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Paleo Mega Lake of Rey Identification and Reconstruction of Quaternary Lake in Central Iran

RESEARCH PAPER

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ABSTRACT

This study presents evidence for the existence of a vast and ancient lake that occupyed a large area of central Iran during the Holocene. The northwestern fringe of the lake, located in the southeast of Tehran, was chosen as the study area. Remains of a Paleo Lake scarp was studied using aerial photographs, Quick Bird satellite imagery, and topographic maps. Furthermore, archeological sites within the region were identified and located, and evidence for the lake was obtained through correlation of these data. Eight shorelines were identified between 1100 – 950 m above sea level, with a depth of 3 – 15 m, and a 43 km in lenght. The results indicated that the active Quaternary faults named North Rey, Kahrizak, and South Rey are in fact the three main topographic levels of the paleo lake and from now on they cannot be considered as the faults. Soil granulation and thin sections showed the presence of non-compacted lake sediments. Results revealed a remarkable association between the location of ancient settlements and altitude of the identified paleo shorelines. All settlements older than 5,000 years were located at 1,000 m. Certainly, the past climate of this region was very different from its contemporary one. Dating studies will provide valuable information about the exact age of the Paleo -Lake and paleo climate changes.

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1 INTRODUCTION

Pedrami (1981) described two faults called Vali Abad and Saleh Abad in Rey city, Tehran province, Iran. Berberian (Berberian et al. 1985) named them as North Rey and South Rey faults. Later, extensive studies were conducted on these faults, and numerous papers were published on their geometry and even historical and prehistoric earthquakes that may have occurred associated with the movements of these faults (Ambraseys and Melville 1982; Berberian and Yeats 1999; Ghodrati Amiri, Motamed, and ES-Haghi 2003; Ghodrati Amiri, Mahmoodi, and Razavian Amrei 2008; Jafari 2003; Nazari 2006; Solaymani Azad 2009). However, there is a fundamental flaw, that is, these scraps, which had been identified as faults, are parallel to the topographic contours. Geologically, the exposure of a fault is parallel with a topographic contour, when that fault is horizontal (Ramsay and Huber 1987). There is no such tectonic regime in the Central Alborz region of Iran, which is a young collision zone (Berberian 2014), so such faults cannot exist in this area. In addition, Rieben (1953, 1955, 1960, 1966) pointed to the presence of lake-like sediments in the southern portion of Tehran, which was later called as the Bs unit on the Tehran Geological map (Dellenbachs 1964). Nazari *et al*. (2010) found no evidence of active faults in the trenches dug parallel and perpendicular to the Kahrizak, North Rey and South Rey scarps. In fact, no clutter or displacement was observed in the sediments. According to Nazari, these scarps are a morphological phenomena unassociated with faulting.

Evidence such as the existence of horizontal scarps parallel to the topographic contours, as well as the existence of lake sediments in the vicinity of these scarps indicate the existence of a paleo-mega lake in this part of Iran. This was later confirmed by Berberian and Yeats (2016). Thus, the present study focuses on the doubts about the nature of the mentioned faults and strengthening of the hypothesis regarding the presence of an ancient lake extending into the southeastern area of Tehran at the end of the Quaternary period. It is possible that that local or global climate changes may have influenced this region.

Climate change, as one of the major global challenges is being investigated by researchers, scientists, planners, and politicians partly due to the persistent increase in the global warming associated with the greenhouse effect (Akkermanns et al. 2010). Jones *et al.* (2013) stated that the climate of Iran changed in the fourth millennium B.C. Hamzeh *et al.* (2016; 2017) determined the Holocene paleoenvironment of the Sistan basin by dating the core sediments from the dry lakebed of Hamoun. Mehrjardi (2002) studied the climatic change in Yazd region using the micro-morphological evidence. Changes in the alluvial fans along the foothills of the Alborz Mountains showed that the climate of Tehran area has changed in the last millennium (Beaumont 1972). Okhravi and Djamali, (2003) and Djamali *et* al. (2006) documented the evidence regarding the presence of a historical lake in the Zavieh and Saveh region south and southwest of the study area. Climate change in the Middle East (Akkermanns et al. 2010; Peterson et al. 1979; Dastorani et al. 2011), especially in Iran has been reported by many authors (Kehl 2009; Mohammadi 2012; Farshad 2013; Amiri and Eslamian 2012; Schmidt et al. 2011; Lateef 1988; Kehl et al. 2009). Change in the water levels in the lakes around the world (Street and Grove 1979) as well as the Urmia lake (Zoljoodi and Didevarasl 2014; Jahanbakhsh, Adalatdost, and Tadayoni 2011; Mahmoei et al. 2012), Sistan Playa (Jarahi and Nadalian 2013b; Vekerdy and Dost 2006; Smith 1974; Costantini and Tosi 1978), Hoze Soltan Playa (Huntington 1905) Haj-Ali-Qoli Playa (Jarahi and Nadalian 2013a; Mousavi et al. 2013), Great Kavir Desert (Jarahi 2016; Jarahi, Naraghiaraghi, and Nadalian 2016), Zaribar Lake (Snyder et al. 2001; Stevens, Wright, and Ito 2001), Caspian Sea (Naderi Beni et al. 2013; Ramezani et al. 2008), and other places (in Iran) has been studied previously (Mehrshahi 2002; Roberts and Wright 1993; Ramesht 2001). Various extensive studies have been conducted about the ancient lakes in the world. Drake and Bristow (Drake and Bristow 2006) studied changes in water level in the Sahara Desert during the Holocene. They believed that the Megachad paleolake was bigger than the Caspian Sea 7,000 years ago. Bouchette *et al*. (2010) simulated the mean hydrodynamics of the Megachad using a three-dimensional numerical model. Bachofer et al. (2014) and Schuster et al. (2009; 2014) delineated the paleo shorelines in the Lake Manyara Basin using TerraSAR-X Data. They found four levels of shoreline with a maximum of 76 m above today's level. There are several papers and reports publishing valuable information about past climatic conditions and the presence of numerous lakes in the Central Iran, close to the study area.

First, the historical books and reports will be reviewed. The ancient lake of Saveh is one of them. An account of a now absent Saveh Lake (named after a city in the southwest of the study area near the Great Kavir Desert) is mentioned in Tarix-I Qom (Qomi and Qomi 1934; Dieulafoy 1887; Dickie et al. 1978; Hill and Grabar 1967). He reports the drying of Saveh Lake during the Hakhamaneshi period between 500 – 400 B.C. According to this account there was a lake between Ekbatan (ancient Hamedan) and Rhagae (ancient Rey). Hassan Qomi and Oomi (1934) indicated that there was a great lake covering the land of Saveh and Qom. In addition, Hossaini Qumi (Huntington 1905; Qummi 1976) mentioned that one of the Persian kings discharged the lake located in Aveh (25 km south of Saveh city). There are many comparable stories about now absent lakes in Iran (e.g., in Golpaygan) (Okhravi and Djamali 2003).

Mustawfi Qazvini (Qazvini, Browne, and Nicholson 1330) stated that the Saveh Lake was situated in the Saveh town and was fed by the Mazduqan-Chay, the long river passing through the southern part of Saveh. This story has been similarly recounted in some major books listed below (Okhravi and Djamali 2003):

- Tarrx ur-Rusul-i va al-Mula of Muhammad-ibn-i Djarir-i Tabari (260 H.Q.)(Tabari 1972)
- Tarix-i Ya'qabi of Ahmad-ibn-i Abi Ya'qab (3th century H.Q.)
- Mudjmal ut-Tawarix-i va al-Qisas of an anonymous writer of 6th century H.Q.
- FarsnAma of Ibn ul-Balxi (7th century H.Q)
- Tarix-i Guzida (730 H.Q.) and Nuzhat ul-Qtdab of (740 H.Q.) of Hamd Mustawfi Qazvini
- Nuzhat ul-Qulub of Hamd Mustawfi Qazvini (740 H.Q.)
- Athar va Axbar ulebad of Zakareya ibn-i Mahmud Qazvini (7th century H.Q.)

Based upon these texts, it appears that the lake had started to dry up in the first millennium B.C. The water level was down from Hamedan (elevation of 1800 m) to Saveh (level of 1100 m). Then, during the Parthian and Sassanian dynasties, the lake level was near the Varamin in SE of Tehran (elevation of 1000 m). But, currently, there are no traces of this lake.

The study area is located to the south and southeast of Tehran, south of the Central Alborz Mountains (***Figure 1***). ***Figure 1*** shows the level of 1000 m above sea level, as one of the main levels of the paleolake. Obviously, the study area covers only a small part of the northwestern shores of the paleolake. As mentioned earlier, this research mainly focuses on the hypothesis regarding the existence of an ancient lake in the southeastern area of Tehran. Given that, each of the scarps of North Rey, Kahrizak, and South Rey is parallel to a separate altitude, it can be expected that the changes in the lake's water level could have left several different levels. Thus, the present study is conducted to study the evidence and phenomena left over from the ancient lake southeast of Tehran. In fact, the existence of such a lake is officially studied for the first time in this paper. Most of the mentioned scarps have disappeared because of urban development in recent decades. However, there is still abundant evidence.

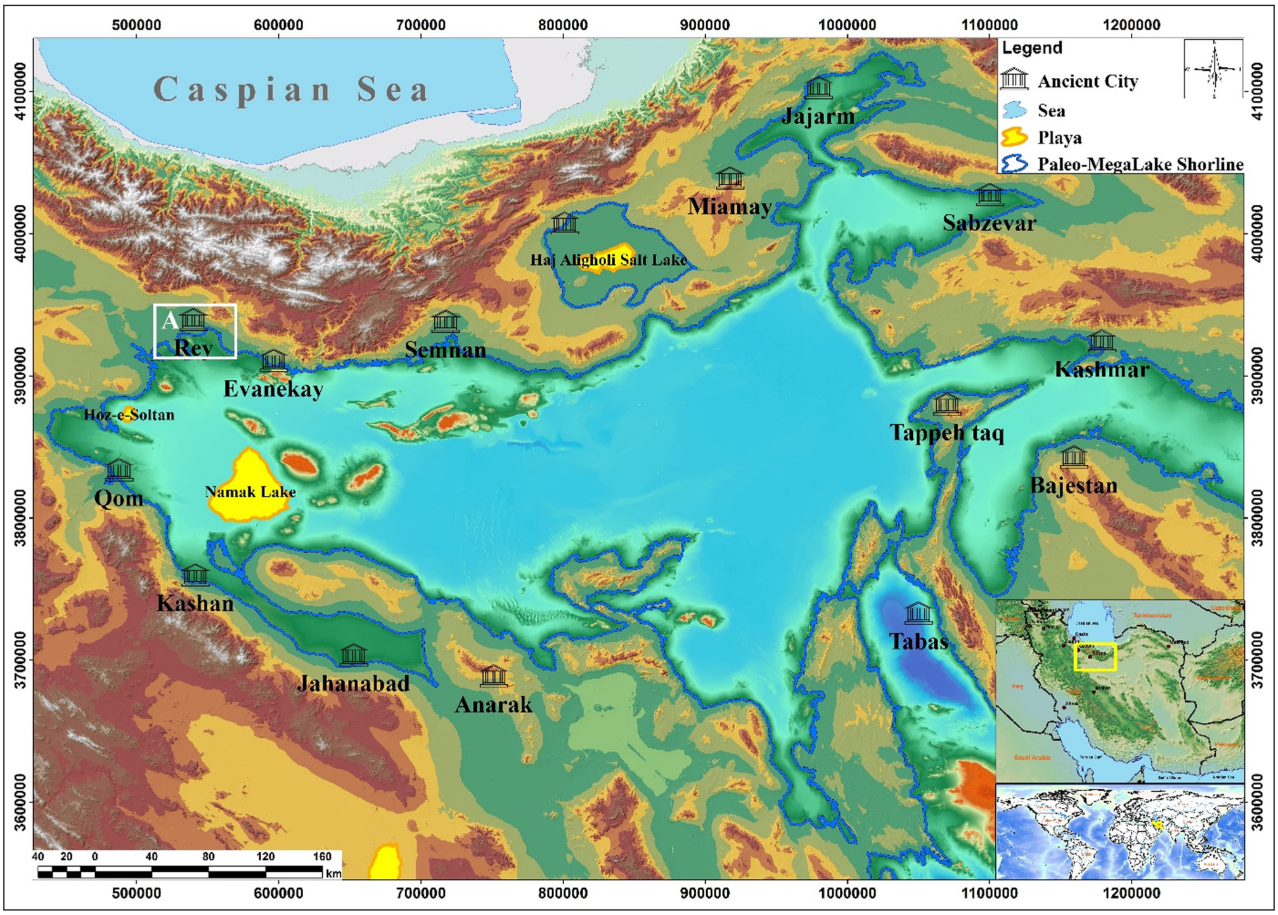

Figure 1 The study area (Box A) is located on the southern slopes of the central Alborz Mountains. As can be seen, the ancient lake (Blue line) was vast and covered 137000 km^2 of northern Iran (at an altitude of 1000 m above sea level). The city of Rey, one of the ancient cities of Iran, is located on the northwest coast of this lake. Note to the distribution of other ancient cities on the shores of the Paleo lake. The Digital Elevation Model (DEM) with an accuracy of 10 m was taken from the United States Geological Survey (USGS) to provide the map background.

2 METHODOLOGY

As mentioned before, the existence of numerous and horizontal scarps are discussed in the southern region of Tehran. The main objective of the present study was devoted to remote sensing. The exact position of the scarps was determined using the SDclass (1969) aerial photographs, Landsat satellite images (1977–2015), and DEM (10 m). Then, their main parameters including height, length, altitude, and other information were calculated and mapped. In addition, suitable stations were identified for field visits. The second part of this study was devoted to field reconnaissance for ground proofing. A comprehensive survey was conducted of the scarps while investigating the stations identified by remote sensing techniques. The valleys geographic setting is almost perpendicular to the scarps formed by the rivers and used as natural profiles. These profiles can be used to record the sedimentary singularities, the slope of sediment stratigraphy, changes in the thickness of sedimentary layers, and changes in the thickness of sediments across the precipice. Water wells as well as Qanats can greatly help to obtain the sedimentary information. Various sediments were sampled with proper dispersion. The third section included the laboratory studies such as the sedimentological and microscopic studies on thin sections prepared from the samples. Such sections are made of hard or semi-hardened sediments.

3 RESULTS

3.1 REMOTE SENSING

Remote sensing provides valuable information about the extent and distribution of the ancient lake features. The development of urban expansion in the recent decades has caused some of the evidence and remnants of the ancient lakeshore to be destroyed or to disappear entirely (***Figure 2***). Some of these features are currently owned by governmental agencies and cannot even be visited. The Landsat satellite images captured from 1977 to 2015 (48-year period) were used to study the lakeshore in the eastern part of the study area (Cadre D in ***Figure 3***). Remains of the paleo shoreline can be seen in the form of light bands (almost white). Clearly, most of the evidence has been lost over nearly half a century. The main factor involved in the development of urban development in this region can be related to the construction and expansion of the Tehran-Mashhad Freeway. Towns such as Enghelab, Qiyam Dasht, Khavaran, and Khavarshahr are among the residential areas playing the most important role in the destruction of the evidence of the ancient lake. This is only a small part of the study area that indicates the destructive role of urban planning in eradicating the remains of the lake.

The 1969 SDclass satellite imagery dataset was used with a resolution of 3.5 m for separating and mapping the lakeshore. Notably, there are older aerial photographs taken after 1955 from this area. Dimensions of these images are small, and their accuracy decreases from the center to the edge of the image, increasing the error of the studies. Surface changes in the region between the dates of these photos until 1969 are very insignificant and negligible due to the low rate of urbanism development during that period. After the SDclass satellite imagery dataset was accurately geo-referenced using the Quick Bird satellite images, with GPS control points, all the phenomena and artifacts related to the remains of the ancient lake were measured. White stripes can be seen running parallel to each other. Each of these bands, which are in the form of the scarps recounts one of the water levels of the ancient lake. ***Table 1*** shows the information about the scarps.

Paleo shoreline of PS1 formerly known as the North Rey Fault begins at Cheshmeh Ali in southeastern Tehran and continues north of Islamshahr city. The PS1 coast consists of a 12-m scarp that is more than 16 km long. The scarp follows the 1100 m altitude along its route and is generally the highest known beach in the current study. The lake's white sediments are a hallmark of this scarp and other known scarps making it easy to be identified in the satellite imagery.

Paleo shoreline of PS2 scarp ranks the second with an elevation of 1050 m in terms of altitude. The PS2 is the longest identified paleo shoreline and includes two sections for a total length of 45 km. The average height of this scarp is about 13 m and it divides the plain south of Tehran into a northern and southern half. The western boundary of this shoreline disappears in the Islamshahr region. But its eastern boundary can be traced back to the Khavarshahr city after a 5-km gap. This section is one of the best areas for identifying and tracking the shorelines in the study area. The scarp PS2a, which is 2 m lower than the PS2 level, cannot be considered a western continuation of the PS2 scarps due to the lack of sufficient information. However, it will be possible to establish a clear relationship between the two scarps after investigating the thickness of the subsurface sediments, depth of the bedrock, subsidence rate, and finally the rate of groundwater changes. But for now, the second scarp is introduced as a subset. In general, this collection of scarps is known as the PS2a series to the PS2d between the Khavarshahr city and the Parchin (***Figure 3***). This series consists of four main scarps, with a height of 3 – 12 m, and the length of 3 – 13 km. These scarps occur at elevations of 1030, 1040, 1045, and 1048 meters.

Paleo shoreline of PS3 scarp has a height of 15 m is located 20 km south of Tehran and 10 km south of Rey with an almost east-west trend (***Figure 3***). This scarps was first described by Berberian *et al.* (1985) as the Kahrizak Fault.

After that, de Martini *et al.* (1998) dug two trenches on the Kahrizak scarp and estimated a slip rate of 3.5 mm/year. However, Nazari et al. (2010) considered these scarps as the shores of an ancient lake based upon geophysical and long-term seismological studies. They suggested a height of 1000 m for this beach. However, the remote

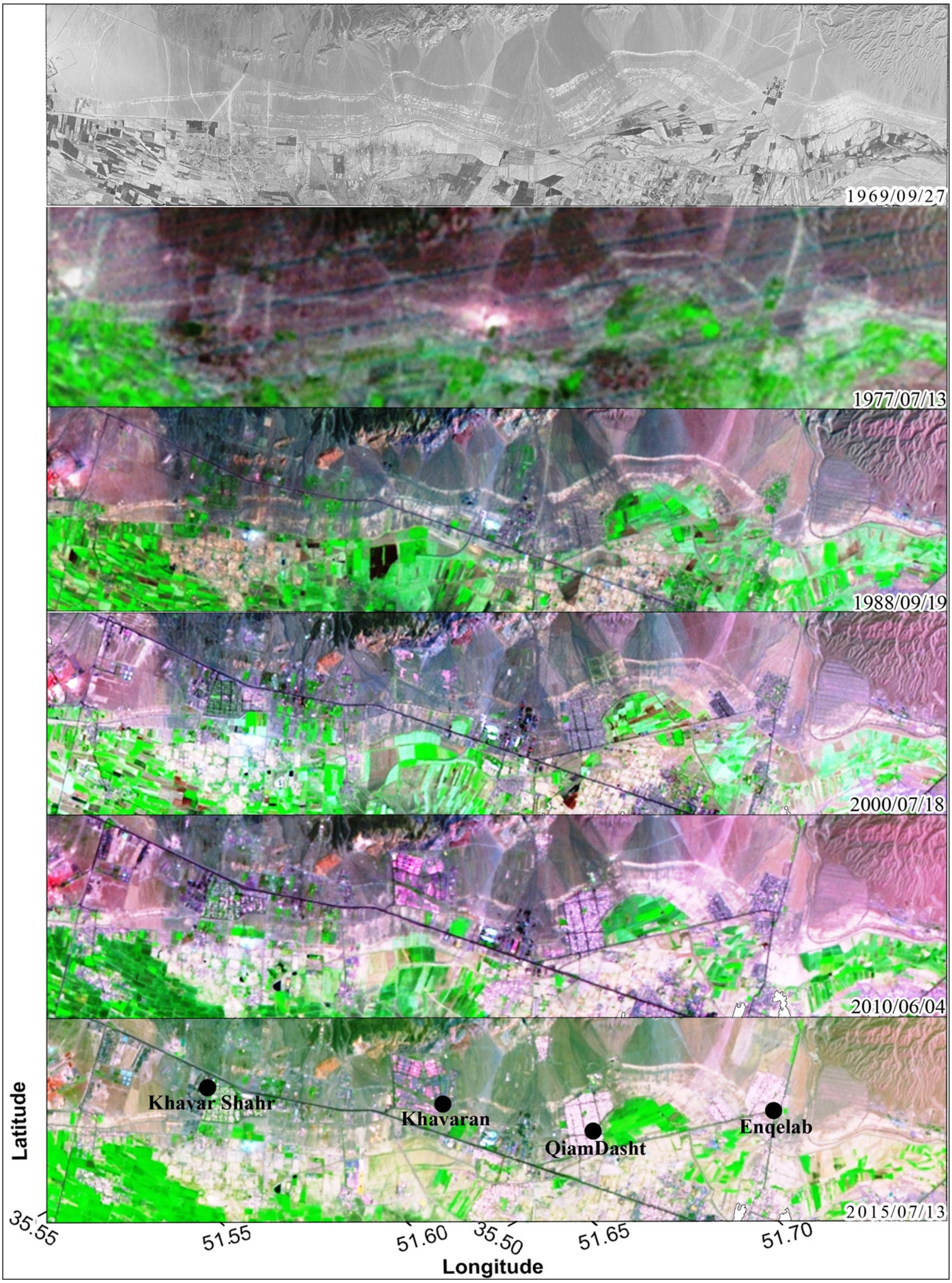

Figure 2 Urbanism development and its effect on the shoreline traces (white color bands). Upper image is of SDclass satellite and others are Landsat series. (Cadre D in ***Figure 3***).

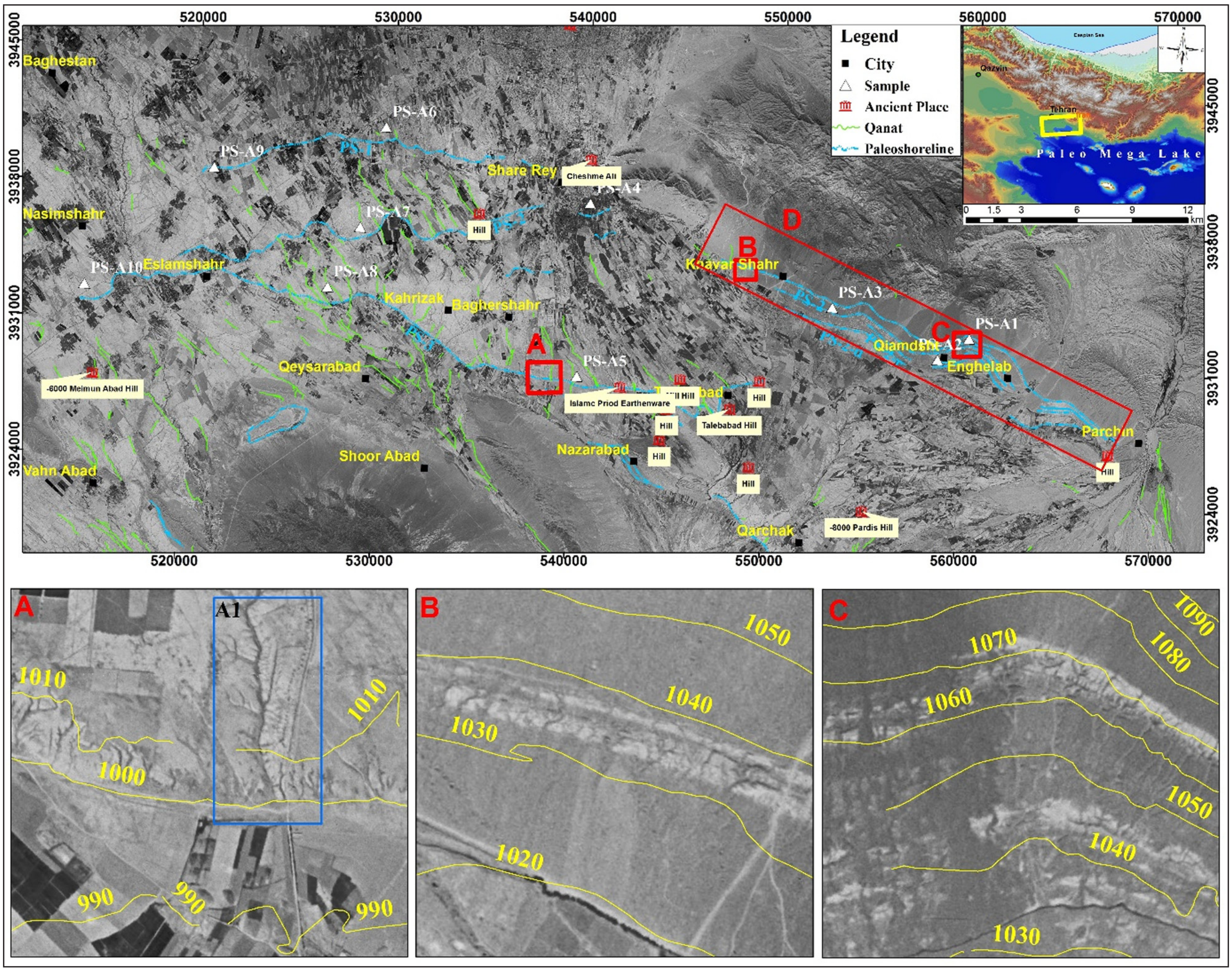

Figure 3 The position of the scarps of the ancient lakeshore (white stripes) in the southeastern region of Tehran is shown on the 1969 satellite images. The scarps are all horizontal and parallel to the topographic contours. In the area of Rey plain, where agriculture is being conducted adjacent to human communities, the number of visible scarps is much lower than in more marginal areas, such as the eastern part of the study area (east of the Parchin city). Note the high density of the Qanats in the southern region of Rey. In the lower part of the image, the three areas where the most evidence can be seen are considered for further study.

PALEO SHORELINES	ALTITUDE (M)	LENGTH (KM)	HEIGHT(M)	LOCATION
PS-1	1100	16	12	North of Rey
PS-2	1050	24 & 21 &	13	Parchin to Khavarshahr cities, & South of Rey
PS-2-a	1050	3	3	
PS-2-b	1045	14	3	
PS-2-c	1040	4 & 3	8	
PS-2-d	1030	7 & 4	5	
PS-3	1010	41	15	South of Kahrizak
PS-3-a	950	8	8	West of Varamin

Table 1 The information on the paleo shorelines in SE Tehran.

sensing studies and comparison of the results with the topographic maps, indicte that this scarp does not correspond to the 1000 m elevation described above. Scarp erosion (caused by the natural and human factors) has caused the slope of the upper parts to be much softer than the heel of the scarp. From 1000 (lowest level) to 1010 m, the slope is steep and then, to the level of 1015 m, the slope is milder and then, the natural slope of the earth is restored. According to the available evidence, an elevation of 1015 m can be suggested as the main level of the ancient lake in the Kahrizak region. The two important factors of erosion and urbanization have eliminated most of the evidence in this area. In this regard, the conclusion depends upon comparison of this level with other areas in southern Tehran.

3.2 FIELD STUDIES

Several field studies that were made in the south to southeast area of Tehran are described that were focused upon accurately identifying and mapping the paleo shoreline. The Marne and sandy Marne sediments of the lake are light cream in color (depending on the percentage of iron in the sediment) with a 10 – 15- m high scarp, clearly distinguishable from other geological phenomena in the region. Sandy parts with calcareous cement, in the form large numbers of rocky nodules can be seen in the areas where erosion has not been able to carry them away (***Figure 4***). There is a difference in color in comparison when compared with other sediments, for instance an abundance in waterways make them easy to identify in the field. In stream and river exposures, the longitudinal axis of these nodules is often vertical with branches surrounding it. Frequent and nested drillings by worms, as well as high porosity are prominent features of these nodules when the samples are observed manually or under the microscope. Rieben (1955) and Berberian et al. (1985) have already considered this in describing the Kahrizak clayey silts. Numerous holes in various sizes, resulting from worm drilling (worm tubes) are abundant in the samples. Interestingly, a very large number of broken pottery fragments (Kāmbakhsh-Fard 1991), related to the ancient artifacts and tools dating back to 3200 years BP can be found when walking along the edge of the scarp and around it (***Figure 4***). Therefore, the age of sediments is older than the artifacts. Almost, a complete profile of the sedimentary series of lake deposits can be seen in the areas where seasonal streams and rivers have incised trenches into this sedimentary unit (Cadre A1 in ***Figure 3***). As expected, no evidence of creases or faults was found during study of these trenches. The lake sediment thickness gradually increases and reaches its maximum value at the edge of the scarp while traversing the river (***Figure 5***).

The study area has an extensive and complex network of qanats (***Figure 3***) densely distributed upon the plain of Tehran at an elevation of 950 to 1100 m. Nearly all the qanats have been dug in lake sediments between these two elevations. Study of the qanat wells in the Khavarshahr region excavated along the scarp route revealed a thin layer with a less than 15 cm of thickness including wide-lying alluvium and debris on the upper horizons of the sediments. Beneath this layer, a period of light cream-colored limy marl layers can be seen separated by the interbedded limy sand with a less than 10 cm of thickness (***Figure 6***). The alternating marl and sandstone can be seen to the bottom of the well (12 m deep). Studying the lower parts of this depth requires digging trenches.

Figure 4 Samples collected from the Kahrizak scarp. Worm tubes are abundant in the samples. The dimensions of these holes range from 5 to 50 mm showing the variety in the size and age of the worms during the life of the lake. Broken pieces of the ancient pottery can be seen abundantly on the top of the scarp (the key is 6 cm long and is placed as a scale).

Figure 5 The more than eight meter deep channel of the Kan River, is incised into lake sediments (1080 m above sea level) south of Chardange city (South Rey scarp). The white fold line shows the boundary of light-colored lake sediments with older units (northward view). They are completely horizontal between the layers with light to dark cream colors in this profile. The river trench is almost perpendicular to the shoreline. The thickness of the sediments increases by traversing from north to south. Sedimentary units suddenly disappear at the edge of the scarp. (Box A1 in ***Figure 3***).

Figure 6 Qanat wells near Khavarshahr with 2 m diameter and about 12 m depth, on the PS2-d scarp. The placement of lake sedimentary layers on high-permeability sediments (Series B) has caused the subsurface water to flow beneath these sediments. The ancient people passed through impenetrable units and built the horizontal channel of the Qanat between these two sedimentary units by digging the qanat to reach the lower layer. Most of these wells and qanats have collapsed and been blocked due to subsurface erosion of tunnels and subsequent qanat collapse. Qanats have now been OSL dated to about 4,000 years BP. They provide a lower limit bracketing date for the lake sediments.

3.3 LABORATORY STUDIES

3.3.1 Soil Classification

Ten samples of unstructured sediments were taken from the scarps of the region in order to investigate the characteristics of the shoreline sediments, and to determine the origin and type of the sedimentary environment (Roser and Korsch 1986; Veldkamp and Kroonenberg 1993; Bhatia 1983) (***Figure 3***). Attempts were made to obtain these samples with appropriate distribution from different parts of the region. They were tested for granulation, Atterberg limits and definition of the plasticity limits. For this purpose, first, the surface soil was removed to a depth of 30 cm to ensure that the sample was taken from the sediments of the paleo shoreline. According to the Unified Soil Classification System (USCS), the lake's sediments are classified into the ML group (***Figure 7***). Liquid limit, plastic limit, and plasticity index were determined while performing the test on the samples to determine the limits of Atterberg. Sediment of the lake was classified into CL (Lean Clay) type with very low permeability (***Figure 8***).

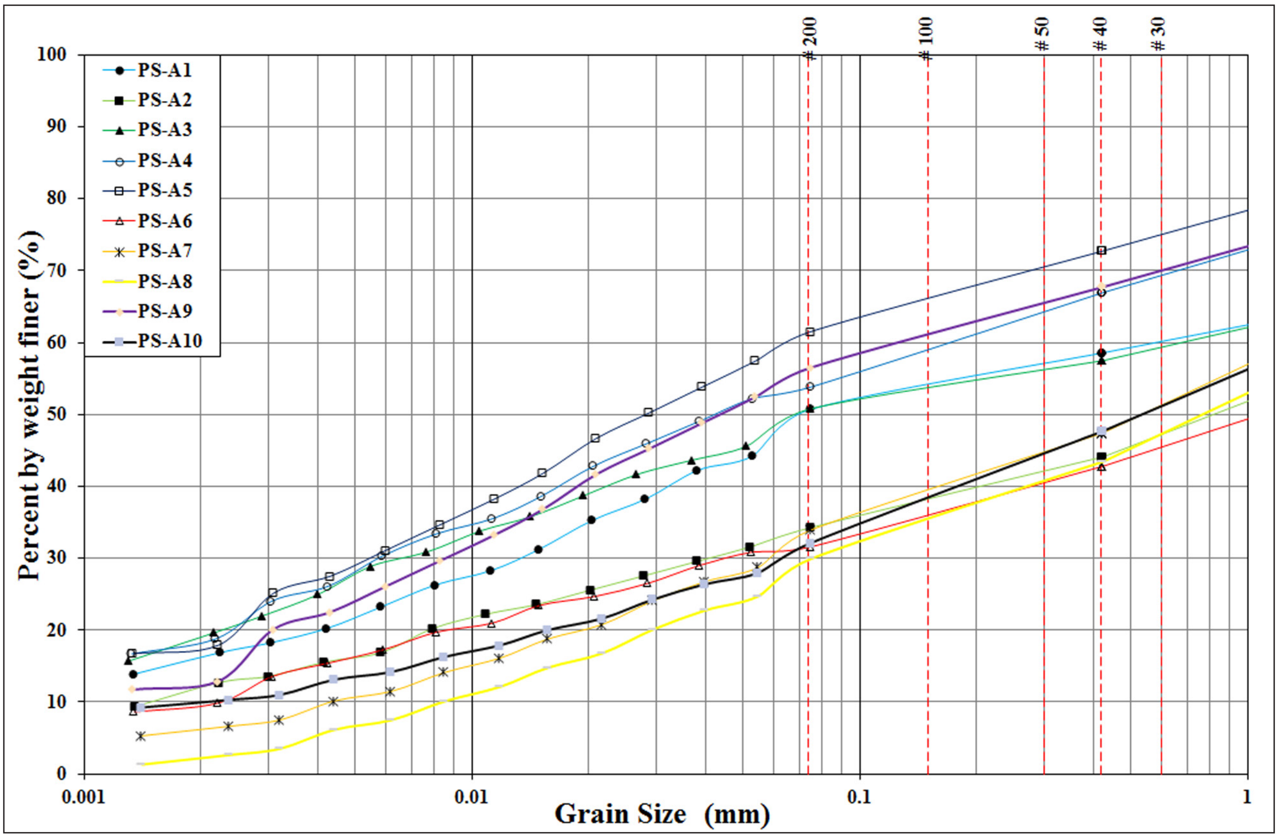

Figure 7 Granulation test of the sedimentary samples in the study area. The mesh size used for granulation is shown at the top of the chart. The second part of sediments that was smaller than mesh size of 200 was determined by the hydrometric test., i.e., hydrometer analysis.

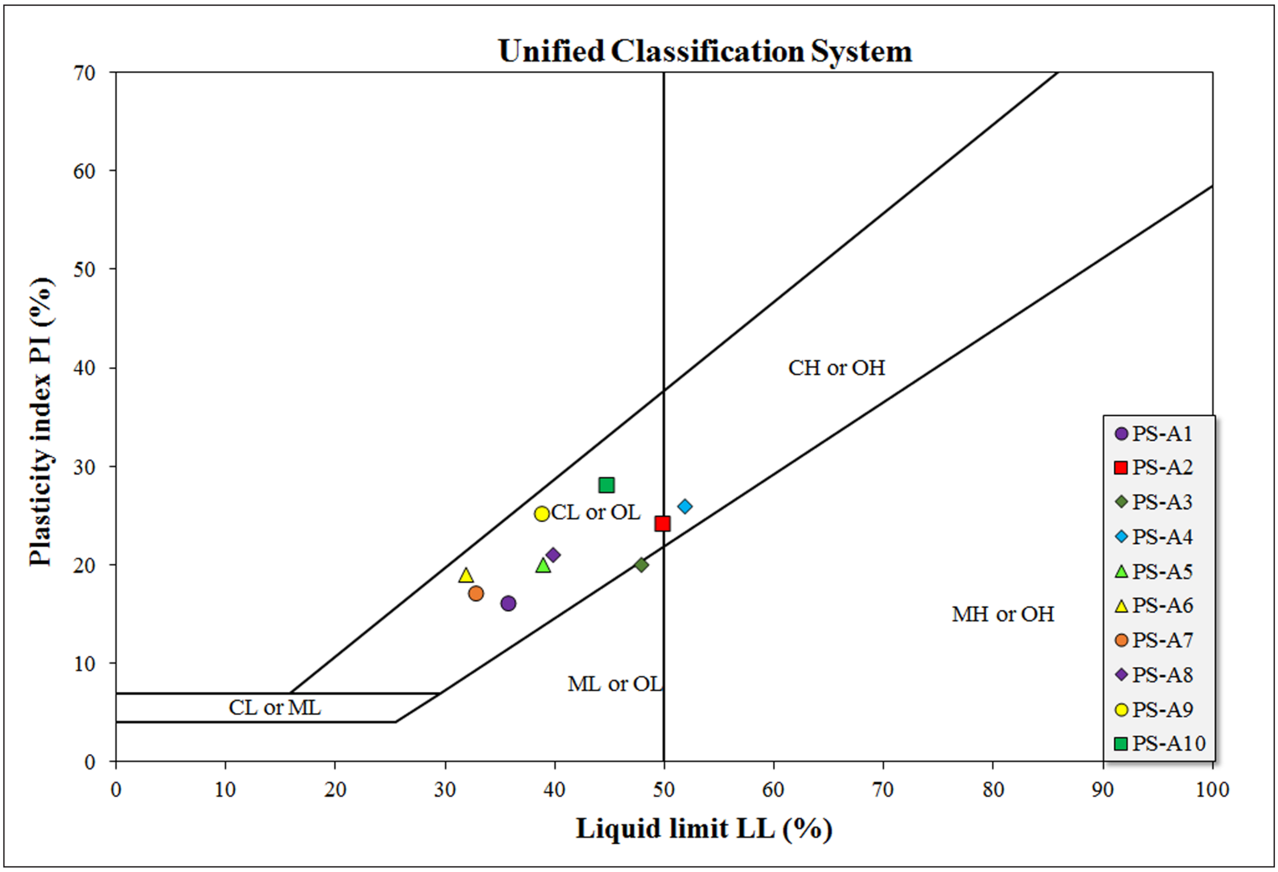

Figure 8 Test results regarding determining the plasticity of sedimentary samples that indicate the CL range. Such soil has very low permeability.

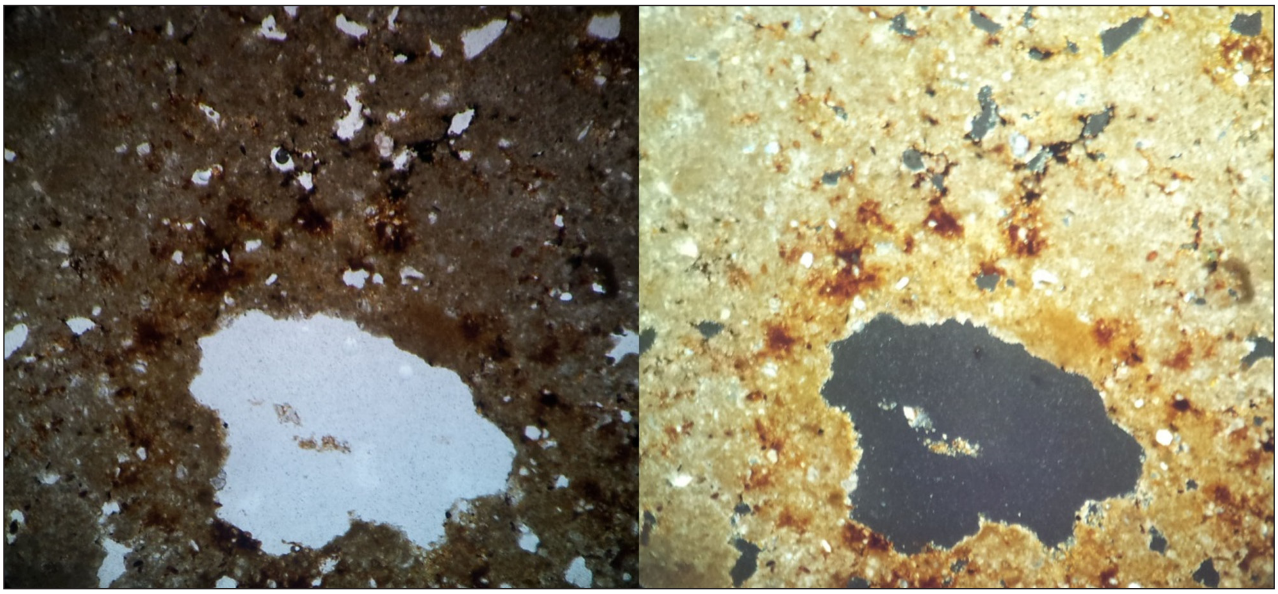

Figure 9 Micrograph related to the Rey scarp (PS-A9). The relatively thick clay skin under the plain-polarized and crossed polarized lights. Brown spots in lower part of the image show the presence of iron oxide on the drilled edge caused by the worms.

3.3.2 Thin Section Studies

Sedimentation of the lake sediments is very low and attributed to the limited time from deposition. With an exception of bone-shaped nodules, the rest of the sediment is still uncompacted and can be drilled even without using tools. In this part, thin sections were prepared from 12 hardened nodule samples. Microscopic lithology studies were performed on them. Sediments were identified as fenestral lime mudstone with texture, discoloration in normal and polarized light, and porosity and citric acid testing (Scholle and Ulmer-Scholle 2005; Tucker 1991) (***Figure 9***). This type of sediment is formed in the sedimentary environments up to semi-calm freshwater to brackish environments. These types of nodules, with the mentioned features are actually the remnants of the worm-drilling path in the lake sediments. Identifying the type of organism causing these excavations requires further study.

4 DISCUSSION

Settlements are established in the areas where there are favorable living conditions (Pacey 1993). Shorelines of the seas and lakes are one of the most developed residential areas compared to other areas (Mikhail 2016). The paleo-shoreline of the ancient lake located in the southeast of Tehran has served as a good platform for the formation of a settlements in terms of soil development, climatic conditions, access to fresh water, and lacustrine communication links, in its time and even to this day. The establishment of settlement requires a sufficient area with suitable soil for agriculture, brick production, and pottery. There are several brick kilns in the Kahrizak region that have used the sediment of the lake as the main material for brick production. Furthermore, vast expanse and relatively mild topography play an important role in choosing the lakeshore to build a settlement.

The first signs of the formation of settlements in southern Tehran include the discoveries of the Qarchak Campus Hill, which is 8,000 years B.P. (Gillmore et al. 2011; Gillmore et al. 2009) and Segaz Abad; Maghsoudi et al. 2014). Following that it dates back to the Neolithic and Bronze Age (5200–4300 years ago) based on the discoveries of the ancient Cheshmeh Ali Hill (Wong, Petrie, and Fazeli Nashli 2010). According to the evidence for settlements in and around the Rey region up to the present day, this region has a long history of human occupation.

The development and expansion of human societies in the Tehran area is the main reason for the disappearance of paleo shoreline evidence. The scarps have been repeatedly influenced by erosion and urbanization, and most of them have been destroyed. In some areas, the network of streams or excavations resulting from the construction of roads and buildings has led to the creation of a new topography. However, phenomena such as heterogeneous subsidence and erosion have caused scarps not to be exactly parallel to specific elevatons, and sometimes to be slightly different from the topographic contours. Given these interpretations, if the tectonic uplift of the region is ignored (Berberian 2014), the levels for each scarp will always be less than the actual initial level. Each of these scarps represents a water level for the paleolake.

Therefore, the significant number of these levels indicates major changes in the water depth.

Obviously, such changes are directly related to the changes in the regional and ultimately global climate. Further comments on the long-standing climate debate requires the additional study. But, certainly, higher levels indicate increased relatively stable annual rainfall, which would result in stable water levels, and lower levels would indicate decreased annual rainfall, which may or may not have been characterized by greater climatic fluctuation.

Remote sensing studies showed that in the central Iran, all the settlements formed at altitudes below 1,000 m are less than 5,000 years old indicating the unfavorable conditions of the settlements at that time. In other words, the existence of a vast lake in this area has led to the formation of the settlements on its shoreline. Human beings have moved to lower regions and formed new younger settlements there following the decrease in the water levels and change in the climatic conditions (Pacey 1993; Selin 2008). Iranian qanats are less than 4,500 years old (Fattahi 2015) meaning that humans had not previously acquired the technology to dig the qanat, or they did not need to build the qanat to discover its technology because of easy access to the freshwater and humid climates. If we accept that such a lake had existed in the south of Tehran, other confirmatory evidence must be found in other parts of central Iran. This case is confirmed despite the paleo shoreline for 1000 m of altitude in the Kashan region, where the 8,000-year-old Sialk civilization is located. Numerous ancient cities such as Saveh, Jahan Abad, Anarak, Jajarm, Sabzevar, Bajestan, etc., have been built exactly on the mentioned altitude, all of which are more than 5,000 years old (***Figure 1***).

CONCLUSION

In this study, geological evidence for the presence of ancient lakes south and east of Tehran was investigated. In addition, it was suggested that the location and development of the ancient settlements in that area of Tehran was related to the existence of high shore lines related to deep Holocene Lakes. It is suggested that the presence of such lakes was related to a much different climate than the one presently occurring in the area.

In general, the geological evidence indicates the existence of a vast paleolake in central Iran the paleo shorelines of which extend to the Rey and Kahrizak regions. The coastline, in the form of numerous scarps is 3 – 15 m high and 3 – 43 km long. Study of rock samples taken from the shoreline scarps indicated their formation in water ranging from fresh to brackish water environments.

The sediments of these scarps are of fenestral lime mudstone and are light cream in color. Light brown hardened nodules, having a high porosity due to worm drilling can be seen on the surface of the earth and the texture of sediments. These sediments are slightly permeable. Therefore, they have played an important role in the transfer of groundwater and have overshadowed the explanation regarding the qanat network.

Shoreline evidence suggests that there were changes in the lake's water level ranging from 1,100 to 950 m. At least eight stages of climate changes may be reflected from these changes in paleolake shorelines. From nearly 8,000 years ago to the present day, several periods of human settlement have been established in the region. It has been proposed that these geographical locations are linked to the presence of the lake shoreline and the various levels of the paleolake.

Therefore, geomorphic and geologic data suggest that there was a paleomega lake in the southern region of Rey sometime in the late Quaternary. This lake underwent several major changes in its water level. However, dating of the lake deposits is still a problem. One issue is the carbonate content of the sediments. OSL dating may help or paleomagnetic dating as well. Currently, there is not enough evidence to determine the relationship between the age of the lake and that of the settlements. Tephrochronolgy, which is low cost, and can be easly performed in laboratories in Tehran might offer a solution. Such studies on different soil horizons, in sediments beneath the paleo shorelines, as well as on top of them might provide a way of providing some dating control on the lakes.

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COMPETING INTERESTS

The author has no competing interests to declare.

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