

**Radioactive Minerals.** R. Dhana Raju. Geological Society of India, P.B. No. 1922, Gavipuram P.O., Bangalore 560 019. 2005. 65 pp. Price not mentioned.

In an attempt to popularize geology among students of science and technology (S&T), the Geological Society of India (GSI), Bangalore, has a programme of publishing 'a series of education pamphlets' (to use the words of its President, B. P. Radhakrishna). The 65-page book under review is one such.

Ever since America dropped atomic bombs over the Japanese cities of Hiroshima and Nagasaki on 6 and 9 August 1945 respectively, to terminate World War II, radioactive minerals (minerals containing uranium and/or thorium) became important in most countries. As uranium is the principal raw material for atomic energy, the subject of radioactive minerals has continued to be important. Way back in 1949, the United States Atomic Energy Commission, in cooperation with the US Geological Survey, had published a booklet entitled *Prospecting for Uranium*. This was followed by R. D. Nininger's *Minerals for Atomic Energy*<sup>1</sup>. These publications were primarily aimed at arousing public interest in USA in searching for uranium. Among the other important books on radioactive minerals are those of George<sup>2</sup>, Frondel<sup>3</sup>, Heinrich<sup>4</sup>, and Frondel *et al.*<sup>5</sup>. Although the book under review is intended for students of S&T, its contemporary relevance to students of mineralogy and economic geology is beyond question.

The five chapters of the book have much useful information presented through a concise text, 38 illustrations, and four tables. Chapter 1 on 'Radioactivity, radioelements and radioactive anomaly' highlights the naturally-occurring radioelements, thorium and uranium; gives the decay series of thorium-232, uranium-235, and uranium-238; illustrates the model of a <sup>235</sup>U atom; specifies the contents of uranium and thorium in the earth's crust and in some common rock types, and introduces the reader to the analytical methods for determining the radioelements in samples from radioactive areas. Chapter 2 on 'Radioactive minerals' discusses the geochemical processes involved in the formation of radioactive minerals, classifies the primary and secondary radioactive minerals, and gives the important properties of 19 radioactive minerals,

such as their chemical formulae, uranium and thorium content, colour, hardness, specific gravity, and system of crystallization. Highlights of this chapter are the ten photomicrographs of selected radioactive minerals. Chapter 3 on 'Exploration for radioactive minerals' details the investigative methodology for discovering uranium and thorium ore deposits, gives the flow-sheet for producing yellow-cake, and outlines the procedure for laboratory studies of monazite (Ce, La, Nd, Th)PO<sub>4</sub>-bearing beach sands. Chapter 4 on 'Occurrence and major deposit-types of radioactive minerals with Indian examples and resources', gives the salient features of 15 major types of uranium deposits in the world: unconformity-related, sandstone, quartz-pebble conglomerate, hydrothermal veins, breccia complex, intrusive, phosphorite, collapse breccia pipe, volcanic, surficial, metasomatite, metamorphic, lignite, black shale, and other types. This chapter has a geological map of India showing the important deposits and occurrences of radioactive and other atomic minerals. Chapter 5 on 'High-tech industrial applications, supported by U, Th, rare metals and rare earths', summarizes the sequential steps of the 'nuclear fuel cycle' in India, involving the exploration and establishment of uranium and thorium deposits; mining and milling of the ore; conversion of yellow cake to UF<sub>6</sub> and fuel fabrication; generation of electricity; and the spent fuel storage, reprocessing, and vitrification. This chapter also highlights the three stages envisaged by the late Homi J. Bhabha, Father of India's nuclear programme, for the country's nuclear power production. The chapter concludes with brief accounts of the nuclear and high-tech industrial applications of some rare metals like niobium, tantalum, beryllium, lithium, the rare-earth elements, zirconium and hafnium.

The book has several deficiencies: It lacks a subject index, glossary, and a list of selected readings on radioactive minerals for the interested reader to pursue further. In the caption for figure 19 (p. 32), 'yellow cake' is referred to as being UF<sub>6</sub>, which is not correct. It is a magnesium diuranate (compare with the subtitle under item 3 on p. 59 'Conversion of yellow cake to UF<sub>6</sub> and fuel fabrication'). In the section on Indian examples of uranium deposits (pp. 48–51), it is not clear whether the tonnages mentioned re-

fer to U<sub>3</sub>O<sub>8</sub> or to the ore. Figure 29 (opposite p. 50), which is a 'Geological map of India showing atomic (radioactive) mineral deposits and important occurrences, with legend of geology (I) and deposits/occurrences of U(II), Th(III) and rare metal-rare earths (IV)', has a cluttered look. The font for the 'legend' and numbers on the map is too small and illegible. In several places in the text, the author has used the abbreviation 'etc.'. This should have been avoided, and the items involved specified. The proof-reading is unsatisfactory. For example, the 'List of contents' shows chapter 2 as starting from p. 10, whereas it actually starts from p. 11. For the eight illustrations on p. 41, the captions are stated to be 'on opposite page', whereas the captions are on the reverse of p. 41, i.e. on p. 42.

Notwithstanding these deficiencies, the book is commendable for its contents, style of presentation, and high quality of production using a reader-friendly font and milky white paper. GSI, Bangalore, should have the book translated into the major Indian languages, so that every Indian interested in radioactive minerals can own a copy. In a second edition of the book, apart from including a subject index, glossary, and a list of selected readings on radioactive minerals, the author should consider the possibility of presenting the illustrations in colour, wherever feasible.

1. Nininger, R. D., *Minerals for Atomic Energy*, D. Van Nostrand Company, Inc., New York, 1954, p. 367.
2. George, D'Arcy R., *Mineralogy of Uranium and Thorium Bearing Minerals*, RMO-563, USAEC Technical Information Service, Oak Ridge, Tennessee, 1950.
3. Frondel, C., *Systematic Mineralogy of Uranium and Thorium*, US Geological Survey Bulletin 1064, Washington DC, 1958, p. 400.
4. Heinrich, E. W., *Mineralogy and Geology of Radioactive Raw Materials*, McGraw-Hill, New York, 1958, p. 654.
5. Frondel, J. W., Fleischer, M. and Jones, R. S., *Glossary of Uranium- and Thorium-Bearing Minerals*, US Geological Survey Bulletin 1250, Washington DC, 1967.

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