks. An excellent example is seen in Blue Mountain, which rises boldly above the general level of the surrounding country, and was never covered by Neocene lavas. Mount Elizabeth, Mount Lewis, and Mount Provo, all of which are composed of quartzite, are other examples. Portions of this old eroded surface are preserved underneath the lavas, and the nearly level lines of contact between the lavas and the underlying older complex, as seen on the canyon sides, furnish the datum plane from which the old eroded surface, now so thoroughly dissected by modern streams, may be reconstructed. Little can be said of the character of the topography during the earlier stages (Cretaceous time) of this long period of erosion, but the fact that the Bed-rock series consists of highly metamorphosed rocks and contains also large areas of granitic rocks, which must have solidified from fusion at some depth, is an indication that the region has been deeply denuded and probably passed through all the stages of a youthful topography, characterized by lofty peaks and ridges, deep canyons, and tumultuous torrents, before approaching the quiet old age typified by a low plain.

Monadnocks.

The volcanic material which was thrown out toward the close of the Neocene came chiefly from vents near the crest of the range. Probably while the eruptions were still in progress there began an elevation which increased the slope toward the southwest. The streams which were then beginning to establish their channels on the lava-cloaked surface were thus given great cutting power. The impetus given the streams at that time is in part still retained. The larger ones have long since cut through the volcanic mantle and have sunk deep canyons into the underlying Bed-rock series, which they are still engaged in deepening.

Neocene rivers.

Drainage.—In a broad way, it may be said that there is evidence that three considerable rivers existed in Neocene time in the Big Trees quadrangle. Two of these rivers flowed in broad valleys. One originated in the Pyramid Peak quadrangle and flowed nearly south through the northwestern portion of the district to near Sheep Ranch, whence it drained westerly into the Jackson quadrangle. The other river had a westerly course from near Bradford's mill to Vallecito, and thence flowed farther west into the Jackson quadrangle. The former existence of these two valleys, while not certain, is highly probable. The evidence rests largely upon the disposition of the rhyolite-tuff areas. The two rivers indicated above represent the older river system of the quadrangle, and existed during the pre-volcanic period. At a later date, after the region had been flooded with andesitic lavas, a stream originating in the Dardanelles quadrangle entered the Big Trees district near Clover Meadow and pursued a general southwesterly course, crossing the site of the present canyon of the Stanislaus at Parrott Ferry. The former existence of this river is shown by a chain of areas of certain basaltic-looking lavas, designated latite, which appear to have flowed down the river channel from a source near the summit of the range to Knights Ferry, at the east border of the San Joaquin Valley.

Auriferous gravels.—The gravels deposited by rivers that existed in the Big Trees quadrangle in Neocene time can be divided into two series: an older series, deposited before the eruption of the andesitic lavas, and a younger series, deposited after the andesitic eruptions began.

The older Neocene gravels.

The older gravels are generally light in color, being composed chiefly of quartzose pebbles. They rest directly upon the eroded edges of the Bed-rock series, and are frequently capped by a bed of rhyolitic tuff. Near Vallecito and Douglas Flat the older Neocene channel, as shown by the extent of the gravels and residual cappings of rhyolite tuff, must have been very broad. The stream which occupied it flowed westward into the Jackson quadrangle. This old channel is sometimes called the Central Hill channel. Even these earlier gravels, although usually consisting chiefly of quartzose pebbles, are not entirely devoid of volcanic material. At a point about 3 miles east of Douglas Flat, in a bluff overlooking the Stanislaus, the gravels are exposed beneath a bed of rhyolite tuff. A tunnel has been run into them at this point, and it can be seen that pebbles of rhyolite occur, together with those of quartz, quartzite, chert, and siliceous porphyries, showing that rhyolite eruptions had actually begun before the gravels were covered by the bed of tuff. Similar light-colored gravels have been preserved between Rose and Knight creeks, south of Stage's ranch. It is possible that the last-named areas, taken in connection with the patches of rhyolite tuff extending as far east as Bradford's mill, mark the general nearly east-west course of a broad river valley of early Neocene time, as previously suggested.

Gravels of the Central Hill channel.

Gravels of the Fort Mountain channel.

In the drainage areas of the Jesus Maria and Esperanza creeks there has been found a very definite channel, called the Fort Mountain channel. The gravel of this old stream bed has been mined by drifting beneath the rhyolitic lava cap at a point on Jesus Maria Creek and at several points on Esperanza Creek. The elevation of the channel on Jesus Maria Creek is about 2300 feet, and, so far as can be determined from the topographic map, the altitude of the channel increases to the north, so that it is quite certain that the stream drained to the south. On the ridge between Esperanza and Jesus Maria creeks this channel forks. The main channel, or western fork, appears to be continuous beneath the lava and to connect with the gravels east of Railroad Flat, in the Jackson quadrangle. The east branch extends under the lava ridge north of the head of Esperanza Creek, and has not been traced farther north with certainty. The Lampson channel of the Jackson quadrangle forms a west branch of the Fort Mountain channel. South of Jesus Maria Creek there is an extensive series of gravels, capped in part with rhyolite, which appear to be a part of the Fort Mountain channel. So far as can be judged from the topographic map, the elevation of these gravel masses is very nearly the same, or slightly lower than at the Banner gravel mine on Jesus Maria Creek. It is therefore likely that the river flowed south to near O'Neil Creek, and thence took a westerly course into the Jackson quadrangle, probably passing near Cave City and down the drainage of Calaveras Creek.

On the south slope of an andesite-capped ridge $3\frac{1}{2}$ miles northeast of Woodcock's mill, in the northwest portion of the quadrangle, is a small deposit of river gravel capped with rhyolite tuff. The gravel, as exposed at an hydraulic washing, is about 30 feet in thickness. The pebbles are chiefly of quartz, quartzite, and rhyolite. The rhyolite capping appears to extend north under the andesite. This gravel channel possibly connected at one time with the Fort Mountain channel, but the evidence is not conclusive.

Gravels of the andesitic period.

The gravels of the andesitic period will now be described. After the earlier gravels were buried under rhyolite tuff, which was probably the first product of Neocene volcanic activity in the Big Trees quadrangle, there followed an interval of erosion, during which fresh gravels, usually of no great thickness, were spread in part over the rhyolite tuff and in part over the Bed-rock series. When not found resting directly upon rhyolite tuff or immediately beneath it, it is not always possible to say whether a given deposit of gravel antedates or is subsequent to the rhyolite eruptions; for the older gravel has evidently contributed its resistant white pebbles to later deposits, and, as has been seen, the gravels beneath the rhyolite may contain rhyolitic pebbles. Three-fourths of a mile southeast of Murphy there is a small lenticular area of gravel of a peculiar character resting in a hollow in the limestone, which was evidently deposited in close connection with the rhyolitic eruptions. The upper portion of the deposit, exposed in an open cut, is chiefly a fine white silt, apparently of rhyolitic origin. This contains abundant well-rounded pebbles of white pumice which readily float on water. The material shows the cross-bedding characteristic of stream deposition. An inclined shaft, said to be about 200 feet in length, has been sunk in the deposit, at an angle of about 28° with the horizon, and reaches an underlying bed of coarse gravel containing large, imperfectly rounded fragments of quartz. This underlying gravel was washed for gold, with what success is not known. Another patch of light-colored gravel, containing considerable rhyolitic material and cross-bedded white silts, occurs about 1½ miles southeast of Vallecito, beneath the latite of the Table Mountain flow.

Relation of andesitic gravels and tuffs.

The post-rhyolitic erosion was interrupted by the andesitic eruptions, which took place near the crest of the range. In the western portion of the quadrangle the first manifestation of a renewal of volcanic activity appeared in the formation of gravels composed largely of andesitic pebbles but including also pebbles of other rocks. These earlier, partly andesitic gravels are sometimes auriferous, and have been hydraulicked northwest of Douglas Flat. They pass upward without any sharp break into andesitic breccias and tuffs, which are frequently represented by waterworn andesitic pebbles embedded in varying amounts of finer andesitic material. Where the number of pebbles derived from the Bed-rock series is proportionally large, and especially where the material has been washed for gold, it has been mapped as Neocene gravel. It should be understood, however, that andesitic gravels, fine tuffs, and coarse breccias were all laid down during the period of andesitic eruptions, and that all three classes of material, with various intermediate facies, may be found in the areas mapped as Neocene andesite tuff. The andesitic areas on the ridges northeast of American Camp, to the south of the Middle Stanislaus, are chiefly volcanic gravel. Still other gravels associated with light-colored sands and clays are found in portions of the pre-andesitic channel preserved beneath the areas of latite, particularly near Shaws Flat. These gravels, as a rule, are not extensive and are concealed beneath their lava covering. They have been mined at various points by tunneling through the rim rock of the ancient channel until the bottom gravels were reached. The channel in which they lie was buried beneath andesitic silts, gravels, and breccia, while the latite itself lies in a later channel cut in the andesitic deposits. The older channel, in which the gravels occur, has been called the Table Mountain channel.[1]

Gravels of the Table Mountain channel.

Columbia gravels.

The gravels formerly washed on an extensive scale near Columbia are of a character somewhat different from that of the gravels met with in other portions of the quadrangle. They rest upon limestone which, previous to or during their deposition, was dissolved and eroded away in a remarkably irregular manner. Where the gravels have been removed the exposed limestone presents a very rugged surface. The gold and gravels were caught in the deep crevices between the fantastically shaped projecting points of limestone, as in huge natural riffles. Much of the material found in these cavities is said to have been fine clay, and was the matrix in which, according to Whitney, various bones of extinct mammals, particularly those of the mammoth, were found. Although probably in the main of Neocene age, the auriferous deposits on the limestone in the vicinity of Columbia, with the exception of the patch about half a mile northwest of the town, are not typical well-rounded stream gravels, but are composed of subangular, little-worn fragments, largely quartzose, which appear to have been washed into the crevices by small streams from the waste of the rocks in the immediate neighborhood. Much of the cherty material may have been derived directly from the limestone area, for the soil covering portions of the latter is full of similar siliceous fragments. The deposits may thus be in part of Pleistocene age. The soil and detrital material over most of the limestone area west and south of Columbia has been so thoroughly worked over by the early miners that it is often impossible to determine what may have been the original character of the surficial deposits in a given spot.

[1] See W. H. Storms, Twelfth Ann. Rept. State Min. California, p. 482.

In the higher eastern portion of the quadrangle gravels derived in Neocene time from the rocks of the Bed-rock series are not known.

Rhyolite.—Those lavas that are rich in silica (70 per cent or more) and in alkalies (6 per cent or more), with little lime, are called rhyolite. Such rocks are usually light in color, many rhyolitic tuffs being quite white on weathered surfaces.

Rhyolite tuff.

Rhyolite in the form of tuff is fairly abundant within the limits of the Big Trees quadrangle. Numerous areas occur near Vallecito and Douglas Flat, where they evidently form fragments of a once extensive bed which has been dissected by erosion. The rhyolite underlies the andesite, as can be seen at many points east of Douglas Flat, to the northwest of Sheep Ranch, on Esperanza Creek and near Hale's mill on the South Stanislaus. The tuff, while sometimes soft and friable, is usually consolidated into a firm fine-grained white or pinkish rock, of somewhat porous texture. Such indurated facies often contain crystals and fragments of sanidine and quartz, and when exposed in vertical bluffs, as is often the case, they occasionally show a columnar structure, the columns being generally 4 or 5 inches in diameter and in sections a foot or so in length between the horizontal joints. This columnar structure is well shown in the hill capped by rhyolite tuff just east of Vallecito and at other points in the vicinity. The tuff might in such cases be mistaken for a massive lava flow. The microscope, however, shows that the rock is a true volcanic ash, made up of small shreds of volcanic glass in a matrix of still more finely comminuted material. A few broken crystals of sanidine and quartz, with some scales of biotite, are usually scattered through this glassy matrix.

Some rhyolite of local origin.

Extensive beds of similar tuff occur from Sheep Ranch northward to Calaveras Valley. Smaller areas are found at intervals as far north as the ridge south of East Panther Creek. It is possible that these isolated patches were all connected at one time, and that they were deposited in a river valley extending from what is now the ridge south of East Panther Creek to Calaveras Valley, where the Fort Mountain channel gives positive evidence of a former river valley. A considerable area of rhyolite tuff resting on granite is crossed at Avery on the road to Big Trees. Other patches occur south of the Middle Stanislaus near Stage's ranch, on Deer Creek, near Hale's mill, and at other points in the neighborhood. An area at Stage's ranch shows clearly the relation of the rhyolite to the early gravels and to the overlying andesite. As previously suggested, the rhyolite deposits extending westward from Bradford's mill to Stage's ranch were probably deposited in a broad river valley which may have connected with that at Vallecito. The thickness of the various areas of rhyolite tuff in the quadrangle varies from a few feet to 500 feet on Esperanza Creek. While the rhyolite lavas probably came largely from vents east and north of the Big Trees quadrangle, there is evidence that some of it had a local origin. Thus just north of the South Fork of the Mokelumne at the western edge of the quadrangle is a butte of massive rhyolite which evidently came out at that point. Near the river a tunnel has been run into this mass, and inquiry showed that it had been exploited for precious metals. An assay was therefore made, which showed that the rock contains both gold and silver.

Age of the rhyolite.

Rhyolite is the oldest Neocene igneous rock in the quadrangle. As previously stated, it is capped at many points by andesite, and on the ridge south of East Panther Creek it is capped by both andesite and basalt. The peculiar lava called latite overlies rhyolite at Bradford's mill, at Avery, and at several points along the Stanislaus River east of Murphy.

Basalt.—Lavas made up of basic lime-soda feldspars, augite, and magnetite, and usually olivine, are called basalt. Such lavas are found in the quadrangle only in the drainage of the Mokelumne. There are several small areas on the ridge south of East Panther Creek, and two small masses on a spur a little east of Devils Nose. All of these areas were perhaps formerly connected and formed one flow. This basalt overlies rhyolite at one point and underlies andesitic tuff at another on the ridge south of East Panther Creek. The basalt is therefore probably younger than the rhyolite and older than the andesite.

Distribution of the andesite.

Andesite.—Massive andesite was nowhere encountered within the quadrangle, but in fragmental accumulations of varying coarseness, from fine tuffs to coarse breccias, this rock is extremely abundant and caps nearly all the important ridges in the area. Such ridges and peaks as are free from andesitic material owe their exemption to one of two causes. Either they are composed of resistant material and stood sufficiently above the old eroded surface upon which the andesites were laid down to project like islands above the desolate waste of lava, or else they have since lost their former volcanic covering by erosion which has brought them below the general level of the old Neocene surface. Probable examples of the former class are found in the quartzite masses of Blue Mountain and Mount Elizabeth, while in the latter division may be placed the long narrow ridges lying within and near the apex of the angle formed by the junction of the North and Middle forks of the Stanislaus River.

The extensive distribution of these andesitic deposits over the quadrangle, and the shape of the areas, show very clearly that the topography of early Neocene time must have been quite different from that of the present day. Such a broad, even distribution of clastic material could have taken place only upon a surface of prevailingly gentle relief, before the deep dissection which is so characteristic a feature of the existing landscape. That the old surface was not altogether devoid of irregularities has already been indicated. Evidence of a former depression below its general level is seen near the head of Beaver Creek in the eastern part of the quadrangle, where that stream crosses a mass of andesitic breccia through which it has not yet cut into the Bed-rock series although the rocks of this series occur much higher up on the slopes in the immediate vicinity.

Andesite breccia.

The clastic andesites vary considerably in the size of the fragments of which they are composed, the amount of rounding which the latter have undergone, and the distinctness with which the material is stratified. The most common form, due in part to its resistance to erosion, is a rough breccia composed of fragments of various sizes and showing no traces of stratification or assortment. Breccia of this character is of very frequent occurrence as the topmost member of a series of andesitic beds capping a ridge, and particularly so in the higher portions of the quadrangle. Another common facies is a breccia in which the angular fragments of andesite are smaller and lie in an abundant matrix of more finely comminuted material of the same kind.

Andesite conglomerate.

Andesitic conglomerates, in which the pebbles are well rounded by water transportation (see fig. 3 on the page of illustrations), occur at many points in the quadrangle, very commonly in the basal portion of a thick andesitic deposit; but they are not confined to the bottom of the series. A coarse andesitic conglomerate, with pebbles frequently over a foot in diameter, occurs on the tops of some of the loftier ridges, as, for example, along the crest of the high ridge overlooking the canyon of the Stanislaus about 4 miles northeast of Fennessy's house. In this case the conglomerate is the upper surviving member of an andesitic accumulation at present 800 feet thick.

Andesite sand.

From these coarse deposits of volcanic material all gradations may be found down to the fine andesitic sands and tuffs showing well-defined and regular stratification (see fig. 4 on the page of illustrations). Such fine-grained stratified material is well shown around Calaveras Valley near the western edge of the quadrangle. While the finer material is more common in the lower foothills and along the edge of the Great Valley to the west of the present area, yet its deposition was not confined to these districts. Well-stratified andesitic sands occur just beyond the limits of the quadrangle east of Clover Meadow, where they are capped by coarser conglomerate and breccia.

Location of eruption.

The entire problem of the source, mode of eruption, and method of deposition of these extensive andesitic accumulations is one of much interest. The volcanoes whose eruptions furnished material in such great volume undoubtedly lay to the east of the Big Trees quadrangle, near the crest of the range, but their exact position has not yet been and may never be determined. It is impossible to describe all that took place during this portion of Neocene time with the same certitude attainable in descriptions of the volcanic activities of the present day. But some attempt to picture the events of a time that has left its mark so strongly affixed to the existing topography may lend additional interest to the andesitic accumulations which must attract the attention of any observant traveler in the region.

Origin of the fragmental andesite.

While some of the coarse breccia may have poured down the slope as mud flows, the water necessary to give fluidity to the mass being possibly derived in part from subterranean sources and in part from the copious and violent rains that are know to be a frequent consequence of volcanic eruptions, much of the finer material must have been deposited in broad bodies of water, probably produced by the clogging of the drainage by the vast amount of loose material so suddenly thrown into the streams. On the other hand, the coarse conglomerates found on the present ridge tops at altitudes above 7000 feet indicate rapid and powerful, though probably shifting, streams of water high up on the Neocene slope. The old stream beds in the Bed-rock series having been filled up with volcanic detritus, the water, probably more abundant then than now, was compelled to find its way down the débris-cumbered slope as best it could, having no fixed channels to carry it off.

Temporary lakes on the lava plains.

Prevented from permanently establishing new courses by the constant accession of fresh material thrown out from the volcanic vents above, the streams became overburdened and obstructed, and were forced to expand into temporary lake-like sheets, in which the finer materials were deposited in comparative quiet. Such a lake existed in the neighborhood of Calaveras Valley and Esperanza Creek. Fossil leaves are found in the shales or pipe-clay deposited in this body of water. As will be later shown, there was at least one interval during the period of andesitic eruptions in which a long stream was enabled to establish its channel down the slope, and even to cut through the andesitic material into the Bed-rock series.

Mineral composition of the andesite.

The larger fragments and pebbles of which the breccias and conglomerates are composed are usually dark to light gray in color, somewhat harsh and porous in texture, and of typical andesitic aspect. Some facies show phenocrysts of hornblende an inch in length, but the porphyritic crystals are usually smaller than this, and in some varieties plagioclase feldspar is the only constituent apparent to the naked eye. Augite is not, as a rule, a conspicuous megascopic mineral in these rocks. Under the microscope the andesites are found to be hornblende-andesites, hornblende-pyroxene-andesites, pyroxene-hornblende-andesites, and pyroxene-andesites. There is no sharp line to be drawn between these varieties.

Latite.—Associated with the clastic andesites of the quadrangle is a series of massive lavas comprising three members. Two of these are dark, rather basaltic-looking rocks, to which the name basalt has hitherto been commonly applied. On the geological map these two basaltic varieties are shown as a unit. The third is a light- to dark-gray, fragmental-looking rock, of somewhat harsh feel, usually containing abundant sparkling scales of black mica. These rocks were erupted as fluid molten lavas and ran down an important stream channel which had been excavated during a lull in the andesitic eruptions. They are thus younger in age than one portion of the andesitic tuff-breccias, but older than another portion.

Table Mountain channel.

The stream channel which these lavas usurped entered the quadrangle just east of Clover Meadow and ran in a southwesterly direction to a point a mile and a half south of Fennessy's meadow. Thence turning westward, it crossed the present line of the North Fork of the Stanislaus at Squaw Hollow, and continued down the west bank of this river to Parrott Ferry. Turning southeastward at the latter point, it again crossed what is now the Stanislaus Canyon and continued on into the Sonora quadrangle to Shaws Flat and thence southwest to Knights Ferry. This channel is known to miners as the Table Mountain channel. The stream was a long one, holding much the same relation to the Neocene slope that the Stanislaus, with its North and Middle forks, holds to the present general drainage system.

The first of the three lava flows ran down this channel, following the course indicated, into the Sonora quadrangle, where its remnants now form the striking topographic feature of Tuolumne Table Mountain. The relatively low northern end of this mountain just appears within the southern border of the Big Trees quadrangle, near Shaws Flat. Since its eruption, erosion has greatly reduced the former continuity of the Table Mountain flow, and to-day it is represented only by a series of strips and patches which rest upon a great variety of rocks, showing that the intervolcanic stream had been able to cut a fairly deep channel before its work was so summarily interrupted. Where these residual patches occur along the canyon of the Stanislaus, as at Parrott Ferry, east of Vallecito and Douglas Flat, and south of Big Trees, they form flat benches which break off abruptly on the side next to the river in picturesque columnar cliffs or palisades, sometimes 200 or 300 feet in height. The unconformable relation of this flow to the andesite is best seen about half a mile northeast of McKay's mill, where its vesicular base is well exposed resting upon an eroded slope of andesite tuff, while only a short distance away it lies directly upon the granite and gneiss of the Bed-rock series.

Table Mountain latite.

The rock composing the Table Mountain flow is characterized by its abundant porphyritic crystals of labradorite feldspar lying in a dark, fine-grained matrix. Under the microscope it shows phenocrysts of labradorite, augite, and usually a little olivine, in a groundmass of lath-shaped labradorite crystals, grains of augite and olivine, and globulitic glass. There is always a little accessory magnetite and apatite present. The rock may be termed an augite-latite. Three chemical analyses, of specimens taken from portions of the flow 15 to 20 miles apart, show it to contain from 56.1 to 59.8 per cent of silica, 5 0 to 6.5 per cent of lime, 2 5 to 3.9 per cent of soda, and 3.4 to 5.0 per cent of potash.

Biotite-latite

The second flow was poured out on top of the Table Mountain flow, but did not descend so far down the slope. The most westerly mass that can be referred with confidence to this second flow is in the basin of Love Creek, south of Big Trees. Two patches of very similar glassy lava occur on Mill Creek, south of Avery, which may possibly be a part of this flow; but their correlation is somewhat doubtful, as one of them is overlain by lava indistinguishable from that of the Table Mountain flow. The lava of the second eruption differs in its distribution from those which immediately preceded and followed it, inasmuch as it is not confined to the general line of the buried Neocene stream channel. It occurs in small patches in various parts of the Stanislaus drainage, as well as in the drainage area of the South Mokelumne, and even in that of the Tuolumne River at Bradford's mill. It is generally much thinner than the Table Mountain flow, being usually less than 50 feet in thickness. It is typically shown in the vicinity of McKay's mill. It sometimes exhibits a rude columnar parting, the columns being short and stout. The rock cleaves most readily in planes transverse to the columns, and shows brilliant scales of biotite lying in a dark-gray ground. Pebbles and angular fragments of andesite and latite are found in many specimens, giving the rock a decidedly tuff-like aspect. The matrix is evidently highly glassy, and contains blebs and flamboyant wisps of dark obsidian.

The microscope shows the rock to contain crystals of labradorite, biotite, and a little augite, lying in a streaked glassy groundmass. The peculiar structure of the groundmass is due to the drawing out of the viscous lava by the movement of flow after crystallization had already begun, the resulting streaks and bands being distorted and broken as the cooling magma became more pasty. This rock may be called a biotite-latite. Chemical analyses of two specimens, taken about ten miles apart, show from 61.0 to 62.3 per cent of silica, 3.2 to 4.9 of lime, 3.7 to 4.2 of soda, and 4.4 to 5.2 of potash.

Dardanelles latite.

The last flow, called, from its typical occurrence on a group of peaks a few miles east of Clover Meadow, the Dardanelles flow, is an augite-latite so closely resembling the rock of the Table Mountain flow that in certain facies the two are practically indistinguishable. It is usually finer grained, with less abundant porphyritic crystals, and as a rule contains a little more silica. Like the first flow, it is confined to the general line of the Neocene stream channel, but has not been certainly identified lower down the slope than about 2 miles below McKay's mill. A chemical analysis shows it to contain 59.4 per cent of silica, 4.6 per cent of lime, 3.7 per cent of soda, and 5.0 per cent of potash.

The distinctive chemical characteristic of all three of these lavas is a rather high percentage of total alkalies, with the potash slightly in excess of the soda. Chemically they stand between typical andesites and typical trachytes, and correspond to the intermediate group of plutonic rocks called monzonites. Such lavas, the volcanic equivalents of the deep-seated monzonites, have been named latites. (See Bull. 89, U. S. Geol. Survey.)

PLEISTOCENE.

Erosion.—The geological record within the Big Trees quadrangle during Pleistocene time has been preserved mainly in the strong sculpturing by erosion, deposition having played an exceedingly unimportant part. With the cessation of volcanic activity at the close of the Neocene, the streams were again able to assert themselves and to set about the establishment of the present drainage system. With the increased fall given them by the Neocene upheaval, they were enabled to attack with vigor the volcanic mantle which covered the region, and to sink their gorges deep into the Bed-rock series. The andesitic tuffs and breccias which once concealed nearly all of the older rocks were thus dissected into their present irregular and detached areas. The continuity of stream erosion was, however, broken in the higher portion of the region by the epoch of glaciation.

Gravels.—Pleistocene gravels occur at intervals all along the present streams. Some of the loose materials lie distinctly above the present water levels and were evidently deposited when the rivers ran at higher levels. In some cases, as near Vallecito, where the Pleistocene gravels rest partly upon Neocene gravels, it is not always possible to discriminate sharply the former from the latter.

Alluvium.—The proportion of alluvial, or bottom, land within the quadrangle is small, and is almost confined to grassy meadows, usually in the head-water regions of streams. Beautiful meadows are found in Bear Valley in the northeast corner of the quadrangle, at Lord's ranch in the southeast corner, and others of less extent at other points. In many of these the grass is cut for hay, while others are simply fenced and used by the stockmen as feeding and gathering grounds for their cattle preparatory to the annual autumn retreat to the Great Valley.

Glaciation.—There is abundant evidence of the former existence of glacial ice in the high eastern portion of the quadrangle. This evidence consists of bare granite slopes showing glacial polish and scoring, of transported bowlders of granite left stranded on rocks of unlike character (see fig. 1, page of illustrations), and of definite piles of loose rocks—moraines, composed of materials which have fallen on the ice and been carried down the slope and left on the ridge tops and canyon sides. River canyons that have been occupied by glaciers are commonly U-shaped. As only the upper portions of the main canyons, chiefly to the east of the quadrangle, exhibit this form, it would appear that the ice streams never extended far down the present drainage. There is some evidence, however, that at an early stage of the Glacial epoch the Pleistocene rivers occupied shallow valleys, and it was perhaps during this time that the glaciers extended farthest west, where they left moraines which are still preserved at some points. Thus in the neighborhood of Bear Creek on the slopes of the North Mokelumne Canyon, at Squaw Hollow in the canyon of the North Fork of the Stanislaus, and on the ridge south of the Middle Stanislaus south of Bakers Crossing there are small remnants of moraines. After this early period of greatest ice extension, when the river valleys were shallow, it may be supposed that the ice sheet retreated to the higher mountains to the east of the Big Trees quadrangle. During this interglacial epoch the rivers are thought to have greatly deepened their canyons. After this period of canyon cutting, the ice sheet again advanced westward, gouging out the loose rock, polishing the bed rock, and to some extent eating into it, thus transforming the V-shaped river-cut canyon into a glacial U-shaped canyon.

First period of glaciation.

Second period of glaciation.

The chief evidence of the first period of glaciation lies in the existence of the most western moraines above referred to on the ridge tops and canyon sides, and in the gentle slopes of the upper part of the canyon. The upper gentle slopes are supposed to be the sides of the early shallow river valleys. The canyons adjacent to the most western moraines do not show the characteristic U-shape of glaciated canyons, strongly suggesting, as previously stated, that these moraines were left there at an earlier period when the canyons were shallower. In the process of deepening the canyons in the supposed interglacial epoch, the glacial markings and scorings and the terminal moraines left by the retreating ice of the first epoch in the lower parts of the shallow river valleys would of course be obliterated, and only the moraines on the ridges and higher slopes would be left to attest the former presence of the ice. Some of the ponds and meadows of the upper drainage of the Stanislaus were formed by the clogging of the streams by morainal dams.

Glacial potholes.

In fig. 2, page of illustrations, is shown a view of some potholes in the canyon of the North Mokelumne River 5 miles northwest of Bloods. The potholes lie 25 feet vertically above the present water level of the river. They are about 250 in number and cover a surface of approximately 2000 square feet. To the north is a glaciated cliff of granite about 40 feet high, on the side of which is another pothole. It may be presumed that these potholes were formed by a glacial river falling from this granite cliff. Just above the potholes salt water oozes out of cracks in the granite and, flowing into the nearest potholes, crystallizes into salt, which is gathered by Indians and others for culinary purposes.[1]

No prominence was given to the study of glacial phenomena in the Big Trees quadrangle, and it is probable that more moraines exist than are shown on the geological map.

ECONOMIC GEOLOGY.

Gravel mines about Columbia.

Neocene auriferous gravels.—The gravels deposited by the Neocene rivers were formerly worked on an extensive scale, with large profits, in the southwestern portion of the quadrangle, but there is now little being done in this district. Columbia, once the center of a stirring mining population, has sunk into decay, and a similar fate has overtaken the little settlements of Shaws Flat and Springfield. Their appearance of semi-desolation is strangely heightened by the bare and bleached points of limestone which stand like closely set gravestones about the dilapidated houses. On account of the depth of the cavities in the limestone in which the gravels near Columbia lay, and the difficulty of securing deep drainage, most of the auriferous detritus had to be hoisted with derricks, and washed into the sluices from raised dumping platforms. As much as $100,000 per week is said to have been shipped from Columbia between 1853 and 1858, but the industry had already greatly declined in 1870, and in 1896 mining was going on in a small way at one point only.

Gravels about Vallecito.

The deeper gravels beneath the Pleistocene gravels just east of Vallecito, although not on limestone, resembled those of Columbia in the difficulty experienced in securing the requisite deep drainage whereby they could have been profitably washed by ordinary hydraulic methods. It was necessary to mine the gravel by drifting, and raise it to the surface through vertical shafts, some of which are said to have been over 100 feet in depth. The reported depth of this part of the old channel is interesting, as it lies below portions of the later channel covered by the latite flow to the east, and is nearly surrounded by the ancient rocks of the Bed-rock series. Its gravels are apparently continuous with those exposed below the andesites on the northwest of Vallecito, and the former outlet of the stream must have been in that direction. Before and during the andesitic eruptions this depression in the early Neocene stream bed must have become filled with gravel and buried beneath the volcanic tuffs and breccias. The later intervolcanic stream, which cut out the Table Mountain channel down which the latite flowed, did not reëxcavate this buried hollow, but cut a new course to the southward, not very different, as shown by the distribution of the latite, from that of the present Stanislaus. Since that time later erosion has again brought partially to light the old channel at Vallecito. Southeast of the town are two patches of gravel whose situations with reference to the existing topography allowed them to be formerly hydraulicked and in great part washed away. A considerable deposit of gravel occurs about 1½ miles southeast of Vallecito, beneath a patch of the latite. This mass was being worked by tunneling on the west side of the hill in 1896, while an excavation on the east side attests the earlier employment of the hydraulic method. The gravels north of Douglas Flat, which are partly andesitic, were formerly hydraulicked on an extensive scale, but nothing is now being done in this locality. In the neighborhood of Vallecito and Douglas Flat the Neocene gravels, of varying thickness, cover a wide area, but they have not been extensively exploited except at the points noted. A small patch of gravel occurs about a mile south of Murphy, which was being worked in a desultory manner in 1896. It is probably a continuation of the deposit formerly hydraulicked on the south side of the andesitic area north of Douglas Flat. The gravels east and north of Sheep Ranch were formerly worked at several points, particularly at the eastern edge of the town. The river which deposited this gravel was perhaps a branch of the one occupying the Fort Mountain channel, in which case the stream drained to the northwest and joined the Fort Mountain channel north of O'Neil Creek. Deposits which are regarded as belonging to the Fort Mountain channel occur on the ridge north of O'Neil Creek and thence north at frequent intervals to the vicinity of Railroad Flat. As much of this river deposit is hidden by the rhyolite that overlies it, only a few areas appear on the geological map. The name of the channel appears to have been taken from a picturesque andesitic hill which is situated 2 miles north of Calaveras Valley. This hill is locally known as Fort Mountain. There is no evidence, however, of any prerhyolitic river deposit at Fort Mountain. The volcanic conglomerates that make up the hill show evidence in their varied bedding of shifting currents. But the waters that arranged these conglomerates in layers probably belonged to a temporary sheet of water that accompanied the volcanic eruptions. The Fort Mountain channel has been mined east of Railroad Flat, on Esperanza Creek, and at the Banner Blue gravel mine on Jesus Maria Creek. At the Banner mine the gravel is worked by means of a shaft sunk through the rhyolite capping. The channel is said to be 125 feet wide. A level line run north from the Banner mine shows the present grade of the Fort Mountain channel in this vicinity to be 70 feet to the mile. The river gravels on the ridge north of O'Neil Creek have been mined at several points. In 1896 the gravel at the Brassila mine was being worked by drifting under the lava cap. The Fort Mountain channel is supposed not to have crossed O'Neil Creek, but to have drained west into the Jackson quadrangle.

Gravels near Douglas Flat.

The auriferous gravels of the Fort Mountain channel.

Banner gravel mine.

Auriferous gravels of the present streams.

Pleistocene auriferous gravels.—Wherever gravels occur bordering the existing stream beds in the southwestern and western part of the quadrangle they have been washed to some extent for gold. Several areas are indicated along the Stanislaus from Robinson Ferry up to Abbott Ferry, and most of them have been exploited by the hydraulic method. Although never occurring far from the stream, yet they are as a rule distinctly above its present high-water mark, and record a stage when its bed stood higher than it now does. Most of the gravel forming the upper part of the deposit immediately east of Vallecito appears to be Pleistocene, although it has been so thoroughly turned over in many places that there is considerable doubt as to the original position and age of much of it. It does not appear to have ever had any great depth over much of the area, as the bed rock is exposed in several places where apparently no great amount of gravel has been artificially removed. The pebbles consist of andesite, rhyolite, quartz, and other rocks, all of which may

[1] Am. Jour. Sci., 3d series, Vol. XLIV, 1892, p. 453.

have been derived from the immediate vicinity. Pebbles from the dioritic area just west of the town are abundant. Near Columbia, Pleistocene gravels are still being worked to some extent by hand sluicing at Browns Flat, and by hydraulicking at Yankee Hill. Other deposits which were formerly worked at a profit occur southeast of Douglas Flat on Grapevine Creek, on the South Fork of the Stanislaus, and near Murphy.

In addition to these earlier Pleistocene gravels, the present beds of nearly all the streams in the western part of the quadrangle have proved more or less auriferous, and there are few or none of them that have not had their gravels turned over and washed, in many cases more than once.

Gold-quartz veins.—Some activity was manifest in 1896 near Robinson Ferry, where prospecting was being carried on at the Melones, **Robinson Ferry mines.** Stanislaus, and Calaveras Consolidated mines situated on the south slope of Carson Hill, at the Adelaide at Robinson Ferry, and at the Norwegian mine on the south side of the river. None of them, however, were established on a paying basis, although the Carson Hill group had been producers several years ago. The Mother Lode, as exposed on the south slope of Carson Hill, comprises several veins which show a tendency to converge near the ferry. They are, however, exceedingly irregular, and in the Stanislaus mine the ore occurs in small cross stringers of quartz in black Calaveras slates, near a mass of talcose schist. The ores of the mines in the immediate vicinity of Robinson Ferry are, as a rule, rich in tellurides of gold, **Tellurides of gold, silver, lead, and nickel.** silver, and lead. Petzite, hessite, and calaverite (tellurides of gold and silver), and altaite (telluride of lead), have all been described from the Stanislaus and Melones mines, as well as the rare mineral melonite, a telluride of nickel. In addition to the tellurides, the veins contain free gold, pyrite, and a little galena, in a gangue of quartz with usually some dolomite and occasionally a little albite.

The other gold-quartz veins of the quadrangle all lie to the northeast of the linear system of the Mother Lode, of which so short a section is included within the general area near Robinson Ferry. The Belleview mine, formerly known as the Hyde mine, is in the same granitic **Belleview mine.** area as the mines of the Soulsbyville district in the Sonora quadrangle. Unlike most of the mines of that district, there are not large amounts of sulphides in the Belleview vein. Galena, containing some antimony, and chalcopyrite were noted in small amounts. The region north and east of American Camp is a rather promising one and contains numerous quartz veins, most of them as yet undeveloped. The Keltz mine, situated in the canyon of the South Fork of the Stanislaus, is on **Keltz mine.** a vein lying within the siliceous schists of the Calaveras formation, just to the west of a dioritic dike. The dip varies, but is usually from 35° to 45° SE. The vein rock of the Keltz, in contrast to that of the Robinson Ferry group, is free milling, consisting chiefly of quartz, pyrite and free gold. The Riverside mine, now idle, is on the north bank of the South Fork of the **Riverside mine.** Stanislaus, about a mile west of the Keltz. Where seen, the vein is a strong one, upward of 5 feet in thickness, and is composed largely of ribbon quartz. The ore shows both copper and iron sulphides. The Star mine is in schist on the north side of Rose Creek, **Star mine.** and is working upon two diverging veins. Nearly all the quartz seen is of a dark color. It is said to be very rich in spots. The mine has recently been reopened and a rich body of ore found, containing free gold and sulphides of copper, iron, and lead. The dark color of the quartz of the Star mine has been shown by Dr. Stokes, of the United States Geological Survey, to be due to finely disseminated carbonaceous material. On the north side of Knight Creek, within the granodiorite area, a prospect was noted in which the vein material consists of dark quartz containing pyrite and scales of molybdenite. The vein of the Eagle prospect, on Eagle **Eagle prospect.** Creek, is from 6 inches to 3 feet in thickness, and strikes nearly N.–S. magnetic, dipping about 44° E. The country rock of the mine is the Calaveras formation. A dike was noted along the vein. Free gold, pyrite, chalcopyrite, and zinc blende are present in the ore.

A series of quartz veins occurs on both sides of the Stanislaus in the Calaveras formation near Collierville. Although several tunnels have been run on them, they are all in the prospecting stage of development. The vein rock of the Homestake claim, near Collierville, is a dark quartz **Mines near Collierville.** containing pyrite, free gold, and a little galena. A small mill was formerly run on the ore from the Collier claim, which adjoins the Homestake, but the ore is said to have contained tellurides, in which case probably a large proportion of the gold was lost in the tailings which were not saved. The strike of the Collier-Homestake vein is nearly due E.–W., and the dip about 80° N., although sometimes nearly vertical. The True Business and Sailor Boy veins, on the east bank of the river, strike, like the Collier, nearly E.–W., which is also the general strike of the dark siliceous slates and accompanying limestone lenses on both sides of the river. The North Chimney Rock vein has apparently a nearly NE.–SW. strike, with a steep southeasterly dip. The country rock is hard siliceous slate, and the vein rock quartz, containing abundant pyrite. The strike of the schists and slates is here nearly E.–W., and the dip 65° S. The Dorsey vein is nearly vertical and strikes about N. 54° E., and, as exposed at the surface, is 6 or 8 inches wide.

The Oro y Plata vein, formerly the Blue Wing, outcrops just north of Murphy, in limestone close to the contact with the Calaveras schists. It was formerly extensively **Oro y Plata or Blue Wing vein.** worked, and possesses interest on account of the unusual association of sulphides in the ore. Ordinary vein quartz forms a part of the deposit, but is accompanied by brown jasper. Cinnabar, stibnite, and galena are present in the ore, and it is also said to contain copper. The Mayflower and Mayday claims are prospects in the Calaveras schists northwest of Murphy. Their veins, like those near Collierville, conform to the nearly E.–W. strike of the inclosing schistose rocks. The Sheep Ranch mine has been more extensively developed than any other mine in the quadrangle, but is at present idle. **Sheep Ranch mine.** The vein lies in dark siliceous slates, and strikes N. 55° W. The dip is northeasterly about 75°. The thickness of the vein varies from a few inches up to several feet, and consists of numerous stringers of quartz with intermingled slate. The ore consisted of pyrite and free gold in a gangue of dark quartz, and was free milling. It is said that in the lower levels the sulphurets were not considered worth saving, all the gold being caught on the plates.

A large number of quartz veins containing some gold and silver have been exploited in the rocks of the Calaveras formation to the north and west of Blue Mountain. In many of these claims the quartz is dark in color, as at the Star mine on Rose Creek. None of these veins appear to have developed into permanent mines. The Cook mine, on the ridge slope north of the Licking Fork of the Mokelumne, has been worked at different times. The ore is very base, being composed largely of sulphides. Pyrite, zinc blende, and arsenopyrite are present in large amount.

The granodiorite area north of Woodcock's mill contains numerous quartz veins, many of which have been exploited for gold. These claims are in the West Point district, which in the Jackson quadrangle has afforded some producing mines. The Lockwood mine is a type of the mines of the West Point district. It is located about 1½ miles northeast of Woodcock's mill. **Lockwood mine.** The quartz vein has a northwest-southeast course. The ore is free gold, pyrite, pyrrhotite, and other sulphides, in a gangue of quartz. The sulphides are present in very large amount. A fine-grained dioritic dike cuts the vein of the Lockwood mine, and the ore is said to have been richer near the dike.

Gold and silver in rhyolite.—There is a butte of rhyolite shown on the geological map just north of the South Mokelumne, at the west margin of the sheet. This rhyolite appears to have been erupted at this point. It has been exploited by means of a tunnel, the mouth of which is near the river. A sample of the rhyolite from the dump was assayed by the Selby Smelting and Lead Company of San Francisco, the result showing that it contains .03 ounce gold and .25 ounce silver per ton.

Iron.—A deposit of limonite, which has been prospected to a small extent, occurs in the Calaveras formation adjacent to a small lens of limestone about a mile northeast of Murphy. It is not likely to prove of economic value.

Marble.—Several small quarries have been opened in the limestone on the Bannister ranch, about half a mile northeast of Abbott Ferry. The marble is apparently of fair quality and the supply is practically unlimited. Veined, pure white, and variegated marbles are all present within a comparatively small area. The markings of the veined variety are a little too faint for a thoroughly effective stone of this class. The material is dressed in the quarries to supply local demands, the lack of transportation facilities restricting it to the home market.

H. W. TURNER,
F. L. RANSOME,
Geologists.

May, 1898.

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

TOPOGRAPHIC SHEET

CALIFORNIA
BIG TREES QUADRANGLE

(Placerville) (Pyramid Peak) (Markleeville)

(Jackson) (Dardanelles) (Sonora) (Yosemite)

38°30' 120°30' 20' 10' 120°00' 38°30'
20' 10' 38°00'

CONVENTIONAL SIGNS

CULTURE (printed in black)

- Roads and buildings
- Private and secondary roads
- Trails
- Railroads
- Street railroads
- Tunnels
- Bridges
- Ferries
- Fords
- Dams
- Locks
- U.S. township and section lines
- Located township and section corners
- Township and section corners not found
- Triangulation stations
- Bench marks (B.M. ×)
- Mines and quarries
- Prospects
- Shafts
- Mine tunnels (showing direction)
- Mine tunnels (direction unknown)

CONVENTIONAL SIGNS

RELIEF (printed in brown)

- Figures (showing heights above mean sea level instrumentally determined) 5463
- Contours (showing height above sea, horizontal form and steepness of slope of the surface)
- Depression contours
- Levees
- Cliffs
- Mine dumps

DRAINAGE (printed in blue)

- Streams
- Falls and rapids
- Intermittent streams
- Canals and ditches
- Lakes and ponds
- Intermittent lakes
- Glaciers
- Springs
- Salt marshes
- Fresh marshes
- Tidal flats

The above signs are in current use on the topographic maps. Variations from this usage appear in some maps of earlier dates.

A. H. Thompson, Geographer.
L. M. Douglas, Topographer in charge.
Triangulation by H. E. C. Feusier.
Topography by R. H. McKee.
Surveyed in 1890-91.

Scale 1/125000
1 ½ 0 1 2 3 4 5 Miles
1 ½ 0 1 2 3 4 5 Kilometer
Contour interval 100 feet.
Datum is mean sea level.

Edition of June 1898.

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

HISTORICAL GEOLOGY SHEET

CALIFORNIA
BIG TREES QUADRANGLE

A. H. Thompson, Geographer.
E. M. Douglas, Topographer in charge.
Triangulation by H. E. C. Feusier.
Topography by R. H. Mc.Kee.
Surveyed in 1890-91.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometer

Contour interval 100 feet.
Datum is mean sea level.
Edition of Jan. 1899.

Turner
Ransome
Turner

Geology by H. W. Turner.
Assisted by F. L. Ransome.
Surveyed in 1891, 95, and 96.

LEGEND

SUPERJACENT SERIES

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles.)

PLEISTOCENE

- Pal — Alluvium *(bottom lands and meadows)*
- Pm — Moraines
- Pgv — River gravels *(in part auriferous)*

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines.)

NEOCENE

- Ng — Auriferous river gravels

BED-ROCK SERIES

CARBONIFEROUS

- Cc — Calaveras formation *(argillite, limestone, quartzite, and mica-schist; contains gold quartz veins)*
- ls — Limestone *(in the Calaveras formation)*

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs. Metamorphism is indicated by short dashes combined with the Igneous patterns.)

SUPERJACENT SERIES

NEOCENE

- Nat — Andesitic tuff and breccia
- Nl — Latite
- Nbl — Biotite latite
- Nb — Basalt
- Nr — Rhyolite

BED-ROCK SERIES

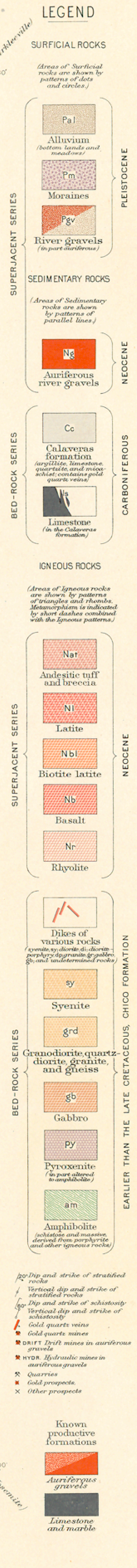
EARLIER THAN THE LATE CRETACEOUS, CHICO FORMATION

- Dikes of various rocks *(syenite, sy; diorite, di; diorite-porphyry, dp; granite, gr; gabbro, gb; and undetermined rocks)*
- sy — Syenite
- grd — Granodiorite, quartz-diorite, granite, and gneiss
- gb — Gabbro
- py — Pyroxenite *(in part altered to amphibolite)*
- am — Amphibolite *(schistose and massive, derived from porphyrite and other igneous rocks)*

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

ECONOMIC GEOLOGY SHEET

CALIFORNIA
BIG TREES QUADRANGLE



A.H. Thompson, Geographer.
E.M. Douglas, Topographer in charge.
Triangulation by H.E.C. Feusier.
Topography by R.H. McKee.
Surveyed in 1890-91.

Scale 1/125000
Contour interval 100 feet.
Datum is mean sea level.
Edition of Jan. 1898.

Geology by H.W. Turner.
Assisted by F.L. Ransome.
Surveyed in 1891, '95, and '96.

SPECIAL ILLUSTRATIONS

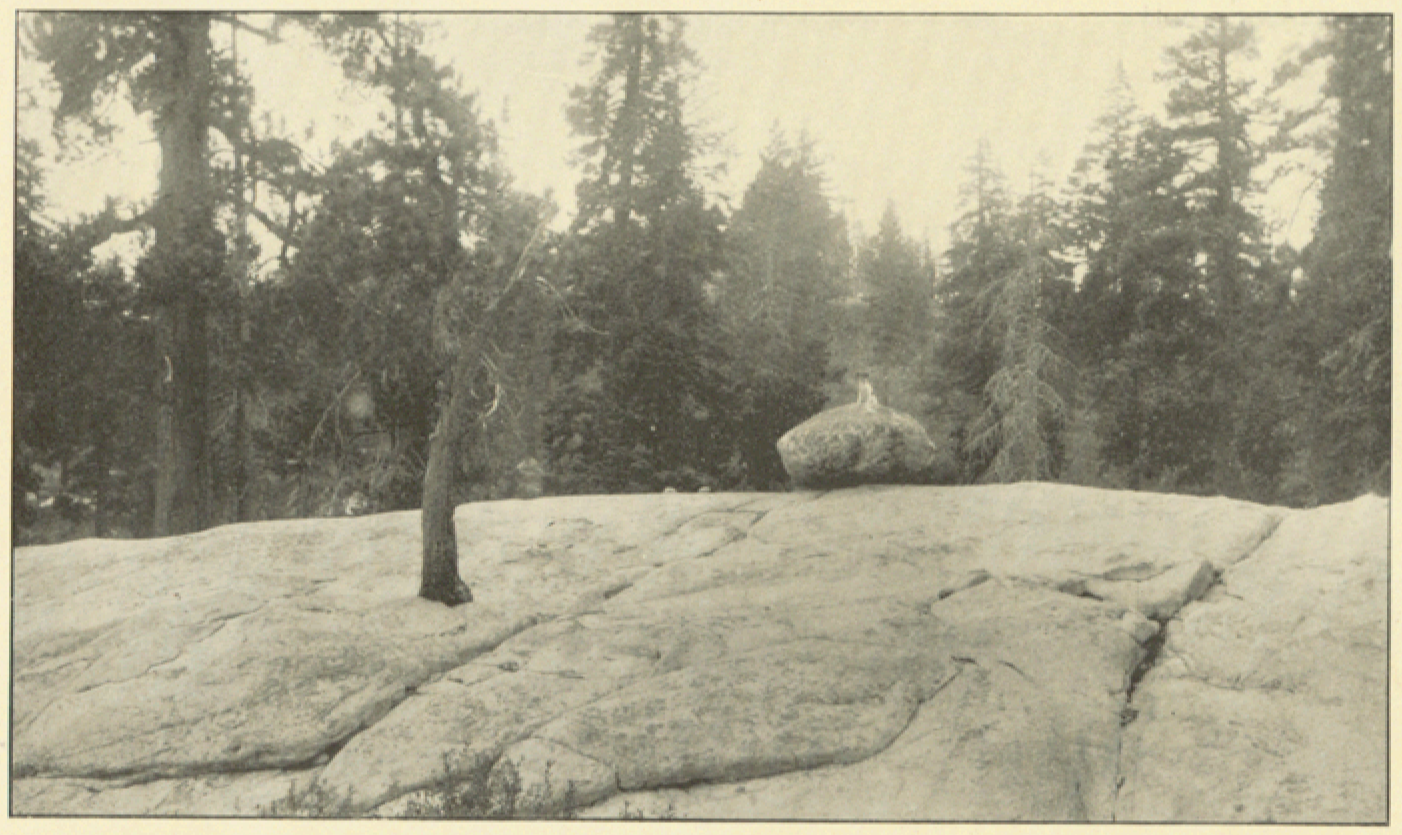


FIG. 1.—PERCHED BOWLDER ON A GLACIATED ROCK SURFACE, NORTH OF BLOODS.

FIG. 2.—POTHOLES IN THE CANYON OF THE NORTH FORK OF MOKELUMNE RIVER ABOUT 5 MILES NORTHWEST OF BLOODS.

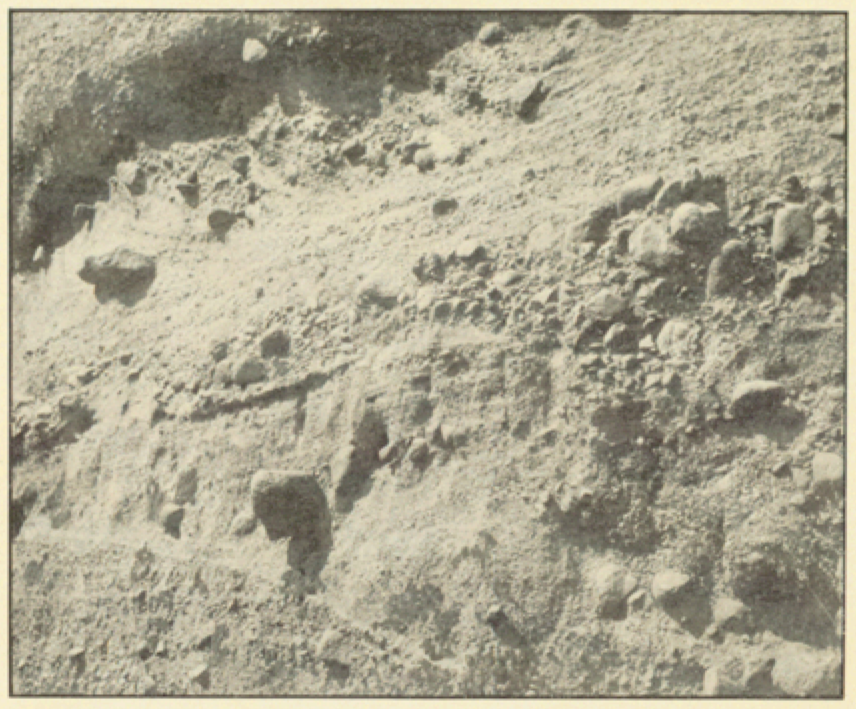


FIG. 3.—ANDESITIC CONGLOMERATE, SHOWING IRREGULAR BEDDING, AT FORT MOUNTAIN.

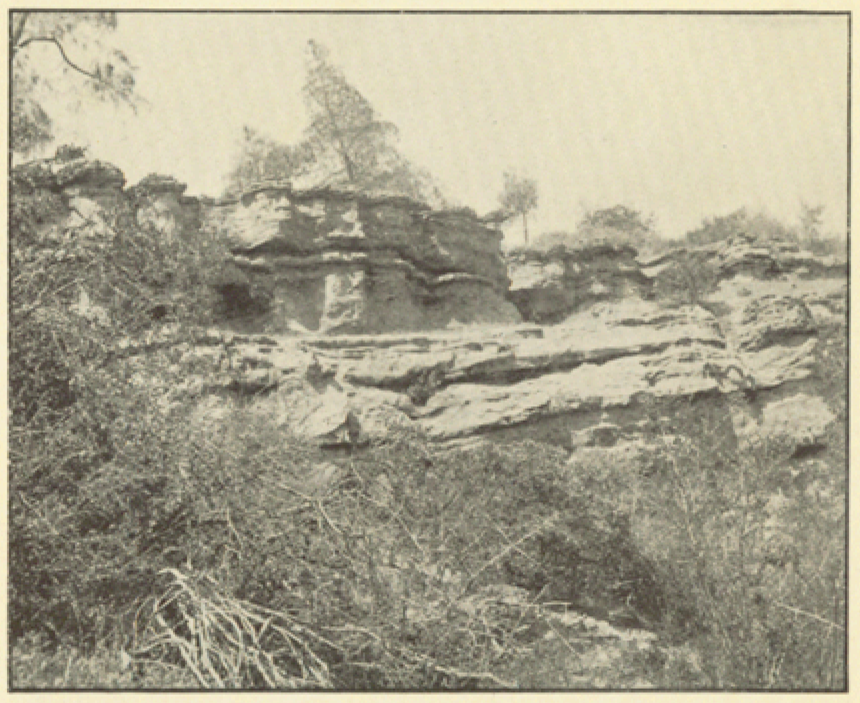


FIG. 4.—BEDS OF FINE-GRAINED ANDESITE-TUFF, NEAR THE HEAD OF ESPERANZA CREEK.

FIG. 5.—TYPE OF THE BIG TREES *(SEQUOIA GIGANTEA)* OF THE CALAVERAS GROVES

forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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 formations are remote one from the 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 rocks of different areas, provinces, and continents, afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the color or colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions of the periods, frequently used in geologic writings, are bracketed against the appropriate period name.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the first (Pleistocene) and the last (Archean). The formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations.

Period.	Symbol.	Color.
Pleistocene	P	Any colors.
Neocene { Pliocene, Miocene }	N	Buffs.
Eocene (including Oligocene)	E	Olive-browns.
Cretaceous	K	Olive-greens.
Juratrias { Jurassic, Triassic }	J	Blue-greens.
Carboniferous (including Permian)	C	Blues.
Devonian	D	Blue-purples.
Silurian (including Ordovician)	S	Red-purples.
Cambrian	€	Pinks.
Algonkian	A	Orange-browns.
Archean	Æ	Any colors.

Each formation is furthermore given a letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations of the Pleistocene render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the metamorphic rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Historical geology sheet.—This sheet 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 particular colored pattern and its letter-symbol on the map 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet 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 symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

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 name 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 the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting 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 in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane that cuts a section so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section 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:

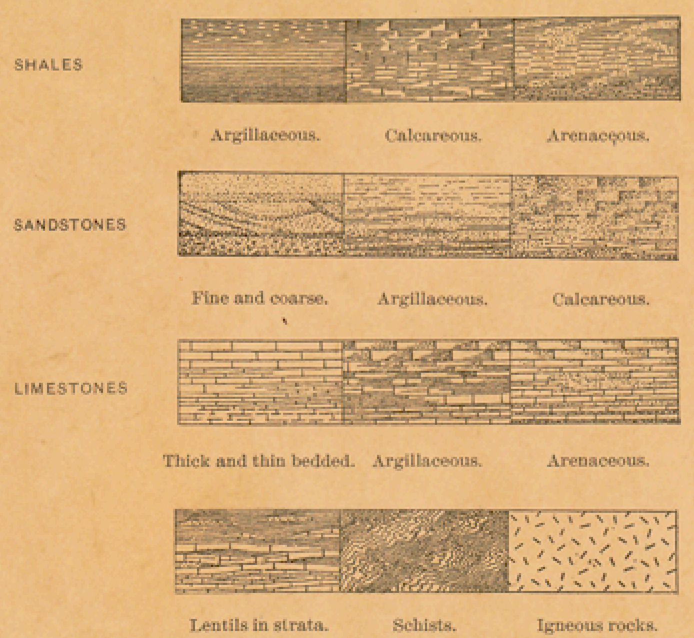


Fig. 3.—Symbols used to represent different kinds of rock.

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 beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets. That they are now bent and folded is regarded as proof that forces exist which have from time to time caused the earth's surface to wrinkle along certain zones.

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

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the 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 swelled upward 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 strata thus rest upon an eroded surface of older strata 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 this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration 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, marking a time interval between two periods of rock formation, is another unconformity.

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

Columnar-section sheet.—This sheet contains a concise description of the rock formations which occur in the quadrangle. The diagrams and verbal statements form a summary of the facts relating to the character of the rocks, to the thicknesses of the formations, and to the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest measurements. The average thickness of each formation 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 is placed at the bottom of the column, the youngest at the top, and igneous rocks or other formations, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied by its name, a description of its character, and its letter-symbol as used in the maps and their legends.

CHARLES D. WALCOTT,
Director.

Revised June, 1897.