THE STAUROLITE AREA OF PATRICK AND HENRY COUNTIES, VIRGINIA*

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Staurolites from Patrick County have attracted considerable attention for many years because of their tendency towards a cruciform type of twinning, and their use as watch charms and pendants for necklaces. A brief description of their location, mode of occurrence and uses, as well as of the artificial crosses has been recently given.[1]

The writer made field studies in the above named counties during the summer of 1936, mapping the extent of the staurolite-bearing and associated rocks, and followed this during the past fall and winter with a study of thin sections. This brief description gives the results of study on a region of Virginia which has received comparatively little attention up to the present time.

Staurolites occur intermittently in a rather narrow area, which extends from four miles below Stuart to Appomattox Court House. This paper will be confined to a description of the region occurring in Patrick and Henry Counties from which most of the collections have been made. Within this area there are two excellent collecting localities. One of them is at the southwestern extremity of the larger staurolite lens, located on state highway No. 631, four miles southwest of Stuart. The staurolite crystals here, while of the largest size observed within this area, occur embedded in the rock (see Fig. 1). The other locality for collecting is at the northeastern extremity of the same lens, on the border of Patrick and Henry Counties, twenty miles by road northeast of Stuart, or thirteen miles by air line. In this last named locality there is an abundance of loose crystals lying upon the surface.

The staurolites in these two counties occur in two belts approximately parallel to each other. One belt begins at a point four miles southwest of Stuart, and extends approximately in a N. 50° E. direction for a distance of nineteen miles. The other belt begins at a point nine miles northeast of Stuart, and one-half mile southeast of the first belt, and extends to and beyond the Franklin County line. Both belts are roughly lenticular in shape and have a maximum width of two and one-half miles.

The three principal rocks associated with the staurolites are a biotite chlorite schist, a sericite staurolite schist, and an iron stained quartz

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[1] Roberts, Joseph K., Virginia staurolites as gems: *Am. Mineral.*, vol. **19**, pp. 549–552, 1934.

mica schist. The rocks form a portion of the Wissahickon formation where the Martic overthrust block over-rides the Lynchburg gneiss. They form a sharp contact with the Lynchburg gneiss along their northwestern boundary and grade into less metamorphosed Wissahickon on the southeast. These rocks appear to be products of retrogressive metamorphism and may be termed phyllonites.

The staurolite crystals occur as reddish brown idioblasts, one tenth of an inch up to one and one-half inches in length, in each of the three rock types, and are altered wholly or in part to sericite and chlorite. They contain numerous inclusions of small garnets, which weather out giving the appearance of pits in the staurolite crystals. The staurolites seem to be most numerous at the ends of the lenticular belts.

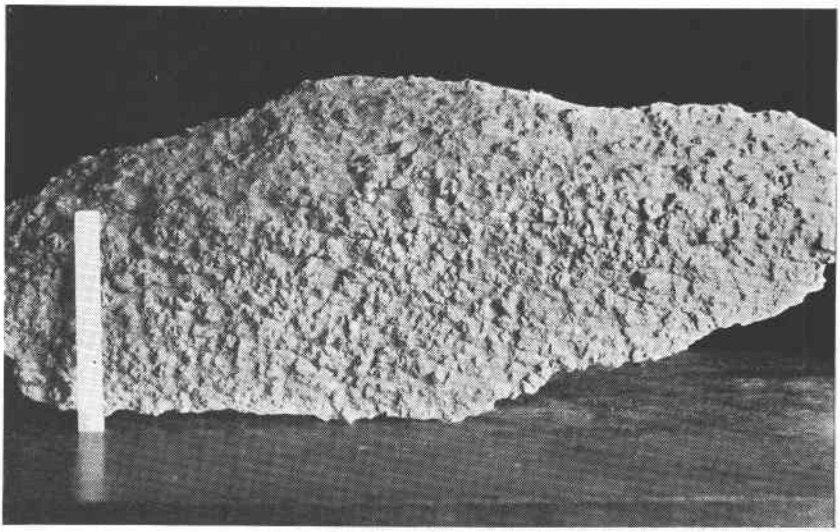

FIG. 1. View of a slab of sericite schist, showing staurolite crystals. Scale of 6 inches to left.

The staurolites are generally twinned, although not a few occur as simple crystals with usually only a prism and basal pinacoid developed. Occasionally other crystal forms appear, particularly macro- and brachypinacoids and domes. No bipyramids were observed. Penetration twins according to two laws are common, yielding X-shaped and cross- or plus-shaped twins. A careful study of many crystals has shown that 75% are twinned according to the first law. In this type of twinning, the twin plane $Z(232)$ crosses at angles varying from 35 to 60 degrees. The greater number are nearer the latter figure. Many of them show multiple twinning, a given crystal being penetrated by two or more crystals. Aggregates containing a number of the X-shaped twins, as well as simple crystals, are of frequent occurrence.

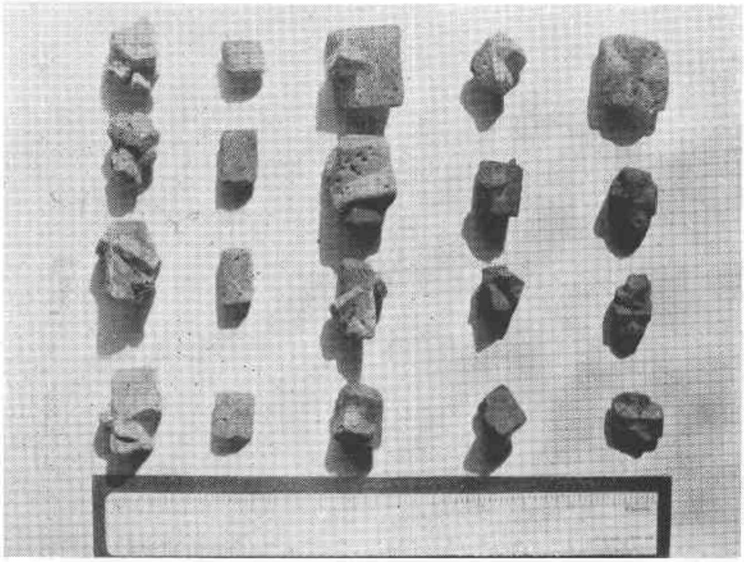

FIG. 2. Various types of staurolites found in Henry and Patrick Counties, Va., showing single crystals, aggregates, X-shaped and +-shaped twins.

Cruciform crystals crossing nearly at right angles make up less than 5% of the total number observed. Excellent specimens are relatively rare. Here the twin plane is generally referred to as {032}. The crystal forms observed on twins of this type, as well as those on the X-shaped twins, are the same as those occurring on the simple crystals.

The staurolites are greenish gray to reddish brown in color. Much of the brown and red colors result from limonite stains. The brown color observed in crystals on the market is not characteristic of the natural crystal. Many, no doubt, have been artificially colored. Practically all specimens show numerous pits which have resulted from the dropping out of inclusions. Where these inclusions are still present they are usually garnets. The greenish color can be traced to the alteration products, chlorite and sericite, as is shown under the microscope.

A study of thirteen thin sections of staurolite has revealed the following microscopic features: cleavage varies from weak to strong, dependent upon the degree of alteration and number of inclusions. The direction of cleavage is parallel to {010}. The crystals exhibit a marked pleochroism, the color being orange yellow in the fresher specimens and grading down to pale yellow in the more altered ones. The direction of slowest vibration is parallel to the *c* axis, and the character of the pleochroism may be indicated as follows: Along the *c* axis, light yellow or orange yellow; parallel to the *a* and *b* axes, colorless or pale yellow. The optic sign of the mineral is positive.

All the sections of crystals from Patrick and Henry Counties contain inclusions of such quantity that they compose approximately 50% of the total mass. They are, in order of abundance, quartz, garnet, graphite (?), muscovite, biotite, tourmaline, and magnetite.

The small anhedral grains of quartz (average size less than 0.1 mm. in diameter) are by far the most numerous of the inclusions. In places they almost obliterate the staurolite by their abundance. Garnet (almandite) crystals, usually broken, vary from 0.2 to 1.5 mm. in diameter. The garnets in turn contain inclusions of quartz, muscovite, and a black opaque material. This ragged, black, opaque material, in the form of needles, varies up to 0.3 mm. in length and is of approximately parallel orientation; it is abundant in all thin sections. These needles were tentatively identified as graphite. Penfield and Pratt[2] have shown that the regularly arranged opaque material in the staurolites from Lisbon, New Hampshire, is carbonaceous material. Muscovite occurs sparingly in small plates around the edges of the staurolite crystals, and occasionally as small needles oriented at random through the crystals. On the other hand, the few plates of biotite observed were always within the staurolite. Tourmaline is quite abundant as an accessory mineral, occurring in small pleochroic crystals. Magnetite is scattered throughout the slides in masses of irregular shape and size.

Twinning is to be observed in nine of the thirteen slides examined. In only a few cases could the twinning be recognized in thin sections without crossed nicols. The majority of the sections of the mineral were cut parallel to *c* axis on one crystal, and perpendicular to *c* on the penetrating crystal, so in the unaltered twins, the difference in the degree of pleochroism makes recognition possible. Contrary to the assumption suggested by the megascopic appearance, not one of the twins examined microscopically showed one crystal penetrating entirely through the other. It appears, after a cursory examination, as though each side of the penetrating crystal were a separate entity, because their terminations inside the penetrated crystal are always wedge-shaped, and in most cases stop

[2] Penfield, S. L. and Pratt, J. H., On the chemical composition of staurolite and the regular arrangement of its carbonaceous inclusions: *Am. Jour. Sci.*, vol. **47,** pp. 81–89. 1894.

short of the center of the other crystal. In only one instance were the two wedges pointing directly towards each other (see Fig. 3). Nevertheless, careful megascopic examinations show such a genetic relationship between the two sides of the penetrating crystal as to preclude the possibility of it being two separate entities. The penetrating and penetrated crystals probably grew simultaneously, and since the penetrated one is usually the larger, it may have absorbed that part of the other which

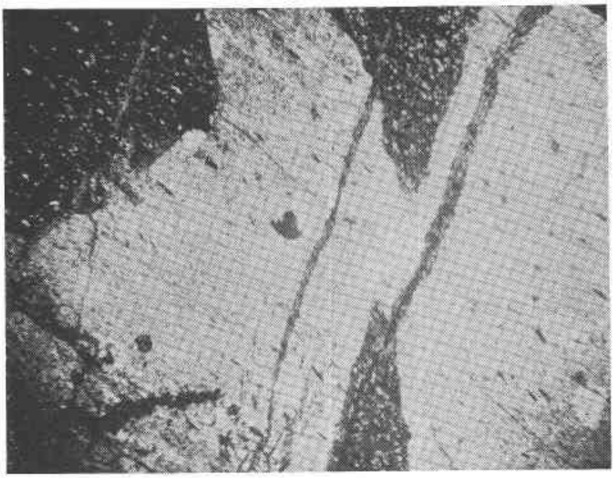

FIG. 3. View showing penetration twins in a staurolite crystal, where points are approximately diametrically opposed. X-Nicols, ×20 diameters.

was within its boundaries and used the material to further its own growth. Another possibility is that the twin in some cases may not have been cut directly through the center. This would expose only the top of the penetrating crystal, provided the section was cut parallel to the *c* axis of both crystals. This would give the wedge-shaped appearance. However, since the majority of the slides used were cut parallel to the *c* axis of one crystal and normal to the *c* axis of the other, if the penetrating crystal extended entirely through the other, it certainly would have been observed.

The staurolites are almost universally altered. In many cases the alteration is complete, the former existence of the individual is indicated only by its crystallographic outline. The alteration products are sericite, chlorite, and limonite. The alteration to sericite generally begins along fractures and cleavage planes and works outwards, until in some cases, the entire crystal is involved. In many of the intermediate stages a crisscross pattern results from alteration along intersecting planes. The size of the individual flakes of sericite vary, being larger in the middle of the altered areas and decreasing in size outwards. These altered areas of sericite are usually stained with limonite. Limonite also occurs as alteration rims around most of the garnets.

The alteration of staurolite to chlorite, while not as abundant as its alteration to sericite, is not infrequent. The variety is usually pennine,

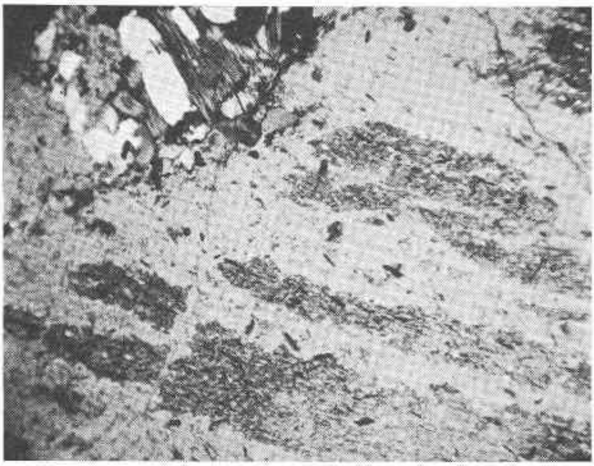

FIG. 4. Staurolite showing characteristically weathered condition, light areas are sericite and dark areas are staurolite remnants. X-Nicols, ×20 Diameters.

although sometimes clinochlore is present. Various stages of alteration can be recognized by the pale yellow color of the staurolite, and the light green color of the pennine. In some cases the alteration to pennine is complete with only the crystallographic outline of the staurolite remaining. Chlorite also occurs as an alteration product of garnet and biotite. Some of the chlorite exhibits pleochroic halos around inclusions of quartz. It appears as though this quartz is also secondary, having filled spaces formerly occupied by some other radio-active mineral. In other instances quartz fills spaces originally occupied by garnets.

There is evidence from the biotite-staurolite-garnet association that the rocks were formed under conditions of static or load metamorphism in the mesozone of von Grubenmann, and the amphibolite facies of Eskola. The great number of inclusions of quartz, biotite, muscovite, garnet, tourmaline, and zircon in the staurolite indicates that it was one of the last minerals to form. Krishman[3] finds in an occurrence of stauro-

[3] Krishman, M. S., On the occurrence and distribution of staurolite in Gangpur State, Bilear and Orissa, India: *Indian Sci. Congr.*, 20th (Patna), p. 345, **1933**.

lite in India that the largest and best formed crystals occur in close proximity to igneous injections, and further, that basic sills exert more influence than granitic bosses. He believes that although injections did not contribute any material, they have been of help by increasing the mobility of the molecules during metamorphism by increasing the temperature.

It is of particular significance that to the writer's knowledge, in all reports of diapthoritic areas accompanying major overthrusts, mention is made of staurolite. The staurolites of India as well as those in Patrick and Henry Counties, Virginia, occur in such an area. The sericite-chlorite association, characteristic of the epizone of von Grubenmann, and the green schist facies of Eskola of rocks that still contain some of the mineral characteristics of the mesozone is highly indicative of retrogressive metamorphism. It appears as though the larger staurolitic areas are, in the majority of cases, exposed only by overthrusts. Of significance also is the highly altered condition of staurolite when exposed in this manner. A comparison of staurolite from Patrick and Henry belts with specimens from an isolated occurrence to the west, near Galax, Virginia, collected by Dr. W. T. Schaller of the U. S. Geological Survey, showed the former to be so much more altered and to have incorporated so much more foreign material that thin sections of the weathered and fresh staurolite in thin sections could very easily be mistaken for two different minerals. Dr. Schaller kindly gave some of the fresh staurolites to the writer for comparison with specimens from Patrick and Henry Counties. Evidently the fault plane of the Martic overthrust block allowed free passage for ascending hot waters. All of the rocks in proximity to the fault plane, as well as the staurolites themselves, show mineral associations highly suggestive of hydrothermal alteration. The presence of epidotized meta-gabbro dikes, pyrite, limonite, sericite, chlorite, secondary quartz, and the universal alteration of the staurolite are all indications of this condition.