5. The Alkaline Rocks of Almunge.

By

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(With Pl. II—XIII.)

Contents.

Introduction.

It was in a somewhat unlooked-for manner, that the writer was led to take up a closer investigation of the alkaline rocks of the Almunge district. While working at the petrographical Institute of Heidelberg under Prof. ROSENBUSCH's guidance during the winter of 1906—1907, my attention was called to the peculiar optical character of the amphibols in some sections of the Almunge syenite, which ROSENBUSCH many years before had received from Prof. HÖGBOM, who in 1893 first drew attention to the rocks in question. The Almunge syenite was at that time considered as representing a differentiated facies of the surrounding archean granites, but as the syenite and especially the amphibols showed such marked alkaline features, whereas the surrounding country rock has no such character, ROSENBUSCH was inclined to believe, that the syenites represented a separate and younger intrusion of alkaline rocks. He urged me to investigate the matter, as soon as an opportunity offered itself. It was, however, not till the spring of 1912, that I was able to take up a survey of the Almunge district. The petrographical features of some of the rocks were soon found to be of so singular a character, that a detailed research was at once planned and led to the discovery of a series of rocks of highly alkaline character, ranging from the syenites already mentioned to nepheline- and cancrinite-bearing rocks of very varying composition. It is a fine testimony of the sensitiveness of optical petrography, that the honoured old veteran in Heidelberg from a few stray sections of the original syenite in a way foresaw the geological relations of the rocks of Almunge, long before a detailed survey disclosed the interesting problems, which here awaited their solution.

For valuable help and good advice while working out the following paper I am much indebted to Prof. HÖGBOM, Geheimrat Prof. ROSENBUSCH, Prof. F. D. ADAMS, Prof. LACROIX and Prof. DALY. Through the courtesy of Prof. J. G. ANDERSSON, Director of the Geological Survey of Sweden, the two mineral analyses have been carried out in the laboratory of the Survey by D:r R. MAUZELIUS. The rock analyses have been made by D:r NAIMA SAHLBOM (6 analyses) and D:r MAX DITTRICH (1 analysis); for all the conscientious and careful chemical work I wish to tender my cordial thanks. Prof. A. HAMBERG has kindly allowed me to make some determinations of refractive indices on his private total refractometer, and given me every assistance in the work, for which I am much indebted.

Concerning the use of petrographical terms in the present paper some words of explanation may be given to avoid any misunderstanding or confusion. The principal axes of elasticity in a crystal will be designated X, Y, Z, instead of $\mathfrak{a}$, $\mathfrak{b}$, $\mathfrak{c}$, commonly used, which are easily confused with the crystallographic axes a, b, c. The terms salic and femic will, at the earnest request of the originators of these terms,[1] be limited to normative minerals, for the qualitative description of modal minerals the terms felsic and mafic will be used. According to the definitions of the American petrologists the terms norm and normative are used for the standard mineral composition, such as it is calculated from the chemical analysis. For the actual mineral composition, the terms mode and modal will be used.

[1] Journal of Geology, Vol. XX 1912, p. 560.

Relating to the sketch map, I wish to remark, that the distribution of the different types of granites, surrounding the alkaline rocks has n general been inserted according to the old Survey sheet and TÖRNEBOHM's general map of the district.

General Geology of the Almunge District.

As a glance at the accompanying geological sketch map will show, the alkaline rocks of Almunge form a somewhat oblong area of between 3,5 and 4,5 km:s length and 3—3,5 km:s breadth, the whole area measuring about 13 square kilometer. The surrounding country rock is formed of old archean granites and gneiss-granites of two somewhat different types, a usually light to dark gray, gneissose hornblende-granite and an acid, red, generally more massive granite, often all but destitute of dark minerals. Both these types have a wide occurrence in this part of the country. The hornblende-granite is generally known under the name of Upsala granite. The distribution of the two types of granites can be seen on the Survey map as well as on TÖRNEBOHM's general map of the district (Mellersta Sveriges Bergslag, sheet 6). In this map the red and gray granites are separately marked, and one can observe, how a 5 km. broad belt of red granite in a N-NE-erly direction stretches from round about Östuna past Almunge church to the lake Kärfven, on all sides surrounded by the gray granites of the Upsala type. The contacts between these two types are singularly indistinct and complicated; the rocks towards their limits rapidly change their structure, become fine-grained and schistose and seem gradually to fade into each other, without it often being possible to determine any definite contact-line or decide which of the granites has been the younger. These facts are clearly displayed in the old Survey map, where one often finds a long and narrow zone of 'gneiss' or 'hälleflintgneiss' marked out along the contact-line between the two granites. TÖRNEBOHM and HÖGBOM, who have both studied the district, have not been able to agree as to the relative ages of the two granites, TÖRNEBOHM[1] considering the red granite which he describes as 'a fine- to medium-grained rock, with a granular rather than a granitic-crystalline structure'[2] as the youngest, whereas HÖGBOM is inclined, if there is to be any distinction in age made at all, to place the Upsala granite as the younger.[3] Investigations in the field have still not been able to give a definite answer to the question, as to which type of granite is to be considered the elder, or if both, as HÖGBOM is most inclined to believe, are to be considered as more or less contemporaneous, through differention processes separated phases of the same great granite batholith. In some places it has cer-

[1] Mellersta Sveriges Bergslag, Blad 6, Beskrifning, p. 32—33.

[2] Ibid., p. 14.

[3] Geol. För. i Stockholm Förh. Bd 15 (1893) p. 270.

tainly seemed to me evident, that the red granite is the younger, intruding the grey Upsala-granite in numerous veins. At other places the relations are, however, strangely indefinite and then the problematical, generally fine-grained gneissose rock appears along the boundaries, often showing a marked flow-structure parallel to the contact. I cannot omit to call attention to the striking resemblance between this type of acid, red, nearly massive, aplitic granite with its surrounding gneissose rocks on the one hand here in Upland and on the other hand in the south of Finland. SEDERHOLM has in his fundamental researches on the classification of the Precambrium of Fennoscandia called attention to the striking similarity between the rocks on both sides of the gulf in his *Svecofennian* range and has consequently applied his interpretation of the Archean of Southern Finland also to the rocks of Upland. As an example I cite SEDERHOLM's description of the geological relations at Tvärminne:[1] 'the predominant rock is a gray gneissose granite. Its very distinct foliation is certainly due to dynamic action. Of later age is a commonly reddish granite which is connected with pegmatitic and aplitic rocks evidently belonging to the same magma. It is often quite massive, in other cases it passes by gradations into gneissose varieties. This younger granite often forms well defined dikes and veins intersecting the gneissose granite obliquely to its foliation. In other cases both rocks are so intricately co-mingled, that no line of demarcation can be drawn between them.' This red granite SEDERHOLM interprets as a palingenetically regenerated variety of the gray gneissose granite. The similarity between the geological relations of the country rock and this red, massive, aplitic granite on the south coast of Finland and in parts of eastern Upland is so great, that one is nearly forced to accept one of the two alternatives: either SEDERHOLM's interpretation of the palingenetic evolution of southern Finland is in principle wrong or we have to reckon with the possibility if not probability of the same explanation for the corresponding formations of eastern Upland. A glance at any geological map of Upland will suffice to convince the reader, that the country rocks are very irregularly distributed and the contacts very much influenced by secondary processes. It would then lie near to assume, that the rocks, now laid bare to our view, represented a very deep-seated section of the earths crust, brought to light by a regional upheaval of the country and a secular denudation. On the other hand, however, the wide-spread existence of volcanic rocks in the form of much changed porphyries and their tuffs, which certainly are older than the majority of the granites, seem to contradict such a supposition. These rocks seem to have been formed under perfectly actualistic conditions, i. e. as superficial lavaflows, and could hardly put in an appearance amongst the deep-seated granite magmas, if they had not been thrown down to a very considerable depth by great regional movements in the earths crust. But it is just movements like

[1] Granit och Gneis. Bull. Com. Geol. Finl.

these, which are connected with the palingenetic changes referred to, the rocks on their downward path meeting the rising magma of some great batholith, which so largely occasions the specific plutonic metamorphism of these rocks.

It would lead too far exhaustively to discuss this question here. My object in touching upon it at all has been to give an idea of the milieu, in which the alkaline rocks of Almunge occur. The district is much covered by glacial drift, wherefore the definite answer to these questions must be sought at places, where the rock is better laid bare, as is the case along the coast of eastern Upland, where on the naked, ice-polished cliffs of the innumerable islands a study of the details of the complicated rock structure can be made in a more satisfactory fashion.

Characteristic for the whole Almunge district are furthermore the numerous fragmental inclusions in the granites, and especially in the gray granite of the Upsala type. These inclusions are very varying, some being leptites, others amphibolites, others again schistose rocks of varying composition. The syngenetic basic inclusions of the Upsala granite, such as described by HÖGBOM,[1] are also numerous. About 7 km south of Uddnäs a broad band of paragneisses with interbedded limestone is conspicuous on the geological map of the Survey.

It is hardly wonderful, that, considering the extreme variation of the country rock, and the large amount of foreign inclusions, which are met with everywhere, the relatively small area of dark nepheline-bearing rocks buried away in the woods round Almunge so long evaded the attention of the surveying geologists.

Previous Surveys.

The district round Almunge was geologically mapped by the Survey during the years 1866—67. From the geological description of the sheet Rånäs by E. SIDENBLADH, published 1868, it is evident, that already at this early date the unusual structure of the syenitic rocks had attracted the attention of the mapping geologists. SIDENBLADH describes,[2] how the feldspars are without noteworthy features in the granites of the district, *except round Seglinge,* (see map), where they are 'twinned, so that one half is dull, while the other is highly glistening, giving the rock a peculiar appearance'. In this type of rock large amphibols are also mentioned, one crystal by Seglinge having measured 3 inches. As early as 1868 the geologist in charge has evidently here held in his hand the coarse-grained umptekite of Seglinge with its large hastingsite amphibols. From several other places rocks are described by SIDENBLADH, which according to their structure would be classified as syenite-pegmatites.

[1] Geol. För. Förh. Bd 15 (1893) p. 251.

[2] Sveriges Geol. Undersökning, Bladet Rånäs, p. 21.

Possibly these rocks have belonged to the numerous coarse-grained veins or segregations of nepheline-syenite-pegmatites. TÖRNEBOHM had also noticed the singular character of the Almunge syenites. In 1882 he mentions the rocks in the description[1] to his map on 'Mellersta Sveriges Bergslag', sheet 6, particularly dwelling on the large feldspar crystals, the amphibols and the large amount of apatite and zircon as the most characteristic features of the rock. TÖRNEBOHM has, however, evidently happened to slice some unusually acid types of the umptekites, rich in quartz, as the rocks are the whole time termed granites, though the difference to the surrounding archean granites is always emphasized. In discussing the relative age of the Upland granites TÖRNEBOHM writes:[2] 'Youngest of all is *possibly* the reddish, amphibol-bearing granite east of Fladen in Almunge parish'. Here, as has been the case in so many other places, TÖRNEBOHM has nearly intuitively drawn the right conclusion as to the geological relations, without having studied the region in sufficient detail to be able to offer any positive proofs.

HÖGBOM was the first to draw general attention to the rocks of Almunge. In his well-known paper on the archean granites of the province of Upland[3] a short but concise description of the normal syenite is given, by which its essential petrographical features are clearly described. HÖGBOM's paper was, however, of a general character, dealing with the archean rocks of the whole province. No detailed survey of the Almunge district was therefore undertaken, and several of the most interesting rock types evaded attention, well hidden away, as they happen to be, in the woodlands south of Sågen. The geological relations between the syenite and the surrounding country rock could in consequence of too few observations not be exhaustively discussed, though HÖGBOM inclined most to interpret the syenite as only a differentiated facies of the granites. The natural explanation of this opinion lies in the fact, that the syenite and related rocks are surrounded by an acid, often aplitic or protoclastically gneissose marginal zone, which in its general appearance often reminds much more of the acid, red granite of the district than of the typical syenite. This marginal zone has not before been recognised as genetically belonging to the alkaline rocks, and consequently every transition was naturally found between the syenite and the marginal zone. The real contact is generally to be found some 100 meter further out but is itself often of such an ill-defined character as to be hardly noticed if not actually sought for.

ROSENBUSCH mentions the locality of Almunge in his Physiography[4] specially drawing attention to the optical characters of the amphibol,

[1] Beskrifning till Geologisk Öfversiktskarta öfver Mellersta Sveriges Bergslag. Blad 6, p. 14.

[2] Ibid. p. 33.

[3] Geol. För. Förh. Bd. 15 (1893) p. 266—268.

[4] Physiogr. d. massigen Gesteine, 4 Aufl. (1907) II: 1, p. 152.

which is described as optically negative, with the axial plane vertical to the plane of symmetry. The syenite is referred to as a quartz-bearing umptekite. ROSENBUSCH concludes with the following sentence: »Es wäre sehr auffallend und schwer zu erklären, wenn dieser quarzführende Umptekit wirklich mit dem Upsalagranit zu einer geologischen Einheit verbunden wäre».[1]

The rocks which form the small alkaline province of Almunge, can despite their great variation be restricted to two separate groups: the alkaline syenites or *umptekites* and the *nepheline-bearing rocks.* For the latter group, which is characterized by the mineral combination albite-nepheline the name of *Canadites* is suggested, which name would include all albite-bearing nepheline-syenites with a subordinate amount of normative lime-sodafeldspar. A nearer definition of the new group, as well as my reasons for giving it a special name, will be given further on. Both the umptekites and the canadites occur in massive as well as protoclastically gneissose development. Through intermixture a group of intermediate or hybrid rocks occur, which will be treated in connection with the canadite group. Besides the petrographic features of the rocks, which will be treated in detail under each separate group, the relations of the different rocks to one another as well as to the surrounding archean are of special interest and of importance in interpreting the general history of the igneous complex in question.

The Umptekite Group.

Relation of the Umptekite to the surrounding Archean Formations.

As already mentioned, differences in opinion have long existed as to the relation of the Almunge syenite to the surrounding rocks. Some geologists have considered the syenite as a differentiated part of the Upsala granites, into which it was supposed to pass without any distinct contact being determinable, others were in consequence of the alkaline character of the rocks, rather than because of definite observations, more inclined to assume a separate intrusion of the alkaline magma to have taken place. We will now follow the contact somewhat closer and see, in what way a detailed observation favours the one or the other theory.

Before entering into a closer investigation of the contact phenomena I must, however, advance some general notes on the geological relations of the contact.

[1] In HÖGBOMS: Fennoskandia, Handbuch der regionalen Geologie, Bd. IV: 3, p. 80, a few words are inserted about the age of the Almunge rocks. ROSENBUSCH is there said, owing to the petrological character of the rocks, to ascribe to them a post-archean age. Prof. HÖGBOM has requested me to correct this statement, which is due to a slip of the memory, ROSENBUSCH having expressed no definite opinion in print as to the age of the Almunge rocks.

The syenite rocks of the Almunge massif are towards the margin rarely normally developed. The difference between the typical syenite of the more central parts and the marginal facies of the same rocks is often so great, that at first sight one would hardly suspect any genetical relations at all to exist between the two. In fact this outer contact zone often much more resembles certain fine-grained portions of the red granite of the country rock round about, which to some extent explains, that former surveyors have reckoned it to the surrounding granites and in consequence naturally assumed, that the syenite gradually developed into the granites of the environs.

The differences between the normal syenite and this marginal zone are both chemical, mineralogical and structural. As a more detailed description of the rocks will be given under the petrographical division, I will here restrict myself to the most essential features.

Chemically the marginal rocks are somewhat more acid and distinctly more salic than the normal syenites.

Mineralogically the same rocks are generally characterized by the more abundant presence of quartz and by the amphibols, which are the most abundant mafic minerals of the umptekites, being partly or in many places wholly replaced by mica.

Structurally the difference between the central and periferical rocks is still more pronounced, a fine-grained granular or aplitic often gneissose structure being dominant towards the margin, the schistosity, however, regularly following the contact line and thereby documenting itself as being of protoclastic origin.

As is seen on the geological sketch map this modification is relatively uniformly developed around the whole massif. It has, however, not been possible everywhere to follow the contact line in detail; in many places it is covered by glacial drift or alluvial clays, in others a great amount of assimilation of the surrounding granites has taken place, thereby obliterating the contact almost completely. The marginal zone, as indicated on the map, is therefore in many places in detail very schematic, and in it are included all the different modifications of the umptekites, which have originated by contact influence, whether only structural or only chemical, and formed through assimilation of exogenous material from the country rock around.

Beginning at the south end of the syenite area, just where the road from Almunge church to Uddnäs makes a small bend west-ward round a hillock, (over which the old road is still visible), the contact is to be found at the northern foot of the same hillock. Passing from the gray, gneissose Upsala granite round the Söderby lake the first rocks to be met, are some fine-grained varieties of the marginal modification of the umptekite, showing a rather marked banded structure. The rock is nearest the contact of a reddish colour, but soon fades into the usual light yellow or white rocks, most common in the marginal zone. Just to the east at the foot of the hill, types very rich in muscovite are common, which at a first glance look more like sillimanniet-gneiss than anything else. The syenite here has evidently intruded the Upsala granite in broad dikes parallel to the contact, the granite appearing again below the first outcrop of the syenite. What is seen at the foot of the hill is therefore possibly only a series of dikes, the real contact lying just northward, but covered by the field clays. Following the road, the next outcrop on the left is already well in the .umptekite massif, though still of a marginal character. The gradual transition can afterwards be followed step by step up to Uddnäs. To the right of the road several outcrops of the Upsala granite still occur, either indicating a very uneven contact or representing large inclusions of the surrounding rock.

Following the contact eastward from the small hillock first mentioned, it is easy to perceive, that the limit of the driftcovered forest landscape represents the contact between the Upsala granite and the syenitic rocks. The small low outcrops in the fields here belong without exception to the syenite, the rocks of the woodland just as regularly to the surrounding granites. The geological border line is here as in many other places well marked in the topography, and here as elsewhere, where this is the case, the syenitic rocks coincide with the low ground, the granitic country rock forming the higher woodland round about, which partakes in the old precambrian peneplain of the whole district. Without doubt this condition is due to the fact, that the alkaline rocks weather more easely than the surrounding archean formations.

The contact line itself is, however, hardly visible along this bit of ground, being covered by the alluvial deposits. Many dikes, generally parallel with the contact, intrude the granite, but are because of their acid character not always in the field distinguishable from normal aplites, which occur everywhere in the district.

Where the forest line bends northward towards Oppgården, the contact evidently follows this topographical line, some small outcrops in the field just west of the farm buildings being of the usual marginal type of the syenite, whereas the farm itself stands on normal granite.[1]

From Oppgården one can follow the contact in more detail, first northward and then in a westerly and northwesterly direction past Strömsberg to the high road to Knutby. Everywhere the contact line shows the same general features, the surrounding country rock being the gray Upsala granite, nearest the contact often cut by dikes and veins of aplitic syenite. The border line itself is generally here sharp and well defined and has been laid bare at some dozen different places. One can hardly

[1] The numerous veins of aplite, intersecting the granite between the farm buildings in all directions, do not seem to belong to the alkaline rocks; at least no features are left in the highly acid dikes, almost destitute of dark minerals, which could indicate their origin from the umptekite magma. It seems therefore nearer at hand to refer them to the red granite, or to the numerous aplitic dikes, belonging to the Upsala granite itself, which so often are found intersecting it.

doubt the intrusive nature of the syenite in relation to the surrounding granite along this part of the contact line.

Before proceeding, I must, however, call attention to the great quantity of inclusions of mostly dark coloured, fine-grained rocks, which occur nearly all along the contact north of Oppgården and often accumulate to such a degree, as nearly to obliterate the contact line itself. Exactly the same phenomenon is moreover repeated at many places along the northern and northwestern limit of the syenite massif. I will therefore here deal somewhat in detail with these phenomena, afterwards only mentioning the occurrence and referring to what has been said here.

It seems perfectly clear, that the inclusions in question have nothing to do with the umptekite rocks or their syngenetic associates. Nothing has ever been found in their mineralogical composition, which could indicate such a relation. Neither do they, however, in detail resemble the surrounding granites, from which it might be supposed, they had been derived. Apart from their origin, the processes which the inclusions have undergone in the umptekite magma are obvious enough. In many places one can follow, how the fragments have been more or less fused by the syenitic magma. Sometimes they are angular with sharp and well defined edges, at other times they are rounded or elongated and the borders show evident signs of assimilation processes. Small veins of syenite often intersect the inclusions or stray feldspar crystals from the syenite have wandered into the darker rock, giving it a porphyric appearance, the origin of which can, however, not long be doubted (Pl. II, fig. 2). The structure of these inclusions is often that of a typical hornfels, that is to say, no order of crystallization whatever can be established. It seems therefore evident, that the foreign fragments have been caught up by the umptekite magma, and more or less fused and recrystallized.

But there are two more questions to be answered relating to these inclusions, namely: what was their origin and petrographical character before recrystallization and why are they so distinctly accumulated along the contacts? To answer the first question their chemical and mineralogical composition must be decisive. One can say, that the rocks in question are built up of quartz, orthoclase, albite or plagioclase, varying between albite and andesine, biotite, diopside and amphibols, the mafic minerals, however, more frequently occurring separately than all together. Even with due consideration to secondary changes through assimilation with the syenitic magma, the chemical composition of the inclusions must be classed as variable, and it is hardly possible to say for certain, that they have originated from any special rock type. The great variation of the Upsala granite with its dioritic differentiation products and its many basic inclusions could without doubt give rise to rocks, which in a more or less recrystallized form would correspond to the contact inclusions of the Almunge umptekite. The absence of aluminium-silicates seem also to point to a primary magmatic rather than to a sedementary origin. The leptite inclusions of the district hardly correspond to the rocks in question, their composition being essentially more acid and felsic. From what I have seen of these inclusions -- and sections have been made from at least half a dozen different localities — I am most inclined to look upon them as more or less fully recrystallized fragments of some eruptive rock, ranging between a granitic and dioritic composition. This is, however, just the composition of large areas within the Upsala granite, which for example grades into diorites not far east of the Almunge district (see map). And as the inclusions evidently are not derived directly from the contact, to which they now border, but, as will be referred to below, probably have been brought to their present position from deeper levels by the rising umptekite magma, variations in the composition of the Upsala granites at such depths may well occur, which would correspond to the variations of the inclusions.

To answer the second question, why the inclusions have accumulated in such a marked way along the contacts I must already here briefly dwell on the geological interpretation of the Almunge rocks more extensively to be treated further on. The result of the detailed survey of the district seems to indicate, that the whole area of alkaline rocks represents a deep-seated cross-section of a channel, through which magma has flowed perhaps for a considerable time, giving rise to intrusive or extrusive rocks at higher levels, long since eroded away. If this explanation is correct, the accumulation of fragments of rocks from greater depths around the peripherical parts of the channel would be quite a natural feature, the flow of magma naturally having continued longer in the central parts. As will be seen further on, many other details find a simple explanation by this theory.

Returning to the contact between Strömsberg and the high road, great masses of these dark inclusions, often several meter in diameter, are everywhere to be seen, always close to the contact line. At one or two places I have noticed the fragments also in the granite on the outer side of the contact, though only a few meter from the syenite. I hardly think this observation need clash with the explanation given above. Stray fragments may easely have been forced into the fractured and perhaps partly softened wall rock of the channel.

North of the high road the contact evidently follows the valley running northward east of Sågen. Straight east of this little farm the contact is, however, to be found on the west side of the main valley, in the wooded slope just opposite the farm buildings. The intrusive nature of the contact is here again quite distinct.

North of Sågen we come to a region where the surrounding rock is no longer the gray Upsala granite but the red acid granite, which as already mentioned like a broad band stretches in a NE direction right over the Almunge district. The nature of the contact here also changes its character to a certain extent, the contact line towards the red granite invariably being less distinct. Through more intense assimilation of granite material, the contact is often represented by a perfect transition between the marginal syenite and the red granite. Both rocks moreover being nearly destitute of dark minerals, it is also only natural that the contact is difficult to locate. It seems as if the rising syenitic magma had more easily assimilated the acid, red granite than the gray Upsala granite, which would also explain, why the contact towards the former is so much more indefinite.

By Mörtsjön, where the contact line passes, masses of dark inclusions remind one of the phenomena already described. The whole northern contact from Mörtsjön to Norrby has much the same character. The marginal facies of the syenite often looses its typical aplitic structure and intermediate rocks, formed through assimilation of the granite, obliterate the contact. By Norrby a pretty clear section is visible just north of the farm buildings, masses of dark inclusions interwoven with veins of syenite, marking the border line of the alkaline rocks (Pl. II). W of Eneby (across the fields) good exposures of the contact can be found under the moss covering again showing huge fragments of dark rock, here typical diopside hornfels, caught up in the umptekite, which at this place has not assumed the usual marginal facies but almost retains its normal development.

By Broängen a number of broad dikes, several meter in width, are found transsecting the gray granite of the Upsala type, which here again appears. The contact from this point turns southward, probably following the valley down towards Stora Ellringe. The western side of this valley consists of rocks of undefinite types, intermediate between the gray and the red granite of the district; on the eastern side of the valley the rocks are formed of a granitic modification of the marginal syenite, with numerous basic inclusions as usual indicating that the contact is close at hand. From Stora Ellringe southward little is able to be seen of contact phenomena, the contact line mostly being covered by the alluvial clays or by the Lake Fladen. At Lilla Ellringe the contact is probably represented by some broad dikes, intruded into the Upsala granite close to and parallel with the contact line. The syenite here also shows a marked protoclastic structure, striking in the same direction as the contact. The appearance of nepheline-bearing rocks somewhat complicates the features at Lilla Ellringe, which will be alluded to later on. The surrounding rocks are partly a rather bleached type of the Upsala granite, and partly further west alternating red and gray granites or intermediate types.

From Lilla Ellringe the contact line curves eastward, passing under the lake. The next outcrop of syenitic rocks is at the south-eastern end of the lake. The contact line itself has not been able to be traced in detail here but in all probability passes along one of the marked depressions, which run in a south easterly direction through the woodland. In the northern part of this small woodland, bordering the lake west of Uddnäs, the rocks certainly belong to the syenite group, in the southern part on the other hand they pass indefinitely into the red granites of the country rock, which, as seen by the map, here again put in an appearance. The same indefinite character of the contact, as was found along the northern border towards the red granite, here immediately appears again; at many places in the field you can hardly feel positive, if you are hammering a marginal acid type of the syenite or the red granite. One can at such places scarcely locate the exact contact nearer than at 30—50 m. As has been remarked, this phenomenon is not interpreted as indicating a consanguinity between the two rocks, but only as a zone of more intense assimilation between the syenitic magma and the red type of granite.

Some 500 m further eastward the contact again becomes well defined, the red granite at the same time being replaced by the gray Upsala granite. Passing over the road, we are at our starting point, having followed the margin of the alkaline rocks round the whole area.

As a result of the detailed investigation of the contact between the umptekite group of rocks and the surrounding country granites, the following conclusions may be drawn.

1. The contact between the umptekite and the gray Upsala type of granite is generally well defined and of an intrusive character. Dikes of the marginal type of the syenite often intersect the granite, generally however running parallel to the contact.

2. Towards the red acid granite, which borders the alkaline area to the north and northeast as well as to the southwest, the contact line is not so well defined, the red type of granite having more easely surrendered to the assimilating powers of the syenitic magma, giving rise to intermediate types by allowing a greater exchange of material to take place between the two rocks.

3. A large amount of inclusions of dark rocks have accumulated along the contact. Many of these have been fused and re-crystallized by the syenitic magma and now show typical hornfels structure. In places, where recrystallization has not taken place, the structure and mineralogical composition of the inclusions are those of a diorite or nearly related type of rock. It is presumed, that these dark inclusions are fragments of the country rock, brought up from lower levels by the rising syenite magma. The variability of the Upsala granite is such as easely to include types, which might be the origin of the contact inclusions.

4. The younger geological age of the alkaline rocks compared with the surrounding granites is not always evident along the contact, this being due to the amount of assimilation, which at certain points has taken place. The structure of the syenite seems, however, to indicate that the alkaline rocks have intruded the region not only after the solidification of the granites, but also after the regional (and eventually palingenetic) deformation of the same. The gneissose structure of the syenite is bound to the con-

tacts, which it in its strike follows, thereby documenting itself as of protoclastic origin. It is the writers opinion that the geological relations between the umptekite and the surrounding country rock as well as between the different types within the alkaline group itself are best explained in assuming, that the whole area represents a relatively deep section of a channel, through which the alkaline magma has once risen and possibly flowed for some length of time. The amount of assimilation along parts of the contact would in that case be easely explained. It seems improbable, that the small area of the Almunge rocks, only measuring 13 square km. should represent the whole intrusion of alkaline magma in this isolated position amid thousands of square miles of archean granits surrounding it.

Mineral composition.

The mineral composition of the umptekite rocks is relatively simple and if types, boardering to the nepheline-bearing rocks, which will be treated later, be excluded, subject to but insignificant variations.

The following minerals have been observed.

Quartz,	Feldspars,
Hornblende,	Pyroxene,
Fayalite,	Biotite,
Muscovite,	Garnet,
Calcite,	Sphene,
Zircon,	Apatite.
Magnetite,	

Quartz. The relative amount of quartz in the syenite rocks is very variable. In the typical umptekite it is of rare occurrence. The large percentage of quartz, mentioned in former descriptions, undoubtedly originates from specimens of or bordering to the granitic variations of the syenite. — The quartz is throughout the last mineral to have crystallized. Nothing in the way of graphic intergrowth with the feldspars has been observed. In certain of the more coarse-grained rocks the quartz has accumulated in the angular spaces between the feldspar crystals. Large parts of a rock section can then be free of quartz, whereas in other parts, where several such angular spaces accidentally join, the mineral can be relatively abundant. Otherwise the quartz in these rocks has no feature of special interest.

Feldspars. The feldspars of the umptekite and its associated rocks are, as HÖGBOM and ROSENBUSCH have already mentioned, of several different kinds, orthoclase, microcline, albite or a highly sodic plagioclase and perthite being the normal constituents of the rocks.

Microcline-microperthite is by far the predominant feldspar of the normal umptekite; in many places it nearly exclusively builds up the syenite. This microperthite consists of microcline and albite in rather variable proportions. In general, however, albite is prevalent. In sections after P one is in a position to follow in detail the interesting structure of the perthites. Often a part of the feldspar is pretty normally developed, with small angular patches of twinned microcline distributed in the large albite crystal. But in other places a very interesting transition from this microcline-microperthite to microcline-cryptoperthite is observable.[1] The small distinctly twinned angular microcline individuals grade off into narrow streaks or bands, where at first the double microcline twinning is still discernable, but gradually disappears (see Pl. III, fig. 2). Further on the dimensions of the lamellæ are so minute, that one can only by strong magnification follow the inhomogeneous structure of the feldspars. Finally the lamellæ seem to divide up into minute little squares of untwinned microcline which only by their corresponding refraction indices and optical orientation can be identified as belonging to the original microcline individual.

This part of the feldspar under weaker magnifications naturally looks like a uniform crystal, though higher magnification discloses the perthitic structure. It is because of this transition from normal microperthite to a nearly submicroscopical intergrowth that these feldspars show the transition from microperthite to cryptoperthite in such an instructive and obvious way. The perthitic structures moreover closely resemble those described by USSING in his classical description of the Greenland nepheline-syenites.[2]

On M the structure of the perthite is that of broader or narrower among themselves parallel lamellæ intersecting the basal cleavage planes

[1] Here and in the following pages the word cryptoperthite is used in the sense given by USSING: »Kryptopertit anvendes for saadanne Kalinatronfeldspater, hos hvilke man virkelig ved omhyggelig Undersøgelse kan finde mere eller mindre tydelige Tegn paa en submikroskopisk pertitisk byggning. Navnet Natronortoklas (resp. Natronmikrolin), bibeholdes da for de Kalinatronfeldspater, som selv i de tyndeste Preparater og ved stærk Forstørrelse synes fuldt homogene, saa at enhver nærmere Forestilling om deres Struktur kun er hypotetisk. Den væsentlige Forskel mellem Mikropertit og Kryptopertit ligger efter denne Definition alene i Dimensionerne af de enkelte Kali- og Natronfeldspatlameller eller Smaapartier, som opbygge Feldspaten». (Meddelelser on Grønland, heft 14 Kjøbenhavn 1898 p. 18. In translation: Cryptoperthite is only used for such potash-soda-feldspars, in which one actually by a close study can find more or less evident signs of a submicroscopic, perthitic structure. The name soda-orthoclase (and soda-microcline) is reserved for those potash-soda-feldspars, which even in the thinnest slices and by high-magnification seem perfectly homogeneous. The essential difference between micro perthite and cryptoperthite lies according to this definition only in the dimensions of the individual potash- and soda-feldsparlamellæ which constitute the feldspars.)

[2] Meddelelser om Grønland Heft 14. Kjøbenhavn 1889, p. 43, compare Pl. III, figs 1 and 2.

of the albite at an angle of 71—72° (measurements obtained 70 1/2°, 71°, 72°, 72 1/2°). The extinction of the perthite was measured in several orientated sections and gave the following result.

	on M	on P
Albite	18°—19 1/2°	4 1/2°
Microcline	5°—6°	16 1/2°

Besides this microcline-micro- and cryptoperthite orthoclase-microperthite is a usual constituent of the normal umptekite. It is sometimes of a coarser, sometimes of a finer structure, varying with the grain of the rocks. Otherwise there is little to say on its development. It seems as if the amount of orthoclase-microperthite was greater in the quartz-bearing parts of the umptekite, the microcline-perthite being more abundant in the quartz-free variations. In sections of the granitic facies of the umptekite, I have hardly observed any microcline-perthite at all, though individual microcline is generally present.

Besides the perthitic feldspars the different ingredients, orthoclase, microcline and albite all occur in individual crystals. Whereas in the coarse-grained varieties of the umptekite the perthitic feldspars are dominant, the granular, aplitic or protoclastic marginal zone is nearly destitute of these. Microcline and albite are here generally the principal components.

Albite is however present in every variety of the umptekites though often in very subordinate amounts. It seems unusually constant in its chemical composition, most measurements have given extinctions corresponding to pure albite or to an extremely acid oligoclase-albite (Ab to $Ab_{95}An_5$). It shows the usual twinning according to the carlsbad and albite laws, less frequently according to the pericline law. Microcline generally shows the normal doubly polysyntetic twinning ('Gitter'-structure), when found in single individuals. In some sections, however, a feldspar irregularly polysyntetically twinned according to the albite law, and with a refraction index essentially lower than that of albite, may be observed. The extinction angles show, that it cannot be soda-microcline (anorthoclase), but instead must be normal microcline, only not showing the usual double twinning. Here again we meet with a resemblance to the Greenland syenites; USSING emphathizes how the microcline in the Greenland nepheline-syenites *never* shows the normal 'Gitter'-structure[1] but instead an irregular but characteristic twinning according to the albite law. BRÖGGER[2] has previously described the same phenomena from the Christiania-fjord. USSING asserts, that this kind of twinning is probably characteristic for microcline just in nepheline-bearing rocks. There seems no doubt, how-

[1] l. c. p. 7.

[2] Zeitschr. für Kristallogr. Vol 16, p. 561.

ever that the same structure occurs in many of the umptekite rocks, as well as in the nepheline-bearing canadites of Almunge, as will be touched upon later on. The most striking circumstance is not so much the appearance of this irregular twinning of the microcline according to the albite law, as the coexistent microcline, to all appearance normally developed with the typical 'Gitter'-structure. Orthoclase is in many of the umptekite rocks principally confined to the perthites, individual crystals being at times quite scarce. In other variations, and especially in those rich in quartz, the orthoclase is abundant and well developed in large carlsbader-twinned crystals. Soda-orthoclase or soda-microcline have not been observed in the umptekite rocks.

Hornblendes. The hornblendes of the umptekite of Almunge are perhaps the most interesting of the rock-forming minerals and, as already mentioned, early drew attention to the Almunge rocks in consequence of their unusual optical properties, which differ essentially from those of the amphibols in the surrounding granites. I have in consequence studied the hornblendes of the district somewhat in detail and will here briefly state the chief results.

The commonest hornblende in the umptekite occurs in large but imperfect crystals, which in the coarse-grained varieties round Seglinge can attain a length of several centimeters. The colour is megascopically deep black with a high lustre on the cleavage planes. Under the microscope a strong pleochroism is observed in bluish green and yellow colours. The most characteristic feature is perhaps the position of the axial plane at right angles to the plane of symmetry, as already described by ROSENBUSCH. The position of the axial plane is, however, often difficult to determine, the optical angle of the hornblende being so small, that only sections nearly vertical to the acute bisectrix give any definite information. Several sections have therefore been made parallel to the different crystallographic faces. A section parallel (010) shows the obtuse bisectrix Z, a section parallel (100) shows the acute bisectrix X, well in the field. In the first instance the direction of elongation in the hornblende is that of the greater elasticity, in the second instance that of the smaller. This observation in parallel light confirms the transversal position of the axial plane as observed in convergent light.

The optical orientation of the hornblende is therefore $b = Z$, the axes Y lying nearest the vertical c.

Other striking features of this amphibol are its small axial angle, and its extremely weak birefringence. The axial angle 2 E approximately does not exceed 25°—30°. Because of the strong axial dispersion the different sections of the interference figure are in white light brightly coloured in reddish and bluish green tints. Taking into account the extremely low double refraction, which causes the axial figure to be very indistinct, as well as the minerals own deep colouring, it is only natural, that all observations in convergent light are very indistinct. In many cases it can even be difficult to distinguish the vague axial figure from an uniaxial cross.

The axial dispersion is as already mentioned strong with $\rho < \nu$.

The extinction angle c : Y is 35°—41°, which is somewhat higher than ROSENBUSCH's first figures.

The optical character of the hornblende is negativ.

The absorbtion colours are

X = yellowish green,
Y = bluish green,
Z = olive green,

with Y > Z > X.

A chemical analysis (I) has been executed on material from the coarse-grained umptekite of Seglinge by R. MAUZELIUS. I a gives the molecular ratios of the analysis.

	I	I a	
SiO_2	37,49	62,07	63,14
TiO_2	0,86	1,07	
Al_2O_3	10,81	10,58	15,29
Fe_2O_3	7,52	4,71	
FeO	25,14	34,97	73,54
MnO	0,95	1,34	
MgO	1,34	3,32	
CaO	9,77	17,41	
K_2O	1,91	2,02	
Na_2O	2,06	3,32	
H_2O	2,01	11,16	
	99,86		

The hornblende evidently belongs to the group characterized by PENFIELD and STANLEY[1] as showing an excess of RO in relation to SiO_2 and at the same time a corresponding increase of the sesquioxides, which according to these authors are bound as alumo-fluor-hydroxyl- or other bivalent sesquioxide-radicals, substituting one or more of the hydrogen atoms of the metasilicate amphibole acid. According to an older conception of SCHARITZER[2] the hornblende would represent a mixture of ortho- and metasilicate molecules. The ratios $(R_2O + RO) : R_2O_3 : SiO_2$ are 4,13 : 1 : 4.08 or approximately 4 : 1 : 4, if the water is left out of account. Reckoning the sesquioxides as entering the orthosilicate molecule with the formula 3 $(R_2O . RO)$ R_2O_3 3 SiO_2, the hornblende would accord-

[1] Am. Journal of Science, Vol. 23 (1907) p. 42.
[2] Neues Jahrbuch 1884: II p. 147.

ing to SCHARITZER consist of the syntagmatite orthosilicate and the actinolite metasilicate molecules in the molecular ratios 3 : 1, corresponding to the formula 3 $(R_2O\ RO)\ R_2O_3\ 3\ SiO_2;\ RSiO_3$.

According to later investigations, however, the water must be considered as an essential ingredient in the constitution formula of the hornblendes, and I have only referred to the classification of SCHARITZER because of the near relations of the hornblende in question to an amphibol, which has been characterized as a true orthosilicate hornblende.

The fact is that I have only found one detailed description of a hornblende which as well in its optical properties as also approximately in its chemical composition corresponds with the hornblende just described, and that is the hastingsite, first described by ADAMS,[1] and later and more fully by GRAHAM[2] from the nepheline-syenites of the Bancroft district in Ontario. The resemblance with reference to the optical properties is as good as complete. The small axial angle, the low birefringence, the strong axial dispersion, the absorbtion colours and the position of the axial plane at right angles to the plane of symmetry are all properties in common for both hornblendes. The angle of extinction in the hastingsite was first found by ADAMS to be over 30°, GRAHAM gives the maximum angle to be about 30°; in the Almunge rocks the hornblende has somewhat higher angles, sections after (010) giving extinctions up to 41°. The chemical composition is also similar. The Almunge hornblende is somewhat richer in SiO_2, but it must be kept in mind that it originates from a rock, essentially richer in silicia than the nepheline syenites of Bancroft. The hastingsite from Dungannon was described as a pure orthosilicate hornblende. Assuming this interpretation of the constitution for comparison with the amphibol in question, the latter would be a mixture of the hastingsite molecule with a metasilicate in the molecular ratio 3 : 1. Later researches have, however, made probable, that all amphibols are salts of one and the same metasilicate acid, the greater or smaller excess of the constituents R_2O and R_2O_3 being bound as bivalent radicals. The amphibols here in question certainly show no such divergence from the crystallographic forms of the amphibol group, as to justify the assumption of an essentially different molecular constitution. I think therefore the definition of hastingsite as an orthosilicate hornblende hardly satisfies our present ideas of the chemical constitution of the amphibol group.

I have not the slightest hesitation in classifying the hornblende from the umptekite of Almunge as very nearly related to the hastingsite of ADAMS and GRAHAM. But when it comes to define what is meant by a hastingsite, a good definition is still wanting. Chemically the hastingsites cannot as yet be separated from many other hornblendes as the following table will show, where I have tried to collect the chemically nearest related hornblendes without taking into consideration their optical properties.

[1] Am. Journal of Science Vol. XLVIII (1894), p. 13.

[2] Canada, Dept. of Mines, Geol. Survey branch, Memoir n:o 6, p. 244.

	I	II	III	IV	V	VI	VII
SiO_2	37,49	38,03	38,26	34,18	42,50	36,86	35,42
TiO_2	0,86	0,22	1,00	1,53	—	1,04	1,34
Al_2O_3	10,81	11,59	14,66	11,52	9,91	12,10	8,89
Fe_2O_3	7,52	6,81	4,32	12,61	5,07	7,41	9,73
FeO	25,14	23,72	22,66	21,98	22,57	23,55	24,48
MnO	0,95	1,11	0,35	0,63	—	0,77	1,17
MgO	1,34	2,87	4,23	1,34	2,39	1,90	0,17
CaO	9,77	9,75	9,67	9,87	11,35	10,59	6,93
K_2O	1,91	1,90	1,98	2,29	1,92	1,20	3,23
Na_2O	2,06	2,30	1,34	3,29	3,65	3,20	5,13
F	—	0,05	0,09	—	—	0,27	—
H_2O	2,01	1,20	1,97	0,35	0,36	1,30	3,15
	99,86	99,50	100,44	99,60	99,85	99,99	99,64

I. Hastingsite, Seglinge, Almunge.
II. Hornblende in Pegmatite, Österskär, P. GEIJER. Geol. För. Förh. Bd 35 (1913) p. 147.
III. Hornblende in Pegmatite, Stockholm. P. GEIJER, ibid.
IV. Hastingsite, Dungannon, Ontario. Am. Journ. of Science, Vol. XLVIII, p. 13.
V. Hornblende in Umptekite, Wausau, Wisconsin, Wisc. Surv. Bull. XVI (1907).
VI. Hudsonite. Am. Journal of Science, Vol. XV, p. 264.
VII. Hornblende. Beverley, T. M. P. M. Vol. XIX, p. 312, 1909, p. 227.

The chemical composition of these hornblendes is strikingly similar and, if the amphibols could be grouped according to their chemical properties only, these would constitute a small but natural group, characterized by low SiO_2, Al_2O_3 about 10, FeO (Fe_2O_3 included) round 30, CaO about 10 per cent and relatively low alkalies. Turning, however, to the optical properties, there is little to be found in common for the group, the angle of extinction varying from 9—40°, the axial angle from 16—70°, the birefringence from strong to very weak and so on. If on the other hand one of the optical properties such as the position of the axial plane at right angle to the plane of symmetry is taken as basis for classification, the result is just as meagre. Besides the hastingsites from Dungannon, Ontario, and from Almunge, some examples of amphibols with transversal axial plane described by different authors, may be quoted.

BECKE:[1] hornblende in a 'Grünschiefer im Kalkphyllit' near Lauersbach.

HLAWATSCH:[2] hornblende in nepheline-syenite-porphyry from Val dei Coccoletti, Predazzo.

[1] Tscherm. Min. Petr. Mitth. Vol. XXI, p. 247.
[2] T. M. P. M. Vol. XX, p. 43.

HLAWATSCH:[1] osannite from Cevadaes.
PALACHE:[2] crossite from Contra Costa Hills.
LANE:[3] hornblende in theralite, Michigan.
FREUDENBERG:[4] anophorite from shonkinite, Katzenbuckel.

Many more examples might be cited, but the instances referred to will amply suffice to show, that only the fact of the axial plane being at right angles to the plane of symmetry, is quite insufficient for a natural classification of the amphibols. HLAWATSCH[5] has already pointed out, in what very different kind of rocks amphibols of this character occur. The very crossing of the axial plane from parallel to normal to the plane of symmetry is described (by FREUDENBERG) from the anophorite of Katzenbuckel and surmised in the hastingsite from Dungannon (by GRAHAM) and in a hornblende out of gabbro-diorite of Jablainca (by HLAWATSCH).[5]

Although I therefore do not hesitate to classify the hornblende of the umptekite as a hastingsite, I am not able to give a strict definition to this specific amphibol. I have referred to the above analysis to show, how little the chemical composition or one or other of the optical properties alone suffice for a natural classification. After having described the second variety of hornblende in the umptekite, I will again refer to the definition of the hastingsite group.

The hastingsite often shows a parallel intergrowth with biotite, long, thin lamellæ, parallel to the cleavage-planes, reaching through the whole length of the crystal. Fine reaction rims consisting of small droplike diopside crystals, elegantly arranged round the edges of the hornblende, are very common. The diopside crystals then invariably radiate from the hornblende. This feature is identical with the 'reaction rims' described by WRIGHT from Beverley.[6]

Besides the hastingsite there is another hornblende in the umptekite, characterized by higher birefringence, extinction angles of 20°—25° and strong pleochroism in yellow and olive green or reddish brown colours.

This hornblende has often a very patchy appearance, the colour varying in the same crystal from olive green to reddish brown. The reddish parts generally constitute the central part of the crystal, being surrounded by the olive green variety, or else several zones alternate, the outermost, however, generally being the green variety.

The optical properties of this hornblende are:

Axial plane in plane of symmetry $b = Y$.

Extinction angles $c : Z = 20^\circ$ for the reddish brown hornblende, some 5° higher for the green.

[1] ROSENBUSCH Festschrift 1906, p. 68.
[2] Bull. Dept. Geol. Univ. of Cal. Vol. 1, p. 181.
[3] Bull. Dept. Geol. Univ. of Cal. Vol. 4, p. 384.
[4] Mitt. Grossh. Bad. geol. Landesanstalt. Bd V, 1906.
[5] T. M. P. M. XXII, p. 499.
[6] T. M. P. M. Vol. XIX, p. 308.

Birefringence low, though essentially higher than in the hastingsite. Axial angle small; optical character negative.

The absorbtion colours are:

	green hornblende	brown hornblende
X	yellowish green,	yellowish brown,
Y	olive green,	brownish green,
Z	bluish green,	reddish brown,

in both cases $Z \geqq Y > X$.

These optical properties correspond very nearly to those of the so called arfvedsonitic amphibol or brownish green alkaline hornblende mentioned by ROSENBUSCH in his Physiographie.[1]

Very closely related amphibols have been described by F. E. WRIGHT from the umptekite of Beverley[2] and from the alkaline rocks of Cabo Frio,[3] by PIRSSON and WASHINGTON from the umptekite of Belknap mountains[4] and from Red Hill,[5] and from several other alkaline provinces.

There seems hardly any doubt, that these different amphibols are links in a series grading from barkevikite towards some of the green or blue alkaline amphibols. WRIGHT has already indicated how the amphibols from Beverley show relations to both barkevikite, hastingsite and arfvedsonite.

MURGOCI[6] has discussed the relations between the chemical composition and the optical properties of the amphibols, and comes to the conclusion, that it is not the increase of the soda content nor the amount of Al_2O_3, or Fe_2O_3 which regulate the variations in the optical properties of the amphibols, but instead the proportions between the molecular ratios of Fe_2O_3 and Al_2O_3. The higher the percentage of Fe_2O_3 in proportion to the Al_2O_3, the larger the extinction angle, the smaller the optical angle around X (usually the acute bisectrix) and the lower the birefringence is said to grow. MURGOCI writes further: »Of course when 2 V becomes smaller around a negative bisectrix, $\gamma-\beta$ also becomes smaller and finally attains the value zero, when the amphibole becomes uniaxial. But the rule is still more general, the variation of γ and β can proceed in such a manner, that $\gamma-\beta$ passing through zero then becomes negative, i. e. β takes the place of the former γ and vice versa. In this case we have an amphibole with transverse axial planes and have established a continual variation from the common amphibol with parallel axial plane,

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[1] Mikrosk. Phys. II: 1, p. 138 and p. 199.
[2] T. M. P. M. Vol. 19, p. 311.
[3] Ibid. Vol. 20, p. 246.
[4] Am. Journal of Sc. Vol. XXII, p. 449.
[5] Ibid. Vol. XXIII, p. 267.
[6] Bull. Dept. Geol. Univ. of Cal. Vol. 4. N:o 15, p. 384.

through the uniaxial amphibol to the amphibol with transverse axial plane».

If the variations of the optical properties of the amphibols be really functions of the molecular proportions between Fe_2O_3 and Al_2O_3, the amphibols with small axial angle round the negative bisectrix or with transversal axial plane ought to be rich in Fe_2O_3 in proportion to Al_2O_3.

For some amphibols, which undoubtedly would belong to this group the molecular percentage of $Fe_2O_3 : Al_2O_3$ has been calculated.

1.	Hastingsite. Almunge	Fe_2O_3	30,8 %
2.	» Dungannon	»	41,2 %
3.	Amphibol. Beverley	»	41,2 %
4.	Crossite. Contra Costa Hills	»	68 %
5.	Anophorite Katzenbuckel	»	70,9 %
6.	Osannite Cevadaes	»	91,6 %

To a certain extent MURGOCI's theory seems to hold good, though it hardly suffices alone to explain all the variations in the optical properties. MURGOCI says himself, that very probably a large quantity of FeO together with Fe_2O_3 affects the increase of the angle of extinction in a greater measure than Fe_2O_3 alone. Probably, however, the amount of alkalies and H_2O influence the optical properties of the hornblende group at least in just as high a degree.

It is of certain interest to note, that the chemically so nearly related hornblendes described by GEIJER from the Stockholm granites, as well as the hudsonite, in this respect only slightly differ from the hastingsite, the molecular percentage of $Fe_2O_3 : Al_2O_3$ for the Stockholm amphibols being 15,9 and 27,3 % Fe_2O_3 resp.; the hudsonite has very much the same proportion, namely 28,1 %. It will be remembered that all these three amphibols, though chemically so very like the hastingsite from Almunge, show none of its characteristic optical properties.

It would lead too far exhaustively to discuss the question of the relation between the optical properties and the chemical constitution of the alkaline amphibols in this place. In what has been written I have only endeavoured to give the general characters of the groups of amphibols represented in the Almunge rocks.

With reference to these amphibols, I do not think, from what I have been able to see, that any essential difference can be established between the hastingsite and the arfvedsonitic amphibol or the green and brown alkaline hornblendes. They seem rather to form links in a series, in this case grading from the brownish hornblende, to the greenish or bluish green amphibol with axial plane in (010), and further passing through the zero point of the axial angle to the hastingsites with transverse axial plane. A. C. LANE has already indicated such a series,[1] FREUDENBERG[2] and HLAWATSCH[3] have both described amphibols, the optical properties of which point to the same conclusion, and GRAHAM[4] is of the opinion, that even the original hastingsite may have a variable position of the axial plane in relation to the plan of symmetry.

I would therefore preliminarily, until our knowledge of the relations between chemical composition and optical orientation in the hornblende group has increased, define hastingsite as a hornblende with small axial angle, with a probably undefinite position of the axial plane, in such a sense, that the axial angle may pass the zero point, first for red, then for blue light, at the same time as the axial plane passes from a position parallel to the plane of symmetry to a position at right angles to the same, further with low birefringence, with the axes Y or Z lying nearest c, forming large extinction angles, and with strong axial dispersion.[5] Chemically these hornblendes would be characterized by low Al_2O_3 (about 10%), an equal or nearly equal amount of Fe_2O_3, 20—25% FeO, about 10% CaO and relativly low alkalies.

Pyroxene. With the exception of the reaction rims round the hastingsites in certain parts, pyroxenes are hardly to be found in the umptekite rocks, and where some isolated grain has been observed, it seems to be the result of magmatic reaction on the amphibols. The pyroxene is an uncoloured diopside of normal optical properties.

Fayalite. Fayalite occurs sporadically in the more acid varieties of the umptekite, corresponding to the appearance of the same mineral in the quartz-syenite of Wausau, Wisc.[6] where the fayalite habitates certain parts of the quartz-syenites, but is not known from the quartz-free syenites of the district. The same distribution has been described from such various quarters, that it seems to be the general rule, that when fayalite occurs in the alkaline rocks, it is strictly bound to the more acid varieties.

Biotite. Both green and brown lepidomelane are common in the umptekite rocks. In several sections I have observed both varieties together, the central parts of a crystal being brownish, the peripherical green. Sometimes the colour is deep reddish brown, probably indicating a high percentage of TiO_2, as is common in alkaline rocks. In these biotites the axial angle is quite perceptible, and an extinction angle of several degrees has been measured. The biotite is, as already mentioned,

[1] In MURGOCI: Bull. Dept. Geol. Univ. of Cal. Vol. 4. N:o 15, p. 384.

[2] Mitt. Grossh. Bad. Geol. Landesanstalt. Vol. V, 1906.

[3] T. M. P. M. Vol. 22, p. 499.

[4] L. c. p. 246.

[5] MURGOCI has proposed the name laneite for amphibols with very small axial angle, low birefringence, undefinite position of the axial plane and strong axial dispersion. According to the definition given above these amphibols cannot be separated optically from the hastingsites, and as this name has priority, I have retained it.

[6] Journal of Geology. Vol. 12 (1904), p. 551.

often intergrown with the amphibol, the basis corresponding with the cleavage planes of the hornblende. Small inclusions, partly of zircon, partly possibly of some other mineral, are exceedingly frequent in the biotite and in many cases give rise to very marked pleochroitic halos (Höfe).

Muscovite is bound to the marginal zone of the umptekite, where in places it has a very widespread occurrence. The muscovite flakes often show a subparallel arrangement, giving the rock a characteristic lustre. Its microscopical characters are normal and without special interest.

Garnet. Only a few stray occurrences of garnet have been observed in the umptekite rocks. It has been found in small rounded grains of a light gray colour and with an anomalous but low birefringence in gray colours.

Zircon. Already TÖRNEBOHM has mentioned the widespread occurrence of zircon in the Almunge rocks. It is a nearly constant accessory mineral, occurring both as individual crystals and as inclusions especially in biotite. The larger zircon crystals are often of a reddish or reddish brown colour and without crystallographic terminations, showing rounded or jagged contours, whereas the smaller crystals show the usual prismatic and pyramidal forms. Basal sections show the well-developed prismatic cleavage and give in convergent light an uniaxial negative figure.

Sphene. This mineral is also abundant in nearly all the umptekite rocks, occurring in irregular grains of a yellowish brown colour and often with quite a perceptible pleochroism.

Apatite occurs in all the rocks of this group. Though it is such a frequent ingredient, it is seldom developed in larger crystals, mostly occurring as inclusions in the other minerals, especially in the amphibols.

Magnetite is as a primary constituent not common in the umptekite. In the normal development of the rocks it is hardly met with except as an alteration product of the amphibols or the fayalite. In one or two places, however, magnetite appears in such amounts that the syenite might there well be compared with a magnetite-syenite.

Calcite. A small amount of this mineral is nearly always to be found even in the freshest rocks. As it there scarcely can have been formed by the decomposition of the surrounding minerals, no traces of such a process being visible, the calcite must be an infiltration product, probably deposited at an early date of the metasomatic period of the rocks.

Chlorite, epidote and other secondary minerals occur at such places, where the rock has been exposed to a more intense decomposition.

Geological Relations and Petrographical Character.

Normal Development.

The typical umptekite of Almunge can be said to be restricted to the central part of the district between Gränby, Hällen and Eneby As soon as one begins to approach the more peripherical parts, the syenite changes character and quickly grades into the marginal types.

But even within the parts, where the typical syenite is best developed, the rock is remarkably varying in appearance and structure. Exceedingly coarse-grained varieties occur for example just SW. of Seglinge or north of Johannesdal in the forest north of the road to Knutby. In these varieties the separate feldspar- and hastingsite crystals can attain a length of 5—6 cm.

The colour of the umptekite is also rather varying, ranging from an olive green to a light red, depending on the feldspars, which are slightly pigmented sometimes in the one colour sometimes in the other. The mafic minerals show a great inclination to collect together, giving the rock a very characteristic spotted appearance. (Pl. III, fig. 1).

In many places, especially perhaps round Hällen, the large tabular perthitic carlsbader-twinned feldspars show a subparallel arrangement, causing a beautiful flow structure in the rock.

In its typical development the umptekite is a medium-grained rock consisting of microcline- and orthoclase-microperthite, albite or oligoclase-albite, hastingsite, some biotite, a rather variable but never essential amount of quartz, zircon, apatite and sphene and nearly always some calcite. In a section the rock often shows traces of an unsettled or interrupted crystallization. The feldspars are generally jagged and often surrounded by a granulated zone of feldspar, which sometimes gives the rock a pseudoporphyric appearance (compare Pl. IV, fig. 1 and 2). The amphibols and the biotite cluster together, often showing a parallel intergrowth. Especially the amphibols are often poikilitically intergrown with feldspar.

A typical specimen of pink medium-grained umptekite from Seglinge has been analyzed by Dr. NAIMA SAHLBOM and is quoted under column I. II—V give some analyses of nearly related rocks.

	I	I a	I b	II	III	IV	V
SiO_2	62,57	103,59	69,62	63,71	62,99	61,18	58,75
TiO_2	0,22	0,27	0,18	0,86	0,16	—	0,77
Al_2O_3	16,72	16,36	10,99	16,69	14,25	19,72	17,46
Fe_2O_3	1,32	0,83	—	2,92	2,78	3,71	2,37
FeO	4,25	5,91	5,09	0,66	5,15	1,32	2,45
MnO	0,07	0,10	0,07	0,20	0,18	—	trace

	I	Ia	Ib	II	III	IV	V
MgO	0,52	1,29	0,87	0,90	1,30	—	1,03
CaO	1,76	3,14	2,11	3,11	2,72	2,64	2,55
K_2O	6,00	6,36	4,28	2,79	6,35	5,66	5,87
Na_2O	6,27	10,10	6,78	8,26	4,86	5,28	6,81
P_2O_5	0,20	—	—	—	—	—	0,30
BaO	0,05	0,03	0,02	—	—	—	—
S	0,13	—	—	—	—	—	—
H_2O	0,37	—	—	0,19	0,18	0,32	0,74
	100,45	147,98	100,01	100,19	100,92	99,83	99,88*

* With Cl. 0,65; CO_2 0,12; SO_3 0,16.

I. Normal Umptekite, Seglinge, Almunge, NAIMA SAHLBOM anal.

Ia. Molecular proportions, multiplied by 100.

Ib. » » calculated on a sum of 100.

II. Umptekite, Umpjaur, Kola Peninsula. W. PETERSSON anal. Fennia 11. N:o 2 (1894) p. 206.

III. Umptekite, Beverley, Mass. F. E. WRIGHT anal. T. M. P. M. XIX, p. 312.

IV. Umptekite, Wausau, Wisc. W. W. DANIELS anal. Bull. Wisc. Geol. Survey. N:o 16 (1907), p. 202.

V. Umptekite, Cabo Frio. F. E. WRIGHT anal. T. M. P. M. XX p. 248.

OSANNS classification gives:

s = 69,80	A = 11,06	a = 11,51	n = 6,13
	C = 0	c = 0	
	F = 8,16	f = 8,49	

which brings the rock into Type Umptek with the formula

$$s_{68,5} \quad a_{11} \quad c_0 \quad f_9.$$

Using the quantitative system the norm of the rock is:

Orthoclase	35,58	sal. 86,53
Albite	49,25	
Nepheline	1,70	
Acmite	0,92	fem. 13,31
Diopside	6,75	
Olivine	3,45	
Magnetite	1,39	
Ilmenite	0,46	
Apatite	0,34	

This gives the rock the following position in the quantitative classification:

Class (I) II	Dosalane,	
Order 5	Perfelic,	Germanare,
Rang 1	Peralkalic,	Umptekase,
Subrang 3	Sodipotassic,	Ilmenose (near Umptekose).

The analysis shows the rock to be a typical umptekite. C in Osanns classification is O, that is to say there is no plagioclase whatever amongst the feldspars. The analyses II to V, have all been chosen from umptekites, which geologically are united with nepheline-bearing rocks. They therefore not only in their chemical composition, but just as much in their geological relations correspond to the Almunge umptekite. In all respects except in the relative proportions of the alkalies in RAMSAYS' type rock, the chemical correspondence is very close. And when looking over the mineral composition of several of these rocks, such similarities often occur, even in the most unessential details, that one can hardly doubt the very close geological relationship between the rocks. The analyses also show, what a well defined and natural group these rocks form. In several of the above cited umptekites one might well expect the occurrence of hastingsite amongst the amphibols. The bright green hornblende of the Red Hill syenite, mentioned by BAYLEY,[1] has for example not been described in such detail, that you can form any definite opinion as to its optical properties. The analyzed hornblende from Wausau has not either been studied enough in detail to determine its optical properties; chemically it is, as already shown, very nearly related to the hastingsites.

I have mentioned that the mafic minerals of the Almunge umptekite are apt to cluster together, giving the rock a spotted appearance. In places the dark minerals have concentrated still further, forming dark patches in the umptekite, with but subordinate amounts of felsic constituents. These patches are chiefly composed of hornblende, biotite, the usual feldspars and sphene, the feldspars in the most basic places, however, appearing in considerably reduced quantities. Blotches, consisting nearly exclusively of biotite and some hornblende are occasionally met with, for example by the farm buildings at Seglinge. These dark basic rocks are, however, nothing else than accumulations of the mafic minerals of the umptekite.

In several places the normal umptekite, which is free or all but free of quartz, grades into a rock of much more acid composition and rich in quartz. The transition from the umptekite is gradual and passes through rocks, which would, if analyzed, probably show a typical nordmarkite composition. The greater part of these rocks are, however, essentially more acid than the nordmarkite group and must be classed as veritable granites. Singularly enough this granitic facies looses the alkaline cha-

[1] Bull. Geol. Soc. Am. Vol. 3, p. 246.

racter of the umptekite completely. The perthitic feldspars quickly disappear and are substituted by orthoclase and plagioclases, ranging between albite and oligoclase. In some sections I have identified the hastingsite of the umptekite though this has always been in the transitional nordmarkitic rocks. In the granite itself a usual green hornblende and biotite occur. The whole composition of this rock is therefore that of a normal calcalkalic granite. On the other hand it must be remembered, that, as already PIRSSON and WASHINGTON[1] have indicated, the alkalic nature of rocks of high silicia content can be to a great extent masked by a large dilution with silicia. If this rock is to be considered as a differentiation facies of the syenite or if it originally has been an inclusion of foreign granitic material, which has been partly or perhaps wholly fused, so that the contacts have become perfect transitions, is therefore not possible to say. It seems strange that such an essential quantity of plagioclase should enter into the most acid differentiation facies of the umptekite, which itself has hardly a trace of plagioclase feldspars. I am therefore most inclined to consider these granitic areas as the remains of not wholly absorbed inclusions of the country granites or syntectic rocks formed by assimilation of exogenous material of high silicia content. On the sketch-map these areas have not been specially marked, partly because they are of such small dimensions, partly because the transition is so gradual, that the contact can hardly be drawn except after a microscopic study of the rock sections. The largest area is west of Seglinge north of the lake Fladen, about midway between the shore and Skärpan. Just north of Skärpan is another small granitic area, a third is found on the road eastward from Gränby just under *b* in Almbo on the map. At the last place a contact can be observed, and it looks as if the umptekite showed a slightly chilled edge against the granite. Several other small patches of granite have been noticed; just south of Hällen the umptekite, which here otherwise is perfectly free from quartz, becomes exceedingly acid, large quartz crystals appearing in great abundance. At this place however, the rock has not in any other way changed character, so that if an assimilation of foreign material has taken place, this must have been of a highly silicious substance.

With the exception of these granitic portions the umptekite is on the whole of a very uniform mineral composition. The structure is somewhat more variable, parts being well crystallized and then often showing the already described flow structure, other parts having a more granulated appearence indicating an unsettled process of crystallization. This fact as well as the different colouring tends to give the rocks the appearence of being more variable, than is really the case.

A singular variety of the syenite is met with near Strömsberg. In connection with the general mineral composition of the umptekites, I remarked that magnetite hardly ever occurred in the normal syenite. At

[1] Am. Journal of Science Vol. 22 (1906), p. 442.

one place, however, near Strömsberg magnetite unexpectedly appears in considerable quantities. The general mineral composition of the rock as well as the proportions between the minerals remain, however, about the same as before so that the rock can in no way be considered as only a basic differentiation facies of the syenitic magma. The rock is somewhat pegmatitic in its structure, and probably only represents a pegmatitic segregation of the magma. The amount of magnetite is unexpectedly great, single individuals often measuring several centimeters. The magnetite seems to be a perfectly primary constituent in the rock, and is, as already mentioned, of interest, just because of the nearly total absence of this mineral in other parts. The chemical composition of the rock would probably bring it near the magnetite-syenites, though structurally it has nothing in common with these rocks and in every case contains less sodic constituents than this group.

Marginal facies.

One can in many places follow the gradual transition from the normal umptekite to the typical marginal facies. The change is as already mentioned both chemical and structural; the former principally consisting in the rocks gradually assuming a more acid and salic composition, the latter in the structure becoming aplitic and often protoclastic.

Typical specimens of the marginal facies differ from the normal umptekite principally through the hornblende having been nearly completely substituted by biotite. The perthitic feldspars have also disappeared, and orthoclase, microcline and albite in single individuals have taken their place. Muscovite and often small quantities of fluorite contribute to give the marginal facies its character of an endogeneous contact rock. The structure is granulated throughout, only occasionally some larger perthitic feldspars, reminding of the umptekite, appear, and give the rock a kind of porphyric structure. In places, for example along the southern border of the area, muscovite becomes quite an essential constituent. The biotite is then often to a great extent changed into epidote.

The gneissose structure, which is so often met with within this marginal facies, is in its dip almost vertical, its strike generally following the course of the contact line. There is no doubt, that this structure is of purely protoclastic origin. Cataclastic deformation of the rock-forming minerals is but rarely met with.

In places where a greater assimilation has taken place, the chemical change is naturally greater. Here the rock has also evidently crystallized under more tranquil conditions, giving rise to intermediate or hybrid rocks. At such places, as for example by Mörtsjön or W of Eneby or south of lake Fladen, the contact line can not be laid out in detail.

An analysis of the marginal facies near Broängen has been made by Dr. NAIMA SAHLBOM. The material was taken from a broad dike, which intersects the Upsala granite just east of the farm. I chose the material from this locality rather than from the marginal zone itself, because these dikes frequently radiating from the syenite, are often megascopically very like the usual aplites of the country rock and it was essential to definitely prove their consanguinity with the syenite magma. The mineral composition is, however, identical with the marginal zone itself, and the analysis may therefore be taken as representative enough. Analyses II—III give the chemical composition of some nearly related rocks.

	I	Ia	I b	II	III
SiO_2	64,74	107,22	72,08	66,50	64,04
TiO_2	0,06	0,07	0,05	0,70	0,62
Al_2O_2	19,94	19,51	13,12	16,25	17,92
Fe_2O_3	0,61	0,38	—	2,04	0,96
FeO	1,10	1,53	1,54	0,19	2,08
MnO	0,04	0,06	0,04	0,20	0,23
MgO	0,18	0,45	0,30	0,18	0,59
CaO	0,94	1,67	1,13	0,85	1,00
K_2O	4,02	4,26	2,87	5,53	6,08
Na_2O	8,20	13,21	8,88	7,52	6,67
P_2O_5	0,11	—	—	—	—
S	0,09	—	—	—	—
CO_2	0,15	—	—	—	—
H_2O	0,33	—	—	0,50	1,18
	100,51	148,36	100,01	100,46	101,37

I. Nordmarkite. Marginal facies of Umptekite, Broängen, Almunge, NAIMA SAHLBOM anal.

I a. Molecular proportions of I.

I b. » » calculated on a sum of 100.

II. Lestiwarite (Nordmarkite-aplite) Kvelle, Lougental. Ganggefolge des Laurdalits, p. 216.

III. Nordmarkite, Tonsenaas, Christiania. Zeitschr. für Kryst. Vol. XVI, p. 54.

OSANNS classification gives

$$s = 72{,}13 \quad A = 11{,}75 \quad a = 15{,}92 \quad n = 7{,}56$$
$$C = 1{,}31 \quad c = 1{,}78$$
$$F = 1{,}70 \quad f = 2{,}30$$

which brings the rock nearest the type Nordmarkite. The position is really between this type and type Lestiwarite (syenite-aplite) for which the figures are:

Type Nordmarkite	$S_{70\cdot5}$	a_{13}	$c_{0\cdot5}$	$f_{6\cdot5}$
Type Lestiwarite	S_{75}	$a_{17\cdot5}$	c_{0}	$f_{2\cdot5}$
Nordmarkite, Almunge	S_{72}	a_{16}	$c_{1\cdot5}$	$f_{2\cdot5}$

Using the quantitative system, the norm of the rock is

Orthoclase	23,35	sal. 97,23
Albite	69,17	
Anorthite	3,89	
Corundum	0,82	
Olivine	1,37	fem. 2,79
Magnetite	0,93	
Ilmenite	0,15	
Apatite	0,34	

This gives the rock the following position in the quantitative system:

Class I	Persalane	
Order 5	Perfelic	Canadare
Rang 1	Peralkalic	Nordmarkase
Subrang 4	Dosodic	Nordmarkose.

The chemical composition of the marginal facies differs less from the normal umptekite, than would be expected from the very different appearance of the two rocks.

A noteworthy feature is the absence of quartz in the norm of the nordmarkite. The rock from which the material for the analysis was taken, was so fine-grained, that the different minerals could not be detected with the naked eye, but from the general megascopic appearance of the rock one would have expected a more aplitic composition with at least some amount of free silicia. Nearly 70 % of the rock consists of albite, and 96 % is made up of feldspars according to the norm of the rock This shows that the chemical change which has taken place in the marginal facies, at least at this place, is essentially a reduction of the femic constituents, which in the normal umptekite form 13 %, in the marginal facies only 3 % of the rockforming minerals. The nordmarkite is in other words here a salic, fine-grained facies of the umptekite.

The next question to arise is, whether the nordmarkitic marginal facies is to be considered as an endogenous differentiation product or if the umptekite has changed its chemical composition through assimilation of the enveloping rocks. Without being able to give a definite answer to this question, I may mention one or two facts, which seem to me to point to the possibility of both these causes having united forces. Where a gradual but perfect transition between the marginal facies and the surrounding red granite seems to occur, one can hardly doubt that a good deal of exchange of material also has taken place. As the surrounding granites are the more silicious of the two rocks, the marginal facies would naturally assume a more acid character. On the other hand, structurally the same marginal facies occurs against the Upsala granite, where as far as can be judged by studying the contact, very little exchange of material has taken place. It should be noticed, that the change in chemical composition here is far less than would be expected from the appearance of the rock, as the analysis and microscopical study have shown. I therefore think, that a great part of the marginal facies is to be considered as an endogenous salic modification of the normal umptekite, but that in places and especially towards the red acid granite of the country rock, a good deal of assimilation has taken place, which has given the marginal facies here a more acid and from the umptekite more diverging composition. The aplitic, granulated or protoclastic structure is restricted to the former contact phenomena and is unquestionably to be interpreted as an endomorphic structural modification along the contact.

Aplitic, salic marginal facies of igneous rocks have often been described in the geological literature. The nearest equivalent to the rocks of Almunge is described by PIRSSON and WASHINGTON[1] from the Belknap Mountains of New Hampshire. The main mass of rock is there composed of a pulaskite, in chemical as well as in mineral composition closely related to the umptekite of Almunge. On nearly all sides this rock passes gradually into a marginal facies of a light-coloured aplitic rock, which is by the authors interpreted as an endogenous 'aplitic, persalic, marginal facies' of the main massif.

The analyses are reproduced (II und II a) and for the sake of comparison the Almunge analyses are again cited (I and I a).

	I	I a	II	II a	III
SiO_2	62,57	64,74	60,75	69,76	59,01
TiO_2	0,22	0,06	0,63	0,36	0,81
Al_2O_3	16,72	19,94	19,68	18,22	18,18
Fe_2O_3	1,32	0,61	1,54	0,25	1,63
FeO	4,25	1,10	2,98	1,59	3,65
MnO	0,07	0,04	—	—	0,03
MgO	0,52	0,18	0,81	0,40	1,05
CaO	1,76	0,94	2,29	2,68	2,40
K_2O	6,00	4,02	5,90	2,06	5,34
Na_2O	6,27	8,20	4,89	4.06	7,03
P_2O_5	0,20	0,11	—	—	—
S	0,13	0,09	—	—	Cl 0,12

[1] Am. Journ. of Science. Vol. XXII (1906) p. 509.

	I	I a	II	II a	III
BaO	0,05	—	—	—	0,08
CO_2	—	0,15	—	—	—
H_2O	0,37	0,33	0,32	0,65	0,65
	100,45	100,51	99,79	100,03	99,98

I. Umptekite, Seglinge.

I a. Nordmarkite, Marginal facies of I.

II. Pulaskite, Belknap M:ts. Am. Journ. of Science, Vol. XXII p. 450.

II a. »Adamellite-aplite», Marginal facies of II. Ibid. p. 446.

III. Umptekite, Red Hill. Ibid. Vol. XXIII p. 273.

The same authors describe a contact facies of nordmarkite round the umptekite and nepheline-syenite massif of Red Hill in New Hampshire.[1] Though no analysis is given, the rock is evidently closely related to the marginal facies at Almunge both in its geological relations and chemical composition. The analysis of the umptekite is given under III. I need further only call attention to the umptekite of Kola as marginal facies of the lujaurites,[2] of the pulaskite of M^t^ JOHNSON, Ontario, as marginal facies of essexite,[3] of the alkaline syenite of Ahvenvaara as contact modification of the ijolithe[4] to show, that such salic endo- or exomorphic contact features are not so very scarce.

One feature along the contact is worthy of special notice. At Lilla Ellringe a singular exomorphic contact influence seems evident. The geological relations are just here somewhat complicated through the appearance of nepheline-gneisses along the contact line, and will again be dealt with later on. The protoclastic, gneissose nordmarkite passes in an only $^1/_2$ a meter broad dike between nepheline-gneiss on the western outer side and Upsala granite on the inner eastern side of the contact. It is not possible to say if the rocks of the marginal facies here belong to the massif itself and therefore represent the real contact line, in which case the Upsala granite, spoken of, would represent a large inclusion, or if only some dikes parallel to the contact be visible and the real contact line must be sought a little further eastward, hidden by the alluvial deposits. From what I have seen of the contacts, I am inclined to think the latter eventuality the most probable. Between the nordmarkite dike and the granite, there is however an interesting formation locally developed. It might be described as a cordierite-pseudoconglomerate. Large

[1] Am. Journal of Science. Vol. 23, p. 276.

[2] Fennia 11, p. 197.

[3] Canadian Record of Science 1903, p. 230.

[4] Bull. Com. Geol. Finl. 11, p. 33.

rounded balls of cordierite, with a diameter of from 5 to 25 cm lie embedded in a matrix of muscovite and quartz (Pl. VI, fig. 1). The cordierite nodules consist of one single crystal, twinned on (110), producing a pseudohexagonal structure. On basal sections the different twins show symmetrical extinction at 30° from the twinning lines; in convergent light the negative acute bisectrix appears. On these basal sections the whole field is divided into the three twinned individuals, which are intricately interwoven (see Pl. VI, fig. 2). The cordierite is periferically a good deal changed into muscovite and quartz (pinite); the inner parts of the crystals are however generally quite fresh. Nothing more can be said about this singular formation than that it occurs on the contact between the marginal nordmarkite and the Upsala granite, and must therefore represent the contact influence of the syenitic magma either on the granite, which here also has an unusually bleached appearance, or on some incidental inclusion in the granite. Possibly a secondary enrichment of magnesia might have taken place along a local fault just here, so that a chloritic »sköl» or something equivalent might have existed, which by the contact influence of the syenite has given rise to the singular formation.

The Canadite Group.

Relations of the Canadites to the Umptekite Rocks.

Though partaking in only a very subordinate way in the building up of the alkaline province of Almunge the nepheline-bearing rocks are certainly those, which attract the greatest attention. A hasty glance at the sketch-map would give the impression, that the canadites were the younger rocks of the district, intersecting the umptekite in the form of broad dikes with an approximately N.—S. strike. When I first began mapping the district, I started with this supposition, but soon found several circumstances, for which it was difficult to find any likely explanation, if the canadite rocks were to be considered as the younger. Some rocks, which were laid bare just east of Byske, gave a definite answer to the problem, the relations between the canadites and the umptekites in this place not being able to be explained in any other way than that the former were the oldest rocks. A photograph from this place (Pl. VII) shows the umptekite in narrow but well defined veins intersecting the dark nepheline-bearing rock in all directions. The contact is sharp, no traces of assimilation being visible. A certain amount of flow structure along the contact as well as the absence of any chilled edge in the umptekite seem to indicate, that the canadite has been highly heated, before crystallization of the surrounding rock began. I have subsequently in many places found the relations between the two rocks in full accordance with the facts at Byske and it seems that no other explanation is possible than that the canadite rocks are the older, occurring as large inclusions in the umptekite, which intersects them in numerous veins and occasionally shows a chilled edge against them (certain sections near Hällen). It is however probable, that generally a great deal of assimilation has taken place between the two rocks, which has given rise to a series of highly characteristic intermediate types, occurring along many of the contacts. Where this is the case, no sharp contact between the two rocks is found, a gradual transition instead taking place. At such places one might be inclined to consider the nepheline rocks as only a differentiation facies of the syenite magma, lower in silicia and therefore with the lenade minerals well developed. At other places however, such as at Byske, the contact is perfectly sharp so that the canadite there at least cannot represent a differentiation facies in place. On the other hand the consanguinity of the two rocks cannot be doubted, and it is possible that no very great difference in age exists between them. If the interpretation of the geology of Almunge, which has already been given, namely that the area represents a deep-seated section of a channel or neck, through which magma has flowed perhaps for some considerable time, the canadites would as the older rocks naturally represent the composition of the earlier eruptions. A glance at the geological map will show the somewhat periferical position of the nepheline-bearing rocks in relation to the area on the whole. In the central parts of the area these rocks are not represented. In most cases they are to be found in or near the marginal facies, for instance near Stora Ellringe, at Uddnäs, Sågen etc. Only in the vicinity of Skallerbol, Upptorp and Ryggestalund do the canadites stretch to any extent into the umptekite, but there they still occupy a periferical position in relation to the area on the whole. If the canadite rock therefore once filled the whole neck, but was followed by a later flow of umptekitic magma, remnants of the earlier rock might well be preserved along the sides of the channel, in the same way as I have tried to explain the accumulation of basic inclusions along the very contact. In every case one can safely say, that the intimate relation, which has so often been shown to exist between umptekites and nepheline-bearing rocks, also takes place in Almunge, even though one cannot assume, that the former only are a differentiation facies of the latter in situ, as for example in the Kola peninsula.

Mineral Composition.

Before entering upon a more detailed description of the different types of nepheline-bearing rocks, I will give a short account of the chief minerals, entering into the composition of these rocks. On the whole the mineral composition is more uniform than one would be inclined to suppose judging from the great variety of types occurring in the district. It is more the accumulation of felsic minerals in one part and of the mafic elements in another, which brings about the inhomogeneous appearance of the canadite rocks, whereas the individual minerals of the different types are very much the same, not only relating to the principal minerals of the rock but also to the more accessory components.

The following minerals have been observed.

Feldspars,	Muscovite,	Fluorite,
Nepheline,	Zircon (Malacon),	Epidote,
Cancrinite,	Thorite (Orangite)	Garnet,
Sodalite,	Vesuvianite,	Chlorite,
Analcite,	Natrolite,	Calcite,
Hornblende,	Hydronephelite,	Pyrite.
Pyroxene,	Apatite,	Magnetite,
Biotite,	Sphene,	

Feldspars. The feldspars of the canadite group consist of albite, orthoclase, microcline, soda-orthoclase, microcline- and orthoclase-perthite. In the most basic types plagioclases grading from albite to oligoclase and occasionally into andesine are to be found.

Albite is by far the most common feldspar in all the rocks belonging to the canadite group. In fact in most of the normally developed types albite, nepheline and cancrinite are often the only felsic minerals present. The albite is always fresh, generally occurring in well defined idiomorphic crystals, often slightly larger than the other components in the rock. Twinning is common according to the albite and carlsbad laws, scarce according to the pericline law. A brilliant blue lustre (Farbenspiel) is common, especially in the albite of the pegmatitic veins. It is most prominent on M and on a face at angle with P and M in the clinodiagonal zone.

The optical properties of the albite are otherwise normal. The extinction angle was found to be

on M	18°—20°
» P	2°—4°

The extinction angles are those of pure or all but pure albite. To control the optical determinations a chemical determination of the alkalies in an albite out of a pegmatitic vein south of Sågen was made, which gave the following result:

Na_2O	10,80 %
K_2O	0,30 %

The theoretical amount of Na_2O in pure albite is 11,82%. An analysis of albite from the well-known nepheline-syenite of Litchfield[1] has given

[1] Bull. Geol. Soc. Am. Vol. 3, p. 238.

Na_2O	10,81%
K_2O	0,39%
CaO	0,31%

or almost identically the same proportions as the Almunge albite. As will be seen, this is not the only respect, in which the litchfieldites resemble the canadites of Almunge.

Orthoclase occurs in variable but, in relation to the albite, always in very subordinate quantities in the nepheline-bearing rocks. It is fully allotriomorphic, being the last mineral to have crystallized, later than both albite and nepheline.

Microcline occurs principally in the gneissose forms of the nepheline rocks, developed in much the same way as in the marginal zone of the umptekite. The structure of these rocks being granulated and fine-grained, the microcline occurs in small rounded or angular grains, generally showing the typical 'Gitter'-structure. In the normal eugranitic canadite microcline is of rarer occurrence excepting in perthitic intergrowth. Where it does occur, however, it shows the same irregular twinning according to the albite law, as mentioned in the description of the same mineral in the umptekites. The double twinning is not found in the normally developed nepheline-bearing rocks.

Microcline-microperthite, which is the most essential feldspar in the umptekites, is scarce in the typical canadite rocks. In the intermediate rocks near the contact to the umptekite, the perthite, however, immediately appears. A closer study shows, that no sooner do the quantities of nepheline and cancrinite in the nepheline-bearing rocks commence decreasing, than the perthitic feldspars, and especially the microcline-microperthite begin to appear, increasing in the same proportion as the other two minerals decrease. The development of the perthites in the nepheline-bearing rocks is on the whole the same as in the umptekites; I will therefore refer to the description given above. The relative proportions of albite and microcline seem, however, to vary somewhat in the different rocks. Whereas in the umptekites the amount of albite and microcline in the microperthite is about the same, or the albite appears in a moderate excess (approximately albite to microcline as 1 : 1 to 2 : 1) the amount of albite in the microcline-perthite of the rocks, bordering to the canadites, is very much more dominant, the proportions occasionally reaching albite: microcline as 9 : 1 (ab_{90} or_{10}). Again the nearest analogy is to be found in the Litchfield perthites,[1] the proportions between albite and microcline there, in certain instances, being approximately ab_{94} or_6. An analysis of microcline-microperthite from the latter locality gave 10,17% Na_2O and 0,99% K_2O. I have no doubt, that these proportions are also to be found in many perthites from the contact facies of the canadite rocks from Almunge.

[1] Bull. Geol. Soc. Am. Vol. 3 p. 234.

Soda-orthoclase is in Almunge confined to the nepheline-bearing rocks. This feldspar often shows a very inhomogeneous structure. Between crossed nicols the extinction of a crystal is far from uniform, the feldspar dividing up into numerous patches, which show extinction angles varying several degrees. A slight difference in refraction is also often noticeable between the different parts of a crystal. It seems probable that these different patches in reality represent different sub-microscopic mixtures of soda- and potash-feldspars. It has not yet been possible to separate the potash-soda-feldspars or make sections of them parallel to any crystallographic face, so that exact determinations of the extinction angles on M and P have not been able to be made, and no data as to the chemical composition have been obtainable. It is of course under such circumstances not possible to say if the content of soda is molecularly in excess of the potash, i. e. if the feldspar is a veritable soda-orthoclase or only a soda-bearing orthoclase.[1] The indefinite, cloudy extinction, the slight difference in refraction in different parts of the crystal, indicating an inhomogeneous composition, as well as extinction angles of 7°—9° on faces, approximately parallel to M, (showing a nearly central appearance of the obtuse bisectrix), seem however unquestionably to indicate, that an orthoclase rich in soda is present.

Plagioclase. In the most basic varieties of the canadites, which grade into theralitic rocks, plagioclases begin to enter into the mineral composition of the rock. In every case, however, the plagioclases are less calcic, than one would expect to find in a rock of that composition. Every transition from pure albite to oligoclase and exceptionally to andesine can be found. Even in the rock types with only little over 40% SiO_2, the plagioclases do not reach any more calcic composition,

[1] BRÖGGER has first intimated, that the uniform or submicroscopically perthitic potash-soda-feldspars constitute a series, which to all appearance can crystallize either monosymmetrically (soda-orthoclase) or assymetrically (soda-microcline) independently of the chemical composition. GROTH and USSING accordingly define a soda-orthoclase as a microscopically uniform potash-soda-feldspar with an excess in the molecular proportions of soda over potash; the compound alkali-feldspars with a smaller content of soda being referred to othoclase (soda-bearing orthoclase). IDDING'S seems, however, to have a perfectly different conception of the potash-soda-feldspars, defining soda-orthoclase as 'an orthoclase with notable amount of soda', and adding, »that it has been found, that the soda in these crystals does not equal the potash molecularly. When the soda equals or exceeds the potash, the crystals exhibit triclinic symmetry and are soda-microcline». (Rock Minerals 1911, p. 235.) This definition of soda-orthoclase and soda-microcline not only differs widely from the meaning, BRÖGGER first gave these names, but also contrasts sharply to BRÖGGER'S conception, that the difference in the crystallographic system is *not* dependent on the chemical composition. No definite observations are cited by IDDING'S in his text-books as a basis for this interpretation; the crystallographically monosymmetric but optically asymmetric soda-orthoclase from Obsidian Cliff with equal ratios of potash and soda, can hardly be decisive one way or the other. I have in this paper retained BRÖGGER'S definitions with the modification of USSING, cited on p. 143, but have considered it neccessary to point out the difference in the use of the names for the compound alkali-feldspars, so as to avoid any misunderstanding.

and frequently retain a composition corresponding to oligoclase or even oligoclase-albite. This feature of the plagioclases of retaining a high degree of soda-content, even though the rock itself may contain a low content of SiO_2 and high CaO (7—8 %) is very characteristic for just this group of rocks. This subject will be more fully treated further on. There is otherwise nothing to remark in the development of the plagioclases. In their general appearance they resemble the albite, showing the usual twinning according to the albite and pericline laws, more seldom according to the carlsbad law. Zonar structure has been observed, but is not common.

Nepheline. The nepheline is, as is the case with most of the other minerals, in the Almunge rocks generally quite fresh and undecomposed. The colour varies somewhat, when perfectly fresh the nepheline is gray to quite colourless and of a vitreous lustre, by beginning decomposition greenish, brown or pink colours appear.

The weathered surface of the nepheline rocks is very characteristic. The nepheline, as being most easely decomposed, is represented by marked depressions (pl. VIII, fig. 1 and 2). The form of the nepheline crystals is then very distinct, the common four and six-sided circumference indicating the idiomorphic development relative to the other minerals. The amount of nepheline in the rock can at a glance readily be approximately determined on the weathered surfaces. Often you get a better idea of the percentage of nepheline in the rock, by turning back the moss covering in the field and studying the weathered surface, than through the study of microscopical sections.

In the schistose varieties the nepheline is frequently accumulated in streaks or bands, which easily weather out, leaving long, narrow characteristic depressions. In places such streaks can measure several centimeter in breadth, and many decimeter in length (see Pl. X, fig. 2) and even under the microscope reveal no other minerals than pure nepheline.

Although on the whole the nepheline is quite fresh, it is in certain groups of rocks much changed. This is the case in many of the pegmatitic veins or segregations and also in the contact facies of the nepheline-bearing rocks. The alteration products of the nepheline take the form either of gieseckite or of 'Spreustein' pseudomorphoses. In the former case the principal decomposition product is muscovite, which then generally lies with its cleavage flakes parallel to the basal face of the nepheline. The finest examples of these gieseckite pseudomorphoses are to be found in a pegmatitic vein in the umptekite just east of Hällen, along the track leading towards Sågen and on the right hand side at the first small hill after crossing the field. The pseudomorphoses here are of a light green colour, 10—15 mm. in diameter, and generally show the crystal form of the original nepheline. Between the muscovite flakes hydronephelite and analcite are to be found as »Zwischenklemmungsmasse».

In the contact rocks the decomposition is essentially different, the result more often being a confused aggregate of muscovite, natrolite and hydronephelite than the more regularly constructed gieseckite pseudomorphoses. The colour is then more often pink than green. The decomposition of this kind in every way resembles the »Ranitspreustein» of BRÖGGER,[1] whereas the gieseckite pseudomorphoses resemble the decomposition products of nepheline as described by USSING[2] from Akuliarusek and by ADAMS and BARLOW[3] from Bancroft. A decomposition of nepheline into cancrinite and analcite has occasionally been observed and will be treated under the headings of these minerals.

In many other respects the appearance of the nepheline in the Almunge rocks reminds one of the nepheline of the Bancroft nepheline-syenites. The same vitreous lustre, the same characteristic weathering and in general the same decomposition into gieseckite is recorded from both districts.

Cancrinite can quite be said to be one of the essential rock-forming minerals of the canadites. It occurs in two distinctly different modes, as a primary constituent and as a secondary mineral. As a primary constituent the cancrinite occurs in irregular grains, with an elongated or rounded form much in the same way as the primary cancrinite occurs in the Litchfield rocks or in the cancrinite-syenite of Kuolajärvi.[4] An inclination to develop in prismatic forms is often observable. The cancrinite occurs inclosed in both feldspar and nepheline and is certainly often contemporaneous with both these minerals. Its distribution is somewhat irregular; frequently one part of a microscopic section proves very rich in cancrinite, while another part is all but devoid of this mineral. It has not been found to attain macroscopic dimensions.

The amount of cancrinite is, however, in general relatively large. In an analysis of a perfectly fresh canadite without any trace of calcite, 1,10% CO_2 was found, representing 17,46% cancrinite. For comparison I quote some figures on the amount of cancrinite in other nepheline-syenites.

Cancrinite-syenite, Pyhäkuru, Finland	29,04%
» » Särna, Sweden	26,03%
Canadite, Almunge, Sweden	17,46%
Nepheline-syenite, Alnö, Sweden	7,00%
» » Monmouth, Bancroft, Ont.	5,14%
Litchfieldite, Litchfield, Maine, U. S. A.	1,99%

As will be observed the amount of cancrinite is very large compared with the amount in other rocks and is only surpassed by the veritable cancrinite-syenites of Särna and Kuolajärvi.

[1] Zeitschr. für Krystallogr. Vol. XVI, p. 234.
[2] Meddelelser om Grønland. Vol. XIV, p. 121.
[3] Memoir Geol. Surv. of Canada. N:o 6, p. 301.
[4] Bull. Comm. Geol. Finland. Vol. 1, p. 3.

The secondary cancrinite occurs as a decomposition product of nepheline in some rock types from the woodland northeast of Skallerbol. It is easely distinguished from the primary cancrinite by a more fibrious development, with distinct cleavage planes, and by its relations to the nepheline, with which it is always associated, generally accompanied by hydronephelite or some zeolitic mineral. But as previously mentioned cancrinite is not the usual decomposition product of the nepheline, and the amount of cancrinite, which has any intimation of being of secondary origin, is not great.

Sodalite is of rare occurrence in the Almunge rocks. It has been observed in a few sections of the coarse-grained varieties of the nepheline-gneiss from Lilla Ellringe, where it can be readily distinguished from analcite by its rather well developed octahedral cleavage. Possibly it also occurs as a decomposition product of nepheline from the same locality, but this has not been able to be proved with certainty.

Analcite. Analcite has been found in many of the nepheline-bearing rocks. In several of the more basic types from Upptorp large individuals can be observed filling the spaces between the other minerals. The rock is on the whole perfectly fresh, so that the analcite does not seem to be a decomposition product of the surrounding minerals. The characteristic, short cubic cleavages are generally well developed. — The analcite as a distinctly secondary mineral, being a decomposition product of nepheline, has a very different appearance. In the fine-grained nepheline-gneisses of Lilla Ellringe the nepheline crystals are often periferically surrounded by a zone of an isotropic mineral of low refraction, which also in numerous crevaces intersects many of the crystals. In some few places I have here also observed an ill-defined cubic cleavage, indicating that the mineral is analcite. It is possible that this decomposition product is in part sodalite, though I have not been able to prove it by microchemical methods. One can, however, safely say that the essential part is analcite which in its development much reminds one of the descriptions given by BRÖGGER[1] and USSING[2] of the decomposition of nepheline into this mineral.

Hornblende. Relating to the optical properties and the development in general of the hornblendes I will refer to what has been said in the description of the mineral composition of the umptekite group. The same hornblendes occur in the canadites though in different proportions, the amount of typical hastingsite being essentially reduced, whereas the greenish brown alkaline amphibol here plays the dominant part. These hornblendes have in the canadites, and especially in the femic varieties, often a more barkevikitic composition, than in the umptekite. The central parts of many zonal crystals have a distinctly reddish brown colour and small extinction angles ($c : Z = 15—16^{\circ}$).

[1] Zeitschr. für Krystallogr. Vol. XVI, p. 223.
[2] Meddelelser om Grønland. Vol. XIV, p. 113.

Pyroxene occurs in many of the basic varieties of the canadites. It is a light green ægerite-augite, often showing a periferical intergrowth with hornblende. The optical orientation is c : X = 35—38°; the axes of greatest elasticity lying nearest the vertical. The pyroxene belongs to the group of ægerite-augites with small amounts of the ægerite molecule, which have so often been described from different alkaline rocks. They, however, do not pass periferically into ægerite or more deeply coloured pyroxenes, essentially richer in ægerite molecules, as is often the case, but seem instead to retain their chemical composition unusually constant, judging from the consistency of the extinction angle at 37—38°.

Identically the same pyroxene is met with in the nepheline-gneisses at Lilla Ellringe, and especially in the coarse-grained varieties of these rocks.

The amount of pyroxene is however never great in the canadites, the hornblende always being the predominant mafic mineral present. Even in the most abundantly pyroxene-bearing rocks only a few stray crystals of the light green ægerite-augite are at the most to be found in one and the same rock section.

Biotite is present in the same development as in the umptekite rocks. I therefore refer to the description in the former chapter.

Muscovite. Apart from the decomposition products of the nepheline, muscovite is often found in the nepheline-bearing rocks, in many places in good sized flakes, more or less substituting the biotite. This is especially the case in some of the pegmatite segregations, as well as in certain of the white nepheline-syenites.

Amongst the other minerals the following are worthy of special notice.

Zircon is of rare occurrence in the normal canadites but is found in several of the pegmatitic segregations. Under the microscope it often reveals an interesting zonar structure. A great part of the zircons belonging to these rocks are isotropic and belong to the hydrated series known under the names of malacon and cyrtolite. Every transition from perfectly isotropic to distinctly birefringent specimens can be observed. Sometimes normal zircon with its usual optical properties can be found together or alternating with the more or less changed varieties in the same crystal. The colour of the changed zircons is dirty white to yellow, sometimes with a brownish tinge. Often however the most isotropic parts are perfectly clear and colourless. There is no fixed relation between the isotropic parts and the normal zircon. Sometimes the one can appear in the centre, and the other periferically, sometimes it is just the reverse. One can also find the two modifications alternating in zones. Between the quite isotropic forms and the normal zircons, every kind of intermediate stage evidently exists, presumely depending upon the amount of hydration, which has taken place. As BRÖGGER[1] has already

[1] Zeitschr. für Krystallogr. Vol. XVI, p. 110.

indicated these isotropic substances probably do not have any fixed chemical composition. It seems evident, that this hydration of the zircons has taken place at a very early date. It has certainly nothing to do with atmospheric weathering, as all the other constituents of the rock are quite unaltered. The hydration must then be ascribed to some stage of the immediate post-magmatic period. BRÖGGER[1] arrives at the conclusion that the changes of the zircon in the Norwegian pegmatites round Langesundsfjord have taken place before or during the formation of the zeolitic minerals, which period follows after the pneumatolytic stage, and in reality differs from it only by the temperature having been essentially lower. This refers, however, to the nepheline-syenite-pegmatites, where the sequence of crystallization is more easily followed than in the igneous rocks themselves. The localities in Norway and in Almunge seem in any case to have in common, that the formation of the malacon must be attributed to an early period in the history of the rocks.

The amorpheous malacon occurs just as the normal zircon in well defined crystals of about 5 mm in length, showing the usual prismatic and pyramidal faces. The best development is found in some pegmatitic veins just east of Upptorp.

Orangite. In several of the pegmatitic segregations in the canadite rocks a dark yellow to dark brown amorpheous mineral occurs, which has every resemblance to thorite or rather to the more light coloured modification orangite. Megascopically the mineral is very like the orangite from Langesundsfjord, such as this mineral is represented in the collections of our Institute. The colour is from dark reddish brown to black, the lustre very high. Under the microscope the mineral shows itself to be perfectly amorpheous and transparent with a light to dark yellow colour. Numerous irregular cracks intersect the mineral in all directions. A certain indication of zonar structure is visible, though nothing in the optical properties changes in the different zones, which are separated from eachother by narrow bands of the same substance, but showing a characteristic flow structure. In some sections a faint birefringence is observable in one or two places, where the mineral is darker coloured and where hydrate of iron has been separated out. Whether these parts are the last remains of the primary crystallized substance, out of which BRÖGGER[2] concludes first orangite and later thorite have developed, can not be determined. In the same way as every transition seems to exist between zircon, malacon and cyrtolite, the same transitions may well be possible in the thorite group. The parts of the orangite, which are birefringent, do not in any other respect, however, differ from the surrounding isotropic mass. No determinations in convergent light were possible.

[1] Zeitschr. für Krystallogr. Vol. XVI, p. 110.

[2] Ibid. p. 121.

Vesuvianite. The singular occurrence of vesuvianite in so many varieties of the canadites is perhaps the most remarkable feature in the mineral composition of the Almunge rocks. The mineral occurs in at least half a dozen different places, at considerable distances from each-other. It is in general one of the first minerals to have crystallized, being idiomorphic against nepheline and the feldspars and often occurring as at least partial inclusions in them. The vesuvianite is found in up to 2 cm long prisms with the forms (100) and (110) generally well developed. The optical properties are generally normal. The optical character is negative, the refringence moderate, the birefringence weak. Anomalous biaxial crystals occur in some parts.[1]

A determination of the refractive indices gave

$$\omega = 1{,}7311 \qquad \varepsilon = 1{,}7269$$
$$\omega - \varepsilon = 0{,}0041.$$

The determination by HLAWATSCH on a brown vesuvianite from Ala very closely agrees with these values.

Vesuvianite from Ala	$\omega = 1{,}732$	$\varepsilon = 1{,}726$	$\omega - \varepsilon = 0{,}006$
» » Almunge	$\omega = 1{,}7311$	$\varepsilon = 1{,}7269$	$\omega - \varepsilon = 0{,}0041$

The specific gravity is = 3,415.

Anomalous birefringence colours such as have been described by HLAWATSCH[2] are common, though no variation in the optical character of the mineral has been observed; in every section, which has been studied, the crystals have always been negative.

The result of D:r MAUZELIUS' analysis is quoted in the following table.

	I	I a	
SiO_2	36,16	59,87	62,98
TiO_2	2,49	3,11	
Al_2O_3	17,59	17,21	19,66
Fe_2O_3	3,91	2,45	

[1] As this was the case in the rocks where I first detected the vesuvianite I was led astray in the determination of the mineral, thinking I had a biaxial mineral to deal with. Several of the optical determinations very nearly agreed with those of the mosandrite johnstrupite group of minerals, and an unusually high percentage of Ce_2O_3 in the rock seemed to strengthen the supposition, that a mineral of this group might be present. Some sections from one of the other localities, however, revealed the uniaxial character of the mineral, and a chemical analysis by D:r R. MAUZELIUS of the Geological Survey, executed on carefully sorted material, confirmed without doubt the very unexpected presence of vesuvianite as one of the rock-formig minerals of a truly magmatic rock.

[2] T. M. P. M. Vol. 21, p. 107.

	I	I a	
FeO	1,80	2,50	64,97
MnO	0,34	0,48	
MgO	0,81	2,01	
CaO	33,67	59,98	
K_2O	0,13	0,14	13,18
Na_2O	0,86	1,38	
H_2O	2,10	11,66	
	99,86		

I. Vesuvianite in canadite, Sågen, Almunge.

I a. Moleculur proportions of I.

The chemical constitution of vesuvianite can hardly be said to be known. RAMMELSBERG[1] has discussed the chemical composition and showed, that the proportions $R^{II} : R_2^{III}$ keep very close to 4 : 1, whereas the proportions $R^I : R^{II}$ are more variable ranging from 1 : 2,4 to 1 : 8. The analysis in question differs in several respects from the typical vesuvianite composition. The ratio for RO is a few percent lower than is generally the case, the proportions $RO : R_2O_3$ being 3,3 : 1 instead of the usual 4 : 1. The ratios are $SiO_2 : R_2O_3 : RO : R_2O = 4{,}78 : 1{,}49 : 4{,}93 : 1$ reckoned on R_2O as 1.

WEINGARTEN[2] gives 12 analyses of various vesuvianites with the approximate ratios

$$SiO_2 : R_2O_3 : RO : R_2O = 4 : 1 : 4 : 1,$$

but evidently only analyses suitable for this formula, have been included in his discussion of the constitution, which is given as Si_2O_7 (Al, Fe^{III}) (OH, F) (Ca, Mn, Mg, Fe^{II}). RAMMELSBERG[3] gives a series of ratios (16 analyses) counted on RO as 4, in which the following limits are found.

$$SiO_2 : R_2O_3 : RO : R_2O \text{ as } (3{,}1-3{,}6) : (0{,}9-1) : 4 : (0{,}25-0{,}9).$$

The analysis of the vesuvianite from Almunge, reckoned in the same way, gives:

$$SiO_2 : R_2O_3 : RO : R_2O = 3{,}87 : 1{,}21 : 4 : 0{,}79.$$

As is seen by these comparisons the vesuvianite in question differs from all former analyses by the ratio for RO being somewhat lower. I cannot

[1] Mineralchemie. Zweites Suppl. 1895, p. 260.

[2] Zusammens. und Konst. d Vesuvian. Diss. Heidelb. 1901.

[3] Zeitschr. d. Deutsch. Geol. Gesellsch. Vol. 38 (1886), p. 508.

here enter into a detailed discussion on the different opinions on the constitution of vesuvianite. The fact, that the analysis in question slightly differs from the previous ones, is perhaps in reality not extraordinary, if the very different conditions, under which the mineral has been formed, be taken into consideration. Nowhere in the geological litterature have I been able to find any analogy to the appearance of the vesuvianite, as here, in a typical igneous rock. Former occurrences have strictly been confined to recrystallized rocks, due to contact metamorphism or more seldom to gneisses, calcite-diopside schists and amphibolites.

The most striking feature in the occurrence of vesuvianite in the nepheline-bearing rocks of Almunge, is its widespread distribution within the area. The mineral is found in the canadite just east of Stora Ellringe, in the woodland just south of Sågen and on the high road near Andersberg, three localities about as far from eachother as the distribution of the canadite rocks allows. Still more remarkable is the very uniform distribution in the rocks. The vesuvianite is seldom found in greater quantities or clusters, on the contrary it partakes in the formation of the rock in the same regular way as any of the other rock-forming minerals. The supposition of the mineral representing inclusions of calcareous material in the canadite rocks, more or less completely transformed by contact-metamorphism into vesuvianite-'fels', is certainly excluded. If the origin of the vesuvianite has been an exogenous calcareous rock, this must have been perfectly assimilated by the canadite magma. There can be no doubt that the mineral is of a primary origin in such a sense, that it has crystallized out of the magma contemporaneously with the other minerals. The only circumstances, with which the appearance of the vesuvianite seems in any degree comparable, is the presence of calcite in the Alnö rocks. The calcite is there without doubt primary in the same sense as the vesuvianite in Almunge, and the generally adopted explanation of the Alnö calcite is the complete assimilation of calcareous matter by the igneous magma under such geological circumstances, that the carbon dioxide has not been able to escape. The geological relations at Bancroft also indicate a perfect assimilation of calcareous material by the igneous magma, irrespective of what opinion one holds as to the original source of this magma. There seems hardly any other means of explaining the development of vesuvianite in the Almunge rocks, than assuming, that a very complete assimilation of some calcic rock, possibly an impure limestone has taken place. So many other features, indicating the assimilation of foreign matter, have been found in the area, that this explanation seems to be quite likely. The very heterogeneous composition of the rocks, filling an old magmatic channel or volcanic neck, has often been related, and a deep-seated section of such a channel, such as possibly is the case here, would naturally show features of greater assimilation than would be possible at higher levels.

The theories, which DALY has formed concerning the assimilation of limestones as the origin of the nepheline-bearing rocks, would be in full accordance with such a process of assimilation. Until more is known about the distribution of the vesuvianite, I prefer, however, not to enter into an exhaustive discussion on this subject. The appearance of the mineral is so unexpected in the association, in which it occurs, that some quite unlookedfor explanation may possibly be found, after more detailed investigations have been made. I will therefore for the present restrict myself to relating the facts concerning the appearance of the vesuvianite, leaving the theoretical discussion for the future.

Geological Relations and Petrographical Character.

General character.

The nepheline-bearing rocks of the Almunge district are in general characterized by the combination nepheline-albite. In many of the normally developed types these two minerals are, with the exception of a small but variable amount of cancrinite, the only felsic components distinguishable.

The amount of mafic minerals, is generally very large, giving the rocks a dark colour. In calculating the norm of these rocks an essential amount of lime-feldspar, varying between 8 %—20 %, is found, whereas in the actual mineral composition the feldspar is all but pure albite. This circumstance is very characteristic for all the nepheline-bearing rocks of Almunge and tends more than anything else to attribute to them an independent position in the large family of nepheline-bearing syenites. Before entering into a detailed description of the Almunge canadites a few words may therefore be said about their systematic position.

Nepheline-syenites may be defined as phanerites carrying alkaline feldspars and nepheline in variable proportions. This group of rocks has been rather differently subdivided by different authors: ROSENBUSCH[1] names the foyaite-type as including the greatest part of the nepheline-syenites. Its feldspars are given as essentially to exclusively potash-feldspars. Subdivisions according to the mafic ingredients give rise to the groups pyroxene-foyaite, biotite-foyaite, amphibol-foyaite etc. ROSENBUSCH's parallel group would be potash-feldspar-free nepheline-syenites, whereas such rocks as are characterized by the predominance of some special mineral such as cancrinite, eudialyte etc. give rise to cancrinite-syenite, eudialyte-syenite and so on.

IDDINGS[2] is more consistent in his subdivisions of the nepheline-syenites. His specific varieties of these rocks are:

[1] Mikrosk. Phys. II: 1, p. 210.
[2] Igneous Rocks. Vol. II, p. 239.

I. Nepheline-syenites with little or no lime-soda feldspar.

1) Orthoclase-nepheline-syenite.
2) Orthoclase-albite-nepheline-syenite.
3) Albite-nepheline syenite.

II. Nepheline-syenites with subordinate *normative* lime-soda-feldspar, (which may not appear as feldspar in the mode, but may enter into mafic minerals as well as felsic ones).

Closely associated with this group IDDINGS places the shonkinites, which are defined as phanerites with alkali-feldspars and an equal or nearly equal amount of mafic minerals and with a small but notable amount of feldspatoids. The alkali-feldspars may be orthoclase or albite, or compound potash-soda feldspars.

In IDDINGS' classification the Almunge rocks fit perfectly into section II, »nepheline-syenites with subordinate normative lime-soda-feldspar». As representatives for this group the nepheline-syenites of the Haliburton-Bancroft district in Ontario, Canada, are cited. The feldspar in these rocks is chiefly albite or a sodic plagioclase. The mafic minerals are lepidomelane and hastingsite. The normative lime-feldspar enters in most places almost completely into the mafic minerals, leaving the modal feldspars pure or all but pure albite. These features correspond in nearly every detail with the rocks of Almunge.

Instead of the lengthy and awkward definition necessary to characterize the group, I have, in agreement with the Canadian geologists, proposed to call this special group of nepheline-syenites *canadites,* the name indicating the country, from whence this type was first described and where it has its greatest distribution. *The canadites are consequently defined as nepheline-syenites with nepheline and albite or a highly sodic plagioclase as principal felsic ingredients. The abundant mafic minerals contain a certain amount of normative lime-feldspar, which is not present in the rock, leaving the modal feldspar free or all but free of calcium.*

The very close relationship between the nepheline-bearing rocks of Almunge, and the nepheline-syenites described by ADAMS and BARLOW from the Haliburton-Bancroft district will be amply manifested by the petrographical description of the rocks as well as by the similar chemical composition. At the same time the natural but well restricted group of nepheline-syenites, for which a new name is here proposed, will, I think, become obvious.

Through increase of the mafic minerals the canadites in their modal composition grade into IDDINGS' subdivision of shonkinites, which is characterized by the combination nepheline-albite plus an equal or nearly equal amount of mafic minerals. The normative composition of the rocks brings them, however, nearer the theralite group, due to the relatively high percentage of normative lime-feldspar, which is not present in the rock, but enters the mafic minerals in the mode. In reality this more femic group is entitled to just as independent a position amongst the shonkinites or theralites, as has been attributed to the canadites by IDDINGS amongst the nepheline-syenites.

The canadites would according to the definitions, given by ROSENBUSCH, principally belong to his 'kalifeldspatfreier Typus', if consideration is taken only to the modal and not to the normative composition. Reckoning with the latter, the canadites may be said to represent an *equivalent to the theralites, occupying more or less the same position to the theralites, as the foyaïtes occupy to the shonkinites.* The femic varieties would then grade into theralites, rich in nepheline, but differ, as mentioned, fundamentally from these rocks by the modal feldspar still being pure albite or a very sodic plagioclase.

Normal Development.

Perhaps the most characteristic features of the Almunge canadites are their great diversity of types. Only a few feet apart rock specimens may be collected, which grade from dark coloured basic rocks, rich in mafic minerals, to white or pink specimens all but devoid of any dark minerals at all. It is, however, possible to select some types, which are relatively consistent and may be taken as representatives of the different varieties of the nepheline-bearing rocks.

Amongst the eugranitic canadites which will be treated first, the most common type is a dark-coloured rock, with at first sight a nearly dioritic appearance. The weathered surface, however, in the field immediately reveals the very high percentage of nepheline (Pl. VIII). The rock is medium-grained; megascopically feldspar, nepheline, hornblende and biotite are readily distinguished.

Under the microscope the following mineral composition is observed: nepheline, albite, compound soda-potash feldspars, microcline and orthoclase, cancrinite, the two different amphibols, and biotite, with apatite and zircon as the most usual accessory minerals.

The rock is generally wonderfully fresh, not even the nepheline showing any traces of decomposition.

The most abundant feldspar is albite, developed in large crystals with twinning according to the albite and occasionally according to the pericline law. A soda-potash-feldspar, evidently with an essential amount of soda, is also often found, showing the inhomogeneous structure, so characteristic for the compound alkalic feldspars in these rocks. Orthoclase is not common, and where it does occur, the extinction angles on M seem to indicate a certain content of soda. As all the analyses of the canadites show a very strong predominance of soda over potash, the molecular ratios $Na_2O : K_2O$ being about 6 : 1, it is also to be assumed, that soda would enter into all the feldspatic constituents in a larger or smaller degree.

The amount of nepheline in this normal type is roughly about 15—20 per cent, though types with still higher percentage of lenads are not unusual. As previously mentioned, the percentage of cancrinite is very varying; the amount of CO_2 in an analysis of a typical canadite, free from calcite, indicated about 17 per cent of cancrinite. In this rock the cancrinite is certainly of a primary origin. Naturally in rocks with a high percentage of cancrinite the amount of nepheline is essentially smaller than before mentioned.

The amphibols are generally of the olive green type, described above as the greenish brown alkaline hornblende. They are generally developed in long, well defined, slender prisms. Biotite is sometimes very plentiful, sometimes scarce. It often shows a parallel intergrowth with the amphibol. Apatite is always present, zircon is found in the pegmatitic segregations but is not usual in the normal canadite. Magnetite is hardly ever to be found even in the smallest grains.

The typical normal development of the massive canadite is found at Byske, east of the farm buildings and in the woodlands south and west of Sågen, where a long band of this rock stretches nearly down to the high road to Knutby. In seeking for the typical development of the rock, one must, however, keep to the central parts of the areas, marked as canadites on the map; along the margin the rocks often assume a more complicated composition.

At one or two places, for instance a locality, lying just south of Sågen, the rock is lighter in colour and of a more salic nature, the dark coloured minerals having essentially diminished in quantity.

A chemical analysis has been made by prof. MAX DITTRICH of a specimen of the typical medium-grained, dark coloured canadite from Byske.

The rock is in sections free from calcite, the CO_2 being bound in cancrinite. The Ce_2O_3 determination is the middle of two very closely corresponding determinations. SO_3 has been determined direct in solution of hydrocloric acid giving 0,10%. In a melt of soda-salpeter 0,14% SO_3 was found. The result is therefore 0,10% SO_3 and 0,01% S. The analysis is given in the following table under I, II—III give the analyses of two closely related rocks.

	I	I a	I b	II	III
SiO_2	48,60	80,46	56,88	51,58	51,90
TiO_2	1.34	1,67	1,18	0,35	—
Al_2O_3	19,89	19,46	13,76	19,40	22,54
Fe_2O_3	2,97	1,86	—	4,26	4,03
FeO	5,76	8,01	8,29	5,25	3,15
MnO	0,36	0,51	0,36	0,20	—
MgO	1,32	3,27	2,31	0,49	1,97
CaO	4,43	7,89	5,58	3,64	3,11

	I	I a	I b	II	III
K_2O	2,26	2,39	1,69	4,23	4,72
Na_2O	8,74	14,07	9,95	7,49	8,18
P_2O_5	0,56	—	—	0,15	—
ZrO_2	trace	—	—	—	—
Ce_2O_3	0,59	—	—	—	—
BaO	0,05	—	—	—	—
Cl	trace	—	—	—	—
F	0,06	—	—	—	—
CO_2	1,10	—	—	1,53	—
SO_3	0,10	—	—	—	—
S	0,01	—	—	—	—
H_2O+	1,73	—	—	1,02	0,22
H_2O-	0,21	—	—	—	—
	100,11	139,59	100,00	99,59	99,82

I. Canadite, Byske, Almunge. M. DITTRICH anal.

I a. Molecular proportions.

I b. » calculated on a sum of 100.

II. Nepheline-syenite (canadite), Monmouth, lot 16, conc. 9. M. CONNOR anal. Geol. Survey of Canada, Memoir 6, p. 264.

III. Laurdalite, Lunde, Lougendal, Norway. G. FORSBERG anal. Zeitschr. für Krystallogr. Vol. XVI, p. 33.

The chemical composition of the rock is in several ways uncommon and shows the independent position of the canadites, intermediate between nepheline-syenites, poor in potash and theralites, rich in nepheline.

OSANN's classification gives:

$s = 58,06$	$A = 11,64$	$a = 8,26$	$n = 8$
	$C = 2,12$	$c = 1,53$	
	$F = 14,42$	$f = 10,21.$	

No type in OSANNS tables corresponds well with this composition.

The quantitative system gives the following norm, cited under I. II gives the norm of the closely related canadite from Ontario.

	I		II	
Orthoclase	13,26	sal. 80,74	25,02	82,08
Albite	35,95		34,84	
Anorthite	8,81		6,67	
Nepheline	19,03		15,50	
Nosean	1,19		—	
Calcite	2,50		—	

	I		II	
Calcite	—	fem. 16,16	3,45	16,62
Diopside	1,90		0,90	
Olivine	6,15		5,05	
Magnetite	4,31		6,15	
Fluorite	0,07		—	
Ilmenite	2,53		0,73	
Apatite	1,20		0,34	

This gives the rock the following position in the quantitative system

Class II	Dosalane,	
Order 6	Lendofelic,	Norgare,
Rang 2	Domalkalic,	Essexase,
Subrang 4	Dosodic,	Essexose.

In comparing the analysis with those of the essexose subrang the canadite is seen to be exceptionally low in CaO and high in Na_2O. The only analysis with which it has these points in common is the canadite of Ontario. From this rock it differs chemically by lower K_2O, and normatively by a smaller amount of orthoclase. The nearly complete absence of chemically closely related rocks shows more than anything else the isolated position and characteristic features of the canadites, which perfectly well entitle them to the independent group, to which they have been attributed by IDDINGS, and for which here the new name of canadite has been suggested. A very small difference in the proportions between Na_2O and K_2O in favour of the former would bring the rock into the subrang persodic, where it would represent the first type known. The Almunge canadites show a general tendency of approaching this group and I have no doubt that specimens could be selected, which in their chemical composition would represent this subrang. The natural consequence of the great preponderance of soda over potash, which is common for all the Almunge canadites, is the very insignificant amount of orthoclase or microcline in the rocks, most of the normative orthoclase being bound in the compound soda-potash feldspars (soda-orthoclase).

Anywhere amongst the normally developed canadites of Almunge darker varieties of the rock may be found, where the mafic minerals have accumulated. It is very characteristic, that, though the different mafic minerals have increased so essentially, the feldspar in most cases still retains its composition of a highly sodic plagioclase, very near albite in composition. In some cases, however, a plagioclase varying between oligoclase and andesine appears. The other feldspars are present in much the same relative proportions as in the former rocks. Even a microscopic study of these rocks does not reveal any other essential difference from the normal type, than an increase of the mafic minerals, whereas the felsic constituents have remained in the same development and occur in much the same proportions as in the normal type. A small amount of light green ægerite-augite, as well as a colourless garnet occur, however, rather regularly in this variety.

The best locality for studying these dark theralitic rocks is near Upptorp or in the woods south of Sågen.

An analysis by D:r NAIMA SAHLBOM is given under I in the following table. II—IV give some analyses of closely related rocks.

	I	I a	I b	II	III	IV
SiO_2	43,68	72,32	49,18	43,66	43,67	42,72
TiO_2	1,10	1,37	0,93	1,21	0,78	0,38
Al_2O_3	20,15	19,72	13,41	17,35	20,91	25,08
Fe_2O_3	2,94	1,84	—	7,88	3,54	2,00
FeO	8,97	12,48	10,99	5,40	8,01	4,36
MnO	0,23	0,32	0,22	—	0,05	0,16
MgO	4,38	10,86	7,38	4,27	1,46	0,97
CaO	7,24	12,90	8,77	9,39	7,37	6,92
K_2O	1,99	2,11	1,44	2,07	2,25	2,69
Na_2O	7,00	11,27	7,67	5,12	6,73	11,02
P_2O_5	1,38	—	—	1,32	0,11	0,19
Cl	0,07	—	—	—	—	—
F	0,20	—	—	—	—	—
CO_2	—	—	—	—	2,37	2,99
H_2O	0,89	—	—	1,99	2,52	0,88
	100,22	145,19	99,99	99,66	99,77	100,36

I. Theralithic canadite.

I a. Molecular proportions.

I b. » calculated on a sum of 100.

II. Essexite ('Theralite rich in nepheline') Beverley. M. DITTRICH anal. F. E. WRIGHT. T. M. P. M. XX, p. 281.

III. Nepheline-syenite ('Theralitic canadite') Monmouth. N. EVANS anal. ADAMS and BARLOW l. c., p. 270.

IV. Nepheline-syenite, ('Theralitic canadite') Monmouth. N. EVANS anal. ibid., p. 272.

OSANN's classification brings the rock into type Cabo Frio amongst the rocks grouped as 'theralithes rich in nepheline'. WRIGHT's essexite from Cabo Frio is also assigned to this group, and the analyses of the two rocks show a good deal of similarity.

The OSANN constants are:

s = 50,11	A = 9,11	a = 5,00	n = 8,4.
	C = 4,30	c = 2,36	
	F = 23,06	f = 12,64	

Type Cabo Frio has

$$s_{50} \quad a_4 \quad c_{2,5} \quad f_{13,5}.$$

Using the quantitative system the norm of the Almunge rock is given under I, the closely related type (III) from the Ontario district under II.

	I		II	
Orthoclase	11,68	67,33	12,79	74,12
Albite	12,58		22,01	
Anorthite	17,79		20,29	
Nepheline	25,28		19,03	
Calcite	—	31,83	5,41	22,95
Diopside	7,39		—	
Olivine	14,77		10,58	
Magnetite	4,18		5,10	
Ilmenite	2,13		1,52	
Apatite	3,36		0,34	

The Almunge rock accordingly in the quantitative system belongs to

Class II	Dosalane,	
Order 7	Lenfelic,	Italare,
Rang 2	Domalkalic,	Vulturase,
Subrang 4	Dosodic,	Vulturose.

This subrang is in WASHINGTON's collection of analyses[1] only represented by an analcite diabas from California and a hauynophyr from Italy. Analysis n:o IV in the foregoing table refers, however, to a rock from the Bancroft area belonging to this subrang, though essentially richer in lenads than the rock in question. The Almunge representative is transitional to class III, which brings the rock near kamerunose, on the other hand it is intermediate to the essexose rocks, to which the closely related rock from Ontario belongs.

Chemically the rock in question is evidently nearest a theralite. But its modal composition differs by its feldspars in general being less calcic than in the theralites. The normative lime-feldspar is still to the greatest extent contained in the mafic minerals. The same is the case with the nearly related representative from the Ontario district, which again shows the close relation between these rocks as well as their specific character, by which they distinguish themselves from the nepheline-syenites in general. I have chosen to call this rock a theralitic canadite rather than theralite

[1] United States Geol. Surv. Prof. PAPER. N:o 14 (1903).

alone, so as to indicate, that while having a theralitic composition, the rock still retains those singular features, which have been indicated as characterizing the canadite group.

The theralitic varieties of the canadites show every transition to the normal rock, and are evidently to be considered as a differentiation facies of the same.

In several types of the normal as well as of the theralitic canadites vesuvianite occurs in quite considerable quantities. The small outcrops in the fields east of Stora Ellringe consist of normal canadite, perhaps somewhat richer in mafic minerals than the type rock from Byske. The vesuvianite is not very frequent here and can not always be seen megascopically. In the woodland south of Sågen, north of the path leading from Hällen to Sågen, just where it bends northward, the rocks are essentially richer in vesuvianite, and one spot was so rich in this mineral that the rock might well have been termed a vesuvianite-syenite (Pl. IX, fig. 1), about 15—20 % of the rock consisting of vesuvianite. The rock was moreover rich in mafic minerals, especially in biotite, which together with the vesuvianite show a parallel arrangement, giving the rock a schistose appearance. The amount of this type of rock is, however, very small, and is to a great extent already blasted away. But the rocks round about all show a small content of vesuvianite, evenly distributed amongst the other minerals.

Amongst the nepheline-bearing rocks of Almunge light coloured varieties are also to be found, which in many ways contrast to the dark typical canadites and still more to the theralitic types, just described.

The colour of these syenites is light gray or white, occasioned by the predominant percentage of the salic minerals which constitute nearly 90 % of some types. The mineral composition is in several respects different to that of the typical canadites. The feldspars consist principally of albite, microcline and soda-potash-feldspars. The amount of orthoclase is even less than in the typical canadites, the compound feldspars (soda-orthoclase or soda-bearing orthoclase) evidently to a great extent substituting it. Microcline and microcline-perthite begin to appear, in the same proportions as the nepheline begins to diminish. In the nepheline-free types microcline-microperthite is again one of the dominant feldspars. Nepheline is present in very variable amounts, some types readily carrying 10 % nepheline, others being perfectly devoid of this mineral. The nepheline is generally very much changed in all rocks belonging to this group, the decomposition products being 'spreustein'-like aggregates or muscovite. Besides hornblende and biotite a small amount of ægerite-augite is often developed in these white syenites, showing the usual extinction of $c : X =$ about 35°. The amount of the ægerite molecul can, however, just in these rocks vary somewhat, and with it of course the extinction angles and the colour.

Vesuvianite is moreover a common ingredient in many of these rocks, occurring in much the same way as already described in the canadites.

Another mineral occurs in minute crystals in not unessential quantities in many of the rocks belonging to this group. It is a colourless or faint yellow, non-pleochroitic biaxial mineral with a distinct cleavage parallel to the zone of elongation. The axial plane is transvers to the cleavage. Refraction is very high, axial angle not large, optical character negative, the zone of elongation positive. The birefringence is about 0,040, the maximal extinction angle is 30° towards the cleavage. A strong axial dispersion $\rho > \upsilon$ is observable. This mineral has not been able to be determined with certainty, no crystallographic faces having been observed. It invariably occurs round the biotite and hornblende, and also as partial inclusions in these minerals. It is certainly not epidote; neither can it be pectolithe, the refraction index being much too high. It might possibly be a mineral of the wöhlerite or hjortdalite group, containing the high percentage of Ce_2O_3, which the analysis of the typical canadite shows to be present. The mineral is to be observed in small quantities in all the canadite rocks, though specially so in some of the white syenites, which is the reason why I have mentioned its optical properties in this place. It is quite possible that this mineral may be able to be separated and chemically examined, or else be found in larger crystals, which would allow a reliable optical determination.

Apatite is further an abundant constituent of the white nepheline syenite, often developed in quite large crystals. Fluorite is also often to be found.

An analysis of this white nepheline-syenite has been executed by D:r SAHLBOM and gives the following composition:

	I	I a	I b	II
SiO_2	52,04	86,16	60,85	54,68
TiO_2	0,26	0,32	0,23	0,79
Al_2O_3	23,92	23,40	16,53	21,63
Fe_2O_3	1,46	0,91	—	2,22
FeO	4,18	5,82	5,40	2,00
MnO	0,11	0,15	0,11	—
MgO	1,50	3,71	2,62	1,25
CaO	2,38	4,24	2,99	2,86
K_2O	2,37	2,51	1,77	4,58
Na_2O	8,36	13,46	9,51	7,03
P_2O_5	0,26	—	—	0,28
CO_2	0,58	—	—	—
H_2O	2,21	—	—	2,15
	99,63	140,68	100,01	99,81*

* With 0,05 BaO, 0,07 SO_3 and 0,22 F.

I. White nepheline-syenite. Upptorp, Almunge. N. SAHLBOM anal.

I a. Molecular proportion.

I b. D:o calculated on a sum of 100.

II. Nepheline-syenite, Brookville, N. J. Am. Journ. of Science. Vol. VIII, p. 423.

OSANN's classification gives

$s = 61{,}08$	$A = 11{,}28$	$a = 10{,}07$	$n = 9$
	$C = 5{,}25$	$c = 4{,}69$	
	$F = 5{,}87$	$f = 5{,}24$	

The nearest of OSANN's types in type Brookville with

$$s_{64} \quad a_{10,5} \quad c_{2.5} \quad f_{6}.$$

The quantitative system gives the following norm

Orthoclase	13,90	sal. 85,26
Albite	47,16	
Anorthite	6,12	
Nepheline	12,78	
Corundum	5,30	
Calcite	1,40	fem. 11,90
Olivine	7,28	
Magnetite	2,09	
Ilmenite	0,46	
Apatite	0,67	

The rock accordingly belongs to

Class I	Persalane	
Order 6	Lendofelic	Russare
Rang 2	Domalkalic	Viezzinase
Subrang 4.	Dosodic.	Viezzinose

The high percentage of water is due to the 'Spreustein'-pseudomorphoses after nepheline. The CO_2 of this analysis cannot be reckoned as bound in cancrinite, as calcite is present in the rock as one of the decomposition products. The high supersaturation of Al_2O_3 is also a noteworthy feature. Partly it may be due to the decomposition of the rock, whereby some part of the alkalies have been removed, partly to the aluminous alferric minerals. But even reckoning with these two possibilities, the supersaturation of Al_2O_3 is so great, that one would have expected to find some trace of free corundum in the rock.

The nearest connected analysis is that of the Brookville nepheline-syenite, though the Almunge rock differs again by the greater predominance of soda over potash, which has shown itself so very characteristic for the whole group of the nepheline-bearing rocks of Almunge. In this respect it has retained the proportions found in all the analyzed canadites.

The geological relations of these white nepheline-syenites are not perfectly clear. One can, however, easily convince oneself, that the distribution of this rock type is not accidental, but stands in certain relations to the normal canadites. Generally the white syenite is found as a periferical facies around the typical canadite. Such is the case south of Sågen along the western contact of the largest canadite outcrop, where especially north of the path from Hällen to Sågen the white syenite can be seen all along the contact between canadite and umptekite. Such is also the case at Byske, where the white syenite appears behind the farm buildings. The decomposition of nepheline into 'Spreustein' gives the rock in this place a characteristic spotted, pink and white colour. Just south of Skallerbol the same relations between the canadite and the umptekite can be observed in several places.

The amount of nepheline in the white syenite is further very variable, and the whole mineral composition is very much more irregular than in either the umptekites or in the canadites. The norm of the rock shows in comparison with the normal canadite a decrease in lenads from 21 % to 12 %. As mentioned, types may often be found devoid of all nepheline. The structure is also variable, sometimes the rock is medium-grained, sometimes fine-grained and partly granulated. This last structure gives rise to a very characteristic rock, reproduced in Pl. IX, fig. 2. This type has a singularly patchy appearance, the felsic and mafic constituents having gathered together in large patches. The darker blotches consist of hornblende, biotite, and often some vesuvianite, with a good deal of apatite generally present. Nowhere does the hornblende better show the characteristic poikilitic intergrowth with feldspars than in this rock, which may perhaps most easily be studied in a large boulder lying in the garden of a cottage on the high road to Knutby about straight under *s* in Blomsteräng. Identically the same rock borders the canadite on the western side of the large outcrop south of Sågen. Under the microscope many interesting features are to be seen. The nepheline is mostly quite decomposed into muscovite or 'Spreustein'. The feldspars consist of albite, microcline and soda-orthoclase, sometimes in large individuals, sometimes in a fine-grained granulated mass. Vesuvianite is common in many places. In the boulder mentioned near the high road the vesuvianite can be observed in large radiating clusters along certain veins in the rock which otherwise principally consist of biotite. One would here hardly expect the vesuvianite to be anything else than a secondary mineral, but a closer study will soon reveal the mineral distributed here and there in the rock, appearing under such circumstances, that it must be considered as primary in relation to the other minerals. Another detail of interest is to note, how the feldspars sometimes change their composition round small inclusions of hornblende. In a large albite crystal one can plainly see, how the otherwise perfectly uniform feldspar shows a distinctly deviating extinction round such an inclusion, indicating a more calcic composition in the immediate neighbourhood of the hornblende.

It would be a vain attempt to try to describe all the varying types belonging to this group of the nepheline-syenites. The inconsistency of the whole group of these white syenites both in structure and mineral composition as well in as their geological distribution along the contacts of the canadite outcrops seems to indicate, that these rocks are of a hybrid or syntectic nature, having been formed through intermixture of material from both the umptekite and the canadite magmas. If the canadites are the older rocks, as has been indicated above, the umptekite magma may have had plenty of opportunity to react on the canadites. The chemical constitution of the analyzed white nepheline-syenite shows it to be a more silicious and more salic rock than the normal canadites. This composition might well have been formed by a powerful assimilation process. That these white syenites are not to be considered as only a differentiated facies of the canadite seems to be indicated by their position even round many of the smallest patches of the canadite rocks as well as by their appearance independently of any canadite at all, as is the case in several small patches south of Skallerbol.

Schistose Development.

As previously indicated, the structure of the canadites is in many places highly schistose. If the rock at the same time is fine-grained, it is often at a glance difficult to distinguish these varieties of the canadites from the fine-grained leptites of the archean formations around. The photographs Pl. X and XI give some idea of the variations of these fully gneissic rocks. It is striking, that these schistose varieties occur along the margin of the whole area, generally falling within the marginal facies of the umptekite. This is the case at Lilla Ellringe and at Uddnäs, the two places where this facies is best developed. A third place is on the high road to Knutby, east of Johannesdal, the rocks here being laid bare in the ditch on the north side of the road.

The best place for studying the schistose canadites is at Lilla Ellringe, in the grove straight north of the farm, where the moss has been stripped off the rock. The strike of the canadite-gneiss is nearly N—S, roughly corresponding to the direction of the contact as well as to the strike of the protoclastic marginal syenite, which borders the canadite. It here seems obvious, that this schistose structure has been occasioned by the same process in both rocks. The contact between the umptekite and the canadite is well defined, no assimilation here having taken place.

At Uddnäs, or rather in the woods west of Uddnäs (see map) the relations of the two rocks is different and of special interest. The strike is as usual more or less parallel to the contact; it is however possible that the canadites here represent a broad dike parallel to the contact, along which fissure syenitic magma has later intruded. As has been remarked before, the exact line of contact is in this part not easy to define because of the amount of assimilation towards the red granite. The canadite-gneiss, however, is surrounded by the usual marginal schistose variety of the syenite, which intrudes the canadite in numerous veins. These intrusions, which are of small dimensions, have a marked inclination to follow the schistosity of the rock, thereby giving rise to a perfect lit-par-lit injection, which at places is so uniform, that the rock may well be defined as a veritable arterite (Pl. XII, fig. 1). The proportions between the original canadite and the syenite material can of course vary in any proportions; where the rock is most uniformly developed, there is approximately an equal amount of both ingredients.

The structure of the schistose canadites is very much the same as has been described regarding the marginal schistose nordmarkite. In general the rocks are granular, no definite order of crystallization being seen. The schistosity or parallel structure is chiefly due to the subparallel arrangement of the mafic minerals, biotite and hornblende, as is seen in Pl. XI, fig. 2.

The mineral composition of the gneissose canadites in no way differs from the normal development of the rock. The proportions between the different minerals can, however, variate a good deal. This is especially the case at Lilla Ellringe, where parts of the rock show a very coarse texture, as is seen on Pl. X (fig. 2). Near Johannesdal the development of the schistose rock is of special interest, because the white nepheline-syenite also occurs there in a gneissic facies. The rock, however, holds the same position as a marginal facies of the canadite towards the umptekite, as it does in the normal eugranitic types. This circumstance seems to point to the fact, that this facies has been formed through assimilation between the rocks independently of the locality being closer to or further from the margin of the area. At Lilla Ellringe and at Uddnäs, however, where the canadites possibly intersect the country rock in dikes parallel with, but just outside of the contact, no such marginal facies of the canadites has been observed, a feature which would be easely explained by the more rapid cooling of the magma in the dikes outside the area of the igneous alkaline rocks.

The whole question of the gneissose development of the canadite rocks seems therefore to be referable to the same endogenous contact phenomena as have occasioned the marginal facies of the umptekite.

An analysis of a typical fine-grained specimen of the canadite-gneiss from Lilla Ellringe has been made by D:r Sahlbom.

	I	I a	I b	II
SiO_2	56,44	93,44	64,23	56,40
TiO_2	0,12	0,15	0,10	0,84
Al_2O_3	20,52	20,08	13,80	21,36
Fe_2O_3	2,72	1,70	—	2,96
FeO	4,51	5,86	6,36	2,39
MnO	0,06	0,08	0,06	0,49
MgO	0,28	0,69	0,48	0,90
CaO	1,23	2,19	1,51	1,81
K_2O	4,80	5,09	3,50	4,83
Na_2O	9,01	14,51	9,97	8,57
P_2O_5	0,10	—	—	—
Cl	0,06	—	—	—
S	0,07	—	—	—
H_2O +	0,75	—	—	0,01
H_2O −	0,12	—	—	—
	100,49	143,79	100,01	100,56

I. Canadite-gneiss, Lilla Ellringe. NAIMA SAHLBOM anal.

I a. Molecular proportions.

I b. D:o calculated on a sum of 100.

II. Nepheline-syenite (chibinite) Poutelitschorr, Kola. Fennia, Vol. 11, p. 139.

OSANN's classification gives:

s = 64,33	A = 13,47	a = 12,13	n = 7,4
	C = 0,33	c = 0,30	
	F = 8,41	f = 7,57	

which brings the rock nearest type Crazy Mts. with

$$s_{64} \quad a_{13} \quad c_0 \quad f_7$$

The norm of the rock is cited under I. II gives the norm of the closely related nepheline-syenite from Kola.

	I		II	
Orthoclase	28,30	sal. 88,46	28,36	90,2
Albite	37,67		36,68	
Anorthite	2,17		5,84	
Nepheline	18,01		19,31	
Sodalite	0,77		—	
Noselite	1,54		—	

Diopside	3,38		2,51	
Olivine	3,50		1,94	
Magnetite	3,94	fem. 11,26	4,18	10,1
Ilmenite	0,23		1,52	
Apatite	0,21		—	

This gives the rocks the following position in the quantitative system:

Class I	Persalane	
Order 6	Lendofelic	Russare
Rang I	Peralkalic	Miaskase
Subrang 4	Dosodic	Miaskose

In some respects the analysis of the schistose nepheline-syenite from Lilla Ellringe does not agree with the general chemical character of the canadite group. Both the great predominance of soda over potash and the high content of lime, which otherwise are the most characteristic features of the canadites, are wanting in this rock, which instead shows the more normal composition of a nepheline-syenite. A nearly complete correspondence to the analysis is found in the chemical composition of the nepheline-syenite from Kola. Observe the nearly identical norms of the two rocks! It is of special interest to note, how rocks, referring to such very similar chemical composition, yet can differ so essentially in their modal development. The mafic minerals of the Kola syenite are arfvedsonite, ægerite and ægerite-augite, whereas the Ellringe rock carries biotite and hastingsite. The potash of the latter is evidently bound in the biotite and hastingsite, leaving the feldspars nearly pure albite, which together with the nepheline absorb the whole soda content. This explains the absence of the soda-bearing pyroxens and amphibols.

Pegmatitic Development.

It is a noticeable feature, that dike rocks are altogether absent in the Almunge district. Nowhere, neither in the umptekite nor in the canadite has a single real dike been observed. It is evident that the geological circumstances have not been favourable for the formation of any kind of dikes, and if the geological interpretation here given of the district is correct, it is only natural, that no such rocks are met with. The channel of the rising alkaline magmas has naturally not been the place for the development of dikes, and when the flowing ceased, a rapid crystallization has probably taken place, whereby the rocks have filled the channel like an immense plug, which naturally would resist any attempt of deeper lying, still liquid magma to intrude.

On the other hand pegmatitic veins are extremely common in the area, and more especially in the canadite rocks. These veins are generally of no great dimensions, commonly measuring but a few decimeter in width and can only be followed some ten meter or thereabout in length.

The mineral composition is in general the same as in the normal canadites, though the pegmatites have a much larger proportion of felsic minerals, being in general light coloured or white rocks. Albite, nepheline, cancrinite, biotite and hornblende are the essential ingredients. These pegmatitic segregations are, however, also the seat of the scanty supply of rarer minerals, which are abundant in so many of the nepheline-syenite-pegmatites of other districts. Here they are limited to malacon and orangite. The former is often developed in small but well defined crystals. The best specimens of orangite as well as of malacon have been found in a small pegmatitic vein along the northern edge of the canadite outcrop north of Upptorp, about half way between Upptorp and Byske.

It is, however, not only possible but probable that a more diligent search for minerals, than has up to the present been made, will reveal many new minerals in these pegmatites, but to enable a search for these, a large amount of blasting will be required. I hope, however, subsequently to be able to complete the list of minerals belonging to the canadite rocks, and more especially to the pegmatitic segregations.

Just south of Upptorp, a fairly large pegmatitic vein is found, consisting nearly exclusively of albite with but a few stray grains of biotite and cancrinite.

Another locality is perhaps of special interest in connection with the pegmatites. Following the road through the wood from Hällen to Sågen, a broad porphyritic vein of singular appearance is noticed on the road side about half way between these two places and just where the road crosses a small ditch. The dominant rock of this vein is of a spotty, red and white appearance and with a very pronounced porphyritic structure. The ground-mass consists nearly exclusively of granular grains of albite and microcline. The red patches in the ground mass are occasioned by iron pigment, and are in no wise »Spreustein» or any other secondary mineral. The porphyritic crystals, which can attain a length of 10 cm. are microcline-microperthites showing the same transitions between micro- and cryptostructure, as has been previously described in the umptekites. The amount of albite is, however, here always dominant over the microcline. A small amount of biotite and some grains of apatite and zircon are the only other ingredients. This vein or dike without doubt belongs to the umptekite rocks and might according to its mineral composition and structure be termed a *lestiwarite-porphyry*. The ground-mass much resembles some of BRÖGGER's lestiwarites from Kvelle in the Lougen-valley, intruding the laurdalites of that district. In the present case this aplitic and porphyritic vein grades into a pegmatite rich in nepheline. The large weathered nepheline crystals can easely be distinguished on the weathered surface. The structure changes from aplitic to coarse-grained pegmatitic, and the porphyritic structure disappears perfectly. The nepheline-bearing pegmatite is white in colour, but richer in mafic minerals than the lestiwarite. I do not venture to pronounce any definite opinion on the geological relations of these two rock types, the ground being much covered all round. Canadite rocks are, however, quite near at hand, and I have little doubt, that the nepheline-bearing pegmatite can be interpreted as a canadite inclusion in the syenite, which has crystallized with a pegmatitic structure, as is often the case with the white syenites bordering the canadites.

Within the canadite areas pegmatitic development of the rocks is occasionally met with outside of the pegmatitic veins. Such is for instance the case just south of Sågen, where large parts of the otherwise normally developed dark canadite grade into coarse-grained white rocks, with long and narrow amphibol crystals, attaining several cm. in length, large albite feldspars and a relatively small amount of nepheline as the principal constituents. (Pl. XII, fig. 2.)

Chemical Composition.

For convenience sake the four analyses, which have been made of the canadites will here be reproduced together with three analyses of chemically nearly related canadites from Ontario.

	I	II	III	IV	V	VI	VII
SiO_2	48,60	43,68	52,04	56,44	51,58	43,67	42,72
TiO_2	1,34	1,10	0,26	0,12	0,35	0,78	0,38
Al_2O_3	19,89	20,15	23,92	20,52	19,40	20,91	25,08
Fe_2O_3	2,97	2,94	1,46	2,72	4,26	3,54	2,00
FeO	5,76	8,97	4,18	4,21	5,25	8,01	4,36
MnO	0,36	0,23	0,11	0,06	0,20	0,05	0,16
MgO	1,32	4,38	1,50	0,28	0,49	1,46	0,97
CaO	4,43	7,24	2,38	1,23	3,64	7,37	6,92
K_2O	2,26	1,99	2,37	4,80	4,23	2,25	2,69
Na_2O	8,74	7,00	8,36	9,01	7,49	6,73	11,02
P_2O_5	0,56	1,38	0,26	0,10	0,15	0,11	0,19
CO_2	1,10	—	0,58	—	1,53	2,37	2,99
H_2O —	0,21	—	—	0,12	—	—	—
H_2O +	1,73	0,89	2,21	0,75	1,02	2,52	0,88
BaO	0,05	—	—	—	—	—	—
Cl	—	0,07	—	0,06	—	—	—
F	0,06	0,20	—	—	—	—	—
SO_3	0,10	—	—	—	—	—	—
S	0,01	—	—	0,07	—	—	—
ZrO_2	trace	—	—	—	—	—	—
Ce_2O_3	0,59	—	—	—	—	—	—
	100,11	100,22	99,63	100,49	99,59	99,77	100.36

I. Normal Canadite, Byske.

II. Theralitic Canadite, south of Sågen.

III. Salic marginal facies of Canadite, Upptorp.

IV. Canadite-gneiss, Lilla Ellringe.

V. Nepheline-syenite (Canadite), Monmouth, Ont.

VI. » » (Theralitic canadite) Monmouth, Ont.

VII. » » » » » »

Comparing the analyses of the typical canadites (I and II) with the chemical composition of the nepheline-syenites in general, there are particularly two features, which immediately attract attention: the great preponderance of soda over potash, and the high percentage of lime. The former feature the canadites have in common with the nepheline-syenites rich in albite and poor in potash-feldspar, such as the mariupolites, the catapleiite-syenite of Norra Kärr, many nepheline-syenites from Greenland and Kola, and to a certain extent the litchfieldites. But from all these syenites the above quoted canadites distinguish themselves by an essentially higher percentage of CaO, which brings the group nearer the theralites and ijolites. From the first group the canadites, however, differ by the large content of soda, from the latter by the considerable amount of normative feldspars in the rock. The chemical composition therefore accentuates the intermediate position of the canadites just as much as does the mineral composition. Whether one is inclined to place these rocks within the nepheline-syenite group, as IDDINGS has done by ascribing to them a separate section, or one places them in an independent group, as an equivalent to the theralites and occupying in relation to these the same position as the foyaïtes occupy to the shonkinites in ROSENBUSCH's system, the canadites show themselves to be a natural petrographical family. Chemically and normatively the canadites come very close to OSANN's 'Reihe der nephelinreichen Theralithe', but distinguish themselves from these rocks in their actual mineral composition by carrying albite and highly sodic plagioclase instead of lime-soda-feldspars of labradoritic or bytownitic composition.

The general inclination to approach the persodic subrang in the quantitative system is a characteristic feature of all the analyses of the canadites. No analyses are yet known from the persodic subrangs of rang 2, in the 6:th and 7:th orders of class 2, to which the typical canadites belong. This indicates better than anything else the unusual chemical composition of these rocks.

The fact, that the schistose canadite from Lilla Ellringe in its chemical composition shows but an insignificant correspondence with the typical canadites, is noteworthy. If one was to judge by the chemical composition alone, this rock would in fact have to be classed as a normal nepheline-syenite. As has already been mentioned, however, the mode of the rock plainly shows the connection with the typical canadites, the whole content of CaO and most of K_2O being bound in the mafic minerals, whereas the soda enters the felsic constituents, albite and nepheline. We therefore find the same mineral composition as in the type rocks of the canadites, the Ellringe facies only differing in the proportions between the felsic and mafic constituents, the predominance of the former proving the more salic nature of the rock.

Summary.

The description, which has been given of the alkaline rocks of Almunge, has no pretence of being an exhaustive account of the geology and petrology of the district. Doubtless many interesting details are yet to be discovered, which will throw more light on the geological evolution of the rocks in question. But although much may remain to be brought to light, enough of the distribution of the different rocks has been observed to enable one to form some idea of the geology of the district.

According to the interpretation, already given, the alkaline rocks of Almunge represent a deep-seated section of a channel or neck, through which magma has flowed, probably for some length of time, giving rise to intrusive or extrusive rocks at higher levels, long since eroded away. This interpretation is principally founded on a detailed study of the outer contacts of the alkaline rocks which resulted in the following observations. The contact is at least in part of a purely intrusive character. At some places, however, a gradual transition seems to take place from the country granites to the syenites. This is especially the case towards the red acid granite, whereas the contact towards the gray hornblende granite generally shows an intrusive character. The whole umptekite area is moreover surrounded by an endogenous aplitic, often protoclastic marginal zone, where the strike of the gneissose modifications on the whole follow the contact line. The schistosity can therefore not be connected with the regional deformation of the country rock, but must be due to a flowage of the syenite magma itself. The dip of the schistose rocks is generally vertical or all but vertical. The strike and dip of the marginal zone as well as the intrusive character towards the gray hornblende-granite are in full accordance with the theory above stated. The gradual transition towards the red granite also finds a plausible explanation. If the syenite magma has flowed for some length of time through the channel, of which here a deep-seated cross-section is probably laid bare, every opportunity must have existed for the magma to react on the rock walls of the channel. The acid red granite would more readily

succumb to the assimilating influence of the magma than the gray hornblende-granite, and thus the difference in the contact features towards these two rocks would be explained. The numerous inclusions of dark rock, which are everywhere found along the contact, are interpreted as exogenous inclusions which have been brought up from deeper levels by the rising umptekite magma.

The nepheline-bearing rocks must be interpreted as older than the umptekite and can be explained as remains of the older magma, which first filled the channel, but was followed by the intrusion of umptekite, now enveloping some remains of the older rocks as great inclusions. The umptekite magma has, however, reacted on these inclusions, which have partly been re-fused; at the contact rocks of intermediate or hybrid character have often been developed.

As is common in the igneous rocks filling up an old magmatic channel exogenous inclusions of many kinds occur, giving the area an often inhomogeneous composition. Several granitic parts in the umptekite are possibly to be interpreted as the remains of more or less assimilated inclusions of foreign material.

In a paper read before the Geological Society in Stockholm I touched upon the possibility of the alkaline rocks of Almunge having been formed by assimilation of calcareous sediments in connection with a palingenetic transformation of the district. The reasons for and against the possibility of a palingenetic evolution of the country rock have been referred to above. The most interesting feature in connection with this question is without doubt the presence of not unessential quantities of vesuvianite in the canadites. Vesuvianite has always been considered a typical mineral of the contact metamorphism of calcareous rocks. It seems difficult to explain its presence in the Almunge canadites in any other way, than that it represents the remains of otherwise fully assimilated calcareous sediments. Its occurrence would then be comparable with the primary calcite of Alnö or Bancroft, formed through assimilation of limestones by the igneous magma under such circumstances, that the CO_2 could not abscond. The very essential amount of cancrinite in all these rocks would then probably be a manifestation of the same geological features. The presence of a hydrated mineral in an igneous rock is hardly more remarkable, than CO_2 partaking in the constitution of other magmatic minerals under similar circumstances.

Though nothing can be said with certainty about the origin of the alkaline rocks, several features seem, however, to point to the possibility of the origin of nepheline-syenites in some way having been connected with the assimilation of calcareous sediments. As previously mentioned, paragneisses with interbedded limestone are found at no very great distance south of the area, and may possibly be present at deeper levels within the Almunge district itself.

[1] Geol. För. Förh. Vol. 34, p. 695.

Relating to the geological age of the alkaline rocks, positive data are scarce. The contacts towards the surrounding granites seem to indicate that the alkaline syenites are younger than, and intruded into these rocks. But when it comes to a closer determination of the age, the same difficulty arises, as regards several other intrusions of alkaline rocks in the archean formations of Sweden. GAVELIN[1] has recently described a small area of orthophyres in northern Småland, of which he in general gives the same geological interpretation, as has been given for the Almunge rocks, i. e. that the area of the orthophyre rocks now revealed, represent a section of a volcanic neck. GAVELIN comes to the conclusion, that the orthophyrs according to their geological relations and their petrographical characters are of post-archean age, most probably to be parallelized with the rapakiwis of central Sweden. The contacts between the orthophyre and the surrounding archean are, however, very different from what has been described from the Almunge district. The reasons, which GAVELIN gives for ascribing a post-archean age to the orthophyres, would, applied to the Almunge district, not hold good. The vague contacts towards the red archean granite, and also often towards the hornblende-granite are not comparable with the sharp contacts of our post-archean igneous rocks in general. If the area moreover represents the deep-seated section of a magmatic channel, as here suggested, the rocks must be essentially older than the formation of the precambrian peneplain of Skandinavia giving time for the precambrian erosion to lay bare such a deep-seated section. On the other hand, the alkaline rocks show no signs of recrystallization and but insignificant traces of cataclastic deformation, so that the syenites certainly seem to be younger than the regional deformation of the country rock, which has given the hornblende-granite its gneissose structure. Without therefore being able to give any definite answer as to the age of the alkaline rocks of Almunge, the geological features as well as the petrological character seem to indicate, that the rocks belong to the truly archean formation and are probably younger than the great regional movements, which have metamorphized the surrounding granites, but older than the postarchean igneous rocks of the province.

[1] Sveriges Geol. Unders. Ser. C, n:o 241 (1912).

Appendix.

By leaving Upsala by the earliest train for Almunge the principal geological features may well be seen during one day's excursion. It is advisable to begin with the contact features at Lilla Ellringe, where the gneissose canadite as well as the protoclastic marginal facies of the umptekite may be found in the small wooded hillock north of the farm buildings. Notice the strike and dip of these rocks, as well as the cordierite-pseudo-conglomerate on the inner side of the contact (p. 162).

Cross over the fields to the small outcrops of canadite east of Stora Ellringe. The canadite is here massive, and carries vesuvianite, especially in the northern outcrop. Note the syenitic magma intruding the canadite at the same place.

Strike over towards Seglinge, passing a granitic area of the umptekite between Skärpan and north-western Fladen (p. 156). Afterwards typical umptekite is found up to Seglinge. Near Seglinge itself coarse-grained pegmatitic umptekite is seen.

Take the path from Seglinge to Norrby and study the contact features: the marginal zone of the umptekite and the basic inclusions on the contact.

Cross over the fields to Ryggestalund where well developed typical canadite is found.

Follow the path to Byske. Note the contact phenomena between umptekite and canadite on the hillock east of the farm building (p. 163). Note also the white facies of the nepheline-syenite just north of the farm behind the cow-house.

Follow the path to Upptorp. Theralitic canadite is seen on the path opposite the cottage at Upptorp (p. 181). Just south of the cottage pegmatitic segregations of pure albite rock and several types of the white, patchy marginal facies of the canadite are to be seen (p. 184).

Take the path from Byske to Sågen. Study the outer contact towards Upsala granite east of the farm buildings at Sågen (p. 139).

Follow the path towards Hällen and enter the wood to the north just before crossing the western contact of the large canadite outcrop. Note here the typically developed canadite with weathered surface; also a somewhat more salic modification; further the light, pegmatitic development of canadite (towards the NE) with large hornblende crystals. Towards the west (10 m.) the contact towards umptekite is found, note the typical contact modifications of the canadite (white or gray coloured rocks, often with a patchy appearance, generally with some megascopic vesuvianite).

If time allows follow the path to Hällen, passing first, still in the wood, the lestiwarite-porphyry with its large feldspar phenocrysts (p. 192), and further on a nepheline-syenite-pegmatite with large gieseckite-pseudomorphoses (p. 168).

Return to the large canadite outcrop south of Sågen and enter the wood south of the path, following the canadite down towards the high road.

Note the schistose development of the canadite in the ditch east of Johannesdal, with the white marginal type also in schistose development.

Take the path to Strömsberg, note the umptekite rich in magnetite NE of the old pulled down cottage.

Follow the contact through the forest towards Söderby, noting inclusions of dark rocks all along the contact. Passing Uddnäs, note changes in the umptekite till the southern contact is reached by the hillock, where the old road crosses the hill.

Cross over the fields westward towards Fladen, and note the schistose canadite, partly with a lit-par-lit injection of syenite, specially at the southern end of the occurrence (p. 189). Note also the undefined character of the contact towards the red acid granite.

From this point allow one hour to catch the train.

Concerning the sketch-map a few remarks may be added. As already mentioned the distribution of the archean granites and diorite surrounding the alkaline rocks, has in general been copied from the survey map and from TÖRNEBOHM's map of the district. The amount of drift covered ground within the area as well as the small scale of the map have necessitated a very schematic reproduction of the distribution of the different rocks. In following the outer contact, the contact-line will often be found to run very irregularly, but it was not possible to enter all the bends in the map. The same is the case with the marginal zone, which sometimes expands, sometimes is reduced to a very narrow zone. As often the contact only can be followed some 10 m. and then drift covered ground sets in, it was not possible to follow up these small changes or combine all the detailed observations.

The distribution of the canadites has for the same reasons had to be still more schematically drawn. Many areas were so small, that they either had to be left out altogether or else united to a larger complex, although in reality separated by umptekite rocks. This is for example the case with the area south of Skallerbol. Though several parts have originally been mapped in the scale 1 : 4,000, drift covered land always intervenes preventing the different sections from being united and necessitating the very schematic reproduction here given.

Suitable localities for studying the outer contact of the alkaline rocks have been indicated by a *full-drawn* contact line.

Printed 3/3 1914.

Fig. 1. Dark inclusions in the marginal facies of umptekite at the contact. Norrby.

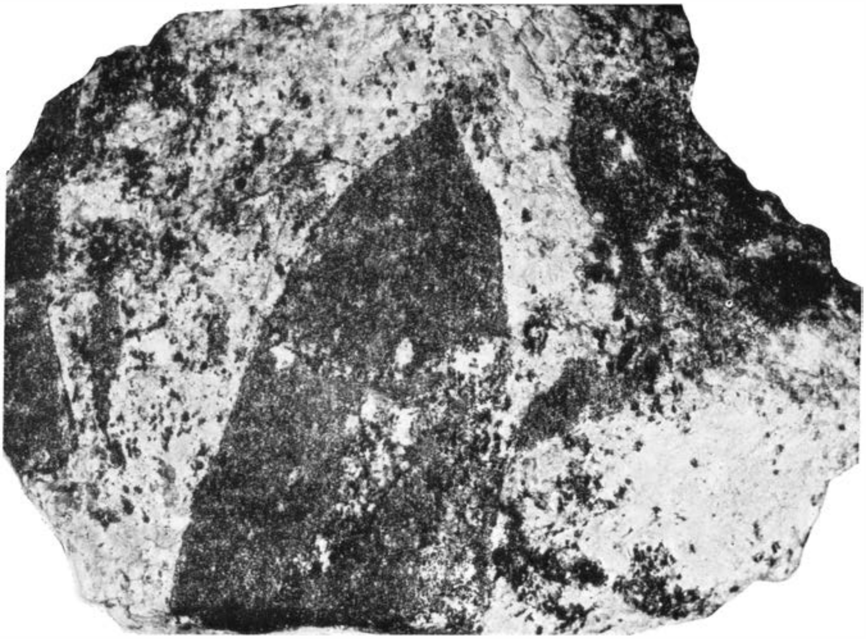


Fig. 2. One of the inclusions in natural size, showing how stray crystals of the umptekite have wandered into the much corroded fragments.

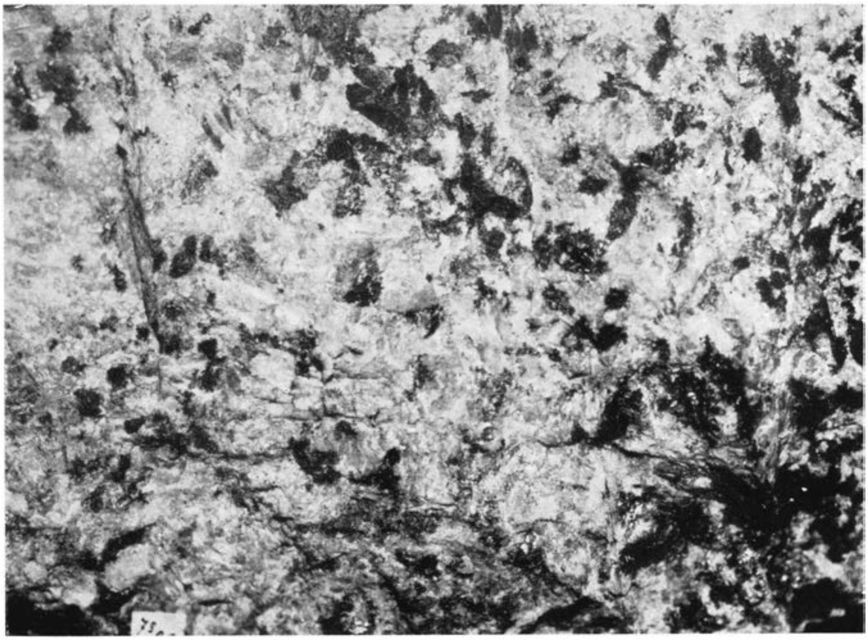


Fig. 1. Umptekite, normal development, principally composed of microcline-perthite and hastingsite. Hällen. Nat. size.

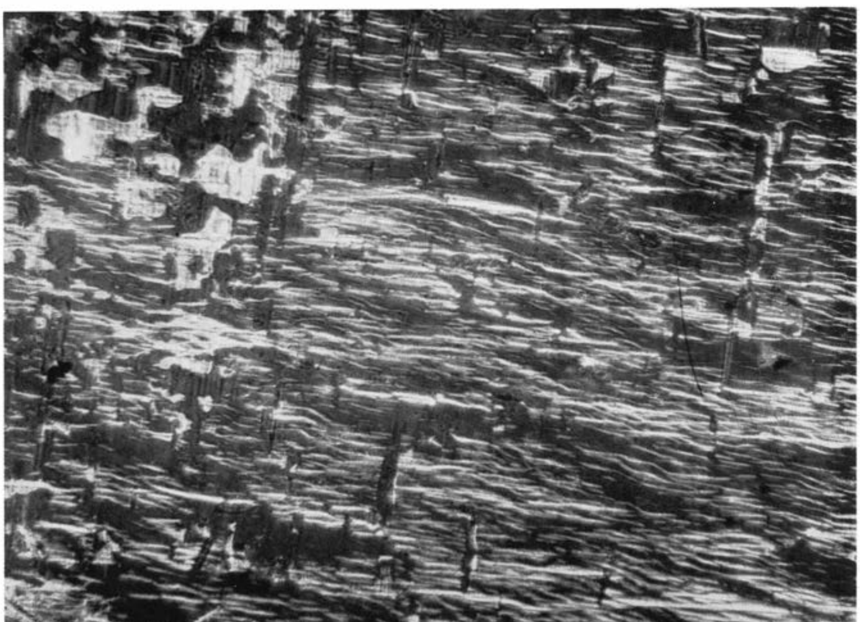


Fig. 2. Microcline-perthite crystal out of umptekite, Hällen, (fig. 1) showing transition from micro- to cryptoperthite.

Fig. 1. Typical section of umptekite showing larger crystals of perthite surrounded by granulated zones of albite and microcline.

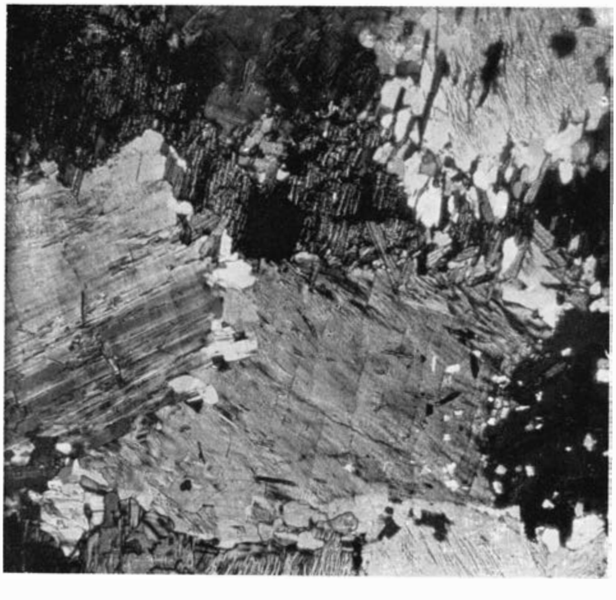


Fig. 2. Section of umptekite, consisting of microcline-microperthite and hastingsite.

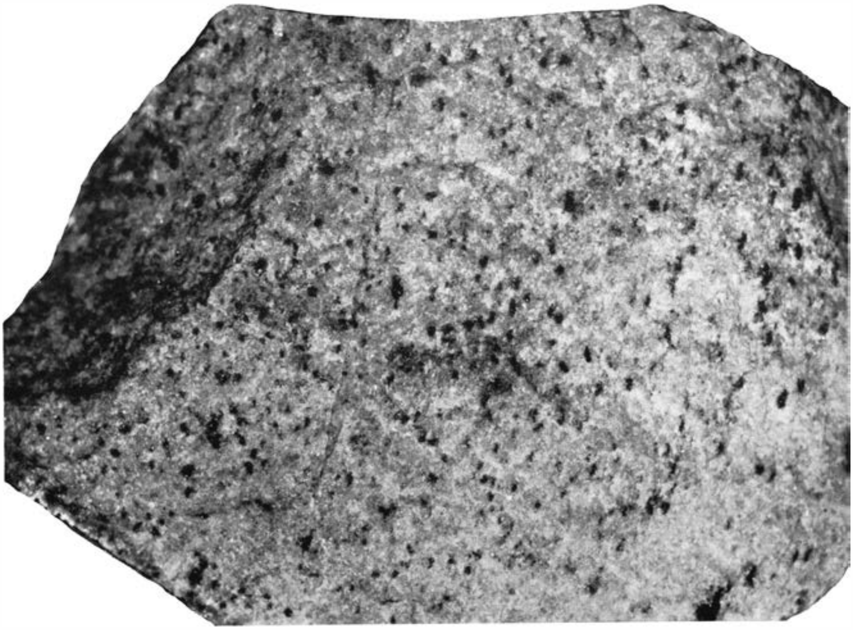


Fig. 1. Nordmarkite, aplitic marginal facies of umptekite, Broängen. Nat. size.

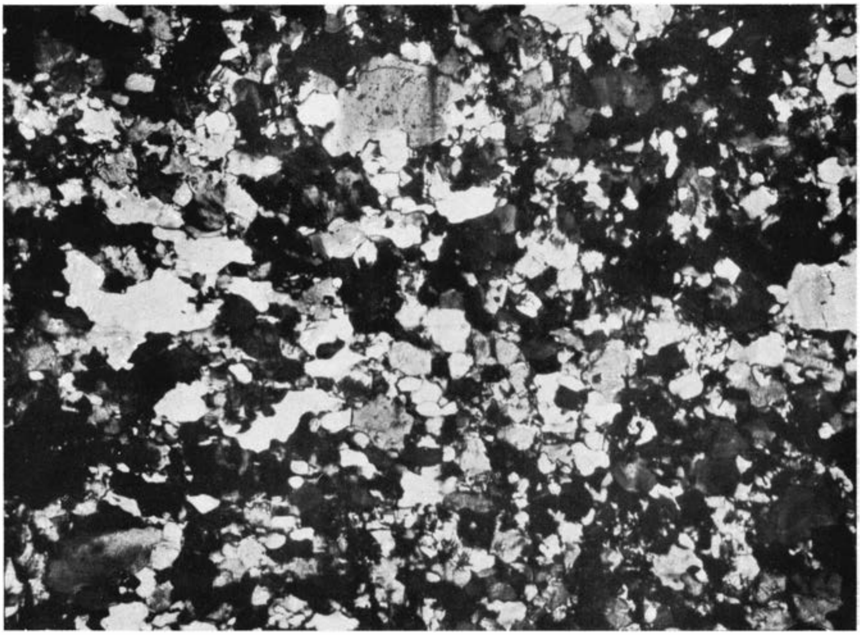


Fig. 2. Section of the marginal facies (fig. 1), showing aplitic structure.

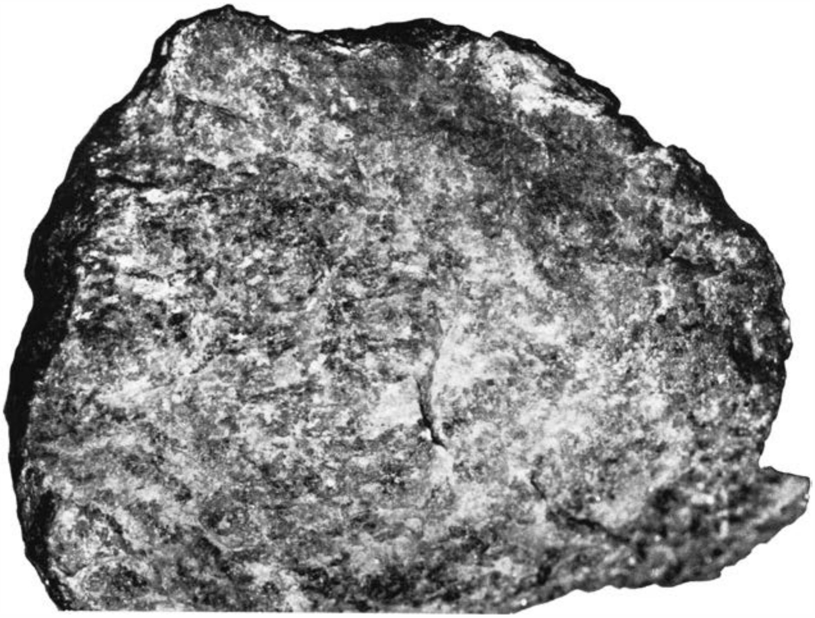


Fig. 1. Cordierite nodule out of the pseudo-conglomerate, consisting of a single crystal in nat. size. Lilla Ellringe.

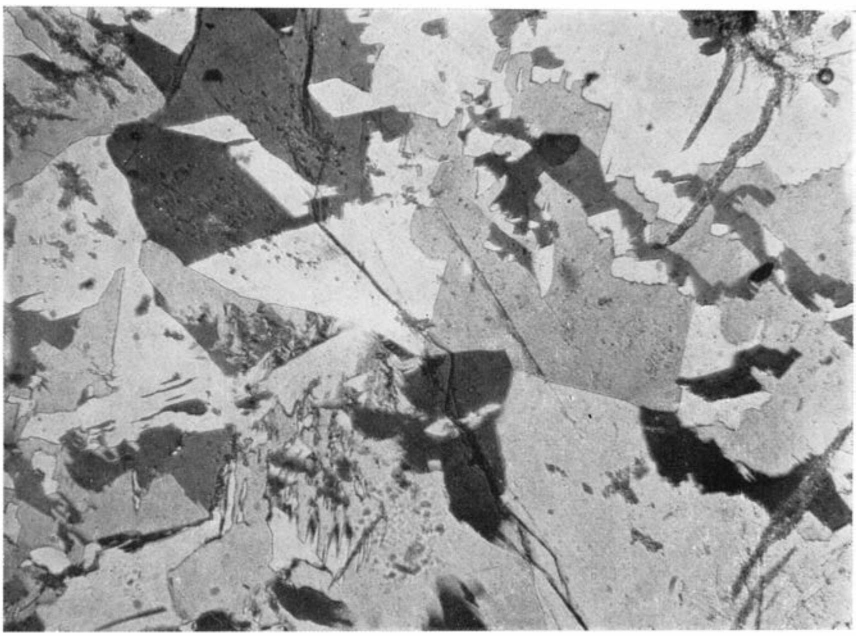
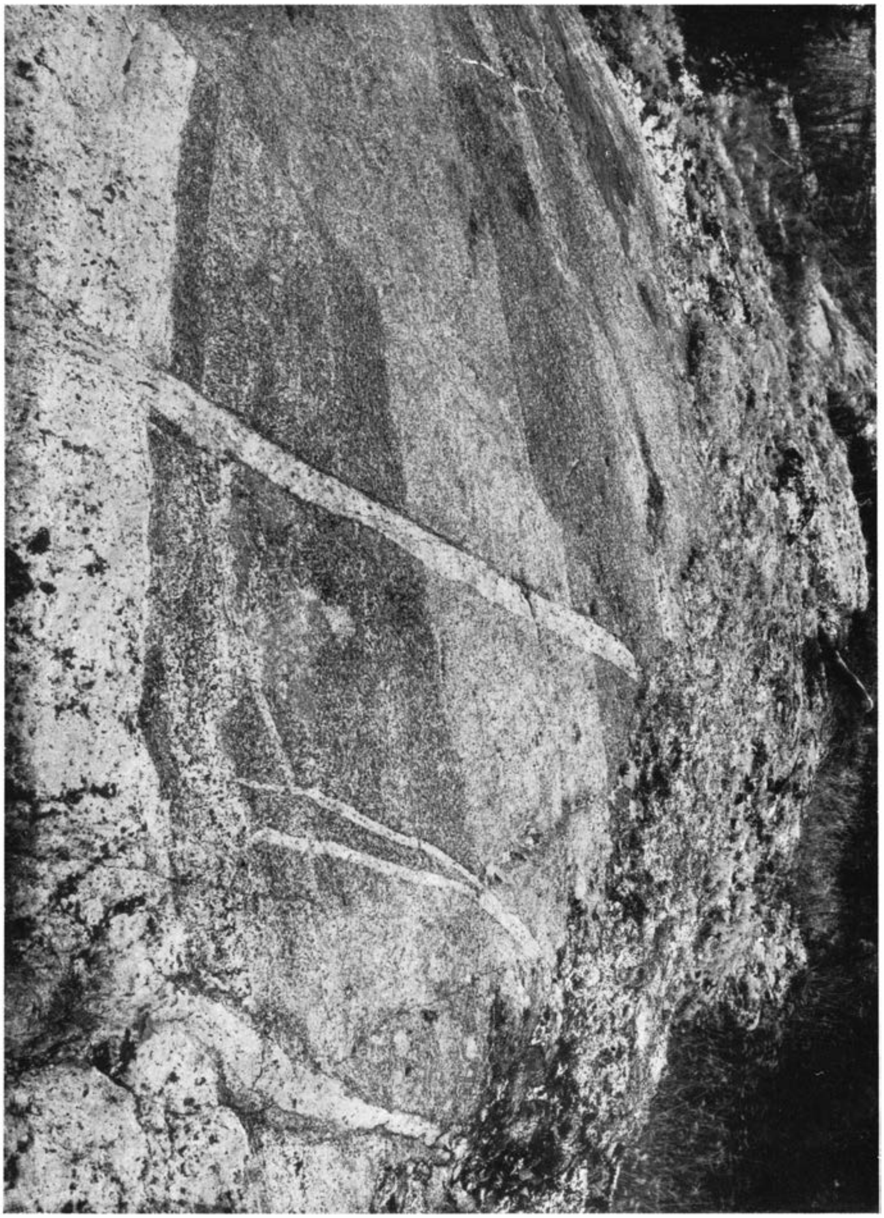


Fig. 2. Section of fig. 1, perpendicular to c, showing twinning in three symmetrically extinguishing individuals, in the photo black, gray and white.



Contact between umptekite and canadite at Byske, showing veins of umptekite in banded canadite. Note typical, spotted appearance of umptekite, without any chilled edge towards the contact.

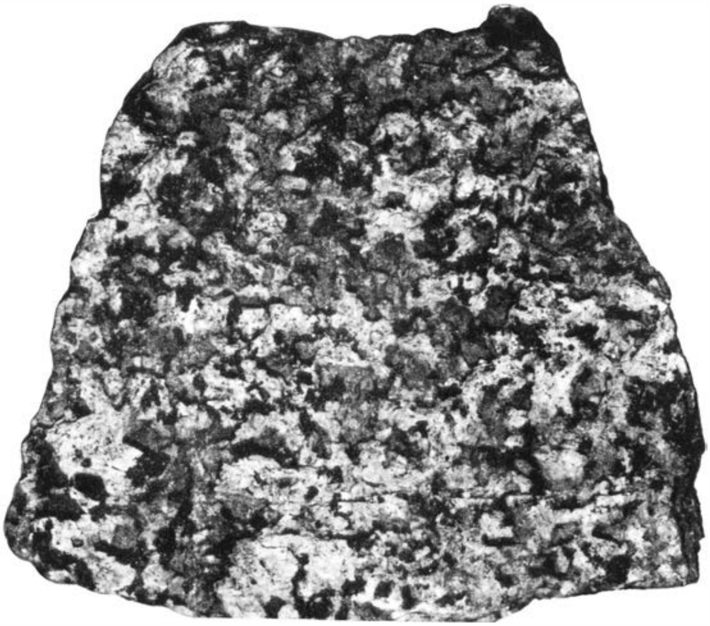


Fig. 1. Weathered surface of typical canadite. Sågen. Nat. size.

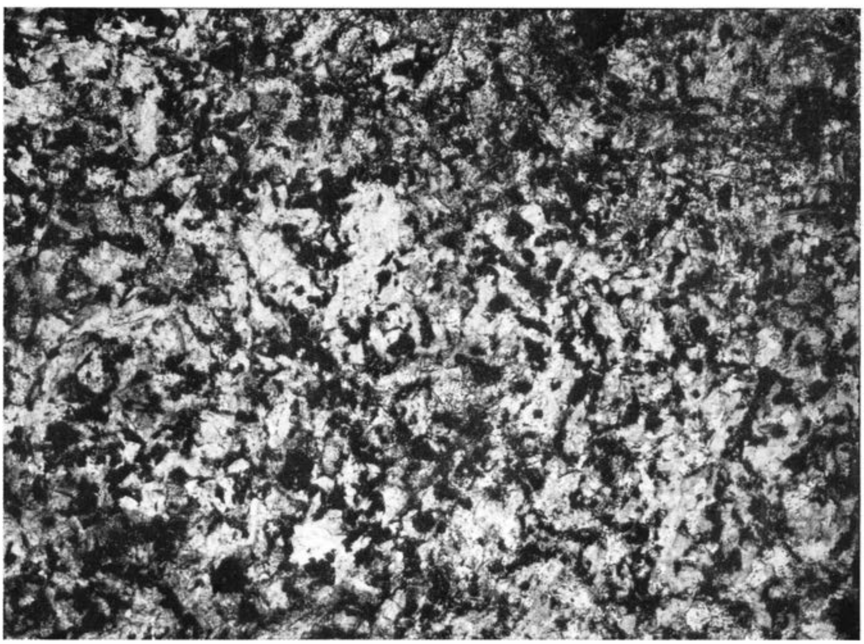


Fig. 2. Weathered surface of canadite, Byske. In the photo the feldspar is white, the nepheline gray, biotite and hornblende black. $^1/_2$ nat. size.

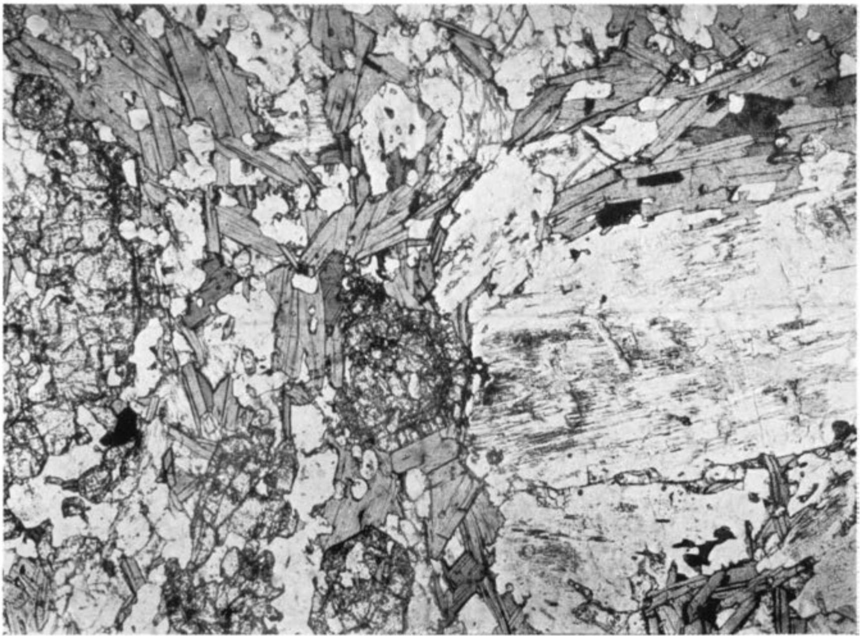


Fig. 1. Section of vesuvianite-bearing canadite. In the photo albite, biotite and vesuvianite are distinguishable, the latter mineral in the middle and left part of the section.

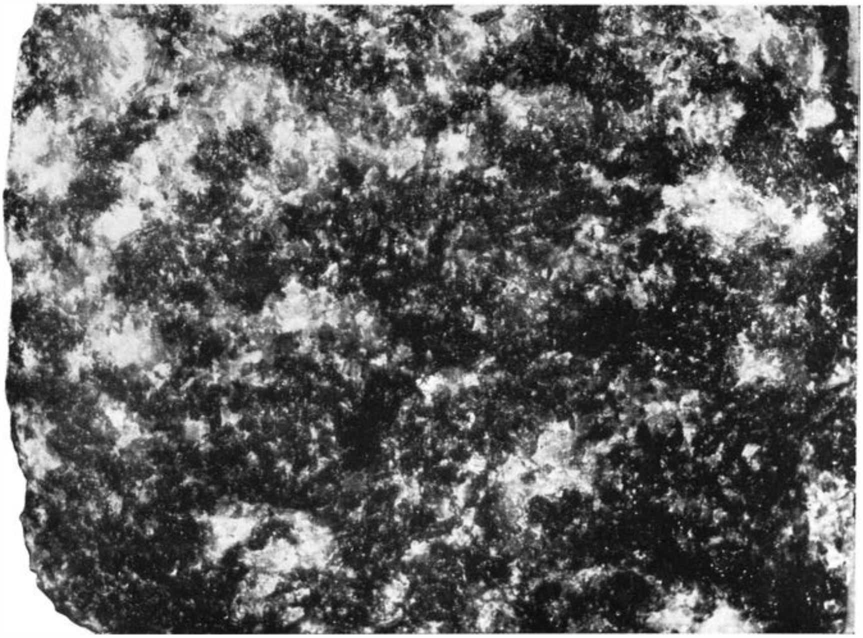


Fig. 2. Typical marginal facies of canadite near contact to umptekite. Nat. size. South of Sågen.

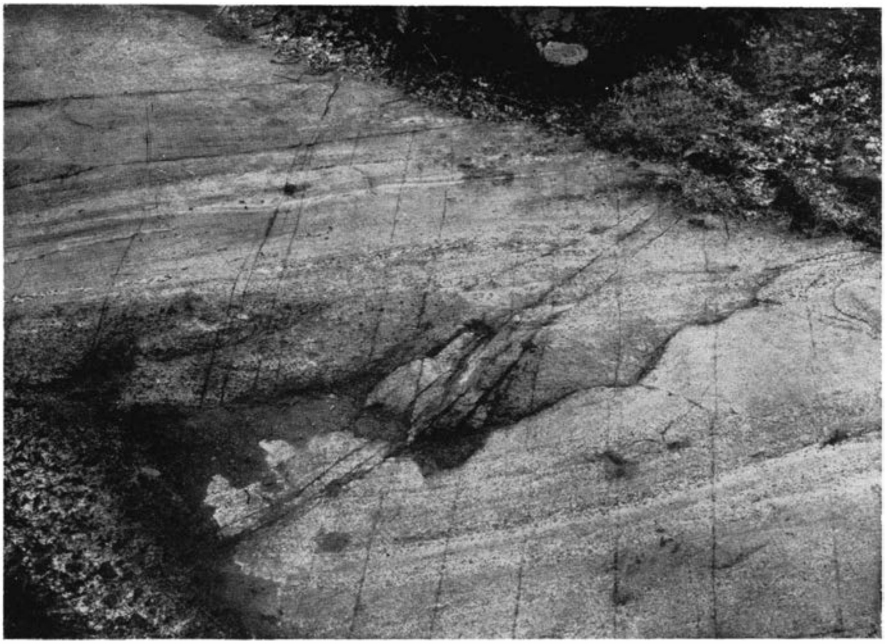


Fig. 1. Schistose canadite, Lilla Ellringe. The small dark spots are weathered nepheline crystals.

Fig. 2. Enlarged, coarse-grained part of fig. 1, showing large portions of nepheline in the foreground and albite crystals in the middle of the photo. 1/2 nat. size.

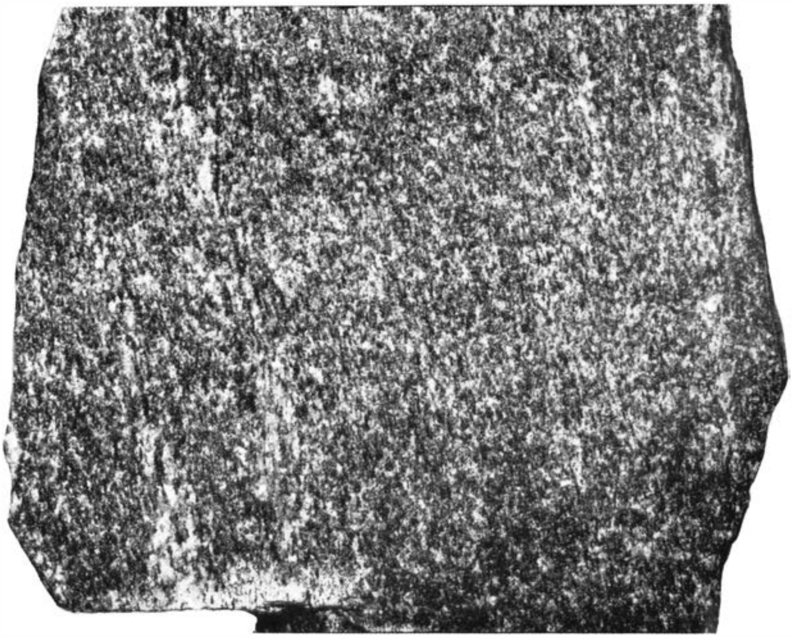


Fig. 1. Fine-grained, schistose canadite, Lilla Ellringe. Nat. size.

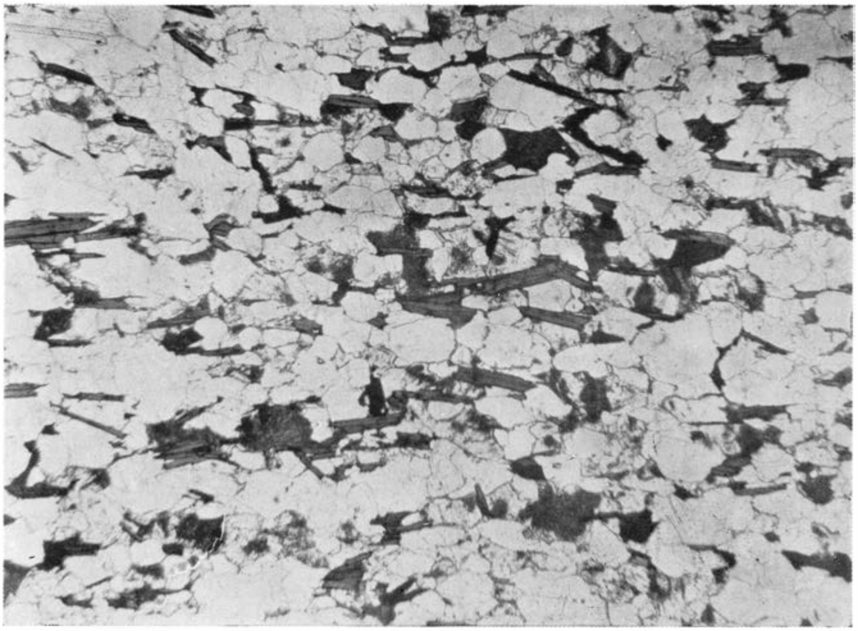


Fig. 2. Section of fig. 1, principally composed of albite, nepheline and biotite.

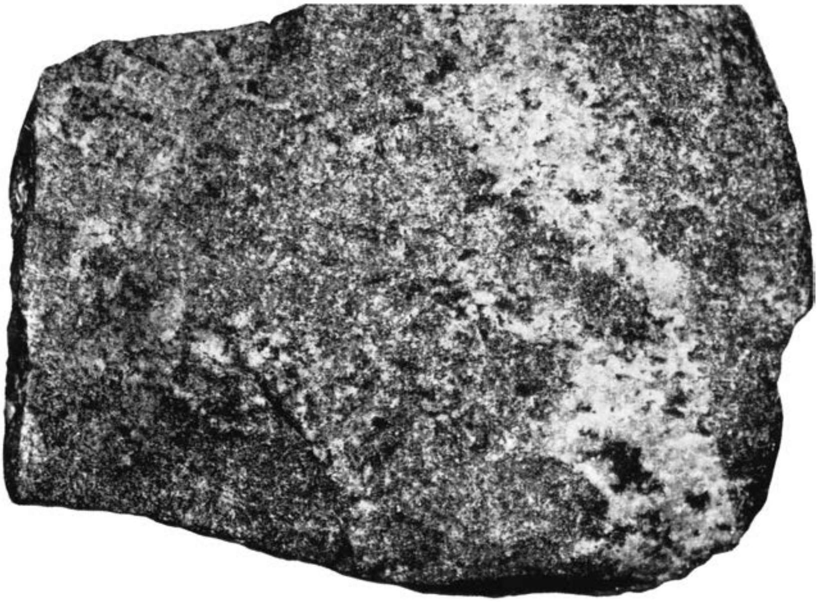


Fig. 1. Schistose canadite, west of Uddnäs, showing the intrusive umptekite magma. The specimen is photographed nearly parallel to the schistosity.

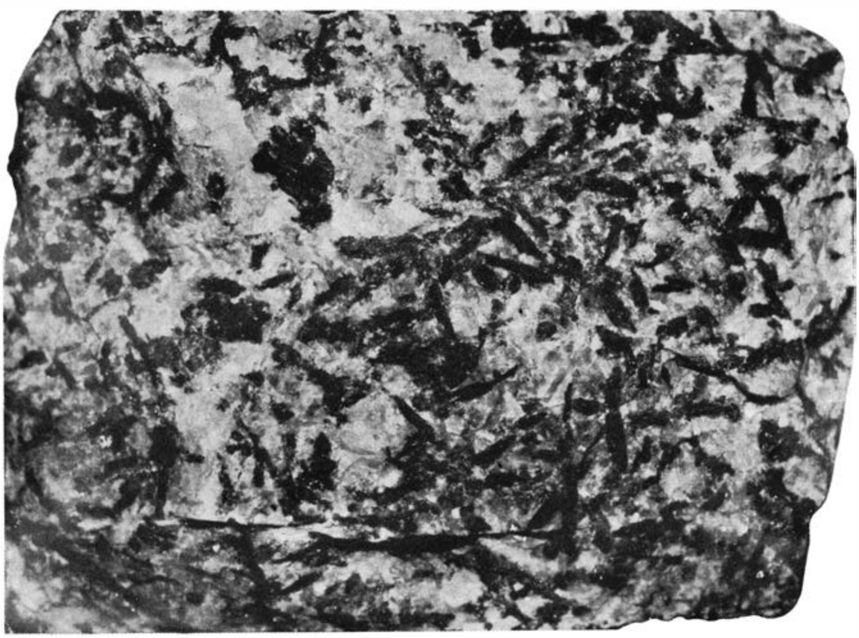
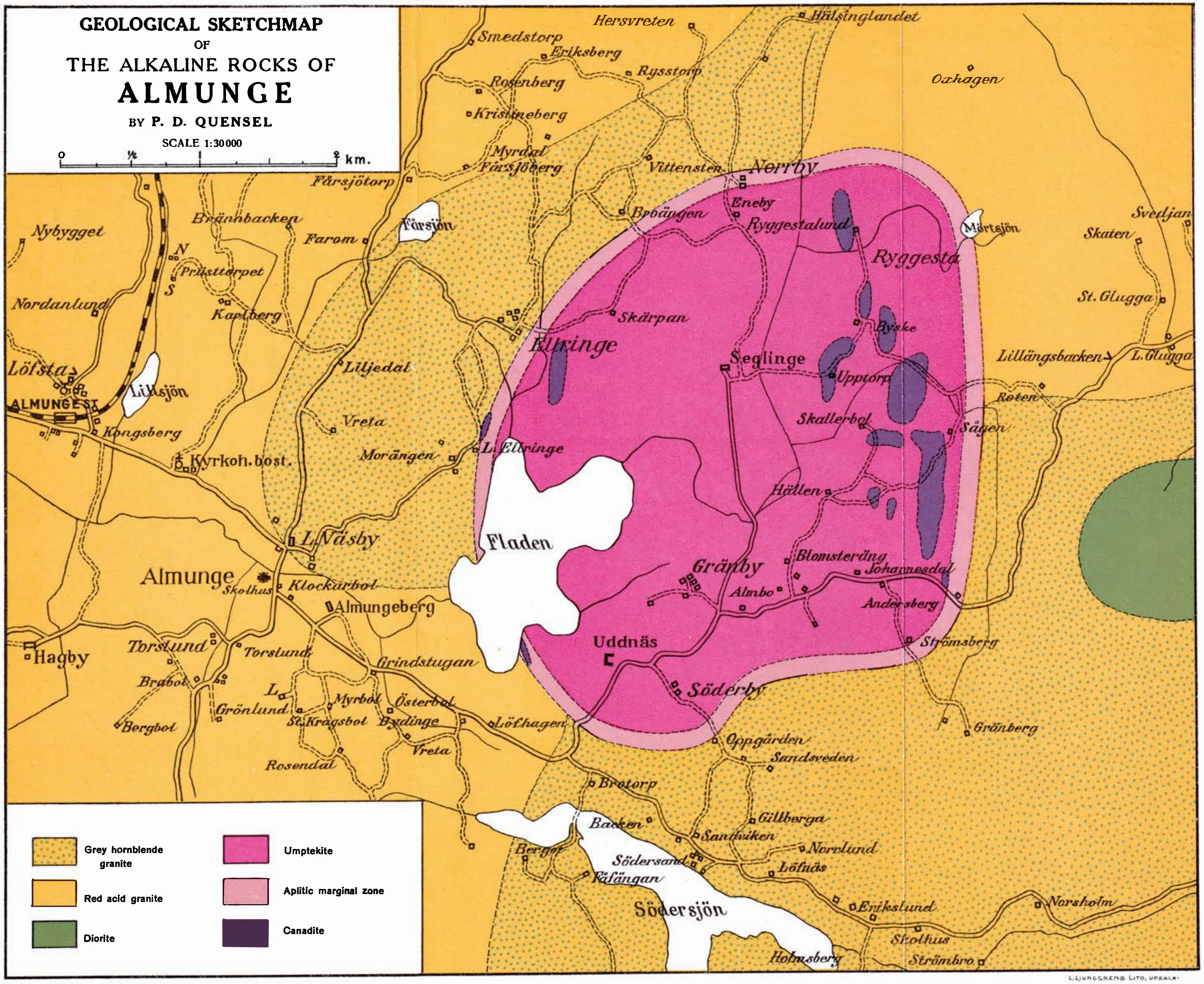


Fig. 2. Pegmatitic canadite. South of Sågen. Nat. size.


GEOLOGICAL SKETCHMAP
OF
THE ALKALINE ROCKS OF
ALMUNGE
BY P. D. QUENSEL
SCALE 1:30000
0 ½ 1 2 km.
Grey hornblende granite
Red acid granite
Diorite
Umptekite
Aplitic marginal zone
Canadite
Almunge
Fladen
Södersjön
Norrby
Ryggesta
Ellringe
Seglinge
Gränby
Söderby
Uddnäs
L. Näsby
Hagby
Lillsjön
Färsjön
Mörtsjön
ALMUNGE ST.
L.LJUNGGRENS LITO, UPSALA.