FORMATION MODELS OF KONYA SINKHOLES AND THEIR RELATION TO EARTHQUAKES

Editor
RAMAZAN DEMIRCIOĞLU

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Preface

‘Sinkhole’, “doline” or structures referred to as ‘opan’ by the locals in the Karapınar (Konya) region are natural karst formations. Karst formations are shapes created in water-soluble rocks (mainly limestone, gypsum, etc.). Naturally formed sinkholes have attracted the attention of people and local and foreign scientists for years, both because of their potential to cause local disasters and because of their interesting and beautiful appearance. The development and spread of written and visual communication with globalisation has increased interest in these structures both nationally and internationally.

Furthermore, both global warming and excessive agricultural water use have accelerated surface deformations (surface faulting and surface fissures) and sinkhole formation, particularly in Konya and throughout Central and Western Anatolia. These formations are attracting worldwide interest in terms of the observed effects of global warming. The subsidence caused by the lowering of the groundwater level due to global warming and excessive agricultural water use has contributed to the increase in the number of sinkholes and the acceleration of sinkhole formation. In other words, while in the past a sinkhole formed every 20 years, today dozens of sinkholes form every year in the Karapınar region.

This also occurs in various ways today. One reason for this is that the decline in water levels in the voids has reduced the support provided by the overlying cover, causing previously existing voids to collapse. New collapses and sinkholes have also developed as a result of surface water infiltration through surface fissures and faults. In addition, excessive irrigation has caused the overlying cover to loosen, and the extraction of excessively fragmented material through drilling has also led to the formation of sinkholes in some places.

Sinkholes are widespread in Turkey, particularly in the Karapınar district of Konya, as well as in other provinces such as Sivas, Eskişehir, Siirt, Diyarbakır, Çankırı, Antalya, Mersin, Afyon, Kırşehir, Kastamonu, etc., and in relatively remote areas of the Taurus Mountains. To date, new sinkhole formations have generally occurred in agricultural areas and areas with low population density. Fortunately, there have been no casualties to date.

The Konya Obruk (Sinkhole) Plateau features numerous sinkholes, each a 'natural wonder,' some of which are water-filled (such as the Kızören Sinkhole) and some of which were water-filled until recently (such as the Çıralı and Meyil sinkholes). In this respect, the region resembles an open-air museum.

This four-part book also deals with sinkholes in the Konya region. The first part examines the relationship between earthquakes and sinkholes, while the second part analyses sinkhole formations in the Altınekin (Konya) region. The third chapter explains the geological and morphological characteristics of a sinkhole formed in the ancient rocks we call the Central Tauride, while the fourth and final chapter models the formation of sinkhole types in the region over time by presenting the geological and structural characteristics of a sinkhole with a similar structure to those found on the Obruk Plateau. The book will contribute to a better understanding of sinkholes in the Konya region and to modelling their formation.

Assoc. Prof. Dr. Ramazan DEMİRCİOĞLU

THE RELATIONSHIP BETWEEN SINKHOLES AND EARTHQUAKES IN THE KARAPINAR REGION (KONYA-CENTRAL ANATOLIA)

ŞEYDA PARLAR[1]
BERKANT COŞKUNER[2]
YAŞAR EREN [3]

Introduction

Generally circular, closed depression areas in the earth's crust are defined as sinkholes (doline, Cvijić, 1893; Williams, 2004; Waltham et al., 2005). Sinkhole formation is essentially a karst processes and is related to rock type, groundwater and fractures (Waltham et al, 2005). Apart from these, there are also secondary causes lead to sinkhole formation. The formation of sinkholes in some provinces after major earthquakes in our country has directed people's minds to whether there is a relationship between earthquakes and sinkhole formations.

[1] Asst. Prof. Dr., Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geological Engineering, Orcid: ID/0000-0003-1048-0100
[2] Asst. Prof. Dr., Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geological Engineering, Orcid: ID/0000-0002-9798-8793
[3] Prof. Dr., Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geological Engineering, Orcid: ID/0000-0002-7899-8507

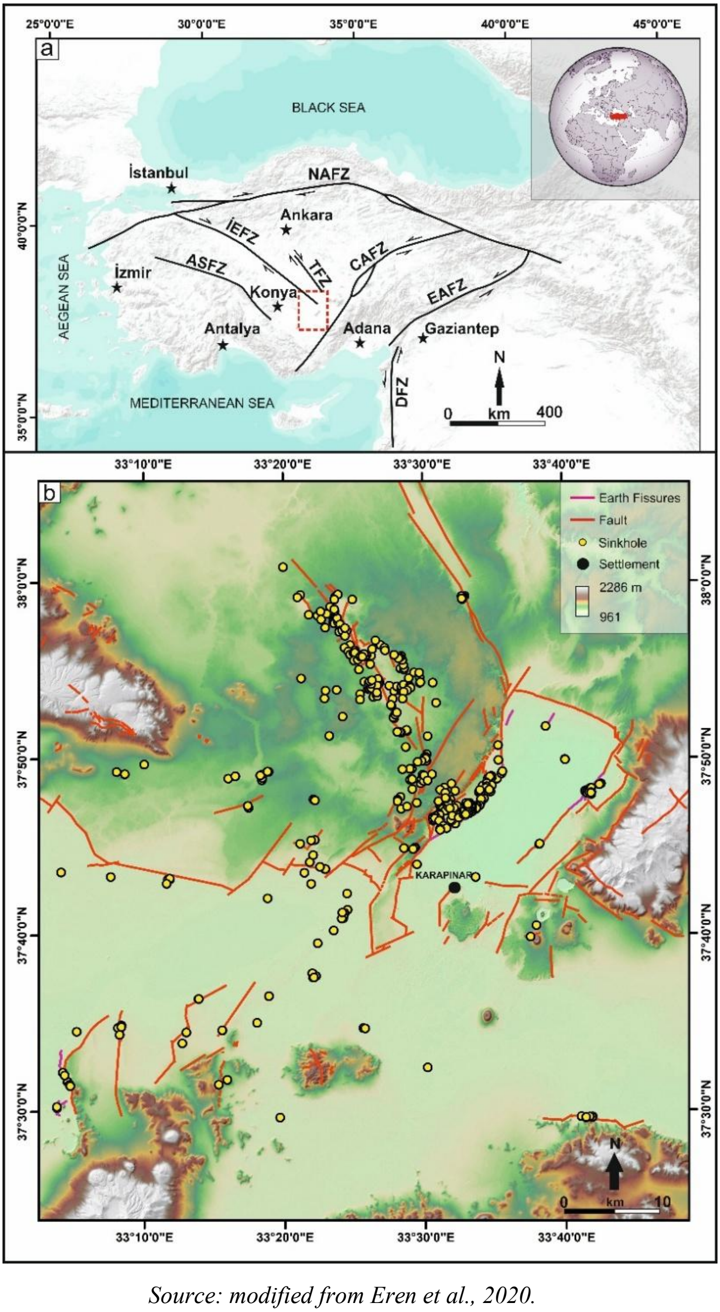
There are many old and newly formed sinkholes in Konya and especially in the Karapınar district and its surroundings in Türkiye. For this reason, one of the best areas where the relationships between sinkhole formation and earthquake tremors can be tested is the Karapınar (Konya) region.

Karapınar District (Figure 1), located in the eastern part of Konya Province in the Central Anatolian region of Türkiye, has many sinkholes with dimensions ranging from 1 m to 1 km. The study area is located approximately 70 km southeast of Konya Province in the Central Anatolia Region and include the Karapınar region (Figure 1).

There are many investigation about sinkholes in Konya Closed Basin (KCB) which includes Karapınar. Some of these studies are hydrogeological and geomorphological, some are about natural heritage, some are about groundwater level changes in the region (e.g. Lahn, 1940; Erinç, 1960; Eroskay, 1976; Eroskay and Günay 1979; Güldalı and Şaroğlu, 1983; Canik and Çörekçioğlu 1986; Erol, 1986, 1991; Biricik, 1992; Çörekçioğlu, 1994; Canik,1997; Canik and Arıgün, 2001; Karadoğan, 2001; Arslan and Göçmez, 2007; Doğdu et al., 2007; Gürler and Timur, 2007; Üstün et al., 2007; Bulduk et al., 2008; Göçmez et al., 2008a, 2008b; Kara et al., 2008; Bayari et al., 2009; Ertek, 2009; Tapur and Bozyiğit, 2009: Günay et al., 2010; Törk et al., 2010; Doğan and Yılmaz 2011; Göçmez, 2011; Özdemir, 2015a, 2015b; Walltham, 2015, Orhan et al., 2020; Eren at al., 2024, 2025).

In the contents of this study carried out in Karapınar and its surroundings (east of Konya Closed Basin-KCB), it is aimed to determine whether there is any relationship between the sinkholes with known formation date and the earthquakes which were occurred in the same periods.

Figure 1: Location map of the studied area



Source: modified from Eren et al., 2020.

Methods

Archive information about earthquakes was obtained from the web page of Boğaziçi University Kandilli Observatory http://www.koeri.boun.edu.tr/sismo/zeqdb/. For this study, a search was conducted for archive information on earthquakes that occurred between 01.01.1900 and 30.06.2025 in the area between 37.00^0-38.50^0 longitudes and 33.00^0-34.00^0 latitudes by selecting the 0.0-9.0 earthquake magnitude range. In order to determine the formation age of the existing sinkholes in Karapınar region, public institutions and organizations records, information obtained from local people and satellite images of the past were used.

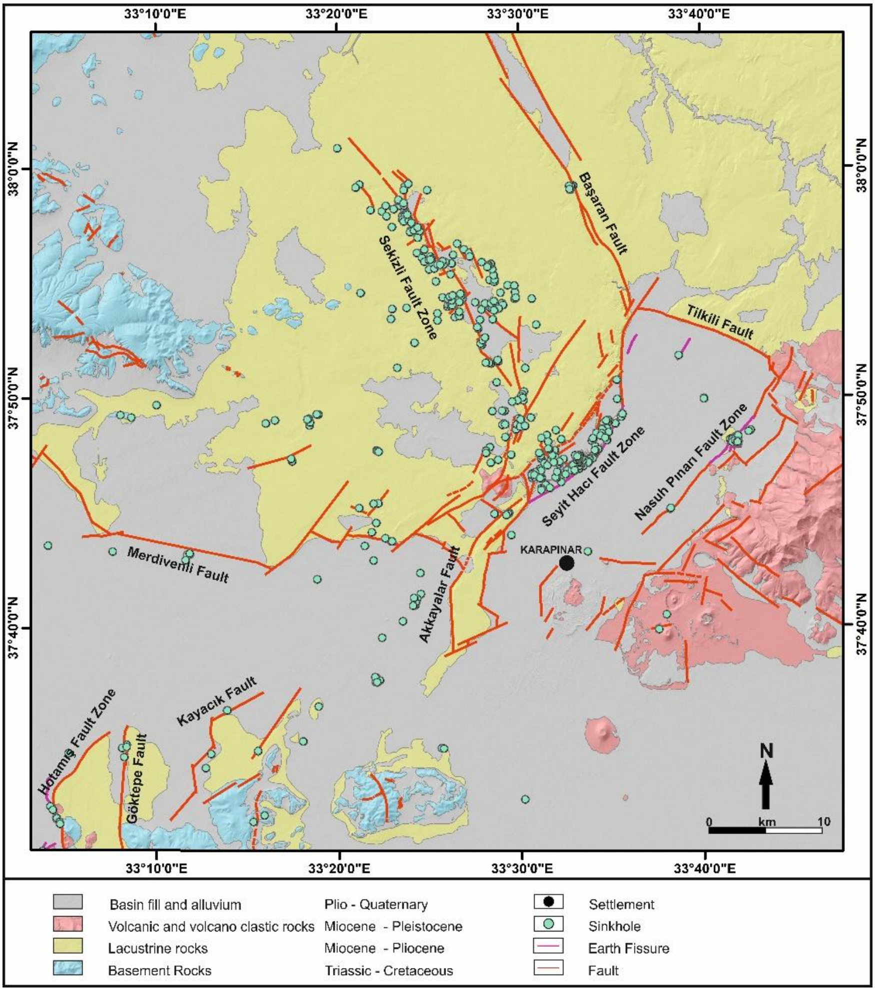
The age of formation of the sinkholes were compared with the seismic events in the earthquake catalogs and the earthquake surface epicenters in the same region and it was examined whether there was a connection between them.

Geological features of the Karapınar region

Rocks in the study area can be grouped under 4 main groups; (1) Triassic-Cretaceous aged basement rocks (2) Miocene-Pliocene aged lacustrine limestones and continental rocks (3) Miocene-Pleistocene aged volcanic and volcano-clastics rocks and (4) Plio-Quaternary aged basin and alluvial rocks (Figure 2).

Triassic-Cretaceous basement rocks crop out in the study area as isolated outcrops of different sizes among other rocks, mostly at higher elevations. The oldest unit of the basement rocks, which crop out in areas elevated by faults in some sections, is composed of quartzite, marble, calcschist phyllite alternation. This unit is conformably overlain by Triassic-Jurassic gray-dark gray dolomites at the bottom and marble, dolomite and crystallized limestones in the upper sections. This unit conformably show transitions laterally and vertically to Jurassic-Cretaceous pelagic limestone and chert interlayered crystallized limestones. The youngest unit of the basement rocks is composed of Cretaceous ophiolitic mixed consisting of serpentinite, volcanite, gabro, crystallized limestone, blocky sandstone and olistostrome.

Figure 2: Geological map of the Karapınar region.



Source: modified from Törk et al., 2019 and Eren et al., 2020.

The Miocene-Pliocene aged terrestrial rocks, which constitute the second assemblage of the study area, unconformably cover the basement rocks and Adakale andesites. The lowest unit of this assemblage is the Miocene-Pliocene aged İnsuyu formation. The İnsuyu formation is made up of red conglomerate-sandstone-mudstone alternations, micritic, silicified limestone, dolomitic limestone, marl, limestone and claystone alternations, and conglomerate and claystone-mudstone alternations in the form of intermediate levels, from bottom to top. The formation consists of ignimbrite-tuff alternations and lacustrine limestones at the top. The youngest units of these Tertiary aged units are conglomerate, sandstone, claystone, mudstone at the bottom and lacustrine limestones at the top.

The oldest unit of the Miocene-Pleistocene volcanic rocks that form the third assemblage of the study area is the Miocene andesites that cut the basement rocks. The second unit of the rocks in question is the Pliocene Karacadağ volcanics. Karacadağ volcanics consist of agglomerate, andesite, basalt, dacite and rhyolite from old to young. The Kılavuztepe basalt is located on top of this unit. The uppermost unit of the volcanic assemblage is the Karapınar volcanics. Karapınar volcanics consist of maar pyroclastics, basalt and scoria.

The youngest assemblage of the study area consists of Pliocene-Quaternary rocks. The first unit of this assemblage is Pleistocene-aged carbonate-bound blocky conglomerates. Pleistocene-aged gravel-block-sand and mud alternation in the form of Divanlar formation unconformably overlies the lower units. This unit is overlain by Tuzgölü formation consisting of gravel, sand, clay, gypsum clay and calcareous clay, horizontally bedded sand-silt and organic soil clay-sand from bottom to top. Koymatyayla formation consisting of horizontally and cross-bedded gravel-sand and carbonate clay, silt, sand and marl unconformably overlies Tuzgölü formation. All these units are unconformably overlain by Pleistocene-Holocene Hotamış formation. Hotamış formation consists of large and small scale cross-bedded gravel, sand, horizontal and cross-bedded gravel-sand, horizontally bedded gravel sand, silt, clay, horizontally bedded carbonated silt-clay, slightly gypsum nodules, cross-bedded gravel-sand and organic soil clay. The youngest units of Quaternary age consist of wind dunes, travertine, slope debris, old alluvial fan, new alluvial fan and alluviums (Törk et al., 2019; Figure 2).

Most of the sinkholes in the study area were developed directly in the Miocene-Pliocene aged Insuyu Formation or in the Plio-Quaternary aged alluvial rocks overlying this formation. Some of the sinkholes are in Mesozoic aged limestone and dolomitic limestone. A few of them have been observed in volcanic rocks.

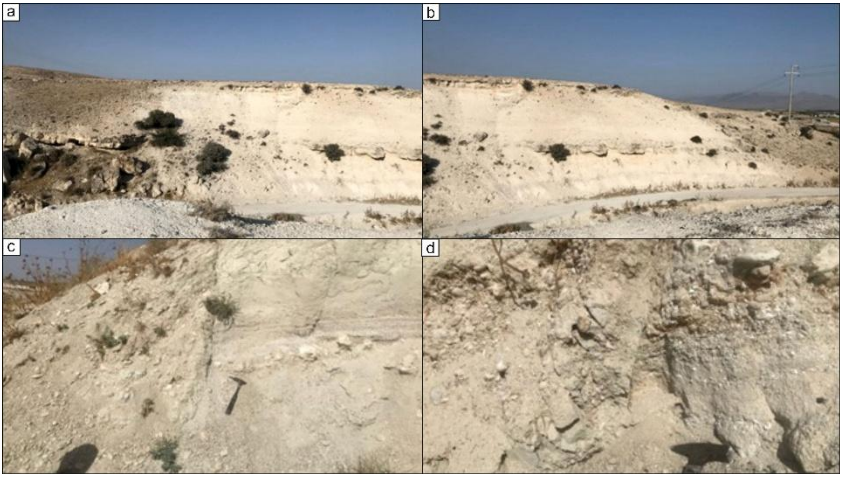
Main faults of the Karapınar region

The study area is located in the region called Central Anatolian Ova Regime (Şengör, 1980) in terms of Neotectonic position. It is located in the Konya-Eskişehir sub-Neotectonic region (Koçyiğit and Özacar, 2003). In this section where an extensional tectonic regime is dominant (Eren et al., 2025) the NW-SE trending Tuzgölü fault zone passes close to the north of the study area and the branches of the İnönü-Eskişehir-Sultanhanı fault zone extend into the study area (Figure 1). Niğde fault zone borders the study area from the southeast. Further south lies the NE-SW trending Ecemiş fault zone with left-directional strike-slip. The NW-SSE trending Göçü fault zone, which borders Bozdağ, is also located in the near west of the study area.

The NW–SE and NE–SW trending major faults and related graben-horsts are dominant structural features of the region (Eren et al.,2025; Figure 2). Besides these, E-W and N-S trending faults developed in the region. Seyit Hacı, Nasuh Pınarı, Sekizli and Hotamış Fault Zones and Kayacık, Akkayalar, Başaran, Merdivenli, Tilki, Akgöl and Göktepe Faults are important structural features.

The Karapınar Basin is bounded by 35 km length and 3 km width Seyit Hacı Fault Zone in the northwest (Eren et al.,2025; Figure 2, Figure 3a-b), 35 km length and 3 km width Nasuhpınarı Fault Zone in the southeast.

Figure 3: Field photographs of (a and b) the Seyithacı fault zones and (c and d) Akkaya faults



Source: Eren et al, 2020 and 2025.

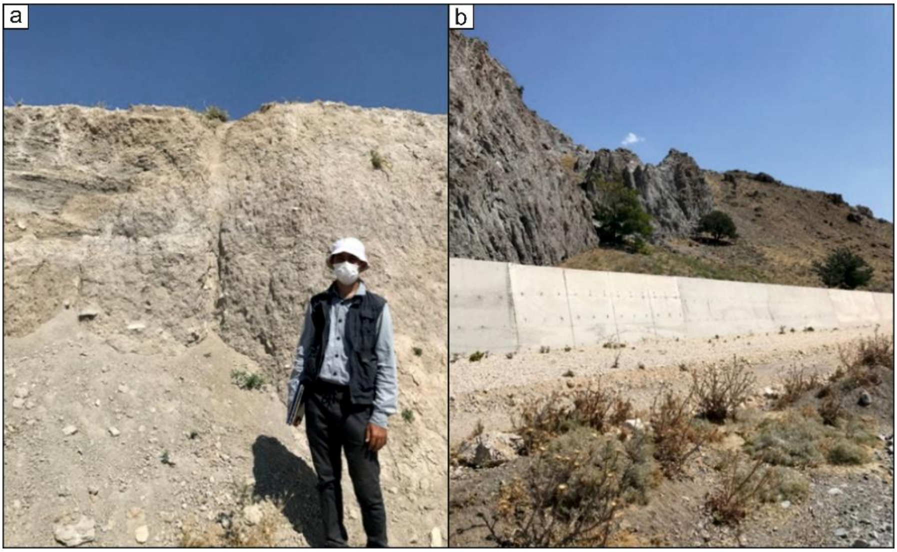
The Akkayalar fault is a normal fault with a minor left lateral slip component (Figure 2, Figure 3c-d). The Sekizli Fault Zone which are located northwest of the Karapınar Basin has 26 km lenght and 2 km width. The NW-SE trending Başaran Fault, located in the northern part of the study area has 28 km length, which is right-lateral oblique normal fault. The WSW-ENE trending Merdivenli Fault is a normal fault with a length of 38 km (Figure 2, Figure 4).

The Hotamış fault zone (Ulu et al., 1994) is a N-S oriented fault located in the southwest of the study area. HFZ starts from the southeast of Adakale and is 12 km in length (Figure 5) The field observations demonstrate that the faults trending E-W and WNW-ESE were cut by NE-SW trending faults and the region was affected first by the NNE-SSW and later by NW-SE oriented extensional tectonic regime.

Figure 4: Field photographs of (a, b and c) the Merdivenli fault zones. (d) small neptunian dikes related to the faults.

Source: Eren et al, 2020 and 2025.

Figure 5: Some field views from the Hotamış Fault Zone



Source: Eren et al, 2020 and 2025.

Earthquake and sinkhole data

Kandilli Observatory seismic data were recorded 182 earthquakes between 1900 and 2020 in the Karapınar region (Table 1, Table 2, Table 3, Table 4, Table 5). The number of sinkholes which of formation date can be determined in the region is 101 (Table 6, Table 7, Table 8). These sinkholes and earthquakes were paired, ordered chronologically, and their distribution was examined by marking them on the map in order to examine the presence of the relationship between them. The majority of earthquakes and sinkholes occurred in the northwest and northeast parts of Karapınar. In general, it is seen that sinkholes are not directly related to earthquakes in terms of temporal and spatial. It was observed that there was a small number of earthquake occurrence just before each sinkhole formation. It has been determined that even in years with intense earthquakes, a small number of sinkholes were formed, and the formed sinkholes are very far from the earthquake locations.

Likewise, it is observed that very few earthquakes have occurred after the sinkhole formation. Despite all these, when the formation time is not considered, there are small earthquake records in the regions where there are sinkholes, albeit a small number.

According to the data of Boğaziçi University Kandilli Observatory (http://www.koeri.boun.edu.tr/sismo/zeqdb/), 182 separate earthquakes with magnitudes ranging from 1.0-5.2 were recorded in Konya, Aksaray and Karaman provinces located in Karapınar and its immediate vicinity for 120 years between 1900 and 2020. These earthquakes (Table 1, Table 2, Table 3, Table 4, Table 5) were formed in the region during the same periods with the sinkholes (Table 6, Table 7, Table 8).

The largest earthquake recorded in the region within 120 years was 5.2 magnitude and occurred on 13.12.1924 in Başaran-Eskil (Aksaray) between 380.000 latitude and 335.000 longitude at a depth of 030.0 km from the surface. The magnitude 1.0 earthquake that occurred on 10.11.2018 in Kavuklar-Ayrancı (Karaman), between 375.780 latitude and 335.180 longitude, at a depth of 003.6 km from the surface, is the least magnitude earthquake recorded in the region during this period. The closest earthquake to the present day which's magnitude was bigger than 3.0 occurred on 25.01.2019 in Esmekaya-Eskil (Aksaray) between 382.327 latitude and 334.810 longitude, at a depth of 003.4 km from the surface and a magnitude of 3.2 (Table 1, Table 2, Table 3, Table 4, Table 5, Figure 6). The earthquake and sinkhole distribution map clearly shows that most of the earthquakes occurred in the northwest and northeast of Karapınar and that there is no correlation between earthquakes and sinkholes formed during the same periods (Figure 6). It is noteworthy that earthquakes larger than 2.0 occurred in the region before 2013, whereas most of the earthquakes after 2013 had magnitudes of 2.0 and less. It was also observed that more than 15 earthquakes occurred in 2006, 2013, 2016 and 2018, thus increasing the number of earthquakes compared to other years (Table 1, Table 2, Table 3,Table 4,Table 5).

Table 1: Information on earthquakes between 1900-2020

Date	Latitude	Longitude	Depth (km)	xM	Type	Location
06.06.2020	381.132	330.595	000.0	1,7	Sm	Katrancı-Karatay (Konya)
30.05.2020	381.108	330.628	017.5	1,7	Ke	Katrancı-Karatay (Konya)
26.05.2020	382.318	333.198	006.9	1,7	Ke	Gumusdugun-Eskıl (Aksaray)
15.05.2020	380.948	330.613	000.0	1,6	Sm	Katrancı-Karatay (Konya)
27.04.2020	380.020	339.417	023.8	1,8	Ke	Demırcı-Emırgazı (Konya)
01.04.2020	381.092	330.483	000.0	1,6	Sm	Katrancı-Karatay (Konya)
17.01.2020	381.577	330.927	000.0	1,2	Sm	Ipekler-Karatay (Konya)
17.12.2019	374.820	337.052	013.0	2,5	Ke	Ambar-Ayrancı (Karaman)
14.12.2019	381.753	331.067	000.0	1,5	Sm	Ipekler-Karatay (Konya)
10.12.2019	380.648	330.342	000.0	1,2	Sm	Karadona-Karatay (Konya)
01.11.2019	380.673	335.145	009.9	1,7	Ke	Basaran-Eskıl (Aksaray)
25.10.2019	376.610	334.628	011.1	1,3	Ke	Karapınar (Konya)
26.07.2019	376.280	337.122	005.0	1,5	Ke	Kesmez-Karapınar (Konya)
11.06.2019	374.473	337.433	012.6	1,7	Ke	Bogecık-Ayrancı (Karaman)
10.06.2019	374.110	333.785	011.8	1,8	Ke	Burunoba- (Karaman)
09.03.2019	375.018	335.932	012.0	2,5	Ke	Kavuklar-Ayrancı (Karaman)
02.03.2019	376.990	336.633	007.3	1,5	Ke	Kesmez-Karapınar (Konya)
28.01.2019	377.887	333.090	018.9	1,8	Ke	Akcayazı-Karapınar (Konya)
25.01.2019	382.327	334.810	003.4	3,2	Ke	Esmekaya-Eskıl (Aksaray)
03.01.2019	379.433	330.752	009.8	1,7	Ke	Yaglıbayat-Karatay (Konya)
19.12.2018	381.508	330.817	000.0	1,8	Sm	Ipekler-Karatay (Konya)
07.12.2018	379.630	330.433	019.6	1,6	Ke	Yaglıbayat-Karatay (Konya)
11.11.2018	375.753	335.425	015.8	1,9	Ke	Kavuklar-Ayrancı (Karaman)
10.11.2018	375.780	335.180	003.6	1	Ke	Kavuklar-Ayrancı (Karaman)
10.11.2018	376.913	333.603	016.0	1,2	Ke	Hotamıs-Karapınar (Konya)
31.10.2018	381.020	333.245	008.6	2	Ke	Bayramdugun-Eskıl (Aksaray)
20.10.2018	380.675	330.543	000.0	1,5	Sm	Karadona-Karatay (Konya)
15.10.2018	374.870	336.545	007.5	1,9	Ke	Ambar-Ayrancı (Karaman)
10.10.2018	374.837	336.730	011.8	2,4	Ke	Ambar-Ayrancı (Karaman)
10.10.2018	380.985	330.798	000.0	1,6	Sm	Katrancı-Karatay (Konya)
09.10.2018	374.775	336.147	005.9	2,6	Ke	Ambar-Ayrancı (Karaman)
27.09.2018	374.203	337.588	015.7	2,5	Ke	Agızbogaz-Ayrancı (Karaman)

Source: http://www.koeri.boun.edu.tr/sismo/zeqdb/, Eren et al., 2020.

Table 2: Information on earthquakes between 1900-2020

Date	Latitude	Longitude	Depth (km)	xM	Type	Location
24.09.2018	374.180	337.253	007.8	1,9	Ke	Saraykoy-Ayrancı (Karaman)
29.08.2018	375.073	332.280	009.0	1,5	Ke	Karacaoren- (Karaman)
26.08.2018	377.305	334.408	013.8	1,7	Ke	Karapınar (Konya)
15.08.2018	381.420	330.725	000.0	1,4	Sm	Ipekler-Karatay (Konya)
31.07.2018	381.145	330.362	000.0	1,6	Sm	Katrancı-Karatay (Konya)
31.07.2018	376.112	330.955	008.0	1,7	Ke	Surguc-Cumra (Konya)
21.06.2018	380.598	330.965	000.0	1,3	Sm	Karadona-Karatay (Konya)
18.04.2018	380.950	331.045	000.0	1,5	Sm	Katrancı-Karatay (Konya)
05. 04.2018	374.458	336.590	011.5	2	Ke	Ambar-Ayrancı (Karaman)
03. 04.2018	379.112	330.503	006.6	2	Ke	Yaglıbayat-Karatay (Konya)
12.01.2018	380.310	332.853	018.6	1,8	Ke	Buyukburnak-Karatay (Konya)
08.01.2018	374.937	331.315	023.2	1,7	Ke	Adakale-Cumra (Konya)
07.01.2018	373.840	337.302	008.0	1,7	Ke	Ayrancı (Karaman)
12.11.2017	377.298	335.268	016.2	1,9	Ke	Karapınar (Konya)
25.10.2017	374.137	335.082	004.7	1,8	Ke	Akcasehır- (Karaman)
25.09.2017	373.840	332.817	005.0	2	Ke	Osmanıye- (Karaman)
24.07.2017	378.993	336.380	012.1	1,7	Ke	Kayalı-Karapınar (Konya)
29.05.2017	377.260	334.015	012.8	1,4	Ke	Hotamıs-Karapınar (Konya)
13.04.2017	381.627	330.675	000.0	1,6	Sm	Ipekler-Karatay (Konya)
25.03.2017	379.185	334.248	008.0	1,7	Ke	Yenıkent-Karatay (Konya)
17.01.2017	378.868	333.978	004.6	1,5	Ke	Yenıkent-Karatay (Konya)
22.11.2016	377.490	334.160	012.9	2,2	Ke	Karapınar (Konya)
22.11.2016	379.172	339.127	007.8	1,7	Ke	Belkaya-Ereglı (Konya)
20.11.2016	376.050	336.817	000.0	1,2	Sm	Kesmez-Karapınar (Konya)
17.11.2016	379.113	337.765	015.5	2,2	Ke	Yamac-Emırgazı (Konya)
19.10.2016	375.273	336.007	005.6	2,4	Ke	Kavuklar-Ayrancı
29.09.2016	382.293	332.983	023.5	1,4	Ke	Celıl-Eskıl (Aksaray)
26.09.2016	381.208	335.487	003.7	1,7	Ke	Guneslı-Eskıl (Aksaray)
26.09.2016	381.075	335.173	004.7	1,6	Ke	Guneslı-Eskıl (Aksaray)
25.09.2016	381.332	335.263	005.3	2,9	Ke	Guneslı-Eskıl (Aksaray)
23.09.2016	376.823	331.960	009.3	2,7	Ke	Sazlıpınar-Karapınar (Konya)
17.09.2016	381.307	334.980	005.3	2,2	Ke	Guneslı-Eskıl (Aksaray)
17.09.2016	381.658	335.303	007.1	3,2	Ke	Guneslı-Eskıl (Aksaray)
17.09.2016	381.613	335.338	005.4	3,8	Ke	Guneslı-Eskıl (Aksaray)
24.07.2016	381.157	335.282	006.7	1,8	Ke	Guneslı-Eskıl (Aksaray)
23.07.2016	382.065	334.793	005.6	2,3	Ke	Esmekaya-Eskıl (Aksaray)
20.07.2016	382.135	336.020	002.3	1,8	Ke	Sultanhanı- (Aksaray)

Source: http://www.koeri.boun.edu.tr/sismo/zeqdb/, Eren et al., 2020.

Table 3: Information on earthquakes between 1900-2020

Date	Lati tude	Longi tude	Depth (km)	xM	Type	Location
24.06.2016	381.903	334.980	006.4	1,8	Ke	Guneslı-Eskıl (Aksaray)
13.06.2016	381.612	335.828	005.3	1,8	Ke	Guneslı-Eskıl (Aksaray)
13.06.2016	381.507	335.625	005.4	1,8	Ke	Guneslı-Eskıl (Aksaray)
18.04.2016	380.957	330.533	000.0	1,5	Sm	Katrancı-Karatay (Konya)
04.03.2016	376.387	334.625	005.8	2,3	Ke	Karapınar (Konya)
14.02.2016	379.025	334.197	010.4	1,6	Ke	Yenıkent-Karatay (Konya)
11.02.2016	380.273	330.855	000.0	2	Sm	Karadona-Karatay (Konya)
30.01.2016	378.167	333.887	000.0	1,5	Sm	Besagıl-Karatay (Konya)
06.01.2016	378.020	336.848	002.5	2,1	Ke	Yagmapınar-Karapınar (Konya)
02.01.2016	379.860	338.682	020.6	1,6	Ke	Demırcı-Emırgazı (Konya)
28.12.2015	380.665	330.705	000.0	1,8	Sm	Karadona-Karatay (Konya)
09.11.2015	381.928	335.605	014.5	1,8	Ke	Sultanhanı- (Aksaray)
23.06.2015	379.413	330.480	000.0	1,4	Sm	Yaglıbayat-Karatay (Konya)
21.06.2015	382.268	335.093	004.2	2,4	Ke	Sultanhanı- (Aksaray)
21.06.2015	382.118	334.772	004.3	2,4	Ke	Esmekaya-Eskıl (Aksaray)
30.03.2015	376.943	335.693	003.2	1,9	Ke	Karapınar (Konya)
15.03.2015	379.228	339.208	015.8	1,8	Ke	Belkaya-Ereglı (Konya)
09.09.2014	378.680	333.503	005.0	2,4	Ke	Yenıkent-Karatay (Konya)
09.09.2014	378.667	333.450	007.6	2,5	Ke	Yenıkent-Karatay (Konya)
21.08.2014	378.827	333.148	005.0	1,9	Ke	Besagıl-Karatay (Konya)
03.08.2014	381.953	334.297	015.2	1,7	Ke	Esmekaya-Eskıl (Aksaray)
12.05.2014	379.592	330.175	008.8	1,5	Ke	Yaglıbayat-Karatay (Konya)
15.04.2014	375.687	333.505	009.9	2,2	Ke	Islık-Karapınar (Konya)
15.04.2014	375.842	333.732	007.8	2,3	Ke	Islık-Karapınar (Konya)
14.04.2014	375.908	333.775	008.3	2	Ke	Islık-Karapınar (Konya)
14.04.2014	375.862	333.725	009.2	2,3	Ke	Islık-Karapınar (Konya)
09.03.2014	376.610	334.210	007.3	1,9	Ke	Hotamıs-Karapınar (Konya)
05.02.2014	378.003	335.772	014.1	1,7	Ke	Karapınar (Konya)
16.12.2013	374.797	333.673	013.8	1,7	Ke	Yenıkuyu-Karapınar (Konya)
07.12.2013	377.540	334.042	020.6	2	Ke	Karapınar (Konya)
07.12.2013	377.040	334.450	005.4	2,6	Ke	Karapınar (Konya)
23.11.2013	378.293	336.067	003.1	2,1	Ke	Yagmapınar-Karapınar (Konya)
23.11.2013	378.138	336.430	005.0	1,9	Ke	Yagmapınar-Karapınar (Konya)
21.11.2013	380.935	330.005	022.6	1,9	Ke	Kızılcakuyu-Selcuklu (Konya)
29.09.2013	376.478	334.665	003.2	2,3	Ke	Karapınar (Konya)
03.08.2013	374.260	333.053	005.5	1,9	Ke	Coglu- (Karaman)
01.08.2013	379.338	339.687	005.0	2	Ke	Belkaya-Ereglı (Konya)

Source: http://www.koeri.boun.edu.tr/sismo/zeqdb/, Eren et al., 2020.

Table 4: Information on earthquakes between 1900-2020

Date	Lati tude	Longi tude	Depth (km)	xM	Type	Location
10.04.2013	374.525	330.088	005.0	2,1	Ke	Erentepe-Cumra (Konya)
11.03.2013	374.637	338.565	015.2	2	Ke	Bogecık-Ayrancı (Karaman)
07.03.2013	374.955	337.582	012.0	1,8	Ke	Bogecık-Ayrancı (Karaman)
17.02.2013	374.580	330.145	009.3	1,9	Ke	Ortaoba- (Karaman)
13.02.2013	377.270	334.023	016.3	1,9	Ke	Hotamıs-Karapınar (Konya)
18.01.2013	380.982	334.228	007.3	2,1	Ke	Guneslı-Eskıl (Aksaray)
18.01.2013	379.128	331.475	015.3	2,6	Ke	Aksaklı-Karatay (Konya)
14.01.2013	374.447	330.400	012.7	1,8	Ke	Ortaoba- (Karaman)
23.12.2012	379.610	330.570	010.5	2,2	Ke	Yaglıbayat-Karatay (Konya)
23.12.2012	379.668	330.663	009.2	2,4	Ke	Yaglıbayat-Karatay (Konya)
23.12.2012	377.038	333.582	005.5	2,3	Ke	Hotamıs-Karapınar (Konya)
30.11.2012	381.628	334.013	005.4	2	Ke	Guneslı-Eskıl (Aksaray)
24.10.2012	379.267	334.908	010.9	2,1	Ke	Basaran-Eskıl (Aksaray)
22.05.2012	378.223	337.327	002.1	2,3	Ke	agmapınar-Karapınar (Konya)
27.11.2011	374.310	331.663	009.7	3,1	Ke	Madensehrı- (Karaman)
18.10.2011	381.078	330.655	005.0	2,3	Ke	Katrancı-Karatay (Konya)
12.09.2011	374.602	339.345	012.4	2,8	Ke	Karaburun-Ereglı (Konya)
09.09.2011	380.742	330.322	008.8	2,4	Ke	Karadona-Karatay (Konya)
19.08.2011	380.705	330.550	014.4	2,4	Ke	Karadona-Karatay (Konya)
06.08.2011	381.257	330.833	010.5	2,5	Ke	Katrancı-Karatay (Konya)
13.07.2011	379.527	330.155	014.2	1,9	Ke	Yaglıbayat-Karatay
17.06.2011	373.712	336.587	009.9	1,9	Ke	HuyukburunAyrancı(Karaman
29.04.2011	378.205	336.000	004.6	3,2	Ke	agmapınar-Karapınar (Konya)
18.12.2010	377.390	336.713	020.4	2,6	Ke	Yesılyurt-Karapınar (Konya)
19.112010	378.730	332.745	005.0	2,9	Ke	Besagıl-Karatay (Konya)
09.112010	380.675	330.548	014.1	2,7	Ke	Karadona-Karatay (Konya)
03.08.2010	381.490	331.932	007.2	2,6	Ke	Kızoren-Karatay (Konya)
27.07.2010	381.758	331.877	003.5	2,6	Ke	Obruk-Karatay (Konya)
14.07.2010	380.890	332.275	005.0	2,5	Ke	uyukburnak-Karatay (Konya)
13.06.2010	379.198	330.168	009.2	2,9	Ke	Yaglıbayat-Karatay (Konya)
24.05.2010	380.777	331.727	005.5	2,6	Ke	Akorenkısla-Karatay (Konya)
20.04.2010	374.508	330.143	005.0	3	Ke	Ortaoba- (Karaman)
22.03.2010	382.045	331.025	005.0	2,3	Ke	Yavsankuyu-Karatay (Konya)
20.03.2010	378.113	335.200	009.4	2,9	Ke	Karapınar (Konya)
10.12.2009	379.092	338.407	005.4	3,2	Ke	Emırgazı (Konya)
08.12.2009	378.185	336.707	021.7	2,8	Ke	agmapınar-Karapınar (Konya)
08.12.2009	379.368	338.722	007.7	3,3	Ke	Belkaya-Ereglı (Konya)

Source: http://www.koeri.boun.edu.tr/sismo/zeqdb/, Eren et al., 2020.

Table 5: Information on earthquakes between 1900-2020

Date	Lati tude	Longi tude	Depth (km)	xM	Type	Location
15.11.2009	378.310	336.437	002.5	3,3	Ke	YagmapınarKarapınar(Konya)
06.09.2009	378.340	335.687	006.8	3,3	Ke	Karapınar (Konya)
03.09.2009	381.650	331.725	004.5	2,5	Ke	Obruk-Karatay (Konya)
25.03.2009	377.902	338.263	004.7	2,6	Ke	Beyoren-Ereglı (Konya)
08.01.2009	379.972	334.822	007.5	3,3	Ke	Basaran-Eskıl (Aksaray)
08.01.2009	380.887	334.130	003.9	2,6	Ke	Esentepe-Karatay (Konya)
26.09.2008	375.858	330.103	005.3	2	Ke	Turkmenkarahuyuk (Konya)
26.10.2007	378.890	331.890	006.4	3	Ke	Besagıl-Karatay (Konya)
12.10.2007	379.303	338.627	005.0	3,7	Ke	Emırgazı (Konya)
24.07.2006	378.205	337.870	013.1	3,3	Ke	Ekızlı-Emırgazı (Konya)
23.07.2006	378.908	338.450	005.0	3,1	Ke	Emırgazı (Konya)
22.07.2006	378.575	339.002	005.4	3,2	Ke	Kızılgedık-Ereglı (Konya)
22.07.2006	379.807	339.388	013.2	3	Ke	Demırcı-Emırgazı (Konya)
21.07.2006	378.470	339.472	012.2	3,4	Ke	Kutoren-Ereglı (Konya)
14.07.2006	379.152	338.515	009.8	3,1	Ke	Emırgazı (Konya)
13.07.2006	378.373	338.525	006.8	3,4	Ke	Goloren-Emırgazı (Konya)
13.07.2006	378.455	338.713	005.7	3,7	Ke	Goloren-Emırgazı (Konya)
13.07.2006	378.365	338.480	007.0	3,9	Ke	Goloren-Emırgazı (Konya)
12.07.2006	378.508	338.638	007.9	2,9	Ke	Goloren-Emırgazı (Konya)
09.07.2006	378.562	338.980	009.0	3,4	Ke	Kızılgedık-Ereglı (Konya)
04.07.2006	379.408	339.143	005.4	2,9	Ke	Belkaya-Ereglı (Konya)
04.07.2006	378.752	338.398	010.8	2,9	Ke	Emırgazı (Konya)
04.07.2006	378.808	338.400	005.4	3,8	Ke	Emırgazı (Konya)
03.07.2006	379.153	339.585	012.0	3,3	Ke	Belkaya-Ereglı (Konya)
30.05.2006	377.468	333.725	032.4	3	Ke	Akcayazı-Karapınar (Konya)
10.05.2005	374.553	330.335	016.0	2,8	Ke	Ortaoba- (Karaman)
17.03.2005	382.300	332.752	017.6	2,9	Ke	Kosealı-Karatay (Konya)
08.11.2004	377.000	334.100	4	3,1	Ke	Hotamıs-Karapınar (Konya)
23.10.2004	380.900	338.300	10	3	Ke	Incesu- (Aksaray)
08.08.2004	378.700	335.300	15	3,1	Ke	Basaran-Eskıl (Aksaray)
17.03.2004	378.800	337.800	9	3,2	Ke	Yamac-Emırgazı (Konya)
07.03.2002	382.300	339.900	10	4,1	Ke	Taspınar- (Aksaray)
05.11.2001	378.200	334.700	18	2,9	Ke	Karapınar (Konya)
26.09.2001	378.200	335.800	10	4	Ke	Karapınar (Konya)
11.03.2001	379.800	339.800	11	3,6	Ke	Obruk-Bor (Nıgde)
17.11.1985	376.000	333.000	10	4,2	Ke	Hasanoba-Karapınar (Konya)
06.08.1973	382.000	331.000	005.0	3,9	Ke	Yavsankuyu-Karatay (Konya)
13.12.1924	380.000	335.000	030.0	5,2	Ke	Basaran-Eskıl (Aksaray)

Source: http://www.koeri.boun.edu.tr/sismo/zeqdb/, Eren et al., 2020.

Table 6: Information on sinkhole formations between 1900-2020

Code	Date	x	y	z	Location
KR450	01.09.2020	535530	4170650	1007	Kamışağılı
KR427	09.2020	548773	4181644	1002	Seyithacı
KR410	08.2020	550329	4183240	1001	Seyithacı
KR298	24.08.2020	544299	4187178	1059	Küllü mevki
KR368	23.07.2020	545733	4189945	1012	Yararlar çiğil
KR144	07.2020	532735	4164632	996	Hotamış SW
KR272	16.04.2020	543658	4195446	1048	Çingir Yaylası
KR447	01.2020	548695	4182762	1023	Seyithacı
KR146	2020	519136	4158676	1018	Kayacık Güneyi
KR214	2020	538409	4197326	1029	Yenikent SW
KR216	2020	541458	4196870	1047	Yenikent SW
KR312	2020	542256	4182390	1047	Üçobruk mevki
KR424	2020	549036	4182251	1003	Seyithacı
KR451	2020	535573	4170672	1008	Kamışağılı
KR453	2020	535601	4170867	1003	Kamışağılı
KR65	2020	561351	4184214	990	Nasuhpınarı/Siyeklik
KR345	12.2019	544931	4181259	1042	Karakuyu
KR307	12.2019	542803	4185234	1057	Üçobruk mevki
KR455	24.11.2019	535482	4171260	1007	Kamışağılı
KR336	10.2019	546537	4182399	1027	Eşeli
KR332	08.2019	545697	4182710	1041	Eşeli
KR450	01.09.2020	535530	4170650	1007	Kamışağılı
KR427	09.2020	548773	4181644	1002	Seyithacı
KR410	08.2020	550329	4183240	1001	Seyithacı
KR298	24.08.2020	544299	4187178	1059	Küllü mevki
KR368	23.07.2020	545733	4189945	1012	Yararlar çiğil
KR144	07.2020	532735	4164632	996	Hotamış SW
KR272	16.04.2020	543658	4195446	1048	Çingir Yaylası
KR210	01.06.2019	543596	4195913	1057	-
KR270	15.02.2019	544950	4195377	1053	Çingir Yaylası
KR335	02.2019	546229	4181944	1025	Eşeli
KR362	2019	546977	4180928	1005	Karakuyu
KR367	2019	545726	4180079	1013	Karakuyu
KR423	2019	548959	4182044	1003	Seyithacı
KR103	09.2018	534572	4169379	1006	Kamışağıl
KR429	5.09.2018	548789	4182149	1010	Seyithacı
KR303	14.07.2018	542556	4186341	1056	Yenikent SW

Source: Eren et al., 2020.

Table 7: Information on sinkhole formations between 1900-2020

Code	Date	x	y	z	Location
KR296	8.02.2018	544209	4187335	1056	Küllü mevki
KR434	2018	547681	4181227	1007	Seyithacı
KR488	2018	561553	4183848	996	-
KR29	2018	561284	4184037	989	Nasuhpınarı/ Siyeklik Yaylası
KR305	2017-2018	542688	4185324	1057	Yenikent SW
KR322	2018?	544066	4185630	1070	Üçobruk Mevki
KR344	2018	545163	4180996	1035	Karakuyu
KR292	05.2017	541244	4190219	1032	Yenikent SW
KR99	2017	517058	4174287	1007	Merdivenli Köyü G.
KR331	2017	545727	4182479	1033	Eşeli
KR339	2017	546608	4182763	1033	Eşeli
KR343	2017	545005	4180925	1039	Karakuyu
KR360	2017	547373	4181123	1010	Karakuyu
KR412	2017	550034	4182910	1007	Seyithacı
KR305	2017-2018	542688	4185324	1057	Yenikent SW
KR445	28.03.2016	548743	4182684	1016	Seyithacı
KR330	2016	545705	4182475	1033	Eşeli
KR338	2016	546834	4182665	1039	Eşeli
KR363	2016	546877	4181002	1007	Karakuyu
KR365	2016	546085	4180377	1008	Karakuyu
KR393	2016	550896	4185468	1011	Seyithacı
KR394	2016	550886	4185368	1010	Seyithacı
KR396	2016	551001	4184960	1002	Seyithacı
KR435	2016	548362	4181464	999	Seyithacı
KR441	2016	548704	4182532	1015	-
KR443	2016	548767	4182562	1018	-
KR444	2016	548717	4182610	1013	Seyithacı
KR26	2015	561180	4184044	997	Nasuhpınarı/Siyeklik Yaylası
KR28	2015	561200	4184060	992	Nasuhpınarı/Siyeklik Yaylası
KR229	2015	539963	4198766	1025	Yenikent SW
KR414	2015	550511	4183087	1007	Seyithacı
KR352	2015-2016	547199	4182244	1024	Karakuyu
KR400	2014	550608	4184902	1001	Seyithacı
KR407	2014	549749	4183927	1030	Seyithacı
KR415	2014	550037	4183170	999	Seyithacı
KR454	2014	535409	4170628	1002	Kamışağılı
KR422	09.2013	549099	4181876	1008	Seyithacı

Source: Eren et al., 2020.

Table 8: Information on sinkhole formations between 1900-2020

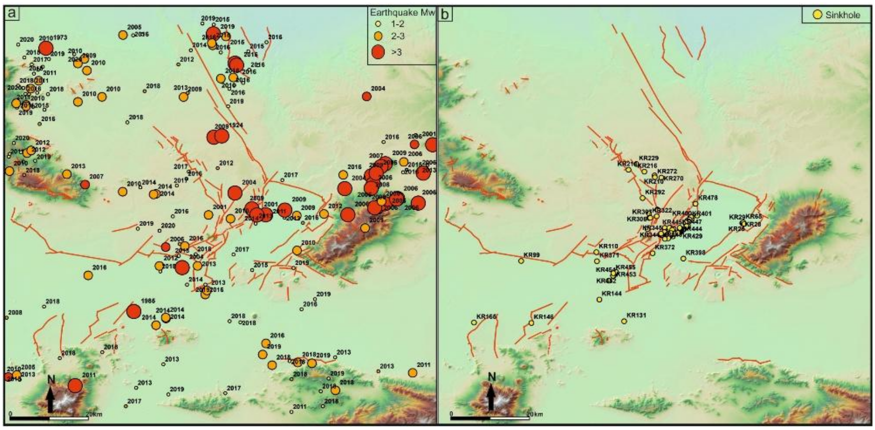
Code	Date	x	y	z	Location
KR120	2012	552210	4186032	991	Seyithacı
KR329	2012	547511	4182454	1025	Eşeli
KR411	2012	550062	4182910	1010	Seyithacı
KR430	07.2012	548788	4182257	1011	Seyithacı
KR351	2011	547195	4182199	1025	Karakuyu
KR418	2011	549568	4182467	1005	Seyithacı
KR419	2011	549425	4182335	1007	Seyithacı
KR431	2011	548749	4182385	1010	Seyithacı
KR428	2010	548758	4181880	1001	Seyithacı
KR397	2009	550952	4185539	1010	Seyithacı-
KR408	2009	549907	4184076	1012	Seyithacı
KR340	02.2009	545638	4181658	1033	Eşeli
KR371	02.2009	532212	4174331	1005	Karapınar
KR131	11.2008	537704	4159160	1012	-
KR150	10.2008	550197	4184641	1003	Seyithacı
KR391	10.2008	551171	4185471	1002	Seyithacı
KR150	10.2008	550197	4184641	1003	Seyithacı
KR391	10.2008	551171	4185471	1002	Seyithacı
KR366	2008	546411	4180114	1002	Karakuyu
KR406	2008	550514	4184408	1000	Seyithacı
KR452	2008	535613	4170841	1006	Kamışağılı
KR366	2008	546411	4180114	1002	Karakuyu
KR406	2008	550514	4184408	1000	Seyithacı
KR452	2008	535613	4170841	1006	Kamışağılı
KR389	11.2007	551167	4185550	1001	Seyithacı
KR165	2007	507642	4158758	1005	Sürgüç GB
KR110	08.2007	532074	4176540	1017	Akkuyu
KR395	07.2007	550725	4185305	1007	Seyithacı
KR401	06.2007	550633	4184848	1011	Seyithacı
KR390	04.2007	551130	4185497	1002	Seyithacı
KR364	2006	547013	4181427	1017	Karakuyu
KR478	2006-2008	551813	4188834	1003	-
KR372	04.2006	543312	4176324	1001	Küpbasan
KR101	2005-2006	536038	4171563	1007	Kamışağıl
KR306	1985?	542595	4185194	1063	Yenikent SW

Source: Eren et al., 2020.

The earthquakes that occurred between 2006-2020 (Table 1, Table 2, Table 3, Table 4, Table 5) and sinkholes (Table 6, Table 7, Table 8) were matched separately by year and analyzed in detail, especially in Karapınar, where sinkholes are concentrated (Figure 7, Figure 8, Figure 9).

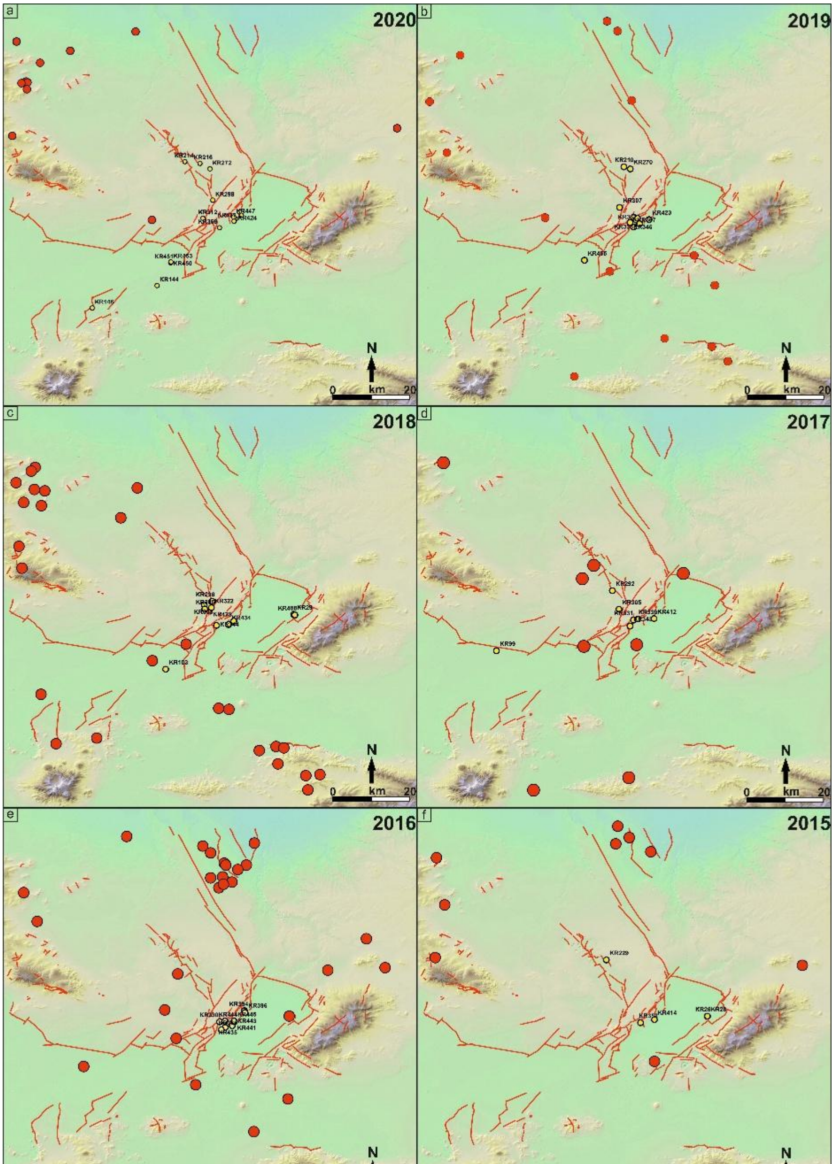
In 2020, earthquakes occurred in the northwestern and northeastern parts of Karapınar and in areas quite far from Karapınar. The sinkholes formed in the same year were formed in the northern and western part of Karapınar in remote areas independent of the earthquakes (Figure 7a).

Figure 6: Map of a. the distribution of earthquakes recorded in Karapınar and its vicinity and b. the distribution of sinkholes whose formation dates have been determined



In 2019, earthquakes occurred in the northern, northwestern and southern parts of Karapınar. Four of them were quite close to Karapınar. Only 1 one of the sinkholes formed in the same year was formed at the point where the earthquake occurred (Figure 7b).

Figure 7: The distribution of recorded earthquakes and sinkholes with determined formation dates, a. in 2020 b. in 2019 c. in 2018 d. in 2017 e. in 2016 f. in 2015



In 2018, the earthquakes occurred in the northwestern, southern and southwestern parts of Karapınar. Of these, 4 were quite close to Karapınar. Only one of the sinkholes formed in the same year was formed at the point where the earthquake occurred (Figure 7c).

In 2017, earthquakes occurred both in the northern and southern parts of Karapınar. Two of them are quite close to Karapınar. Of the sinkholes formed in the same year, 6 of them were not formed at the location of the earthquake but in the nearby area (Figure 7d).

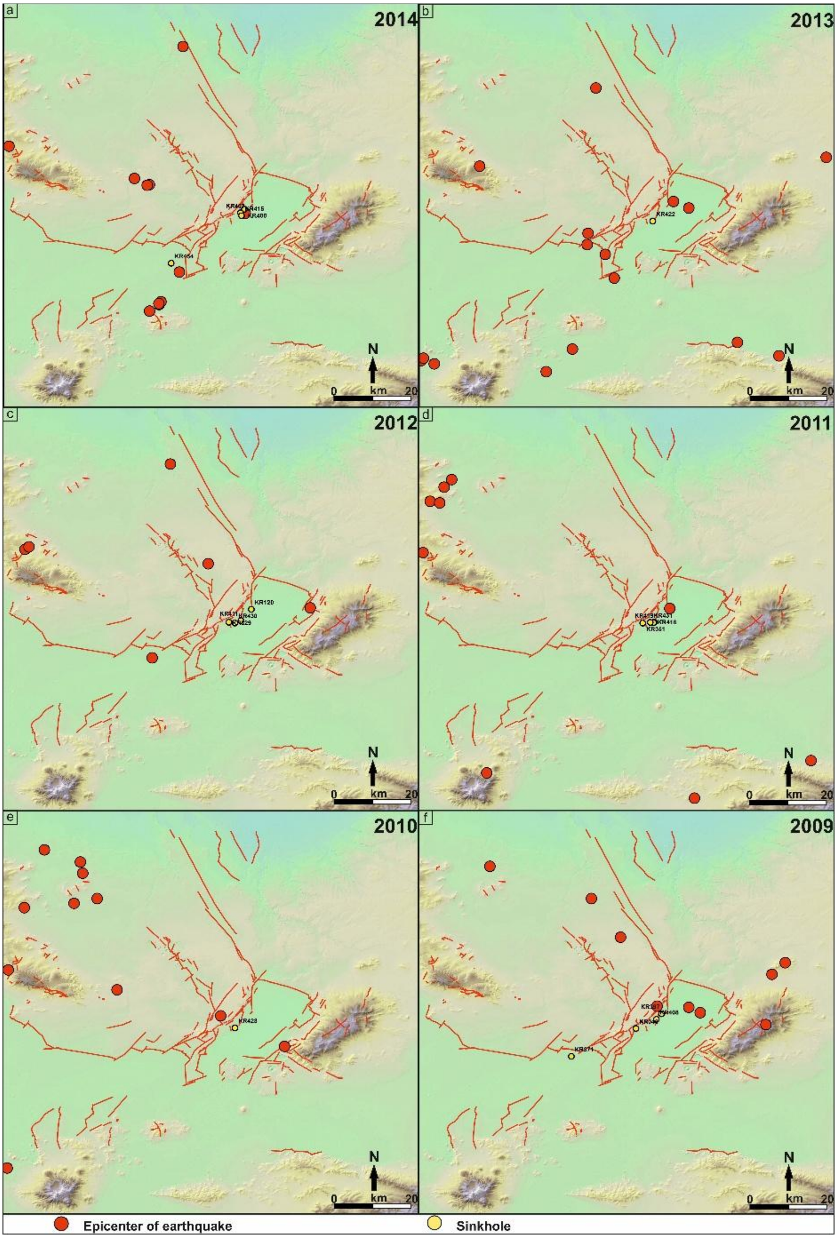
In 2016, most of the earthquakes occurred in the northern parts of Karapınar. Four of these are very close to Karapınar. Only 6 of the sinkholes formed in the same year were not at the point where the earthquake occurred, but in the immediate area (Figure 7e).

In 2015, the earthquakes occurred in the northern part of Karapınar. Only one of them was quite close to Karapınar. Only 3 of the sinkholes formed in the same year were not at the location where the earthquake occurred, but in the nearby area (Figure 7f).

In 2014, earthquakes occurred in the northern, northwestern and southwestern parts of Karapınar. Only two of them were quite close to Karapınar. Only 2 of the sinkholes formed in the same year were formed at the point where the earthquake occurred (Figure 8a).

In 2013, most of the earthquakes occurred in the northern part of Karapınar. Only six of them were quite close to Karapınar. Only 1 of the sinkholes formed in the same year was not at the point where the earthquake occurred, but in the nearby area (Figure 8b).

Figure 8: The distribution of recorded earthquakes and sinkholes with determined formation dates a. in 2014 b. in 2013 c. in 2012 d. in 2011 e. in 2010 and f. in 2009



In 2012, most of the earthquakes occurred in the northwestern part of Karapınar. These are not close to Karapınar. The sinkholes formed in the same year were not at the point where the earthquake occurred, but in the nearby area (Figure 8c).

In 2011, earthquakes occurred both in the northwestern and southern parts of Karapınar. All 4 sinkholes formed in the same year occurred at the same place where the earthquake occurred (Figure 8d).

In 2010, most of the earthquakes occurred in the northwestern part of Karapınar. Only one of the sinkholes formed in the same year occurred at the point where the earthquake occurred (Figure 8e).

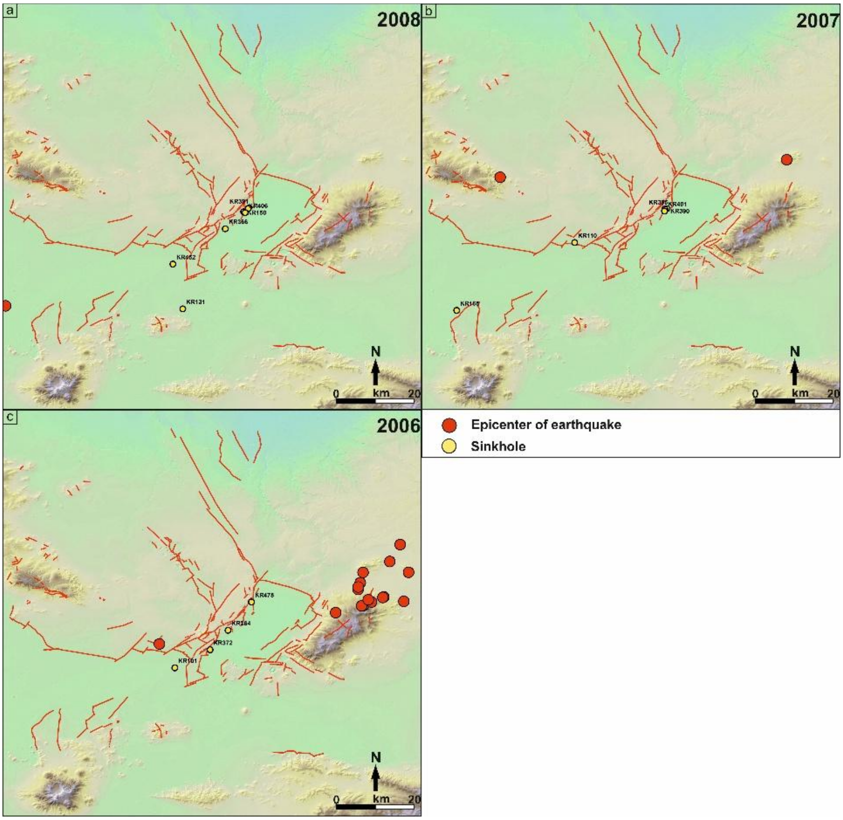
In 2009, the earthquakes occurred in the northern part of Karapınar. In the same year, only 3 of the sinkholes were formed at the point where the earthquake occurred (Figure 8f).

In 2008, the only one earthquake occurred in the southwestern part of Karapınar and in an area quite far from Karapınar. The sinkholes formed in the same year occurred in very far areas around Karapınar, independent of the earthquakes (Figure 9a).

In 2007 the 2 earthquakes occurred in the north of Karapınar and in remote areas. None of the sinkholes formed in the same year occurred at the point where the earthquake occurred (Figure 9b).

In 2006, most of the earthquakes occurred in the northeastern part of Karapınar. Only two of the sinkholes formed in the same year occurred at the point where the earthquake occurred (Figure 9c).

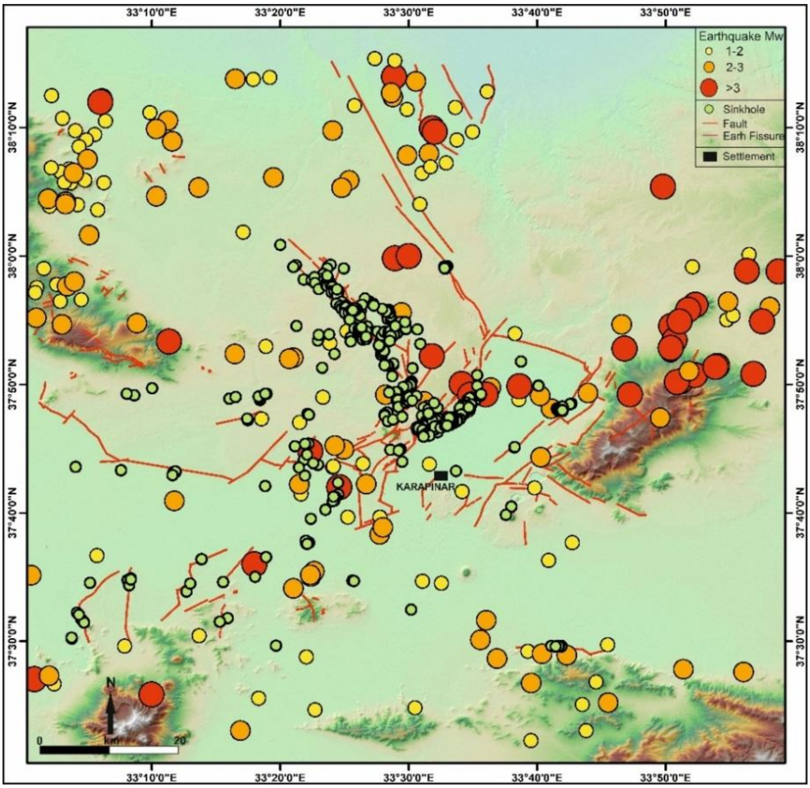
Figure 9: The distribution of recorded earthquakes and sinkholes with determined formation dates a. in 2008 b. in 2007 c. in 2006



When we look at these associations in general, we see that the sinkholes are not directly related to earthquakes in temporal and spatial terms (Figure 10). For example, the number of earthquakes in Seyithacı and its surroundings, where there are more than 100 sinkholes, is only 4 and not more than 10 in total, in Siyeklik plateau, where there are nearly 100 sinkholes, is 1 and 3 with its surroundings, and the number of earthquakes in the region between Niğdeboğazı and Meyil in the northwest of Karapınar, where there are intense old and current sinkhole formations, is 7 together with its surroundings in a period of 120 years. This shows us that earthquake occurrence just before each sinkhole is very very rare. Because it has been observed that even in years with intense earthquakes, few sinkholes can form or the sinkholes can form in areas very far from the earthquake locations.

Likewise, it is observed that very few earthquakes occur after sinkhole formation. In spite of all these, when the time of formation is not taken into account, there are small earthquake records in the regions where sinkholes are located, albeit in small numbers. Together with other parameters, this situation can be taken into consideration in regions with high potential for sinkhole formation.

Figure 10: Distribution of recorded earthquakes and all sinkholes around Karapınar regardless of their formation time



As a result, the relationship between earthquakes that occurred between 1900-2020 around Karapınar and the formation of sinkholes was analyzed. When the matches are examined in general, it is seen that sinkholes are not directly related to earthquakes in terms of time and space. Despite all this, when the formation time is not considered, there are small earthquake records in the regions where there are a few sinkholes. This situation can also be taken into consideration together with other parameters in regions where the potential for sinkhole formation is high.

Acknowledgements

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References

Arslan V. & Göçmez G. (2007). Tuzgölü Havzasında Yeraltı Suyunun Yok Oluşu (Eşmekaya-Sultan Hanı Örneği), *Selçuk Üniversitesi Mühendislik, Bilim Ve Teknoloji Dergisi*, 22 (1): 153-164.

Biricik, S. A. (1992). Obruk Platosu ve Çevresinin Jeomorfolojisi, *Marmara Üniversitesi Yay.* No: 531, İstanbul.

Bayari, C. S., Pekkan, E. & Ozyurt, N. N. (2008). Obruks, as giant collapse dolines caused by hypogenic karstification in Central Anatolia, Turkey: analysis of likely formation processes. *Hydrogeology Journal*, 17: 327-345. https://doi.org/10.1007/s10040-008-0351-9

Bulduk, A., Horasan Ö.R., Tekdere, M. & Solak N. 2008. Konya Kapalı Havzasın 16/2-a Alt Havzasında Yeraltı Suyu ve Seviye Değişmeleri. *Konya Kapalı Havzası Yeraltı Suyu ve Kuraklık Konferansı*, Bildiri Kitabı, 125-134, 11-12 Eylül 2008, Konya.

Canik, B. & Çörekçioğlu, İ., 1986, The formation of sinkholes (obruk) between Karapınar and Kızören-Konya. *Proc. of Symposium on Karst water Resources*, Ankara-Antalya July 1985, IASH Publ. No. 161: 193-205.

Canik, B. (1997). Konya Dolaylarında Suların Oluşturduğu Doğal Anıtlar ve Bunların Korunması, *20.Yıl Jeoloji Sempozyumu Bildiriler*, s.159-166, Konya.

Canik, B. & Arıgün, Z. (2001). Karapınar-Kızören(Konya) Dolayındaki Obrukların Oluşumu ve Karapınar Volkanizmasının Bu Olaya Etkisi, *Karapınar Sempozyumu Bildiri Kitabı*, s.295-303, Konya.

Çörekçioğlu, İ. (1994). Konya Karapınar-Kızören Arasındaki Obrukların Oluşumu ile İlgili Hidrojeolojik Etüt Raporu. *DSİ 4. Bölge Müdürlüğü*, Konya

Cvijić, J. (1893). Das Karstphanomen. Versuch einer morphologischen *Monographie. Geographischen Abhandlung,* Wien V, 3:, 218-329

Doğan U. & Yılmaz M. (2011) Natural and induced sinkholes of the Obruk Plateau and Karapınar-Hotamış Plain, Turkey. *J. Asian Earth Sci.,* 40: 496-508. doi: 10.1016/j.jseaes.2010.09.014.

Doğdu, M. Ş., Toklu, M.M. & Sağnak. C. (2007). Konya Kapalı Havzası'nda Yağış ve Yeraltı Suyu Değerlerinin Đrdelenmesi, I. *Türkiye Đklim Değişikliği Kongresi,* Bildiri Kitabı: 394-402, 11-12 Nisan 2007, İstanbul.

Eren, Y., Parlar, Ş. & Coşkuner, B. (2020). Konya Valiliği il Afet ve acil durum müdürlüğü, Karapınar çevresinde obruk alanlarının belirlenmesi projesi, *Yer Hareketleri grubu Final Raporu*, 193. AFAD; Konya.

Eren, Y., Parlar, Ş., Coşkuner, B. & Arslan, Ş. (2024). Geological and Morphological Features of the Karapınar Sinkholes (Konya, Central Anatolia, Türkiye). *J. Earth Sci.* 35: 1654-1668. https://doi.org/10.1007/s12583-023-1853-z.

Eren, Y., Coşkuner, B. & Parlar, Ş. (2025). An Example of Intracontinental Cross Faults Formation from the Vicinity of Karapınar (Konya-Central Anatolia). *Acta Geologica Polonica*, 75 (1): e35.

Erinç, S. (1960). Konya Bölümünde ve İç Toros sıralarında karst şekilleri. *Türk Coğrafya Dergisi*, 20: 83-106, İstanbul.

Erol, O., (1986). The relationship between the phases of the development of the Konya- Karapınar obruks and the Pleistocene Tuzgolu and Konya pluvial Lakes.b In: Karst Water Resources *Proceedings of Ankara-Antalya Symposium*, July 1985. IAHS Publ. No. 161, pp. 207-213

Erol, O., 1991, The Relationship Between the Development of the Konya- Karapınar Obruks and the Pleistocene Tuz Gölü and

Pluvial Lakes. *Türkiye Deniz Bilim. ve Coğr. Enst. Bült.,* 7: 5-49, İstanbul.

Eroskay, S.O. (1976). The factors influencing the Konya Obruks and their groundwater potentials evaluation. İstanbul Üniversitesi, Fen. Fak. Mec. Seri. B, 41 (1-4): 5-14, İstanbul.

Eroskay, S.O. & Günay, G. (1979). Tecto-genetic classification and hydrogeological properties of the karst regions in Turkey.- *Proceedings International Seminar on Karst Hydrogeology*, Oct. 9-19, pp. 1-43, Oymapınar, Antalya.

Ertek, T. A. (2009). Obruk Platosu'nda Devam Eden Obruk Oluşumları, *TÜBİTAK Bilim ve Teknik Dergisi*, Yıl 42, Ankara, 503: 66-71.

Göçmez, G., Dıvrak, B.B. & Galena, İ. (2008a). Konya Kapalı Havzası'nda Yeraltı Suyu Seviyesinin Değişiminin Tespiti Özet Raporu. *WWF*, İstanbul.

Göçmez, G., Genç, A. & Karakoca, A. (2008b). Konya Kapalı Havzası Yeraltısuyu Seviye Değişiminin İstatistiksel Değerlendirilmesi. *Konya Kapalı Havzası Yeraltı Suyu ve Kuraklık Konferansı*, Bidiri Kitabı, 11-12 Eylül 2008, Konya, 98-107

Göçmez, G. (2011). Konya İlindeki Obruklar ve Traverten Konileri, 26-27 Kasım 2011. *I. Konya Kent Sempozyumu Bildiriler Kitabı*, s.459-464, Konya.

Güldalı, N. & Şaroğlu, F. (1983). Konya Yöresi Obrukları, *T.J.K. Yeryuvarı ve İnsan*, 7(4): 44-55.

Günay, G., ˙Çörekçioğlu,İ., Eroskay, S.O. & Övül, G. (2010). Konya Karapınar Obruks (Sinkholes) of Turkey, B. Andreo et al. (Eds.), *Advances in Research in Karst*. Media, Springer, pp. 367-372. DOI 10.1007/978-3-642-12486-0.

Gürler, G. & Timur, E. (2007). Determination Of Conservation & Usage Methods Of Geoparks-A Critical Assessment For Karapinar Potential Geopark Site, Turkey. *Second International*

Symposium on Development Within Geoparks-Environmental Protection and Education, 12- 15 June, 2007, Lushan-Jiangxi Province-China.

http://www.koeri.boun.edu.tr/sismo/zeqdb/

Kara, M., Toprak, R., Şahin, M., Süheri, S. & Yavuz, D. (2008). Konya Ovasında Sulamada Yeraltı Suyu Tüketiminin Azaltılması Çareleri. *Konya Kapalı Havzası Yeraltısuyu ve Kuraklık Konferansı,* 11-12 Eylül 2008, Konya, Bildiri Kitabı 51-56.

Karadoğan, S., 2001. Karapınar Çevresindeki Farklı Jeomorfolojik Şekiller, Özelikleri ve Turizm Potansiyelleri. *Karapınar Sempozyumu*, 26-27 Ekim 2000, Konya Karapınar, Bildiri Kitabı 339-358.

Kocyiğit, A. & Ozacar, A. (2003). Extensional Neotectonic Regime through the NE Edge of the Outer Isparta Angle, SW Turkey: New Field and Seismic Data. *Turkish J. Earth Sci*., 12: 67-90.

Lahn, E. (1940). Konya mıntıkasındaki karst hadiseleri ve bunların ziraat bakımından ehemmiyeti. *MTA Enstitüsü Mecmuası*, 4: 620- 626.

Orhan, O., Yakar, M. & Ekercin, S. (2020). An application on sinkhole susceptibility mapping by integrating remote sensing and geographic information systems. *Arab. J. Geosci*., 13, 886: 1-17. https://doi.org/10.1007/s12517-020-05841-6

Özdemir, A. (2015a). Sinkhole Susceptibility Mapping Using a Frequency Ratio Method and GIS Technology Near Karapınar, Konya-Turkey. *Procedia Earth and Planetary Science* 15: 502-506. DOI: 10.1016/j.proeps.2015.08.059.

Özdemir, A. (2015b). Investigation of sinkholes spatial distribution using the weights of evidence method and GIS in the vicinity of Karapinar (Konya, Turkey). *Geomorphology* 245: 40-50. DOI: http://dx.doi.org/10.1016/j.geomorph.2015.04.034.

Şengör, A. M. C. (1980). Türkiye'nin neotektoniğinin esasları. *TJK Konferans Serisi*, 2, 40.

Tapur, T. & Bozyiğit, R. (2009). Konya Ovası ve Çevresinde Yeraltı Sularının Obruk Oluşumlarına Etkisi, *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 21:.137-155.

Törk, K. (Proje Başkanı), Erduran, B., Güner, İ. N., Ateş, Ş., Avcı, K., Çınar, A., Keleş, S., Ayva, A., Demirbaş, Ş., Yılmaz, N. P. & Sülükçü, S. (2010). Konya Havzası'nda Karstik Çöküntü Alanlarının Belirlenmesi ve Tehlike Değerlendirilmesi Projesi 2009 Yılı Ara Rapor (MTA Proje No: 2009.14.03.2). Ankara: *MTA Genel Müdürlüğü*, Jeoloji Etütleri Dairesi.

Törk, K., Yılmaz, N.P., Sülükçü, S., Keleş, S., Köklü, Ş., Yeleser, L., S., Aykaç, Özerk, Z.R., Acar, C., Savaş, F., Çakır, K. & Avcı, K. (2019). Konya Ovası Projesi (KOP) bölgesinde (Konya, Karaman, Aksaray, Niğde) karstik çöküntü alanlarının belirlenmesi ve tehlike değerlendirmesi projesi (Final Raporu). *MTA Genel Müdürlüğü*, Ankara Rapor No: 263 s.

Ulu, Ü., Öcal, H., Bulduk, A.K., Karaka, M., Arbaş, A., Saçlı, L., Taşkıran, M.A., Ekmekçi, E., Adır, M., Sözeri, Ş. and Karabıyıkoğlu. M. (1994). Güneybatı İç Anadolu'nun stratigrafisi ve yapısal evrimi. *Proceedings, 9th Turkish Geology Symposium*, 171-182.

Üstün, A., Tuşa, E. & Abbak, R. A. (2007). Konya kapalı havzasında yeraltı suyu çekilmesi ve olası sonuçlarının jeodezik yöntemlerle izlenmesi. *3. Mühendislik Ölçmeleri Sempozyumu*, 24 - 26 Ekim 2007, Konya, 52-61.

Williams, P. W. (2004). Dolines. In: Gunn J (ed.) Encyclopedia of Caves and Karst Science, *Fitzroy Dearnorn*, New York, 304- 310.

Waltham, T., Bell, F. & Culshaw, M. (2005). Sinkholes and subsidence: karst and cavernous rocks in engineering and construction. *Berlin*. 300, https://doi.org/10.1007/b138363.

Waltham, T. (2015). Large collapse sinkholes, old and new, in the Obruk Plateau, Turkey. *Cave and Karst Science*, 42 (3): 125-130.

MORPHOLOGICAL CHARACTERISTICS AND FORMATION MODEL OF SINKHOLES IN THE AREA BETWEEN BOLLUK LAKE AND AKINCILAR (KONYA)

ŞEYDA PARLAR[1]

Introduction

Many sinkholes had been recorded in different locations (Sayhan, 2014; Öner, 2003; Bölük et al., 2022; Tel et al., 2022; Tuncer, 2023) in Türkiye. Sinkholes have been observed mostly in different regions of the Konya Closed Basin (Bozyiğit ve Tapur, 2009; Orhan et al., 2020; Demir et al., 2021; Bilgilioğlu ve Bilgilioğlu, 2023). ,In the Konya region, sinkholes are commonly encountered in the elevations where settlement is very scarce and in the basins between these elevations (Eren et al., 2024a). It was determined that the majority of these sinkholes were formed in Karapınar and its surroundings (Canik and Çörekçioğlu, 1986; Erol, 1991; Doğan and Yılmaz, 2011; Tapur and Bozyiğit, 2015; Özdemir, 2015a, 2015b, 2016; Eren et al., 2021a, 2021b, 2021c, 2021d, 2024b; Parlar et al., 2021a, 2021b).

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[1] Asst. Prof. Dr., Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geological Engineering, Orcid: 0000-0003-1048-0100

Eren et al., 2024b had been examined the Karapınar region sinkholes under 5 groups as following; Basement rock sinkholes, Obruk Plateau sinkholes, Seyithacı sinkholes, Siyeklik sinkholes and basin sinkholes considering the formation mechanisms. One of the regions where sinkhole formations have been observed albeit rarely in recent years is the area between Altınekin and Cihanbeyli Districts. Although previous studies on different topics of geology (Karaman, 1986; Eren, 2000, Droop et al., 2005; Bozdağ and Göçmez, 2013; Tuncer and Pınar, 2017; Altay and Keskın, 2018; Pınar et al., 2018; Durduran et al., 2021; Tuncer and Tuncer, 2023; Uzun, 2024) have been conducted in this region, there is no study detailed investigation on sinkholes.

This study was carried out in an area of approximately 322 km^2 between the north of Bolluk Lake (98 km away from Konya) within the borders of Cihanbeyli District and the south of Akıncılar Village (69 km away from Konya) in Altınekin District in the northeast of Konya. In this area, 9 sinkholes which of four in the north (Group 1) and five in the south (Group 2) with distinct circular or ellipsoidal boundaries were identified (Figure 1).

The field works of Group 1 were carried out in March 2021 and the field works of Group 2 were carried out in April 2025. The Group 1 sinkholes located in the north of Bolluk Lake were named for the first time in this study as Bolluk Sinkhole, Yapalı Sinkhole, Altın Sinkhole and Ekin Sinkhole. From the Group 2 sinkholes, the sinkhole which was located in the north of Akıncılar was named as Şeren Sinkhole and the sinkholes which were located in the northwest of Akıncılar were named as Akıncılar Sinkhole, Yıldız Sinkhole, Hoydus Sinkhole and Parlar Sinkhole for the first time in this study.

Figure 1: Location map of the investigated area

Source: constituted by using https://www.google.com/maps/

The morphological features of these sinkholes were revealed by measuring their depth, long axis, short axis, perimeter, area and distance to the settlement. The field measurements were supported with the measurements received from https://www.google.com/maps/.

In addition, the stratigraphy and geology of the region were determined. In this study this classification based on the depth of the sinkholes were composed; (1) shallow sinkholes (depth between 0-1 meters) (2) slightly deep sinkholes (depth between 1-10 meters) (3) deep sinkholes (depth between 10-50 meters) (4) very deep sinkholes (depth more than 50 meters). Additionally a size classification based on the perimeter of the sinkholes were constituted for this study; (1) very small sinkholes (perimeter between 0-20 meters) (2) small sinkholes (perimeter between 20-40 meters) (3) slightly large sinkholes (perimeter between 40-100 meters) (4) large sinkholes (perimeter between 100-200 meters) (5) very large sinkholes (perimeter more than 200 meters). Moreever, in concept of this study the general shapes of the sinkholes were classified according to the calculated ratio (s/l) of the short axis (s) to the long axis (l) of the sinkholes as following; (1) circular sinkholes (s/l between 0,81-1,00) (2) less circular sinkholes (s/l between 0,61-0,80) (3) wide ellipsoidal sinkholes (s/l between 0,41-0,60) (4) narrow ellipsoidal sinkholes (s/l less than 0,40). The lithologies were defined on the sinkhole walls, and the thickness of the units were measured and recorded. The formation models of the sinkholes were created and evaluated. In addition, their importance in terms of geotourism and geoheritage was emphasized. The author would like to thank Prof. Dr. Yaşar EREN for his knowledge, experience and supports in this study.

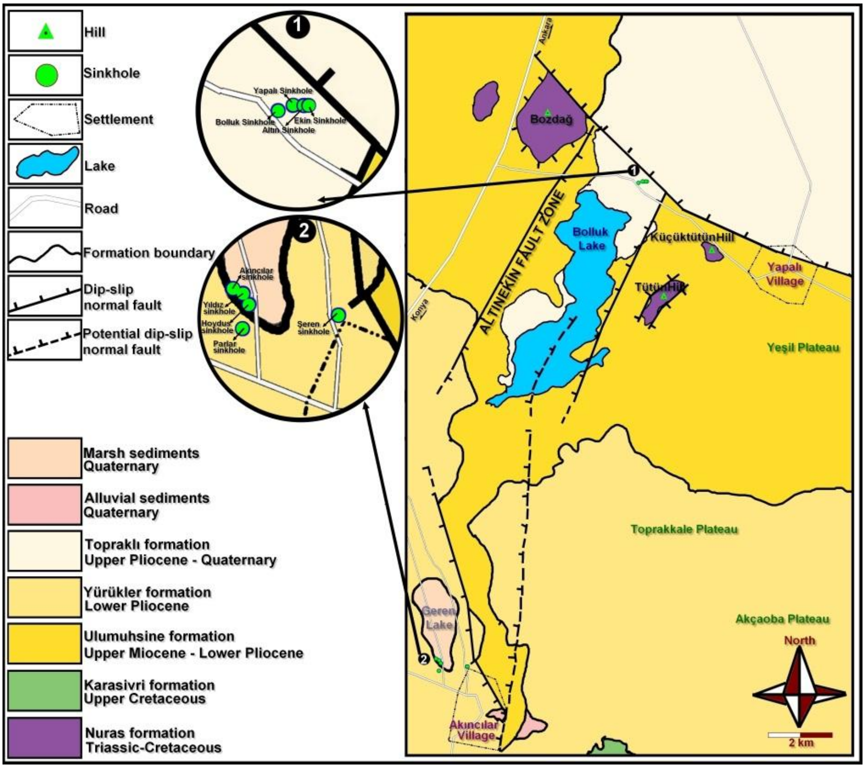
Geology and stratigraphy

In the study area, 7 units were defined and the stratigraphy of the area was revealed. The oldest unit identified in the study area is the Nuras formation which as first named by Karaman (1986). The unit, which is mainly composed of white and light cream colored marbles, is located on the north of the study area and was croped out in very narrow areas on the hills with an altitude of 1000-1200 meters within the plain. The unit was accepted as Triassic-Cretaceous in age by Eren (2000) because it is the equivalent of the Lorasdağı formation.

The Karasivri formation, which was croped out only in a very small area in the south of the study area, is consisted of Karaman (1986) metachert and metacarbonates. The age of the unit, which was overlied the Nuras formation with lateral and vertical transitions and was likened to the Midostepe formation by Eren (2000), was accepted as Upper Cretaceous.

The unit which was consisted of lacustrine limestone and clastics and was outcroped in a very wide area in the northwest, southeast and also south of Bolluk Lake extending to Akıncılar District, is considered as Ulumuhsine formation. While this unit was considered as the Ulumuhsine limestone member of the Dilekçi formation by Göğer and Kıral (1969), it was accepted as the Ulumuhsine formation by Eren (1993) (Figure 2).

Figure 2: Geological map of the investigated area and surrounding



Source: Constituted by using https://www.google.com/maps/ and modified from Karaman 1986; Eren, 2000; Bozdağ and Göçmez, 2013; Pınar et al., 2018; Tuncer and Tuncer, 2023)

The age of the unit which was overlied the Karasivri formation with an angular unconformity was determined as Pliocene by Göğer and Kıral (1969) and as Upper Miocene - Lower Pliocene by Eren (1993). The unit, which was consisted of brown, reddish and grayish conglomerate, sandstone and mudstone and was observed in the wide plains where agricultural activities were carried out in the south of the study area, was firstly named as the Yürükler formation by Eren (1993). The unit which was overlied the Ulumuhsine formation with an angular unconformity was aged as Lower Pliocene (Eren, 1993).

The unit which was overlied the Yürükler formation with an angular unconformity was named as Topraklı conglomerate by Doğan (1975) and as Topraklı formation by Eren (1993). The age of the unit, which was consisted of brownish, grayish conglomerate, mud, gravels, sands and caliche levels and was observed in the wide plains in the north of the study area, was considered as Upper Pliocene - Quaternary (Eren, 1993).

The alluviums carried by the rivers were considered as alluvial sediments, and the sediments formed as a result of the drying of Geren Lake were considered as marsh sediments. Alluvial sediments and marsh sediments, which were overlied the older units in the area with an angular unconformity and were contining to form today, were aged as Quaternary. The Altınekin Fault zone, which presents dip-slip normal fault characteristics trending north-northeast south-southwest, is located in the central parts of the study area and these faults were surrounded the Lake Bolluk (Figure 2).

Morphological characteristics of the sinkholes

A total of 9 sinkholes were identified in the study area located approximately 75 km northeast of Konya as the crow flies (Figure 1) and all of these sinkholes were named for the first time in this study. The depth, long axis, short axis, perimeter, area and distance to settlements of each sinkholes were measured separately (Table 1 and Table 2).

Table 1: Morphological characteristics, measurements and classifications of Group 1 sinkholes in the study area

Group	Group 1

No	1	2	3	4
Name	Bolluk Sinkhole	Yapalı Sinkhole	Altın Sinkhole	Ekin Sinkhole
Perimeter (m)	110.00	25.50	4.37	5.23
Size class	large sinkhole	small sinkhole	very small sinkhole	very small sinkhole
Area (m^2)	938	43.5	1.4	1.98
Long axis-l (m)	34.60	8.53	1.40	1.81
Short axis-s (m)	33.50	6.22	1.21	1.45
s/l	0.97	0.73	0.86	0.80
Shape class	circular sinkhole	less circular sinkholes	circular sinkhole	less circular sinkholes
Depth (m)	2.4	0.3	0.4	0.3
Depth class	slightly deep sinkholes	shallow sinkhole	shallow sinkhole	shallow sinkhole
Distance to settlements (km)	4.154 (Yapalı)	4.126 (Yapalı)	4.113 (Yapalı)	4.110 (Yapalı)
Formation model	collapse of a travertine cone	caprock sinkholes	caprock sinkholes	caprock sinkholes
Lithology	Brownish, grayish conglomerate, mud, gravels, sands, caliche levels			

Bolluk sinkhole

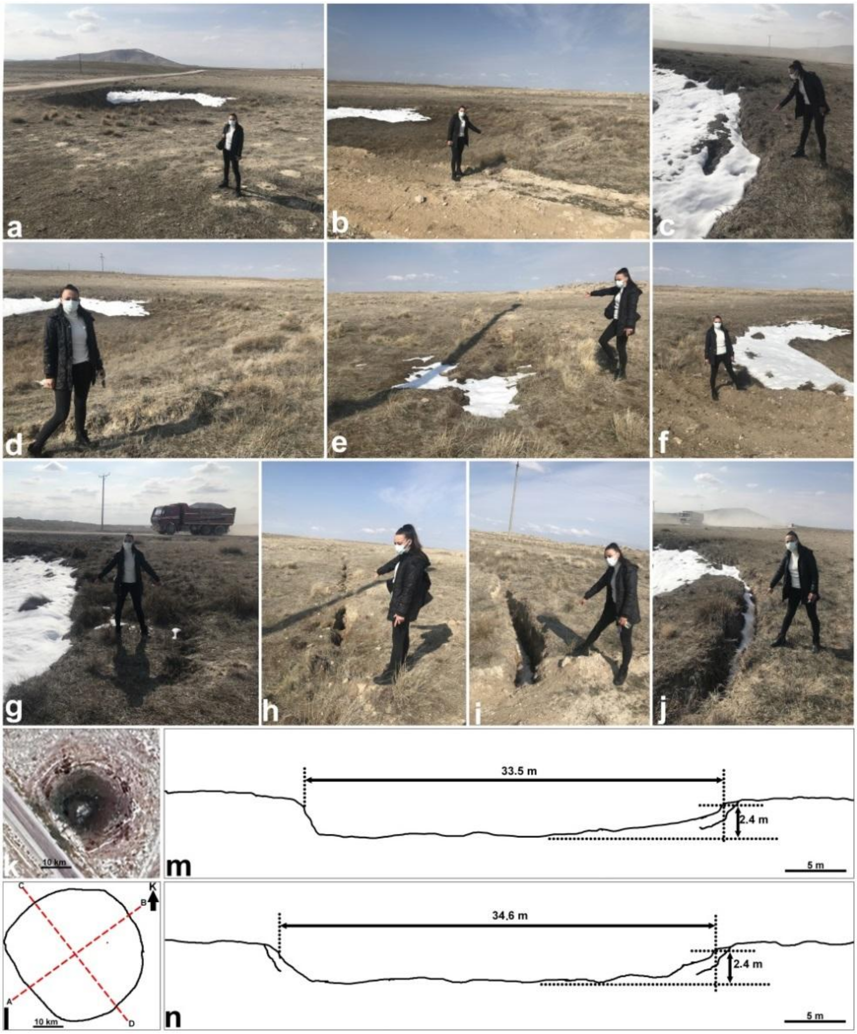
The sinkhole which is located 182.86 meters northeast of Bolluk Lake and approximately 4.154 km northwest of Yapalı Village was firstly named as Bolluk Sinkhole in this study (Figure 3a-d). According to historical satellite imagery, the Bolluk Sinkhole must have been formed before 1985. A perimeter of approximately 110 meters, a long axis of 34.6 meters, a short axis of 33.5 meters, and a depth of approximately 2.4 meters were measured for this circular-shaped sinkhole. It was observed that large circular deep fissures formed around this sinkhole (Figure 3e-j). Based on the crow flies view (Figure 3k-l) of Bolluk Sinkhole, sections of its short axis (Figure 3m) and long axis (Figure 3n) had been drawn separately. Bolluk Sinkhole was classified as large, slightly deep, circular sinkhole (Table 1).

Table 2: Morphological characteristics, measurements and classifications of Group 2 sinkholes in the study area

Group	Group 2				
No	5	6	7	8	9
Name	Akıncılar Sinkhole	Yıldız Sinkhole	Hoydus Sinkhole	Parlar Sinkhole	Şeren Sinkhole
Perimeter (m)	147.00	58.50	23.60	59.20	53.26
Size class	large sinkhole	slightly large sinkhole	small sinkhole	slightly large sinkhole	slightly large sinkhole
Area (m^2)	1643	254	37	231	168
Long axis-l m)	49.70	19.80	8.47	23.70	20.20
Short axis-s(m)	40.40	17.40	6.00	12.70	11.41
s/l	0.81	0.88	0.71	0.54	0.56
Shape class	circular sinkhole	circular sinkhole	less circular sinkholes	wide ellipsoidal sinkholes	wide ellipsoidal sinkholes
Depth (m)	2.7	0.7	1.5	1.1	2.1
Depth class	slightly deep sinkholes	shallow sinkhole	slightly deep sinkholes	slightly deep sinkholes	slightly deep sinkholes
Distance to settlements(km)	0.901 (Akıncılar)	0.867 (Akıncılar)	0.834 (Akıncılar)	0.731 (Akıncılar)	0.178 (Akıncılar)
Formation model	caprock sinkholes	caprock sinkholes	caprock sinkholes	caprock sinkholes	caprock sinkholes
Lithology	Marsh sediments			Reddish, grayish conglomerate, sandstone, mudstone	

Figure 3: Bolluk Sinkhole a-d. General views e-j. fissures formations due to the continuing formation of the sinkhole k.

satellite view l. Schematic drawing of the crow flies view m. of short axess section n. of long axess section

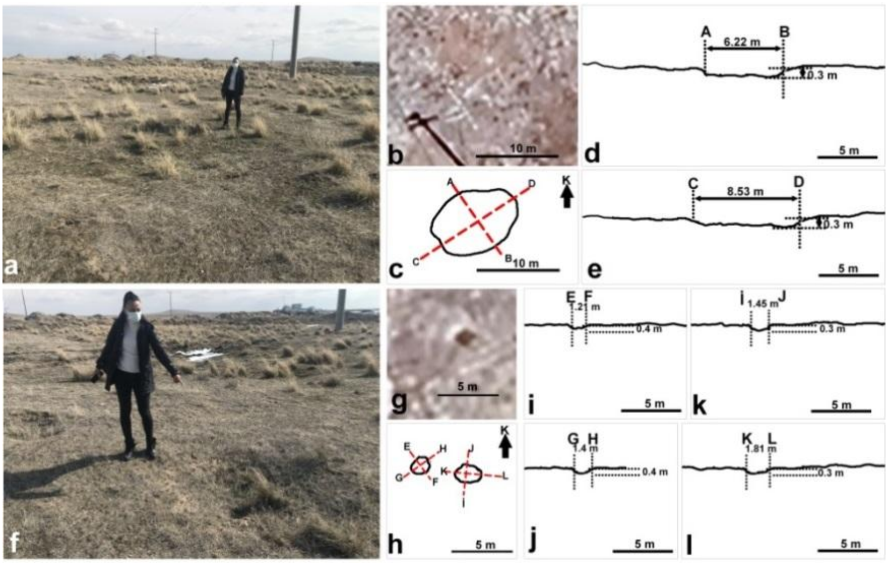


Source: Satellite views were received from https://www.google.com/maps/ and schematic drawings were constituted by using this satellite views.

Yapalı sinkhole

The sinkhole which was firstly named as Yapalı Sinkhole in this study (Fig 4a) is located 224 meters northeast of Bolluk Lake and approximately 4.154 km northwest of Yapalı Village. The historical satellite imagery indicates that the Yapalı Sinkhole must have been formed before 2008.

Figure 4: Yapalı Sinkhole a. general view b. satellite view c. Schematic drawing of the crow flies view d. of short axess section e. of long axess section. Altın and Ekin Sinkholes; f. general view g. satellite view h. schematic drawing of the crow flies view, Altın Sinkhole; i. short axess section e. long axess section, Ekin Sinkhole; j. short axess section l. long axess section



Source: Satellite views were received from https://www.google.com/maps/ and schematic drawings were constituted by using this satellite views.

The measured values of less circular-shaped sinkhole were recorded as following; a perimeter of approximately 25.5 meters, a long axis of 8.53 meters, a short axis of 6.22 meters, and a depth of approximately 0.3 meters. The short axis (Figure 4d) and long axis (Figure 4e) sections of Yapalı Sinkhole were constituted based on the crow flies view (Figure 4b-c). Yapalı Sinkhole was classified as small, shallow, less circular sinkhole (Table 1).

Altın sinkhole

The western one of the two small sinkholes located at 251 meters northeast of Bolluk Lake and approximately 4.113 km northwest of Yapalı Village is named as the Altın Sinkhole (Figure 4f). It can be said that the Altın Sinkhole have been formed before 2010 based on the historical satellite imagery. A perimeter of approximately 4.37 meters, a long axis of 1.4 meters, a short axis of 1.21 meters, and a depth of approximately 0.4 meters had been measured for this circular-shaped sinkhole. According to the crow flies view (Figure 4g-h) of the Altın Sinkhole, the sections through its short (Figure 4i) and long axes (Figure 4j) were produced separately. Altın Sinkhole was classified as very small shallow, circular, sinkhole (Table 1).

Ekin sinkhole

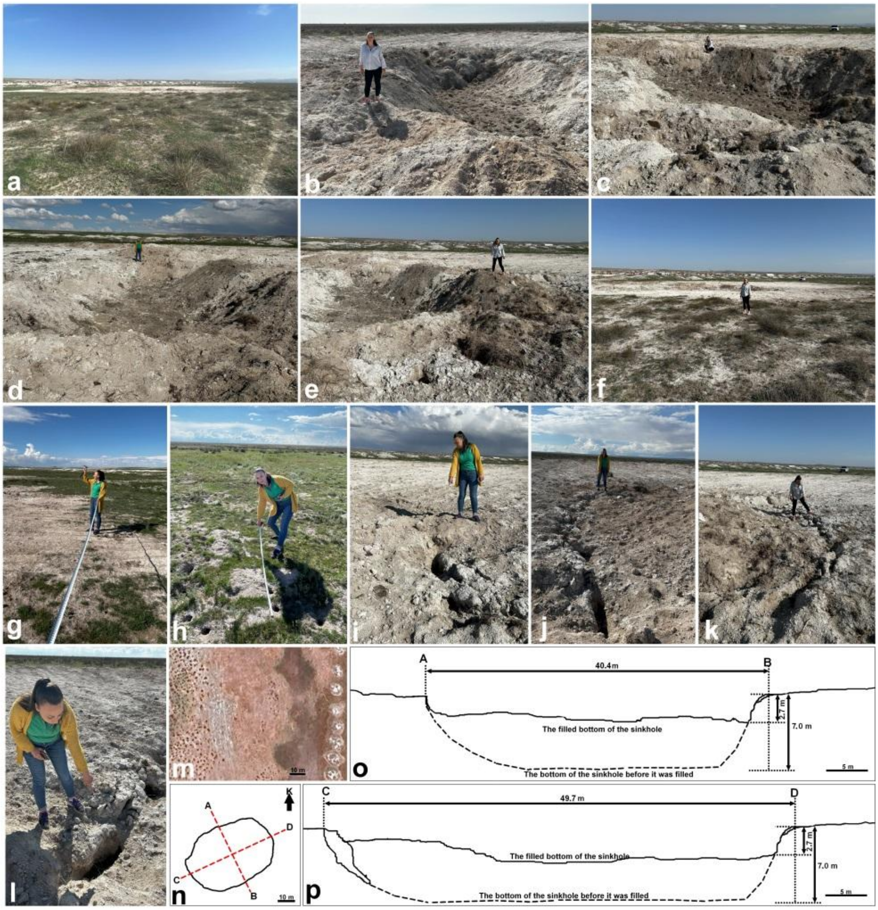
The eastern one of the two small sinkholes which is located at 252 meters northeast of Bolluk Lake and approximately 4.110 km northwest of Yapalı Village was named as the Ekin Sinkhole (Figure 4f). The Ekin Sinkhole must have been formed before 2010 according to the historical satellite imagery. A perimeter of approximately 5.23 meters, a long axis of 1.81 meters, a short axis of 1.45 meters, and a depth of approximately 0.3 meters were measured for less circular-shaped Ekin Sinkhole. Based on the crow flies view (Figure 4g-h) of Ekin Sinkhole, the sections through its short (Figure 4k) and long axes (Figure 4l) were designed separately. Ekin Sinkhole was classified as very small, shallow, less circular sinkhole (Table 1).

Akıncılar sinkhole

The sinkhole which is located approximately 0.901 km northwest of Akıncılar Village was named as Akıncılar Sinkhole. Akıncılar Sinkhole was formed in January 2025 and news were published in the local (e.g. https://www.pusulahaber.com.tr/son-dakika-konyada-dev-obruk-olustu-1775643h.htm) and national press (e.g. https://www.hurriyet.com.tr/gundem/konyada-obruk-olusumu-saniye-saniye-goruntulendi-42647159, https://www.milliyet.com.tr/gundem/konyada-obruk-olusumu-cep-telefonu-kamerasina-yansidi-buyuk-bir-gurultuyle-coktu-7274150,https://www.aa.com.tr/tr/gundem/konyada-50-metre-capinda-olusan-obrugun-genisleme-ani-kaydedildi/3440998). According to the information provided by the local people during the field work carried out in April 2025, the sinkhole was filled by the municipality (Figure 5a-f).

The measured depth was 7 meters and diameter was 50 meters when it was first formed and before it was filled. During field studies, the measured perimeter of the circular-shaped sinkhole was recorded as approximately 147 meters, also its long axis as 49.7 meters, its short axis as 40.4 meters, and its filled apparent depth to the bottom of the sinkhole as 2.7 meters (Figure 5g-h). Although the sinkhole had been filled with material taken from its surroundings, the large circular deep fissures formed around it indicate that the sinkhole continues to form (Figure 5i-l). Based on the crow flies view (Figure 5m-n) of the Akıncılar Sinkhole, sections through the short (Figure 5o) and long axes (Figure 5p) were constituented. Akıncılar Sinkhole was classified as large, slightly deep, circular sinkhole (Table 2).

Figure 5: Akıncılar Sinkhole; a-f. General views g-h. measurement prossess i-l. fissures formations due to the continuing formation of the sinkhole m. satellite view n. Schematic drawing of the crow flies view o. of short axess section p. of long axess section

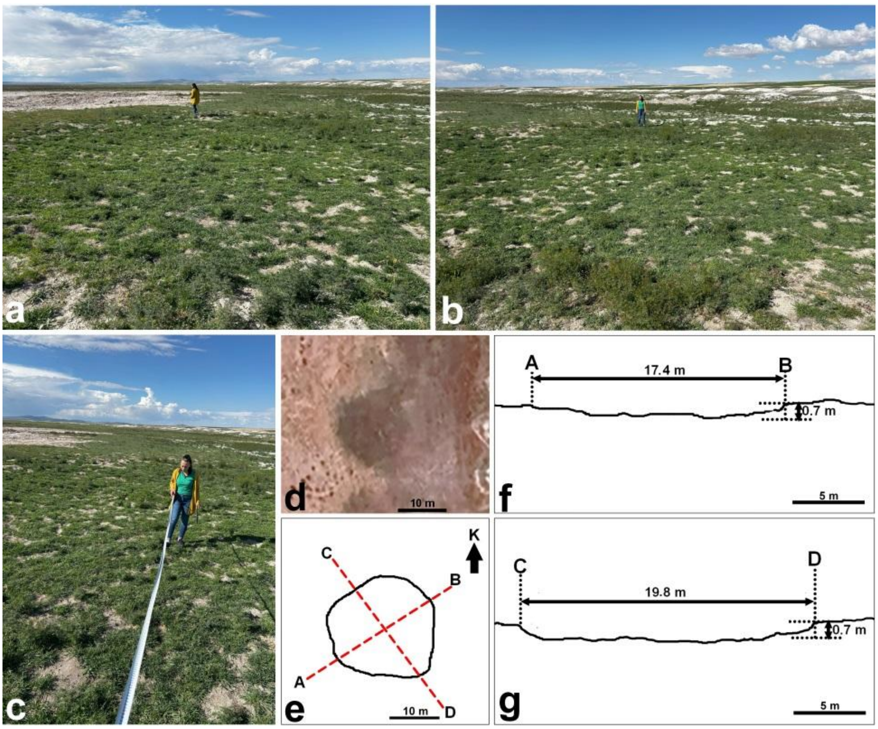


Source: Satellite views were received from https://www.google.com/maps/ and schematic drawings were constituted by using this satellite views.

Yıldız sinkhole

The sinkhole which is located approximately 0.867 km northwest of Akıncılar Village and 5.82 meters southeast of Akıncılar Sinkhole was named as Yıldız Sinkhole (Figure 6a-b). The historical satellite imagery indicates that the Yıldız Sinkhole must have been formed before 2008. The approximately circular-shaped sinkhole was measured as approximately 58.5 meters in perimeter, 19.8 meters in long axis, 17.4 meters in short axis and approximately 0.7 meters in depth (Figure 6c). According to the crow flies view (Figure 6d-e) of the Yıldız Sinkhole, the sections through its short (Figure 6f) and long axes (Figure 6g) were drawed separately. Yıldız Sinkhole was classified as slightly large, shallow, circular sinkhole (Table 2).

Figure 6: Yıldız Sinkhole; a-b. General views c. measurement prossess d. satellite view e. Schematic drawings of the crow flies view f. of short axess section g. of long axess section

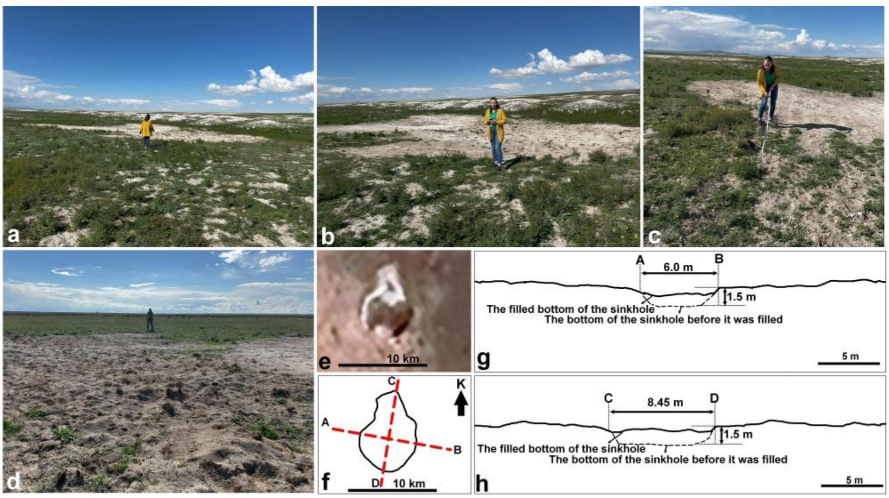


Source: Satellite views were received from https://www.google.com/maps/ and schematic drawings were constituted by using this satellite views.

Hoydus sinkhole

The sinkhole which is located approximately 0.834 km northwest of Akıncılar Village and 35.55 meters southeast of Yıldız Sinkhole was named as Hoydus Sinkhole (Figure 7a-b). According to the historical satellite imagery the Hoydus Sinkhole must have been formed before 2017. During the field studies carried out in 2025, it was observed that the sinkhole was filled. The less circular sinkhole was measured as approximately 23.6 meters perimeter, 8.47 meters long axis, 6.0 meters short axis, and approximately 1.5 meters deep after filling (Figure 7c-d). Based on the crow flies view (Figure 7e-f) the short axis (Figure 7g) and long axis (Figure 7h) sections of Hoydus Sinkhole were constituented. Hoydus Sinkhole was classified as small, slightly deep, less circular sinkhole (Table 2).

Figure 7: Hoydus Sinkhole; a-b. General views c-d. measurement prossess e. satellite view f. Schematic drawing of the crow flies view g. of short axess section h. of long axess section

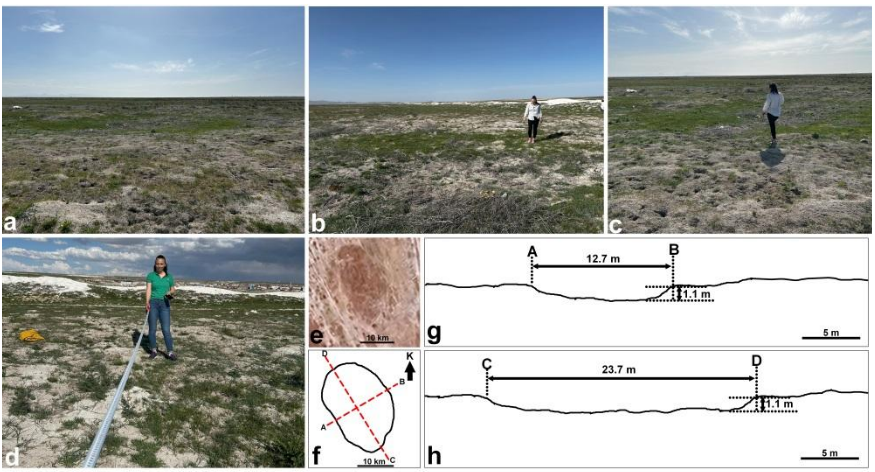


Source: Satellite views were received from https://www.google.com/maps/ and schematic drawings were constituted by using this satellite views.

Parlar sinkhole

The sinkhole which is located approximately 0.731 km northwest of Akıncılar Village was named as Parlar Sinkhole. The Parlar Sinkhole must have been formed before 2008 according to the historical satellite imagery. Although Parlar Sinkhole was not very deep and was hard to notice from a distance, it was becomed more apparent as you approach (Figure 8a-c). The sinkhole, which has an approximately wide ellipsoidal shape, was measured as approximately 59.2 meters perimeter, 23.7 meters long axis, 12.7 meters short axis, and 1.1 meters deep (Figure 8d). According to the crow flies view (Figure 8e-f) of the Parlar Sinkhole, the sections through its short (Figure 8g) and long axes (Figure 8h) were designed separately. Parlar Sinkhole was classified as slightly large, slightly deep, wide ellipsoidal sinkhole (Table 2).

Figure 8: Parlar Sinkhole; a-c. General views d. measurement prossess e. satellite view f. Schematic drawing of the crow flies view g. of short axess section h. of long axess section

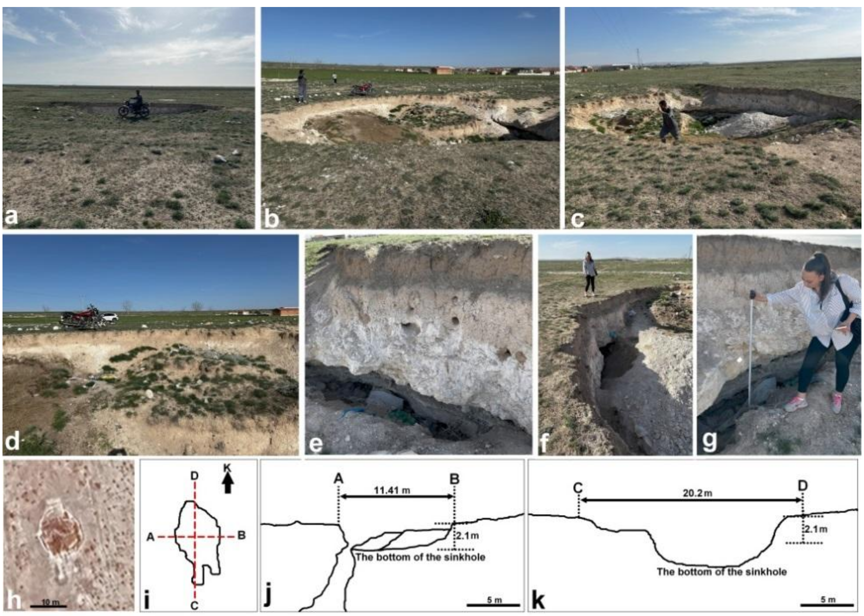


Source: Satellite views were received from https://www.google.com/maps/ and schematic drawings were constituted by using this satellite views.

Şeren sinkhole

The sinkhole which is located 0.178 meters north of Akıncılar Village was named as Şeren Sinkhole. The Şeren Sinkhole must have been formed before 2008 according to the historical satellite imagery. It was observed that Şeren Sinkhole was formed by the union of two sinkholes, one deep and one shallow (Figure 9a-d) and it presents a wide ellipsoidal shape. Measured circumference is approximately 53.26 meters, long axis is 20.2 m, short axis is 11.41 m and apparent depth to the bottom of the sinkhole is 2.1 m.

Figure 9: Şeren Sinkhole; a-d. General views e-f. a space thought to be a cave opening g. measurement prossess h. satellite view i. Schematic drawing of the crow flies view j. of short axess section k. of long axess section



Source: Satellite views were received from https://www.google.com/maps/ and schematic drawings were constituted by using this satellite views.

The northern side of the sinkhole is deeper, with a long axis of 13.3 m, a short axis of 11.4 m, and an apparent depth of 2.1 m down to the bottom of the sinkhole. The southern side of the sinkhole is shallower, with a long axis of 7.9 m, a short axis of 6.8 m, and an apparent depth of 0.8 m to the bottom of the sinkhole. The collapsed part of the sinkhole is observed on the eastern side and it is clearly seen that the surface has dropped by approximately 0.6 m. (Figure 9b-9d). The western side of the sinkhole was observed to be heavily eroded. At here a 1.5-meter wide and at least 10-meter deep cavity with no visible bottom was observed (Figure 9e-f). This cavity was thought to be the mouth of a cave and was dugged by local people. The walls of the sinkhole was a vertical section where lithologies and stratigraphy can be easily seen and the thickness of the units had been measured (Figure 9g). From top to bottom, 0.20 m thick topsoil, 0.35 m thick clayey, sandy, gravelly level, 0.35 m thick sand, mud, clay, carbonate rich level and 1.2 m thick limestone level were measured. According to the crow flies view (Figure 9h-i) of the Şeren Sinkhole, the sections through its short (Figure 9j) and long axes (Figure 9k) were drawed separately. Şeren Sinkhole was classified as slightly large, slightly deep, wide ellipsoidal sinkhole (Table 2).

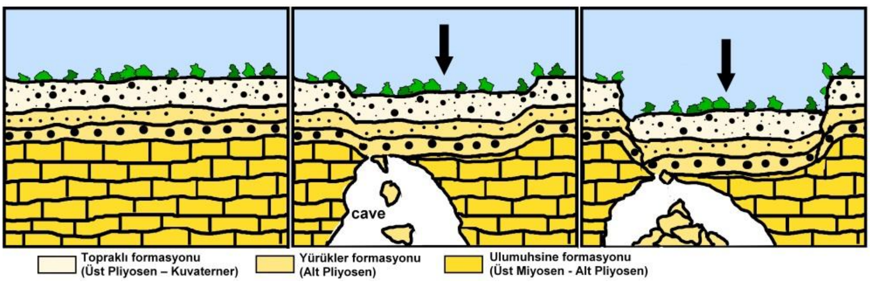
Formation model of the sinkholes

All of the Group 1 sinkholes of in the north were formed in the Upper Pliocene-Quaternary aged Topraklı formation. Of the Group 2 sinkholes in the south, the Şeren and Parlar sinkholes were formed in the Lower Pliocene aged Yürükler formation, while the Akıncılar, Hoydus and Yıldız sinkholes were formed in the sediments croped out based on the drying of Geren Lake. The sinkholes in the region were observed in the younger units which were formed in the Lower Pliocene-Quaternary time period. It is also clearly seen that the sinkholes in the region were located within the Altınekin Fault zone (Figure 2).

Sinkholes have formation mechanisms such as dissolution, collapse, etc. and can be divided into 6 main groups as solution sinkhole, collapse sinkhole, caprock sinkhole, dropout sinkhole, suffosion sinkhole and buried sinkhole (Waltham et al, 2005; Eren et al., 2024a).

In the study area, the underground cavities formed in the carbonate rocks under the cap rocks had gradually expanded over time, the cap rocks above had gradually collapsed and as a result of this collapse, the sinkholes in the region had formed. Thus, it has been concluded that the sinkholes in the region were caprock sinkholes (Figure 10). Of these, only the Bolluk Sinkhole had formed as a result of the collapse of a travertine cone.

Figure 10. Formation model of the sinkholes in the investigation area a. before the formation of sinkhole b. Collapse of the caprocks depending on the formation of underground caves in carbonate rocks c. the final state of the sinkhole



Recommendation

The Group 1 sinkholes were determined in the northeast of Bolluk Lake (Cihanbeyli) (98 km from Konya) and the Group 2 sinkholes were determined in the northwest of Akıncılar Village (Altınekin) (69 km from Konya). These areas can be easily reached via the D-715 Highway from Konya to Ankara.

While driving on the D-715 Highway, when you enter the road to Yapalı Village and drive for approximately 4.75 km, you will reach the Group 1 sinkholes. The Group 2 sinkholes can be reached by entering the road to Akıncılar Village while proceeding on the D-715 Highway and proceeding for approximately 5.6 km. In the last 25 years, many newly formed sinkholes have recorded in different regions of Konya. Although sinkholes have a potential to cause disaster, they are valuable as geoheritage due to both their formation mechanisms and the visual appeal they present after their formation. In this sense, it is important to protect geological structures and evaluate them as cultural values by introducing them to geotourism.

Once formed, sinkholes can cause the ecology in the region to be reshaped. Some sinkholes constitute a closed lake environment because they are watery. Therefore thiswatery sinkholes is a suitable living environment for micro (e.g. Durmaz et al. 2022; Şenkul and Doğan, 2018; Demirel et al. 2025) and/or macro organisms. Especially the deep sinkhole walls had created a suitable environment for niches and nests for some animals, especially birds (e.g. Ulusoy and Bulut, 2020). Additionally, floral diversity can be observed in sinkholes (e.g. Tel et al., 2022). No wet sinkhole was identified in the study area, all sinkholes were dry sinkholes. It was also observed that there were various animal niches and nests on this dry sinkhole walls.

It was observed that some of the sinkholes in the region have been filled. Filling the sinkholes in this way is not a correct and permanent solution. Because it has been observed that the filled sinkholes were continued to form and that circular single or double fissure systems were formed in the fillings. In this sense, it would be beneficial not to fill the sinkholes, to place warning signs around them and to surround them with wires if necessary.

References

Altay Y & Keskın İ. (2018). Determination of Factors Affecting Wheat Production in Altınekin District by Risk Analysis. *Selcuk Journal of Agriculture and Food Sciences,* 32 (3): 496-501, https://dergipark.org.tr/tr/pub/selcukjafsci/issue/76751/1281660.

Bilgilioğlu, S. S., & Bilgilioğlu, H. (2023). Aksaray ili obruk duyarlılık haritasının Coğrafi Bilgi Sistemleri (CBS) ve Analitik Hiyerarşi Süreci (AHS) yöntemleri ile oluşturulması. *Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi*, 12(2): 612-625. https://doi.org/10.28948/ngumuh.1222497

Bozyiğit, R., & Tapur, T. (2009). Konya Ovası ve Çevresinde Yeraltı Sularının Obruk Oluşumlarına Etkisi. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi* (21), 137-155, https://dergipark.org.tr/tr/pub/susbed/issue/61797/924378

Bozdağ, A. & Göçmez, G. (2013). Evaluation of groundwater quality in the Cihanbeyli basin, Konya, Central Anatolia, Turkey. *Environ Earth Sci.* 69: 921-937. https://doi.org/10.1007/s12665-012-1977-4

Bölük, H., Afsin, M., Kavurmacı, M. & Akın, M. (2022). Kozaklı (Nevşehir) jeotermal alanındaki obrukların jeofizik yöntemler kullanılarak belirlenmesi. *Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi*, 11(4): 1074-1084. https://doi.org/10.28948/ ngumuh.1135619

Canik, B. & Çörekçioğlu, İ., (1986). The Formation of Sinkholes (Obruk) Between Karapınar and Kızören-Konya. *IAHS-AISH Publication*, 161: 193-205.

Demir, V., Uray, E., Orhan, O., Yavariabdi, A. & Kusetogullari, H., (2021). Trend Analysis of Ground-Water Levels and The Effect of Effective Soil Stress Change: The Case Study of Konya Closed Basin. *Avrupa Bilim Ve Teknoloji Dergisi,* (24): 515-522. https://doi.org/10.31590/ejosat.916026

Demirel, Z., Parlar, Ş., Coşkuner, B., Yıldırım, A., Dalay, M. C. & Eren, Y. (2025). Konya Meyil Obruk Gölü'nün Karakteristik Özellikleri, Bazı Siyanobakteri ve Diyatom Taksonlarının İzolasyonu, Onların Moleküler-Morfolojik Teşhisleri. *Bilecik Şeyh Edebali Üniversitesi Fen Bilimleri Dergisi*, 12 (1): 27-46. https://doi.org/10.35193/ bseufbd.1409558

Doğan, A. (1975). Sızma - Ladik (Konya) civa sahasının jeolojisi ve maden yatakları sorularının incelenmesi, *Yüksek Lisans Tezi, Î.Ü. Fen Fakültesi*, 40 s. (yayınlanmamış).

Doğan, U. & Yılmaz, M. (2011). Natural and Induced Sinkholes of the Obruk Plateau and Karapınar-Hotamış Plain, Turkey. *Journal of Asian Earth Sciences*, 40 (2): 496-508. https://doi.org/10.1016/j.jseaes.2010.09.014

Droop,, G. T. R., Karakaya, M. Ç., Eren, Y. & Karakaya, N. (2005). Metamorphic evolution of blueschists of the Altınekin Complex, Konya area, south central Turkey. *Geological Journal,* 40 (2): 127-153, https://doi.org/10.1002/gj.1000.

Durduran, S. S., Bozdağ, A., Okka, C. T. & Alkan, T. (2021). Monitoring of Groundwater Level Change with Geographical Information System (GIS), The Case of Konya Altınekin Basin. *Afyon Kocatepe Üniversitesi Fen Ve Mühendislik Bilimleri Dergisi*, 21 (3): 620-631, https://doi.org/10.35414/akufemubid.889321.

Durmaz, O., Altindag, A., Gürgen, G. & Berdi, D. (2022). Zooplankton Fauna and Seasonal Changes of Two Karstic Sinkhole Lakes: Meyil and Kızören (Konya/Türkiye). *Journal of Limnology* *and Freshwater Fisheries Research*, 8 (3): 251-257, https://doi.org/10.17216/limnofish.1056613.

Eren, Y. (1993). Konya Kuzeybatısında Bozdağlar Masifinin Otokton ve Örtü Birimlerinin Stratigrafisi. *Türkiye Jeoloji Bülteni,* 36: 7-23, https://www.jmo.org.tr/resimler/ekler/baa271bc35fe054_ek.pdf.

Eren, Y. (2000). Tuzgölü Havzası Güneybatısındaki (Altınekin-Konya) temel kayaçlarının jeolojisi. Geology of the basement rocks in the southwest of the Tuzgölü basin (Altınekin-Konya). Haymana-Tuzgölü-Ulukışla Basenleri Uygulamalı Çalışma (Workshop). Ed: Derman, S. ve Tekin, T. *Türkiye Petrol Jeologları Derneği Özel Sayı* 5, 113-126.

Eren, Y., Coşkuner, B., Parlar, Ş. & Arslan, Ş. (2021a). Geological and Morphological Characteristics of the Sinkholes Around The Seyithacı (NE Karapınar, Konya). In: Gürçay, G., Khorram, M., eds., *Aegean Summit 2nd İnternational Applied Sciences Congress*, İzmir, Abstract Book, pp. 20-21.

Eren, Y., Parlar, Ş., Coşkuner, B. & Arslan, Ş., (2021b). Sinkhole Formation and Their Geological Features around the Siyeklik Settlement (NE Karapınar, Konya), In: Haydarlou, M. M., ed., *Karadeniz 5th International Conference On Applied Sciences*, Rize, Abstract Book, pp.10-11.

Eren, Y., Parlar, Ş., Coşkuner, B. & Arslan, Ş. (2021c). Sinkhole Formation In Hotamiş-Akgöl Basins In The South Of Karapinar (Konya, Central Anatolia), In: Gürçay, G., Khorram, M., eds., *Aegean Summit 2nd İnternational Applied Sciences Congress*, İzmir, Abstract Book, pp. 18-19.

Eren, Y., Coşkuner, B. & Parlar, Ş. (2021d). Menekirsesi Sinkhole (Karapinar- Konya, Central Anatolia): An Example Of

Geologically Interesting Giant Sinkhole Formation, In: Haydarlou, M. M., ed., *Karadeniz 5th International Conference On Applied Sciences*, Rize, Abstract Book, pp.12-13.

Eren, Y., Parlar, Ş. & Coşkuner, B. (2024a). Chapter 11: Geology, Morphology and Formation Mechanism Of The Çandir Yaren Sinkhole (Selçuklu, Konya), In: International Studies and Evaluations in the Field of Engineering, Ed. Özalp, C. and Bardak, S., ISBN: 978-625-5955-67-8, *Serüven Publishing*, pp. 187-206, https://www.seruvenyayinevi.com/Webkontrol/uploads/Fck/engARALK.pdf

Eren, Y., Parlar, Ş., Coşkuner, B. & Arslan, Ş. (2024b). Geological and Morphological Features of the Karapınar Sinkholes (Konya, Central Anatolia, Türkiye). *J. Earth Sci.* 35:, 1654-1668. https://doi.org/10.1007/s12583-023-1853-z.

Erol, O. (1991). The Relationship between the Phases of the Development of the Konya-Karapinar Obruks and the Pleistocene Tuz Gölü and Konya Pluvial Lakes, Turkey. *Journal of Istanbul University Institute of Marine Sciences and Geography*, 7: 5-49 (in Turkish).

https://www.aa.com.tr/tr/gundem/konyada-50-metre-capinda-olusan-obrugun-genisleme-ani-kaydedildi/3440998 (available: 30/05/2025)

https://www.google.com/maps/ (available: 30/05/2025)

https://www.hurriyet.com.tr/gundem/konyada-obruk-olusumu-saniye-saniye-goruntulendi-42647159 (available: 03/06/2025)

https://www.milliyet.com.tr/gundem/konyada-obruk-olusumu-cep-telefonu-kamerasina-yansidi-buyuk-bir-gurultuyle-coktu-7274150 (available: 02/06/2025) https://www.pusulahaber.com.tr/son-dakika-konyada-dev-obruk-olustu-1775643h.htm (available: 20/06/2025)

Göğer, E. & Kıral, K. (1969). Kızılören dolayının jeolojisi, *M.T.A. Rapor,* No: 5204, Ankara, (yayınlanmamış).

Karaman, M. E. (1986). Altınekin (Konya) çevresinin jeolojisi ve tektonik evrimi. *Türkiye Jeoloji Kur. Bülteni*, 1, 157-170, https://www.jmo.org.tr/resimler/ekler/417dc 8af8570f27_ek.p df

Orhan, O., Kırtıloğlu, O. S., & Yakar, M. (2020). Konya Kapalı Havzası Obruk Envanter Bilgi Sisteminin Oluşturulması. *Geomatik,* 5 (2): 81-90. https://doi.org/10.29128/geomatik. 577167

Öner, E. (2003). Divle Obrugu. *Ege Coğrafya Dergisi*, 12 (2): 83- 92, https://dergipark.org.tr/tr/pub /ecd/issue/4881/66947

Özdemir, A. (2015a). Investigation of sinkholes spatial distribution using the weights of evidence method and GIS in the vicinity of Karapinar (Konya, Turkey). *Geomorphology*, 245: 40-50, https://doi.org/10.1016/j.geomorph.2015.04.034.

Özdemir, A. (2015b). Sinkhole susceptibility mapping using a frequency ratio method and GIS technology near Karapınar, Konya-Turkey. *Procedia Earth and Planetary Science.* 15: 502-506, https://doi.org/10.1016/j.proeps.2015.08.059.

Özdemir, A. (2016). Sinkhole susceptibility mapping using logistic regression in Karapınar (Konya, Turkey). *Bulletin of Engineering Geology and the Environment*, 75: 681-707, https://doi.org/10.1007/s10064-015-0778-x

Parlar, Ş., Coşkuner, B. & Eren, Y. (2021a). The Statistical Analysis Of Dimension Data For All Observed Sinkholes In Karapınar And Surroundings (Konya, Central Anatolia-Turkey). In:

Sakhi, Z., Erkmen, O., eds., *5th International Zeugma Conference On Scientific Researches*, Gaziantep, Abstract Book, pp. 88-89.

Parlar, Ş., Eren, Y., Coşkuner, B., Arslan, Ş. 2021b, Geological Characteristics Of Sinkholes Around The Meyil-Yirce And Akkuyu (Obruk Plato-Karapinar, Konya). In: Gün, S.,, M. M., ed., *2. İnternational Gobeklitepe Scientific Studies Congress,* Şanlıurfa, Abstract Book, pp. 266-267.

Pınar, A., Buldur, A. D. & Tuncer, T. (2018). Bolluk Gölü Traverten Konilerinin Geçmişten Günümüze Değişimi. *Marmara Coğrafya Dergisi,* 37: 233-252, https://dergipark.org.tr/tr/pub/marucog/issue/34834/386373

Sayhan, H. (2014). Mucur Obruğu (Kırşehir). *Türk Coğrafya Dergisi,* (34): 111-121. https://doi.org/10.17211/tcd.36587.

Şenkul, Ç., & Doğan, M. (2018). Fosil ve güncel polen analizleri ışığında Mucur Obruk Gölü çevresinin paleovejetasyon değişimleri. *Türk Coğrafya Dergisi*, 70: 19-28. https://doi.org/10.17211/tcd.342955.

Tapur, T. & Bozyiğit, R. (2015). Current Sinkholes Formations in Konya Province. *International Journal of Geography and Geography Education*, 31: 415–446 (in Turkish), https://dergipark.org.tr/tr/pub/marucog/issue/478/4036.

Tel, A. Z., Ortaç, İ. & Özuslu, E. (2022). Bazı mağara ve obrukların (Mersin/Türkiye) flora ve genel vejetasyon yapıları üzerine bir araştırma. *Biological Diversity and Conservation*, 15(3), 356-368. https://doi.org/10.46309/biodicon.2022.1180111.

Tuncer, T. & Pınar, A. (2017). Altınekin İlçesi'nde Jeoloji, Jeomorfoloji ve Toprak Faktörlerinin Yeraltı Su Kuyularının Dağılışına Etkisi. *Marmara Coğrafya Dergisi*, 36: 260-270, https://dergipark.org.tr/tr/pub/marucog/issue/30253/330015.

Tuncer, K. (2023). Likya Napları Bölgesinde Epijenik Buruk Düdeni ve Gümüşdere Obruğunun (Tavas, Denizli) Jeomorfolojik Özellikleri ve Gelişimi. *Jeomorfolojik Araştırmalar Dergisi* (10): 91-109. https://doi.org/10.46453/jader.1233907.

Tuncer, T., & Tuncer, B. (2023). The Effect of Geographical Factors on Agricultural Activities in Altınekin District. *COMU Journal of Agriculture Faculty*, 11(2): 401-416. https://doi.org/10.33202/comuagri.1258078.

Ulusoy, K. & Bulut Ş.(2020). Wintering Bird Diversity and Population Sizes at Obruk Dam Lake (Corum) in Turkey. *Hittite J Sci Eng.* 7 (4) : 353-358, https://dergipark.org.tr/en/pub/hjse/issue/59994/866503.

Uzun, M. (2024). Tersakan ve Bolluk Göllerindeki (Konya) Yıllık ve Aylık Su Yüzeyi Değişimlerinin Uydu Görüntüleri İle Analizi. *Ege Coğrafya Dergisi*, 33(2): 219-243. https://doi.org/10.51800/ecd.1536680.

GEOLOGY AND MORPHOLOGY OF THE BELKUYU SINKHOLE (KONYA, TÜRKİYE)

BERKANT COŞKUNER[1]
YAŞAR EREN[2]

Introduction

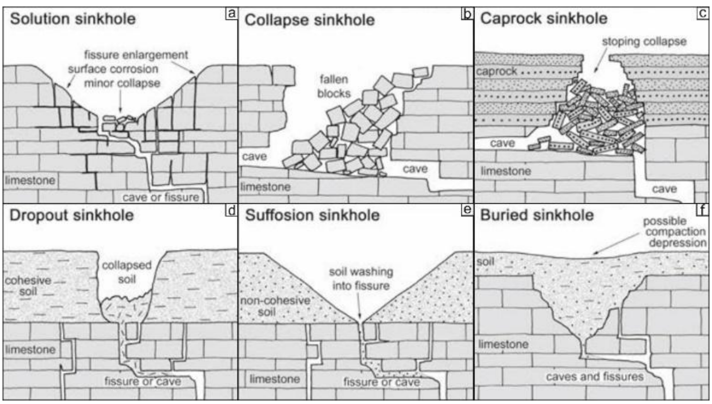
Konya (Central Anatolia, Turkey) region includes many sinkholes with different characteristics and sizes. (Erinç, 1960; Eroskay, 1976; Eroskay and Günay, 1979; Güldalı and Şaroğlu, 1983; Canik and Çörekçioğlu, 1986; Erol, 1991; Bayari et al., 2009; Doğan and Yılmaz, 2011; Göçmez, 2011; Günay et al., 2010; Özdemir, 2015a, 2015b; Orhan et al., 2020; Eren et al., 2024a). Especially in recent years, the widespread formation of sinkholes in the region has attracted attention. The most well-known sinkhole area in Konya is the Obruk Plateau in the Karapınar region. In this area, many sinkholes with different diameters and depths are observed. The morphological characteristics of the sinkholes and the structural features of the region were examined in detail with the studies carried out in the Karapınar (Eren et al., 2021a, 2021b,

[1] Asst. Prof. Dr. Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geological Engineering, Orcid: 0000-0002-9798-8793
[2] Prof. Dr. Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geological Engineering, Orcid:0000-0002-7899-8507

2021c, 2021d; Parlar et al., 2021a, 2021b; Eren et al., 2024b; Demirel et al., 2025; Eren et al., 2025)

The sinkholes are formed as a result of karstic processes where soluble rocks such as limestone, dolomite and gypsum are found (Cvijic, 1893; Williams, 2004; Waltham et al., 2005). Groundwater which is rich in carbon dioxide circulates along fracture systems in the region, dissolving soluble rocks over time and causing the formation of underground cavities and cave systems. Although multiple factors contribute to the formation of sinkholes, the basic mechanism is the expansion of the cave systems towards the surface and the collapse of the roofs of underground cavities (karst cavities). In addition to natural causes, anthropogenic factors such as the collapse of underground mining galleries, excessive groundwater and material extraction via drilling, or overuse of groundwater resources can also induce surface deformations that lead to sinkhole formation.Based on their formation mechanisms, sinkholes are classified into six major types: solution sinkholes, collapse sinkholes, caprock sinkholes, dropout sinkholes, suffosion sinkholes, and buried sinkholes (Waltham et al., 2005) (Figure 1).

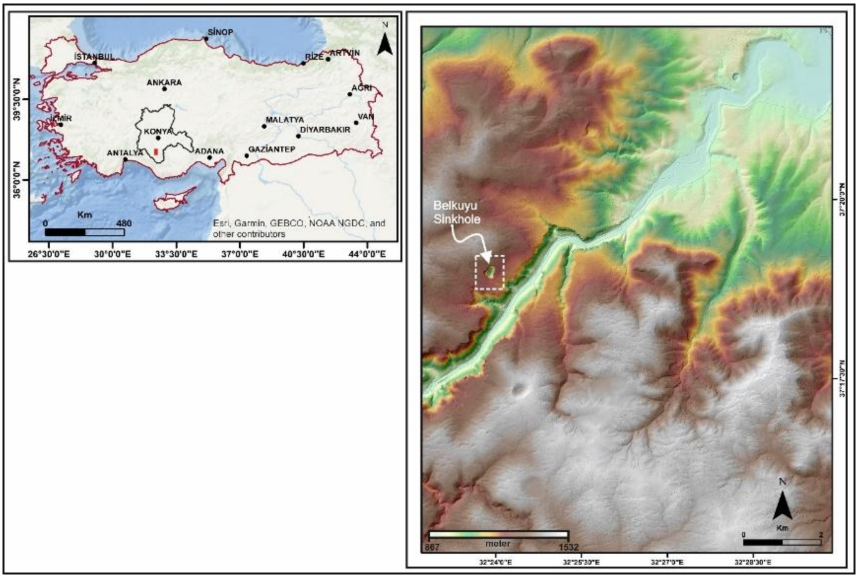
Figure 1: Sinkhole types.



Source: Waltham et al. 2005

In the Konya region, sinkholes are generally found in sparsely populated elevated areas and in the basins between these elevations. The Belkuyu Sinkhole investigated in this study (Figure 2) is located approximately 60 kilometers south of the Konya city center and represents a significant example for geological and morphological analysis.

Figure 2: Location map of the study area.



Geological features

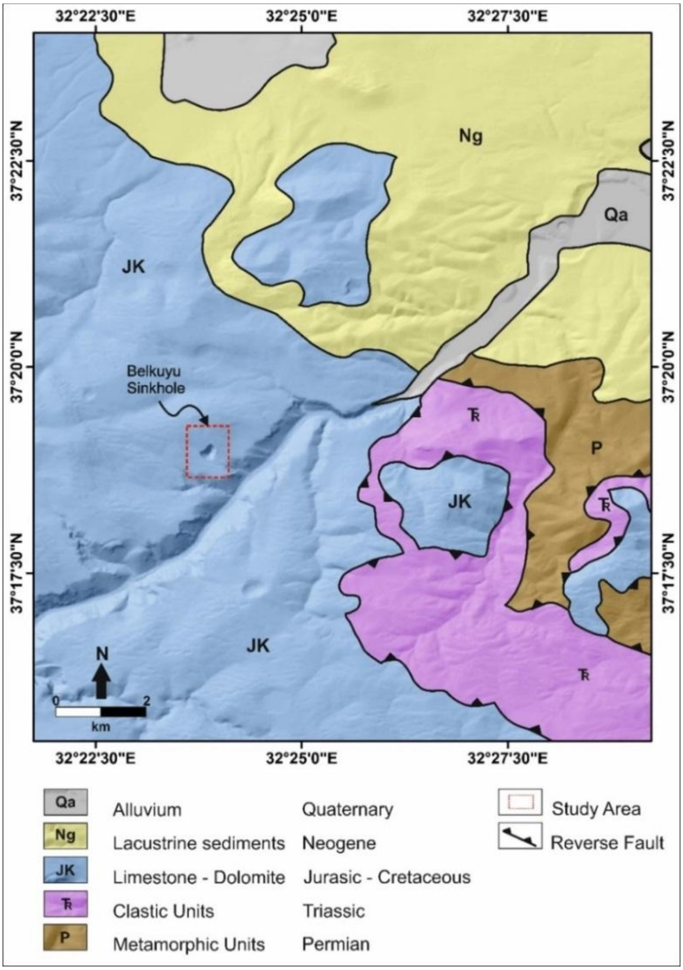
The study area, located in the southern part of Konya Province, comprises Paleozoic and Mesozoic units that have been affected by pre-Alpine, Alpine, and late tectonic events (Kaaden, 1966; Wiesner, 1968; Göger and Kıral, 1969; Eren, 1993, 1996, 2003a; Eren et al., 2004; Özcan et al., 1988, 1990; Kurt, 1996, 1997; Kurt and Arslan, 1999; Ulu et al., 1994). The main morphological structures consist of the region NW-SE oriented elevations and NE trending basins. The upland areas consist of Paleozoic - Mesozoic aged metamorphic and carbonate rocks, while the depression areas contain lacustrine, terrestrial and volcanic units belonging to the Miocene-Pliocene periods. (Keller, 1974; Besang et al., 1977; Eren, 1996, 2001, 2003b, 2011; Eren et al., 2024; Koç et al., 2012; Hüseyinca and Eren, 2007; Aksoy, 2019; Asan et al., 2021; Friedrichs et al., 2020; Gençoğlu et al., 2022).

The Paleozoic-Mesozoic aged rocks were affected by pre-Alpine and Alpine tectonic movements; in this period they were folded, metamorphosed and structural features such as thrusts, naps and faults were developed (Eren, 1996; 2001). During the younger tectonic phases, NW–SE trending grabens formed due to block faulting, and the underlying rocks were re-fractured and uplifted.

The oldest rocks of the study area are Permian aged metamorphic units. The Permian aged units, which were deformed as a result of Alpine movements and gained a folded and thrust structure, are tectonically overlie on the Triassic aged clastic units. In the study area, Triassic-aged formations with a northwest-southeast orientation are extensively exposed and have been emplaced tectonically over carbonate rock units. The Jurassic–Cretaceous aged carbonate units, which include the Belkuyu Sinkhole, are overlain by terrestrial Miocene deposits in the northeastern part of the study area. All these units are unconformably overlain by alluvial deposits (Figure 3).

In order to better visualize the fracture systems in the region around the study area, lineaments were automatically detected from the hillshade image. Lineaments were automatically extracted from the hillshade image which is generated using 12.5 m resolution DEM data, by employing the Line module of the Geomatica application (parameters: RADI 12, GTHR 80, LTHR 30, FTHR 10, ATHR 30, DTHR 15). Subsequently, a rose diagram illustrating the orientation of the detected lineaments was produced.

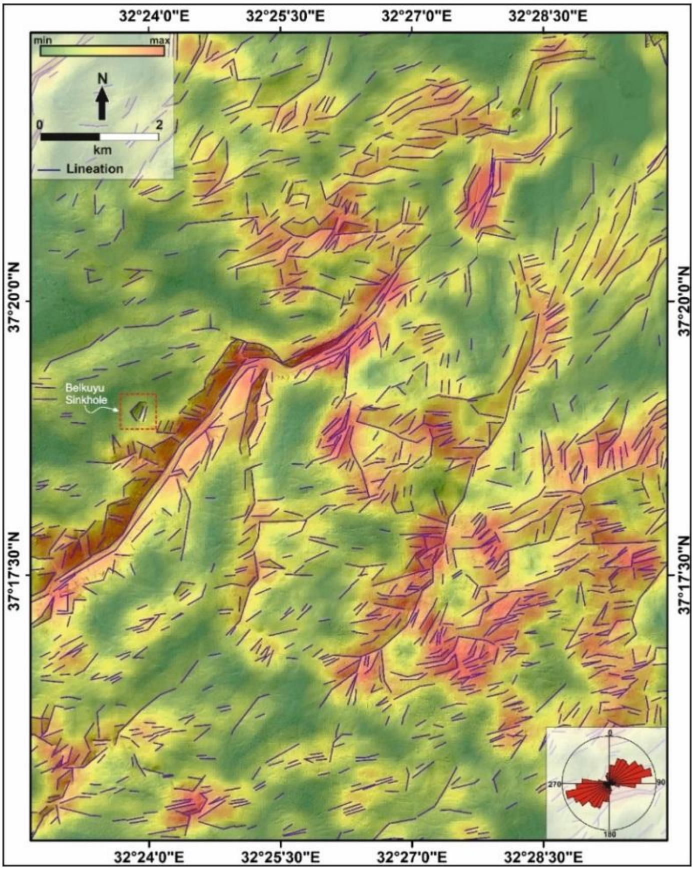
Figure 3: Geology map of the study area.



Source: Şenel (2002)

In addition, a lineation density map was created from these detected lineations. When the density map was analyzed, it was observed that lineations were concentrated in different parts of the study area. It is observed that the density of lineaments in the SE is higher relative to the NW within the study area.When the geological map is analyzed, it is determined that the area with intense linearity in the SE coincides with the thrust zone. It is also thought that the area south of the Belkuyu sinkhole where the lineation is intense may be associated with a fracture system. The rose diagram of the lineament orientations indicates that the lineaments predominantly trend in a NE–SW direction. The fact that the long axis of the Belkuyu sinkhole, which does not present a complete circularity, is also oriented NE-SW indicates that there is a connection between the long axis of the sinkhole and the regional scale lineations (Figure 4).

Figure 4: Regional scale density map of automatically generated lineaments and a rose diagram showing the orientation of the lineaments.



Features of Belkuyu sinkhole

During the field surveys, it was observed that Belkuyu sinkhole was formed within the Jurassic - Cretaceous carbonate rocks (Figure 5). Limestones have medium to thick layers and their bedding plane is close to horizontal. Also calcite-filled veins of different lengths and widths are observed on the limestone unit.

The sinkhole exhibits steep walls, while its base is observed to be infilled with block collapses and colluvial deposits originating from the surrounding lithologies (Figure 6).

As a result of the observations made on the walls of the sinkhole, joint sets with different orientations are observed (Figure 7). Most of these fracture sets have a steep, while a few have a low-angle slope. Fractures have a great influence on the formation of karst structure.

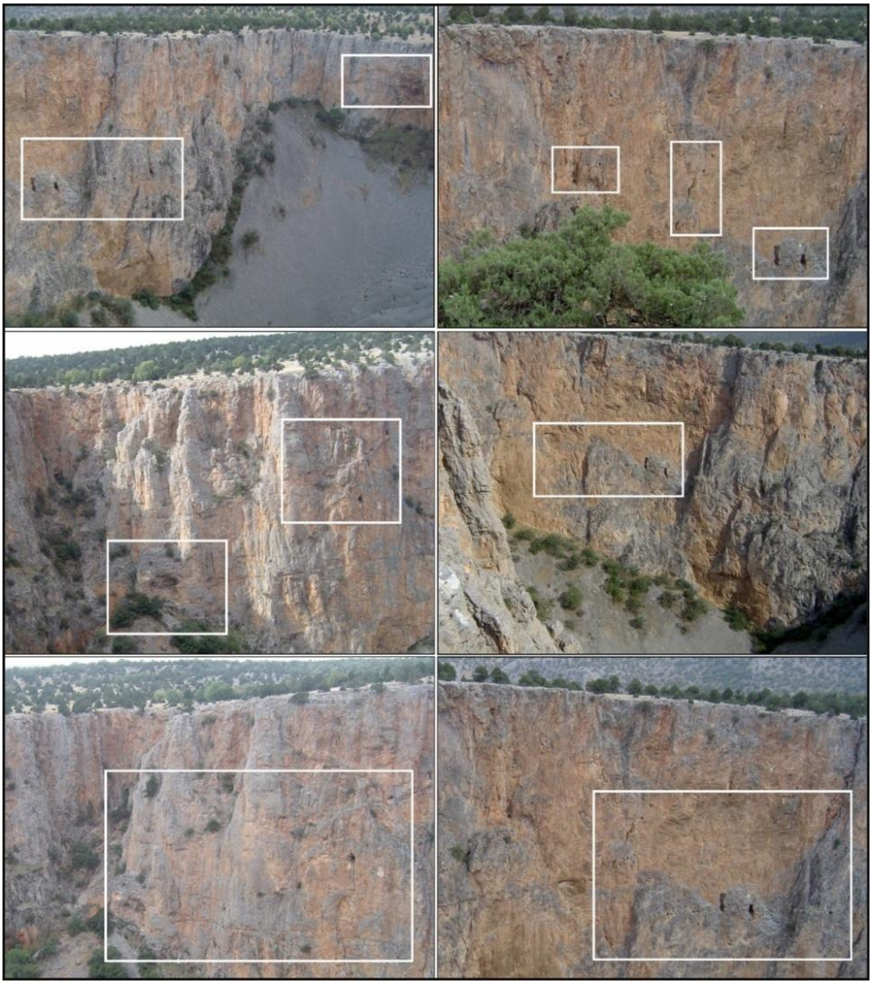
Figure 5: Mesozoic units of Belkuyu Sinkhole.

Figure 6: Colluvial deposits accumulated at the base of the Belkuyu Sinkhole.

Figure 7: The walls of the Belkuyu Sinkhole exhibit multiple joint sets with differing orientations and dip angles.

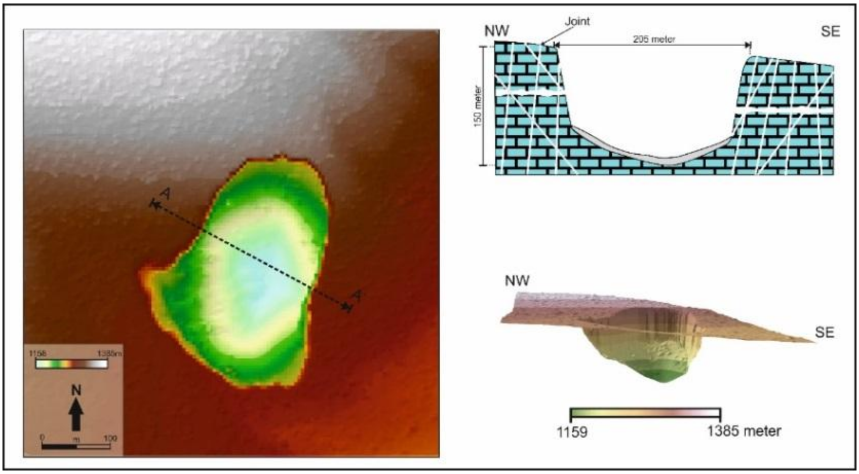
In addition, the karstic cavities in the walls of the sinkhole (Figure 8) show that karstification was effective in the formation process of the sinkhole. These karstic structures observed on the walls of the sinkhole provide us with clues about the previous solution processes.

Figure 8: Karstic cavities observed in the walls of Belkuyu Sinkhole.



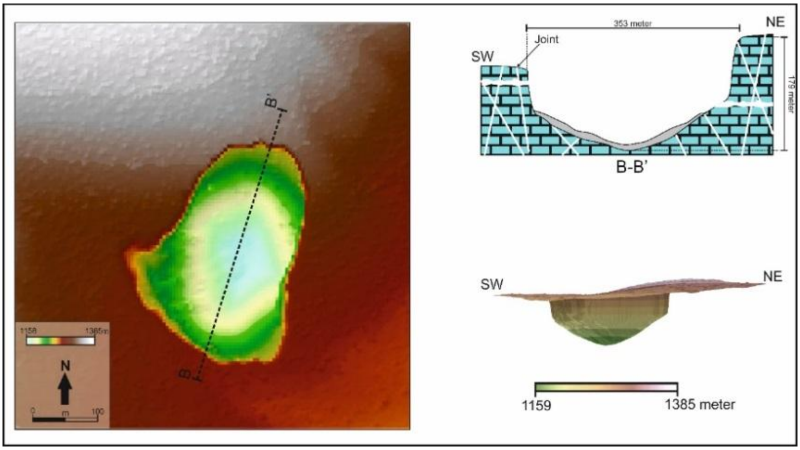
The Belkuyu Sinkhole exhibits an elliptical morphology rather than a perfectly circular form. In order to better understand the morphologic features of the sinkhole, 2 cross-sectional directions, NW-SE and NE-SW, were determined. It was determined that the width of the sinkhole was 205 meters and the depth was 150 meters in the NW-SE direction. It is also observed in the profile that the NW part of the sinkhole is more elevated than the SE part. Furthermore, based on the analyzed profile, the southeastern section exhibits a steeper slope compared to the northwestern section (Figure 9).

Figure 9: NW - SE cross-section of Belkuyu Sinkhole.



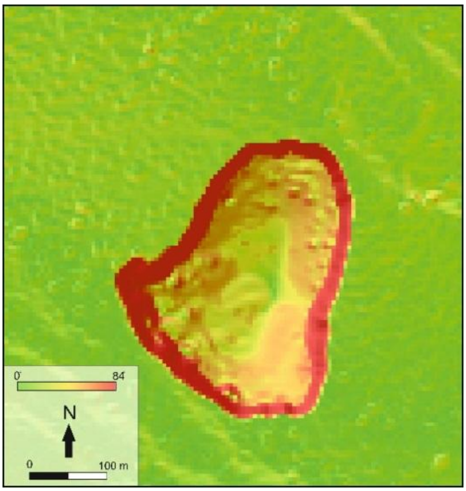
The width of the sinkhole is 353 meters and the depth is 179 meters in the SW - NE direction. It is also observed that the NE part of the sinkhole is more elevated than the SW part (Figure 10). As it is understood from these sections, it is determined that the long axis of the sinkhole is in SW - NE direction and the depth of the sinkhole varies between 150 and 179 meters in the cross sections.

Figure 10: SW - NE cross-section of Belkuyu Sinkhole.



A slope map was also generated for the sinkhole and its surrounding area. According to this map, slope values in and around the sinkhole range between 0° and 84° degrees. While the steepest slopes (up to 84°) occur along the vertical walls, slopes in the wall areas range between 60° and 70°. At the base of the sinkhole, the slope decreases significantly, varying between 0° and 30° (Figure 11).

Figure 11: Slope map of the sinkhole.



Results and conclusion

The Belkuyu Sinkhole is a bed rock collapse type sinkhole (Gutiérrez, 2016) that developed through karstification of Mesozoic aged limestones. The sinkhole has an elliptical morphology, with a long axis measuring 353 meters and a short axis measuring 205 meters. The orientation of the long axis, trending northeast–southwest (NE–SW), aligns with regionally identified automatic lineaments, indicating a strong structural control over the sinkhole's development. Karstification features have been observed along the sinkhole walls, while the base is filled with rock fragments derived from surrounding formations. Numerous sinkholes have been identified in the Mesozoic aged units in the region and this shows that sinkhole formation in Konya region is not limited to Miocene-Quaternary deposits. This observation underlines that older lithologies are also susceptible to karst processes and subsidence events.

This study aimed to thoroughly investigate the geological and morphological characteristics of the Belkuyu Sinkhole, located in southern Konya Province, to better understand the regional sinkhole formation processes. Field observations, geological map interpretations, lineament analyses, and morphological measurements reveal that the Belkuyu Sinkhole formed through a complex and multi-stage karstification process. The sinkhole evolved within Jurassic–Cretaceous carbonate rocks, where the primary mechanism was the dissolution of these rocks by groundwater, leading to the formation of subsurface voids that eventually collapsed and reached the surface. Fracture systems and structural weakness zones in the region have significantly influenced groundwater circulation, thereby accelerating karstification. This highlights the interplay between natural karst processes and tectonic structures in shaping the sinkhole.

The elliptical-shaped sinkhole varies in depth from 150 to 179 meters, depending on the cross-section. Slope analysis reveals that the sinkhole walls can be as steep as 84°, while the base features gentler inclinations ranging from 0° to 30°. Karst cavities, fracture systems, and calcite-filled veins observed on the sinkhole walls confirm active dissolution processes and the geological framework conducive to karstification.

Lineament analysis further demonstrates that the orientation of the sinkhole's long axis is consistent with the NE–SW trending regional fracture systems, suggesting that the sinkhole's morphology is influenced not only by lithological properties but also by regional tectonic controls. The lineament density map and rose diagram confirm that sinkhole formation is closely linked to structural geology.

All available data clearly demonstrate that sinkholes in the Konya Basin can develop not only within young sediments (Miocene–Quaternary) but also within older Mesozoic units. This indicates that karstic processes in the region have been active throughout geological time and that sinkhole formation is possible in rock units of varying ages. The Belkuyu Sinkhole is a significant geological structure formed through the combined effects of karstification, structural geology, morphology, and hydrogeological dynamics. It serves as an important example that can shed light on the formation mechanisms of other sinkholes in the region.

References

Aksoy, R. (2019). Extensional neotectonic regime in west-southwest Konya, Central Anatolia, Turkey. International Geology Review, 61 (14), 1803- 1821. doi.org/10.1080/00206814.2019.1581996

Asan, K., Kurt, H., Gündüz, M., Gençoğlu Korkmaz, G., Morgan, G. (2021). Geology, geochronology and geochemistry of the Miocene Sulutas volcanic complex, Konya-Central Anatolia: genesis of orogenic and anorogenic rock associations in an extensional geodynamic setting. *International Geology Review*, 63 (2), 161-192. doi.org/10.1080/00206814.2019.1706651

Bayarı, C. S., Pekkan, E., Ozyurt, N. N., (2008). Obruks, as giant collapse dolines caused by hypogenic karstification in Central Anatolia, Turkey: analysis of likely formation processes. *Hydrogeology Journal*, 17, 327-345.

Besang, C., Eckhardt, F. J., Harre, W., Kreuzer, H., Mililer, P. (1977). Radiometrische - Altersbestimmungen An Neogenen Eruptivgesteinen Der Türkei. *Geol. Jb.*, B25, 3-36.

Canik, B., Çörekçioğlu, İ., (1986). The Formation Of Sinkholes (Obruk) Between Karapınar and Kızören - Konya. *IAHS-AISH publication*, 161, 193-205.

Cvijic, J., (1893). Das Karstphanomen. Versuch einer morphologischen Monographie. *Geographischen Abhandlung*, 3, 218-329.

Demirel, Z., Parlar, Ş., Coşkuner, B., Yıldırım, A., Dalay, M. C., Eren, Y. (2025). Konya Meyil Obruk Gölü'nün Karakteristik Özellikleri, Bazı Siyanobakteri ve Diyatom Taksonlarının İzolasyonu, Onların Moleküler-Morfolojik Teşhisleri. *Bilecik Şeyh*

Edebali Üniversitesi Fen Bilimleri Dergisi, 12 (1): 27-46. doi.org/10.35193/bseufbd.1409558

Doğan, U., Yılmaz, M. (2011). Natural and induced sinkholes of the Obruk Plateau and Karapınar-Hotamış Plain, Turkey. *J. Asian Earth Sci.*, 40, 496-508. doi.org/10.1016/j.jseaes.2010.09.014

Eren, Y. (1993). Stratigraphy of autochthonous and cover units of the Bozdağlar massif NW Konya. *Geological Bulletin of Turkey*, 36, 7-23.

Eren, Y. (1996). Structural features of the Bozdağlar massif to the south of Ilgın and Sarayönü (Konya). *Geological Bulletin of Turkey*, 39 (2), 49-64.

Eren, Y. (2001). Polyphase Alpine deformation at the northern edge of the Menderes-Taurus block, North Konya, Central Turkey. *J. of Asian Earth Sci.*, 19 (6), 737-749. doi.org/10.1016/S1367-9120(01)00009-8

Eren, Y. (2003a). Konya bölgesinin depremselliği. *Türkiye Petrol Jeologları Derneği Özel Sayı*, 5, 85-98.

Eren, Y. (2003b). Yazır Fayı'nın (Konya) Neo-Tektonik Özellikleri. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, 9 (2), 237-244.

Eren, Y. (2011). Konya'nın jeolojisi, Neo-tektonik yapısı ve depremselliği. *I. Konya Kent Sempozyumu*, 27-28 Kasım 2011, Konya, (pp. 111-120).

Eren, Y., Kurt, H., François, R., Stampfli, G.M. (2004). Palaeozoic deformation and magmatism in the northern area of the Anatolide block (Konya), witness of the Palaeotethys active margin. *Eclogae Geologicae Helvetiae*, 97(2), 293-306.

Eren, Y., Coşkuner, B., Parlar, Ş., Arslan, Ş. (2021a). Geological and Morphological Characteristics of the Sinkholes Around The Seyithacı (NE Karapınar, Konya). *Aegean Summit 2nd İnternational Applied Sciences Congress*, 27-28 March 2021, İzmir, (pp. 20-21).

Eren, Y., Parlar, Ş., Coşkuner, B., Arslan, Ş., (2021b). Sinkhole Formation and Their Geological Features around the Siyeklik Settlement (NE Karapınar, Konya), *Karadeniz 5th International Conference On Applied Sciences*, 19-21 February 2021, Rize, (pp.10-11).

Eren, Y., Parlar, Ş., Coşkuner, B., Arslan, Ş. (2021c). Sinkhole Formation In Hotamiş-Akgöl Basins In The South Of Karapinar (Konya, Central Anatolia), *Aegean Summit 2nd İnternational Applied Sciences Congress*, 27-28 March 2021, İzmir, (pp. 18-19).

Eren, Y., Coşkuner, B., Parlar, Ş. (2021d). Menekirsesi Sinkhole (Karapinar- Konya, Central Anatolia): An Example Of Geologically Interesting Giant Sinkhole Formation, *Karadeniz 5th International Conference On Applied Sciences*, 19-21 February 2021, Rize, (pp.12-13).

Eren, Y., Parlar, Ş., Coşkuner, B., Arslan, Ş. (2024a). Geological and Morphological Features of the Karapınar Sinkholes (Konya, Central Anatolia, Türkiye). *J. Earth Sci*. 35, 1654-1668. doi.org/10.1007/s12583-023-1853-z.

Eren, Y., Parlar, Ş., Coşkuner, B. (2024b). Geology, Morphology and Formation Mechanism Of The Çandir Yaren Sinkhole (Selçuklu, Konya), Ed. Özalp, C. and Bardak, S., *In: International Studies and Evaluations in the Field of Engineering*, (pp. 187-206). Ankara: Serüven Publishing.

Eren, Y., Coşkuner, B., Parlar, Ş. (2025). An Example of Intracontinental Cross Faults Formation from the Vicinity of Karapınar (Konya–Central Anatolia). *Acta Geologica Polonica*, e35-e35.

Erinç, S. (1960) Karst forms in the Konya Section and the Inner Taurus ranges. *Turkish Journal of Geograph*, 20, 83-106.

Erol, O. (1991). The relationship between the phases of the development of the Konya-Karapinar obruks and the Pleistocene Tuz Gölü and Konya pluvial lakes, Turkey. *Journal of Istanbul University Institute of Marine Sciences and Geography*, 7, 5-49.

Eroskay, O., Gunay, G. (1979). Tectonic classification and hydrogeological properties of the karst regions in Turkey. *International Seminar on Karst Hydrogeology*, 1-41.

Eroskay, S. O. (1976). The factors influencing the Konya Obruks and their groundwater potentials evaluation. *İstanbul Üniv., Fen. Fak. Mec. Seri.* B, 41 (1-4), 5-14.

Friedrichs, B., Atıcı, G., Danisik, M., Atakay, E., Çobankaya , M., Harvey, J. C., Yurteri, E., Schmitt , A. K. (2020). Late Pleistocene eruptive recurrence in the post-collisional Mt. Hasan stratovolcanic complex (Central Anatolia) revealed by zircon double-dating. *J. of Volcanology and Geothermal Res.*, 404, 107007.

Gençoğlu, K. G., Kurt, H., Asan, K., Leybourne, M. (2022). Ar-Ar Geochronology and Sr-Nd-Pb-O Isotopic Systematics of the Post- collisional Volcanic Rocks from the Karapınar-Karacadağ Area (Central Anatolia, Turkey): An Alternative Model for Orogenic Geochemical Signature in Sodic Alkali Basalts. *Journal of Geosciences,* 1, 53 - 69.

Göçmez, G. (2011). Konya İlindeki Obruklar Ve Traverten Konileri. *I. Konya Kent Sempozyumu*, 27-28 Kasım 2011, Konya, (pp. 459-464).

Göğer, E., Kıral, K. (1969) Geology of the Kızılören region. *Min. Res. Expl. Rep.* 5204.

Gutiérrez, F. (2016). Sinkhole hazards. In Oxford research encyclopedia of natural hazard science.

Güldalı, N., Şaroğlu, F. (1983). Sinkholes of Konya region. *T.J.K. Yeryuvarı ve İnsan,* 7(4), 44-55.

Günay, G., Çörekçioğlu, İ., Eroskay, S., Övül, G. (2010). Konya Karapınar Obruks (Sinkholes) of Turkey. In: B. Andreo et al. (ed) *Advances in Research in Karst. Media,* Springer, 367-372.

Hüseyinca, M. Y., Eren, Y. (2007). Ilgın (Konya) Kuzeyinin Stratigrafisi ve Tektonik Evrimi. *Selçuk Üniv. Müh., Bil.ve Tekn. Derg.,* 22 (1), 83-96.

Kaaden, W.G. (1966). The significance and distribution of glaucophane rocks in Turkey. *MTA Bull*. 67, 36-67

Keller, J., 1974. Quaternary maar volcanism near Karapinar in Central Anatolia. *Bulletin Volcanologique*, 38, 378-396.

Koç, A., Kaymakci, N., Hinsbergen, D.J.J. VanKuiper, K.F., Vissers, R.L.M. (2012). Tectono sedimentary evolution and geochronology of the middle Miocene Altınapa Basin, and implications for the late Cenozoic uplift history of the Taurides, southern Turkey. *Tectonophysics*, 532, 134- 155.

Kurt, H., Arslan, M. (1999). Geochemistry and petrogenesis of Kadınhanı (Konya) K-rich metatrachyandesite: The evolution of Devonian (?) volcanism. *Geol. Bull. Turkey,* 42(1), 57-69

Kurt, H. (1996). Geochemical characteristics of the meta-igneous rocks near Kadınhanı (Konya), Turkey. *Geosound* 28, 1-22.

Kurt, H. (1997), Geochemistry of metasedimentary rocks of the Kadınhanı (Konya) area, Turkey. *Geosound*, 31, 1-21.

Orhan, O., Yakar, Y., Ekercin, S. (2020). An application on sinkhole susceptibility mapping by integrating remote sensing and geographic information system. *Arabian Journal of Geosciences*, 13, 1-17.

Özcan, A., Göncüoğlu, M.C., Turhan, N., Uysal, S., Şentürk, K., Işık, A. (1988) Late Palaeozoic evolution of the Kütahya-Bolkardağı belt. *METU J. Pure Appl. Sci.,* 21 (1/3), 211-220.

Özdemir, A. (2015a). Sinkhole Susceptibility Mapping Using a Frequency Ratio Method and GIS Technology Near Karapınar, Konya-Turkey. *Procedia Earth and Planetary Science,* 15, 502-506.

Özdemir, A. (2015b). Investigation of sinkholes spatial distribution using the weights of evidence method and GIS in the vicinity of Karapinar (Konya, Turkey). *Geomorphology,* 245, 40-50.

Parlar, Ş., Coşkuner, B., Eren, Y. (2021a). The Statistical Analysis Of Dimension Data For All Observed Sinkholes In Karapınar And Surroundings (Konya, Central Anatolia-Turkey). *5th International Zeugma Conference on Scientific Researches,* 8-9 January 2021, Gaziantep, (pp. 88-89).

Parlar, Ş., Eren, Y., Coşkuner, B., Arslan, Ş. 2021b, Geological Characteristics Of Sinkholes Around The Meyil-Yirce And Akkuyu (Obruk Plato-Karapinar, Konya). 2. *İnternational Gobeklitepe Scientific Studies Congress,* 20-21 March 2021, Şanlıurfa, (pp. 266-267).

Şenel, M. (2002). 1/500.000 ölçekli Türkiye jeoloji haritası Konya paftası. MTA, Ankara.

Ulu, Ü., Öcal, H., Bulduk, A.K., Karaka, M., Arbaş, A., Saçlı, L., Taşkıran, M.A., Ekmekçi, E., Adır, M., Sözeri, Ş., Karabıyıkoğlu. M. (1994). Güneybatı İç Anadolu 'nun stratigrafisi ve yapısal evrimi. *9th Turkish Geology Symposium*, 171-182.

Waltham, T., Bell, F., Culshaw, M. (2005). Sinkholes and subsidence: karst and cavernous rocks in engineering and construction. Bedin. 300.

Wiesner, K. (1968). Konya civa yataklari ve bunlar üzerindeki etüdler, *M,T. A. Ens. Dergisi*, 70, 178-213.

Williams, P. W. (2004). Dolines. In: Gunn J (ed.) *Encyclopedia of Caves and Karst Science, Fitzroy Dearnorn,* New York, 304 - 310.

GEOLOGICAL CHARACTERISTICS OF APASARAYCIK SINKHOLE (ÇUMRA-KONYA) AND FORMATION PROCESSES OF KONYA SINKHOLE TYPES

YAŞAR EREN[1]

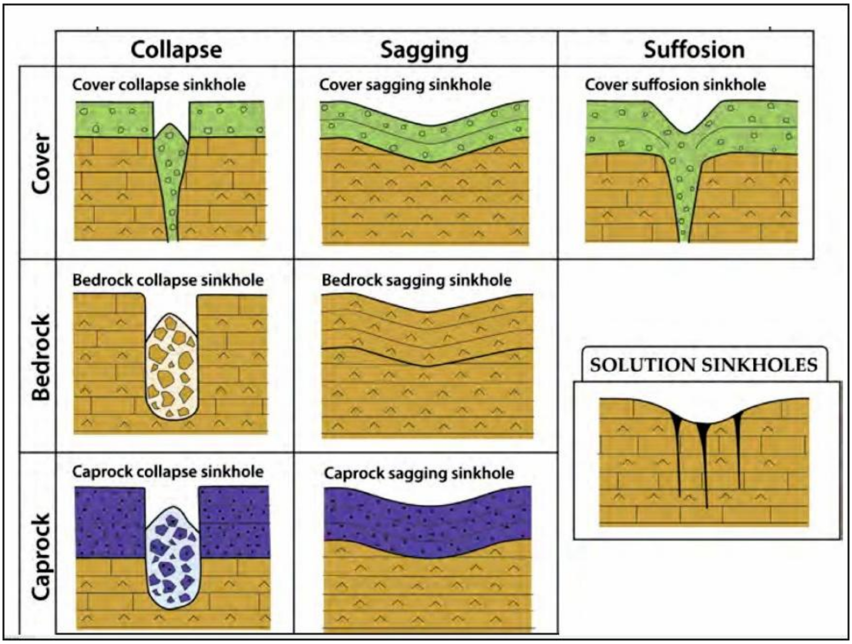
Introduction

Generally, circular and closed depressions in the earth's crust are called sinkholes (doline, Williams, 2004, Waltham et al., 2005; Cvijic, 1893). Most sinkholes develop in soluble rocks as a result of karstification. In Turkey, karst structures of various sizes are found in the Taurus Mountains, which contain widespread limestone and dolomite. In addition, there are many sinkholes of various sizes near settlements in the provinces of Konya and Sivas. In Konya (Central Anatolia, Turkey), and especially in the district of Karapınar, sinkholes of various types and sizes, each a natural wonder, have attracted people's attention for many years (Erinç, 1960; Eroskay 1976; Eroskay and Günay 1979; Güldalı and Şaroğlu, 1983; Canik and Çörekçioğlu 1986; Erol 1991; Bayari et al., 2009; Doğan and Yılmaz 2011; Göçmez 2011; Günay et al., 2010; Özdemir, 2015a,

[1] Prof. Dr., KTÜN Mühendislik ve Doğa Bilimleri Fakültesi, Jeoloji Mühendisliği Bölümü, Orcid: 0000-0002-7899-8507

2015b; Tapur and Bozyiğit 2016, Orhan et al., 2020; Eren et al, 2024 ve 2025). Sinkholes have formation mechanisms such as, collapse, sagging, dissolution and suffosion and can be divided genetically into 8 main groups as bedrock collapse, caprock collapse cover collapse sinkhole, cover sagging sinkhole, caprock sagging sinkhole, bedrock sagging sinkhole solution sinkhole, and cover suffosion sinkhole (Gutiérrez et al.,2014; Figure 1).

Figure 1: Genetic classification of sinkholes



Source: Taken from Gutiérrez et al., 2014

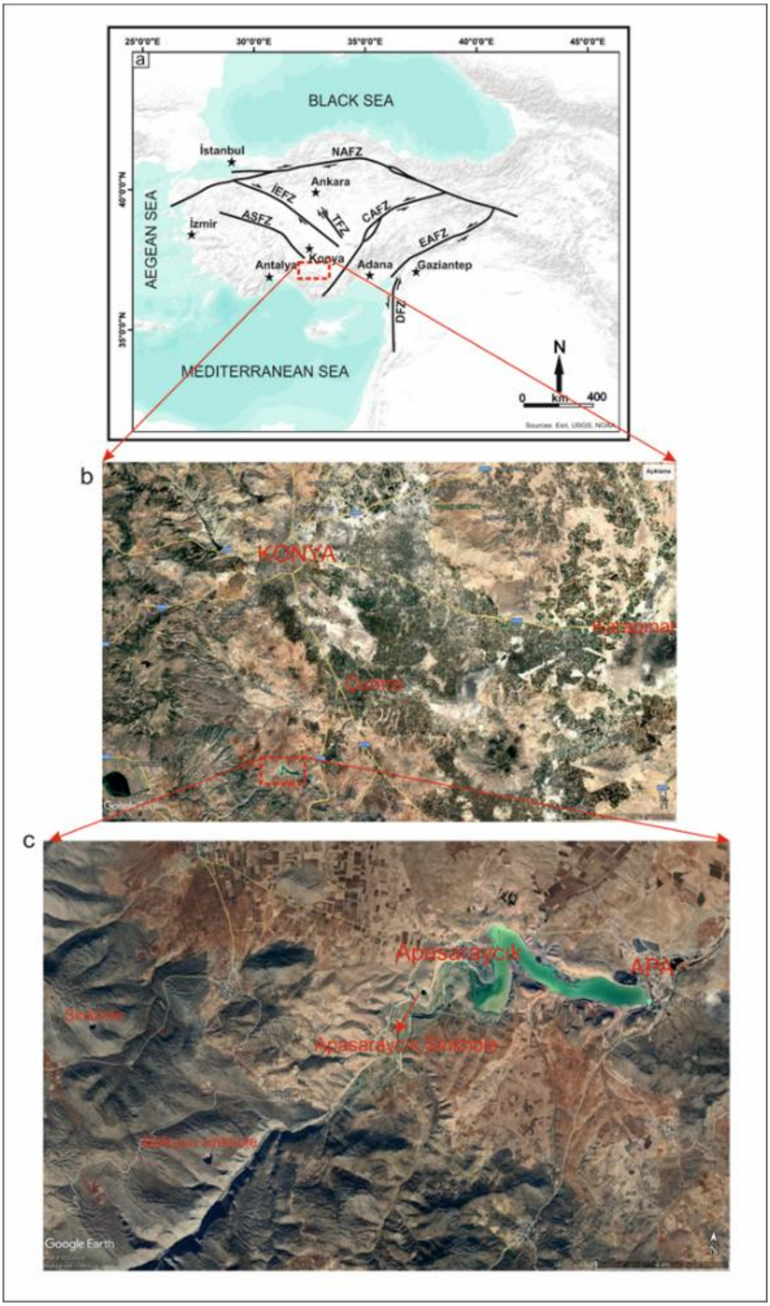
Sinkholes are formed as a result of the dissolution of soluble rocks such as limestone, gypsum, dolomite, etc. by water. Carbon dioxide-rich waters circulating through underground fractures within the limestone and marble gradually dissolve these rocks, creating underground cavities and caves. Over time, the ceilings of the caves collapse as they melt upwards, creating sinkholes. In addition to these, collapse of underground mining galleries, excessive withdrawal of clastic material together with water from underground by drilling, surface deformations due to excessive withdrawal of underground water, etc. may also lead to sinkhole formation.

In the Çumra district, which is a westward continuation of the Karapınar sinkhole region, significant sinkholes such as the Timraş sinkhole, which has a diameter of up to 300 meters, are also found. The Apasaraycık Sinkhole, the subject of this study, is located 55-60 km south of Konya, 36 km southwest of Çumra, and 1.5 km west of the ApaSaraycık neighborhood (Figure 2). The sinkhole, which contains water, is an an old formation, and its age of formation is unknown.

Tectonically, the area is located in the eastern part of the Central Taurides (Özgül, 1976). It is located on the edge of the plains stretching from the foothills of the Central Taurus Mountains towards the Konya and Çumra basins, immediately at the end of the Mavi Boğaz Canyon.

In addition, the sinkhole has developed on a ridge where the stream meanders along the edge of the Apa dam basin (Figure 2c). The sinkholes in the region are mainly found within three main rock groups. One of these is the sinkholes observed in the pre-Miocene limestone, marble and dolomite rocks commonly found in the Central Taurus Mountains, which we call the basement rocks. The second group consists of sinkholes found in Miocene-Pliocene-aged lacustrine and terrestrial rocks that unconformably overlie the former. The third group consists of sinkholes found in Quaternary-aged alluvial rocks that unconformably overlie all of the aforementioned rock groups. In this study, the geological characteristics of the Apasaraycık sinkhole observed in Miocene-Pliocene-aged alluvial and lacustrine rocks will be examined.

Figure 2: Location map of the study area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a
BLACK SEA
İstanbul
NAFZ
Ankara
İEFZ
TFZ
CAFZ
ASFZ
İzmir
AEGEAN SEA
EAFZ
Antalya
Konya
Adana
Gaziantep
DFZ
40°0'0"N
35°0'0"N
MEDITERRANEAN SEA
N
0
km
400
b
KONYA
c
Apasaraycık
APA
Apasaraycık Sinkhole
Sinkhole
Google Earth

Geology

The study area is located south of Konya, on the immediate northeastern foothills of the NW-SE trending Central Taurus Mountains. Paleozoic-Mesozoic marine rocks and ophiolitic mélange-type rocks are widely exposed in this section of the Taurus Mountains (Figure 3). From the foothills onwards, Miocene-Pliocene-aged lacustrine and terrestrial basin sediments are present with a faulted contact. The youngest rocks in the study area are Quaternary-aged alluvial clastics. The Karaman Karadağ volcanic complex is located approximately 60 km southeast of the area.

Stratigraphy

In the study area, from oldest to youngest; Permian Derbent formation, Triassic Aladağ Formation, Triassic-Cretaceous Lorasdağı Formation, Cretaceous Midostepe Formation, Mesozoic Ophiolitic Melange, Miocene Sille Formation, Upper Miocene-Pliocene Ulumuhsine Formation, Pliocene-Quaternary Topraklı Formation and Quaternary Alluvium were identified (Figure 3).

Derbent Formation

The Derbent Formation (Göğer and Kıral, 1969) crops out in a very narrow area in the southwest of the study area, trending NW-SE (Figure 3). The formation is overlain by Triassic-Cretaceous and Miocene-Pliocene units. The unit is predominantly composed of dark-colored metacarbonates-metaclastics alternation and is composed of dark gray and black colored dolomite and dolomitic marbles with medium and thick layers. Among these lithologies are quartzite and graphite schist. The unit that forms the base in the study area is overlain by the Aladağ formation with a lateral-vertical transition conformably. The age of the unit is accepted as Permian (Göğer and Kıral, 1969; Eren, 1993).

Aladağ Formation

It is exposed in a very narrow area in the south-west of the study area. The unit consists of alternating layers of variegated, clastic and carbonate rocks. The Aladağ Formation consists of metadolomite, crystalline limestone, metaconglomerate, and phyllite. It conformably overlies Permian-aged clastic and carbonate rocks and is conformably overlain by Triassic-Cretaceous aged rocks.

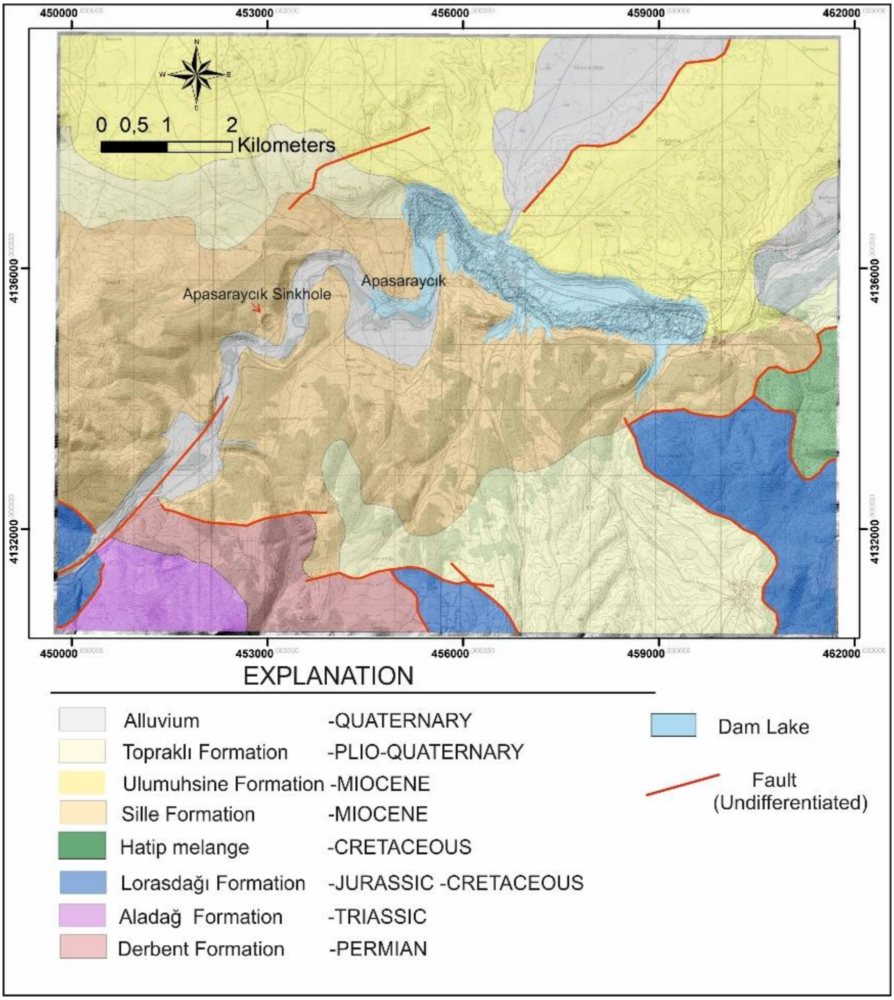
Lorasdağı Formation

It crops out in NW-SE direction in the south of the study area.The unit, which originally consists of shallow marine metacarbonates, was first named by Göğer and Kıral (1969) It crops out over a very wide area from northwest to southeast in the study area (Figure 3). Metacarbonates with gray, blue, white and cream colors also contain metachert and metaquartzite interlayers parallel to the bedding. Karstic cave and sinkhole formations are also present in the unit. The unit conformably overlies Late Triassic rocks and is tectonically obducted by rocks belonging to the Hatip Ophiolitic Melange. It is overlain by Miocene-Pliocene and Pliocene-Quaternary rocks. The age of the unit is Late Triassic-Early Cretaceous (Göğer and Kıral 1969; Özcan et al. 1988 and Eren 1993).

Hatip Ophiolitic Melange

The Hatip Ophiolitic Melange (Göğer and Kıral 1969) consists of limestone, marble and calcareous sandstone blocks within a serpentinite and fine-grained matrix. It is tectonically located on the Lorasdağı Formation in the eastern part of the study area. It was formed as a result of the closure of the Neo-Tethys Ocean and emplaced due to the Alpine Orogeny over the Taurides. The unit is unconformably overlain by the Miocene-Pliocene-aged Sille Formation. The emplacement age is Late Cretaceous.

Figure 3: Geological map of the study area



Source: (Modified from Akbaş et al., 2011)

Sille Formation

The Upper Miocene-Lower Pliocene Sille Formation consists mainly of alternating layers of conglomerate, sandstone and mudstone. The unit, which is widespread in the west and southwest of the study area, unconformably overlies Paleozoic and Mesozoic units that have been deformed by Alpine orogenic events. The main components of the formation are conglomerate cemented by a clayey sandy and carbonate matrix. It contains mudstone and sandstone levels in the form of interbeds. The Apasaraycık Sinkhole is also located within this unit. The Sille Formation, composed of alluvial fan and river delta deposits and unconformably overlying the basement units, shows lateral and vertical transitions to the Ulumuhsine Formation above.

Ulumuhsine Formation

The Ulumuhsine Formation, which consists predominantly of lacustrine limestone, is widespread in the northern parts of the study area. The lithology of the unit consists of beige, gray, creamy yellowish limestone, mudstone, and marl alternations.The thin-thick layered limestones of the formation have white, yellow, cream, beige and gray colors and contain distinctly oncolithic and stromatolithic structures, freshwater gastropod and bivalve fossils. In addition, clayey limestones and marls with white, yellowish, green and gray colors are also observed. The Miocene-Pliocene unit, which conformably overlies the Sille formation, is unconformably overlain by the Topraklı Formation and Quaternary alluviums. The Timraş sinkhole in Çumra and the Obruk Plateau sinkholes in the Karapınar (Konya) region are located within this unit.

Topraklı formation

The Topraklı Formation, consisting of alluvial fan and slope debris deposits, is widespread in the south-eastern and north-eastern parts of the study area. The formation, whose boundaries are generally controlled by faults, consists mainly of unconsolidated blocky gravelly sandy mud-binder units. The formation, which unconformably overlies all older units, shows a transition to modern alluvium.

Alluvium

The alluviums, which constitute the youngest unit in the study area and unconformably overlie all older units, are commonly encountered along the Çarşamba stream. The unit, consisting of unconsolidated clay, sand, and mud deposits, is Quaternary in age.

Structural geology

Permian-Mesozoic rocks of the study area were metamorhposed, deformed, folded, foliated and fractured by Alpine orogenic movements. In these rocks, outcrop-scale folds, thrusts and nappe structures and fractures in variable directions are observed in the Alpine event.

The Basement formations trends NW-SE parallel to the trend of Central Tauride. The thrust contact between ophiolitic rocks and the Mesozoic carbonates also trend NW-SE. This trends also affected later Neotectonic period faults.

During the Miocene-Pliocene period, the basement rocks were uplifted by block faulting. The block faulting developed horst and graben structures in the Central Anatolia (Şengör 1980; Koçyiğit 1984) Depending on the basin formation, the edges of the elevations are bounded by NW-SE normal faults. Faults related to the neotectonic period are in the form of two intersecting systems and are oriented NW-SE and NE-SW.

The NW-SE faults vary in length from 1 to 5 km and present a stepped appearance. In the southeast of the study area, NW-SE trending graben and horst structures have developed in association with these faults. In the horsts, Mesozoic-aged Lorasdağı Formation metacarbonates are exposed, while in the graben, Pliocene-Quaternary-aged Topraklı Formation is exposed.

The lengths of the NE-SW-trending faults vary between 2 and 7 km. The fault observed in the stream in the SW of the study area is most likely an oblique fault and has a left-lateral strike-slip displacement.

The visible amount of strike-slip displacement is approximately 900 m (Figure 3). In addition to these, widespread fractures are encountered in the basement and cover rocks. Widespread fractures oriented NW-SE, E-W and NE-SW are observed in the basement rocks, along with karstic dissolution associated with these fractures.

Morphological features of the Apasaraycık sinkhole

The Apasaraycık sinkhole is located 7 km west of the town of Apa, which is part of the Çumra district, 57 km south of the city of Konya. Its circular shape is immediately noticeable in satellite images. It is located approximately 2 km southwest of Apasaycık village, on the northern slope of Çarşamba Stream (Figure 2c). It is situated on the northeastern slope of the NW-SE oriented Central Tauride. As observed in DEM and Hillshade images, it is located at the transition section between relatively flat areas and areas with low slopes (Figure 4a, b, and c).

The flow direction of the Çarşamba River and the main streams in the region is perpendicular to the NW-SE oriented elevations, from SW to NE. The slope of a large part of the area varies between 10 and 100 degrees. In the southwest and southeast, the slope ranges from 200 to 460 degrees (Figure 4c). The sinkhole is located on a slope facing southwest (Figure 4d).

The Apasaraycık Sinkhole was formed within conglomerate belonging to the Sille Formation, which is Miocene-Lower Pliocene in age and unconformably overlying the Paleozoic-Mesozoic basement (Figures 5a-h). Sinkholes such as Belkuyu Sinkhole are also found within the marbles and crystallised limestones of the base on which the Sille Formation rests (Figure 2c).

The sinkhole, which is approximately circular, has a longest axis of 225 m in the NNW direction and a width of approximately 200 m. The water level is closely related to the water level of the reservoir lake. The water is fresh and contains fish. The water level determined from the topographic map (printed in 1989) is 1037 m. The long axis of the water level was measured as 125 m and the short axis as 88 m (Figures 6a-d).

Figure 4: a. Digital elevation Model, b. Hillshade image, c. slop gradient map and d. aspect map of the study area.

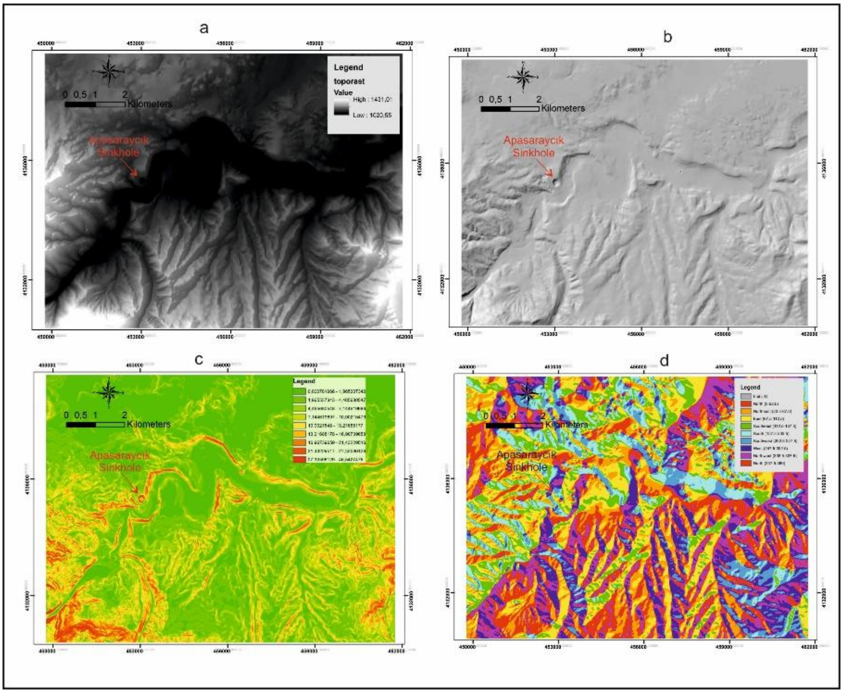


Figure 5: a- h. Field photographs of the Apasaraycık Sinkhole main sinkhole taken from diffent angles (Further explanation is in the text)

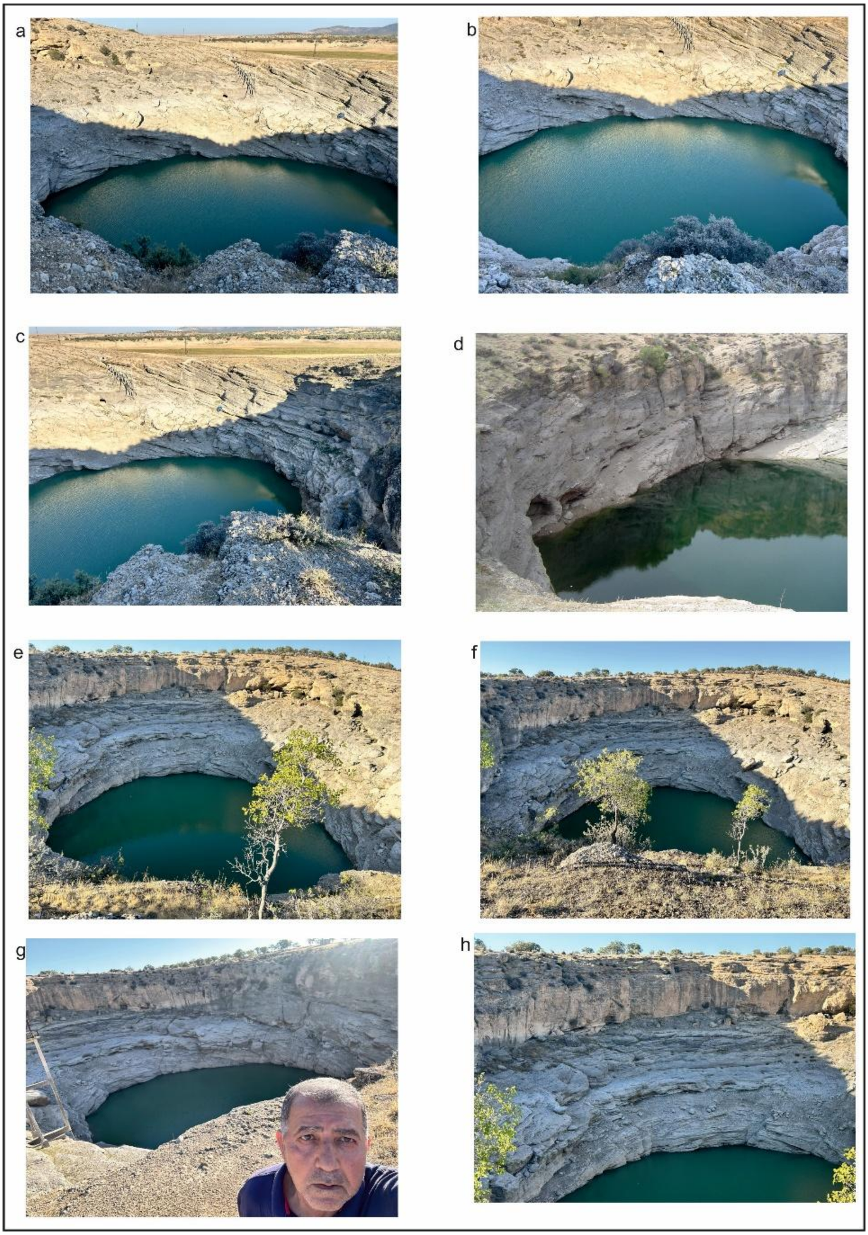
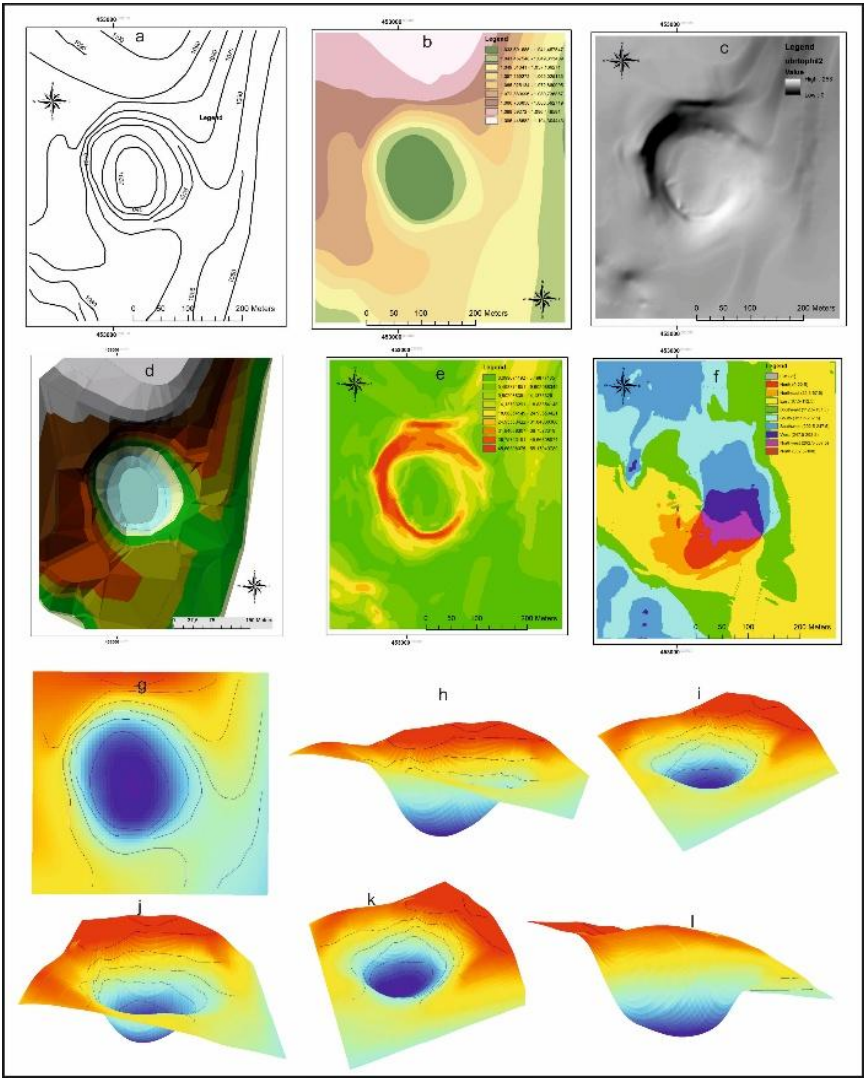


Figure 6: Morphological features of the Apasaraycık sinkhole obtained from 10 m resolution digital topographic maps a. topographic contoursi b. DEM image, c. Hillshade, d. TIN, e. slope

gradient map, f. aspect maps and, g. digital elevation map and h-l. three-dimensional images produced from DEM using the Arc Sceen program (Further explanation is in the text).



Since it was formed by the collapse of the ridge, the eastern edge is 1055 m elevation and the edge depth to the water is 18 m (Figures 5a c and d; Figure 6a). The western edge elevation is 1070 m depth and 33 m (Figures 5a-c), the southern edge elevation is 1060 m depth and 23 m (Figure 5d) and the northern edge elevation is 1090 m depth and 53 m (Figures 5e-f).

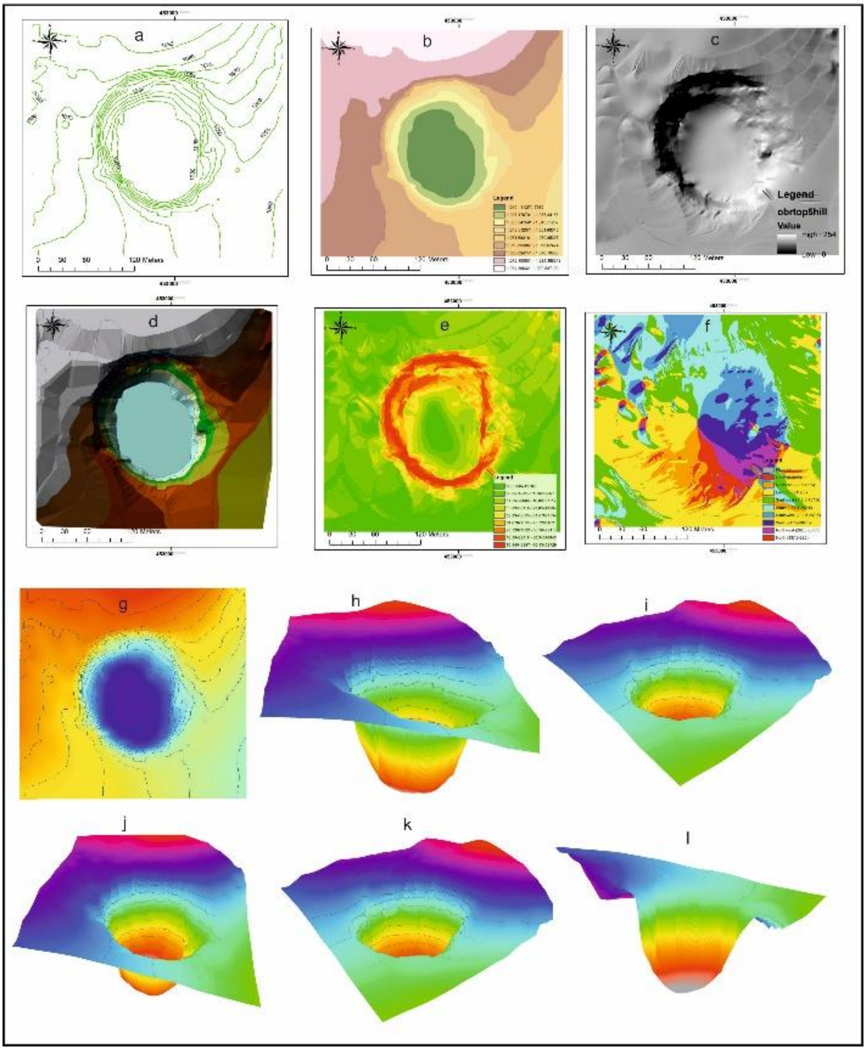
The long axis of the sinkhole is 220 m and the short axis is around 190 m (Figures 6g and h). As can be seen in the slope map, the elevation of the eastern edge is less while the slope of the other edges is higher (Figures 6d and f). The three-dimensional shape obtained from the DEM images shows that the eastern and northern parts of the sinkhole, which slope towards the center, have a less steep slope, while the western and southern sides have a steeper slope (Figure 6g-l).

The water level has been determined as 1030 m from the 5 m resolution (2023) DEM image (Figures 7 a, b and c).

The long axis of the water level is 128 m and the short axis is 102 m. The depth from the eastern edge to the water level of 1054 m is 24 m. The elevation of the western edge is 1070 m with a height of 40 m, the elevation of the northern edge is 1080 m with a height of 50 m, and the elevation of the southern edge is 1059 m with a height of 29 m (Figures 7a-d). On the DEM image, the long axis of the sinkhole was measured as 210 m in the NNE direction, and the short axis as 185 m. The slope map again documents that the southern and western sections have steeper slopes (Figure 7e). The DEM image of the sinkhole and the three-dimensional shape derived from it indicate that the section of the sinkhole up to the water level has a conical shape and inclined shape inward (Figures 7g-l).

Figure 7: Morphological features of the Apasaraycık sinkhole obtained from 5 m resolution raster image (TIFF) a. topographic contours b. DEM image, c. Hillshade, d. TIN, e. slope gradient map, f. aspect maps and, g. digital elevation map and h-l. three-

dimensional images produced from DEM using the Arc Sceen program (Further explanation is in the text).



Measurements taken from Google Earth images show that on 12.2023, the water surface was measured at 127 m along the long axis and 94 m along the short axis (Figure 8a; Table 1).

Measurements for the period 1985-2023 are given in Table 1 and the images are shown in Figures 8a-l. On 8.2011, when the satellite images were clear, the long axis was measured as 155 m and the short axis as 145 m, while in 12.1985, when the images were unclear, the long axis was measured as 155 m and the short axis as 103 m.

A comparison of photographs taken in between 2009 and 2024 of the same month from the Apasaryacık sinkhole demonstrates that the water level in the sinkhole has dropped by approximately 6 m (Figures 9a-d). The water level in the sinkhole, which is affected by the dam reservoir level, rises as the dam reservoir level rises and falls as the dam reservoir level falls.

Since it developed on a slope facing southeast, the northern and western edges of the sinkhole are higher, while the eastern edge is closer to the riverbed. The conglomerates in which the sinkhole developed are yellowish-light brown in the upper sections and white and light gray and cream in color in the lower sections (Figures 5e, f, g, and h). The layers are medium- and thin-bedded. The upper sections are thicker-bedded (Figures 5e-h).

In the northwestern sections, the beddings are nearly horizontal and dip toward the southeast and southwest (Figure 5e and g). A fine-bedded and coarsely foliated structure dominates the conglomerates in the lower sections (Figure 5h). They are occasionally cross-bedded.

The dip of the strata reaches 250-300 on the eastern side (Figures 5a and b and 9a and b). According to Kul (2022), Miocene-aged units are folded in this section. Due to the concentric inclination of the strata towards the east in the western and northern sections, a broad anticline structure is observed (Figures 5e and f and 9c and d). The gravels are cemented by a carbonate binder (Figure 9e).

Figure 8: Google Earth images showing the water level of the Apasaraycık Sinkhole between 1985 and 2023 (Further explanation is in the text).

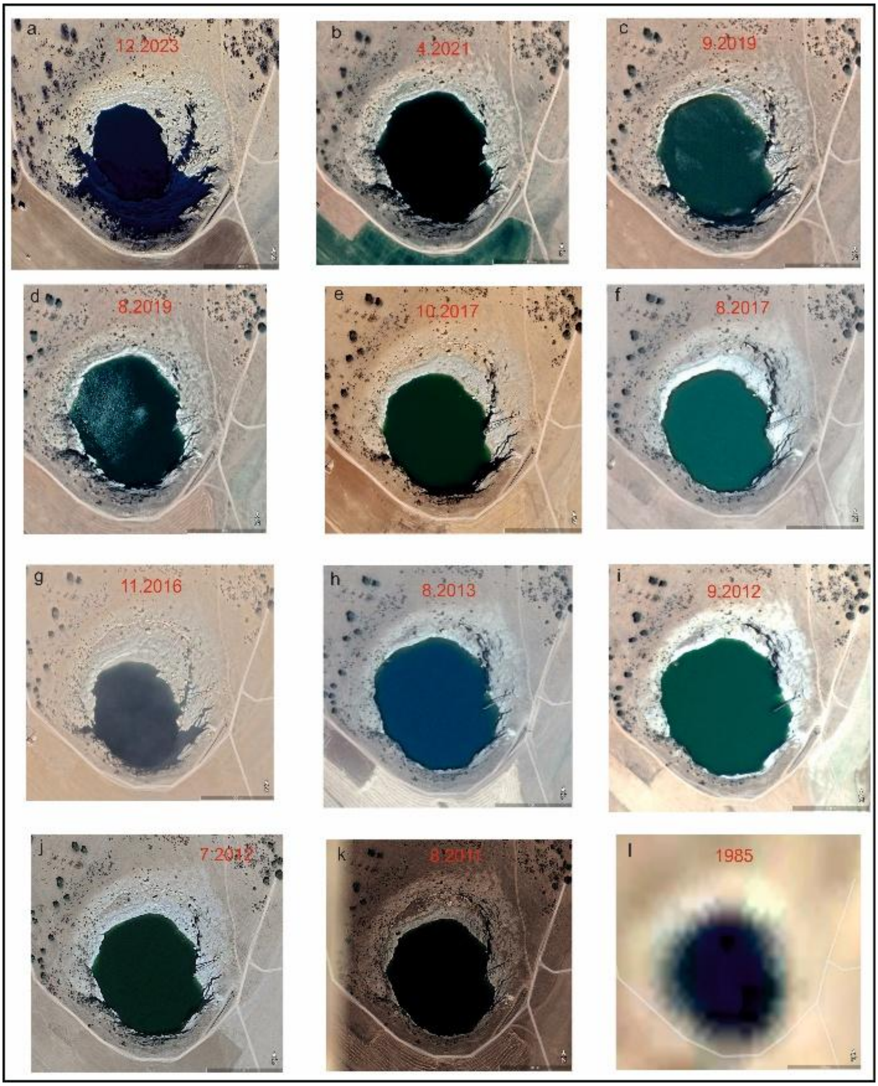


Table 1: Map-scale dimensions of the water level of the Apasaraycık sinkhole between 1985 and 2023

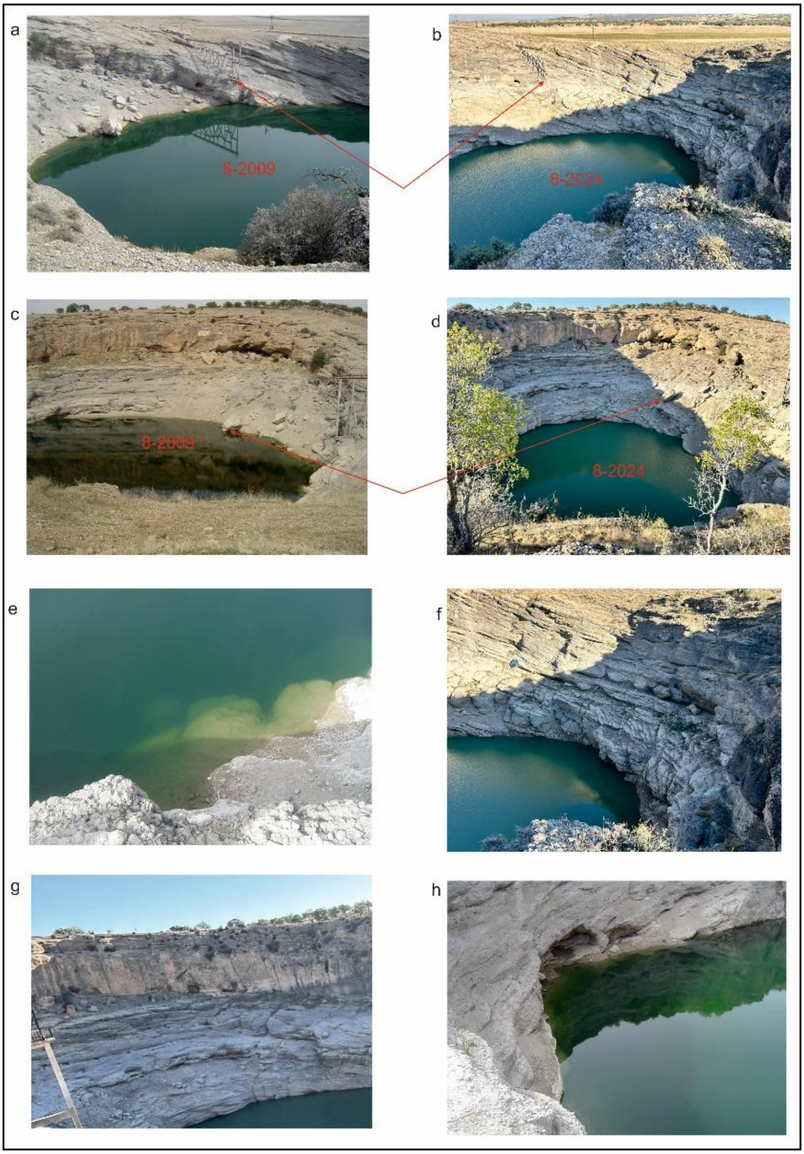
Date	Long axis (m)	Short axis (m)
12.1985	137	103
8.2011	155	145
7.2012	172	155
9.2012	160	139
8.2013	171	152
11.2016	137	115
8.2017	157	147
10.2017	153	134
8.2019	163	138
9.2019	158	136
4.2021	163	128
12.2023	127	94

Although the gravels contain all types of gravel derived from the bedrock, the majority of the gravels are composed of marble, dolomite marble, crystallised limestone, and limestone gravels. The grain size of the gravels varies between block size and fine sand size. The conglomerates contain at least three sets of systematic fractures, two vertical and one inclined, with fracture intervals ranging from 5 cm to 1 m (Figures 5h and 9f and g). Due to weathering along the fractures, the gravel stones have weathered into rounded, lens-shaped blocks, and voids have formed between the layers due to differences in resistance (Figures 9c and h).

Voids of various sizes are present on the slopes of the sinkhole. One of the joint sets observed as a conjugate sets in the vertical section is a north-dipping set parallel to the basement boundary, while the other trends northeast and dips west. In the section whee thick-bedded conglomerates are located upwards, the slope of the joints increases and steepens (Figure 9g).

Figure 9: Views from the Apasaraycık Sinkhole; a-c. Photograps showing the sinkhole's water level in 2009, b and d. Photograps showing the sinkhole's water level in 20024, e-f. joint

sets seen in the sinkhole walls, g. close-up view of cavities in the south wall of the sinkhole, h. large section



A less steeply dipping joint set is cut by steeper joint sets (Figure 5h and 9g). The trends of lineaments in the automatic lineament maps prepared from DEM are parallel to the fault lines in the area and to the trends in this section of the Taurus Mountains (Figure 10a).

Fracture density is higher in the southeastern and western parts of the area (Figure 10b). The rose diagram prepared from the automatic lineaments shows that the lineaments in the region are dominantly concentrated in the N40-50 W direction (Figure 10c). In addition to these, there are lineaments trending N-S, N40-60E and approximately E-W.

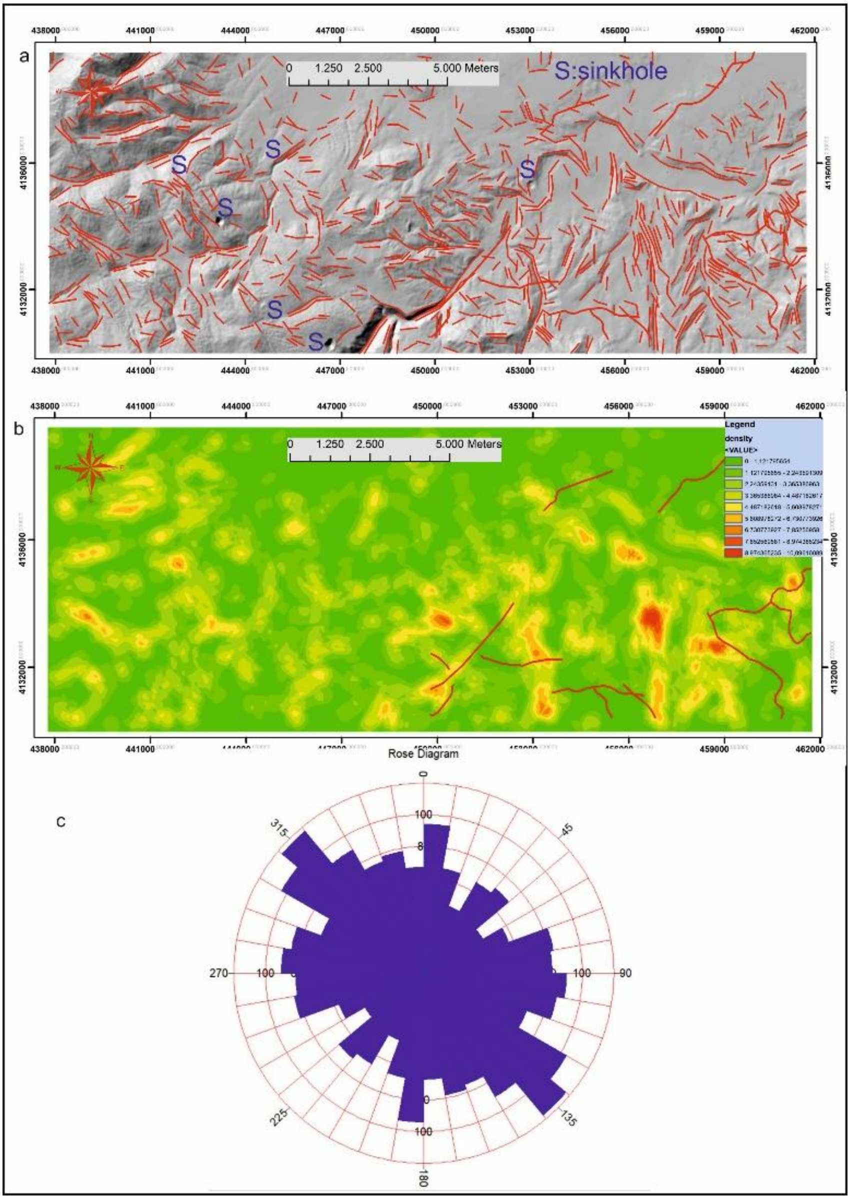
On map view, the sinkhole's mouth appears circular. This ancient sinkhole contains water and is one of the few remaining sinkholes in the Konya region. This is because it is located at the foot of the Taurus Mountains and is located right on the shore of the Apa Dam Lake basin. It is known that the main recharge for groundwater in the Konya closed basin is from the Taurus Mountains, and that groundwater flows from this area to the Tuz Gölü (Canik, 1997).

Because the sinkhole is located at the foot of the Taurus Mountains, it has maintained its watery state to this day. The depth of the sinkhole is unknown, and the water level is decreasing in accordance with the general climatic conditions in the region (Figure 9a-d).

The three-dimensional shape of the sinkhole is cylindrical and steeply inward-sloping until the water body. The appearance of the water body is elliptical with a long axis NNW (Figure 8). The southeastern and western edges of the sinkhole are steep, while the northern edge is slightly sloped.

Figure 10: Automatic lineament map derived from the DEM images in the study area a: Hillshade map with lineaments, b: Lineament

density map and c: Rose diagram showing orientation of the lineament



Formation model

The Apasaraycık sinkhole was not formed within limestone, as is common, but within the conglomerates of the Sille Formation, which contains abundant limestone pebbles. However, Mesozoic limestone and marbles lie immediately beneath the Sille Formation, and sinkholes are common within the marbles that crop out to the southwest (Figure 2c). Therefore, karstic cavities and older sinkholes in the basement, along with other factors (lithology, groundwater, CO_2, and fractures), play a role in the formation of this sinkhole. When we look at the sinkholes around Konya, we see that they are located in 1- Mesozoic limestones and marbles within old basement rocks 2- Miocene-Pliocene old lacustrine-terrestrial formations (mainly in lacustrine limestones) 3- Pliocene-Quaternary-aged alluvial rocks (generally in areas where agriculture is widespread). In addition, 4- those formed due to intense faulting and secondary structures (relay ramps and similar environments) created by faults, and 5- sinkholes related to surface faulting caused by the decline in groundwater levels are also present (Eren et al., 2021a and b; 2024a; Parlar et al., 2021, 2023; Coşkuner et al., 2021).

The sinkholes in the Mesozoic carbonate and metacarbonate rocks (Type 1) were formed as a result of the uplift of the rocks, which acquired a napped-thrust and faulted structure and were deformed due to Alpine orogenic events, in the pre-Miocene period or as a result of karstification under terrestrial conditions in the Miocene and later periods (Figure 11 a and b).

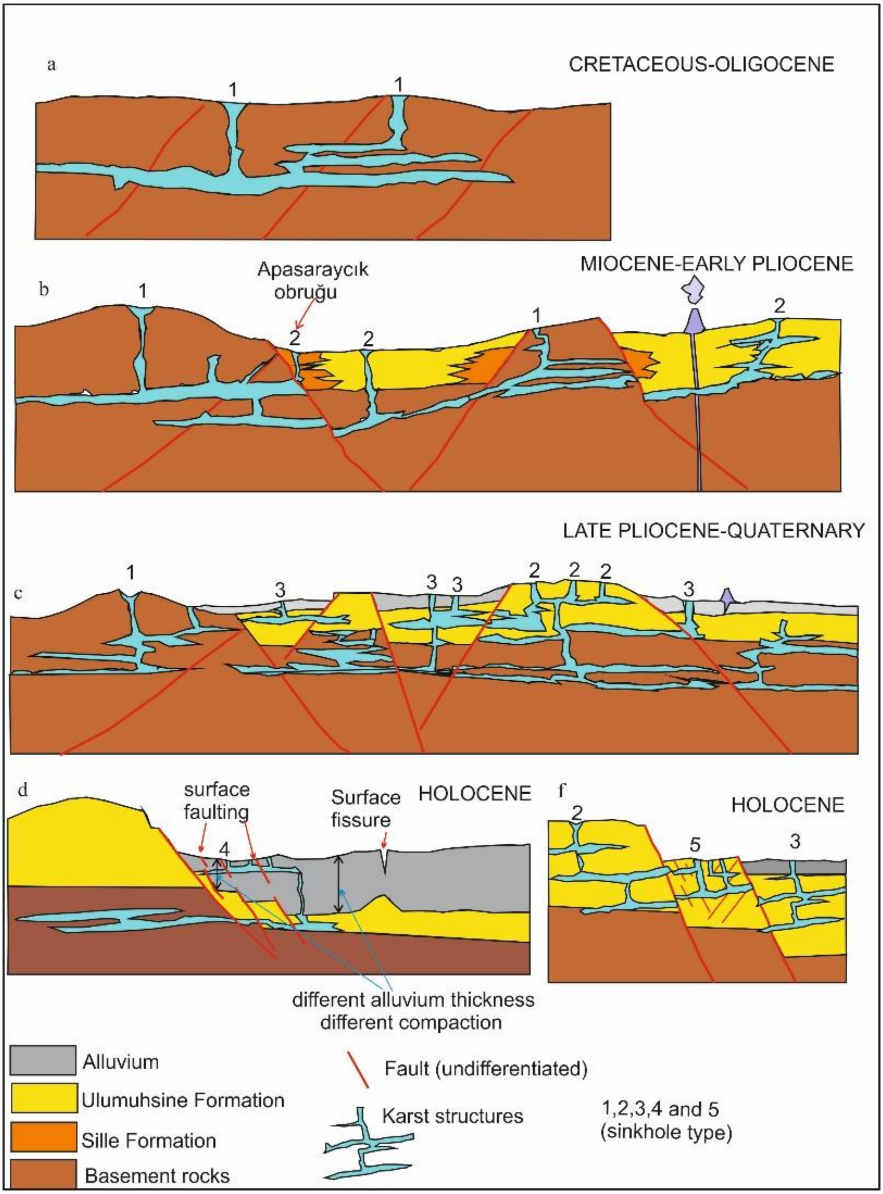
Sinkholes in lacustrine limestone and other Miocene-Lower Pliocene rocks (Type-2), including Plato sinkholes, are related to the formation of lacustrine basins during Late Miocene and subsequent block faulting. These sinkholes were formed as a result of the precipitation of lacustrine rocks in these basins, followed by the uplift and exposure of these rocks prior to the Late Pliocene, and subsequently their dissolution and collapse due to the influence of existing karst systems in the basement (Figure 11b and c).

The third type (basin sinkholes-Type 3) sinkholes are related to the formation of alluvial basins as a result of climatic and structural conditions after the Lower Pliocene. The sinkholes in the terrestrial rocks in these basins are formed by solution and collapse mechanisms, affected by karst structures in the underlying basement and lacustrine rocks (Figure 11 c). The formation of these sinkholes has accelerated in recent times due to various factors associated with the decline in groundwater levels. Especially in recent years, as a result of the rapid decline in groundwater levels, numerous small sinkholes have formed in areas with intense surface faulting caused by differential compaction of sediments parallel to faults at the edges of the basin. This compaction and the solution of thin evaporitic layers within the sediments has led to the formation of hundreds of small sinkholes in small areas. (Figure 11 d, Type 4).

Factors such as the intersection of faults that formed the Miocene-Pliocene and Pliocene-Quaternary basins, or secondary structures associated with the faults (such as relay ramps, small pull-apart basins, etc.) have also contributed to the formation of sinkholes (Figure 11 e, Type 5).

When we look at the location and lithology of the Apasaraycık sinkhole, it is highly probable that a karstic cavity and structural elements at the base played a triggering role in the formation of this sinkhole (Figure 11 b). Accordingly, it developed along a fault that also cuts through the Miocene or later karst systems belonging to the basement rocks.

Figure 11: Schematic model showing the formation of sinkholes in the Konya-Karapınar region over time (not to scale). The sinkhole numbers indicate the type of sinkhole, not their age or order of formation (Further explanation is in the text).



The erosion of Miocene-aged conglomerate covering the older karst structures at the base over time resulted in the formation of the Apasaraycık sinkhole as a result of downward subsidence along fractures and joints where the binder was weak.

The significance in terms of geotourism

Along with other sinkholes in the Konya region, the Apasaraycık sinkhole has interesting features due to its structure, its rarity in the region as a water-filled sinkhole, and the fact that it developed in rocks that are lithologically in conglomerates rather than limestone. These features make it an important structure in terms of both geology and tourism. Additionally, its easy accessibility and the presence of large sinkholes within the surrounding bedrock and cover rocks make it particularly important from a tourism perspective.

References

Akbaş, B., Akdeniz, N., Aksay, A., Altun, İ.E., Balcı, V., Bilginer, E., Bilgiç, T., Duru, M., Ercan, T., Gedik, İ., Günay, Y., Güven, İ.H., Hakyemez, H.Y., Konak, N., Papak, İ., Pehlivan, Ş., Sevin, M., Şenel, M., Tarhan, N., Turhan, N., Türkecan, A., Ulu, Ü., Uğuz, M.F., Yurtsever, A. ve diğerleri. (2011), 1:1.250.000 ölçekli Türkiye Jeoloji Haritası. Maden Tetkik ve Arama Genel Müdürlüğü Yayını, Ankara-Türkiye.

Bayarı, C. S., Pekkan, E., Ozyurt, N. N. (2009). Obruks, as giant collapse dolines caused by hypogenic karstification in Central Anatolia, Turkey: analysis of likely formation processes. *Hydrogeology Journal*, 17, 327–345. https://doi.org/10.1007/s10040-008-0351-9.

Canik, B., Çörekçioğlu, İ. (1986). The Formation Of Sinkholes (Obruk) Between Karapınar and Kızören – Konya. *IAHS-AISH publication*. 161, 193-205.

Canik, B. (1997). Konya Dolaylarında Suların Oluşturduğu Doğal Anıtlar ve Bunların Korunması, *20.Yıl Jeoloji Sempozyumu Bildiriler*, s.159-166, Konya.

Coşkuner B., Eren Y., Parlar Ş. (2021). Karapinar (Konya, Orta Anadolu) Bölgesindeki Obruklar, Kiriklar ve Otomatik Belirlenmiş Çizgisellikler Arasindaki İlişki.. *Isarc 2. International Gobeklitepe Scientific Studies.*, 268-269. (Özet Bildiri/Sözlü Sunum).

Cvijić, J. (1893). Das Karstphanomen. Versuch einer morphologischen Monographie. *Geographischen Abhandlung*, 3, 218-329.

Doğan, U., Yılmaz, M. (2011). Natural and induced sinkholes of the Obruk Plateau and Karapınar-Hotamış Plain, Turkey. *J. Asian Earth Sci.*, 40, 496–508. doi: 10.1016/j.jseaes.2010.09.014.

Eren, Y., Parlar, Ş., Coşkuner, B. Arslan, Ş. (2024). Geological and Morphological Features of the Karapınar Sinkholes (Konya, Central Anatolia, Türkiye). *J. Earth Sci.* 35, 1654–1668 (2024). https://doi.org/10.1007/s12583-023-1853-z.

Eren, Y. (1993). Stratigraphy of autochthonous and cover units of the Bozdağlar massif NW Konya. *Geological Bulletin of Turkey,* 36, 7-23.

Eren, Y., Parlar, Ş., Coşkuner, B., et al. (2021b). Sinkhole Formation and Their Geological Features around the Siyeklik Settlement (NE Karapınar, Konya), *In: Haydarlou, M. M., ed., Karadeniz 5th International Conference On Applied Sciences Abstract Book*, 10–11.

Eren, Y., Coşkuner, B., Parlar, Ş., et al. (2021a). Geological and Morphological Characteristics of the Sinkholes Around The Seyithacı (NE Karapınar, Konya). *In: Güray, G., Khorram, M., eds., Aegean Summit 2nd International Applied Sciences Congress, Abstract Book,* 20.

Eren Y, Coşkuner B, Parlar, Ş. (2025). An Example of Intracontinental Cross Faults Formation from the Vicinity of Karapınar (Konya –Central Anatolia). *Acta Geolog Polon*. 75:35–35.

Erinç, S. (1960) Karst forms in the Konya Section and the Inner Taurus ranges. *Turkish Journal of Geograph*, 20, 83-106 (in Turkish).

Erol, O. (1991). The relationship between the phases of the development of the Konya-Karapinar obruks and the Pleistocene Tuz Gölü and Konya pluvial lakes, Turkey. *Journal of Istanbul University. Institute of Marine Sciences and Geography*, *7*, 5-49 (in Turkish).

Eroskay, O., Gunay, G. (1979). Tectonic classification and hydrogeological properties of the karst regions in Turkey. I*n: Gunay G eds. International Seminar on Karst Hydrogeology,* 1–41.

Eroskay, S. O. (1976). The factors influencing the Konya Obruks and their groundwater potentials evaluation. *İstanbul Üniv., Fen. Fak. Mec. Seri. B, 41* (1-4), 5-14.

Google Earth (2025). Google Earth

Göçmez, G. (2011). Sinkholes and Travertine Cones in Konya Province. *Proceedings of I. Konya City Symposium,* 459-464 (in Turkish).

Göğer, E., Kıral, K. (1969) Geology of the Kızılören region. *Min. Res. Expl.* Rep. 5204 (in Turkish).

Gutiérrez F., Parise M., DeWaele J., and Jourde H. (2014). A review on natural and human-induced geohazards and impacts in karst, *Earth-Science Reviews, 138*, 61–88.

Güldalı, N., Şaroğlu, F. (1983). Sinkholes of Konya region. *T.J.K. Yeryuvarı ve İnsan, 7*(4), 44-55.

Günay, G., Çörekçioğlu, İ., Eroskay, S., Övül, G. (2010). Konya Karapınar Obruks (Sinkholes) of Turkey. In: B. Andreo et al. (ed) *Advances in Research in Karst.* Media, Springer, 367-372. https://doi.org/10.1007/978-3-642-12486-0.

Kul, H.H. (2022). Timraş-Apasaraycık-May Obrukları ve çevresinin jeolojisi, Yüksek Lisans Tezi, KTUN, Lisansüstü Eğitim Enstitüsü, Konya, 68 s.

Koçyiğit, A. (1984). Güneybatı Türkiye ve yakın dolayında levhaiçi yeni tektonik gelişimi. *Türkiye Jeoloji Kurumu Bülteni, 27* (1), 1–16.

Orhan, O., Yakar, Y., Ekercin, S. (2020). An application on sinkhole susceptibility mapping by integrating remote sensing and geographic information system. *Arabian Journal of Geosciences, 13*, 1-17. https://doi.org/10.1007/s12517-020-05841-6.

Özcan, A., Göncüoğlu, M.C., Turhan, N., Uysal, S., Şentürk, K., Işık, A. (1988). Late Palaeozoic evolution of the Kütahya-Bolkardağı belt. *METU J. Pure Appl. Sci., 21* (1/3), 211–220.

Özdemir, A. (2015a). Sinkhole Susceptibility Mapping Using a Frequency Ratio Method and GIS Technology Near Karapınar, Konya-Turkey. *Procedia Earth and Planetary Science, 15*, 502-506. https://doi.org/10.1016/ j.proeps.2015.08.059.

Özdemir, A. (2015b). Investigation of sinkholes spatial distribution using the weights of evidence method and GIS in the vicinity of Karapinar (Konya, Turkey). *Geomorphology, 245*, 40-50. http://dx.doi.org/10.1016/ j.geomorph.2015.04.034.

Özgül, N. (1976). Toroslar'ın bazı temel Jeoloji özellikleri: *Türkiye Jeol. Kur. Bült , 19*(1), 65-78.

Parlar Ş, Eren Y, Coşkuner B, Arslan Ş. (2022). Karapınar (Konya) bölgesindeki Obruk türleri. 9. Ulusal Kop Bölgesel Kalkınma Sempozyumu, (343-344).

Parlar Ş., Coşkuner B., Eren Y. (2021). The Statistical Analysis of Dimension Data for All Observed Sinkholes in Karapinar and Surroundings (Konya, Central Anatolia-Turkey). 5th International Zeugma Conference on Scientific Researches, (88-89). (Yayın No: 6936476).

Şengör, A. M. C. (1980). Fundamentals of the Neotectonics of Turkey. Publication of Geological Society of Turkey, Conference Series 2, Ankara, 1–40 (in Turkish).

Tapur, T., Bozyiğit, R. (2016). Konya İli Obruklarının Turizm Potansiyeli, Marmara Coğrafya Dergisi Sayı: 34, Temmuz/July 2016, S.253-267, İstanbul – • ISSN: 1303-2429 • E-ISSN: 2147-7825, http://www.marmaracografya.com.

Waltham, T., Bell, F., Culshaw, M. (2005). *Sinkholes and subsidence: karst and cavernous rocks in engineering and construction.* Berlin. 300, https://doi.org/10.1007/b138363.

Williams, P. W. (2004). Dolines. In: Gunn J (ed.) *Encyclopedia of Caves and Karst Science*, Fitzroy Dearnorn, New York, 304 – 310.

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