GEOLOGY OF THE SOUTHWESTERN PART OF THE EL PASO MOUNTAINS IN THE REGION OF RED ROCK CANYON MOJAVE DESERT.

by

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INTRODUCTION.

The area described in this report includes the extreme south western portion of the El Paso range ~~which~~ it lies in the northern part of the Mojave desert and ~~takes in~~ comprises the area in and about Red Rock Canyon. The purpose of this report is to ~~show~~ treat the areal geology and structural relations existing. Those engaged in this work were L.C. Hookway, Alex Clark and the writer. Regular trips were made to the field during the academic year of 1927 - 1928. Altogether about two months were spent in the study field.

Previous Investigation.

Investigation in this region was first carried on in 1875 when G.K. Gilbert described the deposits of Red Rock Canyon in The Geographical & Geological Explorations West of the 100th Meridian. The next geologist to visit and describe the sediments here was H.W. Fairbanks. His results appear in Notes on the geology of eastern California, Am. Geol., vol. 17, pp 67 & 68, 1896 Then In 1911 C.L. Baker conducted a reconnaissance for the Dept. of Paleontology of the University of California under the general direction of J. C. Merriam. The results of his work appear in the University of California Bulletin, dept. of Geol. vol. 6, p 354 and vol. 7, pp 117 - 142, 1912.

Geography & Climate.

Red Rock Canyon is situated about 30 miles northeast of the town of Mojave in the El Paso Mountains. These mountains trend about N65E and they extend for about twenty miles in this direction. They are the widest at their eastern extremity, about six

Sierra Nevada is already plural

Mature means very rugged, not subdued.

miles, and narrowest at Red Rock Canyon where they are it is scarcely a mile wide. The highest peak is Black Mt. in the center of the range which is over 5200 ft. high. They represent a subdued topography in rather a mature stage of dissection.

"mature" cannot and be compared or modified except by early, mid, or late

The foothills of the Sierra Nevadas lie to the north of the El Pasos Range and are separated from them by a gentle debris slope. This plain slopes to the south and is much gentler than the southern slope of the range which drops off rather steeply into Kane dry lake basin. This basin is bounded on the south by the western part extent of the Rand mountains. The western portion of the El Pasos rises to somewhat over a thousand feet above this basin. The south base of the range is rather straight as compared with the northern boundry which is very irregular.

repetition

The range is cut by two narrow canyons in the western part which are at right angles to the main axis of the range.. These two canyons are Red Rock, which lies at the extreme western end, and Last Chance Gulch about four miles east of Red Rock. Just north of the main crest of the range are several strike or subsequent canyons. The largest of these is Iron Gulch which runs along the contact between the basement and the sediments. These tributaries have excavated rather large flat basins in their lower parts where they join the upper end of Red Rock canyon.

Due to the arid climate which exists in this region there is seldom water, seldom flows in these washes. There are several springs occur but their flow is not sufficient to produce a running stream. The region is subjected to cloud bursts in certain seasons and this coupled with the fact that the soil forming agencies are very much subdued serves to keep the rock surfaces washed bare. The area is

characterized by steep cliffs with less steep back slopes and talus slopes. The vegetation is very sparce except around a few water holes and consists mostly of clumps of desert sage and cactus.

Field Work.

This region has previously been mapped by the U.S.G.S. and appears on the Searles Lake Quadrangle but with a scale of four miles to the inch and a contour interval of 100 ft. This was much too small to show the geology on and it could not be sufficiently enlarged without making it impossible to locate points accurately, so it was decided to make a new map. A scale of 2000 ft. to the inch and a contour interval of 25 ft was chosen as the most suitable for this work. The instruments used for this work were a small 18 by 24 inch plane table and a small fifteen power K. & E. alidade. Two collapsable Lietz twelve foot rods were also included in the equipment. Since there were no existing control points in the area a base line had to be determined. This was done by using a three mile tangent of t the Southern Pacific Railroad which ran along the base of the El Pasos on the south side. A profile of the tangent was obtained thru the courtesy of the Railroad and the bearing taken from that. The mile posts along the railroad were used as monuments. To determine the magnetic declination the plane table was set up on the tangent and oriented by back sight along the rail. Then a point was located in line with the rail and off the track beyond the curve about a quarter of a mile. The table was then set up at this point and the declination taken with the needle. For the vertical control a bench mark one mile north of the town of Cantil was used. In order to get accurate elevations along the

base line a line of levels was run from the bench mark to the tangent a distance of about six miles. From this base line a series of monuments were set along the crest of the range. In all subsequent setups while doing topography the plane table was oriented by the needle. The method of intersection was found to be very useful in determining the location of high peaks thus saving the effor of climbing them. However, in a good deal of the topographic work it was found that the rod served the best especially in determining points of break in slope, points of curvature, etc. The map submitted in this report is an enlargment of the field copy. It represents a scale of 1000 ft. to the inch. It was thought best to do this so that the geological relations would show up better.

This was done
be better shown.

Acknowledgments.

turning Englishman?

The writer whishes to express here is sincere appreciation and thanks to Dr. J.P. Buwalda for his valuable cooperation and suggestions on many occassions, to the Carnegie Institute of Washington for transportation facilities, and to Prof. W. W. Michael, professor of Civil Engineering, for the generous loan of equipment on several occassions. In addition I wish to thank Mr. Hill who kindly permitted us to use his cabin during our stay in the region.

STRATIGRAPHY.

The rocks in this area may be divided into three classes, the basement complex consisting of a metamorphic series, the Ricardo land laid sediments of lower pliocene age and Quaternary and Recent Alluvium. The basement complex is exposed along the southern part of the range and forms the main ridge. To the north of this lies the Ricardo which extends almost to the foothills of the Sierras where it is covered up by debris slope of alluvium which has come off of these scarps. In the region immediately north of the basement the strike canyons have cut down deeply revealing excellent exposures of the Ricardo in strike ridges and precipitious cliffs. The Riacrdo series is also found south of the basement but the exposures are not very extensive. In addition, Pleistocene and Recent caps are to be found in many places scattered thruout the area.

BASEMENT COMPLEX.

The oldest rocks that are to be found in the basement consist of quartzites and quartzite conglomerates and have been considered as Paleozoic in age. Subsequent to the deposition of these Paleozoics they were intruded by a mass of hornblend diorite porphyry. Overlying these paleozoics is a series of meta-rhyolite intercalated with old conglomerates and sandstones. The relation of these rocks to the Paleozoics is not clear but it may be safely assumed that they are younger and probably represent a stage of the Mesozoic and for all purposes considered in this report they will be regarded as such. repetition

About two and a half miles east of Red Rock Canyon and in the vicinity of Senic Canyon a totally different basement complex is

encountered. Here there is a large mass of granite which contains large phenocrysts of biotite. It extends from this point eastward and is exposed over a very large area. Since it was outside of the area mapped it will not be discussed further in this report.

Quartzites & Quartzite Conglomerate.

The Quartzites were found exposed in one place just north of Sta. F. They are of dark grey to black in color streaked with white. The quartzite conglomerate is exposed extensively on the crest and on the south flank near Sta 1 N. The rock has a dark green matrix with white pebbles which have been drawn out thru metamorphism. The pebbles are all rather small, less than an inch in diameter, and are well rounded. The matrix was probably a sand with a fairly high content of ferromagnesium minerals which would account for the dark green color. It weathers to a dark reddish brown which would seem to indicate that there was some iron oxide present.

Hornblend Diorite Porphyry.

The Paleozoics are intruded by a large mass of hornblend diorite porphyry with apophyses branching out from the main mass The ground mass of the rock is aphanitic in appearance and dark grey in color. The phenocrysts are long narrow crystals of dark green hornblend attaining in some instances more than a half an inch in length. In addition there are also some greyish phenocrysts of feldspar which have been determined as plagioclase.

Metarhyolite.

Over-lying the Paleozoics and intimately associated with the old conglomerates and sandstones is an altered intrusive rhyolite.

Altho the relations in the basement are very obscure due to crushing and weathering it seems logical to assume that the rhyolite is intercalated with the old sandstones and conglomerates. The matrix is a pale cream color and is highly silicified but phenocrysts of feldspar and orthoclase are still to be recognized. It weathers to a reddish brown.

Old Conglomerates & Sandstones.

Exposures of these sediments are to be found at the mouth of Iron Gulch and along the walls of Red Rock Canyon. The conglomerate has a buff colored matrix rather highly silicified so that it is practically impossible to determine the constituents. The pebbles are small, about a half an inch, indistinct wellrrounded and consist of some basic igneous rock. It is of interest to note that in this conglomerate the rock always breaks around the pebbles while in the quartzite conglomerate the rock breaks across the pebbles.

The old sandstone was found only in one locality at the end of a low ridge of basement lying across the mouth of Iron Gulch. It is dark greenishiin color and contains considerable or much a lot of micaeous material and is much less resistant than the conglomerate.

Basalt Dike.

A short distance up Bonanza Gulch a basalt dike is found cutting thrutthe basement. It is very nearly vertical and strikes in approximately a north south direction. Another outcrop of this dike is to beeseen on top of a hill justnnorth of this point. It is black in color and is very dense and aphanitic.

It weathers to a dark brown on the surface. That this is an intrusive dike and not a tilted flow is seen by the massive character and lack of vesicular structure, In one part of the dike several small veins of milky quartz were found cutting it.

RICARDO FORMATION.

The Ricardo sediments are playa lake and fanglomerate deposits. Their ~~of~~ lower Pliocene age is indicated by the large vertebrate assemblage collected from them during the past few years. They extend from Iron Gulch north to the foothills of the Sierra and westward into Jawbone Canyon where they are cut off by a fault running in a north south direction along the base of the mountains. They have a general north dip which diminishes in a northerly direction from about 20° near the basement contact to about 6° near the top of the section. The strike of the beds changes gradually from about N35°E to N10°W as the beds curve around the end of the range. They are also exposed on the south side of the basement where they dip into the basement and flatten out to the south.

The Ricardo has been divided into two parts, the Lower and the Upper. The Lower comprises including all those beds from the basement up to and including the lower lava, the Upper includes the remainder of the section. The reason for this division will be taken up later. The minimum thickness of the series as determined by a traverse run northwest from Ricardo is 4765 feet. The Lower Ricardo has a thickness of 1800 ft. along the section line A-A (Plate I). See also PLATE II for a general section of the Ricardo Series.

PLATE II

This shows a typical section of the series looking across the strike. In the foreground is the basement, in the middle distance the Lower Ricardo and the Lavas, above this the Upper Ricardo and on the skyline appear the snow capped Sierras. Red Rock Canyon cuts thru the basement at the lower left.

Basal Conglomerate.

The Basal Conglomerate of the Ricardo is exposed about a quarter of a mile east of Hills cabin where it lies up against the Metarhyolite of the basement. A few other isolated patches of the conglomerate are exposed along the south wall of Iron Gulch. The irregularity of these patches indicates a very irregular surface of deposition. The dip is about 20° to the north and the thickness varies from zero to a hundred feet.

The Matrix is medium grained with angular fragments of stained quartz. It is greenish gray to red according to the amount of oxidation of the iron in the cement. The small pebbles are angular but the large boulders are rounded and consist for the most part of dark grey to black quartzite. In addition there are a large number of coarse grained granite boulders which show a large amount of quartz stained red by iron.

Further west the typical basal conglomerate grades into a conglomeratic sandstone of a greenish greenish gray color. The pebbles are subangular to rounded and consist for the most part of basalt and andesite with some ash. They range in size from about a quarter of an inch to six or eight inches in diameter. The matrix is medium grained and is composed of angular pieces of quartz and feldspar cemented with a fine argillaceous material.

Ash & Breccia.

Conformably overlying this basal conglomerate is a bed of ash about 25 ft. thick. It is very fine and grey to white in color.and is nearly pure except for a few pebbles are scattered thru it. This ash overlaps the basal conglomerate to the east and

lies directly on the basement. Here it has been altered to an impure bentonite.

Next in sequence above the ash is a reddish brown breccia from fifty to seventy-five feet thick. At first sight it resembles ~~looks like~~ a lava flow but on closer inspection it may be seen to be composed of angular fragments of lava well cemented with a fine grained matrix of the same color.

To the East of here and in the vicinity of Last Chance Canyon this ash and breccia is very extensive and overlies a pink tuff which is very similar to that found in Red Rock Canyon but is much lower stratigraphically.

Lower Ricardo Sandstones.

Excellent exposures of the sandstone series may be seen in the upper part of Red Rock Canyon and in Iron Gulch where they form precipitious cliffs two and three hundred feet high. The series is rather massive in appearance but some of the layers are more resistant and form ledges. This series consists mostly of arkosic sandstones with angular to subangular particles. Feldspar predominates then quartz and biotite which seems to be rather fresh. The massive beds are a grey color and contain quite a lot of clayey material. Then there are thin nearly white beds that have a high content of ash. The resistant ledges are composed of coarser material including some lava and andesite and are of a brick red color. This coloration is not uniform, as in some places it occurs as streaks. This is probably due to some change in the conditions of deposition such as an increased rate of oxidation of the iron and could hardly be due to a subsequent deposition of coloring material.

not good image

As one travels east along the strike of the beds in the direction of Last Chance Canyon the beds gradually become more and more ashy until in Last Chance Canyon the predominating constituent is ash. The texture also becomes finer. There are about 600 feet of this sandstone series above the breccia and then there is a bed of tuffaceous material. This is about seventy-five feet thick. Above this the sandstone again continues for about 650 feet and is similar to the same as that below the tuff bed.

Massive Pink Tuff.

One of the most striking features of the region is the pink tuff bed which caps the sandstone cliffs along the strike ridges. The matrix of this rock is a pink tuff and contains inbedded in it angular pieces of white ash, andesite and basalt. They vary in size from very small particles up to an inch or more in cross section. The color is in general pink but in some places it is a brick red and in others it has faded nearly white. The dip slopes in some places show cracks which have a pattern similar to mud cracks. It tends to weather in rounded forms.

Basalt Flows.

There are two separate and distinct lava flows separated by an ashy sandstone 175 ft. in thickness. This interval varies somewhat; in the western end of the range it is around about 50 ft. while over towards near Last Chance Gulch they almost join each other and then disappear.

The first flow has an average thickness of about 55 ft. altho it thikcens considerably in a canyon directly north of Hills cabin. Here it has a possess columnar structure and is from 75 to 100 ft. thick. It is very vesicular and the vesicles are

filled with quartz, chalcedony, opal and some calcite. A little farther east along the strike there is quite a bit of scoria on the bottom of the flow. The rock is quite black and weathers to a reddish brown. It is aphanitic in appearance. Just east of the highway in the vicinity of Ricardo the first flow is missing for a short distance. On the west side of the road it again appears, and continues for a short distance, and then abruptly ends and is seen no more altho the upper flow continues on.

The upper flow is somewhat the same as the lower in composition but is much thicker, around 100 ft. It has, however, at the bottom a very vesicular bed which contains a great deal of calcite. It may be that this represents a separate flow. There is reason to believe that there has been four separate flows in this series altho the time between them was so short that there was no soil developed. This series is continuous, that is, it may be traced along the strike with no intervals where it is missing.

Upper Ricardo

The beds above the lava flows were all mapped as one unit because they are all very much the same in composition. The ashy bed between the two basalt flows is included with this. It is a grey massive sandstone containing a high percentage of ash which increases as one proceeds along the strike to the east.

The beds just above the basalt are very similar to those below except that they are more arkosic, and contain some cherty layers and some resistant sandstone reefs. It was not easy to determine the top of the section on account of the thick mantle of alluvium

of alluvium. However, the dip is here very small so that it would not make very much difference if this were not quite the top of the section. The thickness as determined by a traverse was about 2600 ft. The sand stone reefs appear rather high up in the section and are composed of hard arkosic conglomeratic sandstones. They consist mostly of angular to subangular particles of feldspar, quartz and lava . About two miles northwest of Ricardo there is a distinct color change from brown to light grey. The brown beds are somewhat more indurated than the grey ones. The contact dips to the north at a small angle. The dip appears to be the same in both beds altho the areal relations suggest an unconformity.

QUATERNARY & RECENT ALLUVIUM.

. The quaternary older alluvium occurs as small caps resting on the Ricardo. These caps are scattered around in various places and lie at different levels. They are a yelloish brown massive beds and contain a variegated mixture of feldspar, lava, felsite, quartzite, cherts, etc. For the most part they rest unconformably on the Ricardo except in one instance in the vicinity of Bonanza Gulch where it is found lying on the basement.

The Recent alluvium is represented by the material brought down by the washes and deposited in their basins in Iron Gulch and Red Rock Canyon. It is unconsolidated and of a sandy nature and contains a heterogenous mixture of pebbles and boulders.

STRUCTURE.

The structural relations in this region have been brought about in the main part by faulting altho folding has taken also occurred place to some extent too. The El Paso Range presents on their south flank a remarkably straight base line from which the slopes rise up steeply. This is in direct contrast to their northern boundry which is irregular and has less steep slopes. The south face is undoubtedly a fault scarp. which it has been produced thru movement on the Garlock Fault which runs along the base. Here the Ricardo sediments are found dipping northward into the basement rocks. On the north flank of the range basement the basal conglomerate of the Ricardo is found lying unconformably on the basement. They strikes N 35° E and dip 20° to the north. and Ricardo beds extend from here to the foothills of the Sierras. The dip gradually decreases from here northward till it is only about 6°. The thickness of the Ricardo represented here is 4765 . Going to the south along the strike of the beds curves around towards the basement showing a and changes from N 35° E to N 10° W. At the end of the range the sediments to the north of the fault join those on to the south and extend west to Jaw Bone Canyon where they are cut off by a north south fault. The Garlock fault dips to the south about 85° and in the vicinity of Red Rock Canyon strikes N 75° E. West of the mouth of the canyon it disappears into the Ricardo and all efforts to trace it were of no avail. It was thought that it might be traced into the Cameron fault or the Jaw Bone fault. It may be that the Garlock fault does not connect up with either of these but is a hinge fault with its fulcrum just west of the end of the range. This seems to be born out by the fact that the strike

should use 3rd or 1st person consistently throughout

of the sediments curves around the end of the range. This, to my mind, indicates a decreasing amount of vertical movement and hence a dying out of the fault. However, this same relation might be brought about thru a horizontal movement and in support of this let me state that there is another factor which cannot be wholly accounted for. It is this. On the south side of the range and about midway between Red Rock canyon and Last Chance canyon ther are two small lava knolls. Also about three quarters of a mile to the west of these there is another patch of lava and about a mile to the east there is a third patch. Now these latter two patches are different in character than the first mentioned. In general they consist of well rounded boulders of vesicular lava very similar to that found in the upper series north of the range. Intermixed with thaselava is a quantity of material from the Ricardo above the first lava flow, aalso well rounded. Hence this material might well represent detrital from the top of the range as it was being uplifted and eroded. But the first mentioned lava knolls cannot be explained in this manner. Here we have an occurrence of large angular lava boulders which are very dense in character. No other kinds of rock occured mixed in with it. Furthermore some of it appears to be looked very much like it was in place. Taking all in all it has all the appearances of a remnant of a flow. Now there are two solutions that present themselves for this problem. First, to the east of here in the vicinity of Garlock there is a lava flow apparently derived from Black mountain which comes down over the south side of the

range and which thru horizontal movement could account for this occurrence near Red Rock canyon. But this would require a horizontal movement of ten miles. The second solution which presents itself is that this is part of first lava series which is exposed north of the range and to which it is very similar especially in the region northwest of Hills cabin where it has a columnar structure (PlateVI). If this is the case it would give a clue to the vertical movement on the fault. Calculations on this basis give a net result of 5100 ft. for the vertical movement at this point. Now before going any farther let me say that there is an exposure of the Ricardo pink tuff south of the range just east of the mouth of Red Rock canyon which also permits of the calculation of the vertical movement on the fault. Here the tuff has been dragged up and is in almost a vertical position lying against the fault plane, (see Plate IX Fig. 12 and structure section B-B Plate I.) Assuming that this bed has been dragged up not more than 200 ft. calculations give a displacement of 4100 ft. This, then is direct evidence for the hypothysis first set forth that the displacement decreases to the west. Unfortunately this argument cannot be stressed too greatly because there is not sufficient evidence in support of the relations suggested for the lava knolls. In order to clearly understand the relations here more detailed work will have to be done. In regard to the displacement, however, the value of 4100 ft. may be assumed to be correct for this point because the structural relations are quite clear here.

There are no other major faults in the area but a number of

small faults exist in the Ricardo on the north side of Iron Gulch near its mouth. Fig. 14, Plate IX shows one of the largest of these; the displacement is about 55 ft. There are a number of others in this vicinity with displacements ranging down to three feet. They may be due to unequal settling or to the fact that the strike of the beds is changing most rapidly at this point. A small spring was found at the base of the largest one.

One of the most striking unconformities of the area is between the first lava flow and the Ricardo series above it. Just west of Ricardo the first lava flow is missing entirely for ashort distance, (~~see~~ Fig. 3 Plate V.) To the west of the highway the first flow again appears and continues for a short distance and then again disappears and is not seen any more altho the second flow continues on uninterfrupted. This could be explained by a period of erosion subsequent to the outpouring of the first flow. In this regard tho it seems peculiar that so much material was removed in one or two places without affecting the region as a whole. Another explanation is that the the lava flowed out into a hill and valley topography and the first flow seen in Fig. 3 is just a finger of the flow extending into a small valley existing at that time. In support of the erosion period is the fact that there is a difference in the fossil dogs between those found below the first flow and those occurring above it. In addition to this there is a petrified forest horizon in Last Chance Canyon which corresponds stratigraphically with the first flow. This would indicate a period of quiessence.

It was for these reasons that the Ricardo lying above this point was mapped as a separate unit, the Upper Ricardo.

Slumping has occured in this area in quite a few places on both large and small scales. In Iron Gulch there are two or three small ones that have occured in the Pink Tuff bed and the sandstones directly underlying it. One of the best developed ones lies directly across the Gulch and a little north of the Hills cabin. This has a topographic expression which may be readily seen on the map. In addition to these there is a large slump which starts at the extreme northern part of the map in the first lava flow and extends from here north. See Plate X Fig 15 & 16. At first it was thot that this was another lava flow below the first one. On closer examination, however it was found to be a slump on a large scale. The sequence of beds was carefully gone over in this area and the series below the top of the slump was found to be the same as that below the first flow above it. One of the best evidences for this slump is the fact that the Pink Tuff bed is abruptly cut off by it. and appears again farther down the slope. Additional evidence is that the Ricardo outcrops on the dip slope as seen in Fig. 15. Fig. 16 shows the face of this slump. It is about a mile in extent.

The Pleistocene sediments which occur in the are are very interesting in the way in which they cap the Ricardo. Fig. 8 Plate VII shows a very striking example of this.

PHYSIOGRAPHY.

This region presents some very striking topography. The main part of the range composed of the basement complex presents a very straight trend with a fault scarp on the south. It is even crested and gradually increases in altitude towards the east. To the north of this ridge lie a series of strike ridges which have been developed in the sediments. Prominent among these strike ridges are those which are capped by the Pink Tuff and the lava series. Plate II gives a rather typical section of the country. Fig. 20 Plate XII shows the back slopes of some of the strike ridges of Pink Tuff.

The range is cut transversely by two canyons, Last Chance and Red Rock, and the relative straightness of their courses would seem to indicate that they were antecedent to the uplift of the range. The walls of these canyons are very steep and in Red Rock Canyon the stream has cut down about 800 ft. Last Chance Canyon is much narrower and more tortous and has cut down thru a greater depth than Red Rock. North of the basement the streams are for the most part parallel to the strike ridges. There are exceptions to this tho. For instane there is a stream just back of the first lava flow which flows parallel to the strike for a distance and then with apparently no reason whatever it turns and cuts directly across the lava ridge; then it follows along the strike back of the Pink Tuff ridge for a way and then again turns abruptly

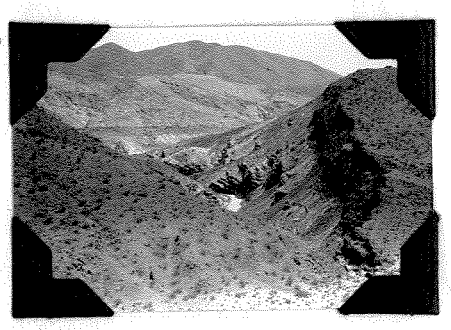


Fig. 22

Ref to figure 22

and cuts across the tuff ridge and empties into Iron Gulch. Another stream which has a complicated course is the one which has carved Last Chance Canyon. This turns and twists whithout any rhyme or reason altho I think that for the most part it follows along the basement contact until it cuts across the range.

These streams all empty into Kane Dry Lake Basin which is a structual depression lying between the uplifted El Pasos to the north and the Rand Mountains to the south. (PLATE XI) There are a few canyons which cut back into the south face of the range but as yet have made little progress and have very steep grades.

The Pleistocene caps lying at various levels indicate periodic movement on the Garlock Fault and the alluvium just to the east of the entrance to Red Rock Canyon would seem to indicate fairly recent movement.

or gradual downward terracing?

HISTORICAL.

The oldes rocks in the area are the Paleozoics in t he basement complex. The sequence of of events is: First deposition of the paleozoics with subsequent intrusion of the diorite. Following this there was uplift and a period of erosion. Then subsidence and deposition of the Mesozoic sediments. Subsequent to this there was metamorphism, uplift and erosion. The area was then again depressed and high lying areas surrounding it shed material which formed the Lower Ricardo deposits in Pliocene Tertiary time. In the latter part of this period there was an extrusion of lava. Followed then

or adjoining areas uplifted?

a period of quiescence and erosion but without deformation. The ashy beds of sandstone bewteen the lavas was next laid down and then there was a second period of extrusion.followed during which the remainder of the Upper Ricardo was deposited. Subsequently the region was uplifted and tilted and the process of erosion now going on. The topography represents a stage of early maturity.

The source of the Ricardo deposits was probably some adjacent high lying land mass in the Tertiary. The transportation could not have been very far because the particles are all angular? The rate of deposition must have been rather rapid because the sandstones are all very arkosic.

In the Paleontological time scale the Ricardo represents lower Pliocene and slightly younger than the Barstow.

ECONOMIC GEOLOGY.

In the latter part of the nineteenth century gold was discovered in the gravels next to the basement. It has been taken out in various amounts and at various times up to the present.

The Cudahy Co. is at present taking out material from a bed of ash in Last Chance Canyon and are using it to make a cleaning compound.

Various companies have from time to time undertaken to mine the salt deposit in Kane Dry Lake but without a very great amount of success.

Agriculture is practically imposible due to the limited rain fall in this reason. Altho with irregation some farmers have obtained fair results.

PLATE III

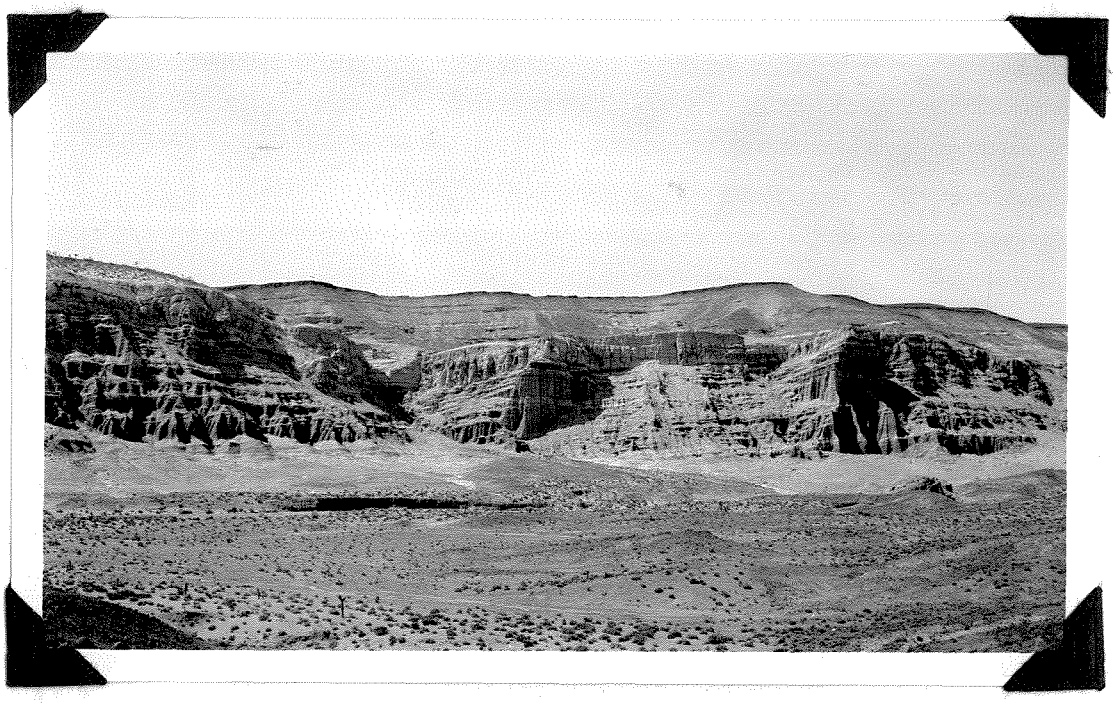


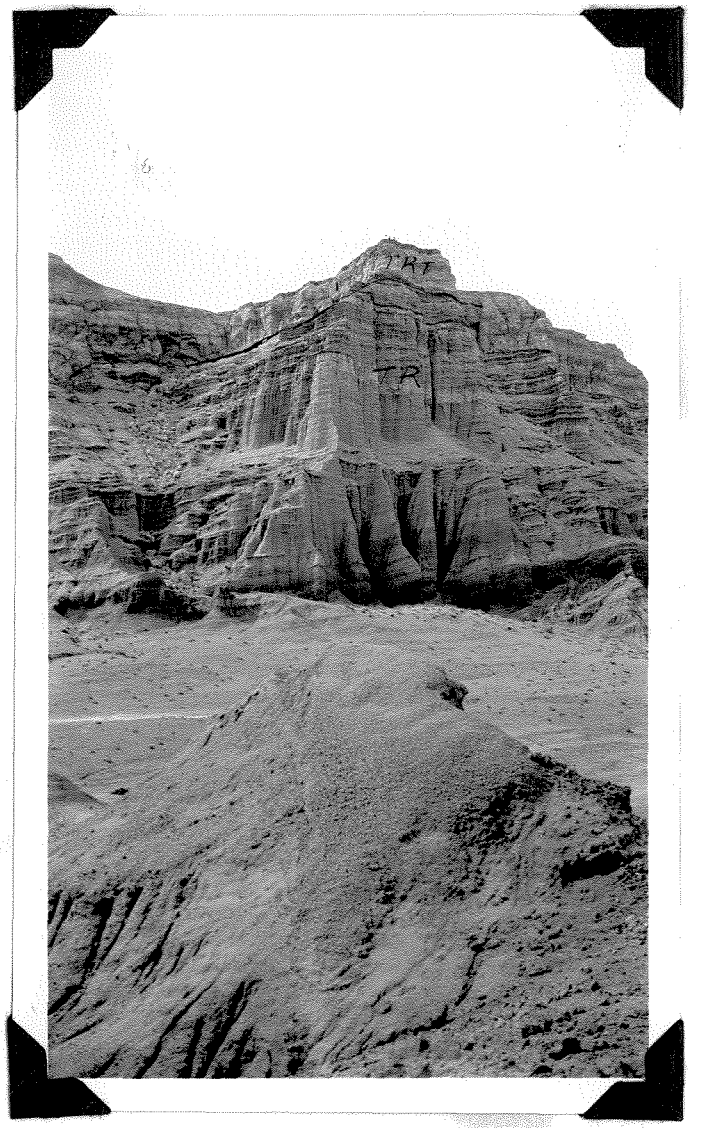
Fig. 1

Exposure of Lower Ricardo in Iron Gulch. Lava Ridge on the skyline.

Fig. 2.

Exposure of Lower Ricardo sandstone, UIron Gulch.

PLATE IV



Typical exposure of Lower Ricardo Sandstone capped by pink tuff bed.

PLATE V

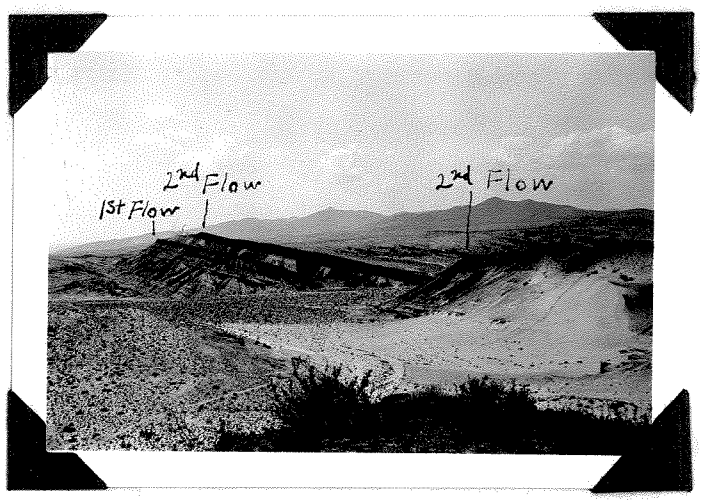


Fig. 3.

Fig. 4.

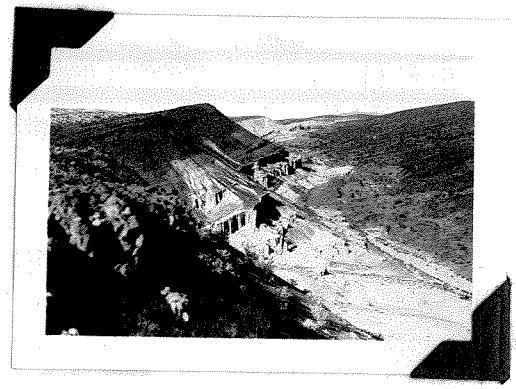


Fig. 5.

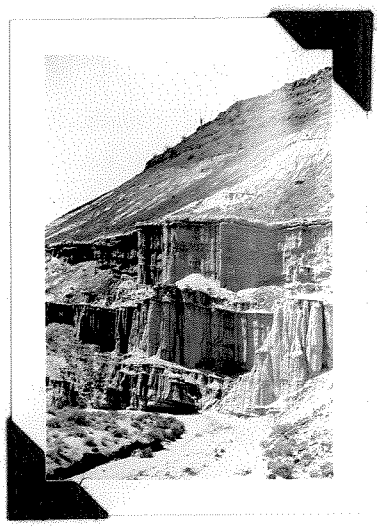


Fig. 6.

PLATE VI

Section showing Lower and Upper Lava series

Columnar structure in Lower Lava flow.

PLATE VII

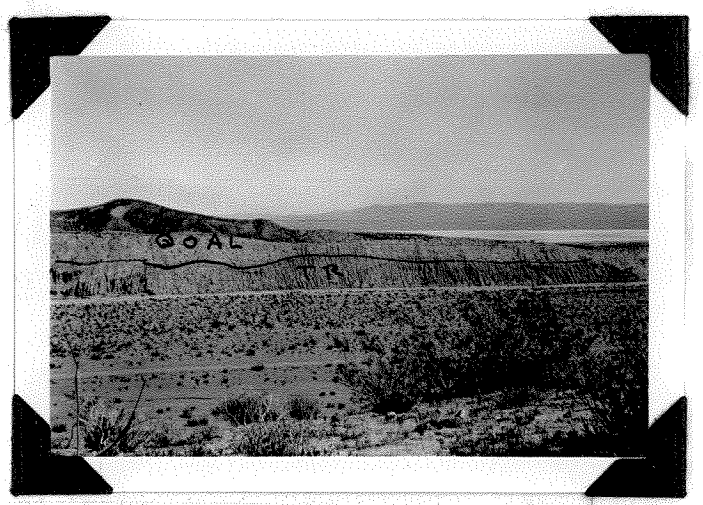


Fig. 7

Pleistocene cap on Ricardo at Mouth of Red Rock Canyon

Fig. 8

Pleistocene cap, resting on Ricardo, Iron Gulch

Fig. 9

Aeolian sand dune

PLATE VIII

Fig. 10

Red Rock Canyon looking north thru the basement

Fig. 11

Red Rock Canyon looking south from the mouth of Iron Gulch

PLATE IX

GFig. 12

Garlock Fault showing breccia and gouge zone, and attitude of fault. Cretaceous rocks on left, tertiary rocks on right, and quaternary alluvial cap on skyline.

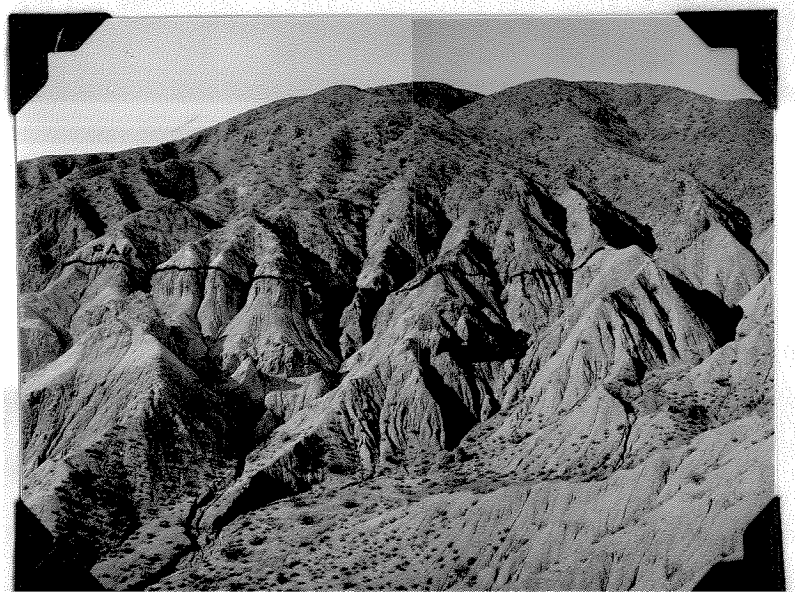


Fig. 13

Line on this mosaic gives the effect of a reverse fault - it slumped as further down canyon

Fig. 14

PLATE X

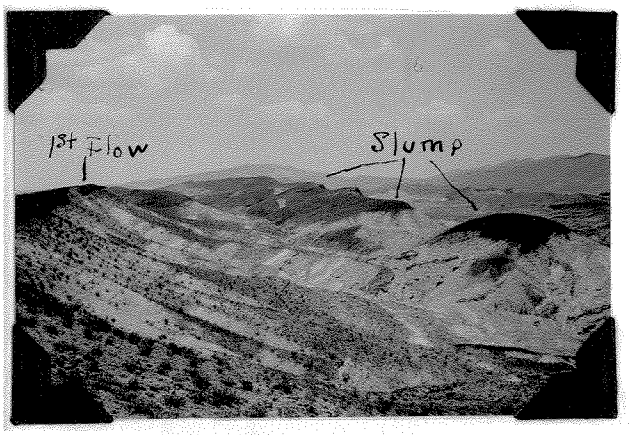


Fig. 15

Fig. 16

Fig. 17

Slumping in ashy sandstone beds in Last Chance Canyon

PLATE XI

Fig. 18

Kane Dry Lake Basin south of the Range.

Fig. 19

Salt deposit in Kane Dry Lake, south face of El Paso Range in the background

PLATE XII

Fig. 20

Iron Gulch, north face of El Pasos in background

Strike ridges of Ricardo capped with Pink Tuff

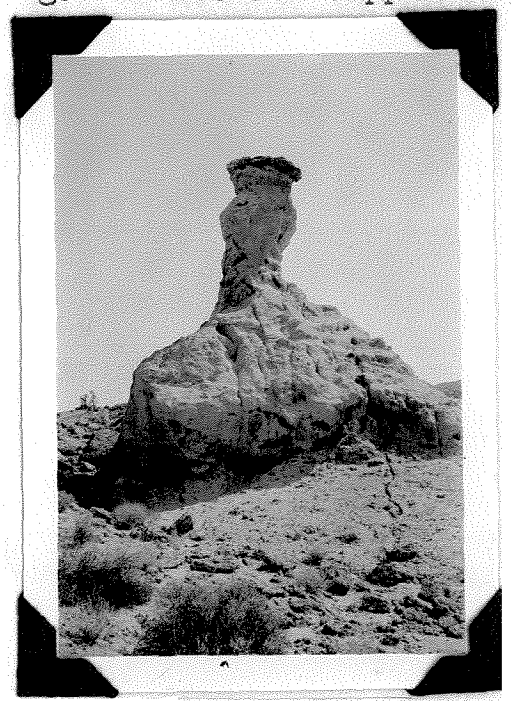


Fig. 21

Striking erosion form prevalent in this region

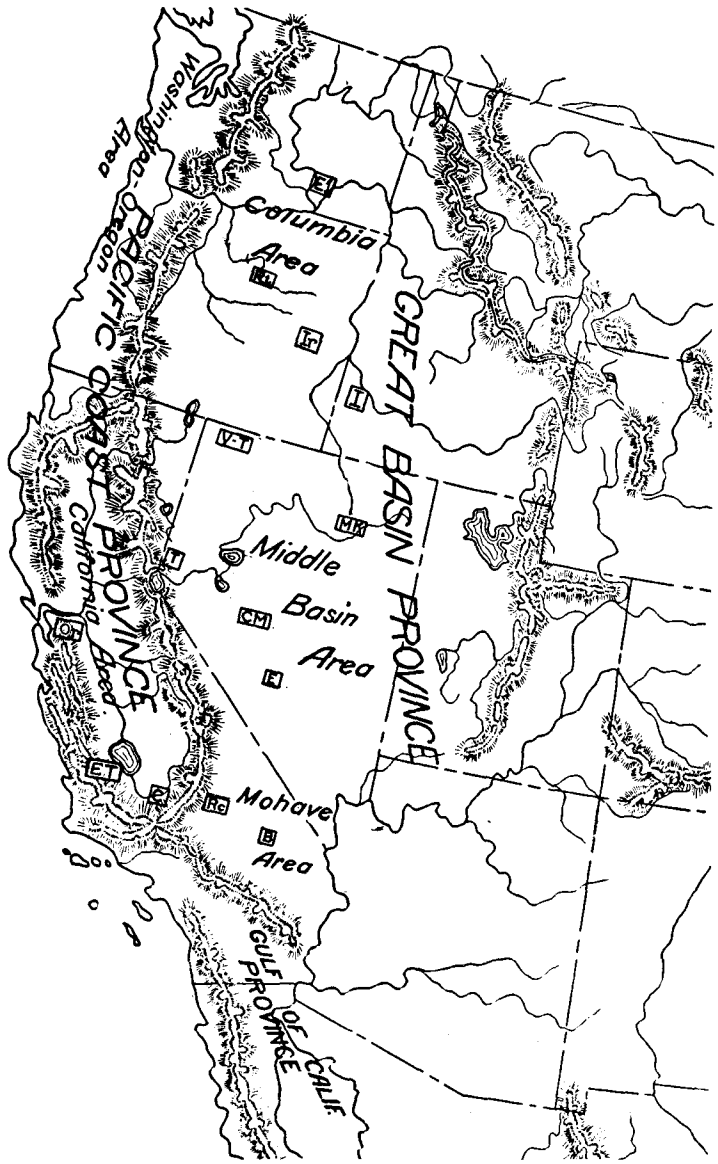


Fig. 1. Outline map illustrating occurrences of Miocene and Pliocene mammal faunas in Tertiary provinces of the United States west of the Wasatch Range. B, Barstow beds; Rc, Ricardo beds; C, Chanac formation; ET, Etchegoin-Tulare beds and Merychippus zone; Or, Orinda beds; E, Esmeralda beds; CM, Cedar Mountain beds; T, Truckee beds; MK, McKnight Miocene; V–T, Virgin Valley and Thousand Creek beds; I, Idaho beds; Ir, Ironside Pliocene; Rt, Rattlesnake Pliocene and Mascall Miocene; El, Ellensburg formation.