GEOLOGY OF THE
EASTERN PORTION OF THE SAN GABRIEL MOUNTAINS

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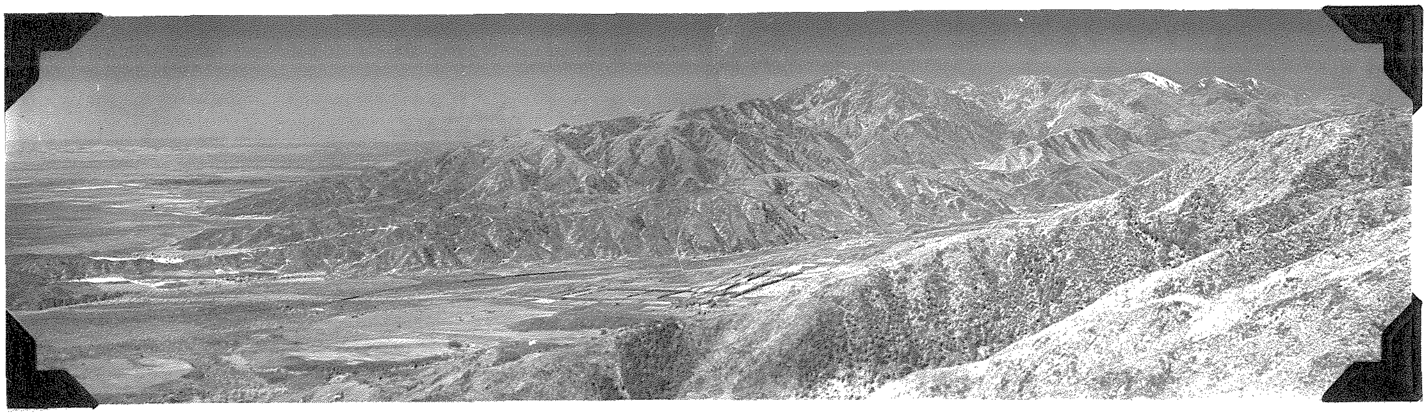
PLATE I



View of the eastern San Gabriel Mountains

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INTRODUCTION

The San Gabriel Mountains form one of the units of east-west trending mountain belt of Southern California. They extend from the San Fernando and Santa Clara Valleys on the west to Cajon Pass on the east, and form a topographic boundary between the Mohave Desert on the north and the Coastal plain on the south.

The area, described in this report, occupies a rectangular block, seven miles long and three miles wide, in the eastern portion of the mountains. It lies entirely within San Bernardino County and includes parts of San Antonio, Cucamonga, Hesperia and San Bernardino Quadrangles.

With the exception of the long straight valleys of Lytle Creek and Lone Pine Canyon, the region is steep and rugged. Elevations range from 2700 feet in Cajon Pass to over 9000 feet at the summit of Telegraph Peak.

Most of the mapped area is quite accessible. The main highway between San Bernardino and Los Angeles Playground at Big Pines is located in Lone Pine Canyon. Paralleling this road and one and one-half miles to the southwest, there is a paved road which extends up the North Fork of Lytle Creek to Stockton Flats. During the greater part of the year it is possible to drive from Stockton Flats across the range to Camp Baldy. In addition to these two public highways, there are numerous roads and trails which have been constructed by the United States Forest Service.

"PREVIOUS WORK"

R. Arnold and A. M. Strong (2), in an early paper on the San Gabriel Mountains, state: "For an interesting mountain region of over 1200 square miles in extent, located, in as important a section of country as that in the vicinity of Los Angeles, the San Gabriel chain has received very little attention from geologists". This statement is almost as true today as it was some thirty years ago.

L. F. Noble, of the United States Geological Survey, has been engaged in detailed mapping along the San Andreas fault in the northern portion of the range. Two excellent summary reports (18 & 18a) on his work have been published but the final paper has not yet been issued by the Geological Survey. Recently W. J. Miller (17) has published a report on the geology of the western San Gabriel Mountains. M. L. Hill (10) has worked on the structure along the south flank of the San Gabriel Mountains in the vicinity of Pacoima, Lopez, and Little Tujunga Canyons. F. E. Vaughan (19) has mapped a portion of the San Bernardino highlands in detail. W. M. Davis (5), W. C. Mendenhall (16), R. T. Hill (11), and others have made general statements regarding the structure and genesis of the range.

With the exception of Miller and Vaughan, these writers have been principally interested in structure and geomorphology and but little concerned with the type and distribution of the so-called "basement rocks". Therefore, it seemed that an area, bordering the San Andreas fault and extending across the San Jacinto and related faults, might offer an interesting structural and petrological problem. With this purpose in mind, field work was started by the present writer in the spring of 1933 and continued in the spring of 1934.

ACKNOWLEDGEMENTS

The writer is indebted to Dr. J. Maxson, Dr. I. Campbell and Dr. J. P. Buwalda of the California Institute of Technology for numerous suggestions and helpful criticisms, that were offered during the course of the work. He is also indebted to Dr. T. Clements, of the University of Southern California, for the loan of a microscope and for valuable advice; to Dr. Anderson of the California Institute for assistance in petrographic determinations; to Donald Curry, Donald McClelland and Glen Ledingham for valuable advice.

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SUMMARY

The rocks of this area have been divided into four groups: an undifferentiated series of folded and banded ortho and para-

gneisses, a series of meta-sediments known as the Pelona schists, unmetamorphosed intrusive igneous rocks and recent stream and terrace deposits. The undifferentiated gneisses are a complex group of rocks consisting of meta-sediments and intrusive igneous rocks of at least three different ages.

Both the undifferentiated gneisses and Pelona schists have been intruded by unmetamorphosed granodiorite and granite. Because of its petrogenetic similarity to the Sierra Nevadan and Coast Range granodiorite, this intrusion is believed to have taken place in late Jurassic.

Melanocratic dikes have been intruded into the undifferentiated gneisses, Pelona schists and the massive granodiorite. These dike rocks approach camptonities in composition.

Pleistocene and recent terrace and stream gravels are found in the valleys of the Middle and North Forks of Lytle Creek.

The San Andreas fault in Lone Pine Canyon and the San Jacinto fault in the valley of the North Fork of Lytle Creek are the main structural features in this area. The topography, structure and distribution of rock types are controlled by these two faults.

UNDIFFERENTIATED GNEISSES

The oldest rocks in this region are a series of folded and banded gneisses. As shown on the accompanying geologic map, these gneisses outcrop on the southeast side of Coldwater and San Antonio Canyons. From here they may be traced across the crest of the mountains and down the Middle Fork of Lytle Creek to the Irvingdale fault which forms their northeastern boundary in this portion of the area.

These gneisses are a complex group of rocks which vary greatly in petrologic character. Coarse-grained dioritic gneisses, mica and hornblende schists, quartzites, and marbles are included in this series. Meta-sediments, which are represented by the marbles, quartzites, and some of the schists have been intimately penetrated by granite and granodiorite. As a result of an imcomplete assimilation of the older rocks, hybrid rocks of an intermediate chemical composition are frequently found.

One of the most interesting exposures of these metamorphic rocks is located on the north side of Glenn Ranch-San Bernardino road, a few hundred feet north of the bridge across Lytle Creek. Rocks of three different ages are present in this one exposure. Massive green and white marbles and intercalated mica schists have first been intruded by a fine to medium grained diorite. Later both the meta-sediments and the diorite have been intruded by a medium grained granite. This relationship of the marbles and schists to the igneous rocks is illustrated in figure #1. The diorite, although badly weathered, shows a parallel alignment of mica and hornblende.

Figure 1. Photograph of meta-sediments (sed.), meta-diorite (di.) and massive granite (gn.), exposed in a road-cut along the Glenn Ranch-San Bernardino road a few hundred feet north of the bridge across Lytle Creek.

Figure #2 shows the intrusive contact between the granite and the meta-sediments. This granite is a massive grey to white igneous rock containing quartz, orthoclase, and biotite. The meta-sediments have been penetrated by narrow bands and seams of granite which has resulted in a composite rock, partly sedimentary and partly igneous in origin. In some of

Figure 2. Contact between granite and "granitized" schists along the Glenn Ranch-San Bernardino road, a few hundred feet north of the bridge across Lytle Creek.

these granitic bands a rude gneissic banding is found. This alternation of micaceous and granitic streaks and bands is the result of an incomplete assimilation of adjoining mica schists, and is an illustration of the process of "hybridization" which has already been mentioned.

Throughout this paper, the writer has attempted to differentiate between gneissic banding, ie: the alternation of distinct lithological types in parallel bands and streaks, and gneissic foliation, which is the alternation of bands rich in one particular mineral.

Numerous inclusions are present in the larger masses of granite and granite gneiss a short distance south of here. In most cases these inclusions appear to be rounded or ovate blocks of meta-sediments which, because of their chemical composition, were not easily assimilated by the rising granite magma. Figure #3 shows the difference in attitude between the schistosity in the xenolith and the banding in the enclosing granite gneiss.

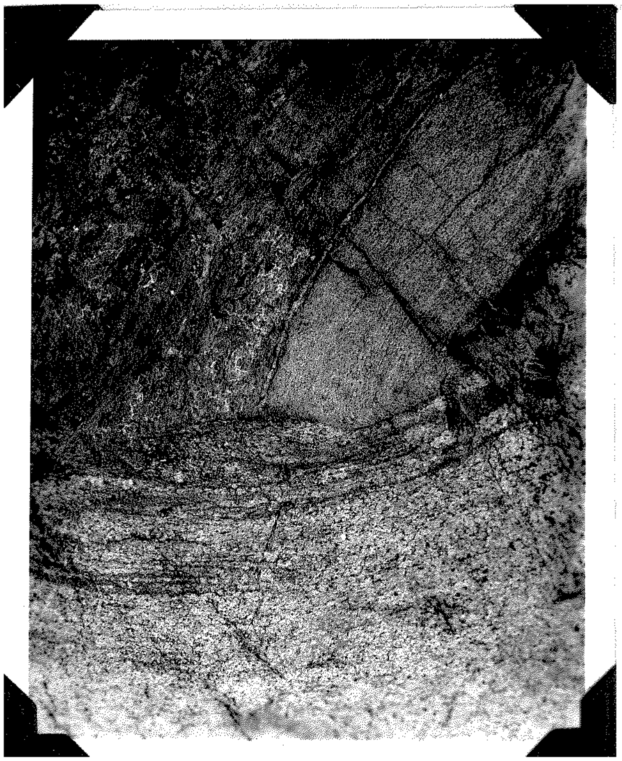

Figure 3. Xenolith in
banded granite gneiss
along the Glenn Ranch-
San Bernardino road,
a few hundred feet north
of the bridge across
Lytle Creek.

A large variety of metamorphosed igneous and sedimentary rocks is found along the Middle Fork of Lytle Creek. In some localities the original character of the sediments is fairly well preserved, while in others it is impossible to distinguish the meta-sediments from the younger intrusives. As an additional complicating factor, the rocks have been sheared and crushed by movements along the Irvingdale fault, which parallels the Middle Fork of Lytle Creek for some distance. Therefore, the relationship of the various igneous rocks to one another and to the meta-sediments is somewhat uncertain.

The meta-sediments are quite similar to those previously described. Massive marbles, impure quartzites, and grey to green mica and chlorite schists are intercalated with coarser grained rocks of uncertain origin. Associated with these meta-sediments and in some cases cross-cutting them, are several bodies of metamorphosed diorite. This rock is light to dark green in color and contains hornblende, biotite and an undetermined feldspar. Both the meta-sediments and the meta-diorite have been intruded by a "rose colored" granite--older than the massive granite which has been described and illustrated on page (2.). Locally, this intrusion has resulted in "granitization" of the intruded rocks. Small seam-like bands of granite only a fraction of an inch in thickness can be traced for several hundred feet from a parent dike. The most noticeable feature of this intrusion, aside from lit par lit injections, is the formation of rose colored carlsbad twins of orthoclase in the green meta-diorites. A more complete description of this "granitization" will be given in the petrographic description of the gneisses.

The youngest rock, present in the undifferentiated gneisses, is a massive granodiorite. This rock is found in small intrusive masses throughout the entire area occupied by the gneisses. Although it was not observed in contact with the "rose colored" granite, the writer believes that the presence of cataclastic structures, in the latter and their absence in the granodiorite, constitutes sufficient evidence for separating the two intrusions.

The gneisses, on the southeast sides of Coldwater and San Antonio Canyons, are somewhat different in appearance from those described along the Middle Fork of Lytle Creek. The old meta-sediments are preserved as roof pendants and inclusions in gneisses ~~of metamorphic rocks~~ of almost certain igneous origin.

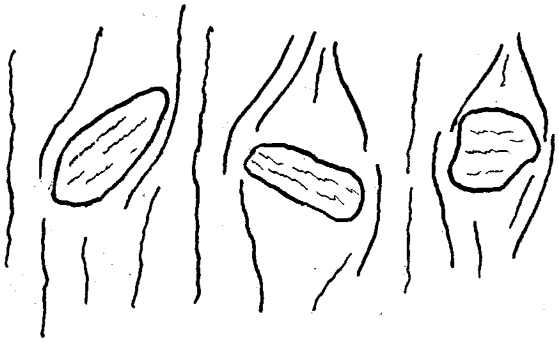

Figure 4. Generalized sketch of inclusions of meta-sediments in igneous gneisses found on the southeast side of Coldwater Canyon. Note the random orientation of the schistosity in these inclusions.

The schistosity in the inclusions may or may not be parallel to the foliation and banding in the enclosing rock. (See figure #4). As illustrated in figure #5, the gneissic structure, in the enclosing rock, appears to be partly due to flow and partly due to an incomplete assimilation of the inclusion.

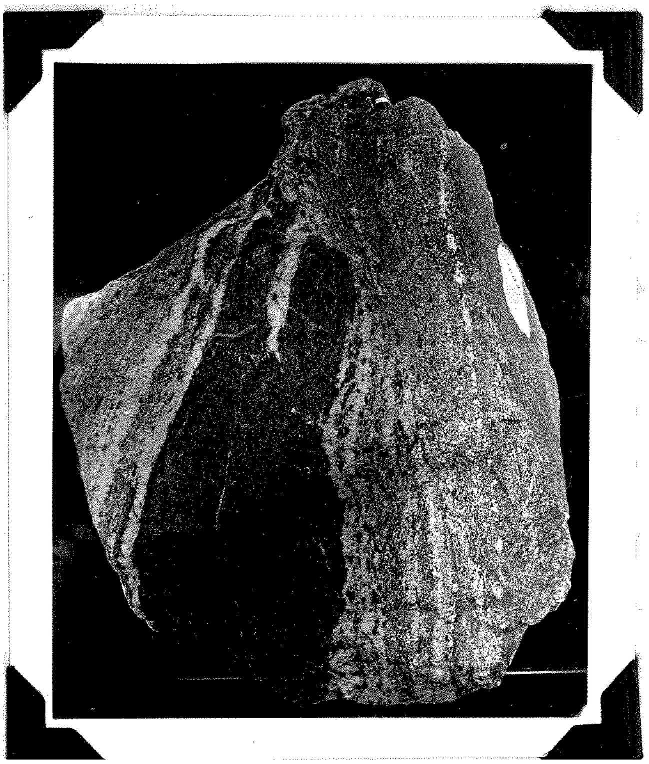

Figure 5. Amphibolite inclusion in banded gneiss. Sample was obtained 2 miles north of the summit of the Camp Baldy-Stockton Flats road. About 1/5 natural size.

There are several possibilities as to the origin of these gneisses--

1. They may have been igneous rocks that were intruded and completely consolidated before the

climax of regional metamorphism was reached and thus have been subjected to the same conditions as the associated sediments.

2. They may have been intruded at the climax of metamorphism or during its waning stages.
3. They may have been intruded after metamorphism and owe their foliation to segregation or convective movements with the magma.

On the basis of field evidence, the writer believes that the first hypothesis may be dismissed. If foliation in the ortho-gneiss is due to progressive metamorphism of a consolidated igneous mass, the schistosity in the xenoliths should not exhibit a random orientation as shown in figure #4, but should be parallel to the foliation in the enclosing rock. A discussion of the last two possibilities will be deferred until after the petrographic descriptions of the rocks have been given.

Petrographic Description of Meta-Sediments

Marble (#G3B)-- Fine to coarse grained marbles are well distributed throughout the undifferentiated gneisses. This section, although not a typical marble, was of particular interest inasmuch as the hand specimen possessed a rude platy parting. The relation of this parting to the bedding and schistosity in the adjoining schists is not known since the hand specimen was collected from some talus at the base of a high cliff in the upper portion of Coldwater Canyon.

Under the microscope, interlocking grains of calcite, which vary in size from .25mm. to 2mm. are seen to make up the greater part of the rock. Small grains of quartz usually less than .25mm. in size, chlorite and a few small crystals of pyrite are also present but probably do not constitute over 20% of the rock.

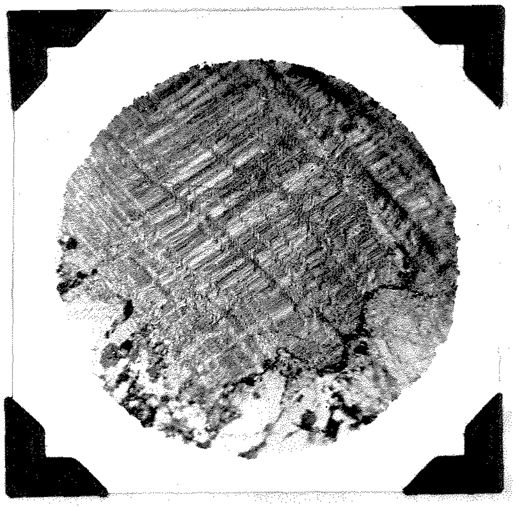

Figure 6. Photomicrograph of marble.(Crossed nicols x 64). Note the gliding planes in the calcite and also the fine grained mosaic of quartz around the border of the large crystal.

Figure #6 shows the gliding planes present in some of the larger crystals of calcite. According to A. Harker (9), these gliding planes may be produced during the process of grinding a thin section of a crystalline limestone or may be the result of mechanical deformation of the rock subsequent to its recrystallization.

Garnet granulite-- An interesting series of gneisses are found along the trail between the summit of the Camp Baldy-Stockton Flat road and Telegraph Peak. Some of the gneisses appear to be sedimentary in origin while others, partly sedimentary and partly igneous in origin, are best described as migmatites. The intrusive igneous material appears to be granitic in composition.

Section 9x was selected from an outcrop of folded and banded gneisses approximately ½ mile from the summit of the Camp Baldy-Stockton Flat road. The writer is inclined to believe that this garnet granulate is a metamorphosed feldspathic sandstone.

Quartz is the most abundant mineral. It is present in large crystals (1.5mm.) and also in small (less than .10mm.) idioblastic inclusions in plagioclase feldspar. Orthoclase and a positive plagioclase feldspar (Ab.85, An.15) are present in about equal proportion and together with the quartz make up approximately 70% of the rock. Veinlets of untwinned albite, intergrowths of quartz and plagioclase feldspar, and myrmekitic intergrowths of quartz and orthoclase were also noted. In addition to these minerals, there are a few fractured crystals of reddish garnet present. Sericite is abundant and appears to be confined to discontinuous parallel seams approximately .5mm in thickness. Muscovite is also quite common.

All of the minerals show the effects of cataclastic deformation. Strain shadows, sutured boundaries and granulation in the quartz, bending of the twinning lamellae in the plagioclase feldspar, and fracturing of the garnet crystals show that this rock has been subjected to powerful mechanical forces. Inasmuch as the garnet and feldspar crystals, once broken, did not possess a recuperative power of recrystallization, one would infer that this mechanical deformation was not accompanied by high temperatures. In short, this rock has been dynamically metamorphosed. This usage of the term, dynamic metamorphism, conforms with that of A. Harker (9) in his recent textbook on metamorphism.

Meta-Diorite

Near the junction of the North and Middle Forks of Lytle Creek, there are several exposures of massive dark green gneisses which are believed to be metamorphosed diorites. These massive rocks appear to cross-cut the meta-sediments, but with the exception of the intrusive contact along the Glenn Ranch-San Bernardino road, these two rocks were not observed in contact.

The meta-diorite is a well foliated, coarse grained rock containing a glassy feldspar, hornblende, biotite and thin seams of chlorite.

Section B6A, which is a hornblende plagioclase gneiss was obtained on the south side of the Middle Fork of Lytle Creek, 2 miles above Irvingdale. Large (average 1.5mm) rounded crystals of basic oligoclase (An. 25. Ab. 75) and orthoclase are present in about equal amounts and form approximately 60% of the rock. These crystals are surrounded by a finer grained matrix, consisting of quartz, untwinned albite, biotite, and chlorite. In addition to these minerals, green pleochroic hornblende (pargasite) is well distributed throughout the section.

This section shows the "round grained" appearance of oligoclase which A. Harker (9) considers to be a characteristic structure of a magma intruded and crystallized under powerful orogenic forces. It is possible that some of the cataclastic effects, believed by the writer to be due to mechanical deformation at a low temperature, were produced by dynamic causes before the completion of magmatic crystallization, and should therefore be considered protoclastic rather than cataclastic structures. If this hypothesis is correct, orogenic forces must have been active for a long period of time since the "rose colored" granite,which was intruded into the meta-diorite,shows every evidence of mechanical deformation.

Two other sections from these hornblende plagioclase gneisses were examined to determine the textural and mineralogical changes that accompany granitization. Section 250A. was made from a rock which was fifty feet from a small dike of "rose colored" granite while section 250B was made from a rock which was at least 150 feet from the nearest visible intrusive. For the sake of brevity and clearness, the results of this work will be presented in summary form.

1. The mineral composition of 250B is not greatly different from the hornblende plagioclase gneiss which has been described. Chlorite is present as pseudomorphs after hornblende and biotite. Magnetite is present in these pseudomorphs and appears to be one of the products of the "chloritization" of biotite and hornblende. Small idioblastic crystals of zoisite are fairly common.

2. Cataclastic effects are common. The larger feldspar crystals are fractured and broken. One band of crushed material traversing the section is made up of fine particles of quartz, feldspar and chlorite which average less than .15mm. in size. A portion of this band is illustrated in figure #7.

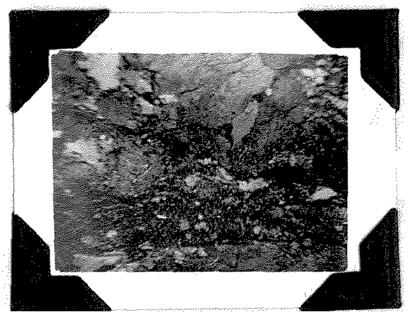

Figure 7. Photomicrograph of crushed band in metadiorite. (crossed nicols x 20)

3. Chlorite and calcite appear to be the only new minerals formed during dynamic metamorphism.

4. Section 250A was made from meta-diorite, which had been permeated by solutions from an intrusive granite dike. In the field this contact rock can be distinguished from the normal meta-diorite by its pinkish color and by a greater abundance of potash feldspar.

5. Orthoclase is much more abundant in section 250A than in section 250B. It is not always possible to distinguish between authigenetic and introduced orthoclase for both varieties have been affected by later cataclastic deformation. However the introduced rose colored variety, which is common in the contact rock, is usually present in sub-idioblastic Carlsbad twins and can be distinguished in this way from the older generation. Fractured and broken crystals of sericitized oligoclase and hornblende, in varying stages of chloritization, are also found.

Surrounding these larger minerals, which average 1.5mm. in size is a finer grained mosaic of quartz, untwinned albite, chlorite, and small fragments from the minerals already mentioned.

These minerals average less than .10mm. in size. The presence of quartz and untwinned albite in the finer grained matrix would suggest that there had also been additions of silica and soda to the meta-diorite during the intrusion of the "rose colored" granite.

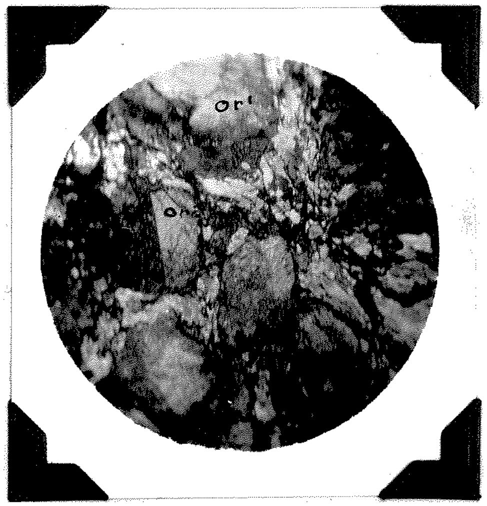

Figure 8. Photomicrograph of meta-diorite adjacent to an intrusion of "rose colored" granite. Note the two generations of orthoclase present: or^1--older porphyroclast somewhat modified by corrasion and cataclasis; or^2--younger sub-idioblastic Carlsbad twins. The arrangement of the finer grained matrix around the porphyroclast of orthoclase is believed to be partly due to mechanical deformation of the rock and partly due to an addition of new minerals. (Crossed nicols x 20)

The fluxion arrangement of the quartz and albite around the larger feldspar crystals, illustrated in figure #8, resembles a true cataclastic structure. Dr. G. H. Anderson (21), of the California Institute of Technology, has proposed the term, pseudo-cataclastic for these textures which resemble true cataclastic textures but which differ from them in the following points: (a) There has been an introduction of new minerals in the finer grained mosaic surrounding the larger crystals. (b) Corrasion borders are present around the feldspars and quartz. Granulation and fracturing of the feldspars would suggest that both true and pseudo-cataclastic textures are present in section 250A.

"Rose Colored"Granite

Small dikes of"rose colored"granite 15 to 20 feet in thickness are fairly common in the undifferentiated gneisses. The rock possesses a distinctive rose color which distinguishes it from the younger Jurassic granite and granodiorite.

Three sections (G7A, G7B, and 14G) were examined. Despite

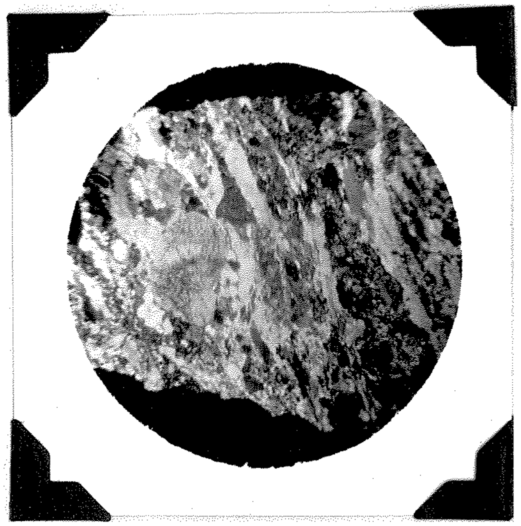

Figure 9. Photomicrograph of banding in "rose colored"granite produced by mechanical deformation. Note the porphyroclasts of orthoclase and the elongated lenticles of quartz. (Crossed nicols x 20)

the fact that these samples were taken from different dikes in widely separated parts of the area, they show little variation in mineral composition or texture. Quartz and orthoclase are present in about equal amounts and together form over 90% of the rock. Chlorite, epidote, magnetite and a few crystals of oligoclase are also present.

This rock shows every evidence of cataclastic deformation. The quartz appears to have been drawn out and recrystallized in elongated lenticles and the feldspar porphyroclast have been fractured and broken. Figures 9 and 10 show the character of this incipient mylonitization.

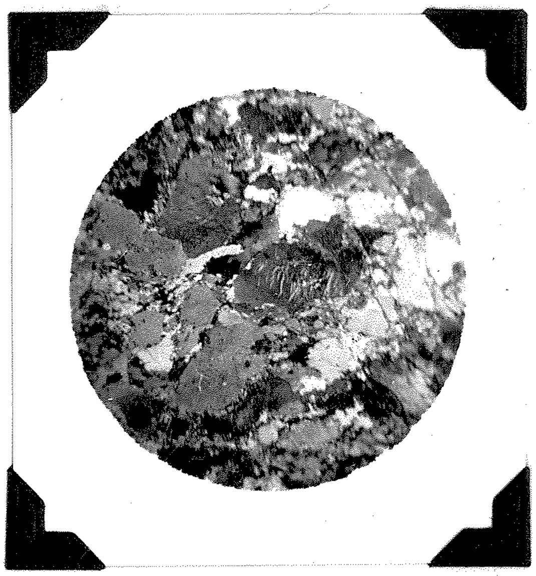

Figure 10. Photomicrograph of section 14G from the "rose colored" granite. Note the "wormy" intergrowth of quartz and potash feldspar near the centre of figure. (Crossed nicols x 20).

It is possible that there has been some addition of new material in the groundmass. The presence of a small veinlet of epidote in section 14G would support this suggestion.

On the southeast side of Coldwater and San Antonio Canyons, there is an interesting group of gneisses which are partly igneous and partly sedimentary in origin. These ortho-gneisses contain inclusions of the meta-sediments and have been intruded by massive unmetamorphosed granodiorite. Both the meta-diorite and the "rose colored" granite are absent from this portion of the area so their relationship to the ortho-gneisses in Coldwater Canyon is not known.

The wide variety of rock types present in this portion of the area precluded any possibility of selecting a few samples and considering them to be representative of the ortho-gneisses. However, if any one type could be said to predominate, it would be a porphyroblastic plagioclase gneiss.

Porphyroblastic plagioclase gneiss (#11x)

This rock outcrops along the southeasterly facing ridge directly across from Telegraph Peak in the upper portion of Coldwater Canyon. It is dark grey to brown in color and contains numerous porphyroblasts of feldspar which vary in size from (1.5mm. to 6mm.).

Oligoclase, which is badly altered to sericite and kaolin, constitutes over 50% of the rock. Due to this alteration, it was impossible to determine the composition of the oligoclase. Quartz, brown biotite, muscovite, idioblastic zoisite, and epidote make up the remainder of the rock.

Strain shadows in the quartz and a slight bending of the biotite crystals were the only evidences of strain noted in this section.

A series of banded and folded gneisses are found in the neighborhood of Telegraph Peak. These gneisses are made up of alternating dark and light colored bands which curve and in some cases almost close in a small circle.

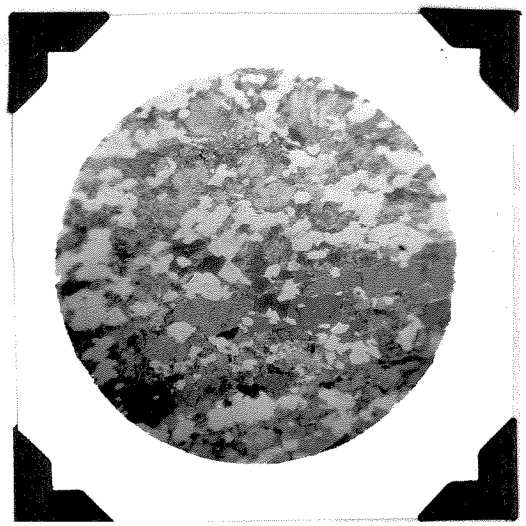

Figure 11. Photomicrograph of section 15x from banded gneisses near the summit of Telegraph Peak. (Plane light x 20)

Figure #11 shows the transitional nature of the contact between the light colored quartzo-feldspathic band and the dark colored band, rich in hornblende. This banding may have been produced by an injection of granitic material into a metamorphosed rock, or it may be a primary banding in an unmetamorphosed igneous rock. Before attempting to decide between these two hypothesis, it would be necessary to collect more data on the field occurrence of this rock.

With the exception of the Jurassic granodiorite, this gneiss has undergone less dynamic metamorphism than any of the other rocks examined from the undifferentiated gneisses.

Injection gneisses are found along the Camp Baldy-Stockton Flat road, some three miles above Stockton Flat, and also on top of the high ridge between Coldwater Canyon and the Middle Fork of Lytle Creek. Figure 12 shows the character of these "lit par lit" injections from the last mentioned locality.

Figure 12. "Lit par lit" injection of granitic material into schistose rock. About 1/4 natural size.

Section 108h was obtained from an injection gneiss exposed in a road-cut along the Camp Baldy-Stockton Flat Road.

This gneiss has been injected into the older meta-sediments. Adjacent layers of marble are locally altered to lime-silicate rocks and in some cases have been "stoped out" and preserved as inclusions in the gneiss.

Megascopically, the rock is seen to contain large ovate porphyroblasts of feldspar(varying in size from 3 to 8mm.), quartz and dark green chlorite.

Under the microscope these large ovate porphyroblasts of feldspar are seen to be made of orthoclase and plagioclase in about equal amounts. Because of the sericitization of these feldspars, it is almost impossible to determine their composition. Quartz is well distributed throughout the section and together with the feldspars makes up over 80% of the rock. Epidote is next in abundance. There is a small amount of biotite,in various stages of chloritization, present in the section. In addition to these minerals, several crystals of zoisite and of calcite were seen. The writer is inclined to believe that this calcite was derived from an adjacent limestone, but there is also the possibility that it may be an alteration product of some lime silicate such as grossularite or anorthite.

Conclusion

The absence of zoning in the feldspar, the presence of cataclastic effects and distinctive metamorphic minerals such as zoisite and epidote,would suggest that the ortho and injection gneisses in Coldwater and San Antonio Canyons were intruded into the older rocks under powerful orogenic forces. The relation of this intrusion to the regional metamorphism of the meta-sediments has been discussed on page 12. Field evidence does not favor the hypothesis that the foliation in these gneisses is due to progressive metamorphism of a consolidated igneous mass. On the other hand, microscopic work showed that the rock had suffered a certain amount of deformation and contained stress minerals such as zoisite and sericite. Therefore, the writer is inclined to favor the second hypothesis outlined on page 12, viz; that these gneisses were intruded into the older rocks during the waning phase of regional metamorphism or during a later epoch of dynamic metamorphism.

Summary

At the risk of repetition, the writer wishes to summarize the result of field and microscopic work on the undifferentiated gneisses.

1. The oldest rocks in this series appear to be a group of meta-sediments. Marbles, impure quartzites, metamorphosed arkosic sandstones (granulites), quartz mica schists and mica schists are included in this group.

2. The schistose and gneissose character of these meta-sediments, and the presence of garnet in some of the rocks would indicate that the original constituents of the sediments have been thoroughly recrystallized.

3. Following this recrystallization, which probably accompanied an epoch of regional metamorphism, the rocks were dynamically metamorphosed. This mechanical deformation modified the textures and structures produced during the previous period of regional metamorphism.

4. The meta-sediments have been intruded by a well foliated diorite. The writer was not able to determine whether this foliation was due to the progressive metamorphism of a consolidated igneous mass or whether it was due to intrusion and crystallization under pressure and directed stress, ie; piezocrystallization.

5. The meta-diorite shows every evidence of dynamic metamorphism. Cataclastic textures and structures are common. Adjacent to an intrusion of "rose colored" granite, pseudo-cataclastic textures have also been developed.

6. Both the meta-sediments and meta-diorite have been intruded by a "rose colored" granite which can be distinguished from the younger unmetamorphosed Jurassic granite and granodiorite by: (a) mineral content, quartz and orthoclase make up over 90% of the rock; (b) presence of advanced cataclasis. Some of the sections show the milled or rolled out appearance of a typical mylonite; (c) rose color which appears to be characteristic of the rock.

7. In Coldwater Canyon a group of ortho-gneisses are found which contain inclusions of the meta-sediments. The meta-diorite and rose colored granite are absent from this portion of the area so their relationship to the ortho-gneisses is not known.

8. The writer believes that the foliation in the ortho-gneisses was produced by crystallization under pressure and directed stress rather than by the progressive metamorphism of a consolidated igneous mass.

9. The meta-sediments, meta-diorite and ortho-gneisses in Coldwater Canyon have been intruded by unmetamorphosed granodiorite. The "rose colored" granite and the granodiorite were not observed in contact.

PELONA SCHISTS

The Pelona schists were first described by O. H. Hershey (10) from the Sierra Pelona highlands at the western end of the San Gabriel Mountains. He considers them to be of pre-Cambrian age and tentatively correlates them with the Abrams schists of the Klamath region in northern California. L. F. Noble (18) has described and mapped a long narrow southeasterly extension of the Pelona schists on the southwest side of the San Andreas fault, that is on the southwest side of Lone Pine Canyon and Swarthout Valley. He also considers them to be of Pre-Cambrian age and thinks that they may be a possible correlative of the Rand schists of the Randsburg district.

The Pelona schists have a wide areal distribution in this portion of the San Gabriel Mountains. As was previously stated, the schists form a long narrow band between the San Andreas fault on the northeast and the San Jacinto fault on the southwest. In addition, the metamorphic rocks north of Coldwater Canyon are lithologically similar to those across the San Jacinto fault; so they are also considered to be a part of the Pelona schists.

These schists have been intruded by masses of Mesozoic granite and by numerous melanocratic dikes of probable Miocene age.

Petrologic Character of the Rock Types

The Pelona schists do not vary greatly in their petrologic character. Chlorite and mica schists are the most common varieties although tremolite, graphite and talc schists are not uncommon.

Intercalated with these rocks are impure quartzites and marbles.

The well defined bedding and the presence of quartzites and marbles would indicate a sedimentary origin for the greater part of this formation. Therefore, the variation in rock types may be largely attributed to differences in the chemical composition of the original sediments.

In general, the schists have a northwest trend and dip at a fairly high angle towards the north. The schistosity is parallel to the bedding.

Schists between Lone Pine Canyon and North Fork of Lytle Creek

This belt of metamorphic rocks has been thoroughly crushed and broken by movements along the San Andreas and San Jacinto faults. When the magnitude of these movements and the incompetent character of these schists are taken into consideration, it is not at all surprising to find that the rocks have been almost reduced to gouge over wide areas.

L. F. Noble (18) has covered this portion of the area in his detailed mapping along the San Andreas fault, so the writer did not attempt to make more than cursory examination of the rocks..

Schists Along the Camp Baldy Lytle Creek Road near Stockton Flats

A detailed examination of the Pelona schists was made in this portion of the area in the hope of securing definite information on their stratigraphic succession and structure. It was found that the general absence of distinct lithologic types and the presence of a great deal of local faulting complicated this study.

A section, two hundred and fifty feet in thickness, is exposed in road-cuts along the Glenn Ranch-Stockton Flat road a few hundred yards below the entrance to Stockton Flat camp grounds. Originally, these schists were well bedded sediments consisting of alternating thick sandstones and thinner shale members. Across Stockton Wash and directly along the strike of these quartz mica and chlorite schists, metamorphosed sediments of an entirely different appearance are found. Here coarse green cholorite schists containing porphyroblasts of orthoclase and magnetite are interbedded with impure white marbles and quartzites. This change might be due to lateral variation or faulting. The latter explanation would seem to be the more tenable inasmuch as undisturbed schists, in other parts of the area, show very little variation in composition along their strike.

Near the summit of the Camp Baldy-Stockton Flat road, the original character of the sediments is beautifully displayed. Thin bedded argillites alternate with massive impure quartz mica schist and together form high cliffs. These rocks aside from a thorough recrystallization of the original constituents, have not been greatly altered during the process of metamorphism. The well preserved bedding planes, illustrated in figure 13 . show the narrow limit of diffusion in a low grade of metamorphism.

Figure 13 . Outcrop of Pelona schists along the Camp-Baldy-Stockton Flat road one-half mile above Stockton Flat.

Petrographic Description

Chlorite orthoclase magnetite schist (#105)--This rock is intercalated with chlorite schists, marbles and impure quartzites on the northwest side of Stockton Wash. Although it is not of common occurrence in the Pelona schists, numerous rocks quite similar to it have been found as float in Coldwater Canyon and in the North Fork of Lytle Creek.

The hand speciment is dark green in color and contains numerous idioblastic crystals of magnetite. Under the microscope, large, rounded porphyroblastic crystals of orthoclase and magnetite, which vary in size from a fraction of 1mm. to 1mm., are the most prominent minerals. Chlorite, present in smaller flakes, is next to orthoclase in abundance. Epidote is also quite common. Zoisite, biotite, hematite, and quartz are present in minor quantities.

Eyed structures, around the ends of hard resistant porphyroblasts of magnetite,are illustrated in figure 14. The magnetite seems to have borne the greater part of the pressure and thus facilitated the development of larger crystals of biotite and chlorite. The growth of biotite at the expense

Figure 14. Chlorite orthoclase magnetite schist. (Ordinary light x 20). Note the development of the larger flakes of biotite around the end of the large crystal of magnetite.

of chlorite seems to have been favored by the lower pressure existing around the ends of the resistant grains of the magnetite. There are a few small flakes of biotite set across the schistocity of the rock in other parts of the section.

Impure Quartzite (#105B)

This rock is interlaminated with the chlorite orthoclase magnetite schist described above. It is white to grey in color and contains abundant quartz.

Under the microscope, the following minerals are present: quartz (70%), calcite (10%), and muscovite (20%). The calcite and muscovite occur as small flakes usually less than .25mm in size. The quartz has a platy appearance and all of the crystals show strain shadows. Sutured and fretted boundaries, and incipient granulation are illustrated in figure .

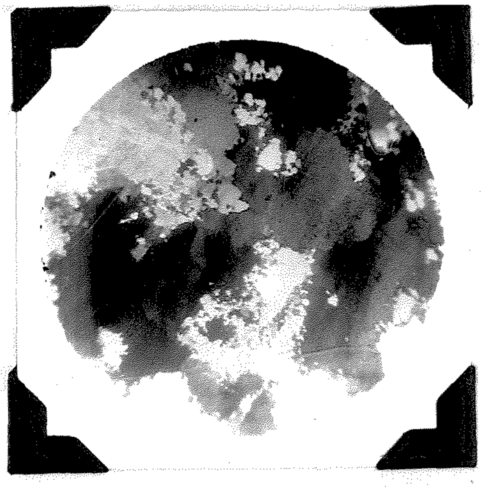

Figure 15. Impure quartzite. (Crossed nicols x 20). Photomicrograph of mortar structure in quartz. Note the flamboyant extinction in the individual crystals.

Quartz Biotite Schist (#150)

This schist outcrops along the forestry road on the top of the ridge between Lone Pine Canyon and the North Fork of Lytle Creek. The rock is dark grey in color and shows a parallel alignment of biotite flakes separated by quartz.

Platy quartz, elongated in the general direction of schistosity of the rock, is the most abundant mineral. The crystals all show undulatory extinction and under high magnificiation, an aggregate of fine grains between the larger crystals may be distinguished. The biotite, which is next to quartz in abundance, is green in color. The individual crystals are elongated, and in extreme cases may possess a ratio of length to thickness as high as 10:1. These two minerals make up over 90% of the rock with garnet, magnetite, and zoisite comprising the accessories.

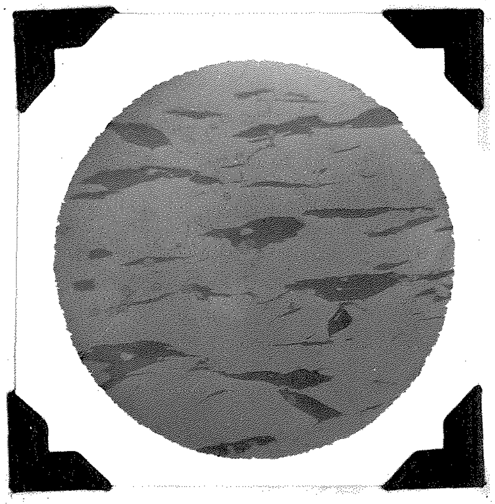

Figure 16. Quartz biotite schist. (Ordinary light x 20). Note the small rounded grains of garnet and zoisite.

The crystals of garnet and zoisite are small, ranging up to .25mm in size. In many cases the garnet crystals have been shattered and drawn out by movements subsequent to their formation.

Actinolite Schist (#151)

This schist is intercalated with fairly coarse quartz muscovite and mica schists on the southwestern side of the ridge between Lone Pine Canyon and the North Fork of Lytle Creek. This rock is of green color, and exhibits a criss-cross arrangement of long acicular crystals of actinolite. A small veinlet of quartz is also present in the hand specimen.

Under the microscope the rock is seen to possess a nematoblastic or fibrous structure due to an almost parallel arrangement of long acicular actinolite. Numerous large square and rectangular crystals of enstatite, which range up to 1.5mm in size, are also present. This occurrence of enstatite, in an area of regionally metamorphosed rocks, is interesting inasmuch as enstatite, according to A. Harker (9),

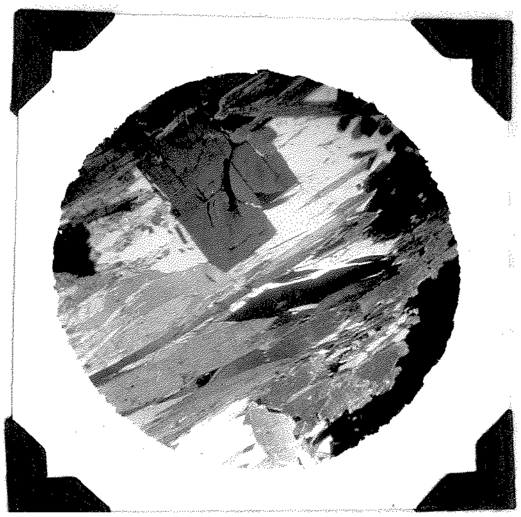

Figure 17. Actinolite schist. (Crossed nicols x 20). The mineral with the rectangular cross section in the center of the photomicrograph is enstatite, while the fibrous elongated mineral is actinolite.

is a typical non-stress mineral. With the exception of quartz which has been introduced since recrystallization of the rock, these two minerals, actinolite and enstatite, make up the greater part of the rock. Small patches of what appears to be serpentine or chlorite were also noted.

Impure Quartzite (#B100)

The hand specimen was collected from an outcrop of the Pelona schists on the northwest side of the canyon one mile to the southeast of Coldwater Canyon. In the field this rock shows the effect of differential weathering. Narrow elongated lenticles of calcite in the quartzite have been weathered out and give the rock an irregular pitted appearance.

Under the microscope, the quartzite is seen to be made up of a fine grained granular mosaic of quartz. Chlorite, calcite, muscovite, untwinned albite, epidote,and zoisite are present in minor amounts and do not make up more than 10% of the rock. These last named minerals appear to be confined to narrow parallel bands in the quartzite and probably represent recrystallized impurities in the original quartzose sediment. However, the calcite does not appear to be confined to these bands for it occupies several cross fractures in the rock.

Folded Muscovite Schist #107

Folded and buckled schists are found in many localities throughout the area occupies by the Pelona schists. Section #107 was obtained from a minutely folded green chlorite schist which outcrops along the Camp Baldy-Stockton Flat road, one-half mile above Stockton Flat.

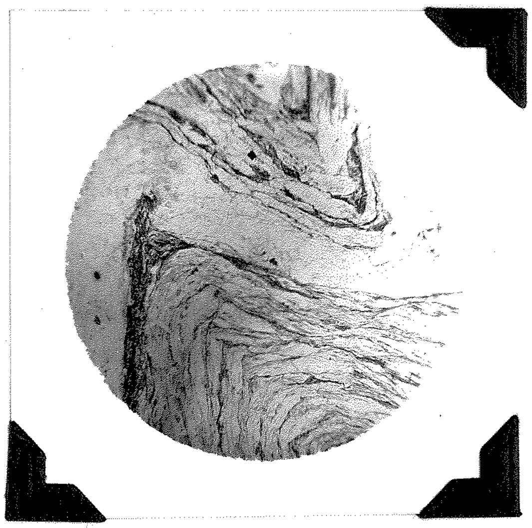

Figure 18. Folded muscovite schist. (Ordinary light x 20)

An unusual variety of micro-structures are present in this section. Figure 18 is a photomicrograph of a small fold which measures approximately 2mm. from the crest of the anticline to the trough of the adjoining syncline. Thinning on the limbs and thickening at the crests and troughs of the folds may be seen in the accompanying figure, and appears to be quite common throughout the rest of the section. This would suggest that a certain amount of solution and recrystallization accompanied the deformation of the rock.

Quartz (30%), orthoclase (40%) are the two most abundant minerals. Muscovite, chlorite and hematite are also quite common and are present as narrow seams between the bands of quartz and orthoclase. The orthoclase contains numerous inclusions of sub-idioblastic quartz. In most cases these inclusions are present in rows, more or less paralleling the banding in the folded schist.

As would be expected, the individual minerals are often deformed. Minute folds and crenulations were noted in biotite; strain shadows are present in the quartz and the orthoclase has been fractured and broken.

Despite the somewhat varied assemblage of rock types described above, the observer is more impressed by the homogeneity of the formation than by its heterogeneity. Coarse clastic sediments are conspicuously absent from the Pelona schists in this area. The lack of variation in the schists throughout the area, the absence of coarse clastic sediments, the absence of lateral variation in the individual beds, the well defined bedding planes and the chemical composition of the rocks, viz. argillaceous, impure calcareous and impure quartzose rocks,suggest that these sediments were deposited in a large body of water at some distance from the nearest high-standing land mass.

Igneous rocks older than the Mesozoic granite were found to be associated with undifferentiated gneisses, but careful search failed to reveal any of these igneous bodies in the Pelona schists. There may have been some basic sills, intruded into the sediments before recrystallization, which are now represented by the chlorite orthoclase magnetite schist described on pages 32-34.

Chlorite, magnetite and epidote are abundant and show that these schists originally contained a high percentage of iron. There are several possibilities as to the origin of this rock: (a) It may be the metamorphosed equivalent of a basic sill intruded into the Pelona schists prior to recrystallization. (b) It may have been a sediment derived from the weathering of a basic igneous rock. (c) It may have received an addition of iron by hydrothermal solutions prior to or accompanying recrystallization. This last hypothesis is not supported by field evidence inasmuch as the nearest visible igneous intrusive mass is several miles to the southeast. In addition, a section made from an impure quartzite intercalated with the chlorite orthoclase magnetite schist fails to show any of the iron bearing silicates that are so common in section (105). It is more difficult to decide between the first two theories. However, the well defined bedding planes and the sharp rather than blended contact of this rock with adjacent layers would favor a sedimentary rather than an igneous origin.

Light colored "granite porphyry" dikes and sills are found at many localities in the Pelona schists and are particularly common near intrusive masses of granodiorite. In the upper portion of San Antonio Canyon, these light colored sills have been injected into the dark green schists and have imparted a banded appearance to the cliffs. This constitutes one of the many scenic features that may be seen from the Camp Baldy-Stockton Flat road.

Figure 19. Light colored "granite porphyry" sill in the Pelona schists. Photograph was taken along the Camp Baldy-Stockton Flat road--2 miles north of the summit.

The Pelona schists do not appear to have been metamorphosed by the intrusive granodiorite. "Lit par lit" injections are found close to the contacts. Small flakes of pyrrhotite will also be seen in a massive green contact rock from the south side of the Irvingdale fault, 1½ miles southeast of Coldwater Canyon.

Figure 20. Pelona schists (ps) and an intrusive sill of "granite porphyry" (gr) cut by two small melanocratic dikes (md) along Camp Baldy-Stockton Flat road, 2½ miles south of the summit.

In addition to the dikes and sills of "granite porphyry", there are numerous dark colored dikes which cross-cut both the "granite porphyry" sills and the Pelona schists. Figure # 20 shows the relationship of these small melanocratic dikes to the schists and light colored acidic dikes.

METAMORPHISM

On the basis of mineral content, it is difficult to decide whether these rocks were metamorphosed during an epoch of regional metamorphism or of thermal metamorphism. Orthoclase is quite common. According to A. Harker (9), the formation of this mineral is inhibited by high stress conditions and consequently is only produced in the higher grades of regional metamorphism--when the stress factor is no longer so important. Enstatite is also an anti-stress mineral. On the other hand associations of quartz and calcite are commonly found, side by side, in the same rock. This, according to A. Harker (9), is an association characteristic of regional metamorphism, ie. high stress is present. Zoisite, which is fairly common in the Pelona schists is also considered to be a typical stress mineral. A possible explanation,of these anomalous associations, would be that these schists were recrystallized under elevated temperatures and moderate stress conditions, ie.,an intermediate case between regional and thermal metamorphism.

The schistosity in the Pelona schists is everywhere parallel to the bedding, and in the meta-sediments associated with the gneisses this also appears to be true.

It is difficult to explain this parallelism of bedding and schistosity in a tract of regionally metamorphosed rocks.

Alfred Harker, in his recent text on metamorphism (9), advances a relatively simple explanation of recrystallization during regional metamorphism. He states: "A metamorphosed rock...shows in its component new crystals a strong tendency to parallelism along planes perpendicular to the direction of orogenic pressure". Thus a possible explanation of the schistosity in the Pelona schists would be that the strata were isoclinally folded and recrystallization of the minerals resulted in an orientation parallel to the bedding and normal to the orogenic pressures. Because this must be regarded as a very special case of folding and subsequent metamorphism, the writer does not feel justified in using this method of explaining the development of schistosity over wide areas.

Another theory is that the schistosity was produced by a combination of superincumbent load and elevated temperatures, ie: static metamorphism. In this particular case, this seems to be the better explanation.

AGE AND CORRELATION OF METAMORPHIC ROCKS

A series of undifferentiated gneisses in the western portion of the San Gabriel Mountains have been described by W. J. Miller (17d.), who states:

"The San Gabriel formation comprises a complex lot of rocks, the chief constituents of the mixture being Rubio metadiorite, Placerita meta-sediments, and an old granite (presumably Echo granite). Both the metadiorite and the meta-sediments have been so much intruded and usually so intimately injected by the old granite that the resulting mixtures are of the nature of a metamorphic-igneous complex". This complex appears to be similar to the undifferentiated gneisses, present in the eastern portion of the mountains.

The relationship of the undifferentiated gneisses to the Pelona schists constitutes one of the problems in this region. The Pelona schists have been intruded only by massive igneous rocks. Therefore, it does not seem possible that these schists are older than the undifferentiated gneisses, which show a long record of intrusion and metamorphism. In making this statement, the writer realizes that the drag folds in the Pelona schists, along the San Antonio fault (see geologic section accompanying map), would indicate that the Pelona schists were older than the undifferentiated gneisses. However, as these folds only show the direction of the last movement, the writer is inclined to believe that the gneisses are probably the older of the two formations. There is also the possibility that the meta-sediments associated with the undifferentiated gneisses are the basal portion of the Pelona schists. Lithologically, they are not greatly different, and their metamorphic recod, ie., regional metamorphism followed by dynamic metamorphism is comparable.

On the basis of former descriptions and correlations, these rocks are tentatively placed in the pre-Cambrian.

JURASSIC GRANODIORITE

Massive granodiorite has been intruded into both the undifferentiated gneisses and the Pelona schists, and locally forms areas of considerable extent. The ridge between the North and Middle Forks of Lytle Creek and a portion of the high area between Coldwater Canyon and the Middle Fork are made up largely of granodiorite. The location and extent of these two masses are shown on the accompanying geologic map. In addition, numerous smaller patches, not shown on the map, of the same massive granodiorite are found intimately associated with the undifferentiated gneisses.

In the field this granite is a massive light grey rock in which porphyritic varieties are frequently found. Orthoclase, quartz and biotite are always present and are easily identified in the hand specimen.

Petrographic Description

A typical specimen (G8A), from the ridge between the North and Middle Forks of Lytle Creek, proves to be a granodiorite.

The granodiorite is a medium grained aggregate of quartz (25%), orthoclase (50%) and perthite (15%). Surrounding these larger minerals which vary in size (.5mm to 2mm) is a finer grained mosaic of quartz and biotite.

Granite Porphyry Dikes

Light colored porphyritic dikes and sills are particularly common in the Pelona schists. Their mineralogical composition, as well as their field relationships, show that these dikes were offshoots of the underlying Mesozoic granodiorite. A summary of their field and petrographic character is presented below:

1. The sills and dikes vary in thickness from a few inches to 15 or 20 feet.

2. In general, the larger intrusives possess a coarser texture than the smaller bodies.

3. Border chilling and a consequent reduction in the coarseness of texture was seen at all contacts.

4. Under the microscope, the rocks were seen to be porphyritic. The phenocrysts, which vary in size from less than 1mm. to over 2mm., are surrounded by a fine grained groundmass. Twinned and zoned orthoclase (50%), perthitic intergrowth of orthoclase and albite (20%), biotite (10%), and a few rounded crystals of quartz (10%) are the principal minerals.

Melanocratic Dikes

Melanocratic dikes crosscut the Mesozoic granodiorite and the metamorphic rocks in the northwestern portion of the area. Porphyritic textures and fine grained chilled borders were seen in all of the dikes. Several thin sections were examined and despite some variations in texture and mineral composition, these rocks may be classified as camptonites (see F. F. Grout's (8) tentative classification of the lamprophyres). Andesine, hornblende, hedenbergite, biotite, and chlorite are the major minerals. Figure 21 shows the contact between granodiorite and an intrusive melanocratic dike.

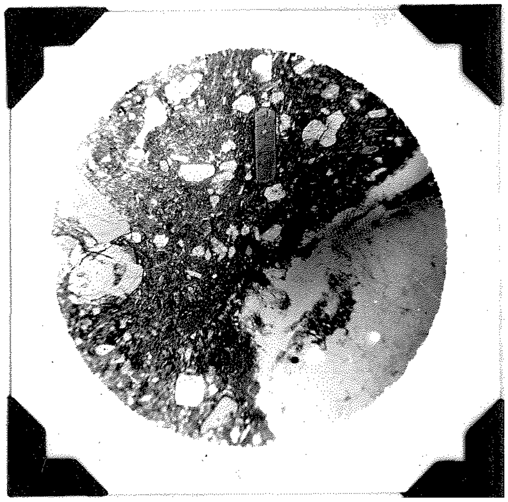

Figure 21. Photomicrograph of contact between granodiorite and intrusive camptonite dike. Section was made from sample obtained on top of Telegraph Peak. (Plain light x 20)

1. The absence of metamorphic textures and minerals in the massive granite indicates that these rocks were intruded after the climax of metamorphism or during its waning phases.

2. The massive granodiorite has been folded, sheared

and broken in the vicinty of the San Andreas, San Jacinto and related faults. Figure #22 is an illustration of folding in the granodiorite which was observed several hundred yards south of the Irvingdale fault in the canyon, 1½ miles southeast of Coldwater Canyon.

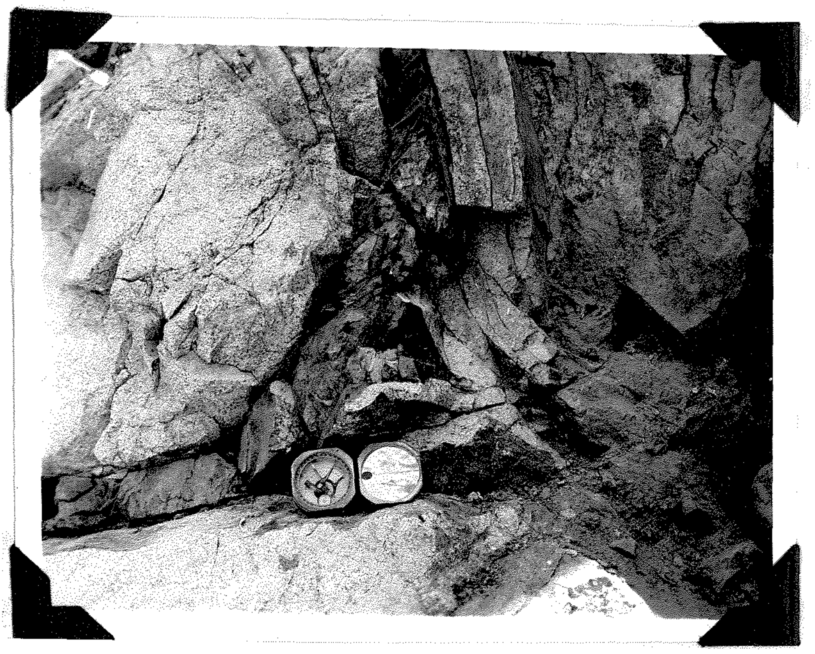

Figure 22. Folding in granodiorite. Dark colored rock is a small melanocratic dike. Photograph was taken in the canyon 1½ miles southeast of Coldwater Canyon.

3. The metamorphic rocks and the granite have been cut by lamproyphre dikes. These rocks have been described as camptonites by the writer.

STRUCTURE

The structure, distribution of rock types and topography of this region are controlled by the San Andreas and San Jacinto fault systems. The intimate crushing and fracturing, that have been the result of long continued movements along these faults, have masked and in some cases completely destroyed the older structural features. Because of this, it is not always possible to distinguish the older from the younger structures.

San Andreas Fault

The San Andreas is the most noted active fault in California. It can be traced over 600 miles in a northwesterly direction from a point in the Salton Basin to Punta Arenas in the coast of northern California. The Fort Tejon earthquake of 1857, the San Francisco earthquake of 1906 and various other shocks of lesser intensity have taken place along this line of seismic activity.

L. F. Noble (18) has mapped the southern extension of the San Andreas fault and shows it crossing the San Gabriel Mountains near Big Pines Recreation Camp at an elevation of 6800 feet. From here it may be traced down Lone Pine Canyon to Cajon Pass and thence along the southern base of the San Bernardino Range to San Gorgonio Pass. The trace of the fault along the southern border of the San Bernardino Mountains is clearly shown in Figure 23.

Figure 23.
Looking eastward from the summit of the ridge between Lytle Creek and Lone Pine Canyon. Mt. San Jacinto on the right and Mt. San Gorgonio on the left are the snow-capped peaks in the distance. Note the trace of the San Andreas Fault along the base of the San Bernardino Mountains.

The peculiar alignment of topographic features along the fault have been admirably described by L. F. Noble (18) who states: "Southeasterly across the area runs a continuously traceable chain of scarps, trough-like depressions and ridges which afford clear and unmistakable evidence of recent earth movements. This line of topographic features, which is so straight that one may see it for twenty-five miles or more, marks the position of a profound fault in the underlying rocks.... Some features involve both recent alluvium and the older rocks, others involve only dissected Quaternary beds and older rocks, and still others involve only early Quaternary and older rocks".

Movement along the fault appears to have been of the strike-slip type with the northeast block moving to the southeast with reference to the southwest block. The amount of displacement is not definitely known but Noble believes that the distribution of Tertiary rocks along the fault would suggest that a horizontal shift of many miles had taken place.

San Jacinto Fault

The San Andreas fault bifurcates at Palmdale on the Mohave Desert and the southern branch, known as the San Jacinto fault, may be traced for over a hundred miles in a southeasterly direction to the Salton Basin, where it probably rejoins the San Andreas.[1] It crosses the San Gabriel Range one mile north of Pine Mountain at an elevation of over 8000 feet and follows the North Fork of Lytle Creek down to Glen Ranch (Applewhite Ranch). Here it reappears from under the stream gravels and cuts across several low ridges before disappearing beneath the recent alluvium in the San Bernardino Valley.

The topographic features along the fault are quite

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[1] Personal communication with Dr. J. P. Buwalda

similar to those described by L. F. Noble (18a) along the San Andreas fault. The trough-like depression occupied by the North Fork of Lytle Creek is comparable to Lone Pine Canyon (see Figures 24-25); the presence of small sag ponds below Glen Ranch and their alignment with saddles in the adjoining ridges offers additional topographic evidence of movement in the underlying rocks.

Figure 24. Looking southeasterly along the trace of the San Jacinto fault. In the foreground--Lytle Creek valley in the neighborhood of Glen Ranch.

San Jacinto Fault Zone

The San Jacinto fault zone exhibits a very complex pattern. The accompanying map shows the location of the major faults, but it could not begin to show the complexity of faulting and fracturing in the adjoining sliver-like blocks.

Figure 25 San Jacinto "rift" valley. View up the North Fork of Lytle Creek.

The San Jacinto fault bifurcates in the extreme southeastern corner of the area. The southern branch, which the writer has named the Irvingdale fault, is almost as clearly marked by topographical features as the master fault. Figure 26, looking in a southeasterly direction down the Middle Fork of Lytle Creek, shows the remarkable alignment of kerncols, kernbuts and saddles along the trace of this fault.

In the high northwestern portion of this region, the

Irvingdale fault parallels the main San Jacinto fault and crosses the summit of the San Gabriel Mountains a short distance to the south of the main fault.

Figure 26. Note the alignment of kernbuts, kerncots and saddles along the trace of the Irvingdale fault. View down the Middle Fork of Lytle Creek.

On the southwest side of the ridge between Lone Pine Canyon and the North Fork of Lytle Creek, there is a marked alignment of saddles, kernbuts, kerncots and gouge zones; so it is entirely possible that there is another fault closely paralleling the main fracture.

Distribution of Rock Types

The distribution of rocks along the San Jacinto fault is shown on the accompanying map. The rocks north of the fault are the Pelona schists; those south of it are the Pelona schists and intrusive Mesozoic granites. In the northwestern portion of the area, the Pelona schists extend across both the Irvingdale and San Jacinto faults, but in the area about Glen Ranch the schists are found only on the north side of the main fault.

On the south side of the Irvingdale fault, one and one-half miles southeast of Coldwater Canyon, there is an intrusive contact between massive granite and the Pelona schists. Approximately two miles farther to the southeast, and on the north side of the fault, another intrusive contact between these same schists and granite may be traced across the ridge to the San Jacinto fault. About 3.2 miles southeast of here and on the north side of the fault, L. F. Noble (18a) has mapped an intrusive contact between massive granites and the Pelona schists.

Movement

The distribution of these Pre-Tertiary rocks would suggest that movement along both the Irvingdale and San Jacinto faults has been similar in kind, if not in degree, to that taking place along the San Andreas fault. In short, movement along all of these faults appears to have been of the strike-slip type with the northeast block moving to the southeast with reference to the southwest block.

It is quite probable that there has been some vertical movement along the San Jacinto and Irvingdale faults. The Irvingdale fault in particular shows a displacement of physiographic features, which would indicate that the southwest side has moved upwards with reference to the northeast side. However, as the evidence for this statement is purely physiographic, the writer will describe these vertical movements in the portion of this paper devoted to the physiographic features of the mountains.

Recent Activity

R. T. Hill (12) has compiled statistics on earthquake shocks, recorded in Southern California for the period from 1780 to 1928, which show that the San Jacinto fault has been the source of nearly six times as many shocks as has the San Andreas fault. Two major earthquakes in Southern California, the Riverside earthquake of 1899 and the Hemet earthquake of 1916, were caused by movement along the San Jacinto fault. With the exception of the Long Beach earthquake of 1933, these two shocks caused greater destruction than any of the previously recorded earthquakes.

With this information in mind, it would appear that the San Jacinto fault is seismically more active than the San Andreas.

Dr. J. P. Buwalda has suggested to the writer that the straight trace of the San Jacinto fault may, at the present time, constitute a line of less resistance than the curved trace of the San Andreas. If this is so, accumulating stresses would be relieved by movements along the San Jacinto before they reached sufficient magnitude to cause slippage along the San Andreas.

San Antonio Fault

The San Antonio fault has a general NE-SW trend and dips at a high angle to the northwest. It can be traced up the north side of Coldwater Canyon to the summit of the range and thence down into San Antonio Canyon.

The fault separates the Pelona schists on the north from the gneisses on the south. Horizontal grooves and slickensides were seen in an exposure of the fault surface in San Antonio Canyon. However, drag folds, in the Pelona schists, would suggest that there has also been some vertical movement -- the north side moving upwards with reference to the south.

Telegraph Peak Fault

The southeastern heading tributaries of Coldwater Canyon have been obliquely cut and captured by a cleft-like fault valley. Figure 27 is a view up this fault valley and shows its oblique trend across the slope of the mountain. Unfortunately, this picture does not show the alignment and matching up of transverse consequent ravines on both sides of the fault. However, this alignment is a very striking feature, and may be seen from the Camp Baldy-Stockton Flats road on the opposite side of Coldwater Canyon.

Figure 27. Looking in a southerly direction up Telegraph Peak fault valley. Note the oblique trend across the slope of the ridge.

Older Structural Features

The presence of cataclastic structures in the metamorphic rocks and their almost complete absence in the Mesozoic granite indicate a period of orogenic activity antedating the intrusion of the granite. Some of the crumpling and fracturing, seen in the schists and gneisses, undoubtedly belongs to this period of deformation.

The absence of rocks younger than the Jurassic granite makes it difficult to assign any definite age to the homoclinal tilt of the Pelona schists and some of the cross faulting. Physiographic evidence indicates that the fault between the Telegraph Peak and Irvingdale faults has not been active since the last uplift of the mountains. This fault, which may be traced across the narrow upland surface, described and illustrated on page 63, is not marked by a line of topographic features which characterize the active faults of the region.

In conclusion, the writer wishes to summarize the results of this work on the structure of the eastern end of the San Gabriel Mountains.

1. The older rocks, viz; the gneisses and Pelona schists have been deeply buried and regionally metamorphosed.

2. After a decline in temperature, these rocks were subjected to powerful mechanical forces. This second or dynamic metamorphism has modified the original textures of the rocks.

3. Following the decline of shearing stress, massive Jurassic granite was intruded into the gneisses and schists.

4. During late Mesozoic or early Tertiary time, the San Andreas, San Jacinto and Irvingdale faults came into existance. Movement along these faults appears to have been of the strike-slip type with the northeast block moving to the southeast with reference to the southwest block.

5. Earthquake statistics show that the San Jacinto fault is more active than the San Andreas at the present time.

A description of the recent structural history of the San Gabriel Mountains is given in the section of this paper which follows.

GEOMORPHOLOGY

The physiographic features of the San Gabriel Mountains have been described in some detail by W. J. Miller (17), W. C. Mendenhall (16), and L. F. Noble (8).

W. J. Miller, in his excellent description of the physiographic history of the western half of the mountains, states: "The mountains formed at the close of the Jurassic ... and seem to have been subjected to erosion during all of Cretaceous time.... During at least part of Eocene time, the sea swept almost entirely around the flanks of the general area now occupied by the San Gabriel mountains as well as some of the region just south of the mountains. That the area must have been high enough to undergo vigorous erosion is indicated by the fact that the clastic Eocene strata accumulated to a thickness of thousands of feet in the immediately surrounding sea.... No matter what may be the uncertainty in regard to the size, shape, structure, and altitude of the San Gabriel Mountain area during Cretaceous and most of Tertiary time, it is very certain, that by late Pliocene or earliest Quaternary time the area had been worn down to the condition of relatively low relief."

Following this period of erosion and some time in the early Quaternary, the uplift of the range was resumed. Vertical movements along the marginal faults and tilting of smaller individual blocks within the mountains occurred at this time. At a later date but before the Glacial Period, L. F. Noble (18) states "that the San Gabriel Range was bowed up locally in the high region about Baldy and north Baldy Peaks". It would appear that this movement was independent of both the San Jacinto and San Andreas faults since they have been elevated along with the rest of the mountains. The effect of this upwarp may be seen in Plate 1. Although the former peneplain has been greatly modified by erosion, it may be traced from its point of emergence from under the alluvium in San Bernardino Valley and Cajon Pass to the summit of the range in the region about Mt. Baldy. The general accordance in elevation of the higher peaks in this region (Mt. San Antonio--10,080 feet; Pine Mountain--9,681 feet; Telegraph Peak--9,003 feet; Cucamonga Peak--8,991 feet;

Ontario Peak--8,756 feet) may also be regarded as additional affirmative evidence for the presence of an old erosion surface at the summit of the range.

The writer is fully aware that the above statements do not entirely agree with those made by W. C. Mendenhall (16) and L. F. Noble (18), who did not believe that there were any old erosion surfaces preserved in the higher portion of the San Gabriel Mountains. However, as further verification of the writer's statements, figures 28 & 29, taken on the summit of the high ridge between Coldwater Canyon and the Middle Fork of Lytle Creek, show the character of the upland surface still preserved on the top of this ridge at an elevation of 7,500 feet.

Figure 28: Upland surface on top of ridge between Coldwater Canyon and Middle Fork of Lytle Creek

GEOMORPHOLOGY

A study of the distribution, attitude and relationship of these various upland surfaces to one another in the eastern San Gabriel Mountains would make a most interesting problem in geomorphology. The surfaces that were found preserved have both a steep northeast and a gentler southeast tilt. Are these attitudes the product of deformation during the Quaternary, or was the old peneplain tilted in this manner during the main uplift of the mountains? How were the sand dunes, illustrated in figure 29, formed? These and various other questions were of great interest to the writer. However, the comparatively short period of time available for field work curtailed this investigation.

Figure 29. View of upland surface on top of ridge between Coldwater Canyon and the Middle Fork of Lytle Creek. Note the sand-dunes covered by vegetation on the edge of the surface.

GEOMORPHOLOGY

L. F. Noble (18), in his description of the topographic features along the San Andreas fault zones, says: "Long, narrow ridges and long narrow valleys trending parallel with the San Andreas fault are the dominant topographic forms. The ridges have even, gently sloping tops. These even tops of the ridges, many of which are composed of heterogeneous rocks of complex structure, are believed to represent remnants of a peneplain".

Figure 30. Looking eastward across the San Gabriel Mountains. Lone Pine Canyon is visible over the top of the ridge in the foreground.

Figure 30, is a view of the San Gabriel Range from the adjacent San Bernardino highlands. The fair agreement in elevation of the even topped ridges across the San Jacinto fault is illustrated in the middle background on the left hand side of the figure. Note also that the northeast side of the ridge between the North Fork of Lytle Creek and Lone Pine Canyon has the appearance of being the back slope of a dissected fault block.

If we are to agree with L. F. Noble (18) that these even topped ridges represent remnants of a peneplain, it should be possible to determine the amount of vertical movement along the San Jacinto and San Andreas faults by the present elevations of these old surfaces, on opposite sides of the faults. Using this method, it would appear that the high mountain block, on the south side of the Irvingdale fault, has been elevated some 1,200 feet with reference to the northern block.

GLACIATION

Glacial features have been described in the San Bernardino Mountains by H. W. Fairbanks and E. P. Carey (6), and by F. E. Vaughan (19). Well preserved cirques and moraines appear to constitute evidence of the former period of ice action. F. E. Vaughan (19) states: "This glaciation was of such local character that the moraines would not extend far beyond the cirques, and no deep glaciated valleys are found in the region.... None of these glaciers appear to have descended much below 8,500 feet, and it will be seen from descriptions given that conditions had to be just right for their appearance at all. Such conditions were northward or eastward facing alcove, which headed sufficiently close to the crest to receive snows which drifted over its summit". A. C. Lawson (15), in his description of the Kern River glacier states, "The lowest point reached by the grand trunk glacier, which once flowed down Kern Canyon, is approximately... 6,600 feet. The moraine is small... for so large a glacier as that occupying Kern Canyon for 24 miles of its length, and seems to indicate that the ice maintained itself at that point but for a short period of time". This region, described by A. C. Lawson (15), is approximately 150 miles north of the San Gabriel Mountains, and the occurrence in the San Bernardino Mountains is only a few miles to the south of the area covered by the writer.

These statements may be contrasted with those made by W. J. Miller (17) who, in his paper on glaciation in the San Gabriel Mountains, says, "The most interesting case of glaciation in the San Gabriel Mountains known to the writer is in Pine-flat Basin, which lies somewhat east of the center of the mountains.... There is good evidence that Pine-flat Basin ... was once occupied by a glacier... which started at an altitude of 8,000 feet and ended at an altitude of 3,000 feet. There is evidence that a glacier formerly occupied the upper two miles of Bear Canyon... which varies in altitude from 4,000 feet to over 6,000 feet.... Careful investigation may reveal evidence of former existance of a glacier in the San Gabriel Mountains. The flanks of Mount Wilson may have housed one or two glaciers, most likely of all however, is the high mountain group in the general vicinity of San Antonio Peak (Old Baldy), but the writer has not examined this region for evidence of glaciation".

Figure 31. View of Mt. Baldy from the northeast.

The critical reader will note that these small glaciers, described by W. J. Miller (17), must have descended to a lower altitude than the Kern Valley glacier in the Sierra Nevada Mountains, and will further note that the gathering ground of these glaciers is at a lower altitude than the terminal moraine of the lowest glacier in the adjacent San Bernardino Mountains. This does not seem possible, and in view of the fact that the writer does not find any indication of former glaciation preserved in the higher portion of the San Gabriel Mountains, it would appear that the features, described by W. J. Miller (17), must be attributed to causes other than glaciation.

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