Geologiska Föreningen i Stockholm Förhandlingar

Publication details, including instructions for
authors and subscription information:

<http://www.tandfonline.com/loi/sgff19>

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Published online: 06 Jan 2010.

To cite this article: N. Sundius (1912) Pillow-lava from the Kiruna District,
Geologiska Föreningen i Stockholm Förhandlingar, 34:3, 317-333, DOI:
[10.1080/11035891209448694](https://doi.org/10.1080/11035891209448694)

To link to this article: <http://dx.doi.org/10.1080/11035891209448694>

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Pillow-lava from the Kiruna District.

By

N. SUNDIUS.

(With Pl. 4.)

Pillow-lava or ellipsoidal basalt is a peculiar form of femic lava rocks, the characteristic feature being that the lava beds do not consist of a continuous rock mass, but are built up, entirely or partly, of separate ellipsoidal or rounded pillow-like parts. This phenomenon has been the subject of much discussion in geological literature, and the terms »concretionary dolerite», »agglomeratic greenstone», »sphaeroidal basalt», and others, show how explanations have varied with the various authors. For Swedish geologists, however, this question has never attained actuality, as this lava form has never, as yet, been observed or described from our country. During geological investigations of the extensive greenstone areas in the Kiruna district, however, I have found phenomena which must be regarded as pillow-lava, and which seem to deserve a description. My field work at Kiruna was carried out during the years 1907—1909, at the expense of the mining company, Luossavaara-Kiirunavaara Aktiebolag.

The greenstones in which the pillow-structure appears have been briefly described by LUNDBOHM¹ as a formation 2·5—8 km in width and striking nearly north-south, and forming the

¹ HJ. LUNDBOHM: Sketch of the Geology of the Kiruna District. G. F. F. 32: 751 — a paper partly based on the researches, made by the present writer and Mr. N. ZENZÉN.

lowest (i. e. westernmost) member of the volcanic and sedimentary series of Kiruna. Next to the east, the greenstones are overlaid by the Kurravaara conglomerate, whose rounded and water-worn pebbles show it to be a marine deposit. To the west, the boundary of the greenstones towards the intrusive rocks occurring there is unknown. The formation is regarded by all who have studied it at all closely as pre-Cambrian in age.

The most striking chemical feature of the greenstones is their soda content, which is unusually high for such femic rocks and has caused the describers to designate them provisionally as »soda-greenstones». This thick greenstone formation is built up of effusive volcanic rocks with subordinate quantities of sedimentary material (greenstone tuffs) interstratified between the lava beds. This fact is especially evident on the heights Valkeasiipivaara¹ and Paltosvaara, lying respectively to the North and South-west of Kiruna, where the bed-rock is well exposed, and where I have had the opportunity of studying it in detail.²

During this examination, I found, as a common feature of the greenstones, certain peculiar phenomena that at the first glance might be taken for agglomerates. In the rock there appear narrow somewhat dark-coloured *schlieren* which surround rounded parts of massive greenstone. Along the surface of the latter parts, which are usually ellipsoidal, and everywhere along the *schlieren*, there occur small hornblende-filled vesicles, which stand perpendicularly to the *schliere*. Fig. 1 shows a surface of this kind of rock.

The *schlieren* are mostly quite narrow (one or a few *cm* in width) and consist of alternating darker and lighter-coloured bands. The latter, which mostly consist of scapolite, are narrower than the former and are often concentrated at the middle of the *schliere*; in the angles where several pillows

¹ See LUNDBOHRN, op. cit. Pl. 32.

² Further to the North the greenstones have been studied by N. ZENZÉN.

Fig. 1.

meet and the *schlieren* widen, the whole centre may consist chiefly of scapolite. That the phenomenon in question is not a clastic deposit is apparent: first, from the fact that the *schlieren* sometimes end blindly in the rock, and partly enclose rounded masses which directly cohere with the rock; secondly, from the jointing of the parts surrounded by the *schlieren* and from their various, but always rounded, forms. Sometimes they form ellipsoidal or sphaeroidal bodies, sometimes pinched and in the ends somewhat elongated forms, which, however always fit together and form a mosaic. As the rock of Pahtosvaara has been subjected to little or no pressure metamorphism, this mosaic cannot have been produced by a later pressure but must have been formed through a crowding of viscous lava bodies (pillows). The size of these pillows is very various. They may reach a diameter of more than 0.5 m, but usually do not surpass a few dm.

The soda-greenstones have generally been subjected to a rather strong metamorphism. They are schistose, and new minerals have been formed; but nevertheless the original structures are so well preserved that in many cases one can reconstruct the original rock. Most favourable in this respect is Pahtosvaara, where the pressure has been very weak. As

to the structures and the mineralogical composition of the greenstones the reader is referred to LUNDBOHM's description.¹ Here it needs only be emphasized that these rocks on Pahtosvaara consist mainly of an acid plagioclase (in laths twinned according to the albite and Carlsbader law) and new-formed hornblende. In coarser varieties, the minerals are often ophitically grouped. In the more fine-grained phases the hornblende forms a denser mass in which the long and slender feldspar laths are scattered, often fluidally arranged.

The inner part of a pillow belongs to the fine-grained types of the soda-greenstones, with which they sometimes cohere. For the examination of the outer parts of the pillows, and of the surrounding *schlieren*, thin sections were made from these parts of the rock from various points on the mountain. The *schlieren* consist entirely of new-formed minerals, chiefly hornblende and scapolite. The hornblende is very fresh and is a »common hornblende» with a strong pleochroism in grass green and yellow colours. It forms irregular grains, sometimes a little fibrous or sheaf-like, irregularly accumulated in broader and narrower bands, alternating with bands of scapolite. Among the hornblende there occur small quantities of biotite, epidote and titanite, the latter often gathered in lines and contributing to the banded appearance of the rock under the microscope. The scapolite appears in larger, irregularly outlined individuals. The scapolite mass is usually clear, but is rich in small inclusions of hornblende, biotite, titanite and even apatite. The optical properties correspond to a rather acid mizzonite.

At the surface of the pillow one can distinguish two narrow zones in those cases where no too great development of secondary minerals has taken place. As a typical case, I have selected for description a slide of a pillow (fig. 2) from the southern slope of the mountain, cut perpendicularly to the surface of the pillow. On one side of the slide there is a stripe of the

¹ Op. cit. pp. 756—759.

Fig. 2. Part of a pillow with zone of vesicles and adherent darker *schliere*. The white and weathered dark stripes are scapolite. $\frac{2}{3}$ of nat. size.

schliere adherent to the pillow. It consists of an irregular aggregate of the hornblende described above, with a little biotite in small patches here and there between the hornblende grains. This hornblende stripe has no sharply defined limit against the pillow, but grades into it by a gradually diminishing size of the hornblende individuals. This soldering together of *schliere* and pillow through the development of secondary minerals brings it about that, in taking a specimen of a pillow some piece of a *schliere* always adheres to it. A certain boundary is, however, marked by the occurrence of a dark brown pigment gathered in small patches around minute feldspar laths (Pl. 4, fig. 1 and 2). Sometimes the pigment »Hof« is so dominant that the feldspars are hardly visible. Beside these minute microlites there occur also larger feldspar laths.

Feldspar microlites with surrounding »Höfe« of pigment form a characteristic feature of the outermost zone of the pillows. In fresh basic rock-glasses, such an amassing of pigment around the first crystallized components is not uncommon. It has, for instance, been described and reproduced by BRAUNS¹ from the glassy surface of the Devonian Deckdiabas

¹ BRAUNS, R.: Der oberdevonische Deckdiabas, Diabasbomben, Schalstein und Eisenerz. Neues Jahrb. Min. Geol. B. B. XXI, p. 305.

of Westerwald. In the present case this phenomenon shows that the pillows originally had a glassy surface, in which, besides a few larger feldspar laths, there occurred small microlites of the same mineral, which had attracted to them pigment-like minute grains probably of ore minerals or titanite. This glassy surface, however, has not exceeded two or three *mm* in thickness.

This zone is, in the slide in question, separated from the inner part of the pillow by a band of new-formed scapolite, reaching a width of a few millimetres. The scapolite occurs as large grains and is exceedingly rich in small inclusions of the minerals it has replaced. Among these inclusions are the dark pigment »Höfe« and hornblende. Through their arrangement, these still show the place of original feldspar laths, although the feldspar-substance has been entirely replaced by scapolite (Pl. 4, fig. 3). In this way it becomes possible to follow, even through the scapolite band, the development of the structure as we proceed further towards the interior of the pillow. The dark pigment spots become more and more rare, the feldspar laths larger and more numerous. In this way one reaches the interior of the pillow, which consists of feldspar, hornblende, chlorite and minute grains of a brownish colour with strong birefringence, presumably leucoxene. The hornblende and the chlorite form a continuous mass, in which the small leucoxene grains lie scattered. This mass does not consist of a felt of hornblende needles and chlorite, but is composed of hornblende units with a dirty grayish green or yellowish colour and undulatory extinction. It is, in all probability, secondarily developed from an originally partly glassy mass. In this mass there lie scattered abundant small feldspar laths and some few larger ones. The latter have a somewhat tabular shape and reach a length of 0.9 *mm* at the most. They are rich in small inclusions of epidote and hornblende, which make the determination of the optical properties difficult. They show indistinct albite twinning lamellae, the extinction,

in the cases where it could be measured, reaching 9° as a maximum. The refraction is like that of the Canada balsam. Accordingly they consist probably of oligoclase-albite, but from the examination of other slides with better preserved feldspar substance it seems possible that they are even more acid. The fine laths reach a length of 0.2–0.3 mm, as a medium, and a width of 0.008–0.025 mm. Nearer to the surface of the pillow they are fluidally arranged parallel to it. Sometimes skeleton forms are still discernible, with forking or sheaf-like brushes at the ends of the lists, a phenomenon of common occurrence in spilitic rocks and also described from *diabase bombs* in BRAUN's paper cited above.¹ The microlites carry small inclusions, which are arranged in a line along their middle. This line probably marks the boundary between the twins, although that can seldom be observed because of the small extinction angles of the laths. Where determination has been possible, figures similar to those for the phenocrysts have been found: thus even the microlites must consist of an acid plagioclase.

The amygdules mentioned above lie in a zone 8–10 mm in width, inside the outer devitrified crust of the pillow. Generally they are elongated at right angles to the surface and have an irregular but rounded shape and sharply defined outlines. Their length is 6 or 7 mm as a maximum. They are filled with the same hornblende as that occurring in the *schlieren*. Besides these vesicle fillings, there occur areas consisting of the same hornblende, but with rectilinear outlines, in their angles very much reminding one of olivine or pyroxene and evidently pseudomorphs of one of these minerals, probably the former. These pseudomorphs reach a size, in some cases, of 1 mm, generally, however, only 0.5 mm or less. Finally, as the last-formed mineral, younger than the hornblende-chlorite mass of the rock, there occur in the slide scattered grains of scapolite.

¹ Op. cit. Pl. XX: 2.

Besides this slide six others have been examined, cut from pillows from various points on the mountain. Some of them consist entirely of scapolite and new-formed hornblende with somewhat biotite; but where the structures and the minerals are still sufficiently preserved, one finds, with few variations, the same structural features and the same combination of minerals as in the slide described above. Sometimes the hornblende mass in the outermost, devitrified crust is exceedingly dense and consists of fine fibres, in the vicinity of the small feldspar microlites and their pigment »Höfe« radially arranged; sometimes the feldspar phenocrysts are a little more numerous with tabular shape and good idiomorphic development. All these, however, are dissimilarities of little consequence, and we can safely generalize the detailed description given above.

Summing up the results of the examination, the greenstone bodies designated pillows have been found to have originally consisted of an outer glassy crust, 2—3 mm thick, passing into a hypocrystalline interior, sometimes with fluidal structures developed near the surface and running parallel to the latter, and with a vesicular zone next to the glassy crust. A slide taken at a distance of 0.5 dm from the surface shows no difference except that the feldspar lists are somewhat more numerous and the assumed olivine pseudomorphs are more rare.¹ (Fig. 3.)

The original composition of the filling between the pillows cannot be determined, as it is now completely replaced by new-formed minerals. The occurrence of the scapolite in these *schlieren* is especially noteworthy. This mineral is abundant in the rocks to the South of Kiruna, and is everywhere of a later development than the rest of the rock. Considering all the facts I have collected, both on Pahtosvaara and in the country South and East of this mountain, concerning the mode of occurrence of this mineral, it appears that it is the product

¹ In the more coarse-grained phases of the soda-greenstones no traces of olivine have been found.

Fig. 3. *The interior of a pillow.* Ord. light. Magn. 35 times. The lighter irregular spots are scapolite. In the upper part of the slide there appears a pseudomorph, probably of olivine.

of a process of regional extent which cannot with any certainty be ascribed to any special kind of rock in the district, and that the agents causing the development of scapolite have preferably followed planes of weakness in the rocks. This fact is especially obvious at Pahtosvaara, where, besides joints, the interstices between the pillows have offered favourable conditions for their circulation in the rocks. In the case described above, the scapolite has also found its way along the inside of the glassy crust, where a plane of weakness must have existed. Further, the often observed paragenetic relation between scapolite and biotite or hornblende ought to be emphasized.

As a conclusion from evidences found in the field and under the microscope it appears that the occurrence of the pillows must be considered as a flow-phenomenon in the lavas, where each pillow has formed an individual with its own surface of cooling. At Pahtosvaara, the pillows occur everywhere in

the fine-grained varieties of the soda-greenstones, and where I have been able to distinguish separate lava flows, they appear along one of the surfaces, or, in one case, throughout the whole thickness of the bed. Further they have been observed in the southern part of Valkeasiipivaara, where, however, the schistosity of the rocks has to some extent obliterated the phenomenon. Further northwards, in the direction of Kurravaara, the structure in question has not been observed, according to N. ZENZÉN, but exposures are rare.

Discussion: The literature concerning pillow-lava is already rather extensive.¹ Lavas with this structure have been found in formations of the most varying age, from the Keewatin of America to recent time, and they have also a great extent, especially in North America in the large greenstone areas of Keewatin and Huronian age, and in the Palaeozoicum of England. It is further evident that the pillow-lavas show an astonishing uniformity in appearance and that they are, as

¹ A list of the more important papers in this respect has been compiled by J. M. CLEMENTS in The Crystal Falls Iron-bearing District of Michigan. Mon. U. S. Geol. Survey, Vol. 36, p. 118.

As a complement, the following papers may be mentioned, which have been published later:

TEALL, J. J. H. The Silurian Rocks of Britain. I. Scotland. Mem. Geol. Surv. 1899, pp. 429, 481.

FLETT, S. J. The Geology of the Country around Plymouth and Liskeard. Mem. Geol. Surv. 1907, pp. 92, 97.

REID, C., and DEWEY, H. The Origin of the Pillow-lava near Port Isaac in Cornwall. Q. J. G. S., Vol. 64, pp. 264—272.

REUNING, E. Diabasgesteine an der Westerwaldbahn Herborn-Drieddorf. Neues Jahrb. Min. Geol. B. B. XXIV, pp. 409—421.

DALY, A. Variolitic Pillow-lava from Newfoundland. Am. Geol., Vol. XXXII, 1903, pp. 65—78.

LEITH, C. K. An Algonkian Basin in Hudson Bay . . . Econ. Geology, Vol. V, 1910, pp. 234, 242.

ANDERSON, T. The Volcano of Matavanu in Savaii. Q. J. G. S., Vol. 66, pp. 621—637.

See also ROSENBUŠCH, H. Physiographie der massigen Gesteine. II. Stuttgart 1908, p. 1275, and VAN HISE, C. R., LEITH, C. K. The Geology of the Lake Superior Region. Mon. U. S. Geol. Surv., Vol. 52, pp. 510—12.

already pointed out by ROSENBUSCH¹ and others, connected with pronounced spilitic structures. Everywhere in the descriptions, the rounded forms of the pillows appear, and likewise the mosaic. Common features are also radial contraction fissures and a concentric structure caused by the occurrence of a glassy crust and by the distributions of the vesicles, which are usually concentrated towards the surface, less often also by differently coloured layers.² In some cases it is described how the longer axes of the pillows are parallel with the «surface of deposition» or even how the vesicles are concentrated on one side (the upper one) of the pillows.³ Also, the development of a variolitic structure seems to be often connected with the appearance of pillows, the variolites forming a crust inside the glassy shell or occurring throughout the whole mass of the pillow. These facts clearly show that the surfaces of the rounded lava bodies have been free cooling surfaces, and that at their piling together they have still been in a plastic state. The filling between the pillows is described as consisting partly of material of the same kind as the associated sedimentary rocks; sometimes also lava fragments are found, but partly there must have existed open spaces between the pillows which have subsequently been filled with secondary minerals, as calcite, chlorite, epidote, and quartz.

In most occurrences of pillow-lava, the pillows are described as free from one another and having a diameter varying from some few centimetres up to several metres. Beds 60—70 metres thick are built up of such pillows «like a pile of partly-filled sacks, heaped on each other, the prominences of one projecting into corresponding hollows in the next».⁴ In some few cases, however, it is remarked that the pillows are

¹ Op. cit.

² CLEMENTS, op. cit. Pl. XI.

³ Ibidem, p. 113.

⁴ ARCHIBALD GEIKIE: The ancient Volcanoes of Great Britain, Vol. I, London 1897, p. 193.

connected with one another by means of short necks,¹ or the pillows may, as at Crystal Falls, grade into not ellipsoidal lava-beds, or occur along one of the surfaces.² It seems that these cases are only two different stages in the development of the pillow structure. In one case only — viz. that described by REID and DEWEY from Port Isaac (Cornwall), where the pillows differ from the common type in their exceedingly high content of vesicles, which increases towards the centre, which is occupied by a large cavity, and where they can be considered as thick-walled lava bubbles³ — it seems possible that a uniform mode of formation may not be sufficient.

Various hypotheses have been advanced to explain the development of pillow-lava. BONNEY and RASIN have regarded it as due to contraction; LAWSON and ELLS have designated it as concretionary; WILLIAMS as a phenomenon of mechanical brecciation. All these hypotheses, however, are untenable, as the filling between the pillows partly consists of sedimentary material, and the surfaces have been surfaces of cooling.

WINCHELL considers it as an accumulation of lava bombs, but even this explanation encounters great difficulties, in the piling up of such masses of bombs, in their plasticity, and in the absence or scarceness of other kind of volcanic ejecta, and finally it becomes entirely impossible for those cases where the pillows cohere with another or with massive rocks.

Other authors, as GREGORY and REUNING, regard the pillow-lava as the result of explosive eruptions (partly submarine), but also this hypothesis fails to satisfy, partly for the reasons already alluded to.

CLEMENTS and DALY have compared the pillow-lava with aa, RANSOME and TEALL with pāhoehoe (partly submarine). But it is different from these two lava types.

¹ REUNING, *op. cit.*, p. 411.

² CLEMENTS, *op. cit.*, pp. 112, 113.

³ *Op. cit.*, p. 267.

TEALL,¹ GEIKIE,² and other authors have emphasized the pronounced association of pillow-lava with marine deposits, especially with radiolarian cherts, and have concluded that the pillow-lava must be a submarine phenomenon. In this explanation most later authors have agreed. Also at Pahtosvaara and Valkeasiipivaara, the conditions seem to speak for this position of the lava outflows. This explanation is supported, among other things, by the fact that at Valkeasiipivaara, within the greenstones, and associated with dense stratified tuffs, there occurs a conglomerate with pebbles similar to those of the Kurravaara conglomerate.

It is also an interesting fact that, where pillow-lava is not accompanied only by tuffs, the immediately associated sedimentary rocks are marine sediments, most often deep-sea deposits as radiolarian cherts, slates (sometimes carrying graptolites), limestone, but sometimes also deposits in shallow water as sandstone and conglomerate. These sedimentary deposits are intimately connected with the pillow-lava, inasmuch as the overlying material has found its way down between the pillows. In some cases also enclosed fragments of the sedimentary rocks in the lava are described, or even larger masses, which find a natural explanation in the steam explosions that must have taken place when the hot lava came in contact with the water. Such phenomena are described by RUSSELL from the Tertiary Snake River basalts.³

Hence it seems that contact with the water has been the factor that has favoured the development of the pillow structure. TEMPEST ANDERSON has confirmed this view in his description of the new volcano Matavanu on Savaii.⁴ He describes the formation of pillow-lava, where the lava flows out into the water, and reproduces such lava on the shore, with ordinary

¹ Op. cit. pp. 85, 431. See also the same author: On Greenstones associated with Radiolarian cherts. Trans Roy. Geol. Soc. Cornwall, Vol. XI, p. 560.

² Op. cit., pp. 25, 184, note.

³ I. C. RUSSELL: Bull. U. S. Geol. Surv. No 199, 1902, p. 116.

⁴ Op. cit.

pahoehoe in the distance¹. " — — — The lava extended itself into buds or lobes. The process was as follows: an avoid mass of lava, still in communication with its source of supply and having its surface, though still red-hot, reduced to a pasty condition by cooling, would be seen to swell, or crack, into a sort of bud with a narrow neck like a prickly pear on a cactus, and this would rapidly increase in heat, mobility, and size, till it either became a lobe as large as a sack or pillow, like the others or perhaps stopped short at the size of an Indian club or large Florence flask".

The necks of these lobes generally have the same length, thus the lobes become heaped together. The same author further writes²: "I am satisfied that — — — pillow-lava (at any rate one form)" — is produced — "from the chilling action of water on the surface before it has time to assume the corded structure of pahoehoe"

It is evident that the phenomenon described by ANDERSON is entirely analogous to the pillow lava of Pathosvaara and that the explanation given by him must be the right one. The process thus is a reciprocal action between rapid cooling on the surface, causing a viscous shell, and the still fluid lava that presses forward and expands this shell to a bubble with a feeding channel. At a further forcing forward of the lava, these lobes might be cut off and form free pillows. It is also evident that this process requires a definite degree of viscosity; and this circumstance perhaps explains the fact that, together with pillow-lava, and in the sediments surrounding it, there often appear lava beds without the ellipsoidal structure.

This hypothesis fully explains some of the occurrences of pillow-lava, as those at Crystal Falls³, Westerwald⁴, and

¹ Ibidem Pl. 52 and p. 632.

² Op. cit p. 633 note.

³ CLEMENTS, op. cit.

⁴ RENNING, op. cit.

Lake of the Woods¹. The transitions from these occurrences to those where only separate pillows occur, and the great analogy between the pillows from nearly all localities where they have been described make it highly probable that the explanation has a general application.

Of equally great interest with the structural features is the paragenesis, as one may term it, of the pillow-lava with silica rocks, and its own chemical composition. Of the former I have already briefly mentioned the radiolarian cherts in England, whose connection with the pillow-lava has been recently discussed by DEWEY and FLETT². In Germany, pillow-lava has been found in association with »*Kieselschiefer*».³ In the Lake Superior region the interest is increased by the fact that the silica rocks there are the jaspilitites of the iron-bearing formations. This relation has been discussed by VAN HISE and LEITH in their recent Lake Superior monograph⁴.

In the paper cited above, DEWEY and FLETT have shown the uniformity in the composition of pillow-lavas in Great Britain. They have emphasized the high soda content of these rocks, and ascribe it to a pneumatolytic albitization. I will not discuss here the difficult question whether the soda-greenstones of the Kiruna district have been subjected to a metamorphism of this kind or not, but will merely emphasize their similarity in chemical and mineralogical respect with the English spilites, features that have been found by N. ZENZÉN and myself, and also appear from the analyses.⁵

¹ LAWSON, A. C.: Report on the Geology of the Lake of the Woods Region. Geol. and Nat. Hist. Surv. of Canada 1885 cc p 53.

² DEWEY, H. and FLETT, S. J. British Pillow-lavas and the Rocks associated with them. Geol. Mag. 1911 pp. 202—9, 241—8.

³ ROSENBUSCH, op. cit, p. 1275.

⁴ Op. cit.

⁵ LUNDBOHM, op. cit. p. 787.

Resumé.

På bergshöjden Paktosvaara samt södra sidan af Valkeasiipi-vaara, resp. SW och N om Kiruna, förekomma i de såsom natrongrönstenar betecknade femiska effusivbergarterna rikliga agglomeratliknande bildningar, som motsvara s. k. pillow-lava. Bergarten är därvid af mörkare »sliror» uppdelad i ellipsoidiska eller olikgestaltade, dock alltid rundade partier eller »pillows», som bilda en mosaik. Af denna mosaikartade sammanfogning samt af det förhållandet, att »slirorna» ibland endast delvis omsluta pillows, som direkt sammanhånga med massiv bergart, framgår, att dessa måste vara egendomliga flytfenomen, bildade medan lavan ännu var i plastiskt tillstånd. Där skilda lavaströmmar kunnat urskiljas, uppträda pillows utmed ytan eller genom hela lavabädden. Mikroskopiska undersökningar ha vidare visat, att pillows ytor varit fria afkylningsytor med ett tunt glashölje ytterst och närmast därinnanför en mandelförande zon. Utfyllnadsmaterialet mellan pillows är emellertid helt och hållet ombildadt till hufvudsakligen hornblende och skapolit.

Största delen af beskrifna pillow-lavor uppträda intimt associerade med marina sediment, delvis sådana, bildade på djupt vatten. Såsom TEALL, GEIKIE m. fl. påpekat, synes detta utvisa, att pillow-bildningen är att betrakta såsom submarin, bildad vid lavans beröring med vatten. Ett dylikt bildnings-sätt — som vinner i sannolikhet genom de af TEMPEST ANDERSON nyligen gjorda iakttagelserna på ön Savaii vid lavaströmmarnas nedrinnande i hafvet — har äfven antagits för pillow-lavan i natrongrönstenarna. Flera förhållanden på platsen, såsom i grönstensformationen inlagradt konglomerat samt det öfverlagrande Kurravaarakonglomeratets af vatten bearbetade material, tala också för ett submarint läge af grönstenseruptionerna.

Mineralog. Inst. Stockholms Högskola mars 1912.

Explication to Pl. 4.

Fig. 1. *Soda-greenstone (Pahtosvaara)*. The outhermost part of a pillow. Ord. light. Magn. 17 times. Feldspar phenocryst and microlites, surrounded by dark pigment. In the upper part of the slide there is scapolite enclosing pigment »Höfe« and numerous small grains chiefly of hornblende, the latter by their arrangement showing the places of former feldspar laths. The light area in the upper right corner is a hollow in the slide; also two cracks are seen.

Fig. 2. *Central part of the same slide*. Ord. light. Magn. 35 times.

Fig. 3. *Part of a scapolite individual*. Crossed nicols. Magn. 35 times. It encloses numerous pigment »Höfe« and has replaced the feldspar substance. The mottled spots to the right are scapolite rich in inclusions mainly of small hornblende grains. The position of former feldspar laths can be distinguished.

Fig. 1.

Fig. 2.

Fig. 3.