Senior Thesis Report

on

The Geology of a Portion of the Mint Canyon Region

Chas. A. Dawson, Jr.

1935

Table of Contents

Introduction page

Physical Conditions

Stratigraphy

Petrology and Petrography

Escondido Series

Table of Contents Cont.

Geologic Structure

Historical Geology

List of Illustrations

The Geology of a Portion of the Mint Canyon Region

Location: The region considered in this report is shown on the north-west portion of the Lang Quadrangle, (Edition of 1933, scale 1/24,000) and the north-east portion of the Humphreys Quadrangle, (Edition of 1932, scale 1/24,000) The region is approximately 45 miles north of Los Angeles and therefore lies in the Coast Range Province. The area mapped is a portion of a synclinal basin extending east-west and lying between the San Gabriel Mountains to the south and the upthrown blocks bordering the San Andreas Fault to the north. See map, fig. 1, page 2. On the map, the San Andreas Fault is well indicated by a series of roads traveling in the fault-trough, shown in the upper right-hand portion joining Sandbergs and Palmdale.

Size of Area: The area mapped is about fifteen square miles, some of which is sufficiently incomplete to warrant additional work.

Purpose of Investigation: The work was conducted as a requirement for the degree of Bachelor of Science af the department of Geology and Paleontology at the California Institute of Technology.

Method of Investigation: The mapping was partially done by a party of two, consisting of Mr. Urhig and the author and, in part, done independently. Excellent maps being

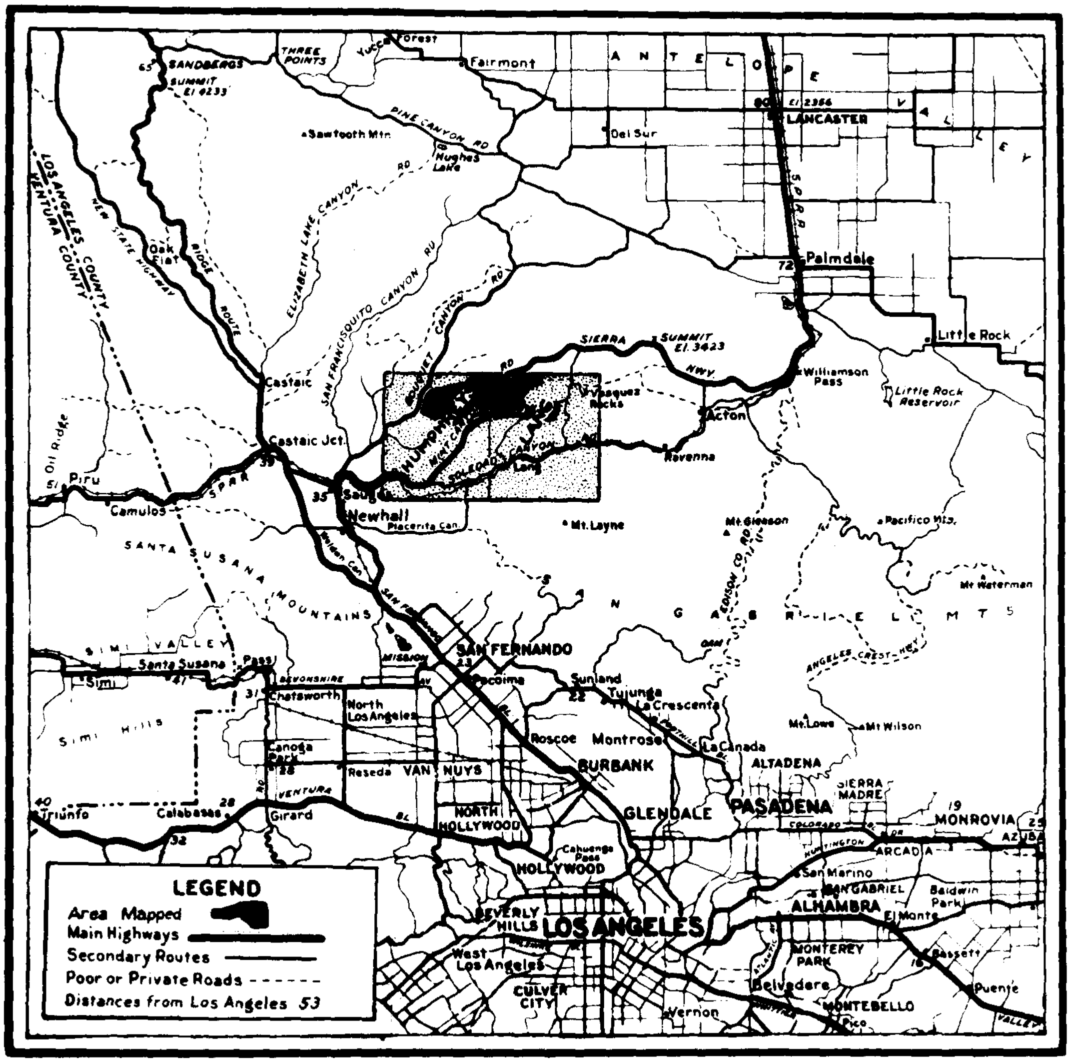


Fig. 1, Showing location of area worked

available, we required no instruments for the location of points on the map. The study of the igneous and metamorphic rocks was made with the use of the petrographic microscope and thin sections.

Summary: Into the pre-Jurassic, steeply dipping paragneisses, probably formerly made up of sandstones, conglomerates and sandy shales, were injected a series of granitics varying in their present composition from quartz monzonites

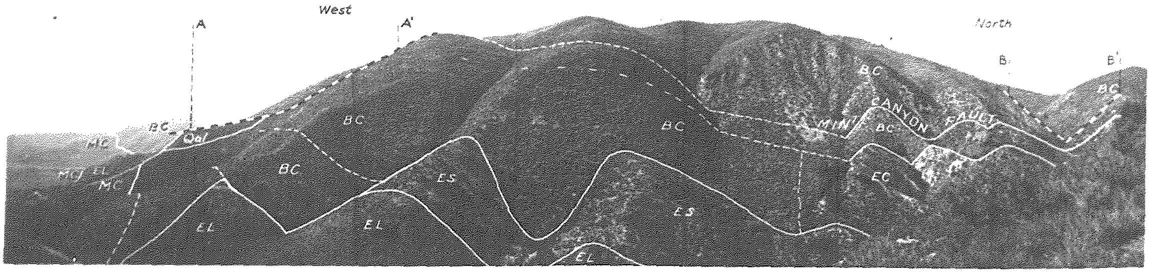


Fig. 2 Panorama of the west side of Forbidden Canyon, showing the fault zone and its relation to the Basement and Escondido. Because of the wide angle included in the picture straight lines appear to be curved. Black and white dashed lines are slopes and should not be confused with faults and probable faults which are shown white. MC-Mint Canyon Formation; BC-Basement Complex; Qal-Quaternary alluvium; EL-Escondido Lava; ES-Escondido Sandstone and Gypsum EC-Escondido Conglomerate.

to granites. The old gneisses were apparently the result of regional, directed metamorphism. There are exposed a number of outcrops showing migmatization which resulted from contact effects during the intrusion of the granitics. The work on these rocks is highly introductory and conclusions on the nature of the migmatite are only suggestive.

A series of closely folded Oligocene(?) sediments and lava have been step faulted in their western extremity where they enter a fault zone, which, through its activity, the Mint Canyon Gorge which is cut in the uplift, was made possible.

Abutting these beds and partly formed of detritus from them, is the Mint Canyon Formation. The contact in the eastern portion of the area is a steep fault which trends east-west. Toward the west, the fault forms the contact between Mint Canyon Formation and Basement. The relations where the contact makes a sudden change in trend toward the north-west indicate that this is also a fault contact. Although there is some indication to show that the contact is depositional, the majority of the evidence collected indicates a fault.

Within the Mint Canyon Formation, in the eastern part of the area, there is a portion of a dome which is cut off on the eastern flank by a north-south fault. The discontinuous relation of the beds forming the dome to the series of north-west dipping beds on the east side of the fault is the chief reason for assuming the existence of a fault. In the west there is also a dome, or tilted nose, but in general, the Mint Canyon Formation has a regional dip of about 18°S. The existence of numerous terraces indicates recent uplift which has caused the cutting back of streams into the former valley floors, accentuating a middle mature topography by the formation of a late youthful stage.

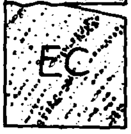
Relief and Elevations: The maximum relief is 1,500 ft., but over most of the area, it is about 500 ft. Elevations range from 1,500 ft. to 3,000 ft. above sea level.

Topography: The topagraphy of this region shows indication of a discontinuous erosion cycle. The uplands are in a middle mature stage of the cycle, with the development of flood plains in the former valleys now represented as terraces. See fig. 2. The slope marked A-A' is typical and shows, at its base, a remnant of a former flood plain containing Quaternary alluvium (Qal.). The low regions show a late youthful stage of erosion as indicated in the same figure by the valley profile B-B'. In many regions a combination of these two features gives the effect of an early mature stage of erosion.

Drainage: The streams of this particular region flow southward where they empty into the Santa Clara River which flows westward to the Pacific.

Vegetation, Cultivation and Exposures: The vegetation is typically Sonoran, and its density is shown in the figure mentioned above. The region is used slightly for the raising of the smaller farm animals and has been mined for gold and borax. Exposures are, in general, good, but due to the nature of the formations involved, give, where most needed, little information on many important problems.

Columnar Section

PERIOD		NAME	CHARACTER OF MATERIAL IN FORMATION
QUATERNARY		QUATERNARY ALLUVIUM	CONGLOMERATE. POORLY BEDDID, POORLY LITHIFIED BROWN BEDS WHICH CONTAIN CHIEFLY ANGULAR MATERIAL AND REWORKED SEDIMENTARY MATERIAL
		HIATUS – UNCONFORMITY	
UPPER MIOCENE 4,000 FT.		MINT CANYON	CONGLOMERATE, SANDSTONE, SHALE. VARYING IN CONSTITUENTS FROM EXCLUSIVELY LAVA DETRITUS IN THE EASTERN REGION TO PREDOMINANTLY GNEISSIC MATERIAL IN THE WEST. LAVA FRAGMENTS DECREASE WITH HEIGHT IN THE SECTION. FRAGMENTS VARY FROM WELL ROUNDED TO POORLY ROUNDED BUT WELL ROUNDED PREDOMINATE, IN THE EAST WHERE LAVA FRAGMENTS ARE NUMEROUS, THE FORMATIONS ARE HIGHLY COLORED, VARYING FROM RED TO GREEN. IN THE WEST THEY ARE PREDOMINATELY GRAY. IN GENERAL, THE SERIES IS POORLY STRATIFIED WITH THE EXCEPTION OF OCCASIONAL SHALES AND TUFFS. THERE IS SOME CROSSBEDDING AND ALSO RIPPLE MARKS. A SERIES OF TUFFS OCCUR IN THE WEST. IN THE EAST LARGE WELL LITHIFIED CONGLOMERATES OCCUR FORMING CLIFFS, BUT IN THE WEST THE CONGLOMERATES ARE LESS MASSIVE AND ARE INTERSTRATIFIED WITH LARGE QUANTITIES OF SANDSTONE.
		FAULT CONTACT	
1,200 FT.		ESCONDIDO LAVA	OLIVINE BASALT, WEATHERS REDISH BROWN, BUT ON FRESH SURFACES, IS BLACK. IN PART IT IS VESICULAR AND AMYGDALOIDAL. IT IS EXTENSIVELY JOINTED. ALSO CONTAINS A SMALL AMOUNT OF FLOW BRECCIA.
		FAULT CONTACT	
275 FT. OLIGOCENE ?		ESCONDIDO GYPSUM	GYPSUM SHALE. GREENISH-YELLOW, CONTAINING UP TO 50% GYPSUM. HIGHLY CONTORTED.
		FAULT CONTACT?	
230 FT.		ESCONDIDO SANDSTONE	ARKOSIC SANDSTONE, VARYING FROM PINK TO GRAY IN SOME CASES WELL LITHIFIED. IN OTHER CASES POORLY LITHIFIED. RICH IN FELDSPAR AND BIOTITE.
		FAULT CONTACT?	
340 FT.		ESCONDIDO CONGLOMERATE	CONGLOMERATE-SANDSTONE MEMBER, CONTAINING EXCLUSIVELY BASEMENT MATERIAL, WELL ROUNDED. VARYING IN COLOR FROM RED TO BROWN. MODERATELY WELL LITHIFIED.
		FAULT CONTACT	
JURASSIC AND PRE-JURASSIC		BASEMENT COMPLEX	PARA GNEISS, INTRUSIVE QUARTZ MONZONITE, AND ASCHISTICS. CONTACT CHIEFLY INTRUSIVE INVOLVING MIGMATITE, ALSO FAULT CONTACT IN PART.

Stratigraphy: The basement complex, designated BC, is made up of two major units. The older of the two is a para-gneiss. Intruded into this is a granitic rock which has been involved, since its intrusion, in a complex series of changes including a modification of its composition and injection by aschistics. The intrusion probably took place during the Nevadian Revolution, following the Jurassic.

The Escondido series named by Hershey,1902(1) and placed tentatively for lack of correlative evidence in the Sespe by Kew(2), is exposed in part of the area mapped. The Escondido of the region to the east of Tick Canyon has been studied in detail by Mr. Ignacio Bonillias. To the west, it has not been carefully considered previous to this report; here, it is best shown in Forbidden Canyon, the first canyon east of Mint Canyon and near the head of the west fork of Tick Canyon. There are exposed here four members; a basalt, a gypsum series, a sandstome and a conglomerate. The stratigraphic relation of these beds can be determined only by correlation with similar formations found to the east.

Permit me to summarize Hershey's stratigraphic succession as exposed in Tick Canyon as given in the previously mentioned paper(1).

Contacting against 5,000 ft. of gneisses to the north, he found:

1-3	Conglomerates and sandstome	1080ft.
4	Red and brown lava, some stained bright green	1200ft.
5	Bright light red sandstone and shale	90ft.
6	Dark brown lava	140ft.
7-11	Red and green sandstone and conglomerate	63ft.
12-14	Dark brown lava, amygdaloidal and coarse grain.	355ft.
15-24	Highly colored shales and sandstone, also conglomerate and gypsum.	786ft.
25	Dark brown lava	150ft.

Comparing this succession with that mapped by Mr. Bonillias, it is obvious that Mr. Hershey's member, No.4, is the lava which outcrops in Forbidden Canyon. From areal relations, one would conclude that the gypsum, sandstone and conglomerate were all related to Hershey's nos. 1-3, but he describes then as follows:

1. Basal conglomerate, buff, vertical

2. Coarse buff and light green sandstone

3. White sandstone, alternating with a white thin bedded or banded material apparently either a rhyolite with flow structure or a rhyolite tuff.

Mr. Bonillias' study of the region led him to believe that the structure is a nearly isoclinally folded syncline striking approximately east-west and plunging west. In addition to this, he found that the group corresponding to Hershey's 1-24 are all on one flank of the syncline. Group 15-24 is the only one which contains gypsum; therefore, we must conclude either, that a portion of this member is brought to the surface in Forbidden Canyon, or that the distribution of gypsum in the various members is rather irregular, and that the beds found in Forbidden Canyon are the result of a local basin of evaporation as Hershey suggests on page 353(1); they may, therefore, be a portion of group 1-3. The absence of borax in Forbidden Canyon, which has been extensively mined in Hershey's group 15-24 in which he noted the occurence of gypsum, indicates with the same certainty that 15-24 is not the same formation as found in Forbidden Canyon, as the presence of gypsum indicates that they are the same formation. I shall assume, then, that the sediments found in Forbidden Canyon correspond in age to Hershey's group 1-3. The character of this group indicates that the conglomerate is lowest, in the section, next above, sandstone and next shale or gypsum. The position of the lava lying nearer the axis of the syncline indicates its younger age. These relations explain the scarcity of lava in the sediments found in Forbidden Canyon.

Hershey, as shown above, states that the group 1-3 is 1080 ft. thick. Between probable fault contacts in

Forbidden Canyon, we find 340 ft. of conglomerate, 230 ft. of sandstone and 275 ft. of gypsum. This amounts to a total of about 950 ft., which is only 130 ft. under Hershey's total value, thus allowing very little, assuming constant thickness, for fault burial, and consequently serving as evidence against fault relations between all of the members of this group. The lava as given by Hershey, is 1,200 ft. thick, and this value is corroborated by what little evidence there is available at Forbidden Canyon. The horizontal outcrop, before it starts to narrow, is 1200 ft. There is exposed by differential erosion a thickness of 500 ft. On this basis, the thinnest possible sheet which would conform to these facts would be 460 ft. with a dip of 25°, and the thickest would be 1300 ft. with a dip of 65°. These values are only extremes of possibility, while probability would indicate a thickness near 1200 ft.

The only other formation mapped for this report is the Mint Canyon Formation, here designated as MC. Kew placed this formation in the upper Miocene, basing his decision on fossil remains. He also gave as its probable thickness, 4,000 ft., and since its full extent in any direction has not been mapped for this report, we must accept this figure as the most accurate available.

In places on the Basement Complex and Mint Canyon Formation, there are to be found occasional terraces of

Quaternary alluvium, designated Qal. See fig. 2.

Petrology and Petrography of the Basement Complex:

Perhaps one of the most difficult and at the same time, the most interesting problem for the petrologist is the determination of the nature of the process by which a migmatite is produced. It is with me a fact greatly to be regretted that not until the field work was virtually finished did I realize the presence of evidence within this area which lead to the discovery and recognition of a migmatized zone. The result of my work on this problem, for it is a problem all in itself, is necessarily inadequate for a complete comprehension of the subject because of insufficient time available for study. This portion of the report, then, is especially introductory and indicates only where there is a possible opportunity for further productive work.

The two major components which make up the basement complex are a metamorphosed series of sediments and an intrusive body which ranges from a quartz monzonite to a granodiorite. For the sake of simplicity, I shall describe these rocks in reverse order to their chronological development, that is, first granitics, then metamorphics, in other words, from the simple to the complex.

The above, at least, was my intention when collecting the samples, but upon examining them under the microscope, I find that the granitics are not as simple as they appeared to be in the field. The least modified specimen and probably the youngest one that was collected from the Mint Canyon Gorge, was found a short distance north of the Lang Quadrangle along the Mint Canyon Road. It is a leucocratic, pinkish-gray, medium grained rock with no evidence of gneissic structure. Its color is largely due to epithermal alteration.

The mineral constituents of this rock, D 100, are as follows:

Essential	Varietal	Accessory	Alteration
quartz 50%	biotite	magnetite	kaolin
plagioclase 40%	muscovite	hematite	sericite
microcline 7%			limonite
orthoclase 3%			

For the sake of future reference, I shall include with each rock description, the thin section and specimen number. The capital D preceeding each number refers to this particular problem, the number refers to a locality marked on the accompanying map and subscripts or lower case letters following the number are used to distinguish different specimens from the same locality.

In the above rock, the plagioclase is probably andesine on the basis of a few satisfactory sections according to the method of Michel-Lévy. It is so badly altered, however, that additional sections would be necessary for an exact determination. Although biotite is partially bleached, it is easily distinguished and is quite a separate entity from the muscovite. Both of these minerals are primary in the strictest sense. The presence of numerous resorbed quartz (qz), inclusions in orthoclase (or)(see plate I,(3), precludes the likelihood of all of them being sections of tongues replacing the orthoclase; and therefore, one may say that the evidence here indicates replacement of quartz by orthoclase. In another portion of this same slide, we find microcline replacing quartz, and orthoclase appears to be converted, in part, to microcline or vice versa; see plate I,(4). These relations indicate that this is by no means a normal rock, and therefore, one finds difficulty in giving it an ordinary name. On the basis of the plagioclase, it would be called a granodiorite, but the high percentage of quartz (50%), the presence of biotite and muscovite to the exclusion of pyroboles, and the presence of microcline suggests that the rock is a binary granite.

In the next specimen, Da, which was also collected north of the Lang Quadrangle in the Mint Canyon Gorge, we find considerably more evidence of modification.

Here, the microcline occurs only in a few small patches, but in its place we find considerable myrmekite. See plate I, (1) my. It is not clear in this case, which has done the replacing, the quartz or the feldspar, but it is fairly obvious here, as in plateI,(2), where we see the sutured intergrowth of quartz of two stages, that this rock has been profoundly modified, and yet, in the external appearance, there is no evidence of metamorphism whatever.

This rock is particularly interesting in the history which it indicates, and I think it will not be amiss to relate its probable history here as a basis upon which to start any future work that might be considered desirable, even though it may not necessarily hold true in the light of all the evidence. Magnetite was followed in its crystalization from a granitic magma by the normal sequence of minerals. Before the rock was completely cooled, residual liquids, possibly from other portions of the body were introduced which were unduly rich in Na and Ca,and thus, the conversion of microcline into myrmekitic plagioclase was brought about. At the same time, much of the orthoclase was converted to andesine as indicated by its very fine and somewhat imperfect twinning. When this process was complete and while the rock was still hot, we find evidence of extensive introduction of quartz and the reworking of quartz already formed. Apparently, then, after the repeated surges of new material had ceased, the rock cooled sufficiently to be thoroughly fractured producing fine cracks which

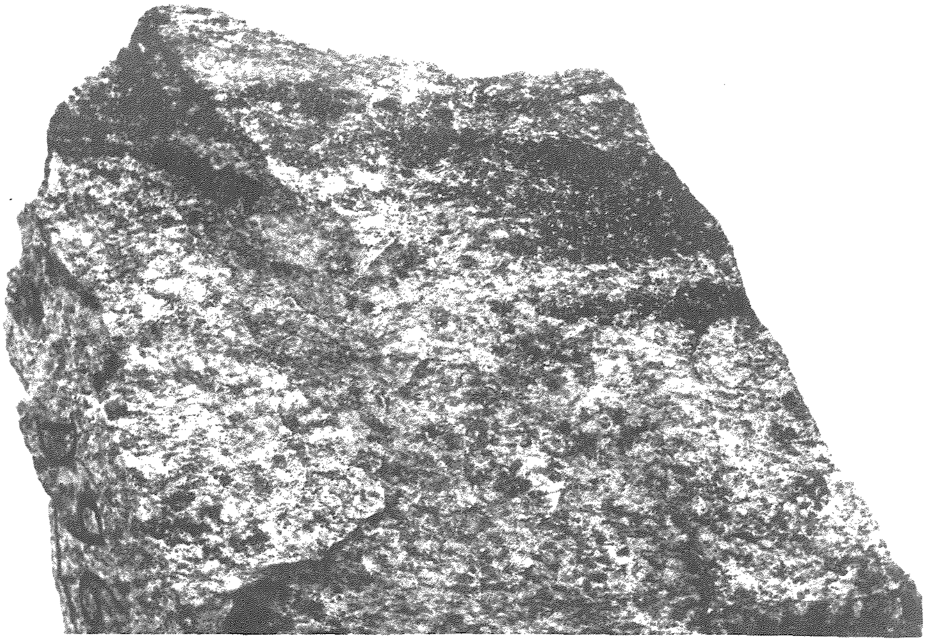


Fig. 3 Sample D 96, showing gneissic texture and schlieren structure near the intrusive contact within the intruding body. Full size.

which are faintly visible in plate I,(2) These might well have been formed due to stresses set up during the final intrusion of the magma into the old gneisses which lay above, and finally, possibly concurrently with this activity, the rock was injected with fine veins of hematite, plate I,(1)

The absence of fine fractures through other specimens suggests that such rocks are of the same age as the intrusion while the presence of fractures in this rock indicates its greater age. The chief distinction in hand specimens between the two types, Da and D 100, is the absence of muscovite in the supposedly older rock and its presence in the younger.

This evidence is of course quite inadequate but as a guide to further work it may lead to something more conclusive.

At 96, a point just at the north end of the Mint Canyon Road as shown on the Lang Quadrangle, there is to be found some of the first major changes in the physical character of the intruding rock. See fig. 3. It appears here to be a gneiss enclosing schlieren of biotite rich rock, undoubtedly coming from the walls of the magmatic chamber. The gneissic texture in this case is perhaps best accounted for by movement within a semi-molten mass during the process of intrusion.

The microscope reveals in many places a granulate ground mass. Microcline is absent, and the plagioclase is as, or more calcic than oligoclase. But, the most interesting feature as revealed by the thin-section, in view of the assumption that the gneissic texture is due to movement after partial solidification, is the remarkably great development of late muscovite. See plate I, (5). This photomicrograph taken with plane light shows only muscovite, the groundmass of quartz, orthoclase and plagioclase not being visible. The muscovite is very intimately associated with all of the minerals, as shown to a lesser degree in plate II, (1), a picture of another rock under crossed nicols; the muscovite, in this case, is the light material. The finding, then, of large quantities of late muscovite is nicely reconcilable to the concept of late movement of the partially crystalized rock. The schlieren also corroborate this view . Penetrating this rock mass are found occasional pink pegmatites resembling in composition the intruding rock.

A short distance south of 96, at a point marked 95, are to be found two rock types; one, $D95_2$, showing no gneissic texture and resembling very much D100, the probable intruding rock; the other, $D95_1$, is a coarsely banded gneiss.

$D95_2$ is a leucocratic, pinkish-gray, medium-fine grained rock. The mineral consitiuents are as follows:

Essential		Varietal		Accessory	Alteration
orthoclase	40%	biotite	15%	apatite	sericite
quartz	40%	muscovite		magnetite	kaolin
plagioclase microcline	5%			zircon	chlorite

Orthoclase is altered to sericite and kaolin. Biotite has wavey cleavage lines and is somewhat altered to chlorite. Plagioclase is oligoclase or possibly a more calcic feldspar. Some of the microcline has been converted to myrmekite. See plate I,(6) my. The microcline appears only as remnants and has only faint microcline twinning.

$D95_1$ is also leucocratic; it is pinker than $D 95_2$, is,as previously stated, coarsely banded, and is medium grained.

Mineral composition is as follows:

Essential		Varietal	Accessory	Alteration
quartz	30%	biotite	garnet	kaolin
microcline	30%		(grossularite)	sericite
plagioclase orthoclase	30%		hematite	chlorite

The biotite is somewhat bleached and somewhat altered to chlorite. As in the above rock, there is considerable granulation. Both microcline and orthoclase perthites are abundant, and microcline, as will be discussed in connection with a later specimen, seems to grade insensibly into orthoclase with at the same time an increase in the included albite making up the perthite.

But, the most interesting feature of this rock is the presence of the garnet, grossularite. This, we can say, is the first evidence of the mixing of sedimentary materials into the magma.

At 98 we find the zone of greatest migmatization. See figs. 4 and 5, page 19. Here, the garnet reaches its greatest amount. See plate II, (5). Here, also, we find the first epidote. Grossularite, Ca Al orthosilicate, and epidote, CaAlFe(OH) orthosilicate, both require Ca for their formation. We shall see later where, at least part of the Ca came from.

The metachrysts, as shown in fig. 4, are orthoclase, but in many places they are microcline. It should be remembered that the first sample to contain grossularite, D95$_1$, contained 30% microcline, while the associated D95$_2$,

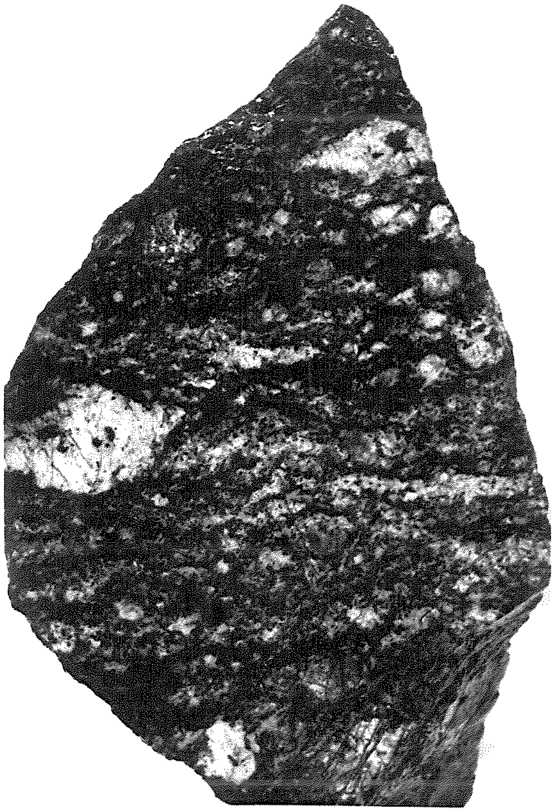


Fig. 4, Sample 98, showing detail of metacrysts. 2/3 X

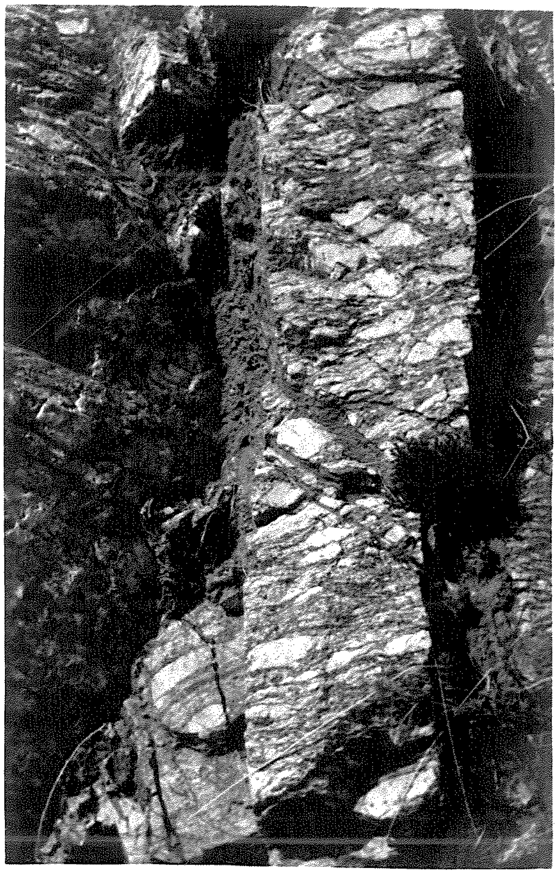


Fig. 5, Location 98, Mint Canyon Gorge , Migmatite. X/6

with the composition of the normal intrusive rock, had less than 5% microcline. This indicates that the microcline was introduced after the solidification of the rock. The reverse of this relation is seen in the case of orthoclase. Whether it is a matter of originally all the potassium feldspar was orthoclase and that part is now microcline by recrystalization is, however, yet to be definately determined. Likewise any other possible original relation of the two minerals has yet to be explained.

South of 98 we run into the pre-Jurassic gneisses. In specimen $D93_4$, we find additional evidence of the sedimentary origin of these rocks. This rock is greenishgray to black, fine grained and finely gneissic. It apparently was a fine grained sandstone cemented with calcite. See plate II,(3),quartz (qz) and calcite (cal). Muscovite is moderately abundant, but epidote is the most outstanding constituent in view of its genesis. Here we have the association of the metamorphic mineral, epidote, with the sedimentary mineral, calcite, in the form of a cement. Grossularite also occurs here, but it is relatively rare. Its greatest occurrence is, as one would expect, in a zone of higher temperature, nearer the contact with the intrusive. Calcite, then, as a cementing material is one known source of Ca, there may be others. $D93_4$ also contains as accessory minerals, pyrite and titanite.

In $D93_2$, a medium gray, medium grain, prominently gneissic rock, we have as essential minerals, an orthoclase perthite, microcline perthite and quartz. The quartz is largely filled by inclusions of rutile. Here, as mentioned previously, there seems to be a relation between the microcline, the orthoclase, and their perthitic nature. Plate II, (1) shows a crystal which is half microcline as shown by the characteristic twinning and half orthoclase?, designated mi, microcline, and or_1, probable orthoclase. Under the high power, one can see an increase in the number of inclusions in going from mi into or_1, and at the same time, the disappearance of one system of twinning. Plate II(2) shows a picture of or_1 under high power in which all the inclusions are allaigned, and the twinning can be seen between them, crossing them at an angle of about 60°. Although this at first glance looks like microcline grating structure, it is, then, the effect produced by a single twinning system crossed by aligned inclusions. Plate II,(4) shows the same section with the stage turned to remove twinning lines and show inclusions alone. Plate II,(1) or_2 shows normal orthoclase perthite, although the perthitic nature is not obvious in the picture.

The question raised, then, is, what is the significance of this series, if it is a true series? I shall not try to solve it, for, as I have already stated, this portion of the report is largely introductory.

In conclusion of this portion of the report,let us review the evidence which leadsto the solution of the nature of the migmatizing process. First of all, we found considerable evidence of modification by ascending solutions, replacing quartz, page 13, line 5, plate I (3); page 13, line 10, plate I (4), also conversion of microcline into myrmekite, page 13, line 23,plate I (1) my; and page 17, line 22; replacement and reworking of old quartz, page 13, line 25, plate I (2); introduction of large amounts of muscovite, page 16, line 14, plate I (5). The formation of grossularite and epidote involve a certain amount of transportation of mineral constituents.

The development of metacrysts as shown in figs. 4 and 5 clearly shows evidence of addition of new material in this case, not necessarily by solution, but possibly by direct injection of segregated magma into the old gneisses, to give a lit-par-lit structure to the migmatite. This theory could be supported by the shape of the stringers in the lower part of fig.5, but in the upper part of the figure, it appears as though the metacrysts had forced apart, by their development, the layers of biotite. The metacrysts of orthoclase seem in all cases to have, as the axies exerting the greatest pressure in separating the layers of biotite, the(b)or(c)axes, in that the (a) axis is never found in this position. The ratio of the axes for orthoclase is, a : b : c :: 0.66 : 1 : 0.56.

No evidence was obtained which would indicate whether the region of migmatization had been involved in any considerable expansion due to formation of lit-par-lit or due to addition of material by solutions.

There is considerable field evidence to show movement of gneisses within themselves on a rather large scale as shown in fig. 6, which shows a flexure in a former

Fig.6 Large scale buckling in the gneisses. Mint Canyon Gorge. Tree on the right is about 30 ft. high.

sandstone and, below it, another sandstone which has been folded back on itself. There are also occasional ptygmatic folds on a small scale to be found in the gneisses. See figs. 7 and 8.

Therefore, it seems probable that modification of existing rocks by solutions, addition to the rock of considerable quantities of material by means of entering solutions and possibly introduction of new material, in the form of magmatic differentiates, have all played a part in the formation of the migmatite, although the first two processes are probably more important.

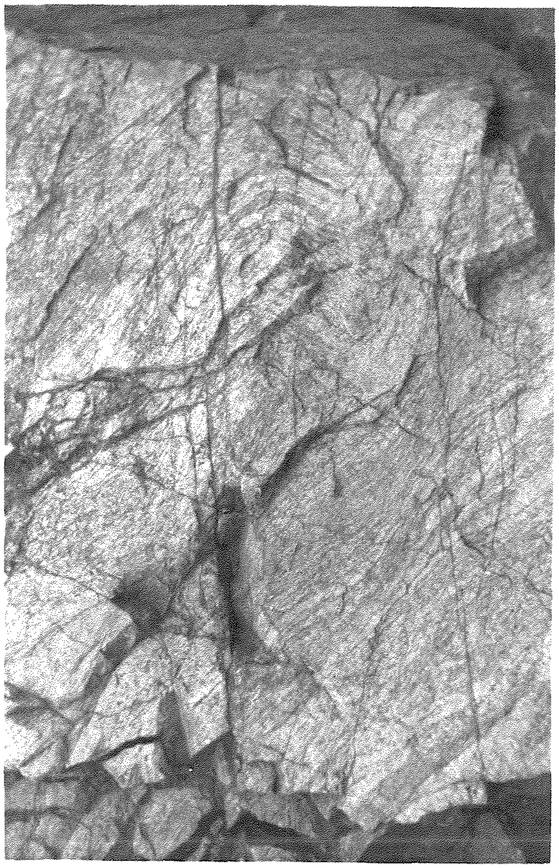


Fig. 7 Ptygmatic folding in the Mint Canyon Gorge. X/6

Fig. 8 Ptygmatic fold in a boulder found in Forbidden Canyon. X/2

Petrology of the Escondido: The conglomerate member is a coarsely bedded conglomerate-sandstone combination. Its bedding is best seen at a distance. It is composed almost entirely of metamorphic pebbles with no lava. The sandstone tends to be arkosic, but there is not any biotite present. The beds are in part will cemented and are rather resistant to weathering. The cementing material is partly calcite, but mostly silica. The beds vary in color from red to gray. Outcrops are better in this formation than in the gypsum or sandstone members. Fig. 10 shows a typical exposure. The strata are dipping steeply to the left as indicated by the orientation of the pebbles.

The sandstone member is in reality an arkose. Its chief minerals are quartz, feldspar and biotite. Intrusive igneous rock pebbles and grains are the chief larger constituents, but fragments of lava occur occasionally. Feldspars are fairly fresh, and the presence of biotite indicates the slight amount of weathering that has affected the rock. The rock varies from gray to red in color and from fine to coarse grain. It is, in general, poorly stratified and poorly sorted. It outcrops as beds with varying degrees of induration. Some of the red beds are very porous and are cemented with calcite exclusively.. The gray members are, in general, harder and contain less calcite. The chief cementing material apparently is quartz. A small amount of ferrous iron compounds are leached out of the gray rock with HCl. Ash beds occur in isolated patches, as also they were mentioned by Hershey in 1-3. The sandstones are more resistant to weathering than the gypsum beds, but due to their softer members do not produce steep slopes, neither do they produce, even on a small scale, a miniature cliff-bench topography. See fig. 2 for typical topographic expression.

Fig.9

Fig.10

Fig. 11

The Gypsum Member is a fine sandy shale which varies to a clay in places. It is named for the great quantity of gypsum which has been deposited simultaneously with the shales. There is considerable variation in the amount of included gypsum, varying from solid slabs two inches thick to as little as ten percent. See fig. 9. Some of the gypsum is fibrous and some massive. Only a very few, small crystals were found which were perfectly clear and showed crystal structure. No colemanite was found that could be distinguished from the gypsum. The shale is a greenish-yellow color. A small amount of calcite is associated with the shale as a cementing material. The rock is badly crumpled and is well exposed in a number of mines. See fig. 11. The rock being very soft, it is weathered away rapidly and stands only on a steep slope because of the protection afforded by the adjacent, more resistant, lava.

The last member of the Escondido is an Olivine Basalt. See plate III 1,2,3. It is moderately fine grained and is

---

Fig. 9 Detail of Gypsum Formation showing the occurence of gypsum (white) within the beds. This is very typical. There is of course more gypsum present than visible since much of it is discolored by the shale. Exposure in Forbidden Canyon. X/6

Fig. 10 Detail of the Escondido Conglomerate showing the rude stratification by the orientation of the pebbles. Exposure in the bottom of Forbidden Canyon. X/6

Fig. 11 Typical outcrop of Gypsum Formation where mining has exposed it to view. Exposure on hillside near the lava contact.

black on fresh surfaces. It weathers brownish-red and in places is a bright green. A few breccias occur which have not been critically studied. D22$_a$ is a fresh sample of a rather well crystalized portion of the lava. Minerals are as follows:

Essential		Accessory	Alteration
labradorite	55%	magnetite	hematite
$Ab_{38}An_{62}$ to			
$Ab_{26}An_{74}$			
glass	20%		
olivine	15%		
augite			

The rock is hypocrystaline and seriate. The larger labradorite crystals show no chemical zoning, but the smaller ones do, some of them showing reversal in zoning. Augite, which occurs about equally with olivine, cannot be distinguished from it in the photomicrograph. Plate III 1,2 shows some interesting growth developments of the feldspars. From the photomicrographs, it is quite clear that during the early stages of crystalization, probably considerably before extrusion, a clear feldspar was forming, then suddenly an introduction of certain impurities began forming inclusions in the growing feldspars. After this had continued for some time, another change took place, which, for a while, stopped crystalization and started resorption of the borders of crystals already formed. When this was completed, many of the feldspars had only a narrow band of inclusions along their border, and others had their crystal faces completely rounded off. See especially plate III 2. Again feldspar began to be deposited on the crystals, this time, free of inclusions, and finally the rock was completely solidified with the formation of various amounts of glass. Plate III, 3 shows a photomicrograph of a thin-section of highly vesicular lava and shows flow structure and a high percentage of glass. The olivine crystals are well shown in this photograph.

In general, the rock is not very vesicular. Those vesicules or other cavities found in the rock are filled with sometimes chalcedony, usually quartz. See plate III 4, an amygdule which has been broken open. In the upper part of the right-hand half, there is a rather large calcite crystal. The remainder of the cavity is filled with quartz.

The lava jointing is quite variable, but it seems to trend toward verticality. The great relative resistance to weathering of this member as compared to the Mint Canyon Formation or other Escondido members explains its more rugged topographic expression. Excessive fracturing, however, in many places tends to reduce this resistance. Fig. 23 p44, showing the gypsum-lava contact, shows how the lava fracturing has reduced it to virtually a talus slope.

Fig. 12 Mint Canyon Formation, Sandy shale, near the lava contact at the mouth of Forbidden Canyon

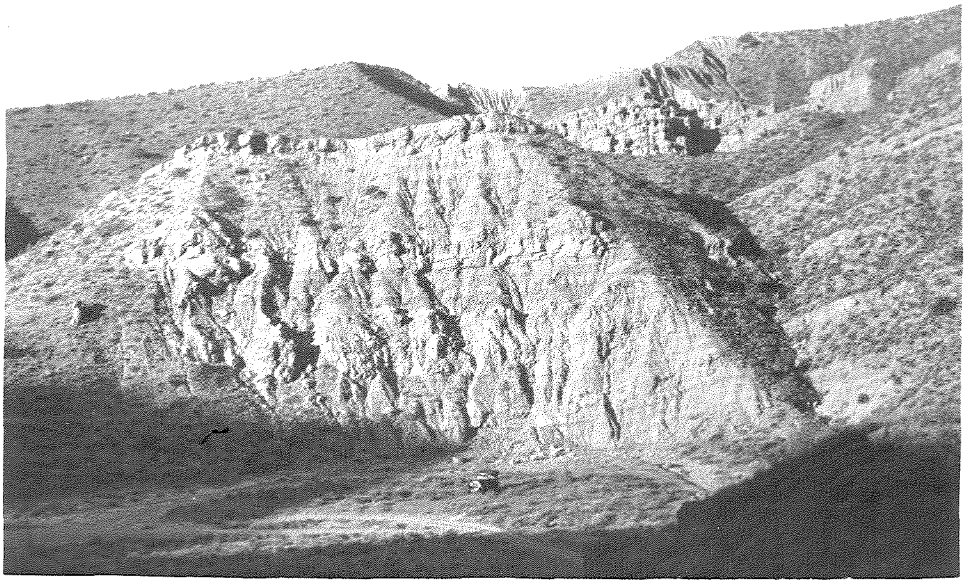


Fig. 13 Mint Canyon Formation in Tick Canyon. Dark members are reddish; light members, green.

Petrology of the Mint Canyon Formation: The Mint Canyon Formation is characterized by moderate dips and its variability in composition, hardness, color, and topographic expression.

Most of the shales occur in the eastern part of the area near the lava contact, that is, in the north. D3b, collected near the contact,is a reddish-brown massive limey shale which has been deposited probably in a desert lake bottom. It is 40% calcite . It very much resembles an altered andesite in color and topographic expression and forms a dip slope which can be located on the map inside the 'cirque' just east of the mouth of Forbidden Canyon. Most of the sediments at this locality are sandy shales; see fig. 12, but, by no means all, for conglomerates also occur; but to the east, are to be found the great'reef' conglomerates.

Near the head of Tick Canyon, these beds are exposed and form a great cliff on the western side. They are composed exclusively of wash from lava beds. Most of the larger pebbles are well rounded, but a rather large percent of the finer material is angular indicating possibly both a rather near and a distant source. The beds are very well cemented. They contain a very small amount of calcite, and hot HCl leaches out a small amount of ferric iron, but

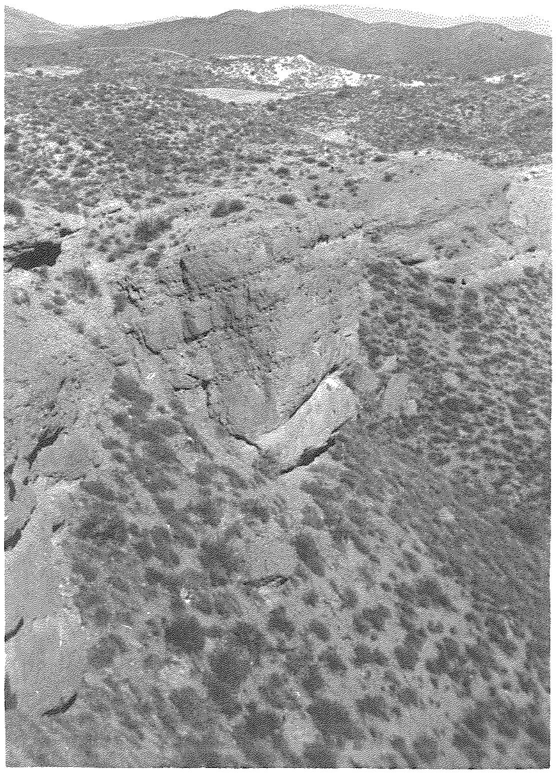


Fig. 14 MC Conglomerate in Tick C.

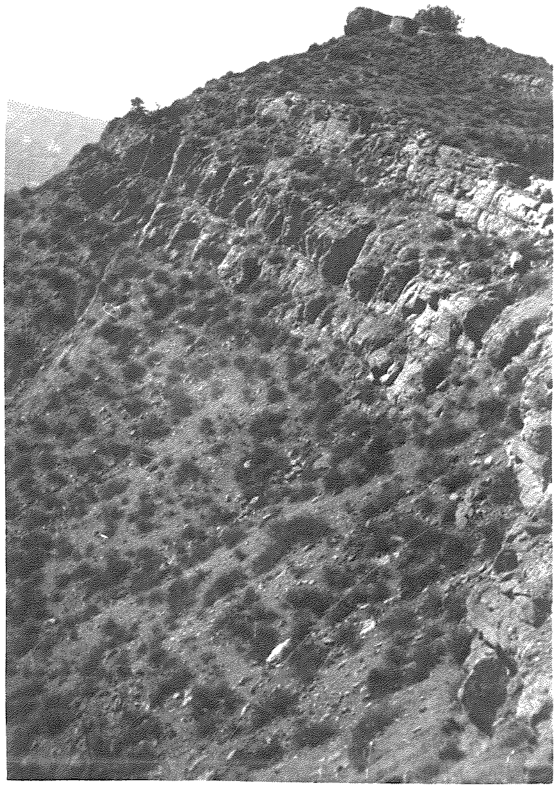


Fig. 15 MC Cong. east of Tick C

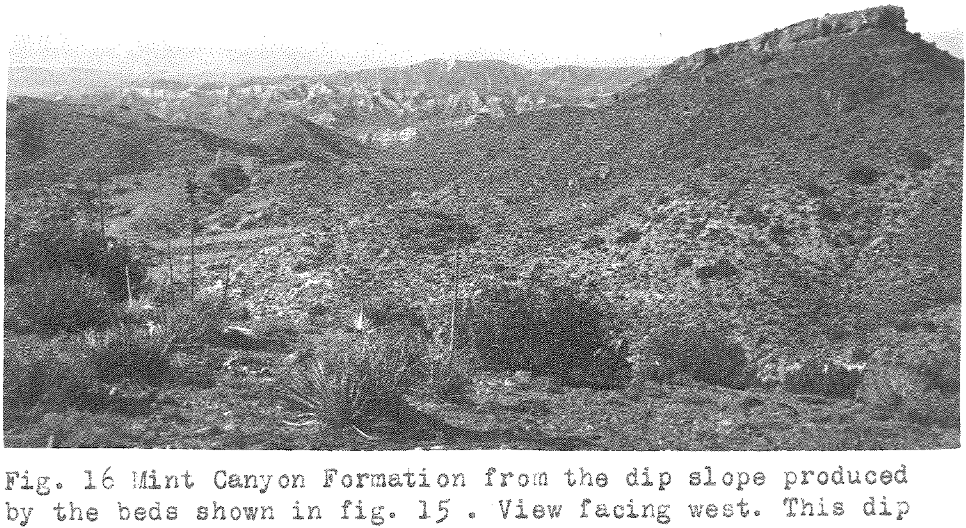


Fig. 16 Mint Canyon Formation from the dip slope produced by the beds shown in fig. 15 . View facing west. This dip slope dips NW while the cong. cap on the right dips south.

the rock is cemented almost entirely by quartz. The rock breaks around the larger pebbles but through many of the finer fragments. In some regions this member is made up of pebbles averaging two inches in diameter and cemented and interstratified with coarse sandstones, while in other places, there is a mixture of all sizes from sand to pebbles. The rock observed from a distance varies in color from pink to green, the green strata in fig.13 p. 30 appear lighter than the pink. Individual hand specimens contain fragments of practically all colors lava is capable of producing. Fig. 14, facing north, shows a typical conglomerate outcrop in Tick Canyon. Permit me to remind the reader that in order to get the proper perspective, these pictures should be observed from a distance equal to the focal length of the camera times the enlargement in diameters, in this case, six inches. Fig. 15, looking south, shows a series of resistant beds which form a great dip slope to the east of Tick Canyon. Fig. 16 is a view toward the west from the dip slope surface showing the southward dipping cap of conglomerate on the right, in the center, can be seen less resistant members of the formation showing as white beds which outcrop on the far side of Tick Canyon.

To the east and to the west of Tick Canyon, the percentage of basement material rises, also as one goes

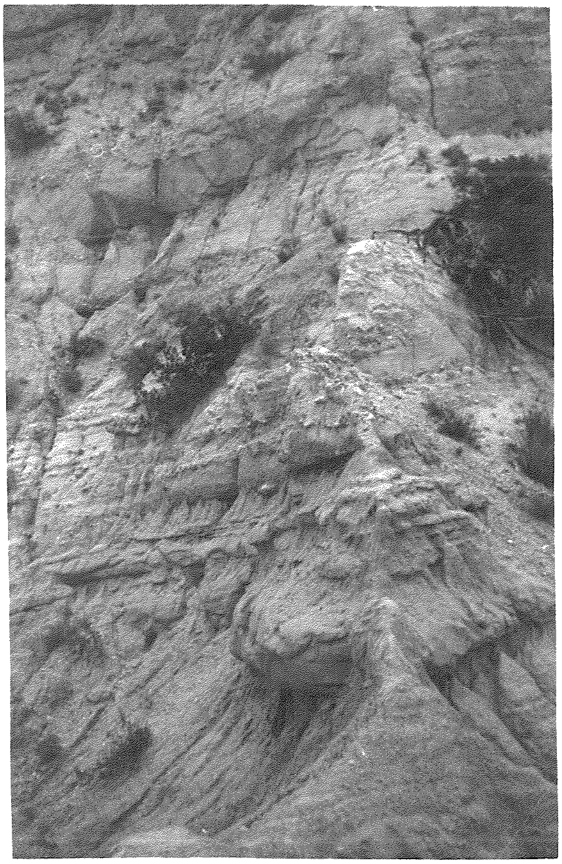


Fig. 17 Mint Canyon Formation

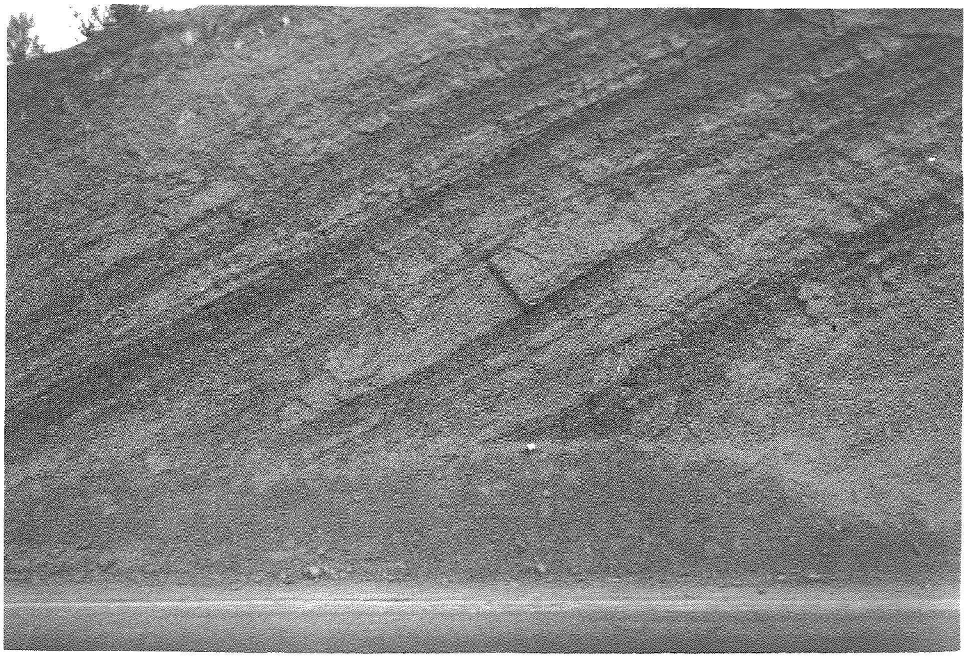


Fig. 18 Shales in the Mint Canyon Formation shown in a Mint Canyon Road cut. Brunton Compass on bank.

south in Tick Canyon, that is, as one rises in the section, the amount of lava material decreases.

A short distance south of the Mint Canyon School, the basement and lava pebbles are about equal; this section varies from conglomerate to fine sandstone. In addition to lava and basement, practically all of which is metamorphic, there are rather common sandstome pebbles (arkoses) containing rounded lava pebbles which grade into pure limestones. There are also sandstone pebbles which contain very little lime and very closely resemble the Escondido sandstones found in Forbidden Canyon. Hershey mentions the occurence of limestones in the Escondido, so, probably all of these come from that formation. The conglomerate occurs chiefly as rows of pebbles in the sandstone. The pebbles found in this locality average about 2½ in. in diameter and have a maximum size of about 6 inches. Practically no biotite is found in the sandstone and the feldspar fragments are badly altered. The sandstones vary from brown to gray. They are mostly coarse grain, but even shales occur in patches. They are poorly sorted and bedded but show some cross-bedding. Their friability makes them very susceptable to disintegration. They show no jointing system or crumpling. See fig. 17, a picture of the above described outcrop.

Outcrops in the Mint Canyon Formation apparently occur whenever there are sufficient numbers of resistant beds to form cliffs. These resistant beds are remarkably discontinuous, in general, and suggest river deposits as their probably origin.

Near the above locality in a Mint Canyon Road cut there is exposed a series of finely bedded shales such as one seldom finds in this formation. See fig. 18., p.34 (Brunton compass on bank at base of cut) Less than two hundred feet away are to be found on the same stratigraphic horizon, some massive sandstones and conglomerates.

Near the northern contact in the western portion of the area, the Mint Canyon Formation is very poorly stratified and sorted and contains chiefly angular material. It is generally brown in color and in places is difficult to distinguish from Quaternary alluvium. Toward the south, it takes on the appearance and character of the material found a short distance south of the Mint Canyon School except that it contains less, and in the far western portion, no lava. See fig. 31 p.60. Higher in the section, the conglomerate becomes coarser and more poorly stratified, containing only basement pebbles and boulders. In this western region, the only member which differs from the above description appreciably is an ash series which occurs interstratified with sandstones and conglomerates. In places, it is very finely stratified, and in others, it is massive and contains plant remains. Certain horizons contain ripple marks. See fig. 20; the picture was taken facing south. On the basis of these ripple cross-sections, one would conclude that the stream which formed them was going from right to left, that is, west to east, but on the basis of ripple crossbedding found at a slightly different level, the stream seems to have traveled from east to west, It is entirely possible that both conclusions are correct in their particular cases, and that we have here a meander which was progressing downstream, say for example, south, and thus at different periods the stream at this particular point necessarily changed its direction. See fig. 19 for the extent of these beds. This picture is taken from the north end of the Great Terrace, facing toward the south-west.

Petrography of the Quaternary Alluvium: The Quaternary alluvium which forms the surface of most of the terraces is a brown, angular conglomerate which is essentially horizontal where bedding is sufficiently good to observe it. See fig. 2. It is, in general, poorly lithified.

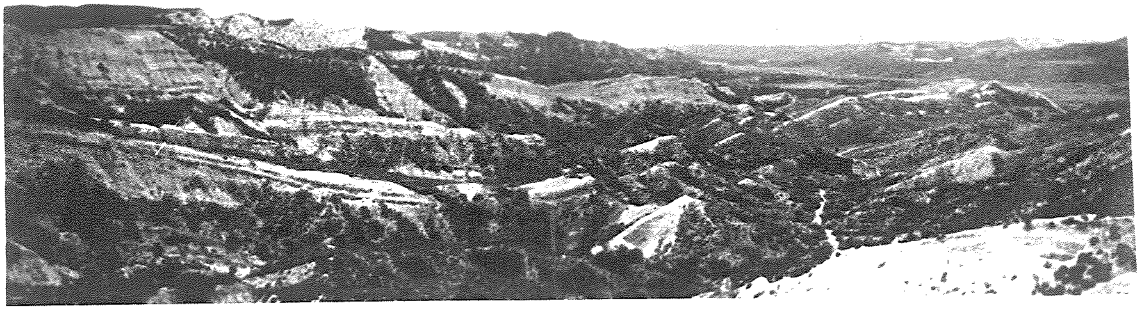


Fig. 19 View toward the south-west from the north end of the Great Terrace. Note the appearance of sections resembling anticlines which are due to erosion only, in the southward dipping strata. Note also how the strata on the left change their strike. This is the western flank of the nose which centers just east of the terrace. The white bed in the right foreground and those visible on a series of hills extending toward the west are tuffs.

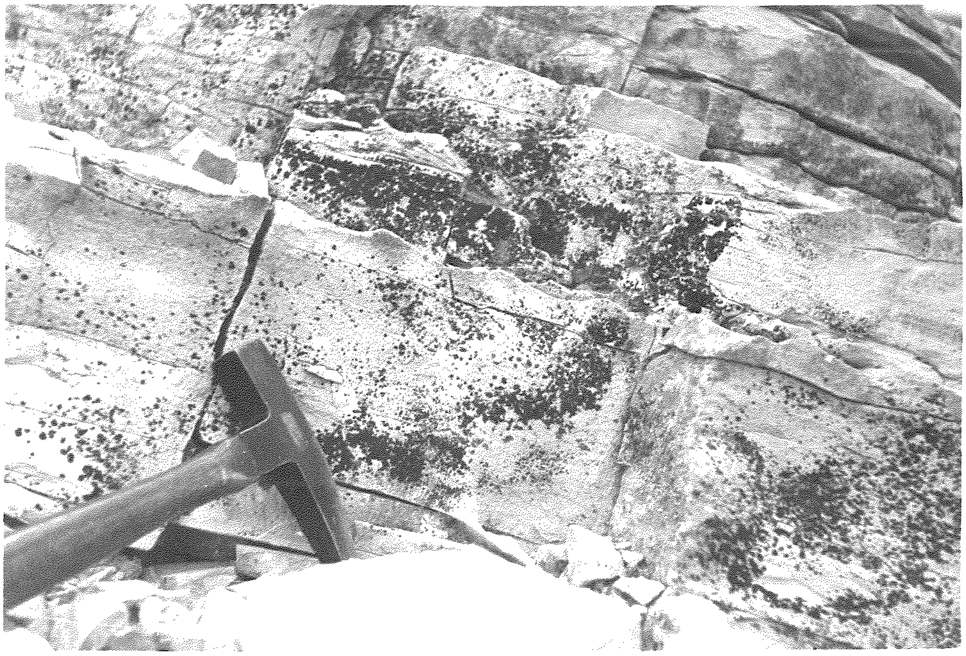


Fig. 20 Detail of tuff beds showing ripple marks in section.

Geologic Structures: Basement Complex: The lack of sufficient area of exposed gneisses makes it difficult to determine directly whether their present attitude, striking approximately east-west and dipping steeply south, is the result of the intrusion of granitics to the north of them or whether it is due to some other activity. The attitude of other gneisses and schists in this general region, all of which also strike east-west, indicates that this characteristic is due to something of greater extent and uniformity than a minor intrusion of magma. The presence of anticlines in the metamorphics to the north-west maintaining an east-west strike indicates that the uniformity of strike was not even due to a major intrusion in the north, since such a phenomenon would produce a uniformly southward dip. Therefore, we may conclude that in the particular area studied for this report, the gneisses do not have their present attitude because of the intrusion of the granitics to the north.

There is still the question to decide since the intrusion did not produce the present attitude, when was it produced, before or after the intrusion? Since there is no variation in this east-west strike feature over a large area, and since we usually do not find minor features in the older rocks, but only the broader features, we may assume that the broadness of this east-west strike

Fig. 21 Fault contact between gneisses and granitics in the northeastern part of the area along the Mint Canyon Road.

Fig. 22 Block of granitic material from same locality as fig. 21

feature is an indication of great age; then we can say that the present attitude of the gneisses was produced during a very distant period which probably preceded the intrusion of the granitics. On this basis we can conclude that the gneisses were both formed, that is, metamorphosed, and tilted before the intrusion of the granitics.

Because of the irregularity of the intrusive contact, it was not mapped. The metamorphics, however, may be said to form, east of Mint Canyon, a wedge shaped area on the southern border of the basement spreading toward the east, with the contact between metamorphics and granitics running through 98 and 99 and then bending toward the north-east. On the other side of Mint Canyon, the contact between granitics and metamorphics has not been investigated. The contact between the two members of the basement to the north-east, some distance off the map, is not exclusively an intrusive contact, but in places is a fault contact. See figs. 21 and 22. Figure 21, facing south, shows a portion of a Mint Canyon road cut. The gneisses are shown on the left side and are dipping toward the south-west. On the right side are the granitics. Fig. 22 shows a block or section of a dike of granitic rock within the gneisses which has been sheared in two places. This picture was taken in the same cut as fig. 21.

Structure of the Escondido Series: The patch of lava and sandstone between Mint Canyon and Forbidden Canyon will be dismissed, for lack of evidence to explain its exact origin, with the statement that it is probably bounded entirely by faults.

The stratigraphy as already determined makes the relations found in Forbidden Canyon both simple and logical. In crossing the canyon from north to south, one crosses the beds in their stratigraphic order: basement, conglomerate, sandstone, gypsum, and lava. The contact between basement and conglomerate is obviously a fault contact, the beds dipping north from 60° to 85°, abutting into the basement.

The contact between conglomerate and sandstone is burried, and it is not known whether the contact is unconformable or a continuous depositional series. To the west of where the contact is burried, the sandstone beds are best shown, but there, they contact directly with the basement, the conglomerate beds being lost under a talus slope and not appearing on the other side. See fig. 2. The absence, then, of the conglomerates above the sandstone contact means, then, that they have been raised above the present land surface and been eroded off. This requires that the sandstone-basement contact is a fault also. To the east, where the sandstone contacts the conglomerate, this hypothesis cannot be used to explain the relationship, but the fact that both members dip steeply to the north and that the conglomerate is found higher on the hillside then the sandstone indicates a fault relation here, provided we accept the statement that the conglomerate is stratigraphically lower than the sandstone.

The relation between gypsum and sandstone is even more doubtful. In the eastern outcrop of gypsum, the beds are dipping south while on the other end of the outcrop they are dipping north. In general, the gypsum bed separates the sandstone and lava, but on the west side of the last ridge showing sandstone (see fig.2), the gypsum occurs only as a patch at the base of the next ridge, with basement separating it from the lava. Both on the map and on fig.2, the gypsum is included in the sandstone. On the east side of the last ridge, the gypsum is in contact with the lava as indicated by small amounts of diggings in the gypsum. See fig.2. Because of the variability of the attitude of the gypsum, one cannot, on this score, draw any conclusions about the relation between gypsum and sandstone, but due to the irregularity of the distribution, especially on the last ridge showing sandstone, fig. 2, I have concluded that the contact is a fault. About half way down the last ridge between the basement and lava, there is a patch of angular basement material which might have been brought up along a fault. Such things as this together with the structures indicates that this canyon is made up of munerous slices which have been brought more or less to the surface, depending upon their distance from the basement block to the north. That is, the structure in this canyon is one of step faulting in which each successive slice to the north has been raised with respect to its adjoining slice to the south.

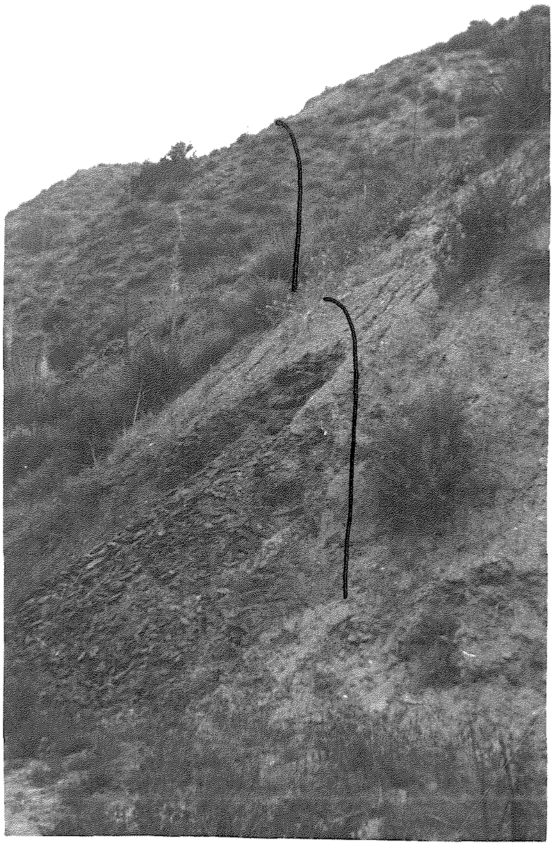


Fig. 23 Lava-Gypsum contact, For. Can.

Fig. 24 Gypsum near the above lava contact. Forbidden Canyon

The movement along these various faults can be determined with even less accuracy than the thickness of the various members. The amount of movement can only be determined with the aid of a knowledge of the shape of the folds which have placed the beds in their present position. In view of the probability that all of the beds are overturned, due to inclination of the axial plane of the syncline of which they are apparently a part, the displacement along the basement-conglomerate fault can be any quantity which approaches or exceeds the height of the original adjoining anticline. This is obviously beyond all hope of determination. Movement along the other faults, or probable faults, is relatively small or absent.

The contact between the lava and gypsum is well shown in fig. 23, which is taken from the bottom of the canyon looking west along the contact, with lava to the left and gypsum to the right. Fig. 24 shows the nature of the gypsum beds about ten feet to the right of fig. 23 and shows them to be dipping slightly to the west. They, therefore, are cut off by the verticle contact which must be a fault.

The cutting off of the three units shown in fig. 2, namely, conglomerate under the talus slope, sandstone and gypsum in the last valley on the north-west side of the canyon, and the lava on the next ridge, appear to be only local faults which cross the formations only, since in no case where a formation is cut off is there any displacement of the neighboring contacts in line with the cut-off. It appears, then, since there is no change near these cut-off contacts of the nature of the formation, as would be expected if the contacts were depositional; then, one must assume that the block of basement to the west of each cut off formation has been raised sufficiently high along a fault for erosion to remove all the Escondido material.

Because of the highly speculative nature of the stratigraphic column, it seems unwise to discuss the relations of these members in greater detail. There is yet the problem of the Mint Canyon Fault.

Structural relations of the Mint Canyon Fault: Upon driving up Mint Canyon Road, one travels for quite a number of miles through moderately low lying conglomeratic hills averaging 2,000 ft. elevation, and then one comes suddenly to a great mass of basement which rises from 2,800 ft. to 3,000 ft.; then one enters the Mint Canyon Gorge which is formed in the uplifted block. It is obvious that there must be a major feature which forms this boundary between these two areas. If one goes up Forbidden Canyon a short distance into the Basement Complex, one will see on the north side of the canyon a zone of gouge about five feet wide. See fig. 25. This zone is about vertical, and if one ascends the ridge to the west and looks toward the east from a point near the T in the

Fig. 25 MCFault gouge Forbidden C.

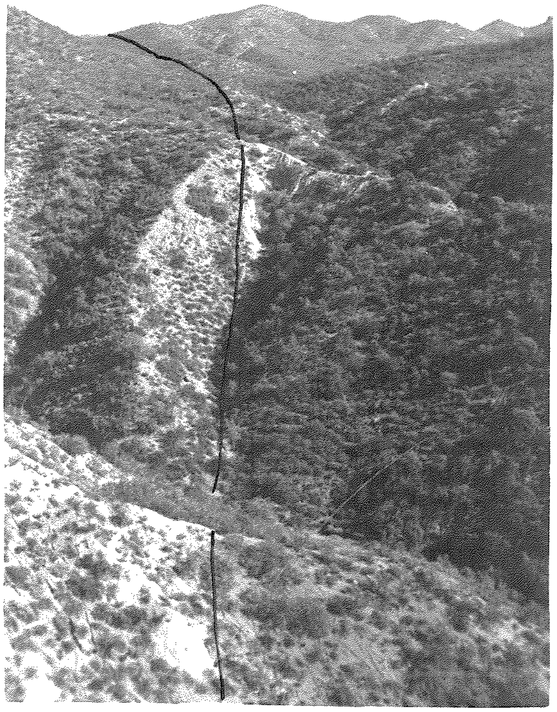


Fig. 26 MC Fault east of Forbidden

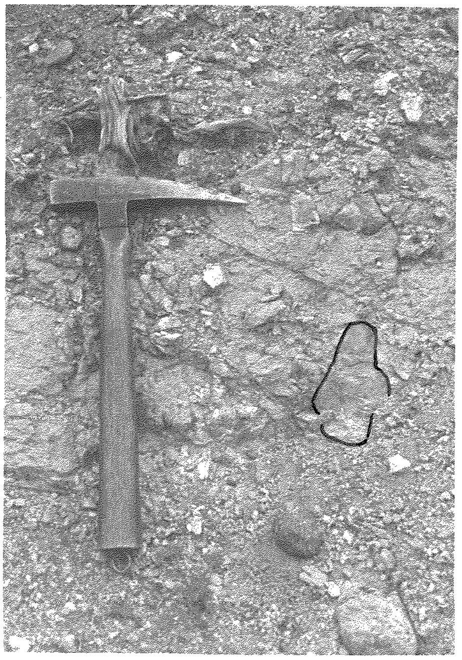
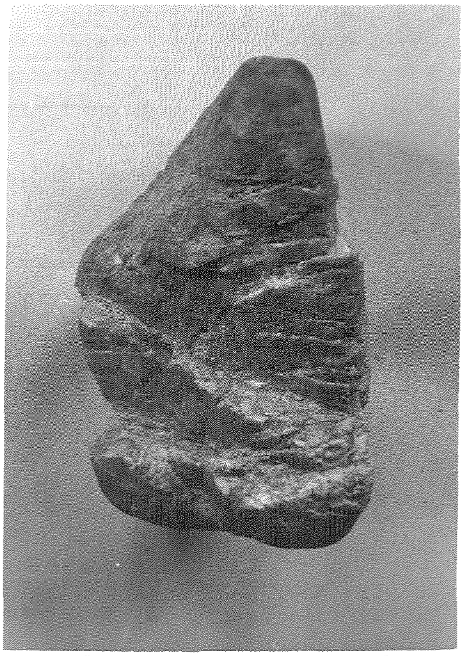


Fig. 27 Escondido cong. F.C.



Fig, 28 Fractured pebble from Escondido cong. shown fig. 27

word Fault (fig.2), he will see the view shown in fig. 26, which has marked on it the approximate trace of the fault surface. Along this line one can find from place to place patches of white fault gouge. The fault was not traced beyond Tick Canyon, where it seems to spread into a fault zone.

To the west, the fault is lost under the talus slope and could not be definitely located on the other side. In Mint Canyon, at the point 51, there was found considerable gouge and thus the fault has been assumed to extend across the intervening country. It is clear, however, that the fault has been greatly reduced in importance. But, we find, at the same time, two definately known and two probable faults paralleling it to the south. In addition to this, we find that these faults increase in displacement toward the west, and thus it is apparent that we are dealing here with a fault zone.

A study of the region near the fault shown in fig. 25 shows evidence of violent faulting activity. There is to be found, about ten feet south of the main fault, a patch of Escondido material, see fig. 27, which has been brought into view at this point by some complicated fault movement within the zone. It is highly fractured in a horizontal plane. Note rock which is outlined. Fig. 28 shows the same rock when it is cleaned off. It is clearly a stream worn pebble which has been repeatedly fractured and recemented. It is rather suprising that the rock should be fractured horizontally when the fault is a vertical one. There have apparently been considerable compressional forces involved in the faulting. The basement is also fractured horizontally.

The exact method by which, and to what extent, this fault zone crosses Mint Canyon is highly problematical. No point on the opposite side of the canyon from 51 could be found to show good evidence of faulting. This fact, together with the occurence of a patch of Mint Canyon Formation on the west side of the canyon, and the general shift of the contact between Basement Complex and Mint Canyon Formation on the west side of the Canyon, toward the south, suggests that there might be a strike-slip fault in the canyon, which would also account for the erosion of the Mint Canyon Gorge.

Structures involving the Mint Canyon Formation: The remainder of the geologic structures are to be found in relation to the Mint Canyon Formation. As previously mentioned, part of the Escondido Formation is cut off by a north-south fault in the eastern part of the area, (see map) and replaced with the Mint Canyon Formation. The boundary of the Mint Canyon Formation with the older rock is continued toward the west by another fault which joins the group of of faults slicing up the Escondido at the mouth of Forbidden Canyon. Near this point, the nature of the contact is best shown. The fault dips south about 70° and the sediments dip south from 30° to 40° decreasing rapidly in dip toward the south. About 200 ft. from the contact they are dipping 23°S. The contact here is very irregular in its vertical cross-section, the sediments being somewhat jumbled by blocks of lava wedged into them. This appearance might be misinterpreted to be a basal member of a depositional series, and consequently, the contact would be an unconformable depositional contact. The fact that this feature can be explained by wedging, indeed more satisfactorily by such a process; that this feature is not found in other places where the adjacent rock is not susceptible to block fracturing, and where, if being a basal member, it would be the same as elsewhere in regard to this characteristic; and finally, that the change in dip, which is far too great to be explained by initial dip, is best explained as due to drag effects, impels the conclusion that the contact is a fault and not a depositional contact. At three points to the west, we find dips of 60°,70° and 55°S. all of which are near the contact while to the south, they average about 17° S. In many regions, a change of dip of 40° near a contact might mean nothing, but in a region in which for miles the dip varies less than 10°, it has great significance.

On the west side of Mint Canyon, the Basement-Mint Canyon contact continues west for about 4,000ft. It then abruptly turns south for about 600 ft. and then west again. After going some 500 ft. in this direction, it turns to the north-west and continues thus to Vasquez Canyon. See map.

Very poor sorting and stratification along the first part of the contact makes a determination of the nature of the contact difficult, but what could be seen in conjunction with the apparent drag folding at 46, together with what was found on the other side of Mint Canyon, indicates that we are dealing with a fault. When we come to the break in the contact, we find, if we cross the next ridge and observe the basement in the next canyon, that the fault is continued through the basement and is found to be about vertical. The shift of the contact south, here, indicates that there is either or both a parallel fault to the east-west fault (continuation of the Mint Canyon Fault), and / or a nearly parallel fault to the north-west, south-east contact. A block, then, of basement has been dragged to the surface at this point by the mass of basement to the north. For the sake of simplicity in the following discussion, I shall call the various contacts by the letters of the blocks on each side. See map.

It has been thought that DC as it occurs to the west is a depositional contact. We know that MC is a fault. The straightness of MA and MB requires that they be fault contacts since depositional contacts in conjunction with such irregularity of ground surface would be easily visible in the field. The contact DM, on this basis, could be either depositional or fault because of the regularity of the land surface at the contact. If MC is a fault, and we assume that DC, as has been previously thought, is depositional, then DM is a fault, for it is imposible to move M with respect to C without moving M with respect to D, if D and C do not move with respect to each other. If we picture DC as a former edge of a depositional basin, DM, being a fault, M must have at one time had sediments on it. Since FA, (equals MC) is a fault, F must also at some time have had sediments on it. Again, unless we picture a very special case, then, of a peninsula projecting into the basin, the whole of M and part of C must have been covered by sediments. Then, if we shall still maintain that DC is depositional, we must agree to the unlikely statement that erosion of sediments off of C has gone just exactly the right amount to make this contact coincide with the fault DM. This is especially unreasonable in view of the fact at this point, if this is a depositional contact, some 4,000ft. of sediment have been removed, which would undoubtedly involve many times this amount in horizontal extent. Assuming, for example, that the contact is drawn correctly to 10 ft. and the basin of deposition had a slope of 20°, then the chances of coincidence of the depositional and fault contacts would be 1 : 1,200. On such a poor probability then, it seems reasonable to assume that the contact DC is also a fault. This is not the only evidence to indicate that DC is a fault especially in the eastern portion of the contact, for it is quite noticable that the contact toward the north-west for some distance is vertical and is therefore independent of the topography.

Farther to the west, it is still possible, however, that the contact is depositional, especially when one finds outcrops of granite some distance south of the contact. There are, of course, two ways of explaining such an occurrence, first, it may be an island on the basement surface which is projecting through the sediments, or second, it may be brought to the surface by faulting. It will be observed on the map that between the break in the fault contact just discussed and Vasquez Canyon, there is at a certain point in the sediments a rather sudden change in dip. This change cannot be accounted for by change of original dip, since it involves from, at least, 10° to 17°, which is much too high considering the nature of the sediments. Let us assume that the average dip of the region is about 20°S, which we can explain as due to a sagging basin to the south. If the change to 30°S at the contact was due to local buckling near a depositional contact, we must have considerable depth to the sediments at the contact to permit the buckling to take place, since it requires depth to produce such deformation. There occurs a change of 17° dip in a distance of only 600 ft. Provided the edge of the depositional basin had an original slope as great as 20° and that the whole region has been steepened in its southward dip by an additional 20°, giving the present bottom of the basin a south dip of 40°, it is highly improbable that with a thickness decreasing in the direction of the contact as rapidly as this would, such a profound change in dip should occur in the region of minumum thickness. If the bottom of the basin slopes south at a smaller angle than 40°, it leaves little space under the surface for the buckling to find relief. I assume, as I must, that the forces involved in producing the change in dip were horizontal compressional forces; vertical forces distorting the basement as near the surface as this would be, if the contact was depositional, would result in faulting, not buckling. If, however, we assume that the contact is a fault contact, then we can have a considerable thickness of sediments near the contact, and thus, the thickening in the various parts of such a fold would have sufficient space to find relief. Assuming, also, a fault contact, we need no longer explain the change of dip as due to horizontal compressional forces, but may more reasonably explain it by drag effect produced by uplift of the basement with respect to the sediment.

To summarize: If sediments are dipping on an average of 20° S and lying on a surface possibly dipping as much as 40° S show only minor folding where they are deepest, then one would not expect to find at their thinnest part variations in the dip from the slope of the basin in which they rest of 17° within a distance of only 600ft., and indeed, with the much better explanation involving faulting and the other characteristics of the contact such as regularity and independence of present topography and relations to the continuation of the contact from the east, one is almost obliged to eliminate the possibility of a normal depositional contact.

At Vasquez Canyon the fault can be observed in the canyon wall. We know fairly definately, then, that both ends of the contact are a fault, while in the center, there is evidence also to indicate such a contact. The presence of granitic outcroping in the sediments, although I have not seen it, should be closely studied before concluding that the contact is depositional, for it might easily have been brought to the surface by a parallel fault to the south of the contact, within the sediments.

The contact dotted in Vasquez Canyon is only suggestive of what appeared to be the situation on an excursion up the first ridge west of the canyon and back down the canyon. On the ridge, at 59, there are to be found tremendous boulders running up to ten or more feet in diameter which would indicate proximity to the border of a depositional basin. The sediments on this ridge contain numerous lava pebbles and anorthosite pebbles, both of which are seldom found in the western portion of the Mint Canyon Formation. Since I have not mapped any of the contact between the Mint Canyon Formation and the rocks containing these pebbles and boulders, I have not included this formation, which Kew considers to be Sespe, in the report.

Structures entirely within the Mint Canyon Formation:

Starting from the far eastern part of the area, about a mile and a half east of Tick Canyon, on the above mentioned dip slope, we find the sediments dipping north-west. See map and fig. 16, page 32. The straightness of the canyon

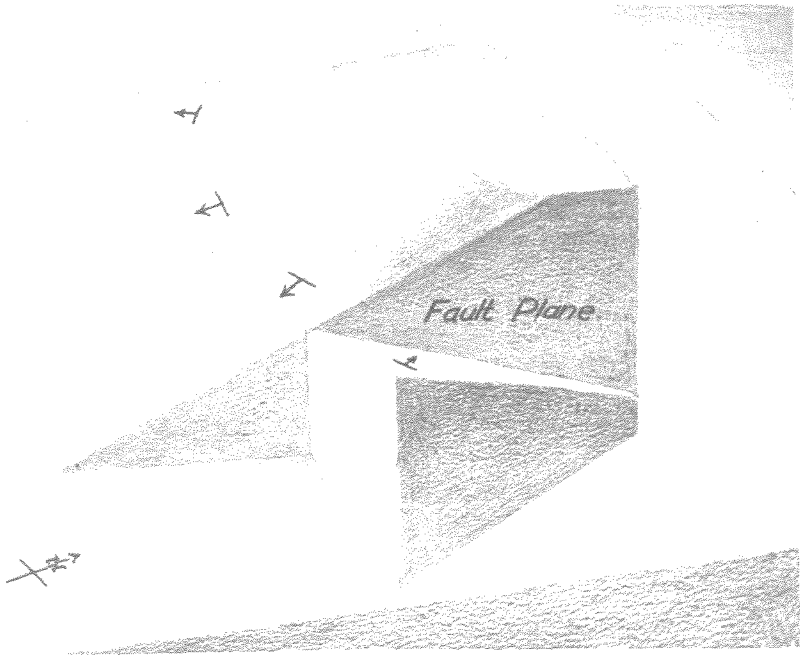


Fig.29 Structure block diagram for a MC structure east of Tick Canyon. The two surfaces marked with strike and dip marks are those observed in the field, the fault plane is assumed from these relations.

to the west of this slope looks like it might be an erosional feature controlled, in part, by a fault. Also, the sudden change in dip, which shows no transition, would indicate faulting. See fig. 29. The dip and strike of the dip slope (top of small block) indicates that if the valley is a syncline, it is plunging north, while the dip and strike to the west of the valley indicates that the syncline, like the anticline (portion of a dome) which is known to exist, would be plunging south. This, together with the sudden change in the dip and uniformity of the dip slope, indicates that the reversal in slope is due to faulting, as suggested in fig. 29. In the diagram, the slopes are drawn approximately

Fig. 30 Minor Fault in Tick Canyon. View facing down stream.

to scale, and it is obvious that with the dips as they are, it would be impossible to form a simple fold so as to make the two surfaces continuous.

Going now to the west, it is possible to follow a cliff-forming conglomerate, from near the dip-slope, all the way across the intervening country to Tick Canyon. Dips were obtainable by sighting across reëntrants into the cliff and are therefore quite accurate, in spite of the poor bedding. Near Tick Canyon the conglomerates are slightly displaced by a fault, but it does not appreciably modify the general structure. See fig. 30 which is taken facing down stream in Tick Canyon. The fault seems to go diagonally across the view and run into the other side of the canyon, but it could not be located there. The **east** side of the fault, as shown in the picture, has been raised with respect to the **west**.

From here, one can follow the conglomerate up the west side of the canyon (see fig. 14 page 32.) until it intersects the road and is burried. From this relation, it is clear that we are dealing with a portion of a dome which has its apex some distance to the north and east of these outcrops.

To the west, there is apparently a syncline. Cliff-forming conglomerates, dipping west, can be easily picked out on the map until **we** get near the Mint Canyon Road where we find, especially well exposed south of the Mint. Canyon School, a series of beds dipping east 10° and striking north-east, south-west. See fig. 17 page 34, facing east. Like the other structures, this seems to plunge south.

West of the Mint Canyon Road, we have another major structure which is more of a warped surface than a dome. It might be described on a structural contour map as a nose. Looking west from a point some distance to the east of the great terrace, one can see the strata, north of the end of the terrace, dipping about 15°S, and then to

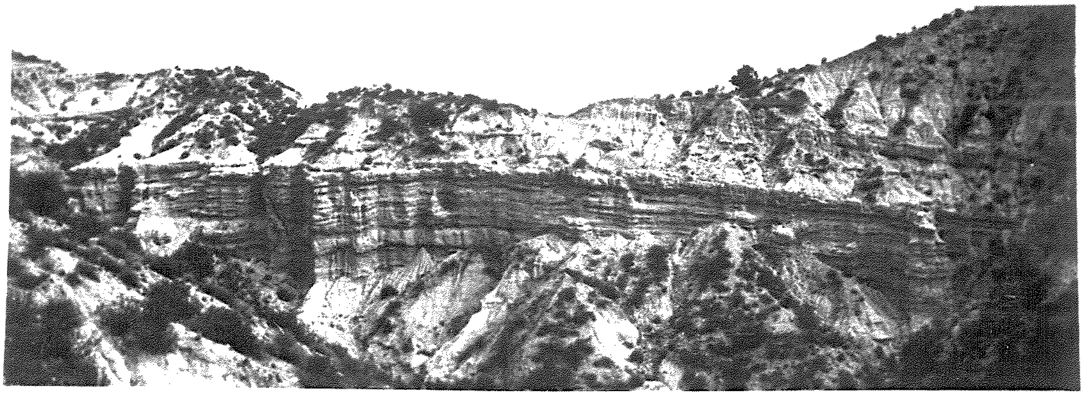


Fig. 31 Section across nose in the Mint Canyon Formation, facing north and near the north end of the Great Terrace.

the south, centering at about the north end of the terrace, one can see a cross-section of what appears to be a low anticline. This is a section of the nose. Viewing this structure from the south where it is well shown on the long ridge running from the north end of the terrace toward the south-east, we can see, here also, what appears to be an anticline. See fig. 31 which is taken facing north-east from a point about a thousand feet south of the center of the nose. In this view, the strata are dipping about 5°S

On the west side of the terrace, Kew has shown two anticlines and a syncline which seem very obvious when viewed from the north end of the terrace; see fig. 19 page 38; but upon close inspection, they are found not to exist, but to be merely due to erosion in the southward dipping strata.

There are occasional faults to be found in various places, but they can be located, in general, only in one place and therefore have little significance.

Historical Geology: Sometime back in the pre-Jurassic, a series of sandstones and conglomerates were deposited and burried under a great thickness of material. These were gradually metamorphosed into a great mass of gneisses. Still in the pre-Jurassic, these gneisses were tilted, some one way, some, another, but all of them maintained an approximate east-west strike. Following the Jurassic came the Nevadian Revolution which intruded great quantities of granitics into the country rock. This process undoubtedly took place over considerable time and may, in this particular area, have proceeded as suggested in the historical discussion given under the heading of the petrology of the basement.

Escondido Formation: We find no evidence of sedimentation in the area until sometime around Oligocene when the Escondido Series was laid down: first conglomerates, then sandstones, shales, gypsum, and ash beds. During this period of deposition, the old gneisses were being eroded and their detritus deposited. Toward the end of this first period, a few lava fragments were brought in, and soon after, a great thickness of lava was spread over the country. For a while, volcanic activity stopped, and sediments burried the lavas. In Forbidden Canyon, we found that the feldspars were fresh, and biotite was common in the sandstones which indicates that the deposition was probably carried on by intermittent streams. Even shales must have been deposited on the land surface in lakes, because of the lack of fossils. Limestones which also occur must have formed in lakes. The abundance of gypsum in some beds indicates, perhaps, evaporation from dry lakes and an arid climate. Following our second series of sediments came more lava, and then again, more sediments until the land mass was apparently reduced to a low level as indicated by the predominance of shales toward the end of deposition.

Formation of the Mint Canyon Series: Sometime in the middle Miocene, mountain making processes buckled the series of Escondido sandstones and lavas into great isoclinal folds, and at the same time, the basement complex was reelevated. In the east, large amounts of the folded Escondido were removed and deposited to the south in a great basin extending to the San Gabriel Mountains. The lavas, which apparently were rather limited in horizontal extent, never gave much material to that part of the basin west of the Mint Canyon Road, and before long, they were largely eroded; and then became buried under a considerable thickness of gneissic detritus.

Deposition of the new beds was carried on largely by rivers, probably on great low lying alluvial fans spreading toward the south. In places we found shales, some of which are nearly limestones. These must have required quiet water, and so, there must have been occasional lakes on the land surface. As has been discussed under Petrology of the Mint Canyon, there is some evidence to show the existance of meanders. Possibly these lakes were formed as ox-bows, although, it seems doubtful in view of the apparently arid nature of the climate.

Post-Miocene Time: Finally the land ceased to receive sediments, and thus it remained until sagging of the basin in which they lay tipped them into their present position, forming at the same time the other structures found in the series. A period of erosion now removed vast quantities of material thus forming the tops of the terraces, now visible throughout the area. On these eroded surfaces, small amounts of alluvium were deposited and may now be seen in isolated patches where recent erosion has left them. The terraces, one finds throughout the area, are not what we commonly think of as stream terraces for they are simply remnants of former valley floors, parts of a middle mature topography, which have been cut back by recent streams.

Bibliography

(1) Hershey, O.H., Some Tertiary Formations of Southern California: American Geologist, vol. 29, pp 349-372, 1902

(2) Kew, William S.W., Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, California: U.S.G.S. Bulletin 753, p. 38.

Explanation of Plates

Plate I

1. Myrmekite (my) in plagioclase(plag) with quartz (qz) replacing the plagioclase. Hematite also shown. (he) Slide Da, X nicols 46X

2. Two stages of quartz development showing sutured contact and numerous fine fractures in the quartz Slide Da, X nicols 46X

3. Carlsbad twin of orthoclase (or) enclosing resorbed quartz (qz) Slide D100, X nicols 46X

4. Microcline which has in part lost its twinning. Slide D100, X nicols 46X

5. Development of muscovite in quartz-feldspar rock. Slide $D96_a$, plane light, 46X

6. Myrmekite (my) in plagioclase enclosed by otthoclase (or). Remnant of microcline (mi) also visible. (bi) biotite, (mg) magnetite, (qz) quartz. Slide $D95_2$. X nicols 46X

Plate II

1. Transition from microcline (mi) to orthoclase perthite (or_1) and final stage in the transformation to orthoclase. (or_2). The light colored material is late formed muscovite. (mu) Slide $D93_2$, X nicols 46X

2. Partially modified microcline perthite Slide $D93_2$, X nicols 142X

3. Metamorphosed sandstone showing calcite (cal) cementing material which in other portions of the rock has been replaced by quartz and changed into epidote. Quartz grains (qz). Slide $D93_4$ X nicols 142X

4. Same as 2 with stage rotated so as to show perthitic nature of mineral. 142X

5. Garnet (ga) development in migmatite also showing biotite (bi) which is partially altered to chlorite. Slide D98 Plane light 46X

Explanation of Plates cont.

6. Showing reduced garnet (ga) development, a short distance from the above location. Most of the medium gray material is late developed muscovite. Hematite also shown. Slide $D95_1$, oblique illumination 46X

Plate III

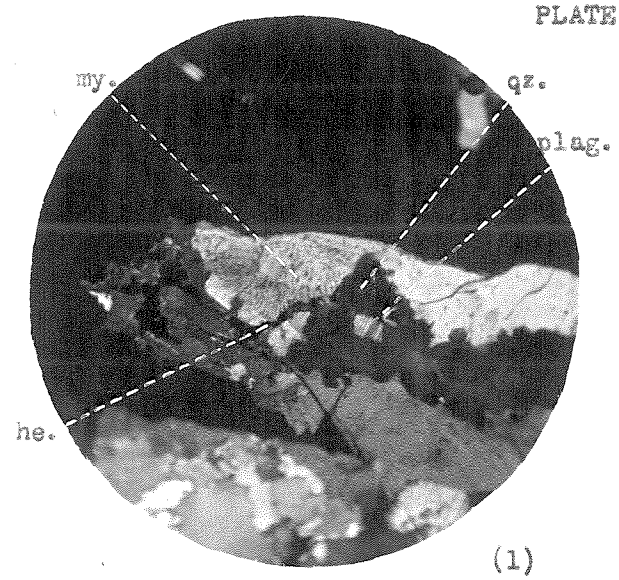
1. Lava from the Escondido formation. Olivine Basalt. Slide $D22_a$ Plain light 46X

2. Same as 1. with X nicols 142X

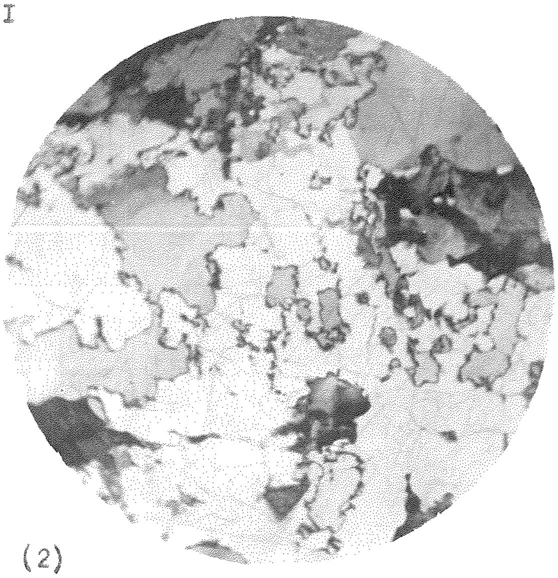
3. Vesicular lava showing flow texture from the Escondido formation. Olivine Basalt. Plane light 46X

4. Broken amygdule from the lava in the Escondido formation. Upper part of the right hand half shows large calcite crystal, remainder is quartz. ~~0.8X~~ 1.5X

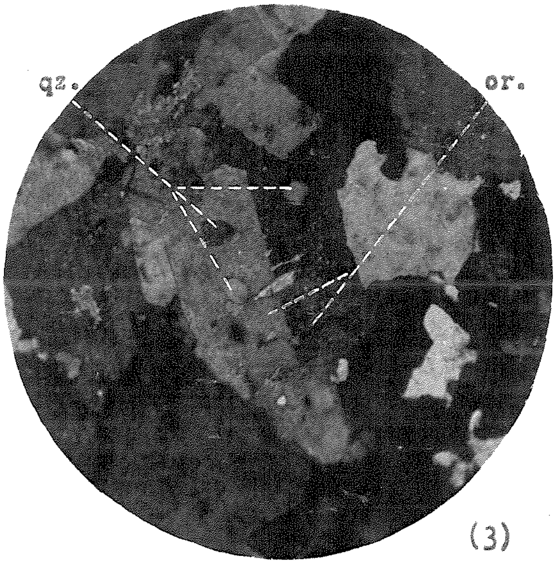
PLATE I



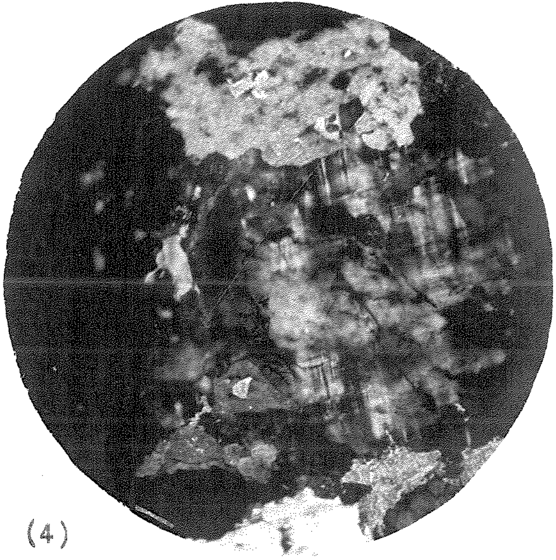
(1)



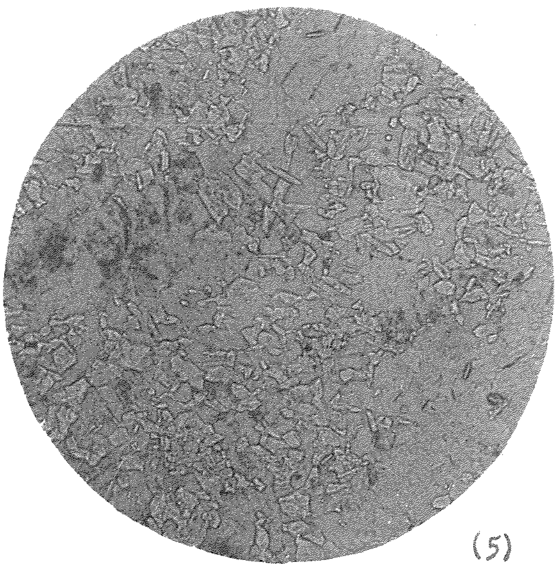
(2)



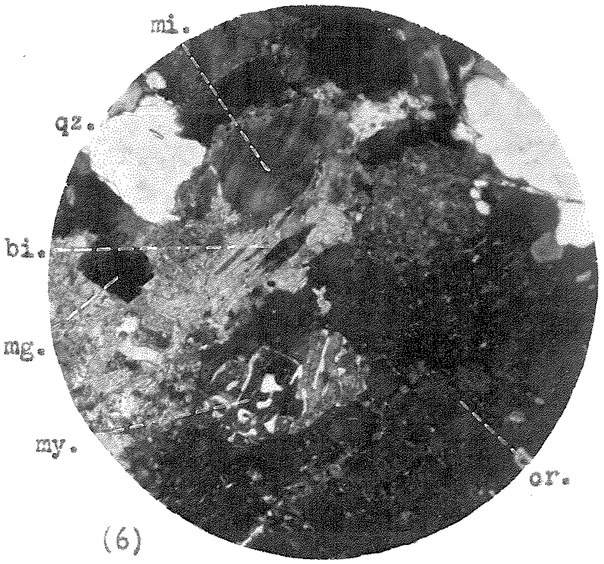
(3)



(4)

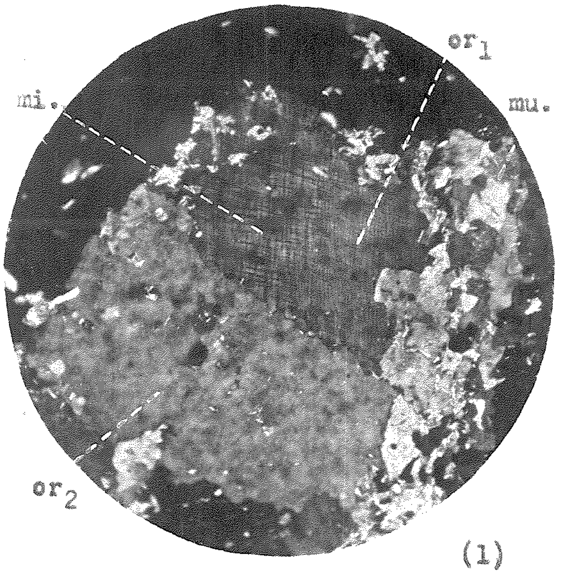


(5)

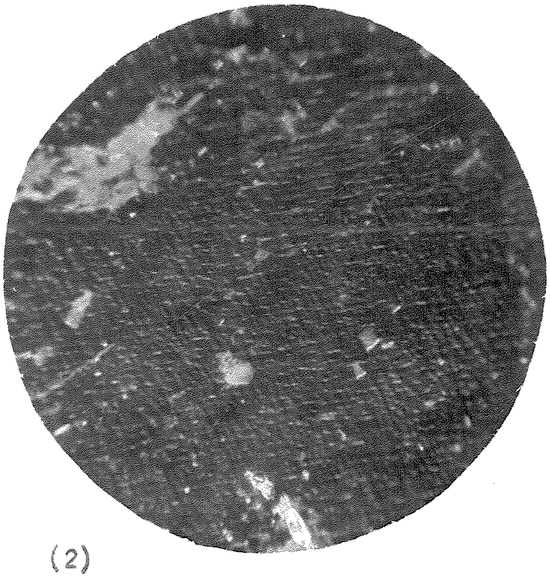


(6)

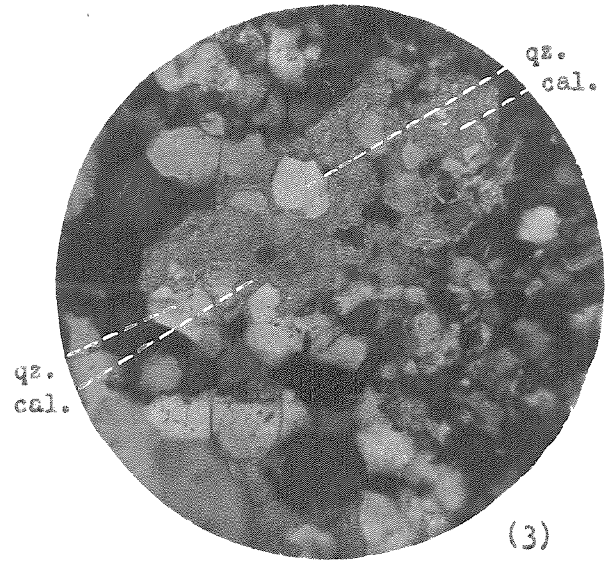
PLATE II



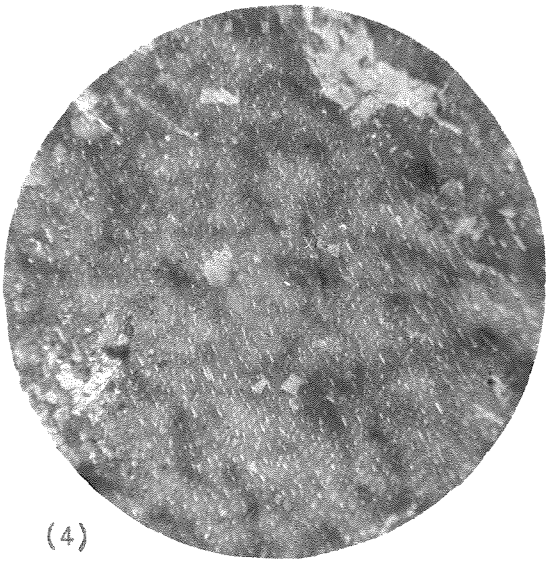
(1)



(2)



(3)

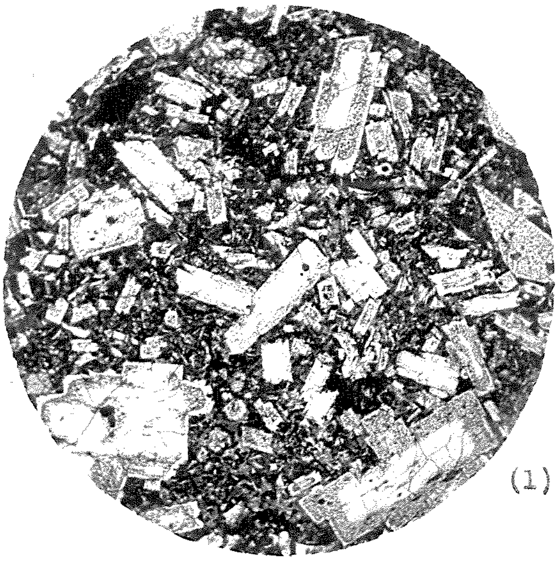


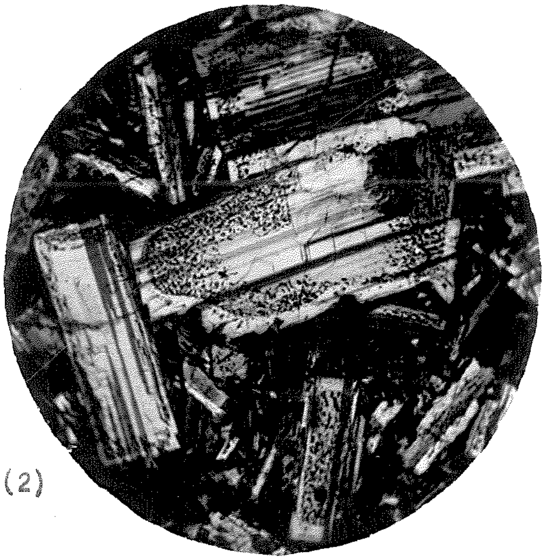
(4)

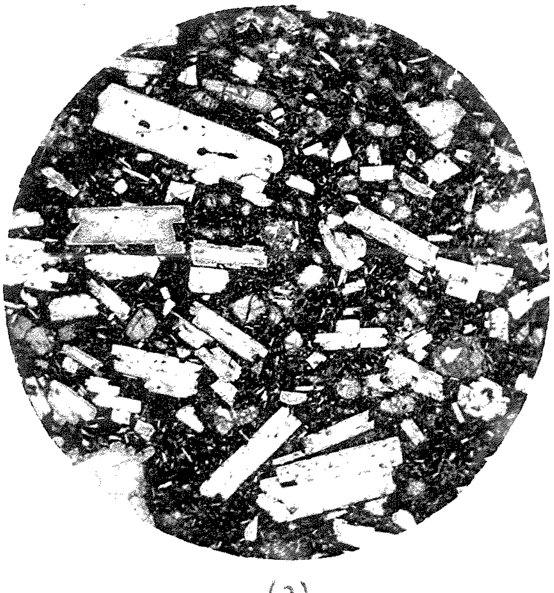
(5)

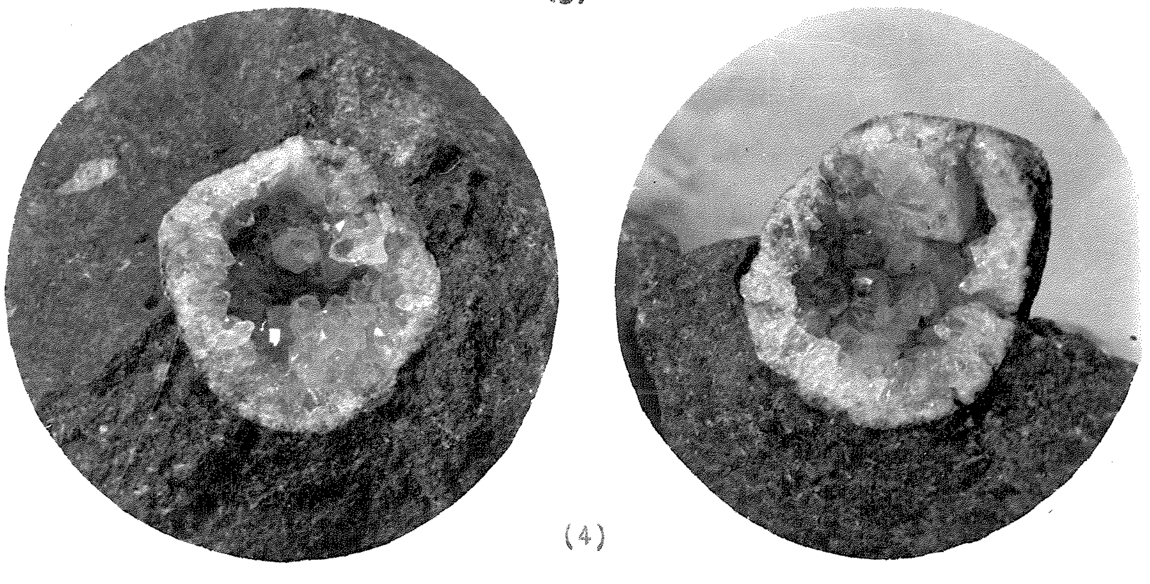
(6)

Plate III


(1)


(2)


(3)


(4)