THE PLIOCENE AND QUATERNARY VOLGANISM IN THE HASAN DAĞ-MELENDİZ DAĞ REGION

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ABSTRACT. — Between Aksaray, Gelveri and the Hasan Dag the «Melendiz River Series» is wedging out to the north against the crystalline basement and the Oligoccne - Miocene «Gypsum series». The series is volcanoclastic and formed in the Pliocene as a result of an ignimbritic volcanism which preceded the basalt volcanism of the Hasan Dag area in the south.

There is a close relation between the orogenic development of the Taurus and the volcanic depositions in the foreland of which the area is a part. The ignimbrite volcanism came to a close with the formation of a rhyodacite-ava. The andesito-basalt volcanism had already started, followed by pyroxene-hornblende basalts and finally by olivine basalts, which formed the terminal phase in the basalt volcanism. The start of the basalt-volcanism may represent the Pleistocene.

INTRODUCTION

During the summer - periods of 1964 and 1965 the volcanic region between Niğde and Aksaray was detailed mapped on a scale 1 : 25 ,000 .

In this region several authors have travelled, making geologic observations of which a short survey will follow below.

Hamilton already visited the area in 1842 and noted the harder and more compact topsection of the rhyolitic tuffs near Aksaray and Ürgüp. He called these tuffs «peperites». He also described lava streams descending from parasite-cones on the north flank of the Hasan Dağ and very young conelets with lava streams, filling up young tuff valleys.

Tchihatcheff (1867) described the harder topsection as «trachyte» and the columnar structure of such a «trachyte» layer on top of the white pumice tuffs near Niğde and Aksaray.

Chaput (1936) described these hard layers too: «These tuffs constitute plateaux with heights of 1150-1200 meters near Aksaray, where they are resting on folded Oligocene gypsum beds and older diorites, whereas north of that city they cover Miocene marls and sandstones of the Tuz Gölü basin».

Tromp (1942) called the limestone beds southeast of Aksaray Pleistocene, but Okay (1957) gave them a Pliocene age.

Tromp described also the Tuz Gölü fault zone and connected the huge extrusions of the Hasan Dag area with it. This fault zone originated at the end of Upper Eocene, but he thinks that the volcanic activity started on it at the end of the Miocene, after widening of the faults. He stated even a Neolithic or Historic volcanism from the fact that the young basalt streams can be seen filling up young valleys in the tuff.

Westerveld (1956) considered the compact tuff banks, especially at the top of the pumice sequence as typical examples of welded tuffs in different states of induration. Fine columnar jointing and steep erosion cliffs are striking features of the top layer, which represents the rock unit designated as «trachyte», «brecciated lava» or «lava» by authors as Chaput and Tchihatcheff.

Vitrophyre eruptions north of the Gölü Dağ and outside the area, are already mentioned by Westerveld and Sassano (1963).

The Melendiz - Hasan Dağ complex forms a mountain range in an east - west direction, with summits just over 3000 meters. Large flat plains surround this mountainous area with heights between 1100 and 1400 meters. The Melendiz River drainage system intersects the flat tuff region and exposes the horizontal bedded tuffites, tuffs and ignimbrite-sheets. The cone landscape has been developed especially southwest of the Hasan Dağ. The steep cones of the Hasan Dağ area have a much younger relief than the more mature topography of Melendiz Dağ.

GEOLOGY

DESCRIPTION OF ROCK UNITS

From old to young the following rock units arc described :

25. Ultrabasic and granodioritic rocks
24. Non-volcanic deposits
23. Göstük tuffite
22. Göstük ignimbrite
21. Karakaya tuffite; detritic member
20. Karakaya tuffite; calcareous member
19. Selimetuff
18. Gelveri ignimbrite
17. Kızılkaya ignimbrite
16. Melendiz Dağ tuff
15. Niğde formation; member of Bor
14. Nigde formation; member of Yakacık
13. Niğde formation; member, of Altunhisar
12. Niğde formation; member of İnli
11. Agglomerates and volcanic conglomerates of the Keçiboydoran Dağ
10. Volcanic vent breccia
9. Andesito-basalts
8. Hasan Dağ ash formation
7 Glowing avalanche deposit of the Hasan Dag.
6. Ash-flow tuff of the Hasan Dağ
5. Basalts
4. Ash-flow tuff of the Göllü Dağ
3. Rhyodacite of the Göllü Dağ
2. Travertine
1. Alluvium

A short description of these rock units will be given below :

25. Ultrabasic and granodioritic rocks

On the northern boundary, north of Ören Tepe and Göstük, small and scattered outcrops of spilites and granodiorites represent the crystalline basement. These rocks are more extensively exposed north of the boundary. In general they are directly covered by the characteristic plateaux of the Kızılkaya ignimbrite (e.g. Mamasun Dam-lake area.) The weathered, dark green spilites show intense fracturing, which gives them a crumbled appearance.

The granodiorite is covered by a thin regolith and shows only fresh outcrops from the boundary northward. This regolith contains in many places a great amount of ultrabasic pebbles (e.g. amphibolites, gabbros, serpentinites and hornblende diorites). From the available field outcrops an age relation between the two rock types could not be stated.

24. Non-volcanic deposits

A small strip in the northwestern part of the region is occupied by the Oligocene-Miocene «Gypsum series» (Tromp). This series is gradually better developed in large exposures, more to the northwest in the direction of Aksaray. In the region itself it forms white pulverized low hills along the western boundary. Here, the series are directly covered by the Kızılkaya ignimbrite plateau, or by the Göstük tuffite.

23. The Göstük tuffite

The tuffite forms the base of the volcanoclastic «Melendiz River series», a series of tuffites, tuffs and ignimbrites, exposed in the drainage area of the Melendiz River, north of the Hasan Dag and wedging out to the north against the cristalline basement, east of Aksaray. This basal formation is exposed in the Göstük valley and in wider exposures along the western boundary southwest of Çeltek.

Small outcrops can be observed below the ignimbrite scarp south of Karakaya Tepe. In the Göstük valley the reddish - brown soft tuffite rests on the spilitic basement. In the west the tuffite, which shows no bedding features, except some zones of basaltic and ultrabasic pebbles, has got a brown and earthy appearance, in which a characteristic dendritic drainage pattern had been developed. Here it rests on the white «Gypsum series» with a very vague contact.

South of Karakaya Tepe the upper part of the tuffite is saved from erosion by the hard Göstük ignimbrite sheet on top of it. It contains thin regular beds of tuffite of varying color and grain size. The softer non - layered lower part forms a more gentle slope at the base of the scarp. A sharp discordance by current action can be observed here with the younger Karakaya tuffite.

22. The Göstük ignimbrite

This gray ignimbrite is exposed, for the greater part, in the area between Ören Tepe, Çeltek and Göstük, in a wide plain and in the flanks of several mesas. South of Kızılkaya the ignimbrite forms a plateau with high vertical cliffs along the Melendiz River.

In the plain the only outcrops are small harvesting places, where the farmers have removed about 50 cm thick top soil. The flat surface of the ignimbrite serves as an excellent threshing - floor. The ignimbrite displays variation in resistance, probably as a consequence of, variation in the intensity of welding. At Göstük, along the roadside in a deep gorge, smoothly rounded surfaces form an apparent contrast with the high cliffs along the river, south of the village. The gray to purple ignimbrite is of an andesitic composition and is fine to coarse agglomeratic, containing dark red and black basalt fragments of grain and pebble size. White pumice fragments of lapilli-size, but also of far greater dimensions (20 to 30 cm in diameter), are abundantly distributed.

Columnar jointing is a common feature. The base of the gray ignimbrite is constantly developed as a white vitric even-grained pumice tuff, not more than 2 meter thick. This white tuff is well-exposed between Göstük and Karakaya Tepe.

The ignimbrite, south of Karakaya Tepe forms an isolated plateau with a low scarp on the northern edge. It is separated from the ignimbrite - plain between Çeltek and Göstük by an old erosion valley, which has been filled up by the Karakaya tuffite formation in the Lower Pliocene. Apparently the ignimbrite had formed an old valley floor or terrace, which later was dissected by the old Melendiz River.

A thin ignimbrite layer covers the Göstük tuffite in the high escarpment south of Çeltek. It surrounds the tuffite and its dendritic drainage pattern and forms the base of the Karakaya tuffite formation. Many cave churches and hermitages have been cut out in this part of the ignimbrite.

21. Karakaya tuffite; detritic member

This well-layered tuffite is for the greater part located in the area between Çeltek and Selime. On the left bank of the Melendiz River it forms the Karakaya Tepe. This hill exhibits well-layered detritic tuffite beds of varying brown to gray colors, grain size and composition.

Coarseness can suddenly change laterally and vertically, due to irregular cross-bedding and cut-and-fili structures which only can be ascribed to fluvial deposition.

Certain beds are rich of dark green or black spilite and basalt grains and pebbles. The latter easily weathers out of the calcareous or sandy matrix and form dark gravel talus Common constituents are rounded pumice and tuff fragments. Mangan-ore and limonite-coating of the grains gives the beds resp. gray and brown colors. Silicified tuffite beds are rare. A certain horizon in the tuffite of Karakaya Tepe contains fossil rests of an elephant, which are determined of Pliocene age, presumably Pontian, *s. l.* The deposition of the tuffite evidently found place in a wide river basin between Çeltek and Selime. These deposits were later dissected by the recent Melendiz River. The flat surface of Karakaya Tepe forms another terrace. A sharp discordance by current action can be observed at the southern border of the basin between this tuffite and the older Göstük tuffite.

20. Karakaya tuffite; calcareous member

From NE to SW the detritic facies of the Karakaya tuffite merges into a calcareous facies. The same change in deposition conditions can be observed vertically, a detritic facies below and an increase in limestone beds in the upper part of the formation.

These features can be best observed at the Akburun Tepe escarpment, southwest of Çeltek. NE of Karakaya Tepe isolated calcareous tuffite mesas occur, resting on the Göstük ignimbrite at the right bank of the Melendiz River. These are the most northeastern occurrences of this facies in the area. North of Karakaya Tepe the top-limestone layer rests directly on the lower part of the Göstük ignimbrite, i. e. the white vitric tuff of which the basal part of the ignimbrite is formed.

The limestone and accompanying calcareous sandstones and sandy limestones are of lacustrine origin. They overly in horizontal banks the gray ignimbrite and the lower detritic and volcanic scoriae banks of the formation (Akburun Tepe, Eskinos-mesa). The compact white to light yellow limestone contains no fossils. Volcanic scoriae banks contains coarse and fine scoriae fragments. Coarse scoriae banks alternate with fine-grained scoriae banks and with harder fine agglomerates, containing black angular basalt fragments, cemented in a compact limestone matrix.

The alternation of hard and soft layers gave rise to a selective erosion in the escarpment of Akburun Tepe and on the flanks of the different mesas. So the limestone banks are usually projecting over the soft detritic and scoriae beds on those places.

19. Selime tuff

At Selime and Yaprakhisar this tuff has the thickest development (between 60 and 100 m). From this area the tuff is rapidly wedging out in northern and western direction. In the nort (Kızılkaya-Göstük) the white vitric and homogeneous pumice tuff varies between 5 meter, south of Kızılkaya, till some centimeters close north of Göstük. This wedging out in northern direction is shown by all rock units, except the Kizilkaya top-ignimbrite. Also in western direction the tuff wedges out entirely between the hard ignimbrite sheet on top and the bedded tuffite at its base, as is shown in the steep sides of the mesa at Çeltek.

East ot the line Selime-Kızılkaya the tuff forms a wide plain, descending northward and in the south bordered by several ignimbrite-mesas. The tuff here is commonly covered by a thin dusty regolith soil. From the east basaltic lavas have spread out over this tuff plain along the eastern border of the area.

A typical feature in this formation is the lateral facies change in an east-west direction. West of the line Kizilkaya - Selime the tuff is white to pink-colored, fine-grained, vitric and bears only small white pumice fragments. At Selime, black basalt- and red tuff-fragments begin to appear, whereas the white pumic fragments grow larger in more eastern direction. North of Gelveri, the basalt-, spilite-, obsidian-, tuffite- and pumice-fragments are more conspicuous constituents. Limonitization of some of them has a coloring effect on the vitric tuff matrix. The pumice fragments are silicified in most cases and form, together with the other constituents, a rough surface (lithic tuff).

The characteristic tuff pyramids («fairy-chimneys») are well-developed in the thick tuff wall between Selime and Yaprakhisar at the right bank of the Melendiz River. The tuff displays in many places smooth rounded surfaces. The not-agglomeratic type in the west is used as building stones and for sculpture. The texture is rather compact and easily workable. The pyramids are probably formed by the protective working of hard ignimbrite blocks, which had tumbled down from the steep plateau edge on the gentle tuff slope underneath the ignimbrite. Another cause may be resistant constituents of the tuff itself, as those mentioned above.

These tuff pyramids, the structure and the composition (dacitic to andesitic) give a close resemblance with the famous Ürgüp tuffs, about 50 km northeast of the area.

Many Byzantine cave churches and hermitages have been made in the tuff at Selime and Yaprakhisar.

Local tuffite beds can be found on top of the Selime tuff, as for instance at Yaprakhisar, Kızılkaya and Çeltek.

At Yaprakhisar a 30 m wide and 2 m thick brown tuffite lens occurs beneath the high ignimbrite cliff, about 100 m above the valley floor. It represents an old river channel formed in the Selime tuff. In the scarp southeast of Kizilkaya the brown tuffite layers form also a short lens between the ignimbrite and the Selime tuff, showing also spilite conglomerate bodies enclosed.

Also in the flank of the Çeltek-mesa, chocolate-brown tuffite beds occur. Here the same cross-bedding and cut-and-fill structures can be observed. Limestone lenses and bodies of spilite pebbles in the middle of the deposit suggest two deposition phases. This may be caused by sudden displacement of the stream channels, in which the tuffite was deposited.

18. Gelveri ignimbrite

This rock unit is only developed in the region of Gelveri on the southwest of the large eruption centre of Acıgöl, east of Gelveri. South of this village the ignimbrite crops out in the deep canyon-like valley of the Melendiz River at Ilısu Köy. The ignimbrite shows the same variation in resistance as the Göstük ignimbrite. In the valley and also in the close vicinity of Gelveri the rock show smoothly rounded surfaces with strong limonitization in places. At Gelveri there is a tendency of growing in resistance from bottom to top.

At Güvercin Tepe, a mesa bordering the Selime tuff plain on the south, 5 km NW of Gelveri, the rock forms a gray hard sheet of dacitic composition between the soft tuff and the hard Kızılkaya top ignimbrite.

This gray ignimbrite sheet can be traced to the west till in the ignimbrite scarp of Selime and Yaprakhisar. It forms the basal part of the ignimbrite wall between Gelveri and Selime.

From east to west the ignimbrite is gradually wedging out. At Gelveri and Ilısu the rock is approximately 20 m thick, at Güvercin Tepe still 5 m. At Selime the thickness has decreased till 1 or 2 m.

Hydrothermal alteration as limonitization may be another cause for the softer appearance of the rock at Gelveri and Ilısu, closest places to the volcanic centre of Acıgöl. Along the valley wall between Ilısu and Ilhara there is an increase in the resistance of the ignimbrite in lateral direction, whereas the brown-yellow hydrothermal coloring changes into a gray color. Towards the NE, in the direction of Acıgöl, the rock changes laterally into a coarse lithic tuff, as can be observed at Sivrihisar, just beyond the region boundary. In the tuff, pumice fragments up to 30 cm in diameter are frequent here.

The gray ignimbrite of Güvercin Tepe shows numerous biotite flakes, basalt fragments and hard silicified pumice fragments of some mm in diameter, causing a rough surface.

The contact zone below the basalt streams from the east, shows a strong red and brown coloring of the ignimbrite, north of Gelveri.

17. Kızılkaya ignimbrite

This ignimbrite forms characteristic mesas between Aksaray, Gelveri and the Hasan Dag. Originally the ignimbrite sheet formed an uninterrupted plateau-landscape in this area. Later the drainage pattern of the Melendiz River formed numerous isolated plateaux. A narrow canyon was formed by the river between Selime and Ilhara.

The plateau scarps form a striking morphologic feature in the area. They represent the only rock unit of the series that is not wedging out. The scarps show an unconformity with the other units of the «Melendiz River series» and directly rests on basement rocks in the north.

In the east the ignimbrite has been covered by basalt lavas of the Acıgöl volcanic eruption centre. In the south the plateau gradually disappears, as can be observed south of Yaprakhisar, below ashes and lapilli deposits of the Hasan Dag ash formation. In the west the ignimbrite abruptly forms scarps along a NW - SE line, some hundreds of meters above the Tuz Gölü plain.

The white to light-gray rhyodacitic to ahdesitic ignimbrite remains constant in texture and in structure throughout the area.

The texture is that of a coarse lithic pumice tuff. The fine and coarse pumice fragments are abundant, distributed in a light-gray or white vitric groundmass. Angular shaped glass shards and shards and phenocrysts of andesine, sanidine, biotite and hornblende build up this groundmass and give it a vitroclastic texture.

The large pumice fragments show a higher resistance than the surrounding matrix and they are therefore clearly outlined on the numerous joint - surfaces.

Common constituents, which also protrude on the rock surface, are dark-colored spilite and basalt fragments.

In several places a softer lower part of the ignimbrite occurs. This white basal part has a lithic pumice-tuff texture with coarse and fine pumice fragments as the only coarser constituents. The more resistant upper part projects over it with a vertical cliff. This vertical change in consistency is gradual and is not ascribed to the existence of two different layers.

A striking structural feature in the ignimbrite sheet are the many vertical joints, which develop a columnar structure as the result of shrinkage during cooling.

The thickness of the sheet can increase suddenly (Kızılkaya, Yaprakhisar) by irregularities in the pre - ignimbritic topography. South of Yaprakhisar the ignimbrite grows to a maximum thickness of about 50 m. The average thickness is between 2 and 5 m.

16. Melendiz Dağ tuff

This tuff formation occurs only in the deep eroded volcanic centres or calderas of the Melendiz Dağ (Kızıl Yokuş caldera, Central Melendiz Dağ) and of the Keçiboydoran Dağ.

Beside tuffs, the tuff formation consists also of tuff - breccia, agglomerates and breccia. The whole formation is strongly limonitized and some zones, especially in the fine-bedded tuffs, show silicification. Obviously strong hydrothermal activity prevailed in these centres of volcanic activity. Beside limonitization and silicification other mineralizations indicate to a «solfatara» stage, as large sulphur precipitations show. The rocks are yellow, brown, green and purple and already conspicuous from a far distance. The limonite and manganese ore precipitations mark fractures and bedding joints, but mostly are disseminated in the tuffs or segregated in fine thin layers (banded tuffs). Also the matrix of the agglomerates and tuff - breccia is brown or purple by this introduction. The hot-water circulation has even attacked the coarse basaltic boulders of the agglomerate. These basalt fragments may sometimes show an alteration into a soft white tuff - like rock with the original basalt core left. Silicification can form glassy tuff banks or irregular bodies with a crumbled appearance.

This formation forms the pyroclastic core of the Melendiz Dağ and the Keçiboydoran Dag. No older formation could be observed here. Only the deep cauldron structures gave the opportunity to study these pyroclastics. In the Hasan Dag area such deep intersections are not present and the core of the Hasan Dag volcanoes is therefore unknown. It is entirely covered by huge basalt-lava streams.

However, from the huge amounts of ashes and lapilli around the volcanic complex, which partly cover basalt lavas far west of the area, it might be deduced that the volcanoes were built up of pumice ashes and pumice lapilli, alternated with some basalt phases.

15. Niğde formation; member of Bor

This facies is developed in the Bor Plain, south of the Melendiz Dağ. Towards the volcanic centres the facies laterally merges into the member of Yakacık (see below).

Lacustrine hard limestone banks are alternated with white vitric tuffs. SE of Bor a hard limestone plateau forms a low mesa with a steep scarp facing the alluvial plain in the south.

Near Bor small manganese ore pockets exist in the limestone. The ore can be seen disseminated in the limestone or can be seen concentrated on fractures. East of Bor some silicified tuff beds are intercalated. To the northeast fluvial intercalations in the tuff occur.

In the southwestern part of the area the limestone occurs in some small mesas (Yank Tepe region).

14. Niğde formation; member of Yakacık

The tuff of this member is exposed in the vicinity of Altunhisar. It forms a part of the pyroclastic base of the Melendiz Dağ.

The tuff can be observed in the large quarry north of Altunhisar, and is covered by a tuff breccia. To the west the tuff shows an evident discordancy with the younger Hasan Dağ ash-formation.

To the southwest it is covered by the alluvium of the Bor Plain. The tuff is of a fine-grained vitric nature. No coarse fragrhents are present in the lower section. A fine agglomeratic tuff character starts in the higher parts. Small pumice and lava

fragments are scarcely distributed in the light-colored, rather compact tuff. The tuff is an easy workable rock and used as building stone. The faint purple or brown coloring is caused by thinly dispersed limonite and manganese ores. These can be concentrated on fractures and form there black and dark brown crusts and fillings.

13. Niğde formation; member of Altunhisar

This member can be called a tuff-breccia or a coarse-lithic-tuff. Also the term «agglomeratic tuff» may be used.

It forms a somewhat larger outcrop than the vitric tuff of Yakacık and surrounds Altunhisar in the north, east and south. It forms the upper part of the quarry wall, north of Altunhisar. Here many ancient dwelling-places have been carved out in the rock. Smaller outcrops of the tuff-breccia can be seen along the road Niğde - Bor, where the rock is overlain by a thin agglomeratic and alluvial cover. Here silicifications occur, as can be observed in the high scarp at the Bor-dam, midway Niğde and Bor.

The tuff-breccia contains sharp angular blocks and boulders of pumice, scoriae and lava. Also smaller fragments are distributed in it. The brown matrix is of a vitric, compact nature. Stratification is absent.

12. Niğde formation; member of İnli

This agglomeratic member has been developed over the tuff-breccia of the member of Altunhisar and can be found on all sides of the Melendiz Dağ. A large exposure can be found in a valley south of Altunhisar. The lower part of the facies shows an evident stratification. The upper part is not stratified.

The lower part can be often defined as volcanic conglomerate. Also a certain sorting of medium sized lava pebbles exists. It is believed that water transport contributed much to its formation.

The upper part shows a chaotic assemblage of small and big rock fragments. They can be defined as coarse agglomerates, conglomerate or volcanic breccia. The biggest blocks reach some meters in diameter. Not only andesite and basalt, but also tuffs and ignimbrite form the elements. The large blocks and boulders are bedded in a gravelly or sandy matrix. The formation of this upper part may be ascribed to «lahars».

11. Agglomerates and volcanic conglomerates of the Keçiboydoran Dağ

In the deep intersected valleys on the north flank of the Keçiboydoran Dağ (Kitreli) and below the basaltic lava cover, a chaotic assemblage of small and large boulders of lava and tuff occur in a loose tuffitic matrix. This formation is much alike the upper part of the member of İnli (see above), but the blocks do not reach such large dimensions. It forms with the Melendiz Dağ tuff formation the pyroclastic core of the Keçiboydoran Dağ. The andesitic elements dominate in the formation.

10. Volcanic vent-breccia

Vent-breccia are locally developed in the Central Melendiz Dağ and in the Keçiboydoran Dağ.

These coarse, massive and unsorted breccia mainly consist of basaltic blocks in a gravelly groundmass. All the elements show a brown or violet coating of resp. limonite and manganese ore.

In some places vertical breccia walls mark the vents. The spines of breccia can reach more than 100 m height and can be observed in the cauldron structures of the Central Melendiz Dağ and Keçiboydoran Dağ. Sub-vertical layering may be faintly seen in these spines, as near Çömlekçi (Kale Tepe). The breccia further away from the vents have a more horizontal layering. The whole valley of Çömlekçi, e.g. the bottom of the cauldron, is filled up with those breccia. The horizontal layered breccia and agglomerates east of Çömlekçi represent the erosion products of the vent-breccia.

The breccia rests on the Melendiz Dağ tuff and is covered by andesito-basalt lavas. In the northern escarpment of the Keçiboydoran cauldron, intercalations of this breccia in the andesito-basalt can be seen.

9. Andesito-basalts

These rocks are for the greater part covered by basalt lavas. They are in general only exposed in the walls of deep intersections in the Melendiz Dağ and Keçiboydoran Dag. Sometimes strongly eroded spines with connecting radial dykes are formed by these rocks. They form the pre-basaltic eruption sites of Melendiz Dağ and Keçiboydoran Dağ.

Some outcrops near the summit of the Küçük Hasan Dag, below large flows of basalts, may give some clue to the composition of the inner parts of this volcano. The Büyük Hasan Dağ has no andesito-basaltic outcrops, only basalt lavas had accumulated on its flanks.

Also in the plain-volcanism, only basalts were discovered.

The andesito-basalt is a transition rock, petrographically as well as in its field appearance. The andesitic parts are most frequently hypersthene-augite-andesites or augite-andesites.

8. Hasan Dag ash formation

This formation covers large areas north, west and south of the Melendiz Dağ-Hasan Dag Range. The main eruption points are the Hasan Dag volcanoes and the numerous small cinder- and lava-cones in the plain.

Also the Göllü Dağ eruption sites and the cones of the Çınarlı region formed enormous amounts of these ashes and lapilli, deposited till far beyond the area boundaries.

There are three types of deposition :

1. Homogeneous deposition
2. Layered deposition
3. Chaotic deposition

The homogeneous ash and lapilli deposits can be found south and southwest of the Hasan Dag (Leskeri Tepe-Yarık Tepe region). The loose, white, vitric ash matrix contains evenly distributed small to medium-sized white pumice pebbles. Less frequent black obsidian fragments and some lava pebbles occur. Many road outcrops can be

seen west of Altunhisar. Layered and sorted pumice outcrops are characteristic for the Göllü Dağ area. Here black obsidian forms an important constituent of the pumice beds. Fine and coarse lapilli beds intercalate. North of Çiftlik a quarry is in exploitation for the production of pavement material.

Near Altunhisar a small exposure of layered lapilli and volcanic ashes with numerous andesitic lava pebbles in the lapilli occur, forming an evident unconformity with the vitric tuffs of Yakacık.

Here also a typical dendritic drainage pattern had been developed in the soft material.

Layered and periclinal dipping ashes and pumice-lapilli can often be seen on the mantle of the numerous ash- and cinder-cones in the plain.

The third type of deposit can be found north and northeast of the Hasan Dağ. South of Çeltek and in the Ilhara region the non-layered ashes contain small and large blocks of lava and tuff, which easily are weathering out of the loose matrix. South of Çeltek the Göstük tuffite is directly covered by this chaotic ash deposit. The ash forms vertical walls in which the andesite, basalt and tuff blocks are clearly visible. They function sometimes as protective tops of steep ash-pillars.

The ashes and lapilli overly the andesijo-basalts of the Melendiz Dağ-Keçiboydoran Dağ. as well as the Kızılkaya ignimbrite; They are overridden by the basalts of the mountain range and of the cones in the plains.

7. Glowing avalanche deposit of the Hasan Dağ

This relative local deposit occurs on the west flank of the Büyük Hasan Dağ and consists of a huge accumulation of light-colored ashes, scoriae, lapilli and tuff and andesite blocks. Volcanic ash, sand and gravel function as groundmass. This assemblage is exposed in steep-sided stream gullies on the northwestern flank of the Hasan Dağ.

This deposit is situated stratigraphically between two basalt outflows. It covers large basalt flows which have been streamed far beyond the western boundary and it is covered by north streaming basalt flows. It is supposed that this deposit belongs to the widespread ash eruptions as it shows a close resemblance with the chaotic ashes, which were deposited north and northeast of the Hasan Dag. It has deposited on the flanks of the volcano from a glowing avalanche, e.g. from a downward flow of a suspension of ashes, scoriae, lapilli and blocks in gas.

6. Ash-flow tuff of the Hasan Dag

This tuff occurs on the southeastern flank of the Küçük Hasan Dağ. It rests on the Hasan Dağ ash formation and is covered by basalt flows of the Küçük Hasan Dag. The areal extent, which is rather small, as well as its structural appearance suggests that the tuff is the result of an ash-flow eruption of the Küçük Hasan Dağ, succeeding the ash and lapilli outburst. The boundary of the tuff is marked by low cliffs which disappear to the west below long-ranged basalt streams of the volcano. The plastic flow structure of the banded, coarse, non-welded tuff is well exposed in these low scarps. The mineral grains, as plagioclase (andesine), quartz, augite, hornblende, obsidian and numerous biotite flakes have segregated in different colored bands

with different consistency. The latter gave rise to a selective erosion, which accentuated the plastic fold structure. Sometimes the tuff shows a strong resemblance with red or white sandstones.

The tuff is separated from the underlying ashes by a coarse assemblage of glassy pumice boulders and cobbles, which form a breccia layer.

5. Basalts

The basalt lavas form the terminal eruption products of the Melendiz - Hasan Dag volcanic range and the volcanic cones in the plain, around the Hasan Dağ, and north of the Melendiz Dağ.

The basalt may be roughly separated in three petrographic groups:

1. The augite-hypersthene basalts, dominating in the Melendiz Dağ, Keçiboydoran Dag and the basaltic region of Çınarlı (north of the Melendiz Dağ).

2. The hornblende-hypersthene basalts, dominating the Hasan Dag area.

3. The olivine basalts, which are characteristic for the volcanism in the plains. They occur as the youngest outflows in the region. They also form discordant dikes in the other basalt types, often with a close-spaced jointing.

The olivine basalt- and scoriae eruptions are of a later phase than the Göllü Dag rhyodacite extrusions. This can be stated from a contact at the northwest side of the Göllü Dağ, outside the region.

The olivine basalts are fine-grained, compact black rocks, without conspicuous phenocrists. The mostly brown weathered olivines form, in general, small and no striking phenocrists. The lava often shows a vesicular structure .

The other two types are generally light to dark - gray lavas, often showing small and large phenocrists of plagioclase, augite and hornblende.

The mutual age relation between the two types cannot be stated directly, by lack of contact. The Hasan Dag lavas are entirely separated from the Keçiboydoran - Melendiz Dağ lavas by a narrow zone of pumice - ashes and tuff. On morphological grounds, however, it may be supposed, that the hornblende - basalts of the Hasan Dag are of a later stage than the pyroxene basalts of the Melendiz Dağ.

4. Ash-flow tuff of the Göllü Dağ

The Göllü Dağ volcanism occupies a small area in the northeast.

The ash - flow tuff can be observed on the southern flank of the Göllü Dağ. A ridge of some hundreds of meters high with a large crater on top, just beyond the boundary, consists of the lower parts of this tuff and the underlying obsidian - rich pumice beds. The pumice represents the earliest outbursts of this eruption site.

The tuff has a plastic flow - structure and can be compared with the Hasan Dağ tuffs. But texture and composition (rhyodacitic) is different. The basal part is composed of a chaotic mixture of purple perlite - balls and black obsidian fragments, reaching diameters of 10 to 20 cm, forming small and large lenticles and bands or nodules in strong folding position. The black obsidian is a typical product of the Göllü Dağ volcanism.

The chaotic, coarse - grained section merges upward into a fine - grained, glassy purple tuff, thinly banded and sometimes with strong plastic folds.

3. Rhyodacite of the Göllü Dağ

The rhyodacitic vitrophyre of the Göllü Dağ penetrates with a short flow into the region, north of Çiftlik. Also the rocks around the crater, e. g. the upper part of the Göllü Dağ, consist of this vitrophyre It is a pure white compact lava which forms a plateau (Küçük Göllü Dağ) with steep cliffs resting on the tuff or directly on the Hasan Dag ash-formation.

2. Travertine

Thinly layered cavernous buff limestones have deposited on the ignimbrite and tuffs, in the area of Yaprakhisar, due to thermal springs.

This hot - water output must have been of a large size, in view of the extension of the travertine. High vertical walls of this rock occur near Yaprakhisar, representing the filling of old fissures. The tuff underneath shows calcification in its upper parts, where hot water penetrated and the travertine was deposited on fractures.

Still hot - water activity occurs south of Yaprakhisar. The water issues in minor quantities along a NW - SE fissure of about 200 meter. Pure white crusts of calcite have been formed along this fissure .

1. Alluvium

The alluvium of the plains are reworked deposits from surrounding higher regions. The plains of Bor and Çiftlik have alluvial material derived from the pumice - and ash - deposits nearby.

VOLCANO - TECTONIC EVOLUTION

Apparently a volcanic activity existed already outside the area. This can be concluded from the deposits of the Göstük tuffite, which were laid down on the crystalline basement and on the Oligocene - Miocene «Gypsum series». These deposits represent the erosion products from a volcanic area, which location cannot be traced with certainty, but presumably must be situated in the Ürgüp region. Here the volcanic activity is of an earlier date.

The first ignimbrite outbursts took place along the NW - SE fault zone on the east side of the Tuz Gölü. This zone came under a sufficient tectonic tension to cause volcanic activity. Other eruption fissure - faults with the same trend can be found in the Acıgöl area, east of Gelveri. South of the Hasan Dag, these fissure - faults have a general NE-SW trend. These tension faults may be caused by the rise and lateral spread of the so called «magma - blisters» (Van Bemmelen, 1961) or by regional tectonic forces, with the result of rising and boiling over of the ignimbrite magma. Van Bemmelen describes such an eruption as a turbulent suspension of magma particles in a continuous gas phase, boiling over the rim of the fissure as a fluidized system of pumice, glass shards, phenocrists and xenoliths, all surrounded by very hot and highly compressed gases, which reduce the internal friction to extremely low values. This mixture reaches the surface in great quantities per time unit. The bulk of the erupted

material spread sidewards of the fissure as a pyroclastic ash flow of very low viscosity, rapidly flooding («flood - tuff») and burying the topography. In the meantime light - weighted ash and lapilli formed large billowing clouds far above the fissure. This material was deposited much later over a wide areal extent.

The ash- and lapilli material was only found on the youngest ignimbrite sheet (the Kızılkaya ignimbrite). Probably the loose material was eroded away entirely from the surface of the Göstük ignimbrite, as a severe erosion period followed this first ignimbrite eruption. Large stream channels were formed in which tuffite beds of Pliocene (Pontian) age were deposited. At first fluvial detritic deposits were formed but gradually more limestone bed intercalations showed a change from fluvial into more lacustrine conditions. This change probably is due to the effect of block-faulting in front of the Taurus orogen. A slight downward movement of the land surface could result in the penetration of the large lakes from the west.

This lake transgression took place from SW-NE and reached the area of Göstük-Kizilkaya. During this time volcanism was still active and eruptions of scoriae took place repeatedly in the region.

From this angular unconformity between the limestone beds, which are slightly tilted and the overlying Selime tuff it can be concluded, that vertical movements tilted the block and that after an erosion period, the limestone banks were covered by the tuff formation.

This tuff was caused by renewed volcanism on a great scale in the Acıgöl fissure-region, east of Gelveri. The fissure eruptions spread a thick tuff layer from east to west. In this direction the tuff is wedging out and gradually changes in character. This change is probably due to a sifting out of the coarser material from the eruption clouds at growing distance from the eruption sites. Only fine particles could form the tuff on a large distance from the fissure, whereas a mixture of fine and coarser fragments formed the agglomeratic tuff nearby. This tuff must have been erupted in one single eruption, as no stratification could be observed in the tuff.

Again followed a period of denudation and deposition of tuffite beds under fluvial conditions. But these tuffite deposits are local and thin, as compared with the pre-tuff tuffite deposits in the area.

The abundance of ultra basic pebbles and cobbles in the tuffite beds indicate to large outcrops of cristalline basement elsewhere.

A renewed ignimbritic volcanism started from fissures in the Acıgöl region and the Gelveri ignimbrite spread out over some distance on the tuff. Also the Tuz Gölü fault zone became active again and the Kizilkaya ignimbrite was formed, covering large parts of the topography. Downward movement of the Tuz Gölü block along the NW-SE fault zone accounts for the straight line of ignimbrite scarps some hundreds of meters above the plain of the Tuz Gölü.

This vertical movements along the Tuz Gölü fault is also easily demonstrated by the Hasan Dağ basalt lavas on the NE flank of the Küçük Hasan Dağ. Streams prior to the movement had been cut off in a straight NW-SE line and a difference in height occurred of more than 100 m. Later, new basalt flows streamed from the volcano (the downthrown block) towards the fault scarp and bent abruptly in NW and SE directions along the scarp-foot.

As already said before, the ash and lapilli outburst to great heights took place during the igriimbritic flooding. These loose, easily eroded ash and lapilli have been saved on the last ignimbritic outflow and show a wide areal extent. It is highly probable that these pumice ashes and lapilli. have buried large parts of the ignimbrite also south of the Hasan Dag. However no exposures there could be seen of the latter.

The andesito-basalt lavas must have been erupted after the consolidation of the ignimbrite shield and before the ash and lapilli deposition ended.

This may be concluded from the fact that the andesito-basalts have been covered by the ashes and lapilli and nowhere could be seen covered by the ignimbrite.

After-effects of the ignimbrite volcanism locally produced a glowing avalanche, followed by local ash flows and eventually rhyodacitic outflows of lava. The glowing avalanche deposit may represent the exploded top-filling of the ignimbrite fissure and the ash-flow tuff may be considered as a transition form between the ash and the rhyodacite lava, filling up the ignimbrite fissure below the top-filling, before eruption took place.

The rhyodacite was followed by olivine basalt eruptions, mainly issuing from the conelets in the plains. This youngest basalt phase is also present as dykes, which cut through the older pyroxene- and hornblende-pyroxene-basalts of the Hasan Dağ-Melendiz Dağ Range.

Mainly on morphologic grounds a longer duration of the Hasan Dağ volcanism in this mountain range is supposed. The Melendiz Dağ shows, in contrast with the Hasan Dağ, an evident mature relief. This may imply a somewhat younger age for the hornblende pyroxene basalts, which are characteristic for the Hasan Dağ area.

The ignimbrite- and basalt volcanism represent certain stages in the orogenesis of the Taurus Mountains.

The apparent shift of the volcanic activity in the Hasan Dağ-Melendiz Dağ Range, in a direction about perpendicular to the orogenic belt of the Taurus, may be properly explained as the result of compressionai forces in the foreland of the orogen due to its gradual uplift. These forces closed the eruption channels from ESE to WNW.

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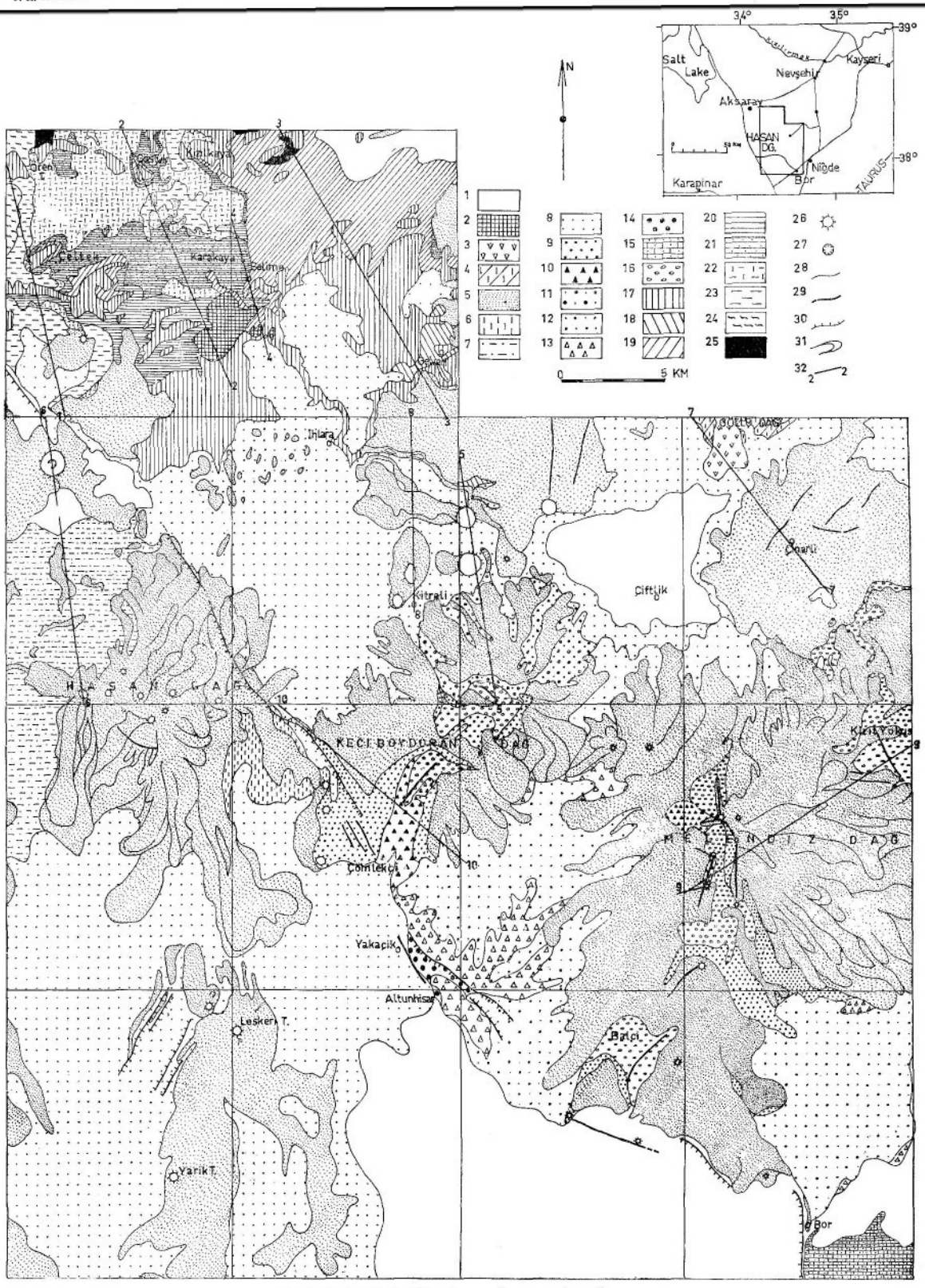
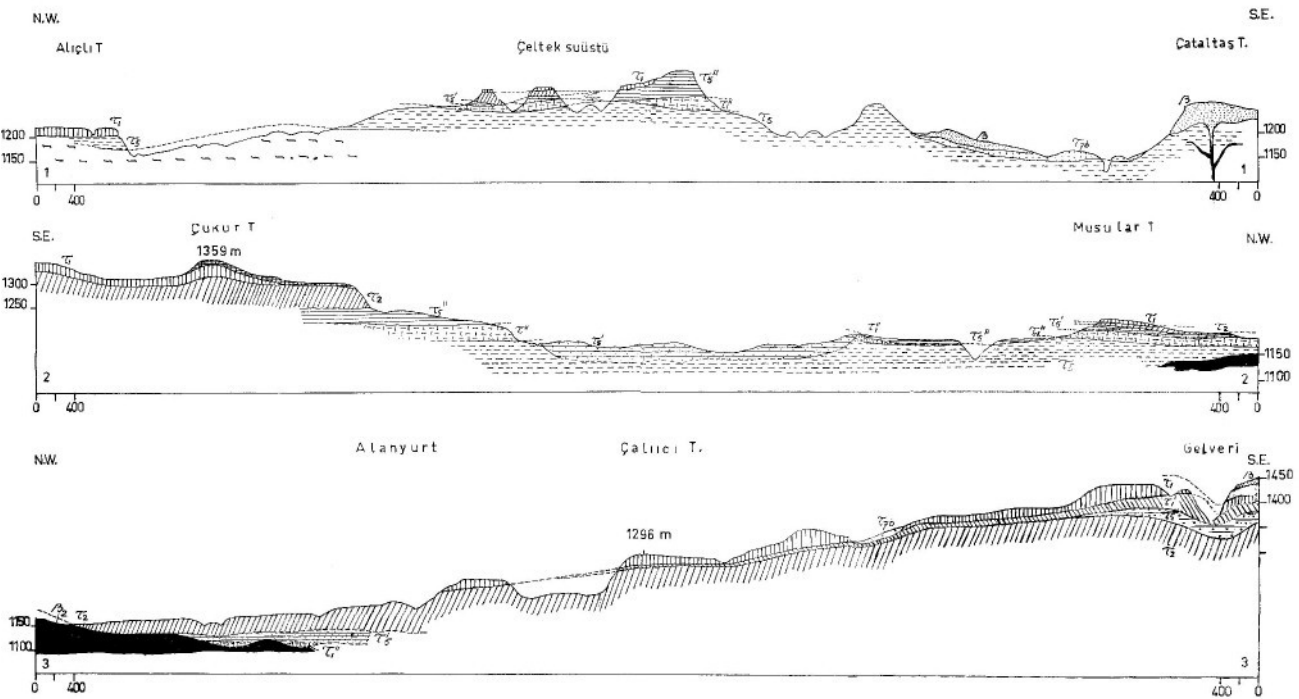


GEOLOGICAL MAP OF THE HASAN DAĞ - MELENDİZ DAĞ REGION

1 - Alluvium; 2 - Travertine; 3 - Vitrophyre of the Göllü Dağ; 4 - Ash-flow tuff of the Göllü Dağ; 5 - Basalt; 6 - Ash-flow tuff of the Hasan Dağ; 7 - Glowing avalanche deposit of the Hasan Dağ; 8 - Ash formation of the Hasan Dağ; 9 - Andesito-basalts and andesites; 10 - Volcanic vent - breccia; 11 - Volcanic agglomerates and -conglomerates of the Keçiboydoran Dağ; 12 - Agglomerates and coglomerates of the Melendiz Dağ (Niğde formation, member of İnli); 13 - Tuff breccia (=coarse lithic tuff) (Niğde formation, member of Altunhisar); 14 - Vitric tuffs of the Melendiz Dağ (Niğde formation, member of Yakacik); 15 - Tuffs with limestone beds (Niğde formation, member of Bor); 16 - Pyroclastic formation of the Melendiz Dağ; 17 - Kızılkaya ignimbrite; 18 - Gelveri ignimbrite; 19 - Selime tuff; 20 - Karakaya tuffite (calcareous member); 21 - Karakaya tuffite (detritik member); 22 - Göstük ignimbrite; 23 - Göstük tuffite; 24 - Tertiary non-volcanics; 25 - Ultrabasics and granodiorites; 26 - Volcanic cone; 27 - Crater; 28 - Formation boundary; 29 - Fissure; 30 - Fault; 31 - Lava flow; 32 - Section.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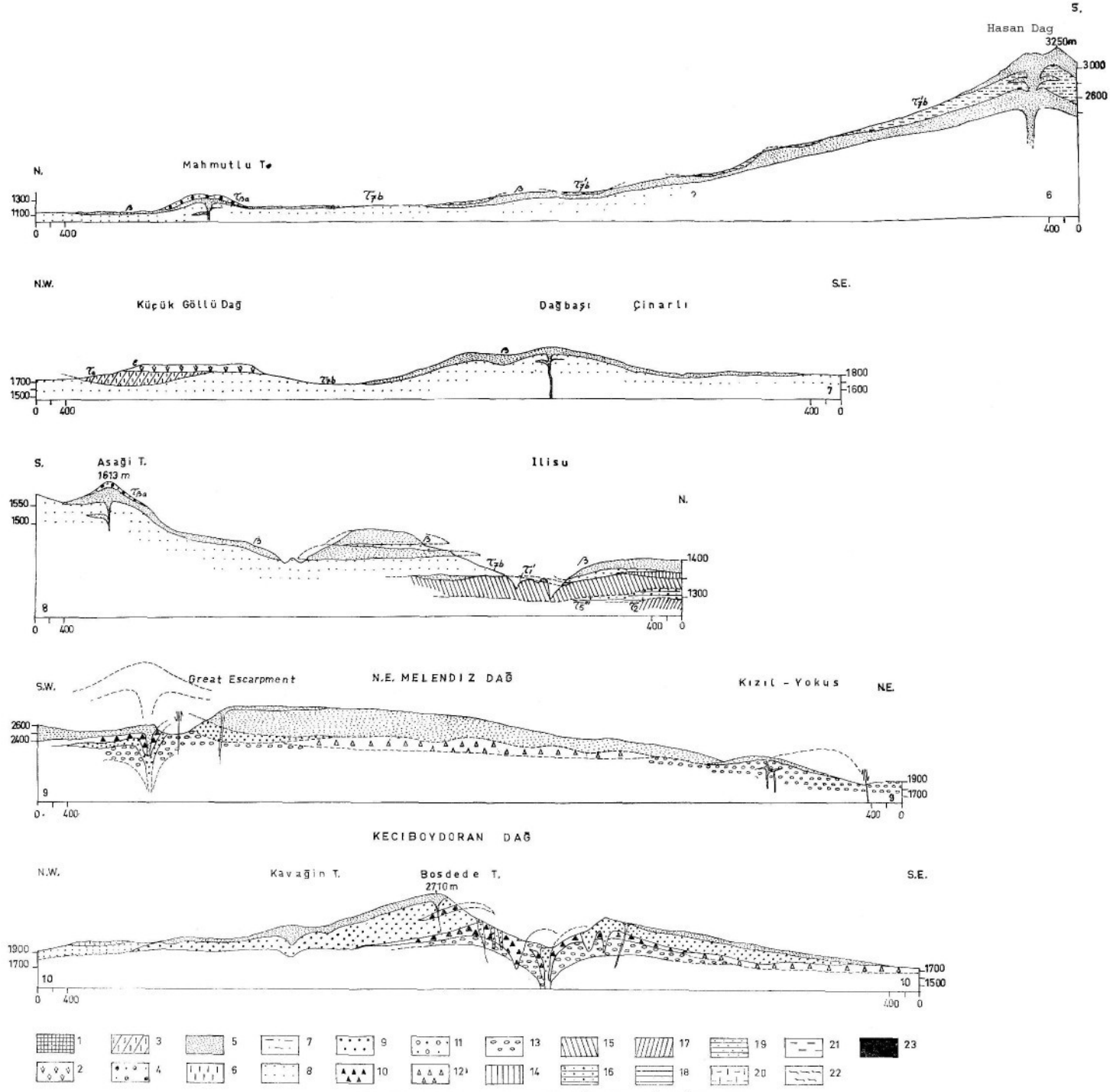

GEOLOGIC SECTIONS OF THE HASAN DAĞI - MELENDİZ DAĞI REGION

1 - Travertine; 2 - Vitrophyre of the Göllü Dağ; 3 - Ash-flow tuff of the Göllü Dağ: 4 - Scorlae of volcanic cones; 5 - Basalt; 6 - Ash-flow tuff of the Hasan Dağ; 7 - Glowing avalanche deposit of the Hasan Dağ; 8 - Hasan Dağ ash formation; 9 - Andesito-basalts and andesites; 10 - Volcanic vent-breccia; 11 - Volcanic agglomerates and - conglomerates of the Keçiboydoran Dağ; 12 - Tuff breccia (=coarse lithic tuff) (Niğde - formation, member of Altunhisar); 13 - Pyroclastic formation of the Melendiz Dağ; 14 - Kizilkaya ignimbrite; 15 - Gelveri ignimbrite; 16 - Gelveri tuffites; 17 - Selime tuff; 18 - Karakaya tuffite (calcareous member); 19 - Karakaya tuffite (detritic member); 20 - Göstük ignimbrite; 21 - Göstük tuffite; 22 - Tertiary non-volcanics; 23 - Ultrabasics and granodiorites.

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