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)

south of Dublin, Pulaski County and 2) beneath the Maude Liskey Property about 0.4 mile southeast of U. S. Route 11, ca. 2.7 miles northeast of the center of Harrisonburg, Rockingham County.

The Rockingham County calciostrontianite was found in a drill core. It occurs as white to cream-colored, radial groups of spear-shaped crystals in calcite-lined vugs in limestone of the Athens formation of Middle Ordovician age. Its identity as calciostrontianite is based chiefly on its x-ray diffraction pattern.

The Pulaski County calciostrontianite occurs as nearly colorless, white and buff, radial and sheaf-like groups of spear-shaped crystals (Fig. 1) in vugs and on joint surfaces in dolomite of the Elbrook formation of Middle and/or Late Cambrian age. Most of the formation is highly laminated at the locality. Nearly all of the vugs are lined with colorless to white calcite crystals, typically scalenohedra terminated by rhombo-
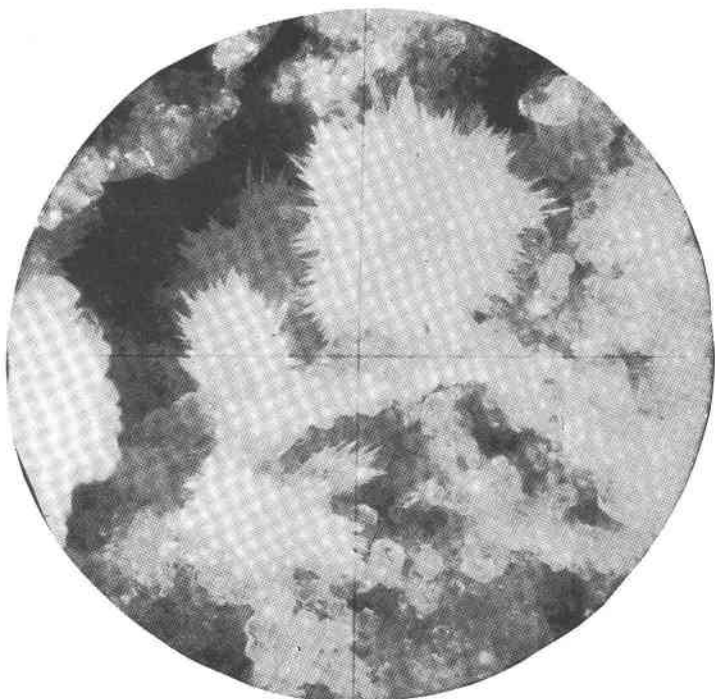

FIG. 1. Calciostrontianite in a calcite-lined vug from Pulaski County, Virginia. The largest radial group is approximately 3.0 mm. in greatest dimension. Most individual radial groups thus far found at the locality are less than 3.5 mm. in greatest dimensions, a few range up to 6 mm.; some radial groups comprise composite masses up to 12 mm. in greatest dimension.

hedra. A few of the calcite crystals are citrine to amber in color. In some vugs groups of calcite crystals are arranged so as to form ridges arranged radially away from a central mass of silica. Such central silica typically consists of granular, loose to partly aggregated, colorless to white quartz around a light gray to milky white, solid, chalcedonic silica core. Typically the size of the core varies directly with the size of the containing vug. Contrariwise, there appears to be no such size relationship between core size and thickness of surrounding granular quartz. Rather, the thickness of the granular quartz appears to be nearly constant (about 10 mm.) in all vugs. In fact, some central masses of granular quartz with greatest dimensions of less than about 20 mm. have no massive chalcedonic cores. Apparently exceptional is one specimen with a large (greatest dimension of ca. 90 mm.) core which has a direct junction with the surrounding dolomite. The granular quartz consists of angular, irregular-shaped grains and crystals (!!?!), nearly all of which pass .062 mm. mesh screen and many of which pass .044 mm. mesh screen. A mass of light blue celestite was found spatially associated with the calciostrontianite in one vug. Also, it is perhaps of at least passing interest that numerous, nearly colorless tabular celestite crystals that range up to eight millimeters in longest dimension were found to occur in three, calciostrontianite-free, calcite-lined vugs (—within dolomite which is more massive than typical, *i.e.*, it is essentially nonlaminated). No granular quartz or chalcedony occurred in these three vugs.

Relationships observed suggest that the vugs occupy space which was occupied by some material other than dolomite, perhaps silica, at the time of the original sedimentation. The paragenetic sequence of the minerals in the vugs, if listed from oldest to youngest on the basis of position with respect to the vug walls, would be calcite, light blue celestite, calciostrontianite, and silica. (As mentioned, the nearly colorless celestite appears to be postcalcite but no interrelationships have been observed between it and the other vug minerals.) However, it appears that this apparent sequence possibly needs to be modified at least so far as the silica is concerned. It seems likely that the silica was not introduced into the vugs after the other minerals but, instead, that it may be residual and derived from silica that previously filled the present vug space. If such silica was a gel and/or calcareous-rich or something similar the lack of enough silica to fill the vugs completely at present might reflect such things as loss of water, loss and/or redistribution of calcareous and/or other material(s) or removal of part of such material(s) during passage of the solutions which, if ever existent, may have been responsible for deposition of the carbonates and/or sulfates. In any case, the granular quartz and massive chalcedony may represent diverse modifi-

cations of a common parent. Observable interrelationships between vug boundaries and adjacent surrounding dolomite laminae appear to support removal or partial removal of the pre-existing filling material(s) after consolidation of the sediment, *i.e.*, deposition of the original filling material(s) was at the sediment-water interface. Otherwise, this aspect remains unsolved.

The following data, except where noted otherwise, were derived from investigation of the Pulaski County calciostrontianite.

1. *X-Ray:* Powder data are presented for calciostrontianite with 8.1 per cent CaO (Table 1). These data are presented despite the fact that they are, to a large extent, repetition of those of Pharr and Mitchell (*op. cit.*) because of the difference in methods used in their and V.P.I.'s laboratories.* The spacings for the calciostrontianite, *e.g.*, 4.34, 3.51, 3.41, 2.54, 2.43, and 2.04, when compared to equivalent reflections of essentially calcium-free strontianite (see Swanson, Fuyat, and Urginic)—4.37, 3.54, 3.45, 2.55, 2.45, and 2.05, respectively—appear to reflect the substitution of smaller radius calcium for some of the larger radius strontium. The Rockingham County material gave d values and relative intensities nearly identical to those given on Table 1 except that the 4.17d reflection was not apparent.

TABLE I. X-RAY POWDER DATA FOR CALCIOSTRONTIANITE FROM
PULASKI COUNTY, VIRGINIA

d (Å)	I	d(Å)	I
4.34	w	1.885	m
4.17	vvw	1.81	m
3.51	vvs	1.80	mw
3.41	vs	1.75	vvw
2.98	w	1.705	vvw
2.815	w	1.66	vw
2.58	vw	1.60	mw
2.54	s	1.55	mw
2.46	m	1.53	vw
2.43	vs	1.49	vvw
2.25	vw	1.47	vvw
2.165	m	1.44	vw
2.075	vw	1.41	vvw
2.04	s	1.30	vw
1.96	m	1.27	mw
1.935	mw	(75 degrees 2θ, end of scan)	

* The x-ray setup used by the writer is a General Electric XRD-5 diffractometer with a No. 2SPG geiger counter type spectrogoniometer. CuKα radiation with a Ni filter was used. A scanning speed of 2 degrees 2θ/min. was used for the complete scan; the lowest 2θ reflection ($d=4.34$) and the three strong reflections with d values of 3.51, 3.41, and 2.04 were checked at a scanning speed of 1 degree 2θ/5 mins.

2. *Optical:*

$$\text{Indices of refraction—}\alpha\text{—}1.522$$
$$\beta\text{—}1.663 \text{ (calc.)}$$
$$\gamma\text{—}1.664$$

Biaxial $(-)$

$2V = 8°$

Slight dispersion with $r < v$.

3. *Chemical:*

$\text{CaO} = 8.1$ per cent* (equivalent to ca. 14.5 per cent CaCO_3).

4. *Thermal:* An exemplary differential thermal analysis curve for pure calciostrontianite is presented (Fig. 2). The heating curve is marked by two sharp endothermic reactions and the cooling curve has two exothermic reactions. The lower temperature endothermic reaction has been found to occur at ca. 860° C. in all runs; the higher temperature endothermic reaction has been found to peak at 925° C. in all runs except one in which the tem-
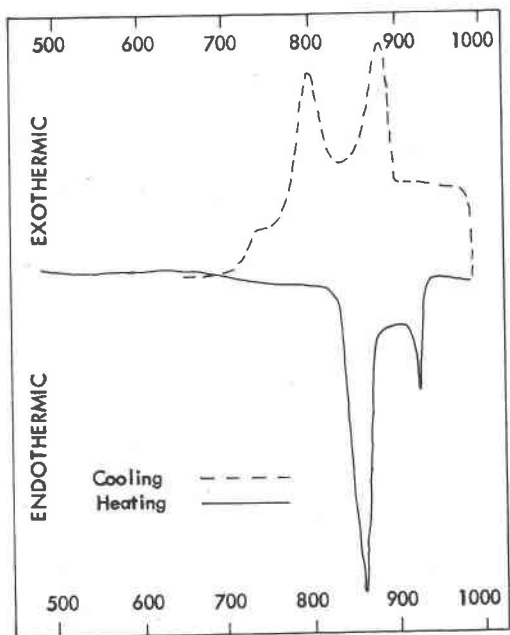

Fig. 2. Tracing of thermal (D.T.A.) curve of calciostrontianite from Pulaski County, Virginia. Curve between room temperature and 500° C. was essentially straight.

perature was 915° C. In all cooling runs, both exothermic reversals occurred at lower temperatures than the complementary endothermic reactions of the heating runs. The higher temperature exothermic reversal occurred at ca. 875° C. in all runs except one in which the temperature was 840° C.; the lower temperature exothermic reversal occurred

* Analyst—Dr. J. W. Murray, Department of Chemistry, Virginia Polytechnic Institute; analyses by Beckman flame photometer with Aminco photomultiplier photometer.

at 790° C. to 795° C. in all runs. The relative peak areas (defined as suggested by Webb and Heystek, p. 352) were remarkably similar in all runs with that of the lower endothermic reaction about 7.5 times that of the higher, that of the higher exothermic reversal about 2 times that of the lower temperature one, etc. In all runs, the conductivity of the material existent between the two endothermic peaks appears to be notably different from the conductivities of the phases existent originally and after the second reaction.

On the basis of the purity of the samples used and the reversibility of both endothermic reactions, as shown by the cooling curve, the writer believes that both reactions reflect inversions—probably from orthorhombic to hexagonal and thence to isometric forms of calciostrontianite. This suggestion is made with complete awareness of the fact that both Cuthbert and Rowland (1947) and Gruver (1950) suggested similar curves for strontianite to reflect only the orthorhombic to hexagonal inversion (one peak) and some reaction involving impurities (other peak). Apparently neither of these reported investigations included the running of cooling curves. The cooling curves plus determination that the material existent at the end of each run is identical to the original material appear to support best the suggested two-inversions interpretation. Permissively corroborative is the fact that differential thermal analyses of structurally similar witherite manifest two such inversions (see, for example, Cuthbert and Rowland; Gruver; and Webb and Heystek—all *op. cit.*).

5. *Miscellaneous:*

> Density—3.67 ± 0.02
> Fluorescence—white to yellowish (long wave)
> white (short wave).

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