The igneous rocks of Ragunda, Alnö, Rödö, and Nordingrå

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By

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(With Pl. 10—11.)

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Introductory.

Among the occurrences of post-Archean igneous rocks in Norrland, the areas here to be discussed offer the greatest interest. They form altogether a petrographical province, the rocks of which may be regarded as co-magmatic.

The acid and intermediate rocks in these areas are characterized by their richness of alkalies, thus being true alkali-granites and syenites, and in the nepheline rocks of Alnö the

alkali enters with a high percentage also in the ferro-magnesian silicates. Although the rocks of Alnö differ, in many respects, from the rocks of the other massives and are also, probably, somewhat younger, it may be suggested that they belong to the same petrographical province. Taken together, all these massives form a complex which may petrographically be compared with the renowned post-Silurian igneous area of southern Norway or with any other foreign igneous complexes in which alkali-granites, syenites, nepheline-rocks of different kinds and various basic rocks have, by differentiation, separated from a common magma.

As to the geological age of these massives only the Nordingrå area offers any direct evidence. As has been demonstrated by the writer in the paper »On the pre-Cambrian geology of Sweden», cited above [5], this massive is older than the Jotnian sandstone-formation of the Ångermanland coast-belt and is separated from that formation by a period of denudation. The massive has in the paper cited been referred to the *sub-Jotnian* division of pre-Cambrian time. The obvious affinity of this massive to the Ragunda and Rödö massives, and the striking analogy between these three areas and the Finnish rapakivi areas, which by their relations to Jotnian sandstone-formations are proved to be of sub-Jotnian age, make it very probable that these massives of Ragunda and Rödö are contemporaneous with the massive of Nordingrå. As for the nepheline-rocks of Alnö, they may possibly be essentially younger, inasmuch as they have been found cutting the rapakivi rocks of Rödö, but no facts are known to lead to such an opinion.

As a peculiarity which the sub-Jotnian rocks of Nordingrå and Rödö have in common with some of the Finnish rapakivi areas, is to be mentioned their geographical connection with *post-Jotnian* intrusive beds of diabase, generally developed as the olivine-bearing type known under the name of »Åsby diabase» (TÖRNEBOHM).

This connection, however, has no petrographical significance, but is probably caused by the sandstone that is associated with these massives and that in Fennoscandia is generally accompanied by that diabase-type. Where the sandstone is wanting, as for example in Ragunda, the Åsby dia-

Fig. 1. Sketch-map showing the distribution of the igneous areas.

base is wanting too, and the massive contains no other olivine-rock which could represent a magma of this type.

All the igneous areas to be considered here have been described at some length in the monographs already cited. As these monographs will be available to the partakers of the

excursions, it is not necessary to detail their contents on this occasion. It may be sufficient briefly to sum up the main features of each area and to call attention especially to the localities which will be visited and demonstrated.

Ragunda.

General sketch.

The »Ragunda massive» is a laccolitic igneous mass, intruded in the Archean, and is chiefly composed of alkali-granite (»Ragunda granite»), grading into syenites (Nordmarkite etc.), and of a gabbroid quartz-diabase (»Ragunda diabase»).

In the deep valleys of the Indal river and its tributaries, the interior of this laccolite — or rather swarm of laccolites — is well exposed. One finds that the diabase is confined to the valleys and to the lower isolated mountains which rise between them, whereas the higher mountains which border the main valley are built up mainly of the granites. The syenitic rocks are confined to the western part of the massive, where they play the same role as the granite in the other parts. The bottom of the laccolitic mass has nowhere been reached by erosion, but it seems probable from some facts, that the diabase is not only covered by the granite and the syenite, but also — at least in the western parts of the area — rests on these rocks, consequently forming a nucleus or core in them. Considering the structures of the laccolitic rocks, which indicate that they were not consolidated under conditions characteristic of bathylithic or great plutonic masses, but rather under conditions prevailing in smaller magmatic bodies and intrusive sheets (micrographic and ophitic structures), it may be suggested that the bottom of these laccolitic rocks does not lie far below the bottom of the valley. The schematic figure 2, compared with the sections and the map in the monograph, will give an idea of the architecture of this massive. At the borders of the massive

remains of the Archean granites and schists which once formed the covering of the laccolite are still to be seen in many localities (cf. figg. 3 to 6). From the topographical features of the massive itself and of its surroundings it may be concluded that the former had originally a gently vaulted shape, with its highest parts rising above the present summit-level of the surrounding Archean. The minimum thickness of the laccolitic mass must have been, in its central parts, at least 300 to 400 *m*. Compared with its extent, however, this thickness is quite insignificant, and the injected body is, broadly considered, rather a disk-shaped sheet than an arched lens.

A very striking feature of the relation between the diabase and the granite is the intricate breaking up of the former by the latter, the granite forming everywhere a net-work of veins and dikes in the diabase, thus giving rise to an intrusion-breccia in which the fragments of the diabase are cemented and more or less metamorphosed by contact with the intruding granite.

Intermediate rocks, generally characterized by their chemical and structural inconstancy, have often been produced by the melting and resorption of the diabase in the granite. The laccolitic rocks, especially the granite, have also intruded into the covering Archean, forming in it numerous apophyses and veins (cf. Monogr. 1, figg.

Fig. 2. Schematic section through the Ragunda laccolite, I Archean; II granite and syenite; III diabase; x dikes; a—b the present land-surface.

2, 3, and 8). Dike-rocks of different kinds cut the rocks of the massive as well as its surroundings. Some of the basic rocks are amygdaloid, thus proving that the thickness of the covering cannot have been great at the time when these dikes were formed.

The surroundings of Ragunda railway station.

Close to the station a dome-shaped hill, *Stationsberget*, rises to a height of 230 m above the railway. It is a laccolite parasitic on the main laccolitic mass and consists

Fig. 3. Stationsberget. *Ragunda granite*, partly covered by the *Archean*. [1]

Fig. 4. Middagsberget. *Ragunda granite* (a and b) covered by *Archean granite*; gg, apophyses from the former in the latter. [1]

of typical »*Ragunda granite*» with a well-developed jointing which dips in all directions outwards from the top. On the southern side of the top the *Archean gneiss* covers the granite, which encloses fragments of the gneiss and sends out veins into it.

To the west of the station the steep hill *Middagsberget* affords better opportunity of studying the contacts. The lower part of the hill consists of the *Ragunda granite*, the upper part of the coarse porphyritic *Refsund granite*,

which is a late Archean (Serarchean) granite (cf. Monogr. 5).

At the foot of the smaller hill, which in the figure lies in the foreground, close to the rivulet Singån, the contact between the overlying older granite and the intruded Ragunda granite can easily be traced a long distance.

In the railway-cutting, fig. 5, the older granite is cut by a number of dikes of the Ragunda granite as well as of some basic dike rocks.

Fig. 5. Section showing the Ragunda granite and the covering Archean granite (cf. figg. 3 and 4). [1].

The localities now mentioned are representative for the contacts between the massive and the covering Archean rocks. Further illustrations are given by other mountains in the neighbourhood. Thus the hill *Vindråberget*, east of the station, shows on its northern slope a prominence of gneiss lying as a cover on the laccolite (fig. 6).

Fig. 6. Vindråberget. Significations same as in fig. 3. [1].

Before leaving the surroundings of the station, it may be noted that the conspicuous hill *Näsberget*, which rises over the valley in the north, contrary to the isolated mountains north of the Indal river, is composed, not of diabase, but of granite.

Hammarforsen and environs.

The rocks which border this celebrated cataract¹ are exceedingly well suited for a study of the diabase-breccia oc-

Fig. 7. *Diabase-breccia*. The fragments are partly resorbed by the granite. Hammarforsen. $\frac{1}{3}$ nat. size. [1].

curing in the lower and central parts of the massive. One finds there all the stages of contact metamorphism exercised on the diabase by the penetrating Ragunda-granite.

¹ On the history of this waterfall, see the monograph on Ragunda [1] p. 88, or the Excursion A 6.

Fig. 8. The precipice of the mountain Stadsberget. [1].

In the hills east of the church the diabase (or the diabase-breccia) reaches more than 200 m above the level of the river.

In the amphitheatric depression on the south side of the mountain *Snöberget* (NNE. of the church) and in the adjacent *Löfliden*, the diabase is covered by a sheet of the Ragunda granite, which in its turn, a little farther to the north, is covered by the Archean granite, already known from the environs of the railway station (cf. Monogr. 1, fig. 2).

Krångede rapids and the mountain Stadsberget.

If possible the western part of this igneous area, which from the tourist's point of view is of great interest, will be visited. In that case the syenitic rocks, some interesting intermediate rocks derived from the resorption of the diabase in the granite, and some basic dike-rocks will be demonstrated. (Cf. 1, p. 107).

Alnö.

General sketch.

The nepheline rocks of Alnö occupy an area of about 12 km² on the northern end of the island. This small area encloses a great number of peculiar rocks and rock-varieties and is quite unique in its petrographical diversity. By a far-reaching differentiation the magma has produced a series of rocks ranging from ordinary nepheline syenites through nepheline-melanite and nepheline-aegirine rocks to basic pyroxene-rocks (»jacupirangites») or olivine- and magnetite-rocks. By various structures and varying amounts of the subordinate constituents (cancrinite, calcite, apatite, etc.) other varieties arise.

The most striking feature of this massive is the occurrence of big bodies of limestone intimately connected with

the nepheline rocks. Generally the limestone is interlarded with the minerals of these rocks, and at the boundaries grades slowly or quickly into them. In the vicinity of the limestone occurrences the nepheline rocks are often also very rich in calcite, which in many varieties of these rocks forms graphic intergrowths with the silicates. Other evidence also proves that the calcite and the limestone have really formed

Fig. 9. *Aegirine-melanite-nepheline rock*. Nat. size.

part of a magma and have been consolidated together with the silicates and silicate rocks. Fluidal structures are very common in the limestone, as well as in the nepheline-syenite bodies which occur at some localities as inclusions in the limestone. Some rare minerals (e. g. pyrochlore, knopite or cerium-perowskite, manganophyllite) have been found in the limestone occurrences in the small islets close to Hörningsholm.

The contact phenomena on the boundaries of the massive are also of interest and contribute to the petrographical diver-

sity of the area. The Archean gneiss has been resorbed by the nepheline-syenite magma on an unusually large scale; and by this process the nepheline-substance has been transformed into albite and perthite, and thus a border of syenite has arisen in which the nepheline is wanting and is replaced by alkali-felspars. Between this boundary form of the massive and the unaltered Archean gneiss all stages of metamorphism and resorption are represented. On the map accompanying the monograph on Alnö, two boundary zones have been marked, the inner representing the syenite just described, the outer representing the still recognizable, but distinctly contact-metamorphosed gneiss. As a principle for the separation of these two boundary belts the presence or absence of gneiss-quartz in the rock has been taken. It ought, however, to be said that in nature these belts have not the distinctness and regularity which is given to them on the map.

The massive rocks of this area are cut by a great number of different dike-rocks, as alnöites, monchiquites, nephelinites, tinguaites. Among them, the alnöites are the most conspicuous. They are often interspersed with endogene inclusions and with fragments of the surrounding rocks. The dike-rocks are even met with at some distance from the massive. The greatest distance from the massive at which dikes belonging to this group are known as yet is from 8 to 10 *km*.

The time for excursions being limited to only one day, the following localities are best suited to give information on the most characteristic petrographical features of the massive.

The landing stage of Äs.

Following the shore some hundred meters southwards from the landing-stage, one has an opportunity of seeing almost all the rocks of the massive represented among the blocks and boulders which are accumulated on the shore-line. Owing to the freshness of their surfaces, these boulders show the mineralogi-

cal and structural characters of the rocks more distinctly than do the weathered and lichen-covered rock surfaces in the inner parts of the island.

Having seen these samples of the rocks of the massive, one turns back to the landing-stage. There, a little to the north, a store of the titaniferous iron ores, which have formerly been worked in some small mines of Ås, Stafsätt, and Släda, gives typical specimens of these ores and of the

Fig. 10. *Limestone with flow-structure and a nodule of the minerals of the nepheline-syenite. Nat. size.*

associated pyroxene- and olivine-rocks. The ores are partly mixtures of apatite and titanomagnetite, partly of olivine, pyroxene or mica, and titanomagnetite. In the latter varieties the mineral baddeleyite (ZrO_2) is a subordinate constituent.¹

¹ The mineral was first identified by HUSSAK in a sample of ore from this locality.

In the vicinity of the landing-stage, some quarries opened in the limestone show the interesting relations between this rock and the adjacent nepheline-syenite (nodules and lumps of nepheline-syenite and isolated porphyritic nephelines and other minerals in the limestone).

Ås.

Close to this village and to the carriage road, some quarries further illustrate the mode of occurrence of the limestone.

Fig. 11. *Nodule of nepheline-syenite in limestone. Ås. Nat. size.*

The hillocky surface of the country around Ås is characteristic of some parts of the massive and is caused by the varying resistance offered by the various rocks to weathering and denudation.

To the north of the village occur some rock varieties which are essentially composed of nepheline and melanite.

Calcite is a primary constituent in some varieties of this nepheline-melanite rock.

Stolpås.

The limestone west of Stolpås is developed as a coarse pegmatite containing, together with the calcite, also pyroxene, melanite, nepheline, orthoclase, apatite, and magnetite.

Graphic and other peculiar intergrowths between these minerals occur in some parts of the limestone area of Stolpås.

Fig. 12. *A—A'* is a twin of calcite after $-\frac{1}{2}R$. Aegirine, nepheline melanite are intergrown in the calcite parallel to oR .¹ Nat. size.

South of the village the nepheline-syenite comes in contact with the Archean gneiss, which is more or less metamorphosed or transformed into the syenitic rock already describ-

¹ This intergrowth is described by the writer in a paper published in *Bull. Geol. Inst. Upsala*. Vol. VIII (1907).

ed (p. 358). In the same locality dikes of a dense, greenish tinguaita are also met with.

Stornäset.

South of the saw-mill. the massive is well exposed, showing different stages of metamorphism and assimilation. The limestone and the nepheline-syenite show interesting relations also in this locality.

Långörsholmen.

At the north-western end of this small island, basic pyroxene rocks are cut by veins and irregular dikes of a salic

Fig. 13. *Parallel dikes of limestone in nepheline-syenite.* $\frac{1}{2}$ nat. size.

nepheline-syenite. The latter becomes dominant over the basic rock at the outermost point of the island, there being in contact with limestone. The contact-line between the two rocks suggests that they were simultaneously in a fluid condition. Great flakes of mica, partly in graphic intergrowth with calcite, are accumulated in the limestone near the con-

tact. The dikes of nepheline-syenite which cut the limestone are often folded or divided into isolated lumps which sometimes show trachytoidal or concentric structures (Monogr. 2, p. 73). Among the numerous dikes which cut the massive rock in this island the peculiar dense limestone dikes, described in monograph 2 (pp. 19 and 91), should especially be observed.

Other localities.

If there is time, some other localities also deserve a visit. In the quarries at *Boräng* orthoclase (containing

Fig. 14. *Graphic intergrowth between olivine and calcite. Söråker.*

baryum), titanite, and pyroxene play a prominent part in the coarse pegmatitic limestone. In the village of *Hartung* a nepheline-melanite rock occurs, the nepheline of which is transformed into a white or light greenish substance contain-

ing about 30 % CaO, 9 % Al_2O_3 , and 41 % SiO_2 . (Monogr. 2 p. 41). The coast strip of *Söråker*, on the opposite mainland, is also worthy of notice for some peculiar rock-varieties belonging to the massive of Alnö, but as there will hardly be a change of extending the present excursion so far, it will be sufficient to refer to the remarks about this locality in the monograph and to the hints for visitors given there.

Rödö.

The small island Rödö, SE. of the massive of Alnö described above, consists for the greater part of a coarse rapakivi-rock which, because of its red colour, has given the island its name (Rödö = red island). This rapakivi holds, in its petrographical characters, a somewhat intermediate position between the rapakivis of Finland and the Nordingrå granite subsequently described, on the Swedish side of the Bothnian Gulf. The massive is accompanied by a great number of dikes, the rocks of which are most varied. Between the acid quartz-porphyrries and the basic porphyrites occur several intermediate rock-types, which are often very heterogeneous and contain more or less resorbed inclusions. Complex dikes, with a femic boundary zone and a salic middle belt are also met with.

These dike-rocks cut the rapakivi massive as well as the Archean rocks. The islets *Skurfven* and *Storholmsfläsjan*, both situated a little to the south of Rödö, display the greatest variety of these dikes and ought certainly to be visited.

Quartz-porphyrries which might be connected with the rocks of Rödö have also been found at some distance from this massive, for instance, in the immediate vicinity of Sundsvall.

Worthy of notice in connection with the Rödö rocks are some small islets, a little to the SE. of *Storholmsfläsjan*;

they consist of an olivine-diabase (Åsby diabase), exactly resembling the diabase which is associated with the massive of Nordingrå.

Whether Rödö and the adjacent small islands just mentioned can be visited on the occasion of the Congress excursion

A. HJ. OLSSON foto.

Fig. 15. *Dike-porphry*, Rödö. Half natural size.

sions now under consideration, will depend on wind and weather. Some of the rock-types of this massive, however, recur in Nordingrå, where at all events they will be accessible to the participants in the excursions.

Nordingrå.

General sketch.

As has been described in the monograph by LUNDBOM [4] and in the paper by the writer »On the pre-cambrian geology of Sweden» [5], the coast belt of the province of Ångermanland, between the towns of Hernösand and Örnsköldsvik, is composed essentially of post-Archean igneous rocks, of which one group, consisting of granites and gabbros, is of sub-Jotnian age and older than the Jotnian sandstone, whereas the other group, represented by diabases, is post-Jotnian and intrusive into this sandstone. The former group occupies the western parts of this area and forms a very mountainous landscape, intersected with firths, lakes, and valleys. The diabase forms a series of table mountains which run as a belt along the eastern margin of the area and constitute the outermost headlands and islands. The sandstone appears in the western escarpments of the diabase mountains as more or less prominent terraces, and rests on the granites and gabbros of the west. The sandstone belt is not continuous; thus the diabase beds partly rest immediately on the granite or gabbro. Broadly considered, the sandstone shows a gentle dip of only some few degrees to the E. or SE., but displacements by faults are not uncommon. Probably the boundary of the granites and gabbros on the western Archean is also to some extent marked by faults. Partly, this western boundary of the area seems to be of a laccolitic character comparable with the boundaries of the Ragunda massive already described. With regard to the distribution of the granite and gabbro in relation to each other and to the Archean, a difference between this area and the Ragunda area is worthy of notice. While the basic rocks of the latter are confined to the interior and to the deeper parts of the igneous mass, in the area here under consideration the basic rocks chiefly occupy the outermost parts or the belt bounding the Ar-

chean; the granites, on the contrary, appear in the inner parts, thus being separated from the Archæan by the gabbro rocks. The Nordingrå massive, on the other hand, shows a striking resemblance to the Jaala massive in Finland, described by FROSTERUS.¹ This similarity is not only in respect to the distribution of the rocks, but is also very striking with regard to their petrographical characters and to the peculiar contact-effects induced by the younger granite or the rapakivi in the first consolidated basic rocks.

The basic rocks of the Nordingrå massive have been marked on the map partly as *gabbros* partly as *labradorite-rock*. The former are fine or medium-grained and composed essentially of labradorite, diallage, hornblende, mica, and magnetite. As subordinate constituents, orthoclase and quartz are often present. Olivine-bearing varieties are wanting. The structure is generally granitoid, but a tendency to diabase structure is not uncommon. The felspar is often developed as tabular porphyritic crystals. The gabbros have on the whole the same petrographical appearance as the basic Ragunda rocks, in which, however, the diabase characters are more conspicuous.

Other varieties of the Nordingrå gabbro are coarse grained and pass into *labradorite-rocks*. The great tabular plagioclase crystals then stand out from the scarcely present dark constituents and often give the rock a porphyritic appearance. In the vicinity of the granite, intermediate rocks often occur to a not insignificant extent, and have been recorded as »gabbro-granites» and »gabbro-syenites». Their extremely varying composition and heterogeneity, together with their mode of occurrence, indicate that they have arisen by a resorption of the basic rocks in the granitic magma. They must accordingly be regarded as genetically analogous to the contact formations of the granite described later.

The *granites* have an unmistakeable likeness to the Fin-

¹ Geol. öfversiktskarta öfver Finland, Sect. C 2, St Michel, Beskrifn. till kartan (Résumé en français). Helsingfors, 1902.

nish rapakivi rocks on one side and the Ragunda granite on the other. They are of a saturated red colour, are often more or less distinctly porphyritic, with the larger felspars lying in a micrographic ground-mass. Mirolitic cavities with quartz, fluorite, and calcite occur in some varieties, and zircon is always present. The femic minerals generally play an insignificant part in the rock. They are mica, amphibole, augite, and magnetite, with the same characters and mode of occurrence as in the Ragunda granite (Monogr. 1, p. 47 et seq.). Some varieties of the granite contain quartz only subordinately and closely approach syenites of the same characters, as the quartz-syenites of Ragunda, but true syenites are wanting in this massive. In the boundary zone of the gabbro and the granite, the former is penetrated by dikes and veins of the latter, and there peculiar phenomena of resorption occur, much resembling the contact-effects of the Ragunda granite on the diabase, already described (p. 354). Although the granitic intrusions are here confined chiefly to the boundary belt and do not, as is the case in Ragunda, extend over the whole area of basic rocks, the resorption here seems to be greater. The »gabbro-granites» and »gabbro-syenites» already mentioned, with their varying composition and structure, occupy considerable areas, as is shown on the map. Only locally do these rocks have the monotony and homogeneity of a definite monzonitic rock; they mostly appear as formed by accidental heterogeneous mixtures of a basic and a granitic magma.

A special interest attaches to the granitic intrusions in the coarse porphyritic labradorites. The granitic magma has often penetrated the labradorite so intricately that a peculiar porphyritic rock arises, consisting of a granitic or micrographic ground-mass in which the labradorite crystals lie embedded. By this process, the femic minerals of the labradorite-rock have generally been transformed into chloritic aggregates, whereas the labradorite crystals seem to have suffered only

insignificant alterations. In many places, one can find all stages of transition, from the unaltered labradorite-rock to the normal granite.

Dike-rocks, which in the other igneous areas here described contribute to their petrographical diversity, play in the Nordingrå massive and its surroundings an insignificant part. Only a few dikes, quartz-porphyrries and basic rocks, have been noted, and they offer no special interest.

Besides the contact-effects on the gabbro rocks now described, attention may also be called to the various stages of resorption which are to be seen between the granite and the bodies of Archean schists included in this rock. The latter have occasionally given rise to recrystallized porphyrite rocks of various kinds. All these manifestations of the contact-effect exercised by the granite are extraordinarily well illustrated in the shore-rocks of the Omne firth (see below).

The younger *olivine-diabase*, which occur in this area of sub-Jotnian igneous rocks, is a medium- or coarse-grained rock with a pronounced ophitic structure. The main minerals are plagioclase, diallage, olivine, and titanomagnetite, which, by their varying amount, produce a rather great variation in the composition of the rock. Often the different varieties form distinct bands, resembling the well-known Tertiary banded gabbros of Skye. In some varieties the titanomagnetite is concentrated to such a degree as to give rise to an iron ore. Some small mines have been worked in this rock.

In some varieties of the diabase, a conspicuous fluidal structure is to be seen, marked either by the alternation of different varieties such as those just described or by the sub-parallel arrangement of the tabular plagioclase crystals. This fluidal structure is generally conformable to the contacts of the diabase with the sandstone and the granite.

Small intrusive sheets of diabase are also met with in many localities between the sandstone beds.

Near the contact, both with the sandstone and with the

granite, the diabase has by resorption lost its olivine and has been transformed into a quartz-diabase with well-developed micrographic structure. Between the diabase and the granite, there have thus been formed some intermediate rock varieties, which might be compared in some respects with the 'gabbro-granites' already described. These intermediate rocks show very complicated contact relations with the diabase and the granite. Sometimes it seems as though the diabase were penetrated by these intermediate rocks and as if the granite were younger than the diabase. This interpretation is apparently supported by the occurrence of red granitic veins in the diabase. These veins, however, may be interpreted as salic segregations from the diabase magma itself and ought not to be considered as genetically connected with the great granite massive, which is not only older than the diabase, but so much older, that a great period of denudation and a later period of sedimentation — the formation of the Jotnian sandstone — intervened between the diabase and the granite (5).

For an account of *the sandstone* reference should be made to the monographs cited above (4 and 5). It may, however, be noted here that the sandstone formation is laid down on the strongly weathered granites and gabbros, the weathered products of which often form its immediate substratum.

Hints for the excursion.

The most interesting localities are to be visited from the sea-side, the steamers on the route Hernösand—Örnsköldsvik calling at a number of ports in the firths and on the islands of this coast line. Coming from Hernösand, one first encounters (to the right) the island *Storön*, a table of diabase, resting on the sandstone, which is exposed at the southern end of the island.

Steering into the beautiful *Gavik firth*, one passes between

the table-mountains of diabase bordering the mouth, and comes into the interior of the firth, which is bordered by a rugged mountain landscape, formed by the gabbro rocks.

On both sides of the southernmost bay, *Ramstaviken*, interesting intermediate forms between the gabbro and the granite are developed.

On the north side of the firth, the mountain *Ringkalleberget* offers a good example of the mode of occurrence of the sandstone, which there forms a terrace below the escarpments of the diabase and rests on the highly weathered gabbro. Small faults, marked by breaks in the sandstone terrace are met with on the western side of this mountain.

At *Häggvik*, the small port in the northernmost branch of the firth, normal gabbro and coarse labradorite-rock are typically developed. In stormy weather, the visitor is recommended to walk from *Häggvik* to *Omne* or *Ulfviken* (2 or 3 hours) through a charming landscape, with wooded gabbro-mountains, pleasant valleys, and mirror-like lakelets. In calm weather, it is preferable to continue with the steamer to the last named localities in the *Omne firth*.

The coast belt between the *Gavik* and *Omne* firths consists of labradorite-rock, gabbro, and diabase. In the small islets *Barstaholmarna*, these rocks are desintegrated by weathering on an unusual scale. In the northern part of this stretch of coast, north of the *Edsätter firth*, the labradorite-rock has partly the character of an intrusion-breccia owing to its intricate interpenetrations by granitic veins. Further north, the diabase recurs, showing a well-developed bedding eastwards and also being in part distinctly banded by the alternation of femic and salic varieties.

Fig. 16. Section through the Ringkalle mountain, showing the gabbro, the sandstone, and the diabase bed. [1].

In the neighbourhood of *Räflan* (south side of the *Omne firth*), the gabbro rocks, the granite, the sandstone, and the diabase are all met with, and interesting contact features between them are well exposed there. This locality is one of the most instructive for the geology of the Nordingrå massive and its associated rocks.

Fig. 17. Sketch-map of the surroundings of *Räflan*. (After HJ. LUNDBOHM).

At *Skälhällsudden* and between *Skatudden* and *Katken* the intrusions of the granite in the labradorite-rock already described occur in all stages of development. At *Hammyrudden*, a little further to the south, the sandstone is exposed, and on the south-eastern side of *Räflan*, close to the path, the bottom layers of the sandstone come in contact with the underlying weathered products of the granite and the gabbro. At *Ulfriken* the same features are repeated.

On the north shore of the Omne firth, east of *Breviken*, the granite is interspersed with large flakes of schist more or less resorbed (cf. p. 369); the effects of contact-metmorphism on these inclusions are very varied and extraordinarily well exposed.

The great granitic area, which succeeds to the gabbro rocks northwards from the Omne firth, is rather monotonous from a petrographical point of view. The contacts with the western gabbro belt, though interesting, are not especially suited for a somewhat hasty visit, inasmuch as the rocks there are generally much more covered than in the coast belt. The great *Ullånger* firth may thus be passed over.

The *Ulfö islands* owe their chief petrographical interest to the contacts between the granite and the diabase; besides which they afford a good opportunity of studying the different varieties of the diabase.

In the fishing-place *Marviksgrundet*, at the south end of the southern Ulfö, the diabase contains bands in which the titanomagnetite is concentrated to such a degree as to produce an iron-ore. The mines, now abandoned, lie just on the shore-line. The ore and the belts of a comparatively salic diabase alternating with it show fluidal structure, arising from the arrangement of the thin tabular plagioclase crystals.

In the immediate vicinity of the *fishing-station Ulfö*, NE. of the hotel, there is a good opportunity of studying the complicated contacts between the diabase and the granite, already described.

It is worthy of notice, that the sandstone is wanting in the Ulfö islands, so that the diabase there comes in contact with the granite. Probably the diabase has been broken up in connection with faults and displacements, so that it does not lie as a regular bed on the granite, but is, at least in part, separated from the granite by the faults. That these faults are contemporaneous with the eruption of the diabase is

shown by the conformity between these faults and the fluidal structure of the diabase in the vicinity of the contacts.

On the eastern side of the Northern Ulfö, a small islet *Gråbuten* (not marked on the map) deserves mention because

Fig. 18. Sandstone covered with and intruded by diabase. Northern end of Skrubban, seen from the west.

Fig. 19. Sketch-map of Trysunda. (After HJ. LUNDBOM).

of the distinct banding of the diabase. In passing along the east side of N. Ulfö, one can distinctly see this banding from the steamer.

Continuing northwards from Ulfö, the steamer first passes the diabase islands *Värnsingarne*. Further to the north, the west side of the island *Skrubban* shows on the shore-line the sandstone-beds intruded and broken up by the diabase which forms the main mass of this island (fig. 18).

The sandstone-formation is also present on the island *Trysunda*, where it lies on the weathered surface of the granite and is covered by the diabase-bed. Iron mines of the same character as the mines in the Ulfö islands have been worked in this diabase.

Between Trysunda and the mouth of the Örnköldsvik firth a row of small islands (Klösan, Vågön, Råskärsön) form the northernmost part of the diabase-belt under consideration. The lower parts, on the western side of these islands, consist of granite, the higher and eastern parts, of diabase, the beds of which have a gentle dip eastwards. The sandstone is wanting in these islands, and the contacts between the granite and the diabase resemble the contacts in the Ulfö islands, already described.

Owing of the exceedingly clear exposure of the rock surfaces in this archipelago, one can form a good idea of the main lines of the geology without leaving the steamer. The points, where a landing is especially to be recommended for petrographical studies, are the localities already described in the *Omne firth* and on the *Ulfö islands*. Among other localities, the surroundings of *Ramsta bay* and *Ringkalle mountain*, both in the Gavik firth, and the island *Trysunda*, offer the greatest interest.