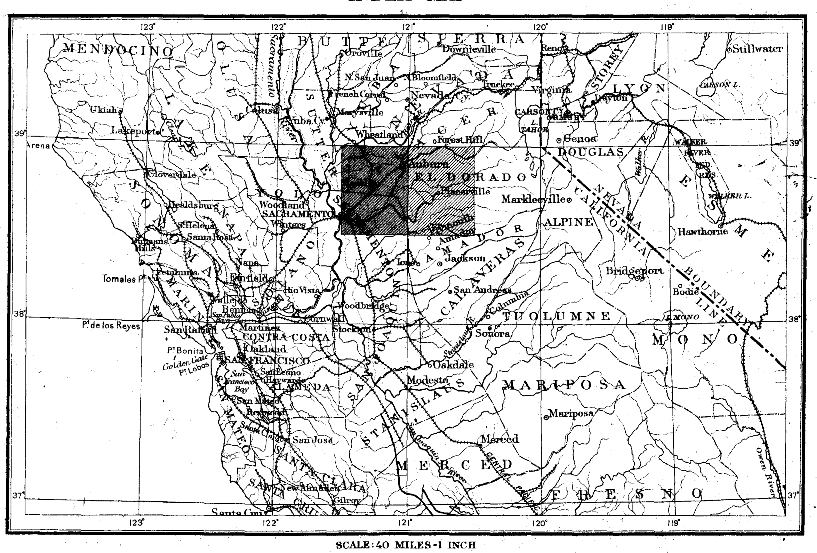
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
J.W. POWELL, DIRECTOR



# GEOLOGIC ATLAS
## OF THE
# UNITED STATES

# SACRAMENTO FOLIO
## CALIFORNIA

INDEX MAP




AREA OF THE SACRAMENTO FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION | TOPOGRAPHY | AREAL GEOLOGY | ECONOMIC GEOLOGY | STRUCTURE SECTIONS

FOLIO 5 | LIBRARY EDITION | SACRAMENTO

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# 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:

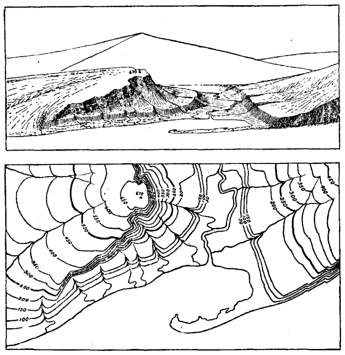

Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

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 | Ꞓ | 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 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:

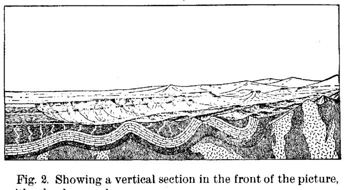

Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

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:

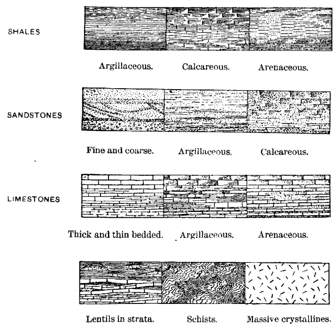


Fig. 3. Symbols used to represent different kinds of rocks.

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,
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# 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 towards the Great Basin and gradually towards 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 down 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 "Bedrock 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 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 gold-bearing gravels and forced the streams to seek new channels. These have been sunk 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 Bedrock 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 can 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, all of the Paleozoic periods, and those of the 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 has been determined at the northeast base of the range. 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 lentils. 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 lower Carboniferous. The Paleozoic sediments are finely exposed in Calaveras county and they will be designated on the Gold Belt sheets as 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, rendering them 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 imbedded 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 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 of the same age.

The genus *Aucella*, whose shell occurs in Russia, flourished on the Pacific coast until well into the Cretaceous and is distributed from Alaska to Mexico. In the Juratrias strata it is associated with ammonites of the genera *Perisphinctes*, *Cardioceras* and *Amaltheus*, closely related to forms of the European upper Jurassic age.

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 the 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 that place.

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 usually with the bedding.

The Mariposa beds carry numerous gold veins, the most important group of which constitutes the famous "Mother lode." It is believed that a great part of the gold veins were formed after this upheaval and as a consequence of it, occupying fissures opened during the uplift. 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 great mass of the intrusive igneous rocks accompanied or immediately followed the upheavals.

The epoch of disturbance following the deposition of the Mariposa beds was the last of those which produced the vertical arrangement of the Auriferous slate series. The strata of succeeding epochs are sediments and tuffs. Lying nearly horizontally 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 been raised 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 Range. 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, California, 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 (Tahone). It appears in the Gold Belt region only at the Marysville buttes, but 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 here 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 Range. 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 appear 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 wetter 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 S.-SW. toward the N.-NE. 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, near 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 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 Sierra Nevada mountains 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 occurred a greater uplift which was accompanied by the formation of normal faults widely distributed through 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

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

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. In the eastern United States it has become usual to regard the beginning of the Glacial Epoch 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 a much later event in California than in New England, and that the close of the Neocene can not be put later than the great andesitic flows.

The Sierra, from an elevation of about 5000 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. It seems rather to have protected it from erosion while intensifying erosion at the lower elevations, just as the lava cap would do. Small glaciers still exist in the Sierra.

There is no valid reason to believe that the Sierra has undergone any great or important dynamic disturbances since the beginning of glaciation. The whole mass, however, has risen bodily a few hundred feet during that time, as is shown by the raised beaches along the coast line of California, recent shells in the Contra Costa hills, and 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, embracing under this term both granodiorite and granite-porphyry. 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.*—This term has been used to indicate areas of gabbro containing primary and secondary hornblende, and for areas containing intimate mixtures of gabbro and diorite.

*Pyroxenite.*—An intrusive granular rock principally composed of pyroxene.

*Peridotite.*—An intrusive granular rock generally composed principally of olivine and pyroxene; frequently of olivine alone.

*Serpentine.*—This is composed of the mineral serpentine, and often contains 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 feldspars 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 usually are considerably and to a variable extent in excess of the alkaline feldspars. The 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 basic igneous rocks.

*Diabase.*—An intrusive or effusive granular rock composed of augite and soda-lime feldspars. 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.

*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 excepting 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.

*Andesite.*—An effusive porphyritic rock of Tertiary or later age. The essential constituents are soda-lime feldspars and ferro-magnesian 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.

# DESCRIPTION OF THE SACRAMENTO SHEET.

## TOPOGRAPHY.

The southwestern part of the Sacramento sheet extends into the plain of the Sacramento valley and includes the first low, undulating hills of the Sierra Nevada, while the northeastern part comprises the foot-hill region proper of the western slope. The lowest place on the sheet, 30 feet above sea level, is Sacramento; the highest point, 2,100 feet, is in the northeast corner near Clipper Gap. One of the main features of the central part of the foot-hill region of this sheet is the great depression about Rocklin developed in the easily eroded granodiorite mass. The steeper hills which rise abruptly around this area are composed of diabase and amphibolite; these rocks have a tendency to form ridges running parallel with the trend of the Sierra, and through them the American river forces its way in a deep and narrow canyon, which opens out upon reaching the granite. Another topographic feature of the sheet is the broad volcanic ridge which begins at Auburn and reaches down to the plains. In the granodiorite area this ridge is quite conspicuous, standing out like a table mountain from the surrounding lowland.

## GEOLOGY.

### BED-ROCK SERIES.

[This series consists of sedimentary rocks which were driven into a nearly vertical position at or before the post-Mariposa upheaval, together with the intercalated igneous masses.]

#### AURIFEROUS SLATES.

*Calaveras formation.*—Northeast of Auburn is an area of dark sandstone, black slate, limestone, and fine grained siliceous rock (phthanite) dipping steeply east and striking north to northwest. In the surrounding diabase and amphibolite there are several small isolated areas of the same character. In many places there is evidence that the fine grained, cherty siliceous rock referred to as phthanite is derived partly at least from the silicification of the limestone. The latter occurs as small and isolated lenticular masses; the limestone mass in the amphibolite three miles east of Auburn extending nearly uninterruptedly for two miles is exceptionally large. Crinoid stems have been found in the limestone two miles south of Clipper Gap, and several well defined Carboniferous fossils, principally corals, were discovered at two places in the same formation in the adjoining Placerville sheet. This area has been referred to the Calaveras formation though the fossil evidence is very meager. Some Paleozoic rocks older than the Carboniferous may be present, but it is not likely that any strata of more recent age than the Carboniferous occur here.

*Mariposa beds.*—The western belt of the Mariposa formation reaches into this sheet extending from the southeast corner to Folsom. It consists of black, little altered slate, and also contains a dark colored sandstone; the whole series dips eastward at an angle of 70° to 80° and the general trend is about north 30° west. The age of this belt is known to be Mesozoic from an ammonite found near Whiterock station, and several belemnites found further south. It is inferred that the slates belong to the Mariposa formation from the great similarity to those of the eastern belt, in which more fossils of the Cretaceous or late Juratrias have been found.

#### IGNEOUS ROCKS.

*Granodiorite.*—The large central area between Rocklin and Auburn is occupied by a granitic rock, very similar to a true granite, but really a granodiorite. The definition of this rock is given above in the introduction describing the general geology of the gold belt; in its normal development it contains both biotite and hornblende, but along the contacts the biotite is often absent and the rock might locally be classed as a quartz-diorite and in places even as a diorite. There is also a tendency to the development of a gabbroitic variety, examples of which on a small scale can often be noted near the contacts as well as in the gabbro areas southeast of Penryn. Near Folsom the granodiorite has converted the black Cretaceous slates into micaceous and hornblendic, feldspathic schists. At places along the contact with the amphibolite, as for instance in Auburn ravine, two miles below Auburn, the granodiorite is shown to be the later rock, it being intruded into the schists. South of Auburn, between the two forks of the American river, there is a system of granitic dikes in the amphibolite. And in Auburn ravine, in the section across the amphibolite wedge of Newcastle, may be seen beautiful phenomena of injection and intrusion of granodiorite into the amphibolite.

The area northeast of Hotaling is composed of a very hard white granodiorite with but little biotite. In its southern part this area contains pyroxene.

*Gabbro-diorite.*—The area east of Salmon Falls consists of a gray to dark green, coarse, granular rock composed of plagioclase and pyroxene, the pyroxene often partly converted to green hornblende; there may also be some primary hornblende in the rock, which is very hard and compact and does not weather easily. The northern part is occupied by high and rough hills covered with a dense growth of grease-wood (Adenostoma).

*Pyroxenite and serpentine.*—Adjoining the area just mentioned is a lenticular body of pyroxenite, a rock composed almost entirely of pyroxene with but little olivine and plagioclase; west of this pyroxenite mass there is a similar one of serpentine probably derived from peridotite; another serpentine area occurs between the two forks of the American river, in a steep range of hills the southern point of which is called Flagstaff hill. Along the contacts of this serpentine some coarse pyroxenite is frequently found under such circumstances as to suggest that the serpentine may have been at least in part derived from this rock. The mass is cut off on the northwest by the Rocklin granodiorite. Where the road from Pilot Hill to Folsom crosses it, it is altered to a peculiar, whitish, slaty rock containing much chlorite.

The long and narrow peridotite area of Pilot Hill is composed only partly of fresh rock; a good deal of it is already altered to serpentine.

North of Auburn there are two serpentine areas of uncertain origin; sometimes the serpentine is slaty, especially near the contacts.

*Diabase.*—The area near Clipper Gap is composed partly of a dark, dense diabase, partly of a diabase-porphyrite with very large feldspar crystals; these two rocks grade into each other and both contain more or less secondary hornblende. A streak of schistose, diabasic, fragmental rock occurs in the northeastern part of the area; it is beautifully exposed in a railroad cut a mile northeast of Clipper Gap.

Between Clipper Gap and Auburn there are several dikes of diabase in the Calaveras formation which are often accompanied by contact breccias.

Diabases and amphibolites occupy a broad, continuous belt along the eastern margin of the sheet. Most of the amphibolite schists are derived from diabase and diabase-porphyrites, although some of them may also have been derived from gabbros and diorites. The contact line of this area with the granodiorite is of considerable interest, since it shows how the latter has partly cut off the diabase and amphibolite and partly pushed them eastward. The contact sometimes follows the strike of the amphibolite closely and sometimes cuts across it. The amphibolite area is marked by distinct topographic features, steep ridges and narrow gulches, which are parallel to the strike of schistosity. This character contrasts strongly with the gently undulating surface of the adjacent granitic area.

Beginning near Auburn and extending in a triangular form beyond the northern limit of the sheet is an area of diabase which is generally massive; an imperfect schistosity is, however, sometimes marked by the direction of the outcrops. The rock is dark green, fine to medium grained, and very frequently contains secondary hornblende; large porphyritic feldspars and augites do not occur. On each side of this triangular area there is a streak of schistose amphibolite of medium to fine grain which changes gradually into massive diabase. The degree of schistosity varies considerably. Near Auburn the two streaks join, forming a belt composed exclusively of amphibolite and allied rocks, which are well exposed along the north fork of the American river. From the granite contact extends eastward a belt of normal amphibolite schist about a mile and a half wide. Then follows a more massive rock, which, though completely converted into amphibolite, appears to have been originally a diabase-porphyrite with porphyritic feldspar crystals. Above this belt there is an exceptionally fine grained and fissile amphibolite schist which is well exposed at the dam of the Folsom ditch. Normal diabase schists and amphibolites extend beyond this to the edge of the sheet. The ridge between the two forks of the American river, from Pilot Hill down to the granodiorite contact, is made up of schists which consist almost entirely of amphibolite and which seem to have been subjected to an intense pressure between the two dioritic masses. This belt of amphibolite schists continues in a southeasterly direction toward Latrobe and sometimes contains streaks of massive rock, which are evidently altered diabase. Near Marble valley the central part of this belt is so massive that the rock shows schistosity only by a parallel arrangement of hornblende crystals. It is not unlikely that a part of this amphibolite has been derived from gabbro or diorite. Westward the amphibolite schist passes by transition into a belt of massive diabase which is from one to three miles wide. From Ben Bolt mountain near Cothrin it continues in a northwesterly direction until cut off by the granodiorite east of Folsom. It is a fine to medium grained, dark green rock, with porphyritic crystals of augite. On the western margin near the Mariposa beds it becomes schistose.

The belt of amphibolite inclosed between the two areas of Mariposa slate is largely derived from a quartz-diabase-porphyrite, which is in part brecciated and fragmental. This rock is intimately connected with the normal diabase through a transition. In the western belt of Mariposa beds there are two dikes of a somewhat coarse grained massive quartz-diabase; the primary bisilicates, however, are now completely replaced by uralite and chlorite.

### 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.]

#### CRETACEOUS PERIOD.

*Chico formation.*—Small patches of the Chico formation are exposed near Folsom, and consist of soft greenish sandstone and clay beds frequently rich in characteristic fossils. These strata are not easily distinguished from the overlying Ione formation.

#### NEOCENE PERIOD.

*Ione formation.*—During the Neocene period the auriferous gravels accumulated on the slope of the Sierra Nevada, and at the same time 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.

Beds of this age, which probably underlie the larger part of the Pleistocene formations in the valley, are exposed only to a limited extent. At Lincoln there is a succession of white sand and clay beds containing a few seams of inferior lignite. North of Rocklin the same series, fifty to a hundred feet thick, is exposed in places below the andesitic beds. The largest development is found south of American river. The strata form characteristic flat topped hills and consist of a succession of light colored clays and white or yellowish white sandstones. On top of the Ione formation there is usually a layer of reddish Pleistocene gravel a few feet thick. The highest point at which these beds are found is about 450 feet above sea level.

The depth of the sediments of the Superjacent series which accumulated in the Great valley is considerable. At Sacramento, according to well borings, they are at least 2,000 feet thick. A part of the sedimentary mass consists of material of volcanic origin and the series probably includes Cretaceous as well as Neocene and Pleistocene strata.

*Auriferous gravels.*—The auriferous gravels represented in this sheet form a part only of those which accumulated in the lower courses of the streams during the Neocene period. The rivers then flowed over a country of aspect very different from that of to-day. It was a sloping tableland, above which undulating hills rose a few hundred feet. This ancient topography is still indicated by the broad, volcanic ridge between Auburn and the plains, by the high plateau of Auburn, and by the old highlands north and south of this plateau.

Only small areas of the auriferous gravels are found on the Sacramento sheet. Gravel which does not consist of volcanic material sometimes underlies the andesitic beds to a thickness of a few feet, and four miles west of Rocklin are some areas which are only partly covered by andesite. There existed during the Neocene period a stream closely corresponding to the existing American river and draining a similar area. Most of the sediments accumulated by this river have in this region been removed by erosion, and its course is therefore difficult to trace. The old south fork probably entered this sheet at Pilot Hill, flowing thence west for a few miles, and then southwest to the gravel areas mentioned, near Rocklin; from this point the ancient channel is completely covered by Pleistocene deposits. The north fork (the tributary coming down from the Forest Hill divide) entered the sheet northeast of Auburn and joined the main stream a few miles south of that town.

*Andesite.*—At the end of the Neocene period a large part of the area of the sheet was covered with andesitic flows from the volcanoes in the high Sierra. Only isolated patches now remain by which the former extent of these lavas can be traced. The andesitic beds are nowhere much over a hundred feet thick, and are entirely fragmental in character. The upper part consists of a well cemented tufaceous breccia with fragments sometimes more than a foot in diameter, which doubtless poured down in the form of a mud flow. Underlying this there is a succession of volcanic gravels and sands interstratified with beds of tuff. The old Neocene highlands, in the northeastern corner and along the eastern margin from Pilot Hill southward, were probably not covered by volcanic flows. Volcanic tuff has been found in deep borings near Sacramento.

#### PLEISTOCENE.

*Earlier Pleistocene.*—The earlier Pleistocene forms a broad belt reaching diagonally across the sheet. Topographically, it corresponds with the first gentle undulations and lowest foothills of the Sierra, and is frequently characterized by flat topped hills. The series consists, in the northern part of the sheet, of a succession of gravels and clays, the former growing finer toward the west. Of general occurrence in this area is the firmly consolidated, yellowish brown sandy clay, to which the name of hardpan is usually given. The cement of this material consists mainly of hydrous silicates of iron.

The central part of the Pleistocene area, from Lincoln down to the American river, is composed of a succession of quartzose sands, clays and hardpan derived from the adjacent granitic area of Rocklin. This series is beautifully exposed in the bluffs following the northern bank of the American river. South of the American river the earlier Pleistocene strata are materially different, being composed of heavy gravels and sands. These were evidently deposited by the shifting currents of the river which, during that period, emptied into the plains at the same point as now. Toward the southwestern corner of the sheet, however, these coarser gravels are replaced by finer sediments with hardpan, and are usually covered by a thin mantle of alluvium.

Along the western margin of the Pleistocene belt, following the old Pleistocene shore line, there is always more or less fine gravel which gradually thins out above a certain elevation. The highest point at which the Pleistocene deposits of the Great valley have been found on this sheet is about 350 feet. Along the present course of the American river there are scattered benches of gravel, indicating progressive erosion of the river bed. These are found at elevations ranging from 20 to 100 feet above the present channel.

No fossils have been found in the earlier Pleistocene series. It is believed that these beds were in part contemporaneous with the glaciation of the high Sierra and were formed largely by morainal debris.

*Alluvium.*—The whole western margin of the sheet is covered by recent fluviatile deposits consisting of black soil, clay and sand, which reach up into the areas of earlier Pleistocene for several miles along the courses of the principal streams. Near Sacramento, and along the lower course of the American river, there are also gravel beds which are included in the alluvial series. The alluvium probably nowhere exceeds 60 feet in thickness. In the northwest corner of the sheet, on both sides of Bear river, lie heavy masses of sandy debris locally known as "slickens," brought down from the hydraulic gravel mines in the Sierra. In the foothill region there is very little alluvial soil.

## MINERAL RESOURCES.

*Gold-bearing gravels.*—The gravels which accumulated in the present creeks and rivers and derived their gold partly from quartz veins, partly from older Pleistocene and Neocene channels, were the first to be worked and they are practically exhausted. The older Pleistocene gravels near Folsom have been extensively worked by the hydraulic process. The benches of the same age remaining along the rivers were frequently rich but they are now mostly exhausted. Neocene auriferous gravels are worked by drifting at and near the Lee mine in the vicinity of Rocklin, as well as at various other places below the andesite. Such mines are found two miles south of Auburn and on the north side of the andesite area between Lincoln and Penryn.

*Gold-quartz veins.*—The chief quartz-mining districts are those of Ophir and Duncan hill, near Auburn. The ores carry native gold, often combined with silver, and also a variable amount of iron and copper pyrites, zincblende, and galena. These metallic sulphides, usually called sulphurets, are frequently rich in gold and silver. The general trend of the vein systems is west-northwest, although some of them cross this direction; the dip is southward at an angle from 30° to nearly 90°; the veins are partly in granodiorite, partly in amphibolite schist, the more valuable deposits being in the granitic mass. Among the more important mines are the Gold Blossom, the Crater Hill, and the Hathaway. Other mines located on or near the contact are the Segregated No. 31, and the Zantgraff. Near Clarksville, in the area of amphibolite schist, much pocket mining has been done on a small scale. The veins here appear to strike from east to west.

*Copper deposits.*—About two miles east of Valley View, in amphibolite schist, there is a streak of decomposed rock impregnated with copper pyrites, which also carries some free gold, probably derived from the decomposition of the pyrites. The deposit has been worked several times for gold. At many other places in the vicinity traces of copper ore have been found.

*Chrome iron deposits.*—In the serpentine area of Flagstaff hill a few pockets of chrome iron ore have been worked.

*Iron deposits.* A large deposit of magnetic iron ore is located at Hotaling on the contact of granodiorite and Carboniferous slates. An attempt to work it failed on account of the great expense of fuel.

*Coal deposits.*—The Ione formation sometimes contains beds of lignite. A bed of this kind from five to twelve feet thick has been mined at Lincoln, but the poor quality rendered the enterprise unprofitable.

*Clay deposits.*—The white clays of the Ione formation are frequently well suited to the manufacture of pottery. This industry is at present extensively carried on near Lincoln, where local conditions permit the clays to be quarried with little expense. In the Cosumnes area of the Ione formation similar clay is found at many places, but it is not utilized at present. In many places there are indications that the clays have been derived from rhyolitic tuff. A bed of very pure quartz sand is also found at Lincoln.

*Limestone.*—The deposits indicated on the map contain a crystalline, bluish or grayish limestone producing a good quality of lime. Kilns are located at Cave valley, Marble valley, Alabaster cave, and other places.

*Building-stones.*—The large central area of granodiorite furnishes an excellent building-stone which is used extensively in the state. The center of this industry is at Rocklin, although there are also quarries near Loomis, Penryn and Lincoln. The granodiorite of Rocklin is distinguished by closeness of grain and contains some white mica, together with biotite and hornblende. The small gabbro area near Penryn furnishes a beautiful, dark, coarse grained stone. The Neocene sandstone area of the Cosumnes contains, interstratified with clays, beds of white sandstone varying to tawny yellow often well adapted to building purposes. Near Michigan Bar a quarry has been opened and the same sandstone is obtained at several points further south toward Ione.

## SOILS.

Along the western margin of the sheet there are deep alluvial soils, many of them of great fertility and ranging from black adobe clay to light sands. Along the broad belt of earlier Pleistocene the soil is commonly a reddish sandy and gravelly loam very frequently underlain by hardpan. In the Neocene southeastern area stiff clay soils predominate.

The foot-hill soils comprise very little alluvium; nearly all of them are derived from long continued disintegration of the rock in place, and they may be divided into three groups:

(1.) Red soil, principally derived from diabases and amphibolites. It is a strong soil, rich in plant food and especially characterized by a high percentage of iron. It is admirably adapted for horticultural purposes.

(2.) Granitic soil, principally derived from the secular disintegration of granodiorite. It is not so rich as the first mentioned, but is easier to work, as well as warmer and deeper, and it is therefore generally preferred.

(3.) Slate soil, derived from the disintegration of the Mesozoic and Carboniferous sedimentary rocks. This soil is light colored, often very shallow, and the poorest of the three.

The andesitic areas have here, in contrast to those higher up on the slope of the Sierra, a very shallow soil, or none at all, and are usually covered by rough bowlders of andesite.

WALDEMAR LINDGREN,
*Geologist.*

GEORGE F. BECKER,
*Geologist in Charge.*

December, 1892.

U.S. GEOLOGICAL SURVEY.
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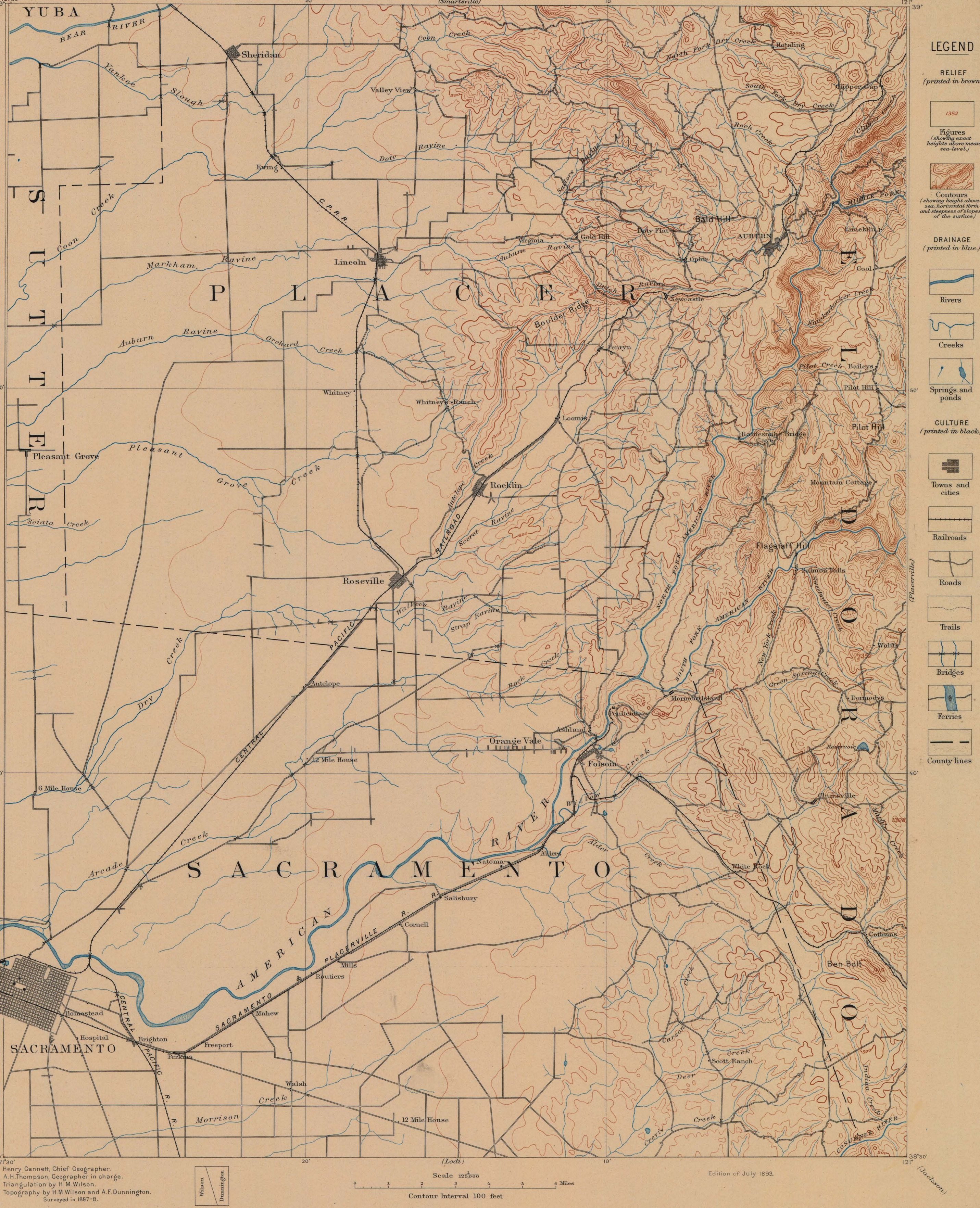
TOPOGRAPHY

CALIFORNIA
SACRAMENTO SHEET




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 1887-8.

Edition of July 1893.

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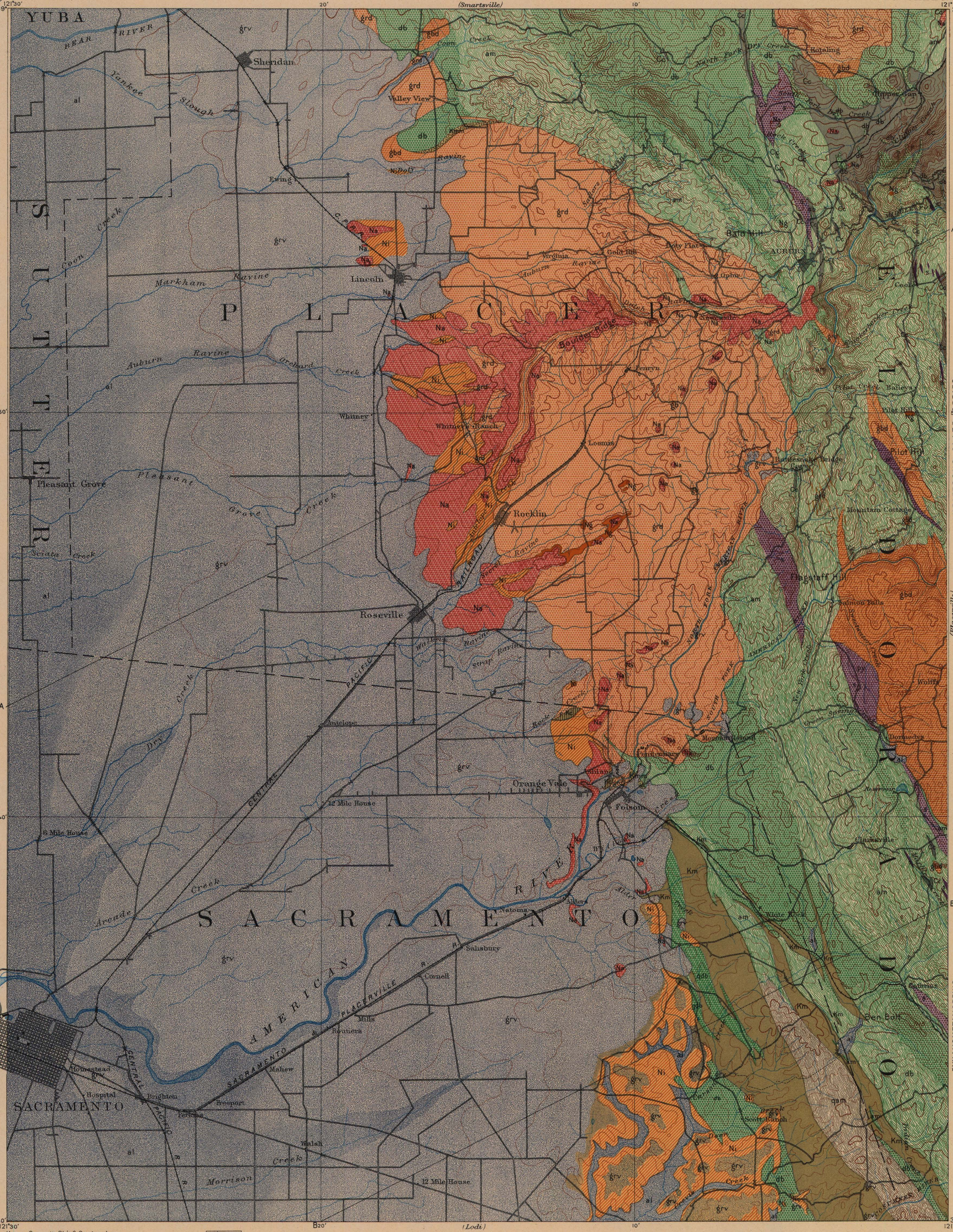
# AREAL GEOLOGY

CALIFORNIA
SACRAMENTO SHEET.




## LEGEND

SUPERFICIAL

PLEISTOCENE
- al — LATE — Alluvium
- grv — EARLIER — Shore and river gravels, sands, hardpan (river gravels frequently auriferous)

SEDIMENTARY

NEOCENE
- Ng — Auriferous river gravels
- Ni — Ione formation (Clays, sand, and gravel, some coal seams)

CRETACEOUS
- Kc — Chico formation

SEDIMENTARY (metamorphic)

AURIFEROUS SLATE SERIES

CRETACEOUS
- Km — Mariposa slates (early Cretaceous or late Jurassic age, roofing slates, quartz veins)
- Kmm — Contact metamorphic rock (of age of Mariposa slates)

CARBONIFEROUS
- Cc — Calaveras formation (slates, cherts and limestone possibly in part early Mesozoic and older Paleozoic)

IGNEOUS

NEOCENE
- Na — Andesite (fragmental)

AGE OF MARIPOSA SLATES AND OLDER
- grd — Granodiorite (Containing locally numerous gold quartz veins)
- gbd — Gabbrodiorite (facies of the granodiorite)
- gb — Gabbro (facies of granodiorite)
- pr — Peridotite
- py — Pyroxenite
- s — Serpentine
- db — Diabase and diabase-porphyrite
- qdb — Quartz-diabase

DYNAMOMETAMORPHIC
- qam — Amphibolite (and schistose quartz-diabase-porphyrite)
- am — Amphibolite (principally derived from diabase; contains some gold quartz veins)

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Wilson | Dunnington

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

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet

Edition of July 1893.

Geo. F. Becker, Geologist in charge.
Geology by W. Lindgren.
Surveyed in 1889-90.

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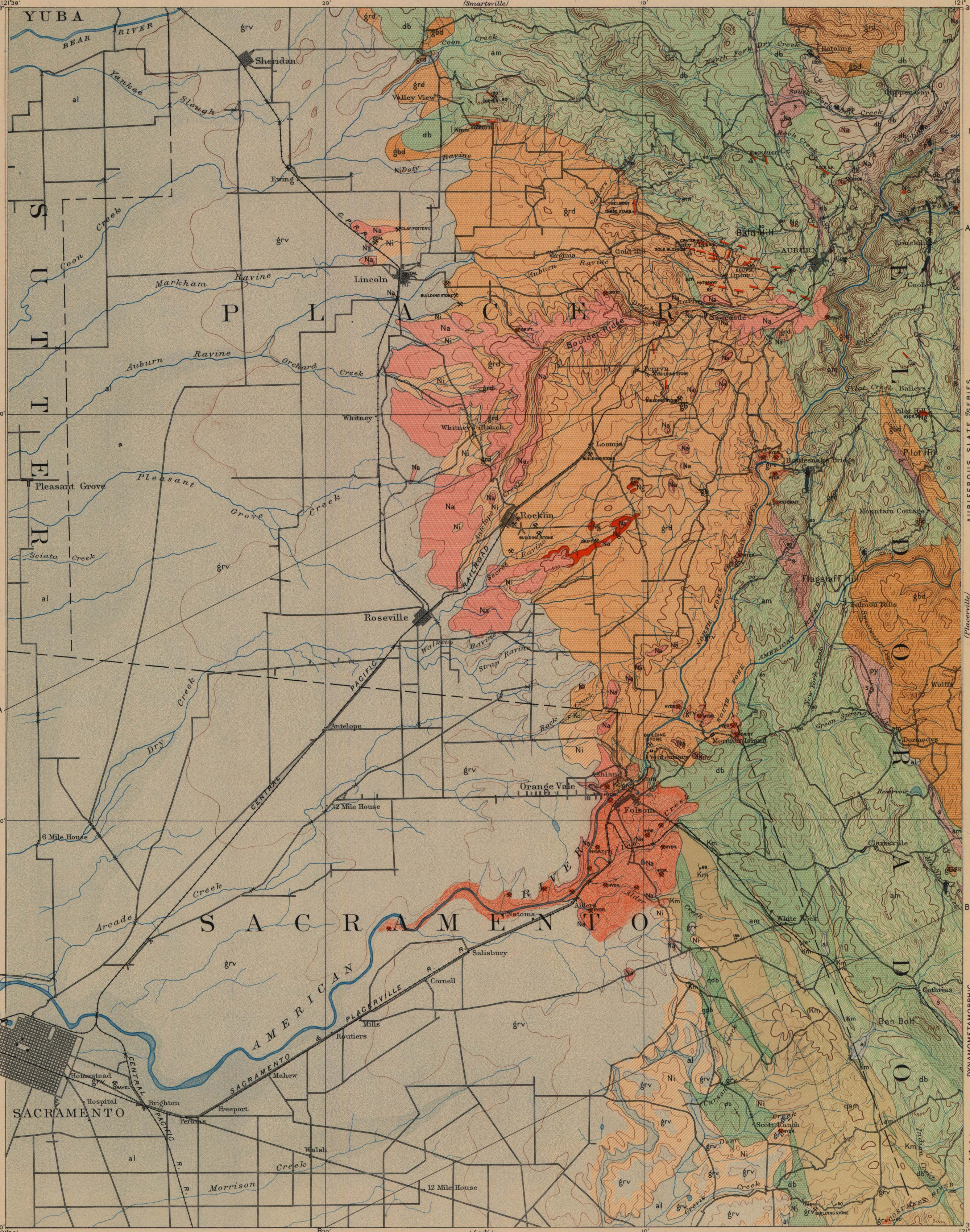
# ECONOMIC GEOLOGY

CALIFORNIA
SACRAMENTO SHEET




38°30′ 121°30′ B20′ 10′ 121° 38°30′

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A.H.Thompson, Geographer in charge.
Triangulation by H.M.Wilson.
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20 Dip and strike of stratified rocks.
Vertical dip and strike of stratified rocks.
Dip and strike of schistosity.

Gold quartz mines.
HYDR. Hydraulic mines in auriferous gravels.
DRIFT Drift mines in auriferous gravels.
Other mines and quarries.

Lenses in Calaveras formation
*Limestone.*

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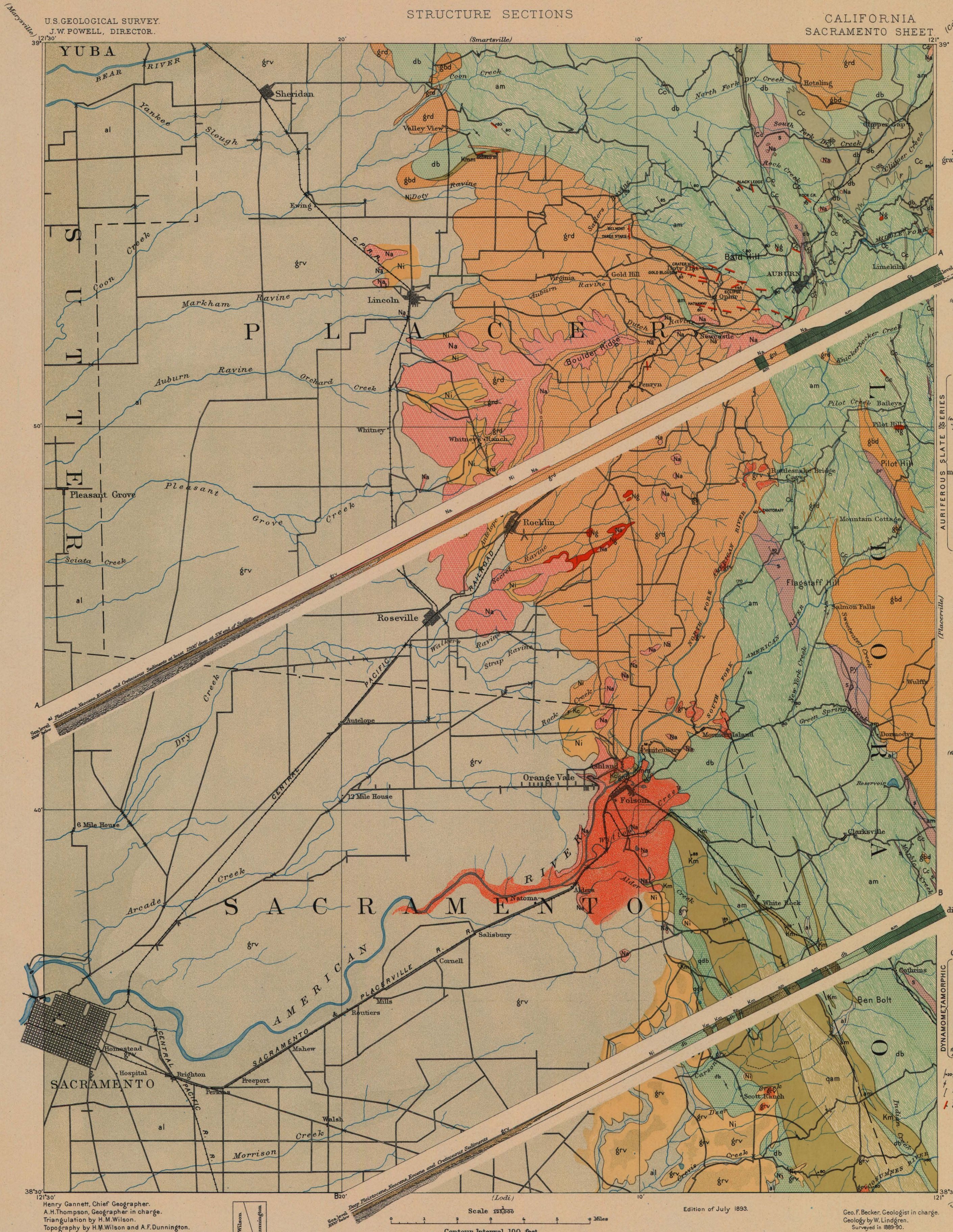
# STRUCTURE SECTIONS

CALIFORNIA
SACRAMENTO SHEET

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