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Facies and depositional sequences of Melendiz Confluence Holocene sediments, Central Anatolia, Turkey

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Abstract

The aim of this article is to investigate the Çiftlik Plain and the Central Anatolia Cappadocia Volcanic Province, the unexplored Quaternary fills, and their climate records. This studies has gained importance as it completes a deficiency in the region.A confluence is where a tributary joins a larger river which depicts an important area of deposition which is an essential geomorphological node that controls the downstream routing of flow and (P2), located between latitudes N38°11' and longitudes E34°27', at an altitude of 1532m above sea level in the Çiftlik Basin. In this Confluence in Çiftlik (M-1 to M-10) (A-J), consisting of paleosols and terrestrial sediments (P2), in which a profile from a collection of 41 specimens was initially examined.

This article evaluates therefore the depositional sequences of sediments brought in by the Melendiz stream that flourished during the Early Quaternary. The Quaternary fills are made up of terrestrial sediments and paleosols and consisted of fined, medium and coarse grains ranging from peat, silt. clay, sands, pebbles of various different sizes. Some of these grains came from the immediate surroundings seen from their coarse and angular shapes while the fined grains must have travelled for a long distance having been worked and reworked by wind and running water. To determine the quality and quantity of the collected samples, the samples were prepared for measurement by passing the necessary processes according to the type of sedimentological, mineralogical, soil types and XRD. By analyzing the data obtained from these measurements, the mineral types, distributions, chemical components, and trace elements contained in partially lithified or unconsolidated sediments of the region were determined. The relationship of these data with paleoclimate has been revealed and compared with the Central Anatolian climate records. The Pliocene lake regressed toward the west on account of the progressions in the structural system and geomorphological cycles during the late Pliocene (~ 3 Ma ago) and the underlying Melendiz Waterway created on the lake base. During the Quaternary the Melendiz Stream created heavily influenced by both the neotectonic system and the environment.

The sediments are very poorly sorted in some levels of unconsolidated or partially lithified sediments and paleosol, and poorly sorted in some levels. On the other hand, quartz, feldspar, amphibole, and rock fragments such as metamorphic, volcanic and igneous are commonly observed in paleosol, silty and sandy levels. In XRD measurements, paleosol, silty and sandy levels contain common feldspar, quartz, amphibole, Opal CT and Opal A minerals. The amounts of smectite, chlorite, illite as clay minerals at these levels vary at various levels of the profiles.

The results of these calculations help us to explain the sediment-paleosol formation processes. They are of the Quaternary and primarily Holocene.

Keywords: Central Anatolia; Holocene sediments; Reconstruction; Melendiz; Paleo climate

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1. Introduction

This work therefore attempts a reconstruction of the Melendiz Confluence river dynamics most importantly by enumerating the sedimentological features of this area,following suite to river dynamics studied on the basis of geomorphology and archaeological data acquired from two Pre-Pottery Neolithic(PPN) sites by Kuzucuoğlu,2013.The section explores the facies type and geomorphology data obtained from the Melendiz valley in Cappadocia, Turkey. Through careful analysis, valuable information is gathered to understand the natural formation and evolution of the valley, as well as insights into human occupation and activities during the Pre-Pottery Neolithic (PPN) period. Geomorphological data provides an understanding of the land-forms, sedimentation processes, and geological history of the valley, while the archaeological data sheds light on the cultural and social aspects of the PPN sites. By integrating these two sets of data, a comprehensive picture of the river dynamics in the Melendiz valley can be established.During the Last Glacial and Late Glacial period, a significant gravel deposit accumulated in the Melendiz River valley. However, before the transition to the Holocene, this deposit underwent incision, most likely due to hydro-climatic factors and tectonic uplift.In western Cappadocia, the Melendiz River can be found east of the Tuz Gölü Fault Zone. In the focal piece of Melendiz Stream Valley, Ihlara Gully draws in numerous sightseers because of its scene, social and archaeological qualities. The Melendiz Valley additionally envelops land and geomorphological highlights that embody the evolutionary history of western Cappadocia. The section aims to explore the specific processes involved in the deposition of the gravel and their implications for understanding the climatic conditions and landscape evolution during this transitional period.

Some researchers have researched on many different aspects of The Central Anatolian Region and Melendiz,viz; The Central Anatolian Plateau is a relatively small Cenozoicorogenic plateau, 400 km wide and 1200 m a.s.l (above sealevel) (Çiner et al. 2015).One of the most tectono-morphologically and historically fascinating areas on the plateau the Central Anatolian Volcanic Province (CAVP), generally known as Cappadocia (Doğan et al,2019).According to Doğan,the CAVP is about 15–90 km wide, 300 km long and runs in a NE-trending continental paleo-magmatic arc (Keller 1974; Pasquaré et al.1988; Koçyiğit and Doğan 2016).While streams in the western part of Cappadocia flow intothe Tuz Gölü closed basin, the northern part of the Cappadocia region is drained by the Kızılırmak River (Doğan 2011;Çiner et al. 2015) that flows into the Black Sea, while the eastern reliefs are drained by short streams flowing into theSultansazlığı closed basin. Born in the MelendizMassif (2963 m) near the town of Niğde, it flows into the Çiftlik plain where it collects tributaries draining the western slopes of the Göllüdağ (2195 m), the northern slopes of the Keçiboyduran (2752 m) and the southern slopes of the Şahinkalesi (2034 m) (Kuzucuoğlu et al. 2015).The absolute length of the river is roughly 90 km. Its course experiences and crosses the Tuz Gölü Fault Zone (TGFZ) prior to finishing close to Aksaray city from where it goes into the Tuz Gölü closed basin.The Melendiz River incisedits valley into thick ignimbrite-intercalated fluvio-lacustrinesediments (Beekman 1966; Doğan 2018; Kuzucuoğlu et al.2018). Aydar et al.(2012), Kuzucuoğlu (2013) and Mouralis et al. (2019), thereis a limited number of studies specifically about the geological and geomorphological features of part or whole of the Melendiz Valley (Beekman 1966; İlkışık et al. 1997; Türkecan et al. 2004; Sarı and Çömlekçiler 2007; Karabacak 2007; Kuzucuoğlu 2013; Kuzucuoğlu et al. 2015, 2018;Karabacak et al. 2017; Doğan 2018; Mouralis et al. 2019; Özsayın et al. 2019).According to Doğan,although the geological features of the valley have been partly addressed in studies of the TGFZ and Tuz Gölü basin (Dirik and Erol 2000; Fernández-Blanco et al. 2013; Özsayın et al. 2013;Kürçer and Gökten 2012, 2014; Gürbüz and Kazancı 2014)and while volcanism was approached with detailed studies such as Le Pennec et al. (1994), Aydar and Gourgaud (1998),Temel et al. (1998), Dönmez et al. (2003, 2005).

1.1. Geology and stratigraphy of the study area

The geology of the Central Anatolian Volcanic Province (CAVP) with the Çiftlik plain in the middle is very interesting. The Central Anatolian province is approximately 300km long and a wide of about 90km.The CAVP is also tectono-morphological in character and has been divided into different sizes by the Tuz Golu fault zone together with the Anatolian fault system, which are of the normal types and are mostly buried beneath the products of recent volcanic eruption (Vedat .T et al.,1993).The Central Anatolian Volcanic Province is of the Neogene –Quaternary age(Mid-Late Miocene to Recent) essentially based on radiometric age determinations on the different sections of the CAVP. Its formation and evolution had been attributed to the convergence between the Eurasian and Afro-Arabian plates.The CAVP has been further structured by minor and major eruption polygenetic composite to monogenetic volcanoes during the Neogene which continued to the Pliocene and Quaternary. This is because there are igneous, metamorphic, volcanic and volcano-sedimentary rocks that are outcropped here with different ages that ranges from the oldest being crystalline complex metamorphic rocks which are pre-Mesozoic in age, Igneous or magmatic rocks which are pre-Upper Cretaceous and considered as basement rocks, the volcanic/volcano-sedimentary rocks being Upper Miocene to Quaternary in age.According to geochemical analyses,the CAVP exhibits mostly calc-alkaline character. The volcanic emissions in the CAVP are varied in shape and character especially tephra which are potential marker horizons for long distance correlation (Mouralis et al.,2019) called tephrochronology using the K/Ar dating method.The basin is situated at an altitude of about 1500m above sea level and has a diameter of approximately 15km and coinciding with what is called the Çiftlik caldera which according to Cemal et al.(1992),has erupted significant amount of pyroclastics in the region(Pasquare et al.,1988).The Çiftlik plain is situated between the Melendiz and Göllüdağ mountains previously occupied by a lake some 1.3ma ago.To the north of the Çiftlik plain,lies the Gosterli fault(GF) and the buried Keçiboyduran–Melendiz fault(KMF) that has more or less affected this area.The Çiftlik basin is surrounded by principal formations or volcanic complexes that serve the basin with her varied sediments in the past and now. These complexes described the volcanism and the formations in CAVP, specifying their ages, lithology, flow pattern, eruptive centers and morphologies which were used in-order to recognise these complexes and how continues these activities had been since Middle-Late Miocene. These complexes suggest a close relationship between faulting and volcanism. These complexes are Keçiboyduran,Melendiz,Çınarlı,Tepeköy, Karataş and Göllüdağ.Basing on their lithostratigraphy ,these complexes will be dealt with from the oldest towards the youngest unit.

Figure 1 Location of Aşıklı Höyük on right bank of Melendiz River (Modified) after Dogan(2019)

1.1.1. Tepeköy volcanics

This Stratovolcano, primarily a caldera of Mid-Late Miocene age, is located on the southern part of the Central Anatolian Volcanic Province (CAVP) and to the southeast of the Çiftlik plain. It exhibits a semi-circular distribution spanning approximately 80 square kilometers and is situated on the up-thrown (eastern) block of a NNW-SSE trending fault, which serves as a boundary separating these volcanics from the Melendiz volcanics (Cemal et al., 1992). According to Gencalioglu K. (2010), the Tepeköy lava flows have been dated to approximately 4.2±0.4 million years ago, as reported by Türkecan et al. (2003), overlaying base surge deposits documented by Geneli (2003). Parts of the Tepeköy volcanics in the west are observed to be overlain by the younger Melendiz volcanics. These volcanics have undergone varying degrees of weathering due to hydrothermal fluids, resulting in a brownish to pinkish coloration in the southwest of the Tepeköy fault, attributed to significant alteration. They primarily consist of andesite-dacitic and andesite-basaltic flows. Common minerals found within this complex include plagioclase, enstatite, hornblende, augite, ortho and clinopyroxene, olivine, and apatite.

1.1.2. Çınarlı Volcanics

To the east of the Çiftlik plain lies another Stratovolcano, covering an area of approximately 50 square kilometers. Based on the K/Ar dating method, it has been determined to be of Late-Miocene age, attributed to a period around 3.3±0.3 million years ago (Türkecan et al., 2003), as stated by Gürel (2016). This unit is characterized as a composite cone, although heavily eroded, with multiple vents. The composition of the complex is predominantly comprised of thick andesite flows, alongside basalt and dacite. This unit is situated beneath the Melendiz volcanics, which date to the Pliocene period.

1.1.3. Melendiz Volcanics

To the south of Çiftlik plain lies a caldera, composite, and Stratovolcano complex. Using the K/Ar radiometric method, its age has been estimated to range from 6.5±0.2 to 5.1±0.15 million years ago (Vedat et al., 1993, 1998). Vedat et al. (1993) assigned it an Early Pliocene age, while Gürel (2016) categorized it as Late Miocene-Pleistocene. Consequently, the complex comprises products from the Upper Miocene, Pliocene, and Pleistocene periods (Türkecan et al., 2004), which clarifies the varying ages proposed by different authors. Situated to the east of the Keçiböyduran mountain, the Melendiz volcanic complex covers an area of approximately 315 square kilometers and exhibits a polygenic nature. The

Keçiboyduran-Melendiz fault (KMF) lies buried between the Melendiz and Keçiböyduran complexes, influencing the evolution of these volcanic formations. The lavas are predominantly hornblende-augite andesite and augite-hypersthene andesite, with tongued-shaped flows comprising mainly of andesite (grey-black) and basalt, exhibiting the most recent age of 1.1±0.2 million years and located south of Çiftlik town. Pyroclastics emitted include volcanic bombs, tuffs, tuff breccia, agglomerates, and breccia. Major minerals present are plagioclase, amphibolites, biotites, and occasionally appearing as phenocrysts. Some parts of this complex exhibit highly limonized and silicified formations, containing manganese and sulfur, resulting in rock colors ranging from green, purple, brown, to yellow. Tuffs form the core of the Melendiz formation, surrounded by ashes, lapilli, and partly covered basaltic lava, with large flat plains encircling this unit.

1.1.4. Keçiböyduran Volcanics

Situated southwest of the Çiftlik plain, between the mountains of Hasandağ and Melendiz, this composite Stratovolcano covers an area of approximately 120 square kilometers. Similar to other complexes, it exhibits a base in the form of an ellipse, with a NE-SW axis measuring 18 kilometers in length (Türkecan et al., 2011). The vent, circular and centrally positioned, comprises highly brecciated and extensively altered andesites, agglomerates, and tuffs, followed by hornblende-biotite and hornblende-augite andesite lava, with a diameter of about 5 kilometers. Predominantly composed of andesite and basaltic andesite lithologies, this complex has been assigned an Early Pliocene age. According to Gürel (2016), the age unit is determined to be 3.2-1.1 ± 0.2 million years ago, based on K/Ar dating by Türkecan et al. (2003).

1.1.5. Göllüdağ Volcanics

Located at the northern part of the Çiftlik plain, Göllüdağ is characterized as a dome with an area of 90 square kilometers. Its age has been determined through various studies to be 0.9±0.2 million years and 1.15-0.86 million years ago (Batum 1978, Bigazzi et al. 1997, Kuzucuoğlu et al. 2013, and Vedat 1998, respectively) using fission-tract dating on obsidian, indicating early Quaternary or Pleistocene origins. This volcanic unit underwent three phases—pre-, syn-, and post-caldera—each with differing impacts on morphologies and environments (Mouralis, 2003). During syn-volcanic activity around 1.39 million years ago, Göllüdağ emitted substantial volumes of pyroclastic materials, filling the caldera and Plio-Quaternary valleys, ultimately leading to the collapse of the caldera and associated morphologies. Post-caldera activity continued for approximately 700,000 years within the Göllüdağ complex, from 1.1 to 0.44 million years ago (Mouralis, 2003). This complex presents a Quaternary rhyolithic complex with volcanic activity spanning a wide time range, from the lower to the middle Pleistocene (Mouralis et al., 2019). Comprising rhyolitic and rhyodacitic lava covering the central portion, along with obsidians and perlitic rocks at the periphery, Göllüdağ is also described as a collapsed volcano structure, partitioned into a Mio-Pliocene substratum at the foot of cliffs in a depression. Göllüdağ stands as a high volcanic mountain, reaching 2143 meters according to Turcan Altin (2011). It includes Kücük (small) Göllüdağ, consisting of rhyolite with vitrophyre at the upper part, dated at approximately 0.430±0.0009 million years ago, and Büyük (Big) Göllüdağ. The main basalt tuff of Göllüdağ is approximately 1.66±0.04 million years old. The mineral composition of Göllüdağ includes orthopyroxene, pyroxenes, opaque minerals, chino-pyroxenes, and amphiboles. No differentiation exists in the eruptive phases of Göllüdağ, and pyroclastic materials associated with paroxysmal eruptions lead to emitted tephra layers. This unit overlays Pre-Quaternary rock units unconformably.

1.1.6. Karataş Volcanics

The Karataş volcanic complex, located northwest of the Çiftlik plain, represents the most recent geological formations within the Central Anatolian Volcanic Province (CAVP), scattered across the area. The name "Karataş" was assigned by Erkan (1990). Comprising monogenetic centers, this complex consists of individual scoria cones and lava flows. Radiometric data, utilizing the K/Ar method, indicates an age range from 0.42±0.04 to 0.08±0.1 million years ago (Cemal et al., 1992, 1993), suggesting a Late Quaternary (Early Pleistocene) origin. The lava flow predominantly comprises black olivine and hypersthene basalt. Aligned along the Tuz Gölü fault zone, the cones range from 0.1 to 2 kilometers in diameter and are extruded in the form of dykes. These cones represent parasitic products of the Hasandağ volcanics.

1.1.7. Quaternary Sediments

The Quaternary deposits in the area encompass a diverse range of formations, including the Keçiboyduran volcanic complex, Quaternary pyroclastic material, debris tuffs, cones, Kuyulutalar basalt, Göllüdağ pyroclastics, Göllüdağ volcanics, and alluvium. Surrounding these complexes, the plains feature deposits of ignimbrites, Plinian air fall, lapilli layers, and dark-colored lavas. These deposits are interspersed with layered reworked volcanoclastic, siliciclastic, lacustrine, and fluvial alluvium from higher elevation points, indicating continuous basin filling in this dynamic environment. Braided river deposits are also present within and around the plain. While some authors propose that the Çiftlik plain may be a caldera, others dispute this assertion.

1.1.8. Early/Middle Pleistocene Deposits

In this region, the predominant sediments consist mainly of volcanoclastic and siliciclastic materials, which are relatively younger compared to lacustrine, palustrine, and fluvial sediments. These younger sediments overlay older volcanic rocks in an unconformable manner. The area has witnessed significant deposition events, including high volumes of Plinian and Pelean pyroclastites, surges, avalanches, pumice ash, and lapilli flows. Fluvio-lacustrine sediments overlay older alluvium from the Plio-Quaternary period. According to Kuzucuoğlu et al. (2013), various morphological and stratigraphical indicators suggest a collapse event dating back to 1.4-1.1 million years ago (Ar/Ar date by Guillou, ISCE). This collapse occurred before the formation of the Göllüdağ massif, which now occupies the depression. The presence of high volumes of pyroclastics in the area suggests that the collapse occurred prior to the extrusion of the domes forming the Göllüdağ massif. Beneath the cliffs of the collapsed caldera, well-rounded basal alluvium and basaltic pebbles are found. Fluvial and lacustrine sediments are inter-bedded with reworked pyroclastics that were extruded during the collapse event. Finally, in situ pyroclastics are observed lying atop the basal alluvium and pebbles. Since the Middle Pleistocene, a combination of pyroclastic, lake, and river sediments has been deposited in this depression.

1.1.9. Upper Pleistocene/ Holocene Deposits

The Middle Pleistocene deposits in the area were largely covered by pyroclastics, which were subsequently heavily eroded along with other debris from basement rocks. This erosion played a significant role in filling the ancient lake. These sedimentary deposits, loosely cemented, consist of reworked volcanoclastic, fluvial, and lacustrine materials. They alternate with layers of pumice, gravels, paleosols, surges, silt, sand, and clay, with varying depths across the Çiftlik plain—deeper layers are found around Ovalibağ to the west, while fan-delta sediments are prevalent to the north. The geological history of the Çiftlik plain is recorded through volcanic eruptions, primarily triggered by Hasandağ eruptions, and the sedimentary records resulting from climate changes. Three main volcanic deposits are identified in the Çiftlik plain: rhyolitic tephra layers from Göllüdağ, reworked volcano-sedimentary deposits from the volcanic substratum, and Strombolian basaltic flows and cones. At the mouths of streams entering the Çiftlik plain, the youngest alluvial fans are found, primarily sourced from nearby ash and pumice deposits. These alluvial fans are unevenly distributed across the plain. Notably, two main types of silt deposits exist here—dark-colored, originating from Melendiz, and light-colored, from Göllüdağ. An incision phase is indicated by the deposition of coarse rounded pebbles and gravels during Late Glacial periods. Additionally, palustrine or marshy sediments, fed by abundant springs in Ovalıbağ, are present. Shallow and deep lake deposits, characterized by massive and fine grains and rich in organic plant material in some areas, are also observed. Flood sediments are predominantly deposited during melting periods (spring) in the center of the Çiftlik plain.

At the Melendiz Confluence, alluvial incisions have formed, depositing pebbles up to 5cm in diameter. These incisions also contain high and low lake deposits consisting of clays, paleosols (gravel), and peat layers cored at 661cm depth.

1.1.10. Stratigraphy

The geological units within the Çiftlik plain, comprising basement metamorphic rocks, plutonic, volcanoclastic, and sedimentary rocks, were deposited across intervals spanning from the Paleozoic-Mesozoic to the Holocene periods. The foundational layers of the study area include Tepeköy (Mid-Late Miocene) and Çınarlı (late Miocene), overlain by Melendiz and Keçiboyduran deposits, dating to the Early Pliocene. The Göllüdağ volcanics rest upon these older units and are dated to the Early Quaternary, while Karataş, the youngest unit, is of Late Quaternary age. Continuous eruptions from these complexes have led to the emission of Quaternary pyroclastics and tuffs debris from Melendiz, Keçiboyduran, and Göllüdağ. These units are all unconformably overlaying the basement rocks. In the basin, recent sedimentary deposits, including volcanoclastic and alluvium materials, unconformably lie atop these older units and are dated to the Late Pleistocene period. The uppermost sedimentary layers in the Çiftlik plain are of Holocene age.

1.2. Tectonic characteristics of the research area

The tectonics of this area can be summarized in the figure below;

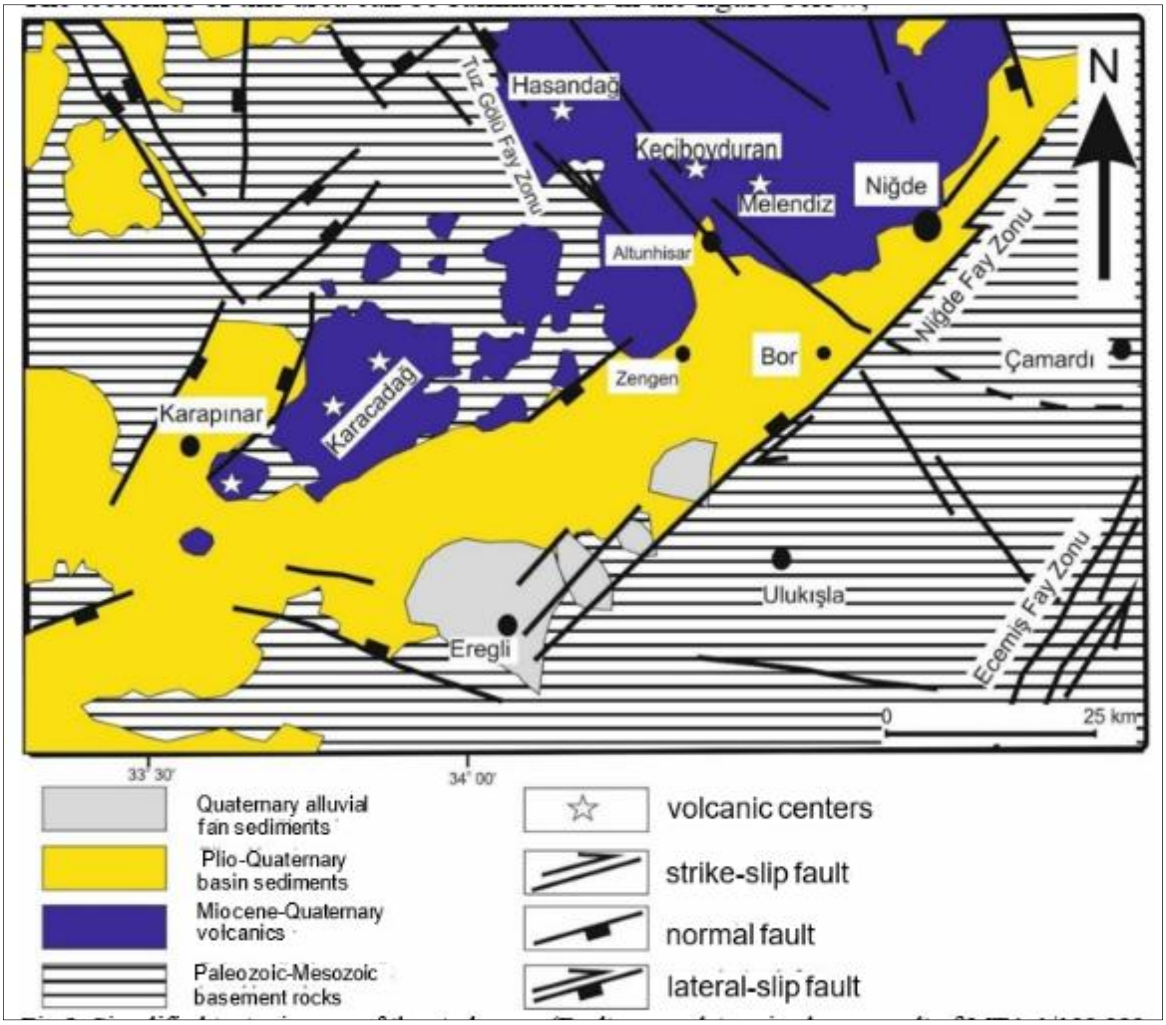


Figure 2 Simplified tectonic map of the study area (Faults were determined as a result of MTA 1/100.000 map studies, satellite and field studies of the region, modified from Gürel and Lermi 2010)

2. Materials and method

The sediment grain size of the soil is of great importance for the distribution of trace elements. As the elements with high mobility are absorbed by the clay and Fe-Mn oxides, they are enriched in the fine-grained components of the soil. Since the best results will be obtained by taking these fine particles, care has been taken to take samples from fine material and parts that do not contain organic material.

More than 10 rock samples, basalt, andesite and limestone, were taken to represent the geology in the region (basic rocks) and to determine the trace element concentrations, and the samples (cm) taken from Çiftlik plain within the scope of this project are given below as a protocol (Type locality).P2, Melendiz Confluence above.

Table 1 Melendiz, (Çiftlik Plain), (Profile 2) - Core Depth: 661cm. 38°11'26.94" N and 34°27'55.56" E (Height: 1532m)

Sample No/cm	CaCO3	Colour	Plant	pebbles %	sand %	Silt %	clay %
MELd1(2-5)	None	Dark grey	Present	--	33	50	17
MELd1(13-16)	None	Dark grey	present	--	5	50	45
MELd1(17-20)	None	Dark grey	present	--	15	45	40
MELd2(0-4)	None	Dark grey	Present	5	35	40	20
MELd2(11-14)	None	Dark grey	Present	2	50	35	13

MELd2(19-21)	None	Dark grey	present	2	55	30	13
MELd3(4-9)	None	Dark grey	None	15	45	30	10
MELd3(11-15)	None	Dark grey	None	15	70	10	5
MELd3(28-40)	None	Dark grey	None	20	60	15	5
MELd4(0-4)	None	Dark grey	None	2	66	20	12
MELd4(11-14)	None	Dark grey	None	4	65	18	13
MELd4(16-18)	None	Grey	None	3	45	32	20
MELd5(200-250)	None	Grey	None	85	5	5	5
MELd5(256-258)	None	Grey	None	5	70	18	7
MELd6(0-3)	None	Grey	None	20	60	12	8
MELd6(5-7)	None	Grey	None	6	75	15	4
MELd6(10-12)	None	grey	None	4	70	16	10
MELd7a(4-7)	None	Orange	None	2	55	32	11
MELd7a(13-16)	None	orange	None	3	67	20	10
MELd7a(22-24)	None	Orange	None	--	5	50	45
MELd7a(26-28)	None	orange	None	--	--	40	60
MELd7a(36-40)	None	orange	None	--	10	40	50
MELd7a(40-48)	None	orange	None	--	5	40	55
MELd7a(70-78)	None	orange	None	--	3	57	40
MELd7a(90-98)	None	orange	None	--	10	50	40
MELd7b(0-3)	None	orange	None	--	5	55	40
MELd8(0-24)	None	Orange	None	70	10	15	5
MELd8(24-28)	None	orange	None	5	5	45	45
MELd8(30-33)	None	orange	None	--	2	40	58
MELd8(40-48)	None	orange	None	--	25	45	30
MELd9(2-5)	None	white	None	5	--	50	45
MELd9(7-9)	None	white	None	--	5	50	45
MELd9(14-17)	None	white	None	2	--	43	55
MELd9(19-23)	None	white	None	20	10	30	40
MELd9(30-32)	None	white	None	--	5	35	60
MELd9(36-38)	None	white	None	--	2	38	60
MELd9(45-47)	None	white	None	--	20	30	50
MELd9(53-55)	None	white	None	--	15	40	45
MELd9(56-58)	None	white	None	--	5	40	55
MELd9(62-64)	None	white	None	--	--	35	65
MELd9(66-68)	None	Grey/white	none	--	10	38	52

A total of 41 terrestrial sedimentary samples were collected from the region for research purposes.

Within the scope of this article, a total of 41 samples of terrestrial sediments, ranging in size from paleosol to clay-silt-sand-gravel, were collected from various profiles. However, due to insufficient financial support, not all samples could be analyzed. Therefore, the initial step involved removing redundant profiles and similar levels or facies. Subsequently, in order to fully elucidate the characteristics of specific levels, sedimentological features and XRD (X-Ray Diffraction analysis) were employed. Ten examples were selected for detailed study, as shown in Table 1 below..

Table 2 Samples compiled for XRD measurements from Melendiz Confluence (P2) (Çiftlik Plain) profiles

Sample	Paleosol	Depth (cm)
M-1	Histosol	17-20
M-2	Histosol	11-14
M-3	Histosol	28-40
M-4	Histosol	11-14
M-5	Spodosol	200-250
M-6	Spodosol	5-7
M-7	İnceptisol	26-28
M-8	İnceptisol	0-24
M-9	Mollisol	40-42
M-10	Andisol	53-55

3. Results

3.1. Hand Drills and Profile Descriptions

Samples were taken during field studies here in the Çiftlik Plain by making a hand drill using sondage with a diameter of approximately 10cm at different areas with the best sediment representation.After this,these samples were examined briefly in the field then later much more accurately in the laboratory.Profiles were made,sorted and classified according to the USA soil classification and FAO-world soil resources report No:103 WRB 2007 (Soil Survey Staff, 1998).

Stratigraphic type section descriptions in the Çiftlik plain are in the following regions:

3.2. Type lithostratigraphic strut section descriptions of the Melendiz (M1, P2 profile) region

More than 6 lithostratigraphic strut sections were excavated on the Çiftlik plain. The most important of these and the second lithostratigraphic vertical section that could represent the whole region was searched and it was determined that this type of section was between Melendiz (M1, P2 profile) (38°11'26" N and 34°27'55" E), (Profile 1); Profile start 1520 m); The findings and results of this study are as follows (Table 3, Figure 10).

Unit 1, (50 cm), brown peat (chocolate-coloured), very well compacted, more prominent after 42 cm, and rootlets widely occluded.

Unit 2, (117 cm), consists of a black paleo-soil alternation with gravel deposition. These levels pass to levels that contain between 54-70 cm brown clay, oxidized, small and sparse pebbles and very fresh plant roots. At this level, between 70-77 cm, brown clay, oxidized and gravelly levels larger than 2 cm begin. At 77 – 130 cm downwards these levels are pebbly and oxidized black paleosol and adjacent to it are brown paleo-soil (clay/silts/sands) levels with sparse gravel 5 cm in diameter. This unit eventually ends with brown paleo soil. Small pebbles are located at the very end of the unit.

Units 3 (14 cm) and units 4 (129 cm) are commonly found in compacted clayey level in unit 3, peat, light colored, clay becomes whitish and shiny as depth progresses. In the lower levels, it passes into the gravelly levels and is about 50 cm. Rhyolite pebbles are common in the upper part and this level passes down to a level containing organic clay and sparse gravel. Below this level, between 250 and 260 cm, sand and gravels belonging to the alluvial fan take an important place. The next 5 cm consists of gray sands belonging to the alluvial fan. The next last 40 cm consists of small pebbles with dark gray sandy clay matrix content. Towards the end of the unit, coals and oxidation zones stand out.

In unit 5 (82 cm) and unit 6 (81 cm), unit 5, green-gray clay with very fine silt and/or sand (no coarse sand) is observed. Towards the bottom of the profile, there is a level between 319-321 cm containing some coal dust. A pumice level with a thickness of 5 mm is also observed. Just below this level it changes to a dark gray clay level and contains no sand (only silt is observed). At this level, pumice pebbles are also detected, albeit rarely. Unit 6 mainly contains knives with a diameter of 5 cm.

Unit 7 (11 cm) begins with a dark gray clay level (sandy at the bottom, no sand at the top). Just below it, at 2 cm, the sand-less dark gray clay level continues, but the presence of sparse pumice pebbles proves that they were eroded from the transported pumice-containing rocks, and it is observed that the next level passes into the gray sandy clay levels rich in plant remains.

Unit 8 (75 cm) and unit 9 (94 cm), unit 8 is completely gravel and unit 9 contains massive blue clay. These levels consist of very large pebbles, especially the first 3 cm. These pebbles can reach up to about 6 cm in diameter. At the end of this 28 cm, there is a lacuna level at exactly 580 cm, perhaps due to erosion or excessive weathering. Both after the discordance level, massive gray-blue clay is detected at certain depths and partially observed in coal content. The profile ends with gravel and sand levels, which reaches a full 661 cm (see Table 3 below.

Table 3 Lithological characteristics of the paleosol and terrestrial sediments found in the vertical section of the Melendiz Confluence region

0- 54 cm; very compacted, brown peat (chocolate colour), (this unit has modern soil several cm thick; Unit I)
54 - 170 cm; black paleosol levels alternating with pebble deposits, intersected by brown clay levels in places, oxidized level, black paleosol containing pebbles, oxidized levels and pebbly levels continue in an alternating manner, 5 cm diameter gravel and brown soil (clay / silt / sand) levels [Unit II].
170 - 185 cm; peat, lighter colored than unit two, compressed clay, white colored and glossy clay, [Unit III].
192 - 321 cm; gravelly, hill-to-peak = rhyolite-rich pebbly and organic clay levels, may contain sparse gravel and sand levels of the alluvial fan [Unit IV].
318 - 400 cm; very fine silty and/or sandy green-gray clay (level where coarse sand ends), dark gray clay and passes downwards to no sand (only silt-containing level), very rare pumice pebbles may also be found (Unit V)
400 – 418 cm; level with gravel fragments (Unit VI)
470 - 492 cm; dark gray clay-rich level (base may contain sand, upper section is sand-less (Unit VII)
492 - 567 cm; gravel content level [Unit VIII]
567 - 661 cm; blue clay, massive, only sparsely (but rare) pebbly, blue clay (gravel may be 6 cm in diameter, massive gray-blue clay), [Unit IX]
call lacun 28 (580) Gravel and sand alternating levels starting from 661, [Unit X)

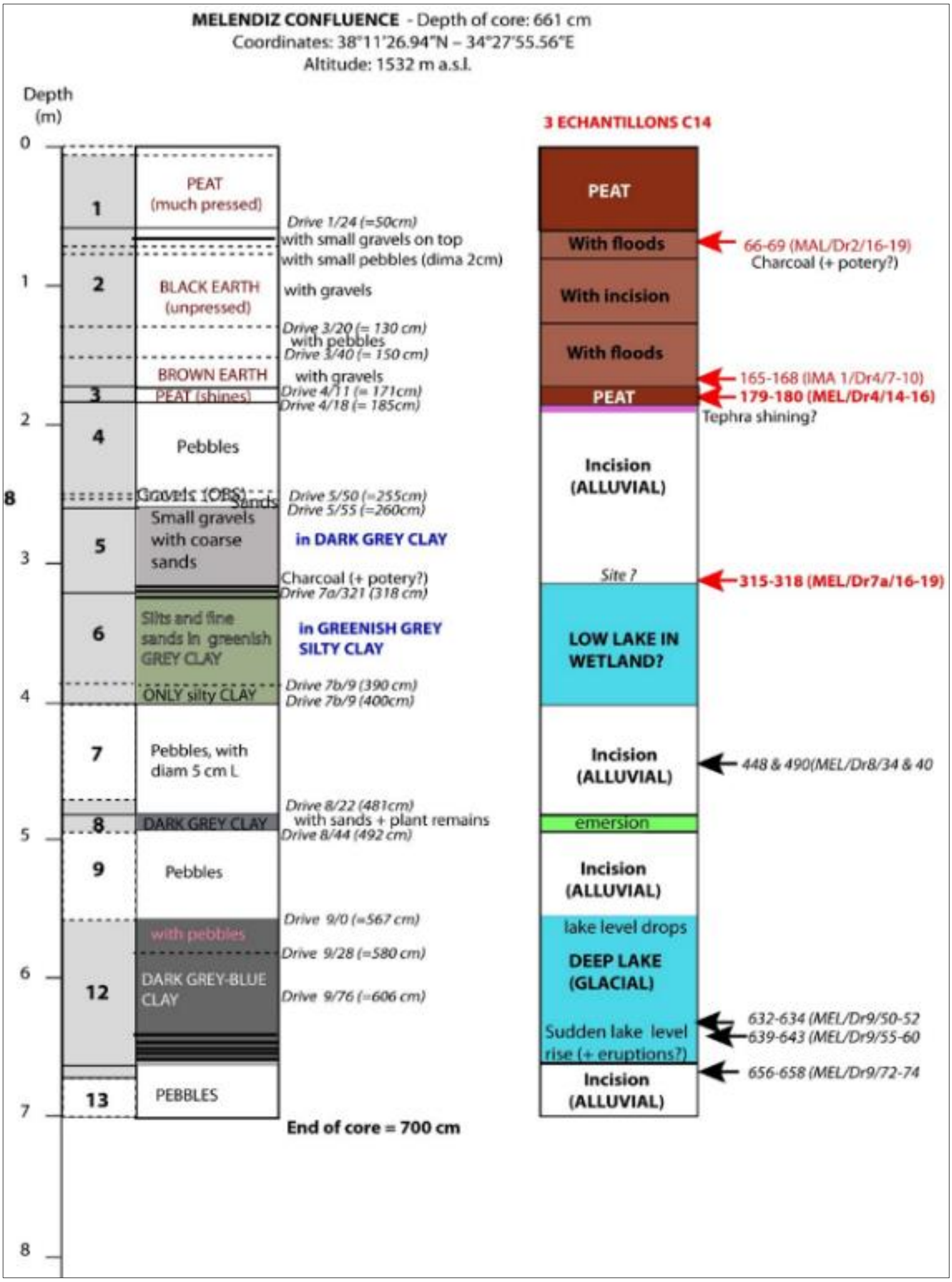


Figure 3 Stratigraphic strut section and lithological features of the Melendiz (Çiftlik) region (Source: Kuzucuoğlu and Gürel, 2022, unpublished)

3.3. XRD Studies and Clay Mineralogy

By analyzing the types of clay minerals present in various layers of ancient soils and loose sedimentary materials in the Çiftlik plain, one can determine the soil classification they belong to. Clay minerals like smectite, paligorskite, and sepiolite are particularly significant indicators of past climates. Additionally, zeolite minerals such as calcite and gypsum in this region can also serve as climate indicators alongside other minerals. The accumulation of these minerals at different levels allows for the retrieval and interpretation of valuable climatic data from specific periods or layers. There exists a correlation between mineral composition, paleoclimate, and the classification of ancient soils. The information presented, sourced primarily from Soil Survey Staff (1998), has been modified to elucidate the connection between paleosol classification and past climates. Numerous sources on paleosols provide examples of how classification aids in making interpretations about ancient climates.

Table 4 From Soil Taxonomy (USA; 1998): Types of Clay Minerals by Compilation Studies and Soil Classification

Alfisol	**illite, aluminum chloride**
Andisol	allophane, imogolite, halloysite
Aridisol	parent rock clay minerals, salts, gypsum, calcite, paligorskite
Entisol	clay minerals of bedrock
Inceptisol	illite, smectite, aluminum chloride
Mollisol	illite, smectite, vermiculite
Oksisol	kaolinite, gothite, hematite, jibs
Spodosol	illite, aluminum chloride, (smectite)
Ultisol	kaolinite, muscovite, hematite, gothite
Vertisol	smectite

The Holocene-era loose sediments and ancient soils specific to the research area are generally loosely connected to each other and bound by various types of cement, including silica, iron oxide, or clay minerals. The pebbles within this unit primarily comprise volcanic rocks (such as basalt, andesite, pumice, and ignimbrite) and fragments of metamorphic rock (with metamorphic base rocks). A total of 10 samples were collected from the region, including paleosols and other unconsolidated sedimentary materials, and subjected to XRD scans. Approximately 10 XRD measurements were conducted and evaluated, as presented in the tables below. Common minerals found in the region include smectite, chlorite, kaolinite, illite, feldspar, quartz, opal-CT, amphibole, serpentine, and analcime. The Holocene clastic rock content is predominantly composed of volcanic rocks surrounding the Çiftlik plain, and XRD measurements were conducted on agglomerations of paleosols, sedimentary clastic layers, paleosol horizons, and some basement rocks. Quaternary rocks, particularly young basalt, tuffs, and ignimbrites within the Quaternary-aged Çiftlik plain, were not included in the study. Detailed mineralogical data for these rocks can be found in research articles by Aydın et al. (2014).

3.4. Melendiz (10 samples) (Çiftlik)

The data obtained as a result of XRD measurements made from whole rock and enriched clay fraction in the profiles of Melendiz region selected as the type locality in Çiftlik plain are given in Table 3 and Figure 4.

As a result of the above Ovalıbağ XRD measurement, the mineral distributions according to the levels and the vertical distributions of these minerals do not show any change due to their lithological properties. Therefore, detailed explanations and comments were not needed.

Table 5 XRD measurements of the samples taken from the stratigraphic column section of the Melendiz region were made. Using these XRD charts, rock types, mineral types and amounts were determined semi-quantitatively; Mineral types and amounts were quantified using these XRD charts and the Siroquant software program

Sample	Rock Type	smc	ill	chl	amp	Op-CT	Qtz	Fds	Opal A
M-1	Histosol	1.5	18.7	19.9	4.2	10.1	11.6	34.0	+
M-2	Histosol	5.7	18.1	17.6	3.9	3.9	6.9	43.9	+
M-3	Histosol	1.4	16.0	13.4	6.1	6.8	6.3	50.0	+
M-4	Histosol	3.4	14.8	7.8	6.6	11.9	5.8	49.6	+
M-5	Spodosol	1.3	2.6	0.5	0.5	4.8	2.9	51.3	+

M-6	Spodosol	2.8	9.9	15.4	2.7	4.8	4.2	60.3	+
M-7	Inceptisol	3.7	18.9	20.4	6.5	3.0	15.0	32.5	+
M-8	Inceptisol	4.8	17.9	10.8	7.8	17.5	12.5	33.6	+
M-9	Mollisol	0.6	10.2	12.0	11.1	7.9	18.2	40.0	+
M-10	Andisol	0.6	11.8	13.3	0.1	4.3	7.5	43.8	+
Ov-!	diatomite	acc	acc	acc	+++	++	+		+
Tuff	tuff			acc	acc	++	++	++	+
Rhyolite					acc	+	++	+++	+

smc: smectite, ill: illite, chl: chlorite, amp: amphibole, o-ct: opal CT, qtz: quartz, fds: feldspar, +: relative abundance of mineral, acc: accessory

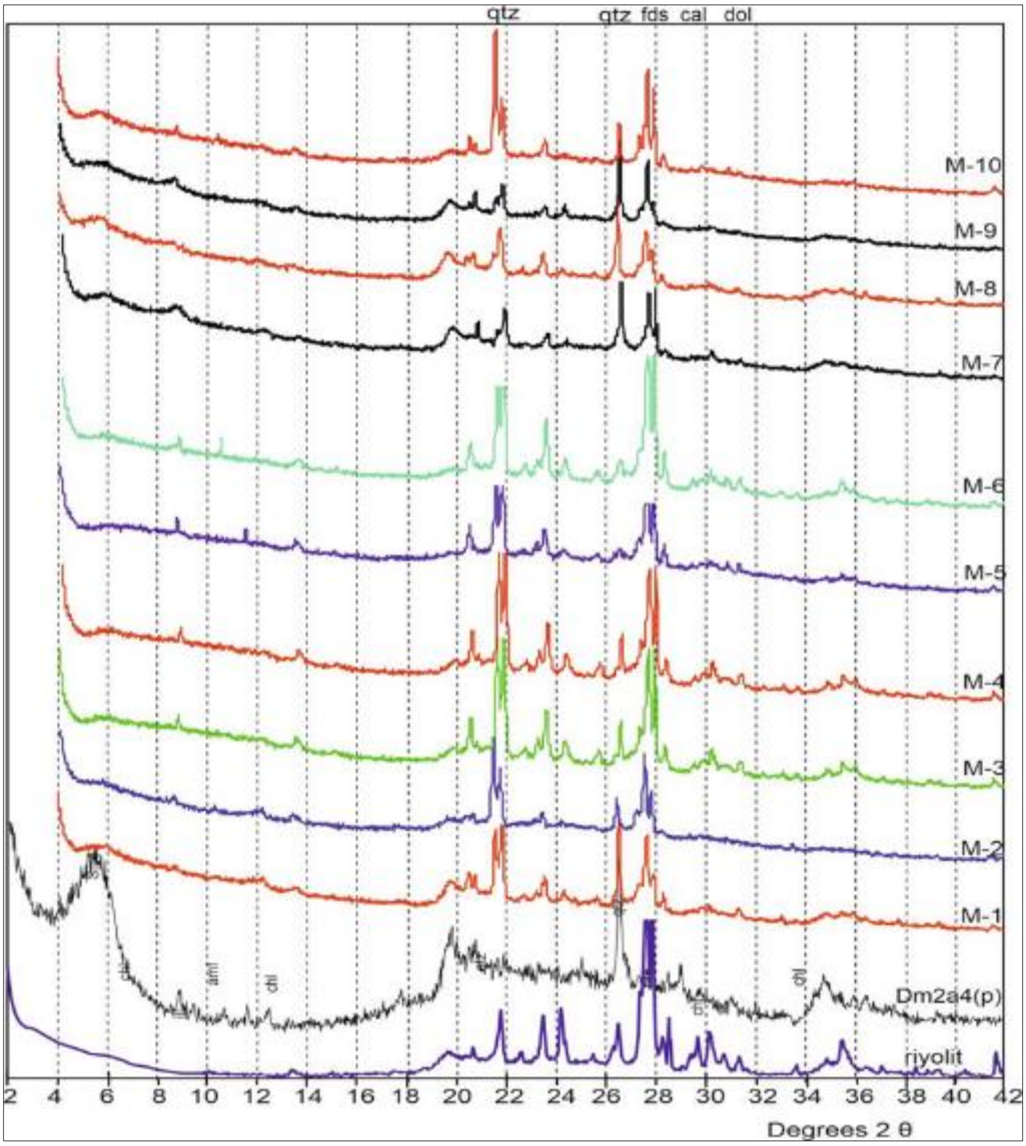


Figure 4 XRD patterns of the Melendiz profile and an example of their evaluation

4. Discussion

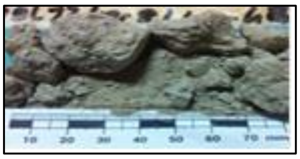
The Niğde - Çiftlik Plain is situated in a relatively low-lying perimeter. To the northwest, it is bordered by the volcanic heights of southern Cappadocia, including Hasandağ, Keçiboyduran, and Melendizdağ. In the north, it extends towards the Sileğin corridor at the base of Göllüdağ. The plain is fed from the Derinkuyu Plain, forming its eastern gravitational basin, and extends towards the northeast. Additionally, the plain is flanked by low-lying areas on its eastern and western sides: to the west are the Cappadocia Keçiboyduran and Melendizdağ formations (dating from the late Miocene and Pliocene), while to the east are deformed volcanic rocks forming the Göllüdağ-Melendiz barrier. Characterized by its notably flat terrain, the Çiftlik plain is covered with dry, low-level steppe vegetation. The elevation of the plain is approximately 1400 meters near Çiftlik, gradually decreasing to 1220 meters in the Derinkuyu plain to the southwest of the research area, which acts as a natural boundary between the two plains. Corresponding with the elevation change, the current flow network of the plain runs from northwest Çiftlik to southwest, namely Ihlara-Aksaray direction.

Faults running from northeast to southwest have formed in the research area, creating a depression zone where the Central Anatolian Volcanic Province spans 300 kilometers in length and 60 kilometers in width. This depression is filled with ignimbrite, volcanic rocks, paleosol, caliche, and sedimentary rocks. The younger Tuz Gölü Fault intersects this basin as a right-lateral strike-slip fault in a northwest to southeast direction. Due to the longstanding activity of similar faults in the region over millions of years, the Bor Plain resembles a chessboard pattern, with travertine, silica, or kaolin clays forming at the junctions of these faults, often observed as hydrothermal outlets.

The arid climatic conditions observed in the Melendiz fluvial system at the onset of the Holocene, coinciding with the occupation of the Aşıklı site (>8300 to 7500 BC), can also be examined in reference to studies conducted by van Zeist & Bottema (1991) and Bottema (1999). These researchers identified a westward expansion of delayed precipitation increase during the Early Holocene in Anatolia, extending up to 2000-3000 years in the central Anatolian plateaus. The mineralogical composition of sediment fill in Eski Acıgöl similarly reflects a decrease in precipitation alongside temperature rise during the initial two millennia of the Early Holocene. Additionally, a glacier advance in Erciyes around 7200 BC, indicative of increased precipitation, was documented by Sarıkaya et al. (2009). In the semi-arid Konya plain, evidence of reduced humidity during the early Holocene is supported by hydrographical data, with local-scale precipitation increase commencing around 6000 BC (Kuzucuoğlu et al., 1999a and b; Kuzucuoğlu, 2002).Hence, the rising temperatures experienced during the initial millennia of the Holocene in Central Anatolia did not coincide with an increase in precipitation. This climatic scenario resulted in arid conditions, likely persisting until approximately 6000 BC (equivalent to 8200/8000 cal. BP) in the Konya Plain.

Table 6 Description of the lithologic and pedologic profiles(cores) and paleoenvironmental interpretation of the Quaternary fills of the Melendiz Confluence (Çiftlik Plain) Central Anatolia,Turkey

Facies	Code	Description	Interpretation	Field Photo
Lithofacies-A Dark peat	Dp	Dark gray, contains small pebbles/gravels, contains plant remains, compacted and massive, muddy matrix, angular to well rounded, poorly sized, fine to coarse grains, ca. 50 cm thick	Fluvial	
Lithofacies-B Black soil	Bk	Black in color, disappearing and containing numerous gravels/pebbles, angular to well rounded, finely granular, numerous plant remains, poorly to moderately sized, 50cm-130cm thick, embedded in muddy matrix,	Alluvial	
Lithofacies-C Brown soil	Bs	Brown to grayish color, rare plant material, numerous gravels and pebbles, sandy matrix, fine to granular, subangular to rounded, weak to medium-sized, thickness 130 cm to 171 cm.	Alluvial	

Lithofacies-D Brown peat	Bp	Brown, contains dark/white pebbles, mud and sandy matrix, semi-angular to well rounded, medium to well sized, thickness 171cm-185cm.	Alluvial	
Lithofacies-E Grey gravel	Gg	Grey to dark grey, medium to very coarse grains, sub-angular to well-rounded, medium to well-sized, granular to cobble grains, thickness 185cm-260cm	Alluvial	
Lithofacies-F Grey silty sands	Ss	Dark grey, medium to very coarse grains, small pebbles, muddy matrix, angular to moderately rounded, poor to medium sized, thickness 260cm-318cm.	Alluvial	
Lithofacies-G Grey sands	Gs	Greenish grey, very fine to coarse grained, embedded in a muddy matrix, well-sized and well-rounded, thickness 318 cm-400 cm	Lacustrine	
Lithofacies-H Orange gravel	Og	The pebbles are 5 cm long, grained pebbles, some pebbles interconnected with clays, sub-angular to well rounded, medium to well sized, thickness 400cm-481cm.	Alluvial	
Lithofacies-I Grey clay	Gc	Grey, fine to very fine grains, some plan inclusions, embedded in muddy matrix, well-sized and well-rounded, 481cm-492cm thick.	Lacustrine	

Lithofacies-J Blue clay	Bc	Dark grey-blue, very fine to coarse grains, subrounded to rounded, muddy matrix, medium to well-sized, massive, thickness 567cm-580cm (riprap) then continues up to 661cm, rare large boulders up to 6cm	Lacustrine	

The profile mentioned above consist of clayey, silty, muddy, sandy, and occasionally pebbly or gravelly paleo-soils, along with sand, silt, clay, or gravel accumulations. Clastic layers in these profiles typically indicate periods of intense wind, storms, flash flooding, and precipitation, such as gravel accumulation. These deposits, lasting less than a hundred or a thousand years, do not show significant paleosol or swamp soil development, hence are described as vegetation-free units. Detailed lithological studies, particularly climate records, can be traced in marshes or alluvial fans around lakes or their shores. Comparing the Çiftlik plain's climate over the past 20,000 years, alternating between rainy and dry periods is observed, especially 11-7.5 thousand years ago (BC) during the Early Holocene, often marked by debris due to flash floods, storms, or natural disasters like earthquakes, volcanism, fire, landslides, etc. Similar detailed studies have been conducted in Central Anatolia by Bottema and Woldring (1984), Fontunge et al. (1999), and Kuzucuoğlu et al. (1999). This study, initiated in 2014, thoroughly examined significant locations in the northern, southern, and central areas of the Çiftlik plain.Similar discoveries were made in nearby areas, such as the Konya plain and Ereğli-Akgöl regions. For instance, Bottema and Woldring (1984) conducted pollen and age analysis on three levels, Fontunge et al. (1999) concentrated on facies and geomorphology studies, and Kuzucuoğlu et al. (1999) conducted facies and mineralogical studies.

Between 7.5 to 6.5 thousand years ago (Middle Holocene), the climate in the Çiftlik basin fluctuated between rainy and dry periods, particularly from 6.5 to 4.0 thousand years ago (BCE), marked by clastic inputs like flash floods, storms, and natural disasters. These environmental changes necessitated significant decisions for human communities living during this time. While the plain was previously humid with abundant water resources and fertile soils, it began experiencing the impacts of natural disasters and dry spells, leading to desertification at a later stage compared to the Bor plain. Consequently, human societies settled near freshwater sources such as lakes, streams, and springs, leading to the formation of many ancient mound areas in Central Anatolia during the late Middle Holocene.

4.1. Geomorphology

Similar to Anatolia, the Melendiz Stream Basin's geomorphology has been shaped during the Quaternary period. Initially formed by volcanic activity, the landscape was later influenced by atmospheric events, resulting in the creation of complex valley forms, cliffs, crevices, caves, and rocky hills. The morphological components observed in the study area and its surroundings include hilly-mountainous areas, piedmont plains east of the Çiftlik district, and the Ihlara Canyon Valley. Erosion, influenced by volcanic ash and tuff, along with surface water, has led to the emergence of unique rock formations and landscapes, particularly evident on the slopes of the Ihlara Canyon Valley due to water and wind erosion.

Limitations

While the article discusses the depositional sequences of sediments brought in by the Melendiz stream during the Quaternary period, there may be a gap in our understanding of the broader paleoenvironmental dynamics and processes shaping these sedimentary sequences. Further research could aim to investigate the drivers of sedimentation, such as changes in tectonic activity, and climate fluctuations, and their impacts on sediment transport and deposition patterns.

Although the research provides some information about the composition and characteristics of the Quaternary fills, there may be gaps in the detailed characterization of sedimentary facies, including variations in grain size and sorting(see Ghislain Berlin et Gürel,2023). More comprehensive sedimentological analyses could help elucidate the depositional environments and depositional processes involved in the formation of these sedimentary sequences.

Despite the analysis of sedimentological, mineralogical, and XRD data, there may be a gap in terms of the integration and synthesis of these datasets to provide a comprehensive understanding of the sedimentary sequences and their paleoenvironmental significance. Further research could focus on integrating multiple lines of evidence, such as geochemical analyses, micro-fossil studies, and geochronological dating, to refine interpretations of paleoenvironmental conditions and climate variability during the Quaternary period.

Therefore addressing these research gaps could enhance our understanding of Quaternary sedimentary dynamics, paleoenvironmental changes, and their implications for regional geology, climate history, and environmental evolution.

5. Conclusion

This research has provided valuable insights into the Quaternary fills and associated climate records of the Çiftlik Plain and the Central Anatolia Cappadocia Volcanic Province. By examining the depositional sequences of sediments brought by the Melendiz stream during the Quaternary period, we have identified a diverse range of terrestrial sediments and paleosols. Through detailed analysis of sedimentological, mineralogical, and XRD data, we have determined the mineral types, distributions, chemical components, and trace elements within the sediments. Furthermore, the relationship between these data and paleoclimate records has been explored, revealing important insights into past environmental conditions. Notably, the regression of the Pliocene lake and the influence of both neotectonic activity and environmental factors during the Quaternary period have been identified as significant drivers of sedimentation processes. The findings from this research contribute to our understanding of sediment-paleosol formation processes, with implications for the Quaternary and primarily Holocene epochs in the region. This area can conveniently be compared and are similar to Ovalibağ in many aspects such as sedimentological, XRD, common mineralogy and Petrography ,age, grain size as researched by Ghislain Berlin ve Gürel. The conclusion therefore is that the sediments are of the same age.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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