AMERICAN SYNTHETIC EMERALD*

Austin F. Rogers, *Stanford University*
AND
Francis J. Sperisen, *San Francisco, California.*

Abstract

The synthetic emerald here described has been made by Carroll F. Chatham, San Francisco, although the method of manufacture cannot be disclosed at present. Cut stones made of the material are small but of very good quality.

The emerald crystals are short prismatic in habit, and in color are comparable to good Colombian emeralds. The chemical analysis shows silica, alumina, beryllia, some chromium oxide, small amounts of alkalies, and small amounts of other constituents.

Optical tests prove that the crystals are emerald. They are slightly pleochroic and show certain optical anomalies.

The synthetic emerald is distinguished from natural emerald by the character of the inclusions.

The first successful synthesis of emerald was that of Hautefeuille and Perrey (1) in France in 1888. Through the courtesy of Dr. J. Orcel, curator of the Muséum National D'Histoire Naturelle of Paris, a small vial of these emeralds was obtained. They are prismatic in habit with the forms $\{10\bar{1}0\}$, $\{0001\}$, and occasionally $\{h0\bar{h}l\}$, and are about 1 mm. long. They have a good emerald green color.

More recently synthetic emerald has been produced in the laboratories of the Interesse Gemeinschaft Farbenindustrie Aktiengesellschaft in Bitterfeld, Germany. This emerald is known as "Igmerald." It was first announced in 1930. A number of papers on the synthetic emerald of the I. G. Farbenindustrie have appeared in the last decade; the most complete one is that of E. Schiebold (2) of the University of Leipzig.

Synthetic Emerald in the United States

The first synthetic emerald produced in the United States was made by Mr. Carroll F. Chatham (3), chemist of San Francisco. Colorless beryl was made by Mr. Chatham as early as 1930. In 1935 he succeeded in making the first emerald crystals of appreciable size (one carat in the rough). Unfortunately the method of producing the emerald cannot be divulged.

A number of different lots of the synthetic emeralds have been submitted to us for study by Mr. Chatham.

Preliminary tests by one of us (F.J.S.) in September, 1940, proved that the specimens were emeralds and the conclusion was also reached that they were synthetic. The articles by Anderson and Payne (4) of the London Gem-testing Laboratory, and by Foshag (5) of the U. S. Na-

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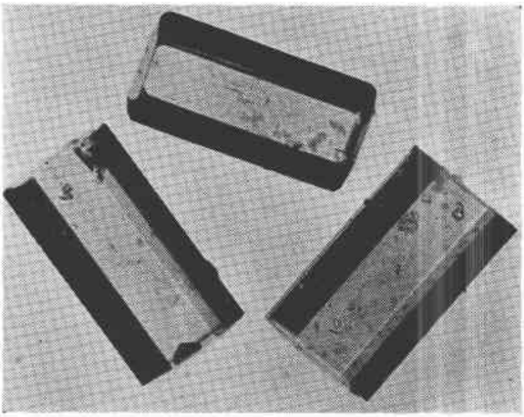
tional Museum were of considerable aid in this examination. Since then the preliminary results have been confirmed by more complete tests.

One lot of the synthetic emeralds consists of small (about 1.3 mm. long) slender, well-developed, prismatic crystals with the forms $\{10\bar{1}0\}$, $\{11\bar{2}0\}$, $\{0001\}$, and occasionally $\{h0\bar{h}l\}$. They are slightly pleochroic



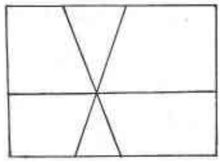
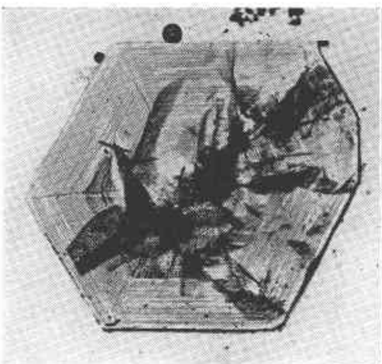


FIG. 1 (×25). Synthetic emerald crystals.
FIG. 2. Vicinal faces replacing the first order prism on synthetic emerald.



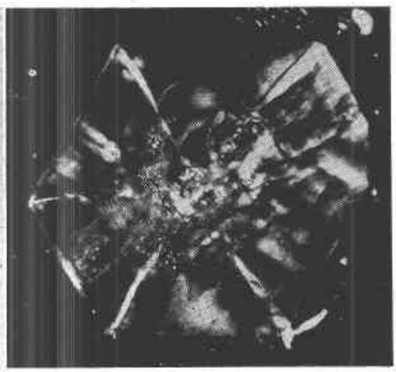


FIG. 3 (×45). Basal section of synthetic emerald showing growth stages and characteristic inclusions.
FIG. 4. (×45). The same section between crossed nicols showing birefringent areas.

from blue-green (α) to yellow-green (γ), have parallel extinction and are length-fast. Groups of these crystals furnish excellent specimens for micro-mounts. Associated with the emerald are a few colorless crystals which are identified as phenacite (Be_2SiO_4) by indices of refraction and crystal habit (forms: $\{11\bar{2}0\}$ and $\{10\bar{1}1\}$).

The main lot of synthetic emerald used in this study consists of crustiform aggregates with euhedral crystals on the free surface. The individual crystals are short prismatic in habit and measure from 2.5 to 5 mm. in longest dimension. The forms are {0001}, {10$\bar{1}$0}, and {11$\bar{2}$0}. On some of the crystals ill-defined vicinal faces take the place of faces of the first order prism. The vicinal forms present are a steep hexagonal dipyramid and a dihexagonal dipyramid as shown in the sketch of Fig. 2.

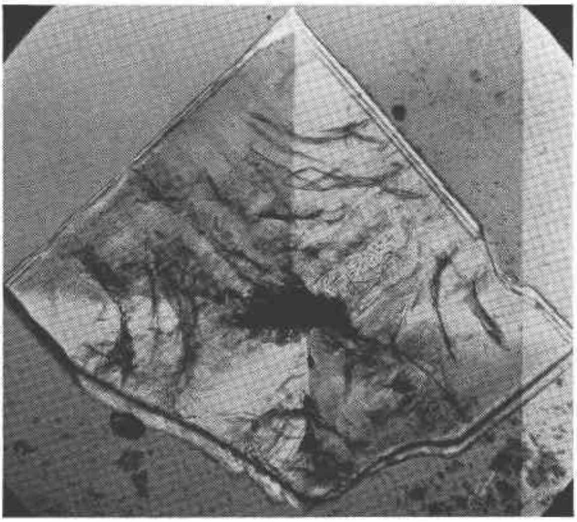


FIG. 5. (×50). Longitudinal section of synthetic emerald between crossed nicols with superimposed quartz wedge.

Sections of the synthetic emeralds about 0.2 mm. thick were skilfully prepared by Mr. Alexander Tihonravov. Photomicrographs of some of these are shown in Figs. 3–6. A basal section bounded by {10$\bar{1}$0} and three faces of the {11$\bar{2}$0} form shows a prominent zonal structure due to a slight color difference in the growth stages (Fig. 3). Between crossed nicols portions of this section exhibit appreciable birefringence which is well brought out in Fig. 4. Thin birefringent strips divide the section into sectors. The main portion of the section is uniaxial with a negative sign.

Optical anomalies are also shown in longitudinal sections such as Fig. 5, which was taken between crossed nicols with a quartz wedge to bring out contrast in the sectors. Here the *c*-axis of the crystal is parallel to the NE-SW direction which means that the habit is thick tabular. The longitudinal sections are pleochroic with α = bluish green and γ = yellow green.

Indices of Refraction

The indices of refraction of the synthetic emerald determined by the prism method on a cut prism of about 60° angle in sodium light are:

$$n_\alpha = 1.573,\ n_\gamma = 1.578;\ n_\gamma - n_\alpha = 0.005.$$

The indices are a little higher than those recorded for the I. G. Farbenindustrie synthetic emerald, but are very similar to indices of the Russian emeralds from the Urals.

Specific Gravity

The specific gravity of about 0.3 g. of carefully selected fragments of the synthetic emerald free from visible impurities determined with a small pyknometer was found to be 2.667.

Inclusions

Inclusions in precious stones are especially important since the inclusions in synthetic stones and natural stones each have their distinctive features. The inclusions present in the Chatham synthetic emeralds are of two kinds: (1) clusters of dark red equant isotropic crystals, ca. 0.01 mm. in size with high relief, which have not been identified, and (2) curved sheets, wisps, or "curtains" of liquid-gas inclusions from 0.003 to 0.015 mm. in size and often elongate. Both kinds of inclusions are shown in Fig. 6, the dark red crystals on the right and the "curtains"

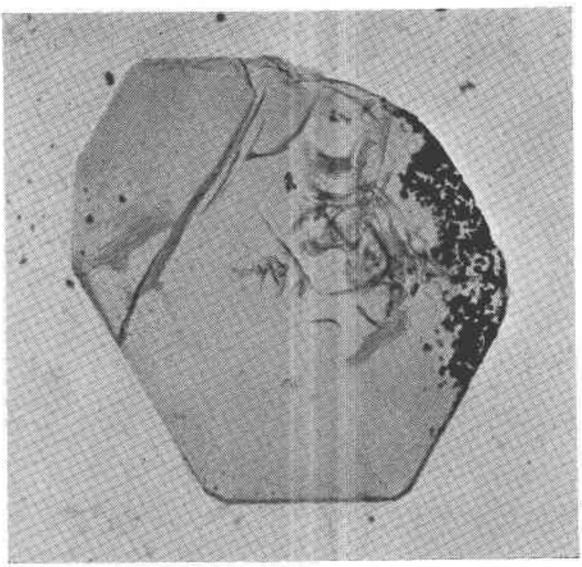


Fig. 6 (×60). Inclusions in basal section of synthetic emerald.

near the center of the section. Under higher magnification the liquid-gas inclusions appear as in Fig. 7. The "curtain" is oblique to the section and only a central strip of it is in focus.

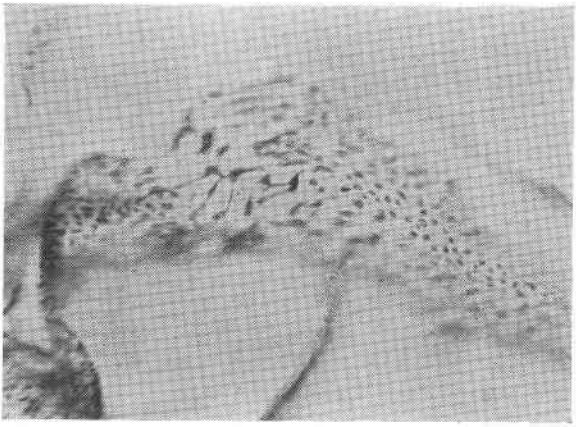


FIG. 7 (×200). Liquid-gas inclusions in synthetic emerald.

For comparison, the inclusions of natural emerald from Colombia have also been studied. The specimens were obtained in Colombia by Mr. Basil Prescott some years ago. Fig. 8 shows a general view of the inclu-

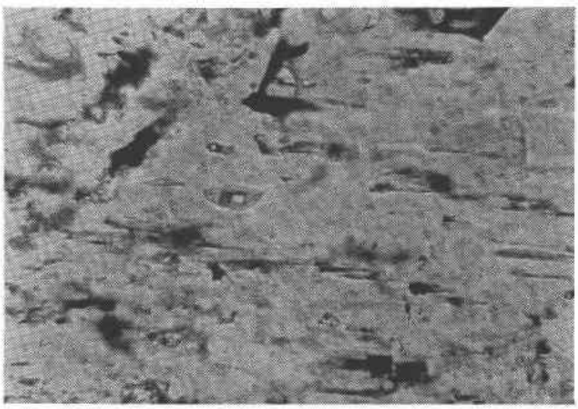


FIG. 8 (×100). Inclusions (negative crystals) in longitudinal section of natural Colombian emerald.

sions which are parallel to the *c*-axis. The dark areas are cavities on the surface of the section which are filled with fine abrasive. Most of the inclusions seem to be negative crystals and these inclusions probably give a sheen to the cut emerald. A higher magnification of some of the inclusions in the natural emerald shows a liquid with gas bubble and an euhedral cubic crystal of isotropic halite as exhibited in Fig. 9. These inclusions are often flask-shaped. Halite inclusions are apparently characteristic of the Colombian emerald for they have been noted by H. Michel (6).

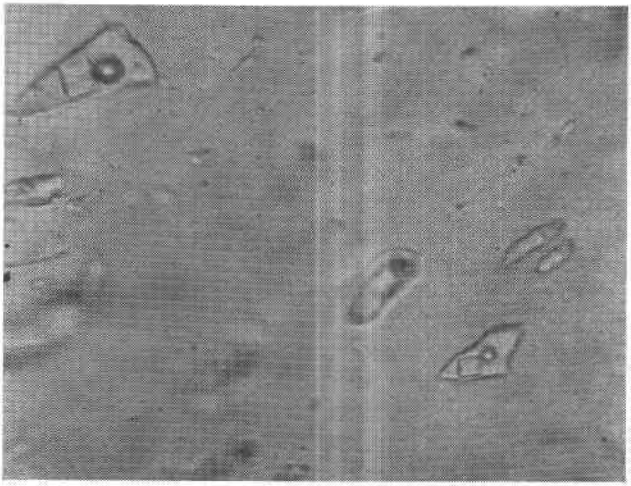


FIG. 9 (×400). Liquid-gas-halite inclusions in natural Colombian emerald.

CHEMICAL ANALYSIS

A chemical analysis of the dark green synthetic emerald made for Mr. Chatham by Curtis and Tompkins of San Francisco gave the following results:

CHEMICAL ANALYSIS OF SYNTHETIC EMERALD BY CURTIS AND TOMPKINS

SiO_2	64.30
Al_2O_3	18.65
BeO	13.20
Fe_2O_3	0.30
Cr_2O_3	2.00
CaO	0.73
MgO	0.10
K_2O	0.21
Na_2O	0.56
H_2O	0.14
TiO_2	0.05
Total	100.24

The emerald green color is evidently due to the chromium content.

Spectrographic Analysis

A spectrographic analysis of the synthetic emerald made in the ultra-violet region by my assistant, Mr. Reynolds M. Denning, showed prominent lines for aluminum, beryllium, and silicon, fair lines for chromium, magnesium, and titanium, and weak lines for calcium, copper, and sodium. The spectrum for the synthetic emerald is reproduced in the central strip of Fig. 10. The spectrogram identifies the specimen as emerald without any doubt. The upper strip of Fig. 10 is the spectrum for the Colombian emerald. The lower strip of the figure is the standard iron ("Armco") spectrum for comparison.

Fig. 10. Spectrograms of natural Colombian emerald (upper strip), synthetic emerald (central strip) and "Armco" iron (lower strip).

Conclusion

Physical and chemical tests of the synthetic emerald produced by Mr. Carroll F. Chatham of San Francisco prove its identity with emerald. It is emerald of good quality which approaches the attractive color of the better grades of Colombian emeralds. This synthetic emerald may be distinguished from natural emerald by the character of its inclusions.

References

1. Hautefeuille, P., and Perrey, A., *Comptes Rendus des Séances de l'Académie des Sciences*, **106**, 1800 (1888).
2. Schiebold, E., *Zeits. Kryst.*, **92**, 435–473 (1935).
3. Personal communication, July, 1942.
4. Anderson, B. W., and Payne, C. J., *Goldsmith's Journal and Gemmologist*, **37**, 407–410 (1938).
5. Foshag, W. F., *Jeweler's Circular-Keystone*, **104**, 73, 75, 91 (1938).
6. Michel, H., *The Pocket-Book for Jewelers*, Part II, Plate XXIIb, G. L. Herz, New York and Vienna. (No date).