Stalk-Like Forms: These forms are most abundant in the neutral end of the series except in C. They usually occur after the first indication of the double salt bundles and are not scattered throughout the tubes to any extent except when the extreme neutral end is approached. Despite the strong concentration of Series E no stalk-like forms are noted anywhere in the series.

Radial Growths: A peculiar form maintained by the double salt is first seen in small amounts in the first three series and becomes quite pronounced in series E. There is a rather strong development of simple crystals of the double salt-monoclinic prisms, pinacoids and domes, and as the acidity of the series is decreased the forms unite to produce rather thick bundles of crystals which are not the same as noted under bundle types. Later developments of cruciform and fish-tail twins are noted and in the last member of the series, thick, nodular types spread more and show radial growths of monoclinic crystals from a common center.

The crystal forms described under double salts are of doubtful value as the composition of the double salt probably varies, viz., (1)$Pb(Ac)_2.PbI_2$; (2)$Pb(Ac)_2.2PbI_2$; (3)$Pb(Ac)_2.3PbI_2$; etc., These three compounds are known and there must be more. We are unable to state at the present time which of the double salts we are dealing with.

THE SIGNIFICANCE OF STRAIN STRUCTURE IN QUARTZ FROM DUCKTOWN, TENNESSEE

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The so-called quartz "floors" in the copper mines at Ducktown, Tennessee, have furnished specimens of transparent quartz of rock crystal quality. Aside from the clearness of the mineral, in itself unusual, it attracts attention on account of a peculiar crossed ribbon structure which it exhibits. One specimen recently examined[1] shows a surface measuring three by five centimeters in area, approximately flat and neatly engraved as if by machine work with two intersecting sets of curved ridges cutting each other at acute angles. The appearance of the area may be compared to the "engine turning" on the back of a watch, a term

[1] A specimen kindly supplied by Professor J. F. Kemp.

employed by Brewster in 1821, when making the first reference to this type of structure on record.[2] Figures 1 and 2 are photographs of the specimen from Ducktown showing the ridges in question in about natural size and under moderate magnification.

Sections of the glassy quartz were cut and studied by etching and optical methods in an attempt to account for the structure. Repeated etching with hydrofluoric acid failed to produce any similar features, hence, it would not seem likely that the phenomenon could be due to any process of natural etching. Optical investigation showed the presence of twinning, and also indicated strain effects within the crystal.

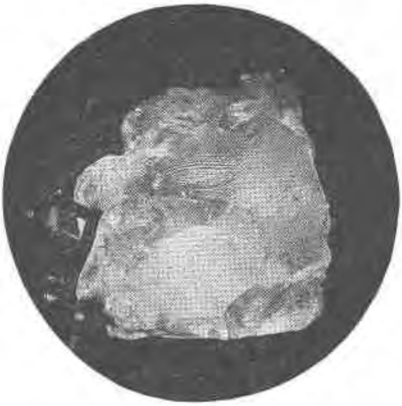

Fig. 1. Glassy quartz from Ducktown, Tennessee, showing strain structure.

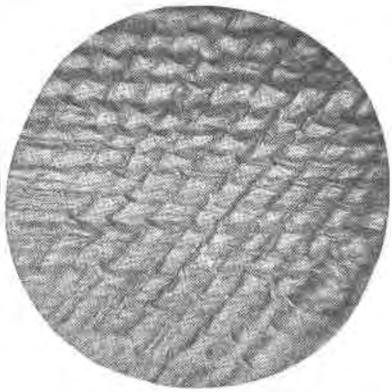

Fig. 2. The strain structure magnified about eighteen diameters.

Similar material from other localities was also studied by the same methods with confirmative results. In observing quartz specimens from different localities, the structure was found to be well developed on material having only one general type of geologic origin. All of the specimens were either pegmatitic or from recognized high temperature veins, although the largest amount of material available for study was pegmatitic. A commercial shipment consisting of a ton of large quartz crystals from Minas Geraes[3], Brazil, contained several excellent examples. Although in a commercial lot of uncertain locality in Minas

[2] Brewster, David; On circular polarization as exhibited in the optical structure of amethyst. *Trans. Roy. Soc. Edinburgh*, Vol. 9, 139–152 (1821).

[3] Examined through the courtesy of the Diamond Drill and Carbon Company, New York City.

Geraes the material was evidently of pegmatitic origin, judging from occasional included crystals of tourmaline and rutile. In addition to the Brazilian locality the structure was observed on quartz fron several of our eastern pegmatites. Vom Rath[4] and Judd[5] described lamellae on quartz from several localities which one would suppose from their descriptions to be pegmatitic. Aside from the pegmatitic occurrences mentioned the feature was found on quartz from the cassiterite-tourmaline veins at Llallagua in Bolivia.

Search on a number of crystals from several localities of either assured or probable low temperature origin failed to reveal a sign of the structure and repeated trials of fracturing in a vise failed to produce the structure, but, on the other hand, did occasionally develop clear cleavages. The latter was particularly true in the case of the quartz from Little Falls, New York. It would seem at least possible, therefore, that the ribbon structure is limited to quartz that has crystallized at high temperatures. Although an exhaustive study would be necessary to establish the point beyond question, it seems reasonable at least to believe that the peculiar markings described can be considered as criteria for high temperature quartz from the ore-deposit standpoint, where temperatures below the inversion point are at the same time considered high temperatures.

The immediate cause of this structure has been explained by Judd[6], who pointed out that it is due to a certain instability in quartz and that the instability becomes apparent when the quartz is fractured through the development of intersecting cleavages. After a detailed investigation he concluded that only unstable quartz would show the feature and that only after fracturing. The effect itself is given by cross fractures in twinned quartz which intersect the basal plane parallel to *r* and *-r* (a magnified view is shown in figure 2). The most interesting conclusion of Judd is that the feature is subsequent to the formation of the crystal and can be reproduced at will on unstable quartz in a pressure machine.

[4] Vom Rath, G.; *Z. f. Kryst*, **5**, 1 (1881).

[5] Judd, John W.; Development of Lamellar Structure in Quartz Crystals by Mechanical Means. *Mineralog. Mag.*, **8**, 1–9 (1888).

[6] Judd, John W.; Additional Notes on the Lamellar Structure of Quartz Crystals and the Methods by which it is Developed. *Mineralog. Mag.*, **10**, 123–135 (1892).

The cause of so-called "stable" and "unstable" quartz is not immediately apparent. It has been attributed by some to pressure twinning. It seems more than an accidental coincidence, however, that a number of specimens of high temperature origin show the ribbon structure and hence must be "unstable" while the low temperature specimens are "stable," and show no strain structure. If temperature can be shown to have an effect on the structure of quartz, it would seem probable that the "unstable" form represents a high temperature variety.

Recent X-ray studies leave no doubt concerning the fact that temperature affects the structure of quartz even below the inversion point of 575° C established by Mügge[7] and Wright and Larsen.[8] Such work carried on by Wyckoff[9] brings out the fact that Laue Photographs taken of quartz heated to a temperature about 40° below the inversion point show a complex twinning which is cleared as soon as the inversion temperature is reached. On cooling again, the structure either may or may not reappear. It is evident, therefore, that a high temperature may be responsible for a complex structure in quartz although such a structure does not necessarily follow. Applied to the case at hand it seems possible that the "unstable" quartz may be a quartz that has been held for some time at a temperature below the inversion point and thus acquired an intimate twinning.

In view of the foregoing it is reasonable to suggest that the so-called "glassy" quartz from Ducktown, Tennessee, showing strain structure has the following explanation.[10]

1. The quartz is itself "unstable" as explained by Judd.
2. The "instability" is probably due to a high temperature origin although not necessarily a temperature above the inversion point.
3. The strain structure is a fracture effect, but produced only on such quartz as has been previously subjected to high temperatures.

[7] Mügge, O.; *Neues Jahrb., Festband*, 181–196 (1907).

[8] Wright, F. E., and Larsen, E. S; Quartz as a Geologic Thermometer. *Amer. Jour. Sci.*, **27**, 421–447, (1909).

[9] The statement on the behavior of quartz at high temperatures as shown by Laue Photographs is based on a discussion with Dr. R. W. G. Wyckoff of the Geophysical Laboratory, who has recently worked on the structure of quartz.

[10] The writer wishes to take this opportunity to thank his colleague Prof. R. J. Colony for ideas gained through critical discussion of the material contained in this article.