GORDON, S. G. (1942) Results of the Chilean mineralogical expedition of 1938. Part VII—the crystallography of alunogen, meta-alunogen, and pickeringite. *Notulae Naturae*, **101**, 1–9.

GRUVER, R. M. (1951) Differential thermal-analysis studies of ceramic materials: III, Characteristic heat effects of some sulfates. *Jour. Am. Ceram. Soc.* **34**, 353–357.

HANAWALT, J. D., H. W. RINN, AND L. K. FREVEL (1938) Chemical analysis by x-ray diffraction: Classification and use of x-ray diffraction patterns. *Anal. Chem.* **10**, 457–512.

HODGMAN, C. D. (1962) *Handbook of Chemistry and Physics*. Chem. Rubber, Cleveland.

LARSEN, E. S. AND G. STEIGER (1928) Dehydration and optical studies of alunogen, nontronite and griffithite. *Am. Jour. Sci.* **15**, 1–19.

PALACHE, C., H. BERMAN AND C. FRONDEL (1951) *The System of Mineralogy*, Vol. II, John Wiley & Sons, New York.

ROSENZWEIG, A. AND E. B. GROSS (1955) Goldichite, a new hydrous potassium ferric sulfate from the San Rafael Swell, Utah. *Am. Mineral.* **40**, 469–480.

WARNE, S. ST. J. AND P. BAYLISS (1962) Differential thermal analysis of cerussite. *Am. Mineral.* **47**, 1011–1023.

THE AMERICAN MINERALOGIST, VOL. 49, NOVEMBER-DECEMBER, 1964

FLUORITE FROM THE BADU PEGMATITE, LLANO COUNTY, TEXAS

ROBERT GREENWOOD, *Geology Dept., Univ. of Houston, Houston, Texas.*

The Badu pegmatite, chiefly composed of microcline and quartz, intrudes carbonate-rich metasediments of the Packsaddle schist (Precambrian). Its total extent at the surface is about 400 by 350 feet, of which the central part is well exposed in an abandoned open-pit working 200 feet long and about 20 feet deep. The pegmatite is located in Llano County about 4 miles southwest of Buchanan Dam and one mile north of Beverly, on land owned by Dr. H. J. Hoerster of Llano. Published descriptions are concerned with the pegmatite as a source of feldspar (Chelf, 1942; Huseman and McMillan, 1947). Apart from quartz, feldspar, muscovite, kaolinite and pyrite, "two small pieces of rare-earth minerals" (Chelf, 1942) have been the only minerals reported. The geological map of Huseman and McMillan can be interpreted in terms of conventional pegmatite zoning (Cameron *et al.*, 1949) as showing a wall zone of graphic granite, an intermediate zone chiefly of microcline, and discontinuous quartz cores.

During a field trip on 25 April, 1964, I found in the south face of the pit, corresponding to the outer part of the intermediate zone, a reddish friable mass about 40 by 20 cm, enclosed in pink feldspar. It consisted of purple and clear fluorite cut by sparse veins of red feldspar 5 mm thick. Fluorite is reported from 22 pegmatite districts in North America, in 19 of which it is associated with rare-earth minerals (Heinrich, 1948). No rare-earth minerals were found at the Badu pegmatite on this occasion. The well-known rare-earth pegmatite of Baringer Hill, now submerged beneath Lake Buchanan 5 miles to the northeast, contains fluorite in crystals up to a foot across, veined by red albite (Landes, 1932). Baringer Hill fluorite is almost colorless to dark violet, and "sometimes became luminous at the temperature of a living-room" (Hess, 1908). The Badu fluorite is coarsely cleavable, massive, reddish-purple with irregular colorless patches; the red feldspar veining it is oligoclase (An_{20-22}) with micro-inclusions of hematite; apparently a very similar occurrence to that of Baringer Hill. Fluorite has also been reported from a mass of pegmatite "about $2\frac{1}{2}$ miles west-northwest of Kingsland" (Paige, 1912, p. 90), roughly 3 miles south of the Badu locality. The Badu fluorite has a specific gravity of 3.178 ± 0.005, which, together with the refractive index of 1.433 ± 0.001 for sodium light, indicates it to be a normal fluorite without unusual amounts of rare earths.

On the basis of fluorescence under short-wave (quartz tube) radiation, the fluorite was separated into two nearly equal fractions for further examination. Fraction A fluoresced very pale green, continuing to phosphoresce for 5–10 seconds after excitation ceased. More than 80% of the fragments in this fraction were colorless. On grinding in a mortar they emitted the characteristic pungent but sweetish odor of ozone and fluorine. This variety of fluorite has been reported from Germany as Stinkfluss (Palache *et al.* 1951, p. 32), and the odor attributed to the presence of free fluorine and possibly calcium atoms in the structure. Similar fetid fluorite, also called antozonite, has been reported by F. L. Sine from the MacDonald pegmatite near Hybla, Ontario (Ellsworth, 1932, p. 208). The act of grinding places the Ca and F in contact with the water of microscopic inclusions, so that hydrofluoric acid and ozone are produced by the reactions

$$F_2 + 2H_2O = 2HF + H_2O_2$$

and

$$3H_2O_2 = 3H_2 + O_3 \quad \text{(Hoffman, 1937).}$$

The reaction $Ca + 2H_2O + F_2 = Ca(OH)_2 + 2HF$ is also probable. The presence of neutral atoms within an ionic crystal structure was postulated by Hoffman (1937) and others, and ascribed to the effects of radioactive bombardment, but it is only during recent years that laboratory studies have substantiated their hypothesis. Neutron irradiation of lithium fluoride crystals, for example, has produced neutral Li and F atoms within the crystal, detectable by nuclear magnetic resonance techniques (Ring *et al.*, 1958). Natural damage to the fluorite structure must in most cases be due to gamma rays, including energetic photons, and to secondary particles, rather than to heavy-particle bombardment. According to Billington (1961), however, "there are only a few instances in which fast particle bombardment produces effects not observed after exposure to ionizing radiation (x-rays and gamma rays)," and ions once neutralized will move into interstitial sites and dislocations where they may retain their neutrality.

Fraction B did not fluoresce under quartz tube radiation, and the odor on grinding was much fainter than that from Fraction A. Approximately 80% of Fraction B is reddish-purple fluorite; the rest is colorless.

The above observations do not support the contention of Hoffman (1937) that only colored fluorite contains free fluorine. In the Badu pegmatite the Stinkfluss variety, as well as the fluorescence, is predominantly associated with the colorless crystals.

Examination of cleavage fragments for thermoluminescence was conducted on a hotplate at about 60° C. Colored or partially colored fluorite fragments all exhibited a white thermoluminescence. Colorless fragments did not thermoluminesce. This behavior is to be contrasted with the fluorescence effects.

References

Billington, D. S. and J. H. Crawford (1961) *Radiation Damage in Solids.* Princeton University Press.

Cameron, E. N., R. H. Jahns, A. H. McNair and L. R. Page (1949) Internal structure of granitic pegmatites. *Econ. Geol. Mono.* **2.**

Chelf, C. (1942) A new feldspar deposit in Llano County, Texas. *Texas Bur. Econ. Geol. Mineral Res. Surv. Circ.* **45.**

Ellsworth, H. V. (1932) Rare-element minerals of Canada. *Geol. Surv. Canada Econ. Geol. Ser.* **11.**

Heinrich, E. Wm. (1948) Fluorite-rare earth mineral pegmatites of Chaffee and Fremont Counties, Colorado. *Am. Mineral.* **33,** 64–75.

Hess, F. L. (1908) Minerals of the rare earth metals at Baringer Hill, Llano County, Texas. *U. S. Geol. Survey Bull.* **340,** 286–294.

Hoffman, J. (1937) Über photolytische neutralisierte Elementarstoffe der Fluorite. *Chem. Erde.* **11,** 368–374.

Landes, K. K. (1932) The Baringer Hill pegmatite. *Am. Mineral.* **17,** 381–390.

Paige, S. (1912) Llano-Burnet. *U. S. Geol. Survey Folio* **183.**

Palache, C., H. Berman and C. Frondel (1951) *Dana's System of Mineralogy,* Vol. 2, 7th ed., John Wiley & Sons, New York.

Ring, P. J., J. G. O'Keefe, and P. J. Bray (1958) Li-7 and F-19 nuclear magnetic resonances in neutron-irradiated LiF. *Phys. Rev. Letters* **1,** 453.