The Geology and Ore Deposits of the Manzana Quadrangle, Los Angeles County, California

A Thesis

by

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* Abstract *

This paper describes the geology and ore deposits of the Manzana quadrangle, an area of about 40 square miles in north-central Los Angeles County, California. Topographically the quadrangle is divisible into two separate parts: a northern half covering parts of alluvium-filled Antelope Valley, the westernmost arm of the Mojave Desert; and a southern half covering a mountainous region that extends eastward into the San Gabriel Mountains.

Nearly all of the mountainous portion of the Manzana quadrangle is made up of intrusive igneous rocks. They range in composition from granite to quartz diorite, but on the average are thought to approximate a quartz monzonite or granodiorite. These rocks can be traced almost continuously into the Sierran granites farther north and hence are believed to be of early Cretaceous age. Genetically related pegmatite and aplite dikes are exceedingly abundant over the entire area of crystalline rocks and are especially abundant along the northern edge of the mountains. The pegmatites range in composition from granitic to syenitic; perthitic and graphic textures indicate that replacement has been an important process in the genesis of the pegmatites. Of especial interest is the presence of gold in many pegmatite dikes of widely differing composition. This gold is shown to be of hydrothermal origin in one case, but in other dikes appears to have been a primary constituent of the pegmatite solutions.

Sedimentary rocks in the quadrangle are confined to a number of small isolated roof pendants making up a discontinuous belt along the northern edge of the mountains bordering Antelope Valley. These rocks have been highly metamorphosed by the intrusive rocks. The age of the sediments cannot be stated more definitely than pre-Cretaceous, but they are thought to be the correlatives of the Bean Canyon Series (Triassic?) which has been described from an area some 20 miles to the northeast.

Volcanic rocks, presumably of Miocene age, occur in an extensive series of flows and tuffs in the western part of the quadrangle. These rocks lap up on the intrusive igneous rocks in depositional contact and dip westward at moderate angles.

The principal structural feature of the Manzana quadrangle is the San Andreas rift, which trends thru the southern part of the area with a direction of about N75W. Its position is marked by a series of straight, narrow canyons which cut across the normal drainage direction of the region almost at right angles. Other physiographic and structural features characteristic of "tear" faults are numerous within the fault zone. Steep vertical and normal faults have played an important part in shaping the topography of the rest of the area.

The mineral deposits of the quadrangle include contact metasomatic deposits, and fissure veins, each genetically related to the intrusive igneous rocks. The contact deposits are restricted to areas of sedimentary rocks where there has been a widespread, though lean, dissemination of pyrrhotite, pyrite, sphalerite and gold. In only a few localities have these minerals been concentrated enough to induce mining opera-

tions. Nearly the entire production of precious metals from the quadrangle has come from fissure veins which, so far as known, are confined to a relatively small area near the center of the quadrangle. These deposits include slightly mineralized gouge-filled faults and quartz veins with walls of gouge. The latter type shows the following metallic minerals distributed sparingly thru white or grey crystalline quartz: arsenopyrite, chalcopyrite, pyrite, galena, sphalerite, gold telluride and gold. The structural and mineralogical features of the fissure veins indicate that they formed under conditions of moderate temperature and pressure, perhaps in the lower Epithermal zone of Lindgren. No definite evidence bearing on the extent of supergene enrichment was found in these deposits.

The various mineral deposits of the quadrangle are thought to represent different stages in the intrusive history of the surrounding crystalline igneous rocks. In the first stage of intrusion, blocks of sedimentary rocks from the walls of the magma chamber were engulfed by the intrusive and metamorphosed to form contact metasomatic deposits. Continued differentiation of the magma resulted successively in a pegmatitic rest-magma containing small amounts of metals and hydrothermal solutions containing abundant metals; these solutions moved upwards thru the crystalline and surrounding rocks to form various types of mineral deposits. The present concentration of roof pendants, pegmatite dikes, and hydrothermal deposits in a belt along the northern edge of the mountains is thought to reflect the original limits of the batholithic chamber.

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* Introduction *

The purpose of this paper is to describe the general areal geology, structure and mineral deposits of the Manzana quadrangle, a small area in the north-central portion of Los Angeles County, California. No previous geologic studies have been made in this area, and it is hoped that the results of this investigation will be of interest to geologists and of practical value to those who are now actively developing the recently discovered ore deposits of the Neenach mining district. With these objectives in view, an attempt has been made in the report to present a broad, generalized picture of the geologic features and at the same time a more detailed and technical study of those features which seemed to merit closer attention.

<u>Field Work and Acknowledgments</u>: The geologic map accompanying this report was prepared during numerous brief visits to the area in the fall of 1935 and the early spring of 1936. The mapping was done on a rather large scale but the result is regarded by the writer as no more than a reconnaissance survey inasmuch as certain portions of the quadrangle are extremely complicated and could only be mapped on a very large scale map. Microscopic and other laboratory studies were carried on during the same period as the field work.

The writer is greatly indebted to all those who have aided this investigation. Thanks are especially due to Professors

Ian Campbell and H. J. Fraser of the California Institute of Technology for their help in the field and laboratory. The generous cooperation of the mine owners and operators within the quadrangle is gratefully acknowledged. Mr. D. L. Danielson has been especially kind in this respect as it was chiefly thru his efforts that access was had to the mines of the district.

* Geography *

Location and Size: The region described in the following report lies about 35 miles north of Los Angeles and comprises the area known as the Manzana quadrangle[1]. It is bounded by meridians $118^\circ 30'$ and $118^\circ 36'$ and parallels $34^\circ 42'$ and $34^\circ 49'$. The Manzana quadrangle covers approximately 40 square miles with its northern limit the Los Angeles County--Kern County boundary. The Neenach mining district lies near the center of the quadrangle. The general location of the quadrangle with respect to southern California is shown on the index map of fig. 1.

The principal means of access to the area is a state highway which passes thru the center of the quadrangle and connects to the east with the Los Angeles--Bishop highway and the main line of the Southern Pacific Railroad at Lancaster, and to the west with the Ridge Route highway from Los Angeles to Bakersfield and the San Joaquin Valley. Most of the mountainous portion of the quadrangle is made easily accessible by the fairly numerous secondary roads.

Topography: The southern half of the area is made up largely of crystalline rocks which represent a small portion of a huge mass of similar rocks extending almost continuously to the San Gabriel Mountains, 40 miles to the east. The San Andreas rift crosses

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[1] the Manzana quadrangle is one of a series of topographic maps of Los Angeles County prepared by the County in cooperation with the United States Geological Survey on a scale of 1/24000. It covers an area within the Tejon quadrangle of the Geological Survey.

this portion of the area and divides it roughly into two blocks having markedly dissimilar topography. The northern and larger

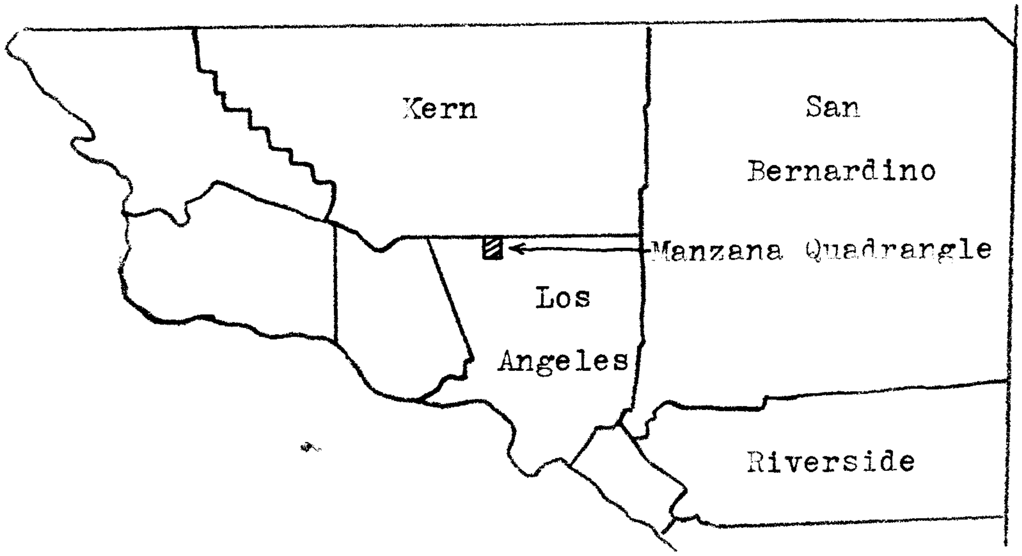

Fig. 1: Index map of part of southern California showing location of the Manzana Quadrangle.with respect to southern counties.

of these blocks is an area of rather low relief characterized by rounded hills and gentle slopes. Hereafter this area will be referred to as the Neenach Hills. The drainage is in general towards the north into Antelope Valley, but is partly stagnated in the vicinity of the peculiar mid-mountain valley occupied by Tweedy Lake. The bedrock is deeply weathered within this portion of the quadrangle and outcrops are scarce even in the bottoms of canyons.

South of the San Andreas rift, the topography is much more rugged and the relief much greater. The mountains rise abruptly to their highest points on Sawmill Mountain (5000 feet) and Liebre Mountain (5400 feet) in the southwestern corner of the quadrangle. The drainage fromthis portion of the area has been greatly deranged by movements on the San Andreas rift and is now largely determined by the rift-valleys Oakgrove Canyon

Fig. 2: View of the Neenach Hills from Antelope Valley. Sawmill Mtn. in distance.

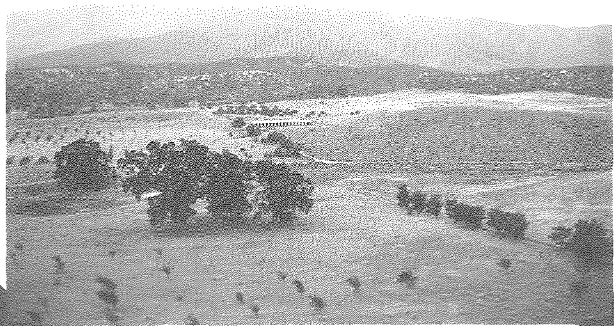

Fig. 3: Sawmill Mtn. from Tweedy Lake Valley.

and Pine Canyon.

Towards the north the Neenach Hills descend gradually into the alluvium-filled Antelope Valley, the westernmost arm of the Mojave Desert. Antelope Valley drains eastward along an intersequent line determined by the junction of alluvial fans from the Neenach Hills to the south and the Tehachapi Mountains to the north. The north edge of the Manzana quadrangle lies north of this line, part way up the alluvial slopes of the Tehachapi Mountains.

Fig. 4: View northward over the Neenach Hills. Antelope Valley in distance.

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* Descriptive Geology *

General Outline: The rocks of the Manzana quadrangle include sediments (and their metamorphic equivalents) of Triassic(?) age, igneous rocks of Cretaceous(?) age of plutonic, volcanic and dike origin, and alluvium belonging to several periods of the Quaternary.

Petrology:

Intrusive Igneous Rocks: Most of the mountainous portion of the Manzana quadrangle is composed of coarsely crystalline plutonic igneous rocks of rather variable composition. They represent the extreme western portion of the San Gabriel "batholith", a huge mass of igneous rocks making up the San Gabriel mountain range farther east. The segment of these rocks north of the San Andreas rift passes under a capping of Tertiary volcanic rocks in the western part of the quadrangle; south of the San Andreas rift, the crystalline rocks extend on to the west a few miles into an area of obscure geology which is not properly a part of the San Gabriel range. The area of the Manzana quadrangle may be considered, therefore, as nearly the extreme limit of the San Gabriel "batholith".

The crystalline rocks vary widely in composition from granites to quartz diorites. Along the north edge of the Neenach Hills, the fresh rock exposed by mine workings is generally a rather basic rock of quartz monzonitic or quartz dioritic composition. In hand specimens it is a dark, basic appearing rock having abundant large plates of hornblende and biotite scattered among coarse crystals of quartz and plagioclase. In thin sections these rocks are seen to have as essential minerals quartz and plagioclase feldspar, the latter mineral having a composition ranging from oligoclase-andesine (Ab_7) to andesine (Ab_6). Strongly pleochroic crystals of hornblende and smaller flakes of biotite are the principal accessories. Minor amounts of titanite, apatite, magnetite, and pyrite complete the mineral assemblage.

In fresh specimens, alteration is generally confined to a slight kaolinization of the feldspar, chloritization of hornblende and biotite, and oxidation of magnetite to hematite, but where these rocks form the walls of hydrothermal mineral deposits the alteration may be more intense. In such cases, a stronger chloritization of the ferromagnesium minerals and the introduction of sulfide minerals such as pyrite and chalcopyrite is the usual result. Some specimens of slightly altered wall rock have been observed in which solutions bearing pyrite and chalcopyrite penetrated by a selective process along rows of biotite flakes, chloritizing the biotite and depositing the sulfides but exerting little effect on the other rock minerals.

Rocks similar to those just described are exposed farther within the batholith in Kings Canyon. Thruout the remainder of the Neenach Hills the bedrock is very deeply weathered and practically no outcrops of fresh rock can be found. Specimens of float or weathered bedrock from widely scattered localities over this area indicate that the average composition of the igneous rocks approximates a quartz monzonite.

The segment of crystalline rocks south of the San Andreas rift shows considerable difference from the rocks described above. In road cuts along the Forest Service road which branchs off from the Pine Canyon highway near the southeastern corner of the quadrangle, the rocks exposed are generally more siliceous than those in the Neenach Hills and over considerable areas show a general absence of ferromagnesium minerals. The average composition is perhaps that of a granodiorite or, in places, a granite.

A more notable feature of this terrane, howev-er, is the great abundance of included and partially assimilated blocks of schist within the igneous rocks. These schist fragments occur often in discreet masses enclosed by the crystalline rocks, but over most of the area they are evidenced only by a dark banding in the igneous rocks. Such delicate banding of original schist septa leads to the conviction that injection has played little or no part in the intrusion of the igneous rocks into the schists.

Over considerable areas the banding of these gneisses shows a general parallelism although it changes abruptly at various places. The source of the schist inclusions is not definitely known, but where they are least metamorphosed they strongly resemble the schists of the Pelona Schist series occurring over wide areas farther east.

The two areas of igneous rocks separated by the San Andreas rift are thus considerably different in their petrologic features. Since they undoubtedly represent portions of the same intrusive, however, no distinction was made between them in the field mapping. Neither local and irregular variations in composition nor differences in the types of rocks intruded would be sufficient cause for such a distinction.

Patches of sedimentary rocks, wholly different from the schists described above, occur along the northern edge of the Neenach Hills and at various other localities within the range as typical roof-pendants or stoped blocks of the roof and walls of the batholithic chamber. It is considered significant that they are especially prominent along the northernmost fringe of the hills and are not found within the range even at much higher elevations. This would seem to indicate that the present northern limit of the mountains marks approximately the northern limit of the batholith, at least at this elevation. At greater depth, of course, the igneous rocks very likely continue beneath the entire region to the north, but at the depth within the batholith now exposed the abundance and size of the roof-pendants probably can be taken as a safe indication of the proximity of the walls of the magma chamber.

The intrusive igneous rocks of the Manzana quadrangle make up a small part of a huge mass of similar rocks which can be traced eastward into the San Gabriel Mountains, and northward thru the Tehachapi Mountains to the Sierra Nevada batholith. The Neenach intrusives would seem, therefore, to be the approximate age equivalents of the Sierran granites and hence late Jurassic or early Cretaceous in age.

Sedimentary Rocks: Small patches of sedimentary rocks occur at many localities within the Manzana quadrangle, but relatively few are sufficiently large to be mapped. With a single exception, the mappable areas of sediments are confined to a belt along the northern edge of the Neenach Hills; however many other small patches were encountered within the area of igneous rocks and one occurrence was noted as far within the range as upper Kings Canyon. In all cases the areas of sediments are surrounded by igneous rocks and they unquestionably represent roof-pendants or stoped-off blocks of the batholithic wall rocks. The inconstancy of the sediments is well shown in the mines of the district where a country rock of sediments at the surface may change to igneous rocks with a few feet of depth. Great difficulty was experienced in mapping the distribution of the sedimentary rocks and their extent as shown on the geologic map accompanying this report is intended only to indicate the limits within which sediments are found. Multitudes of other roof pendants not exposed at the surface or too small to be shown on the geologic map were also found in the course of the field work.

The sedimentary rocks consist chiefly of sandy shales, sandstones, and limestones in varying stages of metamorphism depending on the size of the mass in which they occur. A thin-bedded sandy shale showing very little metamorphism is very abundant in the large roof pendants where igneous rocks are not near-by. Near contacts or in small patches, however, metamorphism has often been extreme. The more sandy beds have recrystallized to quartzites whose clastic origin may be unrecognizable except

Fig. 5: Outcrops of sedimentary rocks in a roof pendant near the northern edge of the Neenach Hills.

in thin sections. The impure sandy members have formed well banded biotite schists where metamorphism has been intense. Limestones, now recrystallized to coarse calcite, are also very abundant. The principal metamorphic effect is a simple recrystallization but at several localities considerable material has been added by the intrusive. The tunnel of the Antelope View mine passes thru a body of limestone which has been completely changed to coarse bladed tremolite and wollastonite. In the Peters mine a mass of limestone has been recrystallized to a coarse aggregate of calcite crystals in which there are abundant scattered grains of sulfide minerals, added by the intrusive. And numerous other small roof pendants have been prospected for the slight quantities of sulfide minerals or gold which have been added to them by the igneous magma.

Although the areas of sedimentary rocks show extremely complicated structures, the broader structural features of the roof pendants are still discernible. The prevailing attitude of the beds in the larger roof pendants is an east-west strike and a steep dip to the south. The present isolated masses appear to have originated from a continuous belt of southward dipping beds which was broken up by intrusion and possibly by later faulting along a north-south set of faults. The contacts between the sediments and the intrusive rocks are very often found to be marked by zones of gouge and it might be supposed that the two groups of rocks are entirely in fault contact. However such gouge zones are usually so small as to indicate only very slight movements insufficient to account for the position of the sediments within the igneous rocks. It seems more reasonable to suppose that originally the contacts were entirely intrusive and that later the readjustments which necessarily accompany the crystallization of a magma selected such contacts as planes of movement; or the intrusive may have come in along fault zones which remained planes of weakness and responded to later stresses by slight movements.

No more definite age than pre-Cretaceous is known for the sedimentary rocks as they contain no fossils so far as known and their relations with other sedimentary rocks of adjoining regions can not be determined. However Simpson[1] has described roof pendants of similar rocks which occur in the intrusive rocks of the Tehachapi Mountains about 20 miles to the northeast. These sediments were named by him the Bean Canyon Series and their age set at probably in part Triassic and possibly in part Jurassic. From Simpson's description of the Bean Canyon Series it appears

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[1] Simpson, E.C.: Geology and Mineral Deposits of the Elizabeth Lake Quadrangle, Calif. Jour. Mines and Geology, Oct., 1934.

probable that the sediments of the Manzana quadrangle belong to the same group.

Volcanic Rocks: In the western portion of the Neenach Hills the intrusive rocks are covered by an extensive series of volcanic rocks. The series comprises a complex group of variable flows, breccias and tuffs which extends beyond the Manzana quadrangle for many miles to the west.

In composition the volcanic rocks are chiefly highly siliceous rhyolites, but some andesitic and basaltic types are also represented. They have almost every possible shade of color from white to green, red and black, and they stand out brilliantly against the drab slopes of intrusive rocks. Texturally, these rocks are almost exlusively fine grained. The flow rocks are chiefly cryptocrystalline flows, vitrophyres, or glasses and thick flows of green, red and black obsidians are among the most common types found. Even the flow breccias, which macroscopically are coarse grained, are very fine grained in both matrix and included fragments. Flow textures of remarkable delicacy are rather characteristic features of these rocks; where they are expecially regular, they are useful in determining the attitude of the flows, but commonly they are highly contorted and of no help in deciphering the structure.

Along the southern part of the contact between volcanic and plutonic rocks, the flows appear to lap up in depositional contact on the intrusive rocks and to dip westward at moderate angles. Along the northern part of the contact, however, the flows have been rotated into vertical attitudes along a large fault which forms the contact from Spencer Canyon on to the northeast to the alluvium of Antelope Valley. The glassy volcanic rocks beside this fault have been thoroughly brecciated and pulverized by movement on the fault.

There is no direct means in the Manzana quadrangle of dating the volcanic rocks aside from the probability that they are post-Cretaceous. The most logical assumption is that they belong to the greatest period of volcanic activity in southern California which came in Miocene time.

Dike Rocks: The Neenach mining district, on the northern edge of the Neenach Hills, lies in an area of quartz diorite which has been injected with great numbers of pegmatite and aplite dikes. Locally these dikes are so abundant that their erosional debris conceals the coutry rock and gives an impression that the entire terrain is composed of pegmatite. Elsewhere in the region pegmatite dikes are common but less abundant. This concentration of dike rocks along the northern edge of the mountains may be more apparent that real as exposures become poor and outcrops very scarce within the body of the range while they are relatively abundant along the fringe of the mountains. However the concentration of pegmatites along the margins of a batholithic mass is an expectable phenomenon and in this case would indicate that the limit of the batholithic invasion was near the present northern limit of the mountains--a fact which is also suggested by the abundance of roof pendants along the northern edge of the mountains.

In most cases the dike rocks are typical pegmatites consisting essentially of pinkish microcline and glassy quartz crystals which range up to several inches in diameter; lesser amounts of coarse biotite and fine grained magnetite are also common constituents. The textures of different dikes range from aplitic to graphic depending on the grain size and relative distribution of the feldspar and quartz crystals. Very coarse grained dikes show no definite arrangement of the minerals. Many pegmatites of intermediate grain size consist of hypidiomorphic grains of quartz and feldspar having an arrangement best described as "granitic"; these rocks can be called simply "granite dikes". Small dikes of aplite are common but less abundant than pegmatites. They consist of small anhedral grains of feldspar and quartz having a typical "aplitic" textural arrangement. Wherever the relations could be seen, the aplite dikes were found to be older than the pegmatites.

An unusual variation of the prevailing dike rock of the region is exposed in the Tuttle mine. In hand specimens it is a light colored, fine to medium grained rock, consisting almost entirely of feldspar with a little quartz and small amounts of dark chlorite grains. Texturally, the fine grained facies appears almost aplitic, but thru most of the dike the individual grains have a more subhedral outline than in a typical aplite. In thin sections, two feldspars--orthoclase and albite--are seen to be present, making up perhaps nine-tenths of the rock with quartz forming the remainder. A peculiar feature of this rock is that it contains great numbers of small cavities between the component mineral grains. In general these cavities are very minute and highly irregular, but occasionally they reach a size of around one centimeter and then may be filled with small, prismatic crystals of clear quartz. These cavities are possibly due in part to leaching out of the chlorite grains, but their abundance, irregular shape and even distribution suggest that they have some genetic implication. Since the chemical composition of the rock suggests a high temperature of formation, ~~however~~, and therefore probably high pressure, The most plausible explanation would be that the dike "magma" crystallized to a porous mass with a final, interstitial liquid which was then either squeezed out, or finally crystallized without filling the voids. The same effect might be produced by injection of the dike under lower pressures than usually obtain in pegmatitic solutions, but this appears unlikely in view of the high temperature of formation.

The Tuttle dike described above is perhaps best called a syenite pegmatite, although it is unusually fine grained for a true pegmatite. However granite pegmatites are also exposed in the Tuttle mine and it is possible that the two types have some genetic relation. Unfortunately the exposures in the Tuttle mine are too poor to permit a detailed examination but several observations suggested to the writer that the two types of pegmatite were gradational--that is, differentiates of some common source solution. The Tuttle dike is a large and complex body of pegmatite and the occurrence within it of a syenitic body unique among hundreds of other pegmatites in the region plainly shows that unusual factors were involved in its formation. This subject will be discussed further below.

Two occurrences of a peculiar dike rock composed solely of quartz and albite were found in the district. One of these outcrops on the hill above the Antelope View mine and is also exposed in the tunnel of the mine; the other occurs near the mouth of Baldwin Grade Canyon. At the former locality, the albite occurs as the brilliant white platy variety known as cleavelandite, and is intergrown with large masses of grey crystalline quartz. Individual crystals in this rock range up to six inches in diameter. Both of these quartz-albite dikes have been prospected and assays show them to contain small amounts of gold.

A group of prospect holes in upper Baldwin Grade Canyon have exposed numerous pegmatite dikes which illustrate a rather more complex paragenetic history than most of the dikes in the region. Two of these dikes are lens-shaped bodies dipping only about 30 from the horizontal. They show a remarkable variation in width; one of them dwindles from 8 feet to a few inches in thickness within a horizontal distance of 15 feet along the strike.

These dikes are made up of huge masses of pink microcline, white albite, and glassy quartz as much as 12 inches in length. The feldspars are concentrated along the margins of the dikes and grey or white crystalline quartz fills in the center to form a tabular vein-like mass in the very center of the dike. In one case the only mineral present besides quartz and feldspar is biotite, in black lustrous plates up to 6 inches in diameter; in another, fine grained masses of green muscovite are rather abundant. These dikes are generally "frozen" tight to the walls, but sometimes narrow seams of gouge can be found along their margins which appeared to the writer to be of pre-intrusive origin in view of the general absence of fracturing within the dikes.

Some difficulty was experienced in identifying the abundant pink feldspar of these dikes. In thin sections it shows none of the characteristic cross-twinning of microcline and for some time it was thought to be orthoclase rather than microcline. This conclusion was so opposed to the generally-held opinion of petrologists that orthoclase is non-existent or very rare in pegmatites, that a more detailed study of the mineral was made. Examinations were made of cleavage grains in immersion oils and of numerous thin sections.

In thin sections, the pink feldspar shows several peculiar microscopic structures. It is commonly filled with abundant veinlets and irregular spindles of albite arranged parallel to one another in the form of "vein" perthite. A peculiar variety of this perthite consists of microcline(?) containing albite laths bent into sharp angles resembling the bent twinning lamellae of strained plagioclase crystals in metamorphic rocks. So far as the writer is aware, such structures have not heretofore been described and the descriptive term "chevron perthite" is therefore suggested. (see pages 28 - 30 for photomicrographs of these textures)

The majority of the feldspar shows no perthitic structure but there is always present an obscure ragged spindle texture without the usual cross-hatched appearance of microcline. This is believed to be an expression of the usual microcline twinning which lacks the customary appearance because it is developed on an almost submicroscopic scale and hence does not fully appear on thin sections of standard thickness.

Cleavage fragments of the pink feldspar were also tested in immersion oils. Perhaps the only safe method of discriminating between orthoclase and microcline is the measurement of the extinction angle on the 010 cleavage trace. Cleavage fragments of either mineral parallel to 001 (the most perfect cleavage) show the trace of the well developed 010 cleavage. Orthoclase shows extinction parallel to this direction, while microcline has an extinction angle of around 15 degrees. This discrimination is ordinarily not possible in this sections and the customary procedure is to rely on the presence or absence of microcline twinning in differentiating the two minerals. However several recent investigators have pointed out that orthoclase may invert to microcline during the grinding of the thin section, and this criterion cannot, therefore, be relied upon too much.

Probably the determination of all potash feldspars should be made on thin chips because cleavage fragments of the proper orientation to give the maximum extinction angle can be readily selected, and there is little or no danger of artificial inversion. In the case of the doubtful feldspar described here, 001 cleavage chips showed extinction angles on 010 ranging up to 15 degrees, definitely proving the mineral to be microcline rather than orthoclase. Moreover, the thinnest edges of chips showed the characteristic cross-hatched twinning of microcline developed on an unusually small scale. Apparently the twinning is too delicate to be evident in thin sections of standard thickness and appears only as an obscure texture without cross-hatching.

The microcline vein perthites such as those described above have been shown by Anderson[1] to be albite replacements along small fractures in the microcline. This is borne out by much other evidence of replacement in the dikes of Baldwin Grade Canyon, showing that albite has replaced microcline. Pink microcline commonly occurs as residual masses within albite in such a pattern as to strongly suggest replacement. Thin sections of such structures show transitions from vein perthite to patch perthite or antiperthite in which small "patches" of microcline occur as residual islands in large albite crystals.

Both microcline and albite in these dikes show delicate graphic intergrowths with quartz. The intergrowths are always fine grained structures and may not even be apparent except in thin sections. These also are regarded as replacement structures for reasons which will appear below.

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[1] Anderson, Olaf: Genesis of some types of feldspar from granite pegmatites, Norsk Geologisk Tidsskrift, Vol 10, pp 116-207, 1928.

A detailed microscopic and field study of the dikes of Baldwin Grade Canyon suggests to the writer the following sequence of events as the probable paragenetic history:

1) after opening of the channels, "granitic" pegmatites of microcline, albite and quartz crystallized along the channel walls, the relatively fine grain size being due to chilling. Both albite and quartz are essentially later than microcline in the dikes but they appear to have formed to some extent in this stage.

2) continued and slower crystallization resulted in the formation of very large masses of microcline with some albite and quartz until the quantity of microcline in the crystallizing solutions had been exhausted. This was essentially a microcline stage but was overlapped by succeeding albite and quartz stages.

3) albite continued to crystallize, replacing to a considerable extent the previously formed microcline. This stage is represented by perthites and other, large scale replacement structures.

4) the remaining silica-rich solutions actively attacked the albite and microcline, forming delicate graphic intergrowths by replacement of the feldspars.

5) the remaining open spaces in the center of the dikes were filled by glassy quartz.

The graphic intergrowths of quartz and feldspar such as are described here are believed by some writers to represent simultaneous crystallization from a solution of eutectic composition; others regard them as due entirely to replacement. In deciding which of these processes has been operative in the occurrence described here, it must be noted that by the eutectic hypothesis it is necessary to account for two eutectics, one between quartz and microcline and the other between quartz and albite. Now it is impossible for two eutectics involving a common constituent to form from a single solution and it is therefore necessary under this hypothesis to suppose either that they formed from a continuously flowing solution of gradually changing composition, or from several distinct surges of solutions having different compositions. In the writer's opinion these explanations are unlikely because they must assume a very rapid change in the composition of the pegmatite solution. Moreover they demand that the pegmatite chambers were continuously or repeatedly opened to the flow of solution. The discontinuity and lenticularity of the dikes, however, would seem to indicate that the first beginning of crystallization would tend to close off the channels and largely inhibit a continued flow of solution. Some flow must be assumed to account for the removal of replaced material and the decrease in volume of a crystallization solution, but it seems physically impossible that there could have been a continuous passage of large volumes of solution thru openings of this kind. It is therefore believed that no great quantity of solution entered or left the pegmatite chambers after the initial influx and that the resulting dikes were essentially the crystallization products of the initial solutions. Under this hypothesis the graphic intergrowths of quartz-microcline and quartz-albite must be of replacement origin. The removal of the replaced feldspars demands the outflow of solution from the dike chambers, but since only a relatively small volume of the dikes has been affected by replacement the removal of this material could be accomplished by a small volume of solution passing out into the surrounding rocks.

Economic Aspects of the Pegmatites: Particular interest attaches to the pegmatites of the Neenach district because many of them have been prospected and are known to contain native gold. The group of dikes in Baldwin Grade Canyon described above have been extensively investigated as gold prospects by numerous short prospect tunnels and shallow open-cuts. The quantity of gold contained in these dikes is not known, however, as no assay figures were available to the writer.

Near the Antelope View mine several small openings have been made in very coarse grained granitic pegmatites which gave assay figures of around ½-1½ pennyweights of gold per ton. Assays from two of the peculiar quartz-cleavelandite dikes gave similar values. In none of these cases are veins or mineralized fissures in evidence to which might be attributed the source of the metallizing solutions. Numerous mechanical concentrations of these rocks were made in an effort to determine whether or not any other minerals indicative of a hydrothermal origin of the gold were present. In all cases the only heavy mineral besides slight amounts of native gold was very fine grained disseminated magnetite. As will be shown later, the typical hydrothermal mineral deposits of the district always contain several of the following minerals in addition to gold: arsenopyrite, galena, sphalerite, pyrite, chalcopyrite, and gold telluride, and native gold is a relatively rare constituent. The complete lack of any of these characteristic hydrothermal minerals and the lack of any field evidence pointing to a hydrothermal introduction of the gold into the dikes, seem to the writer fairly good proof that such gold represents a primary constituent of the pegmatite solutions. Unfortunately it occurs in such minute quantities that its relations to the other dike minerals could not be determined, but it is believed to be evenly distributed thru the dikes and to occur almost entirely in quartz, with little or none in the feldspars.

There are, of course, great numbers of pegmatite dikes in the region which so far as known contain no detectable quantities of gold. In all of the mines of the district, for example, such dikes are very numerous. In these cases no attempt was made to determine the gold gontent inasmuch as the obvious association of the dikes with later hydrothermal deposits would strongly suggest that whatever gold was found was introduced by later solutions after consolidation of the dikes.

The most unique and interesting dike in the region is the one exposed in the Tuttle Mine, near the center of the Manzana quadrangle. The peculiarities of this rock with respect to petrology have already been described above, but the most spectacular feature of the dike is its abundance of coarse native gold, which is now being mined. Fine gold seems to be disseminated thru the entire body of this dike and to some extent in the wall rocks of quartz monzonite. Several specimens of the pegmatite examined by the writer, which to all outward appearances would never be suspected of containing gold, showed amazing quantities of the metal when concentrated by panning. The gold occurs in crystalline masses generally about 1/32 to 1/16 inches in length or finer, but some were found as large as 3/16 or 1/4 inches in length. It was generally found, especially in the coarse masses, that the gold was intimately associated with the small grains of chlorite scattered abundantly thru the entire dike.

The interesting problem of genesis presented by this deposit could not be fully elucidated to the writer's satisfaction because of the conditions at the mine at the time of his visit. Preparations were then being made to install a small test mill and to begin deepening the shaft (then only 65 feet deep). The shaft was deeply flooded and the walls completely boarded as far as sinking had progressed. The only exposures available to examination were in four small crosscuts from the shaft at a short distance below the surface.

A significant exposure occurs in the uppermost of these crosscuts (only fifteen feet below the surface), where a wall of the porous syenitic pegmatite is traversed by two narrow seams of gouge. These small faults and the pegmatite immediately adjacent to them are relatively rich in coarse native gold; at increasing distances from the faults, the gold values progressively drop off until the quantity of gold becomes inappreciable in the rock 8 or 10 feet away. The two faults are only the more well-defined of a number of similar seams of gouge making up a general zone of fracturing in the pegmatite. The gouge within these fractures is a fine, white material, too incoherent to be examined microscopically, but showing no effects of oxidation. Numerous mechanical concentrations of this material were made to determine what heavy minerals might be present. In no case was any heavy mineral other than native gold found to be present.

Aside from the mineralogy, the above data are certainly strong evidence for introduction of the gold by hydrothermal solutions after consolidation of the pegmatite mass. All significant features of the deposit point to this conclusion--the occurrence of small, mineralized faults within the pegmatite, the gradual decrease in tenor of the rock away from the faults, and the association of the gold with chlorite, suggesting hydrothermal alteration of a primary ferromagnesium mineral in the dike by the gold-bearing solutions. Moreover, the porous nature of the pegmatite would afford a particularly favorable site forthe wide diffusion of the mineralizing solutions and would lead to a general dissemination of gold thruout the entire dike.

It should be noted however that these hydrothermal solutions must have been wholly different fromthose that formed the other fissure vein deposits of the district. It will be shown later that native gold is relatively rare in all other hydrothermal deposits, and that several sulfide minerals are always present. The mineralized fissures of the Tuttle pegmatite thus represent a unique type among numerous sulfide-bearing veins occurring over a considerable area and within a short distance of the Tuttle mine. In other words, the gold of the Tuttle pegmatite can not be explained as part of a general hydrothermal period which followed formation of the pegmatites of the region and produced the numerous veins of the district.

While no definite proof can be advanced at this time, the writer feels that the several unique features of this pegmatite must have some genetic relationship. The composition, abundance of gold, and character of metallization ofthis dike are features unduplicated anywhere else in the region and seem to require a common genetic explanation. A possible explanation that has occurred to the writer is that the dike has evolved by a sort of minor differentiation within its own chamber. The original solution may have differed somewhat from the normal in containing relatively little silica and an unusual amount of gold. The crystallization differentiation of this solution in the final chamber, or somewhere along the channel, or in some chamber removed from the parent magma, might produce the complex body of syenitic and granitic pegmatites such as the Tuttle dike. The final residuum of the differentiation would be a watery solution containing the concentrated gold of the entire original mass. Finally, this solution might move upwards along cooling-fractures in the consolidated rock to produce the deposits that we now see.

This theory is presented only as a suggestion for the possible genesis of the Tuttle dike and remains at present without definite proof. While it may appear somewhat fantastic, it is felt that unusual theories are no less valid than widely-accepted ones when they are applied to unusual phenomena. The Tuttle pegmatite, being a unique feature may require a unique explanation.

Alluvium: The northern half of the Manzana Quadrangle is completely covered with a veneer of alluvial material washed down into Antelope Valley from the Neenach Hills to the south and the Tehachapi Mountains to the north. It consists of loose, unconsolidated materials ranging in size from coarse sands and boulders near the edge of the mountains to fine silts farther out in the valley. The alluvium is all of Quaternary age but a distinction in mapping was made between alluvium and older alluvium, on the basis of erosional history.

The older alluvium includes alluvial fans which are no longer receiving additions of sediment and have undergone some measure of dissection. They are especially noticeable in the western portion of the quadrangle, where streams from Spencer and other canyons have deeply incised a huge, flat-topped fan belonging to an earlier period of deposition. Outwards into Antelope Valley, the older fans gradually merge with the recent alluvium.

Numerous other small remnants of older alluvium are found at many places along the edge of the Neenach Hills. They are all attributable to a slight uplift of the region in Quaternary time, perhaps along the San Andreas rift.

Two small patches of older alluvium, resembling bench

Fig. 6: Old alluvial fan now undergoing dissection. Photo taken near mouth of Spencer Canyon.

gravels, occur in Kings Canyon near its present mouth and testify to an interesting case of stream capture. The stream in Kings Canyon formerly turned sharply northward near the eastern end of the canyon and flowed into Antelope Valley via a broad, flat canyon deeply filled with alluvium. Small benches of alluvium, now almost eroded away, mark the former extent of this alluvium-filled canyon far up into Kings Canyon. The streams of Kings Canyon have now abandoned their former course and flow eastward into Antelope Valley by a shorter and steeper course; consequently the old alluviated channel has been cut across by the present rock-cut channel. The position of the present stream-course may be partly controlled by the location of the Kings Canyon fault, but it is probably in large part simply the result of headward erosion from Antelope Valley which established a steeper gradient than existed in the old canyon and the latter was consequently abandoned. Another factor may have been an increased flow of water in Kings Canyon because of some topographic disturbance in the headwaters of the canyon along the San Andreas rift. This might permit a rough correlation of the alluvium in the old stream-course of Kings Canyon with the old alluvial fans of Antelope Valley, since the latter also were probably the result of fault movements.

What appears to be a still older generation of alluvium, lying at elevations of from 100 to 300 feet higher than the old fans, occurs just east of Spencer Canyon overlying flow rocks of the volcanic series. It consists of rounded boulders of granitic and volcanic rocks, in general much coarser than any material found in the more recent alluvium. At present it is nearly all eroded away and now consists of only a thin veneer of boulders lapping up onto the volcanic rocks. This alluvium would seem to indicate a still earlier uplift of the region in Quaternary time.

Fig. 7: View showing the old alluviated valley of the Kings Canyon stream now cut across by its present course. In the foreground is a "bench" of alluvium formerly continuous with the old valley.

Plate I

Plate I

Photomicrographs of Pegmatite Feldspars from dikes of Baldwin Grade Canyon

A: Incipient vein perthite; large vein is twinned albite; poorly defined veins of albite run across section; beginnings of albite replacement can be seen in microcline along fractures parallel to the large vein. X-nicols, X48.

B: Vein perthite of albite in micro-cline. White areas are quartz. X-nicols, X48.

A

B

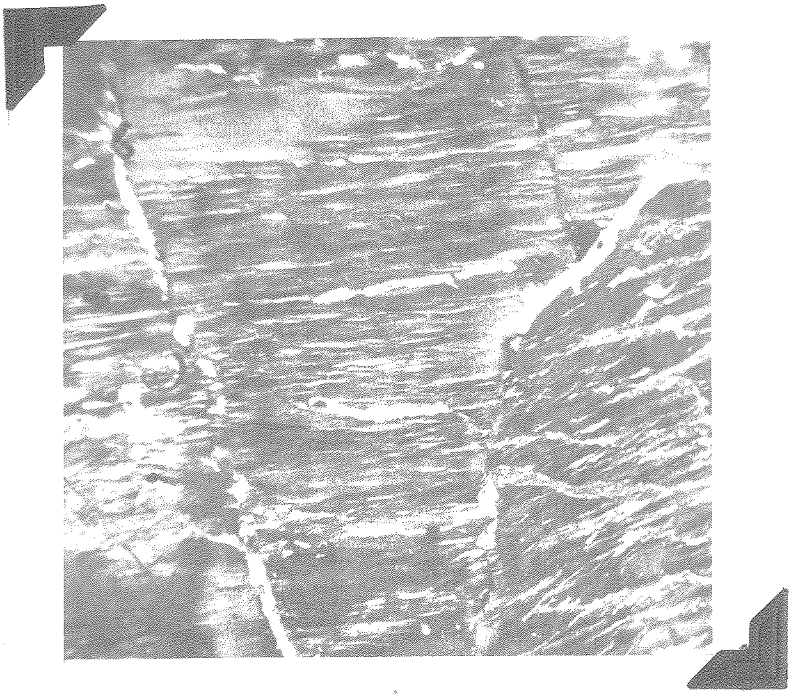
Plate II

Plate II

Pegmatite Feldspars (cont'd)

A: Vein perthite; albite veinlets replacing microcline along fracture cracks. X-nicols, X48.

B: "Chevron" perthite, a variety of vein perthite; albite replacing microcline. X-nicols, X48.



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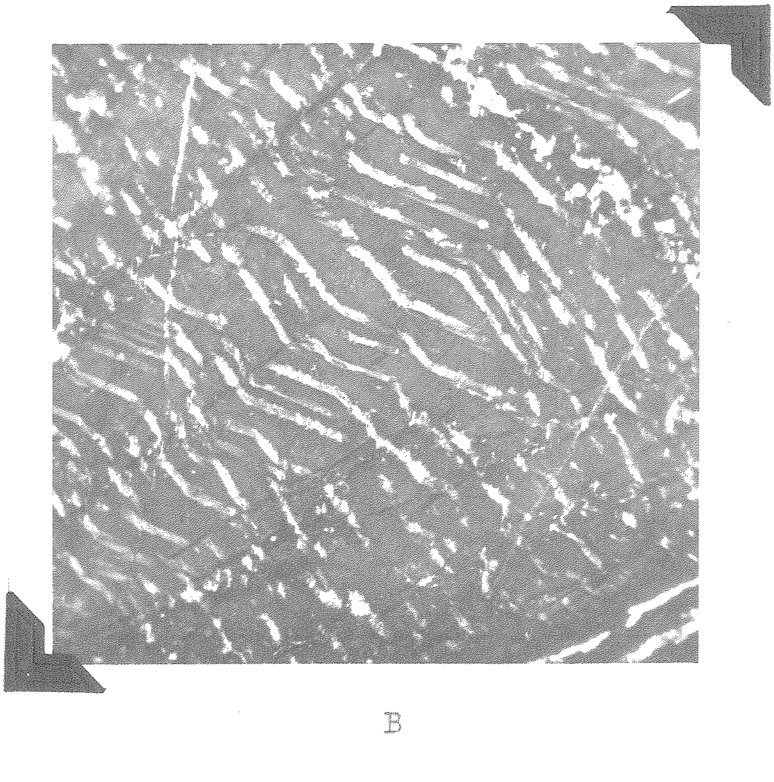

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Plate III

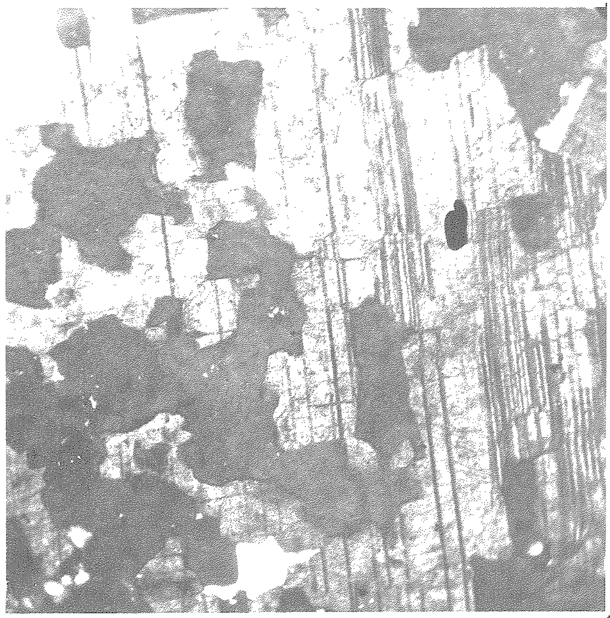
Plate III

Pegmatite Feldspars (cont'd)

A: Patch perthite; twinned albite replacing redisual "islands" of microcline. This type of perthite is transitional with vein perthite. X-nicols, X44.

B: Replacement graphic intergrowth of quartz (white) and albite. X-nicols, X48.

note: all photomicrographs on Plates I, II, and III are from thin sections of specimens taken from a dike in upper Baldwin Grade Canyon, ½ mile west of the Peters Mine.



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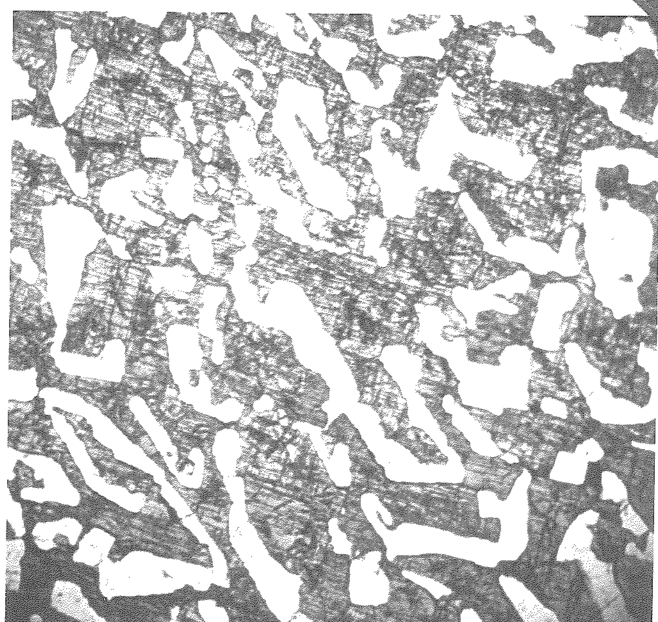

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* Structural Geology *

Structurally, the area covered by the Manzana quadrangle may be considered as made up of two blocks of plutonic igneous rocks separated by the San Andreas fault zone. This division of the area into two blocks is in part a physiographic one, but in a larger sense is structural inasmuch as the blocks are parts of the same batholith that were formerly a great distance apart and have been brought into adjacent positions by movements along the San Andreas fault.

The faults of the region fall into two groups, one characterized by strike-slip or "tear" movements, and the other by essentially vertical displacement along vertical or steep normal faults.

The San Andreas Fault System: One of the major structural features of California is the San Andreas fault, a huge crustal break with a length of over 600 miles, extending from a point off the Oregon coast to the Gulf of California. The San Andreas fault passes thru the southern part of the Manzana quadrangle with a trend of about N 75° W. Its entire length thru this area is marked by a narrow trough known as Pine Canyon. Pine Canyon is the principal drainage feature of the entire area; in a strict sense, however, it is not a canyon at all, but a series of canyons having entirely different drainage directions. Towards the east from the summit near the extreme eastern limit of the canyon on the Manzana quadrangle the canyon slopes to the east and the drainage is entirely in that direction; from this point westward to the vicinity of Devils Gulch, the drainage is downward in a "V" to the head of Kings Canyon; around Devils Gulch, the drainage is northwards into the Tweedy Lake depression and then eastward into the western branch of Kings Canyon; west of Sawmill Canyon the drainage is westward and then northward thru Oakgrove and Pine Canyons into Antelope Valley. The general trend of Pine Canyon and its seve-ral changes of slope are all anomalous to the normal regional drainage northward into Antelope Valley, and together constitute the most important physiographic evidence for the location of the San Andreas fault zone.

The San Andreas fault is not a single fracture although there appears to be one main line of weakness. Numerous other faults branch off from and later re-join this fault to form long, lenticular slice-ridges and valleys. Across its entire width the fault zone is thoroughly brecciated and the character of the rock in the individual slices almost indeterminable. For this reason, the location and mapping of the branch faults was largely dependent on the recognition of physiographic features such as peculiarities of drainage, offsets in alluvium, and alignment of saddles. Curiously enough, the sinking of slices along the fault to form sag-ponds, so characteristic of the fault in other regions, appears not to have taken place in Pine Canyon or else has been continuously obscured by rapid erosion.

One of the most striking evidences of recent faulting is found at the mouth of Devils Gulch. Devils Gulch is a long, flat-floored canyon leading northward from the slope of Sawmill Mountain and draining a considerable area. Where it joins Pine Canyon it is abruptly cut off by a slice ridge of granitic rocks and alluvium and the entire drainage is ponded. Since the time of the faulting responsible for this ponding, the streams have been able to cut their way thru the ridge into Tweedy Lake to the north and Kings Canyon to the east, but at one time this entire drainage must have been effectively dammed. A similar history is responsible for the formation of Hidden Lake, ½ mile farther east.

Fig. 8: General view westward along Pine Canyon showing typical topography along the San Andreas rift.

Fig. 9: Ponded drainage at the mouth of Devils Gulch. The main branch of the San Andreas rift follows the base of the ridge on the right.

These features attest to the extreme recency of movement along the San Andreas fault. Structures that disrupt the drainage patterns of large areas are of necessity highly unstable

Fig. 10: Fault scarplet in alluvium along the main branch of the San Andreas rift. Sawmill Mtn. in background.

and consequently must be either very large structures or of very recent origin if they have escaped rapid obliteration. In the case of the San Andreas fault both conditions are true. The position of Pine Canyon cutting across the region almost at right-angles to the regional northward drainage shows the presence of a very large structural control; on a smaller scale, the ponding and damming of streams by low slice ridges indicates that some of the movement has been of very recent date--at least within the last few hundred years.

The diagnostic features of the San Andreas fault are all characteristic of a strike-slip or "tear" fault and most of the movement along it has no doubt been by horizontal slipping with little or no vertical displacement. However there is a difference in elevation of 750-1,000 feet between the areas on the north and south sides of the fault which is best explained by supposing some vertical movement to have accompanied the strike-slip movement.

There is no evidence within the Manzana quadrangle by which to measure the total horizontal displacement along the San Andreas fault; however some 75 miles to the east there is good evidence to show that the southern side of the fault has moved more than 20 miles westward with respect to the northern block since Miocene time. How long before Miocene time the fault was active is completely unknown, and likewise how much greater than 20 miles the total displacement may be, is unknown. As already noted above, the igneous rocks of the Liebre Mountain block south of the fault contain numerous inclusions of schistose rocks which were possibly derived from the Pelona Schist series occurring over a large area a few miles to the east. This would likewise suggest that the Liebre Mountain block had moved westward with respect to the Tweedy block in agreement with the direction of all recent movements.

Across most of the quadrangle, the San Andreas rift is marked by a narrow and well-defined zone of fracturing. Towards the west, however, the fault zone broadens considerably. Near Sawmill Mountain Ranch one branch of the fault swings about 10 degrees northward from the regional trend and passes down Oakgrove Canyon, defining a huge block within the fault zone.

Another large tear fault joins the San Andreas fault near this point. This fault lies within a low ridge between Pine Canyon and Tweedy Lake valley and is marked along its length by a continuous line of saddles, straight canyons, and brecciated rocks. It is clearly traceable for nearly a mile and a half but becomes obscure east of the entrance to Tweedy

Lake valley.

Fig. 11: View westward along a succession of saddles marking the trace of a large team fault that branchs off from the San Andreas rift.

Kings Canyon Faults: Just east of the Manzana quadrangle, the edge of the hills facing Antelope Valley is a steep fault scarp along which the Kings Canyon fault lies. The scarp increases in

Fig. 12: View showing the Kings Canyon fault scarp from a distance. The scarp gradually decreases in elevation to the east (left, on the picture).

elevation westward to its highest point (about 4200 feet) just within the Manzana quadrangle. However the fault lying at the base of the scapp at its eastern end cuts within the scarp on the Manzana quadrangle.and rapidly dies out in displacement. It is evident that another en echelon fault parallels the Kings Canyon fault and is responsible for the elevation of the western end of the scarp. This fault swings gently up the long straight line of lower Kings Canyon with little evidence to mark its presence other than a difference of a few hundred feet elevation between the blocks on the two sides. This fault also appears to die out rapidly to the west. Its position has no doubt controlled the location of Kings Canyon in an east-west position otherwise

Fig. 13: View westward up Kings Canyon from a point near its mouth. In the foreground is a flat "bench" of alluvium that formerly extended up the canyon.

anomalous to the normal drainage of the region. Both of the Kings Canyon faults are steep normal faults along which the southern blocks have moved upwards with respect to the northern.

Other Normal Faults: The peculiar mid-mountain depression of Tweedy Lake valley is essentially a structural depression defined by steep faults. The north edge of the valley is marked by a low ridge bounded on both sides by steep east-west faults of rather small displacement. The north face of this ridge is a small fault scarp about 200 feet in height showing practically no erosional dissection. The steep and deeply dissected canyons north of the ridge lead up to this face and are abruptly terminated. The essential movement along this fault appears to have

Fig. 14: General view over the eastern part of Tweedy Lake Valley.

been a rotation of the southern block by which the northernedge was uplifted some hundreds of feet. At the same time another fault developed a short distance to the south alongwhich the

Fig. 15: View eastward along the small fault scarp at the northern edge of Tweedy Lake Valley. The low hills to the right represent former topographic eminences on the depressed block.

southern block was dropped down. The result of these movements was to leave a depressed block sloping northward against an elevated ridge which blocked the drainage and left an intermontane basin with stagnated drainage. A number of low rounded hills nearly buried in alluvium border the southern edge of the elevated ridge. They appear to represent former topographic eminences on the depressed block which are now being gradually buried by waste from the surrounding hills. The other sides of the valley are suggestive of fault movements but no clearly defined fault lines could be found.

Another large normal fault marks the northern end of the contact between the volcanic and plutonic igneous rocks in

Fig. 16: View along the fault contact between volcanic and plutonic igneous rocks east of Spencer Canyon.

the western part of the quadrangle. Two prospects along the line of this fault show thick zones of gouge and brecciated igneous rocks, and thruout its length the adjoining glassy volcanic rocks are thoroughly brecciated. The movement on this fault appears to have involved a dropping and rotation of the northern block so that the volcanic rocks now stand vertically.

Minor Faults: Within the mines of the Neenach mining district, faults of considerable magnitude are extremely numerous. Although these faults are often marked underground by zones of gouge as much as 5 feet thick, they have in general no surface expression whatsoever and cannot be traced. For this reason they were not mapped although a very detailed study might permit the structure to be exactly worked out.

The abundance of these minor faults where underground exposures are available suggests that the entire area of crystalline rocks in the Manzana quadrangle is broken by similar fractures, although they may well be especially abundant in the vicinity of the mining district. Unfortunately the deep weathering of the bedrock and the lack of strong relief prevent the location of whatever faults may exist in the other parts of the area.

Age of the Faulting: The faults of the San Andreas fault system are active faults, as evidenced by recent seismic activity along the length of the rift and the abundance of physiographic features characteristic of recent faults of this type. The steep vertical-displacement faults, however, cannot be dated so closely. The normal fault along the northern edge of the volcanic rocks is evidently of post-Miocene age, and the presence of a large scarp along the Kings Canyon fault suggests that it too may belong in the late Tertiary. However many of the faults exposed in the mines of the Neenach mining district evidently belong to an earlier epoch of faulting which closely followed the igneous intrusion. Their age is probably early Cretaceous.

* Economic Geology *

The district herein described as the Neenach mining district includes a large number of mines and prospects scattered over the Manzana quadrangle, but is essentially confined in economic importance and size of development to a small area near the center of the quadrangle along the extreme northern edge of the Neenach Hills. The only settlement in the district consists of a general store and group of mining buildings in a small canyon leading from Antelope Valley into the hills near the exact center of the quadrangle. Due west of this canyon lies the westernmost and largest area of sedimentary rocks in the quadrangle; within this area lie all of the most important mines and from it has come nearly the entire production of the district.

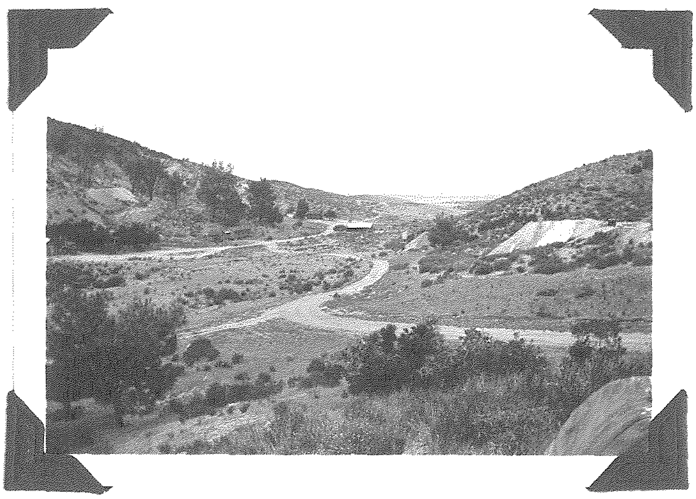

Fig. 17: The small settlement near the center of the Neenach mining district.

<u>History of Mining</u>: The earliest mining in the Neenach district appears to have begun some two decades ago at the Big Chief mine on property owned by the American Smelting and Refining Company. This property is said to have produced some gold in its early history but has long since been idle and is now badly caved and flooded. The high-grade deposits now being mined in the district

were not discovered until very recent years. In 1931, W. J. Rogers found high grade gold ore while developing water on his property and this discovery stimulated very active prospecting over the entire region. As a result of this increased activity, many more mineral deposits were found, some of them richer than the original strike.

Lands within the mining district are owned exclusively by ranchers and mining operations on small parcels of land are carried on by leasers. This arrangement has probably tended to slow up production somewhat.

Production: No exact figures on the production of the mining district are available. Up to September, 1934 the total production was somewhat less than $100,000; up to the present date, the total amounts to something more than $500,000, most of which has come from the Rogers-Gentry mine and the Camp lease on the property of W. J. Rogers.

Types of Deposits: There is a wide variety of mineral deposits within the quadrangle, and they may be classified in several different ways. According to the source rock of the mineralizing solutions, two groups may be distinguished: 1) mineral deposits related to the Tertiary volcanic rocks in the western part of the quadrangle, and 2) deposits related to the intrusive rocks of Jurassic-Cretaceous age. Within the latter group, several different types may be recognized. The obvious association of the ore deposits with metamorphosed roof pendants of sedimentary rocks illustrates one type in which mineralization was an exomorphic effect of contact metamorphism. The second, and most important type in this group includes true fissure veins of somewhat variable mineral character and structure. Lastly among the deposits of this age must be listed the pegmatite dikes, which have been prospected at numerous localities for the gold they sometimes contain. The pegmatite dikes have already been described; the remaining types will be described in the order given above.

* *

Tertiary Ore Deposits: Within the area of volcanic rocks in the northwestern portion of the Neenach quadrangle, numerous small prospect pits and tunnels have been opened up in an effort to locate ore deposits within these rocks. At the present time no commercial bodies of ore are known, and in fact no metallic minerals whatsoever were evident in any of the prospects examined by the writer. In most cases prospectors seem to have been attracted by the most brightly colored rocks rather than by geologic conditions favorable for the occurrence of ore.

Extensive areas of the flows and tuffs of the volcanic series have been silicified by innumerable small veinlets of chalcedony, chalcedonic quartz and opal. These silicified areas stand out vividly in the landscape in consequence of their white color but they do not seem to have attracted many prospectors, although geologically they are favorable sites for the location of ore deposits. This silicification is, no doubt, an end-stage phenomenon of the volcanic activity and providing that metallic elements were present in sufficient amount in the source magma, it is likely that ore deposits will be found in these silicified areas. Many of the spectacularly rich gold and silver bonanzas of the western United States have formed in a similar manner.

The only evidence of metallic mineralization found by the writer in the area of volcanic rocks was in a small specimen of float found in Spencer Canyon. This rock contained minute specks of a yellowish metallic mineral, possibly pyrite or chalcopyrite. This shows that some mineralization at least has accompanied the extrusion of the volcanic rocks.

Deposits of Jurassic Age: By far the most important mineral deposits in the Manzana quadrangle are those whose formation can be directly attributed to the intrusion of the igneous rocks of Jurassic-Cretaceous age. They include contact metasomatic deposits, pegmatite dikes, and fissure veins, each type representing a distinct period of intrusive activity.

* Contact Metasomatic Deposits *

Thruout the areas of sedimentary rocks within the quadrangle, metallic minerals are found in surprisingly wide distribution. The fact that the sediments occur only as highly metamorphosed roof pendants within the igneous rocks leaves little doubt but that the metallic minerals were introduced during a late phase of the igneous intrusion that engulfed the sediments. These deposits are considered here as "contact metasomatic" deposits rather than "contact metamorphic" deposits because the metal content of the sediments is the result of an additive process.

This type of mineralization took place over wide areas of sedimentary rocks with little concentration into bodies of metallic minerals which might be economically valuable. Just northeast of the Rogers-Gentry mine, for example, is a large body of recrystallized limestone containing minute grains of sphalerite and chalcopyrite disseminated thru the entire mass and with no indication whatsoever of concentration into veins. In many of the mines of the district, this type of mineralization is obscured by a later hydrothermal mineralization and the amount of metallic minerals attributable to the earlier period is not exactly determinable. However at the Antelope View and Peters mines, and at several prospects, the records of contact metasomatic mineralization are very clear and no later hydrothermal phase appears to be present.

The Peters mine lies about 2 miles southeast of the principal group of mines in the Neenach mining district and 1½ miles within the mountains from Antelope Valley in upper Baldwin Grade Canyon. The mine workings are located in a small roof pendant consisting almost entirely of recrystallized limestone. Sulfide minerals are scattered thru this entire body of calcite with little or no concentration into large masses or definite veins. The minerals present are, in order of abundance: sphalerite, pyrite, pyrrhotite, and gold. In hand specimens the dark sphalerite is the most conspicuous mineral, occurring in small scattered masses thru the calcite and occasionally concentrated to some extent. In polished sections sphalerite is generally found surrounding the other sulfides and to a large extent replacing them. The paragenetic succession in this ore is: pyrrhotite, pyrite, sphalerite, gold, in order from earliest to latest.

The Antelope View mine is located in section 26, T8N R16W near the contact between a narrow roof pendant of sedimentary rocks and the surrounding igneous rocks. The tunnel of the mine cuts thru a narrow mass of meta-sediments which are complexly injected by granitic rocks and numerous pegmatite dikes. Much of these sedimentary rocks are thoroughly recrystallized; limestone beds have become coarse masses of calcite with development of some lime-silicate minerals, sandstones have recrystallized to quartzites, and the shaly beds have become biotite schists and gneisses. Assays of rocks from various places within this tunnel show that there has been a widespread metallization of the sediments--particularly of the schists--by gold-bearing solutions. The amount of gold present seldom exceeds $10 per ton and is generally far less than that figure. No definite fissures are exposed within the mine and the mineralization appears to have been simply a pervasive metasomatic addition to the sediments by the intruding igneous rocks.

Another interesting contact metasomatic deposit is located near the mouth of Baldwin Grade Canyon. A small prospect tunnel has exposed a very small mass of metamorphosed sediments completely surrounded by the igneous rocks. The original sandy shales have been highly metamorphosed to dark,banded quartzites in which minute blebs and stringers of a sulfide mineral can be seen. In polished sections the sulfide is found to be largely pyrrhotite in elongate blebs lined up into bands parallel to the banding of the quartzite. Small amounts of chalcopyrite are also present, and assays of the quartzite show the presence of small amounts of gold.

The other mines of the district show the same metamorphism of the sediments and a widespread but lean dissemination of sulfides. In addition there is a concentration of sulfides along later fissures and it is difficult to discriminate between the mineralization due to the earlier metasomatic action and that which might be attributed to a wide diffusion of solutions from the later fissures.

* Hydrothermal Vein Deposits *

Occurrence: While the contact metasomatic period of igneous intrusion resulted in a widespread mineralization of the metamorphosed sediments, there was practically no concentration of the valuable minerals into large bodies of commercially valuable ore. However, later in the history of igneous intrusion, numerous

Fig. 18: View of the Camp mine, one of the most productive mines in the Neenach district. The original discovery was made in the small cut shown in the left-center of the picture.

large faults developed in the sediments and surrounding igneous rocks and along these channels hydrothermal solutions moved upwards carrying much silica and abundant sulfides. The resulting mineralized fissures and quartz veins contained gold and silver in sufficient quantity to constitute high grade ore. Mineral deposits of such hydrothermal origin are found in varying size at numerous localities over most of the Manzana quadrangle. In economic importance and size of development, however, these hydrothermal deposits are essentially confined to a small area in and surrounding the westernmost and largest patch of sediments along the northern edge of the Neenach Hills. Practically the entire production of valuable metals from the mining district has come from a few mines in this area, and these are the only properties being actively developed at the time of writing.

Structural Features: In many of the mines of the district, numerous faults are exposed, ranging in size from slight fractures in the igneous rocks to large faults having zones of gouge up to 5 feet or more in thickness. These fissures have served as the principal structural control of the formation of the ore deposits by determining the paths of the mineralizing solutions. The large faults appear to fall into two main groups having north-south and east-west strikes. The principal mineralization has been along the faults of the east-west set, while the northe south group is of later origin and offsets all east-west structures. The faults range in attitude from vertical to dips of around 45 degrees but they are generally very steep.

In all of the mines of the district these faults have controlled the passage of mineralizing solutions. Generally, however, they are filled with thick, pasty gouge which in most cases has prevented the active circulation of solution necessary to form a high grade ore deposit. Solutions have slowly risen thru and around the zones of gouge and have permeated to some extent the wall rocks, forming mineral deposits of generally low grade. In most of the prospects of the district, such mineralization is evidenced only the reddish and yellowish colored gouge where small quantities of sulfides have been oxidized. In a few cases, the ascending solutions appear to have had sufficient viscosity to make their way thru the gouge and form definite quartz veins. One of the controlling factors here was no doubt the amount of quartz contained in solution; where silica was abundant, the solutions had enough "strength" to force their way thru the restraining gouge; where little silica was present, the solutions were relatively "weak" and were limited to a sluggish flow. From the present character of the gouge it seems very unlikely that continuous open fractures could have ever existed within it; more probably the openings were created and maintained by the hydrostatic pressure of the mineralizing solutions, with perhaps the force of crystallization of quartz contributing in small measure to this pressure. Where such channels were once established they would permit longer and more rapid circulation of solution and thus make possible the formation of large quartz veins.

Definite quartz veins have been found in the district only in the Rogers-Gentry and Camp mines. In these mines there is exposed a group of parallel quartz veins striking in a general east-west direction and dipping southwards at steep angles. Without exception, the veins lie in zones of gouge, which, in these mines, is generally black in color.

The structural features of the quartz veins are well illustrated in the Camp mine. In the west drift on the 100-level of this mine is a rather flat-lying vein, 4 to 6 inches wide carrying abundant sulfides. The vein lies in the center of a gouge zone about 12 inches wide and appears to have formed from silica-rich solutions which had enough hydrostatic pressure to push their way thru the pasty gouge. Farther west the drift follows another large fault marked by a wide zone of black gouge. This gouge zone is filled with innumerable anastomosing stringers and veinlets of quartz containing only small amounts of sulfides. A similar zone of quartz veinlets in gouge is exposed in the shaft of the Rogers-Gentry mine.

The abundance of the sulfide minerals in these quartz veins seems to be related directly to the pressure and viscosity of the mineralizing solutions and indirectly to the character of the solution channelways. Solutions with high hydrostatic pressure and with much dissolved silica (consequently with relatively high viscosity) were especially able to penetrate thru zones of gouge along large channels and to continue active circulation along such paths as were once established. As the solutions became more highly attenuated by precipitation of silica, or if originally they contained less silica and were at lower pressure, they were less able to create large channels and conversely, were more able to utilize the smaller channels. At the same time, however, the possibility of continued circulation thru open channelways diminished and consequently there was less oportunity for concentration of sulfides. The combination of persistent quartz veins and concentrated sulfide minerals is thus not merely one of chance but depends on certain conditions of genesis--particularly on the composition and hydrostatic pressure of the solutions.

<u>Mineralogy</u>: The mineralogy of the quartz veins is rather simple. Small masses of various metallic minerals are disseminated thru the quartz with only rarely a concentration into veins or large bodies of sulfides. Even the richest ores show only finely divided sulfides scattered thru the quartz, and of course in lower grades of ore the percentage of sulfides is still lower. The sulfide minerals present are, in order of abundance: arsenopyrite, chalcopyrite, galena, and sphalerite. The valuable constituents of the ores are native gold and gold telluride, both of which occur almost entirely as auriferous sulfides, that is, within other minerals. Hand specimens or mechanical concentrates of the ores show practically no indication that gold is present and assays or polished sections are necessary to show

the presence of the metal.

Ore Minerals: Native gold is a rather rare constituent of the quartz veins. It is occasionally found in polished sections in small masses associated with various sulfide minerals. From its pale color it is apparent that the gold is alloyed with considerable silver, and an occasional reddish tinge suggests the presence of some copper. Assay figures indicate that the gold-silver ratio varies from about 10 to 1 to 5 to 1, which is equivalent to a range of from 900 to around 800 fine.

The scarcity of native gold in the richest ores indicates what further observations have seemed to bear out--that the value of the ore is largely dependent on the abundance of gold telluride. In polished sections this mineral is found as minute pin points of high reflectivity, generally occurring within arsenopyrite. It occurs in such small masses that an estimate of its abundance in the ores is almost impossible, but it is significant that the richest ores are those containing arsenopyrite in greatest abundance. No masses of sufficient size were found on which a determination of the mineral species could be made; however the ratio of gold to silver in these ores suggests that the gold telluride is more likely calaverite than sylvanite, krennerite or petzite.

The most abundant metallic mineral in the quartz veins is arsenopyrite. This mineral occurs usually in small, widely disseminated grains, but occasionally makes up narrow concentrated veinlets. When it is mechanically separated from quartz it is often found to be in perfect prismatic crystals terminated and flattened vertically by brachydomes.

The remaining sulfides--chalcopyrite, pyrite, galena

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and sphalerite--are less abundant and do not occur at all in some of the rich veins.

The associations of the sulfide and gold minerals are well illustrated by two veins in the Camp mine. The metallic constituents of the rich vein on the 200-level consist almost entirely of arsenopyrite with gold telluride, and there is little or no gold or other sulfides. On the 100-level is a smaller vein of lower tenor which contains a little native gold with chalcopyrite, galena and sphalerite and only small amounts of arsenopyrite. The association of arsenopyrite and gold telluride is thus of greater value than that of native gold with other sulfides than arsenopyrite.

Gangue Minerals: Quartz appears to be the only gangue mineral in the fissure vein deposits. It is somewhat variable in character but is generally coarsely crystalline and white or grey in color. Rich specimens from the Camp mine show a characteristic banding; the outer edges of the vein are of grey crystalline quartz with abundant fine grained arsenopyrite; the center portions are of coarsely crystalline white quartz with fewer and larger masses of arsenopyrite. Much of this quartz is "loosely" crystalline and consequently very friable; some veins, on the other hand, are composed of very much more compact quartz.

A few specimens of pegmatite containing numerous small veinlets of calcite were found on the dump of the Richardson mine. No trace of the veins could be found within the tunnel and the mode of occurrence is therefore not known. Thin and polished sections of this rock show a microbrecciated aggregate of quartz and microcline grains penetrated by an anastomosing network of coarsely crystalline calcite veinlets ranging in width from ¼ inch down to microscopic dimensions. That some metallic minerals have been introduced into the rock by the carbonate solutions is evidenced by a few minute grains of sphalerite in one polished section that was examined.

This locality is the only one known in the district where definite veins of calcite have been formed. It seems unlikely that a single, unique deposit of calcite could have formed during the same period of hydrothermal activity in the region when elsewhere large quantities of quartz were being carried in solution. A more plausible source of the carbonate might be the sedimentary rocks--particularly limestones--which were intruded by the igneous rocks. During the early stages of intrusion when the advancing magma was at a very high temperature, the heating of limestone would very likely be sufficient to cause a partial dissociation of calcite into lime and carbon dioxide. The lime would actively react with silica to form various lime-silicate minerals, while the carbon dioxide would be carried into the surrounding fractured rocks in the gaseous state or in solutions given off by the magma. When precipitation began in a cooler environment, veins of calcite would be formed. This process is regarded as the proper explanation of the calcite veins described above. Similar veins may later be found where other bodies of limestone have been intruded and lime-silicate minerals formed.

One occurrence of epidote as a gangue mineral was noted at a small prospect a short distance east of the entrance to Baldwin Grade Canyon. The epidote occurs in very coarsely crystalline masses in a quartz vein of quite different character than those of the mining district. The presence of epidote and the glassy appearance of the quartz suggest that this vein was formed at very high temperatures. No metallic minerals could be found.

Paragenesis: The paragenetic sequence of ore minerals as determined from polished sections of ore from the Camp mine is as follows, from earliest to latest: arsenopyrite(?), pyrite, chalcopyrite, galena and sphalerite(?) (the relation of sphalerite to galena is not known). The position of the gold minerals in this sequence is not exactly known but gold telluride is probably earlier than arsenopyrite. Native gold possibly formed after chalcopyrite but may be later than all sulfides. Arsenopyrite appears to have crystallized contemporaneously with quartz, but began later than quartz.

Oxidation and Supergene Enrichment: The depth to which rocks are altered by atmospheric agents is chiefly dependent on the depth below the surface at which the ground-water level lies. Above this level fractured surface rocks are exposed to the oxygen of the atmosphere and to downward percolating surface waters containing oxygen and carbon dioxide. In ore deposits the soluble oxidation products of sulfide minerals are also added to the descending surface waters and these substances exert a potent oxidizing effect on the rocks below. Below the level of ground water, oxygen is excluded and no oxidation of the rocks is possible. The level of permanent ground water thus roughly divides a zone above in which oxidation is going on, from a zone below in which reduction is the dominant process.

There are two mechanisms by which gold deposits may be enriched by such supergene processes: a mechanical "enrichment" may result if valueless material is carried off from the ore deposit during weathering; or chemically, gold may be taken into solution under certain conditions by descending solutions and later re-precipitated at lower levels where oxidizing agents are not present. In the case of either mechanical or chemical enrichment of gold deposits, the result is a zone of enriched ore which is succeeded below by the relatively lean primary ore.

In the Neenach district the ground water level lies at varying depths below the surface depending on the location of the mine. On ridge tops, no water may be struck above 150 or 200 feet of depth; in canyons, the water level may be less than 50 feet below the surface. No definite evidence was found in the mines bearing on the question of supergene enrichment. In the Smith mine (abandoned), oxidized ore of good grade is said to have been exposed until an inclined winze was sunk beyond the level of ground water into the zone of primary ore. At this point the gold values abruptly gave out and almost barren sulfide ore alone remained. Unfortunately this mine was deeply flooded at the time of the writer's visit, but specimens of the primary ore found on the dump resemble the ore of the Camp mine in which auriferous arsenopyrite is the valuable constituent. These facts strongly suggest that some enrichment has taken place, but no confirmatory evidence from other mines has been found. The study of many polished sections of the primary ores has given no indication of any chemical enrichment. It is therefore likely that in those mines which have penetrated below the level of permanent ground water the high grade ores will continue so with depth.

Deposition of the Ores: The mineralogical composition of the quartz veins indicates that they formed at moderate depths within the earth's crust, possibly a few thousands of feet beneath the surface. According to the generally accepted classification of Lindgren, they might be placed in the upper Mesothermal zone and fall into the same general category as the veins of the Mother Lode system of northern California. However the occasional presence of druses and comb structures in the vein quartz and the abundance of gold telluride in the Neenach veins are suggestive of less intense conditions of temperature and pressure than are supposed to have prevailed during formation of the Mother Lode veins. For this reason, they are perhaps best placed in the lower Epithermal of Lindgren, or the "leptothermal" of Graton.

The hydrothermal solutions which formed the quartz veins are believed to have formed as an end-stage differentiate of the large batholith now represented by the surrounding igneous rocks.

Post-Mineral Deformation: The ore deposits and country rocks are often shattered and broken by innumerable small fractures which formed after deposition of the ores. In places the rocks are so "heavy" as to have handicapped mining operations by requiring an excessive amount of timbering. As far as mining has now progressed, no fractures large enough to be called faults have been found cutting the veins, but it is possible that they are cut off by a north-south set of faults slightly younger than the east-west faults within which the veins lie. The extensive facturing of the rocks in this district is not surprising when it is remembered that it lies very near to the San Andreas fault--a major zone of fracturing in the earth's crust that has been seismically active from at least Miocene time (perhaps 30 million years ago) up to the present day.

Age of the Deposits: Since they are genetically related to the surrounding plutonic igneous rocks, the ore deposits are slightly younger than the intrusives, and hence early Cretaceous in age.

* *

* Genesis of the Mineral Deposits *

One of the most striking features of the Manzana quadrangle is the apparent concentration of pegmatite dikes, hydrothermal mineral deposits, and roof pendants of metamorphosed sedimentary rocks along the northern edge of the Neenach Hills. This association of features related both in space and time is too regular to be merely fortuitous and seems to the writer definite proof of a genetic relation.

As has been repeatedly intimated above, each of these associated features considered separately suggests that they approximately define one wall of the intrusive batholith. Thus the abundance of xenoliths or roof pendants in an igneous rock is commonly taken to indicate proximity to the walls of the original magma chamber; likewise, pegmatite dikes and hydrothermal solutions, both of which are end-stage phenomena of magmatic differentiation, form in greatest abundance around the periphery of their parent magma. When all three features are found in a narrow and well-defined belt, the implication is overwhelmingly strong that they result from a common cause. The connecting link is, of course, the mass of intrusive igneous rocks in which they occur, and it is to the original composition of the magma and the spatial distribution of its emplacement chamber, that the concentration of roof pendants, pegmatite dikes, and hydrothermal mineral deposits in a relatively small area must be attributed.

With this principle in mind, the genesis of the varied mineral deposits of the Manzana quadrangle may be outlined in the following series of steps.

1) In late Jurassic or early Cretaceous time, a huge batholith of igneous rocks was intruded into a series of sedimentary rocks. At the depth now exposed within the batholith by erosion, the limits of intrusion were approximately at the present northern edge of the Neenach Hills. Blocks of the sedimentary rocks were stoped off during intrusion, engulfed within the igneous rocks and heated to temperatures high enough to cause their recrystallization into metamorphic rocks. Gaseous and liquid emanations given off by the crystallizing magma permeated the sediments to produce a widespread but lean mineralization.

2) As crystallization proceeded, a rest-magma especially rich in the constituents of quartz, potassic and sodic feldspar, and water was formed. Numerous fissures, opened by cooling-stresses in the main mass of the crystalline rock, were closed by successive invasions of the pegmatitic rest-magma to form various types of pegmatite and aplite dikes. These solutions contained little or no metallic minerals with the exception of small quantities of gold and magnetite.

3) Subsequent stresses faulted and fractured the intrusive, sedimentary, and dike rocks and admitted the remaining, more highly attenuated solutions of the rest-magma. These solutions contained abundant silica and a relatively high concentration of gold, copper, iron, lead, zinc, sulfur and arsenic, and by their crystallization fissure vein deposits were formed.

The development of the ore deposits, beginning with the original emplacement of the intrusive rocks, probably took place as a continuous process without long periods of time between the different stages. Although they differ widely in character, the mineral deposits formed in each of the three stages of magmatic history outlined above are thus closely related in a genetic way.

To complete the sequence of mineralization in the Manzana quadrangle, there began in Miocene time a widespread extrusion of volcanic rocks over much of the area. The last stage in this effusion brought a permeation thru the flows of silica-rich solutions containing small amounts of metallic elements. These solutions crystallized into innumerable veinlets of opaline and chalcedonic silica. The mineral deposits thus formed are wholly unrelated to those formed from the intrusive rocks at a much earlier date in geologic history.

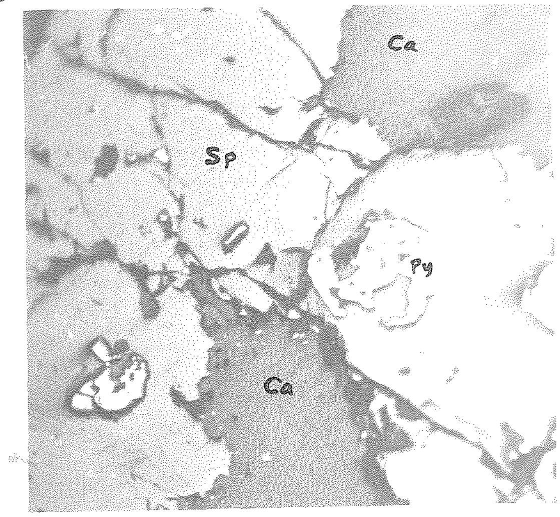
Plate IV

Plate IV

Photomicrographs of Ore Specimens

A: Polished specimen of ore from Peters mine; sphalerite(sp) replacing pyrite(py) in calcite gangue(ca). X52

B: Pyrrhotite(po) in quartzite from small roof pendant near mouth of Baldwin Grade Canyon. X59.



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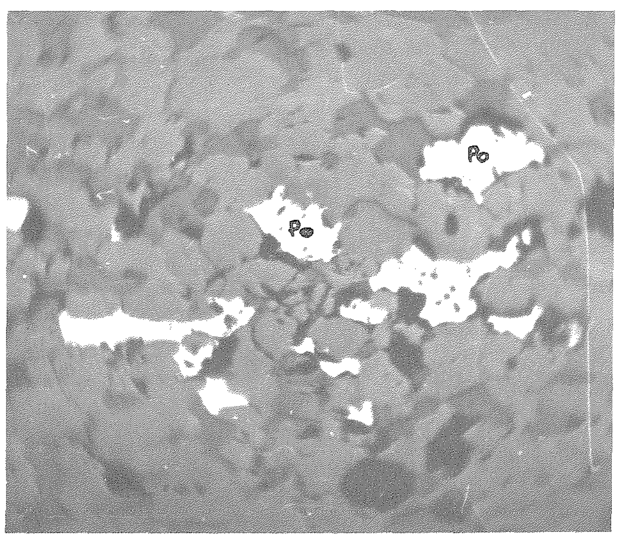

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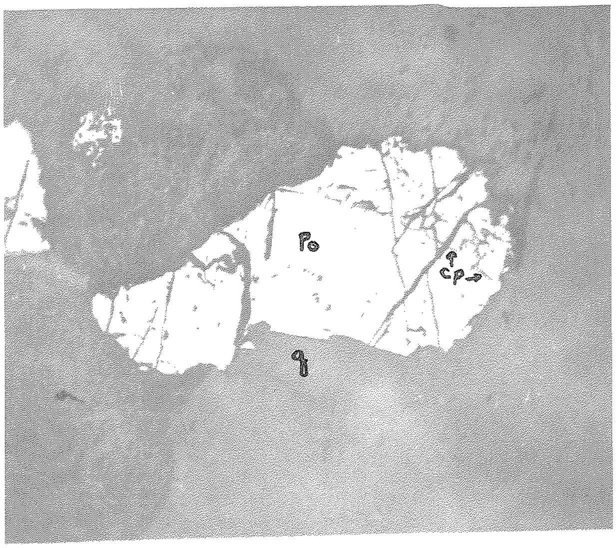
Plate V

Plate V

Photomicrographs of Ore Specimens

A: Chalcopyrite(cp) veining pyrrhotite (po) in calcite gangue. Peters Mine. X37.

B: Galena(g), sphalerite(sp) and chalcopyrite(cp) in quartz(q). Camp mine. X52.



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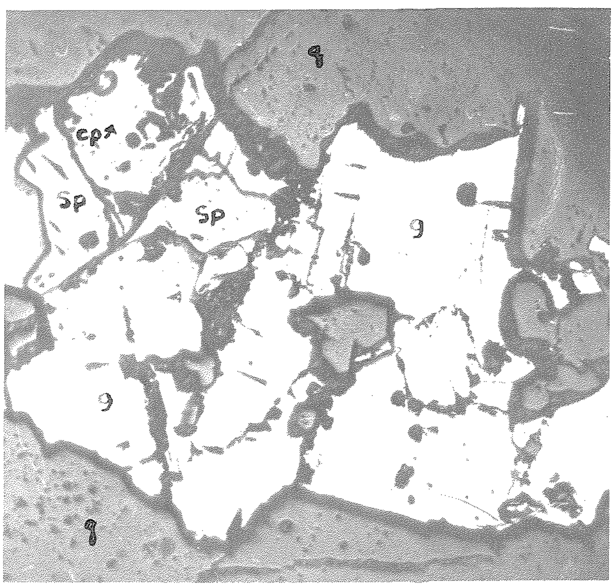

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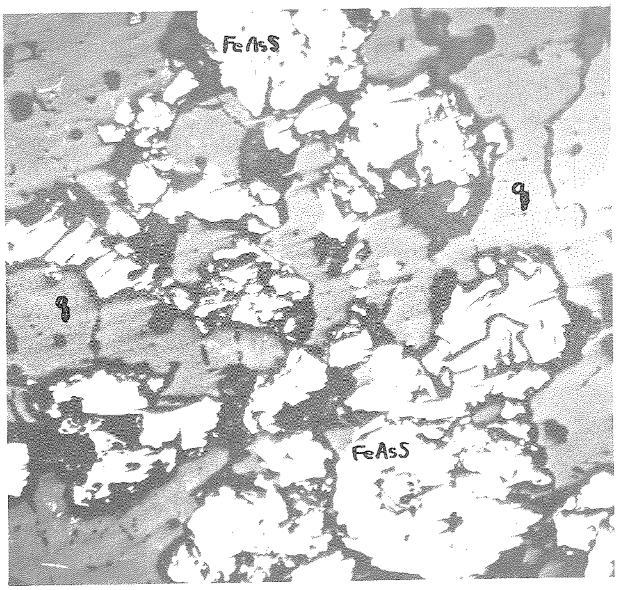
Plate VI

Plate VI

Ore Specimens (cont'd)

A: Arsenopyrite(FeAsS) in quartz. High-grade ore from 200-level, Camp mine. X52.

B: Ore from vein on 100-level, Camp mine. Gold(Au), chalcopyrite(cp), and arsenopyrite(FeAsS) in quartz(q). X225.



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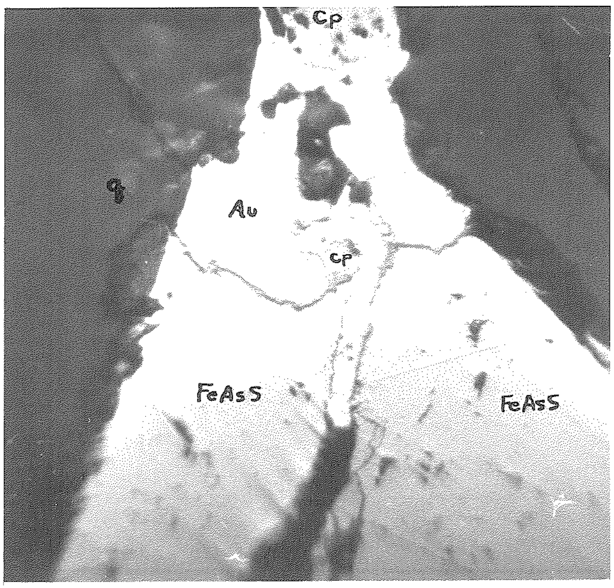

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Plate VII

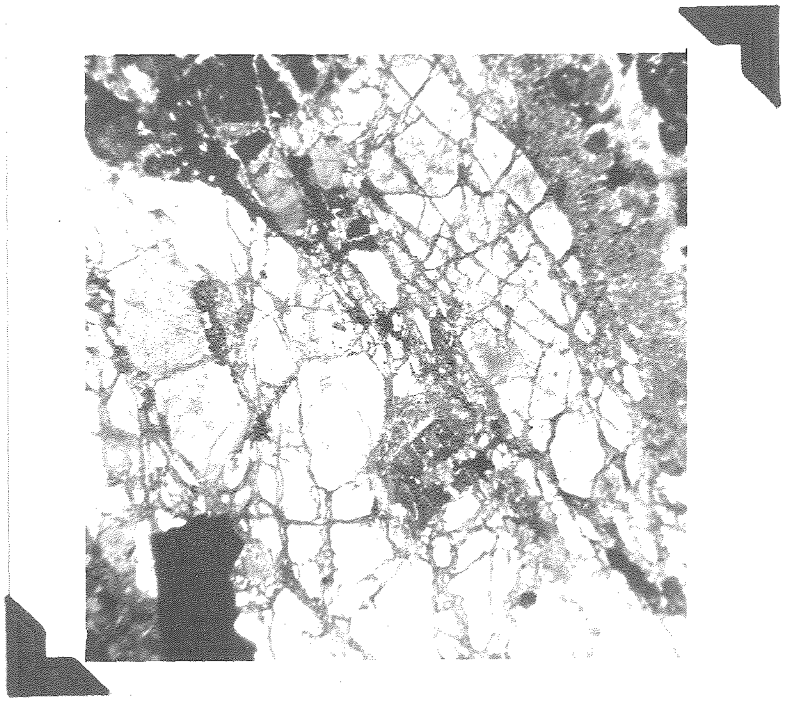
Plate VII

Ore Specimens (cont'd)

A: Galena(g) and sphalerite(sp) in fractured quartz(q). Camp Mine. X44

B: Thin section of pegmatite from Richardson tunnel. Calcite veining microbrecciated quartz and microcline grains. Dark areas are grains near extinction. (picture taken with gypsum plate) X38.

A



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