

morphology of the kaolinite. The gross hexagonal outline of the flakes is maintained in all cases. The phosphate reaction products tend to group themselves along the edges and in the spaces between flakes. The sulfates, on the other hand, seem to be attached to the basal surfaces of the kaolinite flakes rather than as random aggregates. The difference in solubility between these two reaction products may, in part, account for this effect.

The use of electron microscopy as an analytical tool is emphasized inasmuch as routine *x*-ray analyses failed to detect the changes that had taken place.

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#### REFERENCE

MURRAY, H.H. (1951) The structure of kaolinite and its relation to acid treatment. Ph.D. thesis, University of Illinois.

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#### SYNTHETIC EMERALD

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Synthetic emerald has always been of considerable interest as a gem material. Recent work in solid state physics indicates that beryl containing chromium (and other transition metal ions) is also of research interest and may be of value for certain electronic applications (Geusic *et al.*, 1959; Gerritsen, 1962). While emerald has previously been synthesized, by growth from flux systems (Hautefeuille and Perrez, 1888; Dana, 1949; Smith, 1958; and Alexander, 1949) and hydrothermally (Van Praagh, 1947), the procedures employed are inconvenient and/or result in relatively small crystals. Furthermore, successful deposition of single-crystal emerald on seeds using these methods has not been reported. Emerald crystals sufficiently large for gem fabrication have been grown (Smith, 1958), but commercial value of the resulting product has prevented the pertinent data from reaching either the scientific or the patent literature. The purpose of this note is to describe a flux system that shows considerable promise for the synthesis of large emerald crystals.

In the course of exploratory work on the growth of metal oxide and silicate single crystals from molten salts, small emerald crystals were

grown from  $\text{PbO-PbF}_2$ ,  $\text{B}_2\text{O}_3$ ,  $\text{Li}_2\text{O-MoO}_3$  and  $\text{MoO}_3$  systems. The best results, in terms of yield, size and physical quality, were obtained with melts containing 1.2 g.  $\text{BeO}$ , 3.2 g.  $\text{Al}_2\text{O}_3$ , 10.6 g.  $\text{Li}_2\text{SiO}_3$ , 0.4 g.  $\text{Cr}_2\text{O}_3$  and 75.0 g.  $\text{MoO}_3$ . Melts approximating this composition were the only ones that yielded good quality emerald deposits on natural beryl seeds. Powders containing the component oxides in the proper relative amounts were mechanically mixed and then fused in tightly-covered 50-ml. platinum crucibles. After soaking for 6–18 hours at  $975^\circ\text{C}$ ., the melts were cooled at a uniform rate of  $4^\circ\text{C./hour}$  to  $790^\circ\text{C}$ ., at which time the crucibles were removed from the furnace and allowed to cool in air. The resulting emerald was recovered by digesting the contents of the crucibles in hot water or in hot 20 per cent nitric acid. The emerald phase was identified by petrographic examination and confirmed by  $x$ -ray powder patterns.

In the absence of seed crystals, numerous hexagonal prisms of emerald, averaging 1 mm in long dimension (parallel to the  $c$ -axis), resulted from a typical experiment (Fig. 1). The crystals were transparent, relatively free of inclusions and exhibited the typical emerald-green color. Many of the prism faces exhibited growth spirals (Fig. 2). Back-reflection  $x$ -ray photographs gave well-defined diffraction spots, indicating good crystal quality. Subsequent use of the crystals as seeds resulted in further growth (to approximately 1.5 mm in length) accompanied by a substantial reduction in nucleation of new crystals. Petrographic examination of the interface between the original seed and subsequent deposit revealed that little etching of the seed had occurred which, in turn, suggests that the systems are near saturation for the conditions employed.

Single-crystal emerald of good physical quality was deposited on natural beryl seeds. In a typical experiment, the thicknesses of the deposits on the base and prism faces, of a seed approximately 1 cm across the base by 1 cm long, were 0.8 and 0.4 mm, respectively (Fig. 3). This is a substantial deposit in view of the small size of the crucible and short growth time (2 days) employed. Although the emerald layer was translucent in the immediate vicinity of the seed surface, the majority of the material was transparent and exhibited very few defects and/or inclusions. Back-reflection  $x$ -ray photographs and petrographic studies showed that the structural features of the seed were reproduced by the deposit. The dominant feature of back-reflection  $x$ -ray photographs taken perpendicular to the basal plane was evidence for a mosaic sub-structure exhibiting a maximum deviation in orientation of approximately  $2^\circ$ .

The principal secondary phase (insoluble in dilute nitric acid) obtained from these experiments was chrysoberyl ( $\text{BeAl}_2\text{O}_4$ ). Heating the melts to temperatures above  $975^\circ\text{C}$ . resulted in an increase in the chrysoberyl yield and a corresponding decrease in emerald yield.

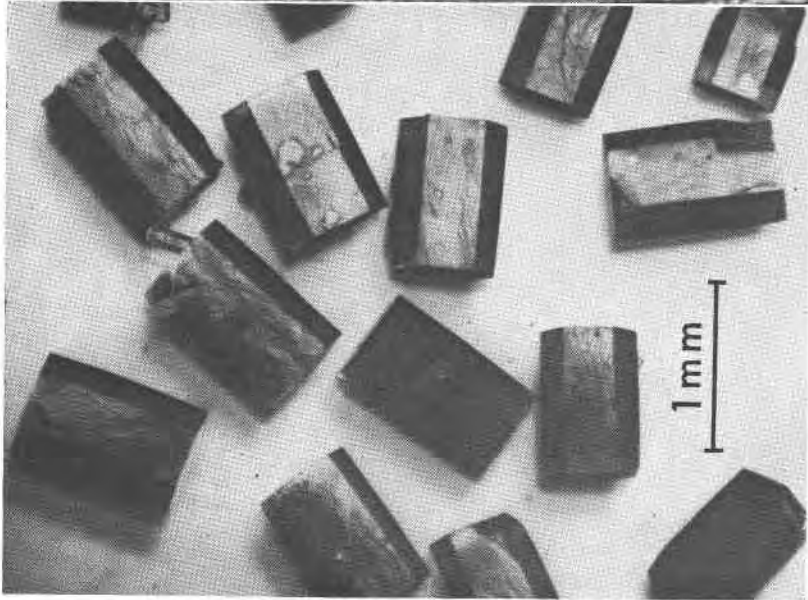
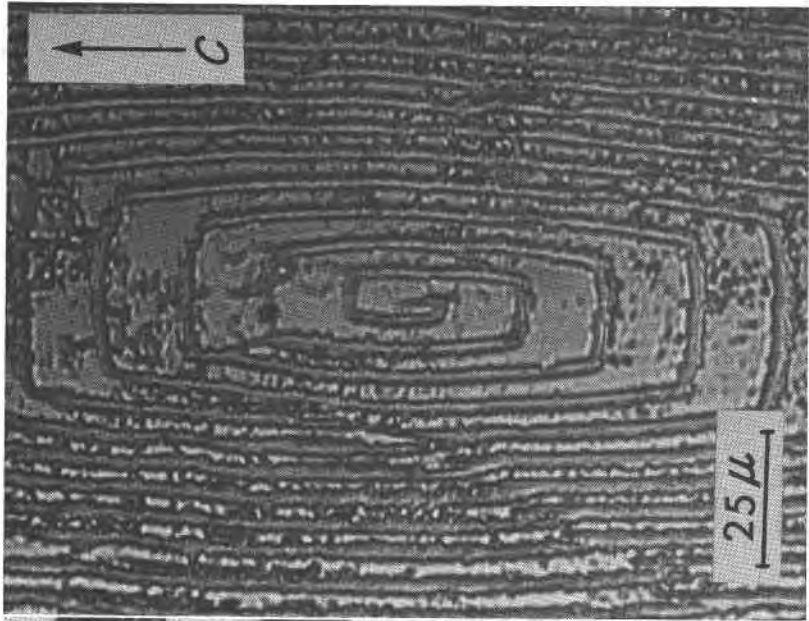


FIG. 1. (left) Emerald crystals grown from  $\text{MoO}_3$  flux.

FIG. 2. (right) Growth spiral on the  $(10\bar{1}0)$  face of a synthetic emerald crystal.

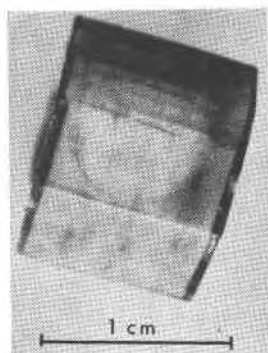


FIG. 3. Single-crystal emerald deposited on a natural beryl seed.

We wish to express appreciation to Miss Frances Woods for assistance with crystal growth and sample processing.

#### REFERENCES

- ALEXANDER, A. E. (1949) *Jour. Chem. Educ.* **26**, 254-257.  
 DANA, E. S. (1949) *A Textbook of Mineralogy*. John Wiley & Sons, Inc. New York, 4th ed., p. 580.  
 GERRITSEN, H. J. (1962) *Applied Optics*, **1**, 37.  
 GEUSIC, J. E., MARTIN PETER AND E. O. SCHULZ-DU BOIS (1959) *Bell System Tech. Jour.* **38**, 291-296.  
 HAUTEFEUILLE AND A. PERREZ (1888) *Compt. rend.* **106**, 1800.  
 SMITH, G. F. HERBERT (1958) *Gemstones*, Pitman Publishing Co., New York, 13th ed., 203-206.  
 VAN PRAAGH, G. (1947) *Geol. Mag.* **84**, 98-100.

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#### TRIDYMITE (LOW FORM) IN SOME OPAL OF NEW MEXICO

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#### INTRODUCTION

Many opal samples from New Mexico were studied, and it was found that none of these is completely amorphous. There is always a crystalline or cryptocrystalline phase in opal. It has been pointed out by Levin and Ott (1932) that many opal samples are not amorphous as previously suggested. It may be true, however, that the original opal is precipitated as a truly amorphous substance and then is changed partly to a crystalline or cryptocrystalline phase. The most common crystalline phase is quartz.