In the spring of 1954, Carl Roach collected samples of high-grade vanadium-uranium ore from the Peanut mine, Bull Canyon, Montrose County, Colo. The Peanut mine is in the Salt Wash sandstone member of the Morrison formation of Late Jurassic age. The ore samples contained two new quadrivalent vanadium minerals and abundant crystals of native selenium.

A sample collected in June 1954 by M. E. Thompson from the Parco No. 23 mine, Thompsons district, Grand County, Utah, contained crystals of native selenium associated with zippeite, metatyuyamunite, metarossite, montroseite, and corvusite. The Parco No. 23 mine is also in the Salt Wash sandstone member of the Morrison formation.

The physical properties of the selenium from the three localities are similar. It occurs as purple-gray metallic acicular crystals, usually as felty aggregates of very small crystals. The largest of the crystals is not more than 2 mm. in length. By transmitted light the crystals are nearly opaque, but they transmit red light and show parallel extinction. By reflected light they are anisotropic and dichroic (creamy white and darker).

Native selenium was reported from several carnotite deposits of the Colorado Plateau by Hillebrand, Merwin, and Wright (1914) on the basis of sublimation tests. The selenium crystals described above give a red sublimate in the closed tube. Although selenium is not easily recognized in the hand specimen, further occurrences of native selenium will undoubtedly be found in sandstones containing uranium and vanadium minerals.

Reference

Hillebrand, W. F., Merwin, H. E., and Wright, F. E. (1914), Hewettite, metahewettite, and pascoite, hydrous calcium vanadates: *Am. Philos. Soc. Proc.*, **53**, 31–54.

AGE DETERMINATION OF ZIRCON CRYSTALS FROM CEYLON*

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Introduction

Zircon crystals from Ceylon have long been known to gemmologists for their abundance and high quality as semiprecious stones. Because of extraordinary variations in physical properties, such as the indices of refraction and density, they have captured the attention of mineralogists for almost the last 100 years. However, very little is known regarding

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their age. Wadia and Fernando (1944) suggest a pre-Cambrian age for the pegmatites from which the zircon of the gem-bearing gravels is believed to have been derived.

Analytical Procedures

In making age determinations on 21 crystals of gem quality zircons from Ceylon, the alpha-particle emission of each sample was measured by a thick-source alpha-counting method in an ionization chamber. The counting rates, corrected for absorption, geometry, and background counts, were converted to units of alpha per milligram per hour assuming a theoretical absorption factor of 2.22×10^{-3} for zircon. For each sample a sufficient number of counts were recorded to reduce the probable counting error to less than 2 per cent.

The lead content of each sample was determined quantitatively by a recently developed spectrographic method (Waring and Worthing, 1953). This method is applicable to samples containing as little as 1 ppm lead with an error of less than 10 per cent.

Fluorimetric uranium analyses were made on 12 of the zircon samples and are believed to be accurate to ± 5 per cent.

Equivalent uranium may be estimated from the following equation:

$$eU \text{ (per cent)} = 2.75 \times 10^{-4} I$$

where I is the activity index in α/mg/hr. The ratio U/eU (column 5, Table 1) ranges from 0.83 to 1.17. The average of the ratios, 1.01, indicates that the alpha activity is due principally to uranium. A small amount of thorium may be present in those samples where the U/eU ratio is considerably less than 1.00.

Age Calculations

The ages were determined by a modification of the lead-alpha activity method described by Larsen and others (1952). The modifications used will be described more fully in another paper. The approximate age was first calculated for all the specimens from the formula

$$t = \frac{2600 \text{ Pb}}{\alpha} \qquad (1)$$

where t is the age in millions of years, Pb is the lead content in parts per million, and α is the alpha activity per milligram per hour. The constant, 2600, is based on the assumption that these zircon samples contain little or no thorium. As these ages are older than 300 million years, a correction was made similar to that described by Keevil (1939). Thus

$$t = t_1 - \tfrac{1}{2} k t_1^2 \qquad (2)$$

TABLE 1. AGE OF ZIRCON FROM CEYLON

Sample	α/mg/hr	Lead (ppm)[1]	Uranium (ppm)[2]	U/eU	Age (M.Y.)[3]	Corrected age (M.Y.)[4]
1	103	22	330	1.17	526	554
4–33	150	37	410	0.99	602	603
2	273	65	730	0.97	583	580
3–16	352	80			558	
5–1	380	88			568	
4–36	430	91			521	
3–11	533	115			530	
3	643	150	1470	0.83	571	546
3–42	649	143			542	
2–37	652	148			556	
2–13	850	196			566	
4	882	205	2470	1.02	569	575
2–18	913	200	2300	0.92	539	527
2–23	985	227			565	
6	1185	275	3580	1.10	569	587
2–17	1245	270	3180	0.93	532	524
7	1583	392	4760	1.09	604	623
9	1815	450	4880	0.98	604	603
1–2	2040	440			530	
10	2197	529	6450	1.06	587	602
1–26	2210	498	6280	1.03	553	560
			Average	1.01	561 ± 26	574 ± 32

[1] Determined spectrographically by C. L. Waring, U. S. Geological Survey.
[2] Determined fluorimetrically by F. Cuttitta, U. S. Geological Survey.
[3] Approximate age in millions of years, calculated from equations (1) and (2).
[4] Age in millions of years, corrected for possible thorium.

where t_1 is the approximate value given by equation (1) and k was chosen as 1.90×10^{-4} for these specimens, the Th/U ratios being very close to zero.

As there may be a minute amount of thorium in some of these specimens, more accurate determinations were made on 12 of the samples. By making a uranium analysis thorium, if present, can be determined by difference to yield a more accurate value for the constant in equation (1) and for k in equation (2).

The ages based on equations (1) and (2) for all the zircon samples are shown in Table 1. The ages for 12 zircon samples on which uranium analyses have been made are shown in column 7.

Discussion

The possible loss of uranium, thorium, their radioactive daughter products, and lead by natural leaching or other geologic processes must be considered for the suite of samples. Several samples of varying lead and alpha-activity content have been acid treated in 1:1 aqua regia at a temperature of 80° C. for half an hour. Alpha activity and lead determinations on the acid-treated material showed no measurable change. It is therefore assumed that natural leaching has not altered the Pb/U ratio of the zircons. The good agreement of the ages over the range of samples tends to bear out this assumption. All the lead is believed to be of radiogenic origin. The presence of any original lead in the zircon structure, that is, lead present at time of crystallization of the zircon, should show up in a sample of very low lead content. For example, in sample 1 which contains 22 ppm of lead, the result would be an appreciably greater age than the average if significant amounts of original lead were present.

The average age of the suite of 21 zircon crystals as determined by the Larson method is 561 million years, and the age of the 12 samples corrected for possible thorium is 574 million years. The age of the gem-type Ceylon zircon is probably about 570 million years. A geologic time table compiled by Marble (1950) shows that this value is equivalent to late pre-Cambrian age.

Holmes (1927) obtained 585 million years from the average lead-uranium ratios in a thorianite from Ceylon. In his calculations he used the approximate formula for young rocks. Using the correction (equation 2), this age would now be calculated as approximately 565 million years.

Nier (1939) extracted the lead from a thorianite sample from Ceylon and analyzed it isotopically. The results of this analysis—531, 461, and 485 million years from the Pb^{206}/U^{238}, Pb^{208}/Th^{232}, and Pb^{207}/Pb^{206} ratios, respectively. On a specimen of Ceylon zircon, Tilton and Aldrich (1955) have recently obtained 540, 544, 555, and 538 million years from the Pb^{206}/U^{238}, Pb^{207}/U^{235}, Pb^{207}/Pb^{206}, and Pb^{208}/Th^{232} ratios, respectively.

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References

Holmes, Arthur (1927), The Age of the Earth. New York, Harper and Brothers Publishers, pp. 1–80.

Keevil, N. B. (1939), The calculation of geological age: *Am. Jour. Sci.*, **237**, 195–214.

Larsen, E. S., Jr., Keevil, N. B., and Harrison, H. C. (1952), Method for determining the age of igneous rocks using the accessory minerals: *Geol. Soc. Am., Bull.* **63**, 1–118.

Marble, John P. (1950), Report of the committee on the measurement of geologic time 1949–1950: *Nat. Research Council*, p. 18.

Nier, Alfred O. (1939), The isotopic constitution of radiogenic leads and measurements of geologic time II: *Phys. Rev.*, **55**, 153–163.

Tilton, G. R., and Aldrich, L. T. (1955). The reliability of zircons as age indicators: *Trans. Am. Geophysical Union*, **36**, 531.

Wadia, D. N., and Fernando, L. J. D. (1944), Ilmenite, monazite and zircon (sessional paper VI of 1926, revised) Gems and semi-precious stones of Ceylon: *Prof. Paper* no. **2**, Records of the Dept. of Mineralogy, Ceylon.

Waring, Claude L., and Worthing, Helen (1953), A spectrographic method for determining trace amounts of lead in zircon and other minerals: *Am. Mineral.*, **38**, 827–833.

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The Russian mineralogist Konstantin Konstantinovich, born March 5, 1875, died Dec. 21, 1954.