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Abstract

Historical documents indicate a significant waterbody in the Central Iranian Plateau. We reveal that a large lake existed in the northern part of the plateau around 16–14 ka BP, with evidence of alternating dry and wet periods. Our geochronological data show a gradual decline in lake level from approximately 11.5 ka BP to 8.2 ka BP, decreasing by 250 m to an altitude of 850 m. A sharp drop in air temperature around 8.2 ka BP likely led to settlement at lower, more fertile altitudes. We suggest that the Masileh Basin, which persisted until the Sasanid Empire, may be linked to the ancient Lake Saveh referenced in old myths. Further examination of sediment cores from the basin reveals a rich depositional history marked by varying paleoenvironments that correlate with regional climatic shifts. Pollen analyses indicate a once-thriving ecological mosaic, supporting diverse flora and fauna, which provided sustenance to early human communities. As the lake receded, archaeological evidence suggests an adaptation pattern among these populations, characterized by a transition from aquatic to more terrestrial subsistence strategies.

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Iranian Plateau in the Late Quaternary: a time when Iran was green!

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Author:

Hamid Nazari

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ABSTRACT

Historical documents indicate a significant waterbody in the Central Iranian Plateau. We reveal that a large lake existed in the northern part of the plateau around 16–14 ka BP, with evidence of alternating dry and wet periods. Our geochronological data show a gradual decline in lake level from approximately 11.5 ka BP to 8.2 ka BP, decreasing by 250 m to an altitude of 850 m. A sharp drop in air temperature around 8.2 ka BP likely led to settlement at lower, more fertile altitudes. We suggest that the Masileh Basin, which persisted until the Sasanid Empire, may be linked to the ancient Lake Saveh referenced in old myths. Further examination of sediment cores from the basin reveals a rich depositional history marked by varying paleoenvironments that correlate with regional climatic shifts. Pollen analyses indicate a once-thriving ecological mosaic, supporting diverse flora and fauna, which provided sustenance to early human communities. As the lake receded, archaeological evidence suggests an adaptation pattern among these populations, characterized by a transition from aquatic to more terrestrial subsistence strategies.

Interestingly, the presence of charcoal fragments in the sediment points to periods of fire activity, possibly linked to human intervention or natural forest fires, which in turn affected land use and the surrounding ecosystems. The timing of these events, around 8–6 ka BP, aligns with the rise of sedentary agricultural societies, suggesting that the adaptive strategies to declining lake resources prompted innovations in farming techniques.

Our findings further suggest that customary practices evolved alongside the lake's fluctuating waters, leading to a complex interaction between humans and their environment. The eventual establishment of trade networks, as indicated by the discovery of obsidian and other artifacts, implies that the Masileh Basin served as a crucial hub for cultural exchanges during the late Holocene.

Moreover, the cultural significance of Lake Saveh, as narrated in historical texts, emphasizes its role in shaping the identity of the region. Myths and traditions surrounding this waterbody are potentially rooted in the collective memory of its once-great expanse, serving as a symbol of abundance and community resilience. The narrative continuity from ancient times into the Sasanid period highlights a profound connection between the landscape and the sociocultural evolution of the region.

Our research not only sheds light on the hydrological dynamics of the Central Iranian Plateau but also opens avenues for understanding the intricate relationships between environmental change and human adaptation. As we delve deeper into this historical narrative, we strive to unravel the complexities that shaped ancient societies and their enduring legacies within the context of a dynamically changing landscape.

Keywords: Paleoclimatology, Paleolake, Lake Saveh, Geochronology, Iran.

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1- Introduction

Central Iran forms a part of the Turkey-Iran Plateau, one of the two major plateaus in the Alps-Himalayas collision system with Tibet (Dewey et al., 1986; Allen et al., 2004). Convergence between the Arabian and Eurasian plates cause deformation in the Central Iranian Plateau in the Late Cenozoic (Vernant et al., 2004). The study area covers a large part of the northern half of the Central Iranian Plateau (Figure 1), with three main embayments, including the Kavir desert, Qom-Aran, and Garmsar Plains (Figure 1). The Central Iranian Plateau has been particularly important for human settlement and migration since the Paleolithic Period (Figure 1). Many studies have described the long-standing presence of humans along the coasts (e.g. (Stiner, 1994; Erlandson and Moss, 2001; Klein et al., 2004; Erlandson and Fitzpatrick, 2006; Wenke and Olszewski, 2007; Ghamri-Fatideh et al., 2014; McLaren et al., 2014). Certainly, in the Iranian Plateau, Quaternary lakes have been effective in the development of civilian centers (Ramasht, 2001). The possible existence of a paleolake in Central Iran has been suggested in geological, geographical, climatic, and archaeological documents (ex.: Huber H.,1960, Mokhtari 1995, Afshar Sistani A., 1999, Djamali M., 2002, Nazari H., 2006, Nazari et al., 2010). However, the specific locations of a paleolake in the Central Iranian Plateau have not been conclusively demonstrated, nor has the evolution of such a lake (duration, drying rate, and so on) been described. According to the existence of many ancient settlements as prehistoric/historic sites and the buried human remains in the Central Plateau, is it possible to establish a linkage between the shorelines of an ancient lake and the time of human presence around it? What is the interaction between the existence, expansion, or drought of these possible paleolake on the cultural and civilization development from the Neolithic onwards?

The significant question is how prehistoric people used different resources to supply and develop their societies from the Paleolithic period but also very important during the Neolithic period onwards which is known the north central plateau of Iran. While in the north central plateau, from the Neolithic period, people preferred to settle at the edge of alluvial fans to establish their villages, irrigate their agricultural lands, it seems that water resources in the lower parts (nowadays a desertic region) were not used as supplementary resources for the farmers and herders. From a review of literature, it is clear that paleolake and seas shores have in Africa, Europe and Asia had critical role in shaping Neolithic villagers during the Early and Middle Holocene period (Czekaj-Zastawny et al. 2018, Gross and Huber 2018, Rose, 2010). According to many archaeologists (e.g., Rose, 2010; Usner, 1987), seaside habitats have always been important to humans. This importance to hunters and gatherers has increased with the extinction of large livestock since the Holocene.

Hence, the coastal areas were attractive for human life and food needs with the rising sea in 7,000 years ago (Rose, 2010).

Lake Saveh is believed to have existed in the Saveh region over the past millennia, and was suddenly dried out for undiscovered reasons (Afshar Sistani A., 1999). In some religious documents, this event of the last decades of the Sassanid Empire was mentioned coincident with the birthday (in 570 AD) of the Prophet of Islam. The number of documents mentioning the existence of a lake in the Saveh region is remarkable, suggesting that Lake Saveh should be considered according to the myth (Djamali, 2002). These subjects were motivated to find out whether Lake Saveh remained from a larger paleolake in the Central Plateau, and given widespread climate change, it was able to survive until the Sassanid Empire period (224–651 AD).

In this article, we first describe references to Lake Saveh in historical documents and review the ancient descriptions of the lake from the geological literature. We then describe our findings and results of our research in the field of geomorphology and quaternary stratigraphy. Finally, we integrate archaeological, historical, and geological data to verify the existence and evolution of the paleolakes across the Central Iranian Plateau. In addition, we examine the environmental probability of the lake(s) from geomorphological and climate perspectives to argue which areas could be reverted back to a lake under humid or wetter conditions. The water supply sources and the location of Lake Saveh should also be considered.

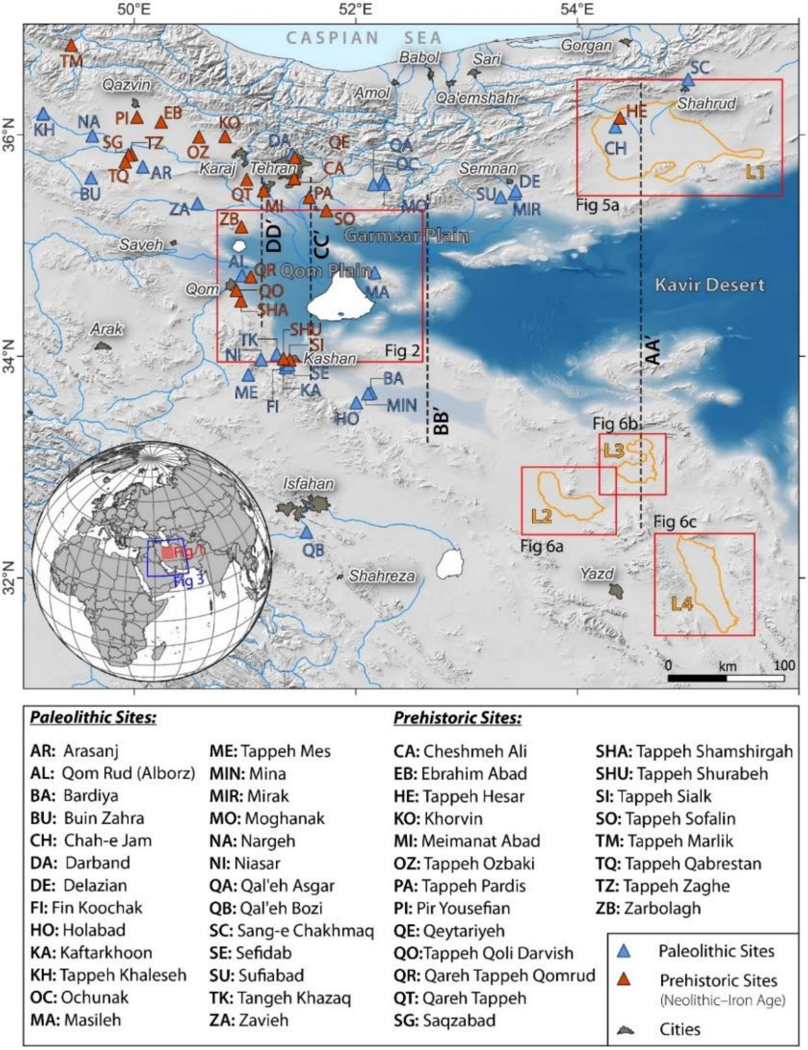

Figure 1: Map showing the location of the Paleolithic and prehistoric sites (from neolithic to iron age) in the northern areas of the central Iranian Plateau on the hill shade SRTM Digital Elevation Model (DEM) with 30 m resolution (Farr et al., 2007). The Blue shade demonstrate Lake Saveh (see Section 0 for more details). Black dashed lines show the location of N-S topographic profiles across the lake (Figure 11). Orange polygons represent the reconstructed lakes (see Section 0, Figure 5, and Figure 6 for more details)

2- Geology and Tectonic setting of the Central Iranian Plateau

Tectono-sedimentary evolution of the Central Iranian Platform begins with forming of separate sedimentary basins throughout the Paleozoic and early Mesozoic (Stöcklin, 1968). Central Iran was affected by Cimeride orogen in the Middle Mesozoic (Early Jurassic), with contractional deformation associated with intense magmatic activities during the Mesozoic and Cenozoic (Berberian and King, 1981; Stöcklin, 1968).

Central Iran included part of the Turkish-Iranian Plateau, which is one of the two major plateaus of the Alpine-Himalayan collisional system in tandem with Tibet (Dewey et al., 1986; Allen et al., 2004). The Persian part of the Alpine-Himalayan orogenic system has a complex Permian to Quaternary history due to its sequential breaks and closures (Stöcklin, 1968). These plateaus and basins are embedded in the Eurasian Plate, the northern state of the famous hydrocarbon, the Zagros fold-and-thrust belt, which forms on the Arabian Plate (Agard et al., 2005; Allen and Armstrong, 2008; Morley et al., 2009, Ballato et al., 2011). The Central Iranian Plateau is one of the major and extensive structural areas which lies at the center of Iranian territory in the shape of a triangle and is one of the largest and most complex geological zones in Iran between the three tectonic domains of Alborz to the north, Lut to the east, and Zagros to the south and southwest. Central Iran has undergone various structural changes and has a complex structure. The structural-sedimentary development of the central Iranian platform begins with the formation of distinct sedimentary basins throughout the Paleozoic and Lower Mesozoic, where the accumulation of marine sediments was attenuated (Stöcklin, 1968). Orogeny in Central Iran began with reverse faulting and folding from the mid-Mesozoic (early Jurassic) and is accompanied by intense magmatic activity during the Mesozoic and Cenozoic (Berberian and King, 1981; Stöcklin, 1968). According to Kaz'min and Tikhonova (2008), Central Iran subsided from the Cretaceous to the Paleogene due to the activity of the extensional back-arc basins. The Great Kavir Basin, located in the center of Central Iran, is an intracontinental rift basin with several kilometers thick of Eocene marine and continental sediments that are mainly formed by evaporite, carbonate, and red-colored deposits (Rahimpour-Bonab et al., 2007). These sediments were distributed in the form of 50 large domes of evaporites, limestone, and continental Red Formation deposits south of the town of Semnan (Rahimpour-Bonab et al., 2007). Paleomagnetic data from Central Iran show that a large Paleogene

Ocean was connected to the Great Kavir basin or isolated from surrounding areas (Soffel and Forster, 1984).

The Saveh area, which includes a significant part of the Central Plateau of the study area, also underwent four stages of deformation based on structural and stratigraphic evidence: the first phase of deformation (Upper Eocene - Upper pre-Oligocene), the second phase of deformation (Upper Oligocene - Lower Miocene), the third phase of deformation (Middle Miocene - Upper Miocene) (Morley et al., 2009; Ballato et al., 2008) then finally, the youngest phase of the Saveh deformation is characterized by the reactivation of the Kushk-e Nosrat fault (Figure 2) (Orang et al., 2014). The oldest rock units in the Saveh area are an Eocene pyroclastic complex that has been associated with deformation, uplift, and especially erosion before the advancing sea and the successive deposition of the Qom Formation (Oligocene Upper to Lower Miocene).

Thus, the Qom formation base presents a nonconformity exposure inside the extension basin of the Kushk-e Nosrat and Kooh-Charkhi regions. The second deformation stage was dominated by the Upper Oligocene-Lower Miocene due to a dextral transtensional regime along the lateral curvature of the fault.

From the Middle Miocene, new sedimentary basins formed in the Saveh region and the upper Red Formation (consisting of sandstones and argillaceous rocks), then the equivalent Hezardarreh or Kahrizak Formations (including the sequence of conglomerates and, to a lesser extent, clay and sandstone) forming sedimentation with the contribution of increases in volume of detrital matter. With the syn-sedimentation of the upper part of the Upper Red Formation (from the Middle Miocene to the Upper Miocene), a new phase of deformation in the Qom-Saveh terrain begins, which gave due to the dominance of the dextral transpression regime (Morley et al., 2009). The deformation persisted at least until the Late Miocene when the sequence of the Upper Red Formation and the equivalent Hezardarreh or Kahrizak conglomerate Formation was also folded (Ballato et al., 2008), where the youngest deformation is determined by the reactivity of the Kushk-e Nosrat fault and the formation of sinistral strike-slip faults (Orang et al., 2014).

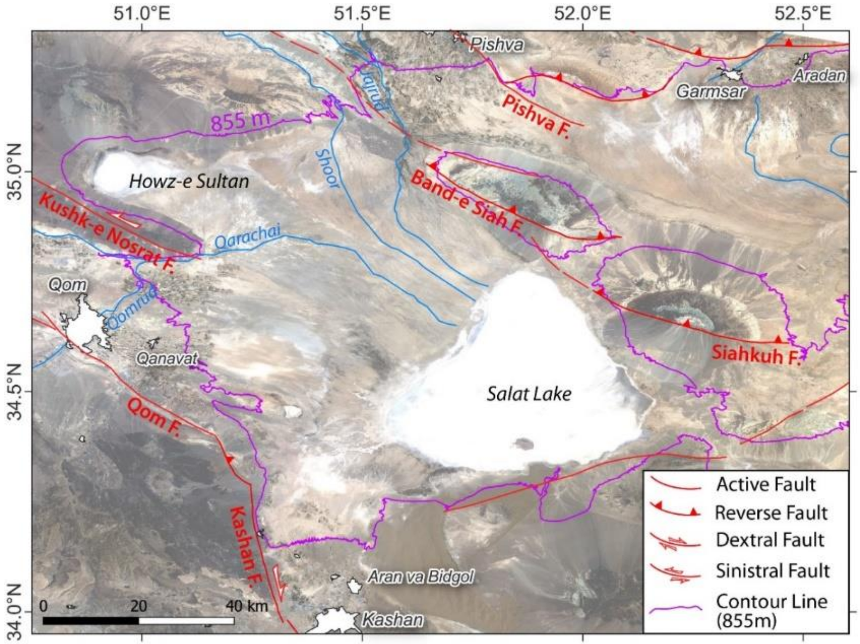

Figure 2: Main faults controlling the Salt Lake and Howz-e Sultan basins (faults are from Fathian et al. (2021) and the references therein) on a background of Landsat 5 imagery (earthexplorer.usgs.gov). Violet curves

represent the contour line indicating the water border at an elevation of 855 m.

3- Influence of Quaternary climate change on humans in the Iranian Plateau

The Quaternary period covers the last 2.588 ± 0.005 million years (Cohen et al., 2013) with two particularities which are climatic fluctuations (Gibbard and Head, 2009; Gibbard et al., 2010) and human evolution (Lahr and Foley, 2016; Benjamin et al., 2017) distinguishing it from other geological periods. The Pasadenian orogeny is the most important stage of Quaternary orogeny in Iran. It caused a large amount of subsidence in the Central Iranian Plateau (great desert), which formed a depression within the peripheral highlands.

3-1- The Quaternary climate and human history in the Iranian Plateau

Climatic evidence may be reflected in geomorphology features, such as glacial frosts, river terraces, or lakes, which indicate the lower to middle Pleistocene climate changes in Iran (Kehl, 2009). For example, Bobek (1963) has stated the wetter climatic conditions for the Central Iranian Plateau in the early Pleistocene, assuming that the brown silt layers and clay layers are located at a lower cross-section with a thickness of 350 m from the desert embankment in Masileh, which previously was described by Huber (1960) and deposited in a semi-stable lakeside environment. Based on the extension Playa in Iran Krinsley (1970) described that the climate of the Iranian Plateau during the Lower-Middle Pleistocene may have been colder, and according to the reduced evaporites, have been wetter than today. In other studies, on the loess deposits of the southern part of the Caspian Sea (e.g., Frechen et al., 2009; Kehl, 2009), climate change assessment has become possible during the Pleistocene. These studies show that a temperate and rainy environment dominated the Central Iranian Plateau during the MIS 7, 9, 11, and perhaps older glacial phases (Kehl, 2009). It seems that the birth date of early modern humans is shortly before the onset of the very cold glaciation, known as the sixth stage of the marine isotope or the late seventh stage (McDougall et al., 2005; Shea et al., 2004).

During the Ice Age, a colder and drier climate prevailed over Iran (Bobek, 1959), a colder and wetter climate than today (Pluvial) (Scharlau, 1958). As a third theory, during both the cold glaciation and almost warm interglaciation periods, the geographic location and topographic conditions of the Iranian Plateau made humidity equilibration possible (Mehrshahi, 2002).

In Lower Pleistocene, in the Central Iranian Plateau, the climate was wetter than today (Bobek, 1963). Based on the extent of the playa in Iran, the lower–middle Pleistocene seems to be colder and, due to the decrease in evaporation, was wetter than today (Krinsley, 1970). The Iranian Plateau experienced a cold and dry climate between 200 to 130 ka BP, while the climate of the 5e MIS phase has been warmer and more humid than in the Holocene (Djamali et al., 2008). Paleo-palynology on Urmia Lake shows that the Iranian Plateau experienced continuous glacial (Bonab glaciation) with a cold and dry climate between 200 and 130 ka BP. Undoubtedly this has had a significant impact on the depletion of environmental resources in the north of the Kavir desert and was likely a factor in the dispersal of human communities (Djamali et al., 2008). From 100 ka BP until the onset of the Holocene, the climate in the Iranian Plateau, with some fluctuations, has been mostly cold and dry in some humid periods. However, warm and humid periods have played a significant role in establishing human societies.

The Caspian Sea in the north and Urmia and Neur lakes in the west show a relatively warm and humid climate from 40 to 35-32 ka BP (Coolidge, 2005; Djamali et al., 2008). Then, around 32 to 24 ka BP, this area experienced relatively lower temperatures, resulting in the Caspian Sea level reaching ca. 55 m below its present level (Coolidge, 2005) probably caused the settlement shift from agriculturally based into the nomad pastoral life (Fazeli Nashli et al., 2023b, in press).

Eventually, the last Ice Age began at about 26 to 23 ka BP and continued for nearly 4,000 years until 20–19 ka BP (Harris, 2010, Düring, 2011). The last glacial period peaked 21ka BP in Iran (Ebrahimi and Seif, 2016). This extremely cold weather caused the maximum temperature in the hottest months of the year, July and August, to reach 10 to 12 degrees Celsius on the Iranian Plateau, and as a result, most of the vegetation of the area was extirpated (Djamali et al., 2008).

Archaeological evidence supports that the abandonment of much of Iran by human or hominin groups during the Last Glacial Maximum (LGM), at least between c. 26 and 20 ka BP and possibly much longer which widely across Turkey and Greece (Düring, 2011) and all of Central Asia (Coolidge J., 2010). Such sharp abandonment of Iran should be related to the coolness and aridity of the Late Glacial Maximum (Matthews and Fazeli Nashli, 2022).

At the end of the Upper Paleolithic and the beginning of Epi-Paleolithic, and with the end of the Great Ice Age around 20 to 19 ka BP, climate fluctuations in the Central Plateau moved toward greater stability with warmer, more humid climates that lasted for 2,500 years (Harris, 2010; Mathews and Fazeli Nashli, 2022). However, the persistence of this hot climate was not enough to compensate for the effects of the Great Ice Age on the restriction and even diminishing of the Central Plateau lakes. Short-term sustainability also led to the reactivity of habitual and seasonal water resources, increased plant growth, and, consequently, animal abundance (Harris, 2010). A gradual global warming, which began at 20 ka BP, accelerated at about 14.6 ka BP (Bryson and Bryson, 1999; Roberts, 2002). This widespread climate change provided the basis for the Neolithic Revolution and rural life (Darabi, 2022, Matthews and Fazeli Nashli, 2022). In fact, dusty, dry and cold climate in the Iranian Plateau since the Last Glacial Maximum ended abruptly around 14.6 to 12.7 ka BP (Safaierad et al., 2020; Vaezi et al., 2019) which was synchronous with the Bølling–Allerød period known as warm and humid climate in northwestern Europe

(Weaver et al., 2003). In the Jazmurian playa, southeast of Iran, increased fluvial inputs coupled with a low abundance of evaporite sediments indicated a greater influence of the Indian Ocean Summer Monsoon (IOSM) between 14 and 13.2 cal. ka BP (Vaezi et al., 2019).

Younger Dryas (12.7 to 11.6 ka BP) is one of the abrupt events of climate change in the Late Ice Age. At this time, the climate in the northern hemisphere became colder (Cuffey and Clow, 1997). The Iranian Plateau experienced dusty dry climate (Mayewski et al., 1997; Sharifi et al., 2015; Vaezi et al., 2019) in a same time. In contrast, the Jazmurian playa was dry and dusty between 13.2 and 11.4 cal ka BP, as reflected by an increase in aeolian sands and the presence of evaporate minerals. The dust record from southeastern Iran, spanning the period 19 to 7 cal. ka BP, with a direct link between frequent occurrences of dust plumes originating from the Arabian Peninsula and North Africa and rapid southward shifts of the westerlies associated with changes in the winter stationary waves during the Younger Dryas, and the 8.2 ka BP event (Safaierad et al., 2020).

The Holocene is subdivided into the lower, middle, and upper Holocene parts (Walker et al., 2012), indicating that the boundary between the lower-middle Holocene and middle-upper Holocene are 8.2 and 4.2 ka BP, respectively. Such events have affected on the rise and collapse of human societies on the occupation of the north central plateau of Iran (Fazeli Nashli et al., 2022). The warmth of the Holocene climate permitted the growth of plant and animal species susceptible to domestication, which led to the existence of rural life in the Holocene (Roberts, 2002). As mentioned above Evidence suggests that the sudden climate changes during the Holocene may have an important and transformative role in the rise and fall of human civilizations (Cullen et al., 2000; De Menocal, 2001; Brooks, 2006; Riehl, 2009).

During the early Holocene, high solar insolation and orbital-scale teleconnections (Fleitmann et al., 2007; Gupta et al., 2003; Overpeck et al., 1996) led to melting the ice sheets and increase the sea level and temperature. During this period the Iranian Plateau experience humid condition with different timings of peak of humidity in different region of it (Vaezi et al., 2019; Sharifi et al., 2015). In the SE Iran, period of strong IOSM activity during the early Holocene, coincide with higher fluvial input c. 11.4 cal. ka BP. The early Holocene in southeast Iran was wetter than other analogs in south Asia because of inputs from both IOSM and Mid-Latitude Westerlies (MLW). Several intense dry periods with sharp increases in aeolian inputs occurred after the early Holocene due to the southward migration of the Intertropical Convergence Zone. Based on the dating analysis, the west of the Iranian Plateau has experienced humid climatic conditions, at least from the last part of the early Holocene (11.7 to 8.2 ka BP) to the first part of the middle Holocene (8.2 to 4.20 ka BP; Sharifi et al., 2015). In western and Central Iran, the transition period occurred from dry and dusty conditions during the Younger Dryas (YD) to a relatively wetter period with higher carbon accumulation rates and low Aeolian input during the early Holocene (9–6 ka BP). This period was followed by relatively drier and dustier conditions during the middle to late Holocene, which is consistent with orbital changes in insolation that affected much of the Northern Hemisphere (Sharifi et al., 2015). The geochemical fingerprint of dust particles deposited during the low-flux, early Holocene period (11.7–6 ka BP) is distinctly different from aerosols deposited during high dust flux periods of the Younger Dryas and the mid-late Holocene (6 ka BP–present) (Sharifi et al., 2018).

The southeastern Iran sites such as Tepe Yahaya, Tepe Gaz Tavila, Tal-i Iblis and Tepe Gav Koshi west of the Jebal Barez Mountains in western Kerman Province and also Tal-e Atashi shows the earliest agriculture villages in southeastern Iran from the seventh to the sixth millennium BCE. One of the ancient pieces of evidence of being wet from the early Holocene was an ancient site of Tal-e Atashi (Hill of Fire). The Tal-e Atashi site is located 30 kilometers east of the new city of Bam and is a suggested timeline for the first period of settlement in Tal-e Atashi at the end of the sixth millennium and the first half of the fifth millennium BC. According to observations, the site has a large habitat of about 5.7 hectares depending on the Prehistoric culture without pottery (Garazhian and Rahmati, 2012; Garazhian, 2009, Mutin et al., 2020).

Geological and geochronological data combined with archaeological and historical data indicate the existence of an immense lake (Figure 3), in the same order as the Aral Sea, in the northern part of the Central Iranian Plateau end of the Pleistocene-early Holocene period (between MIS 2 and 1). This lake most likely existed during the previous interglacial MIS 5e period as well, which experienced dry periods during which it desiccated as well as wet periods during which it was filled again (Nazari and Ritz, 2019).

The most ancient evidence of humidity in the first part of the middle Holocene is the presence of archaeological sites in the present warm and dry range, such as the first settlement. Gav Koshi is located in the northwest of Jiroft date back late seventh millennium BCE, indicates the route of early formers to the subcontinent and the archaeological site of Tal-e Atashi, related to the late centuries of the 6th millennium and the first half of the 5th millennium BC, 30 km east of the new city of Bam support full sedentary societies in the edge of Kavir (Garazhian and Rahmati, 2012; Garazhian, 2009, Mutin et al., 2020, Shakouei et al., 2022) as well as the Sialk site—the lowest settlement back to 6000 to 4900 BC—in the southwest of Kashan (Soltysiak and Fazeli Nashli, 2010; Marghussian et al., 2017, Fazeli Nashli and Nokandeh 2019, Fazeli Nashli et al., 2023) has left the favorable climate conditions in the Central Iranian Plateau. Humid climatic condition in the Sassanid period was confirmed in many studies (e.g., Djamali et al., 2009; Stevens et al., 2001, 2008; Wasylikowa and Witkowski, 2008).

The presence of certain natural and cultural markers in the area reflects the different environmental and climatic conditions of the past. One of the archaeological markers is the high density of sites. These settlements are proof of climatic, environmental, and water resources sufficient for them in the past (see Figure 1). Back to the north central plateau, the ancient site of Sialk southwest of Kashan, whose lowest levels of settlement dates back to 6000 and ended 4900 BCE (Soltysiak and Fazeli Nashli, 2010; Marghussian et al., 2017) shows the favorable climatic conditions on the north Central Iranian Plateau during the sixth miilennium BCE.

One of the questionable areas is Lake Mirabad, which despite its short distance from Lake Zarivar experienced drought in the latter part of the early Holocene and the first part of the middle Holocene (Stevens et al., 2006; Griffits et al., 2001). However, the shortest interval dependent on humid climatic conditions obtained from various studies For Lake Zarivar, covers 8.95 to 6.87 ka BP, even with the in-depth study of areas such as Lake Parishan, the desert of Mighan, Nimblok Khorasan or Neur Lake, the humid climate in the latter part of the early Holocene and the first part of the middle Holocene were visible (Figure 3).

In the early Holocene, there was little or no spring rainfall due to the northward expansion of the descending air in subtropical high-pressure over Iranian (Djamali et al., 2010). In the middle Holocene, the increase in spring rainfall and the shortening of summer droughts enabled oak trees to grow (Djamali et al., 2010). Based on OSL ages, the period of ongoing fluvial incision began soon after 8200 BP (Fattahi et al.,2007). Detailed records of lakebed deposition in the presently arid interior of Iran are rare, though the available data indicate highest level of the lake at 9 to 7 ka BP from SE to NE Iran (Walker et al., 2012). The major periods of Holocene landscape development hence correlate with a period of time where water was more abundant than at present, with the incision of rivers into thick alluvial deposits possibly occurring due to a combination of decreased sediment supply and high levels of precipitation and with the formation of inset river terraces possibly responding to century-scale fluctuations in precipitation. The increased temperature in the Northern Hemisphere, inferred by geochemical data at the beginning of the Holocene, best explains the change from the Younger Dryas high stand to early Holocene low stand conditions (Aubert et al., 2017).

About 8200 years ago, in the early Holocene, an unexpected phenomenon known as the event of 8.2 ka BP was first detected on the Greenland ice cores. Scientists have shown that the temperature has dropped to 3.3 degrees Celsius over two decades (Alley et al., 1997). The event of 8.2 ka BP in Iran, from the north in the central Alborz to the south in the Central Plateau, based on absolute dating (e.g., Nazari, 2006; Hollingsworth et al.,2010; Ritz et al.,2012; and Barzegari et al., 2017), could be detected by inherited ages which measured from the cosmological and luminescence age analysis (Rizza et al., 2011; Le Dortz et al., 2009, 2011, 2012; and Nazari et al., 2014). The first wave of early farmer to the central plateau of Iran and further to the northeastern of Iran started from c. 7200 BCE but a remarkable population movement within the region coincidence with the end of RCC 8.2 ka (Flohr et al., 2016, Fazeli Nashli et al. 2023b, in press). It seems such farmer villages settled on the edge of alluvial fan from one side and also based on the current information freshwater resources surrounded the lower parts of alluvial plains.

Similar to the Great Kavir (i.e., desert in Persian), the Central Iranian Plateau is covered mostly by quaternary alluvium deposits. In the western part of Dasht-e Kavir, the area which contains the Dasht-e Kavir depression in the east, the Aran-Qom depression in the west, and the Garmsar depression in the north (Figure 1 and Figure 3) as the low current lands, the old alluvial cones (Pleistocene) (Emami, 1991; Vahdati Daneshmand, 1991). The absence of archaeological remains dating back to the second millennium BC suggests that the lake rose in the late Bronze Age (NB / pre-Islamic archaeological remains are confined to the edge of the ancient lake). However, the existence of cultural remains from intermittent human settlements in the Iron Age within the area of the former lake suggests that there may have been a period of drought again.

Precipitation sources in SE Iran changed from a monsoon-dominated regime to one influenced mainly by the MLW during the late Holocene (Vaezi et al., 2019). However, in the Jiroft area, due to human clearance and intensified agro-sylvo-pastoral activities, and climatic factors, the land cover shifted from open xeric scrublands to a more open degraded landscape. The principal human occupation was cereal cultivation and herding (Gurjazkaite et al., 2018). It is likely that during the more arid periods, communities retreated and abandoned agriculture, facilitating successional processes. The latter period which started with the rule of the Persian empires (550–650 BC), and continued through the Islamic era, coincides with intensive human activities and the highest degradation of vegetation (Gurjazkaite et al., 2018).

In the late Holocene, two cold and humid periods are identified: first of all, the colder and more humid period from 2.9 to 2.3 ka BP coincided with the Iron Age (Gutierrez – Elorza and Pena– Monne, 1998). This period, which is synchronized with the Medes kingdom, and the Achaemenid Empire, also recorded as very wet period coeval with extensive agricultural activity in the Jiroft Valley (Vaezi et al., 2022). There is no doubt that the Iranians have experienced a humid climate, at least in part, since the Sassanid dynasty. For example, humid climatic conditions can be confirmed by the first stage of large-scale arboriculture (1.5 to 1.25 ka BP) in the Almalo range (Djamali et al., 2009b). Recently Vaezi et al. (2022) have shown that humid condition governed southeastern Iran between 1.6 and 1.3 ka BP coincide with the Sassanian Empire.

The second one from 1300 to 1600 AD (Calkin and Young, 2002) which is named as the Little Ice Age (McFadden and McAuliffe, 1997; Gutierrez et al., 1998; Gutierrez - Elorza and Pena-Monne, 1998; Calkin and Young, 2002). Between the two mentioned cold periods, the second Holocene warm period dominated, followed by the last warmed period from the 16th century until today (Calkin and Young, 2002).

Concerning the paleoclimatological study, the last glacial period peaked at ca. 21 ka BP (Ebrahimi and Seif, 2016). The process of gradual global warming that began around 18,000 BC accelerated to about 12,000 BC (Bryson and Bryson, 1999; Roberts, 2002). This widespread climate change provided the basis for the Neolithic Revolution and the emergence of rural life (Darabi, 2022). The Holocene began at nearly 12 ka BP, after glaciers melted in late retention and warming (Cuffey and Clow, 1997). The warmth of the Holocene climate permitted the development of plant and animal species susceptible to domestication, which led to the emergence of rural in the Holocene period (Roberts, 2002). Three theories are suggested about the Quaternary climatic conditions in Iran:

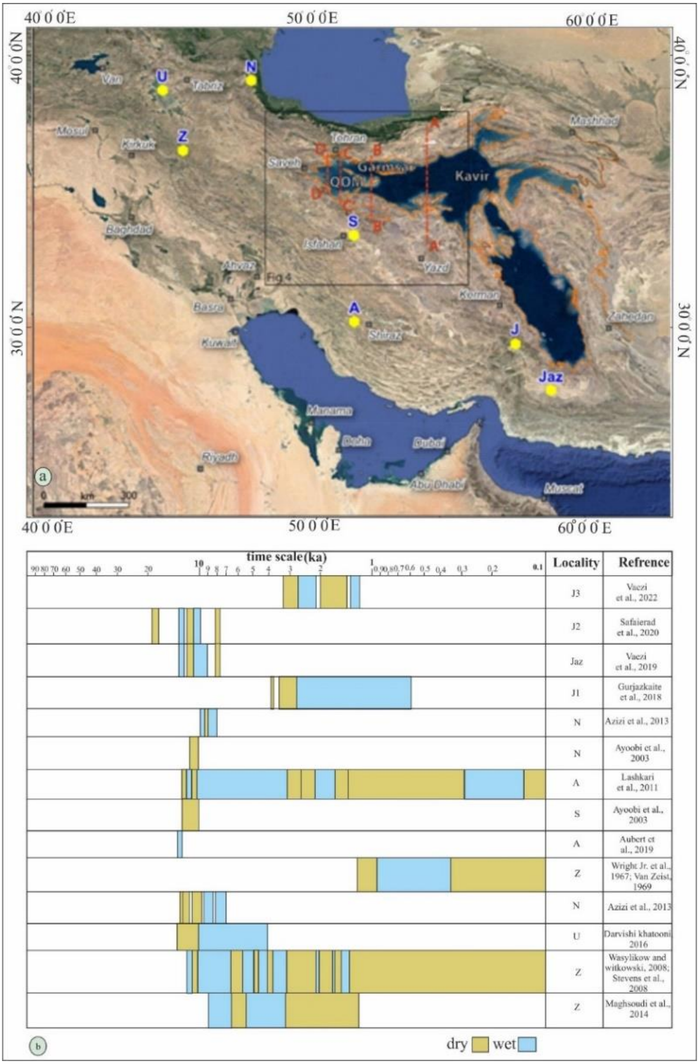

Figure 3: (Up) General map of the Paleo-Shores (brown and blue contours) in the northern half of the Central Iranian Plateau showing the area covered by an immense ancient lake (see Section 0 for more details). Orange and blue contours denote the altitudes of 1015 and

1020 m, respectively. Brown dashed lines represent the topographic profiles in Figure 11. (Bottom) Summary of the climatic conditions in Iran (A: Arzhan Lake; J1-3: Jiroft/Konar Sandal peats; Jaz: Jazmurian Playa; N: Neor Lake; S: Sialk; U: Lake Urmieh; Z: Lake Zarivar).

4- Archaeology of the Central Iranian Plateau

Based on archaeological data and information, the history of the Iranian Plateau 300 ka BP can be divided into following periods of Lower Paleolithic, Middle Paleolithic, Upper Paleolithic, Epi-Paleolithic, Neolithic, Chalcolithic, Bronze and Iron Age (Fazeli Nashli et al., 2022, Matthews and Fazeli Nashli., 2022). We very briefly describe the sequences of chronology of the region from the Middle Paleolithic period onwards.

4-1-The Middle Paleolithic (250 to 40 ka BP)

In the northern part of the Central Iranian Plateau, evidence of Middle Paleolithic period is evident in some places such as Chahjam south of Damghan, Mirak south of Semnan, Sufiabad southwest of Semnan, Moghanak and Ochunak in the Damavand Plain, Sepiddasht (Bouin Zahra), Nargeh, Zaviyeh and Arasanj in the desert of Qazvin, Hollabad, Niasser, Kaftar Khoon, Ghale-Goshe, Masileh and Thappe-Mes in the west of the desert of Kavir (Figure 1). Recent research program in Mirak southern of Alborz Mountain support the possibility of Paleolake in the southern of Mirak Middle and Upper Palaeolithic period in the Damghan region (Kharazian et al., 2002), (Appendix: Table 4).

4-2- The Upper Paleolithic and Epipaleolithic (40- 18 ka BP to 12 ka BP)

Archaeological data indicate a marked decline during the Upper Paleolithic settlements on the Central Iranian Plateau (Vahdati Nasab, 2015). Some Upper Paleolithic sites identified in the Central Iranian Plateau are Delazian, Sufiabad on the northern edge of Kavir, as well as Sefidab, Hollabad, and Ghale-Goshe (Bardia) in the west (Figure 1) (Shidrang, 2009 and 2014 Vahdati Nasab et al. 2019; Matthews and Fazeli Nashli., 2022). Epipalaeolithic sites include at several sites along the northern and western fringes of the Iranian central plateau, including Delazian, Chah-e Jam, Soofi-Abad and Bardia, (Appendix: Table 4).

4-3- From Neolithic to the Iron Age

So far, the earliest farmers and herders came to the two key regions of the north central plateau and the northeastern Iran around 7200 BCE in a land-locked basin, endemically semi-arid to arid region with a sophisticated architectural layout, an agriculture staple-based economy with a simple irrigation system, complexity in mortuary practices, flow of information exchanges, intensity of interaction, interregional interaction and long-distance trade. The time range between 7200 to 5200BCE is the last episode of Neolithic period with the progress of subsequent economic, social and political developments during the later pottery Neolithic. During the Chalcolithic periods people went on deep social inequality and emergence of urban layout all support progressive societal development (5200-3000 BCE). The Bronze Age in Iran covers from 3000 and ends 1250 BCE (Matthews and Fazeli Nashli, 2022; Fazeli Nashli et al., 2022). The time range of Iron Age start from 1250 and ends 550 BC. This period is divided into three eras: Iron I (1250 to 1050 BC), Iron II (1050 to 800 BC), and Iron III (800 to 550 BC). From the Neolithic to the Iron Age, this region featured with social evolution, rise and fall of societies which mostly related to the environmental crisis both regionally and globally (Appendix: Table 5).

5- Lake Saveh

The ancient manuscripts of Iran are full of legends whose scientific study can open many facts related to the historical and natural evolution of Iran. One of these stories is the legend of Lake Saveh. Examination of the available manuscript on Lake Saveh reveals that during the last millennia, there was a lake in the Saveh region which dried out around the time of the birth of the Prophet of Islam in the last years of the Sassanid dynasty in Iran. Examples of documents that refer to Saveh in the pre-Islamic era: The Travel Book of Marcopoulos in the fourteenth century (Polo, 1926), the Poutinist Plateau (223-187 BC), as well as the road guide Isidore (first century BC). In addition to these documents, there are artifacts from pre-Islamic archaeological sites in the Saveh region (e.g., Qiz Ghale or Temple of Anahita, the goddess of fertility and healing, wisdom and water, see Figure *13*), which confirm the pre-Islamic civilization along the shoreline of where we propose Lake Saveh to have existed.

5-1- History of Saveh region

Saveh region is located between major cities such as Hamedan and ancient Ray with al various historical periods, it has been part of Hamedan and sometimes Ray. Given the prehistoric ancient sites, it can be said that Saveh has its roots in previous millennia. The evidence shows that this area was very populated and was part of the Median central state—i.e., areas that range from the north to the Aras River and the Alborz peaks in the south of the Caspian Sea—from the east to the salt desert of the Kavir Plain and from the west and south to the Zagros Mountains, including Azerbaijan, Kurdistan, and Iraq Ajam(old synonym word which refers to the western part of Central Iran) and subsequently an integral part of governments such as the Achaemenians, Parthians, and Sassanids (Diakonov, 1966; Azkaie, 1990). The existence of an ancient castle of Asiaabad, which is a very large castle near the city, shows the history back at least to the Sassanid period (Rezvani, 2007; Rezvani and Vahdati Nasab., 2010).

The archaeological sites of each area are considered some of the most enduring evidence of civilization and its historical antiquity. According to Azkaie (1990), the name 'Aaveh' has an ancient history dating back to medieval times and is, in fact, the distorted Greek 'Abakhine' or 'Abakine,' 'Abakeh' or 'Epake,' and 'Avakeene.' About the village of Qardin in the history book of Qom (Ashari Qomi, 1982) is written: When King Keikhosrow reached Mount Andes and Mahin, he founded the village of Qardin. Tariznahid is attributed to the Godarz dynasty, and Elvir is located in the Kharghan section northwest of Saveh, and according to the evidence, it can be attributed at least to the Medean and Achaemenid period (Amirhosseini, 2011). Historical manuscripts referring to the post-Islamic Saveh are abundant. as a first reference, the name Saveh appears in manuscripts from the Islamic period of the 6th century AD which referred to the lake of this region.

5-1-1-Post-Islamic Saveh

Historical manuscripts referring to the post-Islamic Saveh are abundant. The name Saveh appears in the writings of the Islamic period from the sixth–seventh century AD. Abu Hanifa Davood Dinouri in Akhbar ol-Tawal (nineth and tenth century AD) and Gardizi in the History of Gardizi (11th and 12th century AD) while telling the story of the Abu Muslem uprising following the death of Nasribne Sayar, the last Umayyad governor in Saveh in the 8th to 9th century AD. Ibn Faghih in al-Baladan (9th century AD) mentioned Saveh as one of the villages of Hamadan, and Ibn Fazlan mentioned Saveh as the "city of Saveh" in his travelogue (930 AD) (Mokhtari, 1995).

Ibn Hoghel, a fourth-century AH (tenth century AD) tourist, said:

'... distance from Hamadan to Saveh is 30 Farsakh (~187km), and Saveh is a clean and good city through Iraq (refers to western part of the Central Iranian plateau), which has a lot of camel and most of the pilgrims go to Hajj with them, because people there, are cameleer taking the people of the beyond the river (Central Asia) to Mecca and it is from Saveh to Rey' (Ibn Hoqhel, 345 AH; 966 AD) (Appendix: Table 5).

Hamdullah ebne Abi Bakribne Mohammad ibn Nasr Mostofi Qazvini, the historian from fourteenth century AD in Nezhat al-Quloob, expresses the following of Saveh name:

"Saveh is an Islamic settlement… and first on that land was the lake. On the night of Muhammad's birth, the lake's water was submerged, and it was from evangelism! And they built a city on that land whose origin is unknown", (Mostofi Qazvini, 1957).

In recent centuries, European travelers and Orientalists have sometimes referred to the city of Saveh in their writings. One of them is German Adam Olearius, who also crossed Saveh from Sultanieh (Zanjan) to Kashan and painted a beautiful picture of the city's exterior (Olearius, 1989). The Iraq Ajam (refers to the western part of the central Iranian plateau) travelogue, which describes the Nassereddin Shah's travel to the central Iranian provinces, also mentions Saveh.

<u>5-1-2-The Etymology of Saveh</u>

In etymology, the term Saveh could relate to water, as some people in Saveh say that Saveh is actually 'Se Aaveh or Abeh' derived from 'Oe,' which locally means water (Nahchiri, 1992). Therefore, it is most likely called 'Abe' or 'Aaveh' because of the water in the distant past in this region (Alviri, 2001). It is strongly mentioned in Borhan that the city was named after Torani hero, a relative of Kamus Koshani who was called 'Saveh Shah' and killed in the battle with Rostam (Kholf Tabrizi, 2001). Some experts also refer to the name of the Saveh city as 'Se-ab / Se-aw,' formed close to a collection of three rivers (water) which the name of the city is associated with them: 1) Vafargan river in the south of the current city of Saveh; 2) Mazalghan river crossing the central part of Saveh Plain; 3) Shoor River which flows in the northern part of Saveh (border between Tehran and Saveh) (Amir Hosseini, 2011).

The name of Saveh is stated in Dehkhoda's dictionary: The name of a famous city in Iraq (Iraq Ajam: old synonym which refer to the western part of Central Iran), and it is said that there was a lake where one person drowned every year to protect them from flooding, and on the night of the birth of the Prophet Muhammad, the lake dried out.

5-1-3-The Etymology of Saveh

Reference to the existence of a lake in the Saveh area was first mentioned in the history of al-Rosol al-Muluk by Muhammad ibn Jarir Tabari in 260 AH. Tabari quotes Hani Mahzouni as saying: 'Hani Mahzouni who lived one hundred and fifty years, has been narrated, Ivan Kasra trembled on the night of the birth of the Prophet Muhammad, and fourteen gaps fell, and a Persian fire extinguished which had the light up for thousand years and the Lake Saveh plunged ...' (Tabari, 1972).

In the history of Yaqubi, written by Ahmad ibn Isaac Yaqubi, on the night of the birth of the Prophet Muhammad, the gaps of Ivan Kasra collapse, the Lake of Saveh dries up, the thousand-year-old fire of Pars burning turns off, and the Zoroastrian princess sleeps and sees the slender camels slinging the fat Persian horses across the Dejleh (Yaghoubi, 2003).

Zakaria Ibn Muhammad ibn Mahmoud Qazvini wrote in the works of Alabad and Akhbar al-ebad (14th century AD): ‘It is a famous city located on the desert and close to the lake that dried out on the birth night of the Prophet Muhammad and I saw the position of that lake where the barley was cultivated, and some elders said that there were some ships on that lake’ (Qazvini, 1994).

But Ja’far ibn Mohammad ibn Hassan Ja’fari has also mentioned the story of the lake of Saveh and its drying out to the birth time (6th century AD) of the Prophet of Islam in Yazd history (15th century AD). He describes the expansion of Lake Saveh in the Sassanid period and in much of Central Iran from Hamedan to Yazd.

5-2- Geological evidence of the ancient lakes in the Kavir desert region

Based on facies analysis in the west of Zavieh, Djamali (2002) showed that Lake Saveh, at least in this small range, is not a large lake, but it has been a water ecosystem where sedimentation has taken place in lakes, swamps, ponds, canals, and floodplains of river systems. Okhravi and Djamali (2003) reviewed historically ancient Lost Lake Saveh. They stated that the co-ordination of topographic and shorelines indicates that the eastern parts of the Zarand basin are capable of forming a water basin and are likely the most probably place for an ancient Lake Saveh (see Figure 3).

Despite current dry climate conditions, many desert basins present morphological and stratigraphic evidence that suggests basins like the Great Lakes of the past (Snyder and Langbein, 1962; Mifflin and Wheat, 1979; Williams and Bedinger, 1984). The surface area of ancient lakes is a key variable in the assessment of paleoclimatological conditions (Sack, 2009).

Geomorphological studies (Nazari et al., 2021; Jarahi, 2021) show that the northern half of what is now the Central Iranian Plateau included a large lake, and its remains can be seen in the form of various playa throughout the desert. Lake terraces (Fan et al., 2014), analysis of sediment profile and lake evidence (Sack, 2009), ancient hills and pottery kilns (Dolukhanov et al., 2010; Krivonogov et al., 2014), topographic position (Hutchinson, 1957; Reeves, 1968), gully set and baseline change (Goudie, 2003), and Local names (Saffari et al., 2014) are some of the most important and significant morphological factors that could be associated with an ancient lake.

6- Reconstruction the Paleo-shorelines

From a synthesis of geological and geochronological data combined with archaeological and historical data, we show that the northern part of the Central Iranian Plateau corresponded to a huge lake (Figure *4*), at least as large as the Aral Sea, at the very end of the Pleistocene-early Holocene period, there are c. 16 Ka, at the transition between marine isotope stage MIS 2 and 1. The morphological and stratigraphic markers of this ancient lake are still visible in some areas of the Central Iranian Plateau, especially in the Kavir desert, the Qom-Aran desert, and the region of Masileh. Moreover, the morphological, archeological, and historical data allow reconstruction of its evolution during the past 15 ka BP. These various data allow showing that this huge lake (which most likely also existed during the previous interglacial MIS 5e period) experienced dry periods during which it gets evaporated and wet periods during which it was filled again. Indices showing the presence of the lake around 16-14 ka BP are ancient shorelines located at an altitude of c. 1100 m found in many places around the current Great Kavir depression.

The spatial distribution of archaeological and historical data indicates the drying out of the Masileh Basin, in a region higher than the heights of the Kavir Desert. We believe that the Masileh Basin has survived to the Sassanid Empire. The eastern part of the Kavir Basin had dried out earlier. The lake of the Masileh Basin (the Great Salt Lake and the Howz-e Sultan basins) probably corresponds to the ancient Lake of the Saveh which is mentioned in the old myth.

Ancient sites' locality regards the height of the Paleo-shorelines. The Late Neolithic landscapes (6000-5200 BC) are above the Paleo-shore with a height of 850 m. It is interesting to parallel with the Neolithic landscape in the Ararat basin situated 800 km NW, where a lake existed in Late Neolithic and its shoreline varied in the elevation range of 833 - 865 m, (Karakhanyan et al., 2022).

Anyway, in the Iranian Plateau, the areas of Cheshmeh Ali (Fazeli Nashli et al., 2014), Tappe Pardis (Fazeli Nashli et al., 2010), Sialk North (Fazeli Nashli et al., 2009), Sadeghabadi (Valipour, 2011), the Qareh Tappe Qomrood area (Kaboli, 1999) and the Qeshlagh Agh Tappe site (the Cultural Heritage Monuments; http://iranshahrpedia.ir) exits in this area, which indicates that before settling in these areas, the water level of Lake Central (Central Iranian Plateau Grand Lake) had dropped below 855 m. The Chalcolithic and Iron Age zones in the Tehran Plain extend over the altitude of 820 m and, in the Qom Plain, over 850 m, and at the end of the Sassanid sites of the Tehran Plain and Qom, they extend over 820 m. Accordingly, the water level (about 8.2 ka BP) has fallen below 855 m before settlement in Neolithic sites, which we can consider the shoreline lower than 855 m.

The archaeological sites of the Qom Plain did not reach an altitude lower than 855 m (Figure *2*) until the Sassanid period. This distribution diagram of an ancient site may indicate the existence of a natural factor that did not exist and not allowed the expansion of the former colonies until the Sassanid Period at altitudes below 855 m in the Qom Plain. The settlements spread during the Transitional Chalcolithic Period (4300–5200 BC) in the Tehran Plain and reach levels as low as 850 m. Due to the morphology of the Central Iranian Plateau, we can assume that there was a closed water basin to the west of the region, namely Salt Lake and Howz-e Sultan basins. The eastern part of the region was unloaded earlier than the western part, while the western part could have been unloaded independently to survive.

The Salt Lake and the Howz-e Sultan basins (Figure 2 & Figure 4) which are near Saveh, are themselves a sub-area of the northern half of the Central Iranian Plateau. It is located to the west of this area and has a higher height than the eastern part of the area. Despite the evidence of paleo-shorelines in both parts, and although these basins have the general conditions of a lake basin, there are disturbances in parts of both basins that prevent the closure of both basins.

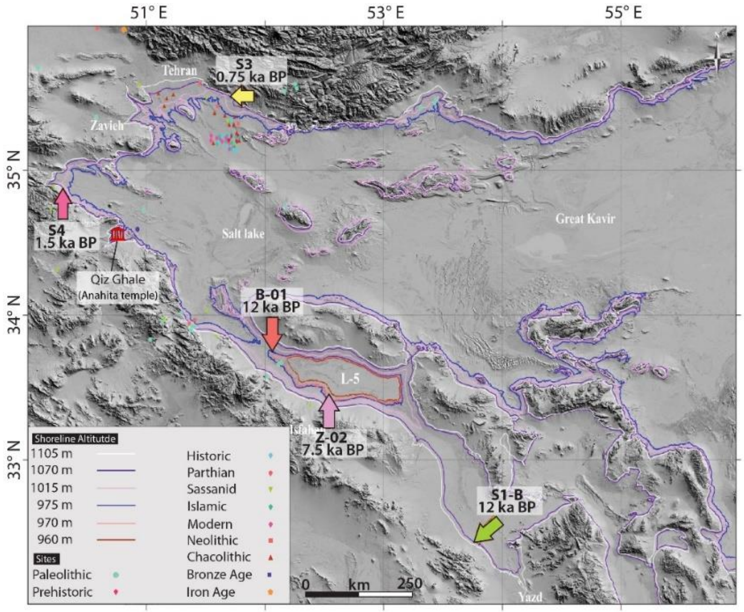

Figure 4: Map showing the western part of the ancient Lake Central in the Central Iranian Plateau. The colored arrows highlight the dating samples and their locations, Qiz Gale (Anahita temple) is located at the altitude of 1250m.

However, it should be noted that despite these disturbances, the two basins reach a specific height where traces of coasts are found below these heights are completely closed (for Lake Central, 865 m, and for the submarines Salt Lake and Howz-e Sultan basins 810 m) But the closure of the basin in the upper levels in both basins, where evidence of paleo-shorelines is present in the highlands, has been overlooked by the disturbances. Thus, disturbances may have occurred after the formation of the lake and have caused water levels to drop.

We reconstructed the topographic contours utilizing the SRTM Digital Elevation Model (DEM) with a 30 m (1-arc) resolution (Farr et al., 2007) in order to find the location of the Paleo-shores that match the topographic contours (Figure *3*) at different levels, which is presented as a series of paleo-shores along their height, indicating Figure 1, Figure 5 & Figure 6.

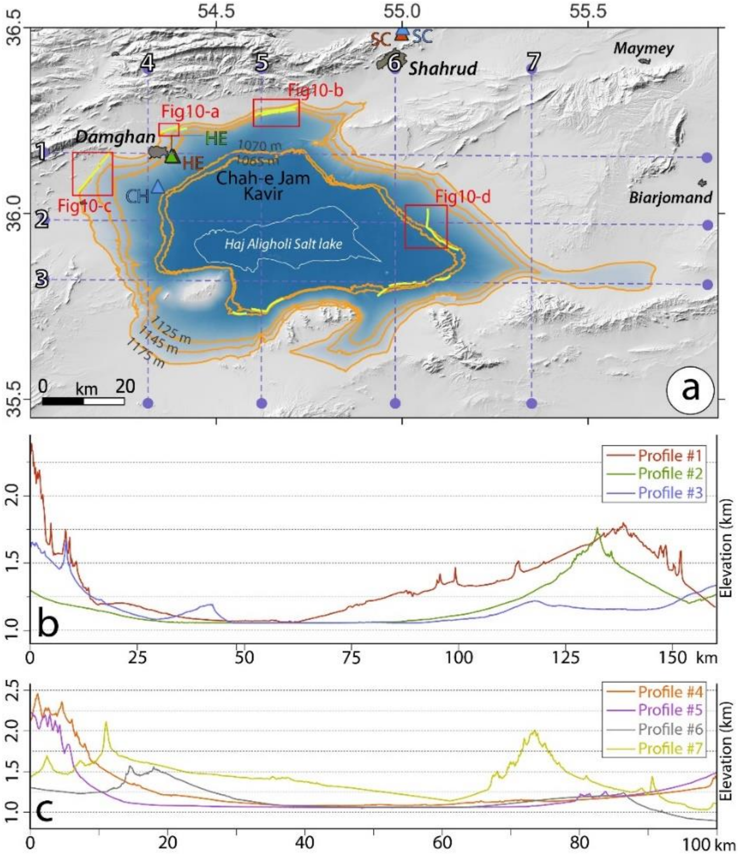

Figure 5: a) Map view of the L-1, reconstructed based on the topographic data, on the hillshade SRTM DEM 1-arc (Farr et al., 2007). Yellow lines illustrate the paleo-shorelines' remnants (see Figure 10). Orange lines represent the contours. Red, green, and blue triangles indicate the Paleolithic and prehistoric sites (see Figure 1 for the abbreviations). Horizontal and vertical dashed blue lines denote the profiles in panels b and c, respectively. b) W–E topographic profiles (1, 2, and 3) across the L-1. c) N–S topographic profiles (4, 5, 6, and 7) across the L-1.

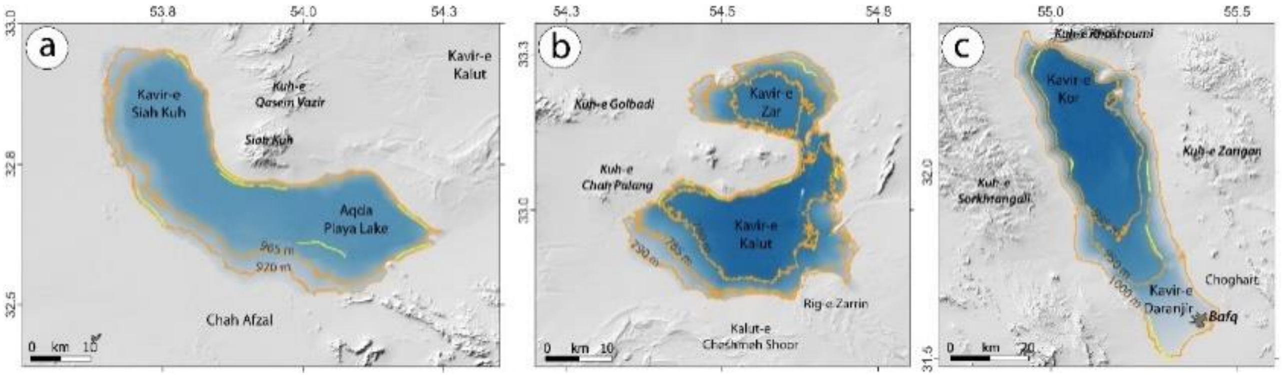

Figure 6: Map view of the reconstructed L-2 (a), L-2 (b), and L-3 (c) on the hillshade SRTM DEM 1-arc (Farr et al., 2007). Yellow markers represent the remnants of the paleo-coastlines.

6-1-Determining the age of paleo-shorelines

Determining the age of the lake sediments at each level defines how the water level drops due to the large difference between the shores. To determine the age range of the banks, we obtained Optical Stimulated Luminescence (OSL; Figure *7*) and radiocarbon (^{14}C) samples from the alluvial deposits associated with the paleo-shores (Figure *4*).

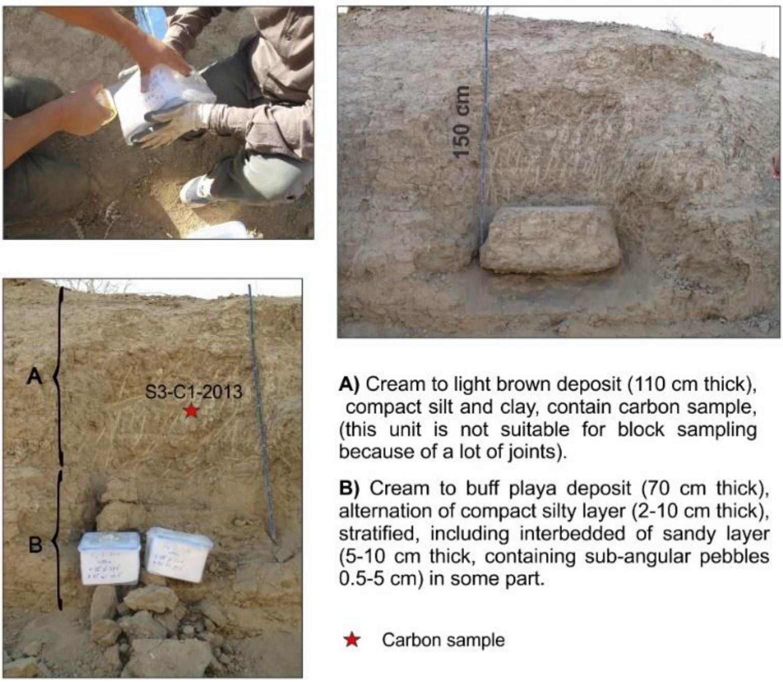

Figure 7: OSL and ^{14}C sampling in the site S3 location, south east of Tehran, highlighted in Figure 4, Table 1 and Table 2.

In order to complete the studies and for the temporal reconstruction of the basin, due to the difference between the probable subsidence rate in the center of the basin and the probable uplift rate on its banks, the sedimentation of deposits and separate strata in the core drilled in the Namak lake in the north of Kashan was performed (Figure 8). Previously, these 50-meter cores were drilled in order to explore the mineral resources of potash (Figure 8a).

Table 1: Results of the age determination of alluvial sediments associated with the Paleo-shorelines by optical luminescence (OSL) method.

Sample	**Longitude**	**Latitude**	**Height (m)**	**Age** (years ago)
B-01-2016	52.0702° E	33.7435° N	975	7020 ± 270
Z-02-2016	52.5368° E	33.4621° N	962	6940 ± 740
S1-B	53.7663° E	32.4143° N	1105	11320 ± 650
S-3	51.6848° E	35.5272° N	1070	930 ± 180
S-4	50.3124° E	34.8830° N	1015	1300 ± 110

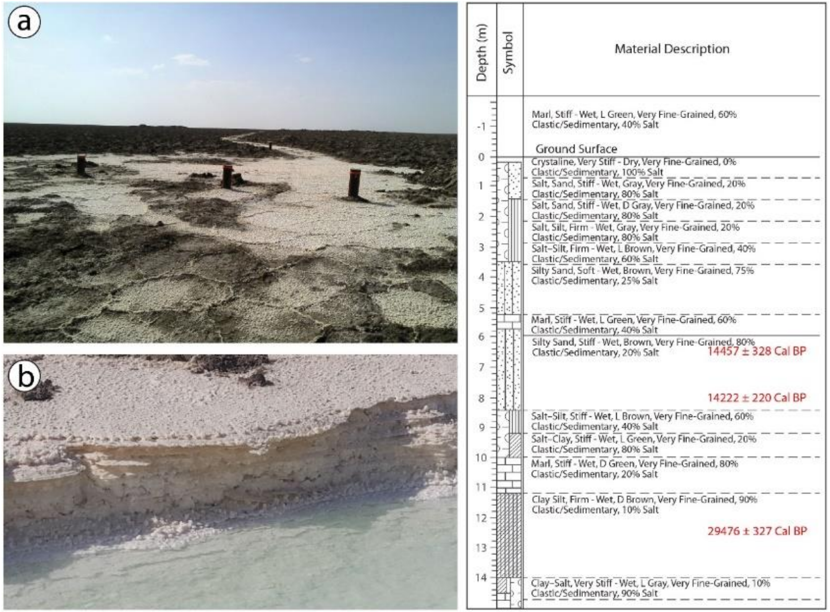

Figure 8: Exploration cores (a) and a view of superficial evaporitic deposits in place of drilling (b) in Salt Lake, NE Kashan, and an example of the log description from Borehole D6 after Feasibility Study of Iran Namak Lake Preliminary Economic Assessment, KUMMIDCO 2018 (right panel) and its corresponding ages (see Table 2)

The 3 obtained radiocarbon ages (Figure 8 & Table 2), especially those from the summit (IR18-BD6-01 and IR18-BD6-02) are consistent and clearly indicate a lake at 12315-12190 BP, i.e., ~14 ka ago; Which fits with Saveh and with the other dates that we have around 12 ka (Table 1), and confirms a first filling at the MIS 2/1 transition.

Table 2: Results of the age determination of alluvial sediments associated with the Paleo-shorelines by C14 radiocarbon analysis, (Moreau et al., 2013 and Dumoulin et al., 2017).

Sample	**Longitude**	**Latitude**	**Height (m)**	**Age** (CalBP)
IR18-BD6-01	51.8205° E	34.5279° N	790	14457± 328
IR18-BD6-02	51.8205° E	34.5279° N	790	14222 ± 220
IR18-BD6-03	51.8205° E	34.5279° N	790	29476 ± 327
IR18-S3-C1	51.6848° E	35.5271° N	1075	1135 ± 30
IR18-S4-C3	50.3124° E	34.8830° N	1024	16380 ± 413
IR18-Qz-C1	50.2089° E	34.9114° N	1250	941 ± 16

6-2- Estimating the disappearance water volume, and the cause of its disappearance

In order to better understand the rate of decline of the Lake Central surface with the available shoreline evidence aligned with the topographic contours, we estimated a large difference between each topographic level.

The topographic profile of each shoreline, derived from SRTM 1arc DEM, makes it possible to understand the morphological conditions of this zone. Figure 5 shows topographic profiles and illustrates how the morphology obtained from the N-S and E-W profiles (Figure 5b and c), as well as the position of the profiles in the L-1.

According to the smallest basins remaining as a result of the drop in the water level, the drying out of the large Lake Central can be divided into three stages. The first stage encompasses the widest coastal range of this area (Figure 5 & Figure 9) and includes 5 shores with altitudes of 1105, 1090, 1075, 1040, and 1030 m above present sea level (APSL) (derived from SRTM DEM), passing through this stage until the second stage, the smaller basins L-2, L-3, and L-4 remain and may have formed independent local lakes (Figure 6). In the second stage, after the water levels of the two banks drop to 1020 and 1015 m, the smaller L-5 basin (Figure 4) can continue to survive on its own (Figure 6a). In stage three, Lake Central contains a set of paleo-shores at 975, 950, 855, 850, 805, 795, 765, and 745 m APSL (Figure 11).

Basin L-1 (Figure 5) is an independent watershed, and if the Central Plateau of the large lake is confined to the northern half of the Central Plateau with a closed basin, the smaller basins L-6 and L-7 can also be independent lake basins.

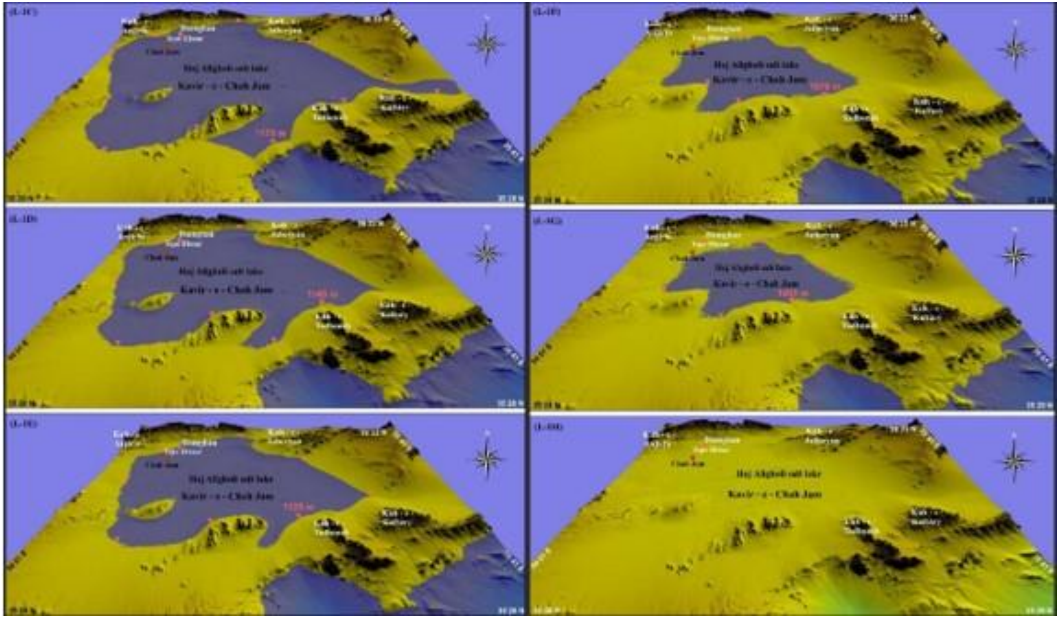

Figure 9: Three-dimensional reconstruction of water level drop in L-1 on hillshade SRTM DEM. Pink triangles show reconstructed paleo-shorelines (left). Three-dimensional reconstruction of water level drop in L-1 Lake on SRTM DEM, Pink triangles show reconstructed paleo-shorelines (right).

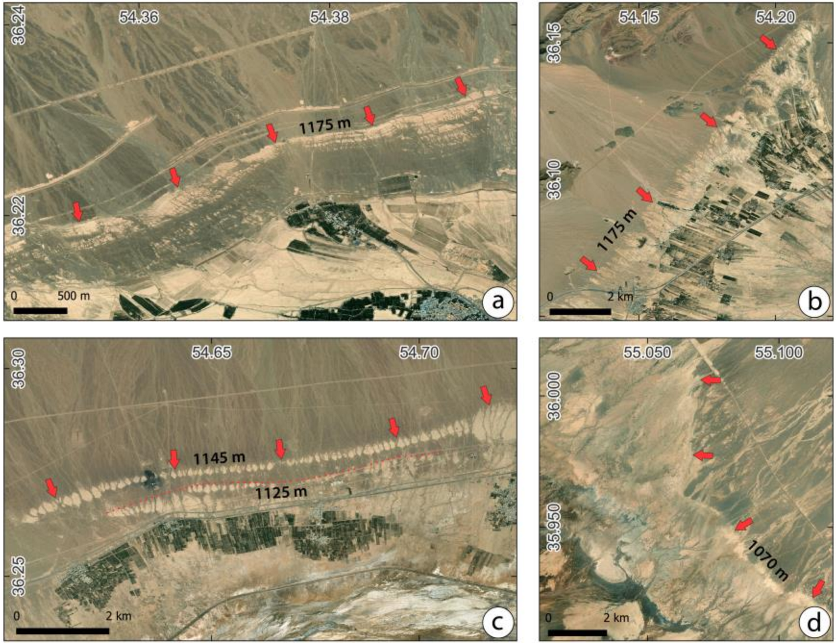

Figure 10: Close-up views of L-1 shoreline markers on ESRI satellite imagery (see the indicator locations in Figure 5a). Red arrows highlight the markers

Our geochronological data (Table 1) suggest that between the beginning of the Holocene (c. 11.5 ka BP) and 8 ka BP, the lake level gradually decreased by 250 m, to reach the altitude of 850 m. The maximum difference in height was between 1075 and 1040 m over 35 m, between 1015 and 975 m, i.e., between the first and second step over 40 m, between 950 and 855 m over 95 m, between 850 and 805 m on the west side from Central Lake in the third stage of 45 m and finally between 850 and 765 m from the east side of Central Lake in the third stage at 85 m.

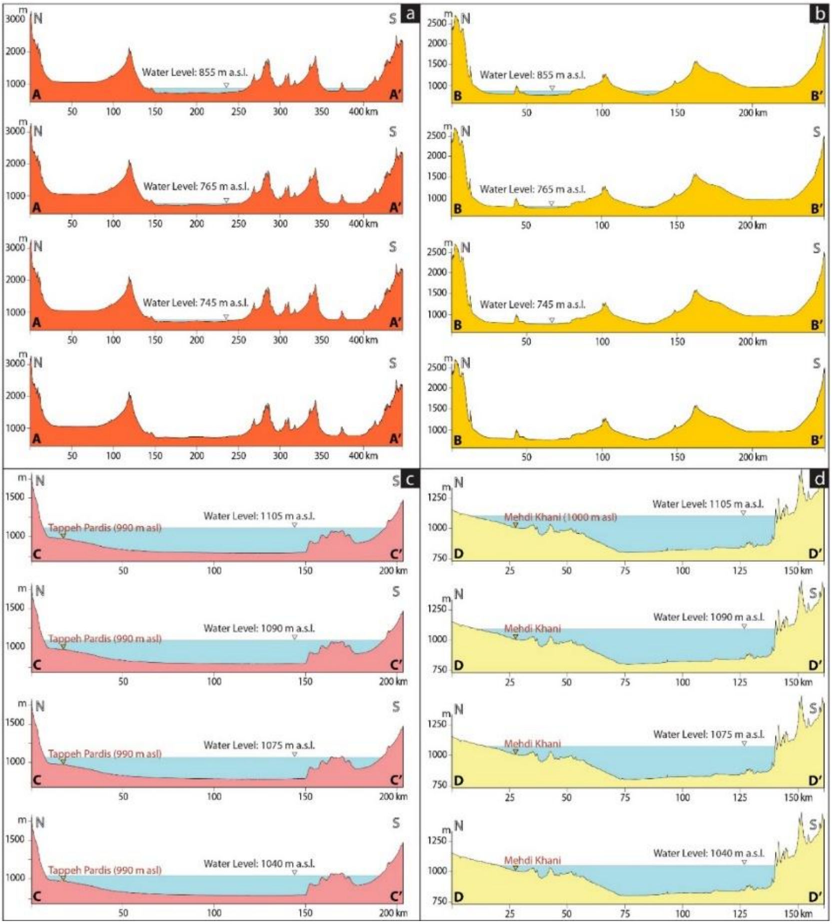

Figure 11. N-S Topographic profiles across Central Lake and different levels of water drop (see Figure 1 and Figure 3 for the location of the profiles).

7- Discussion

To prove the existence of a large lake in the Central Iranian Plateau, the first step is to prove the wetter conditions (water resources of the basin’s water supply) in the past and to have a morphologically closed basin that could contain a large amount of water. Water resources include rivers, atmospheric rainfall, high groundwater levels and solid resources (snow) around the basin, the presence of solid resources and wetter climates are the most important. According to the results of climatic studies of the Iranian Plateau, in the Pleistocene and in the Holocene, the Iranian Plateau has experienced successive wet and dry periods. Data from various climatic studies on the Iranian Plateau, combined with dating, show that most of the data from 10 to 7 ka BP are available in relation to humid climates, which has been repeated few times in Iran.

The quasi-altitudes and the solid resources (snow and ice) accumulated at altitude could be cited as the main supplier of water to the Quaternary lakes. So, to provide at least some of the Great Lakes water in the northern part of the central Iranian shelf, the glaciers had to be wider than the current one, which means that the water-ice balance line or limit snowfall is lower during ice ages, (Table 3). Long-range variations in the ice line between past and present glaciers are one of the few methods available to examine Late Pleistocene glaciers (Seif, 2015).

Table 3: Past and present elevations of the water and ice balance line (Equilibrium Line Altitude) in different parts of Iran (after Ebrahimi and Seif, 2016).

Glacial Extensions	**Previous Balance Line altitude** (m)	**Current Balance line altitude** (m)	References
Central Iran / Jopar and Lalezar	3050- 3200	4550	Kuhle, 1974, 1976, 2008
Zagros / Oshtrankuh Mountains	2950- 3050	4500	Seif, 2015
Northwestern Iran / Iran-Turkey border, Agri Mountain	3000	4300	Sarikaya et al., 2011
Northwestern Iran / Iran-Turkey border, Bozol Mountain	2100	3600	Wright, 1962 / Based on Cirque floor
Zagros / Zardkooh Mountain	3000	> 4200	Preu, 1984
Northwestern Iran / Sahand, Sabalan	3600- 3700	4500-4450	Zomorrodian-2003
Alborz / Takht-e Soliman Mountains	3300	4100	Zomorrodian-2003
Alborz / Damavand Mountains	3700	4500	Zomorrodian-2003
Zagros / Zardkooh Mountains	3350	4100	Zomorrodian-2003
Central Iran / Shirkouh and Jopar	3200- 3400	4600–4740	Zomorrodian-2003

Throughout the Pleistocene, snow across the country was 600 to 800 m lower than the current elevation, and the average temperature was 4 to 5 degrees lower (Bobek, 1963). Based on a study of the Iranian Playas, Bobek (1963) concluded that the permanent altitude of the snowfall was 1800 m lower in the northern outer slopes of Zagros and Alborz during the maximum expansion of the last Ice Age period, known as the Wurm (Krinsley, 1970). Pedrami (1991) mapped permanent altitude of the snowfall of Iran in the late Wurm using field observations in 26 regions of the country, ranging from 1400 m in the Masuleh Valley to 3200 m in Shirkouh Yazd and the Kerman Range. He had set the permanent altitude of the snowfall for the Wurm end at 2,600 m APSL in most parts of Iran. The Pleistocene glaciers were widespread in Iran, and at that time, the snow line was 600 to 1100 m lower than the current maximum, the average temperatures were 4 to 5 degrees Celsius lower, and the ratio between precipitation and evaporation was higher (Ferrigno, 1991). According to Ferrigno (1991), the Pleistocene glaciers have been reconstructed and cover twice the current size, which means the expansion of lake water supply centers after the Wurm.

So, it makes sense to accept that the drop in the water level of Lake Central and climate change have now changed the situation in such a way that humans who entered the Neolithic period are moving to warmer and more fertile plains in the lower altitudes and settle in areas such as Cheshmeh Ali, Tepe Pardis, Sadeghabadi, Sialk, Shurabeh and Qara Tappeh Qamroud. The remains of Neolithic ecosystems around the lake site in the northern half of the Central Plateau indicate the suitable environment for the formation of nuclei of civilization in these regions. If the water level fell from a height of 1105 m to 975 m between 11,320 ± 650 years and 7290 years respectively (Table 1), the annual rate of water level falling is about 3.2 cm per year.

$$\frac{1105m - 975m}{11320 - 7290} = \frac{130 \times 100\ cm}{4030\ year} = 3.2\ cm/yr$$

It seems logical if one accepts that the lowering of the water level of the central lake and climate change have modified the conditions, it is that the humans who entered the Neolithic era moved to warmer plains and more fertile at higher altitudes. They prefer the lowest residential areas such as Cheshma Ali, Tepepardis, Sadeghabadi, Silk, Shurabeh and Qorhatephi Qamroud. become the remains of ecosystems related to the Neolithic era, around the site of the lake in the northern part of the central plateau, indicating the existence of environmental capacities for the formation of nuclei of civilization in these ranges.

We admit the presence of water for many years where all of these areas have been submerged, and the enclosure of an ancient area that the preponderant element in their construction is clay and mud; even their dishes are made of pottery. So, all these areas must have been demolished on the Sassanid land (224–651 AD), such as Ray, Pakdasht, Varamin, and the village of

Qanavat Qom (see Figure 1 & Figure 4 for the ancient sites). Therefore, a possible explanation could be the heterogeneity of the basin's topography, similar to the elevations and paleo-relief of the past. The paleo-relief model could allow older settlements to be survived even in times of progress and rising lake water levels.

In addition, as a supplementary data, Contrary to what is seen in the eastern Mediterranean lands, the presence of Desert kites: dry-stone constructions comprising long convergent walls ending in an enclosed area, are known since the 1920s as hunting mega-traps (http://www.globalkites.fr) has been reported in Jordan, Egypt, Syria, Saudi Arabia as well as Armenia west of the Caspian and in the Kazakh desert to the east (e.g. Barge et al.,2015). Since the desert kite is seen from the eastern Mediterranean to the eastern Caspian, it is not wrong to expect to find a sign of this structure in the Iranian plateau as the only possible linkage between the eastern and western Caspian, when the lands of North Caspian were almost frozen.

The existence of such a paleo lake in the central desert zone of the Iranian plateau at the beginning of the Holocene could be a reason for not finding any sign of the remnants of a Desert kite, at least at a lower topographic level than 850 meters!

In order to compare old settlements and topographical levels, it is necessary to consider the oldest settlement at a given period and to examine the displacement with respect to the contour lines in time, assuming that there was a continuous occupation in the areas during the periods, it is important to consider the new establishments that have been settled in the new era, as these establishments can show the change in the environment. Thus, the locality of the most important prehistoric archaeological sites should be present, from the Paleolithic to the Iron Age, in the northern half of the Central Iranian Plateau. After examining the position of these sites and a list of prehistoric/historical monuments, the elevation lines of the topographic contour were retrieved from the SRTM DEM.

Due to the position of Little Fin at the height of 1040 m, ancient Paleolithic areas (3.4 million to 250 ka BP) can be seen above the Paleo-shore at an altitude of 1030 m of course, if we consider the only two pieces of masonry, desert-glazed and rusty, which show lasting weathering, and may even represent an Early Middle Paleolithic, it is reasonable to state that the position of the ancient Paleolithic sites found in the region is about a Paleo-shore 1105 m high, or lower than this level.

As for the Middle Paleolithic sites (250 to 40 ka BP), with the exception of the Masileh area, other areas are located above the Paleo-shore with a height of 975 m if we examine them. The Upper Paleolithic areas (40 to 18 ka BP) measure over 970 m in terms of height but in terms of location, were not less than 975 m related to Lake Central and also less than 960 m related to lake L-6. All Epi-Paleolithic sites (18 to 12 ka BP) except

Alborz (Qomrud) are in an area of about 975 m, but according to the Alborz area, which is located west of the Qomrud or Anarbar river, it can be said that the Ep-Paleolithic areas lie above the Paleo-shore with a height of 855 m.

Traces of Late Neolithic sites (6000-5200 BC) are visible above the ancient shores with a height of 850 m. The site of Cheshmeh Ali is between 5260 and 4940 BC (Fazeli Nashli et al., 2010), and Sialk North is dated (5894 -5725) BC. at (4982 -4973) av. (Fazeli Nashli et al., 2009).

This means that before settling in these areas, the level of the large Central Plateau Lake was lowered below the shore by 855 m. The Chalcolithic zones of the Tehran Plain exceed 820 m, and those of the Qom Plain exceed 850 m. Evidence of Bronze and Iron Age sites in the Tehran Plain is over 820 m and, in the Qom, plain above 850 m. While, the Sassanid sites of the Tehran and Qom plains extend above 820 m.

On the other hand, the prehistoric monuments that exist in the area and are considered to be a lake are mostly no more than a thousand years old, while those around the lake are over fifteen hundred years old. These guides are Mill Hill Gabri (Rey Fire Temple; Figure 12), Mill Varamin, Salt Spring (Cheshme Shore) Mill, along the Tehran-Qom Highway, and Mill Fortress and Mill Saveh further west near the town of Saveh (Qiz Ghale; Figure 13).

Figure 12: Rey Fire Temple in the south of Tehran.

The Saveh Qiz Ghale (Daughters' Castle/ Anahit Temple) was a Sassanid fortress for the worship and veneration of Venus before Islam and before the drying out of Lake Save at the end of the Sassanids. Although the age obtained (Table 2) from a lingering piece of wood in the door hinge confirms that the castle more or less continued its activity in the first four centuries of Arab rule from Iran, i.e., probably until the lake in front is completely dry.

Figure 13: Qiz Ghale (Anahita Temple) in Saveh. The inset figure (left) indicates the lingering piece of wood in the castle and the measured radiocarbon date of 941 ± 16 Cal BP, (Table 2).

A humid climatic condition in the Sassanid period has been confirmed in numerous studies such as (Djamali et al., 2009; Stevens et al., 2008; Wasylikowa and Witkowski, 2008). The etymology of Saveh testifies to the dependence between the name of the city and the presence of water in this area. Based on many ancient hills in the Saveh region, historical documents show that the history of Saveh dates back to pre-Islamic times (e.g., Polo, 1926; Ashari Qomi, 1982; Afshar Sistani, 1999). According to numerous references, such as the historical and geographic books, the existence of Lake Saveh, and drying out on the night of the birth of the Prophet of Islam (570 AD; 1448 years ago), this event may be studied outside the body of a legend. Another event that has been mentioned in several cases, in addition to the collapse of the Kasra Arch, the extinguishing of the Pars fire, as well as the drying out of Lake Saveh, is the flow of the water in the desert of SamAveh.

It should be noted that the status of Lake Saveh has been assigned to varying degrees, and it is also evident that the existence of loopholes that have been the site of the formation of small and large lakes across Iran during different periods are based on the Quaternary climate change and geomorphological status of the Iranian Pau. Therefore, it would not be correct to attribute the small lakes of the Zarand region to Lake Saveh (Djamali et al., 2006) without dating the information of the deposits of the lakes in the region, which determine the moment of the presence of the water.

According to the travelogue Naseruddin Shah Qajar (The king of Iran 1848-1896 AD), in 1881 AD, Hoz Sultan Lake was formed by the destruction of the Qara Chai River dam by Amin al-Sultan (Barthold, 2007; Mohhaddeth, 2008; Amir Hosseini, 2011). Qarachai is a river that originates from the western highlands of Hamadan and finally flows into Namak (Salt) Lake. The existence of a lake in the region of Abeh and the creation of an exit route by one of the Ajam kings (Ashari Qomi, 1982) could be related to Salt Lake and Howz-e Sultan, which had no outlet. Regarding the distribution of ancient sites around the Salt Lake and the Howz-e Sultan basins, we can admit that these basins were closed until the Sassanid Empire, and then an event (drought?) caused the Sassanid buildings to lie in the basins. Additionally, the lack of coastal evidence at a distance between 850 and 810 m may indicate a rapid decline in the water levels during this period. Therefore, it can be assumed that Namak Lake and Howz-e Sultan basins are in the same area as Lake Saveh in terms of morphology and climate; the conditions were met for the formation of the lake in this area. The presence of several fire temples around this basin can be attributed to the presence of Lake Saveh (Figure 12 and Figure 13).

Regarding the location of Lake Saveh, one of the notable points is the existence of pre-Islamic monuments on the shores of this area, while we also see post-Islamic monuments inside the lake, so a comparison between how historical monuments is distributed and when they were built. This may be a sign of the existence of water in this region during pre-Islamic times and of the drying out of the region after Islam. One of the most important of these historical monuments is the Caravanserai.

Based on the location of Tepe Hissar site and Tepe Sialk, it can be said that the societies of Tepe Hissar and Sialk formed next to the Chah Jam Desert and Dagh-e-Sorkh Beach, respectively, which could form a lake in humid climates. With regard to Sialk, the age determination data around Dagh-e Sorkh beach also indicates the existence of a lake in this area while living in the Sialk region. So, it would not be wrong to assume that the people of Sialk, in addition to Dagh-e Sorkh beach, benefited from Lake Saveh.

8- Conclusion

Our synthesis of historical documents on ancient Lake Saveh, alongside literary descriptions, archaeological records, and geomorphological, stratigraphical, and geochronological results, leads to several conclusions. Settlement patterns in the Central Plateau of Iran during antiquity appear to have been influenced by climatic conditions, particularly during the last glacial maximum approximately 21,000 years ago. Following this period, temperatures increased progressively, accelerating around 14,000 years ago

(Bryson and Bryson, 1999; Roberts, 2002), as highlighted in the borehole log from D6 (Figure 8). After the Ice Age, between 12.8 and 11.6 ka BP, the Young Dryas introduced a colder climate in the Northern Hemisphere (Cuffey and Clow, 1997). Once the Young Dryas ended, global warming resumed, contributing to ice cap melting and rising sea levels. Shorelines at Saveh, Qom, and Tehran, dating to around 11 ka BP (11,320 ± 650 years), indicate a significant lake occupied the Central Plateau at the end of the Young Dryas. This lake, which likely reached its highest levels during this time, eventually drained due to geological changes (e.g., earthquakes) but maintained a central, deeper part that intermittently filled and dried during the Holocene (Ebrahimi and Seif, 2016).

The lake's central area corresponds to Namak Lake, north of Kashan, where a 50-meter core analysis reveals a progressive sequence of wet and dry periods (Figure 8, Table 2). Archaeological data, including artifacts and monuments, correlate with the lake's evolution over time. Late Neolithic sites (6000 to 5200 BC), dating around 8 to 7.2 ka BP, are found in the northern Central Plateau, above an ancient shoreline at 850 m. This suggests the lake had receded to below this level before 7.2 ka BP, coinciding with a climatic event at 8.2 ka BP. A notable expansion of Transitional Chalcolithic sites (5200 to 4300 BC) occurred below 850 m in the Tehran Plain, while masonry remains were visible in the Qom Plain near Salt Lake and Howz-e

Sultan basins at higher elevations. Bronze and Iron Age sites in Tehran are located above 820 m, with those in Qom extending above 850 m. These shifts in settlement patterns may relate to nomadic pastoralism during the Iron Age and the search for new grazing lands. The Qom Playa and Namak Lake area, being a closed basin, still received water from nearby rivers (Jajrud, Qarachai, Shoor, and Qomrud; Figure 2), which were fed by glaciers on surrounding hills (Figure 4). However, the central basin, covered by fewer glacial deposits, gradually dried out, leaving no traces of shorelines between 850 and 765 m, although remnants are visible in the east. This ancient paleo lake might explain the absence of Desert kite remnants at elevations lower than 850 meters.

In summary, geochronological data suggest that from the onset of the Holocene (~11.5 ka) to around 8 ka, the lake level decreased by 250 m to approximately 850 m, likely due to increased evaporation from a warmer, drier climate. About 8200 years ago, a sudden temperature drop prompted Neolithic people to migrate from higher altitudes to more fertile lowlands, settling in areas such as Sialk, Shoorabeh Hill, Gharehtappeh, Qomrood, and Cheshmeh Ali. The distribution of archaeological and historical data indicates the drying of the Masileh Basin, situated above the Kavir Desert's elevation. Evidence suggests the Masileh Basin persisted during the Sassanid Empire, while the eastern Kavir Basin dried earlier. The complex interplay of environmental changes and human adaptation in the region continued to shape settlement patterns through subsequent millennia. As the climate stabilized and temperatures fluctuated throughout the Holocene, communities began to adopt more diversified agricultural practices, resulting in increased sedentism and the establishment of more permanent settlements. The gradual transition from a predominantly nomadic way of life to a more agrarian-based society can be attributed to the availability of resources provided by the dynamic lake system and surrounding river basins.

As archaeological findings reveal, the emergence of these permanent settlements during the Neolithic and Chalcolithic periods played a crucial role in the formation of social structures and the development of complex societies. The interplay of climatic changes and resource availability influenced the distribution of populations; therefore, sites like Sialk and Cheshmeh Ali became hubs of cultural and economic activity, reflecting significant adaptation strategies to the environmental conditions. The subsequent eras, marked by the advent of metallurgy and the rise of urban centers, introduced new dimensions of interaction among communities as well as trade networks. The expansion of agricultural practices, particularly in favorable areas around the Qom and Saveh plains, facilitated the rise of chiefdoms, which began to exert influence over broader regions. Notably, interactions with neighboring cultures resulted in technological and cultural exchanges, thus enriching the local traditions and facilitating innovations in tools and agricultural methods Furthermore, the archaeological record suggests that the fluctuating climate throughout the later Holocene, including periods of aridity and increased precipitation, directly affected the sustainability of these emerging societies. For instance, periods of severe drought likely prompted migrations and population relocations as communities sought more reliable sources of water and fertile land. Conversely, wet spells led to population growth and urban expansion, as evidenced by the proliferation of sites associated with the Bronze Age in the Tehran Plain and the proximity to the lake areas. The historical narrative of Lake Saveh and its surroundings thus reflects a microcosm of human resilience in the face of environmental challenges. As climatic conditions evolved, so too did the strategies employed by its inhabitants. From early hunter-gatherers to established agriculturalists and then toward urbanization, the responses of these populations to their changing landscape underscore a long-standing relationship with the environment that resonates in the cultural heritage of the region today. The implications of this historical analysis extend beyond the ancient context, encouraging contemporary discussions on sustainable land-use practices and the importance of adaptive strategies in a world facing rapid climate change. Understanding the past not only enriches our grasp of human history but also offers valuable lessons for addressing future environmental challenges, reinforcing the necessity to foster a sustainable relationship with our changing planet.

Appendix

Table 4: Characteristics of the Paleolithic sites in the northern part of the Central Iranian Plateau.

Site Name	**Coordinates**	**Height** (m)	**Enclosure Type**	**Age**	**References**
Tang Khazagh	34° 01' 07.75" N 51° 17' 13.01" E	1100	Hypaethral	The Lower Paleolithic	Biglari and Shidrang, 2006; Biglari, 2004a; Berberian et al., 2012
Fin Koochak	33° 56' 00.00" N 51° 22' 00.00" E	1040	Hypaethral	The Lower Paleolithic /The Middle Paleolithic	Berberian et al., 2012; Biglari, 2003
Tappe Khaleseh, Yazi-Tappe	36° 11' 22.00" N 49° 10' 28.00" E	1537	Hypaethral	Late Neolithic	Awli, 2004, Alef
Moghanak	35° 33' 54.00" N 52° 16' 00.00" E	1850	Hypaethral	The Middle Paleolithic	Berillon et al., 2007a
Ochunak	35° 35' 51.66" N 52° 14' 57.84" E	2050	Hypaethral	The Middle Paleolithic	Berillon et al., 2007b
Masileh	34° 45' 23.87" N 52° 10' 15.94" E	1065	Hypaethral	The Middle Paleolithic	Malek Shahmirzadi, 1994
Zavyeh	35° 22' 48.59" N 50° 34' 13.76" E	1200	Hypaethral	The Middle Paleolithic	Heydari Guran et al., 2015
Booin Zahra (Aghchehdam)	35° 36' 38.60" N 49° 36' 36.31" E	1880	Hypaethral	The Middle Paleolithic	Vahdati Nasab et al., 2009
Nargeh	35° 59' 31.85" N	1250	Hypaethral	The Middle	Biglari,

	49° 37' 20.13" E			Paleolithic	2004b
Arasanj	35° 42' 41.20" N 50° 04' 40.20" E	1312–1361	Hypaethral	The Middle Paleolithic	Massomi et, al, 2010
Tappe Mes	33° 50' 01.00" N 51° 01' 49.00" E	2184	Hypaethral	The Middle Paleolithic	Eskandari et al., 2010
Mirak	35° 28' 09.7" N 53° 25' 54.6" E	1015	Hypaethral	The Middle Paleolithic	Rezvani and Vahdati Nasab, 2010
Sufiabad	35° 26' 14.99" N 53° 18' 30.78" E	1031–1059	Hypaethral	The Middle Paleolithic	Vahdati Nasab and Aryamanesh, 2015; Vahdati Nasab and Feiz, 2014
Chahjam	36° 04' 23.99" N 54° 20' 34.67" E	1050–1094	Hypaethral	The Middle Paleolithic	Vahdati Nasab and Hashemi, 2016
Niasar	33° 58' 13.98" N 51° 08' 41.78" E	1725	Hypaethral	The Middle Paleolithic	Conard et al. 2005
Hollabad	33° 34' 55.60" N 52° 00' 17.96" E	1200	Hypaethral	The Middle Paleolithic	Conard et al. 2005
Kaftarkhoon	33° 54' 00.00" N 51° 22' 00.00" E	1375	Hypaethral	The Middle Paleolithic	Monochot and Mashkour, 2010
Delazian	35° 29' 43.61" N 53° 26' 40.09" E	1050	Hypaethral	The Upper Paleolithic	Vahdati Nasab et al., 2010
Sefidab	33° 55' 29.28" N 51° 23' 34.69" E	1030	Hypaethral	The Late Paleolithic	Conard et al. 2005; Berberian et al., 2012
Ghale-Gooshe 1 (Bardiya)	33° 40' 17.26" N	970	Hypaethral	The Late Paleolithic /	Conard et al. 2005

	52° 08' 07.01" E			Epipaleolithic	
Ghale-Gooshe 19 (Mina)	33° 39' 44.71" N 52° 06' 33.59" E	970	Hypaethral	The Late Paleolithic / Epipaleolithic	Conard et al. 2005
Ghale Asgar	35° 33' 06.30" N 52° 09' 36.45" E	?	Hypaethral	Epipaleolithic	Biglari, 2012
Ghomrood (Alborz)	34° 43' 43.88" N 50° 58' 17.72" E	870	Hypaethral	Epipaleolithic	Kaboli, 1999

Table 5: Characteristics of some prehistoric sites in the northern part of the Central Iranian Plateau.

Site Name	**Coordinates**	**Hight (m)**	**Age (Period)**	**References**
Tappe Cheshmeh Ali	35° 36' 24.37" N 51° 26' 43.43" E	1075	Islamic, Parthian, Neolithic and Chalcolithic	Fazeli Nashli et al., 2014; Schmidt, 1935
Tappe Pardis	35° 26' 08.52" N 51° 34' 44.31" E	990	Partihan, Iron Age, Late Neolithic and Chalcolithic	Gillmore et al., 2011 ; Marghussian et al, 2017
Meimanat Abad	35° 29' 47.50" N 51° 10' 07.10" E	1053	Late Chalcolithic	Fazeli Nashli, 2001 ; Yousefi Zoshk et al, 2015
Tepe Sofalin	35° 18' 58.00" N 51° 44' 06.00" E	966	Late Fourth Millennium to Iron Age III	Hessari, 2011
Khorvin	35° 59' 09.61" N 50° 49' 10.70" E	1575	Iron Age	Vandenberg, 1964
Tappe Zagheh	35° 49' 24.00" N 49° 58' 31.00" E	1252	Transitional Chalcolithic (Sialk II)	Moghimi and Fazeli Nashli, 2015
Piryousofian	36° 09' 35.34" N 50° 01' 30.66" E	1225	Early Bronze	Fazeli Nashli et al., 2011
Sagzabad	35° 48' 59.99" N 49° 57' 08.53" E	1275	Bronze and Iron	Fazeli Nashli et al., 2011 ; Pollard et al., 2012 ; Maghsoudi et al., 2014 ; Malekzadeh et al., 2014
Zarbelagh	35° 10' 12.61" N 50° 58' 02.97" E	1308	Iron Age II and III	Malekzadeh et al., 2014
Shamshirgah	34° 30' 04.95" N 50° 57' 51.03" E	1040	Iron Age	Fahimi, 2010
Tappe Qabrestan	35° 48' 56.75" N 49° 56' 50.72" E	1257	Chalcolithic Period	Schmidt and Fazeli, 2007; Maghsoudi et al., 2014

Gholi Darvish	34° 35' 47.47" N 50° 55' 18.80" E	935	Early Bronze Age and Iron Age	Mucheshi and Tala'i, 2012; Alibaigi and Khosravi, 2014
Tappe Hissar	36° 09' 14.60" N 54° 23' 08.38" E	1120	Chalcolithic, Bronze and Iron Age	Schmidt, 1937; Dyson and Howard, 1989
Sialk	33° 58' 06.51" N 51° 24' 15.36" E	944 & 950	From the Late Neolithic to the Iron Age	Berberian et al., 2012; Soltysiak and Fazeli Nashli, 2010 and 2023a
Shorabeh	33° 56' 26.00" N 51° 21' 43.00" E	1066	Late Neolithic	Berberian et al., 2012
Ebrahimabad	36° 06' 59.06" N 50° 14' 36.81" E	1232	Late Neolithic 2 and Transitional Chalcolithic	Fazeli Nashli et al., 2009 ; Pollard et al., 2012
Qareh Tappeh Qomrood	34° 43' 08.40" N 51° 03' 06.70" E	855	Fifth Millenium BCE	Kaboli, 1999

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