The groundmass has a rough trachytic texture. The principal constituent is orthoclase, but at location no. 11 there is also microperthite. The feldspar, normally 0.25 mm.×0.10 mm. in size, makes up 95 per cent of the mineral assemblage. Much of the feldspar is altered to a colorless mica and calcite. Locally a small amount of plagioclase (Ab_{68} at no. 2 and Ab_{90} at no. 11) is present. Aegirine, with pleochroism in yellow and shades of green, occurs in irregular bunches and as needles up to 1.0 mm.×0.02 mm. in size. At locality no. 9 aegirine comprises 30 per cent of the minerals but usually the amount does not exceed 5 per cent. Remnants or 'ghosts' of biotite are numerous, the biotite having altered to chlorite and magnetite. Sphene locally altered to leucoxene, magnetite altered to red iron oxide, and unaltered apatite and zircon are invariably present in minor amounts. Many irregularly shaped patches of calcite are present. Locally, as in portions of the intrusions at nos. 2, 8 and 11, a small amount of nepheline may have been present but has altered to cancrinite and a colorless mica.

TORBERNITE IN MISSOURI FIRE CLAY

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Torbernite, $Cu(UO_2)_2P_2O_8 \cdot 12\ H_2O$, hitherto unreported from Missouri, has been found filling thin cracks in a fire clay deposit of Pennsylvanian age in the north central fire clay district of Missouri. The occurrence is about 14 miles east of Auxvasse and 4½ miles south of Martinsburg, on a farm owned by Mr. Robert Bailey.

Metatorbernite was reported by Grawe (1943) from a fire clay deposit near Gerald, Missouri, in the diaspore region south of the Missouri River, about 50 air miles from the torbernite occurrence. An isolated find of carnotite near Ste. Genevieve, located about 80 air miles southeast across the flank of the Ozark dome was reported by Muilenberg and Keller (1950).

The torbernite occurs in a soft, gray, semi-flint fire clay which has been open-pit mined intermittently. A pocket or seam of torbernite-bearing clay was encountered in a shallow prospecting shaft at a depth of about 10 feet below the upper surface of unweathered fire clay. Rain water filled the shaft which was abandoned and the water has remained high in the shaft ever since, due to the impervious nature of the clay. The writer did not see the walls of the shaft before water filled it, but collected the torbernite from the subsequently slaked fire clay which had been thrown out of the shaft. The clay is typical of Missouri Cheltenham (Keller, 1946) semi-flint fire clay.

The torbernite occurs invariably in a thin coating or scales on the clay along relatively tight joints. Rarely is a torbernite film continuous with an area as much as one-half square inch. Usually tiny flakes are isolated, or the mineral forms tiny, flat, circular, scaly rosettes one-half millimeter or less in diameter. A few of the joints are lightly and discontinuously stained with brown iron oxide upon which (later) the torbernite rosettes were deposited.

Mineralogical Properties

The torbernite is pale, slightly bluish, apple-green in color against the light gray fire clay. Although the flakes adhere closely to the clay, they spring away slightly when pried with a needle. The tiny flakes vary in color in transmitted light from pale green to slightly yellowish green, and show first order yellow interference color between crossed Nicols. Bluish abnormal interference color also is characteristic. Radial structure (probably plates) in the rosettes is shown by the presence of undulatory extinction crosses.

Individual crystals are too small to furnish indices of refraction, but a mean index of 1.584 was determined on the cleanest material. Diffuse interference figures are obtained, similar to those on dried clay film aggregates, ranging from a hazy uniaxial cross to shadowy biaxial brushes of an optic angle of about 65°. Optical character is always negative. Winchell (1951) gives for torbernite: "Nearly uniaxial and negative with $N_o = 1.592$, $N_e = 1.582$." Metatorbernite on the other hand, has indices of refraction in the range 1.620 to 1.640.

A Geiger counter is slightly but definitely activated by the small amount of torbernite available.

By prolonged picking under a binocular microscope, enough of the mineral was segrated to irradiate for an x-ray powder diffraction pattern. Using CuK_α-Ni radiation the following d spacings were obtained, which are compared with those of torbernite from Old Gunnis Lake, Calstock 7112, furnished by Dr. Michael Fleischer[1] from the files at Harvard. Correlation of the patterns is good. Variability in the widest d spacing may be attributed to variation in the degree of hydration between layers.

Origin of the Torbernite

Evidence for the origin of the torbernite indicates that it was dissolved from endogenetic and superjacent Pennsylvanian sedimentary rocks. Missouri fire clay deposits usually give a slightly higher impulse count on a Geiger counter than do adjacent limestones, but not enough difference to be useful in prospecting for fire clay. The fire clay is therefore a potential source of radioactive elements which might be concen-

[1] Personal letter from Dr. Fleischer, Dec. 27, 1950.

Torbernite (This paper)		Torbernite—Phase 13 Old Gunniss Lake, Calstock 7112 Harvard Univ. data	
d	*I*	*d*	*I*
10.2	w	9.41	1
8.84	s	8.85	5
5.49	m	5.47	2
4.93	m	4.96	2
4.32	w	4.37	3
3.70	s	3.69	10
3.59	w	3.52	4
3.24	m	3.26	5
2.99	vw	2.95	3
2.67	m	2.68	5
2.54	w	2.56	3
		2.49	2
		2.39	2
2.25	w	2.26	1
		2.22	2
2.17	m	2.18	5
2.12	w	2.14	3
2.05	m	2.07	4
1.98	m	1.989	6
		1.892	1
1.84	w	1.852	2
		1.821	1
1.77	w	1.781	2
		1.746	1
		1.713	1
1.64	s	1.642	7
		1.613	2
1.58	vw	1.583	2
1.55	s	1.556	8
		1.461	1
1.45	w	1.449	1
1.42	m	1.419	5
1.39	w	1.389	2
1.369	m	1.366	5
1.336	w	1.336	3
1.313	w	1.313	4
		1.264	1
		1.247	1
		1.243	2
		1.222	2
		1.211	2
		1.197	1
		1.159	5

s —strong line
m—medium
w—weak
vw—very weak

trated into minerals. A lateral secretion mode of origin is not likely because of the imperviousness of the clay.

The Cheltenham fire clay was covered in all Missouri fire clay districts by a sequence of Pennsylvanian shales which were subsequently eroded. Some of the shales are black and are slightly radioactive. Pleistocene (Kansan) glacial drift overlay the torbernite-bearing clay most recently. The Burlington (Mississippian) limestone is the thick country rock beneath the conglomeratic and sandy floor of the clay deposit which contains the torbernite.

The clay deposit which contained the metatorbernite reported by Grawe is underlain by the Jefferson City (Ordovician) dolomite. Glacial deposits did not extend to this region but Pennsylvanian shales did cover this region as well as the torbernite one to the north (Keller, 1951).

Hence the two occurrences of the radioactive minerals have in common the possibility that the torbernite and metatorbernite elements were leached out of the overlying Pennsylvanian shales and the upper zones of fire clay while they were being eroded. Descending ground water probably carried them into the jointed clay below but there is no recognizable evidence of any chemical or mineralogical cause for precipitation where the torbernite was deposited. Deposition occurred after iron-oxide bearing solutions had penetrated the joints in the clay. Although a hypogene origin remains a possibility, it seems less logical than a supergene one.

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