In summary, polished thin sections afford a small but valuable enhancement of the quality and objectivity of observation and help to reduce the quantity of interpretation in ore genesis. These improvements will be welcome when it is recognized that a complete theory needs to be built on a careful combination of geochemical and geometric (fabric, structural) evidence.

Polished thin sections also provide more complete information for ore dressing microscopy, where metallurgical properties of minerals are sought. Coatings, alterations (clay, sericite, etc.), intergrowths or locking types and locking sizes can be seen in more detail and in less time. Typical examples are discussed in detail by the present author (3).

ACKNOWLEDGMENT

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VARIATIONS IN INTERFERENCE FIGURES IN SINGLE CRYSTALS OF ZONED SMOKY QUARTZ

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INTRODUCTION

Much attention has been directed to the problem of coloration of smoky quartz and to the related problem of zonation of smoky and colorless quartz in a single crystal. Phillips (1908) recognized a relationship between irradiation and coloration in quartz crystals, noting that coloring and banding developed with exposure of a quartz crystal to radium. He also recognized the significance of impurities in coloration through irradiation, for working with fused boric acid he was unable to effect coloration whereas in impure borax coloration resulted after a few weeks of exposure to radium.

Lind and Bardwell (1923) proposed that the displacement of electrons from their normal position through irradiation was responsible for coloration in quartz and fluorite. Frondel (1945) also favored displaced electrons as a cause for coloration, but at the same time recognized a sensitizing factor (an impurity included during growth) in zoned crystals as evidenced by the differential response of the clear and smoky bands to radioactive emanations. Frondel and Hurlbut (1955) and Cohen and Sumner (1958) attributed coloration to the replacement of a silicon ion by an aluminum ion in the quartz structure. In colorless areas the aluminum content was, in some cases, as great as in smoky areas but in colorless areas it was interstitial rather than replacement. Other structural deviations have been suggested.

Possible explanations for the coloration thus include: (1) inclusion of impurities in either ionic or molecular form, (2) effect of radioactive emanations, (3) structural deviations, and (4) a combination of several of the mentioned factors.

Petrographic examination of zoned quartz crystals from the Wet Mountain Thorium Belt indicates that alternation of colorless and smoky bands is related to a structural change.

Description of Crystals

All of the crystals examined were taken from radioactive veins of the Wet Mountain Thorium Belt in Custer and Fremont Counties, Colorado. This belt includes veins 100 to 5000 feet in length and 10 to 50 feet in width cropping out in a northwest-southeast trending area 10 miles in width and 25 miles in length. Typical minerals of the veins are quartz, barite, and carbonates with minor fluorite, sulfides, iron oxides and thorogummite.

The quartz crystals are euhedral to subhedral with crystal faces generally coated with hematite and sometimes thorogummite. Almost all crystals show some zoning of smoky and colorless quartz (Fig. 1) whether the crystals be only a fraction of an inch or 8 to 10 inches in diameter. Zones may be sharply separated or may show a gradational change from colorless to smoky quartz. Color bands generally continue around the crystal but may be abruptly terminated with a sharp break between colorless and smoky quartz. Color bands parallel the crystal faces and there can be little doubt but that they are also growth bands.

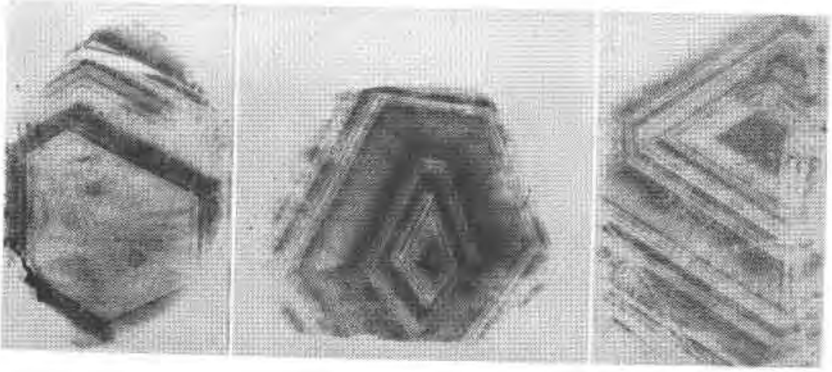

FIG. 1. Thin sections of zoned quartz crystals. Sections cut normal to *c* axis. ×1.4.

VARIATIONS IN INTERFERENCE FIGURES

A peculiarity common to the majority of the crystals examined is the variation in interference figures in a single crystal between colorless and smoky zones, all sections being cut approximately normal to the *c* axis. Colorless zones produce either a uniaxial positive figure or a biaxial positive figure with a small (less than several degrees) 2V. Smoky zones in the same crystal, with few exceptions, produce larger 2Vs (up to about $7\frac{1}{2}°$–8°) than do colorless zones. In several crystals no perceptible difference in 2V could be noted with a biaxial figure appearing in each. This might be attributed to strain. In no crystal does a uniaxial figure appear throughout nor does the 2V ever appear larger in the colorless zone. Smoky zones are pleochroic from brown to green in all specimens.

SUPPLEMENTAL DATA

Some crystals have zones sufficiently broad to permit separation of colorless and smoky material for analysis. *X*-ray powder analyses were made of adjoining zones of colorless and smoky quartz but no structural difference was perceptable.

The abundance of small inclusions throughout the crystals makes highly improbable the detection of an impurity which might be considered to be the cause of the coloration in the smoky material. Semiquantitative spectrographic analyses were run on five pairs of samples (colorless and smoky). Calcium, iron, aluminum, magnesium, copper, and vanadium were found in all samples in trace amounts. Both black and white samples of each pair contained approximately equal amounts of calcium, iron and copper, although small differences in concentration were noted between sample pairs. In general magnesium, vanadium and aluminum were found in slightly larger amounts in the smoky samples.

Aluminum is the impurity suggested by Cohen and Sumner (1958) as responsible for the smoky color.

Loss on ignitions run on three pairs of samples showed the loss of weight between 550 and 600° C. to be greater in colorless quartz than in smoky quartz in two pairs (dark loss 0.08%, colorless loss 0.13%; dark loss 0.03%, light loss 0.05%), thus reducing the possibility of carbon as the coloring agent for the smoky quartz.

CONCLUSIONS

Cyclic inclusion of one or more impurities (probably in ionic form) during growth of the crystal is indirectly responsible for the coloration of smoky quartz. That coloration is directly the result of exposure to radioactive material has been demonstrated on numerous occasions. Recent work indicates that the smoky color develops in quartz in which the impurity is substitutional rather than interstitial. It can thus be concluded that the orderly variation in velocity in smoky quartz in sections normal to the *c* crystallographic axis (biaxial figure resulting) must be due to a structural change resulting from an orderly substitution of one element for another according to a fixed pattern.

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CALCIOSTRONTIANITE FROM PULASKI AND ROCKINGHAM COUNTIES, VIRGINIA

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Strontianite with approximately eight per cent CaO, hereinafter referred to as calciostrontianite, has recently been found to occur in calcite-lined vugs at two Virginia localities other than the one mentioned by Pharr and Mitchell (1959). These are: 1) at the Salem Rock Corp. Quarry on the west side of Virginia Route 100, ca. 315 miles (by road)