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— A DISCUSSION OF THEIR IDENTIFICATION AND CLASSIFICATION

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ABSTRACT

The volcanoclastic rocks of two areas in the Province of Småland, southeastern Sweden and their geological position are briefly described. The nomenclature of volcanoclastites is discussed, and a proposal for the classification of altered Precambrian volcanoclastic rocks is presented on the experience from southern Sweden.

INTRODUCTION

During the mapping of two areas in the Province of Småland (Persson 1973, 1974, Röshoff 1973), southeastern Sweden, problems emerged concerning the identification and classification of altered Precambrian volcanoclastic rocks. These problems caused us to analyse the general features of such rocks in order to find a workable classification scheme.

In spite of the high age of the rocks, many primary structures and textures are well preserved. Nevertheless, the previously proposed detailed classification and identification schemes of Recent, Quaternary and Tertiary volcanoclastites are difficult to use for altered Precambrian rocks, particularly in the field.

Röshoff (1973) investigated an area 12 km NW of Vetlanda (Fig. 1). The early Svecofennian supracrustal rocks of the Vetlanda supergroup (Röshoff 1973) are here composed of intermediate to basic volcanics, the Nömmen volcanic group, locally interlayered with sedimentary material, and of a sedimentary sequence, the Björkö group. The volcanic rocks are mainly volcanoclastic rocks, more seldom effusives. Some of the tuffitic rocks contain organic remains (Vidal

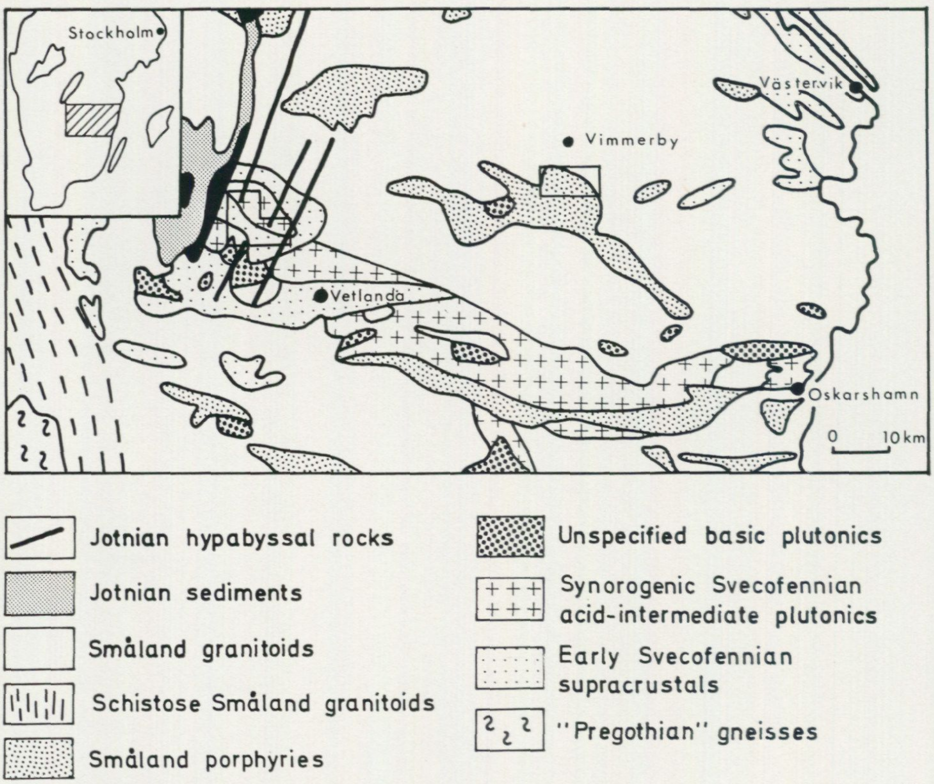

Fig. 1. Generalized geological map of northeastern Småland with areas investigated (mainly after Magnusson et al. 1958).

and Röshoff 1971). The supracrustal rocks were intruded by a series of Svecofennian plutonic rocks, yielding a Rb/Sr whole rock isochron age of 1839 ± 58 m.y. The serorogenic Svecofennian migmatization is of no importance within the area.

The acid volcanics, mainly rhyolites (the Småland porphyries) about 10 km to the south of Vimmerby (Fig. 1) were described by Persson (1973, 1974). They were interpreted as ignimbritic rocks, later intruded by massive granitic rocks, the so-called Småland granites. These volcanics and associated plutonics were considered to be post-orogenic Svecofennian. The Rb/Sr whole rock isochron age of the acid volcanic rocks is 1695 ± 20 m.y. (Åberg 1972).

Röshoff (1975) summarizes the geological evolution of this part of Sweden with main data from Hjelmqvist (1969), Persson (1973, 1974) and Röshoff (1973).

Acid and basic dykes	
Småland granites Granodiorite Diorite Gabbro	Post-orogenic Svecofennian
Virserum conglomerate Småland porphyries (1695 m.y.) Acid and basic vulcanism	
Basic dykes?	
Granite Granodiorite (1839 m.y.) Diorite Gabbro	Synorogenic Svecofennian
Supracrustal rocks Sediments and volcanics	Pre-orogenic

FORMER NOMENCLATURE AND CLASSIFICATIONS OF VOLCANOCLASTITES

Early papers concerning the nomenclature of pyroclastic rocks are by Wentworth and Williams (1932) and Blyth (1940), whose nomenclature is still used and discussed. Fisher (1966 b) has surveyed the concepts of later years.

Pyroclastic rocks only make up a part of the volcanoclastics. All transitions occur between purely volcanic and sedimentary rocks. Attempts to classify all types of these particular rocks have been made, especially during the last 15 years (e.g. Fisher 1958, 1961, 1966 b, Blokhina et al. 1959, Pantó 1959, Török 1962, Vlodavets et al. 1963, Peltz 1972).

Different criteria have been used to obtain workable classifications. Blokhina et al. (1959) and Vlodavets et al. (1963) applied quantitative relationships between the pyroclastic and sedimentary materials, mineralogical composition, and the size and shape of the particles. Blokhina et al. (1959) divided the volcanoclastic rocks into 4 main groups: (1) lava breccias, (2) pyroclastic rocks (100 % volcanic material), (3) predominantly pyroclastic rocks, i.e. tuffites (less than 50 % sedimentary material), and (4) pyroclastic-sedimentary (tuffogenic-sedimentary) rocks (more than 50 % sedimentary material). This classification is partly followed by Vlodavets et al. (1963 cf. Svoboda 1962). Vlodavets et al. (1963) use the prefix "xeno" for pyroclastic rocks with non-pyroclastic components, while tuffites include transported pyroclastics where the non-pyroclastic components are below 50 %. The extrusive-sedimentary rocks are divided into pyroclastic sediments and "volcanomict" rocks where the latter are formed by redeposition. An entirely quantitative classification is used by Hay (1952).

Pantó's classification (1959) is genetically based and also employs grain size. Rocks transitional to sediments are called tuffites and tuff-bearing sediments. The tuffites contain at least about 20 % and at most about 80 % sedimentary material, whereas the tuff-bearing sediments consist of more than 80 % sedimentary material.

Török (1962) separates the pyroclastic rocks according to their genesis into 3 groups which are (1) volcanoclastic or volcanic tuffs, (2) sedimentary pyroclastics: (a) tuffoides and (b) tuffites, and (3) pseudopyroclastics. The first group includes pure pyroclastic rocks, while the second contains sedimentary material. The tuffoide contains more than 90 % and the tuffite less than 90 % eruptive material. The pseudopyroclastics are deformed, igneous massive rocks.

Fisher's classification (1961) considers the process of fragmentation, the size of particles, and the amount of volcanic material. Fisher distinguishes between rocks which have been formed by pyroclastic processes and rocks formed by weathering of older volcanic formations (epiclastic rocks). The pyroclastic rocks consist of primary as well as reworked pyroclastic material. The reworked material has been moved from its original site and redeposited before lithification. Fisher (1961) proposes the following main groups: (1) autoclastic rocks, (2) pyroclastic rocks, (3) epiclastic rocks, and (4) equivalent non-genetic terms for volcanoclastic rocks with fragments of unknown origin. In later work, alloclastic and hyaloclastic processes of fragmentation have been considered (Fisher 1966 b cf. Wright and Bowes 1963). Epiclastic is defined as "a term applied to mechanically deposited sediments (gravel, sand, mud) consisting of weathered products of older rocks" (Fisher 1961).

Peltz (1972) bases his classification on the facies and the genesis of the rocks, their composition, the size and the shape of the fragments, and the type of matrix. He distinguishes between (1) pyroclastic and (2) epiclastic volcanic rocks. The epiclastic rocks include redeposited and subaquatic types.

We thus find that two or three groups of volcanoclastic rocks usually are distinguished. Groups transitional between pure pyroclastic and pure sedimentary rocks are the most interesting, and the greatest differences of classification concern these groups. Blokhina et al. (1959), Pantó (1959) and Vlodavets et al. (1963) have used a quantitative classification based on the amount of sedimentary versus pyroclastic material. Fisher (1961) has a transitional group of rocks included in the main pyroclastic group, and another group which is not defined genetically. Peltz (1972) distinguishes a group among the pyroclastic rocks ("agglomérat mixte" and "tuf lapillique mixte") which is subaerial or subaquatic and of a transitional character. Fiske et al. (1963) have tried to develop a classification of the volcanoclastic rocks for descriptive use. This classification is based on the size of the particles, the shape of the fragments, and the degree of sorting, and has been used for rocks of both known and unknown origin. The latter can be of either pyroclastic or epiclastic origin.

SUGGESTED CLASSIFICATION

Genetic classifications can profitably be used in areas of young vulcanism. In Precambrian terrains the origin of a rock can only rarely be completely assessed. Consequently, genetic classifications of volcanoclastic rocks are difficult to apply. On the other hand it appears impossible to develop a nomenclature completely based on non-genetic terms. Thus the proposed scheme (Table 1) is based on a combination of genetic and non-genetic criteria taken from the previous classifications cited above but here combined to satisfy our requirements within a Precambrian terrain.

The volcanoclastic rocks within the scheme have been divided into 3 main groups: (1) volcanoclastic flows, (2) pyroclastic rocks, and (3) mixed rocks including epiclastic types. Pure sedimentary rocks are excluded.

In the first group we have used the collective term volcanoclastic flows which includes the subgroups autoclastites, hydroclastites, and pyroclastic flows. The autoclastites are effusive rocks, where the fragmentation is caused by flow (flow breccia, lava breccia). Explosion breccias, formed by the expansion of gases within the lava flow also belong to the autoclastites (cf. Wright and Bowes 1963). The hydroclastites including hyaloclastites and pillow breccias are essentially characterized by a low viscosity, and are fragmented by flow in a watery environment (cf. Rittmann 1960, Cucuzza Silvestri 1963). The ignimbritic rocks and the nuées ardentes have been called pyroclastic flows (cf. Rittman 1960, Smith 1960, Steiner 1960, Ross and Smith 1961, Pantó 1962, Cook 1966, Fisher 1966 a, Vlodavetz 1966). Tufflavas or clastolavas (Maleyev 1963) cf. rheoignimbrites (Rittman 1960), ignispumites (Pantó 1963), foam-lavas (Pantó 1962), froth flows (Boyd 1961) have originally been interpreted as intermediate between effusive and pyroclastic rocks (Maleyev 1963, Shirinian 1963 cf. Ross and

TABLE 1. Proposed terminology and grain size limits for volcanoclastites

VOLCANO						
Volcanoclastic flows				**Pyroclastic rocks** **Matrix: Pyroclastic**		
Autoclastites	Hydroclastites	Pyroclastic flows		The shape of the fragments		Rock type
Flow breccias Explosion breccias	Hyaloclastites Pillow breccias	Ignimbritic rocks Nuées ardentes Tuff lavas (clastolavas) cf. lahars		Rounded		Agglomerate (Agglutinate)
				Angular		Pyroclastic breccia
			64			
				Rounded – angular		Lapillituff
			2			
				Rounded – angular	Coarse-grained	Tuff (lithic, vitric, crystal, mixed)
			0.06			
				Rounded – angular	Fine-grained	Tuff (lithic, vitric, crystal, mixed)
			0.004 mm			

Smith 1961, Petrov 1963, Cook 1966). These last special rock types have, however, not been identified in Småland, even if flows seem to exist among some acid types (cf. Persson 1973, 1974). According to Tazieff (1970) the tufflavas can be genetically connected with ignimbritic deposits. In addition, flow may have occurred in, for example, so-called ash-flows (Schmincke and Swanson 1967). Lahars or mudflows of volcanic origin may in some respects be compared to glowing avalanches or nuées ardentes (cf. Mullineaux and Crandell 1962), but according to Fisher (1960), the laharic breccias belong to the epiclastic volcanic breccias. (Concerning the special problem of breccias cf. Fisher 1958, 1960, Wright and Bowes 1963, 1968, Parsons 1967, 1969.)

The rocks within the second group are entirely pyroclastic in origin.

— Pyroclastic is defined according to Wentworth and Williams (1932) as: ”an adjective commonly applied to rocks produced by explosive or aerial ejection of material from a volcanic vent”.

— The nomenclature of the rocks follows the generally accepted classifications published by Wentworth and Williams (1932) and Blyth (1940).

CLASTITES

Mixed rocks

Matrix: Predominantly clastic

The shape of the fragments	General rock types		Specific rock types: Amount of matrix — Abundant	Specific rock types: Amount of matrix — Sparse	
Rounded	Volcanic conglomerate *(Vulkanitkonglomerat)*		Poorly sorted volcanic conglomerate	Well sorted volcanic conglomerate	
Angular	Volcanic breccia *(Vulkanitbreccia)*		Poorly sorted volcanic breccia	Well sorted volcanic breccia	
	Tuffite	Tuffitic arenite *(Tuffitisk arenit)*	Tuffitic greywacke *(Tuffitisk gråvacka)*	Tuffitic sandstone *(Tuffitisk sandsten)*	**2**
	Tuffite	Tuffitic siltstone *(Tuffitisk slamsten)* Tuffitic argillite (0.01 mm) *(Tuffitisk argillit)*			**0.06**
					0.004 mm

— The scale of gradation of the particles is taken from Fisher (1961).

— Fragments over 64 mm are suggested here to be subdivided into agglomerate and pyroclastic breccia depending on the shape of the fragments. Usually, the pyroclastic breccia has a more chaotic appearance.

Even among severely altered rocks it is often possible to distinguish between pure metasedimentary and pure metavolcanic rocks. The mixed types are those which are the most difficult to interpret and classify.

The third group includes mixed rocks, that is, with an unknown quantity of volcanic and sedimentary material. The general concepts of this group are based on Fiske et al. (1963), as that classification system is descriptive, but have here been reworked.

— The general nomenclature is volcanic conglomerate, volcanic breccia, tuffitic arenite, tuffitic siltstone and tuffitic argillite, and follows Wentworth and Williams (1932), Fisher (1961), Török (1962) and Vlodavets et al. (1963).

— The sedimentological term should be used as descriptive terms only to indicate the shape and size of the particles.

— If it is possible to estimate the amount of matrix the proposed nomenclature based on that estimation should preferrably be used (see Table 1).

— The prefix "volcanic" is here defined according to Fisher (1961, 1963, 1966 b) as: "an adjective which can apply as well to sediments derived from volcanic sources as to those produced directly by volcanic explosion".

— The particle scale follows the one used for sedimentary rocks and is consistent with Fisher (1961). This means that deposits with fragments over 2 mm are named volcanic conglomerate or volcanic breccia (cf. Pettijohn 1957), depending on the shape of the fragments (suggested Swedish terms are *vulkanitkonglomerat* and *vulkanitbreccia* respectively).

— As Precambrian fine-grained volcanoclastic rocks often are more or less recrystallized the collecting term tuffite can be used in those rocks with particle size below 2 mm.

— Rocks with a particle size below 0.06 mm are here called tuffitic siltstone or, in rare cases (below 0.01 mm), tuffitic argillites (cf. Török 1962, Vlodavets et al. 1963).

— Epiclastic rocks are included within this group, as it is usually not possible to distinguish redeposited unconsolidated volcanic material from weathered lithified volcanic material.

— It is proposed that supracrustal rocks of doubtful composition and maybe of unknown origin, and neither pure pyroclastic nor pure sedimentry rocks, should be included within this group.

In rocks where the sedimentary material strongly predominates, it is possible to use the term tuffaceous or tuffogen (Swedish term *tuffogen)* before a sedimentological term (cf. Hay 1952, Blokhina et al. 1959, Fisher 1966 b).

In order to show the general features of the relevant Precambrian volcanoclastites in the Province of Småland, some photographs of the main types have been selected (Figs. 2—10).

Fig. 2. Well sorted volcanic conglomerate with an intercalated layer which mainly consists of tuffitic arenite. The knife is 8 cm long. Photo K. Röshoff.

Fig. 3. Matrix of the well sorted volcanic conglomerate of Fig. 2, i.e. a tuffitic siltstone. Phenoclasts of plagioclase, granulated quartz grains and rock fragments in a quartz- and mica-rich groundmass. 2 nic. x50. Photo K. Röshoff.

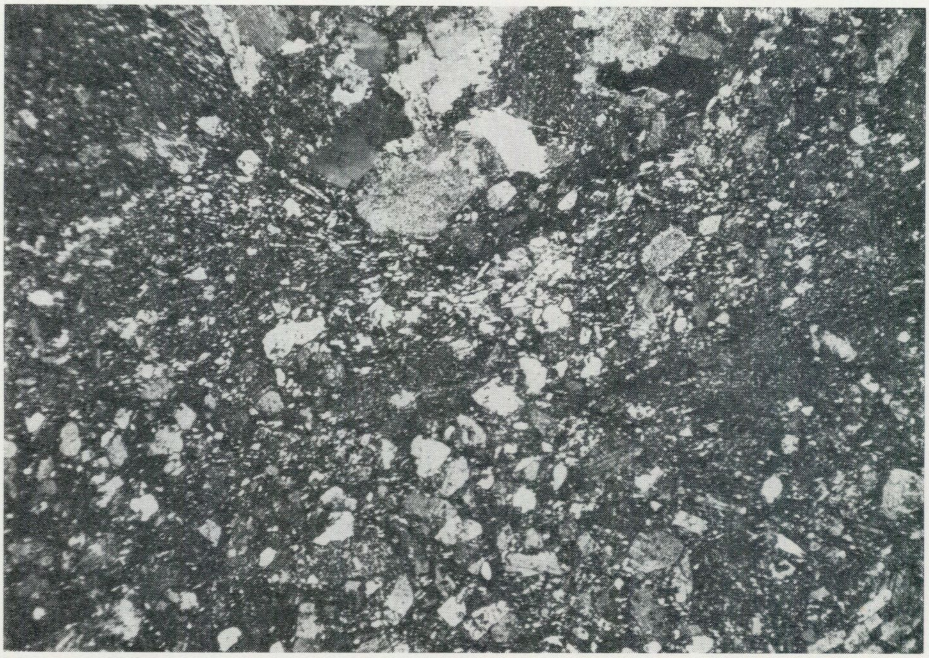

Fig. 4. Tuffitic arenite. Crystal fragments in a quartz- and chlorite-rich matrix. Xenolith of an acid plutonic rock. 2 nic. x20. Photo K. Röshoff.

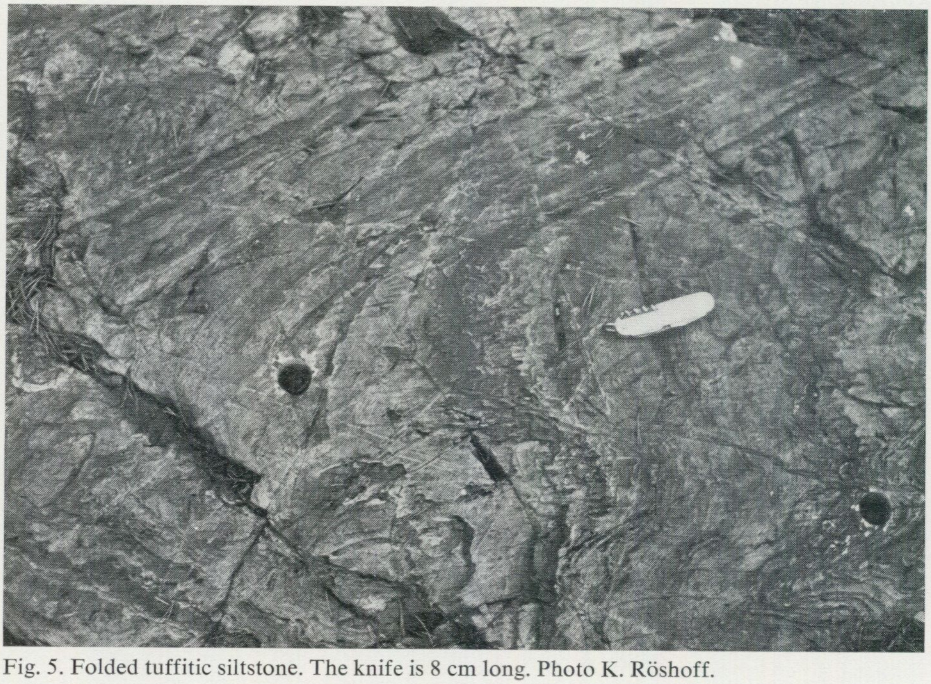

Fig. 5. Folded tuffitic siltstone. The knife is 8 cm long. Photo K. Röshoff.

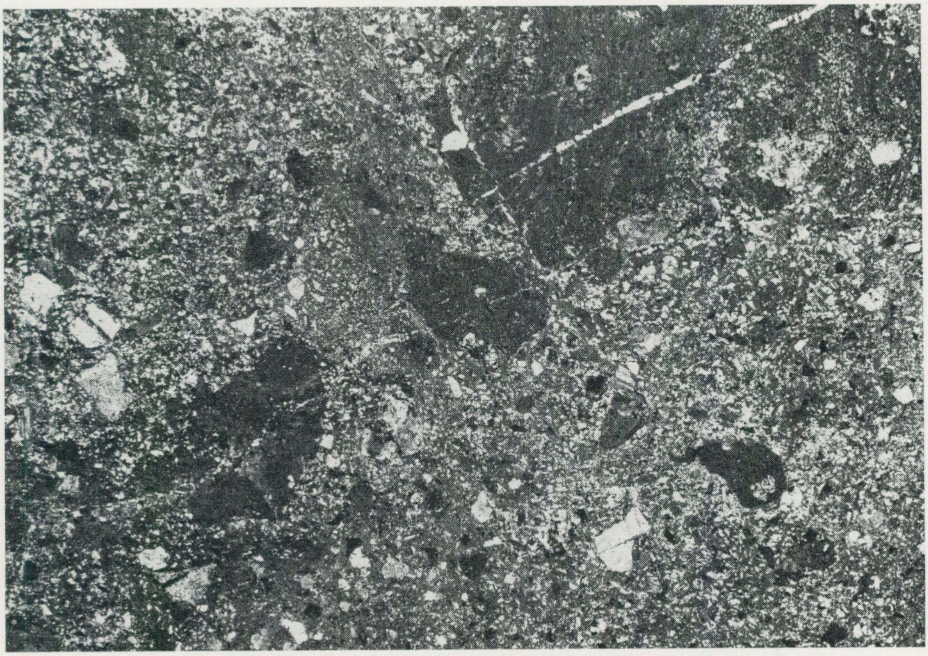

Fig. 6. Green, coarse-grained tuff with spherulite aggregates and a large number of crystals, partly crushed. 2 nic. x7. Photo L. Persson.

Fig. 7. Agglomerate with porphyry fragments. Photo L. Persson.

Fig. 8. Pyroclastic breccia. Intermediate angular volcanic fragments in a greenstone matrix. Photo K. Röshoff.

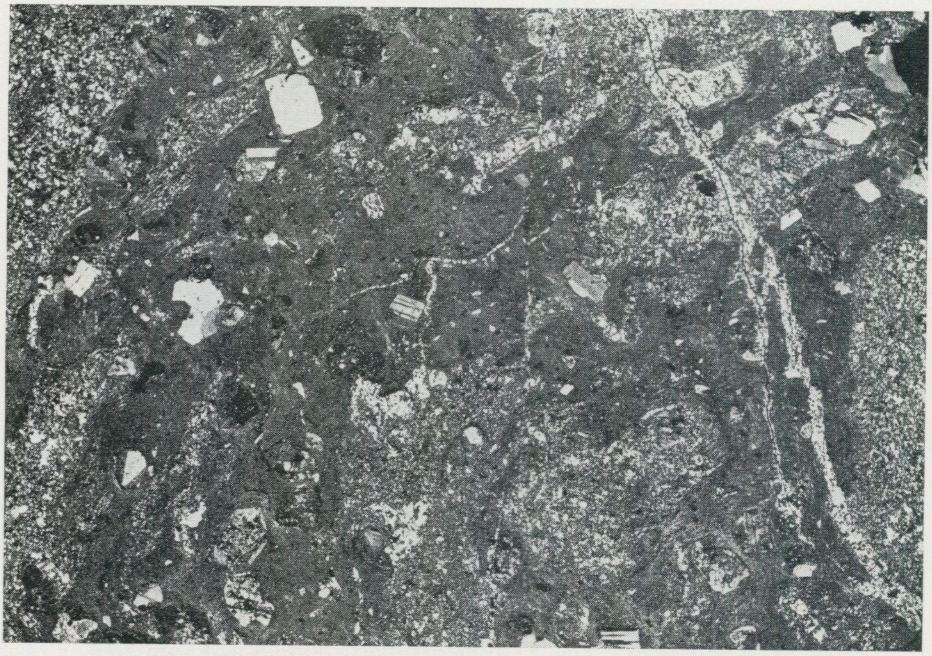

Fig. 9. Ignimbritic rock (dark porphyry). Cryptocrystalline groundmass with spherulite aggregates. Fluidal texture. 2 nic. x7. Photo L. Persson.

Fig. 10. Lava breccia. Dense and amygdaloidal basic volcanic fragments set in a calcite matrix. This rock type shows transitions in the neighbourhood to possible hyaloclastites. Photo K. Röshoff.

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