REVIEWS.

DIE ERUPTIVGESTEINE DES KRISTIANIAGEBIETES. IV: DAS FENGEBIET IN TELEMARK, NORWEGEN. By W. C. BRØGGER. Vid. Selsk. Skrifter I.M.N.Kl. No. 9, pp. 1–408. 1920.

IN a memoir of four hundred pages, furnished with nearly forty mineral and rock analyses, Professor Brøgger has added a fourth volume to his classic series on the eruptive rocks of the Kristiania region.

The Fen district of Telemarken forms a small isolated area of low relief of approximately 4 square kilometers extent, situated on the south-west shores of Lake Nordsjö, and surrounded on its landward borders by abruptly rising Precambrian granites. The area is best approached from Skien, by canal boat to Ulefos on Lake Nordsjö. The occurrence of iron ore and limestone in the Fen region had early attracted the attention of Vogt and other workers, but the unique significance of the area was not appreciated till the discovery by V. M. Goldschmidt in 1918 of microlite, alkali pyroxene, and hornblende, as constituents of the limestones. After this disclosure no further incentive was necessary for a more detailed investigation of the area, which Brøgger has completed in the present memoir.

The rocks comprised within the Fen area include a group of magmatic carbonate rocks, intimately associated with alkaline rocks showing a variable content of primary calcite. No less than thirteen new rock-types have been defined and described from this unique area. The characteristics of these new rock-types and their associated rocks may precede in description the geological history of the Fen region.

(1) *Vibetoite.*

This is the name given to the oldest intrusive of the silicate magma. It is a melanocratic, often coarse-grained rock, practically without felspar or nepheline, and consisting of hornblende, pyroxene, and biotite, and usually rich in apatite (3·51 per cent P_2O_5) and calcite (6·30 per cent CO_2).

(2) *Rocks of the Urtite-Ijolite-Melteigite series.*

These rocks form a continuous series, consisting essentially of nepheline and green pyroxene. The melanocratic member melteigite is a new type from the locality Melteig, and characterized as containing less than 45 per cent nepheline, associated with a green non-aluminous pyroxene (in part aegirine-diopside). True jacupirangite with an aluminous titanium-bearing pyroxene is not recorded in situ. A group of dyke rocks accompany this series, including micromelteigites, tinguaites, and melteigite-pegmatites.

(3) *Rocks of the Tveitåsite-Fenite series.*

These rocks form a probably continuous rock-series, consisting of green pyroxene and alkali-felspar (albite and microperthite). The melanocratic member is tveitåsite, and the leucocratic type is fenite. The fenites are accompanied by corresponding dyke rocks.

(4) *Nepheline-syenite-rocks.*

Quite sparingly distributed is a peculiar type of potash-rich nepheline-syenites, including the new type juvite (6·67 per cent Na_2O, and 8·21 per cent K_2O). This is a medium-grained rock consisting of orthoclase, pseudomorphs of muscovite and cancrinite after nepheline, aegirine, and sparingly biotite. A varietal type is described as biotite-juvite. The melanocratic malignite is also developed. The new rock-type kamperite may conveniently be included here. This rock consists essentially of orthoclase, albite, and biotite. It is a perpotassic type (10·16 per cent K_2O), and the analysis corresponds closely to that of the leucite-basalt of Gaussberg, Antarctica.

(5) *Carbonate-rich rocks.*

(*a*) *Sövite.*—A magmatic carbonate-rock consisting essentially of calcite, with apatite, microlite, biotite, and manganophyllite micas as important accessories.

(*b*) *Rauhaugite.*—A magnesium-rich carbonate-rock ($MgCO_3$ 17·47 per cent, $FeCO_3$ 9·60 per cent), associated with apatite, barite, and magnetite. In the normal rauhaugite, microlite and manganophyllite do not occur.

Apart from large masses of these types, independent dykes of sövite and rauhaugite are developed cutting fenite, etc. The rauhaugite dykes are apatite-rich dolomites (MgO 17 per cent, CaO 31 per cent, P_2O_5 2 per cent.

(*c*) *Mixed Rocks.*—Rocks which must be regarded as mixtures of carbonate magma of sövite type, and of the silicate rocks already enumerated are developed as schlieric intrusions, or as dykes cutting other members of the Fen group. These mixed rocks include hollaite and kåsenite, considered as crystallized products of a mixture of calcite magma and ijolite-melteigite magma, the former relatively rich in silicates (pyroxene, nepheline pseudomorphs, melanite, etc.), and the latter with a relatively small content of silicate minerals; further, ringite, a type resulting from a mixture of calcite magma with a fenite magma constituted of calcite, felspar, aegirine and aegirine-diopside, and apatite.

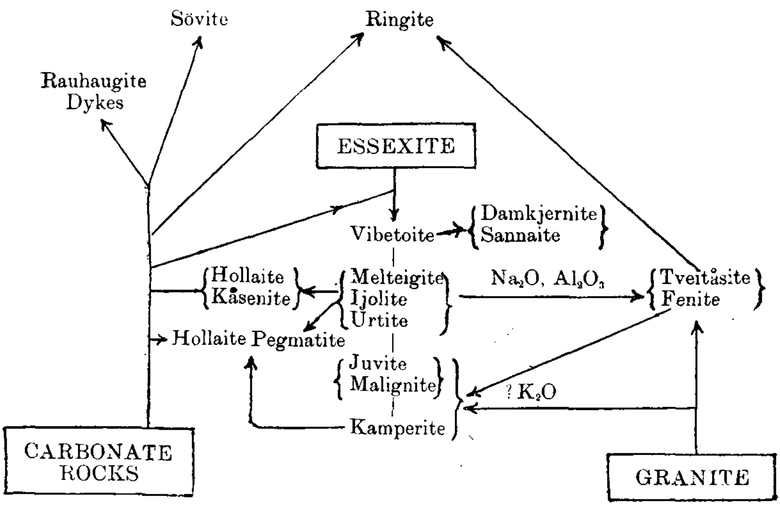
(6) *Damkjernite-sannaite rocks*

An alnöite-like rock which Brøgger regards as the latest product in the intrusive sequence of the Fen region is described as damkjernite. These rocks are melanocratic members of the alnöite group, and show some variety in composition. The normal type contains large phenocrysts of black biotite, and less commonly pyroxene, set in a ground mass of pyroxene, apatite, biotite, magnetite, orthoclase, and a small amount of nepheline pseudomorphs. An exceptional type is present as a dyke rock in the Precambrian granite, and contains large barkevikitic hornblende individuals, and nodules of olivine-enstatite, enstatite-diopside, hornblendite, etc., as endogenous inclusions.

Sannaite, which fills an explosion crater at Ormen, 7 kilometers south-west of the Fen region, is a closely related type, forming the end member of the damkjernite-sannaite group. It differs only by the presence of a higher content of alkali minerals. The phenocrysts are of brown-black hornblende, black pyroxene, and sparing biotite in a fine-grained ground mass of alkali-felspar, aegirine, and, in smaller amount, of nepheline pseudomorphs (muscovite).

(7) The latest eruptive rocks of the Fen area are the diabase dykes of post-Silurian date, and which are so constant a feature in the Kristiania region.

The geological history of the Fen region as pictured by Brøgger may now be shortly summarized, the probable genetic relations of the Fen sequence being indicated in the following scheme.



The opening phase in the Fen history was the drilling of an explosion crater in the Precambrian granite. The initial magma was of basic composition, and probably of essexitic type, confirmation of which is provided by the great dominance of the melanocratic melteigite, and also by the interpretation of the oldest vibetoite as an addition product of a calcite magma and a magma of yamaskitic composition (hypermelanocratic differentiation-product of an essexite magma).

The melteigite of the Fen region can, as Brφgger shows, be considered as derived from an essexite magma by admixture with calcite, with removal of certain percentages of anorthite and iron-rich pyroxene, and, further, CO_2, the former by gravitational sinking of crystals; the more leucocratic types, ijolite and urtite, by further sinking of the denser pyroxene.

The ultimate origin of the great mass of carbonate rocks of the Fen region raises a question of great difficulty. The complete resemblance, chemically and petrographically to the undoubted primary dykes of sövite, lead Brφgger to the conclusion that it must be regarded as a primary magmatic rock. Its ultimate source must be a sedimentary limestone which has been completely melted at great depth. By its purity and comparative poorness in silicates, it is sharply distinguished from the variable calcareous sediments of Palæozoic age in the Kristiania district. Still less does the rauhaugite bear resemblance to these, for dolomites are unknown amongst the carbonate rocks of the Kristiania region. Brφgger is of the opinion that the carbonate rocks must be derived by melting (solution) of an *older* limestone *below* the Precambrian granite.

After its melting at great depth, and separation from the carbonate-enriched stem-magma, the great central mass of carbonatite is pictured as forming a lighter layer floating on the heavy silicate magma. Its intrusion into the crater-neck of the Fen led to its crystallization from above downwards. The solid carbonate rock thus formed was penetrated in its outer part by the silicate magma, giving rise to the vibetoite and melteigite-ijolite intrusions. Pneumatolytic addition of phosphorus, fluorine, niobium, and tantalum occurred before consolidation, giving rise to apatite, and microlite in the resulting sövite. On its under side intimate mixtures of silicate magma and carbonate magma were formed, and gave schlieric intrusions of hollaite and kåsenite.

The melteigite-ijolite magma has produced an intensive contact-metasomatism in the peripheral Precambrian granite. By the action of solutions an important transfer of soda has taken place. The quartz of the granite is replaced by albite, and the biotite by aegirine, oligoclase is converted to albite, and orthoclase into microperthite and albite, until, at the immediate border, the rock is completely transformed to an alkali felspar-aegirine rock—fenite, or its more melanocratic type, tveitåsite. All possible gradations from unchanged granite to the end product fenite can be traced.

That a transition from granite to aegirine-syenite by in situ differentiation is not involved, seems clear from the fact that the destruction of biotite with new-formed needles of aegirine and alkali-hornblende and the development of typical "Schachbrett Albit", so characteristic of secondary felspar, can be traced in thin sections of the transition rocks. Moreover, in intermediate stages some newly formed quartz appears, showing inclusions of aegirine. This quartz, unlike that of the granite, is completely free from undulose extinction. Fenite also occurs as independent dykes, derived by direct melting (or solution) of granite in melteigite-ijolite magma. These penetrate the melteigite group, and have a typical pulaskitic structure. At the border between the fenite and melteigite group are quite locally developed the juvites and malignites. These are possibly derived from a mixture of fenite and ijolite magmas. Their high content of potash is perhaps to be explained as a direct transfer of potash solutions from the fenitized granite, a process complementary to fenitization itself.

Only in the small sack-shaped area in the vicinity of Melteig are the rocks of the melteigite-ijolite group completely fresh. Elsewhere they are completely or partially changed to muscovite-biotite (chlorite)-calcite-fels. It is probable that the potash absorbed in muscovitization of the already crystallized melteigites is also in part derived from the Precambrian granite.

Whilst the rauhaugite dykes which penetrate the fenite near Ringsevja must be regarded as primary, Brøgger is of opinion that the great eastern mass of rauhaugite is metasomatically derived from sövite. The source of the magnesia and iron, if this be so, must be the rocks of the melteigite group, from the destruction of pyroxene in their conversion to muscovite-chlorite-calcite-fels. Furthermore, this metasomatism must have occurred before the intrusion of the damkjernites, for these contain in places xenoliths of the typical rauhaugite.

Against this view of Brøgger must be placed the fact that the normal rauhaugite does not contain either manganophyllite or microlite. The absence of the latter highly insoluble mineral is significant, and may point to the rauhaugite as an independent intrusion, or, if secondarily changed, a derivative of the magma which gave rise to the primary rauhaugite dykes.

At the conclusion of the fenite formation, and possibly its dyke intrusions, the carbonate magma in part retained its fluidity in depth, and was then erupted, partly as dykes of sövite, and less numerous dykes of rauhaugite, and partly as mixed magmas, as ringite, ringite-pegmatite, hollaite-pegmatite, etc. These latter pegmatites often show characteristic intergrowths of their constituent minerals, e.g. calcite and pyroxene.

Significantly younger than the above rocks and representing the last stages in the intrusive sequence are the damkjernite intrusions which appear as dykes in the granite, in the fenite, in the melteigite group, and in the central carbonatite. Some of the damkjernites contain inclusions of these rocks as well as fragments of older granite and amphibolite. The damkjernites, as well as the sannaite, are late differentiation products of the melteigite group, and show a clear relationship with the earliest intrusive vibetoites. Their resemblance to the African and Brazilian kimberlites has led to a careful search for diamond, but without success.

As to the epoch of intrusion of the Fen rock series, Brøgger was at first inclined to regard it as an outpost of the Devonian eruptives of the Kristiania region, but later he has come to consider it as of late Precambrian date, in common with the very closely analogous Alnö alkaline area (? Precambrian). The possibility of a Devonian age cannot, however, be wholly excluded. The assumption of selective solution in depth by a Devonian essexite magma, in the presence of mineralizers, of the calcite of an *overlying* impure calcareous terrane of Palæozoic date, seems here not to be entirely precluded. Whatever be the case, one of the most remarkable and so far inexplicable facts, is the absence of typical contact-minerals in the carbonatite.

The last chapter of the memoir is devoted to a critical comparison with the related rock sequences of Alnö, Almunge, Assynt, and other districts. Into this, and into Brøgger's highly interesting discussion of the distribution of Scandinavian alkaline areas with regard to orogenic axes of folding, it is impossible to enter here. Rocks of the Fen region can be matched in all the above-named alkaline fields, but in the Alnö assemblage, with its metasomatised (fenitised) border-zone, the most marked resemblance is provided.

The great work is dedicated "in old friendship" to the investigators of Alnö, the Kola Peninsula and Magnet Cove—Högbom, Ramsay, and Washington.

C. E. TILLEY.

TUNGSTEN ORES. BY R. H. RASTALL & W. H. WILCOCKSON. Imperial Institute Monographs, pp. ix + 81. 1920. Price 3*s*. 6*d*. net.

THE world depression in trade has sensibly reduced the consumption of ferro-alloys and brought about a heavy fall in the selling price. The interest in this and similar publications is necessarily somewhat limited at the present time. High-speed steel, in which tungsten is an essential constituent, was largely overproduced at the conclusion of the war period, and is still a drug in the market, so that economic conditions are not likely to improve for some time.

The monograph has been compiled from sources indicated in the bibliography included in the volume. It is well compiled, and presents in an abbreviated form the salient features of all the published material on the subject, and should be useful for reference, particularly by those commercially interested in the metal.

Tungsten was one of the metals controlled by Germany before the war, largely in consequence of an indisposition in this country to tackle the problem of the metallurgical treatment of the raw material; and this, notwithstanding that a large proportion of the tungsten mineral is produced within the Empire, and the manufacture of high-speed steel is one of our principal industries. Stern necessity compelled us to evolve processes for production of metallic and ferro-tungsten, and it is hoped that the impetus given by remunerative