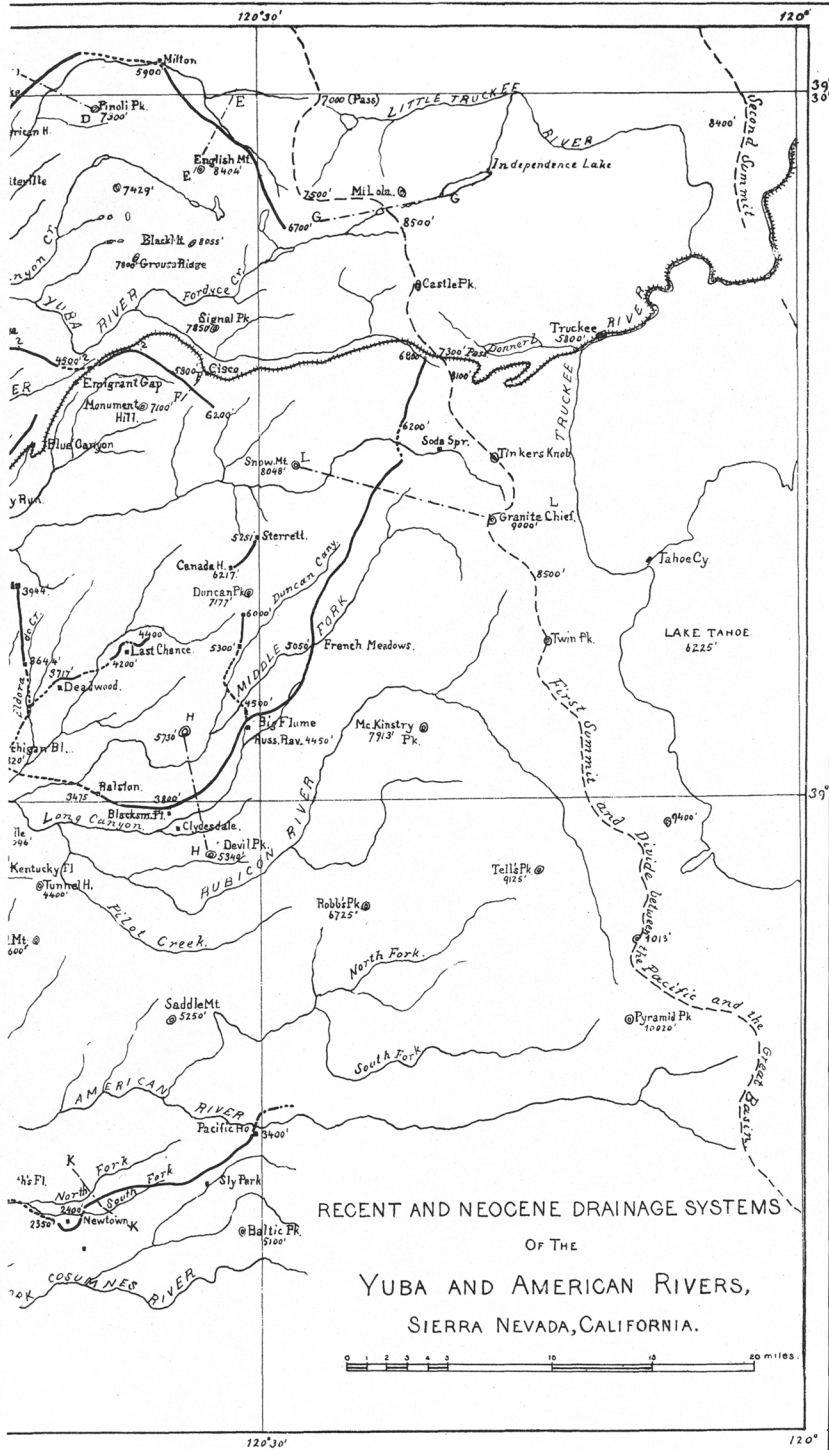




3000' Prominent Bed Rock Hills
/ Approximate course of Neocene Channel (remaining)



RECENT AND NEOCENE DRAINAGE SYSTEMS
OF THE
YUBA AND AMERICAN RIVERS,
SIERRA NEVADA, CALIFORNIA.

0 1 2 3 4 5 10 20 miles.

Approximate course of Neocene Channel (eroded)
Correct position and elevation of Neocene Channel.

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TWO NEOCENE RIVERS OF CALIFORNIA

BY WALDEMAR LINDGREN

(Presented before the Society December 30, 1892)

CONTENTS

	Page
Introduction.....	258
Review of Literature.....	259
Observations on Method of Work.....	262
Outlines of Geologic History.....	263
Topography.....	263
Condition of the Sierra Nevada before and during the Gravel Period.....	264
The volcanic Period.....	266
The Neocene Yuba River.....	268
The main River.....	268
From the Sacramento Valley to French Corral.....	268
The Nevada City and Grass Valley Channels.....	269
French Corral to North San Juan.....	270
North San Juan to Badger Hill.....	270
The North Fork.....	271
The Middle Fork.....	271
Badger Hill to North Bloomfield.....	271
North Bloomfield to Snow Point.....	272
The Derbec Channel.....	273
The Forest City Channel.....	273
Snow Point to Milton.....	274
Milton to Meadow Lake.....	276
The South Fork.....	277
Badger Hill to Dutch Flat.....	277
The Channel at Dutch Flat.....	282
The Liberty Hill Tributary.....	282
The Channel between Alta and Shady Run.....	283
The Neocene American River.....	284
The South Fork.....	284
From the Sacramento Valley to Diamond Springs.....	284
Diamond Springs to Newtown.....	285
Newtown to Pacific House.....	286
The North Fork.....	287
From the Junction to Jones Hill.....	287
Jones Hill to Bath.....	288
The Iowa Hill Channel.....	289

258 W. LINDGREN—TWO NEOCENE RIVERS OF CALIFORNIA.

	Page
Bath to Ralstons.....	290
The Damascus and Last Chance Tributaries.....	291
General character.....	291
From the Ralston Mine to Summit Valley.....	291
The lower Course.....	292
The Duncan Peak Tributary.....	293
The Canada Hill Tributary.....	293
The upper Course.....	293
Discussion of Grades.....	294
Conclusions.....	298

 INTRODUCTION.

The investigations of the United States Geological Survey in the Gold belt of the Sierra Nevada, carried out under the direction of Dr G. F. Becker, with whose consent this paper is published, have included the geologic mapping of the country on topographic contour maps on the scale of 1 : 125,000, or about two miles to the inch. During the course of this mapping much information has been gained concerning the Neocene river channels, now largely covered by deep volcanic flows or cut away by subsequent erosion. The auriferous character of the accumulated gravels gives, as is well known, great practical importance to these channels.

A large number of the productive Neocene gravel deposits occur in the watersheds of the present Yuba and American rivers, which were included in the area assigned to the writer. It has been found that these deposits are parts of two river systems which in a general way correspond to the two modern rivers now draining the same territory.

It is the purpose of the present paper to indicate briefly the direction of the principal forks of the Neocene Yuba and American rivers, to give a more accurate idea of the Neocene topography within this district, and to call further attention to certain channels which might prove remunerative if opened by mining operations. The continuity of some of these can be asserted and their approximate position indicated. It is not proposed in this place to enter upon any elaborate discussion of the many and interesting questions connected with the accumulation of the gravels, nor is it the intention to describe in detail the often complex channel systems of any particular region.*

*The term "Neocene" has been used, consistently with the nomenclature adopted by the Survey, in preference to "Pliocene." The Neocene comprises the Miocene and Pliocene periods of the Tertiary era, between which, in the Sierra Nevada, no definite line can be drawn. It is, indeed, very probable that the first period of erosion, the gravel period and the volcanic period represent a large part of the time between the later Cretaceous and the later Tertiary, but there is no definite floral or faunal evidence to support this.

REVIEW OF LITERATURE.

For the first accurate information as to the geologic character and occurrence of the gravel beds we are mainly indebted to the former state geological survey of California under Professor J. D. Whitney. His volume on the Auriferous gravels,* containing, besides his own extensive observations, the detailed notes of W. A. Goodyear and Professor W. H. Pettee, marks an epoch in the development of our knowledge of these Neocene deposits. The observations recorded in this book are in general accurate and trustworthy. The "review" at the end of the volume by Goodyear appears, in the light of later investigations, as very excellent indeed, and, while one may differ from some of his conclusions, it must be acknowledged that his views of the channels and of the general topography of the country over which they flowed are confirmed by more detailed and extended surveys. To these investigators belongs the credit of having established the fluviatile character and the age of the deposits, of having recognized the two important river systems corresponding to the present Yuba and American rivers, and of having begun to outline the old drainage lines. Professor Whitney concludes that the Sierra Nevada has not undergone any important changes as to the general level and the grade of its channels, and that the carving of the canyons subsequently to the gravel period was principally caused by climatic changes.

In 1886 Professor Joseph Le Conte published a paper on "A post-Tertiary elevation of the Sierra Nevada shown by the river beds,"† in which no new observations were recorded, but which gave an impetus to the investigation by the introduction of a new theory, which, however, had already been suggested by Mr G. K. Gilbert in 1883.‡ In subsequent papers Professor Le Conte has further elaborated his views,§ and in 1891 he published a paper on the "Tertiary and post-Tertiary changes of the Atlantic and Pacific coasts,"|| in which is found a concise statement of his present opinion, which is quoted in full:

"The Sierra was formed, as we now know, by lateral crushing and strata-folding at the end of the Jurassic. But during the long ages of the Cretaceous and Tertiary this range was cut down to a very moderate height, with gentle slopes eastward

* J. D. Whitney: "The Auriferous Gravels of the Sierra Nevada of California." *Memoirs of the Museum Comp. Zool.*, vol. 6, no. 1, 1880.

† *Am. Jour. Sci.*, 3d series, vol. xxxii, 1886, p. 167.

‡ Review of Professor Whitney's "Climatic Changes;" *Science*, vol. i, 1883, pp. 141-142, 169-173, and 192-195.

§ For a more extended review of the literature regarding this subject the reader is referred to Mr H. W. Turner's "Mohawk Lake Beds." *Bull. Phil. Soc. Washington*, vol ix, April, 1891, pp. 385-410.

|| *Bull. Geol. Soc. Am.*, vol. 2, pp. 323-330.

260 W. LINDGREN—TWO NEOCENE RIVERS OF CALIFORNIA.

and westward from a crest which was probably situated along a line just above the Yosemite and Hetch-Hetchy valleys, for there the erosive biting into the granite axis seems to be deepest. The rivers, by long work, had finally reached their base-levels and rested. The scenery has assumed all the features of an old topography, with gently flowing curves. The continental elevation"—previously described in the same paper—"of the Pliocene did not greatly affect the river slopes of this part. At the end of the Tertiary came the great lava streams, running down the river channels and displacing the rivers; the heaving up of the Sierra crust-block on its eastern side forming the great fault cliff there and transferring the crest to the extreme eastern margin; the great increase of the western slope and the consequent rejuvenescence of the vital energy of the rivers; the consequent cutting down of these to form the present deep canyons, and the resulting wild, almost savage, scenery of these mountains."

Mr J. S. Diller, who has studied the geology of the northern end of the Sierra Nevada north of the fortieth parallel, holds similar views as to the age and elevation of the range. They were first set forth in his "Notes on the Geology of northern California,"* which, however, does not include any detailed discussion of the Tertiary river deposits on the western slope. His conclusions may be best stated by quoting from a later paper on the "Geology of the Lassen peak district:"†

"During the whole of the Cretaceous and the Tertiary the great belt of country lying east of the present Sacramento valley, embracing the region now occupied by the Sierra and a large portion of the Great Basin, was above the sea, and subjected to great degradation, which reduced it almost to its base-level of erosion. This gentle plain swept westward toward the ocean directly across the site of the present Sierra. That the north end of the Sierra country was a lowland during the Miocene, as already shown, is rendered perfectly evident by the character of its flora; and the relation of the Miocene conglomerate to the eastern escarpment north of Honey lake is such as to demonstrate that during the Miocene the Sierras were not yet in existence. Similar conditions continued through the Pliocene, for the Pliocene gravels on the western slope of the Sierras were evidently deposited while its inclination was very gentle, before the Sierra region had attained any considerable elevation, and apparently also while it was yet a part of the Great Basin platform. * * * The faulting, by means of which the Sierra Nevada range was separated from the Great Basin platform, took place, in a geologic sense, very recently. The eastern escarpment of the range, at least in its northern portion, was evidently formed after the conclusion of the volcanic activity in its immediate vicinity."

Since the above was written, Mr Diller has published a paper on the "Geology of the Taylorville region,"‡ in which he shows the Taylorville fault to be an *overthrust* instead of a *normal* fault, as he had previously supposed. This change necessarily modifies his earlier views to some extent.

* Bulletin 33, U. S. Geol. Survey, 1886.

† Eighth Ann. Rep. U. S. Geol. Survey, 1889, p. 428.

‡ Bull. Geol. Soc. Am., vol. 3, p. 369.

Dr G. F. Becker, in his paper on "The Structure of a portion of the Sierra Nevada of California,"* considers the range to have existed as such during the Tertiary. From the analysis of the extensive fissure system discovered by him he draws the conclusion that no important tilting of the Sierra has taken place at or since the post-Miocene disturbances, but that the western slope of the range has been increased by distributed faults along these systems.

For the next and very important contribution to the actual knowledge of the Neocene channels one is indebted to Mr Ross E. Browne, who gave the results of his careful and detailed survey of the Forest Hill divide in the tenth annual report of the state mineralogist of California, 1890, pages 435-465 (with maps). Mr Browne's work includes an accurate topographic mapping of the contacts of the Neocene deposits and flows with the bed-rock, surveys of all tunnels and mines, and determination of elevation of all important points. It is the first work of its kind, and stands as a model for the many similar ones which it is hoped the future will bring forth. It is gradually beginning to be recognized that detailed surveys are indispensable when works of such magnitude and cost are contemplated as the opening of important gravel channels. Both on the Forest Hill and Placerville divides large sums of money have been lost by neglecting a sufficiently extended topographic and geologic survey of the region in question.

To Mr Browne belongs the credit of having first distinctly recognized the different systems of later channels (channels of the volcanic period) as contrasted with the older pre-volcanic drainage system. In Goodyear's notes from Forest Hill and Placerville the existence of such channels is, however, plainly implied. Mr Browne also gives a diagram showing the grades of the Neocene rivers with reference to the longitudinal axis of the Sierra with the view of ascertaining whether tilting of the range can be recognized in the grades of the Neocene channels.† He thinks more data are needed, but "that the evidence, as far as it goes, is against any considerable increase in the slope of the Sierra flank—decidedly against an increase large enough to account *per se* for the two thousand feet deeper cutting of the modern river." In the same report Mr John Hobson has carefully described and mapped the Iowa Hill divide in a similar detailed way.‡

Mr Henry G. Hanks§ still appears to maintain a glacial or partly glacial origin of the gravels. I fear that in upholding this theory he is contending against very heavy odds. No evidence whatever of the ex-

* Bull. Geol. Soc. Am., vol. 2, pp. 64 and 73.

† Op. cit., p. 445.

‡ Op. cit., p. 419.

§ Mining and Scientific Press, San Francisco, April 5, 1890, and following numbers.

262 W. LINDGREN—TWO NEOCENE RIVERS OF CALIFORNIA.

istence of Neocene glaciers has thus far been met with in the highest part of the range in this latitude; nor is it likely, in view of the character of the Neocene flora high up on the flank of the range, that such evidence will be found.

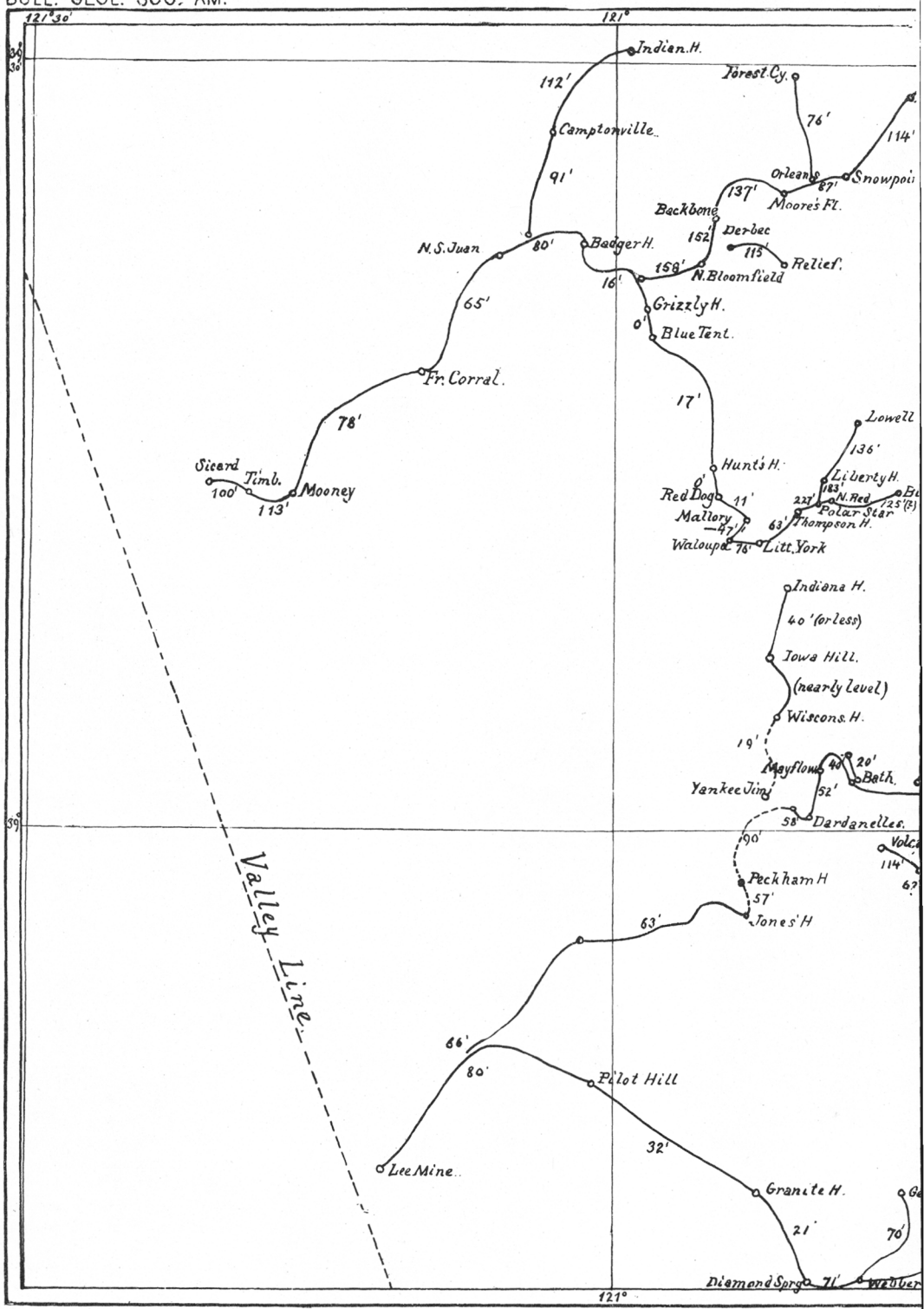
OBSERVATIONS ON METHOD OF WORK.

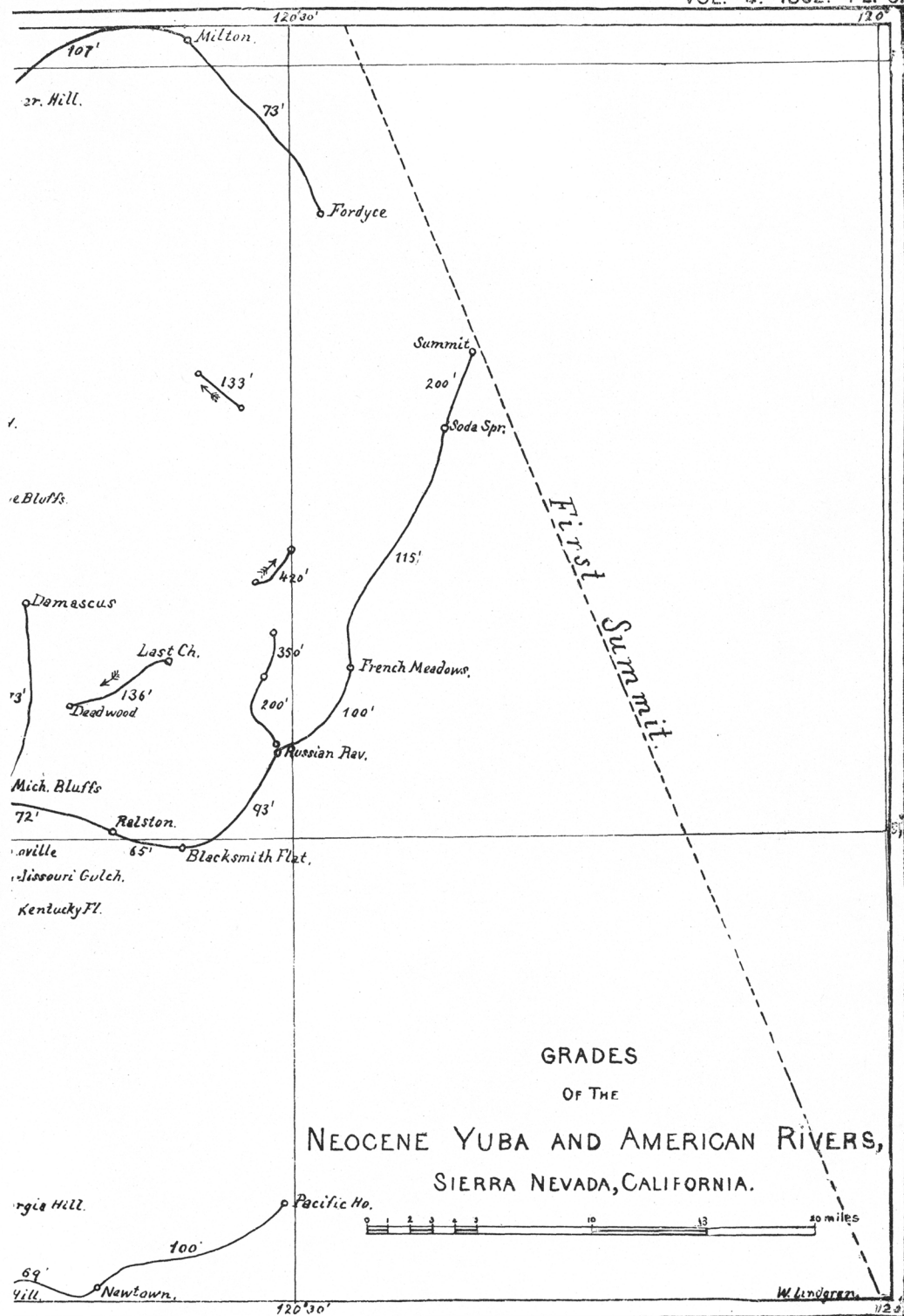
The help of a contour map is almost indispensable in order to obtain a correct idea of the Neocene drainage and topography.*

Each point of the contact lines between the bed-rock and the superjacent Neocene gravels or volcanic flows necessarily marks a point on the old surface of the region such as it was before hidden under Tertiary accumulations. A great number of these contact lines are usually exposed by the canyons and creeks eroded since the close of the Neocene period, and each of them affords a section through a part of the Neocene surface. It will easily be conceded that if the elevation of a sufficient number of points on the contact lines were known, a contour map might be constructed of the Neocene surface, showing the topography and elevation above the sea, provided that no change in level or tilting had taken place in the interval. Even in such a case the map would be valuable as showing the relative topography, and if the existence and amount of the disturbance of the old surface could be ascertained by other means a correct map referred to the old sea level might be obtained from it. The bed-rock points that have been above the surface of the lava flows since the end of the Neocene—and there are many of them in the Gold Belt region—have often suffered a degradation difficult to measure, but probably in most cases not large. The flat tops of many of them show them to have formed a part of the Neocene surface, and the erosion, while scoring and furrowing their flanks, has not yet reached their summits.

Many of the topographic features of the Neocene region may be directly read on the contour maps on which the geologic areas are outlined. If in a certain vicinity all the contact lines between lava and bed-rock run practically parallel with the contours and at the same elevation, the conclusion is easy that the Neocene deposit rested on a horizontal surface, provided no tilting has taken place since. If, again, the contact lines cross the contour lines in an irregular way and at considerable angles, the old surface was broken and irregular; with a sufficient number of contacts

* The part of the Gold belt here under consideration has been mapped on the scale of 1:125,000, or about two miles to the inch, with a contour interval of one hundred feet. It comprises the Smartsville, Colfax, Truckee, Sacramento, Placerville, and Pyramid Peak sheets, and the topography has been executed by Messrs H. M. Wilson, A. F. Dunnington, R. H. McKee, and M. E. Douglas under the charge of Professor A. H. Thompson. The geologic maps of the larger part of the area are finished and are now ready for publication. The Sacramento atlas sheet has just been printed.





the general drainage system may be made out. In the case of an old valley running across a recent creek or canyon, the angles of the contact lines with the contour lines on the opposite sides of the present gorge will easily and directly indicate the ancient trough.

The accompanying map (plate 5) is reduced from atlas sheets of the United States Geological Survey. The elevations are partly taken from the very reliable observations of Messrs Pettee and Goodyear, partly from the maps of the United States Geological Survey, supplemented for short distances by my own aneroid determinations, and partly also from the surveys of Mr Browne. The channels where obliterated by erosion are marked by dotted lines; where remaining though generally hidden under volcanic masses, by heavy black lines. It must be understood that in both cases the indicated position is only approximately correct and showing the probable course of the deepest depression.

The grades given in plate 6 are affected by errors in distance and elevation. The latter are believed not to be great, but the former are difficult to ascertain. An attempt has been made in measuring the distance to follow the probable curves of the rivers; nevertheless the grades are probably all a little too steep on account of underestimating distances, but the differences are not, I think, large enough to be of much importance.

The sections in plates 7 and 8 are taken from maps used in the field on the scale of 1:62,500, or nearly one mile to the inch. In most cases it has been found necessary to enlarge the scale to 3,180 feet to the inch; only section *LL* is drawn on the scale of 6,360 feet to the inch. In all cases the vertical and horizontal scales are equal.

OUTLINES OF GEOLOGIC HISTORY.

Topography.—In this latitude the Sierra Nevada has two summits, separated by the Truckee valley and the deep basin of lake Tahoe. The western summit, whose peaks rise from 8,000 to 10,000 feet above the sea, is also the divide between the Pacific and the Great Basin, while the Truckee river, draining lake Tahoe, has cut a deep canyon through the second or easterly summit on its way to the depressions of the Nevada deserts; on the eastern side of lake Tahoe the last-named summit attains even higher elevations than the principal divide. With the easterly summit and its escarpment this paper does not deal.

On the Pacific slope, in the watersheds of the Yuba and American rivers, one may roughly distinguish three provinces:

First, the foot-hill region, most frequently consisting of prominent ridges of diabase and amphibolite. Many of them, in Neocene times, projected boldly above the river beds, as shown, for instance, in the sec-

tion *A A*. In this province the volcanic flows are not conspicuous. It is probable that the higher parts of the foothill region remained above them, and erosion to a great extent removed them from the lower parts.

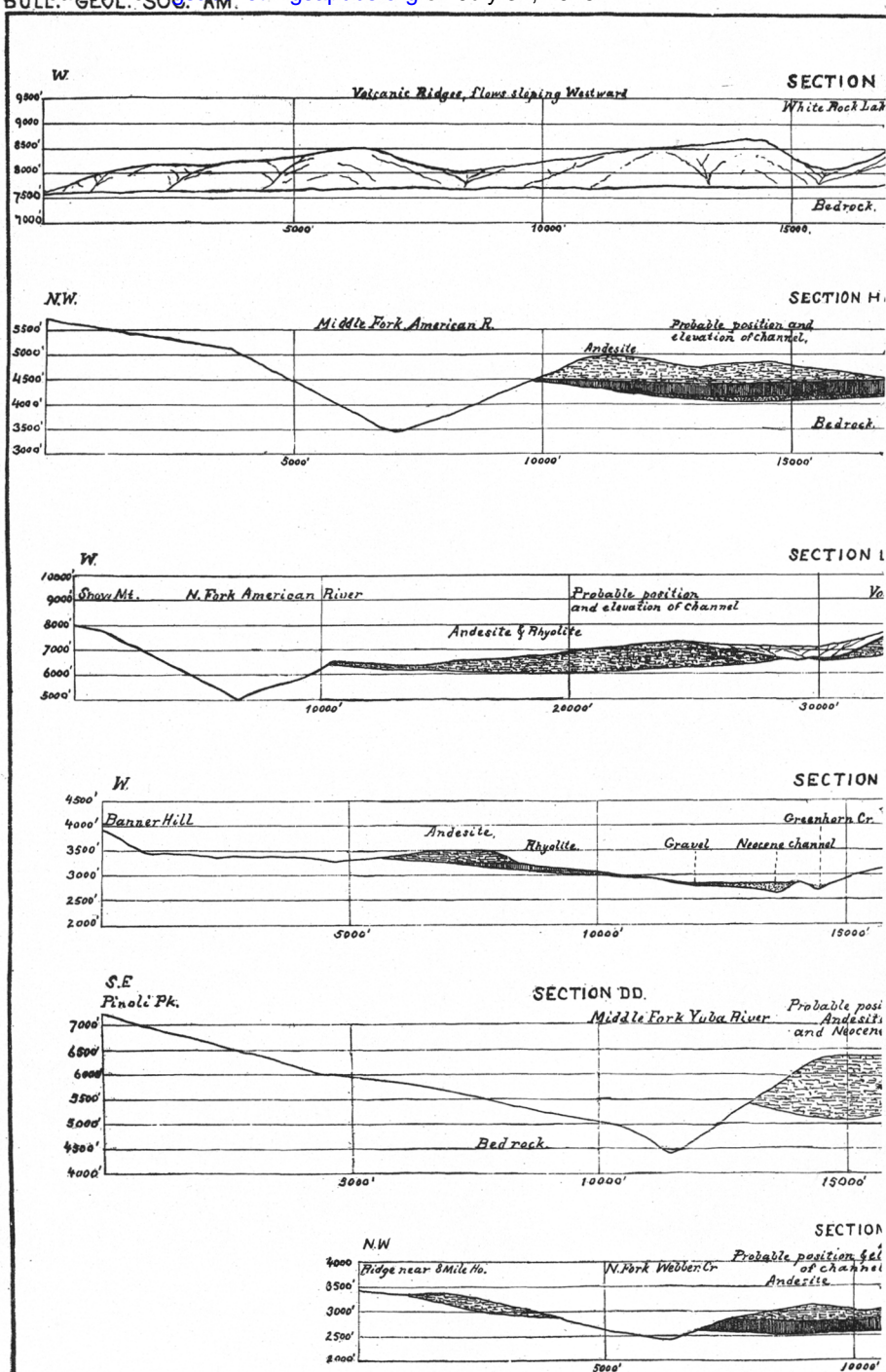
Second, the middle slopes, consisting chiefly of more or less altered sedimentary rocks, the auriferous slates. In this region the broad tables of Neocene lavas have largely effaced the pre-volcanic topography. Often, indeed, ridges of older rocks rise here also above the top of the gently sloping volcanic table-land, but as a rule they are not prominent.

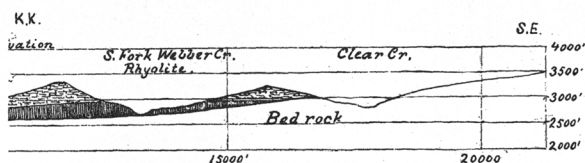
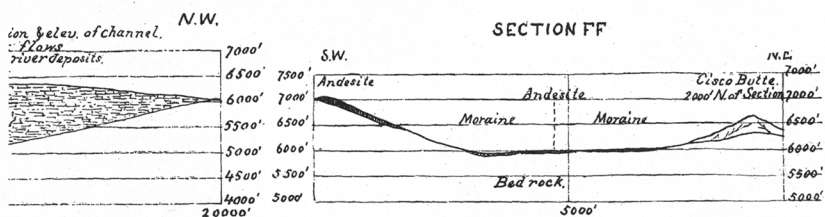
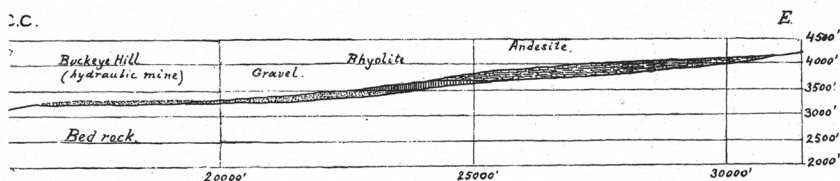
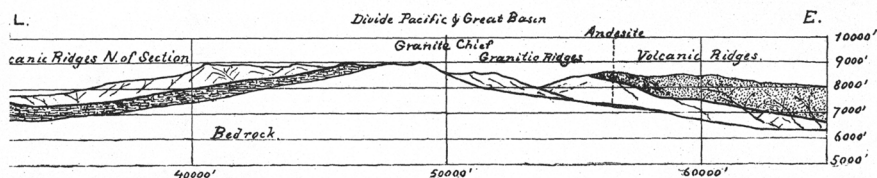
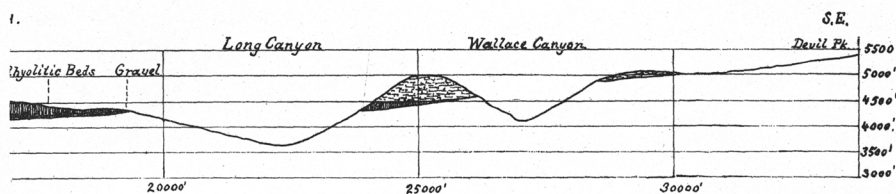
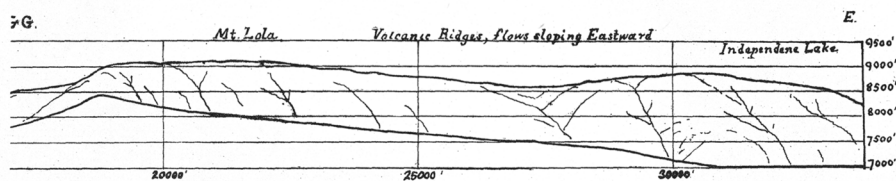
Third, the region of high bed-rock peaks adjoining the divide, in which the character of a table-land, frequently noticeable even here, becomes modified by prominent points of ante-Tertiary igneous and sedimentary rocks projecting conspicuously above the level of the Neocene flows. A glance at the map, on which only peaks of the older rocks are marked with their elevation in numbers, will make clear this distinction. At the divide there are many volcanic peaks, culminating in the extinct volcanoes of mount Lola, Castle peak and others which exceed 9,000 feet in height. The elevations of these volcanic peaks are not given on the map. Were the later volcanic masses removed along the divide the lowest passes would still be about 7,000 feet high.

Condition of the Sierra Nevada before and during the gravel Period.—From the evidence accumulated it cannot be doubted that during the gravel period or the later part of the Tertiary the Sierra Nevada in this region formed a mountain range as distinct, if not as high, as at present. The two Neocene rivers headed near where the corresponding modern rivers begin now, in a region of lofty peaks and ridges. Their watersheds certainly did not extend further eastward than the first summit, and in fact corresponded pretty closely with those of the modern rivers. On the Truckee sheet, at least, the Neocene divide coincides very nearly with the divide of to-day, and only unimportant changes can be noted. East of the divide there was an escarpment of moderate slope, and which is now exposed in many canyons to a height of 1,000 to 2,000 feet; it probably was much higher than this, but below a level of from 6,000 to 7,000 feet above the sea its slope is completely hidden under the immense accumulations of lavas lying between the two summits north of lake Tahoe.

The total height of this escarpment as it was before the eruption of the Neocene lavas should perhaps be measured from the bottom of lake Tahoe to the summit of the western divide, approximately 4,000 or 4,500 feet. There is, on the Truckee sheet, no evidence of any important post-volcanic fault along the western summit, nor is there any decided evidence that the steep eastern slope just mentioned represents a fault formed shortly before or during the volcanic period.

This is illustrated by sections *G G* and *L L* (plate 7). Many similar ones could be selected from the Truckee sheet. In *G G* a contact be-





W. Lindgren.

tween granite and andesite along which the section is laid runs for many miles nearly due eastward across the divide, thus exposing an excellent profile of the Neocene surface. The high volcanic ridges of mount Lola immediately northward are projected on the section. The slopes of the flows are eastward and westward from the central vents of the old volcano of Lola.

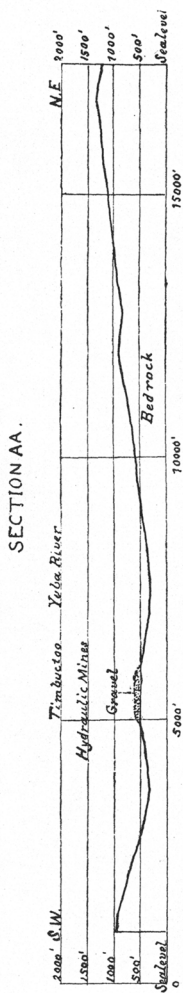
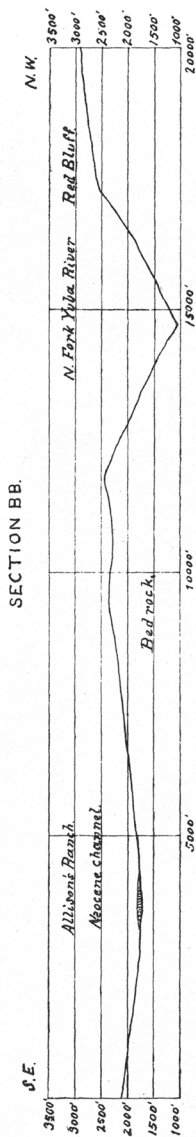
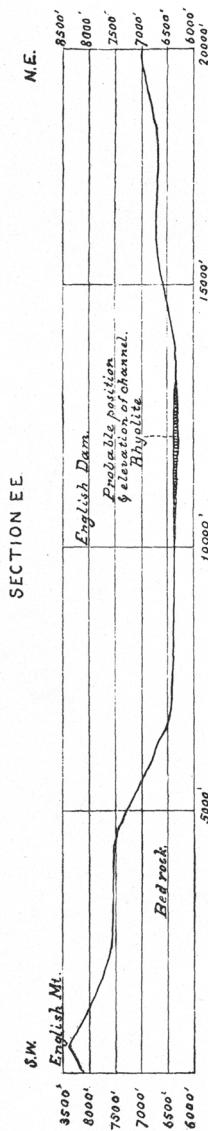
In *LL* a section is made on a smaller scale across the divide showing the depression of the headwaters of the Neocene middle fork of the American river, east of which rises the old divide at Granite Chief. The river heads only a few miles northward and rises rapidly in this direction.

The decided slope eastward from Granite Chief should be noted. That this slope was also that of the Neocene divide is proved by the contact lines of the andesitic masses with the underlying older rocks. This line is projected on the section from the ridges immediately north of it.

From the rugged country in the region of their sources the rivers pursued their course down in broad valleys separated by ridges which even in the lowest foot-hills sometimes reached an elevation of a thousand feet above the channels. The outlines of the ridges were usually comparatively gentle and flowing; still, slopes of ten degrees from the channel to the summit were common and slopes as high as fifteen degrees occurred in the eastern part of the Sierra. The character of a region of old and continued erosion, commencing probably far back in the Cretaceous period, is everywhere plainly evident. In the center of the deep depressions is quite frequently found a deeper cut or "gutter," indicating a short period of more active erosive power just before the beginning of the gravel period. At this time, probably about the beginning of the Miocene period, the streams became charged with more detritus than they could carry and began to deposit their load along their lower courses, especially at places favorably situated, as, for instance, along the longitudinal valley of the South Yuba. Toward the close of the Neocene, gravels had accumulated all along the rivers up to a (present) elevation of about 5,000 or 6,000 feet; above this it is plain that erosion still continued in places with great activity and furnished some of the material deposited in the lower parts of the streams. The coarse character of much of the gravel and the often remarkable absence of fine sediments in the beds point clearly to a somewhat rapid stream capable of carrying off a great deal of silt, and the accumulations are probably due to rapid overloading rather than to low grade of the rivers. The deep channels were filled and the gravels encroached on the adjoining slopes, where they were deposited in broad benches. A maximum thickness of 500 feet of deposits was attained on the South Yuba, and of from 50 to 200 feet in the other parts of the lower rivers. In the lower and middle Sierra some

of the rivers then meandered over floodplains two or three miles wide, above which the divides of bed-rock rise to a height of several hundred feet. In some instances low passes over divides were covered, and temporary bifurcation and diversion of rivers into adjoining watersheds occurred.

The volcanic Period.—At this time the first eruptions of rhyolite began from the first summit, from the volcanic center of Castle peak, they poured down the valleys, at first as molten flows, then as fine breccias and tuffs, and, being mixed with detrital material on their way, they are finally found lower down as semi-volcanic sands, clays and gravels. These beds of mixed volcanic and sedimentary character, usually fine-grained and distinguished by a brilliant white color, have been collectively distinguished under the name of rhyolitic beds, and merge into the tuffs and massive rhyolites of the upper valleys. The rhyolitic flows usually confined themselves to the valleys and only in some instances flooded certain of the low passes. The maximum thickness of these flows near the summit is one thousand feet, but it rapidly diminishes westward. These masses of fine detritus flooded the lower slopes and compelled the rivers to seek new channels, still, however, in general confined to the old valleys. The waters at once began the work of cutting down in the clayey and sandy masses. Then the period of the andesitic eruptions began. Dark-colored mud flows, at first sandy and clayey, again flowed down the valleys; the divides began to be covered. Again the rivers were displaced and again they at once began their work of active erosion, cutting down not only through the accumulated silt to their former levels, but, wherever the intervals between the eruptions allowed it, down through the gravels sometimes deep into the underlying bed-rock. In some districts, especially on the American river, these intervalcanic channels cut and destroyed again and again the older deposits, pursuing a wholly independent course, although in general flowing in the same valleys. They have exactly the same characteristics as the modern rivers. It is important to note that they enable us to fix with accuracy the relative date of the change from the conditions of the Neocene to the conditions of to-day. Whatever causes produced this change, they began to act at this time. The intervalcanic channels were of an ephemeral character; successive eruptive flows changed their direction, and it is to be expected that there were, as shown by Mr Browne, several different systems of them. They occur principally in the watersheds of the American river where the interval between the first and the last andesitic flows seems to have been considerably larger than in the region of the Yuba. Cement channels, as the intervalcanic channels are often called, no doubt also occur in the latter, but as a rule they did not have time to cut down far into the rhyolitic beds before they were filled and replaced



W. Lindgren.

SECTIONS SHOWING NEOCENE DRAINAGE SYSTEMS

by the last great andesitic flows. The intervolcanic channels, being no part of a permanent and established drainage, are not described or further discussed in this paper.

These last flows, coming down in rapid succession from the volcanoes of Weber lake, of mount Lola, of Castle peak, and many others southward, flooded everything and covered up the lower and middle slopes to such an extent that only isolated peaks or ridges protruded above them. Their character is peculiar; they consist of a gray or brown tuffaceous breccia, containing, in the foot-hills as well as in the high range, large, usually angular, boulders of andesite. They came down the slope as successive mud flows, setting soon to a hard and compact rock. Molten andesitic flows are found in the lava-flooded valley between the two summits, and also at some places west of the first summit, but they did not extend far down the western slope.

The thickness of these flows ranges from over a thousand feet high up to fifty or one hundred feet down toward the plains, where they are nearly always underlain by volcanic sands and conglomerates washed down from earlier flows which had not reached so far down.

The eruption of this tuffaceous breccia is assumed to close the Neocene period, and its flows form an important horizon by means of which the Neocene gravels may be separated from the later Pleistocene accumulations. The age of the flows is indicated by the numerous plant impressions common in the clays of the rhyolitic beds, as well as in those of the older underlying gravels, and which, as well known, distinctly point to the Neocene period. Only rarely is there any difficulty experienced in distinguishing the Tertiary from the Pleistocene gravels.

The length of the volcanic period may be roughly measured by the depths of the "cement channels" on the Forest hill divide. They have cut through about one hundred and fifty feet of loose detritus and, at most, one hundred feet of solid rock—not much more than a twentieth of the erosion since the close of the volcanic period.

There have been no andesitic eruptions of later date than those described in the region now discussed, and the continuity of the last overwhelming lava floods can be traced, almost uninterruptedly in places, from the plains of the great valley to the summits of the high Sierra.

When the volcanic activity ceased * the rivers began to seek their final channels, those of to-day. The general drainage was outlined by the

*An eruption of massive basalt occurred in some parts of the Sierra Nevada subsequently to the andesitic eruptions and previously to the glaciation. In the region here considered only small areas of this Pleistocene basalt are found.

Mr H. W. Turner has recently shown (*Am Jour. Sci.*, 3d ser., vol. xliv, 1892, p. 455) the existence of a basalt antedating the andesite in the northern part of the Sierra Nevada. This earlier basalt does not occur in the area described in this paper.

ridges of older rocks still rising above the flows, and to them is to be attributed the fact that the Neocene river system roughly corresponds to the present one; but over the large stretches of volcanic tables the rivers marked their new courses entirely independent of the older streams, now following them, now crossing them in a most irregular manner.*

THE NEOCENE YUBA RIVER.

THE MAIN RIVER.

From the Sacramento Valley to French Corral.—At Smartsville, near Sacramento valley, a stretch of channel three miles long has been preserved. Its character and grade are described in detail by Mr Pettee in the "Auriferous gravels," pp. 379–383. At Sicards flat, about two miles lower down, on the northern side of the river, a fragment of the old channel remains, and three miles further down, on the southern side of the Yuba, the last trace of it is found, but it is not certain whether the elevation given at the last place represents the lowest channel. From here on it is buried under the more recent deposits of the great valley. It should be noted, in this place, that the areas of auriferous gravels indicated by Mr Pettee on the low rolling foot-hills west of Smartsville as Neocene and below the volcanic flows are in reality Pleistocene and rest on the andesitic breccia, and that they consequently have no significance in tracing the Tertiary channel.

The gravels at Smartsville and Sicards flat do not belong to the oldest Neocene deposits, for they contain a considerable amount of andesitic pebbles. They are, however, certainly Neocene, for at Smartsville they are covered by that sheet of andesitic tuffaceous breccia which, in the region under consideration, marks the close of the Neocene period. They must represent the Neocene river in its lower course, for both north and south of Smartsville rise bed-rock ridges, and this place affords really the only outlet possible for the channels of the upper course of the Yuba; the Neocene river broke through the barrier of the great diabase area of Yuba county in a valley or canyon of somewhat gentler profile, but almost as accentuated as that of the recent river. The ridges on each side rise to a height of one thousand feet or more above the old channel (see section *A A*). It might be objected that the channel at Smartsville was deepened during the intervulcanic period of erosion, and consequently no longer represents the bed of the prevolcanic river.

* In the region described postvolcanic faults are rare; those found have seldom more than 10 or 15 feet throw. The Tertiary deposits would greatly facilitate the recognition of any such faults of considerable throw, and I think the probability very slight that the slopes shown in the sections are to any noticeable degree influenced by such postvolcanic disturbances.

This I do not think is compatible with the gentle curve made by the bottom of the old channel. The intervalcanic erosion cut sharp, steep canyons like those of to-day. The deepest "gutters"* in the Smartsville channel might perhaps have been carved by it and it probably swept away earlier accumulations of "white" or quartz gravel. From Smartsville to French Corral there is only one way which the Neocene river could have followed, that of the present river canyon; any other way would necessitate extremely improbable and sudden changes of grade. A scattered line of small deposits indicates that in all probability the old river, near the mouth of Deer creek, received a tributary of which one branch came from Nevada City and the other from Grass valley.

Grades:

Lowest point—Sicards flat, $3\frac{1}{2}$ miles, 60 feet per mile (?).

Sicards flat—Timbuctoo, $1\frac{1}{4}$ miles, 100 feet per mile.

Timbuctoo—Mooney flat, 3 miles, 113 feet per mile (Smartsville channel).

Mooney flat—French Corral, 10 miles, 78 feet per mile.

The Nevada City and Grass Valley Channels.—In spite of the extensive erosion west of Nevada City and Grass Valley there is pretty good evidence that the channels of these places formed the old equivalents of the present Deer creek and connected with the main Yuba river a short distance above Mooney flat, three miles above Smartsville. The Nevada City channel evidently headed a few miles east-northeast of that city in the Harmony ridge, and is exposed in the East Harmony and West Harmony drift mines; † it runs westward with a steep grade, and, curving southward, emerges east of the Sugarloaf, in the old Manzanita diggings, and thence passes on to the hydraulic mines northwest of the city (American hill). From here on it is largely eroded away. The large amount of gravel in the lower part of this channel is remarkable. The low divide toward the main river eastward formed a gateway through which some of the rhyolitic tuffs poured down toward Nevada City.

Grades:

Manzanita—West Harmony, about 76 feet to the mile.

West Harmony—Harmony, about 190 feet to the mile.

The Grass Valley channel is somewhat different in having a comparatively small amount of gravel. It is covered with tuffs and volcanic sands, above which, as usual, lies the compact tuffaceous andesitic breccia. It is separated from the Nevada City channel by a four-hundred feet high bed-rock ridge, culminating in Banner hill. The first point where

* "Auriferous Gravels," p. 380.

† These mines have been developed since Mr Pettee's visit to the place.

it is met with is at the "Buena Vista slide,"* a few miles east of Grass Valley; it is here covered by heavy masses of rhyolitic sand and tuffs—an overflow from the main South Yuba channel; from here it passed by Kres and Union hill across the eroded gap of Grass Valley, and thence on through the volcanic ridge down to Rough and Ready. The possibility is not excluded that this Grass Valley channel belongs to a somewhat later period than that of Nevada City.

Grades:

The average grade from the Manzanita diggings to supposed junction with the main Yuba near Mooney flat, 16 miles, is 115 feet to the mile.

The same from Buena Vista to the same junction, 16 miles, is about 122 feet to the mile.

The actual grade of the Grass Valley channel from Buena Vista slide to Rough and Ready is about 72 feet per mile. This necessitates a heavy fall for the lower part of the Neocene Deer creek.

French Corral to North San Juan.—Between these two points the channel is nearly continuous, and the volcanic beds once covering the gravel are almost completely eroded. This part of the channel has been described in detail in "Auriferous gravels," page 196. et seq. and page 385 et seq., and also previously to this by Mr J. D. Hague.† Attention should be called to section *B B*, which excellently illustrates the topography of the ancient valley. It is seen that, without allowing anything for subsequent erosion, the northwestern side of the valley rose 1,300 feet in a short distance; it culminated in the (not shown) Oregon peak, a high diabase ridge 1,700 feet above the channel.

Grade:

From French Corral to North San Juan the grade is pretty regular and averages, in 7 miles, 65 feet per mile.

North San Juan to Badger Hill.—In seeking to trace the Neocene river further up the slope from North San Juan there are only two places which can be connected with it. The one which doubtless indicates the continuation of the main channel upward is Badger hill. The stream, of which we find the outlet at Badger hill, must in fact have connected with San Juan; high bed-rock bars any other way. This has been universally recognized by all investigators of the region.

Grade:

North San Juan to Badger hill, $4\frac{1}{2}$ miles, 80 feet per mile.

* The elevation of the bed-rock at this place is somewhat doubtful on account of sliding masses of clay and sand; it is probably not far from 2,750 feet.

† The Water and Gravel Mining Properties belonging to the Eureka Lake and Yuba Canal Company, 1876.

THE NORTH FORK.

Another series of auriferous gravel deposits which can be connected with North San Juan begins at Camptonville. That this is extremely probable has been sufficiently pointed out by Mr Pettee.* I may add that here, too, high bed-rock on either side of Oregon creek prohibits any other outlet excepting that cut by the modern canyon.

From Camptonville this Neocene stream, which corresponds to the present North fork, continued to Depot hill by way of Galena hill and Weeds point (p. 428), and then undoubtedly connected with Indian hill, on the brink of the North Yuba canyon. Near this point it probably forked again, the more important stream crossing the present North fork to Brandy City and Council hill and continuing up toward La Porte and Gibsonville. This branch of the old river will not be followed any further northward in this paper. Toward its sources, near the center of volcanic activity in Sierra and Plumas counties, evidences of disturbances of the gravel beds by faulting became very frequent.

At Depot hill the Neocene stream flowed through a canyon, the walls of which rose about eight hundred feet on the western side and one thousand feet on the eastern side, with a slope of ten or eleven degrees.

Grades :

North San Juan to Camptonville, 91 feet per mile (from a supposed point of junction one and a half miles above North San Juan).

Camptonville to Depot hill, $3\frac{1}{2}$ miles, 135 feet per mile.

Depot hill to Indian hill, 1 mile, 100 feet per mile.

Depot hill to Brandy City, 3 miles, 126 feet per mile.

THE MIDDLE FORK.

Badger Hill to North Bloomfield.—It has never been seriously questioned that there is a continuous channel between these points; its lower course is approximately outlined by the gravel area extending between Lake City and Badger hill by way of North Columbia and Cherokee. The gravel beds here attain the enormous thickness of five hundred feet, and up toward Lake City become covered by thick deposits of clays and volcanic flows.

Grade :

For reasons stated later on it is not probable that there is an even grade between North Bloomfield and Badger hill. It is altogether more probable that for the first four and a half miles from Badger hill the grade is very gentle, about 14 feet per mile, and that the steeper grade of the North Bloomfield channel begins at a point somewhat east of

* Auriferous Gravels, p. 428.

North Columbia; this grade would be approximately 158 feet per mile in a distance of 3 miles, an extraordinary contrast indeed. Mr Pettee* assumes an even grade of 72 feet per mile.†

North Bloomfield to Snow Point.—There has been a belief prevalent for a long time that the Bloomfield channel connects eastward with the Woolsey flat, Moores flat, and Snow Point areas. The line of connection is given by Mr Pettee‡ as being via the Derbec and Watts shafts, and necessitates the very improbable grade of 290 feet per mile between North Bloomfield and the latter place, while the grade between Watts shaft and Woolsey flat would only be 60 feet per mile. Mr Pettee thinks faults or rapids might possibly occur some distance east of North Bloomfield.

As to the Derbec shaft, it certainly is not on the main channel; neither is it very well possible that the Watts shaft is, for there is an inlet north of Backbone house which is considerably lower than the lowest point in the Watts channel (3,800 feet). At this point there is a steep lava bluff underlain by heavy masses of clay; enormous slides have taken place, obscuring the relations of the strata, and the lowest bed-rock point is not easily ascertained with precision. My elevation for this point was made with an aneroid from the known elevation of Backbone house directly above; the lowest bed-rock point would be about 700 feet below the Backbone house, and the elevation 3,400 feet, with a probable error of 50 feet. This is just above the point where Bloody Run makes a sharp turn to the east; on both sides of the creek north of this inlet there are benches of gravel at least as low down as 3,500 feet, indicating plainly, with their bed-rock rising eastward and westward, that a new eroded channel once occupied the space between them. From here the Bloomfield channel must have curved eastward and followed the present canyon up to near Woolsey flat, where it again made a bend southward. The gravel exposed on the opposite side of the Middle fork of the Yuba on the ridge between Kanaka creek and the river at an elevation of 4,000 feet, with rising bed-rock northward, lends additional strength to this view. Watts shaft in all probability only represents a tributary to the main river.

From Woolsey flat the continuation of the channel is very distinctly indicated by Moores flat, Orleans and Snow Point, as pointed out by Mr Pettee;§ at Orleans and Snow Point the stream flowed in a comparatively steep, narrow valley. The bed-rock immediately to the south

* Auriferous Gravels, p. 392.

† Mr Pettee's distances vary somewhat from those here adopted, which I have endeavored to measure along the probable curves of the stream.

‡ Auriferous Gravels, p. 399 et seq.

§ Auriferous Gravels, p. 203.

of these points rises in a short distance 700 feet above the bottom of the channel.

Grades :

North Bloomfield to Backbone inlet, 3 miles, 152 feet per mile.

Backbone inlet to Moores flat, $4\frac{1}{2}$ miles, 137 feet per mile.

Moores flat to Snow Point, $2\frac{1}{4}$ miles, 87 feet per mile.

The Derbec Channel.—The Derbec shaft is sunk on a very different channel from that of North Bloomfield; it pays for drifting, which the main channel does not, as a rule, and it carries a great many granite boulders, which I think are derived from a hidden area under the volcanic flows rather than carried down from the granitic area above Washington. It has been mined for a distance of 3,500 feet in an easterly direction from the shaft. It represents a tributary to the main channel, and I think it very probable that it connects under the lava with the Relief inlet. Its course from there upward is very uncertain, as so much of it has been eroded. A connection with the Omega gravel area and others below that on the brink of the South Yuba canyon seems quite probable, but the problem is complicated by the existence of the deep Centennial channel on the Washington ridge, and more investigations are necessary before a final result can be reached. On the other hand, the Derbec channel undoubtedly joins the main channel at some place between North Bloomfield and the Backbone house.

Grades :

Derbec shaft to Relief, 3 miles, 115 feet per mile.*

From the Derbec shaft down to the main channel there is a pretty heavy grade of about 120 or 150 feet to be accounted for, but the distance, allowing for some curves, might have been nearly one mile.

The Forest City Channel.—The channel between Orleans flat and Forest City is sufficiently known from Mr Pettee's notes.† Above Forest City the Neocene valley is continuous as far as City of Six, overlooking Downieville. From here it is not easy to trace it any further.

Between Forest City and the Ruby mine there is, however, a break in form of a mass or dike of volcanic rock. At the Ruby mine there are two channels, one lower connecting with the City of Six, and one upper running toward Forest City. The Bald Mountain Extension is mining a tributary from the northeast. In its former tunnel a basalt dike was found cutting across the andesitic breccia and showing that the eruption of the basalt masses of the Forest hill table mountain took place in this vicinity.

* Auriferous Gravels, p. 405.

† Ibid., p. 433 et seq.

Grade:

From Orleans flat to Forest City, $5\frac{1}{2}$ miles, 70 feet per mile.

Snow Point to Milton.—Mr Pettee regarded it as improbable that any stream ever came down to Snow Point from an easterly or northeasterly direction,* and evidently considered the Forest City channel as the main Neocene Middle Yuba. He states, regarding the country to the northeast of Snow Point,† that “it is thought by some that a channel will be traced from Haskell peak by way of Chips hill (near Sierra City) to a junction with another channel coming from a more easterly direction, and that the two united follow a course under the lava by way of American hill and Nebraska to some point near Forest City. . . . Others think that the high channel followed an independent course toward the south and crossed the line of the present Yuba river near Milton without making any connection at all with the lower channel, which passes by Forest City.” Mr C. W. Hendel, who is intimately acquainted with the mining industries of Sierra and Plumas counties, appears to have been the first to announce the former view as long ago as 1872,‡ but he carries his channel down from Plumas county by Beckwith pass and Gold lake somewhat regardless of grades and intervening bed-rock ranges.

Mr Pettee states that his examination was hardly sufficiently extended to warrant the expression of any decided opinion, but that, while he was not ready to assert that there were no old gravel channels, he did not think it proved that any existed in this vicinity.§

The careful examination of the country between American hill and Milton cannot fail to convince any one of the existence of a decided trough or depression below the lava, so deep as to justify the conclusion that it represents the principal Middle Yuba during Neocene times.

The outlet of this channel is undoubtedly found at or near American hill, on the southern bank of Wolf creek, while Nebraska and the gravels between the forks of Wolf creek represent tributaries to the main river. The gravel banks exposed at Bunker hill (near American hill) are about three hundred feet high, and the deep trough-like channel is clearly indicated. From the outlet at American hill there is hardly any other course possible, down stream, than across the eroded canyon of the Middle Yuba toward Snow Point. That a large channel ever passed across the Graniteville gap at Shand's hotel is, for a great number of reasons, not at all likely. The elevation of this gap is 4,625 feet.

For at least ten miles above American hill the channel is hidden under the lava flow on the north side of the Middle Yuba. On the north-

* Auriferous Gravels, p. 401.

† Ibid., p. 442.

‡ Ibid., p. 210.

§ Ibid., p. 442.

western side the bed-rock is very high, sometimes forming the crest of the divide between the North and Middle Yuba. On the other hand, the lava bed-rock contact runs very low on the slope of the canyon side, while it rises to considerable elevations on the opposite, southeastern side of the river. This relation is clearly illustrated in section *DD* (plate 7). For a long distance above American hill there is no indication that the channel passes out from under the lava into the eroded canyon. Supposing a fairly uniform grade from Milton to American hill, it cannot emerge until about nine miles from Milton, and very possibly less. At any rate, the old channel for many miles above American hill would appear to offer an excellent field for drifting operations. It is easily accessible from the canyon of the Middle Yuba by moderately long tunnels, which, for instance, at the section *DD* would probably have to be placed at an elevation of 5,000 feet. It is quite likely that the gravel in this channel would pay for drifting, especially as it would have received the débris from a part of the quartz mines south and southwest of Sierra City. An attempt to open up this channel was made at the Savage tunnel, about four miles above American hill, but it was abandoned long before completion.

Attention should be called to the deep valley through which the section shows the channel to have flowed. Those accustomed to profiles of equal horizontal and vertical scale will readily recognize the abrupt slopes of its sides. It is not probable that Pinoli peak has suffered any large degradation since the Neocene times, as andesitic flows cover it on the eastern side almost to the top.

High bed-rock continues on the divide north of the Middle Yuba up to Milton, while the lava runs far down on the northern canyon slope. The detailed investigations in this region have not yet been completed, and just where the channel leaves the lava flow and follows the eroded course of the present river is not quite certain. Neither to the north nor to the south is there, however, as far as I am aware, any possible outlet by which it could have turned from this course until Milton is reached.

At Milton, however, there are both north and south of the Middle Yuba places with sufficiently low bed-rock to allow the Neocene river to deviate from its course parallel to the river. The first is about a mile southeast of Milton and forms the distinct outlet of the subsequently described Milton-Meadow lake channel; its elevation is not far from 5,950 feet. The second is northeast of Milton, where a gap appears to exist, with rapidly rising bed-rock on both sides. The approximate elevation of this gap, which I do not know from personal inspection, has been determined by Mr Pettee to be 5,938 feet.* It would seem to rep-

* Auriferous Gravels, p. 442.

resent a tributary coming down from the vicinity of Haskell peak. The high bed-rock ridges near Haskell peak, the northern side of which have been examined by Mr H. W. Turner, preclude, except by assuming very large subsequent disturbances, any supposition that a channel could have flowed northward from Milton.

Grades :

American hill to Snow Point, $4\frac{1}{2}$ miles, 114 feet per mile.

American hill to Milton, 11 miles, 107 feet per mile.

Milton to Meadow Lake.—Between these two places, a distance of 11 miles, there exists a deep channel entirely covered by volcanic rocks. It is easily traceable by means of a lower flow of rhyolite and by means of conspicuous bed-rock ridges rising on either side. The highest of these is English mountain, through which the section *EE* is laid. It shows that in some places, at least, the bed-rock peaks rise to a height of 2,000 feet above the ancient rivers.* The outlet of this channel is, as mentioned above, about one mile southeast of Milton, at the base of a high andesitic bluff underlain by rhyolite; it does not seem as if this rhyolite flow had extended much farther in a westerly direction from here. An attempt has been made to open the channel in this place; an old tunnel is still visible, but I do not know how the enterprise succeeded. Some coarse wash gold is said to have been found in this vicinity; there is no evidence of any considerable amount of gravel. So far up as this the old rivers probably did not accumulate much more gravel than the present streams do now in bars and stretches of slight grade. Whether the channel would pay for drifting is a doubtful question.

The distinct inlet of this channel is found between Fordyce and Meadow lakes at an elevation of nearly 6,700 feet. It is clearly indicated by the trough-shaped depression filled with rhyolite ("white lava") between the high granitic hills west of Meadow lake and the slate ridges of the main divide about two miles to the northeast. It would seem almost certain that this part of the ancient stream—east of Meadow lake—would be auriferous; the detritus from the Meadow lake quartz mines must have been swept down into this trough. Whether auriferous enough for drifting is another question. No gravel is visible at this point; moraines cover, however, a great deal of the ground here and obscure somewhat the relations between lava and bed-rock.

The course of the stream above this point is not known; its uppermost course has been swept away by the erosion of the North creek. High granite ridges rise southward and eastward; in fact we are now near the source of the Neocene river; the Neocene divide is only five or six miles

* A shoulder projecting from English mountain, which has been somewhat exaggerated in the drawing, produces the impression of a terrace. Such a terrace or bench does not exist in reality.

distant and its lowest passes eastward were at least one thousand feet higher than the stream at Meadow lake.

Grade:

Meadow lake to Milton, 11 miles, 73 feet per mile.

THE SOUTH FORK.

Badger Hill to Dutch Flat.—From Badger hill to Dutch Flat or Gold Run extends, about parallel to the axis of the Sierra, a series of extraordinarily heavy gravel deposits, largely denuded of their volcanic cap and especially adapted for mining by the hydraulic process. It formed a part of the old "blue lead," that mysterious stream which was formerly believed to have flowed north and south along the Sierra with a supreme disregard for grades and high slate ridges. The true relations of the deep channel in these deposits have been extensively discussed, especially in the "Auriferous gravels;" but Mr Pettee, who carefully examined the gravel mines along this line, was unable to form an opinion which could reconcile the apparently conflicting facts of grades and directions.

Mr Pettee stated* his belief that no deep channel will ever be found between Badger hill and Grizzly hill, but afterward suggested † that a connection existed between Blue Tent and Badger hill by way of Grizzly hill:

"It seems most probable that this portion of the gravel field represents a broad estuary or lake-like expansion of water at the junction of two streams or where two streams by the filling up of their channels and the covering of the low intervening ridges became practically one. If this latter view is correct, it is not impossible that there may once have been a current from Grizzly hill toward Columbia hill even if the slope of the deep bed-rock is just in the opposite direction."

Mr Pettee‡ feels confident that no deep channel exists between Blue Tent and Scotts flat. He did not, however, examine the intervening ground. The continuity of the deep flat channel between Quaker hill and Dutch Flat is not denied, but he believes that there is also a deep channel with slight grade between Dutch Flat and Indiana hill, which would complicate matters greatly, for the channel at Indiana hill drains directly toward the deep channel of the Neocene American river.

After stating the facts based upon his excellent barometrical measurements, which I have extensively used in this paper, Mr Pettee says:

"It does not seem possible that there was ever a deep channel flowing in either direction between Quaker hill and Indiana hill. Dutch Flat or Thompson hill must have stood at a parting of the ways, and it is very probable that there was another such parting between You Bet and Red Dog."

* Auriferous Gravels, p. 393.

† Ibid., p. 415.

‡ Auriferous Gravels, p. 413.

As a possibility, he mentions in another part of the volume* that the Red Dog channel may have found an outlet along the present Greenhorn river in a southwesterly direction.

The first question to be disposed of is whether or not there is a continuous channel between Dutch Flat and Indiana hill with a southward grade, as Mr Pettee thinks. It is admitted that there is a deep channel coming down along the Dutch Flat diggings, and that the elevation of this is 2,848 feet at Thompson hill. A short distance south of this, Squires canyon crosses the gravel area connecting Dutch flat and Indiana hill at an elevation of about 3,050 feet, or 200 feet above the bed-rock in the low channel of Thompson hill. Regarding the place Mr Pettee † says that "Where the gravel range is crossed by Squires canyon the country rock is seen on each side with a width of about 500 feet of gravel and tailings in the bottom of the canyon. How much more slate was visible before the accumulation of gravel began it is not easy to determine, but it appears as if the slate did not extend entirely across" . . . The result which I reached after two careful examinations was that the bed-rock does extend entirely across the supposed gap, and this effectually disposes of any deep channel connecting Dutch Flat and Indiana hill. The slate proper does not begin until further down the canyon. The bed-rock at the disputed place is the soft and decomposed gabbro of Dutch Flat, which in places looks very much like clay. There are a great many other considerations which favor the same result. The gravel areas of both Plug Ugly and Jehoshaphat hills between Squires canyon and Dutch Flat canyon have the distinct character of inclined benches above the main channel, through which benches a supposed connection southward could only have been effected by a deep and improbable gorge. Dutch Flat and Indiana hill were evidently separated by a low divide corresponding to the present American-Yuba divide. When the deep channel was filled up with gravel masses the stream began to deposit its load on the adjoining broad inclined benches. Finally even the divide was covered by the gravels, and a bifurcation might have taken place in the latter part of the gravel period by means of which some of the waters of the Yuba found their way over to the American watershed.

If the Tertiary deposits and flows were removed from the region between Dutch Flat and Badger hill an old longitudinal valley would be exposed to view with a high ridge rising both on the eastern and the western side. It cuts the strike of the probably Carboniferous clay slates and siliceous slates at a small angle. The lateral ridges are in part composed of harder siliceous rocks, in part of softer clay slates. The only out-

* Auriferous Gravels, p. 173.

† Auriferous Gravels, p. 153.

lets along this line westward are the narrow canyons cut by the present Bear, Steep Hollow, Greenhorn and South Yuba rivers. Through none of these canyons is there the remotest possibility that the ancient river passed westward. High bed-rock is exposed in each case on both sides of the gap cut by the recent rivers, and not even the smallest remains of any Neocene deposits are met with for some distance below any of the supposed gaps. Any such supposition would, moreover, necessitate extremely improbable and curious bifurcations. Along the whole line, Dutch Flat to Badger hill, there are gravels accumulated to an exceptional depth and extent. Above these gravels rest, at many places, the remnants of an eroded flow of rhyolitic tuffs and sands. They are first met with in Canyon creek, about five miles above Alta. They are exposed at Shady run, at Alta, at You Bet, at Hunts hill, at Buckeye hill and at Quaker hill. Again, they are exposed at Scotts flat, on the northern side of Deer creek, and, finally, at Blue Tent, where their volcanic character begins to be less apparent, being largely mixed with other detrital material; but everywhere they form a sheet perhaps a hundred feet thick and resting on several hundred feet of gravel.

The continuity and the direction of these flows of rhyolitic mud are distinctly and unmistakably indicated on the geologic map. Coming down the old channel along the upper course of Canyon creek, they flowed in a southwesterly direction, passing Alta and Dutch Flat, down to You Bet. Turning here with the valley, they flowed northward by Quaker hill to Blue Tent. Between Blue Tent and Badger hill the volcanic masses are completely eroded and the underlying gravel beds exposed.

Mr. Pettee traced the deep channel northward as far as Hunts hill, or even, with a somewhat uncertain elevation, to Quaker hill. If he had examined the relations at Scotts flat and the country between Scotts flat and Blue Tent, I am confident he would have arrived at the same conclusion which has been reached here. At Scotts flat there is the most ample evidence that a very large channel crosses Deer creek, with rapidly rising rim-rock on the east and west. The creek has not quite cut through the ancient river bed, the bed-rock being covered for a distance of nearly a quarter of a mile. The same accumulations of sands and tuffs as are exposed at Quaker hill are found abundantly above Scotts flat and in Rock creek between Scotts flat and Blue Tent. It has been shown that the deep channel as far as Hunts hill has no possible westerly or southerly outlet. High bed-rock all along on the western as well as the eastern side from here northward simply makes any other outlet than by Blue Tent impossible, if we do not assume entirely improbable faults of several hundred feet of throw. There is no point

by which any outlet by way of Nevada City and Grass Valley could be effected. The Harmony and Grass Valley channels are several hundred feet above the Quaker hill channel. There were, however, two low gaps in the ridge through which a part of the rhyolitic masses overflowed both down the Grass Valley and the Harmony channels (see page 269). From Blue Tent, where the deep channel is only 500 feet above the bed of the South Yuba, the direct continuation is given, as indicated by Mr Pettee, by the correspondingly low trough of the Grizzly hill channel on the opposite side of the river. Again, from here there is no possible low outlet except by Badger hill, and this way the Neocene river must have taken. Mr Pettee's own notes in regard to the former depth of the gravel at Spring creek confirm the existence of a deep channel beyond Grizzly hill.* In channels of slight grade such as this one, ups and downs of ten or twenty feet are very common. All these relations will appear much clearer on the geologic map which, it is hoped, soon will be printed.

If the deep channel between Blue Tent and Quaker hill would pay for drifting it would be a magnificent field for enterprise. Unfortunately, there are some doubts concerning this. The gold of extraordinarily heavy gravel beds is more commonly divided through the whole mass than concentrated on the bed-rock. However, drifting operations have been carried on with profit at You Bet, and it is not improbable that this part of the channel would pay well, at least in some places. It is said that an attempt to drift the deep channel at the Blue Tent outlet was not attended with success. The deposit would have to be opened up by long tunnels from the South Yuba canyon at Blue Tent, or east of that place.

Section *CC* is a typical one through the great Neocene South Yuba valley. On it may be noted the prominent bed-rock point of Banner hill—composed of diabase-breccia—and the andesitic and rhyolitic flows, as well as the upper gravel benches and the central trough or gutter. To one peculiarity of the rhyolitic flows attention should be called: although the flows descended the valley in a northwesterly direction and should present a level surface from east to west, still it is found quite generally that the eastern margin is higher by one or two hundred feet than the western. It is perhaps best not to attach too much importance to this as an indication of tilting, for in the first place a part of the flow was drained off through one or two lower gaps toward the west, and in the second place some erosion doubtless degraded the even surface in the interval between the rhyolitic and the andesitic flows.

* Auriferous Gravels, p. 393.

Grades:

Wherever any parts of the deepest channel between Badger hill and Little York are exposed a very slight grade is almost invariably found to exist; it is so at Badger hill, Grizzly hill, Hunts hill, and You Bet. This is a pretty distinct hint as to the general character of the channel.

From Badger hill to Grizzly hill, a distance of six miles, there is a grade of sixteen feet to the mile. From Grizzly hill to Blue Tent across the South Yuba there is practically no grade. From Blue Tent to Hunts hill, a probable distance of eight miles, there is a grade of seventeen feet to the mile. At Quaker hill the value found by Mr Pettee, but which, according to him, is not quite reliable, was 2,650 feet, or 30 feet higher than at Hunts hill. It must be remembered, however, that great inequalities often exist in channels of gentle grade. In the Mayflower channel, for instance, Mr Browne has shown the existence of irregularities of twenty feet above and below the general grade. At Scotts flat the deep channel mentioned before has not been exposed. A shaft was sunk long ago in the creek which did not strike bed-rock until two hundred feet deep, at an elevation of 2,775 feet, but the channel below the level of the creek is about 2,000 feet wide and the probability of striking the deepest depression by a single shaft without drifting is very slight.

From Hunts hill to Red Dog the channel is practically level; neither is there any appreciable difference in level between Red Dog and Niece and West's mine at You Bet, a distance of about three miles, in which the deepest channel is hidden under heavy masses of gravel.* Between these last-named places several drift mines have been opened up, and in them, as shown by Mr. Pettee,† the deepest bed-rock is somewhat higher than at either end of the channel.

From the places there referred to as Heidliff's and Mallory's claims the bed-rock slopes down to Niece and West's about 20 feet. Opposite Niece and West's mine is an isolated fragment of the deepest channel, known as "Waloupa," which place is again 30 feet lower than the bed-rock at Niece and West's. This makes a total length of about one mile in which the channel flowed in a nearly northeasterly direction. It is certainly interesting and worthy of notice that in this rare instance of a northeasterly direction the present grade of the Neocene channel should have the considerable slope of 50 feet to the mile in the opposite direction to that of the river in general, so that if the present grade were also that of the Neocene river it must at this point have flowed uphill for a dis-

* Mr E. C. Uren, of Auburn, has made a spirit-level survey along the surface between the two points and informs me that both have the same elevation.

† Auriferous Gravels, p. 166.

tance of one mile. The character of the gravel at this place is not different from that of adjoining parts of the old river. It must be admitted that this instance strongly suggests a deformation of the Neocene river bed by an increase of the westerly slope of the Sierra.

From Waloupa to Little York, a distance of one and a half miles, the channel has a grade of 76 feet per mile. The direction has now turned westerly.

From Little York to Dutch Flat, a distance of two and a quarter miles, there is a grade of 63 feet per mile.

It should be stated that there is no perceptible difference in the character of the bed-rock between the Quaker hill and You Bet part of the channel and the channel between Waloupa and Dutch Flat. The sudden increase in slope must be traced to other causes.

The Channel at Dutch Flat.—In the Dutch Flat channel a considerable rise of the bed-rock occurs and the width narrows. Large boulders are found on the bed-rock and everything indicates a rapid current. This is partly explained by the belt of hard quartzite and gabbro across which the Neocene stream flowed at this place.

Grade:

In one mile, 227 feet.

The Liberty Hill Tributary.—This stream, which must have joined the main channel at the upper end of the Dutch Flat diggings, can be easily traced by way of Elmore hill, Liberty hill, Lowell hill and across Steep Hollow creek to Remington hill. From here its course has not certainly been determined.

Through the recent operations of a Gold Hill, Nevada, company at the Centennial tunnel and shaft the existence of a deep channel from Phelps hill southward has been proved. According to information obtained from the superintendent, Mr H. Richards, this channel, where at present met with in the tunnel, is wide and flat, and has a grade eastward of 75 feet to the mile. The channel exposed by the San José shaft is stated to be 60 or 70 feet higher than the first channel, and probably connects with it at some point further southward. There is, on account of high bed-rock, no possibility that the Centennial channel connects under the ridge with the Omega channel, and the probability seems to be that a continuous channel exists between Phelps hill and Remington hill, with a general north-and-south direction. If so, its grade must, on the whole, be slight, for Phelps hill is only 200 feet higher than Remington hill, which, with a distance of four or five miles, would give an average grade of 40 or 50 feet to the mile. The Centennial channel contains granite boulders, which would seem to indicate that its headwaters were up in the granite

area above Washington. If this be the case, on the other hand, the Relief channel could not very well have connected with the Omega. Many complicated questions remain to be worked out in this vicinity.

In this connection mention might be made of the curious relations near mount Oro, a few miles east of Quaker hill. The same volcanic area that overlies the Phelps Hill-Remington channel covers this vicinity, but under it at mount Oro there appears to exist, if my information is correct, a depression which, as exposed by old inclines, is much deeper than the rims of the lava flow are at any place; it is at a lower elevation than both Phelps hill and Remington hill, and no possible outlet can be suggested.

Whatever the relations of the Centennial channel will ultimately prove to be, I think it probable that a fork of the principal channel continued from Remington, by way of Democrat and Excelsior, in a northeasterly direction under the volcanic cover for some distance up toward Omega.

Grades:

Upper Dutch Flat to Liberty hill, $1\frac{1}{2}$ miles, 183 feet to the mile.

Liberty hill to Lowell hill, $3\frac{1}{2}$ miles, 136 feet to the mile.

Lowell hill to Remington hill, $\frac{1}{2}$ mile, 90 feet to the mile.

The Channel between Alta and Shady Run.—Cut off for some distance by Little Bear creek, the principal channel is found again emerging from under the volcanic cap at Nary Red, northwest of Alta. Some parts of this channel near Nary Red have been drifted. Near Alta two shafts have been sunk on it. In the one to the north of the railroad, according to information received of Mr E. C. Uren, of Auburn, bed-rock was reached at 200 feet and good gravel found, not rich enough, however, to pay for mining by shafts. At this point the main channel appears to have been joined by a tributary coming in from the west at the Moody gap, on the divide between Canyon creek and the American river and crossing Canyon creek south of Alta. The main channel continues, I have no doubt, under the lava cap up toward Blue Bluffs at Shady run, where it probably forked again, one fork, the deposits of which now are mostly eroded, continuing up toward the Neocene highlands near Cisco, by way of the isolated gravel area of Lost Camp, the other fork continuing for some distance up toward Blue canyon and Emigrant Gap under the lava ridge.

It would seem as if the deep channel from Alta up toward Blue canyon would offer a good field for mining enterprises.* The upper part of it is accessible by tunnels from the steep side of the canyon of the American

*Attention was some time ago, and very justly, drawn to the existence of this channel by Mr James F. Talbott, of Shady run, in a series of articles in the Mining and Scientific Press of June 14, 1890, et seq., vol. 60, No. 24, et seq.

river and the lower part by tunnels from Nary Red, or from certain parts of Canyon creek. It is doubtful whether this channel extends up to Emigrant Gap. The relations of the bed-rock to the lava at this place lead me to believe that it is rather the Omega channel, which extends up by Bear Valley house, near Emigrant Gap, and from there connects with the short distance of channel clearly indicated some distance south of Cisco. The steepness of the sides of this channel, which is remarkable, is illustrated in section *FF*. In a distance of three miles it has a grade of four hundred feet, or 133 feet to the mile. The channels above Emigrant Gap do not, I think, carry gold enough to make their exploitation profitable.

Grades :

Dutch Flat to Nary Red, one mile, about 225 feet.

Nary Red to Blue Bluffs, four miles, about 125 feet to the mile. The bed-rock at Blue Bluffs slopes in toward the ridge.

THE NEOCENE AMERICAN RIVER.

Ridges of older rocks separated the watershed of the Neocene American river from that of the Yuba. The North fork of the American drained the region of Forest hill, and its sources are found near Summit valley, at the crest of the range. The South fork drained the Placerville region, and it appears to have headed among the peaks south of lake Tahoe. Only part of the latter drainage system has been mapped.

THE SOUTH FORK.

From the Sacramento Valley to Diamond Springs.—The accumulations along the lower part of the Neocene American river are to a very great extent destroyed by subsequent erosion, and to reconstruct that part of the river is consequently not very easy ; moreover, it has only a theoretical interest, since nearly all of the auriferous gravels along it are swept away. In discussing the direction of the river from near Diamond Springs, the lowest point to which he traced it down to the plains, W. A. Goodyear expresses the opinion that it probably passed through the gap at Pilot Hill and thence to Folsom, where large accumulations of gravel occur.*

Any other course than by Pilot Hill is indeed out of the question on account of high bed-rock ridges. That it followed the windings of the canyon of the South fork where it cuts through these ridges is so improbable a proposition that it may be left out of the discussion. No remnants of gravels or volcanic flows, however insignificant, are found along this course to give probability to such a view. That the river continued from

*Auriferous Gravels, p. 504.

Diamond Springs in a northwesterly direction toward Pilot Hill is indeed proved by the small remaining deposit of gravel and rhyolitic tuff found at the low, broad gap of Granite hill in such a position that it must indicate the lowest point of the channel at this place. The town of Pilot Hill occupies a similar position in a broad gap, on each side of which hills of older rocks rise to a height of several hundred feet. Besides some Pleistocene angular gravel, there is found at this place a small remnant of another deposit with large, very well rounded boulders, such as can be formed only by a stream of some magnitude. The course from here on is largely hypothetical, but it may be assumed as probable that the river continued in a westerly direction for some miles, joining the Neocene North fork coming down from the vicinity of Forest hill. From here on the two rivers, united, probably flowed in a southwesterly direction to the Neocene gravel masses exposed and mined near the plains between Rocklin and Folsom, at the Lee or Chabot drift mine. From this point the ancient river is hidden under the later accumulations of the plains. The Neocene surface in this vicinity appears to have formed a gently undulating country with little relief as compared with the lowest part of the Yuba river. This is explained by the occurrence of a large *massif* of easily eroded and crumbling granitic rock, over which the old river here made its way. That the gravels at the Lee mine are pre-volcanic cannot be absolutely asserted, but they are certainly of Neocene age.

If the gravel at the Lee mine represents the lowest point known of the Neocene river, it follows that it was here only about 100 feet higher in elevation than the present river in a corresponding position is now.

On the northern side of the sloping breccia table of "Boulder ridge," extending from Auburn to Lincoln, there is another Neocene depression, the gravels of which have been drifted in places; but this cannot represent the lower course of the Neocene American, for a low granitic ridge separates it from the basin in which the continuation of the upper courses of this stream must be sought. On the other hand, the large accumulations of gravel near Folsom are distinctly post-volcanic and were accumulated by the river in early Pleistocene time. That the Neocene river followed the course of the present stream from Folsom up appears very improbable and is not supported by any geologic evidence.

Grades:

Lee mine to Pilot Hill, about 12 miles, 80 feet to the mile.

Pilot Hill to Granite hill, 11 miles, 32 feet to the mile.

Granite hill to Diamond Springs, 6 miles, 21 feet to the mile.

Diamond Springs to Newtown.—After a detailed examination of the gravel region in the vicinity of Placerville, Goodyear arrived at the con-

clusion that a stream of considerable magnitude once approximately followed the course of the present Webber creek from Diamond Springs to Newtown, and into which the complicated channels of the vicinity of Placerville emptied.* His observations did not extend beyond Newtown.

After a careful examination of the region I can only confirm his conclusion, with the addition that this stream without doubt represented the ancient South fork of the American river. It is very distinctly the deepest depression between the highlands of the Georgetown divide on the north and the high ridges on the south separating the Neocene American from the Neocene Cosumnes. The vicinity of Placerville, like the Forest hill divide, is characterized as a broad and flat Neocene depression, in which intervulcanic streams have cut a complicated series of channels. It should be noted that the oldest gravels of Placerville, as a rule, are not deep, and that in most of them occasional rhyolite boulders are found. This would seem to indicate that during the earliest part of the gravel period the conditions were not as favorable here for the accumulation of river deposits as further northward.

About a mile west of Newtown the channel makes a curve, entering the volcanic ridge to the south of Webber creek. It then again turns northward, crossing the south fork of Webber creek about three-quarters of a mile to the northwest of Newtown.

Grades :

Diamond Springs to Webber hill, 2 miles, 71 feet to the mile.

Webber hill to Newtown, 7 miles, 69 feet to the mile.

Newtown to Pacific House.—After crossing the South fork of Webber creek the deep channel disappears under the volcanic capping of the ridge between the two forks of Webber creek, at a place formerly called Iowa City, but now generally known as Snows ranch. From this point it must continue under the eruptive rocks up to the Pacific house, on the stage road between Placerville and Lake Tahoe, where it crosses the present South fork of the American. The existence of a deep trough is unmistakably indicated by rising bed-rock toward the north and the south, by the pitch of the bed-rock wherever exposed along the margin of the volcanic area, and finally by the heavy flows of rhyolite and rhyolitic tuff with which the old depression, up to a certain level, was filled. A typical cross-section of this channel is shown in *K K*, with the probable position and depth of the channel indicated; it is, I believe, sufficiently clear to explain itself. Some extensive mining operations have been and are still carried on to find a deposit under the deep lava-

* Auriferous Gravels, p. 502.

flow north of the North fork of Webber creek, but that any large and important channel will ever be found on that side is very unlikely, except possibly at one point somewhat north of the section where a tributary from the north appears to join the principal river by way of Badger hill and Mooneys diggings (not indicated on the map).

The lower part at least of this large and important channel may not unlikely be found to pay for drifting; it can only be opened up by means of tunnels from near Snows ranch or from some places along the North fork of Webber creek. Inclines along the rim will probably suffer from a heavy influx of water.

At Pacific house the indications of an inlet are distinct, but I do not think that much gold was ever found in the adjoining gulches. Opposite that place, on a bench overlooking the South fork of the American river, a small isolated area of gravel has been washed away by the hydraulic process, and it is quite certain that the old channel crossed the river at this point. More indications of the same channel are found on the north side, a few miles eastward. Its course has not been traced further, but it appears probable that it will be found to cross the river again higher up, and that it headed up toward the Neocene volcanoes on the line between Eldorado and Alpine counties. The channel is not likely to be auriferous above the Pacific house.

A broad belt of Neocene highlands with lofty peaks and ridges occupied the space between the upper courses of the North and South forks of the American river, and on the Georgetown divide a spur extended from these highlands far toward the west.

Grade:

Newtown to Pacific house, 10 miles, 100 feet to the mile.

THE NORTH FORK.

From the Junction to Jones Hill.—The lower course of the North fork of the American river is almost completely destroyed by erosion; its probable course from the valley up to the junction has already been mentioned. Between the Lee mine and the Forest Hill divide there is only one remaining fragment, which, moreover, probably does not represent the very deepest part of the channel, namely, the small patch of mixed andesitic, rhyolitic, and metamorphic gravel found on top of the bluff at the junction of the present North and Middle forks, about three miles northwest of Auburn; the presence of rhyolite in this gravel is a strong proof that it came from the vicinity of Forest hill. This gravel is found in the center of a very broad, low depression bordered on the north by the Neocene highlands of Clipper Gap and on the south by the rising

divide separating the watershed of the Neocene North fork from that of the South fork. There are several small volcanic areas, sometimes underlain by gravel, two or three miles northwest of Auburn, near the railroad; but these are too high to have formed part of the principal channel. Between the small deposit mentioned and Jones hill no trace of the ancient river can be found.

Grades:

Lee mine to Auburn, about 14 miles, 86 feet to the mile.

Auburn to Jones hill, 9 miles, 63 feet to the mile.

Jones Hill to Bath.—A great many difficulties present themselves when an attempt is made to reconstruct the drainage southwest of Forest hill. Mr Browne has shown that a large antevolcanic channel enters the Forest hill divide at Bath and, making a large curve, passes by the Mayflower mine; thence to near Forest hill, where it comes near the margin of the volcanic cap, but turns again at the Dardanelles mine and runs in under the lava in a northwesterly direction.

Another channel enters under the volcanic ridge at Yankee Jim. Whether it connects with the Dardanelles channel is not known. The volcanic ridge continues down to Peckham hill, but only later intervolcanic channels appear to exist below it, which would seem to indicate that the older channel has in this vicinity been nearly entirely obliterated by those of a later period, if, indeed, it ever followed this direction. I have provisionally marked the older channel as following the ridge down to Peckham hill and joining another channel near Yankee Jim.

The so-called Ponds channel near Todds valley is at too high an elevation to have ever formed a part of the lowest antevolcanic channel, and should, I think, rather be considered as a bench gravel deposited after the filling up of the deepest depression.

The question of the continuation of the Mayflower and Dardanelles channels is very much complicated by the existence of a detached series of evidently antevolcanic gravel areas to the south of the Middle fork. I have provisionally connected them with a line running from Jones hill, with an elevation of 2,114 feet, by Floris, with an elevation of 2,530 feet, up to the channel which near Volcanoville emerges from the volcanic ridge south of the Middle fork.* The deposit at Floris is 140 feet lower than the main Dardanelles channel in a corresponding position. Any attempt to explain these apparent contradictions would lead too far into the realm of hypotheses.

It is certain, however, that a channel of some magnitude came down from the highlands of the Georgetown divide, crossed Otter creek at

*Several small Neocene tributaries came down toward this line from the Georgetown divide.

Kentucky flat, and continued from there under the lava cap to a place a short distance to the northeast of Volcanoville; at one intermediate point, Missouri gulch, it is exposed for a short distance.

Grades:

Jones hill (2,114 feet) to Floris (2,530 feet), $5\frac{1}{2}$ miles, 76 feet to the mile.

Floris to Volcanoville, 3 miles, 112 feet to the mile.

Volcanoville to Missouri gulch, 2 miles, 114 feet to the mile.

Missouri gulch to Kentucky flat, 2 miles, 62 feet to the mile.

Jones hill to Peckham hill, $1\frac{1}{4}$ miles, 57 feet to the mile.

Peckham hill to Dardanelles, $5\frac{1}{2}$ miles, 90 feet to the mile.

Dardanelles to Mayflower, $2\frac{1}{2}$ miles, 52 feet to the mile.

Mayflower to Bath, $2\frac{1}{2}$ miles, 40 feet to the mile.

The Iowa Hill Channel.—Difficulties also exist in connecting the Iowa hill channel with the rest of the drainage. I have assumed that a connection existed between Indiana hill and Iowa hill, and that the Iowa Hill channel ran southward and connected with the inlet at Yankee Jim. One of the principal objections to this view is the occurrence of a small gravel body at an intermediate point, Kings hill, which appears to be about 70 feet lower down than the lowest bed-rock at Yankee Jim. The Iowa hill or Morningstar channel, as it is also called, has been described in detail by Mr Hobson,* who concludes that the stream had a grade toward the north, and that coming from some point on the Forest Hill divide it was joined north of Iowa hill by a tributary from Indiana hill, after which it curved westward and flowed down toward the plains along the canyon excavated by the present stream. Mr Hobson's own figures on the maps and the profiles accompanying the paper do not seem to me to warrant this conclusion, as far as the grade is concerned. The bed-rock south of Iowa hill and at the hydraulic workings of the Morningstar has exactly the same elevation, according to the figures on Mr Hobson's map, as the starting point at the southern end of the covered channel at Wisconsin hill, a distance of between two and three miles. North of Iowa hill there is a sudden descent of some 50 or 60 feet, but the distance in which this descent is accomplished is only one-fifteenth part of the whole length of the channel; and it looks very much as if this depression were caused by a slight fault, especially as there are two or three of such disturbances shown on his profile in the Morningstar ground. An examination of Mr Hobson's profiles will inevitably lead to the conclusion that before the faulting, whether this took place by an uplift of the southern side or a downthrow of the northern, there was a

*Tenth Ann. Rep. State Mineralogist of California, p. 420.

slight southward slope from the Morningstar works to Wisconsin hill. Mr Hobson's arguments, based on the occurrence of serpentine boulders in certain parts of the channel and on the relative elevation of the rhyolitic strata, are stronger. There are, however, such difficulties involved in carrying the principal channel in the direction advocated by Mr Hobson that I cannot adopt his view as the most probable.

Bath to Ralstons.—In discussing the upward continuation of the large and deep channel at Bath, which is the same as that of the Mayflower mine, Goodyear indicated several reasons why it was probable that it came down from the Long canyon country, the principal ones being the occurrence in it of granite boulders and its capping of "white lava" (rhyolite). The vicinity of Long canyon was only examined in a cursory way by Goodyear. There is, indeed, at the Ralston mine, in the western part of the divide north of Long canyon, unmistakable evidence of an outlet of a large and important channel; there is, further, a remarkable and striking similarity between the accumulations of the Ralston channel with those of the Bath-Mayflower stream; there is, further, no other way open for the Ralston channel than in the direction of Bath, for higher bed-rock bars the way both to the south and to the north; hence I feel justified in concluding that a connection once existed between the two channels, which has since been eroded by the recent stream of the Middle fork.

Mr Browne is struck with the considerable extent to which the modern rivers on the Forest hill divide have avoided the older channels, leaving them buried under the volcanic flows on the top of the ridges.* To explain it he assumes that the ancient valley was filled with volcanic material only up to its widespread rims, but not to overflowing, and that the modern rivers started by preference along the marginal lines of the deposits. A study of the geologic map of the country north and south of the Forest hill divide will show that there is no good reason for such an assumption. On the contrary, the last flows almost completely flooded and buried the Neocene valley and its divides in this vicinity; the only points rising above them were the high hills to the west of the "Brimstone plains" and the Volcanoville hill to the southward. Only on the upper part of the Georgetown divide were there any continuous and important bed-rock ridges projecting above the general level of the flows.

The explanation of Mr Browne might well be applied to certain parts of the upper river courses, but I do not think it explains the positions of the present streams on the Forest hill divide. Slight inequalities in the surface of the andesitic flows probably determined first the directions.

*Tenth Ann. Rep. of State Mineralogist of California, p. 442.

Grade:

Bath to Ralston, 8 miles, 72 feet to the mile.

That Michigan Bluffs is not on the principal channel is also indicated by the grades, for from that place to Bath, a distance of three miles, the slope is 140 feet to the mile, while from Michigan Bluffs to Ralston, a distance of five miles, it is only 31 feet to the mile.

The Damascus and Last Chance Tributaries: General Character.—Mr Browne has described the Damascus or "white" channel. Its course above Damascus is eroded; it is practically continuous under the lava cap as far down as Gas hill; from there it is eroded for a long distance, but the characteristic deposits are again found at Michigan Bluffs. It is very different from the Bath channel, being almost entirely composed of quartz gravel, due to the fact of its flowing for a long distance over a soft clay-slate with a large amount of quartz veins. A short distance below Michigan Bluffs it must have joined the principal Middle fork.

Tributary to this channel was the Last Chance stream. Coming down from the high country to the northeast of Last Chance, it is preserved under the lava cap for some distance at Last Chance and again at Deadwood. It seems most probable that it joined the main stream some distance north of Michigan Bluffs. The relations of the lava and bed-rock at the two first-named places clearly indicate that this channel flowed in a very distinct depression or valley. Both at Last Chance and at Deadwood there is an older ante-volcanic besides several cement or inter-volcanic channels.

The important cement channel coming down from the vicinity of Secret canyon by way of Hogsback and Red point under the lava flow very likely followed an ante-volcanic valley; but of the deposits of the latter but little is left.

Grades:

Damascus to Michigan Bluffs, $8\frac{1}{2}$ miles, 73 feet to the mile.

Deadwood to Last Chance, 5 miles, 136 feet to the mile.

From the Ralston Mine to Summit Valley.—The divide between Long canyon and the Middle fork of the American river is covered by very deep Neocene deposits and volcanic flows. High bed-rock exists to the north and to the south, forming the sides of a broad and deep depression, the center of which lies buried below the volcanic mass. This deep depression extends in a northeasterly direction up toward Summit valley a distance of about thirty-five miles, in which the deepest channel is only exposed at one point, at the place where the North fork of the American river cuts through it. This is the longest lava-covered stretch of channel in the territory here described. The parallelism with the

present Middle fork should be noted, as well as the bend in its lower course, which closely follows the curve of Long canyon.

The lower Course.—On the Long canyon divide—i. e., from the Ralston mine to the place called Big Flume on the map—the deposits in the channel preserve about the same characteristics. The general form of valley and depth of deposits are illustrated in section *HH* (plate 7).

It appears as if the channel in the Long canyon divide had in most places a broad, flat profile. On the bed-rock, as a rule, lies from twenty to forty feet of non-volcanic gravel, composed of quartz, quartzite and granite. Above this rests a series of alternating rhyolitic tuffs and gravels with rhyolitic pebbles, which ranges in depth from 150 feet at the western end of the ridge to 400 or 500 feet up toward Big Flume. In the western part of the divide the volcanic gravels are heavier, reaching 80 or 100 feet at the Ralston mine. Toward the east they grow thinner and the rhyolitic tuffs begin to predominate. Above the rhyolitic tuffs lie from 700 to 800 feet of andesitic breccia. The center of the channel evidently lies on the southern side of the ridge toward Long canyon, and an almost continuous fringe of gravels and tuffs are exposed along this line. At Blacksmith flat the bed-rock is probably not far above the deepest depression in the center of the channel, which here reaches its most southerly point. A smaller tributary at this place came in from the south by way of Corcorans diggings and Clydesdale, the bed-rock at the latter place, near the point between Long and Wallace canyons, being a little higher than that of Blacksmith flat. Again, at Russian ravine, one mile south of Big Flume, the bed-rock is probably nearly as low as that of the deepest channel.

Numerous attempts have been made on a small scale to mine these gravels. At Ralston's the upper gravels have been hydraulicked with satisfactory results; many small diggings are found along the rim on the southern side of the divide as far up as Big Flume, but nowhere, so far as I am aware, has any systematic and extensive work been undertaken in order to open up this magnificent channel by means of tunnels. It would seem very likely that some paying ground would be found along it; some risk must be taken, for it is of course impossible to predict whether a certain gravel channel will pay for drifting or not without a trial. That the channel exists and that it is of great dimensions is quite certain. Long canyon is said to have been rich in early days as far up as Russian ravine, while the Middle fork contained less gold.

Grades:

Ralston mine to Blacksmith flat (assuming that the bed-rock at the latter place is but little higher than in the deepest channel), 5 miles, 65 feet to the mile.

Blacksmith flat to Russian ravine (on similar assumptions), 7 miles, 93 feet to the mile.

The Duncan Peak Tributary.—A short distance from Big Flume, on the northern side of the ridge, there is a deep trough exposed, and known as Marshall's claim. It is, according to my measurements, 50 feet higher than the bed-rock in Russian ravine on the southern side, and it is filled to a depth of about 100 feet with gravel, of which a little has been hydraulicked. This place is evidently near the confluence of a tributary coming down with steep grade from the vicinity of the old Neocene mountain of Duncan peak. From Flat ravine, on the south side of Duncan peak, it runs down almost as a steep ravine to near the Gray Eagle tunnel; from here it must have connected across Duncan canyon with the main channel of the American river by way of Marshalls inlet. Abrams tunnel on Duncan canyon is probably in the same channel

Grades:

Flat ravine to Gray Eagle tunnel, 2 miles, 350 feet to the mile.

Gray Eagle tunnel to Marshalls inlet, 6 miles, 200 feet to the mile.

The Canada Hill Tributary.—On the northern side of Duncan peak there exists another equally steep channel with thin angular gravel. Starting from Canada hill it runs down in a northeasterly direction to Sterrett's claim in Sailor canyon. From there its course is not determined beyond doubt, but it most probably curved around southeastward and joined the main channel near French meadows.

Grade:

Canada hill to Sterrett's claim, in 3 miles, 1,000 feet, or about 333 feet to the mile.

The upper Course.—From Big Flume the channel makes a curve toward the east and crosses the present Middle fork at French meadows, near Ralston dam. At this point the modern river is higher than the bottom of the old channel, but the distance along which there is no bed-rock exposed is short and there is no reason to believe that the deepest part of the channel is very far below the present river-bed.* Very little gravel is exposed from here up toward Summit valley; the rhyolitic flows have also changed character, containing more massive rhyolite and less of tuffs than before. They increase in depth, their thickness at French meadows being 600 feet, and south of Summit valley a maximum thickness of almost 1,000 feet is reached.

Whether the channel from Big Flume up toward Summit valley will

* Mr J. H. Hammond, in the Ninth Annual Rep. State Min. of California, plate 2, gives a cross-section from this vicinity where some prospecting has been done by tunnels and inclines. He, however, places the channel below the North fork, which certainly is incorrect.

pay for drifting is a very doubtful question. It is accessible only by long and costly tunnels from the North fork side or by inclines from the rims. There are but very few quartz mines along the upper course; the channel here enters the generally barren granitic area of the high Sierra.

Near Soda Springs the deep canyon of the North fork has cut through the channel, exposing on both sides the deep volcanic flows and the curve of the old valley. Section *L L* is laid across the valley a little south of this and shows sufficiently clearly the relations at this point. At Soda Springs the recent river is about 200 feet below the Neocene channel.

We are now near the headwaters of the ancient river; on all sides rise bed-rock ridges and peaks, prominent in Neocene as well as in the present time. North of the North fork the old channel begins to rise rapidly toward the summits. The valley opened up in a sort of amphitheater; one branch extended up toward mount Lincoln, another toward Soda Springs station. The principal valley extended up toward a point about a mile west of Summit station, and its continuation can indeed be traced a little further northward toward the high granitic counterforts of Castle peak. The Neocene river, broad and magnificent on the Forest hill divide, is here nothing more than a ravine.

Grades :

Russian ravine to French meadows, 6 miles, 100 feet to the mile.

French meadows to Soda Springs, 10 miles, 115 feet to the mile.

Soda Springs to Summit, 3 miles, 200 feet to the mile.

DISCUSSION OF GRADES.

On plate 6 a first, and in many respects incomplete, attempt has been made to show in a comprehensive manner the more important facts about the present grade and directions of the ante-volcanic Neocene river beds.

Before endeavoring to draw any conclusions from the present condition of these river beds it should be pointed out that the Sierra Nevada is a very heterogeneous mass, composed of rocks of very diverse texture and hardness, which are apt to influence the grade of the rivers flowing over them. Sudden changes of grade are indeed not uncommon in the present rivers as well as in the Neocene channels. It follows from this that conclusions drawn from short distances of channel or based on isolated occurrences cannot be reliable.

An influence of direction on grade probably also exists, inasmuch as streams flowing parallel to the direction of the range would be expected to have a slighter grade than those breaking across the strike of the slates

or cross-belts of hard massive rocks. Such an influence no doubt exists, but it is certainly not very marked in the modern rivers. In the lower Sierra, in which the direction of the rivers for shorter distances only are parallel to the range, it cannot be stated to occur to any considerable extent; the principal forks have a fall of from 30 to 40 feet to the mile in whatever direction they run. In the upper Sierra the Rubicon river runs for fifteen miles near and parallel to the crest line, but the grade averages very high—about 150 feet to the mile.

The grades of the intervolcanic channels must be left out of consideration in endeavoring to ascertain whether the height of the range has been increased since Neocene times, for it has been shown that their erosive activity was similar to that of the present rivers, and that the changes from the conditions of the earlier Neocene to those of today took place or began to take place before the intervolcanic channel system was established. Referring to Mr Browne's diagram of the grades of the volcanic channels, it may be noticed that they in general show a strong grade in whatever direction they flowed.

Perhaps the first fact that attracts the attention when the grade sheet is studied is the remarkably steep grades prevalent. Down near the great valley, as well as high up in the mountains, grades of from 60 to 100 feet and above are noticed; these are certainly not the grades which would be expected in rivers depositing gravel in a country which, as shown by the topography, had been subjected to a long-continued erosion.

A further study will, however, show that while all of the transverse principal channels have a strong grade, most of the principal forks flowing in a direction about parallel to the trend of the range have a comparatively slight grade. The most striking instance of this is furnished by the Neocene South Yuba from Badger hill to You Bet. The sudden increase in grade from Waloupa to Dutch Flat (Thompson hill), where the river suddenly turns from a longitudinal to a transverse direction, illustrates this relation of grade and direction in an especially suggestive manner. A similar contrast is noticed at the junction of the North Bloomfield with the Grizzly Hill channel, and the course of the South fork of the American from Pilot hill to Diamond springs shows a strong tendency in the same direction. The grade of the longitudinal Forest City tributary is considerably less than that of the main river into which it empties, and the uppermost course of the Neocene Middle Yuba from Milton to Meadow lake in a longitudinal course shows a much lower grade than would be expected.

This generalization does not apply to all of the principal forks, however, for the grade of the important tributary extending from Damascus

to Michigan Bluffs is as heavy as that of the main river running in a nearly east-west direction; nor does it apply to the lesser tributaries. The one emptying into the upper North fork of the American river near Russian ravine has a very heavy grade, although running nearly parallel to the range. The same is true of the fragment of channel exposed south of Cisco. The Canada Hill-Sterrett channel offers an interesting instance of a steep Neocene gulch or creek running for some distance in a north-easterly direction.

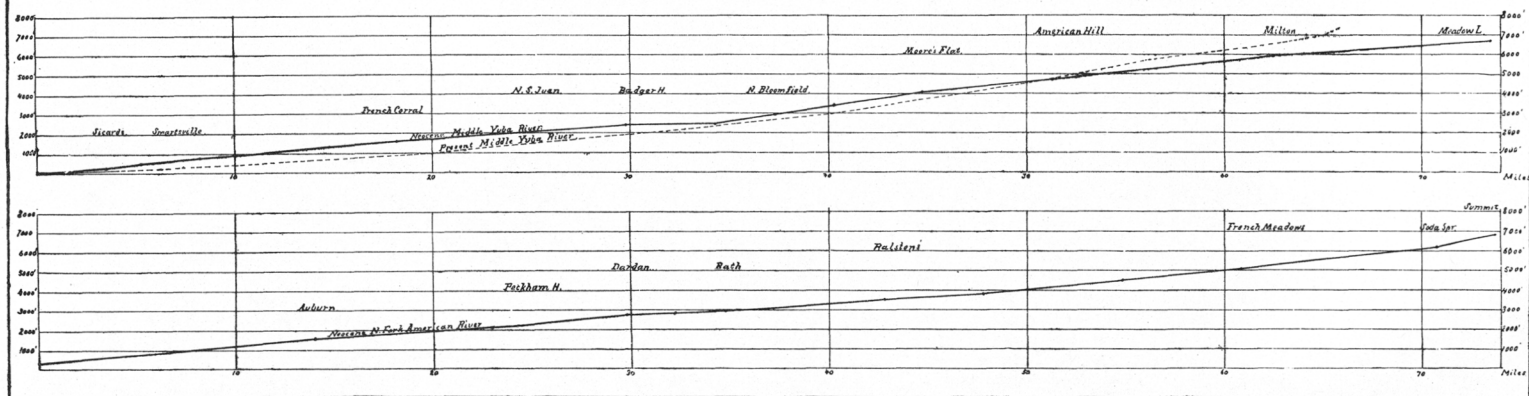
Another fact deserves notice. The North Bloomfield channel up to Moores Flat and the Dutch Flat-Lowell hill channel, in a corresponding position further south, show extremely heavy grades which scarcely can be sufficiently accounted for by harder rock-masses encountered. The North Bloomfield channel cuts with a heavy grade through the same siliceous slates over which the Blue Tent channel flows with a very slight grade. A mass of hard rock is met with at Dutch Flat, but between Dutch Flat and Lowell hill the slates are not particularly resistant.

Taking in consideration the fact that there is no essential difference in the character of deposits between the longitudinal and transverse rivers, the relation of grade and direction explained above is a strong argument in favor of a considerable increase in the slope of the Sierra since the time the ante-volcanic Neocene rivers flowed over its surface.

This uplift was probably gradual and extended over a long period, beginning at or shortly after the initiation of volcanic activity. The evidence from the region of the first summit in the territory here described appears to show that this disturbance ended about the time of the last great lava flows, and that while subsequent elevation might have taken place it has been of slight importance. It is necessary to add, however, that the region of the second summit has not yet been sufficiently examined to warrant the extension of the last statement to the whole range in this latitude.

If this increase in slope be attributed to a simple tilting of a rigid block, such as advocated by Professor Le Conte, if I understand him correctly, a reduction of the channels to fairly uniform grades is impossible; for if the range be supposed to be tilted downward so that the transverse channels with slighter grades become nearly level, many of the other transverse channels in which gravels have accumulated will still have a grade of 80 feet or more to the mile. The maximum amount of tilting to the mile cannot in this case have been more than the minimum grade of the transverse rivers, or from 60 to 70 feet to the mile. This would give a maximum increase of elevation of between 3,600 and 4,200 feet.

If, on the other hand, the increase in slope has been effected by means



GRADE PROFILES OF NEOCENE AND PRESENT RIVERS

of distributed faults of slight throw or equivalent plastic deformation, as held by Mr G. F. Becker,* the grades of the Neocene rivers might more easily be reduced to somewhat uniform figures by assuming that along distances showing exceptionally heavy grades a more intense faulting or deformation has taken place. The considerable and even steep grades of some longitudinal channels show, however, that even by this means the rivers cannot be reduced to gentle and uniform grades.

The vertical curve of the present Neocene channels would appear to offer a criterion by means of which it might be ascertained whether, in addition to the general uplift, the flank of the Sierra has been materially deformed. The grades of two principal forks of the old rivers which in general have a transverse direction have been plotted in plate 9, the distances being taken along the curves of the streams. In the same plate the vertical curve of one of the modern forks has been constructed in order to serve for comparison. The two curves in the upper part of the plate cannot be directly compared, and the difference in the ordinates does not directly indicate the amount of recent erosion, for the curve of the Neocene river is somewhat longer than that of the modern equivalent. It should first be noticed how regular is the curve of the recent river in spite of the fact that the country drained by it is only in the earliest stages of baseleveling. It is, strictly speaking, composed of two curves, the junction of which nearly coincides with the lower limit of glaciation. The existence of the upper curve must be referred to the ice-cap protecting the higher part of the mountains from active erosion during a large part of the Pleistocene.†

If the modern river curve shows such regularity it would be natural to expect that that of the Neocene river, which represents a more advanced stage of base-leveling, should be still more so. But the plotted curve of the Neocene Middle Yuba river does not correspond to the normal curve of erosion. Instead, it appears to be composed of two curves with the convex side upward. I think this convexity, which cannot be explained by differences in the resistance of the rock-masses over which the river flows, must be due to a deformation of the surface during the uplift of the Sierra. The most pronounced departure from the normal curve of erosion results from the present steep grades of the Neocene channels near the valley. This is marked in both the profiles given and must, I think, be regarded as indicating a subsidence of the portion adjoining the sediment-filled trough of the great valley relatively to the middle part of the range, or a rise of the latter relatively to the former. Another deformation would appear to have taken place in the

* Bull. Geol. Soc. Am., vol. 2, pp. 64 and 73; also *idem*, vol. 4, p. 89.

† See G. F. Becker: Bull. Geol. Soc. Am., vol. 2, p. 65.

upper part of the first profile, while that of the second profile seems more like the normal curve of erosion.

It is evident that if, besides the deformation, a general increase in the slope has taken place the curves do not represent that deformation quite correctly, for a diminishing of the slope would affect the grades of the different sections differently according to their angle with the trend of the range. On recalculating the grades for a general decrease in the slope of 50 or 60 feet to the mile it is found, however, that the peculiar convex forms of the curves remain as before or even are slightly more accentuated.

Although the present steep grades of the old Neocene channel can thus be shown to have resulted to a considerable extent from elevation and deformation, it does not follow that the Neocene river system had very slight grades throughout. On the contrary, I believe that a careful study of the Neocene topography, as shown in valley slopes and cross-sections, which hardly can have been influenced by subsequent deformation and certainly have not been faulted to any notable extent, will lead to the conclusion that the Sierra Nevada, before the accumulation of gravels began, was a mountain range greatly worn down by erosion, but not reduced to a baselevel of erosion. It cannot even on the whole be regarded as a peneplain, above which isolated and more resistant hills projected; the declivities and irregularities of the old surface are too considerable for that, nor are the projecting hills invariably composed of the hardest rock-masses.

CONCLUSIONS.

The observations recorded in this paper appear to prove conclusively that the Sierra Nevada in Neocene times, in the watersheds of the Yuba and American rivers, formed a mountain range as distinct as that of today, and that its first summit in general coincided with the corresponding modern divide. They further appear to prove that the grades of the remaining Neocene gravel channels are to a certain extent determined by the directions in which they flowed in such a way as to strongly suggest that the slope of the Sierra Nevada has been considerably increased since the time when the Neocene ante-volcanic rivers flowed over its surface. It finally appears probable from a study of the grade curves of the remaining channels that the surface of the Sierra Nevada has been deformed during this uplift, and that the most noticeable deformation has been caused by a subsidence of the portion adjoining the great valley relatively to the middle part of the range.

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Two Neocene Rivers of California

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Notes

