DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

39

GEOLOGIC ATLAS

OF THE

UNITED STATES

TRUCKEE FOLIO

CALIFORNIA

INDEX MAP

SCALE: 40 MILES=1 INCH

AREA OF THE TRUCKEE FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION | TOPOGRAPHY | HISTORICAL GEOLOGY | ECONOMIC GEOLOGY | STRUCTURE SECTIONS

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BAILEY WILLIS, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER

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EXPLANATION.

…ogical 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, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea-level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the 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 sketch 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 nd 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 minerals, 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.

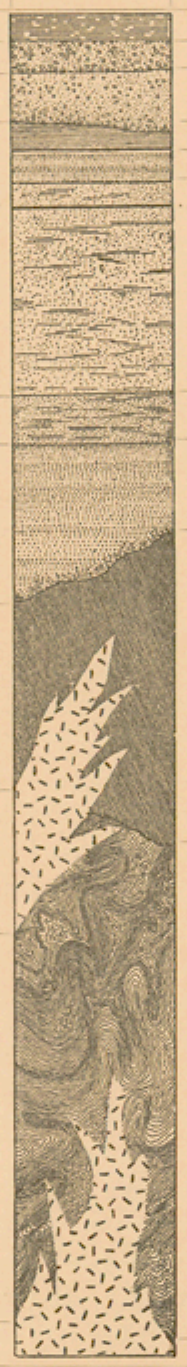
Rhyolite.—An effusive rock of Tertiary or later age. The essential constituents are alkali feldspars and quartz, usually with a small amount of biotite or hornblende in a groundmass, which is often glassy.

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 TRUCKEE QUADRANGLE.

TOPOGRAPHY.

Geographic position.—The Truckee quadrangle includes the territory between meridians 120° and 120° 30′ west longitude and parallels 39° and 39° 30′ north latitude. The area is 34½ miles long and nearly 27 miles wide, and contains 925 square miles. It embraces portions of Sierra, Nevada, Placer, and Eldorado counties, California, while the State of Nevada adjoins it on the east.

Extent of quadrangle. Counties.

Relief.—The quadrangle has, on the whole, a rugged and mountainous character, including, as it does, a part of the summit region of the Sierra Nevada. Many peaks rise above 9000 feet, and the central Truckee Valley is the only area showing a moderate and hilly configuration. The lowest point is found in the canyon of the North Fork of American River, which descends to an elevation of 3700 feet, while the highest peak, located 4 miles north of Hot Springs on Lake Tahoe, attains 9300 feet. Less majestic than the crest region of the southern Sierras, this region is still of surpassing interest, combining with the grandest mountain scenes a great variety of geologic formations and structure.

General topographic character.

The quadrangle may be divided into three parts, of different topographic types:

First, the western mountain mass, forming a part of the main block of the Sierra Nevada. Its lower part is, in this quadrangle, characterized by broad ridges, separated by deeply trenched canyons; its topography is thus similar to that of quadrangles adjoining on the west. The upper region is more irregular, and culminates in a series of lofty peaks, reaching elevations of from 7000 to 9000 feet, along the divide which extends diagonally across the quadrangle.

Second, the irregular depression of Truckee Valley, deeply sunk between two parallel ranges and separated into several parts by projecting lower ridges. Southward and northward the valley is limited by high ridges connecting the eastern and western range.

Third, the eastern range, sometimes referred to as the Carson Range, of which only a small part is shown on this sheet. Narrow, with abrupt slopes eastward and westward, this range follows the eastern shore of Lake Tahoe and culminates, at an elevation of 10,800 feet, in Mount Rose, in the adjoining Carson quadrangle. The whole width of the range appears, on this sheet, only near the northeastern corner.

Drainage.—The main water parting between the Pacific and the Great Basin follows the summit of the main range diagonally across the sheet from a point 2 miles east of Rubicon Springs on the south to a point 2 miles west of Webber Lake on the north. To the west of this water parting the rivers flow into Sacramento River, the drainage being divided between the Yuba and American rivers. The Middle Fork of Yuba River heads in the extreme northwest corner of the quadrangle, while the South Fork drains the country adjoining the Central Pacific Railroad. The North Fork of American River, heading in the vicinity of Granite Chief Peak, forms, near the western boundary line, the remarkable canyon known as the American Royal Gorge, which attains a depth of 4000 feet. The southwestern part is drained by the Middle Fork of the American and by one of its tributaries, the Rubicon, the former flowing in a broad valley with comparatively gentle slopes, while the Rubicon throughout its course in this area has cut a deep canyon.

Tributaries of the Sacramento.

The grades of these rivers, nearly all of which have a westerly or southwesterly course, are very steep. That of South Yuba River ranges from 50 to 200 feet per mile, and averages 100 feet per mile. The North Fork of the American falls 200 feet per mile between the western boundary and Soda Springs. The Middle Fork of the American descends less rapidly, averaging only 100 feet per mile between the western border and a point due south of Soda Springs. Considerable stretches of it have a grade of only 37 feet per mile. That part of Rubicon River which lies within this quadrangle has an average grade of 124 feet per mile.

The water courses east of the summit line referred to find their way to the saline sinks of the Great Basin, a part of them first emptying into the great natural storage basin of Lake Tahoe, well known as one of the most beautiful mountain lakes in the world. Occupying a broad depression between the two summit ridges of the Sierra Nevada, it may in a certain sense be regarded as the southern continuation of Truckee Valley. The lake covers about 190 square miles, of which about 112 square miles fall within the Truckee quadrangle. The outlet of the lake is through Truckee River, which for 13 miles flows nearly due north, then turning to the northeast, traverses Truckee Valley and breaks through the eastern range in a deep canyon. At the northeast corner of the quadrangle the river emerges from the eastern range into the broad flood plains about Verdi and Reno. Truckee River receives several tributaries, of which the more important are Prosser Creek and Little Truckee, which join it in Truckee Valley. The fall of this river and of its tributaries is much smaller than that of the rivers belonging to the Pacific drainage. From the lake, which has an elevation of 6225 feet, to the city of Truckee the fall is only 28 feet per mile. From this point on, the grade varies between 33 and 50 feet per mile, the highest being found in the canyon north of Bronco. Little Truckee River has grades ranging from 14 feet per mile up to 37 feet.

Watershed to Great Basin.

According to the few observations available, the depth of Lake Tahoe is very considerable, the deepest sounding yet made, 1635 feet, being found a short distance south of Hot Springs. The deepest depression extends southward from this point, and the slopes from the shores are in general very sudden. Like most mountain lakes, Tahoe is distinguished by the extreme transparency and exquisite color of its water.

Many glacial lakes of great beauty dot the summit region of the Sierra Nevada. The largest are found at the foot of the steep eastern slope which descends from the water partings. Most prominent among them are Independence Lake and Donner Lake, each about 3 miles long and three-fourths of a mile wide. These lakes are in general not deep. Level meadows of alluvial soil mark the site of many former lakes, which have been drained by silting or by corrasion of their outlets; such are, for instance, Twin Valley and the meadows of Little Truckee River to the east of Webber Lake.

Vegetation, climate, and culture.—The forest zone of the western slope of the Sierra Nevada, which lies between the elevations of 2500 and 6000 feet, is represented to only a small extent in this quadrangle. In the southwest corner excellent timber is found for a distance of about 6 miles above French Meadows along the Middle Fork of American River, and the gently sloping ridges between the Rubicon and the Middle Fork also carry an abundant growth of fine timber. The species most frequently represented are the yellow pine (*Pinus ponderosa*) and sugar pine (*Pinus lambertiana*). The summit region of the Sierra Nevada is here, as everywhere, only scantily covered with timber, among which different kinds of fir and tamarack of no great value prevail. Large areas in this belt are entirely barren, all the soil having been swept away by the action of the Pleistocene ice sheet which once covered the region. The granitic rocks, as well as the slates and schists, are in general destitute of forest, while the andesite and breccia in the glaciated areas, on account of their crumbling nature, are more apt to support a growth of timber.

Distribution of forested areas.

A very valuable forest area covers the ridges of Truckee Valley and the slopes of the lower Truckee Canyon, and connects along the upper Truckee Canyon and across the Mount Pluto ridge with the forest zone fringing Lake Tahoe. In this area the yellow pine is most abundantly represented. The sloping prairies of Prosser Creek and Martis Valley are unforested.

Owing to the moderating influence of the Pacific Ocean the climate is not so severe as the altitudes would lead one to suspect. Moreover, it varies greatly in the different topographic divisions. On the whole it is characterized by dry, warm summers, with occasional thunder showers and by a heavy snowfall during the winter. Over the western slope of the Sierra Nevada the temperature at an elevation of 7500 feet may reach 90° F. during the summer, while during the winter the thermometer very rarely falls below 0° F. or −18° C. On the other hand, frosts frequently occur during the summer at elevations above 6500 feet.

Climatic conditions.

The annual precipitation is very high over the western slope of the mountains, ranging from a maximum of about 57 inches at an elevation of 6000 feet to 48 inches at 7400 feet. A large proportion of this is snow, which near the summits may accumulate to a depth of 20 feet on the level. In Truckee Valley the winter temperature is more severe, the records showing a minimum of −25° F. or −32° C. The precipitation during the winter is much smaller, the snow rarely falling to greater depths than 4 or 5 feet at Truckee. Near Lake Tahoe the climate is intermediate between the two types referred to, as the influence of the large body of water produces an equalizing effect. The lake has never been known to freeze over.

The only towns are Truckee, with a population of 1400, and Boca, with 260 inhabitants. The permanent population is chiefly concentrated in the vicinity of Truckee and at other points along the railroad. Only a few people remain during the winter at the different road stations and summer hotels about Lake Tahoe. During the summer, however, the region is populated by tourists and by cattlemen and sheepmen, who pasture their herds and bands on the mountain meadows.

Settlements and resources.

The principal industries are cattle raising and timber cutting, the latter industry being centered in the vicinity of Truckee. Another important industry is the cutting of ice in numerous ponds constructed for that purpose in the vicinity of Prosser and Boca.

The main line of the Central Pacific Railroad crosses the quadrangle, following the South Fork of Yuba River up to Donner Pass, and thence descending in winding curves to the level of Truckee Valley. Continuous snow-sheds protect the road from Emigrant Gap, in the Colfax quadrangle, to Cold Creek, a few miles west of Truckee. From Truckee the railroad follows the canyon of the river out to the flood plains at Reno. Three chief transmontane wagon roads traverse the quadrangle. One, the so-called Henness Pass road, crosses the mountains along the northern border; the second follows the railroad as far as Truckee; the third, extending along the southern boundary, connects Georgetown, Eldorado County, with McKinney on Lake Tahoe.

The abundant water supply on the western slope is utilized and stored, especially at the headwaters of the South Fork of Yuba River. Meadow Lake, Fordyce Lake, and the Cascade Lakes have been artificially dammed, and constitute some of the most important reservoirs of the South Yuba Water Company. The main ditches, however, take their water from the river lower down, in the Colfax quadrangle. The North and Middle forks of American River are not at present utilized for water supply, although a ditch has been constructed from the Middle Fork at French Meadows to carry water down on the Long Canyon divide in the adjacent area. Gerlé Creek, along the southern boundary of the quadrangle, is utilized by the Georgetown Water Company, and Pleasant Lake, connecting with Loon Lake, forms one of the reservoirs. Truckee River carries a large volume of water (from 500 second-feet at low water to 7000 second-feet at high water), which is extensively distributed in the vicinity of Verdi and Reno for irrigating purposes. In Truckee Valley, however, the climate is considered too severe for successful agriculture. A number of reservoirs might be constructed at the headwaters of the western tributaries of Truckee River.

GEOLOGY.

BED-ROCK SERIES.

Under this general heading are included all of the older rocks of the Sierra Nevada, consisting of sedimentary rocks deposited during or before the Juratrias period, together with eruptive and intrusive igneous rocks, which mostly date from the Juratrias period, or possibly in part from the early Cretaceous. None of the igneous rocks belonging to the Bed-rock series in this quadrangle are younger than the early Cretaceous, and there are probably none which are older than the Juratrias.

The fossil evidence of age is very scant in the sedimentary rocks, but it is believed that enough has been adduced to justify their division into an older, Carboniferous group and a younger group of Juratrias age. To a considerable extent this division is based on comparison with or extension of formations of approximately known age in adjoining areas.

Origin and age of the older rocks.

The sedimentary rocks consist of clay slates, quartzitic sandstone, and some limestone, metamorphosed near the granite contact to schist and quartzites. All are greatly disturbed and most of them have been strongly compressed.

The igneous rocks consist partly of a diabase-porphyrite, accompanied by tuffs, and certainly of Juratrias age; partly, and predominantly, of granitic and dioritic rocks, all of which are probably somewhat later than the Juratrias sediments.

CARBONIFEROUS PERIOD.

Calaveras formation.—Within this quadrangle the rocks referred to the Calaveras formation (Cc) occur only in the drainage basin of Duncan Creek, a tributary to the Middle Fork of American River, but the area extends far into the adjoining Colfax quadrangle. The beds consist of dark quartzites and clay slates to which weathering soon imparts a gray color. They have a northwesterly to westerly strike and a steep northerly dip. As far as can be determined, the schistosity approximately follows the stratification planes; better exposures on the adjoining quadrangle show, however, that this does not always hold good. The large mass of Duncan Peak is composed of a dark-gray or light-gray, very fine-grained, nearly massive, siliceous rock of a chert-like appearance, which may have been derived from limestones by metasomatic replacement. Toward the eastern base of Duncan Peak these fine-grained quartzitic rocks are interstratified with clay slates. Still farther east the clay slates predominate. The age of these rocks has been determined as probably Carboniferous, from a few imperfect fossils found near the mouth of Sailor Canyon, in the northward continuation of the formation, where it adjoins the Sailor Canyon beds, which are of Juratrias age.

The oldest sedimentary rocks, Carboniferous.

The sedimentary rocks bordering against the granite and granodiorite show extremely irregular contact lines, whose jagged forms indicate actual tearing asunder and shattering by the intrusion of granitic magma. While the sedimentary rocks in general can not be said to be extremely metamorphosed, the action of the granitic magma has produced an intense metamorphism along the contacts. The effect has been to alter the beds to schistose, micaceous rocks, sometimes resembling gneiss and often containing andalusite. This contact-metamorphic zone is of varying width, as apparently certain rocks are less susceptible to metamorphism than others. On an average its width may be said to be less than a mile, but it is not uncommon, especially in smaller isolated areas in the granite, to find highly metamorphosed rocks at a greater distance than this from the contact.

The effects of granitic intrusions.

Sailor Canyon formation.—Of special interest among the sedimentary rocks of this quadrangle is the Sailor Canyon formation (Js). It is the only fossiliferous horizon thus far found, the imperfectly preserved remains of ammonites and other shells found indicating that the beds are of Juratrias age.

The Sailor Canyon beds lie partly in the Colfax, partly in the Truckee quadrangle, and are well exposed along the North Fork of American River, as well as in Sailor Canyon. The rocks consist of dark-gray or black calcareous slates, without pronounced fissility, interbedded with subordinate strata of quartzite and limestone. Near the diabase-porphyrite tuffaceous rocks occur, tending to show that the eruption of the igneous mass was approximately contemporaneous with the deposition of the beds. The reddish or brownish color of the outcrops and the lines of stratification are well shown in the rocky bluffs forming the western part of Snow Mountain. The strike of the series is about N. 30° W., and the dip is from 50° to 70°, constantly toward the east. The schistosity is far less strongly marked in this series than in the older sediments to the west of Sailor Canyon. If the beds really form one uninterrupted series, their total thickness between the Paleozoic limestone of Big Granite Canyon (Colfax quadrangle) and the diabase of Snow Mountain must be approximately 6000 feet. But the formation has not been studied in sufficient detail to assert that such a continuity exists. One of the principal fossil localities is near Sterrett's mine, on the western side of Sailor Canyon, just over the line, in the Colfax quadrangle. Many poorly preserved ammonites and shells of Daonella were found here. At the mouth of New York Canyon, a short distance west of the boundary line, the beds contain Monotis shells. A third fossil locality is opposite the mouth of Big

The Juratrias calcareous slates, fossiliferous.

Canyon, the first large stream entering the North Fork from the south. At this place specimens of ammonites were found just below the tuffs of the western edge of Snow Mountain. The fossils are thought to indicate beyond doubt a Juratrias age, although more perfect remains than any yet found will be required for an exact correlation with any of the subdivisions of that period. It is probable, however, that the time of the deposition of the beds ranges between the upper Trias and the lower Jura.

Toward the northwest, in the Colfax quadrangle, the Sailor Canyon beds are cut off by granodiorite and are strongly metamorphosed. Toward the south a sudden bend of the Calaveras formation throws the Juratrias beds eastward, and below the andesite ridge forming the divide between the North and the Middle forks of American River they are again cut off by later intrusions of granodiorite. While there is no positive proof of an unconformity between the Juratrias and the Calaveras formations, still it is very probable, from facts explained in the text of the Colfax folio, that such an unconformity does exist.

JURATRIAS PERIOD (?)

Isolated areas in granite.

Besides the well-established Juratrias beds adjoining the Calaveras formation, there are a number of areas of generally altered sedimentary rocks (**sl** and **slm**) almost or wholly embedded in the prevailing granitic rocks. These areas extend in a northerly direction from Rubicon River to Webber Lake, and probably at one time formed a continuous series, with a general northerly strike. The great intrusion of the granitic rocks during late Mesozoic time shattered this already folded series and left it represented only by torn fragments. The general character of the series is siliceous; it consists chiefly of quartzitic sandstones, clay slates, and fine-grained banded siliceous rocks. Limestone occurs northeast of Fordyce Lake and near the head of Five Lakes Creek. The color of the rocks when fresh is gray to black, but they weather almost invariably to dark-brown or reddish color, thus making the outcrops very conspicuous, contrasting against the gray granitic rocks. The heat and the emanations of the granitic rocks at the time of their intrusion have near the contacts more or less extensively metamorphosed the sedimentary rocks to hornfels, quartzites, and knotty schists. The width of this contact metamorphic zone is very variable, slate, for instance, being much more easily changed than the quartzitic sandstones. Especially in small areas the metamorphic zone is wide, evidence of the changing action being found 2 or even 3 miles from the granite contact. Dikes of granite-porphyry and diorite-porphyrite are very common near the granite contacts.

These areas have been tentatively referred to the Juratrias, the reason being the often striking resemblance of the rock to the Sailor Canyon beds and the fact that in contrast to the Carboniferous series (Calaveras formation) the compression which the rocks have undergone is often relatively slight. On this account the dip and strike of the stratification are easier to determine, and the dips may in general be said to be less steep than those usually found in the sedimentary rocks lower down on the western slope of the range. Still they are, as there, prevailingly to the east. It is difficult without more detailed work to obtain satisfactory results in regard to the stratigraphic structure. The beds have probably been closely folded, and the folds in part overturned, as schematically shown on the structure-section sheet. To complete the description a brief review of the characteristics of the separate areas may be given.

The two long-drawn masses at the southern boundary, in the vicinity of McKinstry Peak, are in larger part extremely metamorphosed and converted to a dark-brown micaceous rock of finer or coarser grain. Somewhat less altered rocks—light-colored quartzites and black clay slates—are found about a mile west of Wentworth Springs. The structure in these small areas is very confused and can rarely be satisfactorily made out.

North of these masses appears a large mass of sedimentary rock, with extremely irregular outline, partly buried under andesite flows (**Na**). It is surrounded by granite, except on the western side, where a belt of diabase-porphyrite separates it from the Sailor Canyon formation. Except near the contacts the metamorphism is not extreme, and the true stratification can in many places be ascertained without difficulty.

Along the North Fork of American River below Soda Springs, black clay slates alternate with siliceous, fine-grained rocks and quartzites. On the Middle Fork of American River the bold, rocky outcrops have a dark-brown to black color, and the stratification may be plainly seen from a distance. These rocks are black quartzitic slates, alternating with finer-grained and fissile clay slates.

South of Greyhorse Valley the sedimentary rocks consist of banded quartzites alternating with dark slates in narrow ribbons. Similar are the rocks exposed in the canyon of the Rubicon and along the lower part of Five Lakes Creek. The above-mentioned black quartzites and slates of the Middle Fork of American River crop out again in the northern part of Five Lakes Creek. Some of these rocks, though at a distance of 2 or even 3 miles from the granite contact, are strongly metamorphosed to hornfels and knotty schists.

The rocks of the northeastern part of this sedimentary area, excellently exposed in the vicinity of Ward Peak, consist of beautifully banded red and gray quartzites, with some clay slates. In places this series contains limestone, and a ledge of highly crystalline marble crops out on the trail from Scotts Springs to Five Lakes Creek, near the bed of the latter.

The isolated sedimentary area at Soda Springs is extremely metamorphosed by the surrounding granodiorite, and contains numerous masses and dikes of granodiorite. The area consists, as usual, of banded quartzitic rocks and clay slates, the latter becoming strongly micaceous near the contact. Garnet and pyroxene rocks are common and indicate that the series contains much lime. A few small streaks of slate are embedded in the granodiorite southwest of Soda Springs.

The small area inclosed by volcanic rocks near Barker Peak consists of clay slates and quartzites, with an abnormal east-west strike and a dip to the south ranging from 38° to 60°. It does not appear much metamorphosed at the contacts. The small area near McKinney consists chiefly of quartzitic rocks in dark-brown, prominent outcrops.

In the northwestern corner of the quadrangle appears, imperfectly exposed by the erosion of the superjacent volcanic masses, a series of schists and slates which are supposed to form the continuation of the Juratrias rocks of Sailor Canyon or of the isolated bodies to the east of Sailor Canyon. Toward the northwest the series is continuous as far as Sierra Buttes, at which place Mesozoic fossils are said to have been found. It is not improbable that this series is the equivalent of the rocks called the Milton formation, which occur in the Downieville quadrangle. Masses of diabase and diabase-porphyrite are intercalated in the slates, and tuffaceous rocks are of frequent occurrence. The exposures northeast of Fordyce Lake consist generally of siliceous micaceous schists, strongly metamorphosed, appearing as gneissoid rocks close to the contact. On the road from Meadow Lake to Webber Lake, near the diabase, there appear greenish or reddish peculiar rocks, strongly metamorphosed, and now largely made up of pyroxene. They are supposed to be metamorphic forms of limestone, though the distance from the granite contact in this case can not be less than 2 miles.

To the west of Mount Lola the sedimentary rocks reach an elevation of 8300 feet. The eastern part consists of gray quartzites and black clay slates, while on the west, near the diabase contact, greenish, banded rocks appear, which probably are diabase tuffs.

Occurrences of igneous rocks older than the granites.

Diabase-porphyrite.—Diabase-porphyrite is an igneous rock consisting largely of augite and a basic soda-lime feldspar, combining porphyritic structure with comparatively coarse grain. In this quadrangle considerable masses of this rock occur, usually in close connection with the Juratrias beds. In most cases these masses should be regarded as effusive rocks—old lava flows—poured out from volcanoes existing during the Juratrias period. This view is strengthened by the fact that tuff or stratified fragmentary igneous rocks occasionally connect the normal diabase-porphyrite with the purely sedimentary series. Some of the diabase-porphyrite may, however, represent intrusions, solidified at comparatively slight depth. The contacts of diabase-porphyrite with the granitic rocks show that the latter are the younger.

For those interested in the petrographic details the following brief notes on the separate areas are given:

The areas south and west of Webber Lake consist of a dark-green rock filled with epidote and other secondary minerals. On the east, near the contact with the sedimentary rocks, banded tuffs appear.

The small wedge-shaped area extending from Meadow Lake to Fordyce Lake consists chiefly of uralite-diabase. Diabasic rocks consisting of augite, plagioclase, and brown mica occur at the northern end of Fordyce Lake.

The area included in the Juratrias slates south of Webber Lake is generally a diabase-porphyrite, and appears as a dark-green, dense rock with smaller crystals of uralite and epidote. Many secondary minerals, such as epidote and brown mica, are developed in this rock.

The largest area of diabase-porphyrite is that extending from Granite Creek across the North Fork of American River, forming a belt from 1 to 3 miles wide, bordered on the east and west by sedimentary rocks. It makes up the large, flat-topped mass of Snow Mountain, and the river, cutting through it, has produced one of the deepest gorges in the Sierra Nevada. The area is characterized by dark-gray, rough outcrops, strikingly different from the light-gray granodiorite and the dark-brown sedimentary rocks. The diabase-porphyrite is hard and massive, dark grayish-green in color, and contains small porphyritic crystals of augite and feldspar. Grains of pyrite frequently occur in it. Under the microscope the rock appears as a normal diabase-porphyrite. Secondary changes have frequently altered the rock considerably. Schistosity and accompanying conversion to amphibolitic schists appear at the northern end, along the contact with the granodiorite. The strike of the vertical schistosity is parallel with the contact. Again, where the belt crosses the Middle Fork of American River an imperfect schistosity has developed, the strike of which is N. 53 W.

In the extreme northeastern corner of the Truckee quadrangle appears a small area of dark-green, fine-grained diabase, massive but highly altered by the development of secondary minerals. In places there is evidence of pressure, shown by the drawn-out form of the minerals. In the Sierraville quadrangle, adjoining to the north, this diabase occupies a considerable area.

General character of the granitic rocks.

Granodiorite, diorite, and granite.—The granitic rocks occupy a large space in the Truckee quadrangle, but are confined chiefly to the western or main range of the Sierra Nevada. The areas form the northward continuation of the great southern granitic mass of the Sierra Nevada. This granular igneous rock, the most recent member of the Bed-rock series, shows by its relations to the sedimentary rocks that it is of intrusive origin, or, in other words, that it was pressed into the torn sedimentary rocks as a molten, more or less perfectly fluid mass by forces the magnitude of which we can hardly understand, and consolidated far below the former surface of the range. These masses are now exposed through the agency of erosion by the removal of the covering rock masses. The prevailing rock is granodiorite, intermediate in composition between diorite and granite, but in it are contained irregular masses of more basic rock—diorite—or more acid rock—granite.

These areas have not been separated from the prevailing granodiorite in mapping the rocks, but their occurrence is indicated briefly in another paragraph. The normal granodiorite is a light-gray rock, weathering into rounded outcrops and easily disintegrated by erosion. The form of the outcrops and their brilliant light color are especially marked in the glaciated region. The granodiorite is a medium- to coarse-grained rock, the average diameter of the grains being 2 to 3 millimeters. The grayish quartz and white feldspar grains are of about equal size. Black mica and hornblende are usually present in about equal quantities. The foils of the former reach 2 to 3 millimeters in diameter, while the hornblende is roughly prismatic, the crystals sometimes reaching 1 centimeter in length. Titanite is nearly always present, in isolated, small, brownish grains. Magnetite is another universal accessory constituent. The appearance and composition of the rock are very constant over large areas, with only small variations in the quantity of hornblende and biotite.

Enumeration of granite masses and description.

The small area west of Webber Lake is a normal granodiorite. Along the contact from the eastern end of Fordyce Lake up to White Rock Lake there is a small development of granitite. The rock is indicated by a slightly yellowish color of the outcrops, and contains large, prominent grains of orthoclase and biotite, but no hornblende is present. Due south of Webber Lake there occurs, inclosed by diabase, a small area of granite-porphyry, a white porphyritic rock containing larger grains of quartz. The upper basin of North Creek, as well as the basin of the South Fork of Yuba River, is eroded chiefly in normal granodiorite. This mass extends down to Donner Lake, Euers Valley, and Twin Valley, until the eastern andesitic contact is reached.

The two smaller areas inclosed in slate and diabase to the west of Lola Peak are composed of normal granodiorite. At the head of Independence Lake and from there up to the divide, the granitic rock contains many inclusions of darker dioritic material. Immediately south of White Rock Lake the above-mentioned normal granite appears in smaller masses. In the vicinity of Donner Pass and at the head of Cold Creek the rock is a granodiorite of grayish color, somewhat more basic than the normal rock. A specimen from near Donner Pass contains 59½ per cent of silica, 6½ per cent of lime, 2¼ per cent of potash, and 3½ per cent of soda. This rock is more closely related to the normal diorite than to the granodiorite.

In the basin of Palisade Creek and to the west of Devil Peak the granodiorite is chiefly normal, though a rock collected half a mile west of Devil Peak somewhat approaches a granitite in appearance and composition. Near the slate area of Soda Springs porphyritic modifications of granite and granodiorite appear, and similar rocks form dikes within the slates. At the head of Squaw Creek and Bear Creek appears a reddish, crumbling granite, which is separated from the granodiorite adjoining to the west by a comparatively sharp contact, and which is composed of large grains of quartz, microcline, and a little plagioclase. The quantity of hornblende and biotite present is small.

The granodiorite of the Middle Fork of American River and of the Rubicon basin is, as a rule, a rock of normal composition, but extending from a point a short distance west of Rubicon Springs beyond the divide separating the Rubicon from Lake Tahoe there is an area in which the granodiorite is decidedly darker in color and more basic in character than usual. This area, similar to the one near Donner Pass, is in places fairly sharply separated from the normal granodiorite, while at other places it changes into that rock by imperceptible transitions. About the headwaters of Meeks Creek the rock is again of normal composition.

The granodiorite of the range rising on the eastern side of Lake Tahoe is largely covered by enormous masses of andesite. Near Hot Springs and State Line Point normal granodiorite appears, but the outcrop along Truckee River in the northeast corner of the quadrangle shows a different type. The rock here is a coarse-grained, dark-gray biotite-granite, distinguished by large, reddish orthoclase crystals. Small foils of black mica occur. The quartz in the rock is not prominent. This porphyritic granite is not known elsewhere in the Truckee or Pyramid Peak quadrangles, but is found in large masses in the southeast corner of the Markleeville quadrangle and along the crest of the Sierra to the south of that area. The granite in Truckee Canyon is soft, decomposed, and crumbling, with yellowish outcrops. It is also very much crushed and fractured, as may be seen a mile north of the bridge, where it contains dikes of andesite. The rock of Granite Peak and its slopes also crumbles to a coarse sand, but contains a great quantity of hard, white residuary bowlders.

Gabbro.—Rocks of a gabbroitic character do not occur abundantly, and are in fact found in only two localities. They are dark-green, very coarse rocks, composed of gray feldspar and dark-green pyroxene, often altered to uralite. A small area of gabbro occurs about a mile west of Anderson Peak, in the glacial amphitheater, where it adjoins metamorphic schists. Another and larger area, about 3 miles in diameter, and connected with the granodiorite by gradual transitions, occurs in Rubicon Canyon west of McKinstry Peak. On the east it adjoins the metamorphosed sediments. This rock also contains some biotite and appears to be an intermediate type between diorite and gabbro.

SEQUENCE OF ROCKS AND STRUCTURAL FEATURES.

Summary of relations of rock masses of the Bed-rock series.

The oldest rocks in the Truckee quadrangle are in all probability Carboniferous, and consist of the cherts, quartzites, and slates of the Calaveras formation. This sedimentary series was apparently folded and compressed before the Juratrias period. The compression was so intense that a series of isoclinal folds has been formed, generally slightly overturned toward the west. At the time of the compression a cleavage was superimposed upon this series, ordinarily, though not always, coinciding approximately with the bedding.

Next in age follows the Juratrias of the Sailor Canyon formation. The isolated areas in granite were probably also deposited during this period. Although greatly disturbed, these strata show evidence of much less compression than do those of the Calaveras formation. The cleavage is less pronounced, and the dips of the strata are, as a rule, at smaller angles than in the slate areas farther west. The detailed structure has not been made out, but it is believed that the diagrams on the structure-section sheet illustrate the true conditions — i. e., that the series forms folds less closely compressed than those of the Calaveras formation and somewhat overturned toward the west. From this general relation of the two formations it is believed that an unconformity exists between them, though of this there is no direct proof.

The deposition and folding of the Juratrias was followed by the great intrusion of the granitic rocks, all probably of late Juratrias or early Cretaceous age. By this intrusion the sedimentary rocks were fractured along extremely irregular lines; parts of them were torn away, and now lie in the granitic mass as detached fragments. An intense contact metamorphism affected both the Calaveras and the Sailor Canyon formations. The pressure of the intruding granodiorite did not produce extensive schistosity in the adjoining older rocks parallel to the contact. Locally it may have had such an effect, as seen, for instance, in the rough schistosity of the diabase-porphyrite along the contact southwest of Devil Peak and from the eastern end of Fordyce Lake eastward. It can not be said that the succession of the different granitic rocks has been definitely ascertained, but, judging from the disposition of the true granites along the sedimentary rocks, it seems probable that the granites preceded the granodiorite. The granitic rocks are not affected by schistosity.

The Bed-rock series is more or less affected by jointing, but in this quadrangle the jointing is nowhere so regular and intense as in the southern half of the Pyramid Peak quadrangle. The joints in the granodiorite are most prominent, and the following directions have been noted: Two miles south of Webber Lake, N. 70° E., dip 70° S; railroad bend 1 mile west of Cascade station, N. 40° E., dip 70° E.; eastern side of Castle Peak, N. 42° W., dip 60° E.

SUPERJACENT SERIES.

Under this heading are described the Neocene and Pleistocene sedimentary rocks and the lava flows, as well as the superficial accumulations due to the glaciation of the range.

NEOCENE PERIOD.

Gold-bearing gravels small in amount.

Auriferous gravels.—The gravels, which were deposited in the depressions or river channels of the western slope of the Sierra Nevada before it was covered by andesitic lava flows, are in this quadrangle only sparingly present, and do not form masses which can be separately indicated on the map. The heaviest gravels probably occur below the rhyolitic flows in the vicinity of French Meadows. Their existence has been shown by prospecting shafts, though they do not crop on the surface. Their thickness is not definitely known, but may exceed 50 feet.

General character and source of the rhyolitic lavas.

Rhyolite.—The period of volcanic activity began toward the end of the Neocene with extensive eruptions of rhyolite, a siliceous lava, which flowed down the valleys of the Neocene range but did not cover the whole slope. As Tertiary gravels are generally absent in this quadrangle, the rhyolite rests on the Bed-rock series, and is to great extent covered up by the succeeding eruptions of andesite. Erosion in post-Neocene time has cut through the covering masses of andesite and exposed the edges of rhyolite sheets at the base of andesitic ridges. Somewhat extensive areas of rhyolite occur on the western slope of the main range and indicate quite accurately the principal Neocene valleys.

The volcanic vents from which the lava streams of rhyolite flowed can not always be located with accuracy, as the masses were much eroded before they were buried beneath the succeeding andesitic eruptions. It is certain, however, that they are scattered along the main summit of the range, from which the flows extended westward.

Below the great andesite areas of the Truckee basin rhyolite may exist, but it is completely covered by these later flows. A small knob of rhyolite, probably marking a volcanic vent, occurs near the eastern boundary line, 3 miles north of Bronco.

The rhyolite of the Truckee quadrangle is a white, gray, or pink, fine-grained rock, somewhat porous and easily dressed with the hammer. It carries small sanidine and quartz crystals in a fine-grained, often streaky and glassy groundmass. Very rarely a little brown mica appears. In some places, as north of Soda Springs, and also toward the headwaters of Long Canyon, the rhyolite is tuffaceous, like clay or fine white sandstone in appearance. Bodies of gravel, so commonly found in the rhyolite farther down the slope, do not occur here. The rhyolite has a decided tendency to form bluffs and terraces, often with nearly perpendicular escarpments, as, for instance, near Summit station and on both sides of French Meadows. A coarse columnar structure may occasionally be observed. The thickness of the flows, which, as stated above, are confined to the river valleys of the Neocene period, does not exceed 1000 feet and is frequently much less.

Details of occurrence of the rhyolitic lavas.

The area near Webber Lake was overwhelmed by a great sheet of rhyolite, now largely covered by andesite and moraines. The thickness of this sheet does not exceed a few hundred feet. Outcrops of rhyolite are found all along the contact with the lower andesite flows to the southeast and west of Webber Lake. Especially fine are the outcrops in the canyon a mile below the outlet of the lake, where the columnar structure of the rock is prominent. Two miles east of Webber Lake the rhyolite begins to dip eastward, and disappears below the later accumulations in Little Truckee Valley. This rhyolite probably connects under the andesite with the flow which filled the deep valley extending from a mile north of Fordyce Lake in a northwesterly direction to Musgrove Valley and English Lake, the latter located in the adjoining Colfax quadrangle. A small knob of a rock allied to rhyolite, probably marking a former volcanic vent, is found surrounded by andesite on the summit of the ridge one-half mile southeast of White Rock Lake.

The heaviest rhyolite flow in this part of the Sierra Nevada extends from near Castle Peak down to Michigan Bluffs and Forest Hill, in the adjoining Colfax quadrangle. The old valley, which is filled with the lava, began near Castle Peak, extended thence to Summit Valley and across to Soda Springs, thence to French Meadows, under the western ridge, and to the headwaters of Long Canyon. The exact point where the flow originated is probably south of Castle Peak, where the rock is now traced to its highest occurrence. It undoubtedly crosses the creek 1½ miles northeast of Soda Springs station, although covered by débris, but can not there be much more than 100 feet thick. It widens rapidly at Donner, or Summit station, and increases in thickness to 400 feet or more; it extends below Summit Valley, and is exposed along the creek in several places; it filled the Neocene Soda Springs Valley to a depth of 1000 feet. This valley was evidently guarded by a narrow outlet, for south of the North Fork of American River the flow decreases rapidly in thickness to 500 feet. A nearly level sheet, now beautifully exposed and free from moraine, covered the Cascade basin. Near Cascade it is only 300 feet thick, but the thickness increases rapidly southeastward. On both sides this wide, troughlike valley was bordered by ridges 2000 feet high — on the west by the porphyrite mass of Snow Mountain, on the east by the granite of the main divide between Lincoln and Anderson peaks.

The great rhyolite flow of Summit Valley continues down in a south-southwesterly direction, and is exposed along the edges of the breccia ridges between the North and the Middle forks of American River. The rhyolite bluff, which is about 500 feet high, skirts the Middle Fork, and at Chalk Bluffs and French Meadows comes down to the river level. It is also finely exposed on Duncan Creek and around the headwaters of Sailor Canyon. At French Meadows it crosses the Middle Fork, and its steep bluffs surround the headwaters of Long Canyon.

A small rhyolite area is noted at the head of Cold Canyon, indicating an overflow from the Soda Springs rhyolite basin across the old divide. The only area farther south along the main range is the steep butte 3 miles north of Rubicon Springs. It has all the character of a volcanic neck, but no flows have been noted in connection with it. Small outcrops of a thin flow of rhyolite are found on the northwestern side of Greyhorse Valley and where the deep Neocene channel crosses Five Lakes Creek.

General character and source of andesitic lavas.

Andesite.—After a considerable interval, during which the rhyolite lavas were much eroded, the volcanoes along the Sierra Nevada poured out masses of a basic lava known as andesite. The extensive andesite areas in the Truckee quadrangle are composed partly of rock fragments embedded in volcanic mud, forming tuff breccia, partly of massive andesite. The former predominates along the summit and on the western slope of the main range, while the massive andesites are found chiefly in the Truckee basin and on the eastern range. A separation of the two kinds does not appear practicable.

The andesite is a rough and porous rock of dark-gray to dark-brown color. Porphyritic crystals of plagioclase are invariably present, as are also crystals of augite and hypersthene; hornblende is less abundant, but appears in many rocks as small, black, glistening needles. The groundmass in which these crystals are embedded has a structure varying from glassy to very fine-grained crystalline.

Biotite-andesites are of rare occurrence, while olivine sometimes enters into the composition of some pyroxene-andesites; the latter may occasionally merge into fine-grained varieties allied to basalts. The hornblende-andesites are mostly of a somewhat lighter color than the pure pyroxene-andesites; a light-gray is frequently noted.

The tuff breccias consist of angular fragments of andesite bound in a cement of finer andesitic detritus. Exceedingly little non-andesitic material is present; scattered granite bowlders may occur. Very rarely, as, for instance, on the ridge 2½ miles east of Devil Peak, there are small quantities of metamorphic, well-washed gravel intercalated in the tuffs.

The irregular fragments of andesite contained in the tuff breccia are of all sizes, from a diameter of several feet down to grains of minute dimensions. Within a small mass of breccia a great many varieties of andesite may be found, differing slightly in color, structure, and composition.

The exposures of tuff breccias often reveal a beautiful stratified structure, resulting from the superimposing of numerous flows slightly different in structure and appearance. Some of the areas, especially near the summits, show a more massive structure, and, becoming harder and more compact, merge imperceptibly into necks and smaller bodies of andesite. The latter commonly protrude sharply from the surrounding breccias. The andesitic ridges are dark gray or reddish gray, contrasting strongly with the light-gray granite on the dark-red slate; long gentle slopes covered by scattered vegetation alternate with precipitous walls strongly resembling fortifications. Excellent instances of this are found in Castle Peak, as seen from the Central Pacific Railroad, as well as in the vicinity of Mount Mildred and the high ridges near Twin Peaks. The andesitic rocks almost universally cap the ridges, and rest either on the Bed-rock series or on the rhyolite. It is evident that the andesitic masses once covered nearly continuously the whole summit region, possibly excepting the tops of Snow Mountain and Granite Peak and a small area adjoining the southern boundary, in which McKinstry Peak and Guide Peak form the culminating points. Subsequent erosion has removed at least two-thirds of these masses along the main range, while in the Truckee basin, where erosion has been less active, the underlying rocks are not yet exposed. The thickness of the andesitic flow is considerable, in places reaching 2000 feet. The depth of the lavas in the Truckee basin is probably not less than 1000 feet and may in places exceed 3000 feet.

Volcanoes which emitted andesite.

The volcanoes which ejected these enormous volcanic masses during the later part of the Neocene period were to large extent located along the crest line of the western range, while few of them, if any, were found lower down on the western slope. The principal foci of eruption were Mount Lola, Castle Peak, Mount Lincoln, Tinker Knob, Squaw Peak, Mount Mildred, Twin Peaks, and Mount Ellis. From each of these foci the lavas were extruded through a great number of vents. It is not often that these vents are satisfactorily exposed. One excellent example is, however, shown half a mile west of Scotts Springs, the two small rounded areas marking two separate vents. Most of the vents were probably of the character shown at the locality mentioned — that is, small rounded or oblong orifices around which the granitic rocks were greatly shattered. Long dikes are conspicuously absent. Small and irregular dikes of andesite occur in the granite in several places on the eastern slope of Squaw Peak. Similar dikes, 1 to 2 feet wide, were noted in granite along the railroad in Truckee Canyon, 1½ miles from the point where the line reaches the eastern boundary of the quadrangle.

Another series of volcanoes extended along the eastern or Genoa Range, which between Truckee and Reno is almost flooded by volcanic masses. Other independent points of eruption were evidently located near Mount Pluto and probably also at other places north of Truckee. The ash cones and the craters have been swept away by erosion. All that is now visible is the interior structure — masses and necks of solid andesite irregularly traversing breccias and tuff breccias of varied appearance.

The evidence shows beyond doubt that the stratified tuff breccias which once covered the whole western slope nearly continuously were largely poured out as successive mud flows, though it may be conceded that volcanic ash showers may have added to their volume, especially near the summit. The equal distribution of large andesite fragments in the tuff breccia all over the slopes is one of the arguments tending to show the predominance of actual flows of mud. It is difficult to estimate the enormous explosive action which must have been necessary for the production of all these fragmentary rocks. Nor is it easy to understand whence the volume of water necessary to form the mud flow could have been derived.

Detailed description.

The andesitic masses about Webber Lake consist of tuff breccia, though in a few places smaller masses and flows of massive pyroxene-andesite appear. The volcanic masses near Mount Lola show excellently and typically the structure of the volcanoes along the crest of the Sierra. Tuff breccias, varying in appearance and stratified or massive in structure, are irregularly mixed with necks of massive pyroxene or hornblende-andesite.

A short distance below the summit, on the southern side, is a neck of gray hornblende-andesite showing exceptionally beautiful columnar structure. On the southern side of Mount Lola three massive flows slope gently eastward from the divide, while toward the west only tuff breccia appears. The larger part of the ridges to the northeast of Mount Lola consists of massive pyroxene-andesite. The long ridges between Independence and Donner lakes consist of breccia, with a great number of massive necks. A columnar, gray hornblende-andesite crops on the southern shore of Donner Lake. Castle Peak and the volcanic areas about the head of Rattlesnake Creek, north of Yuba River, consist chiefly of tuffaceous breccia, but in some places a massive black andesite, sometimes carrying olivine and closely related to basalt, appears below it. This basaltic andesite crops out at the head of Rattlesnake Creek at an elevation of 7000 feet, and appears again with columnar structure north of the Cascade Lakes on the projecting bluff known as the Porcupine. What is probably the same massive flow appears on the hill a mile east of Soda Springs station, where it rests on a thin mass of breccia and is covered by a flow of black basalt, probably of Pleistocene age. It occurs also at the bottom of the Neocene depression crossing Five Lakes Creek. On both sides of Mount Lincoln the stratified tuffaceous breccias are excellently exposed, and are in full view from the line of the Central Pacific Railroad. The long ridges between the North Fork and the Middle Fork of the American, and between the Middle Fork and Rubicon River, consist almost entirely of normal breccia. Only near the eastern end at the Needle and about Mount Mildred do massive necks and flows appear. The Needle is a prominent and extremely steep neck of olivine-augite-andesite.

The great volcanic center of Mount Mildred contains, besides much tuff breccia, some prominent massive flows, magnificently exposed in the glacial amphitheaters. A flow of gray pyroxene-andesite forms the long ridge extending south of Mount Mildred. Squaw Peak, with its many surrounding well-exposed necks, evidently forms the core of one of the Neocene volcanoes. It is composed largely of a gray, massive augite-andesite, but breccia appears on its northwestern side. The volcanic area between the main divide south of Mount Lincoln and Truckee River is made up very largely of massive andesite or of mixed masses of breccia and massive andesite. A prominent flow of columnar augite-andesite, ordinarily normal but sometimes appearing with almost basaltic habit, occupies the summit at the head of Deep Creek and Pole Creek and continues eastward as a gently sloping flow.

The extensive volcanic complex near Ward Peak and Mount Ellis is made up chiefly of breccia, but along the summit a great number of massive necks forming high projecting points appear. Its western end is occupied by a very prominent massive flow of augite-andesite, forming a level table. Barker Peak is a neck of fine-grained hornblende-andesite.

The ridges encircling the northern end of Lake Tahoe are composed partly of massive rock, partly of breccia. Mount Pluto and the ridges which radiate from it are made up of gray pyroxene-andesite. A sheet of coarse biotite-andesite crops out on the northwestern side of Mount Pluto at an elevation of 6800 feet. The same volcanic flow crops out opposite the mouth of Pole Creek, and a similar biotite-andesite occurs at the foot of the high basalt bluff a quarter of a mile west of Tahoe city. At the gap where the road from Hot Springs to Truckee crosses the divide, andesitic breccia prevails, but massive andesite appears farther east along the high peaks and ridges near the Nevada State line. The slope toward Hot Springs is largely built up of breccia. Most of the andesitic area along the eastern edge of the sheet is normal tuff breccia, and only the higher peaks and ridges consist of more resistant massive rock. The ridge east of Juniper Creek consists partly of massive andesites. West of Juniper Creek and adjoining the basalt area is a red, coarse, hornblende-biotite-andesite. The ridge between the Truckee and the Little Truckee is composed of yellowish-gray breccia, necks of massive andesite frequently appearing along the summit.

Thermal action on andesites.

In several places the andesite has been subjected to thermal alteration, due to the action of hot mineral waters on the rock. It is manifested in bleaching of the rock, accumulation of secondary silica, and impregnations of iron pyrite which carries a little gold and silver. Thermal zones of this kind occur along Truckee River opposite the mouth of Squaw Creek, and 2 miles northwest of the divide, on the road between Hot Springs and Truckee. A similar altered area was noted in Truckee Canyon 3 miles south-southeast of Crystal Peak and just south of the railroad bridge. An area of thermal alteration half a mile wide and 2 miles long here extends across the canyon, affecting not only the andesite on both sides, but also the small granite area surrounded by andesite marked on the map. The altered zone contains, besides some bleached and pyritic rocks, massive hornblende and hornblende-biotite-andesites, which have a more or less pronounced greenish color and decomposed aspect, recalling the appearance of older porpyhritic rocks. This is undoubtedly the result of thermal alteration.

Olivine-dolerite. — Intimately connected with the andesitic eruptions is a flow of a coarse rock which presents certain similarities in the field to an augite-andesite, but which upon closer examination proves to be an extremely coarse form of basaltic rock. This has provisionally been designated olivine-dolerite. Similar rocks have been found in the northern part of the Downieville quadrangle. The olivine-dolerite occupies an area bordered on the north by a line drawn somewhat north of the Little Truckee, on the south by Sage Hen Creek, and on the west by Independence Creek. It forms steep bluffs along the creeks and appears as a rough, brownish rock with very small feldspar crystals and larger augite crystals of greenish color. A similar dolerite occurs on the isolated hill a mile west of Boca.

Sedimentary beds deposited in lakes.

Neocene lake beds.—At the close of the epoch of volcanic activity which produced the andesites, Truckee Valley was occupied by a lake, into which sand and clay were washed from adjoining hills. In the vicinity of Truckee these deposits are mostly covered by subsequent (Pleistocene) lake beds and basaltic lavas, and only at Prosser House, near the road, may some of the sands and clays be seen under the covering wash. In Little Truckee Valley the lake beds are much better preserved. Two miles north of Boca they outcrop in a low bluff on the east side of the river and consist of yellowish sands and clays, the latter predominating, covered by a brilliantly white substance, which is probably a volcanic ash and which contains diatoms. Some of the lower clayey strata are dark and contain small seams of very impure lignite. The strata dip southward at an angle of 8 degrees. Unconformably above these strata lie Pleistocene gravels, which are probably fluviatile, spread by the present river.

The region about Dry Creek and the Little Truckee is occupied by these lake beds, covered by thin Pleistocene gravel wash; the low plateau is dissected by sharply cut gulches. Wherever the lake beds crop out they are usually distinguished by a brilliant white or yellowish color. The outcrop where the road to Verdi crosses Dry Creek contains, besides the clayey and sandy beds, several layers of coarser tuff. In Little Truckee Valley, a mile above Dry Creek, the lake beds crop out extensively; they all dip south or southwest 8 to 10 degrees, and are here almost exclusively andesitic tuff, but so distinctly stratified that they must have been deposited in water; they are very different from the coarse tuffaceous breccia of the higher ridges, and do not contain large bowlders of andesite.

One and a half miles and 2 miles northeast of Boca, at an elevation of 5800 feet, the lake beds — mostly white clays — crop out again below the basalt, thus proving that the basaltic flow is later. One mile southeast of Boca, on the Juniper Mill road, where it climbs up on the basaltic plateau, andesitic tuffaceous beds are found, dipping slightly southwest and overlain by basaltic tuff and massive basalt. The elevation here is about 5800 feet. Along the railroad one-third mile east of Boca there are some tuffaceous lake beds again, resting on andesite and covered by a basaltic sheet. Lake beds also crop in Stampede Valley, which probably formed a small detached basin.

Lake beds, which are probably of Neocene age and are very similar to those of the Truckee basin, occur near Verdi, where Truckee River debouches from its canyon into the flood plain at the foot of the eastern range. Small outcrops of them are found, covered by fluviatile material, in the extreme northeastern corner of the quadrangle. The beds consist of whitish or yellowish clays and lie nearly horizontal.

Surface of the Neocene range.

The topography in the Neocene period.—The voluminous lava flows of the Neocene period filled the older valleys and buried many heights. Since that time deep canyons have been cut, exposing the relations of the lavas to the older rocks. These relations have not been disturbed by faulting in Neocene or post-Neocene time, and the surface on which the lavas accumulated therefore remains unmodified except where streams flowing in the later canyons have removed some parts of it. The numerous contacts of the lavas with the older rocks define the old topography. By supposing the lavas removed and the later canyons filled up, we may restore the ancient hills and valleys. This applies chiefly to the western part of the quadrangle, for in the Truckee basin the Neocene eruptives completely conceal the old surface.

The Neocene surface was one of mountainous character. On the whole it sloped gradually westward from a summit line which practically coincided with the present water-parting, and more steeply to the east of this divide down to a level of about 6000 feet. Thence eastward the old slope is covered by andesite. The old divide has at present elevations of from 7000 to 8000 feet. The Neocene surface to the west of the divide appears to have been an irregular table-land, with few sharp peaks rising above it. In this table-land the water courses had cut valleys which were broad and deep, though not so sharply defined as the canyons of the present time. It is not an extremely steep slope, and it bears some evidence of having been modified by erosion to a considerable extent before the andesitic eruptions.

The Neocene valleys.

A strongly marked depression began in the vicinity of Fordyce dam and extended in a northwesterly direction. This was the headwaters of the Neocene Middle Fork of the Yuba. Another deep valley began a short distance south of Castle Peak and continued by Summit Valley and Onion Creek across to the present ridge between the North and Middle forks of the American, and thence down by French Meadows toward the head of Long Canyon. This extremely definite canyon was the headwaters of the Neocene North Fork of American River. In a section from Snow Mountain to Granite Chief the bed rock may be seen to rise within short distances 2000 feet westward and 3000 feet eastward above the old channel. A short tributary to this Neocene stream came from the vicinity of Sailor Canyon, flowing in an easterly direction, between the high hills of Duncan Peak and Snow Mountain. Another important tributary headed near Barker Pass and crossed Five Lakes Creek. Its abrupt character is apparent. From Five Lakes Creek this channel was evidently followed by the volcanic flow down toward Greyhorse Valley to the head of Long Canyon. The flat summit of McKinstry Peak formed a prominent feature in the Neocene landscape.

The escarpment of the main range eastward is well marked from Independence Lake southward, and the conclusion can not be avoided that it existed before the Neocene eruptions. Nothing definite is known of the configuration of the older rocks below the lavas of the Truckee basin. Good reasons exist, however, for believing that they cover a deep Neocene Valley which extended continuously from Lake Tahoe up to Sierra Valley.

The high and narrow Carson Range rises east of Lake Tahoe and continues northward, forming the eastern barrier of Truckee Valley. This range also existed in Neocene times, though the part of it which falls within this quadrangle has been greatly increased in width and height by masses of lava poured out over its flanks. The old granitic core may be seen near Crystal Peak and has been exposed in Truckee Canyon by erosion of the volcanic flows. The contact lines of granite and lava show that a low gap with a present elevation of 6500 feet existed in this range to the southeast of Crystal Peak. Again a part of the granitic core is shown near Hot Springs on Lake Tahoe, the contact line against the lavas rising rapidly eastward.

Fault lines.—No evidence of important faulting is found on the western slope of the Sierra Nevada in this quadrangle. The eastern scarp, on the other hand, is the result of an important fault along a line following its base; but no important dislocation has occurred along it since the lavas were poured out, and it probably antedates the Neocene period.

Fault lines of the Sierra Nevada.

A similar fault line follows the western base of the Carson Range, although covering lavas mask its presence to great extent in this quadrangle. It is possible that in recent times slight movement may have occurred along this fault, as indicated in the description of the Pleistocene period.

A third fault line follows the eastern base of the Carson Range and enters this quadrangle only in the extreme northeastern corner. Along this line there have been several recurring movements. The first movement antedates the Neocene; the second dates from the Neocene volcanic epoch; the third and smallest dislocation has occurred during recent times. But these movements have not taken place equally along the line, and in this quadrangle no strong evidence appears of extensive post-volcanic faulting along the eastern base of the Carson Range.

PLEISTOCENE PERIOD.

Definition and extent.

The Pleistocene period, which is elsewhere defined by that change of climate which caused the development of widespread ice sheets, is here assumed to have begun soon after the andesite eruptions ceased. It might be called the post-andesite period. It comprises two epochs, an earlier one, during which most of the principal canyons that now score the surface were eroded and active volcanoes produced numerous flows of basalt, and a later one, characterized by the growth and disappearance of glaciers on the range.

The epoch of erosion.

The earlier epoch.—In consequence of the andesite lava flows which had filled the former valleys, the streams sought new channels with the beginning of Pleistocene time. They rapidly eroded canyons in the steep slopes and established the principal features of the present river systems. The gravel, sand, and mud which they swept downward form deposits in the Great Valley of California. While the canyons were being thus carved additional eruptions occurred from volcanoes along the Sierra. The lava differed mineralogically, however, from the andesite lavas, and is of the black fine-grained kind called basalt. The following is an account of its occurrence.

Basaltic eruptions.

Along the main range, and also in Truckee Valley, are many large areas of basalt, the flows in places reaching a thickness of 600 feet. Their distribution indicates that they spread from many independent vents. The topography shows that considerable erosion has taken place since their eruption. The basalt is distinctly later than the andesite; on the other hand, abundant morainal material frequently covers the basalt, which was therefore erupted before the close of the Glacial epoch. Basaltic rocks rest on andesite in many small and scattered areas along the main range. Several such areas occur in the vicinity of Mount Lola, forming black outcrops of normal olivine-basalt, often with pronounced columnar structure. Another basaltic area caps the andesite 1 mile north of Summit Valley, and isolated outcrops of the same flow are found on the andesite ridge 1½ miles south-southwest of Castle Peak. A prominent basalt neck protruding through andesitic breccia forms the precipitous cliffs of Devil Peak. Small areas of basalt were noted south of Soda Springs and in the valley of the Middle Fork of American River. Remnants of a basaltic sheet, often with columnar structure, dot the southern slope of McKinstry Peak. The occurrences are grouped in such a manner as to show that the center of eruption must have been near the highest point of the peak. The topography of the surrounding country has evidently not been greatly modified since the eruption, though the gulches have been cut considerably deeper.

The largest basalt flows are met with in Truckee Valley and along the north shore of Lake Tahoe. The area adjoining Tahoe city originated from a vent located high up on the andesitic ridge overlooking Truckee River. The surface of the flow is extremely rough and rocky, and the basalt has a very vesicular character. As indicated by several flat tables and abrupt slopes there were probably several successive flows. Near the lake yellowish-gray basaltic tuffs are common. The bluff at Tahoe city and eastward is made up partly of basalt tuff, dipping 25° south, partly of sand and gravel. It is evident that this flow filled Truckee Canyon, previously cut in andesite, and dammed the lake to a height of at least 700 feet above the present level. Two minor flows occur along the shore between Tahoe city and Hot Springs. The rock in these contains but little olivine, and in places is a typical hypersthene-basalt.

Smaller remnants of basaltic flows occur in Ward and Blackwood creeks. The great basalt flow around the town of Truckee is composed of black, dense olivine-basalt, and had probably several vents of eruption on a line from north to south. It is clear that here again the previously excavated Truckee Canyon was dammed to a considerable height during the eruption, probably, however, not to exceed 300 feet. This flow filled a large part of Truckee Valley and extended eastward. Basaltic tuff overlain by massive basalt is exposed along the railroad 1 mile east of Truckee.

Equally extensive flows are those north and south of Boca. The northern part of the flow appears to have originated 2 miles northwest of Bronco. Still another focus was located on Juniper Creek, and from this the whole eastern side of Martis Valley was flooded. The rock in this flow is of a glassy character, containing but little olivine, instead of which hypersthene often appears. These flows dammed Truckee River in a third place to an elevation of probably 6200 feet above the sea. Masses of yellowish-gray basaltic tuff in places, as for instance 1 mile southwest of Boca, accompany the massive rocks. An extensive eruption of normal olivine-basalt occurred at the same time near the summit of the range to the east of Truckee Canyon, in the adjoining Carson quadrangle. Branches of this flow found their way down the ravines into Truckee Canyon as veritable cascades of molten rock. These can be excellently seen from a high point opposite, such as Crystal Peak, the basalt contrasting with its brownish color against the dark-gray andesite.

Extent and results of glaciation.

The later or Glacial epoch.—The later epoch of the Pleistocene period was characterized by extensive glaciation, during which fully one-half of the quadrangle was continually covered by ice and snow. Finally the glaciers receded, giving to the region its present aspect. Even the smallest remnants of actual glaciers have now disappeared. Small patches of snow remain during the summer at elevations above 8000 feet.

The glaciated region includes practically the whole area west of a line drawn along the shore of Lake Tahoe to Tahoe city, thence along the river to Truckee, thence to a point at longitude 120° 18′ along the northern boundary. Nearly the whole of this area was once covered by vast névé fields, above which only the highest volcanic peaks protruded and beyond the edges of which glacier tongues projected in every valley. The eastern part of the quadrangle evidently received a less amount of precipitation. Though it contained many névé fields, few if any real glaciers seem to have existed in this area.

Moraines.

By the continuous and slow downward movement of the ice to the melting-line, enormous masses of loose débris were swept down from the summits and accumulated as morainal heaps and ridges, chiefly along the edge of the ice sheet. While smaller débris heaps may be found at higher elevations, the great moraines lie at elevations ranging from 5000 to 7000 feet. Above this extend vast stretches of bare rock surfaces, dazzling white smooth outcrops of granodiorite, and reddish-brown slate areas. The glaciated ridges of andesite or andesitic breccia are in part bare, with sombre slopes which exhibit the flow structure; much of them is, however, covered by scattered vegetation. The rock surface is frequently smoothed and scratched and striated by rocks held firmly by the moving ice sheet.

The terminal moraines on the eastern slope cease at elevations of 5900 to 6500 feet. On the western slope they extend farther down, though it is often difficult to determine with accuracy how far down into the rocky canyons the ice tongues protruded; probably, however, they did not descend below an elevation of 4000 or 3500 feet.

The areas designated as moraines on the map include only the heavier deposits of the terminal, lateral, and ground moraines; scattered thin drift is not indicated. The moraines are composed of rough and angular, not waterworn bowlders of all sizes, admixed with finer detritus and sand. The topographic form of the valleys changes as soon as the lower limit of glaciation is reached. Below they are narrow and V-shaped; above, broader and U-shaped, often also characterized by stretches occupied by meadows, separated by rocky portions with steep grade. The long lateral moraines with their sloping straight ridge lines are often conspicuous; the best defined of these are on the eastern slope — near the mouth of Meeks Creek, for instance. Little lakes and meadows of glacial origin dot the landscape. Near the crest of the main range the canyons end in glacial cirques or amphitheaters, separated by sharp ridges (arêtes) leading up to rocky peaks. In the andesite the glacial sapping is especially marked, and the cirques in the volcanic complex of Twin Peak are perfect types of their kind. Though there are many evidences of oscillations of the lower limit of the ice sheet, due to slight climatic changes, and shown by parallel morainal ridges, no satisfactory proof has been brought out in favor of two distinct divisions of the Glacial epoch, separated by a time interval during which the climate was milder.

Detailed description.

The glacier of Webber Lake basin flowed down along the Little Truckee to a point at longitude 120° 18′; below this there are stream terraces, but no moraines. Extensive moraines cover the ridge north of the Little Truckee, while the highest parts of the ridges extending north from Mount Lola were above the level of the ice sheet. Large bowlders of rhyolite and granite may be found far down the river. They probably were transported by floating ice.

Very heavy moraines dam the lower end of Independence Lake. The moraine ends about 2½ miles below the outlet, and from there down to the Little Truckee there are remains of stream terraces only. Heavy moraines lie in the lower parts of Twin Valley and Euers Valley, down to 6100 feet above sea.

The glacier-worn basin of North Creek contains but a relatively small amount of glacial débris. In the valley of the South Fork of the Yuba there is considerable glacial débris on the south side of Summit Valley and from Soda Springs station down as far as Cascade. There the moraines cease abruptly, and down to below Cisco, in the Colfax quadrangle, the canyon is scoured out clean. A great morainal mass has been pushed over the low gap at the Icehouse Lakes, south of Soda Springs station, and looks very heavy from the road, where the rhyolite still may be seen in large outcrops, for about 1¼ mile westward. West of this the great rhyolite sheet lies almost entirely denuded of glacial débris.

While the upper part of the North Fork above Soda Springs is comparatively free from glacial débris, large masses of morainal material have been swept into Onion Creek and the tributaries on the opposite side. Very fine glacial striæ were noted at Soda Springs on the rocks above the hotel. Again, below Onion Creek the rock is bare all the way down through the Royal Gorge, but it is probable that the glacier filled the latter only partially; the sides are extremely rough and do not show glacial striæ. Tributary glaciers came down through lateral valleys. In Sailor Canyon, however, the glacier does not appear to have reached the river. The granite exposed at Palisade Creek is thoroughly glaciated from Devil Peak down to the river. It is doubtful how far down the North Fork the glacier projected. A small tongue possibly reached below the mouth of Sailor Canyon. There is no terminal moraine.

The Middle Fork of American River is also swept bare above the sharp bend south of Soda Springs, but below that, down to French Meadows, enormous masses of glacial detritus accumulated on both sides of the broad valley. From an elevation of 5900 feet there is, for 3 miles down, a very distinct terrace, through which the river has cut down 20 to 30 feet. The cut is with steep sides and is partly in moraine, partly in bed rock. The deposits of this terrace appear to represent a later part of the Glacial period, when the ice streams had retired to the upper valleys, leaving moraine-dammed lakes at their lower ends.

Below French Meadows the river makes a sudden bend to the southwest, and the character of the valley suddenly changes from a broad U-shape to a sharply incised canyon with steep grade. It might be assumed that the glacier ceased here but for the fact that abundant angular morainal material occurs high up on the divide between Duncan Canyon and the Middle Fork, and on the divide between Chipmunk Creek and the Middle Fork. Immediately below French Meadows the ice must have reached up to an elevation of 6000 feet; above this the andesite appears free from glacial drift. How far the glacier tongue extended down the river can not be decided. Even high up on the andesite point between Chipmunk Creek and Long Canyon, at an elevation of 5700 feet, there are bowlders of rhyolite and granite.

The head of Donner Creek is swept bare except for a small amount of glacial débris in a few gulches. The volcanic ridges on both sides of Donner Lake are also comparatively free from moraine. A heavy terminal moraine accompanied by smaller lateral moraines lies between Truckee and Donner Lake and has dammed the latter, although the basin was in the first place undoubtedly produced by the basaltic eruption.

Along Cold Creek there is but little morainal débris on the valley slopes. A rough bottom moraine covers the valley and connects immediately with the Donner Creek moraine. It is somewhat doubtful whether the Cold Canyon glacier connected with the Donner glacier. The point of the ridge between Truckee River and Cold Creek is covered by glacial detritus up to an elevation of 6300 feet.

Immediately at Truckee, lake beds and stream terraces join the moraines. The canyon of the Truckee River between Truckee and Lake Tahoe has evidently never been glaciated, though several glaciers from tributary creeks from the west nearly or quite reached the main river. At Pole Creek and at Deep Creek the glaciers hardly reached the river, or at least did not leave any large terminal moraines. Below Deep Creek there is a meadow, and from there down to Truckee remains of a terrace occur at intervals. About a mile from Truckee the glacial débris from Cold Creek begins. The upper part of Squaw Creek contains comparatively little morainal material, but it is evident that a glacier of considerable size once occupied the valley. Its terminal moraine, largely granitic, reached Truckee River and must have dammed it to a considerable height. The same end moraine also dammed Squaw Creek, and the Squaw Valley meadows were evidently a lake not long ago. Below the terminal moraine there is a long terrace 20 to 30 feet above the river, extending almost to Pole Creek. Bear Creek sent down a glacier as far as Truckee River, but with comparatively small moraines.

The glacier of Ward Creek extended nearly down to the lake. The south ridge is polished off and almost free from morainal accumulations, which seem to have been unloaded on the north ridge. This is largely composed of breccia, which was easily torn up by the ice. The whole slope, about 1½ miles wide, is covered with glacial débris and shows its origin by numerous meadows, marshes, and hummocks.

The Blackwood Creek glacier undoubtedly reached down as far as the basalt knob near its mouth, but it has not left any very prominent moraines. On the south side glacial débris is scattered up to an elevation of 200 or 300 feet. Among the débris very many granite bowlders are noted. No large granite areas exist in the valley — hence it would seem likely that the granite bowlders were carried across the range by the ice. Toward the head of the valley, above an elevation of 6500 feet, there is heavy bottom moraine composed of slate and volcanic rocks. A lake probably once covered the lower part of the valley; hence the character of the broad sloping bottom, which is quite level, with meadows alternating with sandy or gravelly stretches. The smaller gulches between Blackwood and McKinney, heading up near Mount Ellis, were possibly occupied by small glaciers.

The moraine which fills McKinney Creek and the creeks south of it is composed almost entirely of granite in very large bowlders, and forms broad ridges extending out into the lake. One-half mile north of McKinney the granitic moraine begins, and the contrast between it and the terrace of fine pebbles is quite marked. From McKinney for about 3 miles up along the creek the moraine covers everything, and no granite outcrops are seen below about 7000 feet. The lateral moraine between McKinney and General creeks is very typical, extending down as a long sloping ridge with straight back. At McKinney the moraine is modified by the 40-foot terrace; that is, the 40-foot stand of the lake was contemporaneous with or later than the moraine.

There can be no doubt that the great Rubicon glacier overflowed toward the lake through Rubicon Pass, which is very low (7150 feet). At the lakes on Rubicon Pass there is but little morainal matter, and the same is true of the hills surrounding the pass. But the granite basin of Miller Creek, and in fact the whole lower country between Miller Creek and Barker Creek, is covered with granitic moraine, so that it is often difficult to tell whether there is rock in place or not. There is certainly much rock in place on the broad ridge between Cothrin Cove and Miller Creek. Assuming a connected ice sheet between McKinney Creek and the Rubicon, a great deal of débris would naturally have been swept into the sag between Miller and Barker creeks.

General Creek had a much smaller glacier, the terminal moraine of which may be found about 3 miles above the place where Bellevue Hotel formerly stood. The ridge north of General Creek is, as mentioned before, entirely morainal up to the higher points; the south ridge has granite in place nearly all along its slope; the glaciated granite of the upper part is clearly outlined and contrasts with the non-glacial part below the terminal moraine. The top of the same ridge has, however, been covered by a lateral moraine of the Meeks Creek glacier, and presents a long, sloping, straight profile line. The bottom of the valley below the terminal moraine is a gently sloping terrace about one-fourth mile wide and composed of gravel and sand; this continues down to the lake, widening and forming a great ill-defined terrace about 100 feet above the lake.

One-half mile south of Bellevue the heavy and exceedingly well-marked lateral moraines of Meeks Creek begin. The ridges southwest of Meeks Bay are morainal up to an elevation of 7000 feet, although in places the granite may not be far from the surface. Standing at Murphys and looking north, three well-defined lateral moraines may be noticed, one rising behind the other. The Meeks Creek glacier projected below the present lake level, and its terminal moraine is covered by the water.

An ice sheet, originating in the high range north of Pyramid Peak, filled Rubicon Valley and polished and swept clean enormous areas between Rubicon Springs and McKinstry Peak. Just how far down the Rubicon glacier extended is a matter of some doubt, as no terminal moraines have been left in the canyon. It certainly extended below an elevation of 4500 feet and it may have reached the southern boundary of the quadrangle. Greyhorse Valley was filled by a separate glacier, fed from the glacial cirque at its head and connected with the Rubicon glacier. The high ridge at the head of Long Canyon extending up to Mount Mildred rose along the glacier. On McKinstry Peak the ice flow did not extend above an elevation of 7000 feet. Cottonwood Canyon, adjoining Greyhorse Valley on the west, is full of moraine, and much of it was also pushed over by the main glacier into the South Fork of Long Canyon, through the low gap at Big Meadow. Seen from that gap, the canyon of the Rubicon appears glaciated and polished for a long distance above and below. High up on the rocky slopes, at an elevation of 6000 feet, below Table Mountain, and at 5500 feet a mile northwest of the 7510-foot spur of McKinstry Peak, are seen small morainal ridges, appearing from a distance as perfectly straight lines, usually of white granite bowlders strongly marked against gray volcanic rocks or red slate. Below the 7510-foot point there are several other moraines at different elevations.

A branch of the Rubicon ice sheet overflowed the low divide west of Rubicon Springs and filled the basin of Loon Lake and Gerlé Creek. As far down as Gerlé the surface is scoured nearly clean, but between Gerlé and Jacobsens, as well as northwest of Gerlé, the morainal material is thick, in places entirely covering the ridge. Scattered granitic bowlders and other glacial drift are found on the andesite tables on both sides of the Rubicon at the southern boundary of the quadrangle, though the canyon between them does not show marked evidence of glaciation.

Five Lakes Creek along its whole course as far south as the crossing of the andesitic area is a U-shaped valley, mostly with flat, moraine-covered bottom. While the sides are largely rough, rocky hills, the bottom is covered by moraine from one-eighth to one-fourth mile wide, and level, sandy flats appear, suggesting the former existence of a series of Pleistocene lakes. No considerable amount of moraine lies at the mouths of the tributary creeks, whose ravines are sharply cut canyons in their lower courses but widen to amphitheaters with small meadows in their upper courses. From the flat where the Greyhorse trail branches, a dim trail leads down to Hell Hole. The joints of the granodiorite run down slanting westward, and have given rise to a series of shelves, along which the trail winds. These shelves are covered by morainal débris and are hardly visible from a distance, the canyon side appearing inaccessible. At Hell Hole there is a series of gravel flats covered with large oaks and firs. The valley of the Rubicon viewed from this locality is a most imposing sight.

East of Truckee River there are only indistinct traces of glaciers, which hardly seem to have been more than extensive snow fields. In a few of the gulches leading down from Mount Pluto, some evidence of glacial action is found, as, for instance, in the upper part of Shaffers Mill Creek, heading on the northwest side.

Juniper Creek, heading among the high ridges near the State line, was probably occupied by a smaller glacier, and accumulations which resemble small moraines were found at an elevation of 6500 feet.

No distinct evidence of glaciers was found in the range east of Little Truckee Valley, adequate snow reservoirs having been lacking. A small glacier may have existed in the amphitheater east of Lady Bug and Granite peaks, in the northeast corner of the quadrangle. Great numbers of large angular bowlders are found in morainal heaps at its mouth, at an elevation of 5100 feet; but their glacial origin is not established beyond doubt.

Pleistocene lake beds and stream terraces.— During the Neocene period and the earlier Pleistocene epoch, the waters of Lake Tahoe stood much higher than now. The andesitic and basaltic lavas dammed the basin to a level of 700 to 1000 feet above the present water stage, but no beaches corresponding to the higher stages now remain. The waters did not stand long at the high levels, and the shore records were wiped out by glaciation. Distinct beaches are found in this quadrangle up to an elevation of about 100 feet only. At Tahoe city the principal beach, 50 feet above the lake level, is underlain by basaltic tuff and is covered with fine gravel; this terrace is distinct as far as Observatory Point. The higher terraces are not plainly indicated. The point between Truckee River and the lake is covered with fine gravel, as is also the shore up to 100 feet above the lake along to Ward Creek.

Lake deposits and stream gravels of the Glacial epoch.

At State Line Point, however, there is no beach, and between Hot Springs and Observatory Point only a very low one, 15 to 20 feet above the water. Scattered gravel occurs in places at elevations reaching 6700 feet. The first beach deposits along the road north-northwest of Hot Springs are found at an elevation of 6400 feet, but no distinct terraces are present. The small pebbles along the beach between Hot Springs and Observatory Point are largely made up of black, hard, banded slates; there are also larger cobbles of the same kind on the beach up to 8 inches in diameter. The exact locality whence these pebbles are derived is not certainly determined, but they probably come from one of the slate areas along the western or southern shore, where such banded slates are found. They have possibly been transported by floating ice. Along Agate Bay occur sand dunes 10 to 15 feet high, forming in places continuous embankments. Between Blackwood Creek and McKinney there is a fringe of terraces of fine gravel and above this is the talus from the steep volcanic hills. There are here, as well as at various places around the lake, at least two well-marked terraces, one about 40 feet and the other about 80 feet above the lake. On some slopes, however, as near the mouth of Ward Creek, there are well-washed pebbles occurring as high up as 200 and even 300 feet above the lake. These may, however, be due to the action of glacial rivers rather than to wave action on the beach. The principal beach line north of McKinney is the one about 40 feet above the water level, which consists of glacial débris assorted by the waves of the lake. Nearly all along Truckee River, from the lake to Truckee, there are stream terraces at an elevation of from 20 to 30 feet above the river.

In Truckee Valley the Pleistocene deposits are of a more complicated character. After the close of the andesite eruptions followed a long period of erosion, during which Truckee Canyon was cut out very nearly to its present depth. Then came the basalt eruption, covering large parts of the valley and damming up the lake afresh to an elevation of 6000 feet. This Pleistocene lake probably remained during a part of the Glacial period, gradually diminishing in size as Truckee River cut down the outlet. Its beach gravels are found all around the Truckee basin, generally at a constant maximum height. On the western side, toward Sage Hen and Truckee, the height where the wash gravel begins is a little above 5900 feet. In Stampede Valley the height varies between 5900 and 6000 feet. The shore gravel runs over in river terraces, where tributaries entered the lake. Along the Little Truckee the stream terraces reach far up to the base of the terminal moraine. The middle of Martis Valley is mostly covered by finer sediments, fine gravel, and sand, while coarser gravels are found nearer the shore line. On the basalt table south of Boca well-washed, silicified andesite pebbles are found abundantly at an elevation of a little over 6000 feet. Along the lower part of Juniper Creek a distinct terrace ascending along the creek corresponds in elevation with the beach deposit just mentioned.

On the western slope of the Truckee River Range the gravel is, however, found at a higher elevation, pointing to a small uplift. In the ravine between andesite and basalt, 3 miles northeast of Boca, a very distinct pebble beach remains at a little over 6200 feet. Two miles farther north the same beach line is found at 6200 or 6300 feet, while scattered wash pebbles are found even higher up. At the north end of the range gravel is found at 6200 feet, though the beach line is not very definite.

The last distinct moraine is found in the western part of the town of Truckee. East of this there are gravel and bowlder terraces on each side of the river, reaching an elevation of 5900 feet. The terrace northeast of the town is about 100 feet high and in its lower layers is composed of wash bowlders closely packed; in the upper part there are heavier bowlders.

The Truckee lake was evidently drained during the later part of the Glacial period, and the river began eroding the lake deposits. At Truckee the river has cut into the terrace, forming the flat on which the town stands, and in this newer terrace it is at present cutting still deeper. The flat bench, which is of late Glacial or post-Glacial age, extends with an elevation of 20 to 50 feet above the river, and farther down widens considerably toward Martis Valley. It is bordered southward by a distinct bluff toward the older Pleistocene deposits of Martis Valley. Nearly disappearing in the basalt canyon at Prosser, it is found again above and below Boca, as gravel flats 20 to 40 feet above the river. In Truckee Canyon there are many very late alluvial flats 10 to 20 feet above the river, and occasionally slight indications of a higher bench at 50 feet. Granite bowlders of considerable size (6 to 7 feet in diameter) are found on the low terrace and on its slopes several miles below Truckee. Even as far down as Boca granite bowlders 4 to 5 feet in diameter are occasionally met with in the river terraces, and at Boca, between a hotel and a sawmill, in a railroad cut, there is a mass of angular granite and basalt bowlders, probably transported by floating ice. Apparently no glacier reached down so far.

Along the Little Truckee alluvial flats extend little above the river level; the flats are bordered by gravel terraces of fluviatile, late Pleistocene origin, 20 to 100 feet above the river; finally at elevations ranging from 5900 to 6200 feet are found the shore gravels of the early Pleistocene lake. Similar relations obtain on Prosser Creek.

At the mouth of the lower Truckee Canyon, in the extreme northeast corner of the quadrangle, are extensive fluviatile gravel terraces covered with large scattered bowlders, probably carried down by torrents from cloud-bursts.

Lakes.—Over one hundred large and small lakes dot the summit region of the main range. They are nearly all of glacial origin, either dammed by moraines or occupying scooped-out rock basins, the former being in the majority. Webber, Independence, and Donner lakes have morainal dams, though the latter may in the first place have been dammed by the basaltic flow. Lake Tahoe has been dammed by andesitic flows, as stated above. Loon Lake, Pleasant Lake, and others along the southern boundary appear to be rock basins. Many of the lakes have been drained since the close of the Glacial period and their bottoms now form swamps or meadows.

SUMMARY AND GEOLOGICAL HISTORY.

Between the granitic eruptions of late Juratrias or early Cretaceous age and the phenomena of the Neocene period lies a gap in the geological record, difficult to fill. A great mountain range was probably built up where the Sierra Nevada now stands and planed down by erosion to moderate relief. Then followed, previous to the Neocene period, the first differentiation of the Sierra Nevada by breaks and movements along the fault lines on both sides of Lake Tahoe and on the eastern side of the Carson Range. The probable positions of the first two fault lines on each side of the Tahoe-Truckee depression are shown on the map. Direct evidence of the fault is not found, but no other explanation of the topographic features appears reasonable. After the outlines of the range had been thus blocked out, new river systems were established, probably during the Eocene period, and their valleys were eroded, broad and deep near the summits. The auriferous gravels were deposited and the epoch of volcanic activity began. During the epoch a great recurring faulting movement took place along the old break at the eastern base of the Carson Range, while it is thought that no important faulting occurred on either side of Lake Tahoe.

Review of geological events.

No important movement appears to have taken place after the andesitic eruptions along the western fault line, though north of this quadrangle, along the same line, such later movements have occurred. Neither can it be said that there is any conclusive evidence in favor of post-andesitic faulting on either side of the Carson Range, in this quadrangle, except possibly in one place, north of Boca, referred to above.

The questions of the faulting along the base of the Sierra, the manner in which it was accomplished, and the dates of the faults are confessedly difficult, and will bear more elucidation. It is certain that on the western block, the grades of the rivers flowing westward have been greatly increased, resulting in an apparent tilting, but how this has been accomplished is not definitely settled.

A general uplift of the region was probably accompanied by a sinking or settling of certain less well supported blocks, such as that underlying the Truckee basin and Lake Tahoe and that to the east of the Carson Range. The long depression extending from Sierra Valley on the north to Lake Tahoe on the south is one of the most interesting features of this region. As already indicated, it was outlined before the Neocene period by the sinking of a block between two parallel fault lines, and this probably formed a very deep and continuous valley, either closed and filled by a lake or draining toward the north. Volcanic accumulations filled this valley during the latter Neocene and divided it into three basins. Truckee Valley, first a lake, found soon after the close of the volcanic period an outlet along the present Truckee River across the eastern or Carson Range, the outlet probably following an original depression in the surface of the andesite.

Lake Tahoe, likewise dammed high above its present level by the andesitic lavas, found its outlet northward into Truckee Valley.

After the close of the volcanic period and its orographic disturbances followed a period of rest. The western range during this time became deeply scored by canyons, and Truckee River deepened its canyon all along to its present level and drained the Truckee basin. Then followed the basaltic eruption which obstructed Truckee River in at least three places: at the outlet of Lake Tahoe, again raising its level; above Truckee, creating a temporary lake between that locality and the lake; and at Boca, forming an extensive lake in the Truckee basin. The Glacial epoch, probably begun before the basaltic eruptions, continued long after their close. The barriers of the basaltic dams were cut through before the end of the Glacial epoch. The erosion that has taken place since the close of that epoch is of trifling extent; along Truckee River it is considerably less than 50 feet. Though no post-andesitic faults can be shown to exist, it does not follow that this region has not suffered any disturbance since the Neocene period. The Neocene lake beds of Truckee Valley have been gently tilted southward. Further, the fact above referred to, that remains of shore gravels of the Pleistocene lake of Truckee Valley lie about 200 feet higher northeast of Boca than they do on the opposite side of the valley, is of very great interest as proving that some deformation has taken place along the eastern side of Truckee Valley, though its character can not be definitely decided at present. Whether the basin of Lake Tahoe has undergone any deformation in Pleistocene times the observations are not sufficient to decide.

ECONOMIC GEOLOGY.

AURIFEROUS GRAVELS.

Neocene.—Auriferous gravels of Neocene age are exposed only to a very limited extent in the Truckee quadrangle. Shallow gravel containing coarse gold has been found in the deep depression under the rhyolite near the head of Sailor Canyon, at the western boundary of the quadrangle. On the opposite side of Sailor Canyon, at the place called Sailor Meadows, similar deposits have been found. The gravels are developed by means of tunnels run into the bed rock.

At Chalk Bluffs, on the Middle Fork of American River, about 4 miles above French Meadows, an inclined shaft was sunk some years ago for a distance of 400 feet, with the intention of reaching the bottom of the gravel channel known to exist under the ridge north of the river. It is said that good prospects were found, although the bottom of the channel was not reached.

Gold-bearing gravels rare.

Pleistocene.—As this region lies outside of the Gold Belt proper, Pleistocene auriferous gravels of economic importance occur only in a few places, though by panning colors may be obtained from many creeks in the area. Sailor Canyon has yielded a considerable amount of gold, especially near its junction with American River, in the Colfax quadrangle. Some gold has also been found in the upper part of Duncan Canyon and in the Middle Fork of the American below French Meadows. The two branches of Long Canyon, which in the adjacent Colfax quadrangle are in places rich in gold, appear in this area nearly barren. The gravel bars along the Rubicon River, from north of McKinstry Peak down, contain a small amount of fine gold.

GOLD-QUARTZ VEINS.

No gold-quartz veins are being worked at present within this quadrangle. On the rocky mountain slopes to the south of the American Royal Gorge, in the Sailor Canyon beds, and in the adjacent diabase-porphyrite, a few quartz veins have been prospected and contain iron and copper pyrites carrying some gold. Within the isolated schist area of McKinstry Peak a few quartz veins are found. One of them, cropping some distance west of Wentworth Springs, is said to contain as much as $3 per ton in gold. A gold-quartz vein of some promise has been worked at French Meadows on the northern side of the Middle Fork of American River. The granodiorite adjoining it has been subjected to much pressure and made schistose.

Few gold-quartz deposits.

At the outlet of Meadow Lake a few ill-defined veins carrying auriferous sulphides only have been found. Frequent attempts have been made to work them but the isolation of the locality, the severe climate, and the low grade of the ore have thus far prevented success. The veins belong to the Meadow Lake mining district, the largest part of which falls in the Colfax quadrangle.

GOLD-SILVER DEPOSITS.

Several areas in the andesite north of Lake Tahoe have been subjected to extensive thermal alteration, due to hot mineral waters permeating the rocks. The result is a white, soft, decomposed rock, containing more or less iron pyrite. This iron pyrite contains silver and gold, the former preponderating. Prospects have been opened on these deposits at several places, though thus far no ore bodies of economic importance have been encountered. The places are as follows: at the head of Juniper Creek, where a tunnel 600 feet long has been run on a deposit of this kind; in the vicinity of Elizabethtown, a now abandoned settlement on the northern slope of the range, north of Lake Tahoe, on the road from Truckee to Hot Springs, at an elevation of 6500 feet, where many shafts and smaller tunnels were run in this vicinity during the mining excitement of 1864; and in the vicinity of the abandoned settlement of Knoxville, on the east side of Truckee River, opposite the mouth of Squaw Creek. At the latter place there is an area of at least one square mile altered by thermal processes, and the altered rocks appear in fantastic red and yellow outcrops. Many partly caved prospect holes and tunnels were noted.

BUILDING STONES.

Many of the rocks of the Truckee quadrangle are adapted for building stones, though at present there is no extensive demand for this material. The granodiorites are especially suitable in many places, and also the rhyolites. The latter are practically freestones, and, being easily dressed, would be very well suited for building purposes. No quarries have been developed in the quadrangle.

COAL.

Although no workable coal beds occur in the area, attention may be called to the fact that beds of coaly shale, with thin strata of lignite, are found in the Eocene lake beds of Little Truckee River and in the vicinity of Verdi.

MINERAL SPRINGS.

Mineral springs are quite abundant in certain parts of the area. Most of them are found along the summit region of the Sierra Nevada. Extinct mineral springs, indicated by their deposits, are found in a few places, notably to the south of Euers Valley, on the road to Truckee. The only hot mineral spring is found on the north shore of Lake Tahoe, near State Line Point. The spring emerges in the lake about 20 feet from the shore. The flow is strong and the temperature of the water 138° F. There is hardly any taste of mineral salts, but a faint smell of sulphureted hydrogen may be noted.

The cold mineral springs may be divided into two groups: (1) those characterized by alkaline carbonates along with a considerable amount of free carbonic acid, and (2) the cold sulphur springs characterized by the presence of sulphureted hydrogen. A number of springs belonging to the first group are found on the headwaters of the North Fork of American River. At Soda Springs, a well-known resort 5 miles south of Summit station on the Central Pacific Railroad, there are several springs characterized by an abundance of carbonate of soda and chloride of sodium, together with smaller quantities of carbonate of lime and magnesium. Two miles below Soda Springs, on the road to the railroad, there are extensive calcareous spring deposits. Some of these springs are still flowing from little mounds built up by their sediments, while others are extinct. Still farther down on the same river, near Palisade Creek, are the so-called Heath Soda Springs. Their flow is very abundant and they are similar to the soda springs just mentioned, except in containing somewhat less carbonic acid. The temperature of these springs is from 50° to 60° F. or 10° to 15° C. Similar alkaline and carbonated springs are found at Scotts Springs and half a mile west of McKinney. The Rubicon Valley is characterized by a number of mineral springs. The principal ones, Rubicon Springs, furnish carbonated water which is extensively used for medicinal purposes. A small mineral spring occurs near the mouth of Powderhorn Creek.

The cold sulphur springs are fewer in number. At the base of the morainal bluff on the south side of Middle Fork, 5 miles below this pass, is a cold spring flowing moderately and containing much sulphureted hydrogen. Near the junction of Rubicon River and Five Lakes Creek there is found, on the south side of the Rubicon, a spring flowing about a gallon a minute. It has a strong saline taste, and also smells strongly of sulphureted hydrogen. The temperature is about 45° F. Two similar springs are found a few miles further down the river. A quantitative analysis of this water shows the presence of large amounts of chloride of sodium and chloride of calcium, besides a little silica and iron.

At Wentworths, on the road from Lake Tahoe to Georgetown, two mineral springs emerge near the house, while two or three other springs issue one-third mile eastward. The volume of water is moderate, and the temperature is 45° F. In mineral substances dissolved the springs differ considerably, though they are close together. A sample of the most saline water contains abundant chlorides of sodium, magnesium, and lime, with carbonic acid and sulphureted hydrogen as well as a little silica and iron. Much carbonate of calcium is also present. Such a composition of a mineral water is an unusual one for this region.

Superficial springs.—The western part of the quadrangle receives, as stated above, a heavy precipitation, and many snow banks remain on the northern side of the highest mountains throughout the summer. Water issues from numerous springs of superficial origin. The largest springs are, however, nearly invariably situated at the base of the andesitic and rhyolitic hills. The atmospheric waters easily penetrate the porous volcanic rocks and, collecting on the bed-rock surface below them, reappear at points along the contact. Such springs, fed by the porous rocks of the lava hills, are characterized by ample and constant flow and very low temperature.

WALDEMAR LINDGREN,
Geologist.

January, 1898.

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

TOPOGRAPHIC SHEET

CALIFORNIA
TRUCKEE QUADRANGLE

(Downieville) (Sierraville) (Reno)
(Colfax) (Carson)
(Placerville) (Pyramid Peak) (Markleeville)

A. H. Thompson, Geographer.
E. M. Douglas, Topographer in charge.
Triangulation by H. E. C. Feusier.
Topography by A. F. Dunnington.
Surveyed in 1889

Scale 1/125000

Miles: 1 ½ 0 1 2 3 4 5

Kilometers: 1 ½ 0 1 2 3 4 5

Contour Interval 100 feet
Datum is mean Sea level
Edition of May 1897.

LEGEND

RELIEF
(printed in brown)

Figures *showing heights above mean sea level (instrumentally determined)*

Contours *showing height above sea, horizontal form, and steepness of slope of the surface*

DRAINAGE
(printed in blue)

Rivers

Creeks

Lakes and ponds

Marshes

CULTURE
(printed in black)

Towns and villages

Roads and buildings

Trails

Railroads

Tunnels

Bridges

Dams

State boundary lines

County boundary lines

County line and road coincident

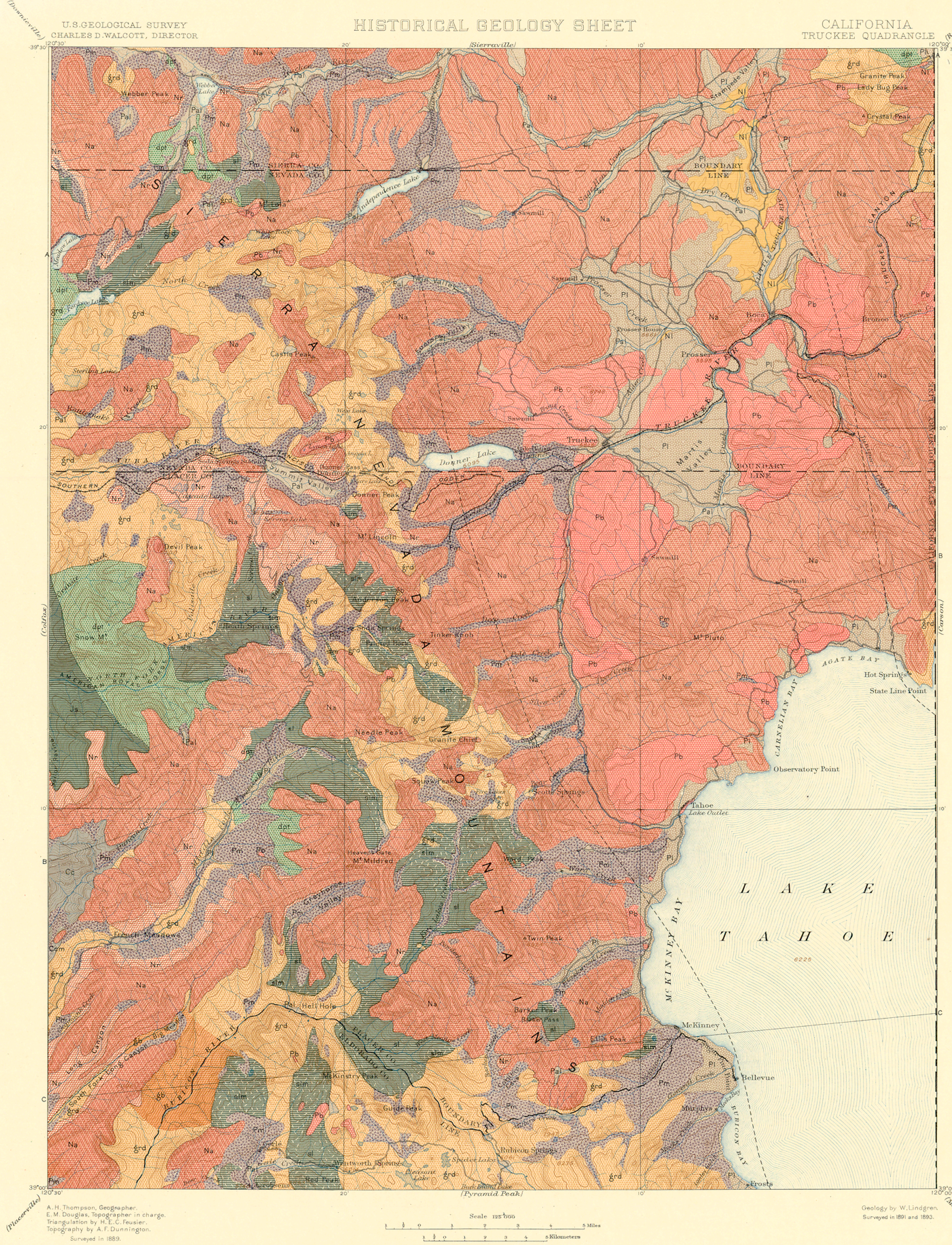
Triangulation stations

Names of adjoining published sheets are printed on the margin.

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

HISTORICAL GEOLOGY SHEET

CALIFORNIA
TRUCKEE QUADRANGLE



LEGEND

SURFICIAL ROCKS

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

SUPERJACENT SERIES

PLEISTOCENE

- Pal — Alluvium *(bottom lands and meadows)*
- Pm — Moraines
- Pl — Lake beds and corresponding stream terraces *(sands and gravels)*

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines. Metamorphism is indicated by short dashes combined with the parallel lines.)

NEOCENE

- Nl — Lake beds *(clay, sand, and tuff)*

BED-ROCK SERIES

JURATRIAS

- Js — Sailor Canyon formation *(slate, quartzite, and limestone)*

JURATRIAS ?

- sl — Slate and quartzite *(detached masses in the igneous areas, probably equivalent to the Sailor Canyon formation)*
- slm — Schist *(chiefly micaceous; derived from the above described slates by contact metamorphism)*

CARBONIFEROUS

- Cc — Calaveras formation *(slate, chert, and quartzite)*
- Ccm — Calaveras formation *(contact metamorphic rocks, chiefly micaceous schists)*

IGNEOUS ROCKS

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

SUPERJACENT SERIES

PLEISTOCENE

- Pb — Basalt

NEOCENE

- Na — Andesite *(tuff, breccia, and massive flows)*
- Nr — Rhyolite

BED-ROCK SERIES

PROBABLY JURATRIAS OR EARLY CRETACEOUS

- grd — Granodiorite *(including smaller masses of granite and diorite not separated)*
- gb — Gabbro
- dpt — Diabase-porphyrite and augite-porphyrite

Probable faults

Sections

A. H. Thompson, Geographer.
E. M. Douglas, Topographer in charge.
Triangulation by H. E. C. Feusier.
Topography by A. F. Dunnington.
Surveyed in 1889.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour Interval 100 feet.
Datum is mean Sea level.
Edition of May 1897.

Geology by W. Lindgren.
Surveyed in 1891 and 1893.

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

ECONOMIC GEOLOGY SHEET

CALIFORNIA
TRUCKEE QUADRANGLE

A. H. Thompson, Geographer.
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Scale $\frac{1}{125000}$

Contour Interval 100 feet.
Datum is mean Sea level.
Edition of May 1897.

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Surveyed in 1891 and 1893.

LEGEND

SURFICIAL ROCKS

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

SUPERJACENT SERIES — PLEISTOCENE

- Pal — Alluvium *(bottom lands and meadows)*
- Pm — Moraines
- Pl — Lake beds and corresponding stream terraces *(sands and gravels)*

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines. Metamorphism is indicated by short dashes combined with the parallel lines.)

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- Nl — Lake beds *(clay, sand, and tuff)*

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IGNEOUS ROCKS

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

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PLEISTOCENE

- Pb — Basalt

NEOCENE

- Na — Andesite *(tuff, breccia, and massive flows)*
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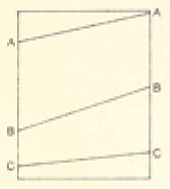
Probable faults

Sections



Dip and strike of stratified rocks
Vertical dip and strike of stratified rocks
Dip and strike of schistosity
Vertical dip and strike of schistosity
Gold and gold-silver prospects
MS *Mineral springs*

U.S. GEOLOGICAL SURVEY
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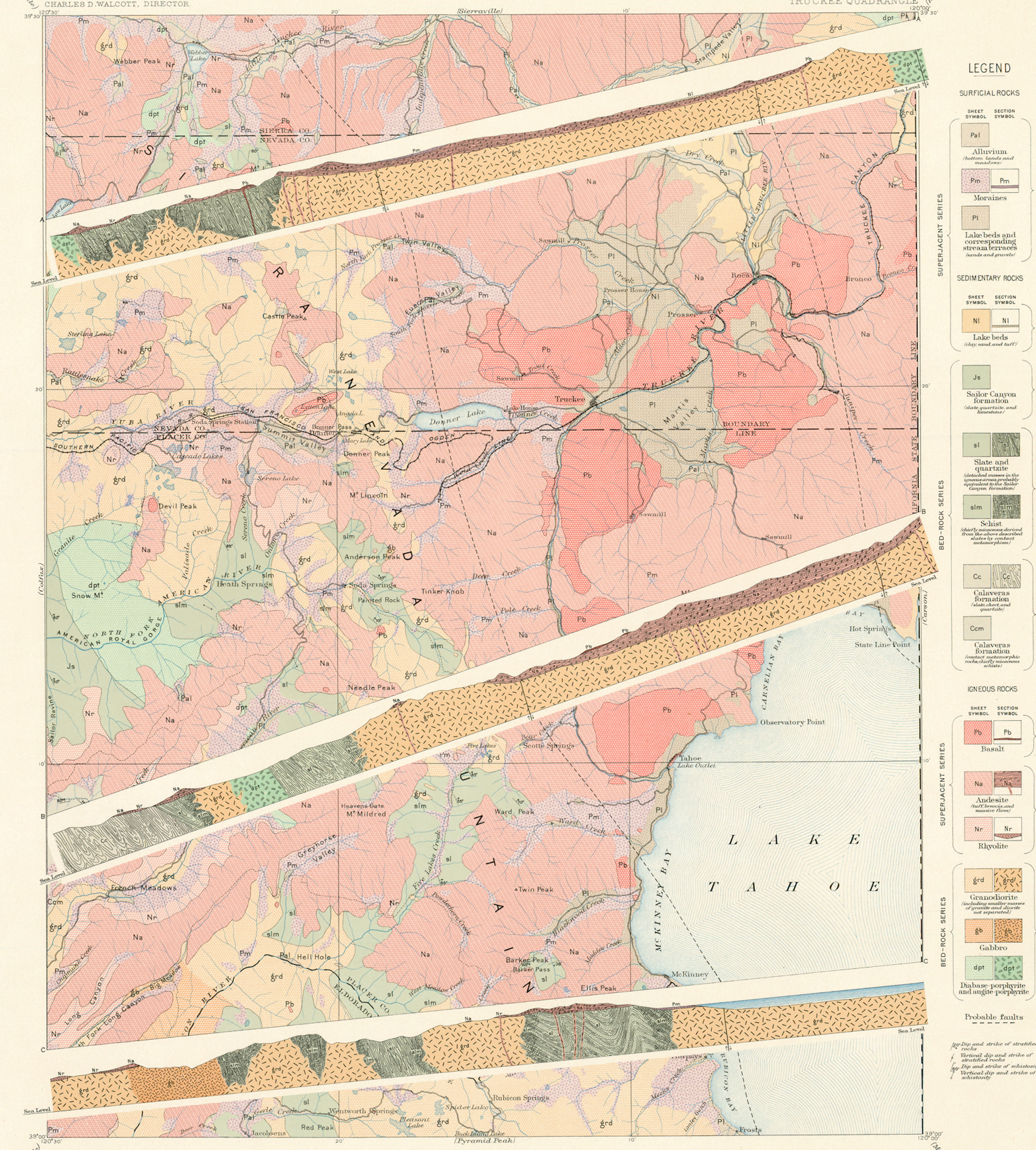
STRUCTURE-SECTION SHEET

CALIFORNIA
TRUCKEE QUADRANGLE



A. H. Thompson, Geographer.
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Surveyed in 1889.

Scale 1/125000
5 Miles
5 Kilometers

Edition of May 1897.

Geology by W. Lindgren.
Surveyed in 1891 and 1893.

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:

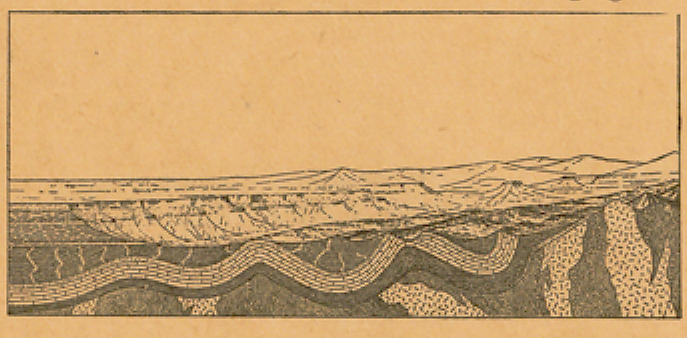

Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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:

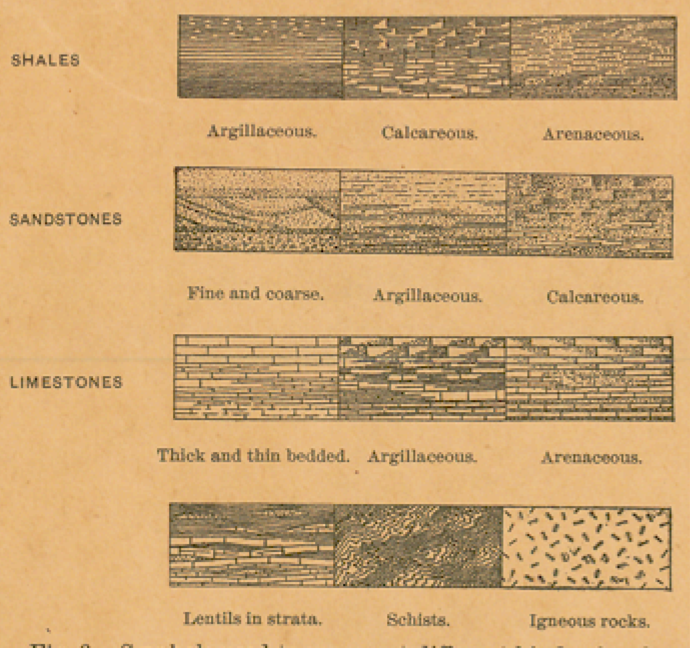

Fig. 3.—Symbols used to represent different kinds of rock.

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.

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