SAPPHIRINE OCCURRENCE OF CORTLANDT, NEW YORK

GERALD M. FRIEDMAN, *University of Cincinnati, Cincinnati, Ohio.*

ABSTRACT

Some of the properties of sapphirine are discussed. The sapphirine of Cortlandt has two modes of occurrence. One occurrence is in emery close to quartz veins, where it was formed by replacement of the spinel which is abundant in the emery. It also occurs in the cordierite-sillimanite hornfels close to the border of the Cortlandt norite, where in the process of deuteric alteration of the norite, magnesium-iron and aluminum oxides passed into the hornfels where they reacted with the silica of the schist to form the sapphirine.

INTRODUCTION

Sapphirine is a rare mineral. From the literature it appears that only nine occurrences of sapphirine have so far been reported.[1] Of these one has been recorded in the United States, which is the occurrence described in this paper. A study of the properties and origin of the American sapphirine, therefore, merits particular interest.

The author is indebted to Mr. Walter Maguire for the analysis of the sapphirine-bearing rock, also to Mr. and Mrs. Palmiotto and Mr. Joe De Luca for permission and encouragement to study the rocks on their respective mining properties.

LOCATION AND GEOLOGICAL SETTING

The sapphirine occurrence is in Cortlandt Township, Westchester County, New York, located to the south and southeast of the town of Peekskill, about 35 miles north of New York City. The mineral occurs in the emery and cordierite-sillimanite hornfels of Emery Hill, Montrose, and on the west, southwest and south slopes of Salt Hill. Samples containing the mineral were obtained from the De Luca quarry at Emery Hill, from an abandoned quarry in Dutch Road, Montrose, from the Kingston mine in Colabaugh Road and from the emery and cordierite-sillimanite hornfels of the western and southwestern part of Salt Hill.

The igneous rocks of Cortlandt Township include peridotites, pyroxenites, norites, and diorites. These are intrusive into Manhattan schist, a strongly foliated quartz-mica schist. Emery deposits occur in the norite, usually close to its border with the schist. The schist where it directly adjoins the norite was subjected to thermal metamorphism and converted into a cordierite-sillimanite hornfels. Sapphirine occurs in both the emery and hornfels.

[1] Palache, C., Berman, H., and Frondel, C., System of mineralogy: 7 ed., **1**, 724–726, John Wiley & Sons, New York (1946).

The emery is essentially composed of spinel, titaniferous magnetite and corundum. The relative proportions of these minerals vary widely. Some samples are largely made up of spinel and magnetite, others contain a high percentage of corundum and only a little spinel. Abundant quartz veins cut the emery. Garnet, sillimanite, cordierite, and sapphirine formed reaction rims around the quartz veins.

The hornfels, largely made up of cordierite and sillimanite, also contains abundant magnetite. Sapphirine occurs in this rock where it is close to the border of the norite.

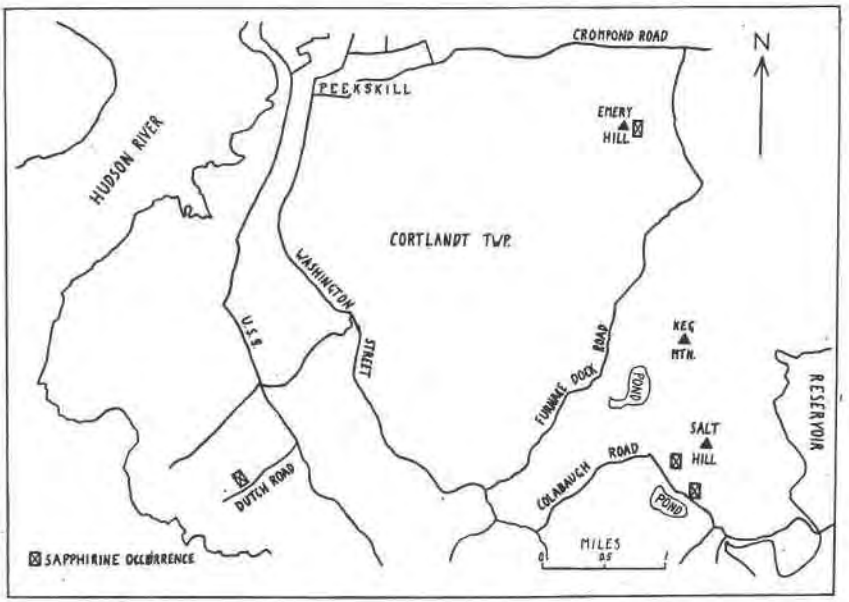

FIG. 1. Index map of Cortlandt Township, Westchester County, New York, showing location of sapphirine occurrences.

PROPERTIES

The sapphirine occurs in the form of small black grains. These vary widely in dimensions, the largest crystals range up to about 1.3 mm. in length and 0.5 to 0.7 mm. in width, the smallest ones are about 0.08 mm. in length and 0.04 mm. in width. Sapphirine crystals which are interspersed between sillimanite blades show extreme elongation, some of the crystals measured were 2.5 mm. in length and about 0.2 mm. and even less in width. Most of the sapphirine crystals are anhedral, some are euhedral to subhedral.

Many sapphirine crystals are studded with opaque inclusions, some

of these are aligned to form parallel rods, others are unoriented. The mineral forming these inclusions appears to be magnetite.

Sapphirine is biaxial negative. Pleochroism is rather strong. α or X, yellowish-green, but varies slightly and may be pink; β or Y, light blue; γ or Z, moderate blue. Absorption $X < Y < Z$. Sections cut normal to a exhibit anomalous interference colors (grayish purple). Occasional crystals cut in other directions likewise show these colors.

Sections parallel to (100) show occasional polysynthetic twinning. {010} = twin plane; b is probably the twin axis. The presence of polysynthetic twinning in sapphirine has previously been reported from two foreign occurrences,[2] but details as to orientation were lacking. A possible second type of polysynthetic twinning with {100} as the twin plane was noted. Contact twins are abundant. This type of twinning has not been previously reported in sapphirine. Contact twinning is observable in plane polarized light because of the strong pleochroism of the mineral.

Cleavage parallel to {010} was noted but is not very distinct.

Occurrence in Emery

Sapphirine is not a primary mineral. It occurs only in emery that was cut by later quartz veins. Two modes of occurrence were noted. In one, the quartz veins are surrounded by reaction rims of garnet which in turn are followed by sillimanite layers which partly overlap the garnet; some sillimanite needles also occur in the quartz. The sapphirine crystals form an outer zone around the quartz veins and are interspersed with spinel grains. In the second type of occurrence, cordierite surrounds the quartz veins and is followed by sillimanite and sapphirine, the latter is in places interspersed with spinel grains.

Occurrence in Cordierite-Sillimanite Hornfels

The cordierite-sillimanite hornfels in Cortlandt Township is the "emery" of the quarrymen and the material that is commercially extracted. The most prominent occurrence of sapphirine in this rock is in the Kingston mine. The mine is bounded on the north by norite. Close to the norite wall the hornfels is largely composed of sillimanite, sapphirine, cordierite, and magnetite. Spinel relics occasionally abound. The sapphirine occurrence, however, is limited to a narrow zone close to the norite wall, beyond this zone sapphirine was not detected. Cordierite is more abundant, sillimanite and magnetite are less common at a greater distance from the norite wall. Spinel relics were noted only close to the norite border.

[2] Palache, C., Berman, H., and Frondel, C., *op. cit.* (1946).

In the De Luca mine of Emery Hill sapphirine is likewise associated with sillimanite, magnetite, and cordierite. Spinel relics were also noted. The composition of the rock in which the sapphirine of Emery Hill occurs is as follows:[1]

	Per cent
SiO_2	16.35
Al_2O_3	53.12
Fe_2O_3	21.16
MgO	3.85
CaO	4.63
H_2O	0.46

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FIG. 2. Photomicrograph showing twins of sapphirine (centre of picture), untwinned sapphirine (at right and lower left), magnetite, cordierite (white), sillimanite (linear crystals in upper part of photograph), spinel (adjoining magnetite in upper part of photograph), and corundum (between magnetite grains in left). Plane polarized light. ×25.

ORIGIN

The sapphirine of Cortlandt Township is a replacement product of spinel. Spinel and quartz are incompatible. Where quartz veins cut emery a new suite of minerals formed resulting from the reactions between the spinel and quartz. These minerals include garnet, sillimanite, cordierite, and sapphirine. Quartz was nowhere observed to enclose or

[1] Walter Maguire, analyst.

adjoin spinel directly, nor did spinel enclose the quartz without the presence of a reaction rim.

The most conspicuous of the new suite of minerals is garnet which forms reaction rims up to $\frac{1}{2}$ inch thickness around quartz veins. Sillimanite likewise was formed in the reaction between spinel and quartz. It occurs as inclusions in quartz and garnet, forms an occasional zone between the garnet and spinel and is interstitial between the spinel grains. The following equation expresses the reaction involved:

$$\underset{\text{spinel}}{3(Mg, Fe)Al_2O_4} + \underset{\text{quartz}}{5SiO_2} = \underset{\text{garnet}}{(Mg, Fe)_3Al_2(SiO_4)_3} + \underset{\text{sillimanite}}{2Al_2SiO_5}.$$

Sapphirine likewise replaced spinel grains close to quartz veins and formed an outer zone around the latter. The sapphirine that replaced the spinel did not necessarily retain the latter's polygonal crystal pattern. Many sapphirine crystals replaced several spinel grains, thereby becoming somewhat elongated. Many spinel grains were only partially replaced. The reaction involved in the formation of sapphirine is represented by the following equation:

$$\underset{\text{spinel}}{15(Mg, Fe)(Al_2O_4)} + \underset{\text{corundum}}{2Al_2O_3} + \underset{\text{quartz}}{7SiO_2} = \underset{\text{sapphirine}}{(Mg, Fe)_{15}Al_{34}Si_7O_{80}}.$$

Cordierite also formed reaction rims around quartz veins. If cordierite occurs, garnet is not normally noted, but sapphirine is closely associated with the cordierite. The formation of cordierite can be expressed as follows:

$$\underset{\text{spinel}}{2(Mg, Fe)Al_2O_4} + 5SiO_2 = \underset{\text{cordierite}}{(Mg, Fe)_2Al_4Si_5O_{18}}.$$

The formation of the sapphirine occurring in cordierite-sillimanite hornfels is in principle similar to that noted near quartz veins in emery. It appears, however, to be earlier than the sapphirine occurring in the latter. As demonstrated by Shand,[2] the pyroxenes and feldspars of the norite gave rise to poikilitic hornblende at a post-pyrogenetic stage of alteration. Magnesium, iron, and aluminum oxides were produced in the same process that gave rise to the hornblende. Shand being concerned with the formation of the poikilitic hornblende in the norite formulated the following equation:

$$\underset{\text{diopside}}{Ca(Mg, Fe)Si_2O_6} + \underset{\text{anorthite}}{CaAl_2Si_2O_8} + \underset{\text{hypersthene}}{4(Mg, Fe)SiO_3} + H_2O$$
$$= \underset{\text{hornblende}}{Ca_2(Mg, Fe, Al)_5H_2Si_8O_{24}} + xAl_2O_3 + y(Mg, Fe)O.$$

[2] Shand, S. J., Phase petrology in the Cortlandt complex, New York: *Bull. Geol. Soc. America*, **53**, 417–418 (1942).

Some of the magnesium-iron oxides gave rise to spinels and were formed concurrently with the hornblende. Most of the oxides, however, were transported by the solutions to the border of the norite where the emery was formed. Magnesium-iron oxides and to a limited extent aluminum oxides that passed into the adjacent schist reacted with the quartz of the schist to give rise to sapphirine close to the norite wall. The ratio of magnesium-iron oxides to silica in the sapphirine molecule is about 2:1. Near the norite border the concentration of the basic oxides was relatively high and sapphirine formed. At a greater distance from the norite the magnesium-iron oxides reacted with the silica of the schist to form cordierite in which the proportions of the basic oxides to silica are 1:5. A study of the chemical composition of the hornfels indicates a decreasing magnesium and iron, and an increasing silica content with increasing distance from the norite.

Sapphirine has been described from Guinea, Canada, Greenland, Italy, Transvaal, Madagascar, and India. In almost all of these localities the mineral association is similar to that of Cortlandt. Spinel is almost invariably associated with the sapphirine, and other emery minerals such as corundum and magnetite were cited from several of the occurrences. Pyroxenes, notably orthorhombic pyroxenes, prominent at Cortlandt, have been reported from most of the localities. Sillimanite and cordierite likewise occur. As the mineral assemblages of the sapphirine occurrences are very similar it seems likely that their modes of origin may also be related.

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