A STUDY OF QUARTZ DEPOSITS
NEAR HIGHWAY HIGHLANDS
LOS ANGELES COUNTY, CALIFORNIA

Thesis by

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Abstracts

Several quartz deposits in the vicinity of Highlands, Los Angeles County, California, were studied in the field, and their relations to the adjoining formations were determined. Oriented specimens were taken from the area, and twenty thin sections were made from them. By the study of these thin sections and the field work, it was determined that these quartz deposits were quartzites. Metamorphism was dynamic, and the intensity of it was high.

Acknowledgements:

The writer is greatly indebted to Ian Campbell, Associate Professor of Petrology at California Institute of Technology, for making many valuable suggestions in every phase of the work, for reading this paper and editing it. The merits that this paper may possess, if any, are due to him, though he should not be considered responsible for its defects.

The writer is grateful to Mr. S.L. Gillan of Glendale, California for giving permission to study these deposits, visiting the area with the writer, supplying a [redacted] map of the area, and the historical information about the development, production and marketing the "silica" from these deposits.

The writer is also thankful to Fairchild Aerial Surveys Inc. for supplying an aerial map of the area and to Mr. R. Van Houne of California Institute of Technology for doing the photographic work and for making the thin sections.

INTRODUCTION

During the summer of 1916, Mr. Silas L. Gillan of Glendale, California ~~located~~ noted several quartz deposits in the vicinity of Highway Highlands, Los Angeles County, California. In the spring of 1918, Mr. Gillan began to produce "silica" for various steel companies in Southern California, where it was and still is used as a refractory material. The production has been fairly steady ever since. Mr. Gillan estimates that the total production has amounted to 25,000 tons.

As this is one of the more unique mineral deposits of Los Angeles County, and as little information on it has been published, a study of the genesis of these deposits seemed to be of considerable interest and was suggested to the writer by Dr. Ian Campbell, Associate Professor of Petrology at the California Institute of Technology, who had made a cursory examination of these deposits some years previous.

The only reference as to the nature of these deposits was by Miller who called them silexites (Miller 1934) without having given much evidence. No important quartzite deposits were reported from this region. Webb noticed quartzite in the Pelona schists of Elizabeth Lake quadrangle. He wrote, "There are several exposures of quartzite in the metamorphic series. This type is not a predominating one, but it is of particular interest. First the beds are never ten inches thick, and from four to six inches in average . . . . etc." (Webb 1932, p. 17)

On the first trip to the area, the deposits in the northern section looked as if they might be silexite or quartzite, but the deposits only a hundred yards to the south looked more like quartzite. The writer was intrigued by this occurrence. For a petrological research the deposits presented a very interesting problem; hence the study was undertaken under the direction of Dr. Ian Campbell.

Location of the Area.

The area lies in the flats between the San Gabriel mountains and the Verdugo mountains, in Los Angeles County, California, and is shown on the La Crescenta quadrangle (U.S.G.S. Atlas). The center of the area is 118 degrees 16 minutes and 30 seconds West Longitude and 34 degrees 14 minutes and 30 seconds North Latitude and covers approximately 9,000 square feet. It is between Highway Highlands and Tujunga just to the south of Foothill Blvd. (Highway No. 118) about one mile to the ~~east~~ west of Highway Highlands.

Scope of the Work and Method of Investigation:

The essential problem was to determine the nature and the origin of the quartz deposits found in the area. It was hoped that this might be accomplished by a study of the areal geology and especially of the relationship of the older formations to the quartz. Also a few oriented specimens were taken over the area, and their thin sections were studied in the laboratory.

A detailed mapping of the area was undertaken in which special attention was given to the highly silisic rocks. About eight days were spent in the field. An enlarged topographic map (scale 1 inch = 200 feet) and an aerial photograph simplified the mapping considerably, making the location of any point a very easy task.

Obvious faults, bedding planes, foliation of metamorphic rocks, contacts of different formations were determined. Oriented specimens were taken to get the thin sections made and study them in detail. Twenty thin sections were studied, more than half of which were of quartz deposits.

Previous Work.

The area under study is a very small one and is in a region which has no important mineral deposits. Little geological work has been done, though the area is very interesting geologically.

Kew (1924) discussed the geology of the western San Gabriel Mountains and referred to the crystalline rocks as the "basement complex." The term covered the metamorphic series and the intrusive rocks as a whole.

Compared with the work done on the Tertiary sediments in the vicinity, one might say that the region has scarcely been studied, except for the work of W.J. Miller. He studied the "Geology of Western San Gabriel Mountains" and published a report with the same title (Miller 1934). As Miller stated, he " . . . entered a practically unique field when he began his study of the crystalline rocks of the San Gabriel Mountains" (Miller 1934, p. 3).

Miller made a great contribution by the paper he published as a result of his work. The problem was an intricate one, and he covered a fairly large area (approximately 70 miles by twenty miles). In a study of this type, there was not opportunity to make a detailed study of these small quartz deposits. They were merely classified as silexites together with other probable silexites.

Topography and Physiography.

The area may be divided physiographically into three sections, i - Central flats, ii - Northern hills, iii - Southern mountains. The first two sections together constitute a portion of the lowlands between the San Gabriel mountains and Verdugo mountains. Each section will now be discussed in detail.

i.The Central flats are covered by Quaternary alluvial sediments. Along the wash on the eastern border of the area (see map) a 15-foot section was seen. The thickness of the sediments are probably many times as much. The sediments are coarse and not well stratified. The average elevation of the flats is 1725 feet above the sea level. As the name indicates, this section has a smooth, flat topography and is cut by two prominent washes and an intermittent stream.

ii The Northern hills along and to the south of Foothill Boulevard are characterized by their low relief, well-rounded tops and smooth convex slopes. The total relief ranges from 100 to 150 feet. The average elevation of these hills is about 1,850 feet above sea level. The highest point is on the central hill which stands 1,900 feet above sea level. On this hill the largest quartz quarry of the region is situated. This quarry will be referred to as Quarry no. 1.

These hills are the most resistant remnants of the old land and escaped complete planation. Long continued erosion reduced their heights and rounded their topography.

The last two sections have an old age expression, physio.

graphically.

iii The Southern mountains comprise the northern slope of the Verdugo mountains. Characteristics of this section are high peaks, steep slopes and deep canyons. The elevation of the highest point within the examined area is 1,825 feet above sea level. Only one mile to the south of this point, the Verdugo mountains rise to 3,000 feet above sea level. The topography is rough, and this section has a youthful expression, physiographically.

Due to differences in appearance, this section will be divided into two sub-sections.

a - Quarry no. 2 and vicinity, at the bottom of the slopes.

b - Quarry no. 3 on the slopes. (see map)

Areal Geology

The following formations were recognized, and their contacts within the area were determined in the field. The order of the list is from the oldest to the youngest.

1 - Metamorphic complex

2 - Quartz deposit

3 - Granitoid rock

3a- Decomposed granitoid rock

4 - Aplite dikes

5 - Alluvial sediments

These formations will now be considered in detail.

1. In appearance the metamorphic complex varies from dark schistose rocks to greenish and yellowish gray highly polished rocks.

The dark schistose rocks are biotite schists, found only at a few spots. Near Foothill Boulevard two exposures of it were found, but it was not possible to determine whether they were rocks in place or boulders. Around Quarry no.1 and Quarry no. 2 they were seen in the pockets which were found in quartz deposits.

The greenish and yellowish grey foliated rocks were the most extensively distributed formation in this region. In the northern hills they were found only on the eastern slope of the main quartz hill (see map). Along the slope they were in the forms of lenses and pockets in the quartz; at the bottom of the slope they formed larger bodies. Further to the east they were covered by alluvial sediments, the largest exposed portion of which was five feet wide and twenty feet long. Their relief in the northern section was very low, mostly at the elevation of alluvial sediments. No dependable dips and strikes of the foliation planes could be obtained, as they were mostly contorted and shattered and were also largely covered by the alluvial sediments.

The southern mountains are largely made of this schistose rock. The study of this formation was limited to the contact zones (the contact with the quartz deposits). Therefore, the exact areal extent of it cannot be stated. The original bedding planes and foliations have the same general bearing of N 46 E. The beds were upturned and dipped almost vertically. The intensity of metamorphism was high. The beds were folded and contorted under the heavy stresses.

The contacts between the schistose rocks and quartz deposits are not sharp. On the west side of the Quarry no. 2 and along the north and east sides of Quarry no. 3, the gradation to the quartz deposits may be seen.

Webb (1932, p. 17) makes a reference to these schistose rocks as "Sillimanite - muscovite schists - crystals of probable sillimanite arranged with long axes parallel and averaging about 5/8 inches in length, in a matrix of muscovite and quartz is the character of this type."

Four thin sections were studied, and the following average composition was determined: Quartz 31%, orthoclase 22%, sillimanite 21%, biolite 9%, muscovite 8%, magnetite 6%, chlorite 2%, and guion 1%. The high intensity of metamorphism is well supported by the abundant occurrence of silliminite. This mineral as found here does not have the common "felted mass of fibers" form, but is in long, slender perfectly euhedral crystals. Most of them lie parallel to the direction of foliation, but some of them are oriented across the plane of schistosity.

The quartz and feldspar grains show a fair degree of preferred orientation and high undulose extinction. The foliation is well seen in the photomicrograph (see fig. 2 and Fig. 3).

2 - Quartz deposits.

Quartz deposits appear as quite pure clean quartz. Two of the northern hills are made of quartz, and two patches were found in the granitoid rocks to the west of these hills. Exposures were also found along Quarry no. 2 and Quarry no.3 (see map). Quartz deposits show foliation and a piece of quartz rock may be broken into thin slabs.

In the northern hills the foliation surfaces are smooth though in places they are somewhat pitted and slightly folded. These surfaces were exposed all along Quarry no. 1, and numerous dips and strikes were taken. They agreed very closely. The strike was N 66°E and the dip 60° SE. The fracture is concoidal across the foliation and smooth parallel to the foliation. Through places dark streaks were seen in the quartz, and these had a bearing of N 20 E.

In the southern section, the foliation and the dark streaks had the same strike and dip. The strike values varied from N 40 E (near Quarry no. 3) to N 46 E (near around Quarry no. 2). The dips were close to vertical.

The largest body of quartz found was in the northern section, the hill at the center. It extends 450 feet in a north-south direction and 550 feet east-west. This hill is also the highest one in this section (see map).

The contacts between the quartz deposits and the metamorphic complex were gradational rather than sharp. Near both igneous and melasedimentary contacts quartz deposits have more feldspar and biotite. This could be seen even around the smallinclusions. Aplite dikes were found cutting the quartz deposits both at the north and the south. The metamorphic complex and the quartz deposits are probably of the same age, as each includes lenticular bodies of the other.

Twelve thin sections of the quartz deposits were studied. The general texture was moderately sutured, though granoblastic texture was also seen (see fig. 4). The rock was inequigranular especially in the northern section. Crushing and fracturing was evident in most of the slides. Highly undulose extinction of mosaic type was seen in every grain. Some grains also showed undulose extinction that swept across the grain as dark and bright bands, while the stage was sotated (see fig. 5). Dust like inclusions continuing across several grains were of frequent occurrence. Some of the large quartz grains had inclusions of feldspar grains. The feldspar grains were not oriented in any particular direction.

The composition of a few of the sections are given below:

Specimen numbers	14	23	33	39	55
Minerals contained	Per cent composition				
quartz	95	85	99.9	86	80
orthoclase		14		7	10
oligoclase	5				8
muscovite		½		3	
biotite					1
magnetite				4	
zircon	✓	✓	✓	✓	✓

The occurrence of micas, magnetite and especially of zircon is worthy of note. Pressure shadows and sesicite developed around magnetite grains. The amount of sesicite vary from grain to grain. On the magnetite grains perpendicular to schistosity there usually is more sericite, and the flakes are generally perpendicular to these faces; in other words, the flakes lie parallel to schistosity (see fig. 10).

Regular arrangement of cracks and Böhm Lamallae are observed in the slides. Their significance will be discussed in a later section of this paper (see page 24).

Dimensional orientation is seen in some of the slides, but optical orientation was common to them all. Over 50% of the grains show regular orientation. This percentage in creases southward in the area. Slides made at and parallel to the intrusive contacts show a poorer orientation of the quartz. Slides made from oriented specimens indicate that the c-axes of the oriented grains are perpendicular to the schistosity. This type of orientation is called "Trener α rule" by Sanders (Hettenau 1938).

3 - Granitoid Rocks

All of the northern hills, except two, are made of granitoid rocks, as indicated before. In the southern section only a small patch in the southern end of Quarry no. 2 was found. The rock has a medium grained granite texture and is composed of feldspars, quartz and biotite. It megascopically has a weathered look.

The contacts between the granitoid rocks and the quartz deposits are sharp and definite. They may easily be separated and the smooth contact be seen. In Quarry no. 1 and on the west side of it these contacts were found. The biotite flakes near the contacts were somewhat oriented parallel to the contact faces. To the east of Quarry no. 1 the contact zones were invariably gullies and were covered by the late sediments.

By a study of a thin section of the rock, the following composition was determined: Orthoclase 33%, microperthite 5%, oligoclase 26%, quartz 28%, leiotite 2%, magnetite 1%. Both quartz and feldspar show some indulose extinction. In spite of its "weathered look" the rock is quite fresh.

There is only slight sesicitization of feldspars. The plagioclases show zoning, the cases of which are andesine (see fig. 8). The leiotite flakes do not show any bending, but they are found in clots of a few small flakes. This rock may properly be called adamellite, due to its texture and composition.

3-a- Decomposed Granitoid Rock.

This rock is most probably themelanocratic facies of t the granitoid rock. It suffered a greater degree of decomposition and has a higher content of leiotite; in addition it contains hornblende. This rock is found at the eastern end of the Quarry no. 1. The outcrop has an area of 20 square feet and is surrounded by the granitoid rock.

From a thin section of the rock the following composition was determined: audesine to oligoclase 35%, orthoclase 10%, clear albite, leiotite 20%, quartz 18%, hornblende 5% and magnetite 2%.

4 - Aplite Dikes:

Fresh rocks had a very light color with medium to fine texture. They are found all over the area cutting all the other rocks. The widths of the dikes vary from half an inch to eight feet. The aplites are most abundant in Quarry no. 2. At the south-western corner of the Quarry an aplite dike four feet wide cuts the quartz deposit across the foliation. The same dike in the southern end turns parallel to the schistosity and joins a larger dike eight feet wide. The aplite dikes at their junction included lenticular bodies of quartz and adamellite.

Two thin sections of the aplite were studied, one from the northern and one from the southern section. They were very much the same in compositionaand texture. The average composition was: orthoclase 45%, oligoclase 25%, quartz 25%, muscovite 3%, biotite 1% and magnetite 1%. Quartz grains near the contact show undulose extinction, but the grains away from the contact do not show any (see fig. 7).

5 - Alluvial Sediments.

A reference was made to the occurrence of alluvial sediments in a previous section. They are poorly sorted, unconsolidated sediments. Boulders from three to four feet in diameter were seen in them, but these large ones were few in number. The boulders represent a good cross section of the formations found in the area. The thickness of the sediments could not be determined. These sediments cover the area between the San Gabriel and Verdugo mountains, except for the northern hills.

Structural Features

No folds were seen in the area. Faults were numerous in the southern section. In Quarry no. 2 there were two major faults, one along the western side and the other along the eastern side. The strikes and dips of the faults well agreed with the foliation planes. Direction of the movement could not be determined, as the slickensiding was not consistent. On both sides of the faults the rocks were badly crushed. Along the eastern fault there was a brecciated zone fourteen inches wide. At the northern tip of the quarry there was another fault parallel to these (see map). A probable cross fault, running almost east-west runs across the quarry. Two ends of the fault were determined on the walls of the quarry. The dip of this fault surface was 75' to the east.

Two major faults appear on the map accompanying Miller's report (Miller 1934), one running along Foothill Boulevard and the other along Tujunga Canyon Road. These faults could not be located, as the area is well covered by the alluvial sediment.

Detailed Study of Quartz Grains.

The work done so far might be considered a good preliminary study for petrofabric analysis of the quartz. However, it is beyond the scope of this paper to do any detailed petrofabric study of quartz. Nevertheless, an attempt is made at an introductory study with partly oriented sections and by the use of a gypsum plate.

Textual Features:

The quartz grains studied may be divided into four groups:

i - Original Grains

These are the grains that have resisted any high degree of deformation, being favorably oriented to begin with. Some gliding along the basal planes (0001) and fracturing, however, take place. Quartz is inequi-granular and ranges from rounded to sharp irregular forms. The smaller grains were the crushed pieces that were not re-crystallized. Real original grains are not represented at all. This type is more abundant in the northern section of the area.

ii - Peripheral Growth:

The interstitial material re-crystallized as a also did the smaller grains and formed growth on the larger grains. Equigranularity is approached. This is well represented by the photomicrograph (see fig. 9), on the boundary of the grains to the north and northwest.

iii - Ribbon Quartz

One of the most abundant types is "ribbon quartz". These grains show undulose extinction along the hand-like needles. Each hand itself shows slight mosaic type of extinction (see fig. 5). The formation of needle quartz may be explained as follows. By the application of stresses, deformation took place. Thus gliding along the basal plane (0001) "basic rule", or rhombic faces (1011) and (0111) "rhombic rule" or both started. Gliding continued until the frictional resistance equalled the applied stresses. Further application of the stresses fractured the quartz along the prism faces and gave the sheaf like appearance of the grains. During the gliding, folding of the glide planes took place, which is the cause of mosaic type extinction.

The needle quartz that is seen now are the only grains which were favorably oriented toward the later stresses and escaped any further deformation.

The gliding by the "basic rule" or "rhombic rule" was not extensive enough to develop the Bohm lamellae (see following section) on these grains, as the fracturing came in too soon and relieved the internal stresses.

iv - Fractured Quartz:

In addition to regularly oriented features in the quartz, there is a regularly arranged system of cracks observed on slide number 14. ~~Fracturing~~ Fractures are made of two sets perpendicular to each other. Heitanen (1938) had found a grain that shows the same type of fracturing, but she did not make any comments. The c-axis of the quartz bisects the angle between the two sets. This type of fracturing is a different type from that which was dealt with before. If [illegible] assumes a strain ellipsoid with c on the major axis, these fracture planes are the maximum shear planes of that ellipsoid. The undulose extinction in the case is not very high, indicating that the fracturing developed early enough to relieve the stresses and prevent any further deformation. (see p e 4 fig. 1) As the quartz grain is not a rigid body, this explanation is not sufficient; but it is believed that the true explanation lies in the same channel.

v - Re-crystallized Quartz:

This is by far the most important type of quartz, in the sections studied. Originally, small grains crystallized and formed optically as well as dimensionally continuous large grains. Some grains contain orthoclase inclusions. The quartz in the process of re-crystallization went around the relatively small grains of feldspar and formed the continuous bodies. The orthoclase inclusions do not even show subhedral crystal development, as they are imbedded in quartz. These quartz grains show undulose extinction of mosaic type showing the prints of later stresses that caused some gliding according to "basic" or "rhombic rule."

Böhm Lamellae:

Under applied stresses quartz fails in two different ways. One gliding parallel to basal plane (0001) and rhombic plane (1011) and (0111). The other is parallel to the prism face.

Smooth gliding of the first type is accompanied by the folding of these planes, which develops the undulose extinction. Assuming that on one grain all the c-axes have the same dip, a section parallel to c-axis may be illustrated as in fig. (1).

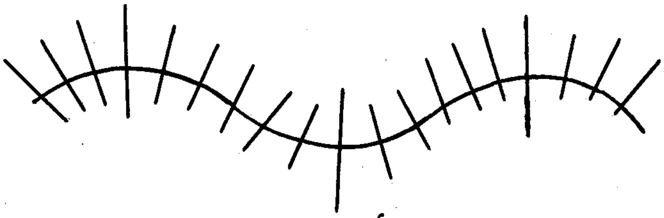

fig. 1

Further application of the force "causes a feeble breaking of the crystal lattice. Probably owing to the screw like structure of the quartz, this breaking may give rise to the cavities now seen in the striations." (Heitanen 144 p. 36) TheBöhm Lamellae thus develops. Heitanen states that the Böhm Lamellae are due to the twinning along the rhombohedral faces.

Knopf (Ingerson and Knopf 1938 p. 173) states " . . . it seems highly probable that the quartz grains have actually deformed in a way that is analogous to the grain mechanism of calcite deformation and that Böhm Lamellae may be traces of rhombohedral plan es that have acted as translation gliding planes."

Fellows (1943 - p. 1419) states " . . . strain shadow develpps parallel to the optic axis of the grains and Böhm

Lamellae form parallel to the base (0001), . . . "

Fairbrain, on the other hand, has a different view. He writes (1942 p. 10) " The original description by Böhm refers, however, to lines of inclusions in re-crystallized rocks which may or may not be relicts of lamellae. Due to this ambiguity in nomenclature, the prefix "Böhm" should be dropped. Deformation lamellae must not be confused with twin lamellae, as they do not resemble each other in the least. There is, moreover, no evidence that quartz twin lamellae are due to deformation, and they are usually not visible unless the grains are etched. The variable angular relation of the deformation lamellae . . is also quite unlike the fixed angle for twins."

The angles between the lamellae and c-axes of the quartz grains ranged from zero to 90 degrees, From the foregoing statements of the authorities on the subject, and observations made on the grains, it is proposed that the lamellae developed along either the basal or the rhombohedral planes. The large range of deviation is due to the rotation of the c-axis of the grains under the later stresses. This type of failure is probably due to the plastic deformation of quartz. The Böhm lamellae are well exhibited by the photomicrograph (see fig. 9).

Still stronger stresses develop fracturing parallel to c-axis. This fracturing comes in when the limit of the gliding is reached, due to the development of the frictional resistance.that equals it. This limit is reached in most cases relatively early; therefore no Böhm lamellae develops. This failure gives rise ruptural deformation (see fig. 5).

Both the plastic and ruptural deformation took place in the quartz of the area. The favorable or reverse position of a grain toward the applied stresses might have been a determining factor as to which type of failure will take place.

Most of the oriented sections were taken perpendicular to foliation. It was found that the general direction of foliation was NE -SW. The c-axes of the oriented quartz grains were perpendicular tp foliation. The direction of the main stresses , therefore, were NW - SE.

Origin of the Quartz

The quartz deposits, generally speaking, may belong to one of the classes listed below:

i - Vein quartz
ii - Silexite
iii - Quartzite

i - Vein quartz may show crustification and comb quartz. They usually would not support inclusions, but a dense, viscous vein forming solution may support considerable inclusions (Carl Tolman 1931). Microscopically, it looks very much like igneous quartz, and it is impossible to differentiate the two as indicated by Johannsen (1932 Vol. II, p.12). The presence of perthite or microperthite in a quartz deposit definitely indicates that it is not a vein quartz. So far this is the only unfailing criterion (Carl Tolman 1931).

In these quartz deposits no crustification or comb quartz was seen. In one of the slides considerable amount of microperthite was found (about 5%). It is unlikely, therefore, that these quartz deposits are vein quartz.

ii - Silexites: The quartz deposits under discussion thus may be either silexite or quartzite. The occurrence of silexites usually show gradation from the present igneous intrusive to the silexite body. There are silexites that do not show any gradation, and are found in the present intrusive (Miller 1919). Two patches of quartz found to the west of the main quartz hill (see map) appears like the type of silexite to which Miller refers.

At first, the quartz deposits were thought by the writer to be silexite. The above cited patches were found. The amount of impurities found were small enough. The first few thin sections studied were made from the specimens taken at or near the contact of quartz and adamellite. These slides did not show any appreciable degree of dimensional and optical orientation. The sutured and inequigranular texture and dusty inclusions suggested that these deposits might be silexite.

Later, in the field it was determined that the adamellites were intruded into the quartz. The grain orientation of the deposit along the contacts were somewhat obliterated. Minerals such as magnetite and rounded zircon were found in the quartz deposit. In the southern section the evidences of metamorphism were even greater, as the slides showed Böhm lamellae, needle and crushed quartz. Also considerable degree of grain orientation dimensionally and optically, strongly suggested the metamorphic origin of quartz deposits.

Quartzites and Conclusion

The field work was confined to a small area as outlined before In an intensive study of this nature all relationships of different formations could not be brought out. The original relationships were somewhat complicated by the intrusions of adamellites and aplites, specially in the northern hills. The southern section shows the relation more clearly.

The quartz deposits have lenticular shapes, and they are cut by the aplites along some of their contacts. The extreme purity of the quartz caused some difficulty in determining its origin as characteristic metamorphic minerals were lacking.

Along the contacts of the quartz bodies and gneisses the gradual change of the composition and texture were observed as indicated before (see p. 13). The exact correspondence of the bedding and schistosity, both in the gneisses and quartz bodies strongly suggested their metamorphic nature.

General appearance of quartz was very much like the quartzites of Buchingham series of Canada, described in an unpublished undergraduate thesis by the writer. Mosely M. Wilson (M.E. Wilson 1919 and many other publications) described the Grenville quartzites which are almost like the quartz deposits under discussion.

The microscopic features of crush quartz, peripheral growth, needle quartz, re-crystallized quartz of Appalachian quartzites studied in detail by R.F. Fellows (R.F. Fellows 1943) coincides with the properties of the quartz grains discussed previously.

The Finnish quartzites discussed by Hietanen (1938) are very much like the quartz deposits under discussion, both megascopically and microscopically. The amount of feldspar in the quartz deposits increases at igneous and metasedimentary contacts. The shiny vein-like appearance is common to both deposits. The Böhm lamellae, sibtion and crushed quartz unmistakably indicate the metamorphic nature of these deposits.

After determining the metamorphic nature of the quartz deposits, it remains to show their origin. The original bedding was well exposed in the southern section. The magnetite grains had haloes around them. The sericite fibres that developed in the haloes were most probably derived from the dust that covered them while they were in the unconsolidated sediments. The development of these sericite fibres parallel to schistosity and their relative abundance in certain faces of the magnetic grains indicate their formation under stress (see fig. 10). The presence of somewhat rounded zircon grains also strongly suggests the sedimentary origin of quartzites. All the zircon grains were subhedral except one (see fig 8).

The texture of quartz, the haloes around the magnetite grains and the formation of sillimanite in abundance conclusively indicates that the metamorphism was largely due to the dynamic effects.

Summing up all the data presented, the quartz deposits in this area are quartzites. They were dynamically metamorphosed, and the intensity of metamorphism was high.

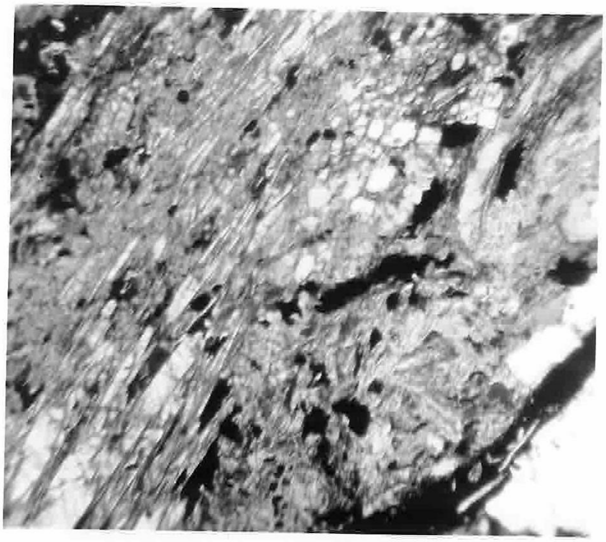

Fig. 2 Sillimanite schist from the northern section (crossed nicols X 22) (Slide No. 3 or 4 = probably 3)

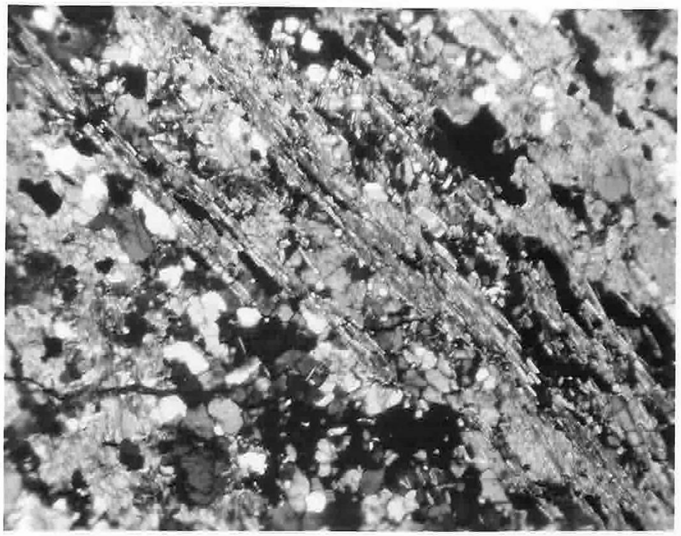

Fig. 3 Sillimanite schist from the southern section (crossed nicols X 22) (Figure No. 48)

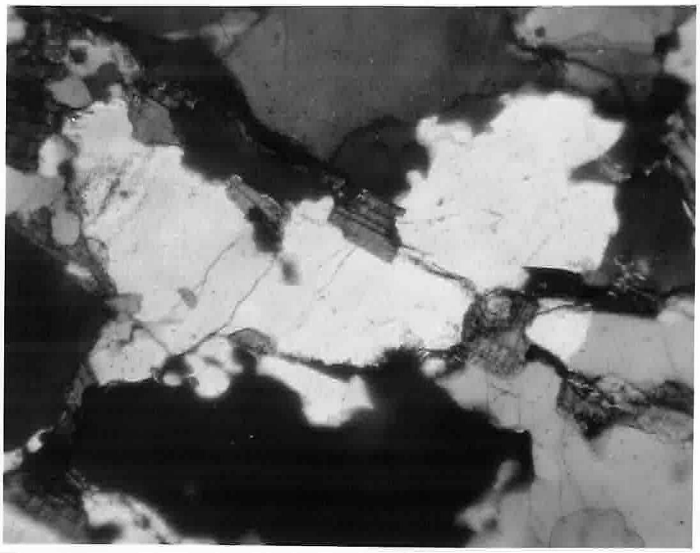

Fig. 4 Quartz in the southern section (crossed nicols X 88) (Slide No. 58)

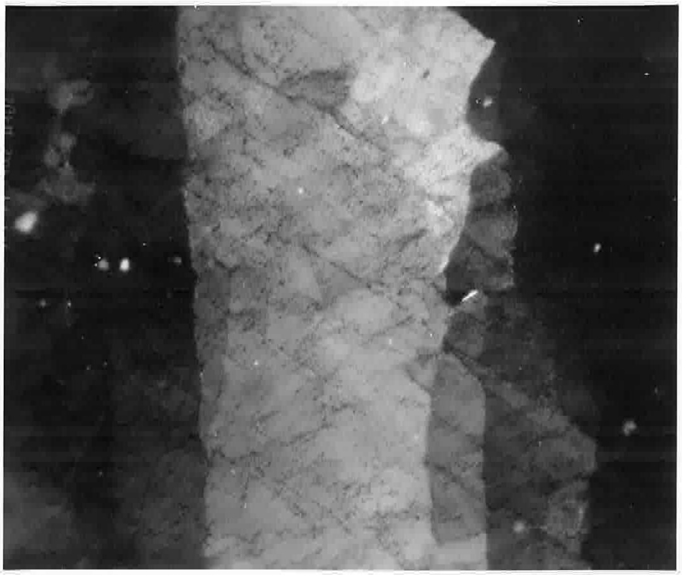

Fig. 5 Ribbon quartz and undulose extinction X 88 (crossed nicols X 88)

Fig. 6 Adamellite from the northern section

(crossed nicols X 22) (Slide No. 7)

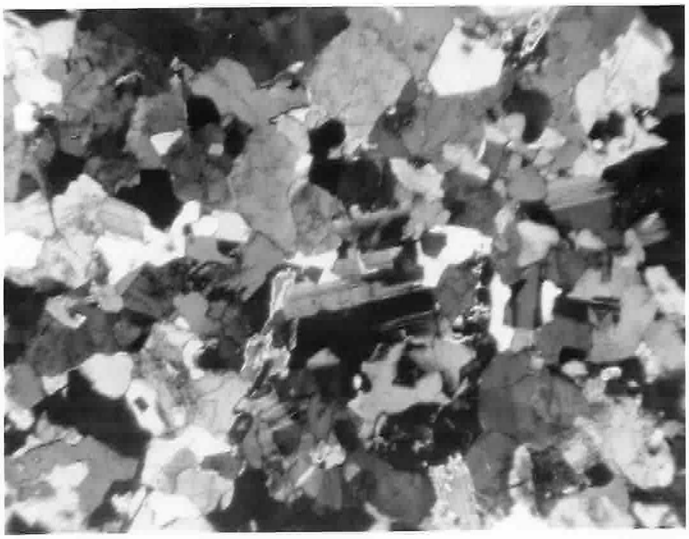

Fig. 7 Aplite dikes in the southern section

(crossed nicols X 22) (Slide No. 39 or 42)

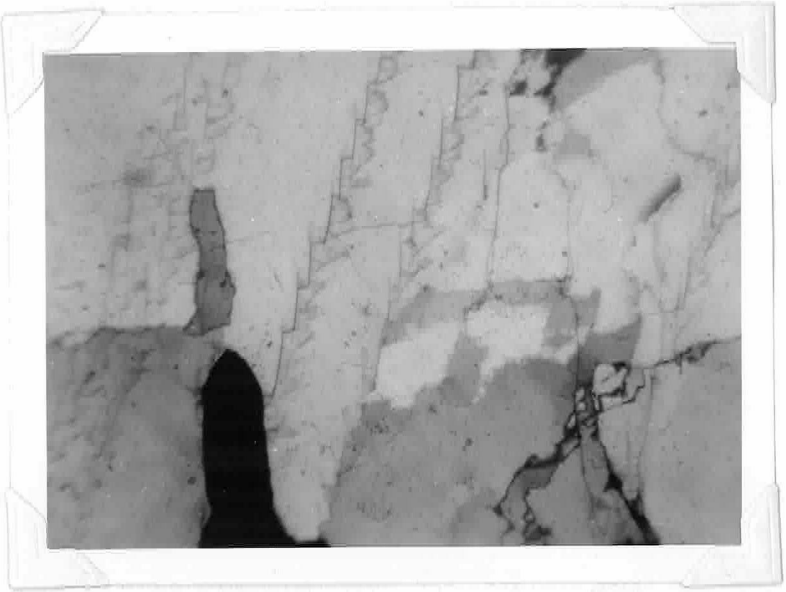

Fig. 8 Unusual cracks in quartz and the euhedral zircon crystal

(crossed nicols X 88) (Slide No. 14)

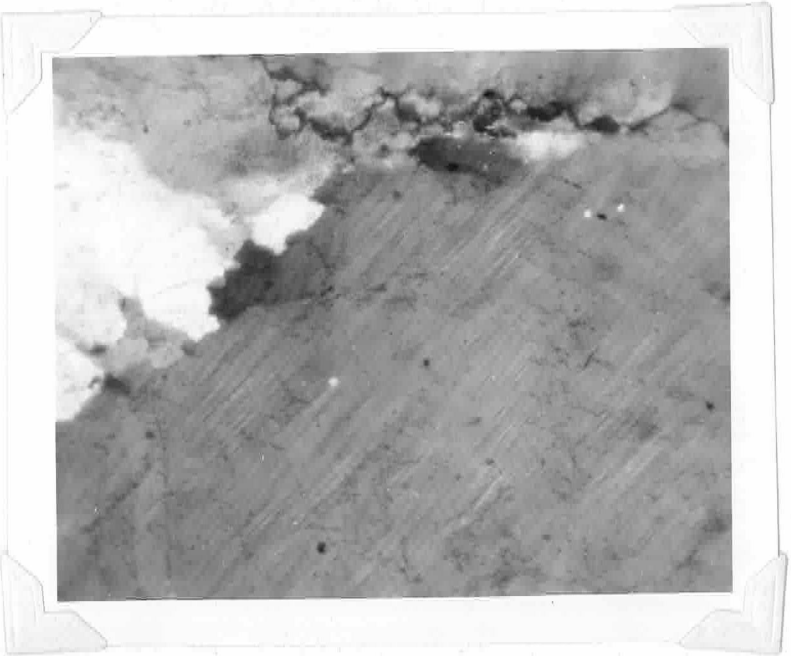

Fig. 9 The Bohm lamellae and peripheral growth in quartz grains

(crossed nicols X 88) (Slide No. 33)

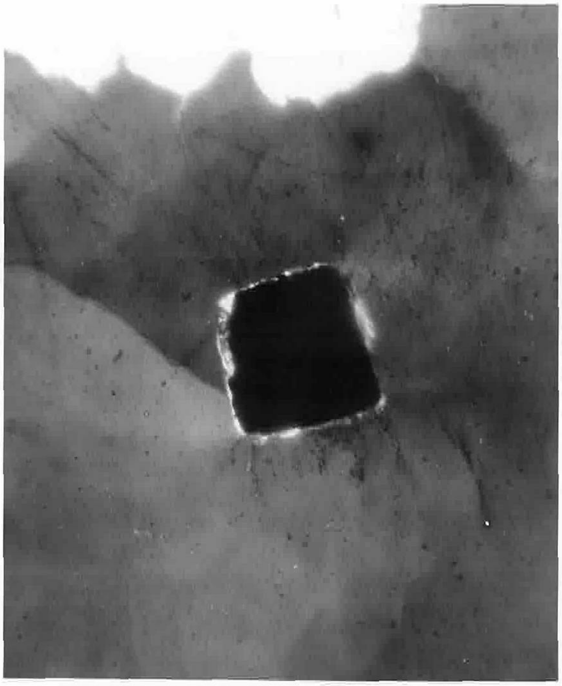

Fig. 10 Magnetite grain with haloes and mosaic type undulose extinction in quartz (crossed nicols X 88) (Slide ? - may be 14, a different field)

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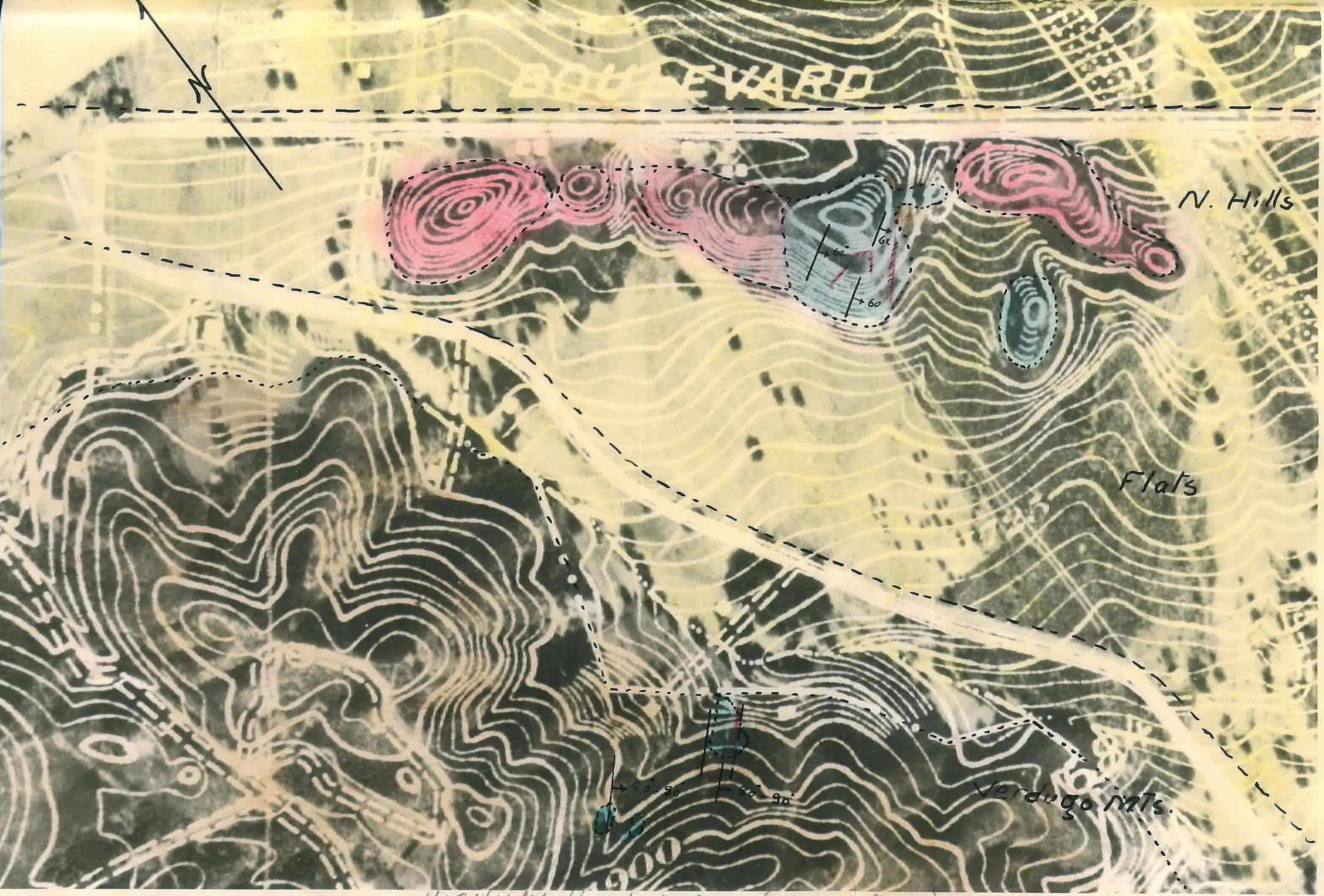

HIGHWAY HIGHLANDS -(W. LA CAÑADA)

Scale:
1 inch = 400 ft.

🟫	Sillimanite Schists
☐	Quartzite
🟥	Granitoid rocks
▨	Aplites
🟨	Alluvium
--------------	Boundary lines
— — — —	Fault
⊥	strikes and dips.