DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

J.W. POWELL, DIRECTOR

GEOLOGIC ATLAS

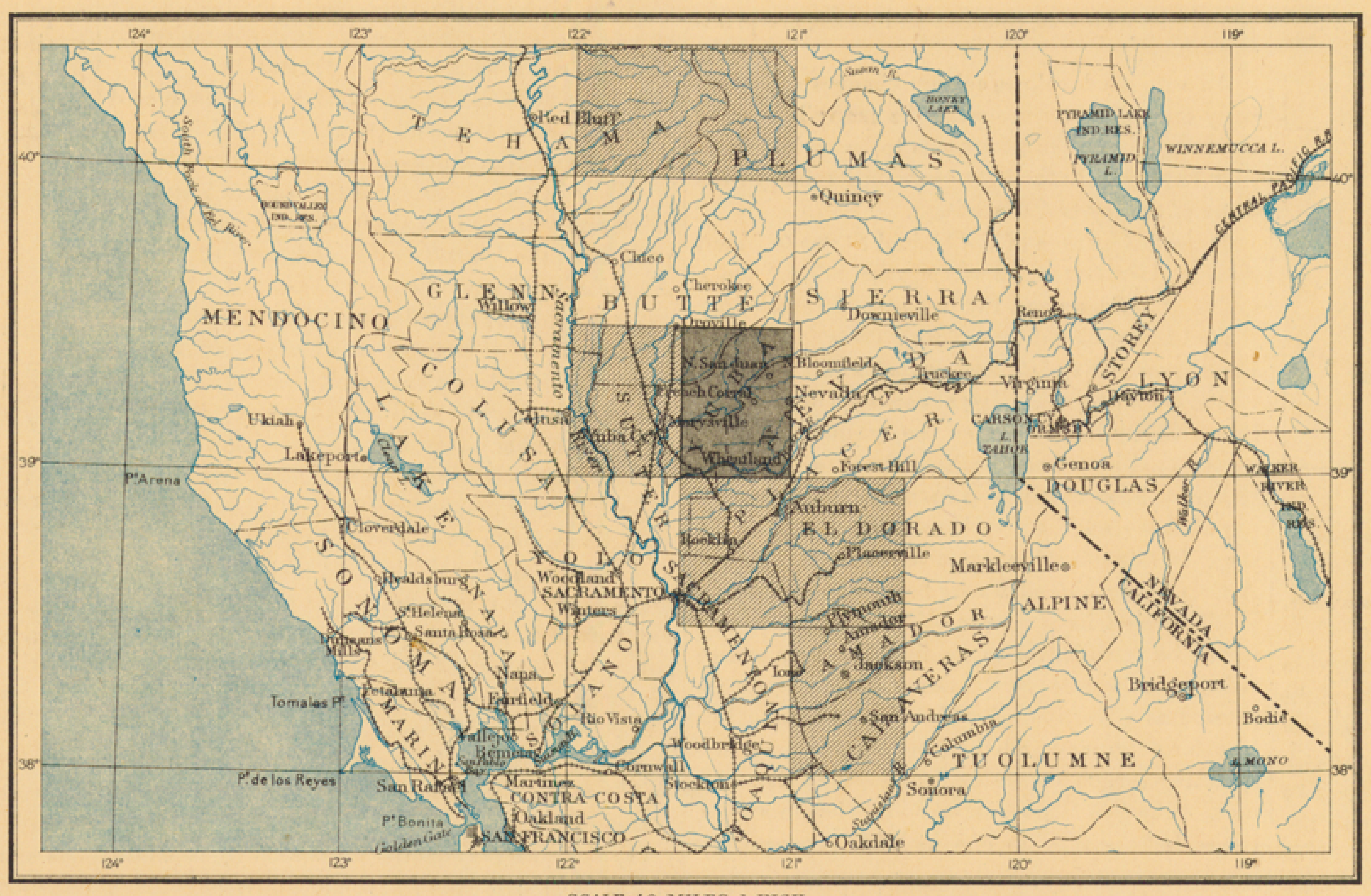
OF THE

UNITED STATES

SMARTSVILLE FOLIO

CALIFORNIA

INDEX MAP



SCALE: 40 MILES - 1 INCH

AREA OF THE SMARTSVILLE FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION　TOPOGRAPHY　AREAL GEOLOGY　ECONOMIC GEOLOGY　STRUCTURE SECTIONS

FOLIO 18　LIBRARY EDITION　SMARTSVILLE

WASHINGTON, D. C.

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

1895

EXPLANATION.

The Geological Survey is making a large topographic map and a large geologic map of the United States, which are being issued together in the form of a Geologic Atlas. The parts of the atlas are called folios. Each folio contains a topographic map and a geologic map of a small section of country, and is accompanied by explanatory and descriptive texts. The complete atlas will comprise several thousand folios.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, prairies, valleys, hills and mountains; (2) distribution of water, called *drainage*, as streams, ponds, lakes, swamps and canals; (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 stated on the map by numbers printed in brown. It is desirable to show also the elevation of any part of a hill, ridge, slope or valley; to delineate the horizontal outline or contour of all slopes; and to indicate their degree of steepness. This is done by lines of constant elevation above mean sea level, which are drawn at regular vertical intervals. The lines are called *contours* and the constant vertical space between each two contours is called the *contour interval*. Contours are printed in brown.

The manner in which contours express the three conditions of relief (elevation, horizontal form and degree of slope) is shown in the following sketch and corresponding contour map:

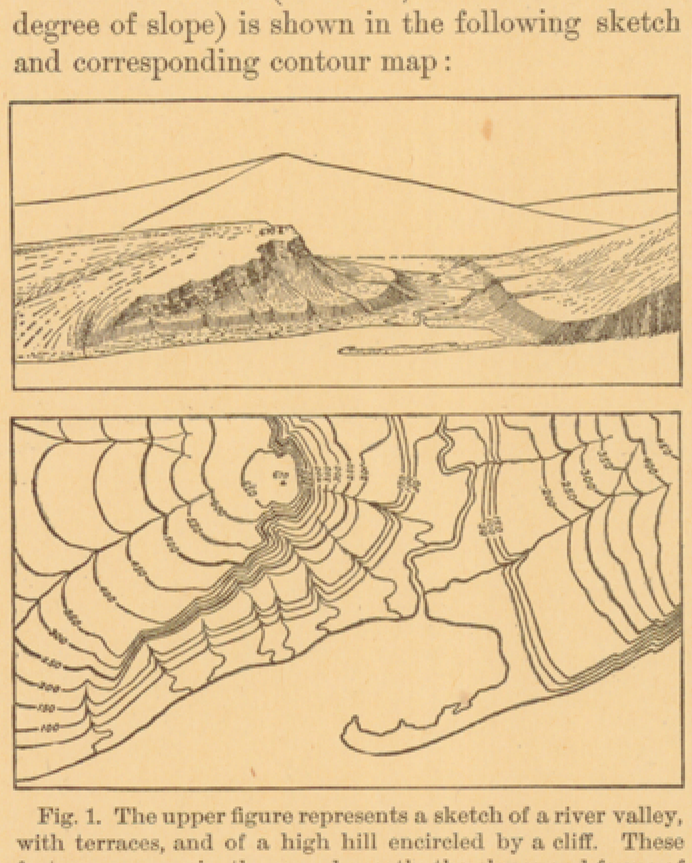


Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

The sketch represents a valley between two hills. In the foreground is the sea with a bay which is partly closed by a hooked sand-bar. On either side of the valley is a terrace; from that on the right a hill rises gradually with rounded forms, whereas from that on the left the ground ascends steeply to a precipice which presents sharp corners. The western slope of the higher hill contrasts with the eastern by its gentle descent. 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 height, form and slope:

1. A contour indicates approximately a height above sea level. In this illustration the contour interval is 50 feet; therefore the contours occur 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 so on with any other contour. In the space between any two contours occur 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 are made heavy and are numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the horizontal 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 define all prominences. The relations of contour characters 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. Therefore contours are far apart on the gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is chosen; for a steep or mountainous country a large contour interval is necessary. The smallest contour interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for districts like the Mississippi delta and the Dismal Swamp region. In mapping great mountain masses like those in Colorado, on a scale of $\frac{1}{250,000}$ the contour interval may be 250 feet. For intermediate relief other contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—The water courses are indicated by blue lines, which are drawn unbroken where the stream flows the year round, and dotted where the channel is dry a part of the year. Where the stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Marshes and canals are also shown in blue.

Culture.—In the progress of the settlement of any region men establish many artificial features. These, such as roads, railroads and towns, together with names of natural and artificial details and boundaries of towns, counties and states, are printed in black.

As a region develops, culture changes and gradually comes to disagree with the map; hence the representation of culture needs to be revised from time to time. Each sheet bears on its margin the dates of survey and of revision.

Scales.—The area of the United States (without Alaska) is about 3,025,000 square miles. On a map 240 feet long and 180 feet high the area of the United States would cover 3,025,000 square inches. Each square mile of ground surface would be represented by a corresponding 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 special case it is "one mile to an inch." A map of the United States half as long and half as high would have a scale half as great; its scale would be "two miles to an inch," or four square miles to a square inch. Scale is also often expressed as 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 "one mile to one inch" is expressed by $\frac{1}{63,360}$.

Three different scales are used on the atlas sheets of the U. S. Geological Survey; the smallest is $\frac{1}{250,000}$, the second $\frac{1}{125,000}$ and the largest $\frac{1}{62,500}$. These correspond approximately to four miles two miles, and one mile of natural length to one inch of map length. On the scale $\frac{1}{62,500}$ one square inch of map surface represents and corresponds nearly to one square mile; on the scale of $\frac{1}{125,000}$ to about four square miles; and on the scale of $\frac{1}{250,000}$ to about sixteen square miles. At the bottom of each atlas sheet the scale is expressed as a fraction, and it is further indicated by a "bar scale," a line divided into parts representing miles and parts of miles.

Atlas sheets.—A map of the United States on the smallest scale used by the Geological Survey would be 60 feet long and 45 feet high. If drawn on one of the larger scales it would be either two times or four times as long and high. To make it possible to use such a map it is divided into atlas sheets of convenient size which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree (that is, represents an area one degree in extent in each direction); 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. These areas correspond nearly to 4000, 1000 and 250 square miles.

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. For convenience of reference and to suggest the district represented each sheet is given the name of some well known town or natural feature within its limits. At the sides and corners of each sheet the names of adjacent sheets are printed.

THE GEOLOGIC MAP.

A geologic map represents the distribution of rocks, and is based on a topographic map,—that is, to the topographic representation the geologic representation is added.

Rocks are of many kinds in origin, but they may be classed in four great groups: Superficial Rocks, Sedimentary Rocks, Igneous Rocks and Altered Rocks. The different kinds found within the area represented by a map are shown by devices printed in colors.

Rocks are further distinguished according to their relative ages, for rocks were not formed all at one time, but from age to age in the earth's history. The materials composing them likewise vary with locality, for the conditions of their deposition at different times and places have not been alike, and accordingly the rocks show many variations. Where beds of sand were buried beneath beds of mud, sandstone may now occur under shale; where a flow of lava cooled and was overflowed by another bed of lava, the two may be distinguished. Each of these masses is limited in extent to the area over which it was deposited, and is bounded above and below by different rocks. It is convenient in geology to call such a mass a *formation*.

(1) *Superficial rocks.*—These are composed chiefly of clay, sand and gravel, disposed in heaps and irregular beds, usually unconsolidated.

Within a recent period of the earth's history, a thick and extensive ice sheet covered the northern portion of the United States and part of British America, as one now covers Greenland. The ice gathered slowly, moved forward and retreated as glaciers do with changes of climate, and after a long and varied existence melted away. The ice left peculiar heaps and ridges of gravel; it spread layers of sand and clay, and the water flowing from it distributed sediments of various kinds far and wide. These deposits from ice and flood, together with those made by water and winds on the land and shore after the glacier had melted, and those made by similar agencies where the ice sheet did not extend, are the superficial formations. This period of the earth's history, from the beginning of the glacial epoch to the present, is called the Pleistocene period.

The distribution of the superficial rocks is shown on the map by colors printed in patterns of dots and circles.

(2) *Sedimentary rocks.*—These are conglomerate, sandstone, shale and limestone, which have been deposited beneath seas or other large bodies of water and have usually become hard.

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 in the ocean, whose shore would traverse Wisconsin, Iowa, Kansas and Texas. More extensive changes than this have repeatedly occurred in the past. The shores of the North American continent have changed from age to age, and the sea has at times covered much that is now dry land. The earth's surface 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 oceans are changed.

The bottom of the sea is made of gravel, sand and mud, which are sorted and spread. As these sediments gather they bury others already deposited and the latter harden into layers of conglomerate, sandstone, shale or limestone. When the sea bottom is raised to dry land these rocks are exposed, and then we may learn from them many facts concerning the geography of the past.

As sedimentary strata accumulate the younger beds rest on those that are older and the relative ages of the deposits may be discovered by observing their relative positions. In any series of undisturbed beds the younger bed is above the older.

Strata generally contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas. By studying these remains or fossils it has been found that the species of each epoch of the earth's history have to a great extent differed from those of other epochs. Rocks that contain the remains of life are called *fossiliferous*. Only the simpler forms of life are found in the oldest fossiliferous rocks. From time to time more complex forms of life developed and, as the simpler ones lived on in modified forms, the kinds of living creatures on the earth multiplied. But during each epoch 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.

Beds of rock do not always occur in the positions in which they were formed. When they have been disturbed it is often difficult to determine their relative ages from their positions; then fossils are a guide to show which of two or more formations is the oldest. 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 one was formed first. Fossil remains found in the rocks of different states, of different countries and of different continents afford the most important means for combining local histories into a general earth history.

Areas of sedimentary rocks are shown on the map by colors printed in patterns of parallel straight lines. To show the relative age of strata on the map, the history of the sedimentary rocks is divided into nine periods, to each of which a color is assigned. Each period is further distinguished by a letter-symbol, so that the areas may be known when the colors, on account of fading, color blindness or other cause, cannot be recognized. The names of the periods in proper order (from new to old), with the color and symbol assigned to each, are given below:

PERIOD.	SYMBOL.	COLOR—PRINTED IN PATTERNS OF PARALLEL LINES.
Neocene (youngest)	N	Yellowish buff.
Eocene	E	Olive-brown.
Cretaceous	K	Olive-green.
Juratrias	J	Gray-blue-green.
Carboniferous	C	Gray-blue.
Devonian	D	Gray-blue-purple.
Silurian	S	Gray-red-purple.
Cambrian	Ç	Brown-red.
Algonkian (oldest)	A	Orange-brown.

In any district several periods may be represented, and the representation of each may include one or many formations. 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; and the formations of any one period are distinguished from one another by different patterns. 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. Each formation is furthermore given a letter-symbol, which is printed on the map with the capital 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.

(3) *Igneous rocks.*—These are crystalline rocks, which have cooled from a molten condition.

Deep beneath the surface, rocks are often so hot as to melt and flow into crevices, where they congeal, forming dikes and sheets. Sometimes they

DESCRIPTION OF THE GOLD BELT.

GEOGRAPHIC RELATIONS.

The Gold Belt of California includes that portion of the Sierra Nevada lying between the parallels of 37° 30′ and 40°. This area is bounded on the east by the Great Basin and on the west by the Great Valley of California, comprising about 17,000 square miles. The Sierra Nevada here forms a single range, sloping somewhat abruptly toward the Great Basin and gradually toward the Great Valley of California. Within this area lie the chief gold deposits of the State, though by no means all of the area is auriferous. At the northern limit the deposits are scattered over nearly the entire width of the range, while to the south the productive region narrows to small dimensions. The mass of the range south of Alpine County is comparatively barren. North of the 40th parallel the range is probably not without deposits, but the country is flooded with lavas which effectually bury 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, and portions of them have been subsequently metamorphosed.

The southern portion of the range is composed of granite. The central and northern part, west of longitude 120° 30′, consists prevailingly of schists, which have been produced by intense metamorphism of both ancient sediments and igneous rocks, and it is chiefly but not solely in these schists that the auriferous quartz veins occur. 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 schists with 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 the 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, 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.

The history of the Sierra Nevada, even so far as it is recorded in the rocks, has not yet been fully made out; but the events of certain epochs are recognized, and these may be stated in a brief summary in the order in which they occurred.

THE 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 dry land 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 a portion or all of the Juratrias period it was at least partly covered by the sea. At the close of the Juratrias, according to the latest paleontological determinations, the Sierra Nevada was upheaved as a great mountain range, the disturbance being accompanied by the intrusion of large amounts of granite.

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 northeast base of the range 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, diabase, and hornblende-porphyrite, which have been rounded by the action of waves. The presence of igneous 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 Paleozoic sediments of the Gold Belt consist of quartzite, mica-schist, and clay-slate, with limestone lenses. Rounded crinoid stems, *Lithostrotion*, *Fusulina*, *Clisiophyllum*, *Spirifera*, and other genera have been found, chiefly in the limestone, and indicate that the age of the rocks is Carboniferous. The Paleozoic sediments are finely exposed in Calaveras County, and on the Gold Belt sheets they will be designated the Calaveras formation. It is probable that some areas mapped as Calaveras may contain strata earlier or later than the Carboniferous.

During an epoch of upheaval some time after the close of the Carboniferous period, these sedimentary strata were raised, forming part of a mountain range. The beds were folded and compressed, and thus rendered schistose. Granite and other igneous rocks were intruded among them, and they assumed somewhat the relations which they now exhibit in the Sierra Nevada. But those masses which now form the surface were then deeply buried in the foundations of the range. They have been brought to the present surface by subsequent uplifts and prolonged erosion.

JURATRIAS PERIOD.

The areas of land and sea which existed during the earlier part of this period are scarcely known. Strata showing the former presence of the sea have been recognized in the southeastern portion of the range at Mineral King, where the sediments are embedded in eruptive granite, and at Sailor Canyon, a tributary of American River. Rocks of this age occur generally throughout the Great Basin and the Rocky Mountains, but the interior sea or archipelago in which they were deposited was apparently separated from the Pacific by a land mass stretching the length of the Sierra Nevada. This land probably originated in the upheaval above referred to, some time after the close of the Carboniferous, and toward the end of the Juratrias period its area became so extensive that the waters of the Pacific seem to have been completely separated from the interior seas. This conclusion is based upon the fact that fossils of Jurassic age in California, so far as known, have closer relations with those of Russia than with those of eastern America.

The genus *Aucella*, whose shells occur in Russia, flourished on the Pacific Coast until well into the Cretaceous, and is distributed from Alaska to Mexico. In the Juratrias strata of California it is associated with ammonites of the genera *Perisphinctes*, *Cardioceras*, and *Amaltheus*, which are closely related to forms of the European Upper Jurassic.

The strata in which these fossils occur are prevailingly clay-slates, which are locally sandy and contain pebbles of rocks from the Calaveras formation. Thus it is evident that they were deposited near the shore of a land composed of more ancient schists, and the generally fine character of the sediment shows that the land which occupied the area of the Sierra Nevada can not have been very mountainous. These strata now occur in two narrow bands along the western base of the range, and are called the Mariposa formation, from the fact that they are well exposed near Mariposa.

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 vertical position, shattering the rock and deforming it, and producing some metamorphism. The clay-shales now have a slaty structure, produced by pressure, which appears to coincide in most cases with the bedding. It was a time of intense eruptive activity. The Mariposa beds were injected with granite, and vast masses of diabase, associated with other basic igneous rocks, date from this time. 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.

The Mariposa beds carry numerous gold veins, the most important group of which constitutes the famous "Mother lode." It is believed that most of the gold veins were formed after this upheaval and as a consequence of it, occupying fissures opened during the uplift.

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

CRETACEOUS PERIOD.

By the close of the Juratrias the interior sea of North America had receded from the eastern base of the Sierra Nevada eastward beyond the Rocky Mountains. From the western part of the continent the waters of the Pacific had retired in consequence of the Juratrias uplift. The Valley of California was then partly under water, and the Coast Ranges seem to have been represented by a group of islands, but during the later Cretaceous the region subsided and the sea substantially overflowed it. Through gradual changes of level the areas of deposition of marine sediments were shifted during the Cretaceous and Neocene periods, and late in the Neocene the sea once more retreated west of the Coast Ranges. The deposits laid down during this last occupation of the Valley of California belong to the Superjacent series.

The advance of the sea spread a conglomerate over the eastern part of the valley in later Cretaceous time, and sandstone and shale were subsequently deposited. This formation is well developed near Chico, and at Folsom, on the Sacramento sheet. It has been called the Chico formation.

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, and it is extensively developed in the southern and western portions of the Valley of California.

NEOCENE PERIOD.

The Miocene and Pliocene ages, forming the later part of the Tertiary era, have in this atlas been united under the name of the Neocene period. During the whole of the Neocene the Great Valley of California seems to have been under water, forming 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 in sensible conformity to it. Marine deposits of the age of the Ione formation are known within the Gold Belt only in the Marysville Buttes. Along the eastern shore of the gulf the Sierra Nevada, at least south of the 40th parallel, during the whole of the Neocene, and probably also during the Eocene and latest Cretaceous, formed a land area 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 brackish-water deposits of clays and sands, and frequently it contains beds of lignite.

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. The Auriferous gravels for the most part accumulated in the beds of these Tertiary 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.

The climate of the late Neocene was warm and humid, much moister than it would have been if the Great Valley had been above water, and erosion was correspondingly rapid.

A mountain-building disturbance occurred during the Neocene period. This was caused by pressure acting from the SSW. toward the NNE. with a downward inclination. One effect of this pressure was to induce movements on a network of fissures, often of striking regularity, intersecting large portions of the range. It is not improbable that this fissure system originated at this time, but there are fissures of greater age. This disturbance also initiated an epoch of volcanic activity accompanied by floods of lavas* consisting of rhyolite, andesite, and basalt, which continued to the end of the Neocene. These lavas occupy small and scattered areas to the south, increasing in volume to the north until, north of the 40th parallel, they cover almost the entire country. They were extruded mainly along the crest of the range, and often followed fissures belonging to the system mentioned above. The recurrent movements on the fissures were probably accompanied by an increase in the development of the fissure system. An addition to the gold deposits of the range attended this period of volcanic activity.

When the lavas burst out they flowed down the river channels. Sometimes they were not sufficient to fill the streams, and are now represented by layers of "pipe clay" or similar beds in the gravels. These minor flows were chiefly rhyolite. 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 facies of the flora is thought to indicate a low elevation, and has been compared with that of the flora of the South Atlantic Coast of to-day.

PLEISTOCENE PERIOD.

During Cretaceous and Tertiary time the older

*The term "lavas" 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.

Sierra Nevada had been reduced by erosion to a range with gentle slopes. An elevation of the range doubtless attended the Neocene disturbance above referred to, and minor dislocations probably recurred at intervals; but at the close of the Tertiary a greater uplift occurred, which was accompanied by the formation of normal faults. These were widely distributed throughout the range, particularly along the eastern escarpment, where they form a well-marked zone to the west of Mono Lake and Owen Lake. As a consequence of this elevation the streams, having greater fall, cut new and deep canyons in the hard but shattered base of the preexisting mountains.

A period of considerable duration elapsed between the emission of the lava flows which displaced many of the rivers and the time at which the higher Sierra was covered by glaciers. In the interval most of the deep canyons of the range were cut out. 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 was often facilitated by the fissure system referred to above, and many of the rivers of the range follow one or other set of parallel fissures for a long distance.

It is a question at what point the limit between the Neocene and Pleistocene should be drawn. It has become usual to regard the beginning of the Glacial epoch in eastern United States as the close of the Neocene. If it could be shown that the glaciation of the Sierra was coeval with that of northeastern America a corresponding division would be adopted. It is believed, however, that glaciation was much later in California than in New England, and that the great andesitic flows mark the close of the Neocene.

The Sierra, from an elevation of about 5,000 feet upwards, was long buried under ice. The ice did not to any notable extent erode the solid rock in the area which it covered, although it removed enormous amounts of loose material. It seems rather to have protected it from erosion while intensifying erosion at the lower elevations, just as would a lava cap. Small glaciers still exist in the Sierra.

There is no valid reason to believe that the Sierra has undergone any great or important dynamic disturbance since the beginning of glaciation. The whole mass, however, has risen bodily a few hundred feet during that time, as is shown by elevation of the Pleistocene shore gravels in the foothill region, by the raised beaches along the coast-line of California, by recent shells in the Contra Costa Hills, and by other significant indications.

IGNEOUS ROCKS.

Rocks of igneous origin form a considerable part of the Sierra Nevada. The most abundant igneous rock in the Sierra Nevada is granite, this term embracing both granodiorite and true granites. 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. Thus granite is a deep-seated rock, and is exposed only after great erosion has taken place.

The rocks called diabase and augite-porphyrite on the Gold Belt maps are not always intrusive, but to some extent they represent surface lavas and correspond to modern basalt and augite-andesites. In like manner, some of the hornblende-porphyrites correspond to hornblende-andesites.

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 series of sheets is as follows:

Gabbro.—A granular intrusive rock consisting principally of diallage or allied monoclinic pyroxene, or a rhombic pyroxene, together with soda-lime and lime feldspars.

Gabbro-diorite.—A term used to indicate areas of gabbro containing primary and secondary hornblende and areas containing intimate mixtures of gabbro and diorite.

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

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

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

Diorite.—A granular intrusive rock consisting principally of soda-lime feldspar and hornblende.

Granodiorite (quartz-mica-diorite).—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 granitic rock might be called quartz-mica-diorite, but this term, besides being awkward, does not sufficiently suggest its close relationship with granite; it has therefore been decided to name it "granodiorite."

Granite-porphyry.—A granite with large porphyritic potash feldspars.

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 dynamo-metamorphic processes from diabase and other basic igneous rocks.

Diabase.—An intrusive or effusive rock composed of augite and soda-lime feldspar. The augite is often partly or wholly converted into green, fibrous hornblende, or uralite.

Augite-porphyrite.—A more or less fine-grained rock of the diabase series, with porphyritic crystals of augite and sometimes soda-lime feldspars.

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, together with a small amount of hornblende or biotite. It is connected by transitions with granodiorite and with the following:

Quartz-augite-porphyrite.—This is the same as the above, except that it contains augite. It is connected by transitions with augite-porphyrites and with quartz-porphyrites.

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, often glassy.

Andesite.—An effusive porphyritic rock of Tertiary or later age. The essential constituents are soda-lime feldspars and ferromagnesian silicates. The silica is usually above 56 per cent.

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

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.	al		1–100	Soil and gravel.
		River and shore gravels.	grv		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	Mariposa.	Jm		1,000 or more	Black clay-slate, with interbedded greenstones and some conglomerate.
		Intrusive granitic rocks.	gr grd			UNCONFORMITY.
	Carboniferous and Older	Calaveras.	Cc		4,000 or more	Argillite, limestone quartzite, chert, and mica-schist, with interbedded greenstones.
		Intrusive granitic rocks.	gr grd			

DESCRIPTION OF THE SMARTSVILLE SHEET.

TOPOGRAPHY.

The Smartsville atlas sheet includes the territory between the meridians of 121° and 121° 30′ west longitude and the parallels of 39° and 39° 30′ north latitude. The area is 34.5 miles long and 27 miles wide, and contains 925 square miles. It embraces portions of Butte, Yuba, Sierra, Nevada, and Placer counties, California.

Relief.—The area includes a part of the foothill region of the Sierra Nevada and, in the southwestern corner, a small part of the nearly level lands of the Sacramento Valley, the elevations ranging from about 50 feet above sea-level in the southwestern corner to 4,200 feet in the northeastern corner. The characteristic feature of the lower foothills is a series of more or less parallel, rocky ridges, running in a northerly or north-northwesterly direction. This is especially marked in Yuba County, where the ridges, beginning with the ridge west of Browns Valley, rise successively higher until the most prominent of all, the Oregon Hills, is reached. In the lower part of Nevada County and in Butte County this character is less pronounced, erosion having produced there a more irregular and broken, hilly country. In the eastern part of the tract another type of topography appears, consisting of irregular and broken plateaus, gently sloping westward. The first of these table-lands is found in the vicinity of Indian Springs, at about 1,500 feet above the sea; from this a steep ascent leads up to the Grass Valley Plateau, at an elevation of about 2,500 feet. The country between the forks of the Yuba River might also be regarded as a plateau, greatly cut up by later and more active erosion. The general surface of these highlands is broken, however, by numerous hills, which rise several hundred feet above the general level.

Drainage.—The principal watercourses draining this territory are the Yuba and Bear rivers, the former separating in three forks in the eastern part of the tract. Important tributaries of Yuba River are Dry and Oregon creeks, in Yuba County, and Deer Creek, in Nevada County; whereas Wolf Creek empties into Bear River in the southeastern corner. Butte County is drained by the various forks of the Honcut, which discharges its waters into Feather River. Through the ridges and plateaus of the foothill region the principal watercourses have carved rugged and narrow canyons to a maximum depth of 2,000 feet, the deepest being those of Yuba River and its principal forks. Beyond the mouths of their rocky gorges Yuba and Bear rivers meander over broad, sandy flood-plains, built up in recent years by the débris brought down from the gravel mines. The flood-plain of Yuba River is, at the western margin of the tract, nearly 3 miles wide, and the bed of the river is in places higher than the surrounding older alluvial country, which therefore requires protection by levees. Considerable quantities of sandy and gravelly débris are still lodged along the courses of the Yuba and Bear rivers, although hydraulic mining with direct discharge into the rivers has been stopped by legal proceedings since 1886. This débris is steadily moving down stream during the freshets of the winters, and if no large masses be added in the future the rivers will eventually scour their canyons of all except the very coarsest material.

Erosion along the principal watercourses has thus been intensely active, and is still active in a lesser degree. The rivers are torrential in character, and break through their gorges in rapids alternating with reaches of more moderate fall. Thus Bear River, from Gautier Bridge to McCourtney Crossing, has a fall of about 80 feet per mile, while above the bridge it descends only from 50 to 60 feet per mile up to the eastern line of the tract. Yuba River from Bridgeport to De Guerre Point has a fall of about 40 feet per mile. Above this point the forks have a much heavier fall, amounting to about 100 feet per mile.

On the broken and irregular plateau between the main rivers erosion is progressing only with moderate rapidity, there being in many cases residuary soils resulting from the secular disintegration of the rocks in place. Along the lesser streams there is commonly a slight grade across the undulating foothill country, changing into rapid descent and cascades near the larger canyons.

Vegetation and culture.—Except for scattered oaks and willows along the rivers and creeks, the plain does not support any arboreal vegetation. The foothill region proper, that is, up to an elevation of 2,000 feet, is, as a rule, densely covered by digger pines (*Pinus sabiniana*), various kinds of oak, and brush (chaparral), the latter consisting largely of manzanita and Ceanothus. Above 2,000 feet the yellow pine (*Pinus ponderosa*) and various kinds of fir and spruce predominate. The principal timber regions in the tract are found in the Oregon Hills and in the northeast corner. The alluvial plains and part of the Pleistocene areas of the valley are used for the growing of cereals. Part of the foothill region is very rocky and rough, and suitable only for pasture. In places, however, good soils are found, which, without irrigation, will yield hay and cereals as well as grapes and various kinds of fruit, although the latter may be much improved by irrigation. Along the central granitic area deep soils are found from Swedes Flat down to Oregon House and Dobbin's ranch, as well as from Rapp's ranch down to Indian Springs and Penn Valley. The Grass Valley Plateau and the plateaus between the forks of the Yuba carry in many places deep residuary soils.

The annual rainfall, comprised between October and April, ranges from about 20 inches in the valley to 50 or 60 inches at an elevation of 3,000 feet. In the valley and foothills below 1,500 feet snow lies, when at all, only for a few hours. The mild climate renders possible the cultivation of the orange and other semi-tropical fruits up to an elevation of 1,500 feet, and at higher altitudes the fruits of the colder climates reach their best development.

Several ditches have been constructed for mining and irrigation purposes. The most important are: Browns Valley ditch, in Yuba County; capacity, 5,000 miner's inches; taking water from the north fork of the Yuba, below Bullards Bar. Eureka Lake Company's ditch, carrying water from the headwaters of Middle and South Yuba rivers down to North Columbia and North San Juan; capacity, 2,500 inches. The South Yuba Canal Company's ditches, supplied from the headwaters of South Yuba River and carrying water for mining and other purposes to Nevada City and Grass Valley, as well as to the divide between Bear and American rivers, farther south; these are very extensive, and the maximum capacity of the main ditch is 8,000 inches. The Excelsior ditch, taking water from the South Yuba a few miles above Jones Bar and carrying it down to the vicinity of Smartsville. The Milton ditch, tapping the headwaters of the Middle Yuba and supplying the gravel mines of French Corral.

GEOLOGY.

BED-ROCK SERIES.

This series consists of sedimentary rocks which were forced into a nearly vertical position at or before the post-Jurassic upheaval, together with the associated igneous rocks.

SEDIMENTARY ROCKS.

Calaveras formation.—The sedimentary rocks occupy but small areas in this tract. Usually they form elongated, narrow masses and streaks imbedded in the predominating igneous rocks. No fossils have thus far been found in the older sedimentary rocks within the limits of the map, but these rocks have, nevertheless, been referred to the Calaveras formation,—the southeastern areas on account of their similarity to strata of known Calaveras age in the vicinity of Auburn and New England Mills, and the northeastern areas on account of their petrographic similarity. The determination is, therefore, only tentative. The areas consist quite generally of more or less fissile clay-slates, black when fresh, but grayish when weathered; siliceous slates; and a grayish, dense, chert-like rock, probably derived by silicification from limestone. Occasionally smaller masses of a gray crystalline limestone are found. Sometimes sandstones occur, as, for instance, in the area just northeast of Grass Valley. No conglomerates have been found. As a rule the schistosity coincides with the stratification whenever the latter is clearly apparent, as, for instance, on Oregon Creek below Junction House; the strike is generally in a northerly direction, the dip being either vertical or, more frequently, at angles from 90° to 60° to the east. Though highly compressed and somewhat altered, the sedimentary rocks are, as a rule, clearly distinguishable as such, and have not been converted into crystalline schists, except at the contacts with the intruded igneous rocks, granodiorite and diorite; along these contacts the heat of the magma and the exhalations from it have usually recrystallized the slates to micaceous and quartzose schists. The altered zone is of variable width, seldom exceeding a half mile, and there is a gradual change to the unaltered rock. The diabase appears to have exercised far less influence on the sedimentary rocks through which it was intruded. Dikes are of frequent occurrence, the sedimentary rocks being older than most of the igneous masses. Places where the intrusion of dikes into sediments may be studied are, for instance, a little below Gautier Bridge on Bear River and in the canyon of Middle Yuba River below Badger Hill. The narrow, long-drawn form of the area extending from Bear River up to west of Nevada City is very peculiar. A short distance north of Bear River several narrow branching areas occur, which apparently have been pushed out in fan-shape by the intrusion of gabbro and serpentine. The area in the vicinity of Badger Hill is a part of the great, continuous area of sedimentary rocks of the middle slope of the Sierra, well shown on the Placerville and Colfax sheets.

A small isolated patch of slates on the south side of Bear River east of Wheatland bears great lithologic similarity to the Juratrias of Sailor Canyon, shown on the Colfax sheet, and may belong to a younger formation than the Calaveras. The characteristic Mariposa beds (Jurassic) are not positively known to appear in this tract, though black slates, more or less tuffaceous, occurring in a small area about a quarter of a mile southeast of Towntalk, between Nevada City and Grass Valley, are lithologically very similar to the Mariposa beds of Colfax.

IGNEOUS ROCKS.

The rocks of the Smartsville tract are, in contrast to those adjoining east and southeast, predominantly igneous and massive, being in a less degree affected and altered by mountain-building agencies.

Porphyrite and diabase.—A very large part of the Smartsville tract is occupied by fine-grained, dark-green, basic rocks, which comprise a closely related series of augite-porphyrites and diabases, the former being the more prevalent. Breccias and tuffs of both rocks form part of the series. The variations can not well be mapped as distinct areas. Subsequent alteration has caused important changes in this series, the most prominent of which is uralitization, or conversion of augite into secondary, green hornblende; these altered rocks, being also very fine-grained and dark-green, are not always easy to distinguish from the fresher specimens, and can not, as a rule, be separated from them in the field as distinct areas. Thus, specimens from many places would, if considered alone and without due regard to their original condition, be classed as dark, fine-grained diorites. Such products of alteration have often been referred to as epidiorite, but are more correctly called uralite-diabase and uralite-porphyrite.

The ridge west of Browns Valley, or the first hills of bed-rock appearing east of the Great Valley in Yuba County, are composed of a massive, dark-green augite-porphyrite with large augite crystals, the outcrops of which are rough and usually brownish in color. South of Yuba River the rock in the continuation of this ridge is more altered, containing a great deal of secondary hornblende.

The largest diabase and porphyrite area of the Smartsville tract extends through the center of the tract from north to south. As a rule the rock is dark-green and fine-grained, and varies in structure from a medium-grained, dark-green diabase to denser, dark-green, porphyritic diabases and still finer grained augite-porphyrites which occasionally show abundant tabular feldspar crystals; usually, however, the porphyritic structure is not very prominent. The fine-grained types are the most common. The direction of the outcrops often indicates a tendency toward schistosity.

Along a belt extending from the vicinity of Smartsville toward the Sugarloaf, on the Honcut, the porphyrite is amygdaloid, the cavities being filled with calcite. West of Spenceville a diabase-breccia occurs. At Lucas Hill the rock is a fine-grained diabase-breccia or tuff. Fine-grained porphyrites occupy the larger part of the Oregon Hills. Extensive uralitization has taken place, especially in the central and northern part of the area. The contacts with the granodiorite and gabbro-diorite are sometimes extremely sharp, as in Honcut Creek north of Sugarloaf, sometimes extremely ill defined, as about Flanly Peak, between Frenchtown and Dobbin, or between Oregon Peak and Yuba River. In many cases it is difficult to avoid the conclusion that a gradual transition exists between the diorite and the diabase.

Dikes of uralite-diabase are often found in abundance near the contacts in the granodiorite or gabbro-diorite of the central area; good exposures of these dikes are seen at the confluence of Willow and Dry creeks, north of Oak Grove; at Missouri Bar, on the Yuba; southeast of Dobbin; and in the canyon of Deer Creek below Anthony House.

The long wedge-shaped area north of Hansonville is separated from the surrounding granodiorite or gabbro-diorite by a very indistinct contact; it consists largely of a dark, fine-grained porphyrite or uralite-diabase, but contains also dike-like masses of gabbro or diorite.

The area east of Grass Valley and Auburn road is composed of some normal diabase, together with a great deal of diabase-porphyrite, with large white feldspar crystals; porphyrite breccias and tuffs also occur in this area. Toward Grass Valley and Nevada City, near the areas of granodiorite and gabbro of these vicinities, the rocks again contain much secondary hornblende. The rock from the North Star mine is an altered diabase-porphyrite; Osborne Hill is principally composed of old breccias of diabase and porphyrite; father north, south of Nevada City, the porphyrite contains apparently primary crystals of hornblende; west of Nevada City a wedge of this same area goes over into amphibolites of varying grain.

Granodiorite.—The large area extending from near Nevada City 18 miles toward the northern edge of the tract is of very uniform composition and texture. It is a light-colored, coarse rock, weathering in rounded outcrops, and consisting of quartz, large grains of black hornblende, black mica, smaller quantities of orthoclase, and much plagioclase (soda-lime feldspar). Between North San Juan and Freemans Bridge muscovite enters into the composition. A few small dikes of a hornblende-porphyrite (camptonite) occur in the South Yuba River northwest of Nevada City. Dikes of quartz-porphyrite and also of aplite are found at a few places. The granodiorite borders, with sharp, intrusive contact, against the Calaveras formation; toward the gabbro-diorite it shows either sharp contact or gradual transition. The area south of Grass Valley contains less biotite; the rock is harder and does not form such prominent rounded outcrops as in the Nevada City area. The small area on Bear River, in the southeastern corner, is similar to the Grass Valley granodiorite. Both areas are intrusive in the porphyrite, and border with sharp contact against it.

A small area of normal granodiorite is found in the first foothills due east of Wheatland. This is really the northward continuation of the large granitic area seen on the Sacramento sheet. North of this, in the foothills between Yuba and

Bear rivers, occur a series of dikes consisting of granodiorites, gabbro-diorites, and quartz-porphyrite. The latter rock is very fine grained; it weathers white, but when fresh is grayish, with a flinty fracture, and frequently shows small quartz crystals.

Enclosed in the main diabase area, there is in the central part of the tract an interesting and peculiar mass of coarsely granular rocks. The length of the mass is about 25 miles and the maximum width 8 miles. Topographically this area corresponds to a notable depression, caused by the more rapid erosion of the coarsely granular rocks. The southern end consists entirely of granodiorites of coarse grain, containing much quartz and plagioclase, some hornblende, and usually also a dark mica; orthoclase is present in smaller quantities. Parts of the area, as at French Corral, contain no mica and might be classed as quartz-diorite. From Squirrel Creek up toward Chaparral Hill the rock varies considerably in structure and grain. Extensive areas of gabbro-diorite occur in connection with this granodiorite, and frequent transitions between the two kinds of rock are found.

The granodiorite of Hansonville and Swedes Flat is essentially similar to the one just described. The rock is composed of quartz, plagioclase, orthoclase, and hornblende; biotite is usually wanting, but sometimes occurs to the exclusion of hornblende, and occurs with hornblende in the granodiorite of Natchez Honcut, northwest of Hansonville. In a few places the rock contains also a little augite. Dikes of a fine-grained, dark rock containing primary hornblende crystals cut the granodiorite. This rock is allied to camptonite. The coarse rock of the small, isolated area crossed by the road about 1½ miles east of north from Wyandotte is composed of quartz, plagioclase, and orthoclase with biotite, and may more properly be called a granite.

Gabbro-diorite.—Under this name are comprised several species of rock, connected by gradual transition in such a way that they can not conveniently be further subdivided on the map. They consist of normal gabbro, norite, hornblende-gabbro, and olivine-gabbro, all of which are frequently altered into uralite-gabbro; and also of the dark, basic diorites without much free silica. They are, in general, coarse-grained rocks of more or less pronounced dark color, and occur mostly near the contacts of the large granodiorite areas, from which they are separated sometimes by sharp contact, sometimes by gradual transition. In all cases the granodiorite is the relatively younger rock, as dikes of it are found in the gabbro-diorites. Shattered zones, in which the granodiorite forms the mass cementing the fragments of gabbro or diorite, are also common. Within the gabbro-diorite are areas of somewhat varying basicity, and whenever a sharper division appears between these it will be found that the darker rock is the older. These granodiorite-gabbro-diorite areas represent, in spite of their often rapidly varying composition, geologic units, intruded and consolidated within a relatively short time interval. The rock in the vicinity of Hansonville and Brownsville is a very coarse gabbro, separated by a very indistinct contact from the diabase-porphyrite wedge toward the west. The area between Challenge and Dobbin consists of mixed gabbro and diorite. North of Indiana ranch a coarse olivine-gabbro occurs. At Oak Grove the gabbro is exceptionally coarse, consisting of anorthite and diallage, converted to uralite. A little south of Oregon House occurs a beautiful hornblende-olivine-gabbro with very large hornblende crystals. Olivine-gabbros also occur near Kentucky ranch.

A little above Bridgeport a mass of dark diorite borders, with sharp contact, against granodiorite and is brecciated by the latter; at other places this same area of diorite changes gradually to granodiorite. Between Bridgeport and Rias Ford there is a gradual transition from granodiorite to micaceous gabbro, with hypersthene and diallage. Northeast of Sweet's ranch a smaller lenticular area of coarse gabbro occurs, which on the north appears to be cut off by a branch of the granodiorite area.

The granodiorite area of North San Juan and Nevada City adjoins along its contact many bodies of gabbro-diorite. At its northern end it changes by gradual transition to dark diorites, which continue up into the area shown on the Bidwell Bar sheet, adjoining. To the northwest of Bullards Bar a narrow strip of gabbro with some serpentine adjoins the granodiorite. The body of granodiorite to the north of Badger Hill changes in its inner part by transition to a hornblende-gabbro. Along the contact north and south of Patterson there are bodies of dark diorite without sharp contact with the granodiorite. The area adjoining the granodiorite northwest of Nevada City is of interesting character and very complex; often it borders against the latter rock with a sharp contact, but south of Yuba River it is less distinct. It consists of a light-colored uralite-gabbro, changing in the southern part to a diorite. In its northern part it is somewhat schistose, and portions of it might be more properly referred to as an amphibolite. Dikes of a light-colored rock allied to granodiorite, and consisting principally of feldspar and quartz, occur in the northern part, and have frequently been rendered schistose by the same pressure which changed the gabbro to amphibolitic rocks. Dikes of uralite-diabase are common in the southern section along Deer Creek. The long area to the west of Grass Valley contains a coarse, light-colored uralite-gabbro.

Pyroxenite, peridotite, and serpentine.—In the same way as the granodiorites contain peripheral areas of gabbro and diorite, the latter are frequently accompanied by smaller masses of pyroxenite, peridotite, and serpentine. Coarse, dark-green pyroxenite occurs in smaller areas, shading into gabbro, at several places west of Nevada City and north of Sweet's ranch. Unaltered peridotite, forming a black, coarse rock with peculiar dull luster, weathering red, occurs at several places in the serpentine between Nevada City and Newtown.

The peridotite and the pyroxenite are connected by numerous transitions. The serpentine in this tract is most intimately connected with the gabbro, pyroxenite, and peridotite, and was undoubtedly derived from either of these rocks, into which it frequently shades.

ALTERED IGNEOUS ROCKS.

Amphibolite.—It has already been mentioned that a large part of the igneous rocks of this area have been subjected to an alteration involving a change of the pyroxene to green, uralitic hornblende. When the change has gone still further, so that all of the original constituents are recrystallized and the rock is converted into an aggregate of secondary amphibole (in part uralite), albite, epidote, chlorite, and other minerals, it is called an amphibolite. It appears as a dark-green, usually fine-grained rock in which the plentiful small amphibole needles are often visible. It may be schistose or massive; the schistose varieties are often referred to as greenstone schists. Diabase, porphyrite, diorite, gabbro, and pyroxenite may be thus altered.

The largest area of schistose amphibolites is the one traversing the whole westerly part of the tract from north to south; it is connected with the porphyrites on both sides by gradual transitions. Exposures near Browns Valley and Brady ranch show conclusively its derivation from these rocks by pressure and chemical action. The rocks show well-defined schistosity up to the northern part of Yuba County, breaking in flat, roughly lenticular pieces. The schistosity is less marked north of the Honcut, and parts of the area are there massive amphibolites. In places it contains some pyroxenite, as, for example, a half mile east of Wyandotte, and it may have been derived from other rocks than porphyrites.

East of the Oregon Hills, beginning at the edge of the Smartsville tract, near Challenge, is another belt of greenstone schists. The part west of the narrow area of Calaveras formation is derived from porphyrites or porphyritic tuffs, as may be seen near Pikes County Peak. The eastern part of the amphibolite area is of coarser grain, and undoubtedly was derived from gabbro-diorite. The belt of amphibolite continues southward, closely following the granodiorite contact, and is well exposed near Bullards Bar. South of the junction of North Yuba and Middle Yuba rivers it breaks up into several belts, separated by more massive but still very much altered porphyrite. The area between Rough and Ready and Wolf Creek Mountain consists of massive and often coarse amphibolites, which have, without much doubt, been derived from the adjoining gabbro and diorite areas. The grain changes rapidly in this area, and less altered, ill-defined masses of diorite and gabbro are included in it. The small area west of Nevada City shows its derivation from diabases and porphyrites very plainly and is only imperfectly schistose.

The northeastern corner of the tract contains a peculiar area of dark-green, amphibolitic rocks, mostly massive, which have a decided tendency to form serpentine, and which, south of Oregon Creek, change into fresher rocks of diabasic character. In parts of this area the rocks are quite coarse, and possibly are derived from gabbros. Near Youngs Hill, and also in the dike a mile east of Junction House, an altered rock with porphyritic feldspar crystals appears, which seems to have originally been a diabase-porphyrite.

AGE OF THE IGNEOUS ROCKS.

The oldest rocks are doubtless the Calaveras slates (Carboniferous and earlier) and the basic, igneous rocks associated with them in the northeastern corner of the area. There is evidence tending to show that these igneous masses are nearly contemporaneous with the slates, although it is probable that the Calaveras formation was uplifted, folded, and compressed long before the igneous rocks of the western foothills were formed. There is further evidence to support the belief that the largest part of the igneous rocks are of late Juratrias (Jurassic) or early Cretaceous age.

The evidence regarding the age of the main porphyrite and diabase area is not conclusive, and it is indeed very probable that different parts of it may be of different epochs. In the southwestern part of the tract granodiorite and associated dike rocks are intruded into the diabase. These rocks are the continuation of the Rocklin granodiorite area (Sacramento sheet), which, without doubt, is post-Jurassic. There is also good evidence that the granodiorite of Nevada City is later than the more or less altered diabasic rocks to the south and west of it, and it is certain that the granodiorite of Grass Valley and that in the southeastern corner of the tract were intruded into the surrounding porphyrites. But in the mixed granodiorite and gabbro-diorite areas of the central part the evidence along the contacts is that both rocks are cut by an abundance of diabasic and porphyritic dikes, usually uralitized, and which appear identical with porphyrite and diabase of the main area. Thus at least a part of these are later than the gabbro and granodiorite. In some places there are indications of a gradual transition between coarse granitic rocks and fine-grained diabases and porphyrites.

The petrographic character of a large part of the porphyrite area indicates that the igneous masses should be considered as very heavy surface flows rather than as intrusive bodies, and if this view is correct the area marks the site of a series of volcanoes of late Jurassic or early Cretaceous age, which probably covered with their now eroded ejectamenta a large section of the Gold Belt to a depth of several thousand feet. Into these heavy beds bodies of granodiorite were subsequently intruded. This is confirmed by the occurrence—principally in the southern part of the area—of large masses of porphyritic and diabasic breccias and tuffs. Occasionally these tuffs are stratified; thus, heavy tuffaceous beds dipping west at a gentle angle are found on the south fork of Wolf Creek 1 mile below the crossing of the Grass Valley and Colfax road. Similarly stratified, old tuffs are noted on the Sacramento sheet in a railroad cut near Clipper Gap, and there traces of schistosity with easterly steep dip are superimposed upon them.

The general sequence of igneous rocks during the Mesozoic eruptions would thus seem to have begun by the intrusion of gabbro-diorite and granodiorite, followed by the extrusion of great quantities of diabases and porphyrites; and larger intrusions of granodiorite ended the eruptive activity. The question of the relative age of the diabase and porphyrite on one hand and of the gabbro and diorite on the other can not be regarded as settled; although part of the former is certainly later than the latter, it is doubtful whether this is always the case.

STRUCTURE OF THE IGNEOUS ROCKS.

After the close of this intense volcanic activity a post-Jurassic epoch of mountain-building followed, during which the erupted masses were subjected to strong dynamic action, which, however, was principally concentrated as an intense shearing strain along two zones. This strain did not result in a single fault, but was distributed over a certain width, producing a schistosity, usually attended with more or less extensive chemical alteration of the rock. The process which produces shearing and chemical changes is usually termed dynamo-metamorphism.

The first zone extends along the lower foothills from Butte County to Bear River, and is indicated by a belt of schistose amphibolites. It continues into the Sacramento tract, and was formed certainly before the intrusion of the Rocklin granodiorite massive. The second zone begins in the vicinity of Challenge and extends as a curved line across the sheet by Birchville, Newtown, Wolf Creek Mountain, and Gautier Bridge. In the upper half of the area it is characterized by a belt of schistose amphibolite and granodiorite of varying width. Between Bullards Bar and Sweetland it is very narrow and follows strictly the granodiorite contact. The displacement on many small faults elsewhere may here be concentrated in one fault. In the lower half of the area the zone of metamorphism is marked by the intensely altered but massive amphibolites of Wolf Creek Mountain. South of this it is less distinct, but appears again north of Auburn, in the Sacramento tract.

Schistose granodiorite is found only along the contact south of Bullards Bar, and appears as a light-colored, imperfectly fissile gneiss, bearing evidence of violent dynamic action. It is not usual to find, as we do in this place, that the granodiorite of the latest intrusion is schistose, and its occurrence may indicate that the meta morphism of this western belt has been produced somewhat later than the first-mentioned zone.

Besides these larger zones of dynamic action, the rocks of the area are cut in numerous places by smaller systems of fracture, along which circulating waters, probably ascending hot currents, have deposited auriferous quartz. These fractures, a few of which are accompanied by considerable dislocations, were produced at the close of the post-Mariposa mountain-building period. The largest faults are on the Merrifield vein, extending from the Providence mine probably for 2 or 3 miles in a north-northwesterly direction, and on the contact vein extending from the Providence mine in a northwesterly direction, following the contact of granodiorite and the Calaveras formation. On both of these veins, which dip toward the east 40°, overthrusts of from 800 to over 1,000 feet on the plane of the vein have taken place. The latter dislocation appears to continue down toward the diorite and granodiorite contact on the South Yuba, though probably not as a single fissure but as a system of branching veins.

SUPERJACENT SERIES.

This series consists of late Cretaceous, Eocene, Neocene, and Pleistocene deposits, lying unconformably upon the Bed-rock series, together with igneous rocks of the same periods.

NEOCENE.

Ione formation.—During the Neocene period, and contemporaneously with the accumulation of the auriferous gravels on the slopes of the Sierra Nevada, there was deposited in the gulf then occupying the Great Valley a sedimentary series consisting of clays and sands, to which the name Ione formation has been given.

There are very few exposures of this formation, most of it being either covered by the Pleistocene beds or removed by erosion before their deposition. Good outcrops of the clays and sands comprising this series are found on Dry Slough, 8 miles northeast of Wheatland, and also on the road to Spenceville, 5 miles from Wheatland. At the former place the beds are about 15 feet thick, dip gently southward, and are overlain unconformably by thin Pleistocene gravels. At the latter place impressions of fossil leaves are found in a yellowish clay. West of Brady ranch, 20 feet of whitish clay and sandstone underlie the andesitic conglomerate. Along the Honcut the Ione formation appears to have been almost entirely eroded away before the deposition of the Pleistocene clays and gravels.

Auriferous gravels.—The Neocene topography of this tract differed materially from its topography of to-day, but the difference in the configuration is, on the whole, less marked than in some other tracts, the principal reason being that a large part of this district was never covered by volcanic flows, and consequently the older drainage is to some extent preserved. The principal feature in the Neocene topography was the high and rugged diabase range of the foothills, rising to an elevation of over 1,500 feet above the rivers. To the east of this high foothill range, on the middle slopes of the range, gentler outlines prevailed, but the general character was still decidedly hilly and undulating. The principal river then draining the area corresponded closely to the present Yuba River. Though Bear River existed, it was only as a less important creek, for in the adjoining Colfax area the south fork of the Neocene Yuba River cut off the present upper drainage of the Bear. The Neocene channel at Bangor may be considered as representing, in part, the present Honcut Creek.

In tracing the Neocene drainage in detail many difficulties are met with on account of the great extent to which the Neocene deposits have been removed by erosion. A large part of the gravels are only partly or not at all covered by volcanic material, erosion having largely removed the latter. The main channel of the Neocene Yuba enters the area east of Patterson, and, forming a curve convex to the south, is at Badger Hill crossed by the canyon of the present Middle Yuba, which has here cut down to a depth of 1,000 feet below the old channel. From Badger Hill to North San Juan the main Neocene channel must have followed the present river canyon. From North San Juan to French Corral the course is unmistakably marked by a succession of gravel areas, now largely removed by hydraulic mining. Along this course the bed-rock hills rise on both sides above the Neocene channel, showing very clearly the character of the comparatively narrow and steep river valley. Through the rocky diabase ridges of the foothills there is but one possible outlet for this channel, namely, at Smartsville, at the same place where the present river breaks through these diabase hills. Between Smartsville and French Corral there is but one course which the old river could have followed, namely, the river canyon of to-day, and as a consequence nearly all traces of the deposition between these two points were removed as the canyon was deepened. At French Corral the depth of post-Neocene erosion is about 700 feet, while at Smartsville it is not more than 200 or 300 feet.

This main stream received, near Badger Hill or San Juan, a tributary from the vicinity of Camptonville, as indicated by Galena Hill, Weeds Hill, and Depot Hill (southeast of Oak Valley). This north fork of the Neocene Yuba River headed farther northeast, in the Downieville area. Near French Corral, Yuba River must have received another tributary, which headed south of Nevada City and the course of which is probably indicated by the Manzanita channel (at Nevada City), Round Mountain (4 miles north of Nevada City), and Montezuma Hill. Another tributary, heading in the vicinity of Grass Valley and Nevada City, is pretty clearly indicated by a few remaining areas; it probably emptied near Mooney Flat. A large section of the channel is preserved at Smartsville, the topography showing clearly the comparatively narrow character of the old canyon cut through the diabase and porphyrite ranges. Below Smartsville the course of the channel was approximately identical with the present river. Fragments of the channel are preserved at Sicard Flat and on the south side of Yuba River about 6 miles west of Smartsville. The shallow gravel in the valley of New York Flat, in which mammalian remains have been found, probably also belongs to the Neocene period. The Neocene channel at Smartsville has a grade of 113 feet per mile; the French Corral-San Juan channel, 65 feet per mile; the Camptonville channels, about 112 feet to the mile; the Badger Hill channel is almost level; the Manzanita and Cement Hill channels of Nevada City have a very slight fall. The grades of the old channels with westerly or southwesterly direction have probably been greatly increased since Neocene time by the tilting of the Sierra Nevada.

The auriferous gravels which accumulated in the Neocene river bottoms may be divided into two classes: first, those that antedate the Neocene volcanic activity in the Sierra Nevada; and second, those that were contemporaneous with the rhyolitic and andesitic eruptions. The former consist of coarser and finer gravels of well-rounded pebbles of quartz and siliceous metamorphic rocks, with some sand. The color of the gravel banks in fresh exposures is usually white or yellowish. To this class belong the Camptonville gravels and the large accumulation from east of Patterson down to French Corral. The thickness of these beds is variable, but often considerable, averaging 150 feet between French Corral and San Juan and reaching 400 feet east of Patterson. These accumulations are heavier along the old Yuba River than along any other Neocene streams of the range. One of the causes producing this accumulation was certainly the presence of a barrier near the mouth of the river, consisting of a high ridge of hard porphyrite and diabase through which the stream must wear its way, thus, as it were, impounding the gravel in the upper course, which was characterized by wider valleys and more gently undulating outlines. The gravels on the tributaries of the main river had probably not accumulated to any considerable depth at the beginning of the volcanic period. At least such is the evidence gathered near Nevada City and Grass Valley.

The well-worn gravel of the old river channel to the north of Bangor is undoubtedly of Neocene age. The gravel of this channel merges into heavy shore gravels, which are thought to be largely of Neocene age, and which grade into Pleistocene shore gravels; the line separating the shore gravels of the two periods must be taken as an approximate one.

Gravels which occur interstratified with rhyolitic or andesitic material are found at several points. The upper part, at least, of the gravel at Smartsville and Sicard Flat is of this character and contains many pebbles of andesite. The total depth of gravel at the former place is not less than 200 feet. Most of the gravels of Nevada City also belong to the earlier part of the volcanic period, as rhyolitic tuffs are found low down in the series exposed there. The maximum thickness at the Manzanita mine is about 200 feet. Gravel, chiefly of siliceous, dark, metamorphic character, is exposed northwest of the city to a thickness of 60 feet.

Several of the smaller gravel areas exposed between Mooney Flat and Rough and Ready carry andesitic and metamorphic pebbles mixed, and belong to the volcanic period.

A period of erosion intervened between the rhyolitic and the andesitic eruption, but it was not of long duration, and the time did not suffice to establish well-defined and independent channels of the volcanic period.

The high, isolated area of well-washed gravel 3 miles north-northwest of Montezuma Hill is noteworthy; it is so much higher than the adjacent gravel channel of North San Juan that it must be assumed to belong to an earlier period.

Rhyolite.—The heavy volcanic flows which usually overlie the auriferous gravels are not extensively represented in this tract. The earliest eruptions of the Neocene volcanoes in the portion of the high Sierra east of this tract were of rhyolitic character, and swept down as mud-flows along the valley of the old South Yuba in the Colfax area. In the Smartsville area they are eroded along the principal channel. The only rhyolitic beds of importance are found immediately north of Nevada City, at Round Mountain (4 miles north of the same place), and at Montezuma Hill. These mud-flows poured into the Nevada City drainage basin from one or two low gaps separating it from the valley of the old South Yuba to the eastward, and reach, in the vicinity of the Sugarloaf, north of Nevada City, a total thickness of between 200 and 300 feet. They consist of white or light-colored sands, sometimes consolidated as soft sandstone, and sandy clays interstratified with gravels in such a manner that it is extremely difficult to draw the line between the two formations. The gravels, however, predominate in the lower part of the series. Some of these white sandstones or clays consist entirely of rhyolitic fragments, but others are mixed with detrital material from the surrounding formations.

Andesite.—Where no rhyolite is present the andesitic beds directly overlie the auriferous gravels. The lower part of the andesitic series usually consists of heavy volcanic gravels and tuffs which contain no gold, or only traces of it. The upper part is formed by a compact gray or brown andesitic breccia, with large angular fragments of andesite, cemented by finer, ground-up andesitic detritus. This breccia came down as successive mud-flows from the volcanic vents located near the summit. The maximum thickness of the andesitic beds is 300 feet. The present areas represent but a small portion of the volcanic sheet once covering the country. At some places where there is no andesite at present, as at French Corral, small patches remaining in the vicinity, such as the small area 3 miles north-northwest of French Corral, show that the depth of volcanic material must have been very considerable. It is evident that the andesitic flows once covered a large part of the northeastern section of the Smartsville tract, but the Oregon Hills and the high diabase ridges of the foothills were not buried. At Smartsville the volcanic capping consists of alternating strata of conglomerate or compact gravel and compact tuff; the thickness does not exceed 150 feet. Below Smartsville the andesitic masses spread out and form a large area skirting the foothills for some distance south at an elevation of about 200 feet; they are here comparatively thin, being not over 50 feet thick, and consist of black volcanic gravel or conglomerate, capped by a thin layer of andesitic breccia. To the west the andesitic beds soon disappear under the Pleistocene covering.

PLEISTOCENE.

Earlier Pleistocene.—After the close of the eruptive activity in this part of the Seirra Nevada the Great Valley was still occupied for a long time by a body of water, in which a series of sediments were deposited. These are referred to the earlier Pleistocene. During this time-interval the canyons were most rapidly excavated, and toward the end of it the higher part of the Seirra Nevada was glaciated. The line between the Neocene and the Pleistocene has been drawn so as to include in the Pleistocene everything of later age than the last flow of andesitic breccia. It is, of course, an arbitrary line, but forms the best and most definite horizon identifiable over considerable areas.

The earlier Pleistocene appears in several areas, separated by shallow alluvium, and bordered on the east by the diabase of the lower foothills. The surface is gently undulating, and the soil is gravelly and poor in character; in places flat-topped hills occur, dipping gently westward.

The series, which in some places is seen to rest unconformably on the Ione formation, consists of gravels, clays, and hardpan, together with small amounts of volcanic tuff. The gravel is largely made up of siliceous pebbles.

The hardpan is a firm, cemented, sandy clay of rusty-brown color. The cement of this material consists mainly of hydrous silicates of iron. Good exposures are seen along the lower Honcut, on the road from Brady ranch to Wheatland, near the southern contact of the andesitic area, and in several places northwest of Wheatland along Dry Slough. The scattered Pleistocene gravels reach up to about 350 feet above sea-level, and at lesser elevations thin patches of them are found in many places on the diabase and andesite of the foothills. They have not been indicated on the map except when thick enough to hide the underlying rock. The total thickness is not known, but it probably does not exceed 100 or 200 feet within the limits of this sheet.

The heaviest gravels are in the northwest corner of the tract, in Butte County. The gravels there represented as Pleistocene merge into gravels, presumably Neocene, which extend above the 500-foot contour. In the field it seemed impossible to draw any line between these higher gravels and those below 350 feet in elevation. These heavy-bodied shore gravels contain very little gold, but they have been washed superficially south of Oroville.

A well has been sunk at Wheatland to a depth of 500 feet. The upper 150 feet were bored through gravel, clay, hardpan, and sand; the lower 300 feet, exclusively through a greenish sand. This latter is presumably either Tertiary or late Cretaceous. The water rises to within 14 feet of the surface, but does not overflow.

Probably of the same age as the Pleistocene deposit of the plain are the small patches of gravel scattered along the upper course of Yuba River, at an elevation above it of from 20 to 100 feet.

Alluvium.—The present system of watercourses is steadily degrading the older formations and depositing the sediment on flood-plains, forming bottom-lands of greater and smaller extent. These fluviatile deposits forming at the present day are referred to as *alluvium*, and consist partly of black, humus soil, which supports an abundant vegetation, partly of sands, fine gravels, red loam, and clays. Considerable areas of these deposits are found in the southwestern part of the tract. They are very shallow, and, as a rule, rest on the earlier Pleistocene, from which they are not separated by any distinct line. Reddish loams, more or less clayey, prevail in this tract, being the final product of the disintegration of the diabase areas to the east.

ECONOMIC GEOLOGY.

AURIFEROUS GRAVELS.

Origin and character.—The Sierra Nevada has been a land area at least since the latter part of the Cretaceous period. The numerous systems of auriferous, quartz-filled fissures formed before this time were, from then on, subject to the incessantly acting forces of erosion. As a consequence the larger part of the gold contained in these veins was gradually concentrated in the channels of the Neocene river system. By an upheaval of the range and accompanying volcanic outbursts the rivers were displaced. They then began to erode their new channels—the canyons of to-day—and the gold in the old alluvial masses, wherever cut away by the new river courses, was subjected to reconcentration. The finest particles were carried down to the Sacramento Valley, where they are now buried under deep sediments, but the greater quantity remained in the bars of the rivers and creeks, together with new accumulations of auriferous material set free by erosion of the new canyons.

These deposits, once very rich, are now practically exhausted, though a gradual process of concentration is still going on in the rivers in the auriferous débris washed down during the last decades from the hydraulic mines. Some of the river gravel is still washed over by Chinese, who are content with the small yield afforded. Gold is so universally present in the tract under consideration that probably no creek could be prospected without finding at least traces of it, and during the first few years succeeding 1848, gold mining was, in fact, restricted to the late Pleistocene alluvial deposits.

Nearly all of these gravels are now exhausted. The loose, detrital material that has been washed for gold east of Browns Valley Ridge (Prairie diggings), at Honcut City, Swedes Flat, and other places north of the Honcut, is made up of angular fragments, with only occasional well-rounded pebbles. It is undoubtedly of late Pleistocene age, and probably derives its gold from small quartz seams in the underlying rocks. Rich alluvial gravels have recently been worked 1 mile southeast of Sharon Valley.

The shore gravels of early Pleistocene age along the western border of the tract contain some gold, and have been mined superficially at many points, especially near the places where the rivers emerge from the foothills.

The remaining sections of Neocene channels, located, as the map shows, at a considerable elevation above the present watercourses, have been mined extensively. For large, well-exposed bodies of gravel, the hydraulic method of disintegrating and washing away the banks by means of water under heavy pressure has been generally used, though its employment is now permitted only for mines having facilities for storing their débris. A large portion of the gold in a mass of gravel is, however, always concentrated within a few feet of the lowest bed-rock in the channel, and this rich stratum is extracted by means of tunnels and drifts; this process, called drift mining, is the one now principally used in mining the old gravel channels.

Hydraulic mining on a large scale will pay if the gravels contain as little as 5 or 10 cents per cubic yard, while drift mining is not profitable unless they contain, at the very least, $1 per cubic yard.

The almost continuous deposits from San Juan to French Corral have been worked throughout their extent, and large parts of these areas are now exhausted; much gravel still remains, however, at the latter place. The maximum depth of these gravels is 250 feet. At Badger Hill, the outlet of the Big Columbia and North Bloomfield channels, and at Patterson, extensive hydraulic mining has been carried on. The gravels are here 300, and even 400, feet deep, and, except at Badger Hill, bed-rock has not been exposed in the center of the channel. The small gravel areas near Camptonville are almost exhausted, but much gravel still remains at Depot Hill, in the northeastern corner of the tract. An area of shallow Neocene gravel has been worked at New York Flat, and in this the gold appears to be largely derived from the adjacent Forbestown quartz veins. At Smartsville and Sicard Flat extensive hydraulic mines have been located. At the former place hydraulic washing is still carried on, the débris being stored in an old gravel pit. Drift mining is resorted to on the same channel, the deposits having been opened up from near Mooney Flat.

Several smaller areas of Neocene gravel between Mooney Flat and Nevada City have been worked by hydraulic or drifting process. A hydraulic mine is now being operated one-half mile northeast of Rough and Ready. A smaller channel, known as the Alta, has been drifted below the volcanic cover between Grass Valley and the Lola Montez diggings; another on which work is now done runs up under the south side of the Rough and Ready volcanic area; still another, from the western end of the volcanic area east of Grass Valley, up toward the eastern edge of the tract. A minor channel runs down from the vicinity of Towntalk, under the lava, to the western end of the same volcanic area.

The Manzanita channel, traversing the ridge just east of the Sugarloaf, north of Nevada City, has been very rich and was mined by the hydraulic and drift processes; drift mines (Odin and Manzanita) are still located on it. Northwest of Nevada City large gravel areas are found in the continuation of this channel; though large parts of these have been washed away, much gravel still remains. This channel is, at the western end of the gravel area, joined by a tributary, coming down under the volcanic cover from the western end of Cement Hill.

The Harmony channel, a smaller but rich tributary, comes down under the volcanic area northeast of Nevada City (Washington Ridge) and, bending to the north, emerges from under it about 2 miles north-northeast of Nevada City.

The gravels of Nevada City have a maximum depth of 150 feet, and are covered by heavy masses of clays and sands partly rhyolitic in character, above which the andesitic breccia rests. The channels at Round Mountain (north of Nevada City) and Montezuma Hill have been drifted. At Montezuma Hill the drifts run from northeast to southwest, below the volcanic masses. At both places there are heavy covering masses of clay. The small volcanic area south of Greenville has been worked by the hydraulic process, and contains andesitic gravel.

About 2 miles south of Wyandotte the Neocene shore gravels have been washed by the hydraulic process, and are well exposed. They contain layers of yellow, friable, micaceous sandstone.

The Neocene river channel to the north of Bangor has been mined by means of drifting from shafts.

Extensive alluvial gravel deposits derived from the hydraulic mines lie in Willow Creek near Camptonville, and in Deer Creek below Nevada City; these may, in the future, be worked over again.

GOLD-QUARTZ VEINS.

General relations.—The gold-quartz veins are *fissures* in the Bed-rock series filled with quartz containing native gold and metallic auriferous minerals. The quartz has been deposited by the mineral waters circulating in the veins. The fissures may be large or small, straight or irregular, though the large ones usually approach a plane in configuration. Sometimes a larger vein may split into a series of stringers. The strike and dip vary greatly in different veins, though at one and the same mining district there is usually a series of parallel fissures.

Nearly all of the quartz veins in this tract are younger than the latest granitic intrusion, and many of them cut the metamorphic schists formed after this intrusion; they are of either very late Jurassic or, more probably, early Cretaceous age. No long or continuous veins are found in this district, the greatest length being between 2 and 3 miles, and this is exceptional. Usually the croppings can be traced only for a few hundred feet.

The veins occur in almost any one of the many rocks making up the Bed-rock series; excellent mines are located in the granodiorite, diabase, slate, and schists. Nor can it be said that any certain direction or dip is especially favorable. Though the auriferous veins are scattered over the whole tract, there are certain parts which are decidedly richer than others, and some regions are nearly barren. The diabase and porphyrite areas of the foothills contain very few veins, and the same may be said of a large part of the central gabbro-diorite and granodiorite area. The porphyrites and breccias of the southeastern corner are very barren, and equally so are the diabase and porphyrite of Bear River.

The gold is seldom equally distributed through the quartz, but is concentrated in more or less regular bodies, or ore-chutes. These are usually of elongated form, and have a steep dip, and each vein may contain several of them, so that if one ore body is exhausted a thorough exploration of the vein will seldom fail to disclose another. There is no appreciable gradual impoverishment in depth in the veins, though the surface croppings of the ore-chutes are apt to be richer than any other part of the vein, this being due to surface decomposition. The deepest mine is the Idaho, near Grass Valley, which has attained a vertical depth of 2,100 feet. Gold ore containing as little as $1 or $2 per ton can, under exceptionally favorable conditions, be profitably mined and milled. The average tenor of ore from the deep mines is perhaps $10 to $15 per ton.

Detailed description.—The diabase area of the western foothills contains, at Browns Valley, a number of quartz veins on which considerable work has been done and which are known to have produced considerable gold, the deepest mine being 800 feet on the incline; of late years only one, the Hibbert & Burris mine, has been worked. On Lone Tree Hill, south of Yuba River, in the lowest foothills, a large but low-grade quartz vein was worked some years ago. In Albin Hill, southwest of Spenceville, are many small but rich veins which have been worked in a small way for a long time. The belt of amphibolitic schists extending thence northward contains many small seams and stringers which yield gold to local alluvial deposits. There are many small but sometimes rich veins (pocket veins) in the Swedes Flat granodiorite area. A number of gold-quartz veins, with northeasterly strike and easterly or westerly dip, occur in the vicinity of Hansonville and Brownsville, though none of them has been worked on a large scale. Several veins are also found near Indiana ranch, but little work has been done on them. The gabbro-diorite near Rough and Ready contains several veins rich in metallic sulphides. Along the granodiorite contact south of Bullards Bar many smaller auriferous veins are found. Others occur in the vicinity of the Limekiln (a few miles north of Pine Hill) and in the streak from here down to Bear River. The quartz-calcite veins at Nickerson's ranch contain some gold and silver, as well as copper.

By far the largest part of the metallic wealth of the tract is concentrated in the immediate vicinity of Nevada City and Grass Valley. The average annual production of gold for the last few years in these two districts has been about $1,300,000. At the former place there is a system of veins running north-south and dipping east about 40°; on them the Providence, Champion, Nevada City, Spanish, and Mountaineer mines are located. The first three are partly or wholly located on the contact, and large overthrust faults have taken place along them. Another system of veins at Willow Valley (Colfax sheet) has an east-west strike and dips northward. A strong and continuous vein (the Orleans-Glencoe), along which, however, but little work has been done, runs west-northwest in the slates just south of the granodiorite contact, and dips 70° south. Besides free gold, the veins of Nevada City carry from 2 to 10 per cent of sulphurets (iron, copper and arsenical pyrites, blend, and galena).

At Grass Valley there are several vein systems. One is parallel to the Orleans vein of Nevada City district, and the dip is usually at high angles to the south. On veins belonging to this system the Coe and Idaho mines are located. The latter, known as the deepest mine and greatest producer in the district, is located on a fault-fissure with a serpentine foot-wall and a diabase and gabbro hanging. Southeast of the Idaho there is another group of east-west veins, among which may be noted the Goldpoint, Union, and Brunswick. Another system contains the north-south veins, with a low westerly dip; among these is the strong and important group extending from the Empire mine down to Osborne Hill; further, the Omaha, Wisconsin, Hartery, and Allison ranch veins, and finally the W. Y. O. D. and Pennsylvania. The well-known North Star mine is located on an east-west vein, with flat dip northward, and has been mined to a depth of 2,200 feet on the incline. The porphyrite hill from the North Star up to Grass Valley is traversed by a great number of flat and narrow but rich veins. The Grass Valley veins are generally narrow, seldom over 2 feet, usually 1 foot, in width, but the gold is coarse and the pay shoots are often very rich; they contain less sulphurets than the Nevada City veins; iron pyrite predominates, though the mines of Osborne Hill carry much arsenical pyrite also.

About 3 miles west of Grass Valley there is another streak, in gabbro and amphibolite, containing workable quartz veins, among which are the California, Seven-Thirty, and Normandie.

Impregnations.—In a few smaller areas within the limits of this sheet the rock is thoroughly impregnated with auriferous iron pyrites, without containing any quartz veins or seams. This impregnation is probably due to the hot mineral waters at one time permeating these rocks. Whenever these impregnated zones have been subject to aerial decomposition the gold in the pyrite has been set free, and thus large bodies of very low grade but free-milling ore have been formed. Such deposits are located and worked near French Corral in granodiorite, and along the schistose streak running south from Sweetland. The Boss mine at Sweetland is working on these impregnated schists.

At Laffertys Peak occurs an area of diabase, altered partly to kaolin, partly to siliceous rocks, and carrying minute quantities of gold and silver. At Pine Hill there is a similar area containing seams of auriferous barite.

COPPER.

In the main diabase area of the lower foothills small quantities of copper ore, principally copper pyrites, are frequently found, partly as fissure veins, partly as slight impregnations in the schists. Between Spenceville and Smartsville there are many quartz veins, with a north-northwesterly strike, carrying copper pyrites and other copper minerals in not inconsiderable quantities; these ores are said to contain also some silver, but very little gold. Spenceville is the only place where the ores have been mined in any considerable quantity. The deposit is located near the contact of diabase and granodiorite, and is evidently a local massing of copper and iron pyrites along one of the above-mentioned veins. In the belt of schists extending from near Birchville to Bullards Bar several veins carrying auriferous iron and copper pyrites have been found. A heavy vein containing copper pyrites, quartz, calcite, and some gold is found near Nickerson's ranch.

QUICKSILVER.

One of the few occurrences of cinnabar in the Sierra Nevada is found near Nickerson's ranch, in the southeastern corner of the Smartsville area. The ore occurs sparingly scattered through a quartzose and dolomitic gangue on the contact of serpentine and quartzite.

IRON.

A few masses of iron ore occur along the contacts of the central area of granodiorite. One, a large deposit of magnetic iron ore, is found 4 miles south of Indian Spring, on the contact of granodiorite and diabase. Another occurs on the contact of granodiorite and Carboniferous slate 1 mile west of Newtown.

LIMESTONE.

The sedimentary rocks of the Calaveras formation contain a few scattered lenses of crystalline limestone. The only kiln in the area is located about 10 miles south-southwest of Grass Valley.

CLAY.

No extensive deposits of clay suitable for pottery are known to occur in the sedimentary formations. Ordinary impure brick clays are, however, common in the earlier Pleistocene and in the Ione formations. The composing porphyrites and diabases often produce a red clayey loam, in many places suitable for bricks. At Pine Hill some exceptionally pure kaolin occurs, together with much of the same material colored by iron; it is here derived from the decomposition of the diabases.

BUILDING STONES.

The granodiorite and gabbro-diorite would in most places furnish excellent building stone. It is quarried near Nevada City, but here contains a great many of the dark hornblendic patches which occur, to a greater or less extent, in all of these rocks. The diabase is also used locally, though it is less suited for building purposes than are the granites.

SOILS.

The alluvial soils are principally confined to the southwestern corner of the tract. The most common is a reddish loam, but dark adobe clays and light sands also occur. Of late years a reclamation of the sandy débris plains along the Yuba and Bear rivers has been carried on to some extent, wherever it has been practicable to construct levees.

The soils of the earlier Pleistocene, covering the first rolling foothills, are, as a rule, of a poor, gravelly character. The underlying hardpan often comes close to the surface.

The foothill soils comprise but little alluvium; nearly all of them are derived by secular disintegration of the rock in place, and may be characterized as *residuary* soils, not having been transported any distance. They may be classified in two groups:

Red soil, principally derived from diabases and gabbros. This is a strong soil, rich in plant food, and especially characterized by a high percentage of iron. It is well adapted for horticultural and viticultural purposes, though sometimes apt to be clayey and stiff. A variety of this red soil, equally good or better, is that found on the high andesitic tables along the eastern margin of the tract. In the lower foothills the andesitic areas are usually very rocky.

Granitic soil, principally derived from the secular disintegration of granodiorite. This is an excellent soil, often not so rich as the red soil, but easier to work, warmer, and deeper. The depth of the disintegration of the granitic areas on the ridges is often considerable, frequently reaching 100 feet.

The soil on the small Carboniferous area is usually poor. Many of the soils in this tract have been analyzed, and the results are published in the reports of the Agricultural Experiment Stations of the University of California.

WALDEMAR LINDGREN,
H. W. TURNER,
Geologists.
G. F. BECKER,
Geologist in Charge.

July, 1895.

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

TOPOGRAPHY

CALIFORNIA
SMARTSVILLE SHEET.

LEGEND

RELIEF
(printed in brown.)

- Figures *(showing exact heights above mean sea-level.)*
- Contours *(showing height above sea, horizontal form and steepness of slopes of the surface.)*

DRAINAGE
(printed in blue.)

- Rivers
- Creeks
- Intermittent streams
- Ponds and Lakes

CULTURE
(printed in black.)

- Towns and cities
- Houses
- Railroads
- Roads
- Bridges
- Fords
- Trails
- County lines
- Triangulation stations

Henry Gannett, Chief Geographer.
A.H.Thompson, Geographer in charge.
Triangulation by H.M.Wilson.
Topography by H.M.Wilson and A.F. Dunnington.
Surveyed in 1885 and 1886

Wilson
Dunnington

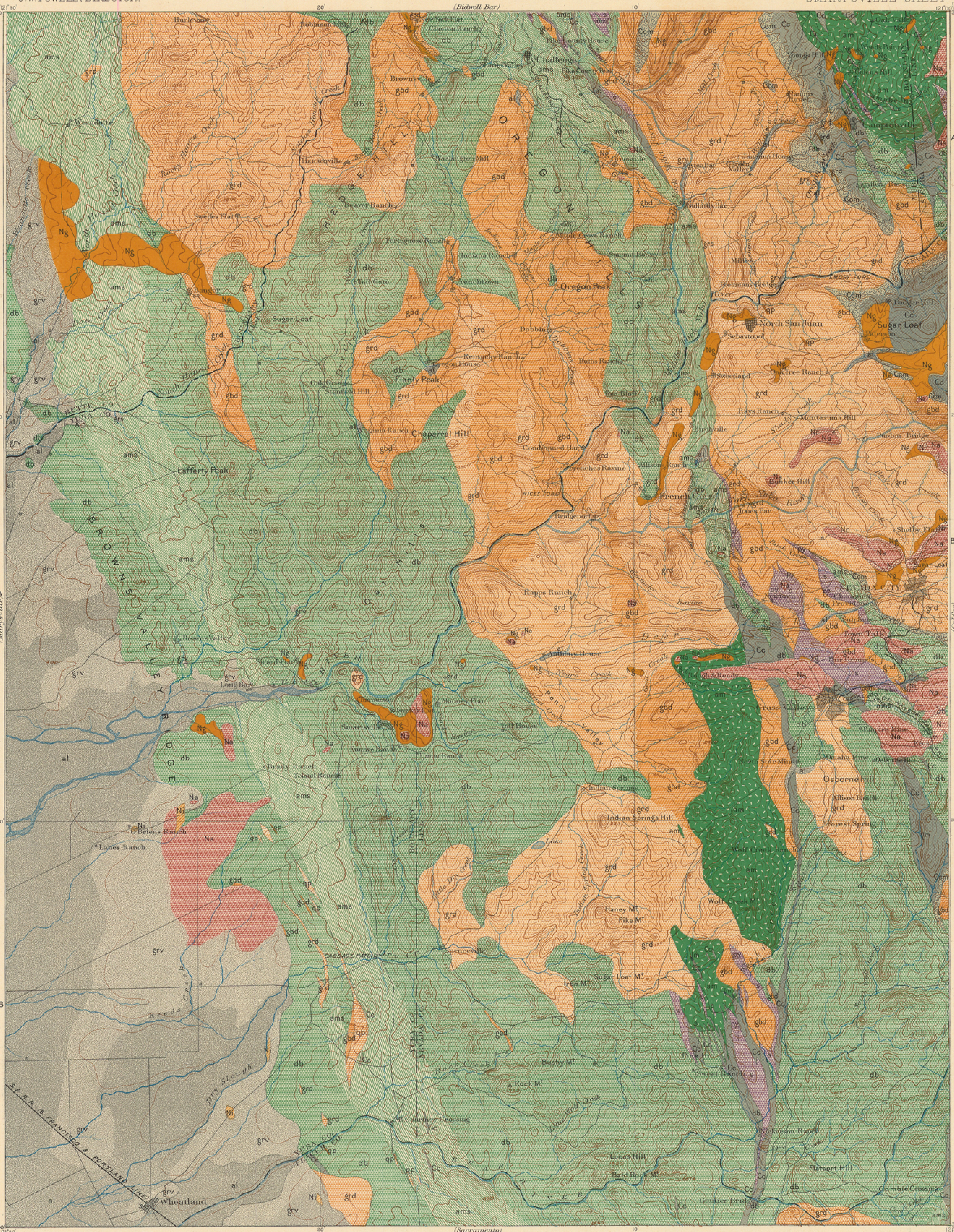
Scale $\frac{1}{125,000}$

0 1 2 3 4 5 Miles

Contour Interval 100 feet
Datum is mean Sea level.
Edition of April 1895.

AREAL GEOLOGY

CALIFORNIA
SMARTSVILLE SHEET



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Edition of April 1895.

Turner
Lindgren

Geo. F. Becker, Geologist in charge.
Geology by W. Lindgren and H. W. Turner.
Surveyed in 1886-91.

LEGEND

SUPERFICIAL ROCKS

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

PLEISTOCENE
- LATE — al — Alluvium *(bottom lands)*
- EARLIER — grv — Shore and river gravels and hardpan *(the gravels frequently contain gold)*

SEDIMENTARY ROCKS

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

SUPERJACENT SERIES — NEOCENE
- Ng — Auriferous river gravels
- Ni — Ione formation *(clay, sand, and gravel. Contains pottery clay and small coal seams)*

BED-ROCK SERIES — CARBONIFEROUS
- Cc — Calaveras formation *(slates, quartzite, and limestone, possibly in part early Mesozoic and older Paleozoic)*

IGNEOUS ROCKS

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

SUPERJACENT SERIES — NEOCENE
- Na — Andesite *(tuffs and breccias)*
- Nr — Rhyolite-tuff *(with some clay and gravel)*

BED-ROCK SERIES — EARLIER THAN THE LATE CRETACEOUS (CHICO FORMATION)
- grd — Granodiorite
- qp — Quartz-porphyrite
- gbd — Gabbrodiorite
- py — Pyroxenite
- pr — Peridotite
- s — Serpentine
- db — Porphyrite and diabase *(massive or fragmental, in part altered to amphibolitic rocks)*

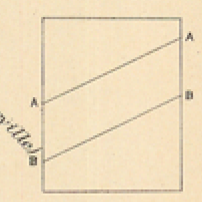
ALTERED ROCKS

(Areas of Altered rocks are shown by patterns of short dashes.)

CARBONIFEROUS
- Ccm — Contact metamorphic rock *(micaceous and quartzose schists of same age as Calaveras formation)*
- lm — Lenses in Calaveras formation *(limestone)*

EARLIER THAN THE LATE CRETACEOUS (CHICO FORMATION)
- am — Amphibolite *(massive. Derived from diabase and gabbrodiorite)*
- ams — Amphibolite-schist *(derived from diabase and gabbrodiorite)*
- grs — Schistose granodiorite

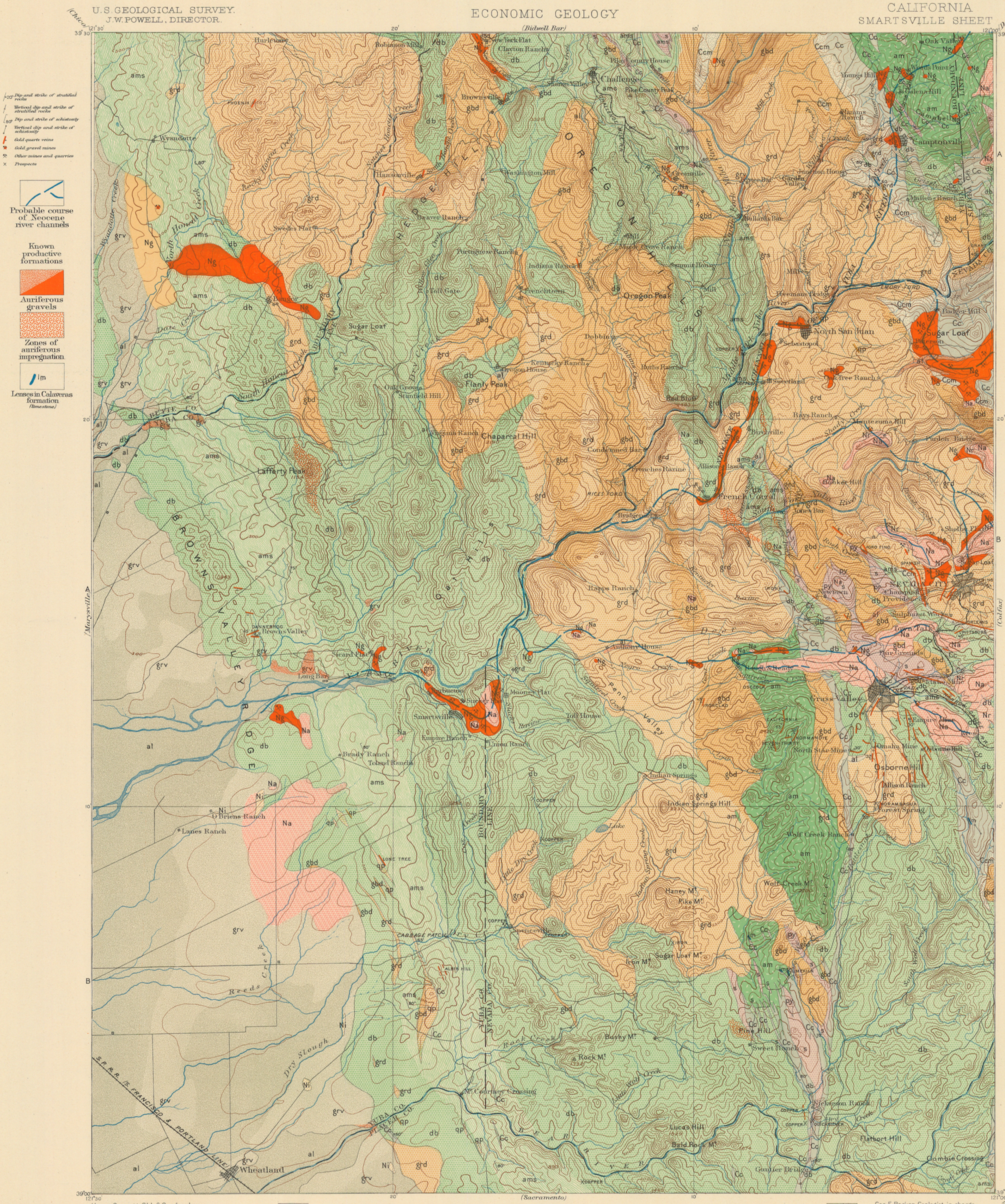
Sections



U.S. GEOLOGICAL SURVEY.
J.W. POWELL, DIRECTOR.

ECONOMIC GEOLOGY

CALIFORNIA
SMARTSVILLE SHEET



LEGEND

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PLEISTOCENE
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Sections

Henry Gannett, Chief Geographer.
A.H. Thompson, Geographer in charge.
Triangulation by H.M. Wilson.
Topography by H.M. Wilson and A.F. Dunnington.
Surveyed in 1885 and 1886

Wilson | Dunnington

Scale $\frac{1}{125,000}$
1 ½ 0 1 2 3 4 5 Miles
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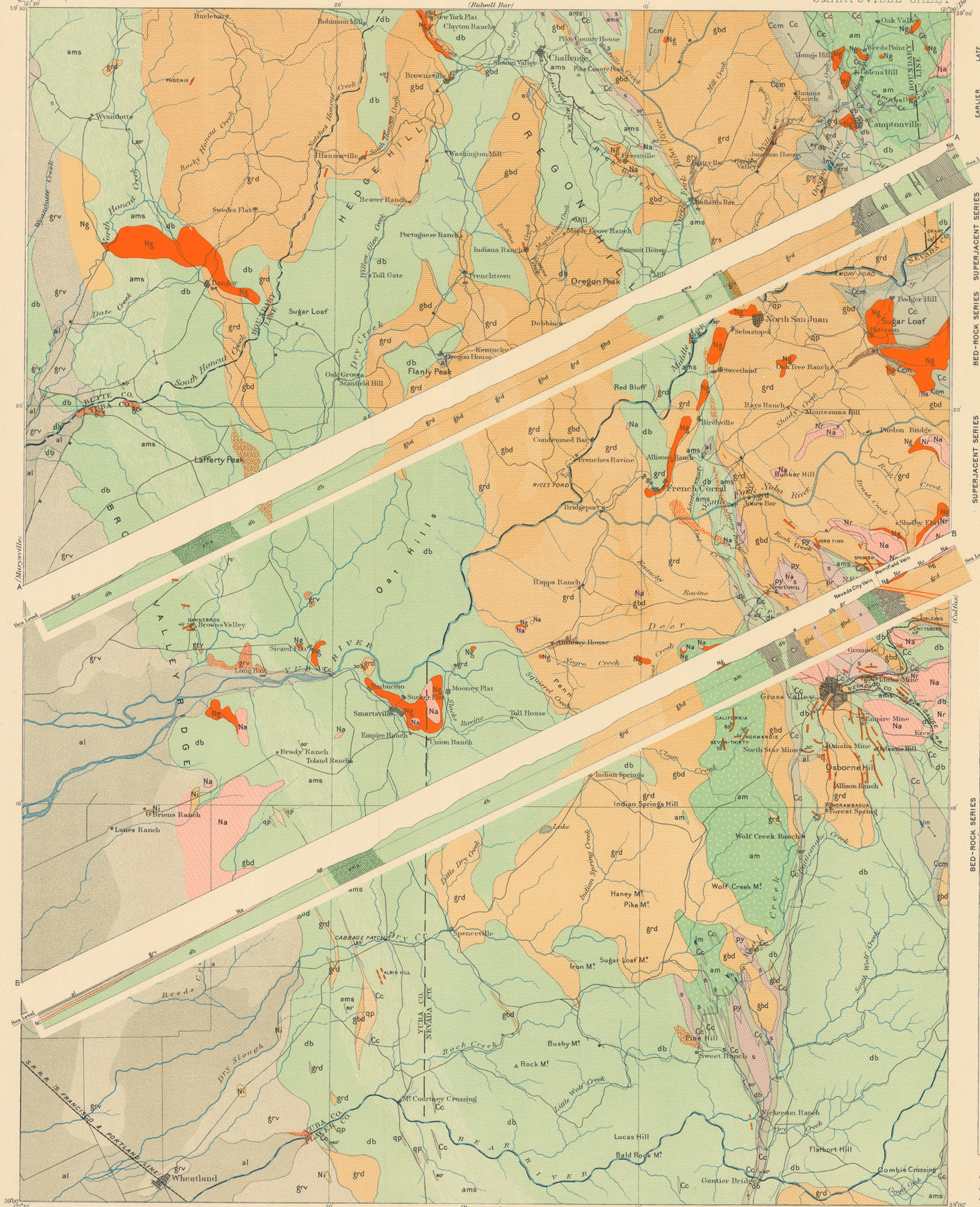
STRUCTURE SECTIONS

CALIFORNIA
SMARTSVILLE SHEET



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LEGEND

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- LATE — al — Alluvium (bottom lands)
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SEDIMENTARY ROCKS

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SUPERJACENT SERIES — NEOCENE
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BED-ROCK SERIES — CARBONIFEROUS
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ALTERED ROCKS

(Areas of Altered rocks are shown by patterns of short dashes.)

CARBONIFEROUS
- Ccm — Contact metamorphic rock
- lm — Lenses in Calaveras formation (Limestone)

EARLIER THAN THE LATE CRETACEOUS (CHICO FORMATION)
- am — Amphibolite
- ams — Amphibolite-schist
- grs — Schistose granodiorite

Zones of auriferous impregnation

Auriferous gravels

pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from volcanoes as ashes and pumice, and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

It is thought that the first rocks of the earth, which formed during what is called the Archean period, were igneous. Igneous rocks have intruded among masses beneath the surface and have been thrown out from volcanoes at all periods of the earth's development. These rocks occur therefore with sedimentary formations of all periods, and their ages can sometimes be determined by the ages of the sediments with which they are associated.

Igneous formations are represented on the geologic maps by patterns of triangles or rhombs printed in any brilliant color. When the age of a formation is not known the letter-symbol consists of small letters which suggest the name of the rocks; when the age is known the letter-symbol has the initial letter of the appropriate period prefixed to it.

(4) *Altered rocks of crystalline texture*.—These are rocks which have been so changed by pressure, movement and chemical action that the mineral particles have recrystallized.

Both sedimentary and igneous rocks may change their character by the growth of crystals and the gradual development of new minerals from the original particles. Marble is limestone which has thus been crystallized. Mica is one of the common minerals which may thus grow. By this chemical alteration sedimentary rocks become crystalline, and igneous rocks change their composition to a greater or less extent. The process is called *metamorphism* and the resulting rocks are said to be metamorphic. Metamorphism is promoted by pressure, high temperature and water. When a mass of rock, under these conditions, is squeezed during movements in the earth's crust, it may divide into many very thin parallel layers. When sedimentary rocks are formed in thin layers by deposition they are called *shales*; but when rocks of any class are found in thin layers that are due to pressure they are called *slates*. When the cause of the thin layers of metamorphic rocks is not known, or is not simple, the rocks are called *schists*, a term which applies to both shaly and slaty structures.

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

Metamorphic crystalline formations 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 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 only.

USES OF THE MAPS.

Topography.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage and culture of the region represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable.

It may guide the traveler, who can determine in advance or follow continuously on the map his route along strange highways and byways.

It may serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold.

It may save the engineer preliminary surveys in locating roads, railways and irrigation ditches.

It provides educational material for schools and homes, and serves all the purposes of a map for local reference.

Areal geology.—This sheet shows the areas occupied by the various rocks of the district. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any particular colored pattern on the map the reader should look for that color and pattern 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 colored 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 of the district. The formations are arranged in groups according to origin—superficial, sedimentary, igneous or crystalline; thus the processes by which the rocks were formed and the changes they have undergone are indicated. Within these groups the formations are placed in the order of age so far as known, the youngest at the top; thus the succession of processes and conditions which make up the history of the district is suggested.

The legend may also contain descriptions of formations or of groups of formations, statements of the occurrence of useful minerals, and qualifications of doubtful conclusions.

The sheet presents the facts of historical geology in strong colors with marked distinctions, and is adapted to use as a wall map as well as to closer study.

Economic geology.—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 geologic formations which appear on the map of areal geology are shown in this map also, but the distinctions between the colored patterns are less striking. 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 in this map, and it is accompanied at each occurrence by the name of the mineral mined or the stone quarried.

Structure sections.—This sheet exhibits the relations existing beneath the surface among the formations whose distribution on the surface is represented in the map of areal geology.

In any shaft or trench the rocks beneath the surface may be exposed, and in the vertical side of the trench the relations of different beds may be seen. A natural or artificial 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*.

Mines and tunnels yield some facts of underground structure, and streams carving canyons through rock masses cut sections. But the geologist is not limited to these opportunities of direct observation. 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. Thus it is possible to draw sections which represent the structure of the earth to a considerable depth and to construct a diagram exhibiting what would be seen in the side of a trench many miles long and several thousand feet deep. This is illustrated in the following figure:

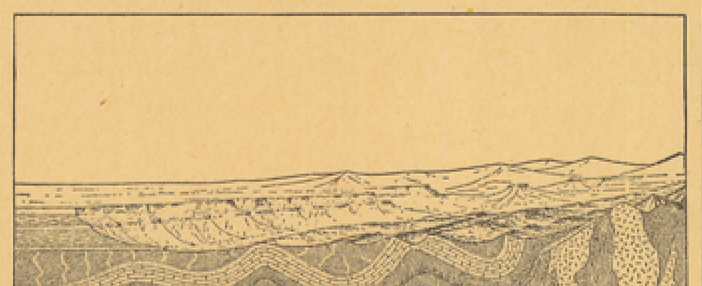

Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane. The landscape exhibits an extended plateau on the left, a broad belt of lower land receding toward the right, and mountain peaks in the extreme right of the foreground as well as in the distance. The vertical plane cutting a section shows 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:

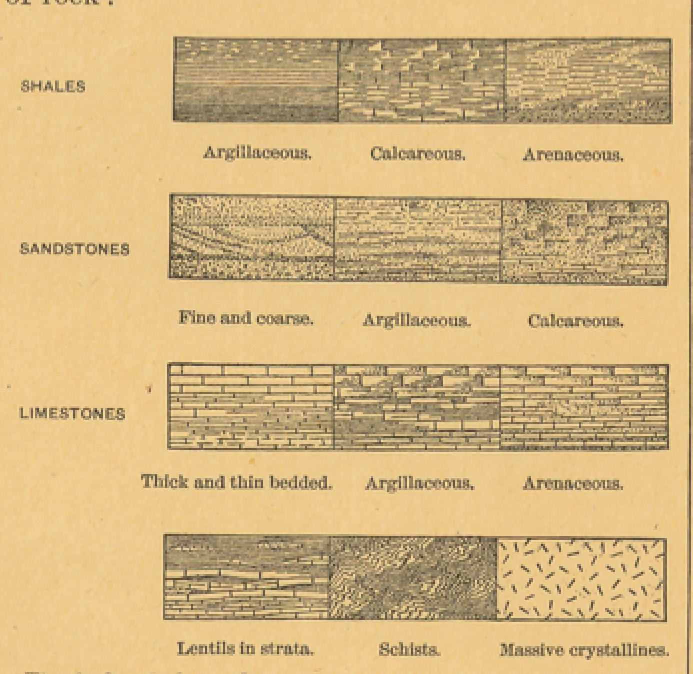

Fig. 3. Symbols used to represent different kinds of rocks.

The plateau in Fig. 2 presents toward the lower land an escarpment which is made up of cliffs and steep slopes. These elements of the plateau-front correspond to horizontal beds of sandstone and sandy shale shown in the section at the extreme left, the sandstones forming the cliffs, the shales constituting the slopes.

The broad belt of lower land is traversed by several ridges, which, where they are cut off by the section, are seen to correspond to outcrops of sandstone that rise to the surface. The upturned edges of these harder 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 thicknesses 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. Where they are now bent they must, therefore, have been folded by a force of compression. The fact that strata are thus bent is taken as proof that a force exists which has from time to time caused the earth's surface to wrinkle along certain zones.

The mountain peaks on the right of the sketch are shown in the section to be composed of schists which are traversed by masses of igneous rock. The schists are much contorted and cut up by the intruded dikes. Their thickness cannot be measured; their arrangement underground cannot be inferred. Hence that portion of the section which shows the structure of the schists and igneous rocks beneath the surface delineates what may be true, but is not known by observation.

Structure sections afford a means of graphic statement of certain events of geologic history which are recorded in the relations of groups of formations. In Fig. 2 there are three groups of formations, which are distinguished by their subterranean relations.

The first of these, seen at the left of the section, is the group of sandstones and shales, which lie in a horizontal position. These sedimentary strata, which accumulated beneath water, are in themselves evidence that a sea once extended over their expanse. They are now high above the sea, forming a plateau, and their change of elevation shows that that portion of the earth's mass on which they rest swelled upward from a lower to a higher level. The strata of this group are parallel, a relation which is called *conformable*.

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

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second group on the left of the section. The overlying deposits are, from their position, 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 or upon their upturned and eroded edges, the relation between the two is *unconformable*, and their surface of contact is an *unconformity*.

The third group of formations consist of crystalline schists and igneous rocks. At some period of their history the schists have been 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 group. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of strata of the second group. During this interval the schists suffered metamorphism and were the scene of eruptive activity. The contact between the second and third groups, marking an interval between two periods of rock formation, is an unconformity.

The section and landscape in Fig. 2 are hypothetical, but they illustrate only 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 sections.—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. The diagrams and verbal statements form a summary of the facts relating to the characters of the rocks, to the thicknesses of sedimentary formations and to the order of accumulation of successive deposits.

The characters of the rocks are described under the corresponding heading, and they are indicated in the columnar diagrams by appropriate symbols, such as are used in the structure sections.

The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest thicknesses. The average thickness of each formation is shown in the column, which is drawn to a scale,—usually 1,000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement of the descriptions and of the lithologic symbols in the diagram. The oldest formation is placed at the bottom of the column, the youngest at the top. The strata are drawn in a horizontal position, as they were deposited, and igneous rocks or other formations which are associated with any particular stratum are indicated in their proper relations.

The strata are divided into groups, which correspond with the great periods of geologic history. Thus the ages of the rocks are shown and also the total thickness of deposits representing any geologic period.

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, not only by the description of its character, but by its name, its letter-symbol as used in the maps and their legends, and a concise account of the topographic features, soils, or other facts related to it.

J. W. POWELL,

Director.