MINERALOGICAL MAGAZINE, DECEMBER 1985, VOL. 49, PP. 729–31

Uranoan thorite in lithophysal rhyolite—Topaz Mountain, Utah, USA

EUGENE E. FOORD

US Geological Survey, Box 25046, DFC, MS 905, Denver, Colorado 80225

ROBERT R. COBBAN

Department of Geology, Denver Museum of Natural History, City Park, Denver, Colorado 80205

AND

ISABELLE K. BROWNFIELD

US Geological Survey, Box 25046, DFC, MS 916, Denver, Colorado 80225

ABSTRACT. Uranoan thorite crystals have been found occurring as a sparse constituent in lithophysae in 6.1 to 6.8 Ma alkali rhyolite flows at Thomas Mountain, Utah, USA. The crystals are associated with sandidine, quartz, topaz, hematite, magnetite, and calcite; they are leek to dark grass green, transparent, well-formed, euhedral prisms, showing development of forms {100}, {101}, and {111}. The mineral is both optically isotropic, with a refractive index of 1.86(1), and X-ray amorphous, indicating its metamict state. Electron microprobe analysis yields: SiO_2 17.3, ThO_2 56.8, UO_2 25.4, total 99.5%, and a structural formula of $(Th_{0.72}U_{0.31})_{\Sigma 1.03}Si_{0.97}O_4$.

This appears to be the first reported occurrence of thorite in volcanic rocks of rhyolitic composition, and may account for part or all of the Th reported in alkali rhyolites and so-called 'topaz-rhyolites' of the western USA.

KEYWORDS: thorite, uranium, rhyolite, Topaz Mountain, Utah, USA.

ONLY recently has thorite been reported from volcanic rocks as an accessory mineral: (*a*) as an incompletely characterized mineral in porphyritic liparite (Urunbaev, 1970); (*b*) green thorite crystals with pink zircon and sanidine in volcanic ejecta from Lazio, Italy (Maras, 1982); and (*c*) green thorite crystals with nosean and zircon in a sanidine-rich unit of the Eifel region volcanics (Hentschel, 1982). The purpose of this paper is to describe uranoan thorite occurring in alkali rhyolite flows in Utah, USA.

Occurrence. Thorite crystals occur in lithophysae in alkali rhyolite flows on the southeast flank of Topaz Mountain, Juab County, Utah; this occurrence shares many aspects with that of the Eifel region. The specific locality is near one of the topaz localities in Topaz Valley, in the Thomas Range, described by Ream (1979), in the centre of the N $\frac{1}{2}$, N $\frac{1}{2}$, sec 16, T. 13 S., R. 11 W., on the US Geological Survey Topaz Mountain 15° quadrangle. These rhyolite flows have been dated at 6.1 (0.4) to 6.8 (0.3) Ma by fission track and K/Ar methods (Lindsey, 1979).

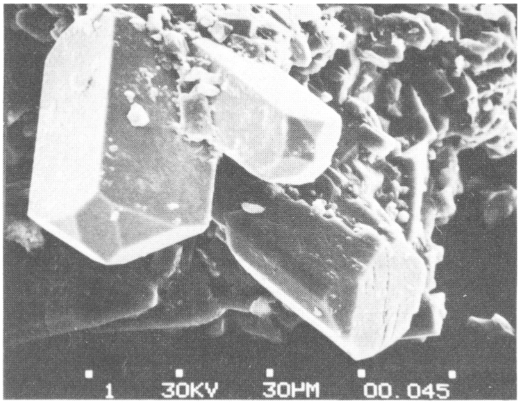
The thorite crystals are associated with sanidine, quartz, topaz, hematite, magnetite, and calcite, lining lithophysal cavities in alkali rhyolite. Sanidine and quartz comprise the lithophysal walls or line vugs near lithophysae and thorite is deposited on them. No minerals were seen on the thorite crystals which appears to be one of the last minerals deposited in the lithophysae and voids. Non-lithophysal titanian magnetite in elongated form was observed in some of the vugs containing thorite, although not directly in contact with the thorite. The thorite crystals usually occur singly, and very rarely are two or more crystals in contact. Thorite is evidently scarce at the locality and makes up only a very small fraction of the rock, but is locally concentrated; there are usually several crystals in each cavity.

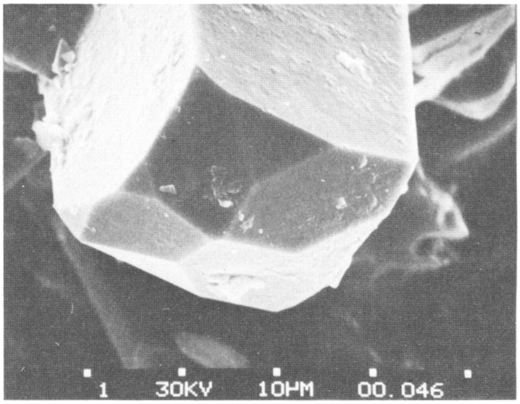
Description. The crystals are a leek to dark grass green, reminiscent of peridot, and are clear, unfractured, transparent, and contain no visible inclusions except at their bases; fragments are light yellow green. The crystals are euhedral prisms, terminated by two orders of pyramids and, where not embedded in matrix, are double terminated. The maximum dimensions of the crystals are 0.2 × 0.08 × 0.08 mm. The following two habits are most common: elongate, with the ratio of the dimensions along the *c* axis to an *a* axis typically near 2, or blocky, with 5 : 3 : 2 as a common ratio of the dimension along the *c* axis and the two *a* axes. Other habits are uncommon.

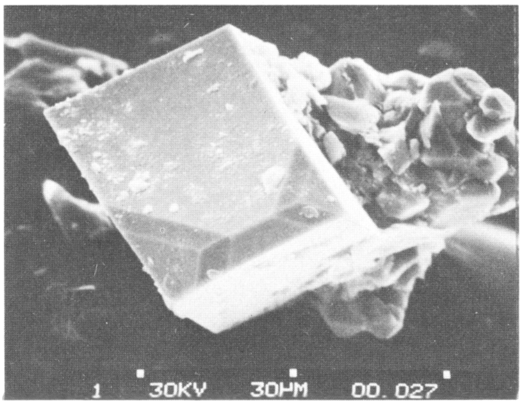
Fig. 1 shows two crystals of thorite and a slightly corroded crystal of sanidine in a lithophysal cavity within rhyolite. Fig. 2 shows an individual crystal of thorite which exemplifies the perfection of development. Forms shown are the second order prism {100} (dominant), the second order dipyramid {101}, and the unit dipyramid {111}. Thorite crystals from the Eifel region volcanics likewise are bound by the {100} and {101} forms (Hentschel, 1982). Thorite crystals from other geologic environments have the first order prism {110} developed as the dominant form rather than the second order prism {100}. Fig. 3 displays uneven development of the terminal forms on a crystal of blocky habit. Forms were determined by direct measurement on a Nedinsco 2-circle optical goniometer. A ρ value for 101 of 41° 45′ was determined for the Thomas Range thorite which compares very well with values for ρ calculated from the data of Frondel (1953) and Fuchs and Gebert (1958): 41° 30′ and 41° 33′, respectively.

Chemistry. SEM examination of the crystals of thorite showed major Th, U, and Si to be present. Electron microprobe analyses were made of four grains of the thorite using an ARL SEMQ instrument with six automated wavelength dispersive spectrometers. Analytical conditions were: 15 kV, 10 na on brass, 2 μm beam diameter, and a minimum of 20 sec count times on samples and standards and 2 sec count times on background positions. Standards used were: Si, natural zircon; U, uraninite; Th, synthetic ThO_2. Multiple analyses of the four grains showed them to be chemically homogeneous. No P, Pb, Fe, Ca, Y, or Dy were detected above background. Metamict thorite typically contains appreciable water, but the near 100 percent analytical summation indicates that only a very small amount is likely present in the Thomas Range thorite. The exceedingly small amount of material prohibited direct determination of the water content. The average of four analyses is SiO_2 17.3±0.3, UO_2 25.4±0.4, ThO_2 56.8±0.7, total 99.5 wt. % (analysts I. K. Brownfield and E. E. Foord).

A structural formula calculated from this analysis on the basis of 4 oxygen atoms is: $(Th_{0.72}U_{0.31})_{\Sigma 1.03}Si_{0.79}O_4$. The high UO_2 content is noteworthy and appears to be one of the highest reported, similar to that of Yang and Li (1980). Additional analyses of uranoan thorite are given in Bonshtedt-Kupletskaya and Smolyaninova (1972), and Speer (1980) has discussed the occurrence of uranium in thorite. The maximum uranium content of natural thorites coincides with the maximum uranium







FIGS. 1–3. FIG. 1 (*top*). Two intergrown crystals of uranoan thorite and one crystal of sanidine. Thorite crystals show development of forms {100}, {101}, and {111}. FIG. 2 (*centre*). Euhedral crystal of uranoan thorite showing nearly symmetrical development of terminal and prism forms. FIG. 3 (*bottom*). Termination of a uranoan thorite crystal showing unequal development of terminal forms. Distance between marks (in μm) is given at the foot of each figure.

content of 20 to 30 mole % $USiO_4$, which is temperature dependent, in synthetic thorite obtained by Mumpton and Roy (1961).

Optics. The crystals are both optically isotropic, with a refractive index of 1.86(1), and is X-ray amorphous, indicating their metamict nature due to the appreciable U content. Synthetic thorite has a mean n of 1.85 and heated synthetic coffinite has a mean n of 1.88 (Speer, 1980). The n obtained for the Thomas Range uranoan thorite (1.86) is in excellent agreement with the data for synthetic $ThSiO_4$–$USiO_4$ and supports the analytical results, indicating that only a very small amount of water can be present. Heating in air or in a reducing atmosphere for one hour at 1000 °C results in recrystallization to a mixture of thorite and uraninite.

Discussion. This appears to be the first reported occurrence of thorite or uranoan thorite in volcanic rocks of rhyolitic composition and adds an additional species to the growing list of minerals found in rhyolite lithophysae.

A suite of elements commonly observed together, including Be, Mo, W, Nb, Sn, Th, U, Li, Rb, Cs, and F is enriched in various igneous environments, particularly felsic differentiates (Burt *et al.*, 1982). *REE*, Mn, Sc, Ge, and Si are also in notable concentrations in these environments. Inasmuch as Th is among this group, a Th mineral, such as thorite, is not unexpected. Analogous cases in other environments, include the California vein, Chaffee County, Colorado, which contains the Th-bearing mineral brannerite in a hydrothermal vein (Adams, 1953); the hypabyssal and upper-level intrusives of the Climax–Henderson, Colorado, porphyries which also contain brannerite (Desborough and Mihalik, 1980).

Rankama and Sahama (1950) pointed out that Th is anomalously enriched in alkali rhyolites and granites but not in regular rhyolites and granites. Burt *et al.* (1982) discuss topaz-rhyolites of the western USA and present geochemical data for twenty-two localities. Anomalous levels of thorium are known to exist in rhyolites, including those of the Thomas Range with 25–60 ppm Th (Burt *et al.*, 1982; Staatz and Carr, 1964). According to M. Staatz (pers. comm., 1983), elevated thorium contents have been found in rhyolites of the Wah Wah Mountains, Utah; the Thomas Range, Utah; McDermitt caldera, Nevada–Oregon; and at an unspecified central Nevada locality. The residence of the thorium, however, has not been established, but the occurrence of thorium in thorite may explain the Th anomalies found in many of these alkali rhyolitic rocks. The mineral is probably present in lithophysae elsewhere in the Thomas Range and other localities.

Conclusions. As at the Eifel region locality (Hentschel, 1982), the thorite at Topaz Mountain has been misidentified as zircon. A thorite-bearing specimen from the Thomas Range in the Paul Seel micromount collection of the Denver Museum of Natural History, Denver, Colorado, labelled by P. Cosminsky as 'zircon and quartz' sent from P. R. Cosminsky to Paul Seel in 1970, shows that the material has been available for several years. Thorite may be an overlooked mineral on specimens of pseudobrookite and topaz from Topaz Mountain.

Thorite thus may be added to the following list of mineral species encountered from rhyolite lithophysae: spessartine–almandine garnet, sanidine, beryl, topaz, tridymite, cristobalite, quartz, opal, zircon (thorite?), pseudobrookite, bixbyite, hematite, ilmenite, magnetite, cassiterite, and fluorite.

Acknowledgements. We thank Mr Karl Hirsch, Denver, Colorado, who collected and kindly provided the material. Crystal forms were measured by R. C. Erd of the US Geological Survey. The manuscript was significantly improved by perceptive reviews by Richard C. Erd and Wallace R. Griffits of the US Geological Survey and an anonymous reviewer.

REFERENCES

Adams, J. W. (1953) *U.S. Geol. Surv. Bull.* 928-D, 95–119.

Bonshtedt-Kupletskaya, E. M., and Smolyaninova, N. N., eds. (1972) *Minerals* **3**, part 1, 127–40 (in Russian).

Burt, D. M., Sheridan, M. F., Bikun, J. V., and Christiansen, E. H. (1982) *Econ. Geol.* **77**, 1818–36.

Desborough, G. A., and Mihalik, P. (1980) *U.S. Geol Surv. Open-File Rept.* 80–661, 16 pp.

Frondel, C. (1953) *Am. Mineral.* **38**, 1007–18.

Fuchs, L. H., and Geberg, E. (1958) Ibid. **43**, 243–8.

Hentschel, G. (1982) *Mainzer Geowiss. Mitt.* 87–90 (in German).

Lindsey, D. L. (1979) *U.S. Geol. Surv. Misc. Inv. Map* I-1176, 1:62 500.

Maras, A. (1982) *Period. Mineral.* **51**, 233–7 (in Italian).

Mumpton, F. A., and Roy, R. (1961) *Geochim. Cosmochim. Acta*, **21**, 217–38.

Rankama, K., and Sahama, Th. G. (1950) *Geochemistry.* Univ. of Chicago Press.

Ream, L. R. (1979) *Mineral. Rec.* **10**, 261–78.

Speer, J. A. (1980) *Reviews in Mineralogy*, **5**, 113–35.

Staatz, M. H., and Carr, W. J. (1964) *U.S. Geol. Surv. Prof. Paper* 415, 188 pp.

Urunbaev, K. U. (1970) *Zap. Vses. Mineral. Obshch.* **23**, 146–51 (in Russian).

Yang, M., and Li, Y. (1980) Uranothorite discovered in rare earth, niobium, iron deposits at Bayan Obo, Inner Mongolia, China. *Kexue Tongbao*, **25**, 594–6.

[*Manuscript received 8 November 1984; revised 11 March 1985*]