Geomorphological Mapping As An Illustration of Geomorphological Evolution Reconstruction: The Example Of The Çiftlik Plain In Cappadocia (Niğde)

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Abstract

The origin of the Çiftlik plain has long been subject to discussion. Pasquarè et al. (1988)'s proposal to identify it with one of the Cappadocian neogene calderas, has been rejected by Le Pennec et al. (1994) and Froger et al. (1998), who locate two neogene calderas in a) the Acıgöl-Nevşehir area, and b) the Derinkuyu plain area. However, Froger et al. (1998) include the Çiftlik plain in their "Derinkuyu caldera".

In addition, the Çiftlik plain is usually considered as filled by the sediments of a former lake, the flat bottom of which would correspond to the plain surface more or less modified by the Melendiz river sedimentation and erosion. However, until the present study, no lake sediment had been evidenced in the plain.

In this context, three series of questions are presented, and answers proposed about:

(i) What is the origin of the Çiftlik plain? i.e. what is the geomorphological definition and designation of the plain according to its genesis and history? Is it:

- **(a) volcanic or volcano-tectonic, ie a caldera or a remnant of a caldera?**
- **(b) unconnected with any structural bordering, ie an area kept out of the expansion of various volcanic complexes?**
- **(c) a tectonic basin, eg a subsiding basin?**

(ii) What is the **nature and age of its fill**? ie to what deposit(s) correspond the **plain fill and its surface sediments**? ie was the plain ever filled by a lake? what event caused the lake to occur? a dam in a palaeovalley, such as a lava flow, an avalanche, an ash-and-block flow, a mud- or debris-flow?

(iii) What are the Early Holocene environmental dynamics of the plain, related to the human occupation in the area as studied in the archaeological excavation of Tepecik-Çiftlik?

Keywords : *Geomorphological mapping, Ciftlik plain, Cappadocia, Volcanism, Caldera, Quaternary*

Introduction

This present paper is written in honor of the great Turkish geomorphologist Prof. İlhan Kayan. It intends to show that a geomorphological map must not only be consistent with the results from field and laboratory research, but that it is also a tool for the synthesis of the evolution history of a geosystem.

Of course, the realization of a geomorphological map relies first on field work, which consists of (a) analyzing a geomorphological landscape at various scales of observation (from large to detailed scales), (b) studying sections for the characterization of rocks and superficial deposits that are correlated with the morphological evolution, (c) inter-correlating sections of superficial deposits on the basis of the stratigraphy interpreted and drawn at each section spot. In the same time, a geomorphological sketch uses raw data from topographic maps and satellite imagery. In a second step, the field results are completed by analyses performed at the laboratory. In a third step, a synthesis reconstructs the evolution of morphologies, spatially expressed by means of a geomorphological map and its legend organized with respect to the chronology of the data.

In order to illustrate this approach, we will present hereafter the geomorphological map of the Çiftlik Plain in the Niğde Province of Turkey. This map, produced for the present article, is based on several field campaigns in the frame of two LGP/LSCE (CNRS & MAE) and MTA (MTA & TÜBITAK) programs, with the addition of two partnerships with Istanbul University archaeological excavations: Kaletepe (from 1997 to 2003, with N. Balkan-Atlı) and Tepecik Çiftlik (from 2010 to 2012, with E. Bıçakçı). For the data collected in the course of these programs and related to the Çiftlik plain, mainly see Pastre et al. (1998), Ferrari (1998), Karabıyıkoğlu & Kuzucuoğlu (1998), Kuzucuoğlu (1998), Mouralis et al. (2002), Mouralis (2003), Türkecan & Kuzucuoğlu et al. (2004).

1. Presentation: Volcanic Activity and Formations, from Pliocene to upper Quaternary Around the Çiftlik Plain

Located between three volcanic highlands (Göllüdağ massif, Melendiz mountains, Şahinkalesi Tepe massif), the plain is a round-shaped closed depression 15 km in diameter at ca 1500m elevation. It is mainly drained by the Melendiz river coming from the south (Melendiz range) and outflowing westwards in a 80 m deep gorge set in lava flows. In the western part of the plain, strombolian scoriae cones have emitted basaltic flows.

The Çiftlik plain: a Mio-Pliocene Cappadocian Caldera?

In Cappadocia, a Miocene to lower Pleistocene volcanic activity (8.5-9 to 2.7 Myrs: Pasquarè et al., 1968 and 1988) has been evidenced in (a) the Keçiboyduran-Melendiz volcanic complex and the Şahinkalesi Tepe highlands, and (b) in the Ürgüp Basin/Nevşehir plateau in which widespread ignimbrite units are emplaced. Due to the neogene age of the calderas which have emitted the Cappadocian ignimbrites, long-time post-caldera activity erosion and sedimentation has wiped the morphological arguments for the identification of these structures. The Mio-Pliocene calderas are thus not visible in today's landscape of Cappadocia. Looking for the location of these calderas, Pasquarè et al. (1968 and 1988), have suggested four possible locations: i) the Çiftlik plain north of Melendiz mountains, ii) the Acıgöl -Nevşehir area, iii) the Derinkuyu plain, and iv) the Sultansazlı plain near the Erciyes volcano. More recently however, the flow directions of the ignimbrites studied by Le Pennec et al. (1994), and on digital earth model (DEM), satellite imagery and gravimetric data (Dhont et al., 1998; Froger et al., 1998) identify only two possible calderas: Acıgöl-Nevşehir area and Derinkuyu plain. Thus, the Çiftlik plain, in spite of its round shape and flat bottom circled by volcanic massifs, is no more considered as a candidate for being the remnant of a Mio-Pliocene Cappadocian caldera.

The Pliocene to Pleistocene volcanic activity in the Cappadocia and the Çiftlik area

Two of the three volcanic massifs surrounding the Çiftlik plain were built during the Pliocene and the lower Quaternary (Türkecan *et al.*, 2003). The ***Şahinkalesi Tepe massif*** is formed by piled neogene ignimbrites and andesitic lava flows covered by Plio-Quaternary basalts and andesites, The ***Melendiz range*** is formed by various volcanoes (rhyolitic to andesitic and basaltic series) dated 7.2 to 1.1 Myrs. In both massifs however, these ages published lack information on the exact location and genesis of the samples, as well as on their relationships with their environment. In addition, during the Quaternary, the Cappadocian volcanic activity produced also: (i) caldera collapses and dome extrusions (Göllüdağ and Acıgöl/Nevşehir); (ii) two great composite volcanoes (Hasandağ and Erciyes); (iii) numerous monogenetic volcanic centres extending in the southern anatolian plateau from Kayseri to Konya through Aksaray and Niğde areas.

Forming the north and nort-east border of the Ciftlik plain, the ***Göllüdağ complex*** results from an explosive activity which started during the lower Pleistocene. Between 1.4 and 1.1 Myrs ago, a caldera collapsed at the location of today's Göllüdağ massif, with an abundant emission of pyroclastites (eg TG-5 syn-caldera phase TG-5 fall-out, Ar/Ar dated 1.39 ± 0.01 kyrs by H. Guillou, LSCE, in Mouralis, 2003). This activity was contemporaneous of a similar explosive activity in the Hasandağ, which also produced pyroclastites contributing to the modification of landscape in the Çiftlik/Göllüdağ areas. After the collapse, from 1.0 to 0.4 Myrs, the caldera was filled by ten rhyolitic domes and their pyroclastites, and also by post-volcanic erosion gradually masking the earlier topography (Mouralis, 2003). During middle Pleistocene, a local basaltic activity in the ***western part of the Çiftlik plain*** and adjacent areas also contributed to modifying the topographies (Türkecan & Kuzucuoğlu *et al.*, 2004).

Finally, during the upper Pleistocene, the volcanism in the ***NE and E parts of the Hasandağ*** impacted the area with high volumes of plinian and pelean pyroclastites, avalanches, *nuées ardentes*, surges, strombolian eruptions (Pastre *et al.*, 1998). Some of these products can be found in the vicinity of the Kitreli and

Mahmutlu villages, where they cover older (middle Pleistocene) strombolian cones, slopes and surrounding areas.

2. The Çiftlik Plain: The Remnant of an Early/Middle Pleistocene Caldera?

Morphological and structural indicators of the caldera collapse initiating the Göllüdağ massif formation

In the north-western, western and southern parts of the Göllüdağ area, north of the Çiftlik plain, Mouralis (2003) and Türkecan & Kuzucuoğlu *et al.* (2004) identified several morphological and stratigraphical indicators of a collapse, which they dated 1.4-1.1 Myrs (Ar/Ar date by H. Guillou, lSCE). Not only the Göllüdağ complex occupies a depressed position at the foot of the Şahinkalesi Tepe and the Melendiz mountains, but large amounts of pyroclastites are present in and around the Göllüdağ massif and adjacent areas. These characteristics are the first indicators of a caldera, which collapsed before the extrusion of the domes forming the massif.

Other indicators of the caldera are collapse-related faults and down-faulting, eg. lineaments near Narköy and Gözterli villages, out north of the map; faulted blocks on the Melendiz highlands border SE of the Çiftlik plain…. The map Fig. 1 shows one morphology inherited from the caldera wall. It is a cliff limiting the Neogene ignimbrites/andesite flows and Plio-Quaternary basalts of the Şahinkalesi Tepe (Mouralis, 2003; Türkecan & Kuzucuoğlu *et al.* 2004).. Located on top of the western slope of a S-N oriented valley north of the Bozköy village, it faces the Göllüdağ domes which are S-N aligned on the other side of the valley. This cliff is a fault scarp generated by a fault-line (direction = 7°E), and it is an outstanding morphological expression of the caldera wall limiting the collapsed center of the Quaternary Göllüdağ complex.

At the foot of the cliff, sections in a quarry show: (a) basal alluvium contains well-rounded andesitic and basaltic pebbles (from the Plio-Quaternary basement) reaching 15cm in diameter. This deposit records the erosion of both the Şahinkalesi Tepe and of a Göllüdağ substratum today either destroyed by eruptions or buried by pyroclastites. The ca 33°E eastward dip affecting this alluvial deposit was caused by the collapse motion of the center of the Göllüdağ complex; (b) above, fluvio-lacustrine layers are interstratified with reworked pyroclastites emitted during the caldera collapse; (c) *in situ* pyroclastites.

Younger units (b) and (c) also dip eastwards, but their 15° inclination suggests a decrease of the subsidence rate of the caldera. Moreover, both units are disturbed by small metric secondary faults, while other pyroclastites emitted during the syn-caldera phase present high-magnitude fault throw (eg 25m: see Mouralis, 2003). This tectonic activity accompanied the up-doming of the Şahinkalesi Tepe above the Göllüdağ caldera (see DEM and treatments of the Landsat images in Le Pennec *et al.* (1994) and Mouralis (2003)).

3. Has The Plain Ever Been Filled By A Lake?

Because of the very flat bottom evocating a lake fill, it is very often suggested that, whether a caldera or an isolated area in-between volcanoes, the Çiftlik plain was previously filled by a lake formed behind one or several volcanic formations. Answering this question needs to evidence (1) lake sediments in or close to the plain bottom, and (2) a volcanic deposit (eg a flow, an avalanche, an ash-and-block flow, or a sedimentary deposit (eg a debris-flow…) that would have dammed a paleo- river network.

Evidences of lake sediments in the Çiftlik plain have been published by Ferrari (1998), Mouralis (2003), (Türkecan & Kuzucuoğlu *et al.*, 2004).

- At the foot of the 1.4 Myrs old caldera wall dominating the S-N oriented Bozköy stream valley, sections in a quarry shows a fluvio-lacustrine unit recording the presence of a lake just before or at the beginning of the Göllüdağ collapse; these river and lake sediments overlay the alluvium resulting from the erosion of the Plio-Quaternary Şahinkalesi Tepe highlands;
- 15m long cores extracted in 1996 at three locations around the Çiftlik plain (CAR core on the slope north of Çardak village; KAD core in the +3m alluvial terrace dominating the Çiftlik flood plain at Çardak village; OVA core extracted from the spring-fed marshes at the foot of the Ovalıbağ village north of the plain), exhibits the following succession.

- The oldest deposit is a diatomite more or less mixed with silts and very fine sands. This lake sediment is accessible today from the surface only on the slopes north of Çardak village. In the three cores, this diatomite contains several rhyolitic and basaltic tephras. These tephras can be traced and inter-correlated between the three cores. According to the geochemical analyses of the pumice glass, the rhyolitic falls belong to the Göllüdağ syn-caldera emissions dated ca 1.4 – 1.1 Myrs (Mouralis, 2003). There was thus a lake in the Çiftlik plain during this period.
- In the OVA and KAD cores, the diatomite is covered by ca 7m of lake-river sediments containing pumices. These alluvial deposits record a complex succession of fluvial erosion-accumulation phases, which occurred after the lake disappeared. Thus, and with the comparison of the diatomite depth in the three cores, there is the evidence that either (a) tectonism provoked the subsidence of the center of the Çiftlik plain or the uplift of the Şahinkalesi Tepe –also evidenced north of Bozköy-, or (b) the change in the deposition conditions from lake to river environment provoked the incision of the diatomite.

Where and how did the lake Çiftlik dam occur?

On the western edge of the plain, strombolian cones have emitted scoriae and basaltic flows. The westernmost of these cones, Boz Tepe, located near Mahmutlu village in the Melendiz mountains foothills, emitted two lava flows which filled the palaeovalley of the river Melendiz. The oldest of this flow, sampled near the bridge over the Melendiz near Mahmutlu, has been K/Ar dated 1.33 ± 2 Myrs (CKUZ 97/8-01: H. Guillou, LSCE); another sample at the northern entrance of Mahmutlu village, has been K/Ar dated 1.21 ± 6 Myrs (CKUZ 97/8-02: H. Guillou, LSCE). These flows filled and dammed the palaeovalley in which a lake appeared. The later outbreak of this dam was favored by:

- the tectonic uplift of the northern part of the plain edges (suggested by the terraced topography of the diatomite roof, revealed by the correlation between the Çiftlik cores);
- the sediment up-filling of the lake. This up-filling was caused by a heavy alluvial and slope-wash input of reworked loose material eroded from the Göllüdağ syn- and post-caldera pyroclastites, which had filled-up the valleys feeding the lake, and covered all the slopes around.

4. The Middle Pleistocene Evolution of the Landscape in the Çiftlik Plain Area and its Morphological Heritage

4.1.The Middle Pleistocene volcanic activity in the Ciftlik area and its morphological heritage

Before the rhyolitic events that formed the Göllüdağ, an erosion palaeo-topography had shaped a basement formed to the north by the previously uplifted Şahinkalesi Tepe and to the south by the Melendiz highlands. In both massifs, an ancient hydrographic system was north-south and south-north oriented (as shown by the valleys fossilized by the 1.4-1.3 Myrs aged Göllüdağ and Hasandağ pyroclastites to the north. This pre-Middle Pleistocene highlands were incised by valleys filled with coarse alluvium and converging towards the area roughly corresponding today to the Çiftlik plain -almost like today-.

Ca 1.4 Myrs, a caldera collapse (eg Bozköy cliff) almost instantly destroyed parts of the previous Neogene and Plio-Quaternary topographies of both the Şahinkalesi Tepe and Melendiz massifs in the area of what is today the NE of the Çiftlik plain and the Göllüdag massif.

Ca 1.3 Myrs ago, the palaeo-Melendiz hydrographic system was dammed by the emission of basaltic lava flows emitted in the area of today's Melendiz gorges. A lake then invaded the downstream parts of the river system (especially in the Şahinkalesi Tepe), penetrating into the caldera. This lake was located in the same area as today's Çiftlik plain. During this period, a several meter-thick diatomite deposited in the deepest parts of the lake (eg near today's Çardak and Ovalıbağ villages). Meantime, the north and north-east of Bozköy was uplifted, in relation to the up-doming of the Şahinkalesi Tepe above the Göllüdağ caldera. This uplift may have contributed to some altitude difference between the lake-occupied depressions at Bozköy in the north (fan delta sediments), and at Çardak and Ovalıbağ (deep lake sediments) in the west. The tectonic movement accentuated the altitude difference between the Sahinkalesi Tepe highlands and the depressions at its foot.

Both during the syn-caldera phase (from ca 1.4 to 1.1 Myrs) and during the post-caldera phase (from ca 1.0 to 0.4 Myrs, pumice ash and lapilli flows and falls covered large areas in the whole region (Mouralis, 2003), burying slopes, valleys and depressions all around the caldera center. First, the impacts of the syn-caldera pyroclastitic flows were most important in the western and south-western parts of the collapsed area where the thickest deposition (15m) occurred. In this area, the pyroclastic flows were channelized in the ancient hydrographic system, which eroded them after their deposition, and transported the consequently reworked material towards the main regional drain (palaeo-Melendiz river basin -and lake-). Hilly and mountainous domes of the Göllüdağ and associated pyroclastites filled-in all previous depressed topographies. In parallel, removal of the pyroclastites by erosion started immediately after their deposition. These processes contributed to the caldera- and lake-filling, and also to the wiping of their morphological limits from the landscape. Meantime, Hasandağ eruptions also contributed to the burial of topographies over the Melendiz mountains (as shown by a tephra interstratified with the Göllüdağ pyroclastic).

4.2.The impacts of the caldera collapse on landscape

After the Göllüdağ volcanic activity ceased, slope-wash and incision of unconsolidated pyroclastites revealed fault scarps and obsidian dykes in the Göllüdağ massif. The downslope accumulation of the consequently reworked tephras and other debris eroded from the basement, terminated the fossilization of the caldera and mantled the down-slope parts of all the reliefs. So that, today, almost no morphologic features related to the collapse and caldera are preserved. After their destruction by post-caldera eruptions, whatever remnants of the crater and wall were left are today buried below a) faulted lake and river sediments, b) rhyolitic domes and associated pyroclastites extruded during the post-caldera phase, and b) later reworked pyroclastites and volcanics. Finally, instead of marking today's landscape by its typical landforms (circular wall, flat and round depression …), the impacts on landscape caused by the caldera collapse are much more visible today in the large amounts of pyroclastites which buried a high variety of palaeomorphologies previous and posterior to the collapse.

4.3.The Çiftlik plain: a long evolution recorded by a series of palaeotopographies buried below middle Pleistocene lake sediments and upper Pleistocene river deposits

Thus, the sediment fills of the Çiftlik plain, as visible from sections in the slopes of the highlands around, record: (a) pyroclastic activities in the area (Göllüdağ and Hasandağ), (b) the rapid destruction of morphologies by volcanic eruptions, (c) river incision eroding soft sediments such as pyroclastites and old alluvium, and (d) lake deposits abandoned after the opening of an outflow. This evolution lasted from ca 1.4 to 0.8 Myrs ago.

According to these archives that have been trapped in the Çiftlik depression below the more recent sediments forming today's surface of the plain, the Çiftlik plain corresponds to a palaeo-river basin partly destroyed upstream by the Göllüdağ caldera which may have been partly invaded downstream by a lake dammed by andesitic basaltic flows, and partly progressively in-filled by eroded/reworked sediments and pyroclastites accumulated below today's surface of the plain. **In conclusion, the plain can then be interpreted as a window of a Quaternary geography preserved in-between the volcanic products of the Melendiz and Göllüdağ massifs, and fossilized below pyroclastic, lake and river sediments accumulated in the depression since the Middle Pleistocene.**

5. The Çiftlik Plain: Upper Pleistocene and Holocene Formations Burying a Middle-Pleistocene Landscape

During the last Glacial (Würm), two types of sediment covers record events in the plain dynamics:

- *Volcanic eruptions:* in the Çiftlik plain, they are caused by Hasandağ eruptions, the emissions of which are responsible for pumice falls covering all kinds of substratum (pumice deposits emitted by the Göllüdağ during the Middle Pleistocene, scoriae slopes and lava flows of the strombolian cones near Mahmutlu, basaltic lava flows of the Melendiz mountains etc...): caption 5.1 in the map Fig. 1.

Concerning mainly the areas west of the Çiftlik plain, the capping of slopes by Hasan dağ pumices is of a much greater extent than the one shown on the map.

- *Climatic changes*: they generated various periods and types of sediment records (erosion and sedimentation) in central Anatolia (Karabıyıkoğlu & Kuzucuoğlu, 1998; Kuzucuoğlu *et al.*, 1999; Fontugne *et al.*, 1999). Together with the incision of streams in the volcanic substratum of the mountainous slopes, the erosion of the detritic and pyroclastic cover of the slopes of the Göllüdağ massif produced many alluvial fans. These fans fringe mainly the northern slopes of the Melendiz massif: they are illustrated in the map Fig. 1 by the captions 6.1 to 6.3 fill. They fill half of the Çiftlik plain in the NW direction. Their material is composed of coarse material made both by substratum rocks (andesite and basalt blocs and pebbles) and by reworked pyroclasts (old and weathered pumices).

These latter formations are similar to other fans developed at the foot of the northern and eastern sides of the Göllüdağ massif, where chopped but reworked Upper Palaeolithic to Chalcolithic pieces are found (Balkan-Atlı *et al.*, 199). The upper Pleistocene age of these fans is also suggested by slope and stream deposits in the Acıgöl caldera (Nevşehir) (Mouralis, 2003). There, the slope debris burying the cliffs of the collapsed structure dated 160-150 kyrs, as well as the terraces of the stream outflowing from the caldera, record three phases of erosion/deposition within and out the collapsed structure (Mouralis, 2003):

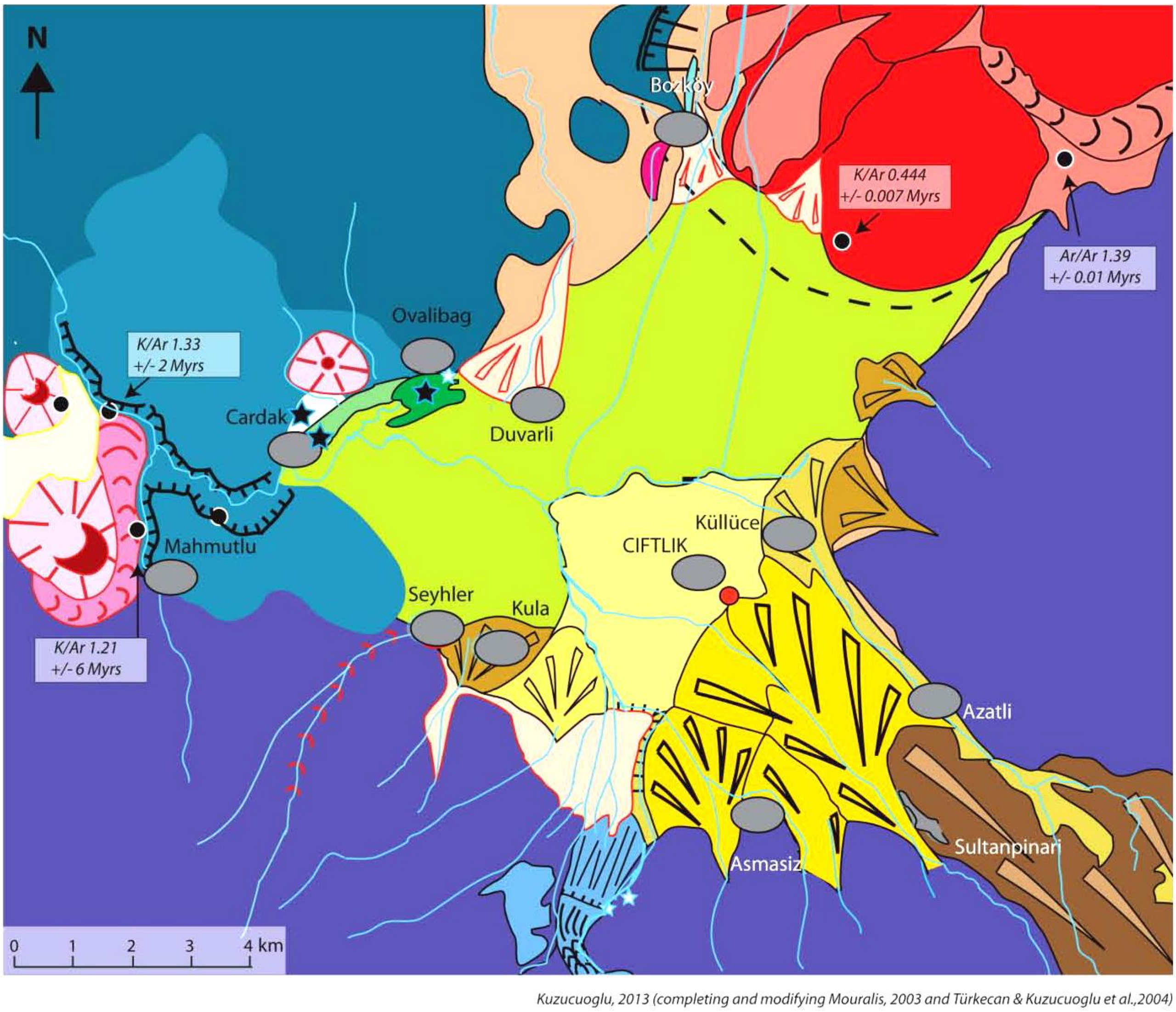

Figure 1: Geomorphological map of the Çiftlik plain (Melendiz Mountains, Niğde Province, Turkey)

Legend of Figure 1

1 = Morphological heritage of the Mio-Pliocene to Lower Quaternary
1.1 Sahinkalesi Tepe highlands
1.2. Melendiz mountains
1.3. Gorge of the river Melendiz through the Melendiz lava flows

2 = Morphological heritage of the Göllüdag massif formation (Middle Quaternary)
2.1. Pre-caldera alluvial deposits
2.2. The fault scarp and fault line above Bozköy (remaining from the caldera wall)
2.3. Probable limit of the Göllüdag caldera
2.4. *In situ* syn-caldera pyroclastites
2.5. Göllüdag domes (post-caldera)
2.6. Post-caldera pumice falls
2.7. Post-caldera pumice flows

3 and 4 = Middle Pleistocene morphological heritages and outcrops related to:
=> Lake occurrence in the Ciftlik plain
3.1. Diatomite outcrop
3.2. Syn-caldera fluvio-lacustrine formation

=> Basaltic (or basaltic-andesitic) activity date 1.35-1.15 kyrs ago
4.1. A large (fissural?) lava flow from the Melendiz massif
4.2. Strombolian scoriae cones
4.3. Flow emitted by the Boztepe strombolian volcano

5 = Heritage of the upper Pleistocene volcanic activity
5.1. Pumice falls emitted by the Hasan dag

6 = Formations resulting from Upper Pleistocene (Last Glacial and Holocene) erosion
=> Last Glacial (before the LGM?) old formation
6.1. Oldest, pumice-dominated, river deposit reworking pyroclastites icovering the Melendiz slopes

=> LGM, ie Last Glacial Maximum (?), alluvial fans and high altitude formations and lanforms
6.2. Upper coarse alluvial fan (LGM?)
6.3. A terrace +40m above mountainous torrent
6.4. A coarse periglacial or glacial debris flow
6.5. A coarse periglacial coarse material glacis
=> Late Glacial, ie coarse fan covered by EarlyHolocene flood silts (?)
6.6. Lower coarse alluvial fan (LGM?, Late Glacial?), with material from the Melendiz highlands
6.6. Lower coarse alluvial fan (LGM?, ate Glacial?), with material from the Göllüdag massifs
6.7 +3m terrace above the flood plain
=> Holocene (recent)
6.8. Flood plain silts originated from the erosion of dark coloured volcanics in the Melendiz range
6.9. Flood plain silts originated from the erosion of light coloured pumice pyroclastics in the Göllüdag massif
6.10. Marshes (topped by a Middle-Age peat)
6.11.Springs

7 = Other information
Neolithic to Chalcolithic arachaeological site of Tepecik-Ciftlik (Istanbul Univ. excavation site)
Location of samples for datings (K/Ar in lava flows, Ar/Ar in feldspars of pyroclastites, 14C in organic matter) cited in the text
Location of cores CAR, KAD and OVA
Villages
River network

(a) between 150 and 90 kyrs ago, Acıgöl syn-caldera pyroclastites and obsidian dykes were exposed and eroded by streams which deposited the reworked material inside the caldera;
(b) between 90 and 30 kyrs ago, slope erosion processes affected all unconsolidated material in the area, revealing the Kocadağ dome ring-dyke and forming a wide 24-25° inclined glacis over the caldera fill;
(c) during the Pleniglacial (LGM), erosion was weaker because temperatures and humidity decreased (with a rise in evaporation and less water available for run-off on the surface) (Kuzucuoğlu *et al.*, 1999);
(d) during the Late Glacial warming, renewed stream incision exported sediments out of the depression. This change in erosion responded to the precipitation increase during the period.

In the Çiftlik plain there are at least 3 generations of upper Pleistocene/Holocene alluvial fans. They are evidenced by their geomorphological and sedimentological characteristics: stepped fans (with a geomorphological signification similar to that of stepped terraces), grain size and origin of the material:

- The *oldest upper Pleistocene (?) deposit* is formed by a sand-sized deposit in the Kula area (caption 6.1), culminating 10m above a younger fan deposit incising it. The origin of its sediment from the erosion of the Melendiz dağ slopes, as well as its strong association with the Göllüdag middle-Pleistocene activity is shown by its grain-size distribution (sand and small gravels) and composition: the dominating reworked pumices are associated with volcanic material eroded from the Melendiz mountains. Meanwhile, the scarce obsidian grains in the sand fraction confirms the Göllüdağ origin of the eroded pumice pyroclastites. Finally, the structure of this mixed Göllüdağ/Melendiz material indicates clearly a deposition by river processes. This thin material-sized upper Pleistocene (?) deposit has been preserved only in SW of the plain.
- In the SW part of the plain where the upper Pleistocene erosion has been more efficient because of high competence of the mountain streams, the Melendiz river exhibits two stepped fans, both composed of very coarse material. The highest one (*Last Glacial?*) was built by the Melendiz river. Its remnant is located between the Sultanpınarı and Azatlı villages (caption 6.2), where it caps unconformably various Melendiz and Göllüdağ outcrops. It is s30m stepped over the younger ones (caption 6.6).

The climatic conditions during the LGM (*Last Glacial Maximum*) are also responsible for morphologies and formations more specific to the higher altitudes dominated by periglacial processes. Some of these morphologies and formations are present on the map:

- a terrace (caption 6.3) with a flat summit is 40m deeply incised by a mountain stream on the side of the Çiftlik-Altunhisar road;
- a coarse periglacial or glacial debris flow (caption 6.4) at the foot of a circus-like cliff. The flow ends with a 5m high straight-lined scarp dominating a mountainous coarse-material glacis (caption 6.5) at the apex of which water is discharged from springs.

The Ciftlik plain: a basin subsiding under the control of an active fault located on its southern edge?

As visible on the map, the general disposition of the alluvial fans SE of the plain suggests a response to some tectonic control, with the fans burying or being limited by an active or sub-active fault. This fault, NE-SW oriented, would limit the Melendiz mountains and border a depression presently subsiding. This suggestion of a tectonic control on the Çiftlik plain deserves to be checked. Besides, such a tectonic control and a subsidence at the location of the Çiftlik plain may also explain several morphological features such as:

- the 40m incision of the terrace observed on the side of the Çiftlik-Altunhisar road;
- the capture of the upperpart of the Azatlı stream by the Çiftlik plain (previous to the capture, the Azatlı stream was flowing towards Niğde area: K. Erturaç's personal communication).

Late Glacial to Holocene deposits in the Çiftlik plain

The youngest alluvial fans (five captions 6.6) are built at the mouths of all streams entering the Çiftlik plain. Below the oldest coarse-material fan at Sultanpınarı, two of these younger fans merge when penetrating into the plain. All the younger fans gently dip below recent flood silts (see below: captions 6.9 and 6.10). At this limit between the fan and the flood plain, rises the höyük formed by the Tepecik-Çiftlik Neolithic to Chalcolithic settlement (8^{th} to 6^{th} mill. BC) (Bıçakçı *et al.*, 2007 and 2012). The construction of this coarse sediment alluvial fan generation is *Late Glacial* (an age fitting with a similar stream incision and terracing phase in the Acıgöl caldera (Mouralis, 2003; Türkecan & Kuzucuoğlu *et al.*, 2004).

North of Çardak village, a deposit composed of round pebbles and gravels in a black organic-rich matrix forms a terrace (caption 6.7) overlooking the roof of the Çiftlik plain by a 3m high scarp. This terrace, located close to the outflow where the plain gets very narrow, indicates a phase of incision previous to today's flood plain. This flood plain is active in the most central part of the Çiftlik plain where flood sediments are deposited during melting periods (mainly spring). The spatial distribution of these flood deposits shows two distinct areas, which are visible at first glance on the satellite imagery. This contrast is explained by the provenance of the silts:

- the dark colored deposit located in the southern part of the plain (caption 6.8), corresponds to the sediment input from the Melendiz basin, with the dominance of volcanic basaltic and andesite rocks;
- the light colored deposit at the foot of the Göllüdağ and Şahinkalesi Tepe highlands, extending through the northern part of the plain down to the entrance of the gorge (caption 6.9), is dominated by pumices delivered by the Göllüdağ pyroclastites.

In the same area (western part of the plain), and facing the convergence of all deposits brought to the plain, marshes (caption 6.10) active since the Middle Ages (according to 4 dates from a core extracted in 2010, dated at Artemis -ref. SacA 23892, 93, 95 and 96-: mean ages between 1280 and 1420 AD). These marshes are water-fed by an abundant spring at Ovalıbağ village (caption 6.11).

Conclusion: The Geomorphological Interpretation of the Evolution of the Çiftlik Plain as Expressed by the Legend of the Map (Fig. 1)

Two types of captions are used in the map:

- Solid colors are used for the rock basement outcrops, whether volcanic (rhyolites, andesites, basalts) or sedimentary (river flood sediments, torrential fans, reworked deposits, marsh, diatomites). Colors used for the volcanic rocks change (a) according both to the geochemical characteristics of the rocks (acid, basic), but also (b) according to the structure of the rocks: dark colored captions for rocks; light-colored captions for pyroclastites.
- Patterns and lines superimposed on solid colors express:
  - the geomorphologic interpretation of the sediments below: strombolian cones and vents associated with lava flows in the case of basaltic formations; lava flow dam; river gorge; alluvial terraces; the dynamic setting of alluvial fans construction with torrential deposits;
  - Some local spots: springs, archaeological sites (höyüks) in villages, Tepecik-Ciftlik archaeological site, village, samples for dating;
  - the river network (blue lines).

The contrasted use of the solid colors *vs* black patterns and lines, aims at underlining the fact that two main formations dominate the successive steps marking the geomorphological evolution of the plain:

- Volcanic formations, in pink, red and purple colors: (a) darker colors are for *in situ* hard rocks; lighter colors are for grained volcanic tephras); (b) rhyolites are in red (with pumice fall-outs and flows in pinkish cream); andesites, basalts and andesitic basalts in violet and purple (with basaltic scoriae forming strombolian cones in pinkish violet);

- Alluvial fans and plain fills are in the yellow and brown colors. Flood deposits at the surface of the plain are green-colored, with dark green for the alluvium eroded from the Melendiz range; light green for the alluvium fed by the Göllüdağ pyroclastites; very dark green for the spring-fed marshes.

Captions also record the reconstruction of the landscape evolution

The surface formations and morphological ***impacts of the various volcanic activities*** in the Çiftlik plain (apart from the highland slopes pertaining to the various massifs limiting the plain on all sides: Melendiz, Göllüdağ, Şahinkalesi Tepe), are three main types of volcanic deposits and landshapes:

(i) *in situ* rhyolitic tephra layers emitted by the nearby rhyolitic Göllüdağ complex (more or less proximal tephras) and by the more distant Hasandağ strato-volcano (distal tephras), which are preserved at specific locations around the plain (mainly over the bottom parts of the surrounding slopes);

(ii) various sets of volcano-sedimentary deposits reworking material eroded from the volcanic substratum and from tephras covering slopes. These deposits compose or are important parts composing many torrential fans filling the plain.

(iii) basaltic strombolian cones and the basaltic lava flows emitted.

Morphological heritage from the Mio-Pliocene and lower Quaternary periods. In the area, this heritage is mainly composed of dark colors for the Şahinkalesi Tepe (caption 1.1) and the Melendiz (caption 1.2) highlands.

Morphological heritage of the Göllüdağ massif formation. In the map, only the features having an expression in the landscape are drawn and shown. The morphological indicators of the Göllüdağ caldera are very few (with the exception of the "Bozköy" fault line) since they are either destroyed or buried bewlo pyroclastites and alluvium. Concerning the Göllüdağ massif, the geomorphological objects drawn on the map are thus related to:

- the outcrops of the pre-caldera alluvial deposit (SW Bozköy and E Bozköy) and syn-caldera fluvio-lacustrine formation (E. Bozköy) (caption 2.1);

- the fault scarp and fault line above Bozköy (caption 2.2), with the addition of the probable contour of the caldera wall (caption 2.3);

- *in situ* syn-caldera pyroclastites burying old topographies west of Bozköy and east of the Küçük Göllüdağ (captions 2.4) and forming river fans and slope deposits over the Melendiz slopes between Kula and Asmasız villages south of the Çiftlik plain (caption 6.1 for this material, reworked);

- the Göllüdağ domes (caption 2.5)

- post-calderas falls (caption 2.6) and remarkable flows (caption 2.7)

Morphological heritages and outcrops related to the lake occurrence in the Çiftlik plain during Middle Pleistocene. In the map, this information is of three types:

- Gorge of the Melendiz river through the andesitic-basaltic flows from the Melendiz volcano: caption 1.3

- Lake sediments (diatomite, fluvio-lacustrine series): captions 3.1 and 3.2.

- Basaltic activity dated ca 1.35-1.15 Myrs ago in the western part of the Çiftlik plain and area:

* a large (fissural?) lava flow from the Melendiz massif at the location of the Melendiz gorge (caption 4.1);

* strombolian scoriae cones (caption 4.2);

* flows emitted by the Boztepe strombolian volcano (caption 4.3).

Heritages from the upper Pleistocene (late Quaternary) evolution of the plain in the landscape

During the last Glacial (Würm), two types of sediment covers record events in the plain dynamics:

- *Volcanic eruptions:* some Hasandağ eruptions cover a variety of older outcrops in the western part of the plain (caption 5.1).

- *Alluvial formations record climatic conditions, ie changes in temperatures and humidity, in high altitudes and/or tectonic subsidence of the Çiftlik plain*. Both the incision of streams in the volcanic hard rock substratum of the Melendiz mountains, and the erosion of the pyroclastic cover of the Göllüdağ slopes produced four generations of alluvial deposits:
  - a 10m thick pumice-rich pyroclastic which had been deposited on the Melendiz slopes and have been reworked by river processes down towards the Çiftlik plain (caption 6.1);
  - an upper and a lower alluvial fans (captions 6.2 and 6.6) composed of coarse blocs and pebbles from the Melendiz mountains, and developed at the mouths of all streams around the southern border of the plain;
  - at high altitudes, a terrace (caption 6.3) deeply incised by a mountain streams marks a heritage of climate conditions colder than today, as it is related to a periglacial or glacial debris flow (caption 6.4) limited by a scarp overlooking a coarse-material covered glacis (caption 6.5).

Since the Late Glacial, the morphological dynamics in the plain are mainly related to the deposition of:

- organic-rich alluvial sediment (coarse, rounded elements) forming a +3m high terrace on the northern edge of the plain (caption 6.7), indicating a succession of climatic changes previous to the Holocene flood deposits below;
- Holocene sediment flood deposits over the lowest fans, with material eroded in the Melendiz mountains (caption 6.8) and in the pyroclastites capping the Göllüdağ massif (caption 6.9).

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