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Giorgio Pasquarè

Outlines of the neogene and quaternary volcanism of Asia Minor. Nota I

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Geologia. — *Outlines of the neogene and quaternary volcanism of Asia Minor.* Nota I di GIORGIO PASQUARÈ, presentata (*) dal Socio A. DESIO.

RIASSUNTO. – Il vulcanismo recente postorogenico in Turchia costituisce una cintura quasi ininterrotta che decorre da ovest a est lungo il contatto tra i massicci mediani anatolici e gli orogeni del Ponto e del Tauro.

Nel presente lavoro vengono messi in evidenza i principali tipi di strutture vulcaniche, dai grandi edifici centrali compositi, ai vulcani fessurali, ai vulcani semplici monogenetici, alle caldere di esplosione, discutendone la loro posizione e il loro ruolo nell'evoluzione del vulcanismo. Vengono inoltre mostrati i caratteri litologici in relazione all'evoluzione stessa, che dimostrano un'appartenenza decisa alla provincia petrografica pacifica con leggera tendenza a facies transizionali mediterranee nella regione egea.

Vengono infine descritte le serie piroclastiche, particolarmente estese in Anatolia Centrale, dandone anche un inquadramento stratigrafico.

INTRODUCTION.

Knowledge on Neogene and Quaternary volcanism and related widespread deposits in Turkey are up to date approximate and fragmentary. Apart from marginal notes achieved by some European travellers of past century as Abich [1] Chaput [7], Frech [8], Philippson [14] and Hamilton [9] we can consider to be specific studies on recent anatolian volcanism only those of Washington [16] on the basalts of Kula, of Blumenthal [4.5] on Erciyes Dağ and Ararat, of Wjkerslooth [18] on the Afyon and Kayseri regions, of Lahn [10] on Hasan Dağ. More recently Westerveld [17] tried to reconstruct the main phases of volcanism in Turkey, using only a few data of the literature and some personal observations along restricted itineraries. Since I have studied anatolian volcanism in 27 months of field work (1), during the four years 1962–1965, I want to give to this note the character of introduction to these studies.

Here the outline and the position of this volcanism in respect of orogenic units are examined.

I have tried to give the most complete and homogeneous view of the phenomenon, with more details only in the best examined zones, as the south anatolian eruptive range between Konya and Kayseri and the Erzurum zone.

(*) Nella seduta del 22 giugno 1966.

(1) Work done on behalf of the Mineral Research and Exploration Institute of Turkey, Ankara.

NORTH–WESTERN TURKEY.

A very large zone including the limit between Menderes massive and Pontus folds, among Çanakkale, Izmir, Uşak and Balikesir, is covered by products of an intensive and complex volcanism.

Great central volcanoes and large volcano-tectonic lines are lacking. On the contrary everywhere small and medium eruptive centers, especially domes, flow-domes, mixed cones, plug-domes are strictly associated and often overlap one another forming a nearly uninterrupted eruptive plate.

Neogenic sediments form the basis of the volcanic complex. They represent lacustrine, alluvial and sub-aereal weathering facies; among them dominate micaceous sandstones, silts, clays and conglomerates, mostly due to weathering of Menderes massive. Their thickness varies from 100 to 300 m. The first appearance of volcanism is represented by hyolodacitic, strongly weathered masses and thin tuffaceous layers.

To this series, with a certain unconformity, the products of an important erosive period, are overlying. The old lavas and tuffs are weathered and reaccumulated in form of tuffites. A weak volcanic activity was still present.

At this moment a strong and extensive volcanic activity occurs. Through fissures rapidly covered by large pyroclastic deposits with which are associated important agglomeratic flows, products forming hyalodacitic endogenous domes rise up.

In the Neogene series, above the aforesaid unconformity, lie sheets of acid, mainly rhyolitic, often pumiceous tuffs, intercalated with argillaceous, sandy and conglomeratic tuffites, 50–100 m thick. Sometimes a part of the tuffaceous series is replaced by agglomerates and agglomeratic tuffs exclusively composed of rhyodacitic and hyalodacitic fragments and almost everywhere covered by lava flows of the main phase. The last ones essentially occur in form of andesites along the Aegean shore and as hyalodacites in the inner Anatolian region.

Hyalodacitic magmatism forms large endogenous domes and flow-domes generally so strongly fissured as to be mistaken with the underlying tuffs.

Through this thick effusive plate the lava residuals rose up in form of plugs, occasionally associated with flow-breccias.

Complex volcanic cones of the same phase, with parasitic intrusions on their limbs, forming either typical hyalodacites or andesites to andesite-basalts, occur. Small but well preserved craters with agglomeratic dacitic tuff-walls are also present.

Along the Aegean coast, especially among Izmir, Bergama and Edremit, an andesitic volcanism in eruptive crests having SW–NE trend predominates. Sapdag, NE of Edremit, is one of the most typical examples. In Ayvalik archipelago several little andesitic cones rise up. Some of them culminate in extrusive protuberances or extend in long, flat and sloping down flows.

The surface of these flows, E of Ayvalik, is drilled with several vertical-wall diatremes.

Among Ayvalik, Altinova and Dikili, andesitic effusions are dislocated by great faults, parallel with the Aegean coast. They intersect at an almost acute angle a system of other faults, fixing the boundaries of the depression of Bergama graben. This depression extends in N–W direction as far as Soma zone, where it is occupied by a large Neogene basin. In it andesites and andesitic tuffs are clearly intercalated with Miocene beds. The main andesitic phase is followed by an important ignimbritic effusion. Its products extend in form of a thick-steady layer over the Neogene series. The ignimbritic layer is preceded by a thick pumiceous sheet.

Ignimbrite occurs N of Bergama and continues southward on Yund Dağ and Yamanlar Dağ as far as Izmir.

In the region of the great hyalodacitic domes, that is among Selendi, Sindirgi and Bigadic, andesitic activity assumes a local character in form of lateral extrusions of ancient domes. Previously the lacustrine sedimentation was spreading more and more and its products, in form of an essentially calcareous layer, covered the underlying tuffites and tuffs. The summit of the series shows again a return of terrigenous more or less argillaceous material, related, may be, to a raising of blocks along the old faults. On this series, after the brief andesitic activity, overlie recent, probably Quaternary, basaltic flows, risen along NE–SW trending fissures. They occur scatteringly in separated centers along the northern boundary of Gediz depression, on the limit of Menderes massive. Basalts of this type are known between the Selendi and Gediz valleys, NE of Kula, near Borlu, on Dumanli Dağ 40 km North of Izmir, on the Aegean coast near Foça and on Karaburun peninsula.

But the most evident volcanic basaltic activity of all the region occurs on Karatepeler range, near Kula. It is a group of 62 volcanic reliefs linearly disposed over a 40 km NE–SW trend distance, parallel with the great fault that originated the graben of Alaşehir. They are separated from it by a crystalline schist zone of Menderes massive.

It is possible to distinguish three periods of activity, characterized by different intensity of degradation of volcanic cones: 1) late Pliocene period, 2) early Quaternary period and 3) recent Quaternary period.

To the first period belong three volcanoes, placed N of Kula and directly resting on Pliocene lacustrine deposits. They are scoriae cones fairly degraded not high, and covered with vegetation.

To the second period belongs the greatest part of volcanic activity, with only slightly degradated volcanoes and still clear craters, disposed along NNE–SSW trending fissures in groups from 3 to 7.

The third period presents three volcanoes situated over a distance of almost 9 km on the bottom of Quaternary valleys, crossing the Alaşehir graben.

Their state of preservation is like that of present volcanoes, with large flows of scoriaceous and block lava leaking at the foot of steep scoria and ash-cones, with craters partially ruined by explosions.

The composition of lava in all the preceding periods is unchanged and recalls that of a dark, very horneblenditic basalt with less augite, olivine and nepheline. The scoriaceous phases generally precede the effusive activity. The lavas open an outlet at the base of scoriaceous cones, partially penetrate into the bodies of the same cones and into the funnel of craters, where they consolidate in form of breccias.

A very different magmatism, quite rare in Turkey, occurs as a late activity of hyalodacitic volcanoes surrounding the Sindirgi depression, a prolongation of those of Bergama–Soma. It is represented by more basic and alkaline lavas, with trachybasaltic composition, forming typical exogenous domes. Among them the most representative are those of Çan Dağ, Adali Dağ and Dede Tepe.

The lava bodies are enclosed in a thick sheet of volcanic ashes and sand, ejected at the beginning of this phase.

Afyon—Eskişehir Region.

In conformity with the sharp convexity to the N of the Taurus region towards Antalya gulf, a volcanic range extends northwards and penetrates into the central anatolian mass as far as Kütahya and Eskişehir.

The largest part of it is included between the Afyon town and the Çöl plain, that lies directly on the Taurus range. The first layers of tuffites and tuffs are interposed in the lacustrine Miocene deposits, sometimes strongly folded, especially between Sandikli and Afyon. These are followed by the products of an intensive explosive activity, with pumiceous tuffs, explosion breccias and flow agglomerates. Finally there is a large ignimbritic flow with andesitic, rather basic character due to the presence of augite, horneblende and hypersthene. The complex culminates in an eruptive ridge having N–S trend and formed of massive andesitic bastions, moved by extrusive trachyandesitic counterforts. A series of trachyandesitic plugs rises up around Afyon town in form of rugged circular-section towers. Their mineral composition is rather similar to that of ignimbritic sheets.

Between Afyon and Eskişehir a clear prevalence of the tuffs over the lavas is observed. Over the lacustrine Neogene limestones and sometimes directly overlying Eocene or overlying the crystalline basement a sheet of white, tender, vitreous and pumiceous tuffs extends. They are covered by an ignimbritic layer in which the monuments of Yazilikaya, Leğen and Maltaş were sculptured. Ignimbrite laterally grades into lithic and agglomeratic tuffs, including fragments of crystalline schists, lavas, pumice and obsidians.

In the lower tuffs lenses of vitreous perlitic rhyolites sometimes occur. Everywhere hydrothermal alterations such as siliceous, limonitic and hematitic fillings are common. Between Kütahya and Eskişehir, in the pyroclastic sheet, more recent, late Pliocene-Pleistocene basaltic emissions occur. These are the limburgitic augite-olivine basalts with fluidal glass of Sofçu, Türkmen Dağ, Inönü and Şeyitgazi.

THE REGION BETWEEN KONYA AND BEYŞEHIR.

Among Konya, the Beyşehir lake and the Suğla lake rises a massive andesitic volcanic group surrounded by a large Neogene basin, that reaches several hundred meters in thickness North and North-Eastward.

In the Neogene series can be distinguished a lower part, with limestones and marls containing Planorbis of Miocene age, and an upper part, with yellow and reddish conglomerates and calcareous intercalations. This latter grades into sandy sediments containing tuffites, vitric tuffs and lithic tuffs, covered by a thick ignimbritic layer of rhyolitic composition. The central part of this system is built up by a group of andesitic cones aligned according to the tauric direction NW–SE. The greatest of them are Alacadağ and Erenler Dağ, more than 2,000 metres high.

NW from Konya, near the village of Sille, within the contact between marbles and schists of the basement and a small Neogene basin, a volcanic cone occurs, on whose flanks short and viscous ignimbritic flows, of probably dacitic character, are seen.

Within the surrounding Neogene series, white, rhyolitic and dacitic tuffs, are clearly interposed. A group of faults, directed SW–NE, separates the volcanic zone from the crystalline massif. A more recent system of N–S faults makes up the eastern boundary of the sinking depression of Konya.

THE ERUPTIVE RANGE ERCIYES DAĞ–HASAN DAĞ.

Between central Taurus and Kirşehir Massif, over a distance of more than 250 km, a volcanic alignment occurs, in which dominate some great composite volcanoes, several minor centers and very large pyroclastic and ignimbritic deposits. The main composite volcanoes of this system are, from East to West: Erciyes Dağ; Develi Dağ, Melendiz Dağ, Keciboydoran Dağ, Hasan Dağ, Karadağ.

Erciyes Dağ is the highest one, 3,916 m high above sea level and nearly 3,000 above the surrounding depressions of Kayseri and Sultansazliği. It is a great polygenetic mixed cone with concave flanks strewn with products of lateral eruptions, endogenous-domes, flow-domes, cinder and scoriae cones, large lava streams.

During the first phase of activity an andesitic lava volcano was built up, with radial rows of endogenous domes and two large and deep craters crowned by steep ring-walls of explosion breccia. It was already a cone of conspicuous dimensions, with a diameter of about 30 km.

Successively a peripheral ring of exogenous domes with pyroxene basaltic flows was originated. Then followed some great lateral olivine basaltic lava streams with cinder, scoriae and bomb cones. Finally two endogenous hyalo-andesitic domes appeared, with previous strong pumice ejections.

The first andesitic phase was accompanied by an extraordinarily violent ignimbritic eruption, whose products are spread over a surface of about 10,000 km².

The age of the andesitic cone is Miocene, the ignimbritic eruption is Pontian, the basaltic activity is Pliocene to Pleistocene age, and the last hyaloandesitic eruptions occurred in historical times.

Develi Dağ consists of a range of andesitic pyroclastic cones intensely transformed by siliceous, ferriferous and manganesiferous hydrotermal solutions and covered by a thick mantle of augite-olivine basaltic agglomerates. Fluid olivine basaltic and augite-olivine basaltic flows make up the tabular summit of the volcano.

Koçdağ is similar to Develi Dağ. Both tend to be arranged normally to the tauric orogene, near a point of maximum bending of the central arch. Over their intersection point rose up the great cone of Erciyes Dağ.

Melendiz Dağ is placed 100 km SW from Erciyes Dağ and consists of andesitic pyroclastic cones ranged in a row, strongly weathered by hydrotermal solutions. It is covered by a radial system of basaltic flows originating from a large group of craters and eruptive rows. It lies WSW–ENE, that is almost perpendicularly to the tauric direction.

As a western prolongation of Melendiz Dağ, Keciboydoran Dağ appears: it is smaller, but of similar constitution. Here two volcanic vents with radial basaltic flows can be seen, overlying agglomerates and flow-breccias.

As in the system Develi Dağ-Koçdağ-Erciyes Dağ, at the anatolian extremity of this Miocene row, rises up a conic volcano 3250 m high, called Hasan Dağ. Its activity originated during Miocene and continued in Pliocene, perhaps until the Pleistocene. The inner composition of this volcano is unknown on account of the recent lava cover. It forms a thick mantle of basaltic flows, mainly originated from two summital craters and several smaller parasite cones, which are mainly visible near the top.

The lava flows reached the surrounding plain, covering a thick layer of pumice and lapilli widely spread on the same plain. At the south-eastern foot of the volcano, some layers of crystal tuffs and thick ignimbritic flows can be seen with intercalated andesitic blocks. They should represent the oldest andesitic phase, similar to that of Erciyes Dağ.

South-West of Hasan Dağ, over a distance of about 30 km, another volcanic alignment appears. It can be correlated to Melendiz Dağ and Develi Dağ, both for its age and structure. In fact it is formed by strictly associated pyroclastic cones with later andesitic and basaltic eruptions. Between this group, called Karacadağ, and Hasan Dağ cone, we can see several cinder and scoriae-cones, sometimes with short lava flows, overlying Neogene and Quaternary lacustrine and pyroclastic beds.

A similar basaltic activity, of Quaternary age, can be observed in the desert plain South-West of the Karacadağ. Here, around the village of Karapinar, the volcanic cycle started with some thick, scoriaceous black lava flows of basaltic character, tormented by deep hollows and tumulus,

up to 40 m high, whose eruption vents are hooded by cones of strongly oxidized scoriae.

The same cycle continues with the explosion of four calderas aligned along a SW–NE fissure, opening into the horizontal surface of the plateau, as perfectly circular hollows with steep walls. The largest ones, Acigöl and Meke Göl calderas reaching a diameter of 1,500 m, are actually lacustrine basins.

The pyroclastic products of these calderas, especially vitric ashes with basaltic lapilli and fragments pulled away from the underlying detritic tuffaceous series, are widespread over the surrounding plateau covering also artifacts and bone levels of historical age. The activity was settled with ejection of basaltic scoriae from a SSW–NNE fissure, crossing with the one of the calderas. This last phase produced three scoria-cones with steep, funnel-shaped craters, one of which lies just on the cross point between the two fissures, that is the center of the Meke Gölü caldera.

40 km south-westward another eruption center rises up isolated in the Konya plateau. It is the group of Karadağ, 2288 m high, whose most interesting volcano—tectonic feature is a system of ring eruption, followed by a central eruption and ended by a caldera collapse. The reason of this peculiar structure must be looked for in the geographic position of the Karadağ, that is just in the center of curvature of the central arch of the tauric orogene.

The oldest phases are represented by some dome-shaped andesitic eruptions, now strongly weathered, arranged in an arch having a radius of about 20 km, that contain a nearly complete ring of andesitic domes. In the middle of the last one rises up the main center of Karadağ, formed by two steep and massive cones of andesitic lavas, strictly joined, with a diameter of about 3 km. One of them contains a caldera-shaped depression which is probably due to stopping and collapse of the summit.

Successively, on the south-eastern side of the volcano, some eccentric eruptions took place, preceded by strong explosive activity with ejection of ashes, lapilli and andesite blocks. After that, on the south-western flank, occurred a basaltic eruption, whose lava flows reached the peripheral ring of andesitic domes and stopped at the limit of the plain. All the described activity seems to be of Miocene age, also on the ground of the relationships between marine sediments of the same age and similar volcanics observed near the northern foot of the Taurus, south of Karaman.

Younger activity is represented by several typical andesitic endogenous domes, precisely aligned along two fissures lying N–S and NNW–SSE, intersecting each other and crossing all the Karadağ volcanic group. They are very wide and flat endogenous domes, generated by the outflow of andesitic, very vitreous lava, the viscosity of which obstructed the flow upon the underlying older lavas. The most typical example is represented by Değle Dağ, originated on the north-western side of Karadağ, as a wide conic volcano of 2 km in diameter and 400 m in height, with steep outer walls formed by andesitic blocks plunged into an entrail lava, and crowned by a surface full of blocks and tumulus.

The activity of Karadağ was settled with a strong ejection of andesitic ashes and pumices, widely spread on the northern side of the volcano and on the plain in front of it. It is difficult to establish with certainty the ejection vent of this last activity.

In addition to the main volcanic alignment, arranged parallel to the Taurus range, other volcanic centers occur north of it, namely near the contact with the Kirşehir Massif. They consist of small central monogenetic volcanoes, of andesitic or basaltic character, all of them related with the former phases of Erciyes Dağ, that is pre-pontic. Exceptions are given by some younger centers as the group of composite calderas with pyroclastic rings of Acigöl, province of Nevşehir, possibly corresponding to the latest activity of Erciyes Dağ. Other younger centers are the great cinder cone of Göllü Dağ partially covered by thick, viscous ignimbritic flows and the wide olivine-basaltic lava streams, whose emission points are covered by cinder and scoriae cones with funnelshaped craters, placed between Göllü Dağ and Kizil Irmak.

The pyroclastic products of the south-anatolian eruptive range, especially the ejectamenta of the great cones, filled up the most part of the depression existing between the Kirşehir Massif and the Taurus orogen, that was particularly accentuated among Hasan Dağ, Erciyes Dağ and Kizil Irmak. The parts of the depression surviving till Quaternary times continued their sinking movement along regional faults from which the volcanic products forming the great Hasan and Erciyes cones rose up. Now these sinking zones are represented by the plains of Tuz Gölü, Sultansazliği and Kayseri, which are filled up with Quaternary alluvial deposits.

Another important volcano-tectonic line follows the course of Kizil Irmak extending for more than 80 km in length between Tuz Gölü and Avanos. From it rose up the hyolandesitic materials forming the Quaternary volcanoes of Acigöl near Nevşehir. This line follows an old tectonic cicatrix in the Kirşehir Massif belonging to a more complicated fracture system, with NW–SE directions parallel to the Tuz Gölü line and SW–NE directions characterizing the eastern part of the middle-anatolian median masses. These directions are clearly intersecting near Avanos, NE of Nevşehir.

Neogene beds are sinking along the southern border of the Kizil Irmak fracture, in form of regional flexure dipping up to 15°-20° and joined together without breaks with tabular Neogene of the anti-tauric region.

North of Kizil Irmak the pyroclastic Neogene continues as sub-horizontal filling-up of large but not deep depressions existing within the Kirşehir Massif.

The pyroclastic Neogene series develops with a thickness up to 300 m, and consists of lacustrine and sub-areal weathering sediments variously contaminated by ejections of vitric ashes, pumices, volcanic sands, lapilli, scoriae and different ignimbritic eruptions. In the lowest part generally occurs fluviatile conglomerate composed of basement fragments such as ophiolites, granites, marbles, followed by a thick argillaceous horizon sometimes bituminous, containing the former traces of vitric ashes. The pyroclastic products

are successively widespread with polychrome, chloritic and feldspathic, argillaceous tuffites, yellow sandy tuffites and conglomerates with tuffaceous matrix. Laterally this series contains pockets of sub-aerial alteration rocks containing vertebrate fauna of Pontic age.

The tuffaceous lacustrine facies increase in the higher part with thick levels of clays and marls and intercalation of sandy, argillaceous or calcareous tuffites with alluvial pockets of lateritic alteration soils with pumiceous fragments rich in pontic vertebrates.

Often, beds of pure tuffs occur, up to 60 meters thick. Among these beds there is a white dacitic, pumice-rich, lapilli tuff, whose cone-shaped erosion originated the famous "Cappadocian landscapes".

In the middle part of the same series occurs a thick layer of pink, pumice-rich, lithic tuff, containing andesitic and basaltic lapilli; in the higher part there is a white, andesitic biotite-rich vitric tuff. At short distance above the latter lies the main ignimbritic blanket, generally of dacitic composition, with uniform thickness included between 10 and 20 m, covering enormous portions of the region. It forms the tabular cover of the Neogene series, except for the zones in which the same ignimbrite is covered by lacustrine limestones, alluvial sands and tuffs.

Connected to the pre-ignimbritic basaltic volcanoes, large and thick agglomeratic deposits are seen, in which the flows are interposed and, especially, superimposed.