GEOLOGY OF A PORTION OF THE TEHACHAPI MOUNTAINS IN THE VICINITY OF JAWBONE CANYON, CALIFORNIA

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by

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TABLE OF CONTENTS

Introduction	1
Location	1
Purpose of Investigation	2
Method of Investigation	2
Summary	4
Geography	5
Topography	5
Drainage	6
Vegatation	6
Physiography	8
Other Land Forms	13
Physiographic Summary	15
Geology	17
Stratigraphy	17
Paleozoic Rocks	17
Granites	20
Ricardo Sandstones and Conglomerates	22
Ricardo Tuff-Breccia	26
Ricardo Agglomerate	26
Jawbone Basalts	27
Piedmont Alluvium	28
Structure	30
Faulting	30
Miscelaneous Structures	35
History	37
Economic Geology	38
Metalliferous Deposits	38
Non-Metalliferous Deposits	40

Plates are arranged according to their subject matter.

INTRODUCTION

LOCATION

The region embraced within this report lies in the West central part of Kern County, California, about twenty miles North and East of the little railroad town of

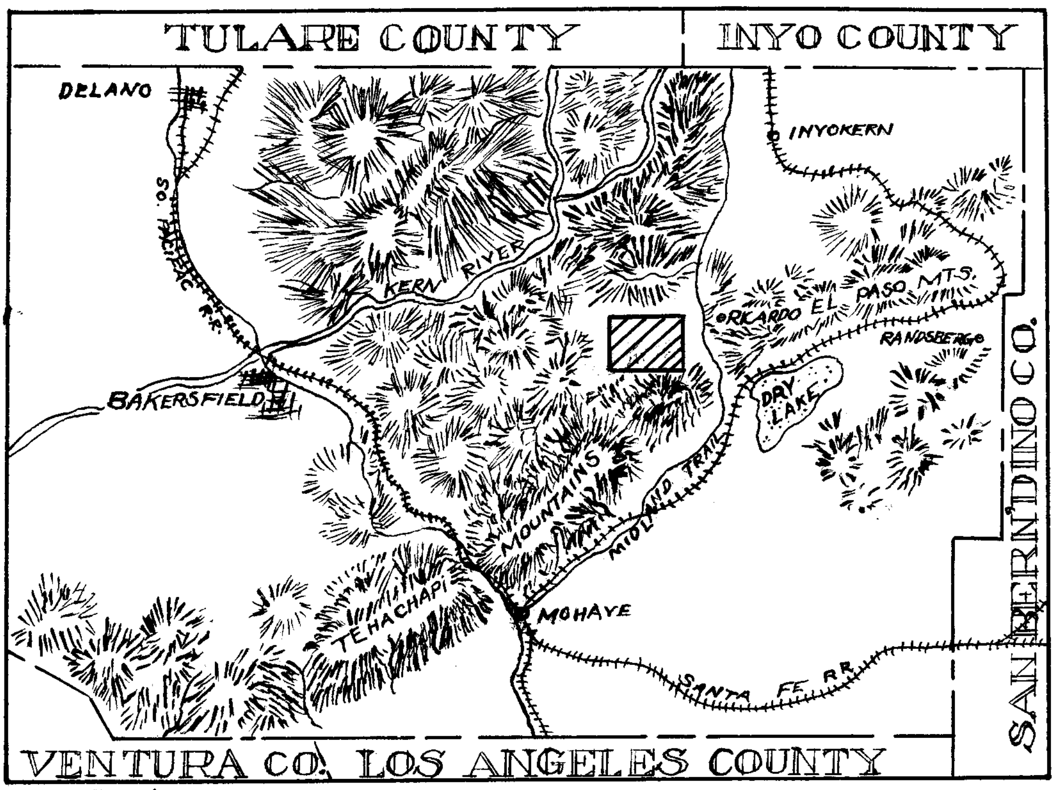

FIG. 1 - Sketch map of portion of Kern County, showing location of Jawbone Canyon Area.

Mohave. It is approximatly 138 miles due North of Los Angeles, and may easily be reached by good road via the Midland Trail.

The area comprises about 45 square miles in the Eastern portion of the Tehachapi Mountains, and is roughly bissected by Jawbone Canyon which trends almost due East and West.

With respect to other great geographic divisions of the Western United States, the area covered lies in the Western portion of the Great Basin province.

North of the town of Mohave, the Tehachapi Mountains trend about N.40°E., and continue in their Eastward extension until they join the El Paso range.

Considered in a broad way, the Eastern portion of the Jawbone Canyon area consists of the flat floor of the Mojave Desert. The floor of the desert is abruptly terminated by the Tehachapi Mountains, and from here Westward, the region is made up chiefly of naked hills and deep canyons.

The trip to Jawbone Canyon by automobile can easily be made in about four hours, from Los Angeles.

Within five miles of the mouth of Jawbone Canyon, lies the Owenyo branch of the Southern Pacifac Railroad.

All of the area above described lies entirely within the Mojave Quadrangle of the United States Geological Survey.

PURPOSE OF INVESTIGATION

The general geology of this region was attacked during the Winter and Spring of 1928 as a research problem in Geology as one of the requirements for the degree of Bachelor of Science in Geology of the California Institute of Technology. The total amount of work here represented amounts to about one full month of field work.

METHOD OF INVESTIGATION

Before beginning the actual field work on the problem, a photostatic enlargement of five times was made from the required portion of the Mojave Quadrangle. Inasmuch as the scale of the original quadrangle is two miles to the inch, the photostatic enlargement (see pocket) has a scale of almost 2000 feet to the inch. Owing however, to the fact that the original contour interval was 100 feet, some difficulty was encountered in accuratly locating stations on the field map.

Where possible, locations were made by the method of intersection, although for most part, this method proved inadviseable, owing to the contour interval. For this reason, some of the contacts between formations are not as accurate as might otherwise be possible.

After making a general reconnaisance of the area, structural and stratigraphic units were studied more in detail, in order to gain the requisite familiarity with their lithologic characteristics.

Contacts were traced, for most part, on foot, although in some instances, the more prominent ones were traced in on the field map from points of vantage.

In some instances, the actual relationships between formations is obscured by a mantle of talus and atmoclastics. In these instances, contacts were of necessity, somewhat generalized.

SUMMARY

The Tehachapi Mountains in the vicinity of Jawbone Canyon show a stratigraphic and structural history dating from the Paleozoic. Orogenic movements have been taking place more or less intermittently from Mesozoic time.

The present range-front presents a bold scarp on the East, with progressively higher elevations towards the North and West. The dominant structural influence has been faulting and uplift. Both normal and reverse faults are present.

Several periods of uplift and erosion have taken place, followed by the deposition of terrestrial sediments and volcanics during late Tertiary time. Denudation of the higher mountain slopes is at present taking place. The piedmont alluvium is being deposited in the lower basins.

The region is in the late-youth stage of the erosional cycle. This is demonstrated by a consideration of both the normal river erosional cycle and the arid erosional cycle of William Morris Davis.

Both metalliferous and non-metallic resources are present, but in limited quantities.

Uplift and movement is taking place at the present time.

GEOGRAPHY

TOPOGRAPHY

The Jawbone Canyon area, in large part, lies in the Tehachapi Mountains, an Eastern extension of the California Coast Range. The monotonous floor of the Mojave Desert abruptly ends against the naked flanks of these mountains, and its flat topography gives way to the rugged, dissected, highlands of the Tehachapi Range.

The Eastern mountain front in the area studied, is more or less arcuate, curving gently in North-Eastern direction. The Westward extension of the area, is a broken country of rugged, granitic mountains, separated here and there, by deep canyons with precipitous walls and steep grades. The prevailing topography is as outlined above, except in the North-Eastern corner of the area, where the granitic hills give way to gentler topography.

The relief of this corner of the region is less strongly marked, and the bolder scarps are replaced by dissected bad-land physiography and bold questa ridges. Alternating soft and resistant beds of the Ricardo formation have here lent their influence in the carving of characteristic land forms. The softer beds have given away to erosion more markedly, and straight, shallow valleys with inferior walls have resulted.

Considered in a broad way, most of the valleys of the region are remarkably straight and free from sharp spurs. As will be discussed later, faulting has exerted a strong influence in the sculptoring of the land forms, and its dominance is clearly disclosed in the geography.

The highest point in the area is Cross Mountain, with an altitude of 5175 feet above sea-level. The lowest point lies in the desert East of Cinco. The maximum relief is about 3000 feet, and the mean relief is about 1700 feet.

DRAINAGE

The master drainage system of this region is of course Jawbone Canyon, which flows in a general East-West direction and empties into the Mojave Desert.

Most of the tributary canyons of any importance, drain either North or South into Jawbone Canyon, while those canyons cut into the Eastern face of the range, drain directly into the desert.

It will thus be seen, that all run-off gradually finds its way into the desert.

VEGETATION

The region is truly arid, most of the rainfall of the year occurring during the winter months and early spring. Vegetation is confined chiefly to desert and arid country flora.

Such plants as the prickly-pear, mesquite, yerba-mansa,[1] rabbit-brush, arrow-weed, cactus, and other arid and semi-arid plants all find their habitat here.

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[1] Meinzer, Oscar E., Plants as Indicators of Ground Water, Water-Supply paper 577, U.S. Geological Survey, 1927.

The precipitaion remains fairly constant from year to year, and seldom exceeds four inches. Periods between rainfall are often of considerable lenghth, and when a rainstorm does pass over the region, it is apt to reach magnitudinous proportions. For this reason, large amounts of detrital material are swept out of the canyons with every shower, and most of the alluvial fans are covered with angular boulders of varying size.

In certain exceptionally cold seasons, some of the higher peaks of the mountains are apt to be covered with a thin mantle of snow, although it seldom stays unmelted for more than two or three days.

PHYSIOGRAPHY

In the normal consideration of the erosional cycle, the cycle of river erosion forms the basis for the concepts formed.

In the area under discussion,however,the land forms and their derivations cannot satisfactorily be reduced to the results and processes which take place in the normal cycle of river erosion.In the first place,the dominant erosional factor in any arid region is wind abrasion,subordinately assisted by intermittent streams and sheet floods. In the second place,the modifying factor which stands second only to erosion,is the influence of faulting on the erosion.

In attempting to deduce the position of an arid region in the cycle of arid erosion,it is first necessary to postulate a basin and highland topography,so that whatever drainage exists will be centripetal.[1]From a consideration

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[1]Davis,William,M.,Geographical Essays,1909,

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of the topographic map (Mojave Quadrangle) it is easily seen that the Jawbone drainage is into the Mojave Desert, either via Jawbone Canyon,or directly Eastward into the desert. At the beginning of the arid cycle,the land may be considered as having any form.

The Tehachapi Mountains,in this vicinity,are for most part,swept quite bare,except where the sparsely growing desert vegetation has succeeded in retaining a relitively thin veneer of small, angular, fragments of detritus. The depositional basin, on the other hand, possesses a nearly level, quite monotonous, central floor of fine waste from the bordering highlands, while in places, it exhibits the varied phenomena of playa lakes, salinas, etc., and thus corresponds fairly well with Davis' notion of arid-cycle youth.

Now consider the drainage ways themselves.

Jawbone canyon is quite straight, and may be considered as being in part a fault drainage, in part an antecedent drainage. This concept is gained from a consideration of the location of the East-West striking fault which runs through the canyon, and by the fact that both the basalt flows and basement complex clearly indicate uplift athwart the course of the drainage.

The sides of this drainage way are clean cut and relitively free from spurs on the fault side of the canyon. Its profile is V shaped and fairly obtuse on the flanks. In addition to these facts, it clearly shows varied evidences of very recent uplift such as trenching and terracing, river gravels high up on its walls, rejuvenated fans (see Plate V), etc. All of the above evidences point to an erosional age comparable with middle or late youth in the normal river erosional cycle.

The tributaries of Jawbone Canyon, for most part, have many physiographic characters in common. Those which run into the canyon on the fault side, are marked by an abnormal

PLATE I

Typical spur saddle developed by movement on Cameron Fault. Solid line indicates trace of fault; dotted line indicates reconstructed portion of spur. Location East front-Tehachapi Range, West of old Cinco.

grade, with marked steepening towards their heads. Their fans are short and steep, and frequently cut off by the fault. Without exception they are degrading, and some of them show two or more terraces with characteristic gulch profiles along the actual stream course. Their walls are fairly steep, and they exhibit a V shaped profile with only moderate flaring towards the top. Again the unmistakable evidences of youth in the normal river erosional cycle. No verb in this sentence

In considering the pysiographic age of the land forms, it is not quite as simple a matter to draw conclusive deductions from their present physiography.

The Eastern front of the granitic Tehachapi Range is marked by a steep scarp whose lower extremity is abruptly terminated by the desert. Fans spreading out from the mouths of Eastward flowing canyons are frequently disjointed and cut off from the floor of the canyons they belong to. In the area studied, no distinctly faceted spurs were observed, but the spurs in the aggregate, nevertheless, clearly exhibit topographic expressions of the Cameron fault. They are usually cut ~~off~~ through in their lower extremities, and marked by Kern-cols and Kern-butts together with striking zones of brecciation. The spur saddles are usually filled with autoclastic material which is highly stained and colored by percolating meteoric waters. (See Plate IV).

Unfortunately, time was not available for study of the major portion of the country due West of the Eastern range front, so that it is impossible to tell whether or not successive Westward ranges possess the typical steep scarp and long back slope of the typical Basin Range of Davis. In the first range, however, this appears to be the case.

It is hoped that at a later date the writer will be afforded the opportunity to examine this region more closely, inamuch as it is both an important and highly interesting region with respect to Great Basin structure in this region.

A consideration of the topographic map, as well as the vista opened up from the highest points of the Eastern range front, show that the Eastern slopes of the Westward ranges are quite bold, and attain progressively greater height from East to West.

The ranges themselves, are quite rugged and bold, and are only moderately rounded. Owing to the nature of the climate and the high resistance to erosion of the granite, it is somewhat difficult to state just what physiographic age the Tehachapi highlands represent, but if they are considered as being merely the interstream divides left in the process of erosion of the incised canyons between, an approximate idea of their place in the erosion cycle may be gained. by a study of the incised canyons.

As is common in the drainage systems already considered, the incised canyons have the usual V shaped profile and are degrading their channels. In addition to these facts, most of them are marked by water-falls where they cross hard rocks, and they are deeply incised with very high, usually

Looking downstream from the head of water canyon. The canyon is here deeply incised in the granite core of the Tehachapi Mountains. Trenching may be seen in the background. A portion of the Los Angeles Acqueduct may just be seen in the upper left hand corner of the picture.

precipitous walls.Water-falls,coupled with the factors above mentioned,seem again to point to a normal river erosional cycle age of middle or late youth.[1] (See plate VI)

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[1] Lahee,Frederic H.,Field Geology,McGraw-Hill,1923.

There yet remains to be considered the erosional stage of a very important part of the region,namely,the region marked by the outcrops of the different members of the Ricardo series.This region is confined chiefly to the Northern portion of the area.

Generally speaking,the effects of erosion upon the different Ricardo members are vastly different from any of the physiographic phenomena yet discussed.

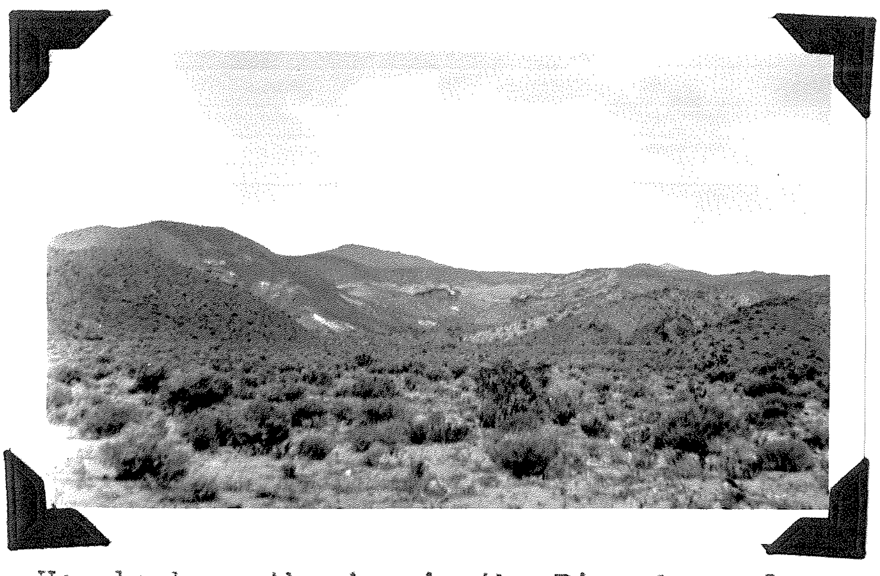
Probably the most striking feature,in a physiographic sense,to be observed in the Ricardo,is the fact that the beds have been tilted by faulting until they dip into the granite.After tilting,erosion has taken place producing some striking physiographic features.

The most important modifying factors are then the effects of wind abrasion and sheet run-off upon the relatively soft beds of the formation.In the aggregate,the green tuff-breccias and conglomerates are the most resistant beds of the series.Wind abrasion has hollowed out a honeycomb of erosional cavities in the sandstone reef-beds,and all of the members,with the exception of the volcanic flows,are noticeably rounded and subdued by its action.

Intermittent streams and sheet run-off have played their

PLATE III

Looking West up Jawbone Canyon from Blue Point. Dip and dissection of Jawbone basalt is shown. No-Name mountain immediate background. Cross-Mountain in background.



Hog-back weathering in the Ricardo agglomerates. Looking North-West from Blue Point.

part in the physiographic cycle by weathering out the softer, and therefore less resistant sandstone and ash beds. The net result of this process has been to leave the more resistant beds boldly projecting into the air in the form of questas. The sharp edges of the projecting questas, have in turn been rounded by attrition with wind-carried sand grains, dust, etc. The net result of erosional activity has been to produce a characteristic bad-land topography.

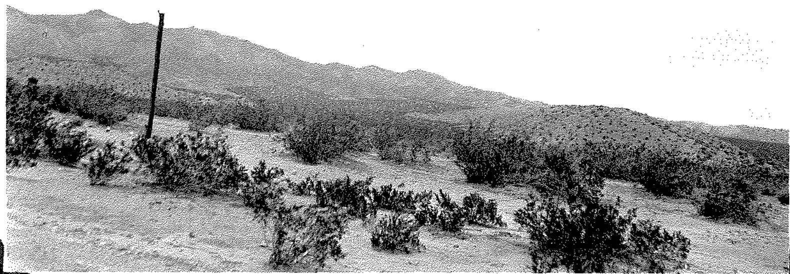
Still another unique feature of Ricardo physiography is the weathering away of softer ash beds capped by resistant volcanic lavas, giving rise to a series of hoodoos. This type of topography is characteristic of certain parts of Painted Canyon.

The stream grades of drainages which tap various parts of the Ricardo, are in general, much gentler than those of drainages in other parts of the area, although dissection is still progressing at a rapid rate. This fact, coupled with similar phenomena as mentioned for other drainage, leads the writer to the conclusion that the Ricardo topography here exposed is also in the youthful stage. (Plates VII-VIII).

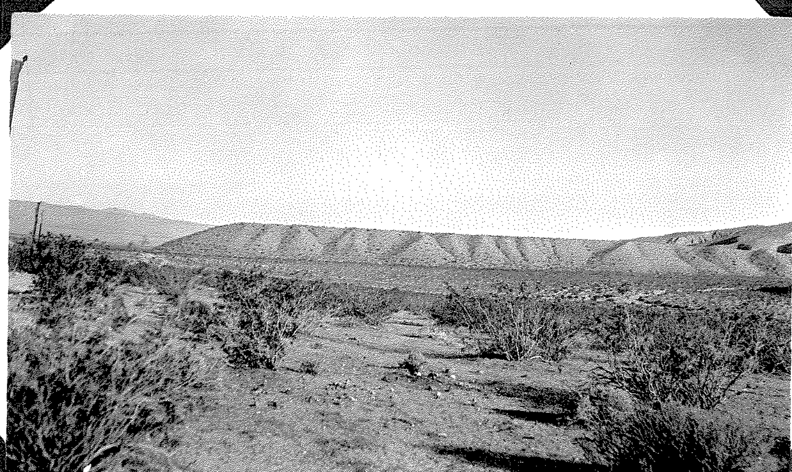
OTHER LAND FORMS

Near the mouth of Jawbone canyon, projecting into that drainage way from the South, may be obsrved the slightly dissected remains of an ancient alluvial fan. This fan slopes very gently to the North, with its highest portion jutting into the granitic basement of the Tehachapi Range. Its Southern edge is terminated by a fault, so that topographically

PLATE IV



Recently uplifted and slightly dissected alluvial fans. The lower picture is the South fan, the upper picture is a view of the North fans.



as well as structurally,it joins the basement complex in a typical fault contact,and represents a beautiful example of topographic unconformity. Directly across the canyon, and almost due North of this ancient fan,may be seen the more deeply eroded remenents of similar fans.The fans on the Northern side of Jawbone Canyon,dip gradually to the South.

The two sets of fans,one on each side of the canyon, both dipping towards each other,and into Jawbone Canyon, seem to suggest the probability that Jawbone canyon was also the master drainage at the time of their formation, inasmuch as they have all been built up within it.

These fans are composed chiefly of reworked and re-deposited Ricardo conglomerates,with a thin veneer of old quaternary alluvium upon their grade surface.The stratigraphic position of the old alluvium on the upper surfaces of the fans suggests the fact that their uplift and present diss-ection must have taken place after the deposition of the old alluvium,and since the dip of their component Ricardo matrix is discordant with that of the surrounding beds,their formation must have taken place in post-Ricardo time.

As has already been mentioned,these old fans form an unmistakable evidence of the very recent vertical movement along the faults of the region. (See Plate V).

In the Northern part of the area,detritus has been swept off of the flanks of the Sierras onto the bveled edges of the tilted Ricardo beds,with the higher granitic peaks projecting through their alluvial mantle. With the possible exception of the river gravels, this alluvium (Qoal.) is perhaps the youngest formation exposed anywhere within the area. Its deposition is proceeding at the present time, with its ultimate goal the Mohave Desert depositional basin.

The topographic expression of this alluvial mantle is everywhere the same, and is best pictured as a gently dipping surface with its highest points well up on the flanks of the higher peaks, and its lower borders spreading out into a gently undulating apron. Outside of the area, as one rides over the Dove Springs road in the direction of the El Paso mountains, certain portions of the old alluvial surface appear so gentle, and so little dissected, as to give the observor the impression of a recently uplifted, peneplained surface.

PHYSIOGRAPHIC SUMMARY

The position of the Jawbone canyon region in the erosional cycle is placed at middle or early-late youth. This conclusion is reached from a consideration of the present land forms, drainage-ways, and depositional basins, both from the standpoint of the arid climate erosional cycle, and the normal river erosional cycle.

The highland regions are due primarily to faulting with present modification by wind abrasion and sheet flooding. Since the predominant land forms are positive and destructional, uplift is assumed to be proceeding faster than degradation.

Bad-land topography is confined chiefly to the areas underlain by the Ricardo formation, and is due mostly, to differential erosion in alternate hard and soft beds which have been tilted by faulting. Questas and bold reef beds are characteristic of this type of physiography.

Hoodoos have been produced by normal arid erosion acting upon softer beds capped by more resistant lavas.

The region as a whole has suffered recent rejuvenation as is attested to by the fact that most of the canyons are deeply incised, fans are abnormally steep, and trenching is characteristic. Ancient alluvial fans now stand at considerable elevations, and are, for most part, only slightly dissected.

GEOLOGY

STRATIGRAPHY

The part of the Tehachapi Mountains in the vicinity of Jawbone Canyon is characterized by a representative, although not type, section of Great Basin Tertiary sediments and volcanics. Poorly indurated and unmetamorphosed Pliocene terrestrial sandstones and conglomerates, are conformably overlain by ~~quite~~ a thickness of greenish tuff-breccia, slightly younger in age, but still representative of the Lower Pliocene. Overlying the tuff-breccia, and also conformable with it, is the uppermost Ricardo member exposed in the area, the Ricardo agglomerate series.

The agglomerate series is unconformably overlain by a relatively great thickness of olivene-basalts, the Jawbone basalt series.

The upturned edges of the Jawbone Basalts are covered with a mantle of granitic debris swept off the Sierran slopes.

The region is particularly interesting in that it contains rocks of Paleozoic and Mesozoic(?) age in great thickness, well exposed. The later Mesozoic(?) rocks are typically represented in the great granite batholithic core of the Tehachapi Range, which has stoped its way up through the older Paleozoic limestones and sandstones, locally metamorphosing them to marbles and quartzites, with prominent cleavage and flow structure exemplified.

Paleozoic Rocks

The type exposure of Paleozoic rocks in the area

General Section of Rock Formations in the Vicinity of Jawbone Canyon, California.

System	Series	Formation	Thickness
Quaternary		Alluvium and River Gravels	
Quaternary	Pleistocene(?)	Old Alluvium Sierran Debris	
Unconformity			
Tertiary	Upper Pliocene(?)	Jawbone Basalts	2095'±
Unconformity			
Tertiary	Upper-Lower Pliocene(?)	Ricardo Agglomerate	1980'±
	Lower Pliocene	Ricardo Tuffs	1822'±
	Lower Pliocene	Ricardo ss.and cong.	4298'
Unconformity			
Mesozoic(?)	Basement Granites		
Paleozoic(?)	Basement Marbles, Quartzites		

investigated, lies in the Southern part of the area, in S.B.Canyon.

In this region, the downcutting of the canyon has exposed a beautiful section of marbles, highly metamorphosed by the later intrusion of the granites.

On weathered surfaces, the marble is a dirty gray in color, streaked by the intersections of flow-cleavage planes with its surfaces. It is almost black on a fresh surface, and as a rule, is almost pure calcium carbonate. Pebbles contained in the original limestone matrix are frequently so drawn out by the metamorphoses as to be several times as long in one plane as in the other. Flow cleavage planes are drawn about these pebbles with considerable thinning near the borders. The pebbles are oriented in the direction of the planes of flowage, and are occasionally sheared by minor slippage within the parent marble. On weathering, the softer marble is abraded and worn away first, leaving the pebbles projecting into the air. Old bedding may be traced by projecting lines of pebbles, to a certain extent.

Later dykes and feeders of both basic and acidic extrusive rocks have forced their way through the older Paleozoics. In the gneissic facies, these extrusions have locally penetrated the gneissic laminae, and have locally given rise to injection gneisses. At times, these later extrusives are considerably mineralized, and form a fruitful basis for prospecting in the region.

The Northern slope of the Southern boundary ridge of

S.B.Canyon is marked by a rather extensive exposure of Biotite gneiss.The ferro-magnesian minerals are relatively fresh and unaltered.As mentioned above,this gneiss is cut into by later extrusive rocks giving rise to injection gneisses.

Further up S.B.Canyon,the black marble gives way to an almost white variety which is locally cut by basaltic dykes.This facies is daintily veined with limonite,and in places stained yellow by it. Characteristic limestone striae show on weathered surfaces,while the fresh surfaces present a sugary texture.

The Paleozoic rocks are too highly metamorphosed to contain recognizable fossils.

GRANITES

The granitic core of the Tehachapi Mountains forms about 80% of the rocks mapped in the area. This rock has welled up through the older Paleozoics,locally metamorphosing them as explained above.It lies unconformably beneath the Ricardo series,and in places,projects up through windows in both the Ricardo and the younger Sierran detritus.

The granites North of Jawbone Canyon are marked by their high content of Ortoclase and by the fact that the ferro -magnesian minerals are but slightly altered.

The dominant color of the feldspar in the granites North of Jawbone Canyon is pink,and the rocks contain such amounts of this pink mineral as to take on its color.Biotite is relatively lean in these rocks,and horneblende occurs only sparingly. Quartz is present, but in much inferior quantities to the Orthoclase. In certain localities, the Northern granites are apt to be quite porphyritic, in which case, the phenocrysts are always the pink Orthoclase; they are apt to attain sizes up to an inch or two in length, and half again as broad. Feldspars are but moderatly altered to Kaolinite, as might be expected from the climatic environment of the region.

The granites south of Jawbone Canyon are remarkable because of their petrologic contrast to those North of Jawbone Canyon. Thay are usually quite rich in Biotite and other of the ferro-magnesian minerals. In contrast, however, these ferro-magnesian minerals are highly altered and decomposed. Large masses of Limonite forming crustifying borders about the ferro-magnesian minerals are the rule rather than the exception. Kaolinite is quite common as the decomposition product of the Feldspar. The Feldspar is Orthoclase, and occurs in the parent rock with quartz, although these two minerals are much subordinated in quantity to those in the Northern half of the area.

Since the Southern granites differ so markedly from those in the Northern province, both in composition and degree of alteration of the ferro-magnesian minerals, it seems reasonable to assume that two different sets of conditions have acted upon the granites. Perhaps the granites South of Jawbone Canyon have been exposed to weathering for a longer period, or perhaps the granites on each side of Jawbone Canyon represent two stages of intrusion. These two hypothesis can not be proven on the basis of the evidence at present available.

RICARDO SANDSTONES AND CONGLOMERATES

Unconformably overlying the Northern granitic basement complex is the Ricardo series; the lower members of the series in the area exposed are dominantly sandstones and coarse conglomerates. This does not by any means, imply that the base of the Ricardo section is exposed in the vicinity of Jawbone Canyon, but the term 'lower members' as here used, is taken to mean the lowermost beds here exposed in the stratigraphic column.

The lowermost member exposed is a rather coarse conglomerate containing particles ranging in size from fine sand up to large cobbles. Dominant color on weathered surfaces is a drab gray to dark brown, chiefly the latter. The beds are massive, poorly indurated, and poorly bedded, they weather into massive, bold, but rounded bluffs, which are locally'stepped' because of differential erosion. Particles are poorly classified and of varying sizes. Sub-angular to well rounded. Chief elements are granite cobbles, with lessor amounts of basalt, ryholite, and even tuff and ash particles. Ferro-magnesian minerals are fairly fresh and unaltered. Feldspars only moderatly kaolinized. Progressive increase in rounding towards the North. Matrix arkosic.

The dominance of granitic cobbles in this conglomerate suggests the possibility that it may be the basal conglomerate of the Ricardo series. In this respect, it differs from the basal conglomerate exposed in the basal conglomerate of the Red Rock Canyon area in the absence of old quartzite cobbles.[1] This fact alone does not preclude

[1]Hookway, L.C., In conversation with the writer.

the possibility of the conglomerate being the basal member of the series, inasmuch as the original source of the basal conglomerate in this area may have been a granitic complex, rather than older metamorphic rocks. The basal member of the Rosamond series, in the type section near Rosamond, is also a granitic breccia(conglomerate).[2]

[2]Baker, C.L., Notes on the later Cenezoic history of the Mohave Desert region in Southern California. Pub.- University of California, Vol.6-No.15, 1911.

Overlying the basal conglomerate, but conformable with it, is the Ricardo sandstone series. This sandstone is fairly well indurated, light-gray to buff on weathered surfaces, with an arkosic matrix composed of fresh, slightly altered, minerals. Since the sandstone as a whole is less resistant to weathering than the intercalated conglomerates, it tends to weather out into trough-like, strike valleys. Particles are sub-angular to well rounded. Wind attrition has locally weathered out cavities and honey-comb caverns in the less resistant members.

Since time in mapping was limited, and since the broader features of the area were the ones necessary to emphasize, no attempt was made to map the conglomerate members separately from the sandstone members.

The occurrence of Ricardo conglomerate east of the granite core of the range,is limited to a thin red bed underlying the tuff-breccia member near Blue Point.The conglomerate is here characterized by the fact that it lies directly over the granite,but unconformable with it. The particles represent the remains of coarse phaneric rocks,angular to sub-angular in shape,and generally much smaller than the particles in any other conglomerate member. The conglomerate is here stained brick-red by the overlying basalt series.

Total thickness of Ricardo sandstone and conglomerate exposed within the area is about 4300 feet.

Since the beds yielded no fossils,other evidence for age determination had to be sought.The sediments can,however be traced directly into the type section of the Ricardo at Ricardo.On the basis of fossil criteria,Merriam and Buwalda[1] have determined the age of these beds as being lower Pliocene,correlative with the Rattlesnake of Oregon.

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[1] Merriam,John C.,Tertiary mammalian faunas of the Mohave Desert.Pub.University of California,Vol.11-No.5,1919.

Lithologicaly,these beds are also comparable to the Ricardo beds of the Red Rock Canyon area.

In order to account for the thickness of these beds,as well as the freshness of the contained particles,it is necessary to postulate the presence of an uplifting mountain mass not far from the sight of deposition during the time of deposition of the beds.

It seems plausable to suppose that this highland region was ~~North~~ South of Red Rock Canyon on the basis of the following facts:(1)The most southerly exposures of the basal conglomerate in the vicinity of Jawbone canyon are characterized by the fact that the particles are chiefly granitic,and are angular to sub-angular.Increase of older rock fragments with greater rounding is apparent as one goes Northward in the series.(2)No ash beds are interculated with Ricardo sediments in the Eastern part of the Jawbone Canyon area to any great extent,but are quite common in the vicinity of Red Rock Canyon.Since ash is lighter than the sandstone and conglomerate particles of the sediments,it would be carried further into the depositional basin than heavier particles.(3)Playa deposits and fresh water minerals occur in the Red Rock Canyon area.[1]

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[1] Baker,C.H.,see previous citation,before.

Climatic conditions during deposition of the series must have been similar to the climatic conditions now prevailing.This is established on the basis of the Ricardo fauna,which closely resemles the present day fauna,and by the fact that the minerals of the Ricardo beds are but slightly altered by weathering.

RICARDO TUFF-BRECCIA

The best exposure of the Ricardo tuff-breccia series is at Blue Point, about four miles above the mouth of Jawbone Canyon.

These beds are conformable with the underlying Ricardo conglomerate, and separated from it by a thin bed of white, rhyolitic ash. On both fresh and weathered surfaces the material is some shade of green, usually bluish. It is very fine grained and well indurated and hard. It's light color is suggestive of high acid content. Particles contained within it are angular, and are for most part, composed of volcanic lapilli; basalt, rhyolite, rhyolitic pumice, and an occasional pebble of angular granite.

Weathering has produced a very pronounced system of jointing within the member which tends to cause it to weather out into a system of blocks. Fresh faces are frequently dendritic. As far as could be determined, bedding is crude or absent, suggestive of aelian deposition. Thickness exposed; 1822 feet.

This member, being very resistant tends to weather out boldly, giving rise to cuestas and bold hog-back topographic forms.

RICARDO AGGLOMERATE

The lithologic characters of this member distinguish it in such a manner that it might very well be called a breccia. The evidences for calling it an agglomerate are listed on the next page.

PLATE V

Looking West in the direction of Blue Point. The beds have been tilted rather sharply to the West, and the illustration shows their upturned edges. The granite is here overlain unconformably by reddish Ricardo conglomerate. Above the conglomerate in succession are white ash, greenish tuff-breccia, and a basaltic cap.

Evidences for calling this member an agglomerate:

1-Fragments are essentially granites with lessor amounts of basalt.

2-Particles are always angular.

3-Always in contact with,and conformable with Ricardo volcanics.

4-In places interculated between tuff-breccia.

5-Smaller basalt flows,Ricardo in age,are interculated with it.In these cases,it shows baking locally.

6-Beds of uniform hardness and composition,with a crude suggestion of bedding.Dips are discordant.

7-Matrix possibly volcanic ash and dust.

8-Volcanic bombs are frequently present.

The rock is rudely stratified,with an adjudged dip of about 24° to the South.Dominant color on both fresh and weathered surfaces,pale red to cream.Particles almost entirely of angular blocks of granite with an occasional volcanic bomb. Weathers conchoidaly and spalls off,leaving pits and depressions.Differs from a true conglomerate in that it contains no truely rounded pebbles.Best exposure on old Kern River road,north-west of Blue Point.Thickness exposed,about 2000 feet.

JAWBONE BASALTS

Directly across Jawbone Canyon and due South of Blue Point,the downcutting of the canyon has dissected the tilted Jawbone Basalt series.This series is composed of several different flows,one above another,and separated only by a thin flow breccia,or mantle of ash.The average dip in the basalts is about 32^{O} to the South.

Lithologically, the basalt series is characterized by the richness of the basalts in Olivene content. This mineral occurs in such large amounts within the lavas, that it frequently forms green crustifying masses on the surface. The normal result of this phenomenon is to give the basalts a superficial green color which is accentuated on fresh surfaces. Weathered surfaces are usually some shade of brown. Another lithologic feature is the presence of lathe-like phenacrysts of plagioclase, which, if it were not for the aphanitic texture of the rock, would tend to throw it into the class of the diabases. Particles of pumice are also present in the basalt. Superficial slipping between flows, has in places given rise to slickensided surfaces.

These basalts differ from the interbedded basalt flows of the Ricardo in the Red Rock Canyon area in texture, Olivene content, color, stratigraphic position, and thickness.

They overlie the Ricardo tuff-breccia with a pronounced angular non-conformity, and since they are in turn covered with old Quaternary alluvium which is assumed to be Pleistocene in age, the age of the basalts is fixed in the stratigraphic column as being younger than the lower-Pliocene and older than the Pleistocene, an age comparable with either lower Peistocene, or middle or upper Pliocene.

Thickness of the Jawbone basalts exposed is about 2000'.

SIERRAN DEBRIS SLOPES
(OLD QUATERNARY ALLUVIUM)

Sloping gently off of the higher mountain slopes, is a relatively thin,homogenous,mantle of granitic debris.This material resembles certain facies of the Ricardo conglomerate so closely,that it is at times exceedingly difficult to distinguish the two.This old alluvium represents an important and general recent geological process that is at the present time taking place,it represents the denudation of the higher mountain slopes and the complementary alluviation of the lower slopes and the basin areas between the ranges.[1]

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[1] Baker,C.L.,see citation before.

In the area of Jawbone Canyon,the particles which make up the old quaternary alluvium are almost entirely composed of angular granite particles.The material is unconsolidated, and thins out on the fan borders.Ferro-magnesian minerals are fresh and unaltered.Surface dip is slight and uniform, except near the base of the hills,where it appreciably increases.

The best exposure of the Sierran debris is shown on the North wall of the Punchbowl,where it is slightly over fifty feet thick in the thickest part.

STRUCTURE

FAULTING

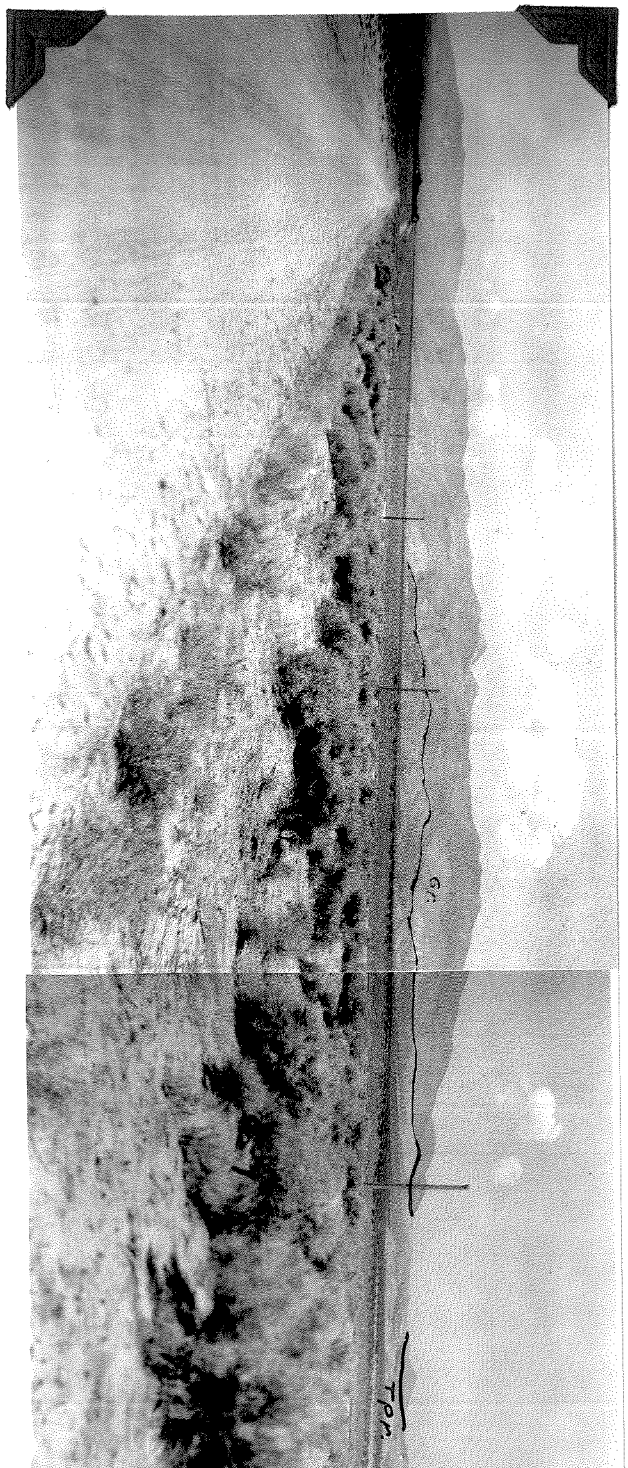
The Tehachapi Mountains in the vicinity of Jawbone Canyon are highly interesting from the standpoint of structural geology. The region in the Southern part, clearly exemplifies the action of great metamorphic agencies. Faulting is developed to a very great extent, and is illustrated strikingly by several great faults, most of them unique because of the fact that movement is evidently taking place along them at the present time. ~~Most of~~ the movements along the faults of the area are vertical.

The largest, and perhaps the most sriking fault of the area is the Cameron Fault which separates the great Tehachapi mountain block from the Mojave Basin. The Cameron Fault strikes about N 50^{O}E along the Eastern boundary of the mountain block until it comes to Painted Canyon (Red Hills), where it suddenly turns and strikes about N15^{O}W until it runs into the Jawbone Fault, about one mile above the mouth of Jawbone Canyon.

It is exceedingly difficult to obtain accurate data as to the attitude of the fault plane within the area. It has a clear topographic expression along the Eastern range front where it cuts off spurs, and, to a certain extent, displaces fans which run into the desert. Recent alluvium cut off by this fault is in places consolidated, and shows a dip (grade) near the base of the range of about 5^{O}, or an

PLATE VI

Panorama of Tehachapi range front.
Looking due South from the town of Cantil.
The region in the very left-hand background is the region of the old Paleozoic rocks. Middle background shows the granitic basement. Ricardo sandstones and conglomerates in right background.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increase of almost 3^{0} over the normal topographic dip further out on the debris slopes.This steepening of topographic dip near the base of the range is evidently caused by drag,and clearly indicates that the mountain block to the West is rising with reference to the Mojave basin.

As a rule,the intersection of the fault plane with the canyons is obscured,but in a few clearly recognizable instances,one point on the plane was observed on the floor of the canyons with two points well up on spur-flanks further down the canyon.If this is indeed the case,then it would appear as though the fault plane dipped steeply to the West.Since the mountain block is topographicaly higher,it would appear as though the Cameron Fault was a reverse fault.

The Ricardo sediments just North of Painted Canyon dip about 25^{0} to the West directly into the Cameron Fault; they do not show any evidence of drag in this region.

Since it is impossible to correlate Ricardo beds West of the Los Angeles Aqueduct with those East of it,no accurate computations of vertical displacement-component along the Cameron Fault can be made.However,it is obvious from the difference in elevation between the summit of the East front and the Mojave Desert,that vertical displacement along this fault must amount to at least 3000 feet.Of course a great deal of the uplifted mass has been swept away by erosion and deposited in the lower basin,so that

PLATE VI I

Looking due West up Painted Canyon. Ricardo volcanics in immediate background. Trace of Cameron fault shown in India ink.

the true figure of vertical displacement would amount to considerably more than the above figure.

That movement is still taking place along the Cameron Fault is attested by the fact that brecciated fault saddles have not as yet been deeply eroded, discordant fans have only a thin veneer of debris covering the trace of the fault, and the East scarp is only slightly eroded.

In order to explain the presence of a thrust fault with relatively great displacement on the East front, with normal faults in the same block further to the West, it appears necessary to postulate the existence of compressive forces coupled with other stresses acting in a generally Eastern direction. That this view is in accordance with other evidence, will later in this section be demonstrated.

About one quarter of a mile below the point where the Cameron fault intersects the Jawbone fault, another fault runs into the canyon from the North. In a general way, this fault trends about N 10° W, and marks the boundary of the Ricardo sediments with the granite. The best exposures of the fault plane are in the Northern part of the Punchbowl. In this region, erosion has stripped away a good part of the fault breccia and exposed the slickensided fault plane itself. The dip of the plane is about 78°_{E}.

In attempting to make an estimate as to the amount

PLATE VIII

Structure in Jawbone Basalt series unconformably overlying Ricardo tuff-breccia. Dip surface of Jawbone basalt in background.

Looking West from the picture above. No-Name Mountain in the background, Cross Mountain in right background.

of vertical displacement due to the Punchbowl Fault, much the same difficulties are encountered as are present in attempting to postulate the amount of vertical displacement along the Cameron Fault. It is practicaly impossible to correlate the Ricardo beds in the Eastern and Western parts of the area, but from topographic considerations, displacement along the vertical component of the Punchbowl Fault is somewhat less than along the vartical component of the Cameron Fault.

North of the Punchbowl, the Punchbowl Fault disappears beneath the mantle of Sierran debris, and, so far as can be determined, the mantle shows none of the evidences of recent movement. If this is the case, then the last movement along the Punchbowl Fault must have occured during a time antedating the Peistocene, if the Sierran debris is assumed to be Peistocene in age. Since this fault appears to be due to East-West tension, a different set of forces or controlling factors must exist North of Jawbone Canyon in order to account for the differences in applied stresses on each side of the canyon. At any rate, the alluvial mantle bears evidence to a time interval between the applications of orogenic forces on each side of Jawbone Canyon; the boundary being the Jawbone Fault.

Just West of Blue Point the structure becomes considerably more complicated. Within the radius of a mile, the Jawbone Fault is intersected by two other normal faults. The most Westerly, the MacDonald Fault, trends almost due

North and South. The topography adjacent to this fracture is very strikingly affected by recent uplift. Stream valleys have extraordinary grades, abnormally increasing towards the head. The brecciated zone of the MacDonald Fault is deeply eroded and worn into gullies by run-off from the slopes above. This rather striking characteristic is preserved even in the granite where it is intersected by the fault plane. These facts, coupled with the presence of freshly slickensided surfaces on the Western block, point clearly to very recent uplift.

The dip of this fault plane is about 85° to the East.

Almost due South of this fracture, on the other side of the canyon, is located the Cross-Mountain Fault which trends in this region about N 30° E, with a dip of 44° to the East. The Jawbone Basalts with the underlying Ricardo, have been dropped down along the fault until the granite-basalt contact is rudely parallel to the dip of the basalts. In places along the trace of the fault, the granite is left projecting into the air in the form of hog-backs. The surfaces in such cases are remarkably fresh and highly polished by the last movement. Spurs sliced by the fault exhibit perfect kern-cols. In some of the spur saddles, the zone of bresciation is cut by later acidic pipes of lava.

Refer to structure-section B-B' (in pocket). In order to account for the present attitude of the displaced beds, it is necessary to postulate the following movements: Gradual uplift of the region as a whole. This is demonstrated by the youthful topography. (2)Relative retardation of the Western portion of block number four. This assumption would fit the idea of movement in its Eastern portion. (3)Blocks 1 and 3 being uplifted faster than block 2. This assumption must be made in order to account for upward movement in block 3 as a whole, and the Eastern face of block 1. (4)Uplift in block 2 slower than in blocks 1 and 3, but faster than in block 4. This would account for the Jawbone fault as being vertical and the MacDonald fault as being normal. Likewise, this would account for the presence of stream gravels high up on the walls of Jawbone Canyon.

The relative displacement between the MacDonald Fault and the Cross Mountain Fault would then amount to some three hundred feet.

MISCELANEOUS STRUCTURES

Unconformities between the Ricardo and the granites on the one hand, and between the Ricardo and the Basalts on the other, are best shown on the Southern portion of Jawbone Canyon in the vicinity of Blue Point.

That the Ricardo-granite contact is an unconformity rather than an intrusive contact, is shown by the fact that baking and metamorphosing of Ricardo conglomerate near the granites is missing. Likewise, the surface of deposition points to a time interval betwwen intrusion and deposition of no mean magnitude.

The Jawbone Basalts are non-conformable with the Ricardo, with an angular descrepancy of several degrees. Also, the Ricardo conglomerate in the Western part of the area is baked and highly stained by the later basaltic extrusion.

The older Paleozoics exposed in the vicinity of S.B. Canyon are interesting from a structural standpoint in that they clearly exemplify flow-cleavage due to intrusion. The flow cleavage planes lie roughly parallel to the boundary of the intruded granite, thus showing that they are normal to the force which was applied during the intrusion.

HISTORY

The geologic history of the region may be briefly summarized as follows:

1-Deposition of limestones overlain by fine sandstones and thin conglomerate beds in shallow marine seas during Paleozoic times.Climate warm and equable.

2-Subsequent uplift,followed by a long period of erosion,possibly peneplanation. Metamorphism of Paleozoics.

3-Intrusion of the great bathylithic granitic core of the present Tehachapi Mountains,probably accompanied by orogenic and tectonic movements.

4-Post-granite erosion and peneplanation.

5-Deposition of Ricardo Pliocene terrestrial sandstones, conglomerates,and fanglomerates,accompanied by volcanic activity in later history.Climate as at present.

6-Tilting and faulting of Ricardo beds accompanied by strong orogenic movements.Continuing to the present.

7-Post-Ricardo erosion for a relatively long period.

8-Extrusion of Jawbone Basalts in Upper-Pliocene(?) time,accompanied,or followed shortly after by mountain making movements.

9-Erosion,followed by deposition of granitic piedmont alluvial mantles from Pleistocene to Recent.

10-Present period of uplift and accompanying erosion.

ECONOMIC GEOLOGY

METALLIFEROUS DEPOSITS

Most of the metalliferous deposits within the area studied are located in the Southern half,usually fairly close to the region through which the Cameron Fault passes.

Two general types of deposits may be differentiated; those which lie within the borders of the Paleozoic marble, or very close to its contact with the granitic bathylith, and those which are formed within the later acidic extrusive rocks.

The minerals which occur within the borders of the marble are characterized by the fact that they are"bunchy," and,where not related to fractures,they do not appear to be continous,nor to occur with any periodic regularity.The richest parts of the deposits are located near the marble-granite contact.Since very little development work has been carried on at depth within the marble,it was impossible to examine the deposits with any great degree of precision.

Characteristic metamorphic minerals are lacking,or at least were not observed in the marble deposits.Certain zones within the marble are characterized by richness of the ore, while another part of the deposit,removed from the first by only a few feet,may be extraordinarily lean.

Horses,and particles of the wall rock,as well as psuedomorphs,or other criteria for the identification of metasomatic deposits were not observed.

Characteristic minerals observed within the marble are Galena, Calcite, Chalcanthite, Malachite.

Practically all of the development work carried on in the exploration of the marble, is located in S.B. Canyon, and consists, for most part of several drifts run into the black marble in the direction of the granite contact. Work is being carried on with perseverance, although more or less intermittently. The longest drift is being driven in the direction of the contact along a minor thrust fault by Mr. Jack Tardey and associates of Long Beach California. Explorations within the marble, have to date failed to reveal a worthwhile ore-body.

The deposits which occur within the area of the later extrusive rocks are more widespread in occurrence, and in general have been more concientiously prospected. The largest deposits are located within the confines of the old Cinco Mining District, for most part within the basement complex due East of the old town of Cinco. Work has been carried on sporadically for the past twenty years within this district.

The ore is characterized by the fact that it occurs more or less in fissures developed within acidic dykes. Veins, as a rule, are small, and vary in size from stringers to several inches in width. The minerals are chiefly those characteristic of primary deposits, Galena, Pyrite, Quartz, etc. Cap rocks frequently show oxidation of the pyrite to Limonite; vugs and honey-comb structure are characteristic. The ore where found, is usually of good grade, and rather rich in Lead, and sometimes Copper; Gold and Silver are usually present only in small amounts. The chief defect in these deposits is the fact that the fissures are of small dimensions, and do not persist with depth.

NON-METALLIFEROUS DEPOSITS

Activities in the non-metallic field within the region under discussion are mainly confined to the mining of products of volcanic action.

The greenish Ricardo tuff-breccia has found some favor as a stucco dash in the manufacture of patent stucco finishes. The chief users to date have been the Kellastone Company of California, although mining operations in this material are now suspended.

An immense tonnage is exposed in the vicinity of Blue Point, and owing to jointing within the tuff-breccia, mining methods have been simple and easy. The method of mining used, has been to "rock" the jointed rock with charges of powder, and then to pry the material thus loosened, out with pinchbars. The broken material was allowed to roll down a chute into a loading bin, and from there, trucked to the Owenyo Branch of the Southern Pacifac Railroad.

Within the last few months, the Cudahy Company has taken over a large deposit of volcanic ash about eight miles from the mouth of Jawbone canyon. The material occurs in a rather tabular body, and well up on the slope of a steep hill. Development work is rapidly progressing.

PLATE IX

Quarry and loading bin of tuff-breccia mine at Blue Point. Quarrying is very greatly facilitated by jointing in the material. The darker beds are more resistant material which is not as highly colored.

The area of Painted Canyon is marked by a large deposit of volcanic ash, locally overlain by Ricardo lavas. The ash has been superficially altered to impure Bentonite. Mill tests upon the material have shown it to be applicable in the manufacture of brick and terra-cotta ware. Quite a large tonnage has been shipped to a brick company in Fresno. The deposit occurs upon the homestead of Mr. Lowell Wert, Cantil, California.

Some fairly large veins of milky quartz are found along the Kelso Valley road, almost at the boundary of the area investigated. With more favorable freight rates in the future, it is possible that this material would stand shipment to Los Angeles.