Ages of uraninite from two British localities.

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Summary. Uraninite from Geevor Mine, Cornwall, has been analysed by the complete lead method and an age of 290 ± 7 million years has been accepted. Similar studies of uranium from Tyndrum Mine, Perthshire, give an age of 230 ± 8 million years. The significance of the results is briefly considered.

THIS is the first of a series of short papers to be published in this Journal presenting age determinations on uranium and thorium minerals. The work is co-ordinated by the Atomic Energy Division of the Geological Survey of Great Britain (hereafter abbreviated A.E.D.). Chemical analyses and lead separations are undertaken by the National Chemical Laboratory (N.C.L.) and isotopic analyses by the Atomic Energy Research Establishment, Harwell (A.E.R.E.).

Uraninite from Geevor mine, Cornwall.[1]

Uraninite at Geevor Mine, Pendeen, near St. Just, occurs in small amounts in the sulphide-rich parts of the lodes close to the margins of the central quartz leaders. The lodes are developed on the north-western

[1] A preliminary account of the determination was issued (1959), with a limited circulation, under the title Age Determination Report No. 6, Atomic Energy Division, Geological Survey of Great Britain. Since then tables (Stieff *et al.*, 1959) incorporating the latest decay constants have become available, and the results now quoted are read from them; this has increased the accepted age by the negligible amount of 2 m.y.

margin of the Land's End granite and generally trend in a north-west–south-east direction. Ore from which the uraninite was concentrated came from the north-western extensions of the tin-bearing lodes, below the ninth level.

Initial concentration was made by James tables at the mine and the material was further purified by superpanner and electromagnetic separator. The fraction of uraninite obtained was pure except for a small amount of cassiterite. This was allowed to remain as it was considered that any contribution of lead from this source would be negligible. The analytical results and apparent ages derived from them are given in table I.

TABLE I. Geevor uraninite.

Chem. anal. wt. %			Lead-isotope proportions in: Uraninite.	Galena.*	Uraninite corrected.	Isotopic ages in m.y.	
		^{204}Pb	$0{\cdot}0026 \pm 0{\cdot}0002$	1	—	207/206	302 ± 85
Pb	3·05	^{206}Pb	$94{\cdot}2 \pm 0{\cdot}04$	18·32	94·15	206/238	290 ± 7
U	$73{\cdot}60_8$	^{207}Pb	$4{\cdot}95 \pm 0{\cdot}04$	15·55	4·91	207/235	291 ± 15
Th	$1{\cdot}80_2$	^{208}Pb	$0{\cdot}891 \pm 0{\cdot}014$	38·10	0·792	208/232	308 ± 30

* Analysis of galena specimen presented by Geevor Tin Mine Ltd.

The agreement between the apparent ages is satisfactory and it is thus concluded that the uraninite has suffered no significant loss or gain of uranium, thorium, or their decay products. The $^{206}Pb/^{238}U$ age of 290 ± 7 m.y.[1] can be given with a higher degree of accuracy than the others, and is therefore taken as the accepted age of the mineral. It is not implied that all uranium mineralization in the south-west of England is necessarily of the same age. This will not be known until the additional analyses now being undertaken have been studied.

The age of the Geevor lodes is not known precisely from stratigraphical evidence. They cut 'killas' which is most probably of Devonian age; and lodes associated with the Dartmoor Granite, 100 miles to the east, cut Carboniferous rocks of Namurian age. Holmes (1959) has adopted the view that granite emplacement and mineralization occurred during mid-Morganian time. Kulp *et al.* (1960), on the other hand, have suggested that the granites are probably of very late Stephanian or Permian age. At present there is insufficient evidence for a choice to be made between these opinions or to enable any acceptable alternative to be put forward.

[1] m.y. = million years.

It is of interest to consider the Geevor results in relation to the ages which have been obtained from analyses of biotites from the Dartmoor and Land's End granites (table II). The spread of the results from the latter is considerable, and it must be questioned whether the correct result has yet been obtained for this material. The most recently reported ages for Dartmoor biotite, namely K–A 290 m.y., Rb–Sr 285±8 m.y., are compatible with the accepted age of the Geevor uraninite.

TABLE II. Ages of Dartmoor and Land's End biotite, in m.y.

	Potassium–Argon			*Rubidium–Strontium*
Reported by:	*Faul**	*Faul*†	*Kulp* et al.	*Lambert and Mills*‡
Dartmoor	295	290	271±5	285±8
Land's End	330	—	250±15	270±9

Analyses for each locality were made on material from the same biotite concentrate.

* These results (Faul, 1960) are recalculated from the original data given by Mayne *et al.* (1959). They were originally published as Dartmoor 305 m.y. and Land's End 340 m.y.

† This is a new determination (Faul, 1960).

‡ It is understood (R. St. J. Lambert, personal communication) that these results (Lambert and Mills, 1960) are preferred to those obtained earlier from the same samples and published by Kulp *et al.* (1960).

Uraninite from Tyndrum, Perthshire.

At Tyndrum a quartz–galena–blende lode known as the Hard Vein traverses folded Moinian quartzites and quartz–mica schists. The vein strikes north-north-east–south-south-west nearly parallel to a major tear fault, but for most of its length is a few hundred yards to the west of the fault. At its south-western extremity the vein meets the fault plane at an acute angle, but does not appear to cross it. Sporadically distributed within the Hard Vein are very minor calcite–baryte–uraninite–chalcopyrite occurrences, which from the field evidence appear to be of later age (W. H. Clyne, unpublished report).

The uraninite analysed was taken from fresh dump material, together with a galena specimen typical of the material occurring in the main quartz–galena–blende vein. The uraninite (variety pitchblende) occurs as botryoidal clusters several centimetres in diameter set in a calcite matrix. Chalcopyrite is distributed as irregular blebs throughout the specimens examined, and is quite abundant within the uraninite. Small amounts of galena are present, unevenly and very finely disseminated within the uraninite and occasionally as larger inclusions in chalcopyrite. This galena does not occur in a sufficient quantity for a separate analysis to be made. The uraninite was separated from the gangue and sulphides electromagnetically. The concentrate thereby obtained consisted of uraninite, which retained the very fine inclusions of chalcopyrite and galena, with a small amount of calcite adhering. The analytical results and the apparent ages derived from them are given in table III.

TABLE III. Tyndrum uraninite.

Chem. anal. wt. %			*Lead-isotope proportions in* *Uraninite*	*Galena*	*Uraninite corrected*	*Isotopic ages in m.y.*	
Pb	6·95	^{204}Pb	0·95±0·02	0·0268	(−0·007)	207/206	247±470
U	$67{\cdot}37_5$	^{206}Pb	47·0±0·14	0·4751	30·04	206/238	230±8
Th	nil	^{207}Pb	16·3±0·20	0·4138	1·53	207/235	232±50
		^{208}Pb	35·7±0·20	1·0	—		

The lead-isotope analyses show that common lead amounts to 68 % of the lead present in the uraninite concentrate. It is therefore important to consider the isotopic composition of the lead used for making the common-lead correction. The common lead forming the Tyndrum main-vein galena has a model age of about 470 m.y., which is approximately twice the apparent age of the uraninite. Its composition is close to that given by Moorbath (1959) for galena from the Abergairn and Ballater area of Aberdeenshire. If the common-lead correction is made using a composition corresponding to 230 m.y., the lead/uranium ages, although not greatly altered, become more discordant, namely: 206/238, 229 m.y.; 207/235, 259 m.y. The 207/206 age, being very sensitive to discrepancies between the lead/uranium ages, becomes 546 m.y. Thus despite its greater model age, galena from the main vein at Tyndrum provides the more satisfactory common-lead correction. For greater accuracy the correction is based on the 208 rather than the 204 isotope, thorium being absent.

The age accepted for the uraninite is the $^{206}Pb/^{238}U$ value of 230±8 m.y. This has the smallest analytical error, and as shown is not significantly altered by variations in the composition of the common lead. According to Holmes's (1959) revised geological time-scale, this is equivalent to an Upper Permian age. The significance of the difference in the 'ages' of the uraninite and galena will be considered in a future communication.

Appendix: Accuracy.

The method of calculation is based on Tables for the Calculation of Lead Isotope Ages by Stieff, Stern, Oshiro, and Senftle (1959). The accuracy given with each apparent age takes into account errors arising from analytical limitations and from the uncertainties in the accepted values of the physical constants, as given by Stieff *et al.* The errors have been obtained by substituting extreme values for each analytical result in the various equations so as to obtain the maximum and minimum ages. Where the largest variation from the mean exceeds 10 m.y., it is given to the nearest 5 m.y. above.

The accuracy of the chemical analyses, in terms of the quantity measured, is: U_3O_8 $\pm 0{\cdot}1$ % (for $U_3O_8 \geqslant 1$ %), U_3O_8 $\pm 1{\cdot}0$ % (for $U_3O_8 < 1$ %), ThO_2 $\pm 1{\cdot}0$ %, Pb $\pm 2{\cdot}0$ %. The errors quoted with the lead-isotope analyses are the standard deviations on ten measurements in each case.

Errors in the isotopic composition of the galena used for common lead correction have not been taken into account. In general the quantity involved is sufficiently small for any such errors to be negligible.

References.

Faul (H.), 1960. Bull. Geol. Soc. Amer., vol. 71, p. 637.

Holmes (A.), 1959. Trans. Edinburgh Geol. Soc., vol. 17, p. 183.

Kulp (J. L.), Long (L. E.), Giffin (C. E.), Mills (A. A.), Lambert (R. St. J.), Giletti (B. J.), and Webster (R. K.), 1960. Nature, vol. 185, p. 495.

Lambert (R. St. J.) and Mills (A. A.), 1960. Ann. New York Acad. Sci. (in press).

Mayne (K. I.), Lambert (R. St. J.), and York (D.), 1959. Nature, vol. 183, p. 212.

Moorbath (S.), 1959. Ibid., p. 595.

Stieff (L. R.), Stern (T. W.), Oshiro (S.), and Senftle (F. E.), 1959. U.S.G.S. Prof. Paper 334–A.