A REPORT ON THE GEOLOGY OF A PORTION OF LOS ANGELES COUNTY LOCATED WEST OF THE CITY OF PASADENA, CALIFORNIA

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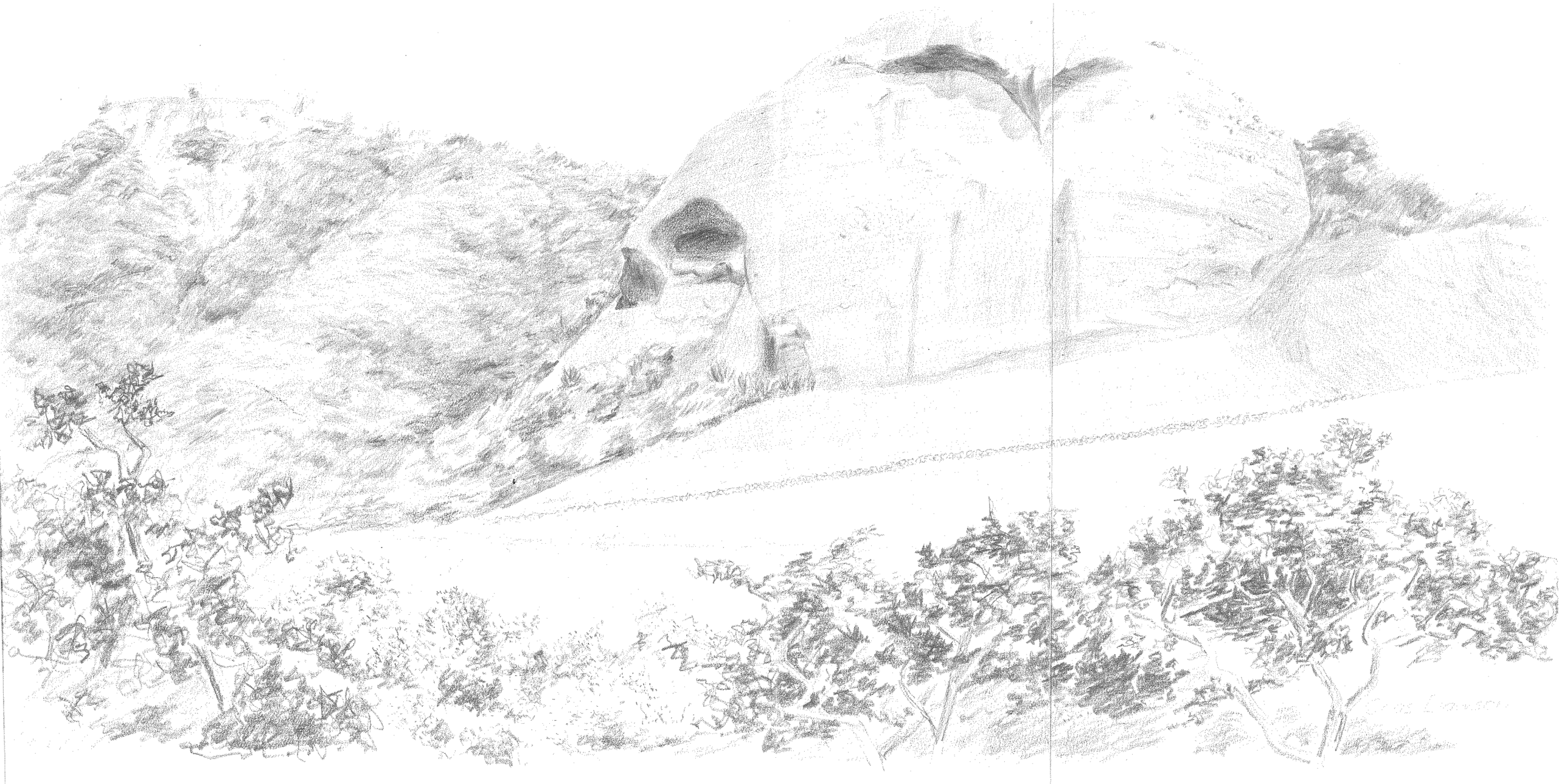


T A B L E O F C O N T E N T S

I N T R O D U C T I O N

The area discussed in this report is located in Los Angeles County and lies partly within the city limits of Pasadena. The area extends from the Arroyo Seco on the east to a northsouth line about half a mile west of Eagle Rock, and from a eastwest line along the southern part of the San Rafeal hills southward a distance of three to three and one half miles.

The map used in the field work is a portion of the U.S. G. S. Altadena Quadrangle with scale 1/24000 and vertical contour interval five and twenty five feet. This map was found to be unusually accurate topographically.

The purpose of this paper is to report the results of a general geological survey of the area outlined above. The usual brunton compas was used for field location. Locations are not indicated by numbers on the map as it was found more convenient in the field work to refer to specific points by their distances and directions from street intersections.

The extreme northern portion of the area is covered with thick brush. All the other parts of the area

are covered with grass or in the more hilly portions, with a light brush covering. The lowest point in the area (located in the south central part) has an elevation of approximately 550 feet while the highest point (located in the extreme northwestern portion) has an elevation of approximately 1,400 feet, giving a total relief of 850 feet.

T O P O G R A P H Y

The region north of the Eagle Rock Fault (see map) exhibits a topography typical of the early portion of the youthful stage of the normal erosion cycle. This is well shown in the steep canyons with V-shaped cross section to be found in the San Rafeal hills in the northern part of the area. These canyons are typical of those seen in the recently uplifted fault blocks of Southern California having steep walls which come down practically to the stream bed and very narrow floors. The topography of the other portions of the area indicates the mature stage of the same cycle. A line of hills extends southward from Eagle Rock (which is located in the central part of the northwestern section of the area) and these hills are extended both east and west in the south and central portions of the area. The eastward extention of these hills in the central part of the area shows many of the signs of youth, namely, V-shaped ridges and steep narrow canyons in which the streams enter the Arroyo Seco from the west decending very steeply to the floor of the Arroyo which is the principle drainage stream of the region. The drainage

throughout the area is consequent, except for the portion north of this eastward extention of these hills where a subsequent drainage is developed, especially noticeable in the canyon of the stream flowing eastward to the Arroyo Seco along the north base of these hills (Laguna Canyon). The region is semi-arid and the streams are all intermittent.*

The rather steep slopes referred to above and the generally soft character of the sedimentary deposits have caused abundant good outcrops throughout the southern and central parts of the area. The crystalline rocks in the northern part of the area are likewise well exposed due to the rapid downward erosion of the youthful streams. Furthermore, the area has been penetrated by a large number of roads which offer many fine additional outcrops due to the cuts made through the hills. Some small portions of the area have been entirely built over so that no exposures are available. This is most particularily true of the area immediately north of Laguna Canyon and of the area on both sides of North Figueroa Avenue.

* However, the region is not sufficiently arid to have given rise to any typical forms of the arid erosion cycle.

S T R A T I G R A P H Y A N D L I T H O L O G Y

Only two sedimentary formations have been distinguished in this area, one of which occupies the northern and central portion of the area and which is tentively called the Annandale formation; it is believed to be of Miocene age, but has not been definitely correlated with any formation included in that period in Southern California. The other formation occupying the southern portion of the area is believed to be the Modello.* Besides these, fairly considerable portions of the area are covered by quaternary alluvium as shown on the map. This alluvium has been differentiated into older and younger alluvium as explained further on. The extreme northern portion of the area is composed entirely of a basement igneous metamorphic complex.

Basement Complex

The basement complex exposed in the San Rafeal Hills in the northern part of the area is rather typical of that seen generally in the fault block mountains of Southern California. The predominant variety of rock

* For a description of the Modello formation see U.S.G.S. Bull. 753, Kew, "Report on the Geology and Oil Resources of Los Angeles and Ventura Counties."

is granite or grano-diorite with probably smaller amounts of diorite as well or it may be that diorite is entirely absent. The material is of course grain, and weathering has progressed to such an advanced stage in most of the outcrops, that the rock may be disintegrated by rubbing with the pick. Consequently it is impossible to distinguish the felspars megascopically, and hence it is necessary to base these distinctions largely on the color of the rock and the proportion of other minerals. There are also considerable areas of metamorphic rocks intermassed with the granite and grano-diorite and though some seem to show traces of former sedimentary features it is impossible to settle the question of their origin since it is quite reasonable that they may have resulted from alteration of igneous rocks, and that the apparent sedimentary features may have resulted from the metamorphism as has frequently been shown to be the case in other areas. The whole mass is interpenetrated by complimentary dikes which show minor displacements in many outcrops. Some of these dikes cut through others, showing some time difference between them, but in all probability the time difference is very small and they all belong to the same period of magmatic injection. One can not avoid the impression that those dikes of acedic composition considerably out-

number the more basic ones, that is pegmatite and aplite dikes as well as quartz veins are more abundant than the basaltic dikes. All of the igneous rocks outcropping in this area are of the subjacent variety and extrusives are entirely absent; further no fragments of extrusives are found in the sediments.

Some developement of porphyritic texture may be noted in both the asedic dikes and the main mass of the igneous rocks. As mentioned above the granite and granodiorite are of quite course texture and the rapid process of weathering on the outcrops is probably due largely to this courseness of texture. This weathering is somewhat more advanced adjacent to the Eagle Rock Fault due to shattering. These weathered outcrops are commonly stained brown due to the decomposition of the basic iron bearing minerals. No minerals of any economic value are encountered in the basement complex except that it is quite possible that some of the quartz veins carry traces of gold. That these traces are considerably below the gold content which would make profitable ores is attested by a few short tunnels driven into them here and there, now abandoned.

The Annandale Formation

This comprises a thick series of poorly sorted conglomerates, sandstones and shales. Whereas the Modello formation is characterized by fine sorting of the mater-

ials and their deposition in thin and extensive beds, the materials in the Annandale formation are not only extremely poorly sorted but they occur for the most part in thick beds which are of quite limited areal extent. This is particularily true of the conglomerates and sandstones which show every gradational stage between true conglomerate and true sandstone and to some extent such gradation may be observed between the sandstones and the shales. The conglomerate is quite massive in the vicinity of Eagle Rock showing only the rudest sort of bedding planes and practically no sand lenses. As one procedes southward through the area sand lenses appear, increasing in frequency and size until the rock becomes sandstone containing conglomerate lenses which decrease in the frequency of their occurence, but which have not entirely disappeared when the first thin beds of shale are noted. The transition from sandstone to shale is much more abrupt than that from conglomerate to sandstone, nevertheless, it is gradational also; in fact decidedly arenaceous beds accur throughout the shales.

South of the main shale member of the Annandale formation sands and conglomerates appear locally with shales interbedded. This is of course a generalized statement of the sequence of materials and considerable variation is found in this portion of the area. Lines have been drawn on the map showing roughly the limits of the con-

glomerate, sandstone and shale zones, but it must not be conceived that these represent contacts; they merely show in a very approximate manner the arbitrarily chosen point in a gradational series on one side of which one name is applied and on the other side another.

Considerable variation among the boulders of the conglomeratic portion of the Annandale formation is noticeable. These include aplites, pegmatites, granites or grano-diorites and some metamorphics. Very occasionally small pieces of shale are noted. It is of course possible that these are derived from an older formation not exposed in the area, or completely removed by erosion, but it seems more probable that they are from shale lenses within the same formation. The supposed conditions of deposition stated below make this probably. These fragments of shale do not resemble the shale of the Modello formation described below. The most conspicuous type of boulder is composed of diorite which is so badly weathered that it readily falls to pieces when scratched with the pick. These dark colored, gray, weathered boulders frequently are larger than the surrounding more asedic boulders and are a very conspicuous feature of the conglomerate and even the sandstone zones.* The matrix of the conglomerate zone and the samples from the sandstone zone are markly sim-

* Boulders very similar to these have been noted in the Topanga Formation in an adjacent area.

ilar as would be expected from the fact of their gradation into one another. They consist largely of quartz with considerable feldspar which is much altered and they contain small amounts of biotite and traces of muscovite and magnetite. The boulders in the conglomeratic sands are subangular for the most part though some subrounded individuals are found; the sands in both the conglomerate matrix and the sandstone are subangular. The shales are composed chiefly of kaolin but in most of the beds considerable fine quartz grains are present. Some muscovite is present in the shale and a few other mineral constituents in very minor quantities.

Local unconformities of limited extent are quite frequent in this formation but the largest of them can not be traced more than a couple of hundred feet.

No identifiable fossils were found, in fact the only occurence of animal fossils consist of a few fragments of calcareous shell material noticed in a conglomerate bed on the west bank of the Arroyo Seco in the central eastern part of the area. These are nothing more than bits of lime with all the markings necessary for identification completely obliterated. Their poor condition is partly due to weathering and partly due to shearing of the conglomerate in which they were found if, as is probable, they were not broken before

deposition . The only other evidence of organic life is a certain amount of carbonaceous material found scattered through the finer sand and shale beds; it is probable that none of this material can be identified. In a few beds in the anticline shown in the central part of the area this carbonaceous material is quite highly concentrated giving the beds a dark to blue color, but elsewhere it is widely scattered. In many parts of this formation the rocks are stained by limonite due to the decomposition of the feromagnesium minerals.

The conditions of deposition seem to have been torential, the material having been transported only a relatively short distance and deposited in a shallow basin by shifting streams. The occurrence of boulders of considerable size in many of the sandstone beds and the interbeded conglomerate and sandstone beds in the northern part of the area and interbeded sandstone and shale beds in the central part of the area are good evidences of freshet conditions. The great thickness of the formation can only be attributed to gradual subsidance during deposition. The gradation of the material from north to south indicates that the chief source of material was to the north. In view of these conditions it is not difficult to understand the above mentioned occasional occurrence of shale or mud pebbles

in the sandstone and finer conglomerate beds. This formation may be of fresh water deposition though it more probably was deposited in a salt water lagoon or possibly an estuary. The occurrence of the carbonaceous materials seems to indicate marsh conditions for at least a part of the time of deposition.

This formation is presumed to be older than the Modello for reasons stated below. It bears a strong resemblance both stratigraphically and lithologically to the Topanga formation exposed in an adjacent area. A particularly characteristic feature of this and the Topanga formation as exposed north of the Verdugo Hills is the occurrence of the badly weathered diorite boulders described above. The general boulder counts made in the conglomerates of the two areas are similar and the sands and shales show strong resemblances.

The Modello Formation

The Modello formation in this area comprises a thick series of medium to fine sandstones and sandy to rather pure shales. The sandstones are commonly white or very light gray in color and are composed in very large part of clean white sand mixed with small amounts of mica and a few other minerals which occur only sparingly. These sandstones generally have been weakly cemented, the cement being lime although in a few beds

the reverse is true and they are very firmly cemented with silica. These sandstone strata are generally thin bedded, sometimes occurring between even thinner beds of shale; at other times a number of these sandstone beds are closely associated together. The shales are very thinly laminated and arranged in quite thin beds. They are composed almost wholly of kaolin with a certain amount of mica, chiefly muscovite and in some cases a considerable portion of fine quartz particles. Many of these shales may be classed as silt stones. Very occasionally thin cherty layers are found interbedded in this formation as exposed in the southern portion of the area. The total thickness of shale is much greater than the total thickness of sandstone, but the proportions of sand and shale vary much locally. No fossils were found in this formation but in spite of their absence the lithologic characters indicate that the materials were deposited under marine conditions at moderate depth.

Queternary Alluvium

Two types of quaternary alluvium are present in the area, the larger amount being shown as older quaternary alluvium which is merely the excess of material derived from the slopes by weathering over that carried out by streams in erosion. Consequently this older

alluvium is found in variable amounts in many of the valleys. The other division of the quaternary alluvium is much more recent and consists of stream deposits over-lying stream-cut benches and noticeable chiefly in the Arroyo Seco. The older alluvium is comparatively fine material mostly without stream pebbles or boulders while the younger alluvium is characterized by the presence of many fairly well rounded stream boulders representing all types of rock found in the basement complex to the north.

Contacts

The contact of the Annandale Formation with the basement complex is a fault (the Eagle Rock Fault). The contact strikes approximately N50W through most of the area and is quite straight but it bends just north of Eagle Rock and strikes almost eastwest due to branding of the fault.

The contact between the Annandale formation and the Modello formation is also a fault. Its strike is almost east and west across the entire area. The Modello does not out crop for some distance south of this fault as it is buried under alluvium.

S T R U C T U R E

Folding

In the Annandale formation the general strike of the beds is northwest-southeast and the dip is to the north except for a small anticline and syncline in the central part of the area, a few minor variations in the extreme southwest part of the formation, and an area of nearly eastwest strike and south dip in the extreme northwest part of the formation. This folded structure, in the central part of the formation, is shown in detail in the chart attached. Along the west bank of the Arroyo Seco and somewhat to the south of this folded structure (west bank of Arroyo Seco several hundred yards south of Laguna Canyon) there is an area in which the dips steepen up rather sharply and a few of the beds are slightly over turned; the strata at this point ~~is~~ *are* practically all shale, the usual sand beds being almost entirely absent.

The general north dip of the beds in this formation is probably due to the fact that the formation lies on a fault block with the Eagle Rock Fault to the north and the Raymond fault to the south and that in recent times the southern fault has been more active than the northern one, tilting the block to the north. The reasons for this belief will be more fully discussed

under faulting.

The area of south dips in the northwestern portion of the Annandale formation is difficult to treat as no definite conclusions could be drawn from the field work. This change in attitude across the canyon immediately west of Eagle Rock may be due to a change in the nature of the Eagle Rock fault at this point. The change in strike just north of Eagle Rock has already been mentioned. Further, in an exposure of the fault to the east of Eagle Rock, it may be seen to dip about 60° to the north, while the outcrop of the fault west of the Rock indicates a decided south dip. Hence it seems probable that the change in both strike and dips of the fault plane may have caused monoclinal warping of the formation at this point, the monoclinal structure striking approximately northsouth and dying out away from the fault. This monoclinal structure would not have to be large as the beds lie almost horizontal just south of Eagle Rock and dip only about twenty-five degrees on the west side of the canyon. Still there is little or no field evidence for such warping, and it is possible that the same sort of adjustment was made by a small fault striking northsouth in the canyon with its greatest displacement to the north at the intersection with the Eagle Rock fault, or it may have been a combination of the

two. (No direct evidence of such a faule is obtainable.)

The small folded structure in the central part of the formation, and the overturned beds mentioned above seem to indicate weak compressive stresses which operated in a northsouth direction and found relief in this section of weaker rocks.*

In the extreme southwestern portion of this formation the beds are somewhat contorted, showing complex folding, but the structures are too small and complicated to map. The indications are** that there was some compression in a northsouth direction associated with the movement on the Raymond fault (to be discussed below) and also slight compression in an eastwest direction. No evidence is obtainable to determine whether or not the two were contemporaneous.

A syncline is shown on the map in the small part of the Modello formation examined. It is interesting to note that the axis of the syncline was subsequently cut by a small fault with some displacement of the axis on one side with respect to the other, and that

* The same effects might indeed have been produced by rotational stresses.

** Again assuming simple compression.

later both fault and syncline were somewhat warped. Unfortunately the axial plane of the syncline could not be determined nor the true displacement on the fault.* If simple compression is assumed for the origin of the syncline the sequence is, first, northeast southwest compressive forces forming a syncline, second, a north-south shearing stress causing the fault at a later time or vertical displacement if the exial plane of the syncline is not vertical, and third, a couple acting at still later time which displaced both fault and anticline.

Faulting

Two major faults extend across the area. The Eagle Rock fault, north of the Annandale formation, is a steep angle reverse fault from the east boundary of the area to Eagle Rock. In this part it strikes approximately N55°W and dips northward, the dip apparently being somewhat steeper where it intersects the Arroyo Seco than at Eagle Rock. At Eagle Rock the fault splits, one branch continuing the northwest trend (with igneous rocks on both sides) with almost 90° dip, while the other branch strikes approximately eastwest with a marked south dip making this portion a high angle normal

* The apparent displacement is horizontal; the west side north.

fault. This westward trending branch is decidedly the more important of the two. No evidence of horizontal movement is obtainable. The vertical movement has been large, probably on the order of two to several thousand feet since no traces of sediment are found on the northern block which has moved up with respect to the southern. A fine exposure of the fault just east of Eagle Rock shows a brecciated zone a couple of hundred feet wide but in the Arroyo Seco the brecciated zone is much narrower. The completely unconsolidated conditions of the breccia indicate relatively recent movement, but movement has not occured sufficiently recently to maintain any scarp in the alluvium east of Eagle Rock. A rather minor fault with the same trend and relative displacement is observable in the Arroyo Seco several hundred yards south of the Eagle Rock fault.

Another large fault known as the Raymond fault transverses the area from east to west at the southern border of the Annandale formation. The displacement on this fault is probably of the order of one or more thousand of feet, the north side being moved up tilting the Annandale formation as stated above. That this fault is active at the present time is shown by a scarp in the alluvium and further by seismographic records.*

* Information, courtesy of Dr. Buwalda.

Interbedded sand and shale immediately to the north of this fault is considerably contorted which suggests that this is probably a high angle reverse fault (diping to the north) similar to the Eagle Rock fault but this can not be actually observed as the fault surface is nowhere exposed. A rather minor fault having the same trend may be observed a few hundred feet to the north in the west part of the area. This is probably a narrow zone of faulting rather than a single fracture as the Eagle Rock fault appears to be. It is possible that this reverse fault may account for the northsouth compression assumed in explanation of the eastwest trending folds discussed above.

Besides these two larger faults the region is traversed by a series of parallel northeast-southwest trending faults in which the major displacement seems to have been horizontal. These faults for the most part show a displacement of the west side northward with respect to the east and this is particularly well shown on the fault exposed at Avenue 64 where this fault cuts the axis of an anticline and a syncline. One or two of these smaller faults having the same trend seem to have been displaced in the opposite direction, however, the evidence for this is slight. The northeast-southwest trending faults are one of the most interesting features of the area showing, as they do, a tendency of the west-

ern portion to move northward with respect to the eastern, but the movement has not resulted in an important fracture, the adjustment having been made along a number of small fractures. These faults are of decidedly minor importance with respect to the Eagle Rock and Raymond faults. That these faults are of later date than the folding in the central part of the Annandale formation is clearly shown by the fact that the one exposed in Avenue 64 displaces the folded structure. The northeast-southwest trending faults have undoubtedly remained motionless for a long period of time and may be considered dead faults. The possibility of a small northsouth fault west of Eagle Rock has already been discussed. There is some evidence of a fault extending eastward from the point at which the Eagle Rock fault branches, but this seems only a minor feature.

A small fault was found in the Modello formation in the extreme southern part of the area as mentioned above. This fault has a peculiar bend in its northern part but it is undoubtedly of only minor importance. It is possible that a fault exists along the north border of the hills south of the Raymond fault, but it is not very probable and no evidence other than topographic could be found for it. The topographic evidence itself may be very differently interpreted. The escarpment at this point can be readily refered to erosion which seems

to be the correct explanation.

Conclusions on Structure

Rather complex stresses have been involved in the folding of the area, but they have been of rather minor intensity. The two major faults are referable to the same system of faulting which has produced the San Gabriel Mountains, and are still active, the Raymond being considerably more so than the Eagle Rock. The northeast southwest trending faults are probably dead and are of only local interest.

HISTORY OF THE REGION

The Annandale Formation is considered to be older than the Modello. It lies on a block which has been faulted up north of the block which bears the Modello, hence it is difficult to see how it could be the younger of the two. Further no trace of it is found overlying the Modello as might be expected if it were younger. Assuming that the Annandale is the older, the complete absence of the Modello above it on the block north of the Raymond fault may readily be explained by considering that the Modello has been completely removed from this block by erosion.

As the igneous rocks north of the Eagle Rock fault are of the deep-seated variety the history of the region seems to be as follows. A long period of sedimentary conditions must have occurred here prior to the tertiary, forming a very thick series of sediments, probably accompanied by gradual subsidence, and followed by a period of subjacent magmatic injection, probably contemporaneous with the injection of the magmas which formed the basement rocks of the San Gabriel range. This magmatic injection period is generally assigned to the Jurassic. Considerable metamorphism of the old sediments must have accompanied this, and it is possible that the metamorphic rocks found on the northern-

most block of the area originated from sediments at this time.

Subsequent to this, the region was uplifted and greatly eroded as shown by the exposure of the originally deep seated igneous rocks and this erosion interval may have extended uninterrupted from the close of the Jurassic to the beginning of the Miocene. At the beginning of the Miocene sedimentation began again, in a fresh water lake or a salt marsh or lagoon. The salt marsh or lagoon seems most probable. Gradual subsidence occurred during the period of deposition, which accounts for the thickness of the Annandale formation and the chief source of materials seems to have been a highland of crystalline rocks to the north, which was probably still in the youthful stage of the erosion cycle. The climate seems to have been semi-arid, since the materials were obviously transported only a short distance and are for the most part quite fresh. The torrential type of deposition seems to be indicated by the irregularity of the sorting.

Following the deposition of this formation there may have been minor uplift with subsequent subsidence or the slow subsidence postulated for the period of deposition of the Annandale Formation may have been accelerated bringing on the moderately deep water marine

conditions indicated by the Modello Formation. The Modello Formation is considered to represent late middle to upper Miocene time. Uplift seems to have occurred at the close of Miocene time.

If any other formations were subsequently lain down in the area, they have been entirely removed by erosion. The older quaternary alluvium is of Pleistocene origin and the younger of recent origin.

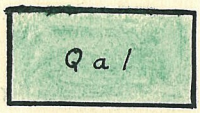
Just when the Eagle Rock and Raymond faults originated is difficult to say, and they may have been active at the beginning of the Annandale sedimentation. However, a large part of the total displacement has occurred since the close of the Modello sedimentation.

ORIGIN OF EAGLE ROCK

This interesting feature of the area lies just south of the angle in the fault of the same name. It is composed of conglomerate and is merely a bold outcrop of the Annandale Formation, though it appears different because it is not stained by limonite as the surrounding masses are, and because it is much more firmly cemented. This much firmer cementation, which is probably due to the infiltration of silica solutions which found their easiest route upward in the fractured area adjacent to the angle in the fault, has made this portion of the formation much more resistant to erosion than surrounding conglomerate beds. The accordance between the attitudes in the rock itself and immediately adjacent to it, and the lack of any evidence of fault structures on the south side except the shattering referable to the fault to the north are added proofs that the feature is merely a remnant due to differential weathering and erosion. That the cementation followed rather than preceded the major movements along the fault is indicated by the much shattered condition of the surrounding conglomerate and the firmness of the same material in the Rock itself.

The "Eagle" on the west face is chiefly due to differential weathering, including spalling and the

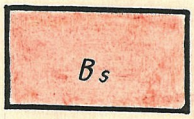
naturally more rapid disintegration due to the steep wall cut on this side by the stream just to the west. Shallow cave-like holes, ten feet high and as many deep and from twenty to thirty feet across are also observable on the west side due partially to local differences in cementation and to sand lenses in the conglomerate.

Quaternary Alluvium. 

Quaternary Older Alluvuim. 

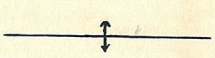
Modello Formation. 

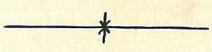
Anandale Formation. 

Basement Complex 

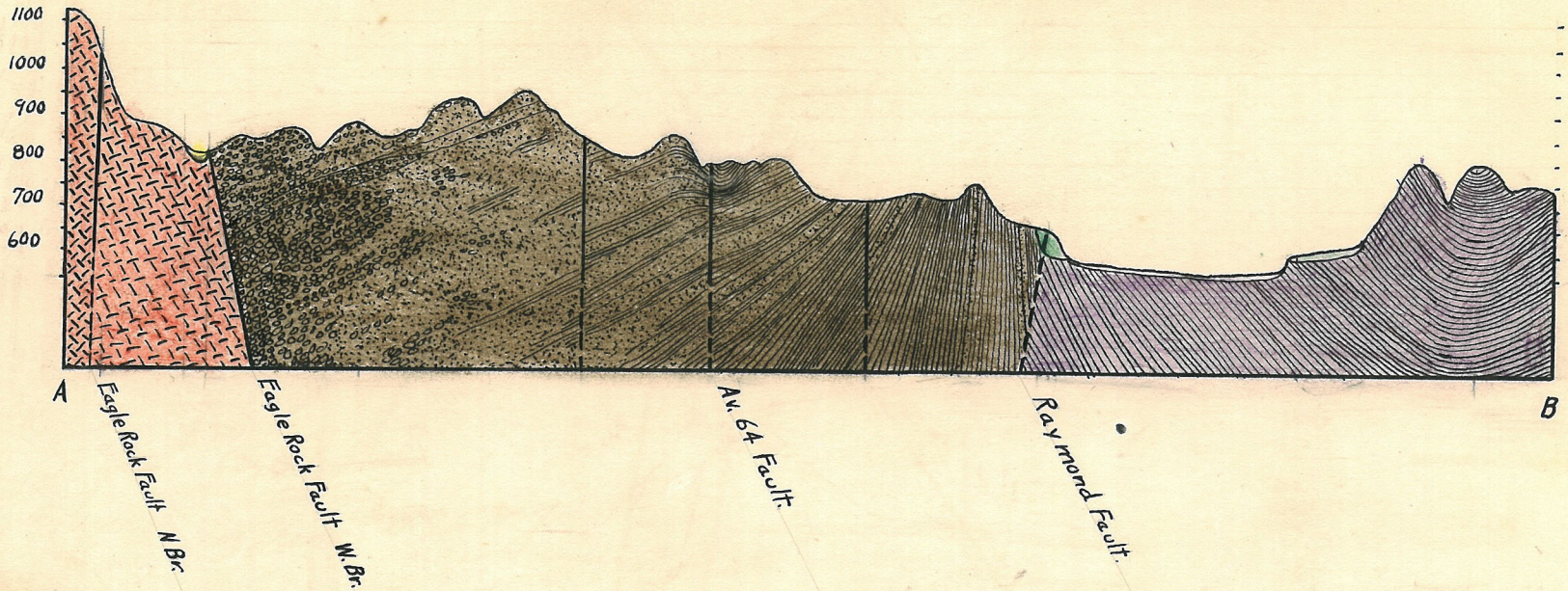
Contact

Fault

Anticline 

Syncline 

Attitude 



Structure Section Along Line A-B

Vertical Scale Five Times Horizontal Horizontal Distance 3.2 miles.

Elevations Shown on Right.

Chart showing structure relations at the Av. 64 cut.