BOOK REVIEWS

THE GEOLOGY OF THE NORTHERN RHODESIA COPPERBELT, edited by F. MENDELSOHN. Macdonald & Co., London, 1961, xvi+523, 84s net.

The new volume on "The Geology of the Northern Rhodesia Copperbelt" was prepared for the Seventh Commonwealth Mining and Metallurgical Congress, Southern Africa, 1961, under the editorship of F. Mendelsohn, with contributions by company geologists.

The first part of the book (p. 17–165) is devoted to a synthesis of the stratigraphy, structure and ore occurrence, with a stimulating discussion of the syngenetic theory of ore deposition as applied to these unusual deposits. This is followed (p. 166–213) by an account of problems of exploration with sections on aerial photography, geophysics and geochemistry. The second part of the book (p. 214–486) gives a detailed description of the individual copper deposits, arranged in five chapters: Bancroft-Nchanga area (66 p.), Chambishi-Nkana basin (62 p.), Roan-Muliashi basin (63 p.), Mufilira area (60 p.), and Bwana Mkubwa area (20 p.). These chapters, to which many geologists have contributed, are uniformly of high quality and present in clear fashion the essential facts on which a theory of ore deposition must be based. Included are nine major deposits and four of lesser importance. Emphasis is on field occurrence of the ore and its relation to stratigraphy and structure, with numerous maps, cross-sections and charts. Mineral distribution and primary zoning are well covered, but only brief reference is made to ore textures and other laboratory data. A geological map of the entire copperbelt forms an important feature of the volume. Data on ore production and reserves are also included, as well as a brief history of the mines.

The account of regional tectonics by Brock and of the structural elements of the copperbelt by Garlick places the ore deposits in their proper geological setting. The dominant structural unit is the Rhodesia-Katanga-Angola (R.K.A.) or Lufilian arc of folds, which extends for 500 miles through the copper province. Dominant in the Rhodesian section is the Kafue anticline, composed of basement rocks flanked by sediments of the Lower Roan series. Associated with the folding was mild metamorphism of the Roan sediments, locally accentuated in the Roan syncline. The orogeny cannot be dated precisely, but involved formations of Lower and Middle Kundelungu age. Approximately coincident with the folding, large bodies of gabbro invaded the Katanga formations, especially in the Chambishi-Nkana and Roan basins. Pienaar gives an informative summary of mineralization in the basement complex. In places the older rocks are "virtually saturated" with quartz veins. Many veins contain carbonate, feldspar and anhydrite, and some contain specularite, tourmaline, pyrite and copper minerals. Tourmalinization of shear zones is not uncommon. Copper veins are abundant in close proximity to several major ore deposits.

The review of the stratigraphy of the Katanga system and the correlation charts are extremely helpful. In the mining areas, the Lower Roan is commonly made up of basal footwall quartzite, ore formation, and hanging-wall formation of quartzite, argillite and dolomite. The typical ore formation consists of argillite (the ore shale) and a basal unit of impure dolomite, but in places it consists of alternating quartzite and shale. Contrary to what may be the prevailing impression, the orebodies are not confined to the ore shale; fully a third of the ore occurs in dolomite, quartzite, arkose or conglomerate. The lateral zoning of the sulfides, which was recognized by the early workers, is now stressed in support of the syngenetic origin of the ore. In general, the sequence downward and along the strike is chalcocite, bornite, chalcopyrite and pyrite. The zoning is also evident across the bedding of the ore formation. The details of mineral distribution, however, are varied and complex. At Chibuluma, the zones are repeated on both sides of a pyrite core; at

Roan Antelope and Mufulira, the zones interfinger and the zonal boundaries transgress the bedding.

The veins occurring in the Lower Roan series are interpreted by Mendelsohn as products of regional metamorphism. They consist chiefly of quartz, carbonate and feldspar; minor constituents include specularite, mica, tourmaline, anhydrite and sulfides. Their similarity in mineralogy to veins in the basement is striking. Veins, in barren strata contain specularite, and only where crossing ore beds do they contain iron-copper sulfides. In places the occurrence of copper minerals coincides with leaching of copper in the adjacent ore seam; in many places the veins are bordered by narrow zones of bleached rock (Figs. 42, 173). At Roan Antelope, however, a vein shows almost solid chalcopyrite for many feet opposite areas where removal of copper from the walls is not evident. No indication of lateral secretion of sulfides is found in veins at Nchanga. At Mufilira sulfides apparently derived from the basement have migrated into and along the veins and out into the wall rock. At Roan Antelope some veins are bordered by tourmalinized rock; here also constituents have apparently "migrated into the veins and out into the arkose" (p. 115).

To many readers of the volume the question of the origin of the ores will be of principal interest. The syngenetic theory is favored and is strongly defended by Mendelsohn and Garlick (p. 130–165). They base their argument on the great lateral extent of the ore (up to 7 miles at Roan), limited stratigraphic thickness of the ore bed, absence of feeder channels, and lack of correlation of ore grade with folds and fractures. They also emphasize the remarkable zoning of the ore minerals, each zone comprising a strip essentially parallel to the trend of the formations. These zones are explained by deposition of ore in a shallow basin, with decreasing copper-iron ratio outward from the shoreline. The pinch-out of the ore formation along the west side of the Kafue anticline serves to identify the ancient shoreline; it lies a few miles east of a major belt that includes Chambishi, Nkana, Baluba and Roan Antelope (Fig. 48). As indicated by cross-bedding, currents came from the northeast, and copper contributed to the basin was deposited in greatest amount close to shore, thus establishing the westward zonal pattern: chalcocite, bornite, chalcopyrite and pyrite. Repeated transgression and regression account for the complex stratigraphic distribution of the minerals. However, 15 miles northeast of the postulated shoreline and on the opposite side of the Kafue anticline are the deposits of Mufilira, where the ore occurs in quartzite rather than in shale. The same basic principles of ore deposition and metal zoning are applied to Mufilira and to most of the deposits of the copperbelt, but the shoreline elsewhere is not specifically indicated. The "syngenetic theory accounts for most of the features of the deposits that have been observed" (p. 146).

According to Garlick, no sulfide deposition took place in oxygenated waters at the shoreline, but in the deeper, stagnant water aenerobic bacteria were adequate to precipitate iron and copper sulfides along with the detrital sand and clay. The metals were deposited as fine, colloidal mixed sulfides; these were converted by diagenesis and mild metamorphism to the mineral assemblages that now make up the ore beds.

The facts of ore occurrence as outlined give strong support to the syngenetic theory, but perusal of chapters describing individual deposits brings out certain features that are difficult to reconcile with the sedimentary hypothesis. Some of the difficulties are noted by McKinnon and Smit in their review of the Nchanga deposits. The two main orebodies transgress the bedding, and in places mineralization is almost continuous through 300 ft of strata, including arkose, banded shale and quartzite. Moreover, only one sixth of the copper occurs in the banded shale, the formation most favorable for syngenetic copper. The absence of granitic intrusives of post-Roan age is not conclusive; the copper may be related to basic magmas which gave rise to extensive gabbro intrusions. The footwall arkose probably had sufficient permeability to permit ore fluids to pass through the beds and reach the base of the ore formation, which was more or less brecciated. These authors also remark that the zoning of ore minerals could be produced by some vague hydrothermal process or by equally uncertain bacterial action. They give greater emphasis to the larger Northern Rhodesia-Katanga-Angola base-metal province, of which the bedded copper ores form a part, and note a broad regional zoning, with ores of several types occurring in the area between the copperbelt and the granitic and syenitic intrusives 150 miles to the south (Fig. 89). They conclude that the origin of the copper deposits is still an open question and stress the need for further research on basic principles of ore deposition, including present-day syngenetic processes, and for study of the many deposits of the larger metallogenetic province. The restriction of the ores to the Lufilian arc of deformation may be of fundamental significance.

In his review of continental structure, Brock also describes the regional distribution of the copper deposits. Those of greatest importance define a "mineralized lineament" some 200 miles in length, which includes stratiform deposits, massive sulfide ores and ores related to faulting. Brock suggests that the lineament defines a fundamental fracture in the basement and that this has played a critical part in localization of the copper deposits.

Jordaan describes the Nkana deposits in detail and summarizes the essential facts, but he comes to no definite conclusion as to their origin. Pienaar tends to favor the hydrothermal origin for the ore at Bwana Mkubwa, relating it to late gabbro intrusives. It should also be noted that to a minor extent the ore minerals occur along cleavage planes and small fractures. The copper-bearing veins in the basement rocks may be significant, but their relation to the ore deposits is uncertain.

The editor and contributors, as well as the mining companies that sponsored the volume, are to be commended for its publication. The volume gives an excellent account of the geology and ore deposits and will long serve as the basic reference on the copperbelt. In general the field relations are described in sufficient detail for the reader to draw his own conclusions as to the origin of the ore.

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DETERMINATION TABLES FOR ORE MICROSCOPY. C. SCHOUTEN. Elsevier Publishing Company, Amsterdam and New York, 1962. 242+v pp., $10.00

The book consists of 23 determinative tables developed and used by Professor Schouten in teaching ore microscopy over a period of years at the Technological University at Delft (The Netherlands). The first five tables cover distinctly colored minerals, each table corresponding to a color group. Each group is subdivided into isotropic and anisotropic minerals and in three of the groups anisotropic minerals are further divided according to hardness or reflectivity. Tables 6–12 cover minerals that are not distinctly colored, arranged in three groups according to reflectivity, with subdivisions on the basis of hardness, optical properties and paragenesis. Tables 13 to 23 cover special mineral groups such as the Ni-Co-Fe arsenides, the silver sulfosalts and the tellurides.

Roughly 300 minerals are included. Reflectivity (if known), hardness relative to associated minerals, color, anisotropism (or isotropism), and brief descriptive notes are given for each mineral, together with comments on diagnosis, page references to descriptions in the well known books by Uytenbogaardt and Ramdohr, and short lists of associated minerals. A mineral that is on the borderline between two groups appears in the tables for both, and numerous cross-references between tables are given.

As indicated above, the determinative tables have no simple, uniform basis. The principal bases used are optical and physical properties, but the tables for special groups are designed to take advantage of the occurrence of some minerals in special parageneses.

The multiple basis of subdivision requires careful study of the scheme of the tables prior to use.

The success of tables of this kind is to be measured in terms of their effectiveness in mineral identification, as indicated by a prolonged period of use. From preliminary appraisal, one would expect the tables to give positive identification of many of the ore minerals. It is evident, however, as the author recognizes, that some minerals will be unidentifiable. Thus, distinguishing the various silver sulfosalts, the manganese oxide minerals, or the tellurides from the data given will not be possible. The principal reason is that descriptions of properties are qualitative, apart from reflectivity data.

The limitations of tables based on qualitative data underscore the importance of developing internationally accepted standard data for reflectivities, microhardness and rotation properties of ore minerals. This task has been assigned to the newly created International Commission on Ore Microscopy. Pending completion of its work, Professor Schouten's tables are an admirable attempt to deal with the identification problem and will be widely used in laboratories of ore microscopy.

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SCIFAX DIFFERENTIAL THERMAL ANALYSIS DATA INDEX, compiled by R.C. MACKENZIE, Cleaver-Hume Press Ltd., London, 1962, £48 plus postage and insurance.

This data index contains 1630 punched cards (4″×6″), including 20 introductory, 1012 mineral, 287 inorganic and 311 organic chemical cards. The individual cards are coded into 28 classes based on the temperatures of the principal and second peak. Additional punched data may be added along the sides and bottom of the cards at the user's discretion. The present index includes data published up to late 1960. It is stated that supplements will be issued at suitable periods. The reviewer noted at least one omission, but in a compilation of this scope some omissions are to be expected.

The data index resembles the A.S.T.M. *X*-ray Powder Data File. Of course, it is not as extensive, nor does it have the degree of precision associated with *x*-ray measurements. However, improvements in technique and a tendency toward standardization are making the comparison of results more satisfactory than was possible previously.

In addition to the usefulness of this data file for comparative purposes, it presents differential thermal information from many journals and books which are not ordinarily available. The Differential Thermal Analysis Data Index should be a valuable source of information to every investigator employing differential thermal analysis.

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PUBLICATIONS RECEIVED

THE PICKING TABLE, Vol. III, No. 2. Mimeographed, 11 pages. Published by The Franklin Ogdensburg Mineralogical Soc., Inc., Box 146, Franklin, N. J., July 1962.

Contains an interesting short article on the Sterling Hill mud zone.

CHART OF THE NUCLIDES, 2nd ed. Issued by the Federal Minister of Nuclear Energy, Bad Godesberg, Federal Republic of Germany; prepared at the Institute of Radio Chemistry, Nuclear Research Center, Karlsruhe.

The chart was developed by Professor Seelmann-Eggebert and co-workers. Requests for the chart and for the five-page pamphlet of explanation that comes with it should be addressed to Publications Office, National Research Council, 2101 Constitution Ave., Washington 25, D. C. The cost is $1.00.

MINERALOGICAL SBORNIK of The Geological Society of Lvov, No. 15. 455 pages. 1961.

In Russian with an English table of contents. It contains 23 major articles, 16 mineralogical notes, 3 biographical notes, 8 critical remarks and bibliography, 1 memorial and 2 proceedings of meetings. The range of topics included in the major articles and in the notes is very board: mineral determination, zircon morphology, metallic bonding, formation of skarns, crystal-bearing quartz veins, spodumene pegmatites, barite deposits meteoritics and luminescence of diamond, to cite just a few.

PRINCIPLES OF STRATIGRAPHY, by A. W. Grabau. Two volumes, paper cover: Vol. I, 581+xxxiv pages; Vol. II embraces pages 582–1185. Reprinted by Dover Publications, Inc., 180 Varick St., New York 14, N. Y. $2.50 each volume.

TREATISE ON SEDIMENTATION, by William H. Twenhofel. Vol I, 460+viii pages; Vol. II includes pages 461–926+xii.

This is a reprint of the second edition completely revised, which first appeared in 1926; reprinted as a paperback by Dover Publications, Inc., 180 Varick St., New York 14, N. Y. Price: $2.35 each volume.

PRACTICAL REFRACTOMETRY BY MEANS OF THE MICROSCOPE, 2nd ed., Roy M. Allen. Paper cover, 46 pages, 15 figures. R. P. Cargille Laboratories, Inc., 117 Liberty St., New York 6, N. Y. $1.00.

A revised edition of a useful handbook for workers in all fields requiring knowledge of techniques in the microscopic identification of minerals and other solid phases. Written especially as a guide and aid to users of Cargille's index of refraction liquids. The cost of the booklet may be credited against orders for sets of the liquids.

EQUILIBRIUM DIAGRAMS FOR MINERALS AT LOW TEMPERATURE AND PRESSURE. Compiled and edited by the Geological Club of Harvard University; Harrison H. Schmitt, editor. 199+ix pp. Paper cover, 186 figures. Geological Museum, Cambridge 38, Mass. $2.80.

A compilation of diagrams depicting the theoretical stability fields of minerals in simple systems at low temperature and pressure. Variables are activities, concentrations, Eh, pH and partial pressures. The types of phase diagrams included are: 1) composition diagrams; 2) partial pressure diagrams for anhydrous systems; 3) partial pressure diagrams for hydrous systems; 4) Eh-pH diagrams for aqueous systems; and 5) block diagrams with combinations of variables. Most timely and useful.