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Autor: Franks, Geoffrey D.

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THE KLEIN TÖDI AREA

INTRODUCTION AND SUMMARY OF PREVIOUS WORK

Pre-Triassic sediments exposed on the north face of Klein Tödi (fig. 19) give the best evidence of pre-Triassic volcanic activity within the eastern Aar Massif. The age of the sediments has not been conclusively proved, but the lithological similarity with the volcanics of the Biferten inlier strongly suggests that both are more or less synchronous, and thus of Upper Carboniferous age. Direct evidence of Permian age is lacking, and the similarity with Verrucano rocks is much less evident than that with the nearby Carboniferous.

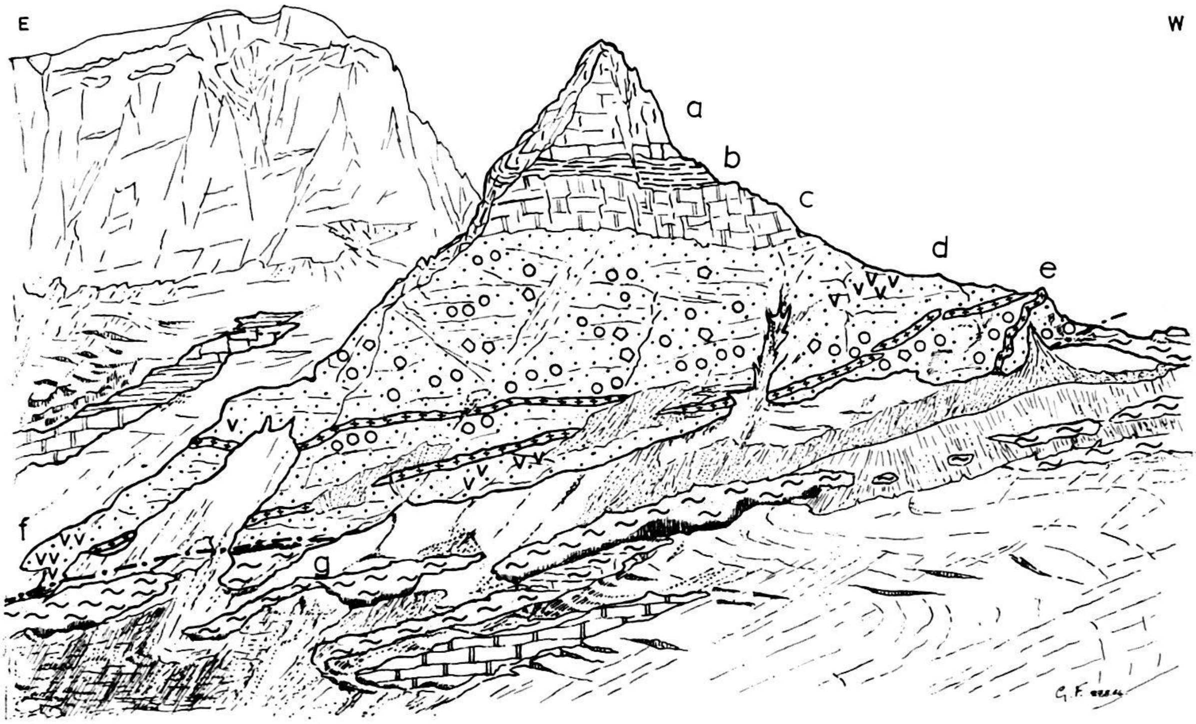

Fig. 19 View of Klein Tödi from the north (footpath at 2640 m) with Tödi (3620 m) in background. Legend: a = Malm, b = Dogger, c = Trias, d = coarse volcanic breccias with areas of lapilli tuffs (v), e = cross-cutting microgranite dykes, f = good exposures of lapilli tuffs, g = gneiss.

The bulk of the sediments are coarse breccias with a black mud matrix, but some finer-grained lighter-coloured well-bedded sediments are present. The presence of lapilli (fig. 20) indicates that some of these at least are of direct tuffaceous origin. Porphyritic microdiorites are found on the southern margin of the outcrops, where they are exposed, and the clearer northern border is a reverse fault contact with older hornblende and granitic gneisses. Two fine-grained porphyritic acid dykes cut across the sediments in an E–W direction from the west ridge of Klein Tödi to the eastern margin of the exposures.

Summary of Previous Work

ALBERT HEIM was the first to describe the rocks on the north face of Klein Tödi as being comparable with the anthracite-bearing rocks of the Bifertengrätli area, and illustrated the exposures in a field drawing – but marking some of the sediments as gneiss (1878, Vol. I, p. 46 and Atlas Pl. XII). The extent of the pre-Triassic sediments was drawn correctly in the map of WEBER (1924), where they were named as conglomerates and breccias of Upper Carboniferous age. WIDMER (1949) described these sediments as graphitic schists, and considered them to be most probably the equivalent of the beds of Bifertengrätli because they lie in the same strike. EUGSTER (1951) doubted the existence of Carboniferous sediments on the grounds that gneisses are exposed on the Sandpass itself, and that the dislocation metamorphism makes recognition of petrographic types difficult. None of these authors mention the lithology and the volcanic nature of the sediments.

LITHOLOGY OF THE PRE-TRIASSIC SEDIMENTS

The coarse conglomerates and breccias which make up the cliffs of the north face of Klein Tödi are best observed in fallen blocks. No primary bedding has been recognised in the western cliffs, and no further subdivision is possible, although the composition of the breccias varies markedly from place to place. Finer-grained well-bedded lapilli tuffs are easily accessible in the lower exposures at the eastern end of the north face (Ref. 711.725/186.250; 2600 m) and prove the volcanic nature of much of the sediment. For the lithological descriptions the north face of Klein Tödi is divided into a western, a central and an eastern area.

The Western Area

The cliffs north of Klein Tödi that lie nearest to the Sandpass, on the western side of the face, are predominantly of grey coloured volcanic breccias with some lapilli, angular blocks, and a quartz-feldspar matrix with calcareous concretions and much iron staining. The presence of lapilli amongst these unbedded breccias shows a pyroclastic origin for part of the material at least. Many of the blocks reach 30 cm in size, but most of the breccias are made up of smaller components up to 10 cm.

The most abundant fragments are intermediate to acid igneous rocks with porphyritic plagioclase and some quartz in the fine-grained groundmass. In some of the fine-grained blocks the plagioclase forms slightly altered crystals with simple outlines, while the larger plagioclase of the coarser varieties often show a zonal alteration. These rocks are porphyritic dacites of similar composition to those in the Bifertengrätli Volcanic Member. Some glassy fragments are seen with plagioclase and chlorite up to 0.05 mm, and in some varieties long plagioclase laths form a massive microlithic texture. Some banded rhyolite fragments are present. Fragments of granite and granodiorite of coarser grain represent material derived from older igneous rocks; in these the plagioclase (up to 4 mm) is often xenomorphic against the larger orthoclase, and the quartz is frequently strained or recrystallised. Single grains in the matrix of the breccias range in size from 0.05 to 0.5 mm and consist of angular, idiomorphic or corroded quartz grains; sericitised plagioclase which shows fresh parts, and sericite, calcite and clinozoisite as alteration products. Much of the matrix and some of the blocks are probably of pyroclastic origin, but the large size and the variety of the blocks speak for their normal clastic derivation.

The Central Area

Farther east, beyond the lower of the two acid dykes, the lighter coloured breccias of the western area give way to coarser breccias with a dark matrix. In hand specimen these are the most polygenic breccias found, and contain large fragments (up to 50 cm) of black shale and quartzite, lighter-coloured acid igneous blocks up to 20 cm, grey sandstones, hornfelses, gneisses and small carbonaceous fragments. Some irregular areas of sandy or tuffaceous sediments are present. The lithology is similar throughout the greater part of the cliffs, as far as may be judged from the accessible parts.

Much of the material is of a volcanic origin comparable with that of the other breccias of this area and of the Volcanic Member in the Biferten inlier. The important characteristics are the large size of the components and the abundance of metamorphic sediments and igneous rock fragments. The metamorphic rock fragments are fine-grained slates, hornfelses and metamorphic sandstones similar to those found in Val Gliems. Some coarse hornblende gneisses are present as angular blocks and are probably derived from the older metamorphic basement. Most of the metamorphic minerals of the fragments are strongly altered and are replaced by sericite and chlorite. A black and dark grey matrix of sand and mud is abundant.

The Eastern Area

The exposures at the eastern side of the north face of Klein Tödi are mainly of lighter-coloured finer-grained breccias and bedded tuffs which appear to lie normally dipping to the SE. Good exposures of lapilli tuffs are seen in the lowest easternmost exposures (grid reference above). The lapilli are sparsely distributed throughout a light-coloured quartz-feldspar rock or may form beds up to 5 cm thick. They are most abundant in the lower part of a crag 5 m high of well-bedded fine-grained tuffs and breccias with a rather light grey colour, and are often associated with fine-grained white glassy fragments of up to 2 cm. Higher in the cliffs the lapilli tuffs give way to coarser breccias in which bedding is only rarely seen.

Small-scale faulting is found in the fine-grained tuffs and lapilli tuffs (fig. 21). These structures correspond in shape and style to those of the Biferten inlier basal conglomerates and volcanics; displacements are usually in the order of 1–5 cm, spaced at regular intervals along one bed. They often die out upwards in coarser beds and were probably formed during the deposition of the coarser volcanic explosive rocks. Displacements with a reverse fault movement uplifting the eastern side have been observed near normal faults lowering the eastern side. The movements do not appear to have given uniform displacements, but are more in the nature of joints. They seem to have a similar N–S strike to the majority of the corresponding faults of the Biferten area.

In thin section the lapilli tuffs are composed of about 10 to 30% of crystalline quartz and plagioclase up to 0.5 mm in size set in a finer grained matrix of comminuted crystals and recrystallised volcanic dust. Idiomorphic shapes are rare and most of the

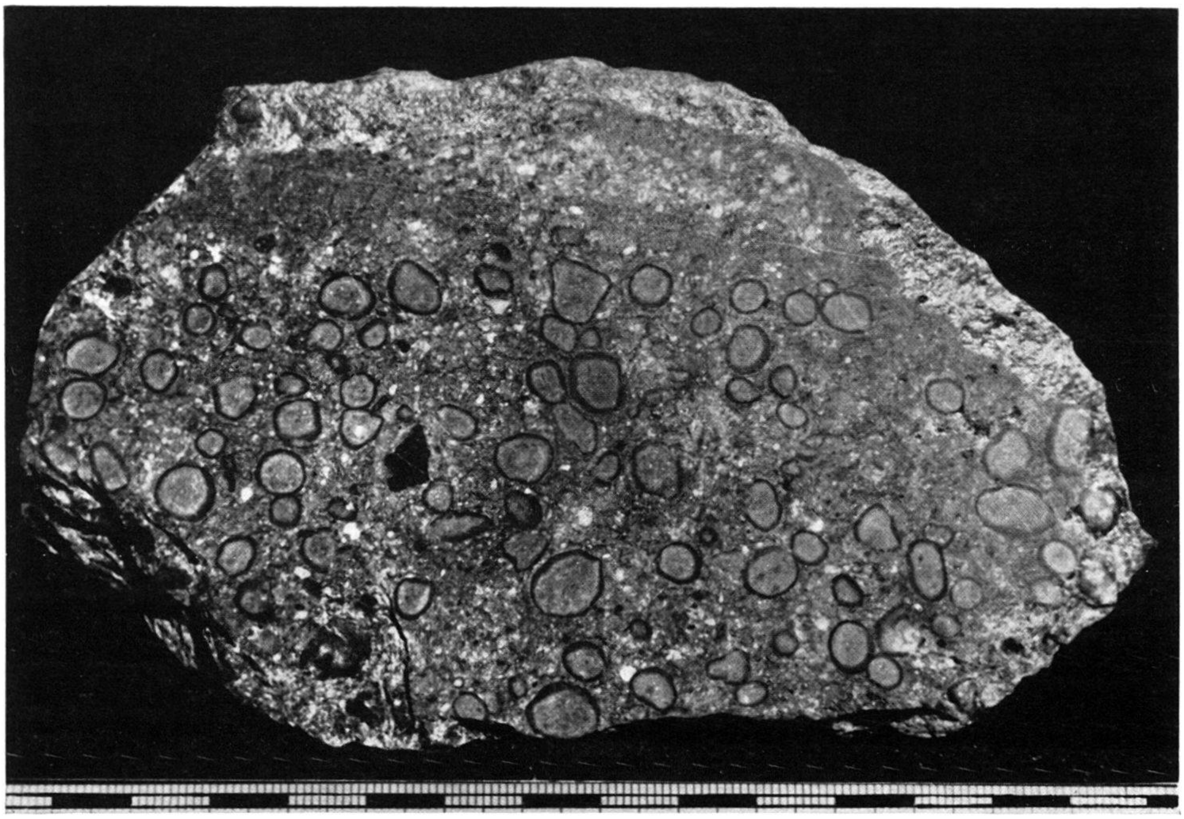

Fig. 20 Lapilli from the north face of Klein Tödi. Scale in cms and mm.

crystals are broken or subangular, and the feldspars strongly altered or replaced entirely by calcite. The lapilli are composed of similar material to the bulk of the rock, but they are of finer grain size and surrounded by a darker rim of devitrified glass 0.2 to 0.5 mm thick (fig. 20). Occasional irregularly shaped or angular darker glassy fragments up to 2 mm are seen. Chlorite and calcite as alteration products

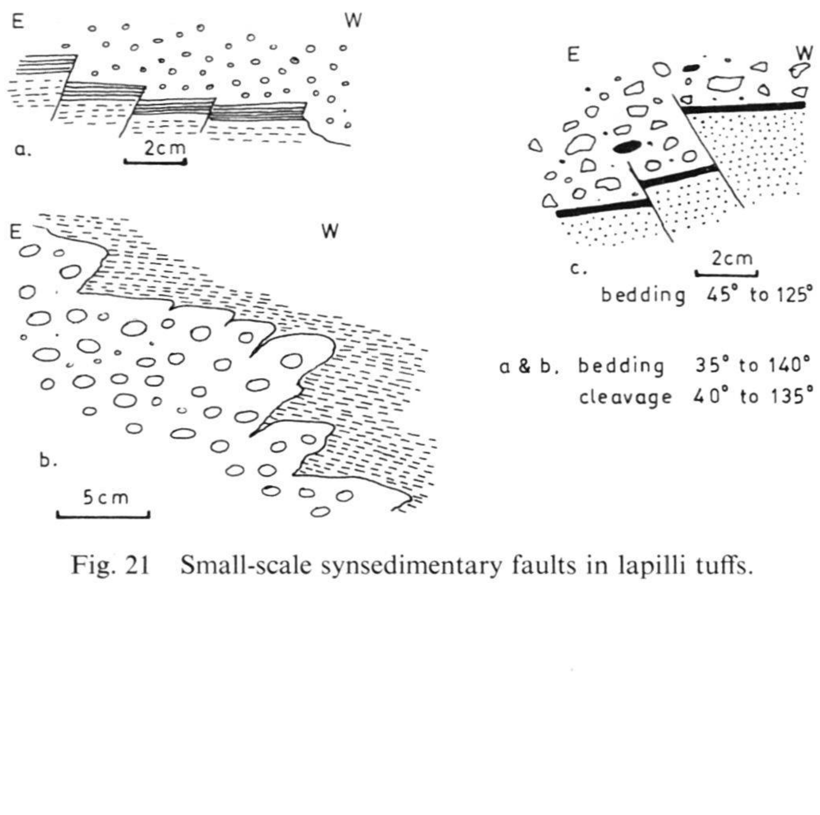

Fig. 21 Small-scale synsedimentary faults in lapilli tuffs.

form large areas up to 1 mm, and sericite is restricted to very fine plates in the groundmass.

Amongst the light-coloured igneous rock fragments of the coarser breccias associated with the lapilli tuffs, the most remarkable are rhyolitic to microgranitic fragments which show textures of welded tuffs of ignimbrites in thin section (fig. 22). These ignimbrites have been determined mainly in specimens from the eastern cliffs, but blocks of similar rock are found elsewhere in the Klein Tödi breccias. In thin section they are seen to contain quartz as idiomorphic or slightly corroded grains which reach 2 mm in size; alkali feldspars and some plagioclase are also present in grains up to 1 mm. The feldspars are mainly altered. Glass shards and quartz splinters reach 1 mm in size, and parts of the fine-grained matrix are recrystallised and welded to give microcrystalline quartz-feldspathic bands which cut the rock irregularly.

INTRUSIVE DYKES OF MICROGRANITE TO RHYOLITE

Three dykes cut the sediments and are shown in fig. 19. In hand specimen they are very light-coloured fine-grained dense hemicrystalline rocks with visible phenocrysts of feldspar and quartz. The thickness of the dykes is 4–5 m, and little visible contact metamorphism is seen in the field, although a thin section of a sediment from the contact showed recrystallisation of the groundmass and new growths of plagioclase.

In thin sections the rock is seen to contain feldspars of up to 1.5 mm and less abundant quartz of up to 0.5 mm scattered in the very fine-grained (0.05 mm) groundmass. The small quartz grains are usually resorbed; some quartz occurs as composite grains made up of fine aggregates of 0.1 mm and may represent recrystallised glass fragments. Orthoclase in large crystals with simple twinning is more abundant than the smaller plagioclase, which is frequently seen in crystal groups. Alteration of the feldspars to sericite and a carbonate is rather strong, and sericite is uniformly dispersed through the groundmass or enriched on cleavage surfaces. No flow structure is evident, although the plagioclase crystals are roughly aligned. Phenocrysts make up only about 10 to 20% of the rock, but from these the composition of the rock is judged to be granitic; i.e. the dykes are of rhyolite to microgranite.

THE GNEISSES AND GRANITE-GNEISS TO THE NORTH OF KLEIN TÖDI

The rocks to the north of the cliffs are gneisses of the "Altkristallin" which have been deformed, but which retain much of their original structure – as seen on the Sandpass. The boundary of the gneisses to the sediments in the south is brecciated and accompanied by quartz veins and quartz segregations. The northernmost sediments are a band 3 m wide of black slates followed to the south by coarse breccias (3 m) and another fault zone marked by 4 m of green schists.

Coarse, deformed granitic gneisses are seen mainly at the base of the eastern cliffs. In hand specimen this rock is coarse-grained holocrystalline with sericitic surfaces and a noticeable chloritic colouration. In thin section it is a holocrystalline rock which was originally coarse-grained, with quartz, orthoclase and plagioclase. The quartz occurs as irregularly outlined grains forming a cataclastic network which

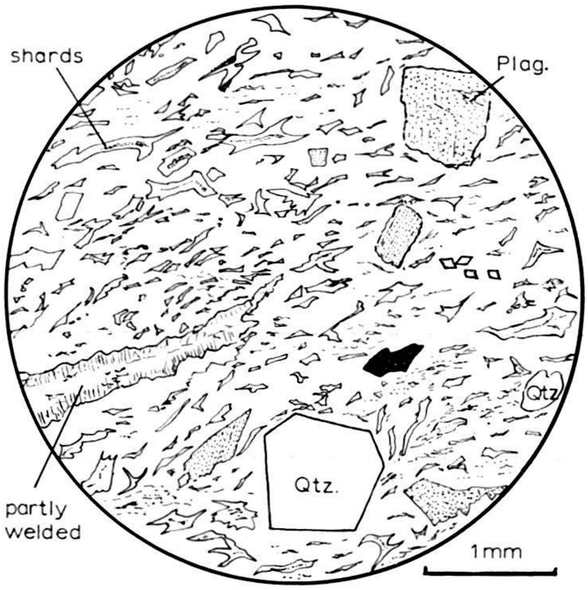

Fig. 22 Thin section drawing of a welded tuff from the volcanic breccias of Klein Tödi: glass shards and local zones of complete welding.

surrounds the other minerals. Microcline is present as altered areas full of sericite and cut by mica plates. It is equal in size to the quartz and contains inclusions of smaller plagioclase crystals. The granite gneiss belongs to an older granitic complex than that of the intrusive dykes. It is believed to be part of the crystalline basement on which the volcanic rocks were deposited, and may be equivalent in age to the Tödi granite.

STRUCTURES

The pre-Triassic unconformity has been strongly deformed by folding and thrusting in the Klein Tödi area, and the pre-Triassic sediments have presumably suffered a similar amount of deformation, although their structures are less clear than those of the overlying rocks. Pre-Triassic structures cannot be distinguished from Alpine structures in this area. The dykes in the basement are seen to be displaced by fractures, and the lapilli are deformed, but the lack of bedding within the coarse clastic sediments prevents further description of the geometry of the basement structures.

In relation to the Alpine structures the Klein Tödi rocks occupy a position comparable to the northern Bifertengrätli/southern Röti area, where the pre-Triassic unconformity has been deformed into an upright position. The displacements lie above shear zones in the basement, and increase in magnitude towards the west; on Klein Tödi the vertical limb of Triassic dolomites is 400 m in extent. In the upper part of Klein Tödi there is considerable overthrusting of the Triassic.

An estimate of the amount of deformation of the pre-Triassic sediments may be obtained from the deformed shape of the lapilli on the assumption that these were originally spherical. The lapilli are flattened on the cleavage, but show only a slight elongation. Measurements of the lapilli are shown in fig. 23, where $2a$, $2b$ and $2c$ are the lengths of the principal axes in hand specimens. The strain indicated by these measurements is shown in the table (fig. 17), where $Z > Y > X$ are the principal axes of the strain ellipsoid. The ratios $Z:Y$ and $Y:X$ are shown on a deformation plot (FLINN 1962) in fig. 17. The plot from this area falls together with plots from other pre-Triassic sediments in a broad group of flattening type deformation.

The elongation direction seen in the volcanic sediments plunges to the SE (145°) on a cleavage dipping to the SSE (50° to 155°); this is approximately the same orientation as that in the Biferten inlier, but it is also a direction of the Alpine structures. The measured deformation is therefore probably a combination of Alpine and pre-Alpine components which cannot be separated.

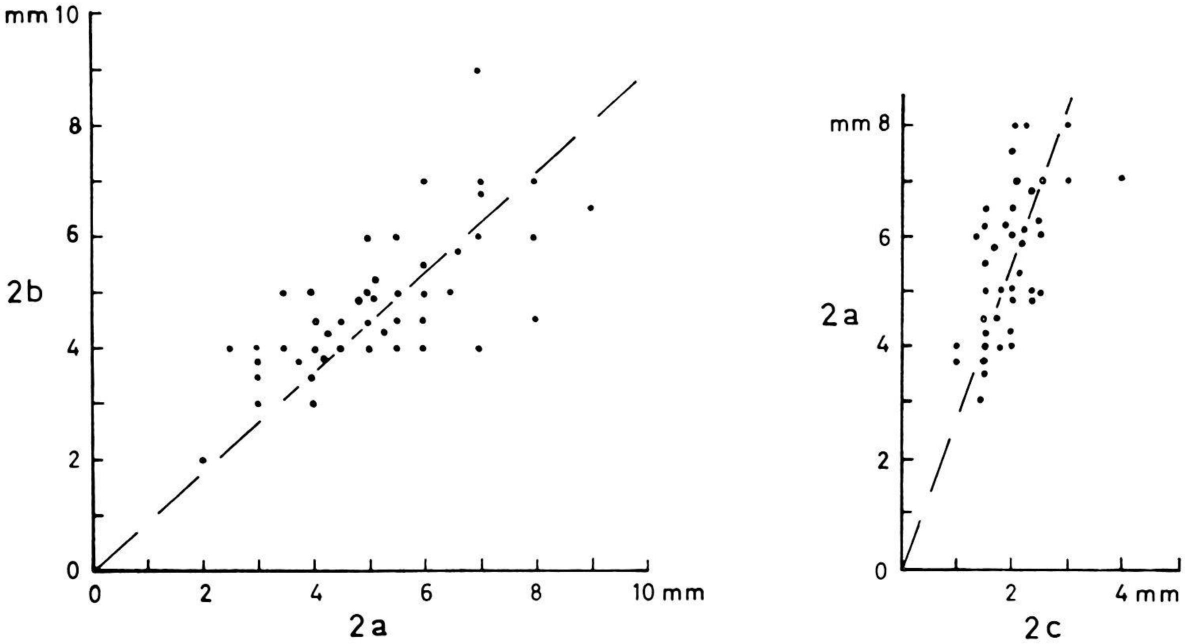

Fig. 23 Measurements of deformed lapilli from Klein Tödi, plotted as in Fig. 16: strain calculation and deformation plot shown in Fig. 17.

DISCUSSION OF THE KLEIN TÖDI VOLCANICS

The Klein Tödi rocks are believed to be equivalent to the Volcanic Member of the Biferten inlier, and add greatly to the reconstruction of the volcanic activity. Three further important facts about the activity emerge:

(1) Lapilli tuffs are absolutely indicative of pyroclastic deposits from a nearby volcanic centre. The ejection of these tuffs was accompanied by small-scale syngenetic faulting.

(2) Ignimbrites or welded tuffs are present as components and are therefore older than the breccias themselves. They may be of similar age to the Sandalp quartz porphyries, and they possess strong similarities with the acid pyroclastic rocks of Windgällen and Tscharren farther to the west.

(3) The breccias are cut by acid dykes which are probably related to a larger granite intrusion, possibly the Central Aar granite. The acid pyroclastic rocks of the breccias are clearly separated from these intrusions by the period of erosion and deposition of the Klein Tödi volcanics. These intrusions may support the late, post-volcanic age of the main Central Aar granite intrusions.

In reference to the Biferten area the Klein Tödi rocks correspond to the late explosive activity. The greater abundance of acid types and the presence of gneiss boulders from the basement are in contrast with the Biferten inlier rocks. This may indicate a slight age difference, the Klein Tödi rocks being somewhat younger, but it is more likely to be a result of deposition on ground which remained under rigorous terrestrial conditions and did not subside into a more protected basin farther removed from the source rocks.

THE MADERANERTAL

INTRODUCTION AND SUMMARY OF PREVIOUS WORK

The Maderanertal cuts into gneisses, granites and schists of the northern border of the Aar Massif. To the north and south of the main valley there are small areas of pre-Triassic slightly metamorphic formations, which are mainly of volcanic origin. Those to the north form much of the core of the Windgällen recumbent anticline, and those to the south form a belt of 14 km by 4 km on the northern border of the main Central Aar granite. It is important that these two outcrop areas be discussed in close conjunction, for although their direct connection has been destroyed by the erosion of the valley they both provide evidence of volcanic activity of probable Upper Carboniferous age. The petrography of most of the rocks has been previously described, and the present study has been aimed at providing an explanation of the origin and history of the rocks which have been qualified as quartz porphyries, quartz porphyry tuffs and as Carboniferous sediments.

Summary of Previous Work

The earliest observations of anthracite-bearing rocks of assumed Carboniferous age in the Maderanertal and of the porphyritic rocks of the Windgällen appear to have been made by ARNOLD ESCHER in 1841, but publication of his notes was held back. His successor, ALBERT HEIM, studied a large area of the eastern Aar Massif, the Windgällen in particular, in the years from 1870 to 1890. The earliest studies grouped together the pre-Triassic low-grade metamorphic sediments as so-called Lower Veruccano or Casanna schists, possibly of Lower Paleozoic age (1878). The crystalline rocks were described petrographically by SCHMIDT (1886); the intimate relation of the porphyritic acid igneous rocks of the Windgällen with Carboniferous sediments, and a comparable relationship on the south of the valley suggested a correlation with other Carboniferous rocks of the Massif. Schmidt discussed the possibilities that the porphyritic acid rocks were a pre- or Lower Carboniferous intrusive stock, or that they were connected as a marginal facies to the Aar granite. He gave petrographical descriptions of 5 types of porphyritic rocks from the Windgällen, some microgranitic and others granophyric or felsitic. The descriptions of Heim and Schmidt were extended over a larger area of the Massif in 1891 and the crystalline rocks were divided into zones similar to those established farther east by BALTZAR (1880) and FELLENBERG (1893).