32 Quaternary Volcanic Landscapes and Prehistoric Sites in Southern Cappadocia: Göllüdağ, Acıgöl and Hasandağ

Damase Mouralis, Erkan Aydar, Ahmet Türkecan, and Catherine Kuzucuoğlu

Abstract

The southern Cappadocia shows a large variety of Quaternary volcanic landscapes, offering the opportunity to observe beautiful and generally fresh morphologies. These landscapes include two rhyolitic complexes (Göllüdağ and Acıgöl), a huge composite volcano (Hasandağ) and numerous monogenic vents, with scoria cones, domes and maars. Natural and anthropogenic sections show a large variety of lava flows and tephra layers. The precise study of this volcanic material allows reconstructing the volcanic and geomorphologic evolution of this area during the Quaternary, including modes of emplacements, chronology of the volcanic successions, morphological impacts on the landscapes. In addition, archaeological excavations in southern Cappadocia testify for the presence of ancient populations since the Middle to Upper Palaeolithic. During the Neolithic and Chalcolithic periods, the southern Cappadocia has been intensively occupied with permanent sites (Aşıklı Höyük, Musular, Tepecik Çiftlik, Köşk Höyük, etc.) as well as non-permanent sites devoted to mining and chopping of obsidian associated with some of the volcanoes.

Keywords

Quaternary volcanism • Obsidian • Volcanic complex • Cinder cone • Composite volcano

32.1 Introduction

The substratum of southern Cappadocia is formed by Tertiary volcanic rocks (Fig. 32.1). The morphologies developed on the Miocene–Pliocene ignimbrites show flat surfaces often deeply incised by the hydrographic network forming mesa and residual hills (Fig. 32.2), while the landscapes associated with Early Quaternary andesitic volcanism present eroded lava massifs (Erdaşdağ, for example). Later Quaternary volcanic activity has partially destroyed and fossilized these previous morphologies.

Being active from the Middle to Upper Pleistocene with highly probable Holocene eruptions, the volcanoes located in southern Cappadocia present well-preserved morphologies. We show in this chapter the high variety of volcanic landscapes associated with these volcanoes. Göllüdağ and Acıgöl rhyolitic complexes are associated with eruption of large volumes of pyroclastic materials, whereas Hasandağ is an outstanding composite volcano, which rises ca. 2000 m above the Cappadocian Plateau. The southern Cappadocia also provides an opportunity to observe a large variety of monogenic vents (cinder cones, acidic domes, maar, etc.) (Figures 32.1, 32.3 and 32.4).

These southern Cappadocian volcanic massifs host ancient populations since the Middle Palaeolithic and the area has been intensively occupied at permanent and not permanent sites during the Neolithic and Chalcolithic times. During this long period, the volcanic landscapes of Southern Cappadocia have provided resources, especially obsidian, for these populations.

D. Mouralis (✉)
Rouen-Normandie University & CNRS, Laboratoire I.D.E.E.S, UMR 6266, Rouen, France
e-mail: damase.mouralis@univ-rouen.fr

D. Mouralis · C. Kuzucuoğlu
Laboratory of Physical Geography (LGP, UMR 8591), CNRS, Universities of Paris 1 Panthéon-Sorbonne and Paris 12 U-Pec, Paris, France
e-mail: catherine.kuzucuoglu@lgp.cnrs.fr

E. Aydar
Department of Geological Engineering, Hacettepe University, 06800 Beytepe, Ankara, Turkey
e-mail: eaydar@hacettepe.edu.tr

A. Türkecan
General Directorate of Mineral Research & Exploration, MTA, Ankara, Turkey
e-mail: aturkecan@gmail.com

C. Kuzucuoğlu et al. (eds.), *Landscapes and Landforms of Turkey*,
World Geomorphological Landscapes, https://doi.org/10.1007/978-3-030-03515-0_32

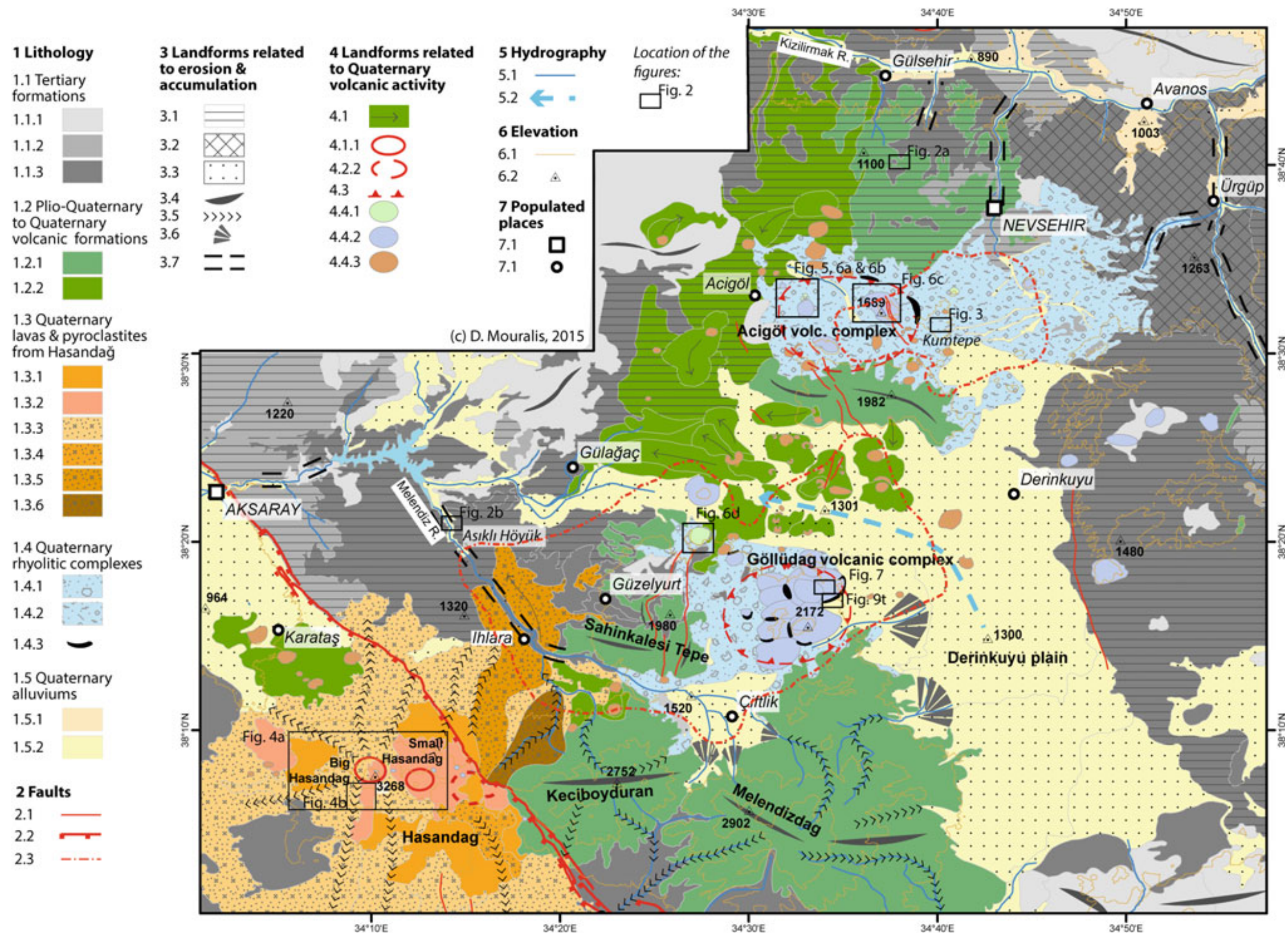

Fig. 32.1 Geomorphological map of the Southern Cappadocia. 1. Lithology: 1.1 Tertiary formations; 1.1.1 Metamorphic and plutonic formations; 1.1.2 Sedimentary formations; 1.1.3 Volcanic formations (ignimbrites and lava flows); 1.2 Plio-Quaternary to Quaternary volcanic formations; 1.2.1 Lavas and pyroclastites; 1.2.2 Quaternary lavas; 1.3 Quaternary lavas and pyroclastites from Hasandağ; 1.3.1 Undifferentiated lavas and domes; 1.3.2 Terminal lavas and domes; 1.3.3 Undifferentiated pyroclastites; 1.3.4 Melendiz debris avalanche; 1.3.5 Yeniköy pumice flow; 1.3.6 Kitreli pumice flow; 1.4 Quaternary rhyolitic complexes; 1.4.1 Main tuff from Göllüdağ volcanic complex; 1.4.2 Main tuff from Acıgöl volcanic complex; 1.4.3 Obsidian outcrops; 1.5 Quaternary alluvial deposit; 1.5.1 Recent alluvial deposits; 1.5.2 Quaternary alluvial deposits; 2. Faults: 2.1 Holocene faults scarp; 2.2 Pleistocene faults (mainly hidden); 2.3 Neogene collapse structures; 3. Landforms related to erosion and accumulation: 3.1 Plateau; 3.2 Erosion dominated landforms (badlands and fairy chimney); 3.3 Accumulation dominated landforms; 3.4 Main crests (erosion dominated landforms); 3.5 Steeply incised gullies; 3.6 Alluvial fan; 3.7 Gorges; 4. Landforms related to Quaternary volcanic activity; 4.1 Lava flows; 4.2 Big and small Hasandağ terminal cones; 4.3 Hasandağ destroyed terminal cone; 4.3 Volcano-tectonic structure (caldera); 4.4 Monogenic vents: 4.4.1 Maars; 4.4.2 Domes; 4.4.3 Cinder cones; 5. Hydrography; 5.1 Rivers; 5.2 Ancien hydrographic networks destroyed by Quaternary volcanic activity; 6. Elevation; 6.1 Contour lines (500 m); 6.2 Elevation (m); 7. Populated places; 7.1 Main towns; 7.2 Small towns and villages. After Atabey (ed.) (1989), Ayhan (ed.) (1989), Dönmez (ed.) (2005), Froger et al. (1998), Kuzucuoğlu et al. (2013), Mouralis (2003), Pastre et al. (1998), Türkecan et al. (2004)

32.2 Two Rhyolitic Complexes: Acıgöl and Göllüdağ

32.2.1 The Landscapes

Despite similar sizes (10–12 km in diameter), Göllüdağ and Acıgöl complexes show different landscapes (Fig. 32.1). Göllüdağ complex is a massif formed by the coalescence of ca. 10 rhyolitic domes. The highest dome (Büyük Göllüdağ) reaches 2172 m. Two massifs formed by Neogene to Plio-Quaternary lavas and ignimbrites surround Göllüdağ complex: Şahinkalesi Tepe to the west (1989 m) and Melendizdağ to the east (2195 m). Göllüdağ massif is flanked by somewhat flat and poorly drained areas: Derinkuyu Plain to the east (ca. 1300 m), Kayırlı corridor (ca. 1300 m) to the north, showing more than 25 dispersed monogenic vents, and Çiftlik Plain to the south (ca. 1500 m).

On the other hand, Acıgöl complex presents the morphology of a plain (1300 m high) where dispersed cinder

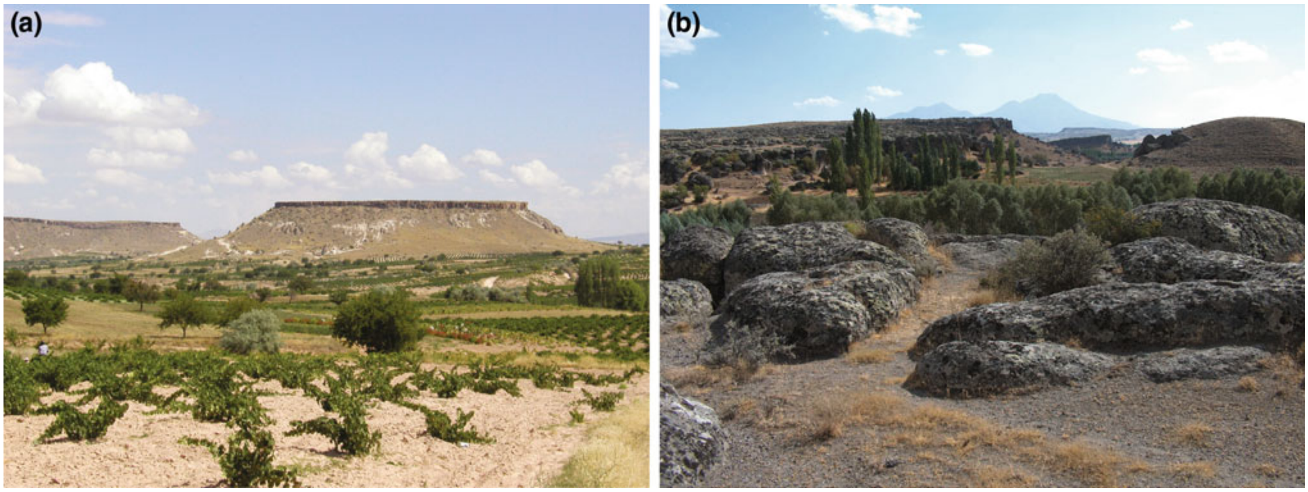

Fig. 32.2 Views of the South Cappadocian Plateau developed over the welded Miocene–Pliocene ignimbrites and eroded during Quaternary. **a** residual hills north-west of Nevşehir (view looking to north-east). The foreground shows Cappadocian vineyards. Photograph by D. Mouralis. **b** Ihlara Valley incised within the Miocene–Pliocene Kızılkaya ignimbrite. Hasandağ appears south in the background. Photograph Aşıklı Höyük Research Project Archives (2013). Courtesy of M. Özbaşaran

cones and rhyolitic domes occur, the highest being Kocadağ (1689 m). The plain is limited to the south by the Neogene andesitic massif of Erdaşdağ (1982 m) and to the east by Kumtepe hills formed by pyroclastic materials emitted during the paroxysmal phase of Acıgöl rhyolitic complex. However, Acıgöl complex is largely open to the west and to the north (towards the Cappadocian Plateau), so that their western and northern limits are unclear.

32.2.2 The Volcanic History

Sections located in and around both complexes record a similar volcanic history, which may be divided into two main stages. The first stage was paroxysmal, showing an explosive eruption and the emplacement of large volume of pyroclastic deposits. In Göllüdağ, Mouralis (2003) and Türkecan et al. (2004) suggest that they covered first more than 720 km^2, including Göllüdağ massif as well as part of Şahinkalesi Tepe, and Derinkuyu and Çiftlik plains. In the case of Acıgöl complex, these authors indicate that the pyroclastic deposits expanded over 450 km^2. In both complexes, this paroxysmal phase is responsible for the emplacement of a high variety of eruption products, including pyroclastic density currents, surges and falls. The sections located in and around Kumtepe hill in the eastern part of Acıgöl complex (Fig. 32.5) give the opportunity to observe and to understand stratigraphy associated with this paroxysmal phase (Druitt et al. 1995; Mouralis et al. 2002).

This paroxysmal activity is correlated with the volcano-tectonic collapse of the central part of the complex and possibly to the formation of a caldera. In the case of Acıgöl, Yıldırım and Özgür (1981) have first described a caldera that was limited to the south by Erdaşdağ. However in the field, evidences of a caldera are scarce, both in the present-day morphologies and in the available geological sections. In the case of Göllüdağ, even if morphology is also unclear, some tectonic features point to a collapse: tilted old alluvial series and depressed elevation of the basement in the centre of the complex (Mouralis et al. 2002).

The second stage corresponds to the emplacement of vents in and around both complexes. Göllüdağ massif is formed by more than ten coalescent domes, some later ones partially cutting and destroying the earlier ones. In the case of Acıgöl complex, six rhyolitic domes have been extruded. Also, in both complexes, the presence of basaltic cinder cones indicates a second source of magma.

The emplacement of the domes generally shows a succession of complementary phases associating phreatomagmatic eruptions and extrusions. Below (part 4 of the paper), we present some of these characteristic successions.

In both complexes, the chronological framework is well-constrained thanks to radiometric dating (mainly using K-Ar) of some lava. It shows that the paroxysmal stage may be considered as a "rapid" and continuous event. In the field, it is evidenced by the continuity of the pyroclastic sedimentation. In Göllüdağ, this first paroxysmal stage is dated ca. 1.39 Ma according to the dating of a pumice fall (Mouralis et al. 2002), whereas its age is ca. 180–160 ka in Acıgöl complex (Druitt et al. 1995; Mouralis 2003; Schmitt et al. 2011). In both complexes, the absence of alluvium or colluvium units interbedded with the pyroclastic deposits indicates the continuity of this paroxysmal volcanic activity.

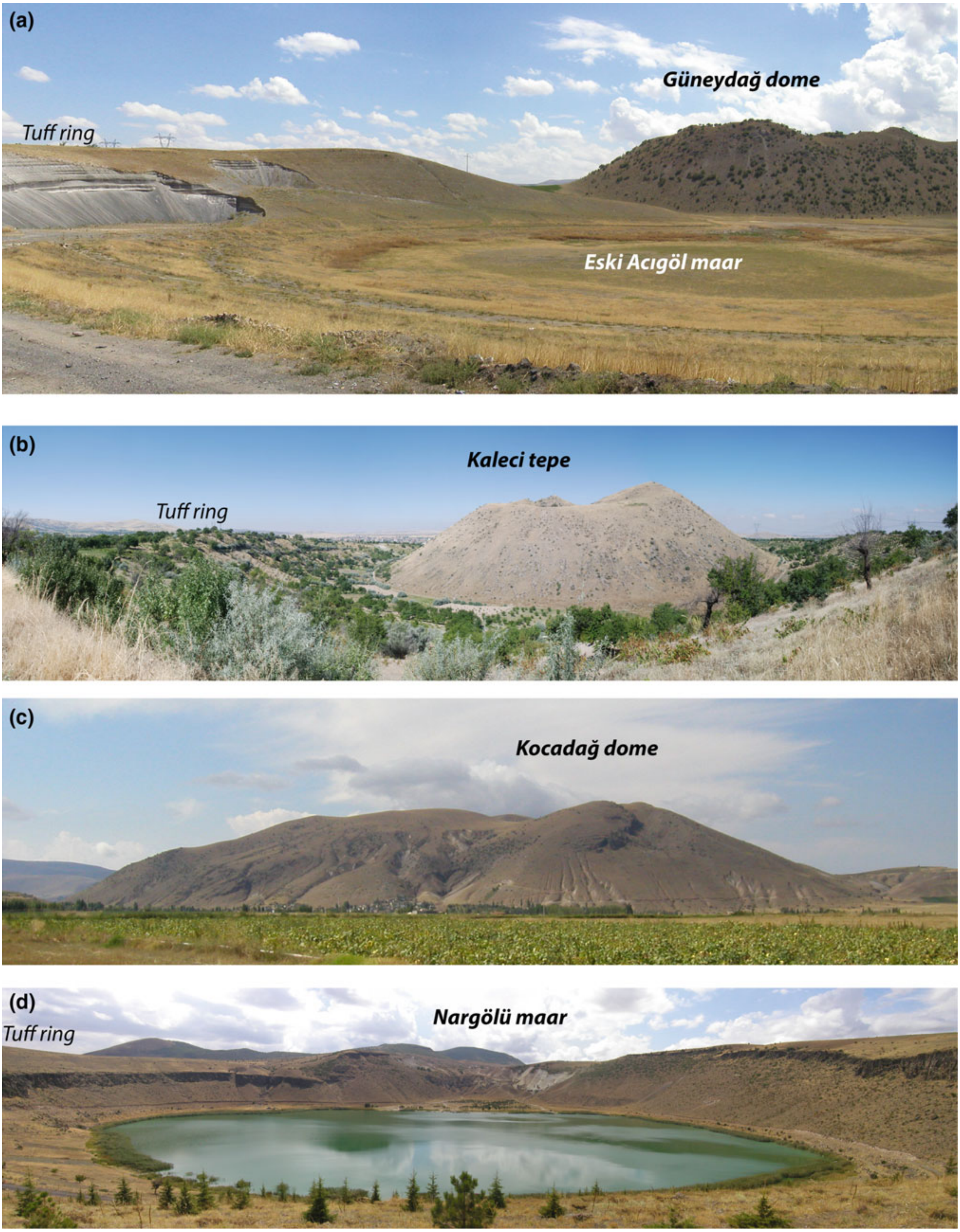

Fig. 32.3 Various domes and maars from southern Cappadocia. **a** Eski Acıgöl maar and Güneydağ dome (see Fig. 32.5). View to the south. **b** Kaleci Tepe and its tuff-ring (see Fig. 32.5). View to the north. **c** Kocadağ dome. View to the north-east. **d** Maar of Nargölü to the south. Photographs by D. Mouralis, except **b**, **c** Kuzucuoğlu

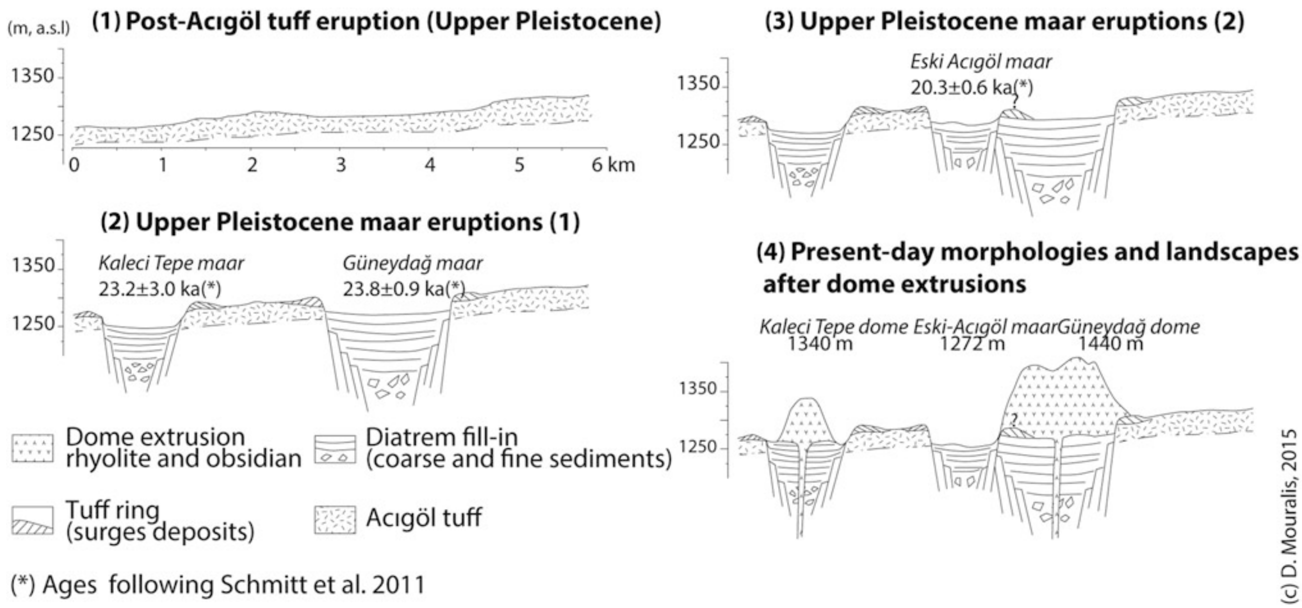

Fig. 32.4 Emplacement of Güneydağ, Eski Acıgöl and Kaleci Tepe volcanoes, exhibiting the alinement of maars and domes

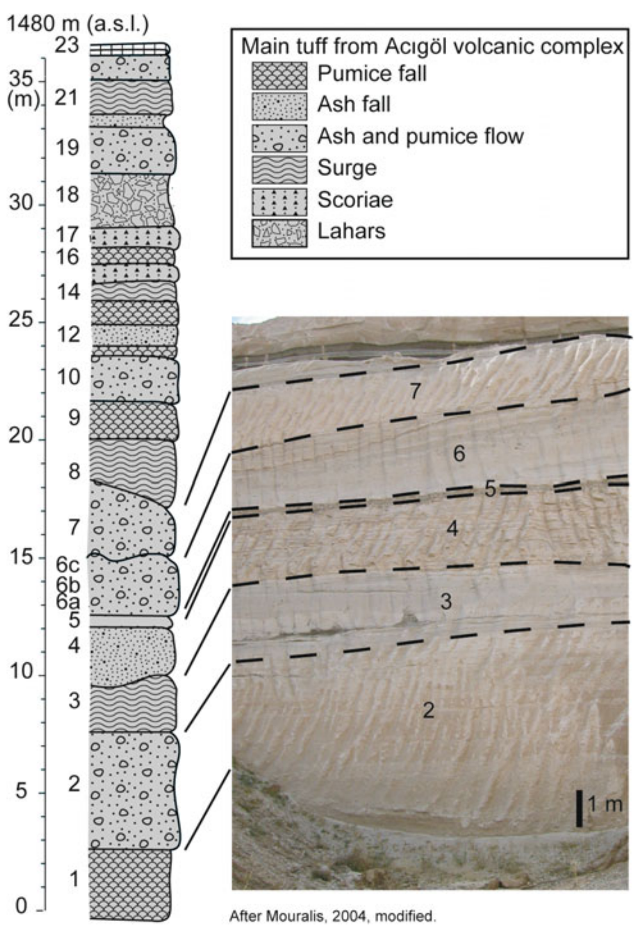

Fig. 32.5 Pyroclastic deposits related to Acıgöl volcanic complex (paroxysmal eruption). Section located near Kumtepe hill. Photograph by D. Mouralis

On the other hand, the second stage, mainly characterized by the extrusion of rhyolitic domes, lasted tens to hundreds thousands years. In Göllüdağ, this second stage took place during the Middle Pleistocene over a period of 0.6 Ma (Mouralis 2003; Türkecan et al. 2004), since the oldest dome (palaeo-Kabak Tepe) is dated to 1.1 Ma and the youngest (Küçük Göllüdağ) is only 0.4 Ma old. Within Acıgöl complex, the oldest dome is Kocadağ (ca. 93 ka, Mouralis 2003) whereas the youngest dated volcano is Eski Acıgöl maar, dated 20.3 ± 0.6 ka using zircon growth (Schmitt et al. 2011). Moreover, Kuzucuoğlu et al. (1998) and Roberts et al. (2001) report a scoriae layer interbedded in the sedimentation of Eski Acıgöl maar at 6.5 m depth and dated ca. 9 ka cal BP. This indicates that volcanic activity in the vicinity of Acıgöl complex probably continued during the Early Holocene.

32.2.3 The Geomorphologic Impacts of Volcanic Activity

Volcanic activity and the emplacement of both complexes are responsible for three main geomorphologic impacts modifying the regional landscapes: (1) destruction of previous relief; (2) deposition of new volumes of lavas and pyroclastic materials; and (3) disturbance of the hydrographic network.

32.2.4 Relief Destruction

Rocks that formed the relief previous to the emplacement of the Quaternary volcanic complexes can be observed only in a few sections because of destruction during the explosive activity followed by fossilization by pyroclastic deposits. In Göllüdağ, an outcrop of basalt to andesite lava uphill above the village of Kayırlı has been dated 1.71 Ma (Mouralis 2003). It indicates an ancient extension of the Plio-Quaternary volcano of Şahinkalesi Tepe.

In and around Acıgöl complex, remains of the deep basement are visible as lithic fragments in some of the pyroclastic deposits associated with the emplacement of domes. For example, the surges associated with Kaleci Tepe contain blocks of granite, whereas the surges associated with Güneydağ present numerous large blocks of diabase. These lithics have been blown off from the volcanic conduit during the phreatomagmatic stage. These blocks do not give any information on morphologies previous to the collapse but they release a few hints on the geology of the deep basement.

It is remarkable that both Göllüdağ and Acıgöl complexes are located within the probable extension of the Neogene collapsed structures that must have accompanied the emission of the famous Cappadocian ignimbrites as defined by Le Pennec et al. (1994), and located by Froger et al. (1998) near Acıgöl–Nevşehir and Derinkuyu areas, respectively. The geographical superposition of Neogene and Pleistocene complexes in the same areas explains why the oldest morphologies related to the Neogene calderas cannot be identified as they have been either erased or/and concealed below younger (Quaternary) deposits.

32.2.5 Evolution of Palaeogeography

Volcanic activity of both complexes is responsible, not only for destruction of previous morphologies during the initial paroxysmic stage, but also for the construction of new relief features mainly formed by domes extruded during the second stage. The emplacement of both complexes has thus involved complete reorganization of regional palaeogeography. Çiftlik Plain is an interesting example studied by Kuzucuoğlu et al. (2013). This round-shaped plain (sometimes suspected to be a caldera) results from a progressive closing related to successive volcanic events. (1) To the north, the Plio-Quaternary Şahinkalesi Tepe lava flows first cover Tertiary andesites and ignimbrites. (2) To the west, basaltic lava flows were emitted by Boztepe cinder cones near the village of Mahmutlu (dated ca. 1.33 Ma: Mouralis 2003). (3) In the meantime, or shortly afterwards (ca. 1.3 Ma), the paroxysmal activity of Göllüdağ complex caused partial destruction of Şahinkalesi Tepe heights. Meanwhile, all the area is covered and filled-in by a large amount of pyroclastic deposits related to this stage. (4) Finally, the domes were extruded between 1 and 0.6 Ma, forming the present-day Göllüdağ massif. With this succession of events, the Pleistocene volcanic activity ended in enclosing the Çiftlik Plain completely, where a shallow lake formed before flowing into a gorge carved by Melendiz River (captured by the Ihlara River) along the borderline between Melendiz and Şahinkalesi Tepe massifs (Fig. 32.1).

32.2.6 Disturbance of the Hydrographic Network

Many evidences indicate the complete disturbance of the hydrographic network by the volcanic activity. For example, in the area located between Şahinkalesi Tepe and Göllüdağ, the sections show palaeotopography of a south–north-oriented valley. The pyroclastic materials emitted during the paroxysmal eruption of Göllüdağ complex filled-in the valley, fossilizing the palaeotopography. Elsewhere, a large amount of alluvium filling the Kayırlı corridor indicates that this area was partly used by a river network that has been totally interrupted by the emplacement of several cinder cones and associated lava flows. In addition to the edification of these cones, the construction of Göllüdağ massif explains the complete disappearance of the drainage in Derinkuyu Plain and Kayırlı corridor.

Only after the end of the volcanic activity, the drainage network began to reorganize (Middle Pleistocene in Göllüdağ area, Late Pleistocene to Holocene in the Acıgöl complex as well as in the Kayırlı corridor). In each area, it is responsible for the origin of large alluvial fans reworking soft pyroclastic material from falls, surges, etc., mixed with eroded lava blocs. These fans blanket slopes all around Göllüdağ massif (Mouralis 2003), Çiftlik Plain (Kuzucuoğlu et al. 2013) and Acıgöl complex (Türkecan et al. 2004).

The Middle to Late Pleistocene activity of Göllüdağ and Acıgöl complexes have thus deeply modified palaeogeography of southern Cappadocia, destroying previous morphologies, constructing new landscapes and disturbing ancient river networks. The present-day landscapes thus result from volcanic activity (destruction and construction of relief) during the Quaternary and from adjustments by erosional processes (erosion and accumulation) during intervening periods.

32.3 Hasandağ: a Huge Composite Volcano

32.3.1 Emplacement of the Composite Volcano

Hasandağ (or Mount Hasan) is a composite stratovolcano with two peaks (Fig. 32.6) named Big and Small Mount Hasan (3253 and 3069 m a.s.l., respectively). The base elevation of volcano is around 1000 m a.s.l. This edifice was constructed in multiple stages identified as Paleo-, Meso-, and Neo-Hasandağ by extrusive dome emplacements and intermittent collapse events associated with ignimbrite emissions (Aydar 1992; Aydar et al. 1995; Aydar and Gourgaud 1998; Aydar et al. 2012). Limited geochronological data indicate the emplacement of the oldest lavas at 7.21 ± 0.1 Ma (K-Ar, see Aydar and Gourgaud 1998) and ignimbrites emplacement during an early caldera collapse at 6.31 ± 20 Ma ($^{40}Ar/^{39}Ar$). These dates are contemporaneous with the widespread Neogene ignimbrite volcanism in Cappadocia (Deniel et al. 1998). Only one K-Ar age for Meso-Hasandağ is published (0.58 Ma: Ercan et al. 1990); it is consistent with subsequent (270 ka: Notsu et al. 1995) ignimbrite activity, dome extrusion with associated block-and-ash flow deposition, origin of peripheral scoria cones and maar eruptions that are collectively attributed to the Neo-Hasandağ stage, responsible for the contemporary form of the volcano.

The Neo-Hasandağ comprises two summits. Numerous collapsed andesitic to rhyodacitic lava domes on its flanks generated widespread pyroclastic deposits. The resulting nuées ardentes deposits (i.e. block-and-ash flows) with 10–20 m thick sequences are today deeply incised, especially on the flanks of the Big Hasandağ. Debris avalanche deposits outcrop to the north of the volcano where they form a wide hummocky surface. The main pyroclastic deposits associated with this activity are biotite-rich pumiceous fall and flow units that are covered by blocky-chaotic mass flows. Their best outcrops are incised by the Güvercin stream south of the Ihlara village and in a road-cut near Belisirma Village in the Ihlara Valley. Rhyodacitic and rhyolitic unwelded ignimbrites are restricted to the lower reaches of the Neo-volcanic edifice in the north, south and west.

32.3.2 Dating the Recent Activity of the Volcano

Hasandağ is considered as active–subactive volcano. According to K-Ar ages, volcanic activity occurred during the Holocene with an andesitic lava dome extrusion at the northern flank yielding a maximum age of 6 ka ago (Aydar and Gourgaud 1998), and another andesitic lava flow erupted at the western base of the volcano (near Aşağı Dikmen village) with K-Ar zero-age (±3 ka: Kuzucuoğlu et al. 1998). Two samples from Big Hasandağ summit domes yielded K-Ar ages of 29 and 33 ka (Kuzucuoğlu et al. 1998).

Recently, pumices collected from the summit of Big Hasandağ were dated by Schmitt et al. (2014) with U-Th/He method measured on zircon crystals to 8.97 ± 0.64 ka and 28.9 ± 1.5 ka ago. The later one matches very well with previously published ages of the summit dome. The Holocene age of the sample dated 8.97 ± 0.64 ka ago is very interesting as it can be linked to an eruption that may have been eye-witnessed by Prehistoric people. During the 1960s, British archaeologist James Mellaart excavated the Neolithic settlement of Çatalhöyük in the Konya Plain. The results provided unique insights into the living conditions of humans at the transition from hunter-gatherer to settled agriculture societies. Among the striking discoveries during the excavation were a high number of murals that were photographed and sketched on site. One of them is famously described as depicting volcanic eruption (Mellaart 1967). If this interpretation is correct, the painting is the oldest depiction of a volcanic eruption and is also the first graphical representation in the world of an event or even a landscape (Clarke 2013).

This interpretation is, however, much debated among archaeologists who are convinced that it is not possible that men drew 9000 years ago a town plan represented from above and/or a “story-telling” picture. Away from this debate about the painting, the point remains that Schmitt et al. (2014) dated pumices sampled at the summit of the volcano ca. 9.5–8.4 ka ago (7.5–6.4 ka BC), i.e. a period similar to that of the abandonment of Aşıklı Pre-Pottery Neolithic site in the Melendiz Valley (7.4 ka BC: see below), and of the first centuries of the Neolithic occupation at Çatalhöyük in the Konya Plain (starting ca. 7.3 ka ago). No large deposit of a Plinian eruption (as depicted by the mural and as sampled by Schmitt et al. 2014) has still been found elsewhere on the volcano or in the area.

32.3.3 Diversity of Monogenic Vents: Cones, Maar and Domes

According to Toprak (1998), the Central Anatolia Volcanic Province (CAVP) consists of more than 820 monogenic vents, comprising accessory vents from rhyolitic complexes and from composite volcanoes. Between Hasandağ to the south and Acıgöl complex to the north, the southern Cappadocia gives the opportunity to observe all the possible forms of monogenic vents from cinder cones to domes and maars, as well as combinations of these elementary forms. Most of these vents are Quaternary in age and show very fresh and clear landforms.

32.3.4 Location and Ages of the Monogenic Vents

In the area presented here, the monogenic vents are mainly located to the north of Hasandağ volcano, and between Göllüdağ and Acıgöl complexes in the so-called Kayırlı corridor. These volcanic vents comprise more than thirty cinder cones, maars and scarcer domes. Basaltic cinder cones are organized along N-S, NE-SW and NW-SE lines (Toprak 1998). The cinder cones and some underlying maars

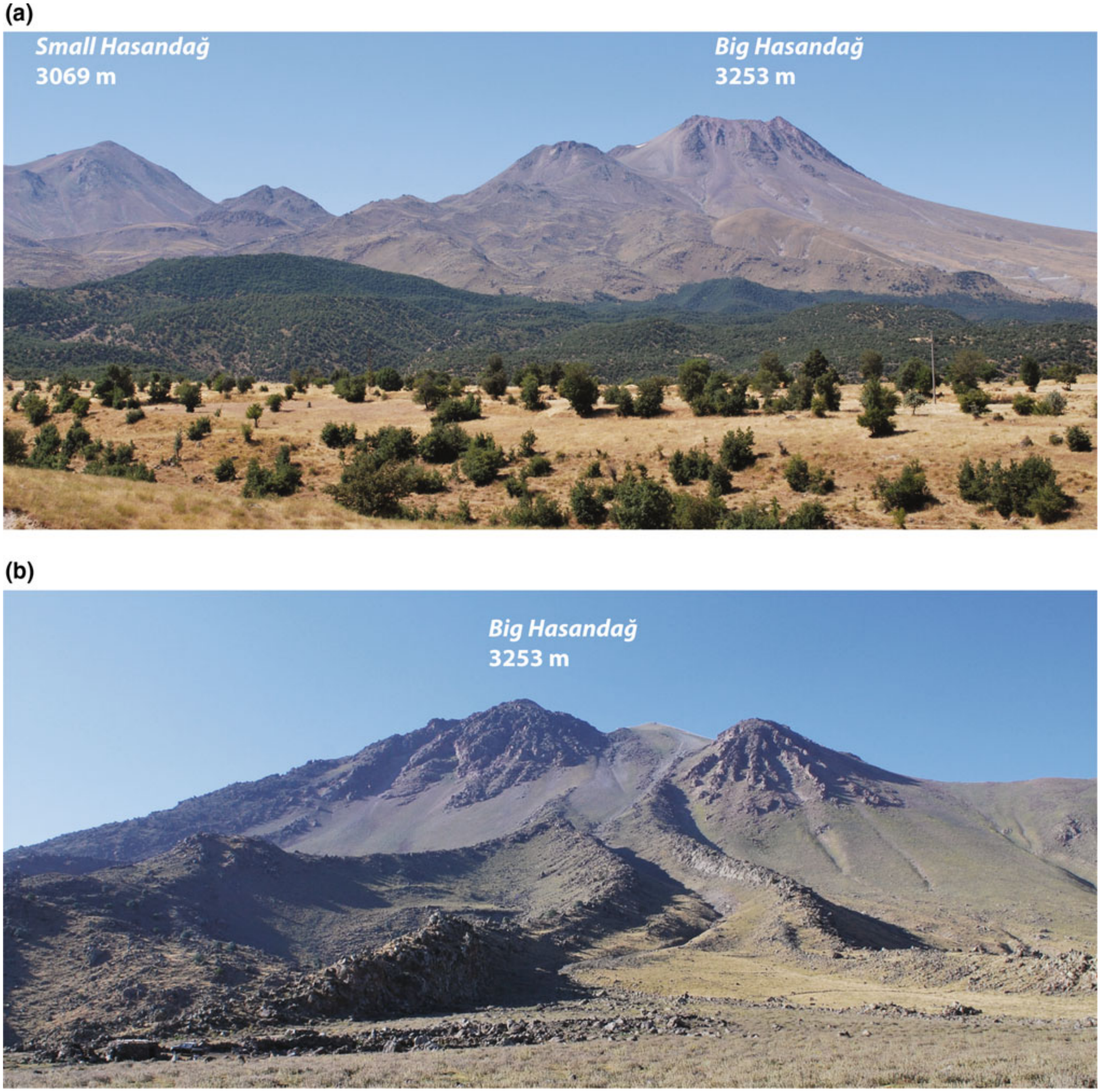

Fig. 32.6 Hasandağ composite volcano. **a** Northern flank of the Hasandağ double-cone volcano (looking south). **b** Southern flank of main cone (Big Hasandağ) showing very fresh lava flows. Photographs by D. Mouralis in 2011

form numerous small clusters rising above the basaltic lava fields. Basaltic maars are mostly covered by cinder cones except Nargölü (also called Sofular-Acıgöl) (Fig. 32.3d). This maar crater filled by a freshwater lake partly impacted by gas inflowing from the substratum was subjected to a geothermal drilling by MTA (Akbaşlı 1992). The coring performed in 2003 in the lake sediments delivered a detailed palaeoenvironmental (England et al. 2008) and palaeoclimatic sequence covering the last 1500 years (Jones et al. 2006). After having been classified as a protected natural site for many years, the maar hosts now two thermal hotels constructed on the outer rim of the crater.

Several cinder cones and their related lava flows are also located at the north-eastern base of Hasandağ and north-west of Mount Keçiboyduran (an old, eroded volcano SW of Hasandağ). Besides, cinder cones, lava flows and maars are also present in the south and west of Hasandağ. The western cluster, located in the north-western part of Hasandağ, comprises at least eight differently scaled cones and a phreatomagmatic maar below Yıpraktepe cone. The fissure lava flows cover more than 50 km^2 around Karataş Village. These lavas are intercalated with Hasandağ block-and-ash flow deposits around Sultan Ana cinder cone (NW and N slopes of Hasandağ). Radiometric ages show that this volcanism is very young, ranging between 120 ka (Ercan et al. 1990) and 36 ka (Aydar and Gourgaud 1998).

32.3.5 Volcanic Successions in Southern Cappadocia

The emplacement of rhyolitic domes associated with Göllüdağ and Acıgöl volcanic complexes took place in the frame of a volcanic succession comprising phreatomagmatism, rhyolitic lava extrusion (with occasional obsidian facies) and explosive eruptions. The sections located in the vicinity of all domes allow one to identify the following emplacement succession (Mouralis et al. 2002; Mouralis 2003). Phreatomagmatic eruptions typically preceded dome emplacement, producing a tuff-ring around a maar (explosion crater). Afterwards, these craters have been partially or totally filled-in by lava domes. Examples of this succession are the Kaleci Tepe (Fig. 32.3b), Güneydağ (Fig. 32.3a), Korudağ (all of them within Acıgöl complex) and most of the domes forming Göllüdağ complex.

In the Acıgöl complex, some monogenetic vents are aligned over N-S fissures (e.g. the Güneydağ dome and its underlying maar, with the addition of two other connected maars (Ulusoy et al. 2009). Another example of such a N-S alignment is Obruktepe basaltic maar associated with three adjacent craters. Original maar features (whether or not associated with preserved tuff-ring deposits) (e.g. Eski Acıgöl) prove that phreatomagmatic eruption events were not followed by any further magma ascent, and the maar crater slowly filled with lakes or marsh sediments. In conclusion, the Acıgöl complex exhibits the contemporaneity of bimodal lavas expressed by associations, in the landscapes, of rhyolitic domes, maars as well as basaltic cinder cones and tuff-rings.

32.4 Poly-phased Volcanoes: Güneydağ, Eski Acıgöl Maar and Kaleci Tepe

Güneydağ dome, Eski Acıgöl maar and Kaleci Tepe offer an interesting example of volcanic succession. New data (Mouralis 2003; Türkecan et al. 2004) complete the previous description proposed by Kazancı et al. (1995). This succession (Figs. 32.3a, 32.4 and 32.5) is reconstructed on the basis of observations from quarries open into the pyroclastic deposits of these three vents.

In the southern part of Güneydağ dome, a quarry presents materials associated with the ring-tuff of the initial maar of the dome. They are partially fossilized by Güneydağ dome lava. They comprise at least 35 layers of different thickness. Some layers contain non-vesiculated fragments while others present vesiculated ones, a contrast expressing fluctuations in the magma–water interaction rate. The base of the section shows lithics-enriched layers including ultra-basic (diabase) bombs reaching 1 m in size; upwards, the proportion of lithics decreases. Some blocs of Acıgöl ignimbrites are also encountered in the lithics.

On its northern edge, the initial maar is partially cut by Eski Acıgöl maar crater. The respective pyroclastic deposits are exposed in a quarry located north-west of Eski Acıgöl maar. These tephras are characterized by the presence of diabase and porphyritic granitic clasts (the granitic clasts are dated 78 Ma by Aydar et al. 2012). With blocs reaching 20 cm in size, their grain size is finer than in Güneydağ surges. A third volcano, Kaleci Tepe, is located 1.5 km north-west of Eski Acıgöl, aligned with the previous two ones. The present-day morphology indicates clearly the succession of a maar partially filled with the extrusion of the dome itself.

In conclusion, three successive stages can be reconstructed: (i) Güneydağ maar eruption is probably contemporaneous with Kaleci maar eruption, (ii) a third maar (Eski Acıgöl maar) partially cuts the northern part of the Güneydağ maar, and (iii) both Kaleci Tepe and Güneydağ domes are extruded within the initial maars.

Fission-track ages of these volcanic products (Bigazzi et al. 1993) have been specified by ages based on zircon growth (Schmitt et al. 2011). These new results partially validate our field observations. Schmitt et al. (2011) give a 23.8 ± 0.9 ka age for Güneydağ pyroclastic materials (the oldest, according to field observation), and a 23.2 ± 3.0 ka for Kaleci Tepe. As Kaleci Tepe is morphologically and stratigraphically younger than Eski Acigöl maar, the authors suggest that the 20.3 ± 0.6 ka age obtained from the Eski Acıgöl maar products are older in reality, by two to three thousand years.

32.5 Prehistoric Sites and Their Relationships to the Volcanoes

In Cappadocia, volcanoes are naturally covered with dense oak forests and juniper forests at higher altitudes, which shelter an abundant game. Populations in these areas also take advantage of the watercourses thanks to the relief favouring precipitations and runoff. Usually, massive volcanic mountains do not attract people because of difficulties to cross them so that contacts, exchanges, communications and transports are scarce. They are not attractive either when soils are poorly developed, organized as patches among rocky outcrops, or developed on acidic rocks. However, the

South Cappadocian volcanic massifs host several important archaeological sites of which the most striking ones are Prehistoric. With a few exceptions, all these sites are related to the exploitation, processing, exchange and trade of obsidian during Prehistoric times, the obsidian being available for mining in several surface outcrops around the many rhyolitic domes forming the Göllüdağ massif (Fig. 32.1).

Kaletepe Deresi 3 is the oldest of the sites known today in the area through excavation and study of the archaeological material (Slimak et al. 2008). Located on the eastern slopes of the Göllüdağ, it contains the longest open-air Palaeolithic sequence excavated in Turkey, as well as the first in situ Acheulean industry documented in Anatolia. The lithic industry at the site illustrates a wide range of technological behaviours and documents changes in raw material exploitation (from rhyolite to obsidian) and artefact manufacturing through the Lower and Middle Palaeolithic. Tephras in the upper Middle Palaeolithic horizons and the rhyolitic bedrock bracket the time span represented (Mouralis et al. 2002; Slimak et al. 2008; Tryon et al. 2009) (Fig. 32.7).

Other famous sites of the area provide key references for the Turkish Prehistory. These are obsidian workshops, which have been active all through the Neolithic to the Chalcolithic and Pre-Pottery Neolithic (PPN) to Chalcolithic sites. Central Anatolian obsidian, besides being used locally, begins to spread across long distances (up to 900 km) after 12 ka BC in direction of the Fertile Crescent. From the ninth to the seventh millennia BC (Neolithic), its exploitation became systematic and its distribution organized to reach many sites in the Near East (Balkan-Atlı and Binder 2012).

Accordingly, and since the 1990s, the obsidian sources of Cappadocia have been the subject of systematic investigations in order to understand their links with the sites where Cappadocian obsidian is found. Surveys found several extraction and processing workshops outcrops, at Göllüdağ, Nenezidağ and Kayırlı especially (Balkan-Atlı et al. 2011). Compositional analyses and knapping technologies allowed establishing linkages between specific sources on the one hand and artefacts in the Fertile Crescent as well as other regions of Anatolia and Cappadocia on the other hand (Binder et al. 2011). At Kaletepe workshop near Kömürcü, for example, (Figs. 32.1 and 32.8), blades, cores and core reduction related to bipolar blades production strategies are identical with those known in the Fertile Crescent (Balkan-Atlı and Binder 2012) while its obsidian is almost absent at local sites which addressed other Cappadocian workshops (Özbaşaran 2012; Özbaşaran et al. 2012). The obsidian knapping at Kaletepe thus only aimed at

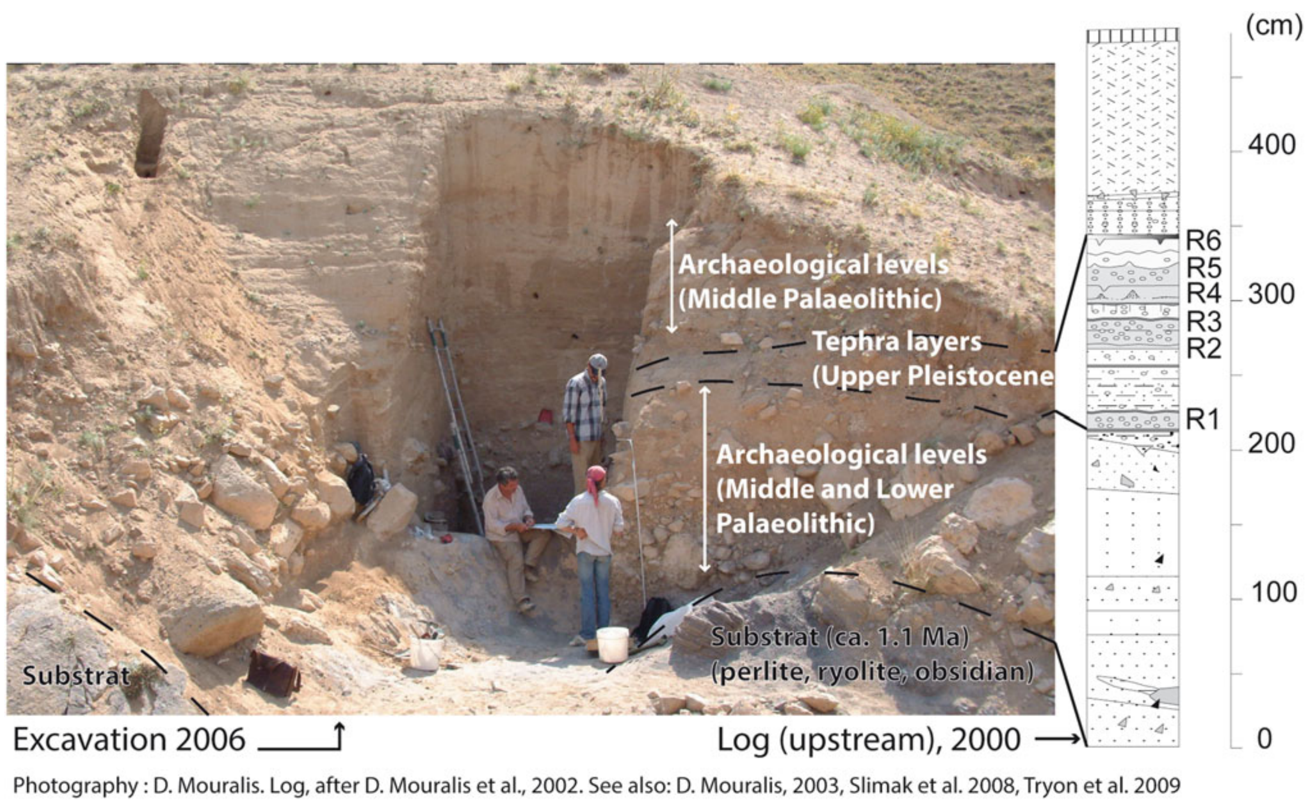

Fig. 32.7 Kaletepe Dere 3 excavation section showing the Lower to Middle Palaeolithic occupation layers overlain by tephras (noted R1 to R5) emitted during the Acigöl paroxysmic phase dated ca. 160 ka ago. Photograph by D. Mouralis in 2003

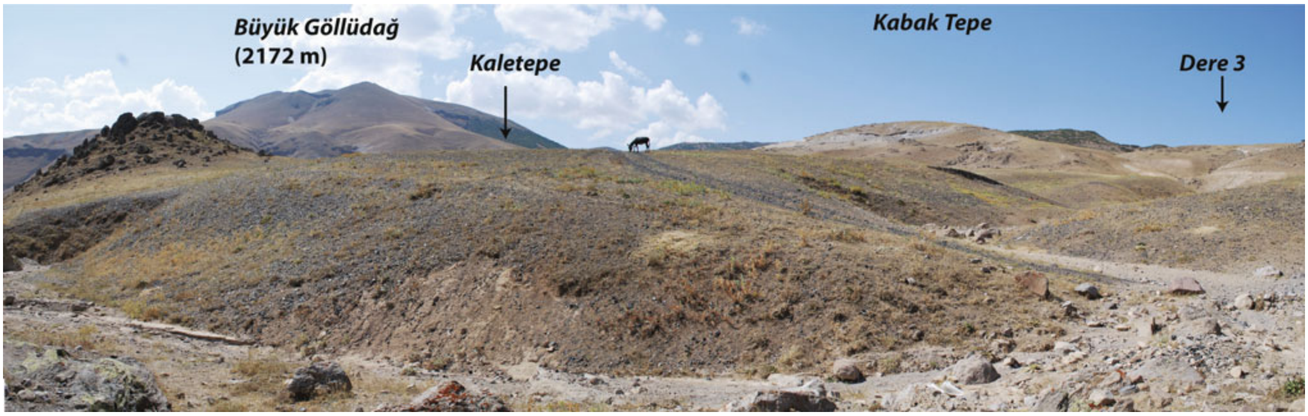

Fig. 32.8 Eastern slope of the Kabak Tepe (Göllüdağ massif): Neolithic obsidian workshop of Kaletepe and location of Palaeolithic Dere 3 excavation. The obsidian blocks on the slope in the foreground are mainly chopped. Photograph by D. Mouralis in 2010

distribution in the Fertile Crescent, while PPN populations of central Anatolia used other local sources for their own knapping strategies.

On the banks of the Melendiz River, Aşıklı Höyük is the oldest and largest PPN settlement of Anatolia west of the Fertile Crescent (Kuzucuoğlu 2013) (Figs. 32.1 and 32.9). Excavated by Istanbul University since 1989, it is the reference site for the Anatolian PPNB, possibly also for older PPNA (under excavation) (Özbaşaran 2012). Occupied from ca. 8.5 ka BC to ca. 7.4 ka BC, this 16 m high settlement accumulation records the history of animal domestication in Anatolia, as well as the development of plant domestication practices. Next to the site, an Arkeopark exhibits reconstructed PPN houses with their internal and external arrangements, which can be visited and in which cultural events are organized. A Late PPNB site specialized in butchering, Musular, has also been excavated on the other side of the river (Özbaşaran et al. 2012). In Aşıklı as well as in Musular and in Çatalhöyük (Konya Plain), exploited obsidian sources were those in Nenezidağ and Göllüdağ; sources addressed and knapping technologies differ in each site and change with time and industry types (e.g. Özbaşaran 2012; Özbaşaran et al. 2012)

During the last centuries of the eighth millennium BC, Aşıklı and Musular were abandoned, and after the eighth–seventh millennia BC turn, agricultural practices expanded and use of pottery became a widespread standard. Other Neolithic sites were founded close to agricultural soil (fertile alluvium) in and around the volcanoes where obsidian workshops continued to be exploited, e.g. Tepecik site in the Çiftlik Plain (Bıçakçı et al. 2012) Köşk, Niğde, Pınarbaşı-Bor sites south of the Melendiz massif, etc., (Figures 32.1 and 32.9). During the Early Neolithic, the value of obsidian far away from its Cappadocian sources is obvious in such objects as the Kaletepe bipolar blades, which spread to Levant and Cyprus.

From ca. 6 to ca. 5 ka BC (Late Neolithic, Early Chalcolithic), obsidian was progressively abandoned as the raw material for tools (for hunting, collecting, cultivating, cooking, household, wood, etc.). After 5 ka BC, objects made of obsidian are replaced by metals. Meantime, obsidian objects of high aesthetic value and indicative of considerable technical skills appear, wearing symbolic and possibly social significance. They were clearly produced for exchange purposes and to enhance social status in terms of wealth, power, wisdom, etc., in a much more restricted cultural area. Such objects have been found at the Neolithic Tepecik–Çiftlik site, buried as a hoar containing beautiful obsidian blades (Fig. 32.9).

During the Chalcolithic, new sites appeared, e.g. Güvercin Kayası in a Melendiz River tributary north of Aşıklı (Gülcür and Fırat 2004), Köşk Höyük (Öztan 2007) and Kınık Höyük (d'Alfonso et al. 2010) at the northern edge of the Bor Plain. After the Chalcolithic, population density in a 30 km radius around the volcanic massifs increased to high numbers within specific periods (exploiting fertile soils available around cities close to water resources) while pulsating within others (in relation to the fate of urban development, centralized States, international trade, raids etc.) (e.g. see: https://tayproject.org). During Hittite, Iron Age, Roman, Byzantine and Medieval periods, the location of occupation sites was increasingly different from the previous ones, except for some sites flourishing on important routes (Fig. 32.9) where occupation lasted longer than at other places. In addition, some sites present a specific usage: military, as the Hittite summer royal quarters at the summit of the Büyük Göllüdağ dome; funerary, as Iron Age tumuli at the summits of some cinder cones; for refuge during troubled times, as Byzantine Nora town hidden in a depression circled by lava flows of Hasandağ.

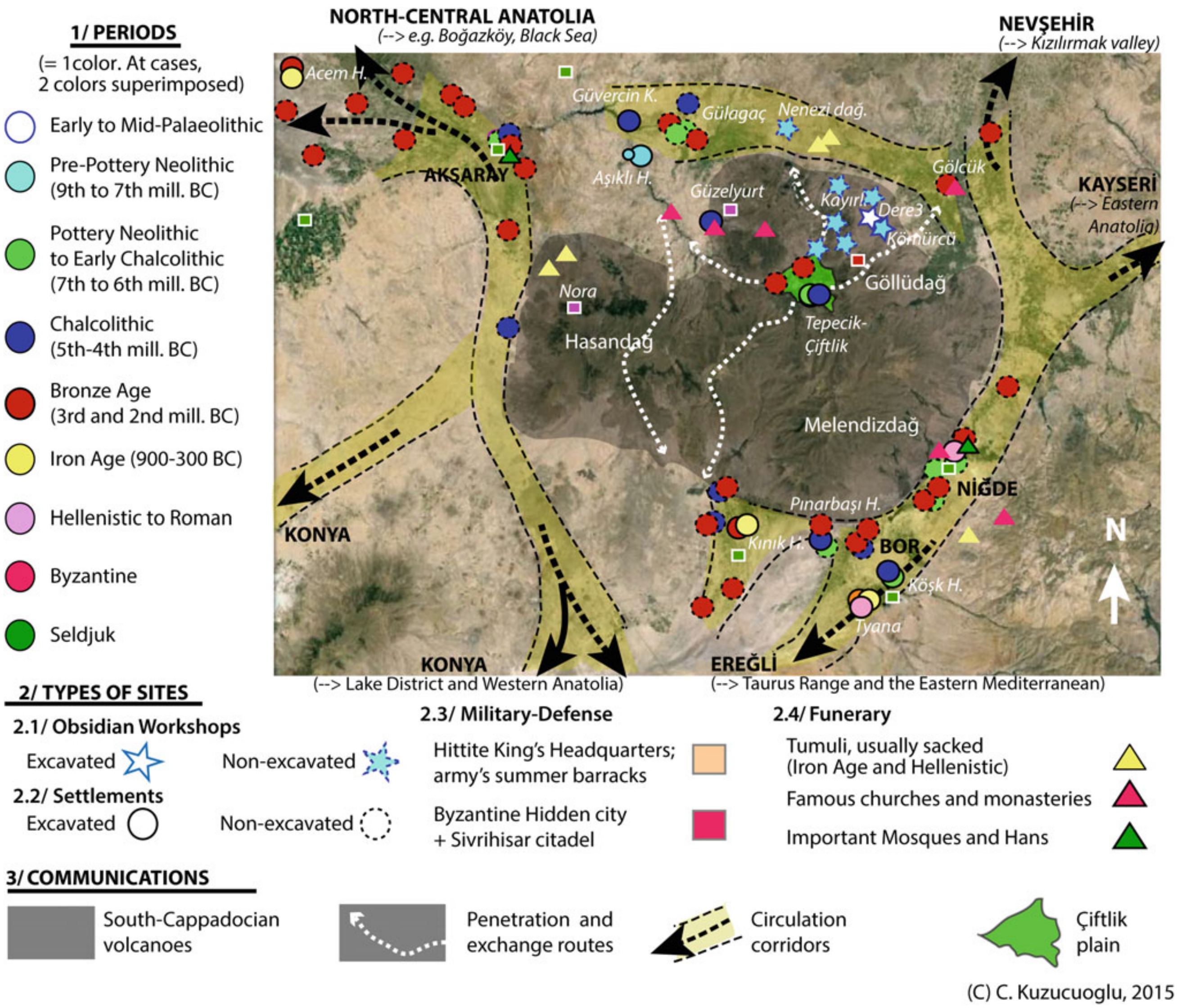

Fig. 32.9 Location and distribution of the main archaeological sites in southern Cappadocia

References

Akbaşlı A (1992) Niğde-Sofular-Acıgöl sıcak su sondajları (NAR-1, MTA-1,2,3,4) kuyu bitirme raporu (Final report for NAR-1, MTA-1,2,3,4 water wells of Niğde-Sofular-Acıgöl). MTAReport 9407, MTA (Maden Tetkik ve Arama), Ankara (Turkey)

Atabey E (ed) (1989) Geologic map of the Kayseri—H19 Quadrangle (Kayseri—H19 Paftası Jeoloji Haritalası). 1:100.000 Geological map of Turkey. MTA, Ankara

Aydar E (1992) Etude Volcano-Structurale et Magmatologique du Strato-Volcan Hasan Dagi, Anatolie Centrale-Turquie. PhD Thesis, Université Blaise Pascal, Clermont-Ferrand (France), pp 200

Aydar E, Gourgaud A, Deniel C, Lyberis N, Gündoğdu N (1995) Le volcanisme quaternaire d'Anatolie centrale Turquie: association de magmatisme calco-alcalin et alcalin en domaine de convergence. Can J Earth Sci 32(7):1058–1069

Aydar E, Gourgaud A (1998) The geology of Mount Hasan stratovolcano, Central Anatolia, Turkey. J Volcanol Geoth Res 85:129–152

Aydar E, Schmitt AK, Çubukçu HE, Akın L, Ersoy O, Sen E, Duncan RA, Atıcı G (2012) Correlation of ignimbrites in the Central Anatolian volcanic province using zircon and plagioclase ages and zircon compositions. J Volcanol Geoth Res 213:83–97

Ayhan A (ed) (1989). Geologic Map of the Kayseri—I19 Quadrangle (Kayseri—I19 Paftası Jeoloji Haritaları). 1:100.000 Geological map of Turkey. Maden Tetkik ve Arama (MTA), Ankara, Turkey

Balkan-Atlı N, Binder D (2012) Neolithic obsidian workshop at Kömürcü–Kaletepe (Central Anatolia. In: Özdoğan M, Başgelen N, Kuniholm P (eds) The Neolithic in Turkey: new excavations and new research (Central Turkey), vol. 3. Archaeology and Art Pub., Istanbul, pp 71–88

Balkan-Atlı N, Kuhn S, Astruc L, Kayacan N, Dinçer B, Balcı S, Erturaç MK, Grenet M (2011) Göllüdağ survey 2010. Anatolia Antiq 19:259–278

Bıçakçı E, Godon M, Çakan Y (2012) Tepecik-Çiftlik. In: Özdoğan M, Başgelen N, Kuniholm P (eds) The Neolithic in Turkey: new excavations and new research (Central Turkey), vol. 3. Archaeology and Art Pub., Istanbul, pp 89–134

Bigazzi G, Yegingil Z, Ercan T, Oddone M, Özdoğan M (1993) Fission track dating obsidians in central and northern Anatolia. Bull Volc 55(8):588–595

Binder D, Gratuze B, Mouralis D, Balkan- Atlı N (2011) New investigations of the Göllüdağ obsidian lava flows system: a multidisciplinary approach. J Archaeol Sci 38:3174–3184

Clarke KC (2013) What is the world's oldest map? Cartogr J 50:136–143

d'Alfonso L, Balza ME, Mora C (2010) Geo-archaeological activities in southern Cappadocia, Turkey. Proceedings of the meeting held in Pavia 20.11.2008. Italian University Press, Pavia, pp 140

Deniel C, Aydar E, Gourgaud A (1998) The Hasandağ stratovolcano (Central Anatolia, Turkey): evolution from calc-alkaline to alkaline magmatism in a collision zone. J Volcanol Geoth Res 87:275–302

Dönmez M (ed) (2005) Geological map of the Aksaray—L32 Quadrangle (Aksaray—L32 Paftası Jeoloji Haritaları). 1:100.000. Geological map of Turkey, MTA, Ankara

Druitt TH, Brenchley PJ, Gökten YE, Francaviglia V (1995) Late Quaternary rhyolitic eruptions from the Acıgöl complex, Central Turkey. J Geol Soc 152(4):655–667

England A, Eastwood WJ, Roberts CN, Turner R, Haldon JF (2008) Historical landscape change in Cappadocia (Central Turkey): a palaeoecological investigation of annually laminated sediments from Nar lake. Holocene 18(8):1229–1245

Ercan T, Tokel S, Can B, Fişekçi A, Fujitani T, Notsu K, Selvi Y, Ölmez M, Matsuda JI, Ui T, Yıldırım T, Akbaşlı A (1990) Hasandağ-Karacadağ (Orta Anadolu) dolaylarındaki Senozoyik yaşlı volkanizmanın kökeni ve evrimi (Evolution and origine of the Cenozoic volcanism in the Hasandağ-Karacadağ area (Central Anatolia). Jeomorfol Derg (J Geomorphol) 18:39–54

Froger J-L, Lénat J-F, Chorowicz J, Le Pennec J-L, Bourdier J-L, Köse Ö, Zimitoğlu O, Gündoğdu Gourgaud A (1998) Hidden calderas evidenced by multisource geophysical data; example of Cappadocian Calderas, Central Anatolia. J Volcanol Geoth Res 85(1–4):99–128

Gülcür S, Fırat C (2004) Spatial analysis of Güvercinkayası, a middle Chalcolithic hilltop settlement in northwestern Cappadocia: a preliminary report. Anatolia Antiqua XIII, pp 41–52

Jones MD, Roberts CN, Leng MJ, Türkeş M (2006) A high-resolution late Holocene lake isotope record from Turkey and links to north Atlantic and monsoon climate. Geol 34(5):361–364

Kazancı N, Gevrek A-I, Varol B (1995) Facies changes and high calorific peat formation in a Quaternary Maar lake, Central Anatolia, Turkey: the possible role of geothermal processes in a closed lacustrine basin. Sed Geol 94(3–4):255–266

Kuzucuoğlu C (2013) Geomorphology of the Melendiz river in Cappadocia (Turkey): setting of pre-pottery Neolithic sites of Aşıklı and Musular, and climate reconstruction during the onset of the Holocene. Geogr Fis E Dinammica Quat 36:95–105

Kuzucuoğlu C, Pastre JF, Black S, Ercan T, Fontugne M, Guillou H, Hatté C, Karabıyıkoğlu M, Orth P, Türkecan A (1998) Identification and dating of tephra layers from Quaternary sedimentary sequences of inner Anatolia, Turkey. J Volcanol Geoth Res 85:153–172

Kuzucuoğlu C, Mouralis D, Türkecan A (2013) Geomorphological mapping as an illustration of geomorphological evolution reconstruction: the example of the Çiftlik plain in Cappadocia (Niğde). In: Öner E (ed) Proceedings in honour of Prof. Ilhan Kayan. Ege University-Faculty of Humanities Publ, Izmir, pp 133–144

Le Pennec J-L, Bourdier J-L, Froger J-L, Temel A, Camus G, Gourgaud A (1994) Neogene ignimbrites of the Nevşehir plateau (Central Turkey): stratigraphy, distribution and source constraints. J Volcanol Geoth Res 63(1–2):59–87

Mellaart J (1967) Çatal Höyük: a Neolitic town in Anatolia. Thames and Hudson, London, p 201

Mouralis D (2003) Les complexes volcaniques quaternaires de Cappadoce (Göllüdağ et Acıgöl)—Turquie : évolutions morphodynamiques et implications environnementales. PhD Thesis, Paris 12 University, Paris (Unpublished)

Mouralis D, Pastre J-F, Kuzucuoğlu C, Türkecan A, Atıcı Y, Slimak L, Guillou H, Kunesch S (2002) Les complexes volcaniques rhyolithiques quaternaires d'Anatolie centrale (Göllü Dağ et Acıgöl, Turquie): Genèse, instabilité, contraintes environnementales. Quat 13(3):219–228

Notsu K, Fujitani T, Ui T, Matsuda J, Ercan T (1995) Geochemical features of collision-related volcanic rocks in central and eastern Anatolia, Turkey. J Volcanol Geoth Res 64:171–192

Özbaşaran M (2012) Aşıklı. In: Özdoğan M, Başgelen N, Kuniholm P (eds) The Neolithic in Turkey, new excavations and new research (Central Turkey), vol. 3. Archaeology and Art Pub. Istanbul, pp 135–158

Özbaşaran M, Duru G, Kayacan N, Erdoğu B, Buitenhuis H (2012) Musular—The 8th Mill cal. BC Sattelite site of Aşıklı. In: Özdoğan M, Başgelen N, Kuniholm P (eds) The Neolithic in Turkey, new excavations and new research (Central Turkey), vol. 3. Archaeology and Art Pub., Istanbul, pp 159–180

Öztan A (2007) Köşk Höyük. In: Özdoğan M, Başgelen N, Kuniholm P (eds) The Neolithic in Turkey, new excavations and new research (Central Turkey), vol. 3. Archaeology and Art Pub., Istanbul, pp 223–235

Pastre J-F, Kuzucuoğlu C, Fontugne M, Guillou H, Karabıyıkoğlu M, Ercan T, Türkecan A (1998) Séquences volcanisées et corrélations téphrologiques au N-W du Hasan dağ (Haut bassin de la Melendiz, Anatolie centrale, Turquie). Quat 9(3):169–183

Roberts N, Reed JM, Leng MJ, Kuzucuoğlu C, Fontugne M, Bertaux J, Woldring H, Bottema S, Black S, Hunt E, Karabıyıkoğlu M (2001) The tempo of Holocene climatic change in the Eastern Mediterranean region: new high-resolution Crater-Lake sediment data from Central Turkey. Holocene 11(6):721–736

Schmitt AK, Danışık M, Evans NJ, Siebel W, Kiemele E, Aydın F, Harvey JC (2011) Acıgöl rhyolite field, Central Anatolia (part 1): high-resolution dating of eruption episodes and zircon growth rates. Contrib Miner Petrol 162(6):1215–1231

Schmitt AK, Danışık M, Aydar E, Sen E, Ulusoy İ, Lovera OM (2014) Identifying the volcanic eruption depicted in a Neolithic painting at Çatalhöyük (Turkey). PLOSONE 9(1):e84711

Slimak L, Kuhn SL, Roche H, Mouralis D, Buitenhuis H, Balkan-Atlı N, Binder D, Kuzucuoğlu C, Guillou H (2008) Kaletepe Deresi 3 (Turkey): Archaeological evidence for early human settlement in Central Anatolia. J Hum Evol 54:99–111

Toprak V (1998) Vent distribution and its relation to regional tectonics, Cappadocian volcanics, Turkey. J Volcanol Geoth Res 85(1–4):55–67

Tryon CA, Logan AV, Mouralis D, Kuhn S, Slimak L, Balkan-Atlı N (2009) Building a tephrostratigraphic framework for the Paleolithic of Central Anatolia, Turkey. J Archaeol Sci 36(3):637–652

Türkecan A, Kuzucuoğlu C, Mouralis D, Pastre J-F, Atıcı Y, Guillou H, Fontugne M (2004) Upper Pleistocene volcanism and palaeogeography in Cappadocia (Turkey). MTA-CNRS-TÜBİTAK 2001–2003 research programme. Tübitak Project No. 101Y109. M.T.A., Ankara, pp 180

Ulusoy I, Labazuy P, Aydar E, Yürür T, Artuner H, Torleif D (2009) Multisource geophysical investigation of the Acıgöl Caldera structure (Central Turkey): preliminary results. In: EGU General Assembly: 7746 (Vienna, Austria)

Yıldırım T, Özgür R (1981) Acıgöl Kalderası (The Caldera of Acıgöl). Jeomorfol Derg (J Geomorphol) 10:59–70