Tridymite in the gangue of a Pb-Cu-Zn occurence

Tridymite in the Gangue of a Pb-Cu-Zn Occurrence

By *C. G. I. Friedlaender* (Halifax, N.S.)*)

With 17 figures in the text

Abstract

Tridymite ascertained in the gangue of the Pb-Cu-Zn occurrence of Dunbrack Prospect, Musquodoboit River, Nova Scotia, has been studied with U-stage methods.

An additional division in alternating sectors of six-sided trillings is formed by a distinct crystalline phase, with $2\,V_z \sim 30°$, while the main part of the composite tridymite crystals has an axial angle $2\,V_z \sim 17°$. Different types of interposition lamellae of tridymite in quartz have been observed.

Résumé

La tridymite reconnue dans la gangue du gisement de Pb-Cu-Zn de Dunbrack Prospect, Musquodoboit River, Nova Scotia, a été étudiée avec la platine théodolite.

Une division additionnelle dans des secteurs alternants de macles avec sections délimitées par six faces est formée par une phase cristalline distincte accusant $2\,V_z \sim 30°$, tandis que la partie principale des cristaux complexes de tridymite a un angle axial $2\,V_z \sim 17°$. Différents types de lamelles de tridymite ont été observés en interposition dans le quartz.

Contents

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*) Dept. of Geology, Dalhousie University, Halifax, Nova Scotia, Canada.

LOCATION – GENERAL GEOLOGY

The mineral occurrence known locally as Dunbrack Prospect is located on the SW bank of the Musquodoboit River, Halifax County, Nova Scotia.

It is near the highway going to Meaghers Grant, approximately 3½ miles NNW of Musquodoboit Harbour. What now remains of former prospecting and mining activities is, however, not very conspicuous so that one can easily miss the location.

The Dunbrack occurrence lies in Devonian granite, near the contact with Meguma slates and quartzites. This indication does not characterize the geological setting adequately: the situation does not seem as simple as that.

In 1888, argentiferous galena was discovered in drift. Since that time, there has been, on and off, some surface prospecting, at times quite extensive. A few unsuccessful attempts at mining have been made (J. P. Messervey, 1929, p. 15–17; J. S. Wroth, 1937).

The economic results were not encouraging. Since 1958, there has not been any mining or prospecting activity. The shafts are now filled with water and the frames are in bad repair. As a result of this, the old workings do not provide artificial outcrops which might complement the somewaht scanty natural outcrops.

The material found on the old dumps show, in accordance with previous observations (F. J. Alcock, 1930), galena associated with chalcocite and malachite. Sphalerite seems to have been overlooked. Numerous secondary minerals can be observed on the Dunbrack specimens, as might be expected in any lead-copper-zinc paragenesis. This is a familiar picture, but the presence of tridymite is something unexpected.

Unexpected also is the range in the genetical interpretation of the occurrence.

— Messervey links the mineralization with a pegmatite dyke striking approximately N-S and dipping 60°–70° E (J. P. Messervey, 1929).

— Alcock describes the deposit as a "fissure vein" striking NW and dipping 70° NE in a zone of weakness in Devonian granite (F. J. Alcock, 1930).

— Wroth holds that the mineralization is associated with a dyke – striking N 47 W and dipping 62° NE – of fine-grained red to gray porphyritic material "resembling a dacite". He states that in places both the granite and the dyke are silicified and then very hard (J. S. Wroth, 1937).

The observations made on the dump material of the Dunbrack occurrence do not disagree with the interpretation of the dyke as a "fissure vein" with silicification of both the dyke and the adjoining granite, but this does not tell us very much.

It has obviously been taken for granted that the mineralization is hydrothermal epigenetic. But this may be a somewhat rash explanation.

There are practically no outcrops in the immediate vicinity of the locality of Dunbrack Prospect. All we have for direct observation is the material accumulated in the dumps of the old workings. Some of this material – pegmatite, quartz vein, granite with infiltration – can be invoked as evidence for such an interpretation. Other observations point, however, to sedimentary or para-metamorphic formation. The pink porphyritic material described by Wroth as "resembling dacite" is an arkosic conglomerate with well delimited, more or less rounded to subangular elements in a fine cherty matrix. Some rocks which megascopically might be termed granitic are also rather to be described as arkosic conglomerate. The genetic interpretation of the Dunbrack occurrence remains therefore open to discussion.

THE SILICA MINERALS

In the Dunbrack association we have, along with quartz, tridymite and chalcedony.

Tridymite

Tridymite crystals are conspicuous by the characteristic trillings. In addition, lamellae in quartz show optical properties matching those of tridymite. We have to distinguish between these two formations.

Tridymite composite crystals

The tridymite crystals show characteristic sixsided sections which appear subdivided in six triangular sectors; the diameters of the sections lie between 0.1 mm and 1.0 mm. Four of the sectors differ only slightly in their extinction position in contrast to the other two. We have thus an "aragonite-type" twinning. The birefringence is low and the maximum angular difference between the extinction positions of the sectors is about 10°.

Where direct observation of the relative refraction is feasible, it is seen that the material with the tridymite twinning shows lower refraction than adjoining quartz.

The tridymite material is biaxial positive. Conoscopically the axial angle was estimated to be approximately 5°. It did not prove possible to determine the orientation of the axial plane with the conoscopic method.

In many of the Dunbrack Prospect tridymites, the six sectors show further internal division. Different patterns of such an ornamentation have been observed. If we designate the sectors with consecutive numbers 1 to 6, the additional division lies in alternating sectors: 1, 3, 5 or 1, 2; 4, 5 or 1, 4.

The appearance of this subdivision varies: in its most regular development it is V-shaped.

A number of photographs (Figs. 1–4) and sketches (Figs. 10–15) illustrate this feature.

A Debye-Scherrer photograph of material scratched from a specimen gave, with the exception of one line (d = 3.7231), only quartz lines. This is not astonishing in view of the rough preparation technique adopted, and considering the grain size and intergrowth development of the tridymite.

No scanning microprobe was available. My observations are thus exclusively optical. They are based on measurements with the Universal-stage (Zeiss instrumentation, with hemispheres n = 1.555; objectives used: UD 20 and UD 6.3).

The results may be summed up as follows:

— the tridymite crystals consist of six sectors. Diametrically opposite sectors (1–4, 2–5, 3–6) have, within the limits of sensitivity of the measurements, the same optical orientation.

— the sectors are optically biaxial positive. The axial angle of the sectors varies between 11° and 23°. Average value of $2V_z = 16°9$.

— the acute bisectrices of the three pairs of sectors coincide.

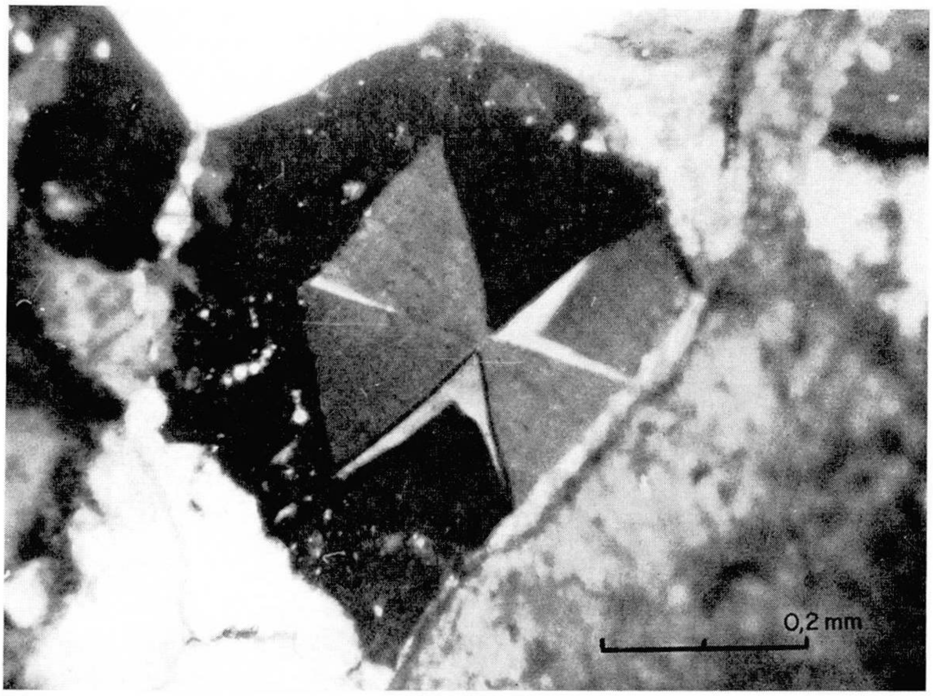


Fig. 1. Tridymite trilling with six-sided delimitation. Crossed polars. Three alternate sectors show an additional roughly V-shaped internal division. ∅ of the composite crystal: 0.3 × 0.4 mm. This photograph has been taken on the Universal stage, therefore only the central part is in focus. The stereographic projection of this composite crystal is given in Fig. 10. The sectors are designated clockwise by the numbers 1 to 6; the sector adjacent to the grey infiltration (malachite) is number 1. The V-shaped parts with divergent optics in the sectors 2, 4, 6 are designated 20, 40, 60 respectively.

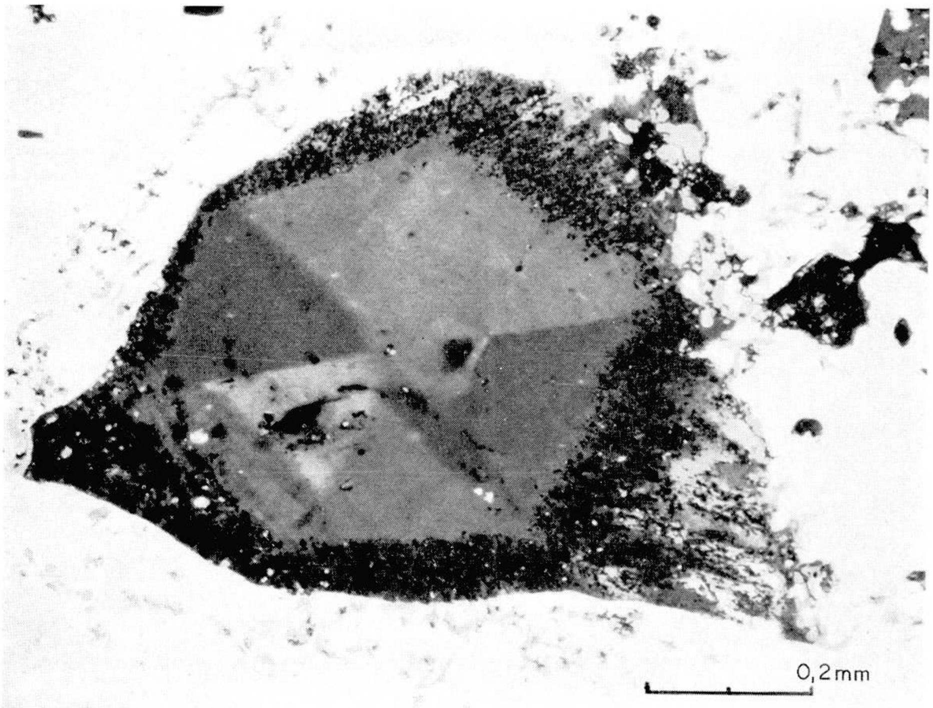


Fig. 2. Tridymite trilling. Crossed polars. Two pairs of the six sectors are in contrasting orientation to that of the third pair of sectors (dark). Rim of minute dark inclusions.

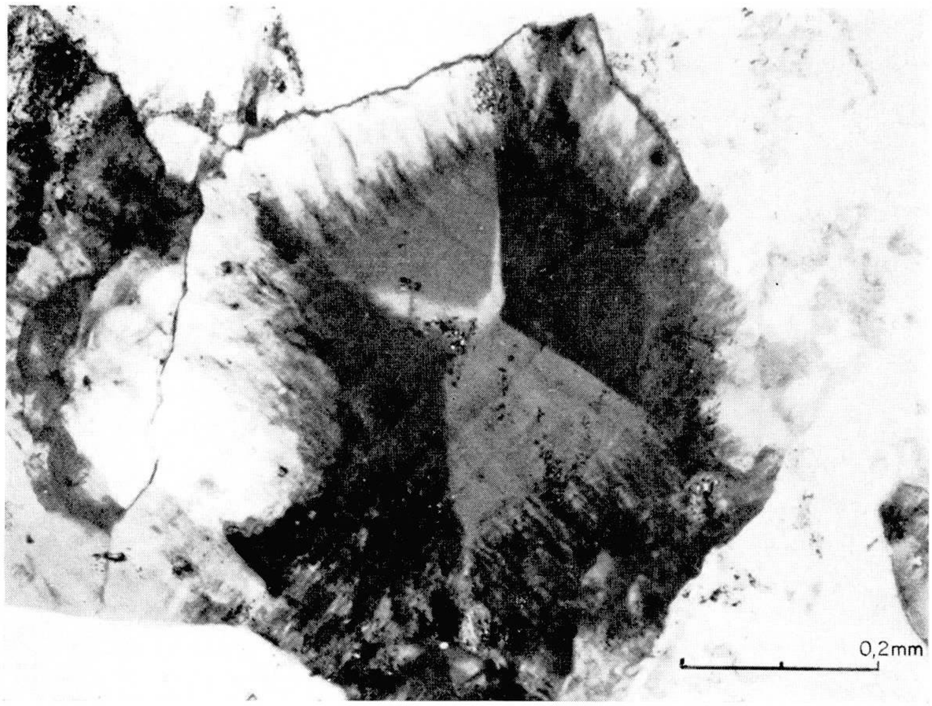


Fig. 3. Tridymite trilling. Crossed polars. Two pairs of the six sectors are in contrasting orientation to that of the third pair of sectors (clear). In one of these, an additional V-shaped internal division can be seen (almost white on photo). Rim of inclusions and of fibrous chalcedony material.

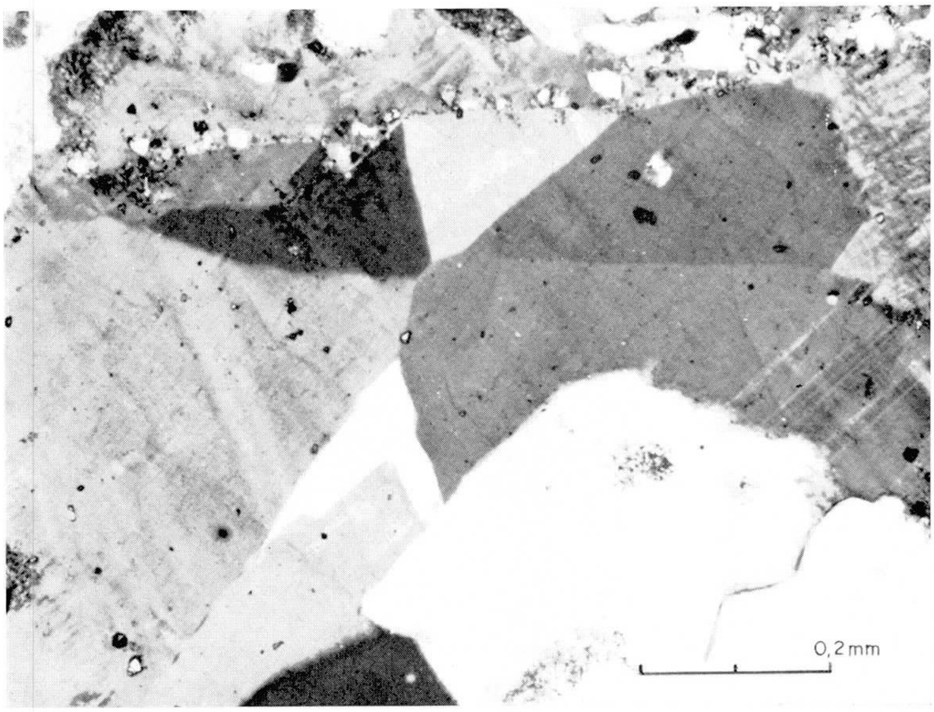


Fig. 4. Tridymite. Crossed polars. Composite crystal of irregular outline. Additional internal division can be seen in two sectors (S, almost white and NW, dark); in one sector (E) there is furthermore a polysynthetic lamellation.

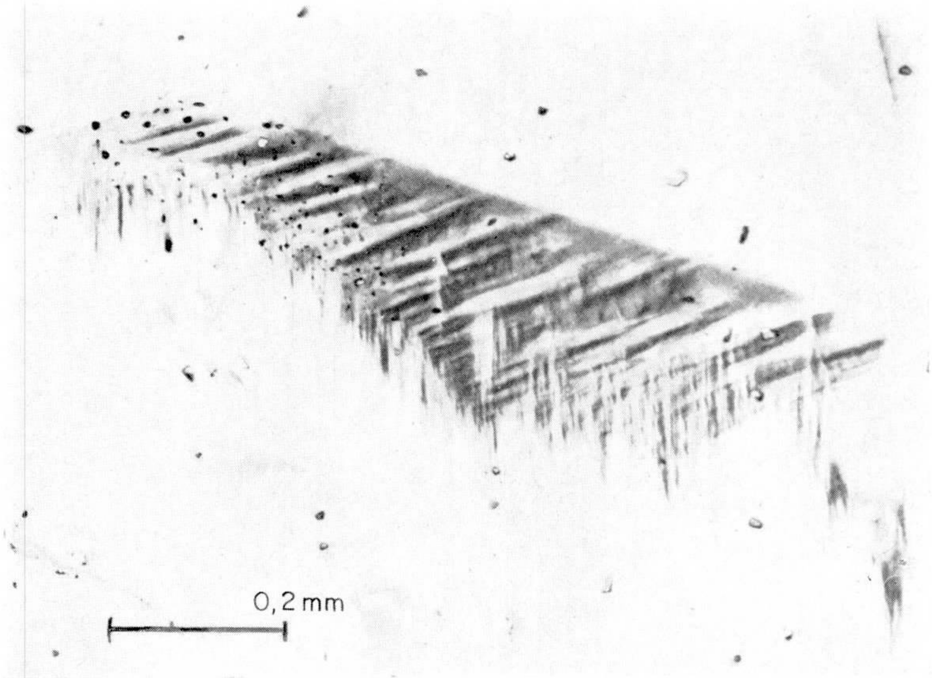


Fig. 5. Tridymite lamellae in quartz. Crossed polars. The lamellae form with each other an angle of $\pm 106°$. The axial angle of the material of the lamellae is $2\,V_z = 36°$. The acute bisectrix coincides with the optical axis of the surrounding quartz. Stereographic projection Fig. 16.

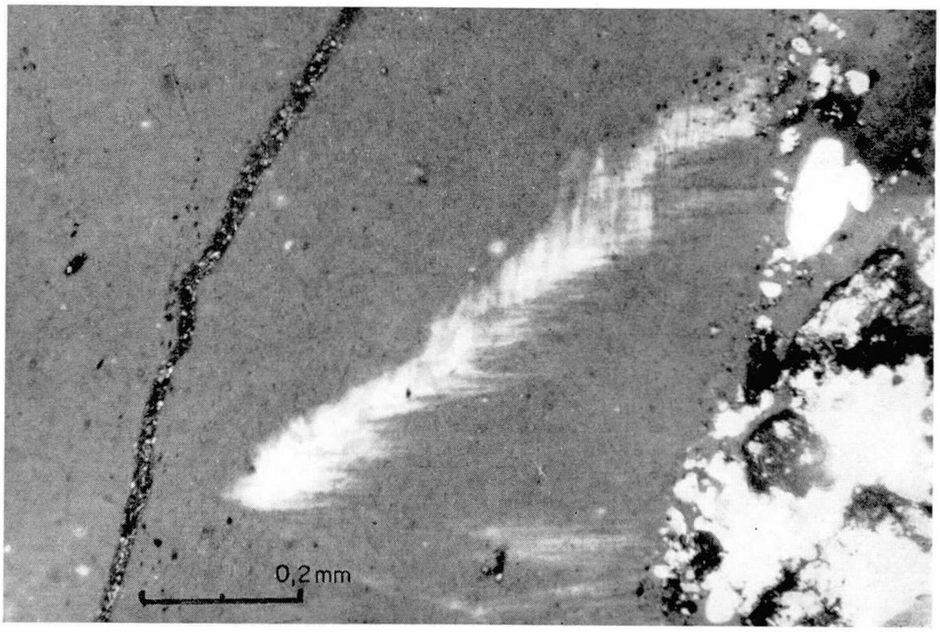


Fig. 6. Lamellae in quartz. Crossed polars. No measurements on U-stage have been made. In analogy to the development shown in Fig. 5, it is inferred that the lamellae consist of tridymite.

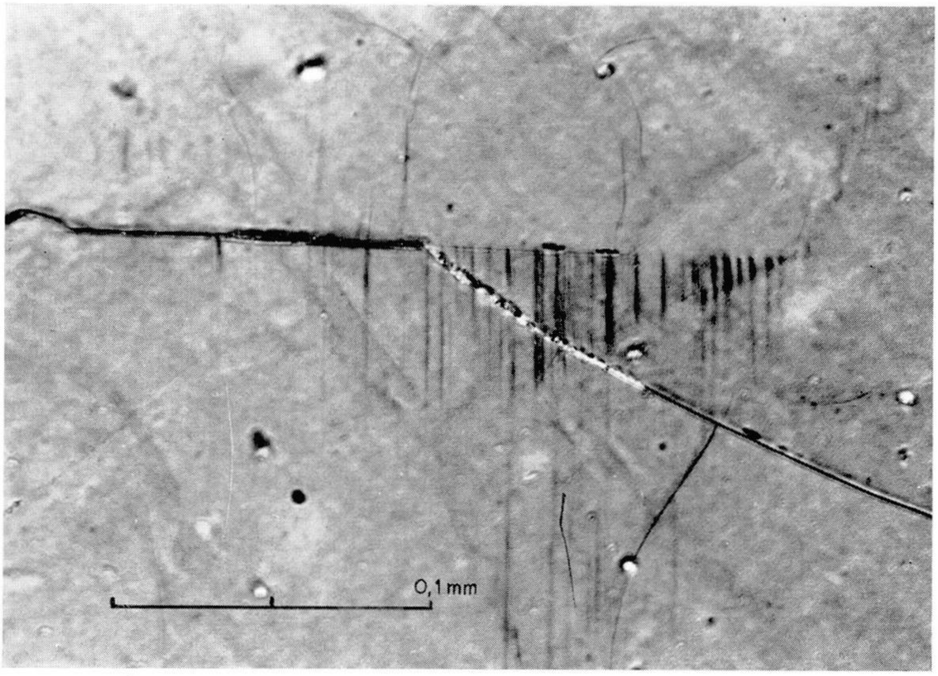


Fig. 7. Lamellae in quartz. Crossed polars. As with the lamellae in Fig. 6, no U-stage measurements have been made. The lamellae are so fine, and discontinuous, that this would hardly be feasible. In analogy to the development shown in Fig. 5, it is inferred that the lamellae consist of tridymite.

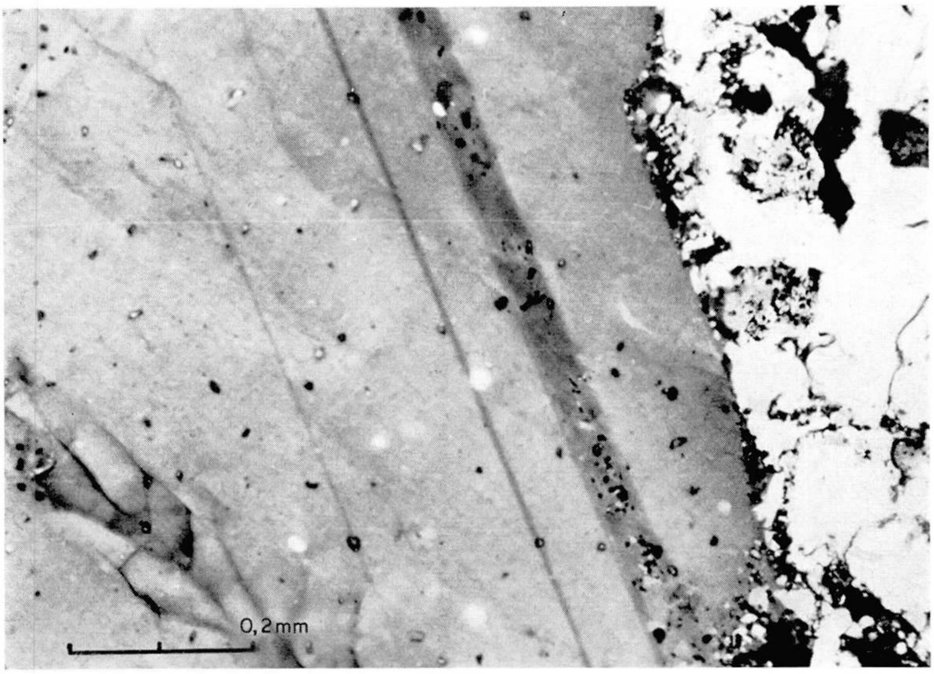


Fig. 8. Tridymite lamellae in quartz. Crossed polars. Aspect resembling that of polysynthetic twinning lamellation. U-stage determination of the broad lamella (width ~0.03 mm) shows that the material is biaxial; $2\,V_z = 23°.5$; the acute bisectrix coincides with the optical axis of the surrounding quartz.

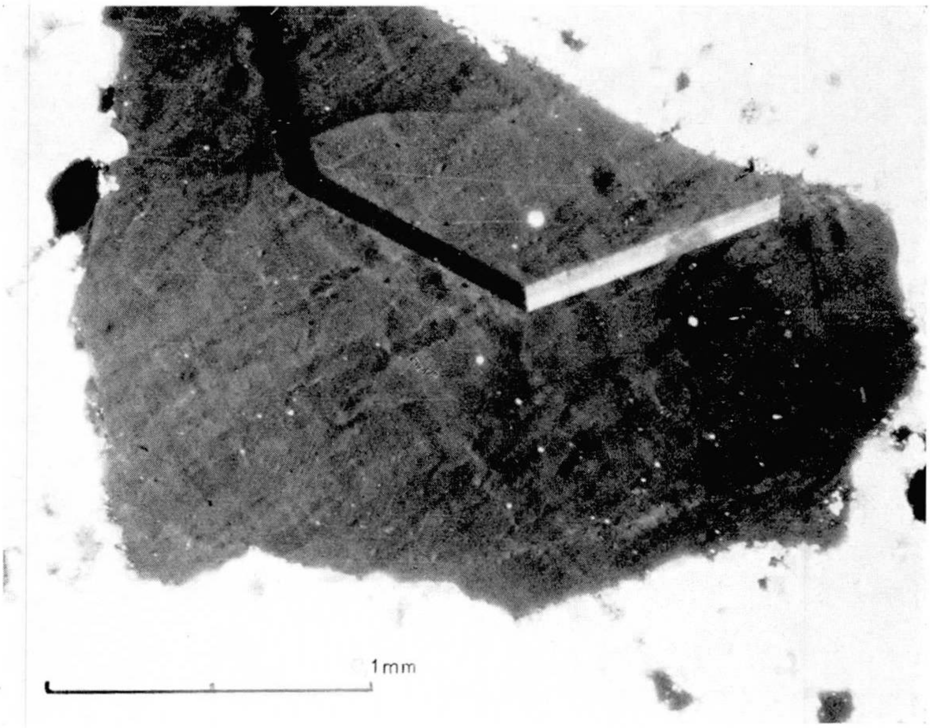


Fig. 9. Frame-like interposition of tridymite in quartz. Crossed polars. U-stage determinations show that the three laths (length ~0.7 mm, width ~0.08 mm) are biaxial and that their acute bisectrices coincide with the optical axis of the surrounding quartz. Stereographic projection Fig. 17. In the lath at right, there is a different orientation on the two parts of the lath separated by the median line, parallel to the elongation.

— the intersection of the planes of apposition of the sectors coincides with the intersection of the acute bisectrices of the three pairs of sectors. The angles formed by the apposition planes approximate 60°.
— the material of the additional internal division has always a markedly larger axial angle than the surrounding main part: $2V_Z \sim 30°$ (range 23° – 36°, average 29°8). It consists thus of a distinct crystalline phase, different from that of the main part.
— the acute bisectrices of the six sectors of the main part of the composite crystal and those of the additional subdivision parts coincide.
— the additional subdivision can therefore not be interpreted as twinning. It constitutes an entaxy, that is a regular oriented intergrowth between two different crystalline phases.

The values of the axial angle have been obtained by direct measurement on the U-stage. No correction has been made to compensate for the difference in refractive index between the segments used on the U-stage (1.555) and the mean refractive index of tridymite ($\sim$1.480). The Troeger nomogram would indicate a correction of 1–1½° (Troeger, 1956, p. 124).

The values of the axial angle are certainly not quite precise. The indication of the range should, however, be adequate.

The difference in the values of the axial angle within one composite crystal exceeds the measurement errors. There appears to be a certain variation in the optical properties of the different sectors of one and the same composite crystal and also between different composite crystals in the same slide.

Figures 11 to 15 indicate the position of the axial plane in the different sectors and in the entactic additional parts. (Figs. 12–15 refer to different tridymite crystals from the same slide.)

Interposition lamellae

Some interposition lamellae display a regular arrangement and are sufficiently broad to permit determination of the optical orientation. Other lamellae are too narrow and discontinuous to permit U-stage measurements.

Two photographs show such developments (Fig. 6 and 7). The quartz frequently shows a discontinuous, scar-like appearance. This may be due to orientational effects within the quartz but it could also be connected with interposition of distinct phases other than quartz.

In Figs. 5, 8 and 9, three different types of interposition in quartz are shown in photographs. The stereographic projection of the optical orientation of the interpositions of Fig. 5 and Fig. 9 are given in Fig. 16 and Fig. 17.

These interpositions may be described as follows:

— lamellae in two not well defined parallel arrays forming an angle of ± 106° with each other when viewed in the direction of the acute bisectrix, but displaying the same optical orientation throughout. In the case represented in Fig. 5, the width of the lamellae lies between less than 1 micron and 0.04 mm. Universal-stage measurement (Fig. 16) shows that the material of the interposition is biaxial, $2V_Z = 36°5$; the acute bisectrix coincides with the optical axis of the surrounding quartz.

These determinations suggest that the interposition material is tridymite. The oriented intergrowth constitutes an entaxy quartz-tridymite.

— lamellae in apparently very regular arrangement (Fig. 7) and
— lamellae in subparallel, somewhat irregular arrangement (Fig. 6).

No U-stage measurements have been made as the lamellae were too narrow. It is inferred by analogy that the material of the lamellae in these developments is also tridymite.

— Parallel laths in quartz, resembling polysynthetic twinning lamellation. The width of the laths lies in the range of the micron up to 0.04 mm (Fig. 8); U-stage determination of the broad lamella in the photograph (width: 0.03 mm) shows that the material is biaxial, with $2V_Z = 23°5$. The acute bisectrix coincides with the optical axis of the surrounding quartz. These determinations seem to indicate that the interposition material is also in this case a tridymite entaxy in quartz.

Bambauer, Brunner and Laves (Bambauer et al., 1961) describe biaxial lamellae in quartz from Madagascar. They observed that a smoky coloration was produced by irradiation with X-rays, neutrons or gamma-rays in the lamellae. Frondel states that tridymite is strongly affected by irradiation (C. Frondel, 1962, p. 137). Bambauer et al. observed further that the axial plane of the material in the lamellae was rotated through the irradiation by 90° and that the axial angle $2V_Z$, estimated at less than ½° before irradiation, is increased by the irradiation to 8–10°. They ascertained by Infrared Absorption Spectroscopy a distinctly higher content of Al, Li and H in the lamellae as compared to that in the neighbouring main part.

— a frame-like arrangement formed by three coplanar laths of almost equant dimensions (length ~0.7 mm, width ~0.08 mm); the lateral laths are linked to the central part in an angle of approximately 130° (Fig. 9). U-stage determination shows that the material making up the laths is biaxial positive. The axial angle $2V_Z$ is $21° \pm 4°$: the three laths do not appear to have the same axial angle. The acute bisectrices of the three laths coincide and have the same orientation as the optical axis of the surrounding quartz. Fig. 17 gives the stereographic projection of the interposition shown in Fig. 9.

The birefringence of the material in the additional internal division appears slightly higher than that in the adjoining sectors of the composite tridymite crystals.

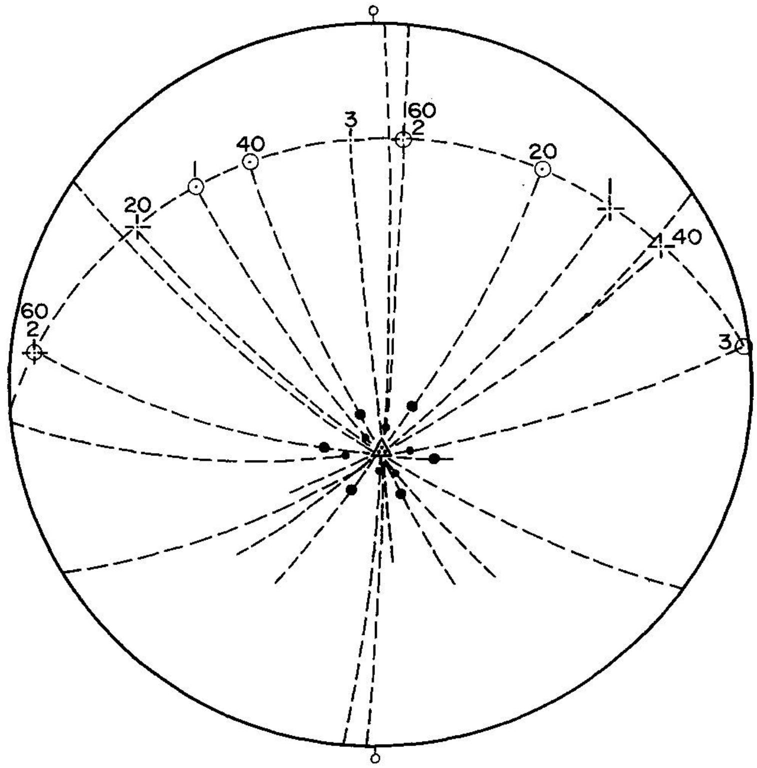


Fig. 10.

Stereographic projection before transformation.

The locus of the acute bisectrices of 1, 2, 3 and 20, 40, 60 coincides.

The great circles normal to the poles of the apposition planes of the 6 sectors intersect in the same point.

Fig. 11 is a stereographic projection after transformation, with a sketch of the outline of the tridymite trilling. See also photograph Fig. 1.

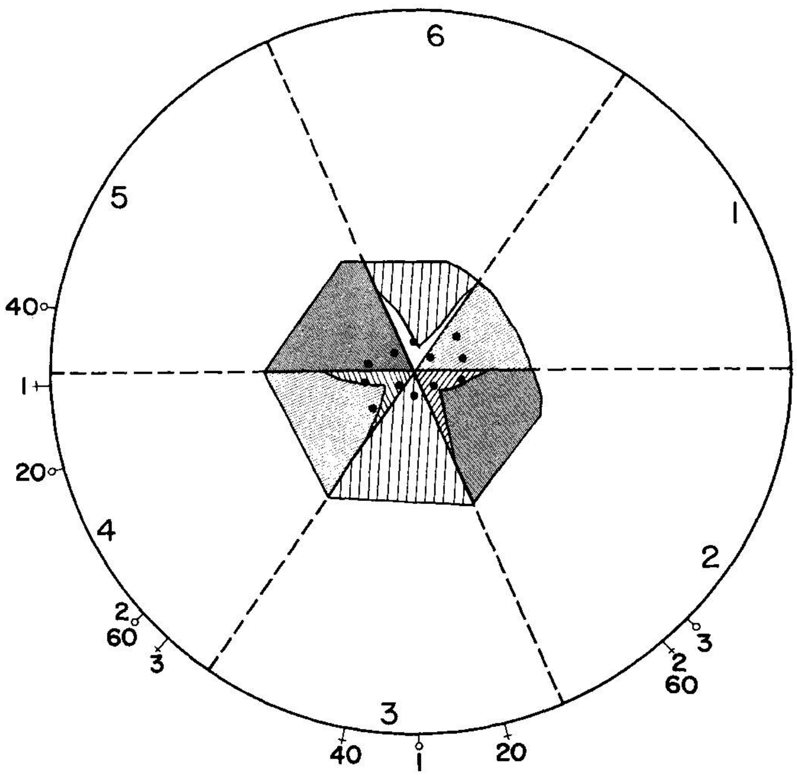


Fig. 11.

Stereographic projection after transformation with sketch of the tridymite trilling. (See Fig. 1 photograph of the same tridymite trilling and Fig. 10 stereographic projection before transposition.)

Dimensions of the composite crystal 0.295 mm × 0.395 mm. The indications of the axial angle in each column represent an average of 10 measurements.

Sectors	$2\,V_z$		
1–4	16°55		16°45
2–5	13°61		14°50
3–6	18°76	18°03	16°25
Entaxy			
20	30°94		31°58
40	28°48		28°71
60	32°71		33°44

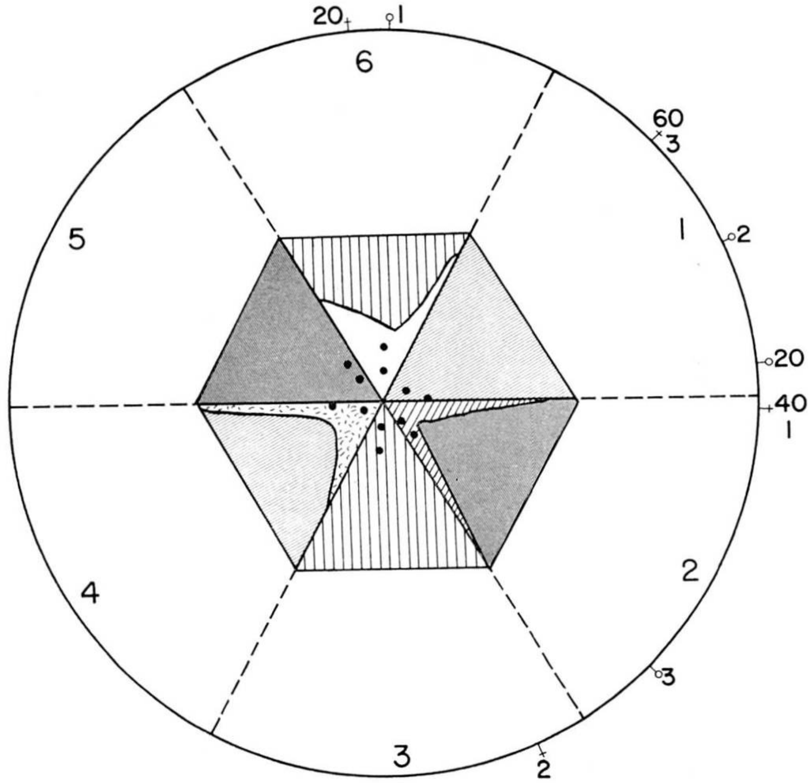


Fig. 12.

Stereographic projection after transposition with sketch of the tridymite trilling.

Dimensions of the composite crystal 0.14 mm × 0.19 mm.

Sectors		$2V_z$
1–4		17°44
2–5	14°57	15°33
3–6		17°95
Entaxy		
20		28°52
40		32°06
60		30°44

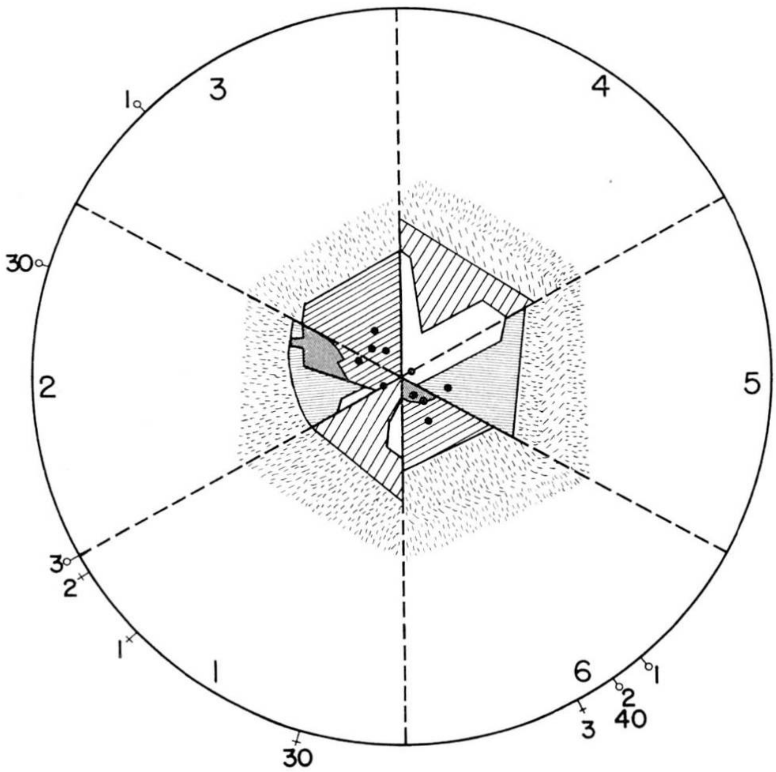


Fig. 13.

Stereographic projection after transposition with sketch of the tridymite trilling.

Dimensions of the composite crystal:
inner part 0.5 mm × 0.7 mm
outer part 0.7 mm × 1.0 mm

Sectors		$2V_z$
1–4		23°84
2–5		16°26
3–6	11°03	14°66
Entaxy		
40 (10)		32°64
30		28°62

Fig. 14.

Stereographic projection after transposition with sketch of the tridymite trilling.

Dimension: ∅ 0.3 mm

Sectors	$2\,V_z$
1–4	29° 76
2–5	16° 28
3–6	15° 0

Entaxy

30	29° 05

The fact that the sectors 1–4 have $2\,V_z = 29°\,76$ is noteworthy. It poses the question whether we have in fact 10 (40), to the total suppression of 1–4 or whether we have here an entaxy 2–5, 3–6/10, 30.

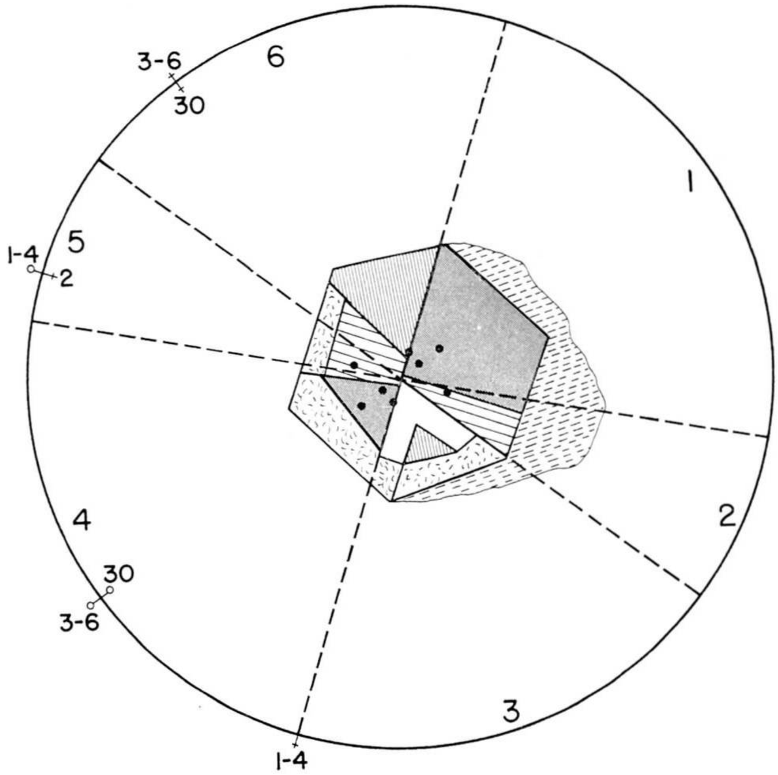


Fig. 15.

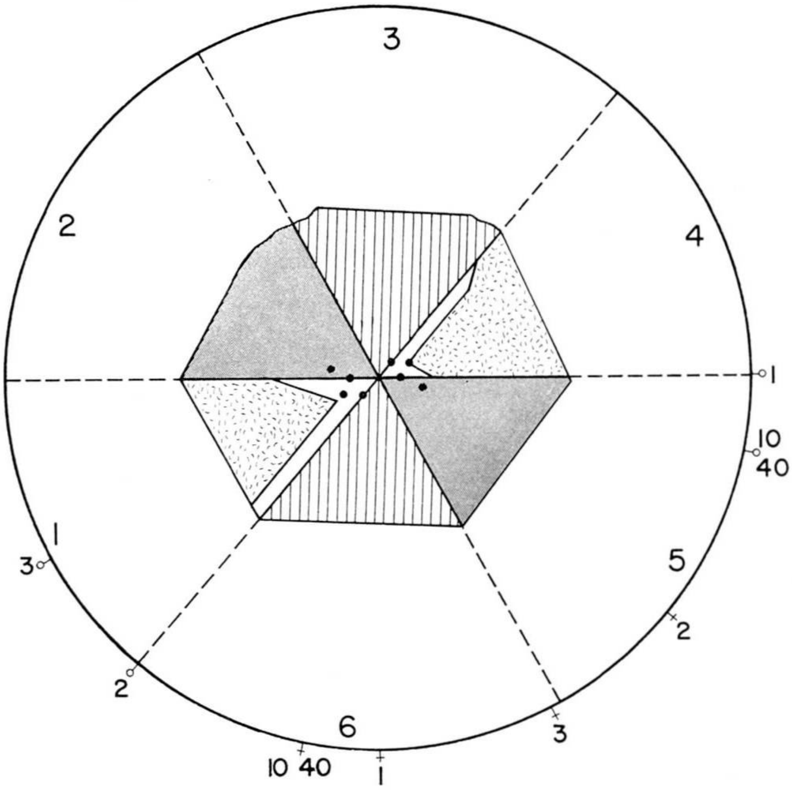
Stereographic projection after transposition with sketch of tridymite trilling.

Dimensions: 0.14 mm × 0.22 mm

Sectors		$2\,V_z$
1–4		15° 63
2–5	12° 41	15° 32
3–6		21° 48

Entaxy

10–40	30° 85



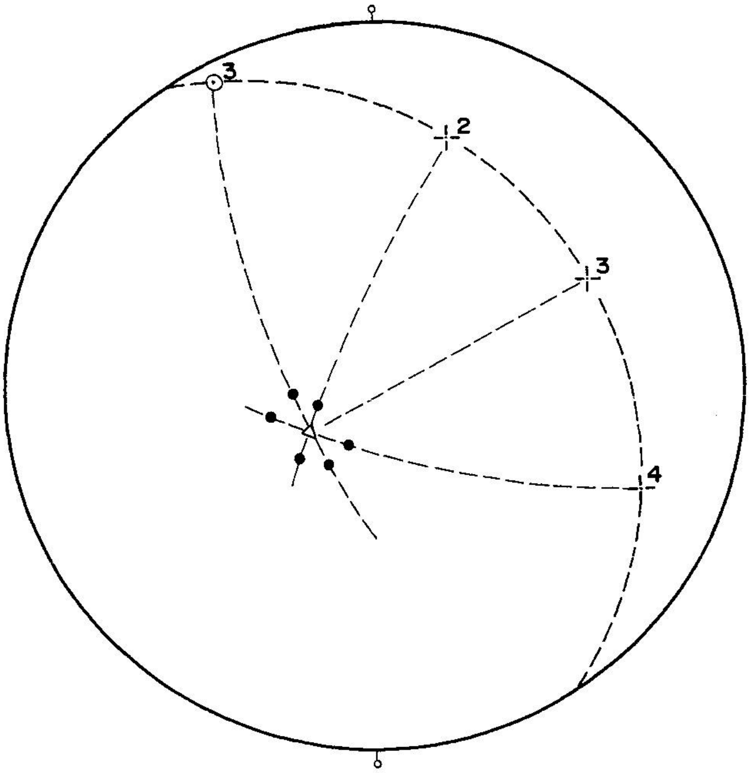


Fig. 16.

Stereographic projection giving the optical orientation of tridymite lamellae in quartz (Fig. 5).

The tridymite has $2\,V_z = 36°5$ and its acute bisectrix coincides with the optical axis of the surrounding quartz.

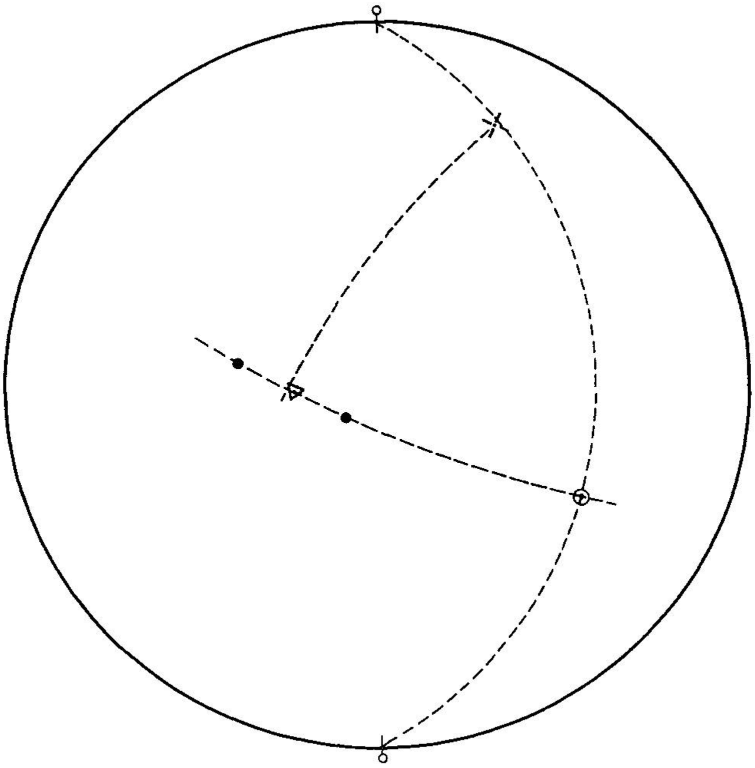


Fig. 17.

Stereographic projection of the optical orientation of the three laths forming the frame-like interposition shown in Fig. 9.

The optical axis of the surrounding quartz (1) coincides with the position of the acute bisectrices of the three laths.

lath	on photo Fig. 9	$2\,V_z$
2	at right	25° 1
3	central lath	22°
4	at left	17° 6

Y of 2 coincides with X of 4
Y of 4 coincides with X of 2

No measurements of the birefringence have been made nor has it been possible to determine the relative refraction of the interposition material in quartz.

The other silica minerals occurring in the Dunbrack association will only be mentioned briefly.

Chalcedony

There are two types of *chalcedony* in the gangue of the Dunbrack Prospect material; chalcedony and lussatite.

— widespread feather-like or subparallel aggregates of quartz are considered to be chalcedony. No difference in refraction was observed when compared with adjoining quartz. The preferential orientation varies.

— the composite tridymite crystals are almost invariably rimmed by a zone of minute inclusions and surrounded by a crust of fibrous material. The refraction appears lower than that of the quartz. The elongation of the fibers is positive.

The properties of the material match those of *lussatite.*

The nomenclature of the different silica minerals varies from one author to another.

Sosman describes lussatite as a low-temperature variety of "non-quartzoid chalcedonic silica" (R. B. Sosman, 1965, 223).

Mallard considers lussatite to be microfibrous tridymite (Er. Mallard, 1890).

Flörke classifies lussatite, in accordance with Braitsch, as cryptocrystalline fibrous low-cristobalite (O. W. Flörke, 1962, p. 96).

Quartz

While tridymite retains our special attention, quartz is the preponderant silica mineral in the Dunbrack Prospect association. It presents a number of peculiarities. These are: well-bounded zones with numerous minute inclusions; stringers of inclusions as well as unaligned isolated inclusions; liquid inclusions with moving gas bubble; ruptures which in part seem to be cleavage fractures; undulatory extinction which may be due to growth irregularities or to subsequent adjustment. Some of these phenomena deserve closer study. For one thing, the grain boundaries may help to unravel the age relations within the paragenesis. It is, however, not intended to study these phenomena in this context.

The irregular, discontinuous scar-like appearance mentioned in the paragraph on tridymite interposition lamellae may be of particular importance in the discussion of the tridymite problems.

THE TRIDYMITE PROBLEM

It has been pointed out by various authors that tridymite cannot be regarded as a temperature indicator denoting formation above 870° C. (O. W. FLÖRKE, 1955, 1959, 1961, 1967; S. B. HOLMQUIST, 1958; R. R. SKELHORN, 1964; see also review in textbooks, e.g. C. FRONDEL, 1962; R. B. SOSMAN, 1965).

On the other hand, tridymite always contains foreign atoms. Traces of impurities affect the transformations of the silica minerals markedly. The transformations of tridymite, in particular, occur over a wide range of temperature.

There are undoubtedly various impurities in the quartz of the Dunbrack Prospect association. This is evident through the numerous inclusions. These might be either primary or the result of secondary infiltration or they may also be due to secondary exsolution. The development of tridymite must be viewed in relation to the distribution pattern of impurities.

Tridymite is generally assumed to be linked to volcanic rocks, Tertiary or younger, but occurrences in plutonic rocks – including metamorphic rocks – have also been described (L. R. WAGER et al., 1953; R. R. SKELHORN, 1964; G. D. OSBORNE, 1950). Silicified fossil wood of Lower Cretaceous age giving an X-ray pattern similar to that of tridymite has been reported from a locality in Virginia (R. S. MITCHELL, 1967).

In a lead-copper-zinc paragenesis tridymite is a rather unexpected constituent. It might after all turn out to be less exceptional than what it now seems to be, as it may easily have been overlooked. The present occurrence has direct bearing on the question of the particular conditions of formation of the Dunbrack Prospect mineralisation.

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