in this new edition. The result is a new book, two to three times as long as the original, but maintaining all its many virtues, not least being the multitude of splendid illustrations.

This great expansion is achieved in two ways. All the old chapters have been revised and new ideas injected into them. For example, the rheidity concept is applied to the flow of glacier-ice, the rise of salt-domes and the more deep-seated operations of rock-deformation; the properties of minerals are related to their atomic structure; fluidization is invoked in the formation of volcanic orifices, and permafrost and turbidity currents receive due attention. These few examples indicate the scope and modernity of the revision. But perhaps more important still is the addition of mainly new chapters dealing mostly with modern applications of physics to problems of the Earth's interior. Here Prof. Holmes comes into his own and presents sparkling discussions of such matters as radiometric dating, convection currents deep in the Earth, heat flow in continental and oceanic segments of the crust, and continental drift. Many of these topics have occasioned violent controversy and will continue to do so, especially the notion of an expanding Earth favoured by the author. These new chapters are therefore compulsory reading for the non-biological geologist—and they would not harm the biological—for they show where a large and lively section of his science is moving to. As already mentioned, the book, like its forerunner, is embellished with hundreds of strikingly beautiful photographs, as well as great numbers of clear text-figures.

At the price, this new *Principles of Physical Geology* is very good value indeed. But with no ungrateful intent, it must be conceded that a book of more than 1,300 thick and large pages and weighing some 6 lb. is on the massive side. It has become a book for the library table, not to be carried about with ease and not to be read in bed or in the train or even in the arm-chair—situations in which most reading now has to be done. It is true that one cannot have too much of a good thing, but it is sometimes better not to have it in one large helping. Might it not have been preferable to have issued the dominantly geophysical additions as a companion volume to the main revision? Be that as it may, here is an excellent survey of the present state of knowledge and the relevant hypotheses concerning the geological machinery of the Earth to be read, in whatever situation, with pleasure and profit.

H. H. READ

MINERAL RESOURCES OF THE SEA

The Mineral Resources of the Sea

By John L. Mero. (Elsevier Oceanography Series.) Pp. xiii+312. (Amsterdam, London and New York: Elsevier Publishing Company, 1965.) 60*s*.

DR. J. L. MERO trained as a mining engineer. He joined the Institute of Marine Resources, University of California, in 1957, and his book is the outcome of a co-operative study between that Institute and the Department of Mineral Technology at Berkeley. It is a worthy supplement to *Raw Materials from the Sea*, by E. F. Armstrong and L. M. Miall, last published in 1946, describing remarkable advances in basic and applied science and technology. Dr. Mero maintains that as a source of minerals the sea has been little exploited relative to its potential, and he believes this is due to lack of knowledge of what is in the ocean and of the possible advantages, and to the absence of suitable technology and of any pressing need, either economic or political, for exploiting the sea as well as the land. Such excuses are melting away in the light of the revolutionary advances of marine science and technology during the past twenty years.

The book does not deal with enclosed seas such as the Dead Sea and the Caspian Sea, but over the open ocean it ranges from beaches to deep ocean sediments, and to a rich sulphur deposit which is being worked below 2,000 ft. of sediment in the Gulf of Mexico.

Heavy minerals such as magnetite, ilmenite, zircon, rutile and monazite are mined from beaches in many parts of the world; also diamonds, gold and platinum, phosphorite, quartz sands and calcareous shell deposits. Other deposits are mined in submerged beaches.

Only three minerals are taken to any extent from the water: common salt, magnesium and bromine. 5 per cent of the common salt used in the United States comes from San Francisco Bay. Calcium and magnesium salts are removed by fractional crystallization before the final evaporation. In the U.S.S.R. and Finland the salt water is concentrated by freezing before evaporation by heat. 99 per cent of the bromine in the Earth's crust occurs in the sea, which is now the chief source of supply. It is expelled by chlorine and it is an advantage to use fairly warm water with little organic contamination. Virtually all the metallic magnesium used in the United States comes from the sea and production could be much increased; cheap sources of lime (calcareous shells) and power are desirable. Much effort is being devoted to research on selective ion-exchange resins for extracting valuable metals.

Offshore banks are worked for shell deposits and for sand and gravels which have often been graded by natural processes. Placer deposits are being recovered from old river valleys afterwards filled with sediments. Increasing amounts of oil are being taken from offshore wells. There are very promising deposits of phosphorite nodules and glauconite.

The book has a chapter on the deep sea sediments and their possible exploitation. It is estimated that calcareous oozes are accumulating eight times as fast as the world is consuming limestone, and Dr. Mero thinks they might be worked. Diatom ooze, which is largely silica, offers similar possibilities.

Nearly half the book is taken up with a fascinating account of what we know about manganese nodules which, from an economic standpoint, promise to be the most important sediment of the deep sea floor. Manganese and iron oxides occur very widely as grains, nodules and rock coatings with some 25 per cent manganese, as much as 1 per cent of cobalt, copper, nickel or titanium, and lesser amounts of other rare metals. It is generally believed that the manganese and iron are derived from the dissolution of igneous rocks, both on land and on the sea floor, and at its slightly alkaline *p*H sea-water is saturated with both. There is evidence that their hydrated oxides filter down through the water and act as scavengers for copper, nickel, cobalt, molybdenum, zinc and lead, which are present at low concentrations in the sea. On the ocean floor the colloidal particles are swept along until retained by a suitable surface. The mechanics of agglomeration is obviously complex with chemical, physical and probably bacteriological processes. The ordinary rate of growth is probably only a fraction of a millimetre in 1,000 years, but even this means that the deposits are forming more rapidly than the world rate of consumption of manganese, copper, nickel and cobalt. The coating has been observed to grow rapidly on identifiable fragments of naval shells. A Second World War shell found at 200 m off San Diego had a coating 1·5 cm thick after 15 years. Much information about the distribution and composition of the nodules is listed, and there are many photographs.

The final chapters deal with technological progress and with the legal difficulties which look like growing even faster than the technological difficulties are overcome. The book presents a challenging picture likely to leave anyone wondering why expeditions to the Moon receive any consideration.

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