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PARAGONITE PSEUDOMORPHS AFTER KYANITE FROM TURKEY HEAVEN MOUNTAIN, CLEBURNE COUNTY, ALABAMA[1]

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ABSTRACT

Paragonite pseudomorphs after kyanite have been found in the Turkey Heaven Mountain kyanite prospects. The pseudomorphs range in size from microscopic grains to megascopic prisms, which resemble andalusite crystals. Optical, *x*-ray and petrographic studies indicate direct hysterogenic paragonite alteration of the kyanite.

INTRODUCTION

An investigation of kyanite prospects in Sections 22 and 29, T. 17 S., R. 11 E., at Turkey Heaven Mountain, Cleburne County, Alabama, disclosed a unique mineral occurrence. The mineral assemblage includes hysterogenic paragonite pseudomorphs after kyanite, which resemble andalusite. The genetic physicochemical parameters are considered as a function of retrograde metamorphism within a restrictive water environment.

GEOLOGIC SETTING

The Turkey Heaven Mountain area is underlain by two metamorphic rock units: 1) the Wedowee Formation, a highly resistant graphite-mica schist, and 2) a unit of the Ashland Mica Schist, an extensively weathered garnet-muscovite schist. Fresh rock exposures indicate a retrograde metamorphic cycle from an almandine-amphibolite facies to a greenschist facies.

At the crest of Turkey Heaven Mountain, the Wedowee Formation over-lies the Ashland Mica Schist. The resistant graphite-mica schist of the Wedowee Formation and associated quartz veins contribute to the physiographic configuration of the area.

The general regional strike in the Alabama crystalline belt is about N. 45° E., and the dip is generally southeast. The crystalline area has undergone primary deformation from the stresses applied generally from the southeast, which produced isoclinal folding and thrust faulting to the northwest. Geologic studies at Turkey Heaven Mountain indicate a second period of deformation in which the stress direction can be expressed as a northeast shear couple that formed nonplanar, non-cylindrical left lateral drag folds. Accompanying shear planes parallel the schistosity of the first deformation.

[1] Publication authorized by the State Geologist, Geological Survey of Alabama.

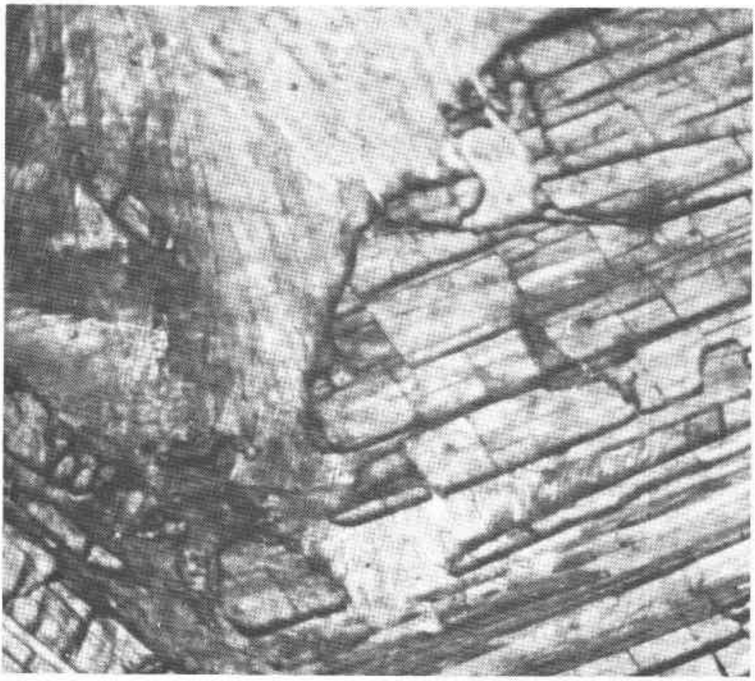

FIG. 1. Photomicrograph showing paragonization of kyanite crystals along (010) cleavage planes (×56).

The kyanite zone follows the sigmoidal drag fold configuration of the secondary deformation, and is restricted to the fracture and shear zones that subparallel the schistosity. The quartz-kyanite veins dip steeply to the southeast and transect the schistosity. The veins are prominent along the central and southern part of the Mountain where they are localized in close proximity to the Wedowee-Ashland contact.

Crystalloblasts and thin blades of kyanite are oriented parallel to the schistosity. They are found on the west and southwest side of the Mountain in the Ashland Mica Schist immediately under the Wedowee-Ashland contact. Away from the Wedowee-Ashland contact the size and regularity of the kyanite veins and abundance of crystalloblasts rapidly diminish.

Retrogressive alteration of the kyanite to paragonite is most pronounced where the greatest secondary deformation is observed. Near the hinge of the horizontal drag fold, paragonization of the kyanite is nearly complete. At the crest of the fold, kyanite, paragonite, and quartz veins are not present. Toward the flanks of the fold paragonization decreases and the ratio of unaltered kyanite to paragonite increases.

The paragonite pseudomorphs range in size from microscopic scales suggestive of sericite, to elongate, oblate prisms 8 to 10 inches long, chiefly elliptical in cross section. The pseudomorphs resemble andalusite instead of the parent polymorph kyanite. The individual paragonite prisms are composed of massive, randomly-oriented laminar plates of scales. The pseudomorphs occur individually in a ground mass of granular to coarsely crystalline quartz and as contiguous growths on kyanite aggregate. Other minerals identified include rutile, muscovite, and amorphous masses of pyrolusite. Graphite inclusions and coatings were observed on pseuomorphs adjacent to the Wedowee Formation.

Experimental Procedure and Results

The physical properties of the paragonite pseudomorphs, in hand specimens, are: blue-gray to greenish-gray interior color; vitreous to pearly luster with an exterior golden or blue sheen; fine granular texture and sometimes laminar plates or microscopic mica books; hardness 2.5: and specific gravity $2.85 \pm .05$.

Optical properties were determined on crystal grains microscopically sorted and selected from separated materials. Sink-float was used to separate the unaltered kyanite and occluded rutle grains from the mica and the mica from the quartz. The mica minerals were washed and dried and carefully hand picked under the microscope for oil-immersion study. Optical data (sodium light) are as follows:

$(-)$ 2V	*ca.* 40°
α	1.586
β	1.598
γ	1.606
$\gamma-\alpha$	.020

These data are in close agreement with McCormick (1934) in his study of paragonite from the type locality, Pizzo Forno, Ticino, Switzerland.

X-ray powder diffraction determinations, by the U. S. Bureau of Mines, Tuscaloosa, Alabama, confirmed the paragonite. Diffraction patterns (2°/min) were made on both oriented and randomly prepared slides using a General Electric XRD-3 diffraction unit with Cu$K\alpha$ radiation. Double diffraction peaks were resolved by slow scanning (.2°/min) into paragonite and muscovite peaks. The diffraction values for the basal spacing of the two micas are indexed on the $(002)_{2M}$ lines. Values for the $d(002)_{2M}$ lines, based on the (004), (006), and (008) lines were calculated and compared. *X*-ray diffraction values for material taken from different pseudomorphs are shown in Table 1.

Petrographic examination of a sequence of thin sections cut normal to the c-axis of the relict kyanite blades, indicates that the kyanite alters to paragonite without intermediate compounds. The paragonite forms with

TABLE 1. $d(002)_{2M}$ DATA ON COEXISTENT PARAGONITE AND MUSCOVITE OCCURRING IN PSEUDOMORPHS AFTER KYANITE FROM TURKEY HEAVEN MOUNTAIN, CLEBURNE COUNTY, ALABAMA[1]

Sample No.	Muscovite Å	Paragonite Å	Difference	Remarks[2]
1	10.03	9.710	.32	Oriented by sedimentation slow scan[3]
2	9.96	9.680	.28	Random packed slow scan[3]
3	10.042	9.662	.380	Random packed
4	10.014	9.688	.326	Random packed
5	9.986	9.662	.324	Random packed
6	10.014	9.688	.326	Oriented by sedimentation
7	10.014	9.688	.326	Random packed
8	9.986	9.688	.298	Oriented by sedimentation

[1] Data concur favorably with Zen and Albee (1964), in their study of paragonite as a thermal indicator of greenschist facies in pelitic schist.
[2] All diffraction patterns, except as noted, run at 2 degrees per minute.
[3] Slow scan at .2°/min.

a spherulitic texture having a sericitic appearance confined to the relict kyanite form and designated *paragonization* by Killig (1913). Alteration of kyanite to paragonite starts at one or both ends of the kyanite crystal and progresses toward the center of the crystal along cleavage planes. The kyanite is microscopically poikiloblastic with anhedral rutile crystals. Little quartz occurs in the kyanite or paragonite pseudomorphs.

GENETIC INTERPRETATION

General physicochemical conditions leading to the formation and decomposition of kyanite have been discussed by Roy and Osborn (1954), Kennedy (1955), Clarke *et al.* (1957), and Osborn (1957). The kyanite at Turkey Heaven Mountain is believed to have formed under two sets of physicochemical conditions. The formation of kyanite under stress conditions is indicated by the presence of strained kyanite crystals oriented parallel to the folded schistosity surfaces of the Ashland Mica Schist. Deposition of kyanite from hydrothermal solutions is indicated by (1) large porphyroblasts and irregular masses of kyanite occurring randomly in the host rock, and (2) the occurrence of kyanite in a prominent quartz-kyanite vein. The major source of the kyanite, therefore, is believed to have been from hydrothermal solutions derived by regional metamorphic differentiation contemporaneous with the waning phases of retrograde metamorphism (Neathery, 1964).

Of particular interest to the genesis of the Turkey Heaven Mountain paragonite is the stability field of the kyanite-paragonite association. Equilibrium relationships in the low soda part of the system Na_2O+ $Al_2O_3 \cdot SiO_2 \cdot H_2O$ were investigated by Sand *et al.* (1957), over the temperature range 290° C. to 700° C. under pressures up to 30,000 psi with restricted water. The mineral assemblage at Turkey Heaven Mountain closely conforms to their three-crystalline-phase assemblage 580° C. to 625° C. at 15,000 psi in which quartz and paragonite exist with kyanite available as a transitional phase.

Subsequent to the major kyanite emplacement, structural deformation altered the parameters of the existing physicochemical system in which kyanite and quartz were original stable phases. Shearing stresses resulting from local rotational deformation produced the necessary grinding and temperature rise to convert the kyanite (Kennedy, 1955), in the presence of minor amounts of sodic plagioclase, to the sodium mica, paragonite. Since the stability field of the paragonite is adjacent to the kyanite polymorph andalusite, hysterogenic alteration of the kyanite produced a paragonite pseudomorph resembling the lower pressure, lower temperature alumino-silicate polymorph—andalusite. Zen (1960), and Francis (1956) also suggest that paragonite instead of kaolinite tends to be a high grade transient form when water is restricted.

Hietanen (1956) concluded that kyanite, stable under stress conditions, either shearing or hydrostatic, would be subject to inversion to the low pressure polymorph, andalusite, under the influence of metasomatic solutions when stresses are released. At Turkey Heaven Mountain the kyanite inverted to paragonite when rotational deformation partially released the stress in the presence of restricted water. The absence of andalusite implies only partial stress release under conditions of high water pressure. Had the stress been totally released, the kyanite would have inverted to andalusite, paragonite, and muscovite instead of kyanite and paragonite. The absence of other members of the system $Na_2+Al_2O_3 \cdot SiO_2 \cdot H_2O$ implies a high temperature phase comparable to that of Sand, Roy, and Osborn (1957). The physicochemical parameters of the mineral system at Turkey Heaven Mountain are stabilized on the transitional boundary between paragonite and kyanite.

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