SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C. N:o 542.

ÅRSBOK 49 (1955) N:o 2

ON THE OCCURRENCE OF IGNIMBRITE IN THE PRE-CAMBRIAN

BY

S. HJELMQVIST

Pris 1 krona

STOCKHOLM 1956
KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER
561065

SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C. N:o 542.

ÅRSBOK 49 (1955) N:o 2.

ON THE OCCURRENCE OF IGNIMBRITE IN THE PRE-CAMBRIAN

BY

S. HJELMQVIST

STOCKHOLM 1956

KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER

561065

Contents.

Meaning of the Term Ignimbrite.

In a paper entitled »Notes on some volcanic rocks of the North Island of New Zealand» (*17*), P. Marshall in 1932 introduced the term ignimbrite for tuffaceous rocks of acid composition which have been formed from *nuées ardentes*, at such a high temperature that the ash particles were still plastic and became agglutinated when they fell, forming a compact and almost lava-like rock. These rocks cover more than 25 000 square kilometres of the North Island of New Zealand in the district of Taupo-Rotorua and have erupted during later tertiary and post tertiary time (*18*). This formation was known formerly as the rhyolite plateau and was believed to consist of a lava flood. The ash material has descended the mountain sides like a hot avalanche or a glowing cloud charged with sand and ash.

Marshall gives no explanation as to the origin of the term ignimbrite; the name is evidently formed from Latin *ignis* (fire) and *imber* (shower).

In American literature the term »welded tuffs» is used for similar formations which were noted in the Yellowstone Park area by J. P. Iddings as early as in 1899 (*12*). Iddings believed the welding to be caused by the deposition of pumice on the surface of an intensely heated area of lava.

In his book »Volcanoes as landscape forms» C. A. Cotton says (*5*, p. 204): »In a thick sandflow or *nuée ardente* deposit some or all of the material may become agglutinated, though probably in most cases portions of it remain incoherent volcanic sand or tuff. The term »ignimbrite» is applicable to all rocks formed by such agglutination. These grade from indurated but open-textured and porous tuff to firmly compacted rocks which have been mistaken for flow rhyolites. This is the condition assumed by deeply buried material which has been compressed under the weight of the upper layers of the deposit. For this process the expression »welding» is perhaps admissible; but the welded product no longer presents any resemblance to a »tuff». It rings under the hammer, and may closely resemble a flow rhyolite, or even obsidian, though generally distinguishable under the microscope from rocks of lava flow origin.»

In a paper at the 1955 Annual meeting of the Geological Society of America (*4*), E. F. Cook discusses nomenclature and recognition of ignimbrites. According to the published abstract of the paper Cook states: »Pyroclastic sheets of probable *nuée ardente* origin have been called sand flows, tuff flows, welded tuffs, and ignimbrites. Sand flow and tuff flow, however, do not express the magnitude of the phenomena involved; the flow concept is hardly applicable to the extremely rapid, all-sided, turbulent expansion of an incandescent cloud. The use of welded tuff to describe a *nuée ardente* deposit is equally unsatisfactory, since such deposits may be wholly or in part nonwelded. Ignimbrite, unlike the other three terms, is adequate.» Accordingly, *welded tuff* is a special form of ignimbrite. In addition Cook says: »Although ignimbrite was first defined both as a rock and as a rock unit, its use could profitably be restricted to the latter.»

As a covering name for deposits of this kind, Fenner uses »incandescent tuff flows» (*10*) and van Bemmelen-Rutten the expression »incandescent tuff sheet» (*2*).

A German term, corresponding to ignimbrite, is *Glutwolkenabsätze* (*22*, p. 59).

Weyl uses the denomination *Gluttuff*, which he divides into *Lockerer Gluttuff*, *Kristallisationstuff* (indurated by endogene, pneumatolytically formed recrystallization), and *Schmelztuff* (indurated by welding of the glassy particles = welded tuff) (*28*, p. 13).

Areas of Ignimbritic Rocks.

Through detailed investigations within volcanic regions, welded tuffs and ignimbrites have recently been demonstrated in several places and this type of rocks is probably much more common than is usually realized (*10*, p. 880; *23*, p. 407).

Weyl (*28*, p. 10) gives a tabulated survey of the occurrences of ignimbrites and *Schmelztuff*, respectively, which is reproduced also by van Bemmelen-Rutten (*2*, p. 128). The table states the size of the area of distribution, the thickness and volume of the layers, as well as their magmatic character and age.

Most of these deposits are of rhyolitic character. A few of them have been described as quartz latite, rhyodacite, dacite, and even basalt.

The area of the deposits varies greatly. Large deposits are known from New Zealand and Sumatra where ignimbrites cover areas of more than 25 000 sq. km. Similar formations cover considerable areas also in the Western United States. Welded tuffs have been described from Yellowstone Park, Idaho, California, Montana, Nevada, Utah, Oregon, and Arizona. In addition, ignimbritic rocks occur in Mexico, Central America, Peru, Queensland, Japan, Sibiria, and Iceland. The quartz latitic, rhyodacitic, dacitic, and basaltic ignimbrites mentioned from Costa Rica, El Salvador, and Iceland are less widely spread than the others, extending over areas of only 35 to 300 sq. km.

The thickness of the different deposits is very varying, from only a few metres to several hundreds. The greatest thickness is found in the series of welded tuffs in Arizona, described by Enlows (*7*). These tuffs are almost 600 m thick but are divided into eight different members, representing the same number of eruptions. The thickest of these members is 260 m. The others range from 1 to 80 m. The welded tuffs in Idaho, described by Mansfield and Ross (*16*), which cover a considerable area (13 000 sq. km) only measure about 6 to 15 m in thickness.

In Europe ignimbrites occur, besides on Iceland, also in Central and South Europe. As early as in 1907 it was pointed out by Völzing that the trass deposits of the Brohl Valley had probably been formed from *nuées ardentes* (*25*, p. 43). Around the Mediterranean there are small deposits of ignimbrites in connection with acid volcanic regions. According to an oral communication by prof. A. Rittmann, ignimbrites form part of the Tertiary rock surface on the island of Ponza in the Tyrrhenian Sea. The present author visited the island in 1955 and collected several hand specimens of the volcanic rocks. The ignimbrites are there light-coloured, massive, normally fine tuffs, which often disintegrate porously since the welded parts are more resistant than the less solid ones. From a structural point of view, they are different from the ignimbrites of New Zealand, as even the hard and compact, macroscopically homogeneous tuffs under the microscope show a characteristic microbreccia appearance, quite unlike that which, for instance, characterizes fig. 1. There are forms, however, which are microscopically more resemblant to the latter type (see fig. 3). In addition there occur coarser tuff breccias or agglomerates to a considerable extent, which form caotic, less compact masses.

Ignimbrites are present also on the island of Lipari, north of Sicily. According to samples collected by the author in 1950, the older liparite, which on Bergeat's map (*3*) extends along the coast south of the town of Lipari, has a typical welded-tuff structure (fig. 2).

With few exceptions all the ignimbrites described above are young formations, belonging to the Pleistocene or to the Tertiary. Most of them are of Pleistocene age. The rhyolitic ignimbrite in Queensland originates from the Triassic (*21*) and the basaltic ignimbrite in Montana from the Cretaceous (*1*).

In his paper of 1954, Weyl suggests that ignimbrites may occur among the German Rotliegendes porphyry tuffs (*28*, p. 27).

Characteristic Features of Ignimbrites.

According to Marshall ignimbrites are distinguished from ordinary tuffs by the following characteristics (*18*, p. 360):

1. They have a uniform and normally fine texture.
2. There is an absence of bedding.

3. They show a pronounced prismatic jointing.

4. The rocks are coherent and have an effective solidity.

5. In micropreparations the rocks typically show »flow structure». This »flow structure» is explained as due to the bending of viscous glass shreds round previously existing crystals.

From lavas ignimbrites are distinguished, *i. a.*, by the following characteristics:

1. The deposits have a disposition that is in ordinary instances approximately horizontal.

2. There is an absence of glassy selvages.

3. A scoriaceous surface is wanting.

4. The specific gravity is low.

5. There is an increase in the specific gravity from the top to the bottom of each formation of the rock.

6. There is no indication of mass flow.

A similar definition is given by Cook. He says (*4*, p. 20 A): »Ignimbrites may be distinguished from lava flows by great extent, horizontal depositional surface, lack of vesicles, presence of compaction but not flow structures (= mass flow), generally low specific gravity decreasing upward, abundance of glass shards, as well as the possible presence of incoherent basal ash, lithic fragments throughout the mass, and upward decrease in hardness. Ignimbrites may be distinguished from air-fall and waterlaid tuffs by absence of bedding, lack of sorting, presence of rude prismatic jointing, compaction structures, and welding.»

Evidences of the high temperature of the ignimbrite material when it was deposited are furnished by Marshall, *i. a.*:

1. The minute particles of glass of which the ignimbrites consist are welded together more or less completely.

2. Occasionally blebs of glass as much as 2 mm in diameter have been formed from the welded shreds.

3. There is often a development of crystalline structure after the ignimbrite material reached the ground.

A characteristic of Tertiary and younger ignimbritic deposits is, as pointed out by several authors, the vertical gradation from a hard, thoroughly welded and coherent base low in porosity, into a less coherent, porous top (*7*, *11*). The Bishop tuff in California shows, according to Gilbert (*11*, p. 1835), a pronounced textural and structural gradation from top to bottom. The degree of flattening of the pumice fragments is determined by the thickness of the section, complete welding occurring only at depths of more than 100 m. There the vitric constituents are compressed, distorted, and aligned and the structure very compact.

This results in rather different rock types in the lower and upper parts of the same member. While the upper phase of a welded-tuff unit may consist of a porous, poorly consolidated tuff, sometimes with angular inclusions of other rocks some of which may be as large as 10—15 cm, the lower part may be a homogeneous, firmly welded rock with aphanitic groundmass and phenocrysts of sanidine and quartz. In most welded-tuff members at Chiricahua, however, the base contains coarse inclusions, such as blocks and lapilli, which gradually give way to ash and dust toward the top (7, p. 1245).

Marshall (*18*, p. 332) distinguishes four different petrographic types of ignimbrite with different geographic distribution:

The Wilsonite type is composed of relatively large fragments of glass embedded in a matrix of stony appearance in which many clear and colourless crystals of feldspar and quartz can be distinguished. Actually the stony matter is found to consist mainly of small shreds of glass which may show a parallel arrangement — the so-called flow structure.

The Hinuera type is characterized by fragments of rhyolite which may be 7—10 cm in diameter. They are embedded in material of a fine texture in which numerous broken crystals of feldspar and a few of quartz can be seen. The matrix consists of irregular but largely linear glass shreds lightly welded together. In this rock there is no flattening of the glass fragments, and no flow structure has been observed.

The Paeroa type contains fragments of different varieties of rhyolite and andesite, sometimes as much as 10 cm in diameter, as well as crystals of feldspar and quartz. The fine portion consists of shreds of glass which do not bend round the crystals but are welded together to some extent.

The Arapuni type is fine and even-grained with clear glassy crystals and crystal fragments of feldspar and quartz distinguishable even in hand specimens. Tridymite occurs very generally, sometimes as small rosettes in cavities, but more frequently along the centre line of axiolites. In hand specimens the rock can hardly be distinguished from typical rhyolite. The minute particles of glass of the groundmass bend round the corners of the feldspar crystals, thus giving the typical appearance of the so-called flow structure.

In most cases the glass shreds show a more or less complete recrystallization although the form of the original glass particles is preserved. This change involves the development of very slender needles at right angles to the surface of the glass shreds extending inwards from it. Marshall uses the term pectinate (comb-like) for this structure. When the feldspar fibres become stouter an axiolitic structure is developed.

At times there is a tendency for some of the pectinate structures to grow at the expense of others and the feldspar needles then tend to form radial structures or spherulites. Even when these are well developed the boundaries of the original glass particles can still be distinctly seen.

Other authors, too, mention axiolites and spherulites as typical structures in welded tuffs.

The coherent, highly welded tuff may exhibit a prominent eutaxitic structure. This is true of the welded tuffs of Chiricahua National Monument in Arizona (7) where flattened lenses of lapilli or larger size give a eutaxitic structure to the rock, megascopically appearing as a streaky, varicoloured banding. By flattening and aligning of the finer fragments a microscopic eutaxitic structure is developed.

The frequency of phenocrysts varies greatly in different ignimbrite deposits —

from scattered crystals to an abundance of phenocrysts. The content of phenocrysts may vary on different levels for one and the same deposit. According to Enlows there generally is an increasing number of phenocrysts downward. The crystals of quartz and feldspar often have corroded and embayed borders (*7*) but as shown by microphotos there are also larger crystals with well developed idiomorphic boundaries (*11*, *18*, *28*).

The glass shards in the groundmass of the welded types have flattened, curved or more irregular forms. Flattened Y-shaped grains are characteristic, constituting fragments of bubble walls, as well as elliptical grains representing unbroken bubbles (*16*).

The glass fragments generally bend round phenocrysts and rock fragments but are also accommodated one to another to form flattened streaks, such bringing about an apparent flow structure.

As appears from the foregoing survey, ignimbrite is a fairly comprehensive concept which includes rocks of varying structures and textures. At one end there are more or less coarse tuff breccias of an unmistakably pyroclastic type, at the other fine and even-grained, hard porphyric rocks, often with an eutaxitic structure which can easily be mistaken for true lava. It is obvious that many ignimbrites have previously been interpreted as rhyolitic lavas. This is true of the ignimbrites of the North Island of New Zealand (the rhyolite plateau) and the deposits of Sumatra, and also of some welded tuffs of North America and Queensland.

With regard to the coarse ignimbrites occurring in older series of strata, their pyroclastic character will generally be established without difficulty. For fine-grained, homogeneous porphyries of ignimbritic origin, however, the situation is another.

It is well known that recent acid lavas occupy only small areas while older porphyries, interpreted as lavas, often have a wide extension. It would be of interest to investigate to what degree the latter — in spite of their apparent lava-like character — may actually be original welded tuffs. Ross expresses a similar opinion: »It seems probable that the possibility should be considered that any even-bedded widely extending 'rhyolite flow' may be welded tuff» (*23*, p. 407).

It seems a priori very likely that ignimbrites form as considerable a part of older volcanic rocks as of younger series. The possibility to identify the fine and even-grained rock types is, however, rather small, on account of the metamorphic development of these older rocks.

The often emphasized gradation of welded-tuff series from hard, firmly welded rocks at the bottom to less coherent tuffs at the top, can most often not be demonstrated since all the less consolidated deposits have been removed by denudation where the entire series has not become changed by metamorphism. Features like increasing specific gravity and decreasing porosity downwards, will probably not be found any longer, no more than the columnar structure. Nor will it be possible to demonstrate that the scoriaceous surface is wanting.

Normally the topographic features which characterize young ignimbrite deposits, will not easily be recognized in these old ignimbrites: the horizontal depositional surface and preferred occurrence in valleys whose irregularities are buried by the incandescent tuff masses.

On the other hand, the absence of bedding, lack of sorting, and great extent in connection with an apparent flow structure should still be present. And what is more, the evidence of welding of original glass shards which characterizes the microscopic structure, should, when conditions are favourable, indicate the manner of formation.

The Eutaxitic Porphyries of Dalarna.

In North Dalarna and adjoining parts of South Härjedalen in Central Sweden there is a large area of only slightly metamorphic, acid porphyries of pre-Cambrian age. They are intersected by granites of rapakivi type and form the base of the Jotnian sandstones of Dalarna, which has caused the designation of sub-Jotnian for both porphyries and granites.

Together with the acid porphyries there occur also porphyrites and — to a lesser extent — clastic sedimentary rocks, such as sandstones and conglomerates. The whole series has an extension of about 6 000 sq. km.

The acid porphyries are partly composed of eutaxitic forms which cover an area of approximately 450 sq. km.

These eutaxitic porphyries are varicoloured. Both red and brown forms are found, as well as violet and almost black ones. Their content of phenocrysts varies greatly. Some porphyries contain only few phenocrysts, others are remarkably rich in larger crystals. The eutaxitic character is often very marked in hand specimens and has also been interpreted as a kind of fluidal structure and the porphyries, consequently, as true rhyolitic lavas.

Under the microscope the eutaxitic structure is even more conspicuous. A study of a large number of thin sections has indicated that qualities characteristic of welded tuffs can often be recognized in spite of the complete devitrification which these rocks have undergone. Among these characteristics are flattened Y-shaped bands or streaks and more creased forms which have originated through compression and flattening out of blebs of glass. Also flattened and elongated lenses occur. A typical feature is the marked discontinuity of the flattened structures.[1]

In the porphyries best preserved, the boundaries of the original glass shards, which bend round larger phenocrysts are clearly visible in the groundmass in parallel light.

On stronger compression the groundmass shows an even parallel banding, which disappears completely between crossed nicols, being replaced by a maculose recrystallization.

[1] Already some years ago, Dr C. S. Ross has called attention to this interpretation. In a letter to prof. P. Geijer of June 5, 1950 he emphasizes the similarity between a thin section among the old collections of the U. S. Geol. Survey, labelled Elfdalen, Sweden, and welded tuff.

Spherulitic structures occur, too, although more rarely. In between the spherulites bended and flattened shards of original glass can be observed in parallel light.

The agreement with characteristic features of much younger welded tuffs is in many cases so obvious that there seems to be little doubt of the ignimbritic origin of these eutaxitic porphyries. The same is probably true also of porphyries whose eutaxitic character is less evident but whose occurrence together with eutaxitic porphyries is clear. The extremely fine-grained rock of hälleflinta-like appearance which also occurs among the porphyries of Dalarna has an entirely different structure and shows under the microscope a more normal ash character.

References.

1. Barksdale, J. D., Cretaceous glassy welded tuffs — Lewis and Clark County, Montana. — Amer. J. Sc., 249, 1951.
2. Bemmelen, R. W. van & Rutten, M. G., Tablemountains of Northern Iceland. — Leiden 1955.
3. Bergeat, A., Die äolischen Inseln. — Abh. Bayr. Akad. Wiss., 20, 1899.
4. Cook, E. F., Nomenclature and recognition of ignimbrites. — Abstr. Geol. Soc. Amer., Nov. meet. New Orleans, 1955.
5. Cotton, C. A., Volcanoes as landscape forms. — Sec. ed., Christchurch 1952.
6. Eckermann, H. von, The Loos-Hamra region. — Geol. för. förh., 58, 1936.
7. Enlows, H. E., Welded tuffs of Chiricahua National Monument, Arizona. — Bull. Geol. Soc. Amer., 66, 1955.
8. Feitler, S., Welded tuff resembling vitrophyre and pitchstone at Bare Mountain, Nevada. — Bull. Geol. Soc. Amer., 51, 1940.
9. Fenner, C. N., Tuffs and other volcanic deposits of Katmai and Yellowstone Park. — Transact. Amer. Geophys. Union, 18. ann. meet., 1, 1937.
10. — Incandescent tuff flows in Southern Peru. — Bull. Geol. Soc. Amer., 59, 1948.
11. Gilbert, C. M., Welded tuff in Eastern California. — Bull. Geol. Soc. Amer., 49, 1938.
12. Iddings, J. P., Geology of the Yellowstone National Park. — U. S. Geol. Surv. Monogr. 32, II, 1899.
13. MacGregor, A. G., Nuées ardentes and ignimbrites. — Nature, 157, 1946.
14. — Eruptive mechanisms: Mt. Pelée, the Soufrière of St. Vincent and the Valley of Ten Thousand Smokes. — Bull. Volcan., 12, 1952.
15. Mackin, J. H. & Nelson, W. H., Early tertiary welded tuffs in the Iron Spring District, Utah. — Geol. Soc. Amer., 61, 1950.
16. Mansfield, G. R. & Ross, C. S., Welded rhyolitic tuffs in Southeastern Idaho. Transact. Amer. Geophys. Union, 16. ann. meet., 1, 1935.
17. Marshall, P., Notes on some volcanic rocks of the North Island of New Zealand. — The New Zealand J. of Sc. a. Techn., 13, 1932.
18. — Acid rocks of the Taupo-Rotorua volcanic district. — Transact. a. proceed. Royal Soc. New Zealand, 64, 1935.
19. Moore, B. N., Deposits of possible nuée ardente origin in the Crater Lake Region, Oregon. — J. of Geol., 42, 1934.
20. Perret, F. A., The eruption of Mt Pelée 1929—1932. — Publ. by Carnegie Inst. of Washington, 1935.
21. Richards, H. C. & Bryan, W. H., The problem of the Brisbane tuff. — Proceed. Royal Soc. Queensland, 45, 1934.
22. Rittmann, A., Vulkane und ihre Tätigkeit. — Stuttgart 1936.
23. Ross, C. S., Characteristics of rhyolite welded tuffs in Western North America. Proceed. 7th Pacific Sc. Congr. New Zealand 1949, 2.
24. — Provenience of pyroclastic materials. — Bull. Geol. Soc. Amer., 62, 1951.
25. Völzing, K., Der Trass des Brohltales. — Jb. Königl. Preuss. Geol. Landesanst., 28 (1907), 1910.
26. Westerveld, J., Welded rhyolitic tuffs or »ignimbrites» in the Pasoemah region, West Palembang, South Sumatra. — Leidsch. Geol. Meded., 13, 1942.
27. — Quarternary volcanism on Sumatra. — Bull. Geol. Soc. Amer., 63, 1952.
28. Weyl, R., Beiträge zur Geologie El Salvadors. V. Die Schmelztuffe der Balsamkette. — N. Jahrb. Geol. u. Pal. Abh. 99, 1954.

Remarks to the Figures.

In order to indicate the structures of typical young ignimbrites, three microphotos of ignimbrites from New Zealand resp. Lipari and Ponza in Italy are included below.

For comparison may also be referred to von Eckermanns excellent microphotos of »felsitic porphyries» from the Loos-Hamra region in Northern Dalarna and Hälsingland which show the same structural features as the Dala porphyries here dealt with (*6*, Pl. LXIX, 2, Pl. LXXI, 1 and 2 and Pl. LXXII).

Fig. 1. Ignimbrite from Te Miro, near Cambridge, North Island of New Zealand. 30 x. To the lower left small phenocryst of oligoclase. The welded groundmass is porous and built up of bent and Y-shaped glass fragments some of which are vesicular.

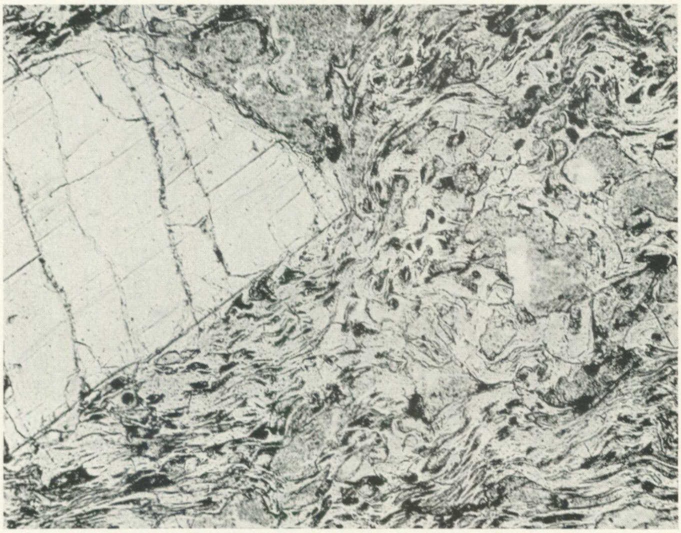

Fig. 2. Ignimbrite from Monte Capistrello, Lipari, Italy. 50 x. Large phenocryst of sanidine in a porous groundmass consisting of contorted and aligned glass shards firmly welded together.

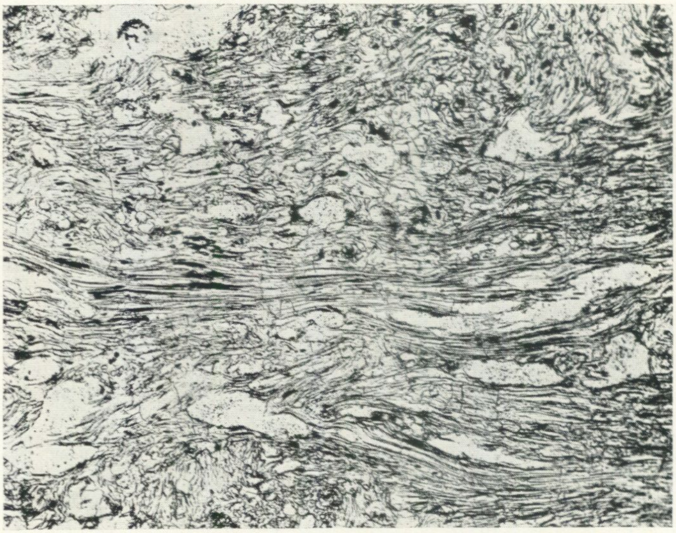

Fig. 3. Ignimbrite from Cala Frontone, Ponza, Italy. 30 x. The fig. represents a welded portion of an agglomeratic tuff with up to 3 cm large lapilli of pitchstone and pumice. The reproduced surface is made up of glass shards which in part are flattened and pressed together.

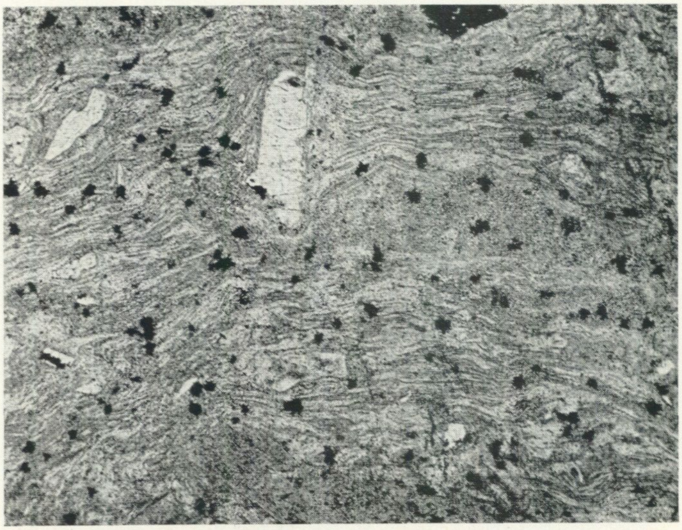

Fig. 4. Eutaxitic porphyry from Blyberg, Dalarna. 30 x. The rock contains numerous phenocrysts of anorthoclase (formerly sanidine) and strongly weathered oligoclase. The groundmass of quartz and feldspar exhibits an apparent flow structure. It is characterized by paler coloured discontinuous streaks showing sharp bendings and Y-shapes and representing original glass fragments now devitrified. (Cfr Enlows 1955, Pl. 4, Fig 3.)

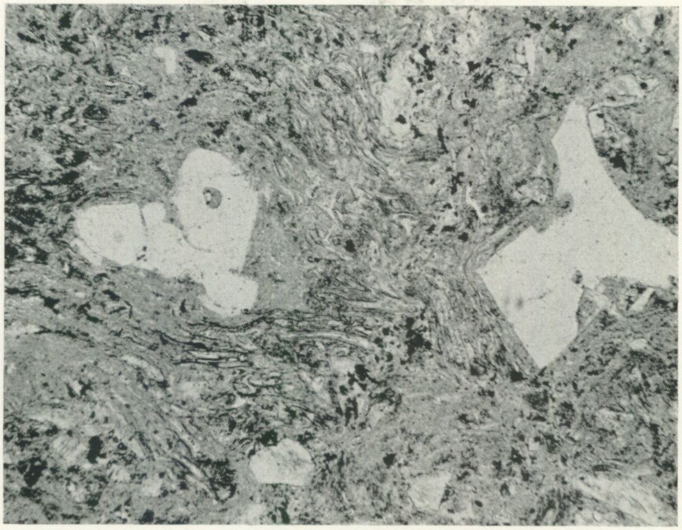

Fig. 5. Quartz-porphyry from Stickosälberget, Dalarna. 50 x. Embayed and broken quartz phenocrysts and larger and less corroded crystals of feldspar in a devitrified matrix of quartz and feldspar, the vitroclastic structure of which is still recognizable in parallel light.

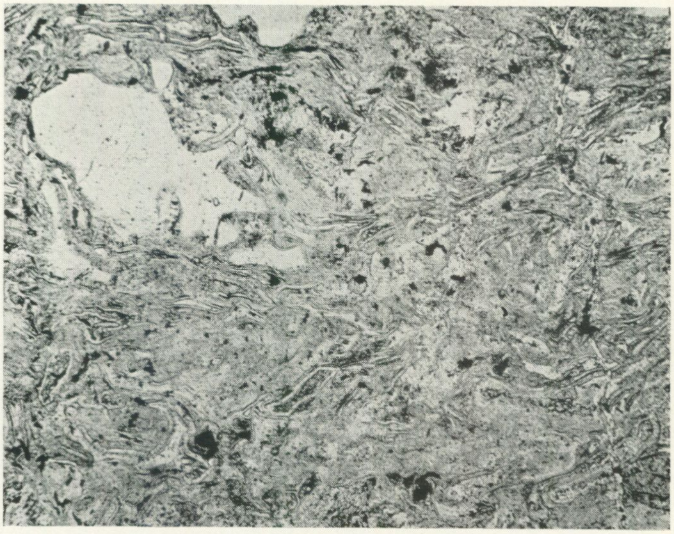

Fig. 6. Same rock as fig. 5. 50 x. Below the centre and to the left there are elliptical grains representing the walls of original bubbles. The rock also contains pieces of collapsed pumice.

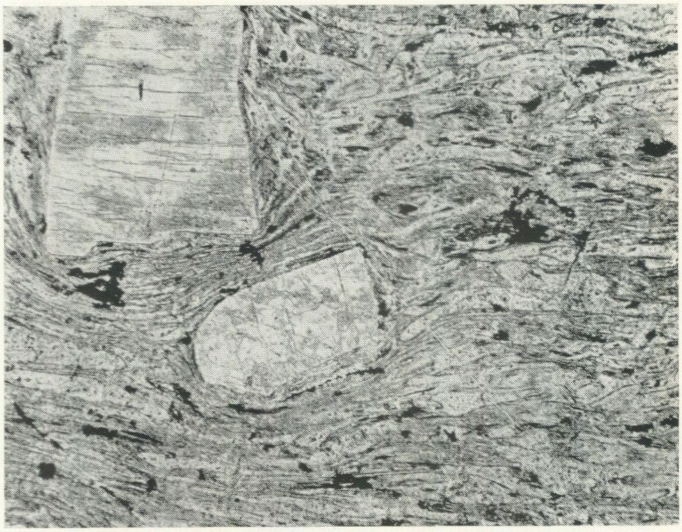

Fig. 7. Eutaxitic porphyry from near Untorp, Dalarna. 50 x. Phenocrysts of anorthoclase and albite are embedded in a groundmass of flattened and elongated grains which bend round the larger crystals, indicating that the original glass fragments remained viscous after they fell. The primary shard structure is evident in parallel light.

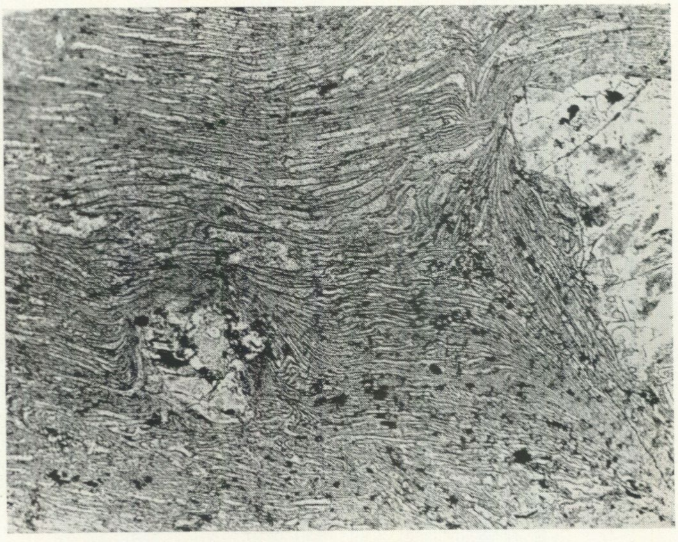

Fig. 8. Eutaxitic porphyry from Näckådalen, Dalarna. 30 x. Phenocrysts of anorthoclase and oligoclase in a markedly flattened groundmass, the elongated grains of which show typical Y-shape or more creased forms.

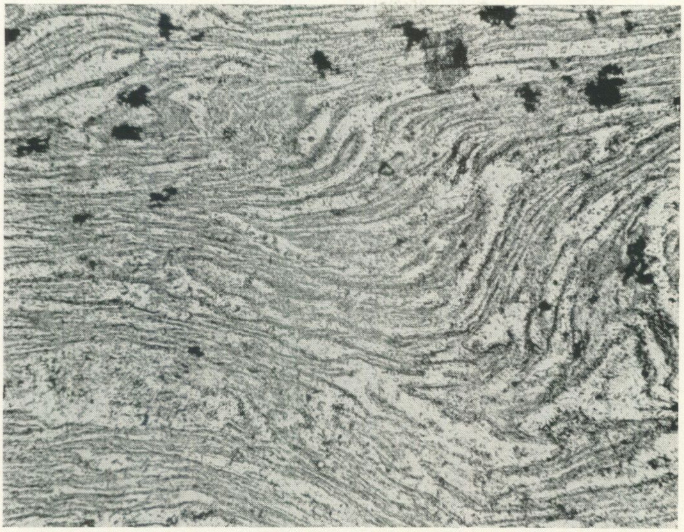

Fig 9. Same thin section as fig. 8. 100 x. Detail showing the distorted and creased structure. In the upper part of the fig. there is an elliptical grain indicating a previous bubble.

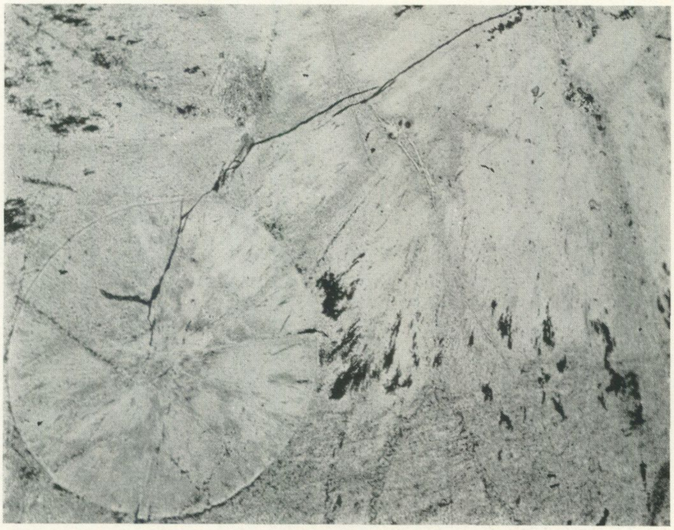

Fig. 10. Eutaxitic porphyry from Såvald Dysberg, Dalarna. 30 x. Large spherulites have been formed, probably in near connection with the deposition of the tuff. Between the spherulites there are remaining portions with a veiled shard structure.

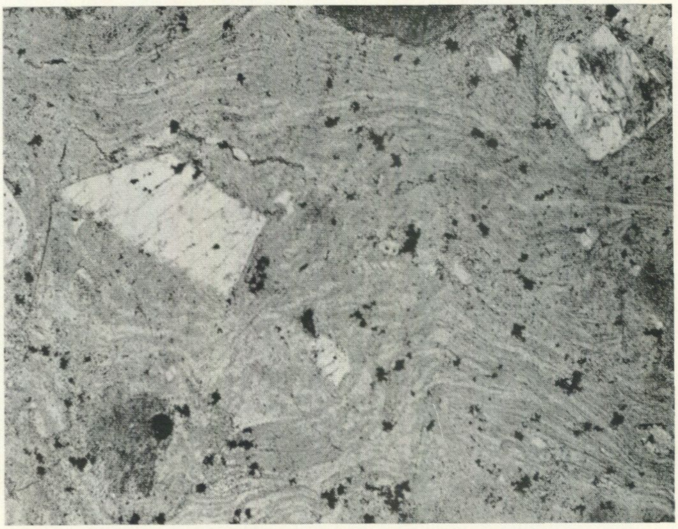

Fig. 11. Eutaxitic porphyry from Blyberg, Dalarna. 30 x. Closely lying phenocrysts of anorthoclase and acid plagioclase, some of them slightly corroded. The groundmass shows discontinuous streaks of lighter colour which are bent and pressed together and display characteristic bifurcations as well as elliptical grains.

Fig. 12. The same as fig. 11, crossed nic. The devitrification has proceeded far, and between crossed nic. the eutaxitic structure is no more visible but is replaced by a maculose appearance.

SVERIGES GEOLOGISKA UNDERSÖKNINGS SENAST UTKOMNA PUBLIKATIONER ÄRO:

Ser. Aa. Geologiska kartblad i skalan 1 : 50 000 med beskrivningar.

Priset för karta i ser. Aa med beskrivning är 10:— kr, för karta enbart 8:— kr.
(Price: map sheet + descriptive text Sw. kr. 10:—, map sheet Sw. kr. 8:—)

N:o 187 *Vårvik* av R. Sandegren och W. Larsson. Under utgivning.
» 196 *Västerås* av P. H. Lundegårdh och G. Lundqvist. 1954
» 197 *Laholm* av W. Larsson och C. Caldenius. T. v. utan beskrivning
» 198 *Halmstad* av W. Larsson och C. Caldenius. » » »
» 199 *Uppsala* av P. H. Lundegårdh och G. Lundqvist. With English summaries. 1956

Ser. Ad. Agrogeologiska kartblad i skalan 1 : 20 000 med beskrivningar.

Priset för karta i ser. Ad med beskrivning är 8:— kr, för karta enbart 6:— kr.
(Price: map sheet + descriptive text Sw. kr. 8:—, map sheet Sw. kr. 6:—)

N:o 1 *Hardeberga* av G. Ekström. 1947, karta med beskrivning
» 2 *Lund* » » 1953, » » »
» 3 *Revinge* » » » t. v. utan beskrivning
» 4 *Löberöd* » » » t. v. » »
» 5 *Örtofta* » » » t. v. » »
» 6 *Kävlinge* » » 1955, t. v. » »
» 7 *Teckomatorp* » » 1955, t. v. » »
» 8 *Trollenäs* » » 1955, t. v. » »
» 9 *Bosjökloster* » » 1956, t. v. » »

Årsbok 47 (1953)

Pris

N:o 530 Tullström, H., Kvartärgeologiska studier inom Rönneåns dalbäcken i NV Skåne 1954 3,00
» 531 Lundegårdh, P. H., Petrology of the Mölndal—Styrsö—Vallda region in the vicinity of Gothenburg. With one plate. 1953 4,00
» 532 Sahlström, K. E., Jordskalv i Sverige 1941—1950. Med en karta. Resümée: Erdbeben in Schweden 1941—1950. 1953 2,00
» 533 Horn af Rantzien, H., De geologiska resultaten från borrningarna i Höllviken. VI: Charophyta from the Middle Trias of the boring Höllviken II. With one plate. 1953 1,50
» 534 Lundegårdh, P. H., Vätögraniten. Summary: The Vätö granite — a younger Svionian granite in Eastern Upland, Sweden. 1954 2,00
» 535 Hägg, R., Die Mollusken und Brachiopoden der schwedischen Kreide. 4. Mit 9 Tafeln. 1954 3,00

Årsbok 48 (1954)

N:o 536 Gavelin, S., A telluride assemblage in the Rudtjebäcken pyrite ore, Vesterbotten, N. Sweden. 1954. 1,00
» 537 Jerlov, N., och Kullenberg, B., Undersökning rörande spridning och avsättning av i vattnet suspenderat slam vid utstjälpning av mudder i Byfjorden våren 1953. English summary. 1954 2,00
» 538 Tullström, H., Hydrogeologiska förhållanden inom Slite köping på Gotland. Engl. summary. 1955 1,50
» 539 Järnefors, B., Skredet vid Intagan år 1648. Under utgivning. . . . .
» 540 Byström, A. M., Mineralogy of the Ordovician bentonite beds at Kinnekulle, Sweden. 1956 4,50

Årsbok 49 (1955)

N:o 541 Pilava-Podgurski, N., Nya geologiska undersökningar vid Utö järnmalmsfält. English abstract. 1956 3,00
» 542 Hjelmqvist, S., On the occurrence of ignimbrite in the Pre-Cambrian 1956 1,00
» 545 Båth, M., An earthquake catalogue for Fennoscandia for the years 1891—1950. — Under utgivning.

Forts. å omslagets 4:de sida

Ser. Ba.

N:o 14 Jordartskarta över södra och mellersta Sverige. Efter de geologiska kartbladen sammandragen vid S. G. U. av K. E. Sahlström. Skala 1:400000.
Mellersta bladet, tryckt 1947 15,00
Södra bladet, tryckt 1948 15,00
Norra bladet, tryckt 1949 15,00

Ser. Ca.

N:o 21 Lundqvist, G., Beskrivning till jordartskarta över Kopparbergs län. Skala 1:250 000. 1951 20,00
» 27 Caldenius, C., and Lundström, R., The landslide at Surte on the river Göta älv.—Special chapters by B. Fellenius and E. Mohrén. With 5 plates. 16,00
» 31 Borell, R., och Offerberg, J., Geokronologiska undersökningar inom Indalsälvens dalgång mellan Bergeforsen och Ragunda.—Med 6 planscher. With English summary. 1955 3,50
» 37 Gavelin, S., och Kulling, O., Beskrivning till berggrundskarta över Västerbottens län. Karta i skala 1:400 000. With English summaries. 1955 45,00

Rapporter och meddelanden i stencil

1. Utredning rörande det svenska jordbrukets kalkförsörjning 1—2. 1931 (Kartorna utgångna) 15,00
2. Sveriges lodade sjöar. Sammanställning av K. E. Sahlström 1945 . . 3,00
3. Rapport över manganmalmsletningen i Jokkmokks socken 1940—48 av O. H. Ödman. Med 4 kartor 4,00

PRINTED IN SWEDEN

Distribueras genom

Generalstabens Litografiska Anstalts Förlag, Drottninggatan 20. Stockholm 16.