

BOOK REVIEWS

THERMOLUMINESCENCE OF GEOLOGICAL MATERIALS. Edited by D. J. McDOUGALL, Academic Press, New York, 1968, 678 p., \$25.00.

Proceedings of the NATO Advanced Research Institute on Applications of Thermoluminescence to Geological Problems, held at Spoleto, Italy, in September, 1966. Sixty five papers were presented at the symposium, by geologists, archeologists, physicists and chemists from 17 countries. Fifty-eight of these papers are published here under the chapter headings: *Theoretical Considerations; Technique; Modifying Parameters; Related Phenomena; Geological Age Determination; Archeology; Radiation Dosimetry; Climate and Paleotemperature; Igneous Rocks, Wall Rock Alteration and Ore Deposits; Meteorite and Lunar Thermoluminescence; Additional Applications*, and a *Bibliography*.

WILLIAM T. HOLSER

MIGMATITES AND THE ORIGIN OF GRANITIC ROCKS. by K. R. Mehnert. Elsevier Publishing Co., Amsterdam, London, New York. 1968. 393 p., 138 illustrations and 14 tables, \$26.

This is a carefully prepared, advanced textbook which fills a need for those interested in petrogenesis. Illustrations are well chosen and clear. In the first chapter the author discusses the problems of classification and nomenclature of migmatites, namely descriptive, functional, and genetic.

The next two chapters deal with the megascopic structures and microfabrics of migmatites. Migmatite is defined as a "megascopically composite rock consisting of two or more petrographically different parts one of which is the country rock generally in a more or less metamorphic stage, the other is of pegmatitic aplitic, granitic or generally plutonic appearance." It is usually possible to distinguish the following parts of a migmatite. (1) The "paleosome" i.e., the unaltered or only slightly modified parent or country rock. (2) The "neosome" i.e., the newly formed rock portion which can be divided into: (a) The "leucosome" made up of light colored minerals. (b) The "melanosome" consisting of mafic minerals. Twelve structures ranging from agmatic to nebulitic are carefully described and illustrated.

Since the microfabrics of the *initial stages* are similar to those of metamorphic rocks and those of the *final stages* to magmatic rocks the *middle range* is especially important. The growth of minerals during metamorphism and the recrystallization of the minerals already present is characterized by a progressive coarsening of the grain size with a loss of the original lineation.

The next two chapters are concerned with experimental petrology and temperatures of formation. The earlier classical results of Bowen, Morey, Shairer, and Niggli on dry melts do not have as direct a bearing on the formation of migmatites as the later work by Goranson and subsequently that of Tuttle and Bowen, Yoder, Winkler, and Wyllie. These are treated in detail with appropriate diagrams.

The author points out that the temperature of formation of magmatic rocks was formerly assumed to be relatively high whereas those who believed in the "transformistic" origin of granitic rocks assumed a very much lower temperature. The probable temperature of formation may be somewhere between these two views. It was demonstrated by Schairer, and later by Yoder *et al.* that the melting minimum of the Na-K feldspar series decreases considerably from 1063°C to 695°C if water is added to the system. Barth obtained rather uniform results in granites from 430 to 550°C.

The author considers *mobilization* to mean that a previously immobile component becomes mobile. He calls the newly formed phases "mobilizate" irrespective of their composi-

tion, i.e., whether they are molten, dissolved, gaseous matter, or mixtures of them. It is pointed out that the geochemistry of metamorphic and migmatite rocks is not developed to the extent of that for magmatic rocks. Processes leading to metamorphism, anatexis, and granitization are complex.

The next two chapters are primarily concerned with the formation of granite from molten (magma) or remelted (anatectic) material. Geophysical and geochemical arguments for and against liquid magmas are treated in detail with appropriate diagrams. There is an excellent discussion of postmagmatic potash feldspar, concave quartz, graphic intergrowths of quartz and feldspar, and myrmekite. The last part of this chapter is devoted to composition and Structure of Plutons and the "space problem".

Palingenetic magma is compared to normal juvenile magma. The origin of anatectic can be quite complex since several remeltings may take place with repeated orogenic cycles.

With a normal geothermal gradient of 30°C/Km the granitic melting minimum 640–660°C is reached at a depth of about 20 km which corresponds to a lithostatic pressure of some 5 K bar. In orogenic belts, however, melting can take place at depths of a few kilometers.

A general review of metasomatic formation of granitic rocks is given in the next chapter. The process of chemical transformation can take place by intracrystalline exchange of atoms by reactions in essentially solid rock or by intercrystalline dissolution and recrystallization of small portions in a "volume for volume" exchange. Previous structure of the parent rock is often observed. Metasomatism may progress so that the border of the paleosome and neosome is relatively smooth and the contact transects the older structures and grain boundaries.

The term granitization implies that a rock appears to be more like granite after its transformation than before and that it did not become molten during the process. Transformation, replacement, and rheomorphism are adequately discussed and well illustrated.

The three main ways in which granite may form are (1) Anatectic melt formed under generally rising *PT* conditions of appropriate rocks which on solidifying form *anatectic granite*. (2) A pre-existing intrusive melt under falling *PT* conditions forms *magmatic granite*. (3) Under essentially constant *PT* conditions a rock of non-granitic composition becomes more like a granite by addition or removal of mobile components thus forming a *metasomatic granite*.

The author states in final paragraph: "Regarding the beginning of the petrogenetic cycle, little at present can be said. It vanishes in the eons of pre-geological epochs. Probably it developed simultaneously with the primary formation of the pre-geological crust, which itself originated by reaction between the former mantle of the earth and its primordial atmosphere."

The excellent translation of this book was prepared by Mr. G. Moore-Lewy. An appendix on the nomenclature of migmatites (5 pages) and a complete list of references (39 pages) are of particular value to anyone working in this or related fields. The only omission that I noticed was with regard to orbicular rocks which in some localities are associated with migmatites.

G. E. GOODSPEED
University of Washington

AKTSESSORNYYE MINERALY V GRANITOIDAKH SOVETSKOGO SOYUZA (ACCESSORY MINERALS IN GRANITOIDS OF THE SOVIET UNION). By V. V. LYAKHOVICH, IMGRE, AN SSSR, Nauka Press, Moscow, 1967, 448 pages, 16 figures, 170 tables, 692 references.

The thirteen chapters in the text may be summarized briefly as follows: background (3–14); accessories in Precambrian platformal and in post-Cambrian geosynclinal granites

and granitoids (15–203); their regional average concentrations, according to age and geography of the rocks (204–261), spatial distribution characteristics of the accessories in multiphase intrusives (262–299); accessories in mineralized granites (300–328); effects of hybridization, metasomatism, weathering (329–397), granitoids as a new genetic type of ores of rare elements (398–418).

In the Soviet Union, the Laboratory of Accessory Minerals was established in the Institute of Mineralogy, Geochemistry, and Crystallochemistry of Rare Elements (IMGRE) in 1955. All of the original data presented and discussed by Lyakhovich, against the background of the world literature, were obtained at that laboratory, by standard procedures (chemical, microscopic, photometric, X-ray spectrographic, X-ray diffraction, others).

The term "accessory minerals," once defined as "... mineral constituents of a rock that occurs in such small amounts that they are disregarded in its classification and definition. Opposed to essential minerals." (AGI Glossary, 1962, p. 2) and as "... a quantitatively negligible, but qualitatively often a characteristic admixture in rocks. ... suited for correlations of rocks within a petrographic province. ... and for ascertaining sources and migration paths of clastic materials" (Geologicheskii slovar', vol. 1, 1960, p. 25) are characterized by Lyakhovich, collectively, as follows, after his review of the not entirely satisfactory definitions, from Holmes (1920) to Turovskiy *et al.* (1960):

- a) ... their quantities in the rock are so small as to require special methods for the production of the concentrates for their study.
- b) they contain the bulk of the rare¹ and dispersed elements of the rock which could not enter isomorphously or endocratically the crystal structures of the rock-forming minerals.
- c) their crystals are very small (tenths or hundredths of one millimeter); accessory minerals are a peculiar form of the ... dispersion of rare elements in rocks. (p. 7).

Composition of the accessory mineral complexes in granites and granitoids is reported in tables 1–70 and discussed in the accompanying text (p. 15–203). The data are organized on a regional basis and grouped as Precambrian (15–48) and post-Cambrian (49–203), represented by (a) Baltic Shield, Russian Platform, Ukrainian and Priazovian massifs and (b) the Northeast, the Far East, Zabaykal'ye, Sayan, Altay, Tuva, Ural, Kazakhstan, Central Asia, respectively. Depending on origin and constitution of the rocks, the accessories are shown separately for different facies of the granitoids, and also by intrusive body and by district within the region.

Some interesting regional distinctions are recognizable even at this point, notwithstanding the wide range of variation in the accessories, both qualitative and quantitative. For example, the accessories in Kirgizian granitoids stand out by their relatively widespread occurrence of galena, native lead, thorite, orthite, the granitoids of Uzbekistan-by their accessory uranotorite, fergusonite, xenotime; granites of Central Asia, as a whole, are relatively low in accessory tantalum-niobates, lithium and beryllium, and so on.

Comparable impressions may be derived for every province and district here examined, as well as at lower levels of the generalization (by facies or stage, phase, etc.), despite the superficially random scattering of the data.

In the concluding words of the monograph, "... a more purposeful orientation. ... is

¹ The rare metals (redkiye metally) are Sn, W, Mo, Bi, Sb, Hg, V, Cd, Ga, In, Ge, Tl, rare earths (Geologicheskii slovar', 1960, vol. II, p. 211). Dispersed metals (rasseyannyye metally), as a group, are not defined in the same dictionary. The accessories, in Lyakhovich's comprehensive study, include minerals of U, Th, Ta, Nb, Be, Zr (Hf), Cu, Pb, Zn, Fe, and native Au and Ag, as well as of the rare metals (tables 2–78).

(now) possible, in view of the foregoing (considerations), in the identification of the areas in which placers of minerals of rare elements may be found. In prospecting for endogenic or exogenic ore deposits, the following types of granitoids are particularly promising: normal biotite porphyroid granites, especially their microclinized varieties, for rare earths; late-phase leucocratic granitoids for uranium, thorium, niobium, tantalum; their greisenized varieties for lithium, beryllium, boron, molybdenum, tin; their albitized varieties for niobium, tantalum, uranium, thorium, zinc. Kaolinized granites may contain appreciable quantities of residual zircon and monazite" (p. 418).

The high merit of the monograph, as an organized body of basic data on the accessories in granitoids, appears self-evident to the reviewer. The statistically determined regional and other averages (p. 204–261) appear to be the best (or the only) sensible way of processing the original results, on the outcome of which the interpretative part of the book depends almost entirely, including the economic implications, as already quoted. The text is so supersaturated with data and names, phenomena and relationships, that the reader may only regret the absence of any index or indices—a common defect of many Soviet publications.

Certain granitoids are or may be ores and their direct beneficiation is within the range of modern technology, notwithstanding their very low grade and the evanescent cutoff. A genetic connection between granitoids and endogenic rare-metals ores, once a widespread belief, was recognized as a fact by the majority at the 5th All-Union Conference on Metallogeny (June '68), "although it was proved that many of the ore fields are tens of millions of years younger than the granitoids. The need of further studies. . . was recognized".¹

Thus the once purely descriptive characterization of the accessories has been expanded, in the last 10–15 years, by the research on behavior of the rare and the dispersed elements in magmatic processes. The fact that they are crystallized as minerals during the magmatic stage itself, i.e. that they are dispersed also as minerals, and not only as isomorphous admixtures, is demonstrated convincingly by Lyakhovich.

V. P. SOKOLOFF

Courtesy American Geological Institute Translations Program.

PRACTICAL X-RAY SPECTROMETRY. By R. JENKINS AND J. L. DEVRIES. Springer-Verlag, New York, Inc., 1967, 181 pages, \$7.80.

The book fulfills the intent described by its title. Despite the limitations suggested by the title, the work never projects a "black box" approach. The included subject areas collectively define a practical treatment of X-ray spectrometry in which each area is adequately developed along theoretical lines.

The text contains nine chapters, entitled *Physics of X-rays; Dispersion; Detection; Pulse Height Selection; Counting Statistics; Matrix Effects; Quantitative Analysis; Sample Preparation; and Trace Analysis*. The first chapter, though perhaps necessary for completeness, contains subject matter that is readily available from other works. The other chapters draw selectively from much new information, and in the reviewer's opinion, the chapters on *Pulse Height Selection, Counting Statistics, and Matrix Effects* are truly excellent. Perhaps there are few analysts who could not learn something worthwhile from these chapters.

The book is well organized and the syntax is generally clear and adequate. The text, unfortunately, shows evidence of insufficient editing. Typographical errors are common. In a few instances, textual descriptions of figures and tables are inaccurate. The mathematical notation is not uniform. Equation 1.3 is incorrect, and Equations 1.6, 1.7, and 1.8 contain subscript errors.

¹ "Priroda," December 1968, p. 98–99.

There are other good texts on X-ray spectrometry. The particular value of this book lies in its compact (181 pages) treatment of the fundamentals of the subject. Despite its mechanical shortcomings, it should prove a welcome addition to the working collections of students and researchers alike.

ROBERT REYNOLDS
Dartmouth College

CLAY IN ENGINEERING GEOLOGY. By J. E. GILLOTT. American Elsevier Publishing Co., Inc., New York, 1968, 296 p., \$21.50.

The chapter headings indicate the tremendously wide scope of this book: *The Nature & Classification of Clays & Soils*, *Physical Geology*, *The Origin & Evolution of Clays Minerals & Clay*, *Composition and Fabric of Clays*, *Physical Chemistry of Clays*, *Moisture Interaction with Clays and Clay Minerals*, *Strength & Rheology of Clays*, *Soil Stabilization*, *Clays as Materials*, *The Mineralogical Analysis of Clay*, *Physical Analysis of Clays*, *Engineering Analysis of Soils*. The author's stated intent is an interdisciplinary text addressed primarily to geologists, mineralogists, and soil engineers who are concerned with geotechnical sciences.

Interdisciplinary exchanges, to be fruitful, must be based upon natural respect and understanding of each other's specialized discipline. It seems to this reviewer that in many instances the author has unnecessarily antagonized those he is intending to help. Soil engineers are not likely to be swayed by the vague definition given for liquid limit—"the water content of a soil (express in percent dry weight) having a consistency such that two sections of a soil cake, placed in a cup and separated by a groove, barely touch but do not flow together under the impact of *several sharp blows*." The statement, "Most confidence can be placed in the results of engineering tests when they agree with the geologic evidence" is sure to impress soil engineers. Clay mineralogists probably will be equally impressed by the author's statement that DTA is more sensitive for identification of non-crystalline constituents than the X-ray method. For a book on clay the two exceedingly short paragraphs on cation exchange capacity seems overly succinct.

On the whole the references provide the reader with an adequate starting point on where to obtain detailed information.

R. TORRENCE MARTIN
Massachusetts Institute of Technology