Geomorphology of a Portion of the Easternmost Ventura Basin

by

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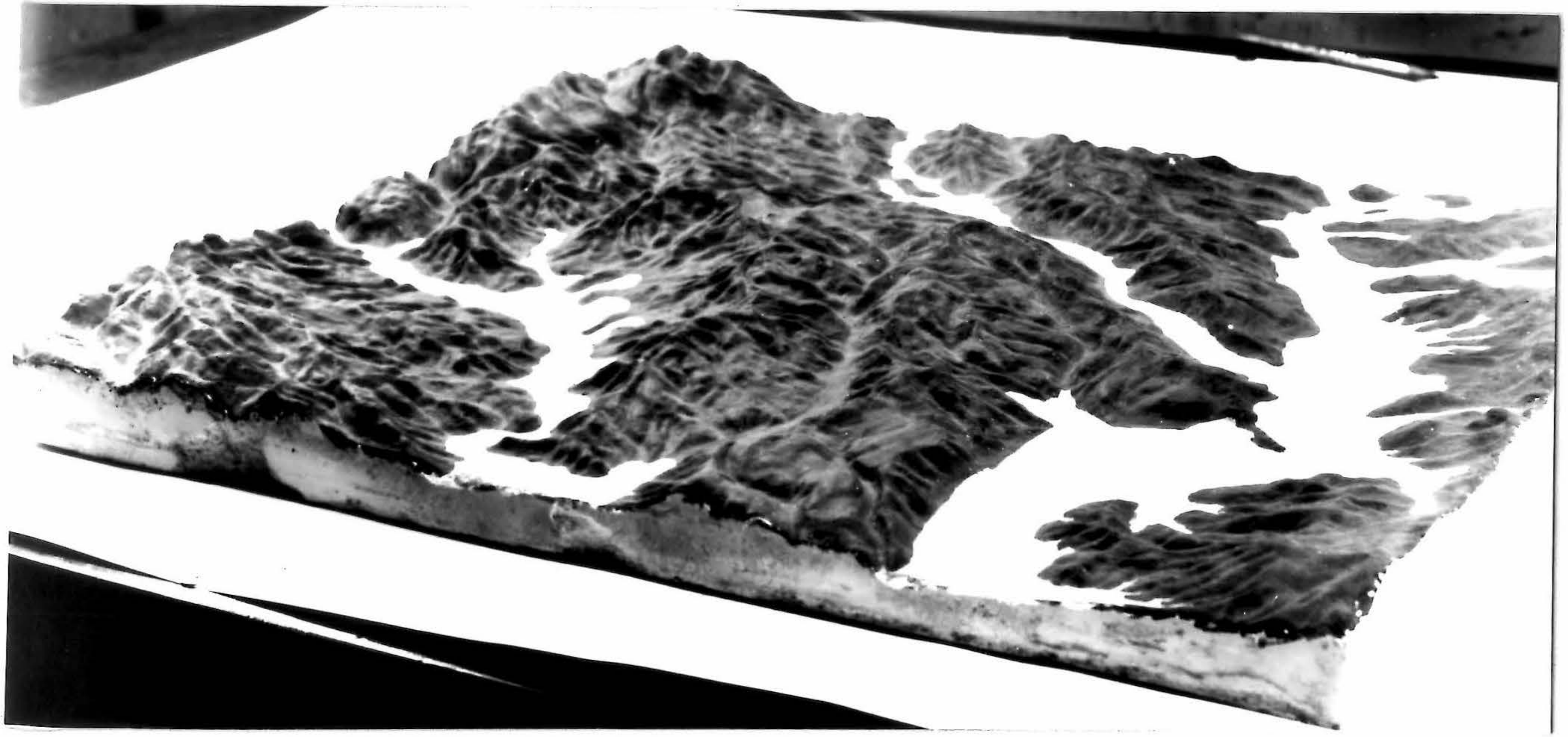

Relief model of the Humphreys Quadrangle, view looking northeast (model and photograph by John Lance).

Abstract

The Humphreys Quadrangle is a portion of the eastern- 3.
most Ventura Basin underlain by a thick series of Tertiary sedimentary rocks. On these rocks a great variety of geomorphic forms have been molded by the processes of running water typical of a semi-arid climate and by several types of mass movement. Among the different catagories of mass movement present, a new type, the <u>siltflow</u>, was observed.

The geomorphic forms of special interest present in the quadrangle are <u>rock cones</u>, open canyonheads, asymmetric canyons, and stream terraces and straths. The author urges the adoption of the definition of strath as that part of an old dissected valley floor, including the floors of tributary valleys, which was not part of the floodplain of the main valley stream.

An old erosion surface, the Puckett Mesa Surface, is present in the Humphreys Quadrangle ~~which~~ and is correlative with certain of the older stream terraces. By correlating the variation of gradient and of fill of the stream terraces 4
with post-Wisconsin climatic fluctuations the age of the Puckett Mesa Surface is set at approximately 6000 B. C. This correlation sets the probable age of the older Rancho La Brea deposits at 6000 to 8000 B. C. and the probable age of the Carpenteria brea deposits at 1000 to 1 B. C. 5

Contents

Illustrations

Introduction

The area discussed in this report occupies the westernmost two thirds of the Humphreys quadrangle, a six and one-half minute quadrangle of the Los Angeles County series lying just north of the $34^{\circ}24'$ parallel 7
and east of the $118^{\circ}30'$ meridian. It covers 25 square miles and is readily accessible by two highways from Los Angeles, one in Bouquet Canyon, and the other in Mint Canyon. Since the topographic surveying was done with considerable accuracy, and in fine detail, it proved practical to do the field mapping on an ozalid copy of the published topographic map enlarged from the scale of 1/2400 to the scale of 1/1200.

Topography

Although the maximum relief of the area is only 1100 feet, the slopes are, in many places, excessively steep, especially in the well developed badlands portions. The 6
elevation, in general decreases from north to south, the highest hills, underlain by shists, being located on the extreme northern edge of the quadrangle. The region is a portion of the easternmost Ventura basin and is drained 8
by the westward flowing Santa Clara River and its tributaries, the southwestward flowing streams in Haskell, Bouquet, and Mint Canyons. Three minor canyons branch off to the east from Bouquet Canyon, namely? which are, from north to

south, Texas, Vasquez, and Plum Canyons.

Geologic Setting

An amazing thickness of dominantly nonmarine Tertiary 9
sediments underlies the entire quadrangle with the exception 10
of the extreme northern edge. The formations decrease in 11
age from north to south, the general direction of dip, and are usually separated by an angular unconformity. Overlying the pre-Cretaceous Pelona schists are the moder- 12
ately indurated, course, angular beds of the Vasquez series of Oligocene(?) age. Above this are the poorly consolidated 13
silts, sands, and gravels of the Tick Canyon and Mint Canyon formations, of Lower and Upper Miocene age, respectively, a portion of the Mint Canyon formation being lacustrine in 14
origin. A thin wedge of the marine Upper Miocene "Modelo" formation protrudes from the west into the center of the area. Next above is the Pliocene-Pleistocene Saugus formation, composed mainly of very poorly consolidated nonmarine sands and gravels, and extending to the southern boundary of the quadrangle. It is underlain in the southeastern corner of the area by the Lower Pliocene, marine Pico formation, which has a similar lithology to the Saugus but is slightly more consolidated.[1] 15

[1]-(Stratigraphic correlation taken from R. H. Jahns, Carnegie Inst. Wash. Pub. No. 514 paper IX, pp. 145-194, 1940 and W. S. Kew, U.S. Geol. Surv. Bull 735, 1924.)

Locally the structure is complicated by small folds in the less consolidated beds, and by minor faults with displacements in the order of tens or a few hundreds of feet. Larger faults occur in the Vasquez Series[1] and

1-(R. H. Jahns, op. cit., pp. 168)

faults also separate the basement complex from the sedimentary formations in many places.

The Humphreys Quadrangle is surrounded on three sides by the various components of the pre-Cretaceous basement complex. Immediately to the north is exposed the southern extension of the Pelona schists. These are dominantly micaceous quartz schists with associated minor amounts of hornblende-rich schists, phyllite, quartzite, and gold-bearing vein quartz. To the east may be found "spotted diorites", porphyroblastic gneisses, syenite, and granodiorite.[2] In addition, several extrusions and concordant

2-(R. H. J., op. cit., pp. 153)

intrusions of andesite and amygdaloidal, porphyritic basalt occur in the Vasquez Series east of the area,[3] and

3-(R. H. Jahns, unpublished map, and W. S. Kew, op. cit., pp. 92) 16

numerous good-sized cobbles and boulders of these volcanic rocks are found in marked quantities in the later terrestrial formations and the terraces. South of the quadrangle the typical complex igneous-metamorphic in the core of the San Gabriels is exposed, which includes, in addition to the "spotted 17
diorites", gneisses, etc., large amounts of anorthosite, 18
and ilmenite-bearing gabbros composed chiefly of hornblende.

Influence of the Present Climate on the Erosional Processes

The climate is subtropical, hot-dry, according to 19

Putnam.[1] In Newhall, a town about ten miles from the

[1]-(W. C. Putnam, Bull. Geol. Soc. Amer., vol. 53, May, 1942, pp. 695)

Humphreys Quadrangle, the mean annual rainfall is about 17 inches, and the mean annual temperature is 61.5° F.[2]

[2]-(W. S. Kew, op. cit., pp. 5) 20

However, the erosion is of a type similar to that in a more humid region because, as has been pointed out by Bryan and others, much of the rainfall occurs in the winter when its effectiveness in the erosional processes is considerably checked by the grasses which spring up in the fall and last through the spring.[3]

[3]-(W. C. P. op. cit., pp. 695) 21

The type of vegetation is closely controlled by the underlying rocks, and the kind of soil to which they give rise. Thus, some areas of conglomerates are covered predominantly by greasewood and manzanita, other areas, chiefly of sandstone, by yucca and "buckweed", and areas of shale by grass. In any case the vegetation is often scant, the 22
thickest growths occurring on the north slopes. Since each of these types of cover has a different effect on the rate and processes of erosin, a considerable variety of topographic form could result from this factor alone.

However, as the declivity of the slopes decreases, the thickness of the soil mantle increases, the vegetative cover tends toward the more grassy type, which in turn directs the erosive processes to form gentler slopes. 23

Therefore, in the late mature stage, all the hills are smooth and rounded, and grass covered in spite of the differences of bedrock, just as they would be in a more humid climate. 24

Geomorphic Processes

General Aspects of Erosion

Weathering

Although the relative importance of chemical and mechanical weathering is still an open question in geology certain generalizations or comparisons can be made ~~of~~ in any one localized area. In the Humphreys quadrangle both the 25
nature of the bedrock and the climate are such that mechanical disintergration is much more dominant than it normally is in humid-temperate regions. In the first place, the loose Tertiary sediments yield unusually rapidly to 26
physical forces. Secondly, some of the chemically less stable components of the source areas have already been removed or reduced to the clays and quartz in the processes 27
of sedimentation.

The aridity of Tertiary time is attested to by the 28
abundance of granite and anothosite cobbles in the sedimentary formations. The aridity of the present is demonstrated by the abundance of fairly fresh boulders and cobbles of granite and anorthosite comprising the bulk of the stream beds arising entirely within areas underlain by the 29
Tertiary formations.

Never-the-less, the significance of chemical weathering must not be underestimated, if for no other reason than that a great abundance of decomposable materials still remain in the formations. The ridges and gentler slopes are strewn with rotten and decayed fragments of the coarse, intrusive rocks, basalt, and the highly unstable Pelona schist. The old mature surfaces even have a fairly well-developed soil cover in places.

The Relative Ease of Erosion in the Tertiary Formations

It is very difficult to estimate rates of erosion in terms of years without indulging in prolonged, careful checking and investigation. Comparison of rates, however, can be readily made in the Humphreys Quadrangle. All of the evidence indicates that a mature topography was developed over the entire area and the surrounding region sometime in the late Pleistocene. Since then there has been rejuvenation producing a very diverse topography on the sedimentary formations, the major streams having cut down approximately 500 feet relative to that mature Pleistocene surface. Now, over large areas to the north, underlain by the Pelona schist, this old surface has been preserved with only slight modification. But in the Humphreys Quadrangle, underlain by sediments, all but a very small portion of this surface has been completely destroyed. In fact, in parts of the southern portion of the quadrangle, low, rounded, gently rolling surfaces have subsequently been produced while the harder, crystalline rocks have still maintained the old erosion surfaces.

These recent, mature surfaces are associated with landslides which have greatly accelerated the reduction of the land forms. A low surface of this type, of an age

intermediate between the previously mentioned late Pleistocene surface, and the present, has been preserved in the landslide region. The time required for its formation could not be greater than the time necessary to cut the broad terrace on the north side of the Santa Clara River, with which it is approximately correlative, and to whose associated stream it must have been graded. Judging from this datum and from the fact that very few fresh "marks" can be observed on the many landslides in the area (indicating that the landslide debris is immediately attacked and quickly reduced by slopewash and other erosive agents) the time required to produce mature surfaces on the areas 30
subject to landsliding is probably of the order of several hundreds of years and certainly not greater than several thousand.

Degradational Processes

The Action of Running Water

Running water has been prolific in its mode of expression in the Humphreys Quadrangle. In many sections around Puckett 31
Mesa and northeast of Bouquet Canyon a typical badlands topography with its delicate and intricate network of rills and gullies has been developed. In contrast to this, where portions of the old mature surface are left, the smooth, rounded hills typical of a temperate climate are developed. The Bouquet Canyon stream and the Santa Clara River have been able to develope fairly broad valley floors on the soft sedimentary rocks, but these are sometimes steep sided

where the meandering river has cut rapidly laterally first on one side and then the other. Segments of abandoned valley floors remain as straths and terraces on the sides of the major streams. Briefly, the forms developed by surface runoff, the chief agent of erosion, are of great variety.

The effects of raindrop impact, a phenomenon akin to the processes of running water, have also been observed in this area. On the ridges underlain by gravely sands perched pebbles standing on little pillars of sand an inch or so high ~~bear good~~ afford evidence ~~for the~~ that operat~~ion~~ed ~~of~~ this process.

Mass Movement

In addition, the surface runoff is greatly aided in its attack of the land, in the Humphreys ~~Q~~quadrangle, by mass movement. Although downhill creep of the surficial materials must be an important degradational process, as ~~it is~~ demonstrated elsewhere, no striking evidence of its action was observed except in those areas with a soil cover. The mature, soil-covered slopes of Puckett Mesa exhibit an unusual result of the process of soil creep. This mesa is the central portion of what was the open canyonhead or headwater basin of Plum Canyon in late Pleistocene(?) or, what will be referred to in this report, as Puckett Mesa time. Since that time rejuvenation has occurred, the surrounding portions of this basin have been dissected and removed, and consequently its drainage area has been reduced to a small fraction of the previous total. Soil accumulated primarily by creep (since a grass cover protects the surface from excessive slope wash) at the narrows through which the basin drained, faster than it could be removed by the reduced amount of runoff water. This has dammed the open canyonhead. For a while the mesa surface formed a closed basin accumulating a thick soil deposit by creep and slope wash at its center, but now it is drained by a gully which has recently broken through from the west side by headward erosion.

More rapid flowage types of mass movement are rare in the Humphreys quadrangle, but an example of a mudflow was pointed out to the author by Mr. Wakefield Dort in the extreme southwest corner of the area. Here the end portion of an inter-ravine spur became dislodged, in a saturated condition, and flowed a few hundred feet down the main ravine.

In contrast, various form of discrete mass movement or landslides are very common. Textbook examples of slumps were observed in the region between Bouquet Canyon and Haskell Canyon, on the cuesta-like scarp south of Bouquet Canyon, in the region around Corner Canyon, and in the southwest corner of the quadrangle. Where these are fresh the typical terracettes of the backward-rotated blocks can be seen. In many cases, (Fig. 1) closed, or nearly closed depressions are left 34
when many other features of the slumps have been obliterated. 35

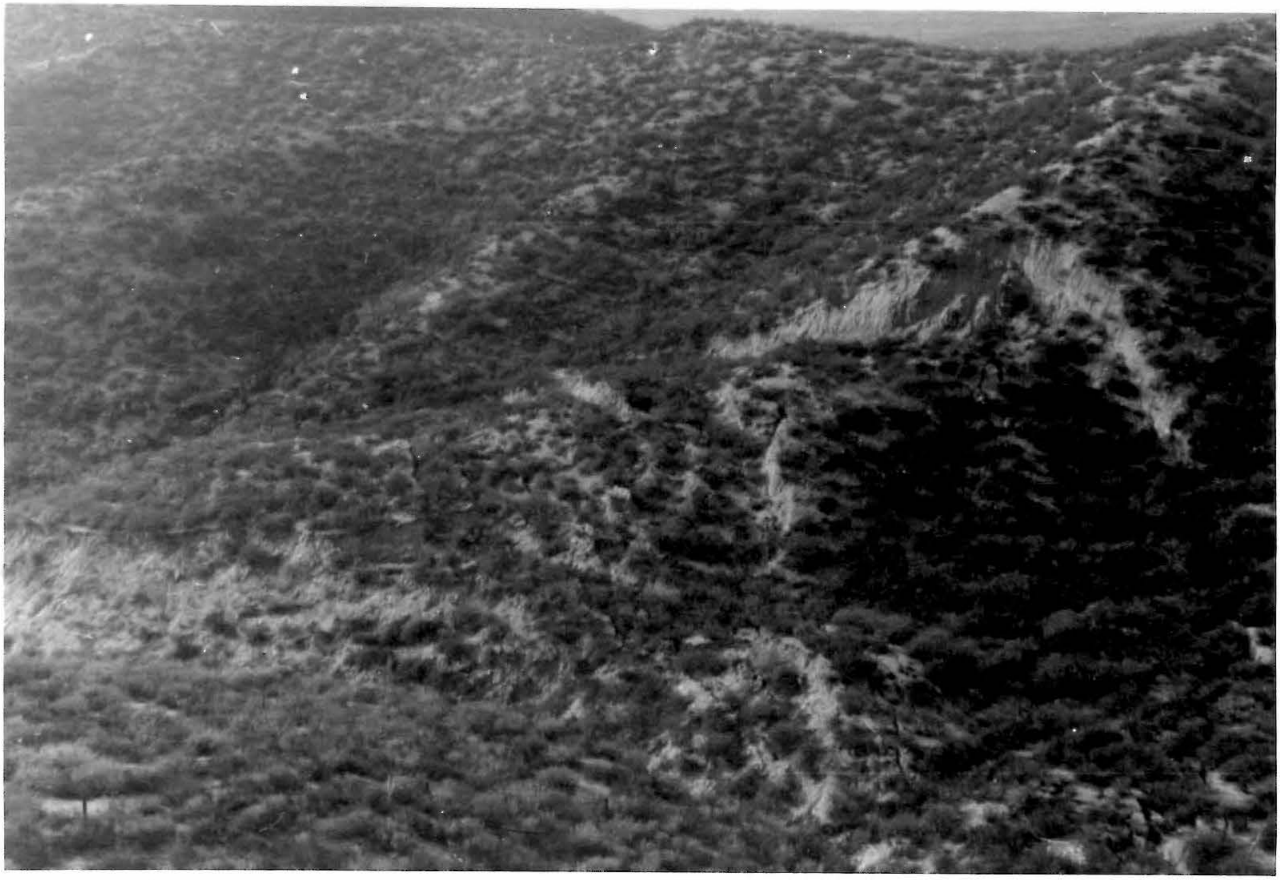

Figure 1. Fresh landslide north of Corner Canyon (looking west). The typical terracettes are well developed here.

Figure 2. Detail of the same landslide seen in fig. 1

Figure 3. Concomitant slide on opposite side of ravine from slide in figs. 1 and 2

All gradational types between the slump and the debris 36
slide are present. The large slide in the southwest corner 37
area is a series of well-defined slump blocks at its head
but at its foot it consists merely of a loose pile of
debris. Other smaller slides in the same region, and to
the north, are definitely more of the earth-flow type. One
slide in the Corner Canyon region, just south of the slump
shown in the figure, 1,2 3?. which? resembles a flow, without much evidence
of discrete slumping at its head. In the region between
Bouquet and Haskell Canyons many of the landslides appear 38
to be almost entirely debris slides. The best developed
of these have a bowl- or cirque-shaped scarp at their head,
and the debris has ~~slid~~ moved down a relatively long narrow U-shaped
trough.

The precise causes of the landsliding differ in each
general region of sliding, but most cases, either directly
or indirectly, are related to over-steepening of the slopes
~~from~~ by rejuvenation. In the Bouquet-Haskell Canyon region,
underlain by very poorly consolidated Mint Canyon beds,
recent rejuvenation has removed the support of unstable
ground at the stream bottom, and the material has slid down,
in many cases as a heap of rubble. There the steep slopes 39
are maintained, for the most part, by the well cemented
gravel terrace caps. The very steep cuesta scarp south of
Mint Canyon is maintained by the more competent beds of
Saugus, "Modelo", and upper Mint Canyon formations at the

top of the scarp. In that region erosion proceeds, in the direction of dip, in a large part by slumping and the subsequent removal of the landslide material by headward working streams.

Evidence for another major factor or cause of land-slides is present in the Corner Canyon and southwest corner 40
regions. In the first place, whatever the physical properties of the rocks requisite for landsliding may be, the formations in these areas possess them and are especially liable to yield by sliding wherever the slopes have been over-steepened by rejuvenation. But, in addition, the largest slides in the Humphreys Quadrangle, which are located in these regions, and occur in beds lying just above major unconformities, where ~~and~~ the material has moved in the direction of 41
dip. Of course, this may be entirely coincidental, but the implication is strong that the slides have occurred on these ready-made slip planes, and have been, perhaps, lubricated by groundwater concentrated at the unconformities.

The modifying effect which of landsliding has exerted on the normal processes and results of stream sculpture is considerable. As has been pointed out, landsliding has greatly accelerated the reduction of the land forms in those areas most subject to this phenomenon. Nearly all of the southwest corner area, which in Puckett Mesa time must 42
have stood above the level of the highest terraces on the north side of the Santa Clara River, now lies topographically lower than these terraces. The Corner Canyon region is

another "low" area, cutting across what would otherwise be a nearly continuous series of terraces on the north side of the Santa Clara River. North of the cuesta scarp, south 43 and east of Bouquet Canyon, is a basin-like area eroded out probably by a process of slumping and removal of debris by headward-working streams previously mentioned. The headwater basin, of which Puckett Mesa is a remnant, was developed in the same general region, and perhaps the opening up of this old basin was partly accomplished by landsliding. In the Bouquet-Haskell Canyon region still another excellent example of rapid reduction by landsliding is found in the westward basin-like projection of Coarse Gold Canyon.

One other type of mass movement was observed by the author in the Humphreys Quadrangle. It does not appear to fit into the classification of C. F. S. Sharpe[1] who made a 44 comprehensive survey of the literature in 1938; assuming the chances are slight that it has been described in the last ten years, this form of mass movement is probably a new type. The best examples may be found on the ridges in the area between Coarse Gold Canyon and Haskell Canyon. Here the Mint Canyon formation is dipping steeply, and consists of alternate beds of gravel, coarse sand, and silt, with occasional tuff beds scattered throughout the section. The beds are poorly consolidated and apparently

1-(C. F. Stewart Sharpe, Landslides and Related Phenomena)

Figure 4. A siltflow crossing a ridge (middle foreground) which may be discerned in this view by the characteristic dessication cracks.

very permeable. However, the silt beds are considerably less permeable than the others, and in periods of heavy rains, which occur spasmodically and infrequently in this part of the country, water becomes concentrated in the top two or three feet of these beds on the rounded ridge tops where the runoff is the slowest. The loose silt, upon being saturated, becomes a semi-plastic mass which sags at the ridge divide and bulges out on both sides, thus flattening the ridge at that place. The flatter and broader the feature becomes, the more readily it is saturated by subsequent rains, so that the process becomes self-augmenting. It works on the same principle as solifluction, without the intervention of freezing, and has somewhat the same result. In terms of type of flow and amount of water the phenomenon is intermediate between an earthflow and a mudflow. On this basis, and considering the type of material involved, the ~~author proposes~~ the name siltflow is proposed for this phenomenon and its product.

Fig. 4

45

The foregoing mode of formation has been inferred from the shape, location, composition, and character of the siltflow, and not from actual observation of its formation. Siltflows occur most often on ridges but one was observed lying diagonally on a gentle slope. They are broken? dissected by desiccation cracks and devoid of vegetation. Typically they are nearly flat and level on top and form a shallow notch in the ridge crest? line.

Aggradation - The Factors Controlling Aggradation by Running Water

Climatic Fluctuation

Passing over mass movement, which is an agent of aggradation in a sense, the only agents of aggradation of any significance in the Humphreys Quadrangle are the runoff waters. Four causes of aggradation by these waters are evident in the area. First, and most important, is the factor of climatic fluctuation, a factor which can only be inferred from the field data. The evidence for climatic change is threefold.

In the northern portion of the quadrangle there are three sets of fill terraces, two of which may be correlative. One set of three terraces, in and around Texas Canyon has 46
a contact with the bedrock in the range of 1980 feet to 47
2020 feet elevation (taken from a topographic map with a 25-foot contour interval). Another fill terrace set is located on the east side of Haskell Canyon, with the bedrock surface at approximately 2070 to 2080 feet elevation, and a third terrace group, in the same area has ~~its~~ the base of fill at about 2000 to 2025 feet elevation. Thus it may be seen that there are at least two, and possible three, periods of alternate cutting and filling are represented. The maximum depth of fill on these terraces is between 50 feet ~~and~~ to 60 feet. This is far in excess of the normal depth of cut and fill of the streams in the Humphreys Quadrangle,

indicated by the many other terraces in the area. It is improbable that this alternate cutting and filling is due either to absolute up and down warping of the land or to alternate eustatic changes in sea level, since the ocean is 50 miles away, and the time necessary for these changes to react 50 miles inland is far in excess of the time required to produce the filled terraces. Therefore, as the character of the terrace gravels is approximately the same in all three sets, climatic fluctuation seems to be the probable cause for the alternation of the fluvial processes.

Similarly, the fill in the canyon bottom of Mint Canyon may be ascribed to climatic fluctuation. A depth of fill of 70 feet is known from the well records, and the evidence of the well logs is substatiated by the fact that, although water scarcely ever runs on the surface in the main stream beds in this region, several hundred gallons of water per minute have been pumped from the wells in Mint Canyon without seriously affecting the water table. A great deal of water is pumped for irrigation purposes from the stream beds of the Santa Clara River and Bouquet Canyon also, in spite of the fact that the only surface runoff in these streams occurs in flood time. A greater than normal depth of fill, which accomodates this underground drainage, is probably present in these streambeds too. Eustatic change of sea level, as a cause of to account for this recent aggradation, is improbable for the same reasons as noted used above, especially when a knick nick point is known to be working headward up the Santa Clara River just west of the Humphreys Quadrangle. 48 Recent downwarping of the area is improbable when, all around, there is conclusive evidence of continual rejuvenation at least up to the very ? recent. Climatic change toward greater aridity seems to be the most probable cause of the filling of the major stream beds. This would tend to increase the grain size and amount? of the detritus, which, in turn necessitates steeper stream gradients developed by aggradation.

The third line of evidence for climatic fluctuation lies in the actual differences observed in the gradients of different terrace levels, including the present stream beds. The highest Santa Clara River terraces have a longitudinal gradient of about 55 feet per mile; The intermediate terraces have a gradient of 31 feet per mile, and the present stream bottom has a gradient of 55 feet per mile. Since the catchment basin of the Santa Clara River has remained about the same since the cutting of the highest terrace, 49 as is indicated by the composition of the terrace gravels, the only feasible explanation for this gradient alternation is climatic fluctuation.

<u>Meandering and Shifting of Major Streams</u>

A secondary form of aggradation resulting in alluvial cones is also present in the Humphreys Quadrangle. Filling of the main streams would, of course, require the filling, to some extent, of their tributaries and minor side gullies.

Some alluvial cones on the west side of Mint Canyon may be due primarily to this effect. But the minor streams have adjusted themselves very rapidly to the recent rise of their local baselevels, in part because their gradients were previously oversteeped from continual rejuvenation, and filling ascribable to that rise is [very] difficult to detect. Another factor which is probably more important in the formation of these Mint Canyon alluvial cones must be taken into account. Minor streams are constantly attempting to grade themselves to their major stream which is meandering back and forth across its valley floor. Thus, when the major stream crosses from one side of the valley to the other, the minor streams and side gullies on the far side must aggrade in order to reach it. Excellent examples of
relation? are seen
this reaction [occur] two and a half miles up Plum Canyon where there is evidence only of downward and lateral cutting by the Plum Canyon stream. Several alluvial cones that have been built out from gullies on the north side of the Canyon are now partially cut away at the base as the stream has begun to shift northward again.

Simple unilateral shifting of a major stream without appreciable downcutting would also produce alluvial cones
which the stream shifted
on the side ~~shifted~~ away from. Bouquet Canyon and the Santa
Clara River have shifted predominantly in one direction, but 50
they have also cut down in doing so. Therefore it would be
questionable to assign any cones on the far sides of these 51
canyons to that cause. 52

Figure 5. Small alluvial cone on the north side of Plum Canyon. The cone has been cut away at the base by the stream ~~meandering~~ shifting laterally to the north.

Figure 6. Plum Canyon (looking west). The anomalous small hills at the base of the stream cut dip slope may be seen in the left background. (photograph by Wakefield Dort)

Tie these illustrations into the text with references to the figure number

Mass Movement

A third controlling factor of aggradation operating in the Humphreys Quadrangle is mass movement. Many of the 53 gullies draining the area north of the Bouquet Canyon cuesta scarp are filled, as can readily be seen by the broadly convex transverse profile of their floors. The principal source of the detritus transported down these gullies is the landslide material slumping off of the scarp just to the south. In as much as the slumping occurs spasmodically, in discrete intervals, the supply of debrie is ~~quite~~ variable, and the streams transporting the debris tend toward alternate cutting and filling, cutting when the supply is low and filling when the supply is renewed.

Aggradation ~~Due to~~ Caused by Reduction of Master Stream Drainage by Capture of the Catchment Basin

A case of aggradation resulting from a special set of circumstances occurs in the more headward waters reaches of Plum Canyon. Here a number of alluvial cones, forming on the south side of the canyon have coalesced and have forced the present small stream against the north wall of the canyon. These cones have developed as a result of the disturbance upset of the equilibrium incurred by the blocking of the drainage from Puckett Mesa. Since Puckett Mesa previously formed a considerable portion of the drainage area of the upper part of the canyon, the blocking of this drainage caused a large reduction of the surface drainage which performed the task of transporting the debris shed from the canyon sides and tributary gullies. After the sudden decrease of the transporting power of the main stream small alluvial cones developed in the side gullies simply because of the inablity of the main stream to carry the normal amount of material away.

Stream Capture

Capture Caused by Difference in Stream Load

Two types of stream-load difference controlling capture may be cited in the Humphreys quadrangle. Both result in steepening the gradient of a stream so that its canyon bottom is higher than the levels of the adjacent, and incidentally shorter, streams. This enables the adjacent streams to capture the stream in question by side gullies, or merely by lateral cutting. In the southwest corner region certain stream gradients are steeper than others nearby because coarser detritus is transported down them. But north of the Bouquet Canyon cuesta scarp some of the longer streams have steeper gradients because they must carry away a much greater quantity of detritus, in large part landslide debris. Here, in fact, one incident of capture may be due more to aggradation than to simple steepening of the gradient.

Capture From Difference in Base Level

Strangely enough, capture simply from difference in local base level of adjacent streams is relatively uncommon in the quadrangle, possibly because of the unusual predominance of other factors governing the elevation of the stream bottoms. The best example of this type of capture occurs 55 where two of the main streams draining the Haskell-Bouquet Canyon area approach each other very closely and then diverge, one emptying into Bouquet Canyon about three fourths of a mile upstream from the other. The lower stream will probably capture the other in the near future. A curious 56 instance of a minor type of capture also occurs in the same immediate vicinity. The main branch of the northeasterly stream has captured the smaller branch about 100 feet farther upstream from their original point of juncture by lateral 57 planation, leaving an "island" consisting chiefly of a very resistant tuff bed which had prevented the upstream migration of the juncture.

Capture from Difference in Stream Length

Two excellent examples of capture due to difference in 58 stream length occur in the Corner Canyon area. In this case the longer streams are able to capture their tributaries by side gullies because at equal distances from their juncture the longer branch will have a gentler gradient than the shorter branch has, and, consequently will be lower. Corner Canyon was able to capture successively one of its northern tributaries in this way where the tributary lay parallel to the main stream.

Capture by Landsliding

Another type of capture is found in the southwest corner area of prominent landsliding. Here one stream is about to capture the headwaters of another stream of approximately the same length but graded to slightly higher level. The headward erosion of this stream has been considerably accelerated by landsliding.

Capture by Monoclinal Shifting

An illustration of stream capture controlled by two main factors--difference in base level, and monoclinal 59
shifting, is afforded by Plum Canyon. Plum Canyon is an as~~s~~ymmetric canyon whose stream has been shifting continu- 60
ously southward, down dip, ever since regional rejuvenation set in. At an earlier stage Plum Canyon emptied into Bouquet Canyon about a mile and a half upstream, and a much shorter, smaller stream occupied the area above the present mouth of Plum Canyon. As rejuvenation progressed Plum Canyon shifted to the south, and the smaller stream worked headward capturing Plum Canyon first near its mouth and then successively farther back, leaving a row of small hills between the present stream course and the stream cut dip slope above. The smaller stream did not shift much to 61
the south because the strata underlying it are more nearly flat. This interpretation is deduced from the anomalous position of the small row of hills and from the configuration of the dip slope. It is possible that the hills represent material slid down the dip slope from the summits above. But this is highly improbable because of the lack of any trace of a slide on the moderately dissected dip slope and because of the lack of anything that might be interpreted

as a breakaway scar on the summits above the dip slope. It is also possible that the hills were formed as an island in the canyon bottom at some stationary or stable period during the course of the regional rejuvenation. Again this is highly improbable ~~in~~ by its very nature, and, in addition, such a stable period would have been recorded by a set of matching terraces on the canyon sides.

Other Factors Governing the Shape of the Land Forms

Structure

As is normal, the structural control of the landscape is manifest everywhere in the Humphreys Quadrangle. Direct expression of the bedrock structure such as hogbacks occur in the Mint Canyon Formation south of the Santa Clara and also north of the Bouquet Canyon cuesta scarp where tuff beds comprise the ridge makers. Dip slopes are developed in the Saugus formation in Plum Canyon and on the Modelo(?) formation directly to the west. Indirect reflection of the structure is given by the hollowed out stratigraphically controlled landslide zones. In the northwest corner where the sedimentary rocks lie in fault contact with the Pelona schist there is a sharp change in slope which could be correctly called a fault-line scarp. The entire subdued basin, underlain by Tertiary sediments, of the which the quadrangle is a part, affords a striking topographic contrast with the surrounding crystalline highlands, reflecting the large scale aspect of the regional structure. In short the bedrock structure is one of the principal determinants of the present land forms.

Rejuvenation

The main outlines of drainage, however, have probably been inherited from the pre-existing stream patterns, and the post-Puckett Mesa rejuvenation has had as large a part as the structure has had in determining the present topographic configuration. The evidences of rejuvenation can be seen everywhere, not only in the terraces and straths, but also in the ungraded profiles of the smaller streams, the old erosion surfaces, and the transitional slopes. Recent rejuvenation is responsible for about 75 per cent of the present relief on the sedimentary rocks. In addition, the terraces, by-products of this rejuvenation, are conspicuous features of the landscape. Fundamentally then, structure and rejuvenation constitute the main controlling factors of the present topography of the Humphreys quadrangle.

Geomorphic Forms

Rock Cones

A difficulty arises, when investigating alluvial cones in the field, in distinguishing between cut and filled surfaces. Thus a conically shaped land form at the mouth of a gully or series of gullies does not necessarily indicate an alluvial cone. One such conical feature, now dissected, proved to be essentially cut on bedrock, with a five to ten foot veneer of gravel in transport on its surface. This form more or less fits Douglas Johnson's description[1] of a

[1]-(D. Johnson, Rock fans of arid regions, Am. Jour. Sci., 5th ser., vol. 23, 1932)

rock fan, but since it is somewhat smaller than a fan it might be more aptly called a rock cone. It is located on the north side of the Santa Clara Valley between Corner Canyon and Bouquet Canyon (feature marked S_B on map). Approximately 1000 feet long at its base, and extending about 1000 feet headward, it has an average gradient of 12.5% and is concave upward. Since it is formed by the coalescing of two gulleys, it is actually a double cone.

The mode of formation of this rock cone can be decifered from its occurence. At a time when the Santa Clara River remained stationary against its north valley wall, over-
steepened by lateral cutting of the river the valley wall 62
retreated, principally by headward gully erosion, in the
soft Saugus formation gravels. Graded to the relatively 63

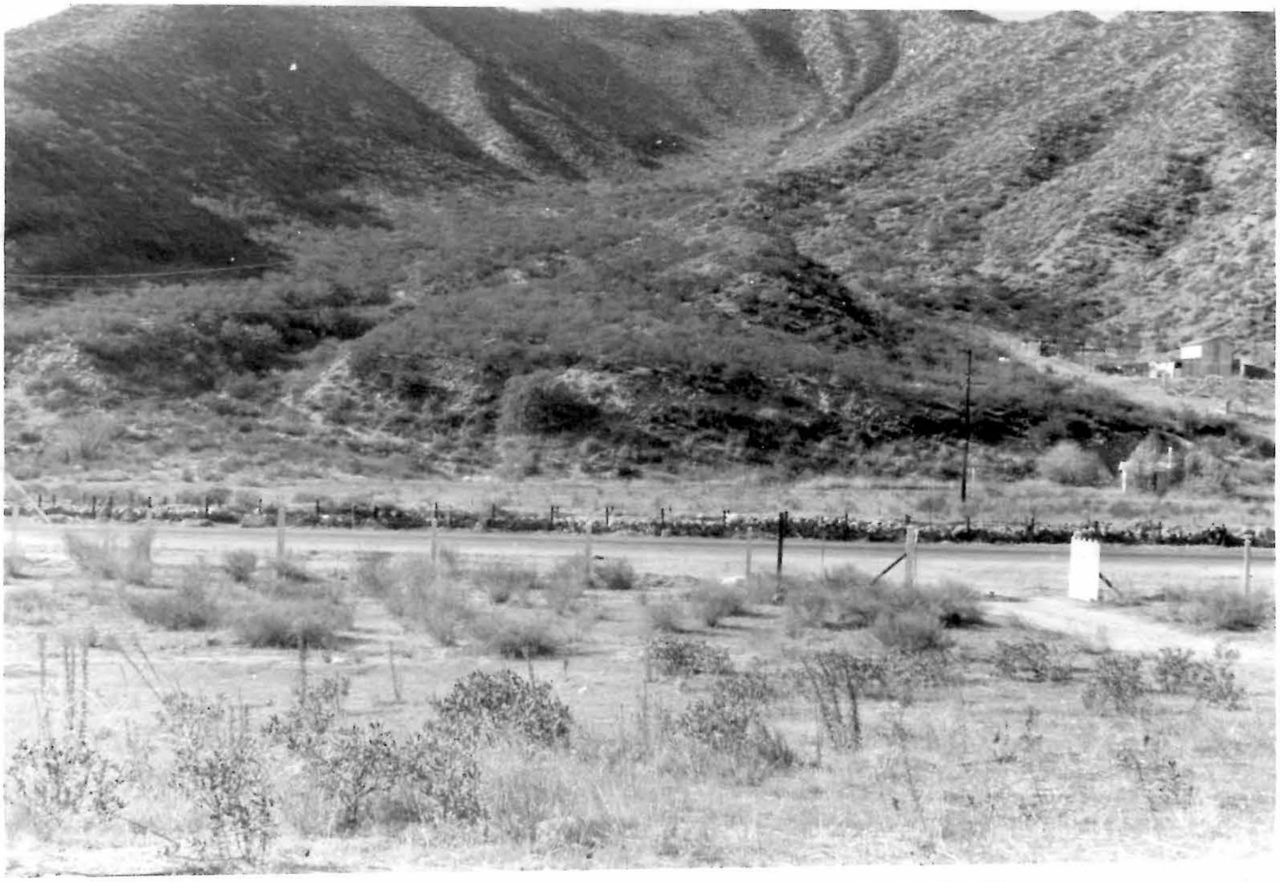

Figure 7. An alluvial cone in Mint Canyon, showing the way in which the alluvial cones wrap around their bounding spurs.

Figure 8. Airplane view of a rock cone at the base of the cliffs on the north side of the Santa Clara River valley. The cone is now somewhat dissected. (photograph by Wakefield Dort)

not clear just where the cone is - identify by a mark on the photo stationary river the gullywash cut a surface steep enough to keep the coarse debris of the unconsolidated Saugus formation in transportation as the Valley wall retreated. The convexity of the cone surface has resulted from the lateral cutting of the gully distributaries. Relatively steep valley walls at the head of this surface were at the same time maintained because the erosion proceeded mainly by headward sapping, the highlands beyond being the flat Santa Clara River Terraces and not supplying any drainage to the gullys. Now the river has begun to cut laterally against the north valley wall again, removing the lower edge of the rock cone so that the relations of the gravel mantle to the bedrock are? perfectly exposed.

An alluvial cone of approximately the same size as the rock cone just described lies immediately to the east and portrays the best criteria for distinguishing between the two types of cones. The alluvial cones often wrap around the spurs on either side, whereas the rock cones do not. Ref to photo.

Open Canyon Heads

Puckett Mesa - An Open Canyon Head

As there has been so much erosion since Puckett Mesa time the origin of Puckett Mesa can only be inferred from its present shape. Surrounded on the east, north, and west 64 by extremely steep slopes typical of badlands topography, at first sight the mesa appears to be the northward extension of Plum Canyon which drains the hills flanking the mesa on

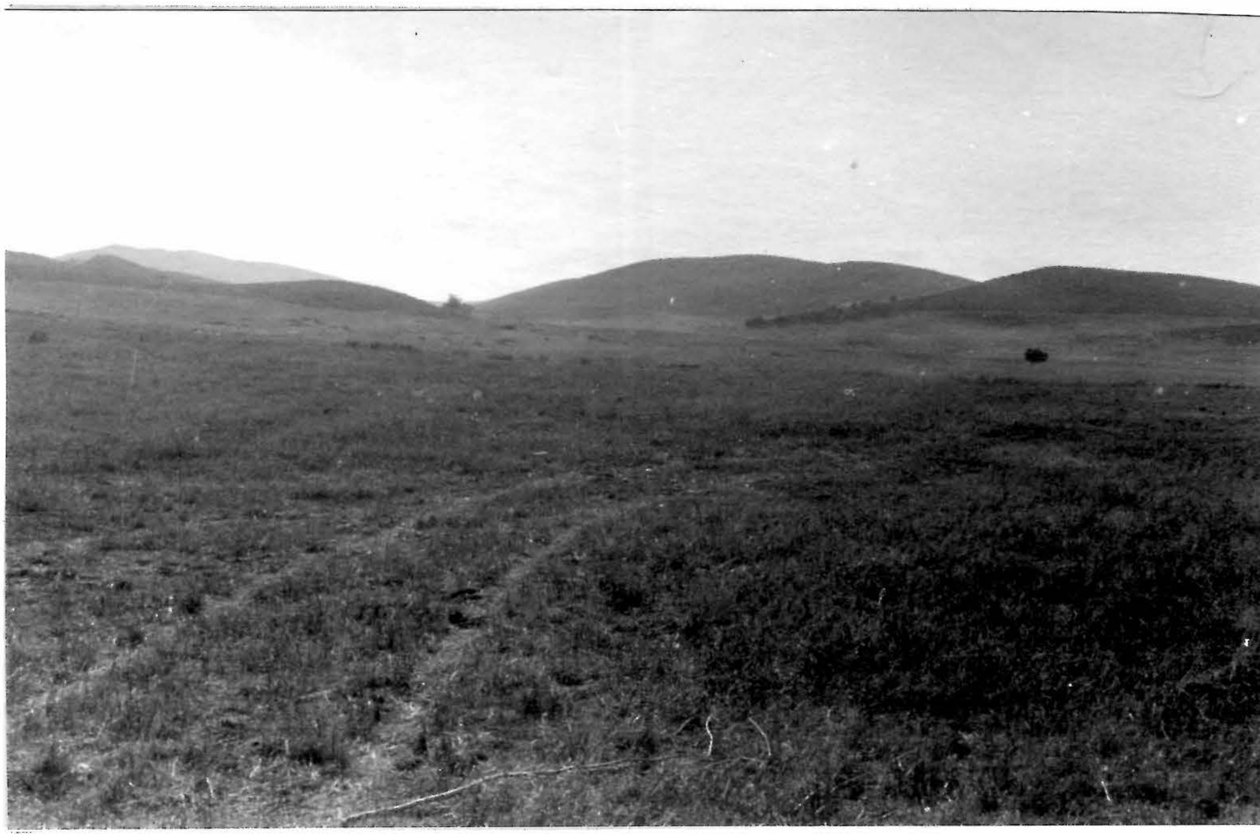

Figure 9. A view taken from the north end of Puckett Mesa looking south, showing the subdued relief of the Puckett Mesa Surface. The surface drainage of the mesa originally flowed through the gap in the hills seen in the background.

Figure 10. Puckett Mesa as seen from the air (picture by Wakefield Dort). The way in which the drainage area of the mesa is being abstracted by younger streams on three sides of the mesa can be seen from this view.

the south. But the surface drainage of the mesa is dammed by a gentle rise, about seven feet high, in the narrows between the mesa flats and the present Plum Canyon. The surface of the mesa forms a very shallow north-south trough, the western edge of which has been cut through by a headward working gully. It could only have been formed by a southward flowing stream draining through the narrows and into Plum Canyon. The narrows have been dammed subsequently by soil creep and possibly slopewash as has been pointed out. Further evidence for this explanation is found in the presence of a well just beyond the rise in the narrows in Plum Canyon which has pumped a small but continuous flow of water all during the last fall and winter in one of the driest years of California history. It is probable that this well is supplied by the entire underground drainage of the mesa which still flows through the narrows. The only alternative explanation of the reversal of drainage would be the sagging of the mesa at the center. This seems highly improbable because of the lack of a heavy caprock and because of the coarse grained texture and consequent fairly rigid nature of the bedrock.

However the damming of Puckett mesa may have taken place, there can be no doubt that it once was drained by Plum Canyon and in this light it must be considered an example of an open canyonhead, or what Kirk Bryan might call, by analogy to the forms he has described from the Papago region, a headwater basin. Although there is a natural tendency for all streams to erode a relatively open, basin-like drainage area near their heads because of the greater number of tributaries there, it is probable that the formation of the Puckett Mesa headwater basin was considerably augmented by structural factors. The mesa lies in a zone of rocks which apparently yield to erosion much more readily than do the formations on either side, as is demonstrated by the way in which the tributary streams and gullies of Bouquet and Mint Canyon have worked rapidly headward in this zone abstracting nearly all of the former 65 basin except its main valley floor. As was pointed out this rapid rate may be in part due to landsliding.

<u>Miniature Open Canyonheads</u>

Two features similar to open canyonheads but smaller in scale are also found in the Humphreys Quadrangle. Perhaps these might be more aptly called open ravineheads. The first of these is a headward basin of a ravine situated due south of Humphreys station, on the extreme southern edge of the quadrangle. It was formed as the floor of a normal, relatively open canyon, graded to the Santa Clara when the river was somewhat higher, and it is now drained by an incised ravine graded to the present level of the river. The other type example? of ravinehead may be found in the area of prominent landsliding, also on the extreme southern edge of the quadrangle. In this case the open ravinehead has been eroded in unconsolidated landslide debris.

Asymmetric Canyons and Shifting Streams

The asymmetry of the canyons or inversely the asymmetry of the land masses, is a striking feature of the topography of the Humphreys Quadrangle, and is controlled primarily by the bedrock structure. Plum Canyon, for example, is a simple reflection of essentially homoclinal structure, wherein the north slope of the canyon is practically a dip slope and the south slope is a cuesta scarp. The "lopsidedness" of the larger canyons, Bouquet and Soledad Canyon, however, is more indirectly related to the structure. Both the Bouquet Canyon stream and the Santa Clara River have been shifting more or less steadily in one direction, leaving terraces in their wake. The side deserted has remained relatively high and less dissected, and the side encroached upon is much lower in relief having been thoroughly dissected and greatly reduced. Thus, these rivers have been gravitating towards zones of weakness which, in the final analysis, are structurally controlled. This phenomenon has resulted in the preservation of sets of terraces on one side of the rivers and the destruction of any terraces that may have existed on the other side.

It is improbable, in the case of the Santa Clara River terraces, that the terrace gravels themselves may have augmented the shifting of the river, by forming a permeable and consequently resistant capping for the bedrock, since the bedrock appears in some instances to be more resistant than the terrace gravels. This is demonstrated by the way in which certain levels have been nearly stripped of the coarser terrace deposits. On the other hand, in the case of the Haskell Canyon terraces, cementation of the terrace gravels appears to have been the main cause of the shifting of the stream and the consequent preservation of the terraces. Here the stream gravels are composed chiefly of Pelona schist which contains a constituent, probably a form of iron oxide, that tends to cement the stream deposits and even materials in transit on the slopes very rapidly. Thus the stream bed soon becomes more resistant than the underlying and adjacent Mint Canyon formation bedrock, and the stream begins to cut laterally and shift its course. The ultimate result has been the curious location of the terraces on the ridge tops. This effect occurs also with the Bouquet Canyon terraces, whose gravels are composed similarly of Pelona schist. Essentially this ridge-top occurrence of stream gravels is the result of a phenomenon similar to gully-gravure, described by Kirk Bryan, but larger in scale, and the process might properly be called, therefore, stream-gravure.

Stream Terraces and Related Erosion Surfaces

Types of Surfaces and Terraces

Geomorphic nomenclature appears to be in a state of confusion with regard to terraces and related surfaces. Original misunderstanding of the true relation of terraces to bedrock may be responsible for some of the diversity in the usage of the word terrace. As pointed out by G. K.

Figure 11. Panoramic view of the Santa Clara River valley looking north. Most of the terrace levels may be seen in this view. Mint Canyon joins the Santa Clara River in this picture at a point near the center.

Gilbert,[1] "river terraces as a rule are carved out, and not

[1]-(G. K. Gilbert, Geology of the Henry Mts., pp. 132, 1677)

built up. They are always the vestiges of flood-plains, and flood-plains are usually produced by lateral corrasion". The usage of terrace in this report is taken from the definition of river terraces, given by C. A. Cotton[2]

[2]-(C. A. Cotton, Classification and correlation of stream terraces) where published 66.

(following Gilbert) "as terraces that border river valleys and mark former levels of the flat valley floors such as have resulted from either corrasion or valley filling by rivers." If the terrace was once part of a continuous valley floor it would be a valley-plain terrace. If it was cut by a meandering but continuously downcutting stream it would then be a slip-off slope or unmatched terrace. Terraces whose surfaces are aggradational, or which have been cut in alluvial fill are referred to in this report as fill terraces.

Following Cotton's definition, then, the terrace surface must be practically flat in transverse profile, discounting ordinary flood-plain irregularities, which are ordinarily very small in the Humphreys ~~Q~~uadrangle. This leaves the problem of classifying the gently sloping erosion surfaces which are found often on the up-slope side of the terraces or flanking the entrenched streams where the terraces, if they ever existed, have been dissected and removed. The relationship of these surfaces to the terraces and to the streams to which they were graded is simple. They are that part of the old valley floor which was formed by retreat and down wearing of the valley wall and not by the lateral corrasion of the former stream. In other words, they were that part of the valley floor which was not the flood-plain proper. These surfaces differ from the terraces in having a concave transverse profile, and the deposits with which they are frequently covered are of immediate local origin, whereas the terrace gravels are derived from much more distant sources.

The term in the literature which most closely approximates this type of surface is <u>strath</u>. Ever since <u>strath</u> was first used by Archibald Geikie it has been altered and redefined by nearly every writer who used the term. As a result its present meaning status is very uncertain and the value of the term is questionable? very low. Geikie[1] first defined straths,

[1]-(A. Geikie, The Scenery of Scotland, pp. 175)

taking the usage from the Scottish vernacular, as "broad expanses of low ground between bounding hills, usually traversed by one main stream and its tributaries, such as Strath Tay, Strath Spey, Strath Conon. The name, however, has also been applied to wide tracts of lowland which embrace portions of other valleys, but are defined by lines of heights on either side." Strath, by this definition, refers to what is now called the valley floor and includes, also, the low portions of the smaller tributary valleys which are difficult to set off from the main valley floor itself.

Used in this way it has a very limited value. The author proposes that the term strath be restricted to mean that part of an old dissected valley floor including the floors of the minor tributary valleys, which was not a part of the main floodplain. In nearly every case the strath in this sense is a cut surface, but in the rare instance that it is an aggradational surface it could be called a fill strath.

Geikie's term in its original sense merely applied to the floor of a wide, mature valley and thus was an unnecessary complication of geomorphic nomenclature. Davis[1] uses

[1]-(W. M. Davis, Rock Floors in Arid and Humid Climates, Jour. Geol. vol 38 pp. 136, 1930)

the term valley-floor strip, or simply valley-floor in contradistinction to floodplain, for that part of the valley floor developed by retreat of the valley sides, and no other term is needed for this surface. Straths bear the same relations to terraces that Davis's valley-floor strips bear to the floodplains. Bucher,[2] in 1932, redefined strath to

[2]-(W. H. Bucher, Science, vol. 75, pp. 130, 1932)

mean a broad valley plain of low relief produced by degradation, including the interstream areas reduced by downwearing, in contradistinction to alluvial plains produced by aggradation. He is followed by Flint,[3] Fenneman,[4] and

[3]-(Longwell, Knopf, and Flint, Textbook of Geology, pp. 444, 1939)

[4]-(N. M. Fenneman, Physiography of Eastern U. S., pp. 181, 1938)

Worcester[1] who identify strath with incipient peneplain.

1-(F. G. Worcester, A Textbook of Geomorphology, pp. 537, 1939)

Fenneman says, "The surface here described is not one of planation, i.e., it is not a former flood plain over which a stream meandered, though flood plains may be included in it. It is strictly an incipient peneplain, a surface whose interstream areas have been worn down, not planed off. . . . Such an incipient peneplain is a strath in the true sense of the word." The straths when dissected, are then called, according to these men, strath terraces. The objections to this terminology is threefold. First of all, the usage is quite a refinement and alteration of the original Scotch meaning, although Bucher considered it a return from previous misusage to the original. In the second place, it is completely synonymous with incipient or local peneplain which is a much more descriptive term. Finally, strath terrace is a misnomer because the surface designated by this term does not have the external relationships or physiographic expression of a true terrace.

Furthermore, Hobbs[2] uses the term strath in an opposite

2-(W. H. Hobbs, Earth Features and Their Meaning, pp. 426, 1931)

sense, completely befuddling the issue - "Scottish lochs . . . are each extended in a longer or shorter delta plain described as a <u>strath</u>, and this local term may well be given a general application."

In his recent book, Geomorphology, O. D. von Engeln, Ref? still further reduces the usefulness of the term strath by identifying it with river terrace. A strath terrace, according to him, is simply the remnant of the floor of a continuous flood plain. The duplication of already established terminology by von Engeln's usage is evident.

Briefly then, the present status of the term strath is highly controversial. A special type of surface is in need of a name. With certain restriction and modification of its original meaning the term strath would fill this need admirably. Strath, defined as proposed, becomes a very useful concept in the classification and correlation of river terraces and related surfaces. Therefore the author strongly urges the adoption of the definition used in this report. is strongly urge.

Still another type of gently sloping surface transecting structure occurs in the Humphreys Quadrangle. The best example occurs in the Corner Canyon area and is mapped on the detailed geomorphic map as a transition surface. This name is used because the ages of different parts of the surface are not correlative. A relatively plane surface was developed in this case because the Corner Canyon stream, to which portions of the surface were sucessively graded, shifted to the south as it cut down. This shifting must have gone on at precisely the unique rate necessary to maintain a relatively straight slope. A larger, somewhat similar surface has been developed north of Placerita Canyon, south of the Humphreys Quadrangle, but this surface is generally concave upward, indicating that Placerita Canyon did not shift rapidly enough to the south, relative to its rate of downcutting, to develope the peculiar straight profile.

Finally, old erosion surfaces were also mapped in the Humphreys Quadrangle. These differ from the subsequent surfaces, graded to lower stream levels, in being, for the most part, soil mantled (in the sense that they have much better developed soil profiles). Generally the old erosion surfaces have an abrupt contact with the younger surfaces. Most of them are correlative and are remnants of the Puckett Mesa surface. One, however, previously mentioned, is much younger and is developed in a landslide area.

<u>Nature and Distribution, Sources, and Economic Value of the Strath and Terrace Deposits</u>

The straths and terraces of the Humphreys Quadrangle may be divided into two main groups on the basis of distribution and the composition of their gravel deposits. The straths and terraces bordering the north side of the Santa Clara River comprise one group, and those in the Haskell-Bouquet Canyon area make up the other.

Pebble counts were taken on several levels of terraces bordering the Santa Clara River, and the whole series of gravels, from the present stream bottom to the highest terraces, displayed a marked uniformity of composition. The major components throughout were: Granitic type pebbles

THE COMPOSITION OF THE SANTA CLARA TERRACE GRAVELS

Per Centage of Pebbles above 1/2 inch in Diameter

Trout Canyon?

Contituents	Valley bottom	Level # 7 (east of M.C.)	Lower Tank level (east)	Lower Tank level (M.C.)	Upper Tank level (M.C.)	Puckett Mesa level
Granite	24	45	33	43	36	31
Anorthosite	25	14	21	15	26	22
Hornblende gabbro	14	-	4	-	16	4
Andesite	11	11	13	12	4	11
Pelona schist	1	2	4	-	-	1
Quartz	2	5	4	8	3	4
Other Metamorphics	10	5	2	3	7	7
Basalt*	2					
Other Volcanics	6	9	9	3	1	7
Other Gabbro#	1	9	9	15	7	12
Sandstone*	4					
Total	100	100	99	99	100	99

* Usually weathered away in older terraces (some of the quartz pebbles are weathered out amygdules)

\# Some of the "gabbro" may have been metamorphic type instead, misidentified because of the highly weathered condition of some of the pebbles.

PLATE II

--averaging 35%, anorthosite pebbles--averaging 20%, and andesite pebbles--averaging 10.5%. Details of composition are given in the chart.

Taking into account the durability of the various rock types the composition of the terrace deposits should be a reflection of the lithology of the drainage area of the streams which formed the terraces. Using this as a criteria it is safe to say that the drainage area of Mint Canyon and the Santa Clara River has not changed appreciably since Puckett Mesa time. The granitic and more basic types of pebbles, the anorthosite, the metamorphic rocks other than Pelona schist, and the plagioclase-hornblende gabbro were all derived ultimately from the San Gabriels to the south 67
and east. The andesite, basalt (including the quartz amygdules), and the other volcanic rocks came from the flows and intrusions to the east and northeast. Perhaps the immediate sources for many of the constituents are the surrounding Tertiary sediments. This would explain the small percentage of Pelona schist present since the catchment basin of the Santa Clara River upstream from these terraces is not underlain by Pelona schist. The straths, of course, have identical compositions with the underlying bedrock.

In general the Santa Clara terrace gravels differ little from the underlying Saugus and Mint Canyon formations, often making the gravels difficult to distinguish from the bedrock. Usually the color of the terrace gravel is somewhat

darker than that of the bedrock, varying from a peach color to a dark-reddish buff. They are all very poorly sorted, containing a large proportion of silt and sand, and ranging as high as one to two foot boulders in maximum grain size. 68
The average grain size probably lies in the range of large pebble to small cobble. On the whole the Santa Clara Terrace gravels are moderately consolidated and moderately stratified, with lenses of sand or of coarser gravel occuring throughout. The average thickness of these deposits, where they have not been partially eroded or stripped away, is around ten feet, ranging from 20 feet near the mouth of Mint Canyon to two feet in the case of the silt deposits found on parts of the broad Tank level terrace farther to the west.

Because of the difference of source area, the Haskell-Bouquet Canyon terrace gravels have a totally different composition from the Santa Clara terrace gravels. They are composed primarily of Pelona schist, ranging in composition from almost pure schist to about 75% schist, depending on their proximity to the schist contact. The Heskell Canyon terrace gravels are nearly all schist with some quartz, derived from the many quartz veins transecting the schist area. The terrace gravels around Texas Canyon 69
and on the west side of Bouquet Canyon contain up to 20% granitic type pebbles derived, evidently, from the Vasquez, Tick Canyon, and Mint Canyon formations which are exposed in the area.

Some of the strath gravels in this area appear, at first, to have an anomalous composition, since they often contain a much higher percentage of Pelona schist cobbles than is present in the bedrock. Careful examination, however, shows that some of the strath material has come from earlier, higher level terraces. The strath deposits of coarse Gold Canyon have been derived chiefly from the Pelona schist which outcrops at the head of the canyon.

In contrast to the Santa Clara terrace deposits, the Bouquet-Haskell Canyon deposits are very easy to distinguish from the bedrock principally because of the difference in composition. On the whole they are somewhat coarser than the Santa Clara material, averaging about medium cobble in 70
grain size, perhaps because they have not been transported as far as have the Santa Clara terrace gravels. They are moderately stratified and much better consolidated than the Santa Clara gravels, and also the underlying bedrock in many cases. This is due to the fact that they have been cemented by some material, probably a composite of iron oxides derived from the biotite in the schist, which has incidentally given a deep brownish red color to the gravels. The thickness of the terrace gravels in this area varies from the normal depth of cut and fill of 10 to 20 feet to depths of about 50 or 60 feet. These thicker deposits are fill terraces and are all of Puckett Mesa age or older.

The chief resources of the Humphreys Quadrangle, excluding the limited farm land are the gold deposits occurring in the terrace gravels and scattered through the Tertiary terrestrial formations. The telltale mark of the prospector's pit may be seen on a great many of the terraces all over the quadrangle. However the only noteable recovery of gold from the terrace deposits was gleaned from the strath gravels of Coarse Gold Canyon. Most of the gold probably came from the quartz veins in the Pelona schist. Concentrating mills have been set up to recover the ilmenite, derived from the plagioclase-hornblende gabbro, occurring in the Saugus formation and the Santa Clara terrace gravels, but such an operation is probably economically unfeasable.

Correlation of the Terraces and Related Surfaces

Although St. Clair, Johnson, and others paint a very discouraging picture of terrace correlation, the problems have probably been over magnified and certain methods have not been taken into consideration. If the terrace correlator realizes the nature of the surfaces he is dealing with, and their possible irregularities, many of the objections raised by his critics can be dispensed with. The normal flood-plain features which D. St. Clair discusses in his *Correlation of River Terrace Remnants* (Science, vol. 86) are relatively small in the Humphreys quadrangle, and are not likely to lead the field investigator astray. Johnson's method of precise leveling[1] means nothing, in the case of

Footnote

[1]-(Douglas Johnson, Problems of Terrace Correlation, Bull. G. S. A., vol. 55, 1944)

the stream terraces of the Humphreys Quadrangle, because careful inspection of the gradients of some of the more continuous Santa Clara terraces reveals that there is considerable discordance between the longitudinal gradients of the terraces and the gradients of the present river bottoms. Unsuccessful attempts by Mr. John Lance at the Calif. Inst. of Tech. to correlate the terrace remnants by levels taken from the very accurate Los Angeles County topographic maps further corroborates the uselessness of the method of pricise leveling under these circumstances.

However, many possibilities for correlation were not considered by Johnson. The author first considered correlation by pebble composition, but, as has been shown, no conspicuous or consistent differences of composition were found with reference to the terrace levels, the composition of the gravels depending chiefly on their locality.

The most reliable datum from which to judge the terraces proved to be not the present stream bottoms but the old Puckett Mesa erosion surface. The main portions of this surface extend into several sections in the center of the quadrangle, and further extensions and the relation of this surface to the Santa Clara terraces to the south were discovered by detailed geomorphic mapping. A mile and a half directly north of the northernmost tip of Puckett Mesa is another old surface at a slightly higher general altitude preserved on the well indurated Vasquez formation. Between this surface and Puckett Mesa lies one small isolated erosion surface remnant on a hill top which, by virtue of its elevation and its general configuration, is of reasonably certain Puckett Mesa affinities. The relatively smooth slopes of the present surface on the Pelona schist on the northern edge of the quadrangle farther to the west have probably changed little since Puckett Mesa time, and are continuous with much larger remnants of old erosion surfaces farther to the north. Of course it can not be absolutely proven that all of these remnants are part of an original extensive surface but the general agreement in altitude (taking into account an upstream increase of elevation), the comparative geomorphic development, and the fact that no other significant erosion surfaces can be found directly above or below any of these remnants, all point to an overwhelming probability that they are all remnants of the same original surface. This surface is the Puckett Mesa Surface, and the time of its final development, before dissection is here referred to as Puckett Mesa time.

Fortunately the Puckett Mesa Surface forms enough points of reference to correlate fairly accurately all of the oldest terraces present in the area. The long fill strath in Texas Canyon is of the same age as the Puckett Mesa Surface remnant on the east side of the canyon which, from the general configuration of its slopes, must have been graded to the level of this strath. Calculating from the gradient of the cut surface beneath the strath fill, that cut surface was graded to the surface underlying the fill of the Bouquet Canyon terraces at the mouth of Texas Canyon, and thus the fills and the strath and these terraces are contemporaneous. Furthermore the elevation of these terraces with respect to Puckett Mesa is just what would be expected for the river level during Puckett Mesa time assuming stream gradients somewhat similar to the present stream gradients.

Three lines of evidence may now be used to correlate the older Haskell Canyon terraces. First of all the two lowermost fill terraces have the right altitude and topographic relations to be contemporaneous with the slightly modified Puckett Mesa Surface remnants directly to the north. Secondly, at the same parallel the present stream bottoms of the east fork of Haskell Canyon and Bouquet Canyon differ less than 25 feet, and consequently, if the stream gradients were not extremely different in Puckett Mesa time, the Puckett Mesa terraces of the two canyons should also differ very little in altitude on the same parallel. The lowermost fill terraces of both canyons are approximately within 25 feet of each other in elevation. Finally, the very fact that these terraces are the lowermost fill terraces in the area is of correlating significance, and indicates that the post-Puckett Mesa dissection was preceded by a period of aggradation, probably in the very last stages of Puckett Mesa time.

This correlation leaves three terrace deposits that are older than the Puckett Mesa Surface, one prominent fill terrace east of Haskell Canyon, standing about 50 to 75 feet higher than the Puckett Mesa terraces in that region, and two patches of terrace gravels lying well above the Puckett Mesa terrace level in the Texas Canyon area.

In the southern part of the quadrangle the uppermost Santa Clara terrace level, defined by the three nobs on the western side of the area, has been correlated with the Puckett Mesa Surface. This correlation was made after a consideration of the terrace gradients and the completion of detailed geomorphic surface mapping in a critical area separating the major portions of the Santa Clara terraces. Give plate no. ref.

The geomorphic map was an attempt to classify all of the surfaces present in the critical area according to age. On the whole, the experiment was more successful than was anticipated. Five distinct surfaces or age groups were recognized above the present or recently cut surface, the oldest being the Puckett Mesa Surface. Next below this is a surface which includes all of the narrow terrace remnants on the west side of Mint Canyon, near its mouth, and the broadest and most extensive terraces in the quadrangle, farther to the west, which will be called the Tank Level group. Below the Tank Level Surface are three less extensive surfaces, which probably have their correlatives among the Santa Clara terraces, but no such levels are outstanding in the Humphreys Quadrangle. In addition, landslide debris and breakaway scarps were mapped separately, and no attempt to classify these was made since their relative age is often more or less indeterminate.

Certain limitations, inherent in the surfaces themselves, as to the preciseness of possible correlations immediately came to light as the mapping was undertaken. initiated ? Since the formation of sideslope surfaces is a slower process than the fairly rapid lateral planation of a floodplain, the age of a sideslope surface is gradational in terms of the corresponding terrace levels. Thus the Tank Level Surface ranges in age between the ages of three closely related but distinct levels in the Tank Level group. Besides this, two "transition surfaces" were mapped, which were definitely transitional in age, one between level number three and level four, and the other between level four and level five. Furthermore, although the general outlines and relations of the surfaces are readily recognizable, the accuracy of the precise details of boundaries and correlation is dependent upon the judgment of the mapper and his familiarity with the area.

A summary of the results of the geomorphic mapping is as follows: The gradational age of old erosion surfaces is clearly demonstrated. Five successive periods of rejuvenation can be recognized, or at least five surfaces have been developed in the rejuvenation of the area. The relation of the Puckett Mesa Surface to the younger surfaces is made clear. Conclusive correlation of the terraces on either side of the area can not be made on the basis of mapping alone because a gap of some 3000 feet in the conti-

Figure 12. A bench formed by the junction of the Tank Level Surface with younger surfaces (background).

Figure 13. Terraces, straths, and landslides (middle background) on the east side of the critcal area.

nuity of the surfaces occurs in the western portion of the area; however the mapping yields corroborative evidence for the correlation made by transit. Finally, as to the accuracy and the validity of the mapping, some cases of correlation depend entirely on personal judgment, and some generalizations were made. For instance, a few ephemeral traces of the younger surfaces were omitted in the northwestern portion of the area because their correlation was more or less arbitrary and they had little bearing on the main purpose of the problem. But taken as a whole the units mapped are fairly well defined and should form a sound basis for further considerations.

The correlation made by the detailed mapping was conclusively tied in by measuring the longitudinal gradient of the main Tank Level terrace and sighting on the terraces on the east side of the critical area from the west side. A value for the gradient Tank Level terrace of 0.58% or 31 feet per mile was obtained by setting up the transit on the 1675 rise at the eastern end of the continuous median member of the Tank Level group and sighting in on the westernmost edge of this terrace at a point a comparable distance out from the valley sideslope. Although some stripping of the terrace has taken place, both of these points are very close to the original surface of the terrace, and the value obtained should be quite accurate and representative, especially since the length of sight was nearly one and three-fourths miles. Using this gradient and sighting back on the terraces just west of Mint Canyon, it was found that the median Tank Level terrace correlated most closely with a level near the southern and lower member of that group. Of course the correlative levels should be expected to be somewhat higher than normal in the area around Mint Canyon because of the sloping transverse profile of the terraces resulting from and equal to the longitudinal gradient of the former Mint Canyon stream which debouched upon the Santa Clara floodplain at this point. The main portion of the Tank Level Surface appears to be more closely related with the median terrace level than the other two members of the Tank Level group.

In the critical area the lowest level of the Puckett Mesa Surface is at about 1975 feet and lies about 150 feet higher and directly north of the Tank Level strath of Corner Canyon. The highest Santa Clara terrace level, defined by the three nobs two miles to the west, lies between 150 and 175 feet above the median Tank Level terrace. Extrapolating along a longitudinal gradient calculated from the topographic map of about 55 feet per mile for this highest terrace, the river level it represents would have been at approximately the right altitude for the Puckett Mesa Surface to have been graded to it. Furthermore, no terrace remnants exist in this area between the highest Santa Clara terrace and the Tank Level group. The validity of correlating this surface as Puckett Mesa in age seems unassailable. Further corroboration of this correlation lies in the close agreement 74 in the gradient it necessitates for Bouquet Canyon during Puckett Mesa time of 50 to 60 feet per mile as compared with the value of 55 feet per mile for the Santa Clara River, during Puckett Mesa Time. Undoubtedly Bouquet Canyon was somewhat steeper than the Santa Clara River then, just as it is now.

The problem at this point remains to correlate the post-Puckett Mesa terraces. The correlation of the Tank Level group to the east of Mint Canyon is a straight forward consideration of distance and terrace gradient. Correlation of the terraces in Haskell and Bouquet Canyon is based on three main lines of evidence. First of all, the Tank Level group is the only well-developed, fairly continuous, post-Puckett Mesa terrace series along the Santa Clara River in the Humphreys Quadrangle. Similarly, in Haskell and Bouquet Canyons there is only one well-developed fairly continuous terrace series (the lower terrace in Haskell Canyon being the equivalent of the upper 75
member of the series in Bouquet Canyon correlating by relative elevations (in a way analogus to that used for the Puckett Mesa terraces), with respect to both the Puckett Mesa terraces and the present stream bottoms. The series is divided into two main portions along the Santa Clara River, the median and the lower portion, separated vertically by about 35 feet; in Bouquet Canyon the series is divided into two main portions separated by about 50 to 60 feet.

Secondly correlating the main upper levels of both series of terraces necessitates an upstream gradient for the Bouquet Canyon series of about 30 feet per mile as compared with the present canyon bottom gradient of about 65 feet per mile. This correlates favorably with 31 feet per mile gradient of the Tank Level group compared with (76) the 55 feet per mile gradient of the Santa Clara River. (73) Finally, correcting for the relative gradients of the Puckett Mesa terraces, the present stream bottoms, and the gradient actually observed on the lower level of the main Bouquet Canyon series of about 33 feet per mile, the series in Bouquet and Haskell Canyons occurs at just the right arranging level with respect to both the present stream bottoms and to the Puckett Mesa terraces to be correlative with the Tank Level group. Furthermore, the fact that both of these terrace groups have proportionately lower gradients than either the older terraces or the present stream gradients (practically only half as great) is of correlating significance in itself, and indicates a more humid climate for this period. The equivalence, then, of these two groups (77) is fairly certain, although the precise correlation of the closely related members may be subject to some differences of ? interpretation.

Correlation of the Tank Level series proved feasible because it is so well defined and therefore probably represents two consecutive sets of valley-plain terraces. However, the terraces occurring between the Puckett Mesa level and the Tank Level group, and those below the Tank Level group are mostly small isolated remnants, and for the most part they probably represent slip-off slope terraces. The lower terraces on the long spur west of Mint Canyon are excellent examples of slip-off slope terraces. Some of these remnants may be correlated locally and their general relations may be derived by comparison with the Puckett Mesa level, the Tank Level series, or the present stream bottom. The Plum Canyon straths, for example were classified in this way. The old landslide surface south of the Santa Clara River is dated with respect to? the level just below the Tank Level series by estimating the river level to which it must have been graded. With the possible exception of that level, no other terrace groups of any significance occur in the quadrangle. Hershey[1] suggested that four terrace levels could be seen in the vicinity of Saugus but these are more likely of local extent, one of the lower levels perhaps correlating with the straths and transitional surfaces in Placerita Canyon. Certainly in the Humphreys quadrangle there are only two principal levels above the present stream bottoms, the Tank Level and the Puckett (78) Mesa level.

[1]-(O. H. Hershey, The Quaternary of Southern California, U. of Calif. Publ. Geol. Sci., Vol. 3, pp. 1-30, 1903)

Causes of Rejuvenation and Terrace Formation

The possible causes of rejuvenation in the Humphreys quadrangle are: eustatic drop of sea level, regional or at

least local uplift, or climatic change towards greater humidity. Other causes such as reduction of load of the streams due to geomorphic old age of the basin, or the sudden increase of stream volume due to capture of other basins are ruled out by the regional physiographic setting of the quadrangle. The case for eustatic drop of sealevel can only be decided on the basis of study of the regional, or world wide coastal conditions. As far as can be ascertained, such a hypothesis is not supported by world wide 79
evidence. Climatic factors and uplift must be the chief considerations. Rejuvenation due to greater humidity alone is improbable because the present stream bottoms have a steeper gradient than the original Puckett Mesa gradients, and, if there had been no uplift, (assuming the river is reasonably graded throughout its course) the present stream bottoms would have to lie above the Puckett Mesa Surface 80
instead of 500 feet below it. The evidence for uplift on this basis alone seems fairly good. It is borne out, moreover by the investigations of others in nearby areas.

~~W. C.~~ Putnam[1] has described the river and marine

[1]-(W. C. Putnam, Geomorphology of the Ventura Region, California, Geol. Soc. Amer. Bull., Vol. 53, pp691-754, 1942)

terraces as well as an old erosion surface in the Ventura region adjacent to the mouth of Santa Clara River. This old surface he calls the Sulfur Mountain surface, and he identifies it with the Timber Canyon surface previously described by Gale[2] from the surrounding area. Old surfaces, 81

[3]-(H. R. Gale in U.S. Grant and H. R. Gale, Pliocene and

and Pliestocene Mollusca Fauna of California, San Diego Soc. Nat. Hist., Mem. 1, pp. 37-38, 1931)

which are undoubtably portions of the Puckett Mesa Surface occur to the north, in Texas Canyon, and in many places in the San Fransisquito and Red Mountain quadrangles. A surface very similar to that in Texas Canyon forms the large part of Sierra Pelona Valley to the northeast, and is, undoubtedly, also a portion of the same Puckett Mesa Surface. That the Puckett Mesa Surface was quite extensive is fairly clear. In addition, remnants of an old erosion surface may be seen south of the Santa Clara River farther west, and in the region around Piru and Sespe Creeks. This is midway between the Humphreys Quadrangle and Sulfur Mountain. That all of the remnants in this entire region are portions of the same surface seems very probable, and if this is so, the Puckett Mesa Surface is the equivalent of the Sulfur Mountain or Tinber Canyon Surface.

Putnam has given conclusive evidence that the rejuvenation in the Ventura region is due primarily to uplift, the marine terraces bearing excellent testimony to this fact. He also has evidence of some post-terrace folding and warping. If the rejuvenation around Ventura and the dissection of the Sulfur Mountain Surface is due to orogenic uplift there certainly is strong reason to believe that the dissection of the same surface thirty miles away is due, in part at least, to the same factors, especially since the uplift is known to have covered a considerable area. That there has been any appreciable, very recent folding or warping in the Humphreys ~~q~~uadrangle, however, seems unlikely, because the correlations based in part on the assumption of a lack of warping are so consistent? coherent ~~to the exclusion of other possible correlations~~ and because the gradients and profiles of the terraces show absolutely no evidence of folding.

Superimposed upon the rejuvenation caused by uplift, never-the-less, are seen gradient changes due, undoubt~~ably~~edly, to climatic variation. It is quite possible that the lowering of the streams down to the Tank Level, for instance, was caused purely by a lowering of the stream gradients brought about by greater humidity. The wet cycles of the last several thousand years are probably recorded by the broader more extensive terraces. The smaller intermediate terraces are most likely, merely unmatched slip-off slope terraces left during the more continuous down cutting. On the other hand, it is possible that some of the broader levels represent stationary periods during an uplift which Putnam has evidence to show is intermittent. Climatic variation, however, is more dominant in producing broad levels because at forty miles from the sea the irregularities of uplift are likely to be in a large part smoothed out. (Not if the uplift is local in this area)

Geomorphic History of the Humphreys Quadrangle and the Surrounding Region

The age of the Puckett Mesa Surface is a question which, if it could be answered, would serve to date the late Pleistocene orogeny of Southern California and the vertebrate and invertebrate fossil deposits of Southern California.

Two rather poorly defined limits may be set to the possible age of this surface. The Puckett Mesa Surface truncates the folded Saugus formation. Since no evidence for folding of the surface can be discerned in the quadrangle the surface must be at least younger than the post-Saugus orogeny. The Saugus has been correlated with the San Pedro formation, which from its prolific marine fauna, has been determined to be at least of Lower Pleistocene if not younger. [T. L.] Bailey[1] has presented considerable

1-(T. L. Bailey, Late Pliestocene Coast Range Orogenisis in Southern California, Geol. Soc. Amer. Bull., Vol. 54, pp. 1549-1567, 1943)

evidence for a mid-Pleistocene orogeny on the basis of both this fauna, with some vertebrate remains, and the "late Pleistocene" fauna obtained from fanglomerates and terrace deposits which clearly, unconformably overlie the San Pedro formation in the vicinity of Ventura. The Sulfur Mountain Surface is definitely younger than this orogeny[2], and,

2-(W. C. Putnam, op. cit., pp. 751)

correlating the Saugus formation with the San Pedro formation, or the Puckett Mesa Surface with the Sulfur Mountain Surface, or simply the post-Saugus orogeny with the post-San Pedro orogeny, it is fairly certain that the Puckett Mesa Surface is younger than the mid-Pleistocene orogeny.

The closest lower limit that can be set for the age of the Puckett Mesa Surface is ~~dated~~ determined by the age of the vertebrate fauna in the fanglomerates near Ventura and in the asphalt deposits on the marine terrace at Carpenteria, both of which are considerably younger than the Sulfur Mountain Surface and undoubtedly younger than the Puckett Mesa Surface also. Unfortunately the age relations of the vertebrate fauna are exceedingly indeterminant. Most of the evidence (R. W. Wilson,[1] I. S. DeMay,[2] and Chaney and

[1]- (R. W. Wilson, Pleistocene Mamalian Fauna from the Carpenteria Asphalt, Carnegie Inst. Wash. Pub. 440, Paper VI pp. 57-76, 1933)

[2]-(I. S. DeMay, Pleistocene Bird Life on the Carpenteria Asphalt, California, Carnegie Inst. Wash. Pub. 550 Paper IV pp. 61-76, 1941)

Mason[3]) indicates that the Carpenteria deposits are younger

[3]-(R. W. Chaney and H. L. Mason, A Pleistocene Flora from the Asphalt Deposits at Carpenteria, California, Carnegie Inst. Wash. Pub. 415, Paper III, pp. 45-79, 1934)

than the Rancho La Brea fauna which Stock[4] has tenatively

[4]-(Chester Stock, Rancho La Brea, A Record of Pleistocene Life in California, L. A. County Museum Science Series, No. 11, Paleontology, No. 7, 3rd ed. 1946)

assigned to the Illinoian-Wisconsin interglacial period. Certainly, on the basis of fossil and structural evidence, Davis's attempt[1] to correlate the marine terraces farther

[1]-(W. M. Davis, Glacial Epochs of the Santa Monica Mountains, California, Geol. Soc. Amer., Bull. 44, pp. 1041-1133, 1933)

down the coast similar to the terraces at Carpenteria, with the glacial epochs is invalidated. The terraces he describes are probably all post-Wisconsin. 82

If an independant means could be used to establish the age of the Puckett Mesa Surface, that date would be a basis from which to judge the relative age of the younger vertebrate fauna and of the orogenic movements which have taken place, evidently continuously ever since the principal mid-Pliestocene orogeny up to the present. Certain evidence is present in the Humphreys Quadrangle with regard to fill terraces and stream gradients which, when matched with the Upper Pleistocene climatic fluctuations, may be the clue to tying in Southern California Pleistocene history with the world wide glacial epoch history.

The first thing to be noted is that the Puckett Mesa terraces have a gradient very similar to the present stream gradients. This means that during Puckett Mesa time the climate was probably somewhat similar to the present climate. Such a climate could be found in the Upper Pleistocene during either the Kansan-Illinoian major interglacial period or the post-Wisconsin period. Three facts point to the post-Wisconsin period instead of the major interglacial period. First of all, a certain amount of time since the mid-Pleistocene orogeny was necessary to form the late mature Puckett Mesa Surface. Secondly, the soft Tertiary sediments yeild to erosion extradordinarily rapidly, and the time elapsed since the major interglacial period is not required to account for the post-Puckett Mesa dissection. Finally, and most important, the sequence of events indicated by the field evidence most closely fits the post-Wisconsin climatic history.

The significance of the Puckett Mesa fill terraces is not to be underestimated. In addition to those already mentioned, large fill terraces of Puckett Mesa age occur in the Saugus quadrangle to the west, and John Lance states (oral communication) that the Puckett Mesa terrace in the Sierra Pelona valley is filled to a considerable depth. Starting with the formation of the Puckett Mesa Surface the sequence of events is as follows: (1) culmination of the development of mature surface under climatic conditions similar to those of the present, (2) aggradation, indicating a stage of increased aridity, (3) rejuvenation and concommitant lowering of the stream gradients, indicating a considerable increase in humidity, (4) continued rejuvenation with a return to steeper stream gradients, part of the steepening of the gradients being due to very recent aggradation. This sequence matches the post-Wisconsin climatic cycle very well. The period of formation of the mature surface corresponds to the post-Wisconsin, pre-xerothermic period; the Puckett Mesa aggradation would represent the Zerothermic or post-Wisconsin optimum; the low gradient stage correlates with the waning of the Zerothermic optimum and increase of humidity; recent aggradation and increase of the stream gradients may be an upswing in the cycle, possibly related to the very recent world wide change in glacier regimen. Other, lower, well developed terrace levels, not present in the Humphreys Quadrangle may represent minor fluctuations of the cycle. Measured in terms of years, this scheme would make the Puckett Mesa Surface about 8000 years old according to the chronology given by (83) Flint[1] in his resume of the post-Wisconsin cycle.

[1]-(R. F. Flint, Glacial Geology and the Pleistocene Epoch, 1947)

The revision introduced into the previous estimates of the ages of the brea vertebrate assemblages of Southern California by the foregoing correlation is considerable. Being much younger than the Puckett Mesa Surface the Carpenteria fauna would be placed essentially in the recent. According to Wilson[2] only four forms are found in the deposit

[2]-(R. W. Wilson, op. cit., pp. 62)

which do not occur in the region today, and the environmental conditions as indicated by the mamalian fauna do not appear to have been very much different than the present. However such a correlation as has been suggested does put such forms as _Canis dirus_, _Panthera atrox_, _Camelops hesternus_, and _Equus occidentalis_ practically on the back doorstep. The slight climatic change in the area since Carpenteria time demonstrated by the flora and avifauna of the Carpenteria brea deposit is probably related to the recent aggradation in the present stream bottoms brought about by increased aridity.

The older Rancho La Brea fauna would probably be contemporary with the Puckett Mesa Surface since it shows such a remarkable similarity with the Carpenteria material, being pre-xerothermic optimum in age, but still showing nearly the same ecologic background. Thus, although considerable revision of the age of the fauna in the direction of the present or upwards in the time scale is indicated by correlating the Humphreys quadrangle terraces with the post-Wisconsin period, this correlation does not, in the final analysis, conflict with any definite paleontological evidence.

The unusually rapid rate of erosion implied by this correlation is also at considerable variance with previous estimates. However, considering the unconsolidated nature of the Tertiary formations 500 feet dissection does not seem unreasonable. In fact, happily enough, it supports the estimate of rate made on wholly independent criteria at the beginning of this paper.

In conclusion, the geomorphic history of the Humphreys Quadrangle may be outlined as follows:

(1) Presence of a terrestrial sedimentary basin during Oligocene(?) and lower Miocene.[1]

(2) Formation of a lake in the basin sometime in the early Upper Miocene and subsequent filling of the lake[1]

(3) Inundation of the basin by the sea during late Upper Miocene.

(4) Emergence, erosion, and reinundation during Pliocene.[1]

(5) Emergence of the basin during late Pliocene and Lower Pleistocene and continued deposition.[1]

(6) Mid-Pleistocene folding and subsequent erosion of a mature surface culminating in the post-Wisconsin, pre-zerothermic interim.

(7) Aggradation and filling of valleys during the zerothermic optimum

(8) Rejuvenation and cutting of several terrace levels with minor drainage changes (as indicated by stream capture) in the post-zerothermic period.

(9) Recent aggradation in the valley bottoms.

In view of the complex forms present, the present geomorphic stage of the Humphreys quadrangle might best be characterized by late youth.

[1]-(These stages are inferred from the bedrock stratigraphy which was not studied in the field by the author)

(64)