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BOOK REVIEWS

ADIRONDACK IGNEOUS ROCKS AND THEIR METAMORPHISM by A. F. BUDDINGTON. *Geological Society of America, Memoir* **7**, published by the Society, December, 1939. 354 pages and colored map. 20 photographs, 30 figures.

While some knowledge of the mineralogy of the Adirondacks was known previous to 1842, Ebenezer Emmons, however, laid the foundations of the geological work upon which Kemp, Smyth, Cushing and later workers could build. Newland worked with Kemp and W. J. Miller began working in the southern Adirondacks. The author of this memoir joined the field workers under the tutelage of C. H. Smyth, Jr., while I joined Kemp. C. Nelson Dale of Hamilton College joined the western workers. Martin and Reed of Princeton and J. S. Brown of Edwards undertook additional work.

Professor Buddington has contributed largely to our understanding of the rocks of the western and northwestern portions of the area and has given a very effective summary of his work and suggestions for the solution of many of the problems of the entire area. He recognizes the difficulty of summarizing the extensive literature and evaluating the conflicting opinions of the various workers.

A brief historical review of the work done stresses the importance of Cushing's "Geology of the Northern Adirondack Region" (1905), Kemp and Ruedemann's "Geology of the Elizabethtown and Port Henry Quadrangles" (1910), and Balk's "Structural Geology of the Adirondack anorthosite" (1931).

One of Buddington's chief interests in the region is the structural relations between the rock units and hence was much impressed by J. C. Martin's publication in 1916 of "The Precambrian rocks of the Canton Quadrangle." Martin showed that the Grenville rocks, together with sills of ancient gabbro, have been compressed into large sigmoid folds. Buddington was not satisfied with W. J. Miller's suggestion that the Grenville strata had not been profoundly folded or compressed. Miller's suggestion came from the study of the southern and eastern Adirondacks; Martin's work was in the western. Consequently, was there this difference in the structure of the two regions? Subsequent work led Miller to admit that there was distinct folding in the northwestern Adirondacks but retained his original hypothesis for the rest of the region. My work would suggest that this point of view is not substantiated.

Chapter 2 deals with the Grenville series under which Buddington discusses the nature and origin of the amphibolite. Many of the bands of amphibolite have been proved in part to be thoroughly altered metagabbros, but he recognizes that some may represent original limestone country rock.

Chapter 3 is devoted to the anorthosites and gabbros. The main mass of anorthosite occupies 1200 square miles. There is a thorough discussion of the Whiteface facies named by Kemp and the Marcy anorthosite named by Miller. New chemical analyses show that the pyroxene is largely hypersthene. Buddington questions that the hornblende is primary in the hornblendic phases of the anorthosite and suggests that it is a product of change from original pyroxene. He stresses the importance of garnet contact zones studied by Kemp between the anorthosite and Grenville marble as clearly indicating the presence of an anorthosite magma. In dealing with the marginal or Whiteface facies of the anorthosite Buddington quotes the following from my papers: "This syntectic is the Whiteface anorthosite, a marginal phase of the Marcy intrusive as well as an assimilation product by magmatic replacement . . . the border facies of the anorthosite is due to syntexis and represents what I call 'xenolithic phantom gneiss'." Buddington says he is in agreement with these conclusions. His picture, therefore, is that the Grenville was first metamorphosed, partially replaced by silicates through the activity of hydrothermal solutions originating in the anorthosite magma. These ancient sediments were broken up, disintegrated and partially incorporated by the still mobile magma.

Thus Buddington departs from the theories of Bowen and Balk regarding the origin of the anorthosite and offers additional evidences for an anorthosite magma to those maintained by the older geologists.

One of the problems of Adirondack geology is whether the Whiteface anorthosite is or is not a chilled margin. Cushing, Miller, and Bowen have so interpreted it. Balk, on the other hand, argues against such a view. The question, therefore, resolves whether the border facies was not originally finer grained than that of the core. Buddington's petrographic studies show that "inherited traces of primary fabric . . . indicate that the Whiteface facies was definitely finer grained than the rock of the core . . . " He concludes that the border facies is in large part more mafic than the core, is finer grained, and is to be interpreted as a relatively chilled zone. Buddington's picture, therefore, is that the anorthosite was emplaced at moderate depths with only such deformations as are common to laccolithic or sheet-like masses. The majority of the deformations suffered by the anorthosite probably come later.

Balk's interpretation of the origin of the gabbros as concentrations of the dark silicates from the anorthosite are interpreted by Buddington as included layers of metamorphic limestone. I have been unable to accept Balk's theory of the origin of the gabbros in the eastern Adirondacks; apparently Buddington has the same difficulty.

The ages of the gabbros, either within or without the main anorthosite mass, are discussed with the conclusion that many are older than the syenite and granite but younger than the anorthosite. I suspect that this is as near to the truth as is possible to state at the present time. It is possible that there are other gabbros which have other ages, but until more detailed work is done Buddington's opinion will probably stand.

Chapter 4 is devoted to the Diana quartz syenite complex. Buddington has been a pioneer in Adirondack work in applying our knowledge of stratiform, gravity-differentiated sheets of siliceous composition to the Diana complex. He has recognized seven facies consisting of pyroxene syenite, pyroxene quartz syenite, feldspar-rich pyroxene syenite, transitional quartz syenite, mafic hornblende-pyroxene quartz syenite, hornblende quartz syenite, and hornblende granite. He employs two methods in estimating the composition of the primary magma, first by averaging all the Rosiwal analyses, and second by making a weighted average based upon the approximate distribution of the different types of facies mapped in the field. Both methods give similar results leading to the conclusion that the transitional pyroxene quartz syenite represents the primary composition. The result of this careful work leads to the conclusion that the intrusives came in as great sheet-like masses, experienced differentiation after emplacement, and experienced metamorphic changes due to stress afterwards.

In Chapter 5 Buddington summarizes similar studies of other quartz syenite complexes within the region and reaches similar conclusions.

Chapter 7 discusses the batholithic masses of granite which constitute the bulk of the intrusives in the western Adirondacks. He believes that these are younger in age than the

Diana, Santa Clara, and Tupper-Saranac complexes. They are hornblendic granites with local syenite differential facies. Biotite enters some of these rocks in relatively small masses, usually in association with members of the Grenville series. These younger granites show transgressive character. In one case the granite cuts across the northern flank of the Santa Clara anticlinorium. Some of these later granites are probably phacoliths which are well shown in the Gouverneur and Canton quadrangles.

Chapter 9 is an excellent summary of the Adirondack igneous complex as a whole. There is a brief discussion of the term "Laurentian granite," a term which was in current use some years ago as the result of Cushing's papers. Buddington is not sure he can recognize the presence of an older granite antedating the introduction of the complexes and the younger granites.

Chapter 10 deals with regional metamorphism, their zones and facies. He recognizes four different zones: (1) where cataclasis is predominant, (2) where crushing and recrystallization prevail, (3) Crushing and recrystallization have occurred with the development of granoblastic gneisses, and (4) where crushing is subordinate. Under (4) he says the rocks exhibit textures due primarily to the crystallization of the magma and show magmatic flowage.

Smyth postulated three stages in the formation of different facies: (1) the formation of secondary hornblende from primary pyroxene, (2) cataclastic crushing, and (3) recrystallization. Buddington's studies have led him to conclude that Smyth was correct, that these changes took place after crystallization, not during the late magmatic stage. The Diana complex shows all types of metamorphism from massive rock through augengneisses to ultracataclastic mylonite.

He discusses the garnet reaction rims which he calls chronolite and reaches the conclusion that they were formed after the complete solidification of the rocks as the result of regional metamorphism subsequent to the emplacement of the quartz syenite.

Chapter 11 discusses the origin of the metamorphism. Most of the Adirondack rocks show evidences of pronounced crushing and deformation. This foliation was interpreted by the early writers, including Kemp, Cushing, Ogilvie, Smyth, and Newland, as due to metamorphism after the rocks were solid. Balk, however, maintained that it was due to differential flowage and movement during the magmatic stage. Buddington has devoted arduous labors to this problem, and reaches the conclusion that the foliation in microstructures now seen were developed largely by deformation in the solid state with the possible exception of part of that in the younger granites.

The pattern of the regional foliation is shown along the northwest border where folds in the Grenville are overturned toward the southeast, and in the southern portion of the mountains the folds are overturned toward the north.

Buddington estimates the depth of burial of anorthosite to account for the deformation and metamorphism by suggesting that there may have been three or four miles of rock between the anorthosite massif and the base of the Diana complex. It seems probable that the major deformation occurred during the cycle of emplacement of the younger granites.

Professor Buddington is an eminent structural and metamorphic petrologist and has interpreted the Adirondack rocks chiefly along these lines. Balk, on the other hand, stresses the field methods of Cloos. I should think that the differences in interpretation between these two are what would be expected. Buddington's memoir, which is really a monograph, is a splendid contribution and summary of the major problems of the region. He has solved many problems. He likewise opens new problems for future workers in this interesting region.

The volume maintains the unusually high standards in typography, illustrations, and binding we all expect from the Geological Society of America. I congratulate the author and the Society on an outstanding piece of work.

HAROLD L. ALLING

DIE ENSTEHUNG DER GESTEINE. Ein Lehrbuch der Petrogenese. Tom. F. W. Barth, Carl W. Correns, and Pentti Eskola. Julius Springer, Berlin, **1939,** 422 pp., 210 text figures. Price R.M. 30, less 25%.

In contrast with many German books, the book under review is a very concise treatment of the subject of petrogenesis. Some parts are so concise that they may be difficult reading for a student who has not already a considerable knowledge of the subject. If used as a text, the instructor would do well to elaborate many of the sections. The book adheres closely to the subject given in the title, and little space is given to description and classification.

The three authors are among the leading students in their respective fields. The topics treated are well selected and cover the latest developments in the science. The authors have a better knowledge of American literature and a better understanding of the American point of view than do most European authors.

The part on the eruptive rocks by Barth includes a discussion of the crystallization of silicate melts illustrated by many equilibrium diagrams. The section on the magma discusses the viscosity, temperature, gas content, and other characteristics of the magma. A longer section discusses magmatic differentiation and the origin of rocks. Barth recognizes the growing conviction that some granitic rocks have been formed by the melting of sediments or other rocks.

The section on the sedimentary rocks by Correns is a quantitative discussion of the subject and includes many diagrams. It includes sections on weathering, the clastic sediments, chemical and biogene sediments and diageneses. Grain-size and shape, mineral composition, and similar topics are discussed.

The section on the metamorphic rocks by Eskola includes sections on texture, including Sander's method of study, recrystallization, mineral facies, metasomatism, and normal metamorphism. In the section on mineral facies Eskola has wisely placed less emphasis on igneous facies than in his former works. Most American students of the glaucophane schists will not admit that they are formed at great depth.

Esper S. Larsen

THE PETROLOGY OF THE SKAERGAARD INTRUSION, KANGERDLUGSSUAQ, EAST GREENLAND. L. R. Wager and W. A. Deer. Meddel. om Grønland, Bd. 105, No. 4, **1939.** 335 pp., 68 figures, 27 plates, one map. Price, Kr. 20.00.

This is a book of very great importance both to descriptive petrology and to petrogenesis. It describes an intrusive body that occupies an area of 50 square kilometers and has the form of an inverted funnel. The intrusive is divided into a layered series that occupies the central part of the complex and a border series that forms a narrow envelope next to the sides and at the top. The contacts between the two are fairly sharp in some parts and indefinite in others.

The layered series is made up of alternate, nearly horizontal bands of darker and lighter material arranged like inverted saucers. Several types of banding are described.

The border series is also layered but the layers are parallel to the contacts. The rocks of both series are gabbros. In the lower part of the layered series the feldspar is labradorite and the mafic minerals have a moderate iron content; the soda content of the feldspar and the iron content of the femic minerals increase upward and in the upper horizon the feldspar is oligoclase-andesine and the olivine is fayalite. The border series varies in a similar way from the contact inward.

The layering and magmatic differentiation are believed to be due to crystallization on the walls of the liquid phase of material brought into place by convection currents. The authors believe that this body shows that with strong fractionation a basaltic magma differentiates to a basaltic magma enriched in iron.

The small amount of siliceous rocks present are believed to have formed from assimilation.

ESPER S. LARSEN

PROCEEDINGS OF THE SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences, Philadelphia, Pa.

A stated meeting of the Philadelphia Mineralogical Society was called to order by President W. Hersey Thomas on December 7, with 48 members and 30 visitors in attendance.

Dr. A. Williams Postel addressed the Society on the results of his studies on the granodiorites of the Philadelphia area. He first described the various facies of the Wissahickon schist, originally a sedimentary series of impure shales, now so highly metamorphosed as to be in the kyanite and sillimanite grades of metamorphism. The schist has been intruded by a series of igneous rocks, the earliest of which were basic and formed sills which have been metamorphosed to hornblende gneiss. Later, there was an intrusion of massive gabbro, and this was followed by the granodiorites—first the Springfield quarry type, then aplite veins, and finally the Ridley Park quarry type.

The Springfield granodiorite is porphyritic, coarse grained and has a gneissic structure parallel to that of the surrounding schists, but the microcline phenocrysts show no cataclastic structures. The basic sills in the Wissahickon vary in thickness and where they are in contact with the granodiorite, the intensity of their alteration is related to their thickness. Only the largest of the sills show unaltered interiors, the rest have been completely changed to biotite gneiss. The Springfield granodiorite is always associated with crushed Wissahickon gneiss, in which the stress mineral kyanite is present, denoting a sheared zone. Near contacts with the gabbro the granodiorite contains inclusions of gabbro and impregnates the gabbroic wall rock with quartz and alters its pyroxene to hornblende and biotite.

The speaker suggested three possible modes of emplacement for the Springfield granodiorite—first, that it was a normal silicate magmatic intrusive and that its foliation was imposed at the same time that the schist received its foliation and metamorphism. However, this could not be the case as the Springfield granodiorite also injects the gabbro which has no foliation or metamorphic structure, thus the granodiorite must be later than the metamorphism of the schist. A second possibility is that the magmatic granodiorite might have intruded the already metamorphosed Wissahickon schist, injecting it lit-par-lit, and assuming its structure. But a difficulty arises from the fact that the foliation of the inclusions in it are without exception parallel to the foliation of the country rock. This leaves only one interpretation. Dr. Postel believes that potash-silica-rich hydrothermal emanations from below have soaked and reacted with the Wissahickon schist to produce the Springfield granodiorite, and that it was never a true intrusive of magmatic form. In support of this hypothesis, he shows that the microcline porphyroblasts of the granodiorite have as inclusions plagioclase and quartz from the earlier schist, that seeming inclusions of basic rocks in the granodiorite are really altered basic sills, that the great variation in composition of the granodiorite is to be expected in a rock which formed as a result of reaction with the Wissahickon schist, which did not have a constant composition to begin with, and finally the constant association of the granodiorite with shear zones in the schist, which could form avenues of approach for the reacting emanations.