THE GEOLOGY AND MINERALOGY
OF
THE LIMESTONE DEPOSITS
AT
CRESTMORE, RIVERSIDE COUNTY,
CALIFORNIA.

Thesis by John W. Daly.

In Partial Fulfillment of the Requirements
For the Degree of Master of Science, California Institute
of Technology, Pasadena, California.

1931.

TABLE OF CONTENTS.

	Page.
INTRODUCTION	1
Location	1
History	1
Purpose of Investigation	2
Method of Investigation	2
Climate	2
Relief	2
Acknowledgements	3
PHYSIOGRAPHY	4
SUMMARY	5
SEDIMENTARY ROCKS	6
Jurupa Series	6
General Statement	6
Undifferentiated Complex	7
Origin of the Undifferentiated Complex	11
The Limestones:	
Chino Limestone Body	12
Chino Quartzite	14
Sky Blue Limestone Body	15
Jensen Limestone	17
Other Outcrops	18
Undifferentiated Limestone and Grano-diorite	19
Age and Suggested Correlation of the Jurupa Series	20
IGNEOUS ROCKS	22
Hypersthene Quartz Diorite	22
Grano-diorite	25
Quartz Monzonite Porphyry	30
Granite Porphyry	35
Pegmatite Dikes	36
Age of the Intrusive Rocks	39
CONTACT ROCKS	41
Garnet Contact Rock	41
Vesuvianite Contact Rock	43
Quartz Garnet Contact Rock	44
QUATERNARY ALLUVIUM	45
STRUCTURE	46
Fracturing	47
ECONOMIC ASPECTS	48
Crestmore Quarries	48
Jensen Quarries	48
Hauser Quarry	49

TABLE OF CONTENTS.

Page.

MINERALOGY 49
Elements 50
Sulphides 50
Oxides 51
Carbonates 53
Sulphates 54
Compounds of Sulphates with Salts of Other Acids.... 54
Phosphates 54
Anhydrous Silicates of Divalent Bases 55
Silicates of Divalent Bases with Hydrogen, Fluorine, Chlorine, or Sulphur 57
Hydrous Silicates of Divalent Bases 57
Hydrous Silicates of Trivalent Bases 61
Silicates of Boron and/or Rare Earths and One or More Other Bases 61
Anhydrous Silicates of Al(Cr,Fe,Mn) and One or More Other Bases 61
Silicates of Al(Cr,Fe^{111},Mn^{111}) and One or More Other Bases, with Hydrogen, Fluorine, Chlorine, or Sulphur 64
Hydrous Silicates of Al(Cr.Fe^{111},Mn^{111}) and One or More Other Bases 66
Compounds Consisting of Silicates with Salts of Another Oxygen Acid 66
Tables 68
CONCLUSIONS 70
BIBLIOGRAPHY 72
ILLUSTRATIONS
Maps
Plate I, Plate II, Plate III..Envelope in Back of Report.
Figures ....Following Page.
Figure 1 18
Figure 2 19
Figure 3 23
Figure 4a,-b 24
Figure 5a,-b 29
Figure 6a,-b 31
Figure 7a,-b 32
Figure 8a,-b 38
Figure 9 40
Figure 10 40
Figure 11 47
Figure 12 48

INTRODUCTION:

This report describes the work done in an area roughly seven square miles in extent. More specifically it includes all, or parts of, sections 31, 32, 33 and 34, T.1.S.,R.5 W.,S.B.B.and M., and of sections 2, 3, 4, 5, 8, 9 and 10, T.2.S.,R.5 W.,S.B.B. and M.

Crestmore lies on the extreme lobe of the Jurupa Mountains, an east west range roughly eight miles long and three miles wide. This range parallels the front of the San Gabriel Mountains and rises above the flood plain of the Santa Ana River in the manner of a typical "inselberg".

The cement plant and the limestone quarries of the Riverside Cement Company are located at Crestmore. In addition it is a station on an interurban line. Hence the locality is accessible to the geologist and mineralogist both by trolley and by way of good paved highways.

Quarrying operations were started at Crestmore some seventeen years ago. The material was first used for cement, road metal, and sugar refining. With the increased value and demand for cement the quarrying operations were given over entirely to cement materials.

Mineralogical interest was first aroused when a specimen of blue calcite with monticellite and xantophyllite were sent to A. S. Eakle. The first publication appeared in 1914 (1) and since then numerous papers have been published by A. S. Eakle, W. F. Foshag, A. F. Rogers and others.

The purpose of the present investigation was to study the general geology and determine the origin of the minerals associated with the limestone and the other rocks of the area. The economic aspects of the deposits were also investigated.

The mapping done in the Crestmore quarries was on a scale of 1"= 100' on a map kindly furnished by the Riverside Cement Company. The hills to the east of the quarries were mapped on a portion of the U.S.G.S. San Bernardino Quadrangle, originally of the scale of 1:62500, but which was photographically enlarged to a scale of 1:31250. A light plane table and a Brunton compass were used in determining locations.

Besides the fact that the climate is of the semi-arid type, common for Southern California, this particular district is the center of strong winds. In the winter, these blow from the Mohave Desert southward thru the Cajon Pass. In the summer the prevailing winds come from the coast thru Santa Ana Canyon.

The highest and lowest points in the area are 2000 feet and 900 feet respectively, the relief in general averages less than this. Regional drainage flows to the southwest into the Santa Ana River.

The underbrush is not thick and is burned over in a large part. As a consequence of this and of the steep relief, exposures are generally good. The quarries offer an excellent opportunity to collect fresh samples. Near the cement plant the rocks have been covered with dust and have been glazed in such a manner that recognition of rock types is often rendered difficult.

The writer wishes to acknowledge the help given by Mr. Rene Engel under whose supervision this work was conducted. He wishes to thank the officials of the Riverside Cement Company, Mr. John Treanor, Mr. G. A. Beckett, and Mr. Earl MacDonald, for their permission to make a geologic map of the quarries. Mr. Thomas Mullan, chemist for the Riverside Cement Company, has very generously made numerous analyses for the author and has collected samples for him. Mr. C. A. Robotham of the Mining Department of the Riverside Cement Company has made many helpful suggestions.

PHYSIOGRAPHY

Physiographically this area possesses many interesting aspects. The topography is of a type which can be described as advanced maturity. The steep slopes of the mountains rise abruptly above the alluvial plains in which their lower parts have been buried. It appears that the Jurupa Mountains represent the higher portions of a fault block which, with respect to the higher San Gabriel and San Bernardino Mountains, has been down faulted. It has been partially buried by detrital materials derived from these higher mountains and carried into this valley by the Santa Ana River and other water courses from the higher mountains.

It is evident from the terraces in the Santa Ana River,bed and the renewed erosion near the base of the Jurupa Mountains, that sedimentation by the Santa Ana River has ceased and degradation is now in progress.

The present position of the peaks and valleys in these mountains appear to be directly related to the rock hardness. For instance, the points where the grano-diorite shows fluxion structure are usually of lower elevation and are flatter than where this structure is not developed.

SUMMARY.

In summarizing the results obtained in this investigation the following points are emphasized:

1. In this area there is a thick series of recrystallized quartzites, arkoses, shales and limestones. This recrystallization is due partly to igneous intrusions and partly to regional forces operating before these intrusions.

These sedimentaries are of Paleozoic age.

2. The sediments have been intruded by a related series of pre-Cretaceous plutonic rocks. From oldest to youngest these rocks are; hypersthene quartz diorite, grano-diorite, quartz monzonite porphyry, granite porphyry and pegmatites.

3. The structure is not complicated by faulting.

4. With reference to the metamorphism of the limestone:

a. The role of the grano-diorite has been principally recrystallization.

b. The large mass of the contact rock and the assemblage of minerals is derived from the quartz monzonite porphyry and solutions from the quartz monzonite porphyry.

c. The effect of the pegmatite dikes is small.

5. The limestone deposits are of sufficient extent to assure capacity production of cement for thirty-five years with a good possibility of much more being developed.

SEDIMENTARY ROCKS.

JURUPA SERIES.

General Statement.

The oldest rocks of these mountains consist of a series of recrystallized sedimentaries, for which the name, Jurupa Series, is proposed. The lower part is composed of undifferentiated quartzites, schists, and gneisses, with small limestone lenses. Hereafter these will be referred to as the Undifferentiated Complex. Lying conformably on the complex are the limestones which are exploited for cement manufacture. On the small scale map (Plate I) these were not differentiated, but on the large scale map of the Crestmore quarries (Plate II) the following divisions have been made: (1) The lower part of the Chino Limestone Body, (2) This is conformably overlain by quartzite and schist beds, called the Chino quartzite, (3) Grano-diorite and quartz monzonite porphyry intrusions separate these lower beds from those of the upper limestone, or the Sky Blue Limestone Body. In mapping this body an effort has been made to distinguish the limits of the development of the blue calcite. This was found to be impossible, but the general distribution has been indicated by the coloring on the map.

THE UNDIFFERENTIATED COMPLEX

The hill northeast of triangulation point Jurupa is made up almost entirely of these rocks and hence furnishes the best exposures. The section has average dip of 43° NE and shows no evidence of duplication. This mass has been intruded by the grano-diorite and by pegmatite dikes, and the true base has disappeared. A computed thickness of the section, measured from its present lowest part, northeastward to the base of the hill where it has been cut off by grano-diorite, gives a figure of 3750 feet. If the thickness is measured from the base northeastward to a point in the valley where the limestone is found overlying the complex, computations show an aggregate thickness of slightly over 4600 feet. Possibly the section has been duplicated by settling during intrusion, faulting, or the strata have been forced apart nearly conformably by the intrusion.

The lower 100 feet is composed chiefly of a hard, thick bedded quartzite which weathers to a dull, greyish buff color. A hand specimen shows it to be of fine to medium grain and composed chiefly of quartz with some minor femic material which is partially arranged in bands. Under the microscope a thin section of this material reveals that the chief constituent is quartz in allotrioblastic grains, which show undulatory extinction and a slight biaxial character due to strain. The maximum grain diameter is .74 mm., however, the average is much less than this.

Augite badly altered to chlorite is found interstitially between the quartz grains. Brown biotite occurs in a like manner and is also altered to chlorite. Some small idioblastic augite crystals are poikilitic into the the quartz. In part of the section a few grains of basic oligoclase can be seen. Pyrite and apatite are the accessories. Hematite is an alteration product of the pyrite.

A micaceous quartzite gneiss is in part interbedded with this rock.

For about 1050 feet above this quartzite a distinctive biotite gneiss, which in places becomes a biotite schist, is the dominant rock. It is distinguished chiefly by its color which, on weathered surfaces is a deep reddish brown and on fresh fracture has a dark grey appearance. The bedding has an attitude of N 42° W, 45° N. while that of the cleavage plane is N 5°E, 45°S. Megascopic examination of a hand sample shows the rock to consist of biotite, quartz and feldspar. The abundant quartz is of two types; the first is in ordinary grains which exhibit undulatory extinction and enclose aggregates of rutile needles; the second type is shattered grains with limonitic stains along the cracks. These grains are unique for they show a distinct biaxial negative character. The determination as quartz is based on measurements of the indices, and on chemical tests. Strong pleochroism characterizes the biotite with X..yellow, Y..Z..dark brownish red. To some extent this mineral occurs concentrated in bands with its cleavage oriented parallel to the direction of schistosity.

Smaller crystals are poikilitic into the quartz. A few grains of oliogoclase-andesine are to be seen between the quartz grains. Apatite, rutile, and magnetite are the accessories. Save for the cataclastic effects exhibited by some of the quartz grains the texture is typically clastic.

Stratigraphically above the biotite gneiss, with a thickness of approximately 820 feet, lies a quartzitic gneiss. The bedding is coarse, seldom less than a foot thick and often in the order of five or ten feet. The rock is extremely hard and weathers to a pale greyish color, which from a distance, makes the outcrops look very similar to those of the grano-diorite. On fresh surface the rock is colored a light grey with dark mottlings of biotite grains.

A thin section shows its mineralogical composition to consist chiefly of quartz grains, with a maximum grain diameter of 1.5 mm. These grains exhibit undulatory extinction, a slight biaxial character, and enclose short rutile needles. A few grains of oligoclase - andesine, which show sericitization, are to be seen interstitial to the quartz grains. Interlaminated biotite and muscovite are present in small amounts. Accessories are confined to a few prisms of apatite and some pyrite grains, which have produced limonitic alteration.

From the top of these beds the section consists of interbedded, thin, quartzitic layers and fissile mica schists. As these mica schists weather rather easily, the points where they outcrop are of low relief, consequently good exposures are lacking; yet what could be seen seemed to indicate that this material too was thin bedded. The rock weathers to a dark reddish brown, and is dark grey colored on a fresh surface. In the hills to the southeast the quartzites are seen to contain completely recrystallized limestone lenses.

Here the section has been cut off by the grano-diorite, or the beds have been spread apart by it. At any rate, in this vicinity, the next good exposure is that of the extreme top of the formation which is found underlying the limestone in the small inselberg jutting out of the alluvium to the northeast. Here one sees that the top of the section is very similar in lithology to that which was described in the paragraph above. Thin bedded, fissile, mica schists are interbedded with thin quartzitic layers.

In a road cut south of the plant of the Riverside Cement Co. a white to grey colored, thin bedded, schist was found very closely associated with, and close to, the grano-diorite intrusive. A megascopic examination showed that the schist was composed chiefly of quartz and a white elongated prismatic, mineral thought to be either tremolite or wollastonite. The microscope proved it to be wollastonite in elongated crystals. The other minerals are: small grains of quartz which show undulose extinction, a few allotrioblastic grains of augite which show some uralitization, garnet (grossularite) in small crystals and strings of crystals all of which exhibit anomalous birefringence, and some undetermined plagioclase grains. The position of this wollastonite schist in the section is not certain but it seems to be well toward the top. It occurs definitely interbedded with the quartzites but could not be traced along the strike. It undoubtedly represents impure limestone beds or a limey lens in the original sandstone which has been altered with the development of contact metamorphic minerals by the intrusion of the granp-diorite.

The quartsite above the wollastonite schist are extremely fine grained and dark grey to black colored on fresh fracture. The beds are thin, never more than two or three inches thick. A thin section shows it to be of a clastic texture, the maximum grain size of which is .82 mm., the average would be much closer to .4 mm. The banded appearance is determined by the variation in the grain size. Most of the grains are quartz which show undulatory extinction, and enclose rutile needles. A few grains of labradorite were found with the quartz. Minor amounts of biotite and muscovite are the only ferromagnesium minerals present, while pyrite and apatite are the accessories.

ORIGIN OF THE UNDIFFERENTIATED COMPLEX.

It is evident from a study of the mineralogical constitution of these schists, quartzites, and gneisses that they were derived from rocks of sedimentary origin that had been subjected to regional metamorphism. The nature of the original sediments was chiefly of thick and thin bedded, fairly pure, quartzitic sandstones, alternating with more impure, clayey sandstones which also contained some lime beds and lenses. These strata, if inference can be made from their lithologic character, i.e. the purity of the sandstones and the conformable deposition on them of limestones, were deposited under marine conditions.

The metamorphism has been sufficient throughout to produce recrystallization of the original grains but the formation of the metamorphic minerals has not been seen except near the contacts. The absence of cataclastic structures show that dynamic forces were not great. From the present field relations it may be judged that the metamorphic agent was the grano-diorite, or at least the series of intrusives of which the grano-diorite is a member. This need not necessarily be the case, however, for the metamorphism may have taken place long before these intrusions, and by forces which were very different. The fact that the quartz grains in the undifferentiated complex show evidence of more stress than does the same mineral in the igneous rocks would indicate that at least part of the metamorphism had been effected before the intrusions.

THE LIMESTONES.

Chino Limestone Body.

This body is being extensively used for cement manufacture, and a quarry has been cut thru it so that the exposures are good. The rock is white, medium to coarsely granular, and medium to thin bedded. The beds are never more than two feet thick, and are often measurable in inches.

Graphitic limestones occur in beds which seem more abundant near the base, but which are found throughout the entire section. These beds are thin and of a light grey color which is due to their mottling by graphite. As has already been suggested by Eakle (3) these beds have probably been caused by the metamorphism of impure carbonaceous beds.

Another conspicuous rock type is the calcite-brucite rock, or the predazzite. The crystals of brucite occur in beds of a medium grained white limestone, with a maximum size of three milliameters. The crystal form is pseudoisometric and they are colored a light pinkish yellow. Eakle (3) mentioned this occurrence and suggested that the brucite was derived from periclase. Rogers proved this in a paper (4) published a few months later and in December 1929 be brought out another paper on this occurrence. The brucite is pseudomorphous after periclase, remnants of which may still be found enclosed in some of the brucite. Other minerals of this rock are small amounts of magnetite, wilkeite in small crystals, a few flakes of graphite, spinel in small crystals and rounded grains with a maximum dimension of .16 mm. and chondrodite in small rounded grains. Hydromagnesite and deweylite are present in parts of the beds as alteration products of the magnesium minerals. Roger's conclusion that this assemblage is due to the hydrothermal metamorphism of an impure magnesium limestone is undoubtedly correct. The relation to bedding is quite distinct and the presence of the graphite lends support to the belief.

It was noted in the Lone Star quarry that although the predazzite was abundant near the grano-diorite-limestone contact, as one followed it along the strike it disappeared near the quartz monzonite intrusions. In view of this observation it seems that the dedolomitization of the limestone must have been accomplished by the grano-diorite, The hydration of the periclase may have been caused by later solutions from the grano-diorite or by the solutions from the quartz monzonite porphory.

A large part of this body is a pure white, medium grained, crystalline limestone which does not show visible impurities. The base of the section has been cut off by the grano-diorite so that the true thickness cannot be ascertained. The maximum exposed thickness is in the neighborhood of 470 feet. The total would undoubtedly be considerably greater.

CHINO QUARTZITE.

The type of structural relation between the Chino Quartzite and the Chino limestone is not precise. They are in part separated by an intrusion of a sill-like mass of grano-diorite. Where they can be seen together they appear to be conformable but attitudes taken on various parts of both bodies show the limestone to be steeper than the quartzite although the strikes are the same. This difference may be caused by a doming effect of the grano-diorite which has separated them.

The top of the quartzite is missing, having been cut off by the grano-diorite and quartz monzonite intrusives, except in the extreme eastern end where it appears to be unconformable overlain by limestone, but exposures are poor and this relation is not certain. A computed thickness of the material exposed gives a figure of approximately 75 feet. The best exposures are to be seen in the face of the north Chino quarry where the crest is made up of thin bedded material which is red colored on a weathered surface. On a fresh surface the color is generally of various shades of grey. The beds are never more than four inches thick and on an average are much less than this. Interbedded with the fine grained quartzite are numerous layers of thin fissile schists.

A section of the quartzite shows the structure to be cataclastic while the shape of the grains are allotrioblastic. Quartz forms the most important constituent. All of the grains show undulatory extinction and a slight biaxial character, while some of them are shattered. Augite is the element next in importance. A considerable amount of labradorite represents the feldspathic element. Considerable muscovite was seen. Apatite, pleochroic titanite, and pyrite, which has given hematitic alterations are the accessories.

SKY BLUE LIMESTONE BODY.

Intrusions of quartz monzonite porphyry and granodiorite have separated this body from the underlying Chino quartzite so that the original relations can only be inferred. The attitude of the various beds differ appreciably. This is probably due to the effect of the intrusion, possibly superimposed on an unconformity or on a fault.

It is in this body that the quartz monzonite has made its greatest intrusions and the limestone has consequently suffered the most from hydrothermal metamorphism. The Sky Blue limestone and the contact rock derived therefrom have yielded most of the rare minerals forming the Crestmore assemblage.

There is no reason to suppose that the original sediment differed greatly from that of the Chino limestone and at present the differences are due only to the varying degree of metamorphism to which each has been subjected. At the base of the section near the grano-diorite contact, where the effect of the quartz monzonite porphyry has been less, the

the material is a white, medium grained, twinned crystalline limestone with some beds of predazzite. As one goes near the quartz monzonite several changes are to be noted. The crystallinity changes, becoming either coarser or finer grained, on the whole coarser, bedding becomes more obscure, the predazzite disappears and the color changes from white to a beautiful blue.

Eakle (3) states: "The cause of the blue color has not been determined, but it is believed to be due to minute inclusions of carbonaceous matter". In this connection the following has been noted: First, flakes of graphite have been found in the blue calcite; second, the color is in no way related to the bedding; third, the color distribution is sporadic but in general becomes more intense as one approaches the quartz monzonite dikes. When heated the color disappears and the mineral becomes a translucent white. This change is accompanied by sputtering and the sample breaks into smaller cleavage rhombohedrons. This shows that the color is due to some included material. Water, a rate earth, or a radioactive substance or carbonaceous or metallic material, may be the explanation but more critical or quantitative analysis has not been made.

Another curious rock type in this body is the so-called sugar calcite or "sugar lime". It is found on the south side of the Wet Weather quarry, which probably has been excavated in a limestone of this type. The "sugar calcite" is made up of a coherent to friable mass of rounded calcite grains which are seldom greater than 7 milliameters in diameter. The grains show twinning lamellae which indicate crystallization under pressure; on the other hand, the looseness of the mass indicates crystallization in an open space. A number of fissures, open and filled, and iron stains from disseminated pyrite, or magnetite have led the author to believe that this has been a locality thru which percolation of water, resolution and recrystallization effects have taken place. Analyses show that the "sugar lime" is exceptionally free of magnesium, the waters probably having leached most of the contained impurities.

Limestone is no longer exposed in the Commercial Rock quarry, but now makes up the quarry floor which is covered for several feet with debris. Hence a study of these rocks could not be made. The contacts as drawn were based on diamond drill data, and are very doubtful as far as detail is concerned.

Exposures do not show the total thickness of this body as the top of the section is covered with alluvium. Calculation of the exposed portion give a figure of over 500 feet. The total thickness can only be estimated, but may well total considerably over a thousand feet.

THE JENSEN LIMESTONE

The limestone which outcrops in the Jensen quarry has a very striking similarity to the Chino limestone. The meterial is white, medium to coarsely crystalline, many of the beds are thin, the thickest ones never being over two feet. Beds of Predazzite and graphite limestone are present, but not as abundant as in the Chino quarry. "Sugar lime" is found in part of the quarry. The body is very badly cut by

Figure I. The floor and face of the Jensen quarry. The darker patches are grano-diorite dikes.

Figure 1.

grano-diorite dikes and small garnet zones are developed on the edges of the intrusions.

The position of these beds in the section is not clear. In general the beds dip near vertical, while to the northeast, although having a similar strike they dip 35° to 45° northeast. A small valley separates these outcrops. Physiographic evidence points to the presence of a fault thru this valley, yet the exposures which are excellent do not lend support to this belief. The grano-diorite in contact with the limestone shows gneissification for hundreds of feet from either side of the contact. This may indicate that the limestone has settled into the viscous magma and the limestone block has moved downward relatively to the exposure of the Undifferentiated Complex.

Other Outcrops.

Outcrops of limestone occur to the east side of the north end of the little valley which cuts thru the center of the area. This is impure and with beds carrying brucite, graphite, and epidote. It rests on the Undifferentiated Complex and there is good reason to believe that it does not extend to a great depth.

Another outcrop is to be seen in the little inselberg which juts out of the alluvium in the north of the area. This rests on a series of finely fissile mica schist and thinly bedded quartzite. The attitude agrees closely with that of the Chino limestone and a prolongation of the strike projects into that body. Thus this limestone represents the base of the section of the rocks exposed in the Crestmore quarries and the rocks found conformably underlying it represent the top of the Undifferentiated Complex (PJU). This limestone is white, medium to coarsely crystalline, with numerous beds of predazzite. Pegmatite dikes and grano-diorite cut the mass, yet no reason exists for thinking that this body does not extend for some distance in four dimensions under the alluvium.

Undifferentiated Limestone and Grand-diorite.

The unit given the above designation and mapped as such on Plate 1 consists of the contact zone on the west side of the Jensen limestone body. It lies between the true limestone and the true grano-diorite and is a hybrid type. It concists of badly gneissified grano-diorite into which numerous blocks of limestone, both large and small, have been carried. Some of these blocks would have been mapable on a large scale, but on the scale used such a procedure would not have been feasible. As an explanation of its origin the author considers that the Jensen limestone had sunk into the grano-diorite, when the latter was becoming pasty and was susceptible to gneissification, and blocks broke from the limestone and settled in it. Another possibility would be to consider it as remnant of lit par lit intrusions which were so numerous that they completely destroyed the original structure as they continued to grow. It has the characteristics of a contact breccia due to magmatic stoping.

Figure 2. Contact of the Jensen limestone, to the left of the car, and the undifferentiated limestone and grano-diorite. As it can be seen in the photograph this undifferentiated rock consists of gneissified grano-diorite and blocks of limestone.

Figure 2.

Age and Suggested Correlation of the Jurupa Series.

Because of the lack of fossils and the isolated position of this mountain range, the age determination and correlation become largely matters of lithologic similarity. Previously described metamorphic rocks occur in the San Bernardino Mountains, The Cuyamaca region, and in the Santa Ana Mountains.

In a description of the older sediments in the San Bernardino Mountains, Vaughan (13,p.352) writes as follows: "The old sediments ...embrace, in ascending order, the Arrastre quartzite, the Furnace limestone, and the Saragosa quartzite.....the quartzite (Arrastre quartzite) is conformably overlain by the Furnace limestone .... Conformably above the limestone lies the Saragosa quartzite .... The limestone grades down into calcareous mica schist about ten feet thick, below this, is a stratum of massive quartzite six feet thick, which in turn is underlain by black and grey mica schist with quartzose layers grading down into a rather thin bedded quartzite......... a rough estimate of the thickness of the quartzite is about 2500 feet. The total may be much greater, ...

...a medium, fine grained, grey, quartzose schist... appeared under the microscope to be practically free from feldspar, only a very small amount of orthoclase and a few grains of plagioclase, probably oligoclase, being present... The rock contains a large amount of biotite as scattered flakes and aggregates. There is considerable muscovite with the biotite and both are often bent."

In describing the Furnace limestone: "In color this rock varies from white to nearly black and in texture from coarsely crystalline, individuals often being half an inch in diameter, to fine and compact ...the limestone is 4300 feet thick. In neither of these two cases do we find the limestone definitely limited, and 4300 feet is therefore a conservative estimate of the total thickness.

"From the evidence available it seems probable that the Arrastre quartzite was deposited in Lower Cambrian time. During Upper Cambrian and Ordovician time the Furnace Limestone was laid down."

On the basis of fossils found in the Furnace limestone and determined by G. H. Girty, Woodford and Harriss (14,p.270) write: Thus a Mississippian (?) age is suggested for at least a part of the Furnace formation. The fossil bed appears to be nearly horizontal, and hence is probably close to the top of the formation...

Hudson (12) correlates the Julian Schist series with the Triassic beds of the Santa Ana Mountains. This Triassic is composed of slates, quartzites, phyllites, tuffs, conglomerates and basic lavas. Some limestone lenses are found in these rocks but they form a minor part (15).

The absence of large amounts of limestone in either the Julian series or the Triassic rocks of the Santa Ana Mountains, and the lithologic difference between these rocks and the Undifferentiated Complex of the Jurupa Series are strong points in favor of the view that these rocks are not correlative. Vaughan's description of the Arrastre quartzite, as can be seen from the preceding paragraphs, compares favorably with that of the Undifferentiated Complex. There are, of course, discrepancies caused by the varying degrees of metamorphism and the differences in thickness, but in neither case is the full section exposed.

On these grounds the Undifferentiated Complex is thought to be the equivalent of the Arrastre quartzite and the Jurupa limestones are correlative to the Furnace limestones.

It is quite clear from a consideration of Vaughan's paper (13) and the one by Woodford and Harriss (14) that the exact age of these rocks and their exact stratigraphic divisions are not known. At least the upper part of the Furnace limestone is quite definitely Mississippian(?).. One can only guess at the position of this horizon in the Jurupa limestone. Nor has the writer a quantitative conception of the time interval represented by the lithologic variation between all of the component members of the Jurupa Series. Hence the Jurupa Series has been assigned to the Paleozoic(?) era without attempting to relate it to any particular period or periods.

IGNEOUS ROCKS.

HYPERSTHENE QUARTZ DIORITE.

This rock is the oldest and most basic intrusive that was encountered in the field. It is found on the extreme eastern end of the Jurupa Mountains. The manner in which it weathers characterizes it and facilitates its recognition. The hillside on which it outcrops is covered with boulders which exhibit spalling and have a distinctive brown color.

In places, especially along the periphery but in the center of the mass as well, a curious phenomena has been observed. Coarse angular pieces of the diorite have been intruded and interlaced by stringers of the grano-diorite. The size of these pieces varies from that of a few inches to one of several feet. An effort was made to map this as a separate unit but the mode of occurrence is too sporadic to permit this. Hence this breccia like rock has been included in the area mapped as the hypersthene quartz diorite.

On a fresh fracture the rock possesses a mottled grey color, and has a medium grained non-porphiritic texture. A hand lense determination show the principal constituents to be plagioclase, quartz, biotite pyroxene and amphibole.

Under the microscope a thin section gives the following data: Apatite and pyrite, which has yielded limonitic alteration products, are the only accessories present. Slightly pleochroic hypersthene occurs in abundance in anhedral grains, and in part has altered to uralite, along the periphery, cleavages, and cracks. A large part of the hornblende, but probably not all, has been derived from the alteration of the hypersthene. These anhedral grains are distinctly, but only slightly, pleochroic. The color varies from a light olive green to a slightly darker one .. Biotite is not abundant but it has a very distinctive pleochroism with X- lemon yellow,Y-Z-deep blood red. The feldspar is a basic andesine and show light zoning. Quartz, the last mineral to crystallize, exhibits undulatory extinction. The texture is holocrystalline, medium grained,

Figure 3. A picture taken near the contact of the grano-diorite and the hypersthene quartz diorite. This illustrates the manner in which the diorite (darker rock) has been intruded and interlaced with stringers of grano-diorite.

Figure 3.

hypidiomorphic, inequigranular.

A thin section of a rock sample taken at the periphery of the hypersthene quartz diorite mass, where the diorite has been interlaced with grano-diorite shows some differences. The chief difference is the texture which in this case is porphyritic. More precisely, it may be described as being holocrystalline, medium grained, porphorytic, hypidiomorphic, inequigranular. Slightly pleochroic hypersthene is again abundant and exhibits uralitization. Hornblende, in part uralitic, occurs in hypidiomorphic crystals showing pleochroic colors which vary from green to olive green. The biotite is scarce, and the pleochroism is different with X-lemon yellow, Y-Z deep greenish brown. This difference in coloration may be due to incipient alteration. The idiomorphic phenocrysts are labradorite, while the feldspar of the groundmass is andesine. Quartz constitutes but a small amount of the groundmass. Small crystals of hornblende, hypersthene and quartz are poikilitic into the labradorite phenocrysts.

The textural and mineralogical differences of these two rocks are of such nature than can be readily explained by differences in the rate of cooling. The field relations, as mentioned above, prove conclusively that the grano-diorite intrusion was later than the hypersthene quartz diorite, and that the latter rock must have been solid when intruded by the grano-diorite. Other things being equal, a previously formed contact would offer less resistance to subsequent intrusions than would any other part of the mass. Hence the

Figure 4a. Photomicrograph of the hypersthene quartz diorite in ordinary light and (b) under crossed nicols. The large dark mineral of high relief is hypersthene, which is partially uralitized. Quartz and a basis andesine make up the ground mass. Apatite and pyrite are accessories. X 30.

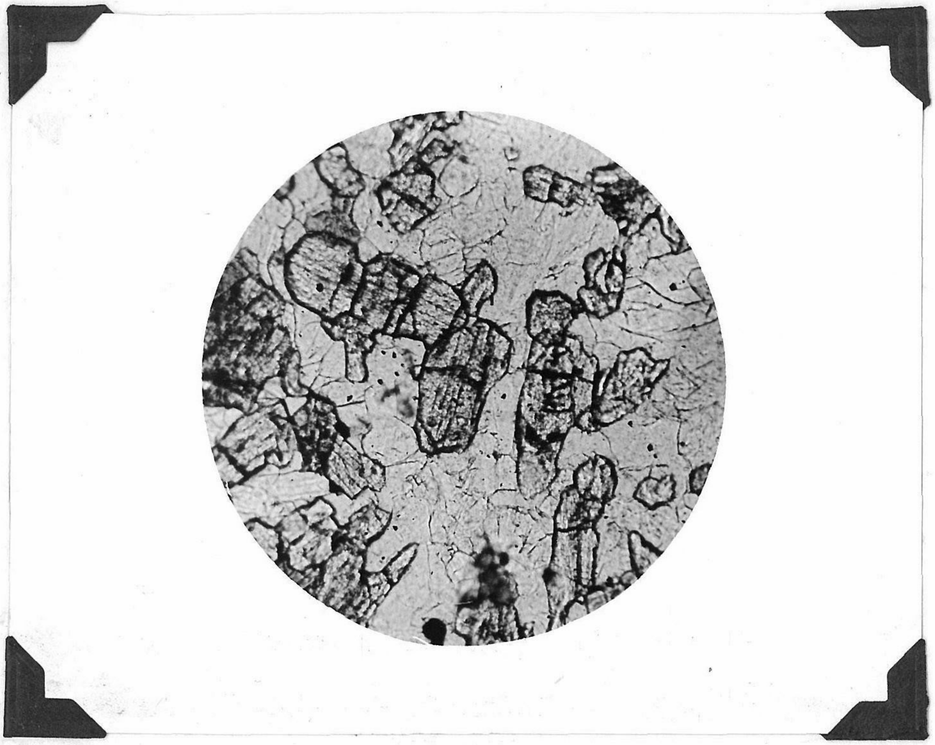

Figure 4a.

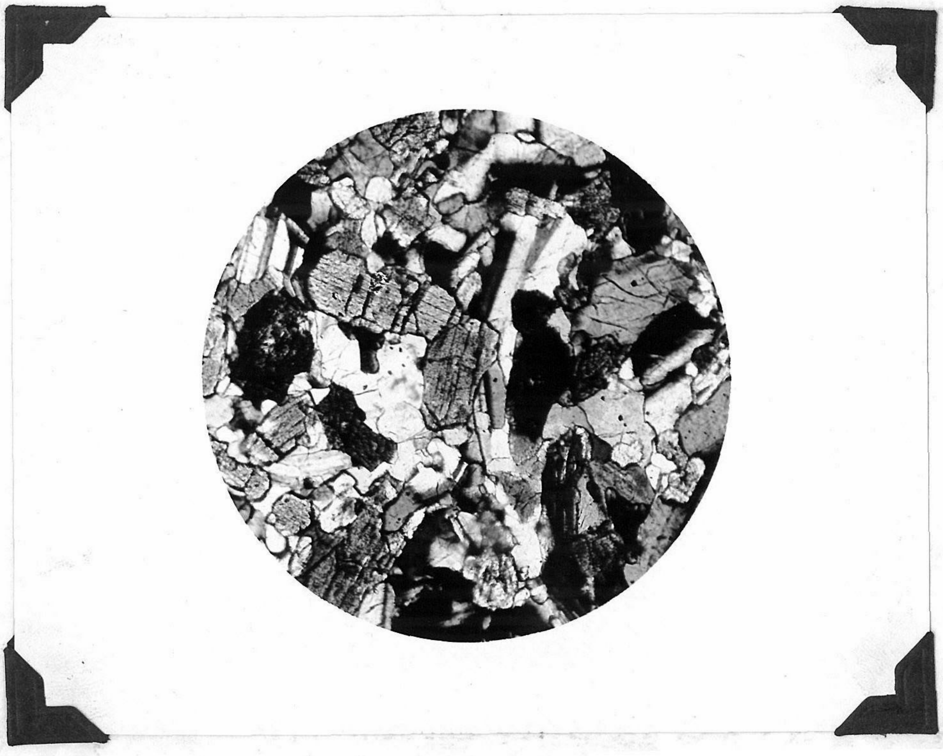

Figure 4b.

periphery of the present mass probably conforms in general to that of the original body, less a small portion which has been carried away. Considered in this light it appears that the second sample represents a border phase where cooling was more rapid than in the center. Thus we find in the first case a slightly zonedbasic andesine, and in the second case labradorite phenocrysts occur in an andesitic groundmass. This is confirmed by the distribution of the porphyritic facies toward the margins of the rock mass.

THE GRANO-DIORITE.

Grano-diorite forms the greatest bulk of the intrusive rocks in the area mapped. It is medium to coarse grained, and on weathering gives a coarse arkosic soil. A light grey color prevails throughout the weathered mass but in patches in the Crestmore quarries pink orthoclase gives the rock a red color. On a fresh fracture the rock has a lighter grey color which is mottled by the dark femic material.

One of the most characteristic features of this rock is the presence of basic inclusions. The inclusions are roughly eff-shaped, from two inches to one foot in their greatest dimension, and are to some extent oriented with their long axis parallel, probably due to flow. They are more resistant to erosion than the grano-diorite. Consequently, on a weathered surface, they protrude from their matrix and give the grano-diorite an almost conglomeratic appearance. They are less abundant near the vicinity of the Jensen Quarry although some were seen there. Megascopically they appear to represent a segragation of the more basic constituents of the grano-diorite, however, microscopic examination proves different.

A section of an inclusion taken in the Chino Quarry exhibits the following: The texture is medium grained, holocrystalline hypidiomorphic, inequigranular. Magnetite and apatite are the common accessories although one large crystal of zircon was found. Augite forms grains, and kernels in the uralitic hornblende, although some unaltered grains are present. The hornblende is uralitic in part and shows strong pleochroism with X--yellow green, Y--olive green, X--green. The abundant biotite shows pleochroism as follows: X--amber yellow, Y--Z deep red brown. This biotite shows chloritic alteration. Andesine forms the greatest part of the felsic constituents and has given place to sevicitic alterations. Small crystals of biotite and hornblende are poikilitic into the andesine, Quartz has crystallized last and shows undulatory extinction.

A section of an inclusion from the Hauser quarry exhibits both mineralogical and textural differences from the one discussed above. The material is holocrystalline, porphyritic with a fine grained, hypidiomorphic, inequigranular ground mass.. Apatite and pyrite are abundant accessories. Hypersthene, biotite and idiomorphic andesine form the phenocrysts. Part of the biotite is bleached and spotted and some of it shows chloritic alteration. This mineral is more abundant than in the previous section and shows a different pleochroism with X--lemon yellow, Y--Z-blackish brown. The idiomorphic andesine shows slight zoning and a reaction rim near its periphery. The hypersthene is uralitized around its rim. Small grains of hypersthene, hornblende, small flakes of biotite and an oligoclase feldspar are the minerals of the ground mass. Quartz was not recognized.

In the first specimen the presence of uralitic hornblende and andesine indicate affinities with the hypersthene quartz diorite. The pyroxene minerals are different but in the grano-diorite pyroxene has not been recognized. Biotite is more abundant in this case, but its pleochroic character is the same. The presence of hypersthene, uralitic hornblende and a strongly pleochrois biotite indicate the relationship of this inclusion to the hypersthene quartz diorite. The absence of quartz and the difference in texture can be explained by assuming that it represents an absorption of the border marginal facies of the diorite by the grano-diorite. The mineralogical evidence coupled with the fact that the inclusions increase in abundance as one approaches the hyper sthene quartz diorite contact gives credence to the explanation that they were torn from the solid diorite mass during the intrusion of the grano-diorite. The rather even distribution of the inclusion, their shape and the relations of the grano-diorite to the diorite at the contact that has been previously discussed, shows that the magma must have been quite liquid when intruded and cooled slowly. The coarse granularity of the rock also testifies to the slow cooling of the mass.

In the south part of the face in Hauser Quarry one can see a roof-pendant of the Undifferentiated Complex surrounded on three sides by grano-diorite. As one approaches the contact he observes that the grano-diorite exhibits prim gneissification. We know from previously cited evidence that the magma was quite hot when intruded and cooled slowly. Thus it is thought that the observed gneissification may have originated in part by the settling of the detached pendant into the grano-diorite when the latter had become pasty and in part due to magmatic flow as shown by dikes and sill like masses which intrude the Chino limestone and quartzite and which exhibit flow structure.

Megascopic examination of a hand sample shows the rock to be composed of quartz, orthoclase, plagioclase, hornblende and biotite. In describing this rock Eakle (3) states: "Labradorite and oligoclase are the triclinic feldspars present but very little albite twinning is seen". A section made from a fairly fresh sample taken in the Chino quarry does not show two generations of plagioclase, only oligoclase. Albite twinning is common. Orthoclase is in subordinate amounts. The feldspars show considerable sericization. Quartz exhibits undulatory extinction. Most of the femic material is hornblende pleochroic with X--yellow green, Y--Z--strong green. Pleochroic colors of the biotite are: X--lemon yellow, Y--Z--dark blood red. Chloritization of the biotite has proceeded to a marked degree. Small crystals of hornblende and biotite are poikilitic into some of the plagioclase particles. A holocrystalline, coarse to medium grained, hypidiomorphic, inequigranular texture characterizes the rock.

At only one place does the grano-diorite exhibite what might be interpreted as an endomorphic contact effect. This is found on the east side of the little valley which divides the area approximately in half and where the grano-diorite intrudes the shallow cover of Undifferentiated Complex about one mile north of Hauser Quarry. The rock is dark grey, fine grained, shows flow structure, and has some large dark spots caused by the local segregations of femic material. A microscopic study shows the texture to be holocrystalline, allotrimorphic, fine grained, inequi-granular Magnetite and pyrite are the accessory minerals. Biotite and hornblende are present, the former being almost completely chloritized while the latter shows some chloritization along the cracks. The salic element, which is entirely oligoclase, is much more abundant than the femic material. There is no quartz present. This rock is diffi-cult to explain by absorption of foreign material. It is more basic than its parent, i.e. it shows a lesser amount of high silica minerals. Intruding as it does the Undifferen-tiated Complex, which is so highly siliceous, one would expect the rock formed by absorption to be high in silica. Under these considerations it seems logical to consider this rock to be cooled margin of the grano-diorite.

Figure 5a. Photomicrograph of a section of the grano-diorite in ordinary light; (b) the same under crossed nicols. Hornblende and biotite are the dark minerals. Oligoclase, orthoclase and quartz are the salic constituents. X 20.

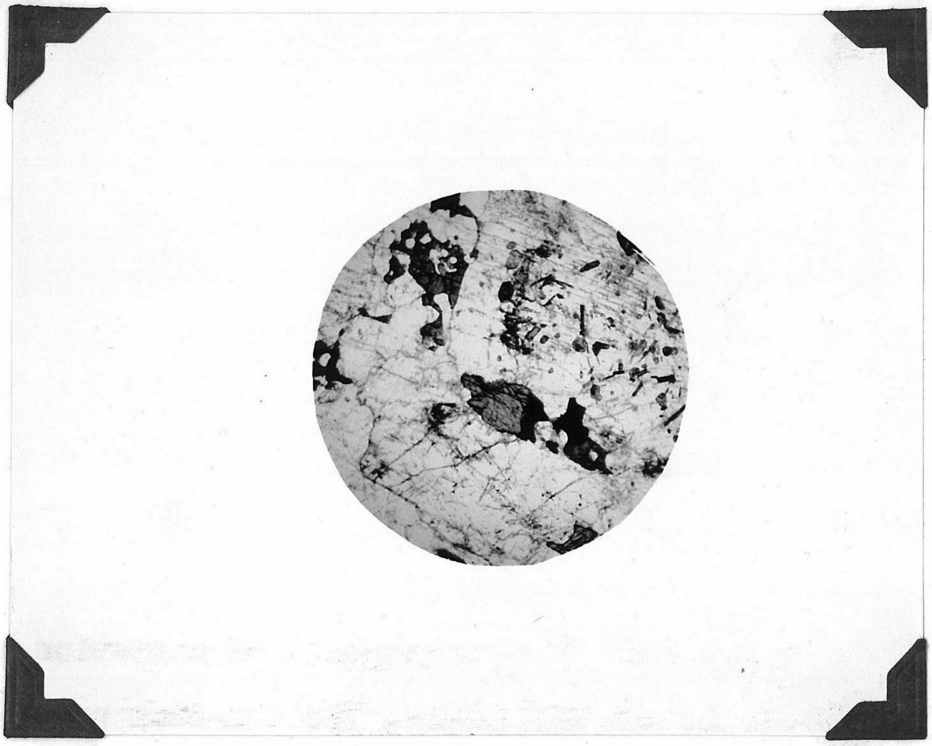

Figure 5a.

Figure 5b.

QUARTZ MONZONITE PORPHYRY.

This rock can be best seen in the Commercial Rock quarry, where the present quarry face is made up largely of the quartz monzonite porphyry and the garnetiferous contact rock. In the southwest portion of the area the quartz monzonite forms several pipe-like masses which cut the hypersthene quartz diorite and the grano-diorite.

The rock in the quarry face is fresh, ash grey colored, with a slight mottling of dark minerals, and fine grained to almost felsitic in texture. On a weathered surface the color is a pale buff. The outcrops are easily identified on a hillside by the color, the fine texture and the fact that its resistance to erosion is such that this rock stands above the surrounding ones. The texture is holocrystalline, porphorytic, hypidiomorphic fine grained, inequigranular. The feldspars are orthoclase and oligoclase both as scattered phenocrysts and as constituents of the ground mass. The feldspars are altered to sericite and calcite. Quartz is an abundant constituent of the ground mass, and occurs in part in micropegmatitic intergrowth with part of the orthoclase. Pale green augite is the ferromagnesium element which occurs in a few scattered grains and aggregates. Eakle (3) notes the occurrence of hornblende but none has been recognized by the author. Pleolchroic grains and aggregates of titanite are common. Apatite and pyrite are present, the latter giving place to hematitic alterations.

The sill like dike which protrudes thru the limestone in the lower Chino Quarry is very fine grained to felsitic in texture. The color on the outcrop is a brownish red, on fresh surface it is a dark grey. Lines of flow and the segregation of the dark minerals into definite bands and a different grain size of the minerals in the bands is apparent even in a hand specimen.

Under the microscope the rock is seen to be fine grained holocrystalline, hypidiomorphic to allotriomorphic, with an equigranular seriate fabric. Flow structure is seen with the biotite rotated with its longer axis parallel to the direction of flow and the segregation of different sized grains into bands. Biotite in small crystals and flakes is the only ferromagnesium mineral present. Pleochroic colors are X..pale yellow,Y..Z..dark brown. The feldspathic element consists of andesine and orthoclase in approximately equal amounts. The abundant quartz encloses rutile and in part forms micropegmatitic intergrowths with the orthoclase. Abundant titanite forms large grains and aggregates. Apatite and pyrite are the other accessories.

A section of a fine grained, grey colored dike which outcropped in the east face of Lower Chino Quarry, but which has now disappeared shows the following: The texture is holocrystalline, fine grained, allotriomorphic, inequigranular. The accessories are: pyrite which has altered to hematite, abundant apatute, and abundant titanite in rounded grains. Diopside forms the pyroxenic element which shows no crystal boundaries but penetrations and embayments by the salic constituênts. A few small crystals of muscovite were seen. The feldspar is dominantly orthoclase, with a few small crystals of plagioclase, probably oligoclase. Quartz is rather abundant.

Figure 6. A photograph taken in the north Chino quarry, looking westward. In the left foreground is the dike, described on page 31, cutting the Chino limestone. Above the limestone lies the Chino quartzite. A grano-diorite dike, showing fluxion structure occupies the right foreground. The headframe of the mine and the cement plant can be seen in the background.

Figure 6.

The mineralogical analysis of this rock indicates it to be more acid than the quartz monzonite, while the texture is that of an aplite. Its time relations to the other intrusives is not clear for at the outcrop it cut only the limestone. Does this represent a fine grained differentiated phase of the granite which outcrops several miles to the west, or is it an offshoot of the quartz monzonite porphyry in its later stages of coöling? The presence of the diopside and titanite suggest a relation to the quartz monzonite. Its relation in space is another point in favor of this view.

The large amount of metamorphism for which this intrusive has been responsible has not left it uneffected. Various endemorphic, as well as exomorphic effects, in which hybrid rocks are developed, have been observed. These will be discussed below.

A small dike cutting the garnet rock and outcropping for two or three feet on the top of Sky Blue hill is very interesting. A hand specimen of the rock shows white plagioclase phenocrysts set in a greenish grey fine grained, ground mass. The microscope reveals these slightly zoned phenocrysts to be andesine with sericitic alteration, while the plagioclase of the ground is oligoclase. Orthoclase is present, both as grains and in micropegmatitic intergrowth with part of the quartz. Some of the feldspar is kaolinized. Although quantitative data are not at hand, the amount of plagioclase appears to be nearly equal or slightly greater than the orthoclase. Diallage in small grains, aggregates, and twins forms the pyroxenic constituent. The material is noticeably pleochroic, the colors

Figure 7a. Photomicrograph of the hybrid type of quartz monzonite porphyry, described at the bottom of page 32, in ordinary light. (b) The same under cross nicols. The dark mineral of extremely high relief is garnet which is slightly biaxial. The cluster in the lower left quadrant is diallage. Quartz, micropegmatite and oligoclase are the other constituent minerals. Pyrite, apatite and titanite are the accessories. X 30.

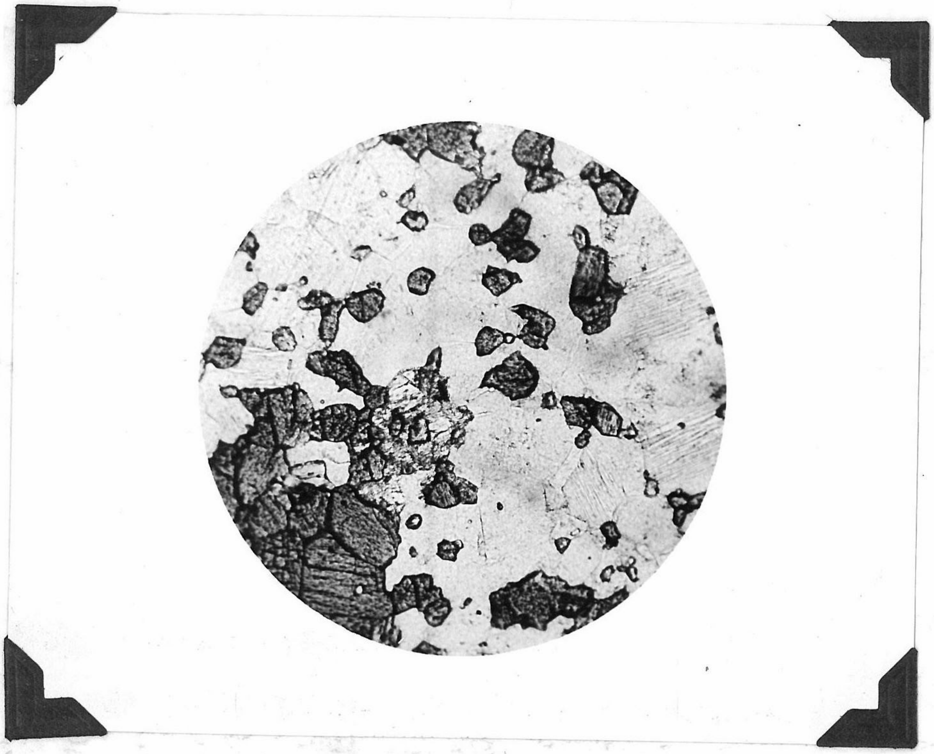

Figure 7a.

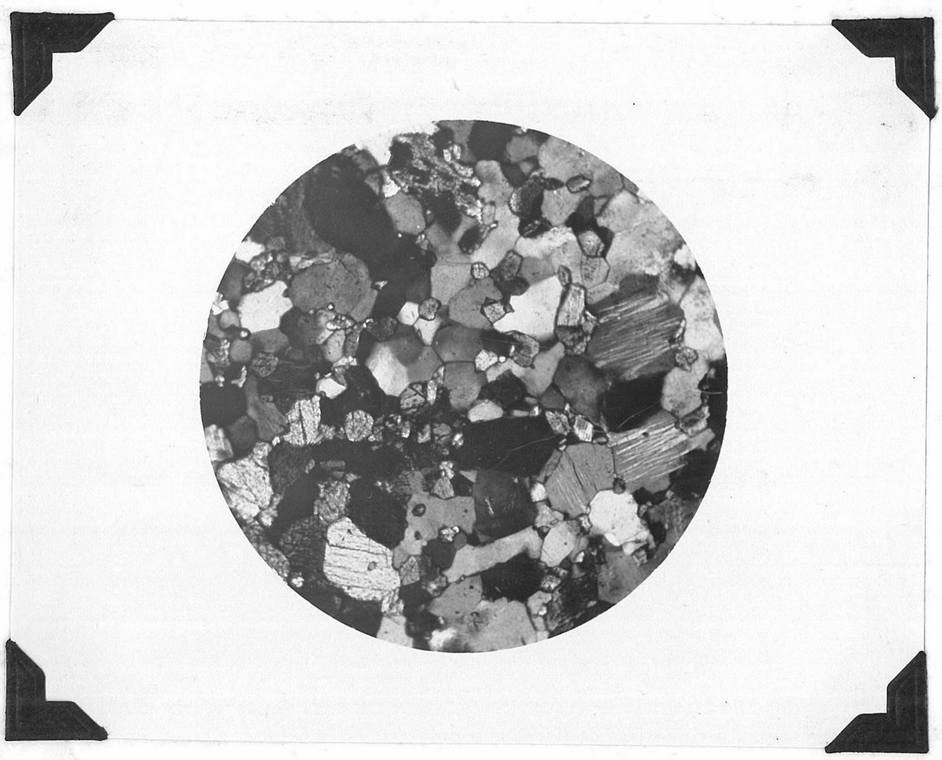

Figure 7b.

varying from green to dark green. An abundance of grossularite garnet grains occur separately, surrounding small diallage grains or, more frequently, marginal to the diallage. Titanite is frequent in grains and aggregates. Apatite and a little pyrite form the other accessories. The texture is hypidiomorphic, holocrystalline, porphyritic, inequigranular, with a fine grained ground mass.

The field occurrence and the ratio of the plagioclase-orthoclase, the quartz, and the type of accessories indicate its monzonite affinities. The occurrence of garnet points to an addition of calcium and aluminum to the magma, while the rather acidic character of the feldspar shows that this addition probably limited to the margin of the dike, was not sufficient to increase the basicity of the feldspars. It is very likely that the crystallization of the garnet and diopside of the garnet hornfels, which this dike intrudes, was contemporaneous.

A rock which cuts the vesuvianite mass in the face of Lone Star Quarry near the limestone-hornfels contact, shows even greater assimilation effects. The feldspar is all andesine, quartz, oligoclase, and orthoclase are absent. Garnet again encloses, or is marginal to the pyroxene, which in this case happens to be diopside. Quantitative data are lacking but the ratio of femic to salic elements appear to be greater in this case than in the previous one. Titanite is abundant in grains and aggregates of grains. Apatite is also present but pyrite is absent. The rock has a holocrystalline, hypidiomorphic, medium grained inequigranular texture.

Thus we see that in this case assimilation has continued after the garnet-diopside crystallization. This may be explained by the fact that here a source of calcium is available, inasmuch as the dike cuts the vesuvianite mass near the limestone.

The quartz monzonite porphyry dike which forms the crest between the Commercial and Wet Weather quarries shows a most distinct border phase. In this case exomorphic effects are scant or lacking, and most of the contact effects are due to the assimilation, by the dike, of foreign material. The border rock is green with light spots of feldspathic material. The microscope shows it to be composed largely of fresh andesine with a minor amount of augite grains. Titanite is present in rather large grains. Apatite and one large grain of hematite pseudomorphous after pyrite(?) was seen.

A sample of a dike which cuts the contact rock above the North Chino quarry is again green colored with white phenocrysts. These phenocrysts and the plagioclase of the ground mass are rather badly sericitized and kaolinized andesine. Orthoclase occurs in the ground mass both free and in micropegmatic intergrowth with a part of the quartz. The orthoclase also shows sericitization. A light green diopside with a slightly high extinction angle, probably due to the presence of some of the hedenbergite molecule, forms the abundant pyroxenic element. Titanite in grains and aggregates is abundant. Apatite and some pyrite with hematite alterations are the other accessories. The texture is holocrystalline, hypidiomorphic, porphyritic with a fine grained inequigranular ground mass.

GRANITE PORPHYRY.

The granite porphory does not come to the surface in the area covered by this report, hence a detailed study of the rock has not been made. A thin section of a sample, collected two miles west of Jensen quarry where the rock is quarried for building stone, was made and studied.

This section shows the rock to be made up chiefly of microcline and quartz. The microcline is of two generations, as large phenocrystsm ahd in the ground mass. A few grains of oligoclase are present. Orthoclase occurs in minor amounts and is in part micropegmatitic with the quartz. Some sericite has developed as an alteration of the feldspars. The quartz, in large and small grains, shows oscillatory extinction and carries included needles of rutile. Biotite is the only ferromagnesium mineral present. The color is black and in thin section shows pleochroism X- greenish amber,Y-Z-deep greenish black. Beside rutile, magnetite and apatite are present as accessories. The texture is holocrystalline, medium grained, porphyritic, hypidiomorphic, inequigranular.

The rock is quite fresh and weathers to a light buff color. On a fresh fracture the color is white mottled with specks of black biotite. It makes a beautiful and durable building stone, and finds use in the construction of churches, public buildings, etc.

This mass intrudes the grano-diorite, and is in turn intruded by the pegmatites. Its relation to the quartz monzonite porphyry cannot be seen in the field. It seems entirely in keeping with the sum of the intrusive phenomena observed in this area to assume that the granite porphyry represents a more acid intrusion of same magma that produced the other rocks, and followed the quartz monzonite porphyry in point of time.

PEGMATITES DIKES.

Pegmatite dikes form the most conspicuous feature of the countryside. They weather to the white color and form ribs which protrude above the country rock and can, in some cases, be traced for miles. They are so numerous and variable in size and extent that to map all of them would be an almost endless task. Hence the aim in mapping was to trace the major dikes in an effort to show their general trend and distribution.

The dikes on the eastern side of the map appear to have a general northwest strike as if they had intruded a zone of fracturing in that direction. However, the dip is not uniform and may change many degrees in the same dike. The dikes on the western side are more chaotic in distribution and much shorter. The width of the dikes varies from one inch or less to as much as 25 feet.

Some of the larger dikes show banding. The outer bands are made up of layers, one-half to one inch thick, composed of graphic intergrowths of albite and quartz. These layers alternate in coarseness and do not carry any other minerals. The inner zone averages in width one-tenth the total thickness of the dike. It is composed of extremely coarse feldspar and quartz with the occasional development of black tourmaline and some biotite. The composition of the feldspar varies between microcline and albite. Quartz is either colorless or smoky.

Any of these constituent minerals may be locally concentrated to the exclusion of the others.

A section of one of the smaller pegmatites from Hauser quarry shows the rock to have a coarse grained granitic texture. The constituent minerals are: Biotite which shows alteration to chlorite and with pleochroism, X..amber,Y..Z.. very dark olive green. The feldspar is albite and exhibits some sericitization. Quartz shows undulatory extinction.

Another sample taken west of Chino quarry shows like relations. Here again the texture is of the coarse grained granitic type. The former presence of biotite is testified by the presence of chloritic pseudomorphs. A small amount of hornblende is found in large idiomorphic crystals. The pleochroic colors of which are light olive green to dark olive green. Albite shows sericitic alteration. Quartz exhibits undulatory extinction.Zircon and apatite are present as accessories.

The literature of the Crestmore quarries states that the pegmatites are there in abundance. The writer has found that this is not the case but rather the contrary. Those that are present are narrow, never being over one foot in width and quite sporadic in outcrop. They are associated with the granodiorite, quartz monzonite porphory, and the garnetiferous contact rock, but were never seen traversing the limestone. Previous workers have reported seeing the pegmatites cutting the limestone, but quarrying operations have evidently destroyed these exposures.

In treating of these dikes Eakle (3) writes as follows: "The pegmatite occurs as intrusive dikes but it is difficult to trace out their boundaries. They appear to be associated more with the metamorphic masses of the vesuvianite-garnet rock. The pegmatite consists mainly of white orthoclase and green epidote. The epidote penetrates the feldspathic mass in long slender crystals, most of which are altered to a bronze-brown color. Quartz occurs as smoke granular masses but is not prominent. Zircon, tourmaline, axinite, and pyroxene and a few other minerals are found as accessories and some minerals have later been developed in the pegmatites by hydrothermal metamorphism."

With the first two sentences the writer finds that he heartily agrees but he must take exception to several of the other statements. After making determinations of the indices on grains from samples of several of the pegmatites the writer has found that the white feldspar referred to is not orthoclase but is albite. In the epidote bearing pegmatites that he has seen the epidote is not a major constituent. The development of epidote is not general and was observed only in some of the pegmatites in this quarry. Quartz occurs as a major constituent in all of the pegmatites seen, except in places where one of the other minerals is sporadically developed to the exclusion of the others. Axinite and pyroxene were not recognized by the author but they may well be present. Zircon, black tourmaline, apatite, and a badly chloritized biotite have been recognized.

Figure 8a. Photomicrograph of pegmatite dike in ordinary light. Figure 8b the same under crossed nicols. The figure shows microline of two generations, as large phenocrysts and as small crystals of a later stage. Quartz, oligoclase, magnetite and apatite are the other minerals present. X 20.

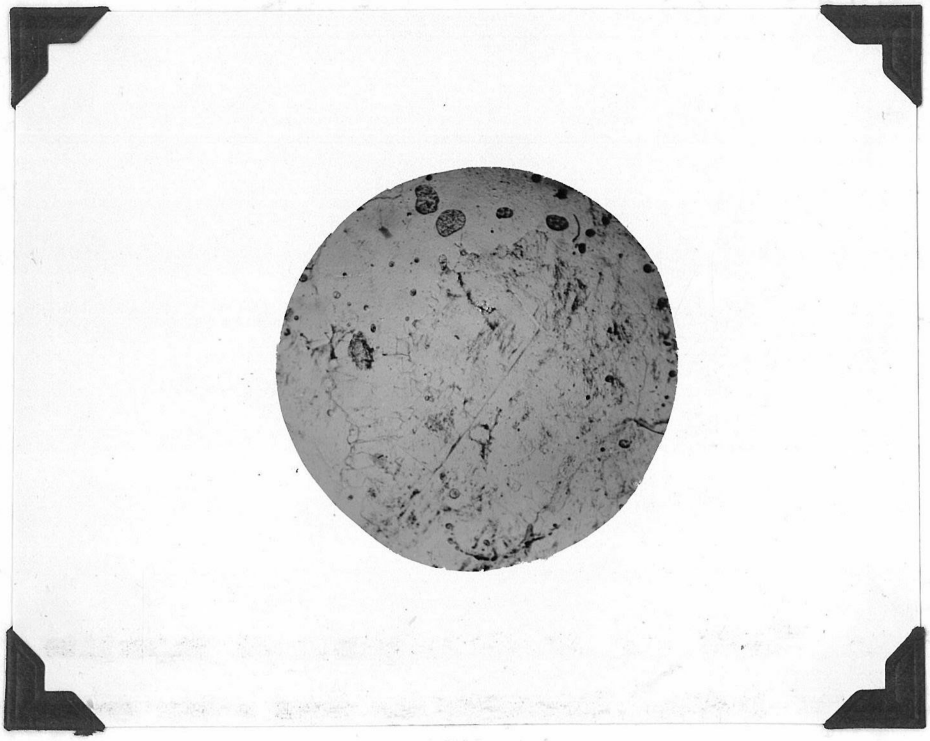

Figure 8a.

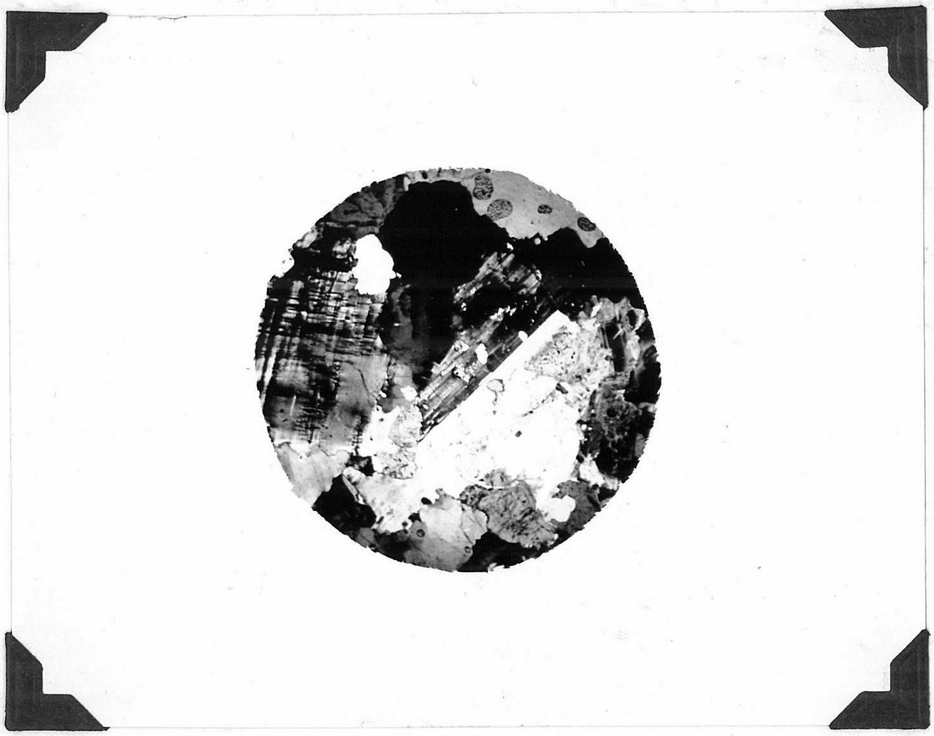

Figure 8b.

The pegmatite is clearly later than any of the rocks which it intrudes. The distribution of the garnetiferous contact rock in the Crestmore quarries has undoubtedly been formed before the pegmatitic injections; consequently the pegmatite could not have been a factor in its formation. The tourmaline, axinite, datolite and apatite indicates that chlorine, fluorine boron and phosphorous were present in the accompanying solutions but in minor amounts. Thus the major effect of the pegmatite would be only that which would result from the action of hydrothermal silicate solutions on the pre-existing minerals and would have but very little of the halides, boron, or phosphorous to add.

AGE OF THE INTRUSIVE ROCKS.

In discussing the age of the granites of the San Bernardino Mountains, Vaughan (13,p.374.) writes: "At the close of Jurassic time there was a great invasion of granitic rocks throughout the Sierra Neveda, and these have been traced down into the San Gabriels. It therefore seems fitting to assign the latest granites of the San Bernardino Mountains, herein referred to as the Cactus granite, to the same age. We have seen that there are older granites than these, which, however, also cut the limestones and quartzites. Do these belong to part of the same great period or to an earlier period which, were the record complete, would be found separated by denudation and sedimentation? A post Carboniferous invasion of the Sierras has been mentioned by Lindgren and Turner."

His references to this early intrusion are rather vague and good petrographic descriptions are lacking. Hence the exact lithologic nature of this earlier invasion is unknown to the author and a comparison on these grounds cannot be attempted.

A hypersthene diorite forms a part of the basic intrusion of the Cuyamaca Region described by Hudson(12). This has been intruded into the Julian Schist Series and an earlier quartz diorite. The hypersthene diorite is followed by intrusions of granite, aplite, and pegmatite in the order named. He has determined the age of these rocks as being pre-Cretaceous and post-Triassic, "probably corresponding in age to the post-Mariposa granitic mass of the Sierra Neveda."

The Jurassic intrusives of the Santa Ana Mountains are dacites, andesites, diabases and grano-diorite. The age determination is very precise.

The igneous rocks of the Jurupa Mountains are therefore called pre-Cretaceous without attempting to designate the exact period. Nowhere in California are intrusions of this magnitude or type known later than the Jurassic. It is very probable that these intrusions occurred during the Jurassic, but no direct evidence of this was found. In view of the fact that in the San Bernardino Mountains, Vaughan has found two distinct intrusions these rocks may well be earlier. There are, however, some striking similarities between the Jurupa intrusives and some of the Jurassic rocks described from the Cuyamaca region and from the Santa Ana Mountains.

Figure 9. Wet Weather quarry is in the right foreground. The floor and part of the face of Commercial Rock quarry can be seen at the left. The light colored rocks at the center of the picture is a dike of quartz monzonite porphyry;above it lies the contact rock,to the right the Sky Blue limestone.

Figure 10. The floor and face of Commercial Rock quarry. A light colored quartz monzonite dike occupies the left of the picture. The darker rock to the right is the garnetiferous contact rock.

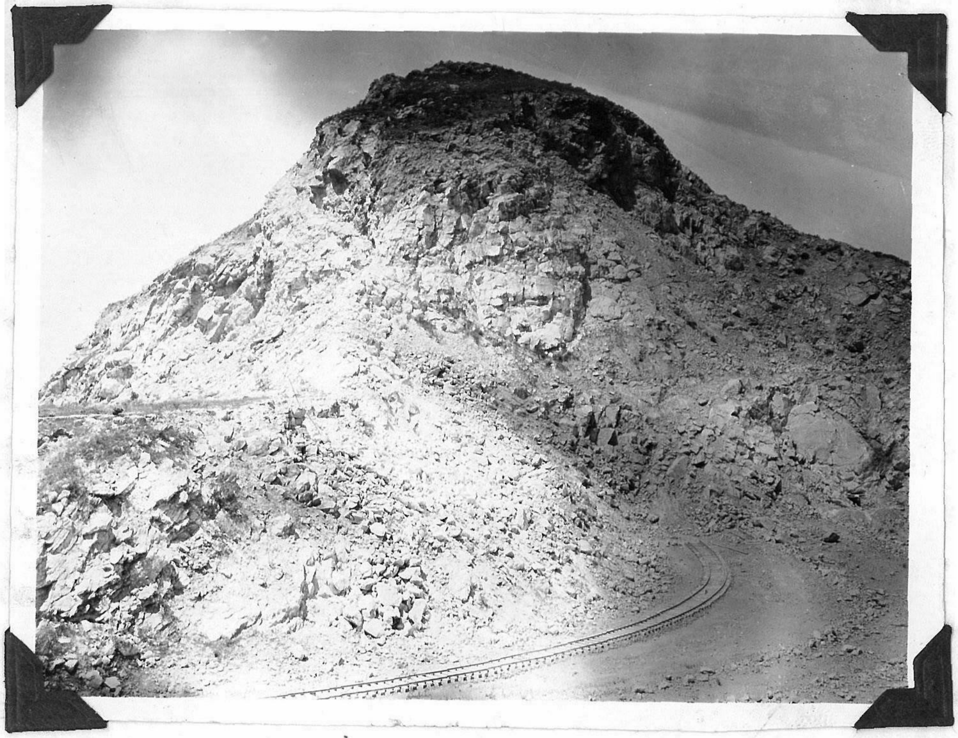

Figure 9.

Figure 10.

CONTACT ROCKS.

GARNET CONTACT ROCK:

In the Commercial Rock quarry the face is made up largely of quartz monzonite dikes and a garnetiferous contact rock. This is the same hornfels that makes up the crest of Sky Blue hill. Where seen in the quarry face the rock is fresh, brown colored, massive and extremely hard. On the top of the hill, where it has been exposed to weathering, it has become a dirty brown color, and forms ragged, angular outcrops.

A section made of the material from the Commercial Rock quarry shows that by far the greatest proportion of the rock consists of badly fractured massive grossularite. Allotrioblastic grains of augute are present, and interstitial between the garnets. The next constituent in importance is calcite which may be found in small grains and rhombohedrons which show repeated twinning striations. A fibrous mineral of low biregringence, which fills some of the smaller spaces was thought to be wollastonite.

Large amounts of wollastonite occur as columnar fibrous masses as much as 4 inches long and an inch wide. The pyroxene mineral is not always augite as is the case in the thin section. Green pyroxene have been examined from various parts of the contact mass and determined by optical tests on grains. From these results the author concludes that the pyroxene is more often diopside or diallage. In some parts of the quarry a white microfibrous mineral has been found which has been called scapolite on the basis of optical determination.

The garnet is for the most part massive but where cavities exist and where it is a minor constituent good crystal faces are developed.

Good reasons exist for believing that the original limestone was impure, but the impurities were certainly not sufficient to explain the development of so large a mass of contact rock, as one finds here. Another factor is the fact that the garnet rock follows the periphery of the quartz monzonite porphyry and is in no way related to the bedding. For this reason it becomes necessary to assume that the development of this rock owes its origin primarily to the introduction of calcium, aluminum, and silica to the original limestone by solutions, contemporaneous with, and following the monzonite intrusion. It is thought for reasons noted above (pg. 33) that the crystallization of the garnet-pyroxene of the contact rock was contemporaneous with the crystallization of the pyroxenic constituents of the quartz monzonite porphyry, and that the mass had solidified before the intruding material. Using wollastonite as a thermometer we see that temperatures above 1200° C did not obtain.

Because of the multiplicity and variable size of the dikes it has been impossible to gauge accurately how far from a contact the garnet hornfels is developed. The maximum thickness between the dikes, as exposed in Commercial Rock quarry is about 200 feet. This is, however, related to two or more dikes, and it is entirely possible that any dike that is exposed would not have had sufficient power to produce a contact metamorphic effect of this magnitude. Nor do all of the dikes, or all parts of the dikes exhibit contact metamorphic effects on the limestones. As has been mentioned previously (pg. 34) the dike which forms the crest between Commercial Rock and Wet Weather quarries does not show mapable exomorphic effects on its north side, only endomorphism, while above it and to the south side garnet-vesuvianite rock has had a large development. The same is true of the number of small dikes which cut the Chino limestone in Chino quarry. Some of them exhibit exomorphism, but very little endomorphism is seen. Where exomorphic effects are observed they amount to a small development of garnet and diopside, and a further recrystallization of the limestone which they cut. These phenomena occur invariably at the tops of the dikes. It is very probable that the mineralizers accompanying these dikes were of very slight concentration, yet this explanation will not hold for the first case. To explain this one must assume that where the contact rock was not developed a system of fracture allowed the mineralizers to escape, or, the mineralizers were concentrated at the top of the dike. The latter supposition seems the most probable one in view of the fact that the maximum development of contact phenomena occurs at the tops of the dikes.

Vesuvianite Contact Rock:

At the corner of Lone Star, Wet Weather and Commercial Rock quarries a different type of contact rock is developed. The chief constituents are vesuvianite and calcite, although some garnet grains are scattered thru the mass and the massive garnet and an unknown foliated white mineral are locally developed. Diopside and wollastonite are sporadically associated with this assemblage. The quantitative proportions of the calcite vary greatly. In places the rock is nearly all vesuvianite, quite massive and with a fused appearance. Again, the amounts are nearly equal with small rounded, green and light brown vesuvianites embedded in it. The other extreme is seen when the mass is nearly all calcite with only a few small rounded grains of vesuvianite embedded in it. The calcite found in the assemblage is distinctive and worthy of note. It occurs as a soft, white, extremely fine grained mass, which, on examination under a binocular microscope, is seen to be composed of small sized aggregates of extremely fine needles and some very small rhombohedrons. It seems very probable that this mixture represents a rapid precipitation of the constituents from a metastable solution. Where it occurs here the rock has a fissile character which simulates bedding. In the south side of the inclined cut leading down to Wet Weather quarry the vesuvianite-calcite association is found definitely confined to certain beds. Thus it is thought that this assemblage owes its origin largely to the initial character of the beds which have made them especially favorable to a development of this type.

Quartz Garnet Contact Rock:

One of the most striking of the contact metamorphic rock types that have been found occurs east of the saddle above the north Chino quarry. Here a small quartz monzonite dike cuts the contact rock near the contact of the hornfels and the Chino quartzite. The rock is medium to coarse grained and composed wholly of granular vitreous quartz and grossularite crystals and grains. The rock has undoubtedly resulted from the action of the contact metamorphic agents on an impure limey quartzite.

The quartz monzonite porphory seems to have been the only intrusive which has been capable of producing extensive contact zones. In the Crestmore quarries the grano-diorite has not produced any contact phenomena, while in the Jensen quarry small garnet zones are locally developed. Contact zones which accompany the pegmatites where they intrude the limestones, have been mentioned in the literature. This assemblage was largely wallastonite with some garnet and diopside. These pegmatites were not observed cutting the limestones, probably because quarrying operations have destroyed these exposures.

QUATERNARY ALLUVIUM.

The quaternary unit consists chiefly of river sands, dune sands and fan deposits which were not differentiated. In general the quaternary deposits on the north side of the Jurupa Mountains consist chiefly of dune sands which the prevailing winds have blown against the mountain front. On the eastern side the deposits are more typically river laid; probably by the Santa Ana River. The detrital material on the south side of these mountains is more typically fan deposits.

At the Crestmore quarries the quaternary fill has been mapped as dune sands although there are a few small fan like deposits on the southern side. Below these dune sands the bare rock surface has been covered with a deposit of calcareous tufa from 1 inch to 2 feet thick. and leached from the limestone outcrop. This probably represents a deposit formed in a moister climate.

STRUCTURE.

In an area so close to the San Andreas Rift one would normally expect to find the rocks traversed and displaced along a number of faults but this is not the case. In the Crestmore quarries only a few small faults were found and have no particular significance regarding the major structures of the deposit. Nor were any large faults to be found in the area that was mapped west of the quarries although abundant physiographic evidence might be cited to indicate their existence.

The series of metamorphosed sediments northeast of triangulation point Jurupa have a uniform northwest strike and a north dip. In the limestones in Jensen quarry the strike is comparable but the beds dip vertically. This discrepancy may be explained by a fault but none was found. A more logical explanation would be to assume that these are roof pendants which have settled in a viscous magma.

The pegmatite dikes on the eastern side of the area have a remarkable uniform northwest trend as if there distribution had been governed by their intrusions along a system of major fractures in that direction. However, their dips are so variable that it is doubtful if such was the case. The pegmatites to the west are more chaotic in distribution. This might be explained by the difference of lithologic types on that side.

FRACTURING:

In the Hauser rock quarries a favorable system of jointing makes this rock amenable to quarrying methods. The three major systems of jointing have the following attitudes: N. 12° E, 55° S, N. 80° E, 25° S., and N.85° W., 74° N. at the extreme north end of the quarry. Attitudes of the joints in the extreme south end of the quarry are, N. 15° E, 54° S., N. 83° W., 83° N., and N 4° W, 29° S. These joints allow the rock to be handled with a minimum of cost.

In the Crestmore quarries the Chino limestone body strikes northwestward and dips 45° to the north. The Sky Blue limestone strike northeastward and dips 55° to the south. The cause of this structural discrepancy is not ascertainable. They are separated by an intrusion but whether this igneous rock has been intruded along a fault, an unconformity, or has itself been a cause of the differences of attitude in the limestones is an unsettled question.

The attitude of the bedding planes and the multiplicity of the joints which have been induced in the limestone by the intrusions allows the limestone to break very easily and makes it especially amenable to the caving system now being employed in the underground work.

Figure 11. A view of Hauser quarry. Note the prominent joints in the grano-diorite.

Figure 11.

ECONOMIC ASPECTS.

Crestmore Quarries:

At the Crestmore quarries the amount of material that can be profitably obtained by open pit methods has been practically exhausted. This had been anticipated some years before and the extent of the underground deposits was explored by diamond drilling and found sufficient to warrant its working by mining methods. Limestone in sight at the present time is sufficient to last for thirty-five years at the present capacity of the cement plant. It is entirely probable that these deposits extend northeastward beneath the fill material.

The small outcrop in the valley northwest of the cement plant is thought to have an appreciable extent in four dimensions and may be a profitable deposit at some later date.

At Crestmore the only factor that must be closely watched is the magnesium content. This necessitates careful sampling and blending of the ore. The weathered grano-diorite is mixed with the limestone to furnish the necessary silica and aluminum.

Jensen Quarry:

Operations in this quarry have been suspended for several years. Most of the material available for open cut methods has been taken. Data for the estimation of the underground extent of this deposit were not available.

Figure 12. Looking northeastward toward the Chino quarry. The headframe of the mine and mine buildings are in the center of the picture.

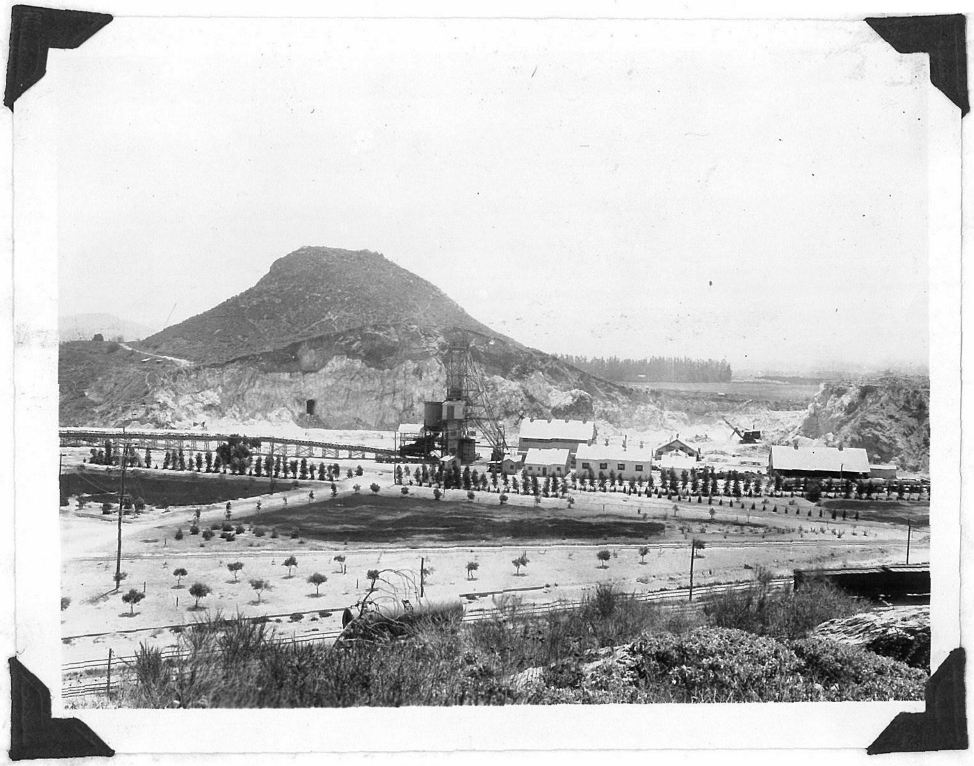

Figure 12.

Hauser Quarry:

At the Hauser Quarry grano-diorite is quarried and used for breakwaters along the southern California coast. Because of the lack of uniform color and grain of this rock it is doubtful if it will ever be useful for building stone. An extremely large tonnage is available and because of the favorable jointing system it can be cheaply and easily obtained. This deposit is owned and operated by the Hauser Construction Company.

MINERALOGY.

As it was impossible to find specimens of all the minerals described from Crestmore, and as it was desired to catalogue all of the minerals that have been reported, many of the descriptions and notes in the following section have been taken from the literature.

On the following pages the minerals are arranged according to Windell's (19) Classification. At the end of this section is an alphabetically tabulated list of minerals which shows their distribution and to some extent their associations.

Elements:

Graphite: (3). Graphite has been seen in small flakes disseminated in the white Chino limestone. It is found in greater abundance in the bottom of the section near the grano-diorite contact, although it has been observed throughout the beds. Graphite has also been found in the Jensen Quarry. In both cases it is definitely associated with the bedding. Thus the graphite undoubtedly owes its origin to contact-metamorphic effects of the grano-diorite on carbonaceous limestone beds as has already been suggested by Eakle (3).

Sulphides: Eakle states (3) that the sulphide are associated with the pegmatite intrusives. The author has not found this to be the case. Where the association has been seen the sulphides seem to be concentrated near the quartz monzonite porphyry, nor are any sulphides found as accessories in the pegmatites as they are in the quartz monzonite. In the author's opinion solutions from the quartz monzonite intrusions are responsible for the sulphide mineralization found in the quarries.

Galena: Galena has been found in a small quartz vein in the contact rock in the Commercial Rock quarry. Eakle reports it from the Sky Blue limestone.

Pyrite: Pyrite occurs as an accessory in the hypersthene quartz diorite, the quartz monzonite and its hybrids, the quartzites of the Undifferentiated Complex, the Chino quartzite, and disseminated in the limestones.

Bornite Chalcopyrite and Chalcocite: These were found in a small cavity at the border of one of the small quartz monzonite dikes in the Chino quarry. Eakle (3) reports these from the contact rock.

Tetrahedrite: The author has identified as tetrahedrite a mineral brought up from the mine. It was reported to be from a vein in limestone. Eakle (3) reports tetrahedrite from the contact rock.

Sphalerite: Reported by Eakle from the vesuvianite-garnet mass or the contact rock. This was not found by the author.

Greenockite: Mentioned by Eakle as coating the sphalerite.

Arsenopyrite: According to Eakle this mineral was found in the Commercial Rock quarry.

Oxides:

Periclase: Remnants of perilase are enclosed in some of the brucite crystals in the calcite-brucite rock. This mineral has been formed by the contact metamorphism of the impure limestone by the grano-diorite.

Brucite: Occurs as small pseudoisometric crystals in the calcite-brucite rock in the limestones. These crystals are a pale yellow color and show a concentric fibrous structure. Some of them enclose periclase. They result from a hydro-thermal alteration of periclase.

Hematite and Limonite: These minerals are oxidation products of the various iron-bearing compounds, and are to be found in all of the rocks described.

Zircon: This is an accessory in the grano-diorite, in some of the enclaves in the grano-diorite, and in the pegmatite dikes.

Rutile: Small needles of rutile have been recognized enclosed in the quartz in the granite porphyry, and in some of the quartz of the Undifferentiated Complex.

Quartz: Quartz is found in all of the rocks in this area, save the limestone. Some vein quartz was found in a small vein in the contact rock in Wet Weather Quarry. In all of the slides examined it showed undulatory extinction and a slight biaxial character.

Chalcedony: Chalcedony was reported by Eakle (7) to be associated with juarupaite in the Sky Blue limestone. Chalcedony has been found by the author in a quartz vein in the contact rock of the Commercial Rock quarry. Some of the altered wollastonite fibers are probably chalcedonic.

Opal: White hyaline opal was found in a vein in the contact rock in the Commercial Rock quarry. Some of the fibrous wollastonite has been altered and the fibers converted to opal. Eakle (3) describes hyaline opal from the cavities in the pegmatites where it coats apophyllite and okenite. He also describes wood opal from the Sky Blue limestone.

Spinel: The occurrence has been described by Rogers in two papers (4,16). It is rather abundant as an accessory in the calcite-brucite of both the Chino and Sky Blue Limestone bodies. The maximum size is about .16 m.m., and octahedrons, distorted crystals, twins and grains are the common forms. The mineral is colorless to pale yellow.

Magnetite: Grains of magnetite were recognized in the enclaves of the grano-diorite, in the granite porphory, the Undifferentiated Complex, and in the calcite brucite rock.

Carbonates:

Calcite: Calcite is one of the most abundant minerals as well as having the greatest variety of forms and occurrences. The different occurrence and forms are listed below.

1. In the Chino and Sky Blue limestone bodies as white, medium to coarsely crystalline limestone beds, also in a green colored coarsely crystalline form. All the grains show twinning striations.

2. In the Sky Blue limestone body as large, twinned, cleavage rhombohedrons of blue calcite.

3. In the contact rock as a constituent and as a secondary mineral.

4. As an alteration product of the plagioclase in the igneous rocks and in the Undifferentiated Complex and Chino quartzite.

5. As small lenses in the Undifferentiated Complex.

6. As small stalactites and stalagmites in the solution cavities in the limestones.

7. Filling veins which cut nearly all of the rocks in the Crestmore quarries. The material filling the veins is white to amber colored, prismatic in form, and oriented perpendicular to the vein walls. These veins vary in size from one millimeter in width to several inches. The calcite in the finer veins appears to be fibrous, with the fibers oriented perpendicular to the walls.

8. As a deposit of calcareous tufa which underlies the dune sands in part. This blanket varies from zero to one foot thick, and contains particles of minerals derived from the rocks which it covers.

Aragonite: Some of the fibrous calcium carbonate in the veinlets is undoubtedly aragonite.

Cerrusite: Mentioned by Eakle (3) as an alteration of galena. This was not found by the author.

Azurite: Azurite and malachite were reported by Eakle (3) as stains in the contact rock.

Malachite: A specimen of white calcite carrying malachite was collected on the floor of the north Chino Quarry. Its position on the quarry face could not be determined.

Hydromagnesite: Occurs as a supergene alteration product of the brucite.

Sulphates:

Anglesite: Mentioned by Eakle (3) as an alteration product of galena.

Compounds of Sulphates with Salts of Other Acids:

Thaumasite: Originally described by Foshag (5) in veins cutting across the contact rock and coating blocks composed largely of spurrite. The genesis was assigned to the action of sulphated waters on the spurrite. Thaumasite is again mentioned by Larsen and Foshag (8) as an alteration product of the rock containing merwinite. The alteration is thought to have developed "during the later stages of the contact metamorphism".

Phosphates:

Apatite: This was found as an accessory in all of the intrusive rocks. It occurs as well in the Undifferentiated Complex and in the Chino quartzite. Eakle (3) describes the occurrence of "greenish blue apatite in granular form associated with green diopside and white wollastonite in white calcite". This occurrence has not been recognized by the author.

Anhydrons Silicates of Divalent Bases:

Olivine Group:

Monticellite: Monticellite has been described by Eakle (3) from the blue calcite and by Tilley from the contact rock. This mineral has not been recognized. Eakle suggests that the monticellite results from the metamorphism of the brucite limestone, while the diopside and vesuvianite were formed during the metamorphism of the pure beds. Thus he accounts for the scarcity of monticellite and Xanthophyllite. This does not appear to the logical, for the percentage of brucite limestone that has been further metamorphosed is quite high and should give a larger amount of monticellite than has been found in the quarries. Original impurities may be the ultimate factor governing the distribution, but the apparent agent is the quartz monzonite porphory. This agrees with Eakle's first observations on this occurrence (2).

Pyroxene Group:

Hypersthene: This mineral is the pyroxenic constituent of the hypersthene quartz diorite, and of some of the enclaves of the grano-diorite.

Diopside: Diopside occurs in the contact phases of the monzonite and is an important constituent of the contact rock.

Diallage: Diallage is found in the hybrid rocks of the quartz monzonite porphyry, and in the contact rock.

Augite: Augite is a constituent mineral of the grano-diorite, the quartz monzonite porphyry, the hybrid rocks associated with the quartz monzonite, the Chino Quartzite, and the Undifferentiated Complex.

Wollastonite: Eakle describes four types of this mineral. They are: (1) Reticulated columnar and fibrous structure, (2) Large well formed crystals, (3) A white massive granular variety, (4) This "consists of distinct crystals which have been formed by later silica solutions acting upon the limestone in the vicinity of the pegmatite dikes and on the outer borders of the contact zones". Of these types the first has been found in the contact rock, and the third in the Chino limestone. In addition a wollastonite schist was found in the hill southwest of the cement plant. The Wollastonite has undoubtedly resulted from the hydrothermal action of the grano-diorite, the quartz monzonite, and the pegmatite on the limestone.

Merwinite: This mineral was named and described by Larsen and Foshag (8) from the Wet Weather and Commercial Rock quarries. Here it occurred "in amounts measurable in tons" and "well away from the contact and beyond the garnet zone." They conclude that "merwinite is therefore a low temperature form...". A careful search did not reveal any of the material remaining, and it has probably been long since converted to cement.

Amphibole Group:

Hornblende: Hornblende occurs in the grano-diorite, the enclaves in the grano-diorite, and in the hypersthene quartz diorite. Uralitic hornblende, arising from the alteration of hypersthene or augite is found in the Undifferentiated Complex, the hypersthene quartz diorite, and in the enclaves in the grano-diorite.

Titanite: Rounded grains and aggregates of this mineral form an important accessory in the quartz monzonite porphyry. It is also found in the Chino quartzite. Pleochroic colors vary from brown to light brown.

Silicates of Divalent Bases with Hydrogen, Fluorine, Chlorine, or Sulphur:

Chondrodite: Described by Rogers in two papers (4,16)..It occurs in minute, subhedral grains in the calcite-brucite rock. Obviously a result of hydrothermal action on the limestone. No evidence at hand indicates the presence of fluorine accompanying the grano-diorite intrusion, thus it seems probable that the necessary solutions were derived from the quartz monzonite porphery.

Custerite: Custerite has been described by Tilley (18) from the vesuvianite contact rock where it is associated with vesuvianite, calcite, and monticellite. The occurrence has not heem recognized by the author.

Hydrous Silicates of Divalent Bases:

Riversidite: A new mineral that was discovered and named by Eakle (3). It occurred as "compact fibrous veinlets in the crevices of the massive vesuvianite.........The mineral is a fibrous crystallization from the solutions carrying the altered wilkeite or crestmoreite". This mineral is no longer found.

Crestmoreite: A new mineral that was described by Eakle (3) from the blue calcite of the Commercial Rock quarry where it occurred as an alteration product of wilkeite. This, like many of the other rare things from this locality, has disappeared.

Centrallasite: (9) Noted by Foshag (9) replacing quartz in a pegmatite which cut the blue calcite in the Wet Weather Quarry. The pegmatite was composed chiefly of feldspar with wollastonite, orange colored prehnite and massive green datolite. Foshag attributes the formation of the centrallasite to the action of sulphated waters on quartz. These same solutions are held responsible for the formation of the prehnite and datolite, and "probably followed directly the crystallization of the pegmatites and are genitically connected with it".

Foshagite: A new species described from the Wet Weather Quarry by Eakle (10) It was found in vesuvianite boulders on the quarry floor. These boulders probably came from the contact mass. The mineral is fibrous and in veins cutting the vesuvianite, with the fibers oriented perpendicular to the vein walls. Thaumasite and calcite were associated with it. This species is no longer to be found.

Chrysotile and Deweylite: A massive green mineral was found in the white calcite of the Chino Limestone in East Chino quarry, a few feet from a small quartz monzonite dike. An analysis was made by Mr. Thomas Mullan of the Riverside Cement Company and the following results were obtained:

SiO2.....	40.88
R2O3.....	1.27
CaO......	5.91
MgO......	37.52
H2O......	12.0
CO2......	2.50
Total..	100.08

Calcite grains couls be seen in the material so CaCO3 and R2O3 were discarded and the other figures recalculated on the basis of 100 per cent.

	percent	mol-numbers	ratios
SiO2......	45.20	.75	3
MgO	41.50	1.04	4
H2O	13.30	.74	3

This gives the formula $3H_2O.\ 4MgO.\ 3SiO_2$, or $H_6Mg_4Si_3O_{13}$, which does not correspond with any of the known hydrous magnesium-silicate minerals. Grains of the material show indices as follows: A minimum of 1.528 ± .005 the maximum is 1.555. ± 005. If this werd one mineral the birefringence would be 0.027 which is much too large compared with the observed birefringence. Thus it is thought that this represents a mixture of chrysotile and deweylite. A mixture of these minerals in the proportion 68.8% deweylite and 31.2% chrysotile would give an analysis corresponding to the above one.

Rogers (4) describes deweylite as replacing hydromagnesite in the calcite-brucite rock, and regards it as a supergene mineral. A section has been made of the material described above and although it is too thin to show the interrelation of the chrysotile and deweylite, they can be plainly seen to replace the primary calcite. Secondary calcite and an isotropic mineral, either garnet or spinel were also seen. In view of its present relation to the quartz monzonite porphyry dike it seems that the genesis of these silicates can be assigned to solutions emanating from the dike and thus their origin is hypogene.

Sepiolite: A white, fibrous mineral was found filling small veins in the calcite near the occurrence of the chrysolite and deweylite. The material is composed of finely interlocked fibers with the fibers oriented parallel to the vein walls. An alaysis by Mr. Mullan gave the following results:

SiO_2	.........44.38
R_2O_3	.... .82
CaO	.........11.90
MgO	.........20.24
H_2O	.........13.09
CO_2	.... 9.49
Total	....99.92

Removing $CaCO_3$ and R_2O_3 and recalculating to 100 per cent.

	percent	mol-numbers	ratios
SiO_2...	57.00	.95	3
MgO ...	26.00	.645	2
H_2O ...	17.00	.945	3
Total	100.0		

The above ratios correspond to the formula; $2MgO.\ 3SiO_2.3H_2O$. This probably represents a mineral between sepiolite and para-sepiolite, but since the water content of sepiolite is variable the mineral has been called sepiolite. Optic properties are: Nm--1.510 ± .005, extinction parallel to the fibers, biaxial negative, birefringence low. It is unattacked by HCl. Nm for sepiolite is 1.52 and for parasepiolite Nm--1.506. This appears to have intermediate indices as well as composition.

Jurupaite: A new mineral described from this locality by Eakle (7). It was found filling a cavity or fissure in the blue calcite of Commercial Rock quarry. This calcite also contained cinnamon garnet. The genesis is attributed to the action of the orthosilicate solutions. This like many of the other minerals has vanished.

Okenite: Found in tufts of fibers and long slender needles as an alteration product of apophyllite and forming a coating on it (3). Neither occurrence has been recognized by the author. Also mentioned by Eakle (7) (3) as an alteration product of Wilkeite.

Hydrous Silicates of Trivalent Bases.

Kaolinite: Many of the feldspars are altered to a white clay. An alteration product seen in a section of one of the hybrid phases of the quartz monzonite was thought to be kaolinite.

Silicates of Divalent and Monovalent Bases.

Apophyllite: This mineral was described by Eakle (3) as occurring in crystals lining the cavities in wollastonite masses formed between the calcite and pegmatite. These masses have disappeared, hence this mineral was not found by the author.

Silicates of Boron and/or Rare Earths and One or More Other Bases.

Tourmaline: Black tourmaline occurs sporadically in the pegmatites. The crystals vary in size from minute needles to crystals five centimeters in diameter.

Datolite: Eakle (3) describes compact massive, glassy white datolite in connection with the pegmatites. This was not seen by the author.

Axinite: A violet colored axinite associated with cinnamon garnet in the pegmatites has been mentioned by Eakle. This mineral was not recognized by the author.

Anhydrous Silicates of Al(Cr,Fe,Mn)And One or More Other Bases.

Garnet Group:

Grossularite: Ca3Al2 Si3 O12: This is the most abundant of the contact minerals found in this locality. It forms the major constituent of the contact rocks associated with the quartz monzonite porphyry in the Crestmore quarries and with the grano-diorite in the Jensen Quarry, as well as being a constituent mineral in the various hybrid rocks formed on the margins of some of these intrusions. In the huge mass of the garnet hornfels in the Crestmore quarries the grossularite is massive, but some good crystals are to be found lining cavities, and in the limestone on the periphery of this mass. These crystals show mostly dodecahedral forms which are often modified by octahedral faces. The grossularite associated with the grano-diorite is generally less compact and the crystals are larger.

Plazolite: $3CaO.Al_2O_3.2(SiO_2,CO_2).2H_2O$. This was a new mineral discovered and described by Foshag(6). His material was collected from the Commercial Rock quarry, "directly connected with green vesuvianite and an unknown, foliated white mineral. The crystals of plazolite are imbedded in the foliated white mineral, and a massive form also occurs directly filling the spaces between the vesuvianite crystals. The limestone composing the hill is intruded by a dike of fine-grained granodiorite. The genesis of the plazolite and associated minerals is directly connected with this intrusion." The grano-diorite is never fine-grained so he probably refers to the quartz monzonite porphyry.

Eakle (7) again notes the occurrence, and points to its close similarity to garnet.

Melilite Group:

Gehlenite: Described by Larsen and Foshag(8) from the Commercial Rock quarry where it was intimately associated with merwinite. This mineral is no longer to be found.

Feldspar Group:

Orthoclase: According to Eakle (3) orthoclase forms the larger portion of the pegmatite dikes. In the samples examined by the author no orthoclase was found in the pegmatites, only albite and microcline. It does occur, however, in the grano-diorite

the granite porphyry, and the quartz monzonite porphyry.
<u>Microcline:</u> This mineral is a constituent of the granite porphyry. It occurs also in large cleavage masses in the inner zone of some of the larger pegmatites.
<u>Albite:</u> Albite is an important constituent of the pegmatites.
<u>Oligoclase:</u> This is the plagoclase feldspar of the grano-diorite, and in the enclaves in the grano-diorite. It occurs as well in the quartz monzonite porphyry, the hypersthene diorite, the granite prophyry, and in the Undifferentiated Complex.
<u>Andesine:</u> Andesine and andesine labradorite form an important constituent in the hypersthene quartz diorite, and the inclusions in the grano-diorite, also in the contact borders of the quartz monzonite porphyry. A few grains of oligoclase-andesine were found in the Undifferentiated Complex.
<u>Labradorite:</u> This has been described by Eakle (3) as one of the constituents of the grano-diorite, along with oligoclase. No evidence has been found for two generations of feldspars. The plagioclase is oligoclase. Labradorite occurs as phenocrysts in some of the basic enclaves in the grano-diorite. A few grains were found in the Undifferentiated Complex and the Chino quartzite.
<u>Bytownite-Anorthite:</u> Crystals of plagioclase of the bytownite-anorthite type were found in a small cavity at the border of one of the small quartz monzonite porphyry dikes in the lower Chino quarry. They were associated with pyrite, chalcopyrite and bornite.

Silicates of Al (Cr, Fe^{111}, Mn^{111}) and One or More Other Bases, with Hydrogen, Flurine, Chlorine, or Sulphur:

Vesuvianite: Vesuvianite is a prominent mineral in the contact rock. It occurs in a massive, green form associated with garnet, diopside and calcite, andhas small brown and green crystals and rounded grains in the calcite of the contact rock and near the periphery of the contact mass. The crystallography has already been studied by Eakle (3).

Scapolite Group:

Scapolite: A grey white scapolite with violet streaks has been mentioned by Eakle (3). The material collected by the author is white and composed of small radiating aggregates of extremely fine needles, so fine that to the unaided eye the material appears almost massive. It occurs in the contact rock associated with wollastonite, calcite, diopside, and grossularite, surrounding them and filling spaces between these minerals. The indices O--1.567 ± .005, E--1.548 ± .005, measured on one sample would indicate, according to Windell's diagram (17) marialite 60%, meionite 40%, or the species dipyrite. Another sample gave values O--1.584, ± .005, E--1.550 ± .005, which corresponds to the values of a mixture of 40% marialite, and 60% meionite, or the species mizzonite. This is an uncommon form of crystallization for scapolite, the fine crystallinity would suggest extremely rapid precipitation of crystals such as one would obtain from the sudden cooling of a metastable mixture. However the associated minerals are very coarse, so that this condition would not apply to all of them.

Prehnite: (3) This is found filling cavities in the white feldspar in the pegmatite. Varieties are the common green drusy prehnite and as light brown to colorless interlocked crystals which lack the drusy surface. This was not noted by the author. Associated minerals were massive datolite and grey quartz.

Epidote Group:

Clinozoisite: A pale, transparent to translucent, greenish grey variety occurs in shattered crystals and grains in a small contact mass associated with one of the smaller quartz monzonite porphyry dikes in the Chino quarry. The associated minerals are garnet and calcite. This undoubtedly results from the hydrothermal action of solutions from the quartz monzonite porphyry on the limestone.

Epidote: Small black crystals, up to three millimeters in length, were found disseminated in the white Chino limestone and associated with the deweylite and chrysotile, near a dike of quartz monzonite porphyry. A green epidote is abundant in some of the pegmatites as already noted by Eakle (3).

Mica Group:

Muscovite: True muscovite is present only as a minor constituent of the Chino quartzite and the Undifferentiated Complex.

Variety Sericite: The sericite variety occurs in all of the igneous rocks and in the Undifferentiated Complex as an alteration product of the feldspars.

Biotite: Biotite is a constituent mineral of all of the igneous rocks of this area. In addition it was seen to be a very important constituent in parts of the Undifferentiated

Complex.

Phlogopite: Eakle (3) reports finding a few flakes of brown phlogopite in the Chino limestone. The author has not seen this mineral.

Chlorite Group:

Chlorite: This is an alteration product of the biotite in the Undifferentiated Complex, and of the biotite and hornblende in the grano-diorite, the enclaves in the grano-diorite, the pegmatite dikes and the hypersthene quartz diorite.

Clinochlore: Reported by Eakle (3) to be present as small green flakes in the vesuvianite masses.

Clintonite Group:

Xanthophyllite: This mineral was first described from this locality by Eakle (3) as disseminated in the blue calcite and associated with monticellite. The above occurrence was not found but small crystals and flakes were found in a locally developed, coarsely crystalline green calcite in the Chino limestone body that was associated with a small dike of the quartz monzonite.

Hydrous Silicates of Al(Cr, Fe^{111}, Mn^{111}) and One or More Other Bases.

The Zeolites.

Laumontite: Eakle (3) describes divergent columnar and fibrous masses of laumonite coating green prehnite, He attributes its genesis to the alteration of the prehnite.

Compounds Consisting of Silicates with Salts of Another Oxygen Acid.

Wilkeite: A new mineral from this locality originally described by Eakle and Rogers (1). They found it in the contact zone associated with diopside and vesuvianite. A nitric acid solution of the predazzite gives a test for the phosphate radical, which according to Rogers (16) indicates the presence of wilkeite.

<u>Spurrite</u>: $2Ca_2SiO_4.CaCO_3$. First described by Foshag (5) and again by Foshag and Larsen (8) as intimately associated with merwinite in the Wet Weather and Commercial Rock Quarries, in masses originally thought to be monticellite. This mineral would also be outside the garnet zone.

Occurrence

Mineral.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remarks. Associations.
Albite							x								
Andesine	x		x		x				x						
Anglesite*														x	
Apatite	x	x	x	x	x	x	x	x	x		x	x			In wollastonite in lms.
Apophyllite*							x					x			In wollastonite in lms.
Aragonite										x					
Arsenopyrite*												x			Disseminated in lms.
Augite			x	x	x			x	x		x		x		
Axinite*							x								
Azurite*													x		
Biotite	x	x	x		x	x	x	x	x		x				
Bornite					x							x			
Brucite										x		x			
Bytownite-Anorthite					x										
Calcite	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Centrallasite*							x								Replacement of quartz.
Cerusite*														x	
Custerite*													x		
Chalcocite					x							x			
Chalcopyrite					x							x			
Chlorite	x	x	x		x		x	x	x		x				
Chondrodite										x		x			
Chrysotile										x					
Clinochlore													x		
Clinoziosite													x		
Crestmoreite*												x			Alteration of wilkeite
Chalcedony												x		x	
Datolite*							x								
Deweylite										x			x		
Diallage					x								x		
Diopside					x								x		
Epidote							x						x		
Foshagite*													x		
Galena														x	
Gehlenite*												x			
Graphite										x		x			
Grossularite					x			x					x		
Greenockite*							x								
Hematite	x	x	x	x	x	x	x	x	x	x	x	x	x		
Hornblende	x	x	x				x								
Hydromagnesite										x		x			
Hypersthene	x		x												
Jurupaite*												x			In cavities in limestone.
Kaolonite					x										
Laumontite*							x								
Labradorite	x										x				
Limonite	x	x	x	x	x	x	x	x	x	x	x	x	x		
Magnetite			x			x		x		x		x			
Malachite										x		x			
Merwinite*												x			Large masses in blue calcit
Monticellite*												x	x		
Microcline				x	x		x	x							
Muscovite							x	x			x				
Okenite*							x					x			
Oligoclase		x		x	x	x		x	x						
Orthoclase				x	x	x									
Opal												x	x		

Mineral.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remarks. Associations.
	Occurrence														
Periclase										x		x			
Phlogopite*										x					
Plazolite*													x		
Prehnite*							x								
Pyrite	x			x	x				x	x	x	x			
Quartz	x	x	x	x	x	x	x	x	x		x			x	
Riversideite*													x		
Rutile						x		x							
Sepiolite										x					
Scapolite													x		
Sericite	x	x	x	x	x	x	x	x							
Sphalerite*												x			
Spinel										x		x			
Spurrite*												x			Disseminated in lms.
Tetrahedrite*													x	x	
Thaumasite*												x	x		
Titanite				x	x						x				
Tourmaline							x								
Uralite	x		x					x							
Vesuvianite													x		
Wilkeite*										x		x	x		
Wollastonite								x		x		x	x		
Xanthophyllite										x		x			
Zircon		x	x		x	x									

Columns: Minerals associated with

1. Hypersthene Quartz Diorite
2. Grano-Diorite
3. Enclaves in the Grano-Diorite
4. Quartz Monzonite
5. Hybrid Types of Quartz Monzonite (Endomorphic Phases)
6. Granite Porphyry
7. Pegmatite Dikes
8. Schists and gneisses
9. Quartzites
10. Chino Limestone
11. Chino Quartzite
12. Sky Blue Limestone
13. Contact Rock.
14. Miscellaneous and Uncertain.

*Denotes those minerals not found by the author but which were described in the literature.

CONCLUSIONS.

In the following lists the various metamorphic minerals are enumerated below the rocks to which they owe their origin. Although there may be a few exceptions this is as accurately as this relationship can be ascertained from the sketchy data presented in some of the literature, inasmuch as many of these minerals can no longer be found at Crestmore.

Grano-diorite.	Quartz Monzonite P.	Pegmatite.	Supergene Solutions.
Chondrodite	Sulphides	Wollastonite	Hematite
Graphite	Thaumasite	Centrallasite	Limonite
Grossularite	Monticellite	Apophyllite	Chalcedony
Periclase	Wollastonite	Okenite	Opal
Brucite (?)	Merwinite (?)	Tourmaline	Aragonite
Spinel	Custerite	Datolite	Cerrusite
Wollastonite	Crestmoreite	Phrenite	Anglesite
Wilkeite	Riversideite	Epidote	Azurite
	Foshagite	Laumontite	Malachite
	Chrysotile		
	Deweylite		
	Sepiolite		
	Jurupaite		
	Grossularite		
	Plazolite		
	Gehlenite		
	Bytownite-Anorthite		
	Vesuvianite		
	Scapolite		
	Epidote		
	Clinozoisite		
	Wilkeite		
	Spurrite		

The above list gives added strength to the evidence presented by the close association of the contact rock with the quartz monzonite porphyry that that intrusive is responsible for the major portion of the contact metamorphic effects and was accompanied by an abundance of mineralizing solutions.

These solutions carried water, silicates and sulphates which acted on the limestones to form a host of different contact metamorphic minerals.

The pneumatolitic solutions which accompanied the pegmatites were charged with the halides, boron, phosphorus and silicates but they were not of very great volume and their effect is closely limited to the dikes.

The effect of the grano-diorite has been chiefly: 1, Recrystallization, 2, Formation of the calcite-brucite rock, or predazzite. The minerals which have formed under its influence are of a type which would result merely from the heat of intrusion and this presents evidence that the grano-diorite was unaccompanied by mineralizers.

BIBLIOGRAPHY.

1. Eakle, A.S. and Rogers, A.F., Wilkeite, A new mineral of the Apatite Group and Okenite, Its Alteration product, Am. Jour. Sci., vol.37, pp.262-267, 1914.
2. Eakle, A.S., Xanthophyllite in Crystalline Limestone, Jourl Wash.Acad. Sci., vol. 6, pp. 332-335, 1916.
3. Eakle, A.S., Minerals Associated with Crystalline Limestone at Crestmore, Riverside County, California, Bull.Dept.Geol., Univ. of Calif. Pibl., vol.10, pp.327-360, 1917.
4. Rogers, A.F., An American Occurrence of Periclase and its Bearing on the Origin and History of Calcite-Brucite Rocks. Am. Jour.Sci., vol. 46, pp. 581-586, 1918.
5. Foshag, W.F. Thaumosite (And Spurrite) From Crestmore, Calif., Am. Mineralogist, vol. 5, pp.80-81, 1920.
6. Foshag, W.F. Plazolite, A New Mineral. Am.Mineralogist, vol. 5, 1920.
7. Eakle, A.S. Jurupaite, A New Mineral. Am. Mineralogist, vol. 6, pp. 107-109, 1921.
8. Larsen, E.S. and Foshag, W.F., Merwinite. A New Calcium Magnesium Orthosilicate from Crestmore, California. Am.Mineralogist, vol. 6, pp. 143-148, 1921.
9. Foshag, W.F., Centrallasite from Crestmore, California. Am. Mineralogist, vol. 9, 1924.
10. Eakle, A.S., Foshagite, A New silicate from Crestmore, California. Am. Mineralogist, vol. 10, pp.97-99, 1925.
11. Eakle, A.S., Famous Mineral Localities: Crestmore, Riverside County, California. Am. Mineralogist, vol. 12, pp.319-321, 1927.
12. Hudson, F.S., Geology of the Cuyamaca Region of California. Bull. Dept. Geol., Univ. Calif. Publ., vol.13, pp.175-252, 1922.
13. Vaughan, F. E., Geology of San Bernardino Mountains North of San Gorgonio Pass, Bull.Dept.Geol.Univ.Calif.Publ., vol.13, pp.319-412, 1922.
14. Woodford, A.O., and Harriss, R.F. Geology of Blackhawk Canyon, San Bernardino Mountains, California, Bull.Dept.Geol.Univ.Calif., Publ. vol. 17, pp.265-304, 1928.
15. Moore, B.N., Geology of the Santa Ana Mountains, Unpublished thesis, Calif. Institute of Tech. 1930.
16. Rogers: Amer.Miner, Vol.14 #12
17. Winchell, A.N., The Properties of Scapolite. Amer.Miner, Vol. 9, pp. 108-112, 1924.
18. Tilley, C.E. On a Custerite-bearing Contact Rock from Calif. Geo. Magazine, pp.371-372, 1928.
19. Winchell, A.N. Elements of Optical Mineralogy, Part II, John Wiley and Sons, 1927.