

## NOTES AND NEWS

### ON THE DISTINCTION OF SILLIMANITE FROM MULLITE BY INFRA-RED TECHNIQUES

RUSTUM ROY AND E. E. FRANCIS, *School of Mineral Industries,  
The Pennsylvania State College, State College, Pa.*

The problem of distinguishing mullite from sillimanite has attracted the attention of several mineralogists. The extensive similarity in  $x$ -ray diffraction patterns and optical properties of sillimanite and mullite has been recognized ever since the original correction was made on the alumina-silica system by Bowen and Greig (1924). Recent attempts to distinguish between these phases has been largely dependent on  $x$ -ray methods (de Keyser, 1951, McAttee and Milligan, 1950). The optical properties of the material also may be used to distinguish between the two phases although some authors claim an overlap in these. A positive method available at the present time is through a study of the thermal properties of the material, since liquid appears in the sillimanite composition at  $1585^{\circ}$  as compared with  $1810^{\circ}$  C. for the mullite composition. None of these methods, however, is applicable where the material is very fine-grained and mixed with other phases. During studies of phase equilibria in the systems  $\text{Al}_2\text{O}_3\text{-SiO}_2\text{-H}_2\text{O}$  (1951) and  $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2\text{-H}_2\text{O}$  (1951), Roy, Roy and Osborn were unsuccessful in positively identifying any of the phases formed as being sillimanite, andalusite or kyanite. Recently andalusite has been reproducibly synthesized (Roy, 1953), stimulating interest in the identification of the phase which had been earlier identified as mullite in the absence of any positive evidence for sillimanite.

During the last two years papers describing the use of infra-red absorption spectra of mineral powders have been numerous and in two of these (Adler, 1950, Keller, 1952) spectra may be found for sillimanite and mullite. Although only single specimens were used, these spectra are different from each other, as noted by Adler (1950). We have therefore investigated this technique further as a possible rapid qualitative method of distinguishing sillimanite from mullite. If the differences are pronounced, it would also indicate the possible usefulness of infra-red techniques in distinguishing phases differing only slightly in structure.

A Perkin Elmer Model 12A instrument with a NaCl prism was used in this investigation. Sillimanite samples were chosen from various localities and mullite was also obtained by various methods as listed in Table 1. All the samples were checked optically and by  $x$ -ray powder patterns. The effect of both particle size and methods of preparation were taken

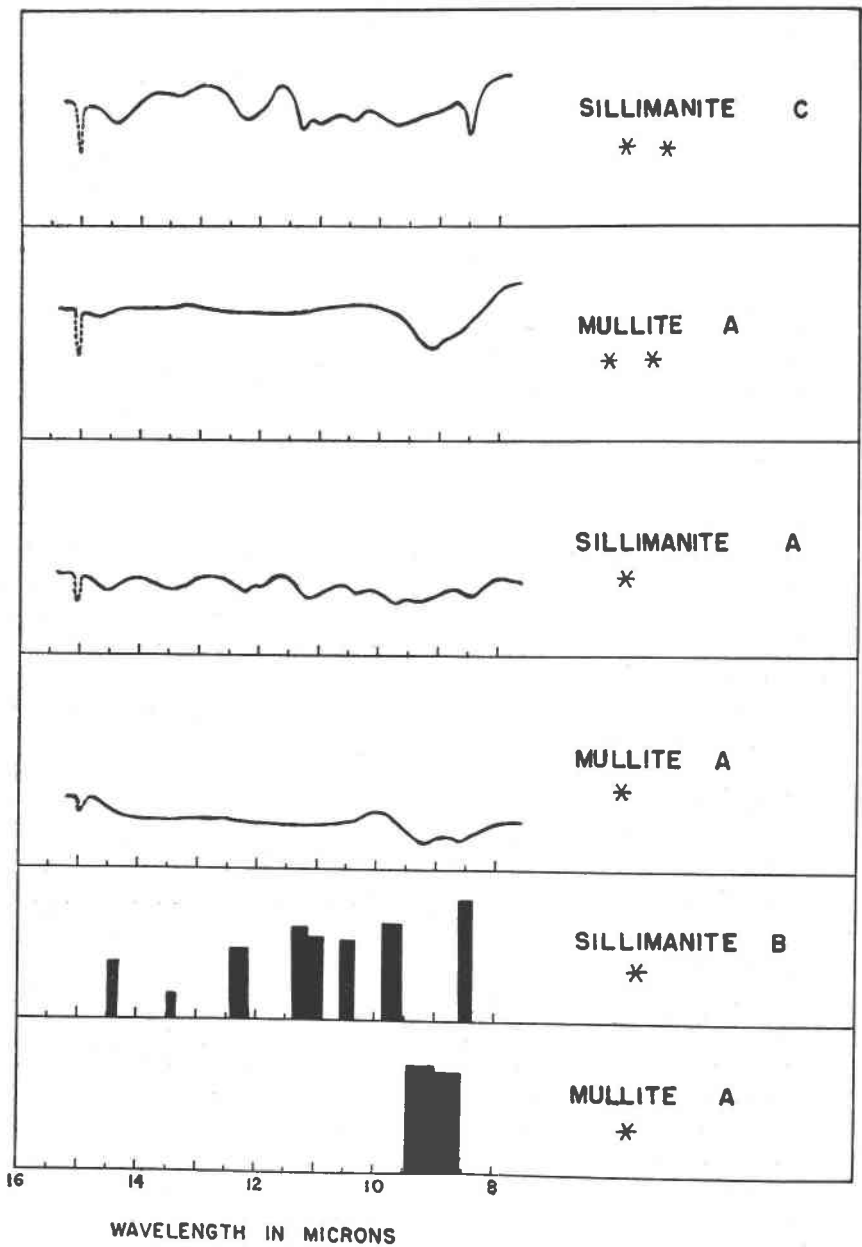


FIG. 1. Typical infra-red absorption curves for sillimanite and mullite. Relative transmission is plotted on the vertical axis. Curves with a single star were obtained with a suspension in Nujol; those with two stars were obtained from samples evaporated from ethyl alcohol, film density .3 mgm./sq. cm. The block diagrams are of the type shown by Launer (1952).

TABLE 1

Sillimanite	A	U. S. National Museum Specimen No. 3732, Brandywine Springs, Del.
	B	U. S. National Museum Specimen No. 3731, Norwich, Conn.
	C	Genth Collection (School of Mineral Industries, The Penna. State College) No. 399.13, Unionville, Pa.
Mullite	A	Single crystals of electrically fused mullite (Corhart).
	B	Langley kaolinite heated to 1350° C. for 12 hours showing essentially complete conversion to mullite and cristobalite.

into consideration. Relatively coarse particles ( $-325$  mesh) and various size fractions calculated to be less than  $2\mu$ , and less than  $\frac{1}{4}\mu$  were obtained by sedimentation in absolute alcohol. The samples were either milled in Nujol and applied to the NaCl plates, or applied as a suspension in absolute alcohol and the alcohol evaporated. The film density varied from 0.1 mgm. to 1 mgm. per sq. cm. in thickness (see Launer, 1952). The mullite samples always gave essentially the same pattern and the sillimanite samples likewise gave the same pattern under all conditions and the patterns of the minerals are quite distinct. Block diagrams such as those recently used effectively by Launer (1952) while not as precise as percentage transmission curves are considerably more useful for such crude identification procedures. Diagrams are shown for the spectra of sillimanite and mullite. It will be seen that mullite has a pronounced absorption at  $9.1\mu$  and minor absorption maxima near  $8.6\mu$ ; whereas sillimanite has several absorption maxima at 8.45, 9.7, 10.45, 11.0, 11.3, 12.25, 13.4 and  $14.4\mu$ . A low sharp absorption at  $6.20\mu$  is not shown since it may not be unique for sillimanite for it did not appear in the coarser samples and may be an impurity in the very fine fractions. It is evident therefore that sillimanite may be distinguished from mullite by very simple experimental techniques. A  $-325$  mesh powder (finer grinding helps greatly) milled in Nujol is sufficient to provide a distinctive infra-red absorption pattern in the  $8-15\mu$  range.

## ACKNOWLEDGMENTS

This work was performed incident to research on hydrothermal crystal growth sponsored by the Frequency Control Branch, Army Signal Corps (Contract Da 36-039- sc-5594) under the general supervision of Dr. E. F. Osborn, Dean, School of Mineral Industries, The Pennsylvania State College.

## REFERENCES

- ADLER, H. H. (1950), Infra-red spectra of reference clay minerals: *Amer. Pet. Inst., Project 49, Report 8*, Section 1.  
 BOWEN, N. L., AND GREIG J. W. (1924), *J. Am. Ceram. Soc.*, **7**, 242.

- KELLER, W. D., SPOTTS, J. H., AND BIGGS, D. L. (1952), Infra-red spectra of some rock-forming minerals: *Amer. J. Sci.*, **250**, 453-471.
- DE KEYSER, W. L. (1951), Contribution to the study of sillimanite and mullite by x-rays: *Trans. Brit. Cer. Soc.*, **50**, 349-364.
- LAUNER, P. J. 1952, Regularities in the infra-red absorption spectra of silicate minerals: *Am. Mineral.*, **37**, 764-784.
- MCATEE, J. L., AND MILLIGAN, W. O. (1950), X-ray diffraction examination of synthetic mullite: *Texas Jour. Sci.*, **2**, 200-205.
- ROY, R. AND OSBORN, E. F. (1952), The system  $\text{Al}_2\text{O}_3\text{-SiO}_2\text{-H}_2\text{O}$ : *Am. Mineral.*, **37**, 300 (Abstract).
- ROY, D. M., AND ROY, R. (1952), The system  $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2\text{-H}_2\text{O}$ : *Bull. Geol. Soc. Am.*, **63**, 1293 (Abstract).
- ROY, D. M. (1953), The hydrothermal synthesis of andalusite: *Am. Mineral.*, In press.

#### AUGELITE FROM PEGMATITES IN NEW HAMPSHIRE

DAVID M. SEAMAN, *Department of Mineralogy, Harvard University  
Cambridge, Mass.*

Augelite,  $\text{Al}_2(\text{PO}_4)(\text{OH})_3$ , has been found in granite pegmatite at two localities in New Hampshire: the Smith mine at Chandler's Mill near Newport, and the Palermo mine near North Groton. The Smith mine was worked for mica during the summer of 1952. Specimens were obtained from the dump heap showing transparent, pale aquamarine-blue crystals associated with lazulite, albite and quartz. The blue crystals were identified as augelite from their optical properties: biaxial positive, 2V medium, with  $\alpha=1.574$ ,  $\beta=1.576$  and  $\gamma=1.588$ . The identification was confirmed by an x-ray powder photograph. The crystals are embedded and poorly formed. Tiny blue inclusions can be seen under low magnification, and the color of the mineral apparently is due to disseminated particles of lazulite. Augelite crystals from the locality at Laws, California, show a similar feature. The Smith pegmatite shows a marked lithium and phosphate phase. Triphylite, lazulite and granular apatite are the most common phosphate minerals. The lazulite occurs in a heterogeneous manner throughout the pegmatite in small masses, and the augelite occurs immediately associated with it. Other less common phosphates that occur at the locality include hurlbutite, tiny beryl-lonite crystals, small twinned crystals of amblygonite and brazilianite as small single crystals and as aggregates of parallelly intergrown crystals up to an inch in length.

Augelite also occurs in the well known Palermo pegmatite near North Groton. The mineral was first identified by A. L. Mackay of the University of London, who found crystals on specimens of whitlockite that had been sent to him for study. A number of additional specimens were then recognized in bulk lots of Palermo material carrying whitlockite and brazilianite that had been collected in 1947 and 1948 and placed in stor-