

Climatic and Environmental Reconstruction Based on Stable Isotopes of Parishan Lake (Iran)

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Abstract. The isotopic documents of lake deposition are suitable potential means for studying the intercontinental, environmental and climatic conditions. In order to study the environmental and climatic conditions of Parishan area in Fars province in Holocene, a Core was taken with the length of 2m from the Parishan lake sediment. From this core, kernel time series was provided from documents of carbon and oxygen isotopes. Results show that during the study period, climatic changes because gradual increasing in the value of δO^{18}_{carb} . This represents a weak dryness process in the area up to now. Contrary to this, carbon isotope documents during the study period show the more vigorous changes. Variability of δC^{13}_{carb} values during the study period is known as the result of changes in the value of evacuation of underground waters to the lake. As it is observed in the process at δO^{18}_{carb} throughout the study period, δC^{13}_{carb} values have an increasing process, yet the observed changes in δC^{13}_{carb} value are more vigorous than δO^{18}_{carb} and it seems that variation of underground waters was not in complete harmony with dryness process of the area. It seems that achievement of underground waters around the lake in the form of well and aqueduct is the intensify factor for the reduction of underground inputs to the lake.

Keywords: Climate and Environmental reconstruction, Stable isotopes, Parishan Lake

Introduction

There is not comprehensive information about environmental and climatic conditions of Iran during the Holocene period. In addition to this, locating situation of Iran in near east as a transition area between Europe, Asia and Africa has a high importance for identifying climatic systems of area. Near east because of its importance as the first home land of agricultural progress and bridling animals was always interesting for researchers. (Bentliff and van Zeist, 1983). Yet, in contrast with other areas, this area was less researched. (Farrand, 1979).

Although in the other countries such as Turkey, Syria and Saudi Arabia, many studies have been done, the information in case of Iran is limited. Most of these researches are related to west and northwest of Iran in direction of Zagros Mountains. These studies include Pollination Biology (Bottema, 1986; Djamali *et al.*, 2008), sedimentology of Urmia lake (Kelts and Shahrabi, 1986), Pollen record of Alamo lake (Djamali, 2009; Ann, 1987), sediment Geo-chemistry (Hutchinson and Cowgill, 1963), Pollination Biology (Van Zeist and Bottema, 1963; Van Zeist and Bottema 1967; El-Moslimany, 1986; 1987), plant microfossils (Wasylikowa, 1967; Bentliff, and Van Zeist, 1983), cladoceran assemblages (Megard 1967), Diatoms (Snyder *et al.*, 2001) and stable isotopes of Zeribar lake (Stevens *et al.*, 2001), ecology of ostracoda (Griffiths *et al.*, 2001) and multievidence studies of Mirabad lake (Stevens *et al.*, 2006). In addition to this, there are sparse documents in the other areas that consist of pollen data of maharlou lake (Djamali *et al.*, 2009), Pollen record in forest areas of north Hyrkanian (Ramezani *et al.*, 2008), stable isotopic Mollusks of Caspian sea (Lahijani *et al.*, 2007) and paleosols of North (Wich and Michael, 2003, 2005; Kehl *et al.*, 2005). Considering the low spatial homogeneity of Iran and its environmental and climatic differences, use of modern

methods and providing more evidence in different areas, especially in the areas that have been studied are essential. Many researches on the lake isotopic evidence showed that this evidence represents useful information about environmental and climatic conditions in the past. Indeed, the isotopic evidence of lake sediments is efficient potential means for the study of intra-continental climatic and environmental conditions (Wang *et al.*, 2002). Efficiency of this method for the lake carbonate uses this method as a means for studying the deep-seated of climate and environment (Andrews, 1997; Leng *et al.*, 2004). For example, isotopic studies of lake sediment at the center of Turkey have provided good documents for climatic and environmental conditions (Roobert *et al.*, 2001). This method was used for the survey of hydrological changes of a lake in Sudan (Hamarlund, 2003). Anatolia plateau has provided some useful information from the isotopic and documents of Van Lake Past environmental conditions (Wick *et al.*, 2003). Along these studies, in this research for providing isotopic evidence of Parishan lake sediment, our aim is to provide some information from climatic and environmental conditions of area as environmental evidence from southern part of the country.

Study Area

Parishan Lake is located in about 15 kilometer of south east of Kazeron County in Fars province (Fig. 1). This lake has been formed at a low deep depression (Shahrabi, 1994; Hammarlund and Thomsen, 2003). In terms of structural and geological studies, Parishan Lake is located at the palm of plaited Zagros (Aghanabati, 2004). With attention to widespread existence of Gachsaran formation at Parishan basin and also Kazeron fault; it seems that formation of lake is related to the movement of Kazeron fault and slide of some parts of the formation during Quaternary. In the north

and south of Parishan district, two mountain chains from west to east were lengthened parallel to each others that are continuity of the same two mountain chains where Kazeron plain is located among them. In the east of lake, there are lime cliff and massive destructive blocks affected by erosion. In the District of Parishan Lake, there are dense and deep rocked lapies. These lapies mainly were extended on the Asmari formation and rocked lapies are visible in the northern parts of west and east of the lake. In terms of hydrology, lake is blocked and lime and marl classes surrounded it, and bed lake formations are formed from chalk and marl classes of Fars group and only at the edge of northern angle, they are formed by Asmari formation. Gachsaran Formation is seen at east south of the lake and includes the layers of chalk, lime, salt and Dolomite with marls. The old alluvial of area consists of silt, clay, lime and new alluvial in the form of cone including pebble, lime gravel and clay in the form of talus that cover hill side and fans seen as the remarkable supplies of underground waters on it. Lake sediments show the limit of

water retreat (Fig. 2). In terms of climatic situations, Parishan area belongs to the warm zones of Fars. This area is known as Persian precipitation zone that surrounds medial parts of Persian Gulf to south of Kerman and Fars. 60 percents of precipitations in this area occur in winter, so it has the highest winter precipitation centralization in Iran (masoodian, 2003). Also, it seems that the main part of precipitation in this area results from Sudanese systems. In this area, the main part of precipitation moisture of area is from tropical seas such as Arab sea, Persian Gulf and Red sea. The space of lake changes during various years as in dry season, the water of lake evaporates and the lake becomes swamp. In recent years, because of reduction of annual rainfall, the lake level has been fallen and the lake has located at the ridge of dryness. Temperature of Parishan lake water is about 4 C° in winter and varying to 32 C° in summer. The General characteristics of basin and Parishan Lake are as follows (Table 1).

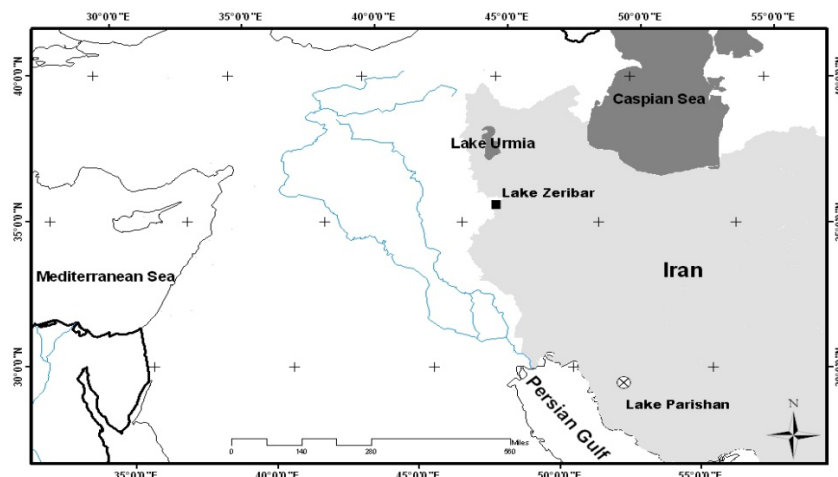


Fig. 1. Map of Parishan Lake Location in the Near East

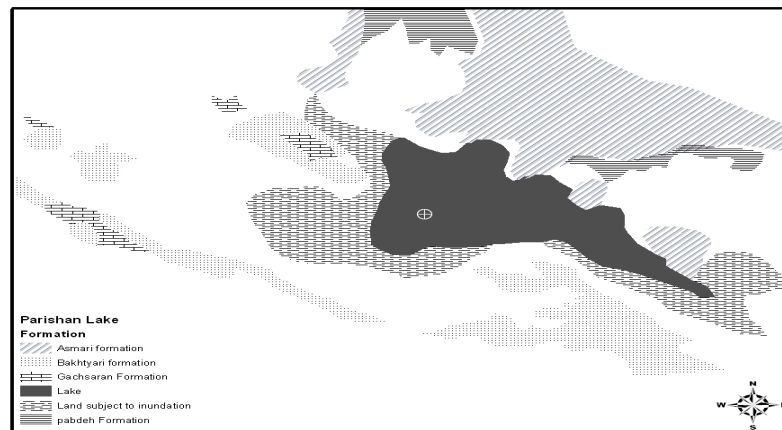


Fig. 2. Map of Main Formations Around the Lake

Table 1. General Characteristics of the Parishan Basin and Lake

Characteristic	Values	Unit
Latitude	29° 28' n	
Longitude	51° 53' e	
Mean monthly evaporation	200.259	mm
Maximum monthly evaporation	398	mm
Precipitation	400	mm
Mean depth	165.4167	cm
Max depth	205	cm
Altitude	820	m
Basin area	257.57	km ²
Lake area	42.5	km ²
Basin primer	98	km
Lake primier	40.5	km
Mean p-e ratio	55	mm
Mean water temp	22.7	c°
Oxygen	6.11	mg/l
P-e & lake level (r ²)	0.86	
Ph	8.19	

Methodology

Elemental Analysis

Sampling operation was done by a corer piston, a model of living stone. Among sediments emerging during recent years near the center of lakes, some cores of water were taken with the length of 2 meter. Because of high adherence of the lake sediment, removing the sediment from lower layers was not possible. After sampling, removed cores were transferred to Geomorphology laboratory of Shahid Beheshti University. At first, in the lab, those cores were divided to 3 to 5 cm parts. Preparation of samples was done based on

S.O.P-core sampling (washing Draft sub-sample-washing- protocol. Doc). All samples were poured in the case or plastic lacuna that was signed and soaked by distilled condensate water solution. Samples in this case should be soaked in this solution at least for 24 hour, but this operation should not last more than 48 hours. During this operation, at least one time, the solution should be striked and in order to prevent the pollutants existing in the air, it's better to cover lacunas. In next stage, all samples are washed in the 63 μm scalp and then, samples are ready for drying and wiping under the temperature

of 60 °C for 24 hours. Wiped samples were poured into the special lacunas and precisely signed to be ready for stage of separating microfossils. In this study, detachment of microfossil operations was done manually. For every sample between 3 to 30 ostracoda, mature sample was separated. But in those samples that have too small number of ostracoda (slight), all of mature and young ostracodas were abrupted for analysis.

Isotopic Measurement of Carbonate Sediments

Bulk isotope compositions of carbon and oxygen were measured in University of Ottawa, Faculty of Science (Earth Sciences) G.G. Hatch Isotope Laboratories, 130 Louis Pasteur. Samples are weighed into exetainers, 0.1 mL of H3PO4 (S.P. 1.91) is added to the side and exetainers are capped and Helium-flushed horizontally. Reaction at 25.0C for 24hrs (calcite) or 50.0C for 48hrs (dolomite) is followed by extraction in a continuous flow. The measurements are performed on

a Delta XP and a Gas Bench II, both from Thermo Finnigan (See Application Flash Report G 31 from Thermo Finnigan). Analytical precision (2sigma) is +/- 0.1permil. The isotopic composition of samples is defined and reported in the conventional δ-scale in parts per thousand:

$$\delta_{\text{sample}} (\text{‰}) = \frac{[R_{\text{sample}} - R_{\text{standard}}]}{R_{\text{standard}}} \times 1000$$

Where R is the abundance ratio of C¹³/C¹² or O¹⁸/O¹⁷ in the sediment samples or in the standard. Isotope ratios are reported related to the PeeDee Blemenite (PDB) standard for carbon and oxygen isotope measurements on bulk CO₂.

Results

Chronology

Based on two age-evaluating samples in Parishan Lake at depths of 70 and 220 cm by Jones, the following model (Fig. 3), was provided for identifying chronological phenomenon. Based on this model, data of this study represent almost 1800 year history.

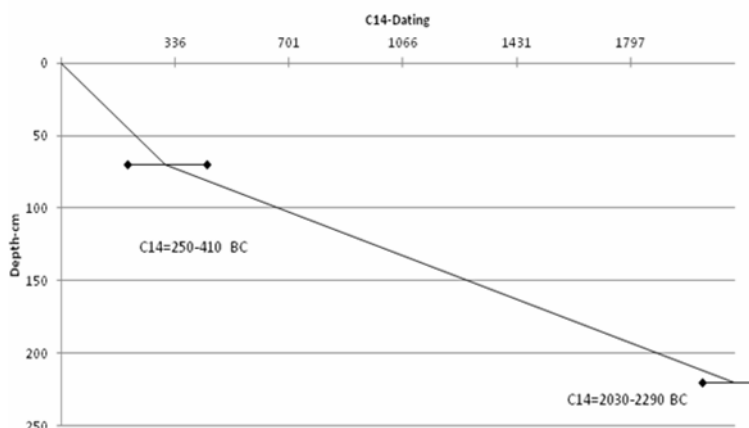


Fig. 3. Two Age-evaluating Samples on Parishan Lake at Depths of 70 and 220 cm by Jones

Isotope Composition of Carbonate Sediment

(δC¹³_{carb} and δO¹⁸_{carb})

The result of isotope analysis of Parishan Lake carbonates are mentioned below (Table II). The values of δO¹⁸_{carb} of carbonate at core of Parishan Lake are varying between 5.1 - 6.7 (n=31) (Fig. 3). Changes of these values were small and

less than 2. Average of these values is 5.92 that in contrast to isotopic evidence of Zeribar and Mirabad lakes, is higher. Standard deviation of these values is 0/63 that represents data transmittal around average and even the data. δO¹⁸_{carb} values from past to now without remarkable changes covered a monotone process so, determining the different zones in these

values is difficult. δC^{13}_{carb} values rather than δO^{18}_{carb} show more variations (Fig. 3). Average of these values is -4 that with attention to the blocking of lake are not unexpected. Minimum of these values is -6.61, maximum is 1.30 (n=31), variation extend of carbon value reached nearly to 7 and standard deviation of these data is 2.35. Overall, these values show more variations during the study process as among these values, 3 zones are remarkable and it's possible to interpret environmental conditions into these zones, separately. The lowest values are located in number one zone. This zone is set among 125 to 195 cm in this zone, values are near to -6 and an increasing process is visible in this zone and shows less values of variation extend. Special characteristic of this zone is to have the least values and the observed lowest values of δC^{13}_{carb} at the core are in this zone. Zone 2 is located among 55 to 125cm, the variation extends of values is more, values are near to -4 and these values have higher quantity rather than zone 1. The increasing procedure

observed in the previous zone is more intensive in this zone. Peak of this zone is reached to -2 that almost are located at depth of 100 cm. This zone with enhancing the value of δC^{13}_{carb} is finished in values higher than zero. Zone 3 that is nearest zone is begun from 50cm. In terms of δC^{13}_{carb} data, this zone is the most different zone. The highest quantities are belonging to this zone. δC^{13}_{carb} values in this zone are nearly upper zero. Transition of zone 2 to this zone with a swift and sudden shift of δC^{13}_{carb} value is characterized by upper zero. After this shift, the values negotiated an almost steady process. Totally, in δC^{13}_{carb} , values have more changes rather than δO^{18}_{carb} and these values show a given increasing procedure up to now. This increasing procedure occurred weaker and less swing in δO^{18}_{carb} values and these values do not show any correlation with δC^{13}_{carb} values. Covariance between these values is - 2.5. A linear relation is not observed between quantities of δO^{18}_{carb} and δC^{13}_{carb} .

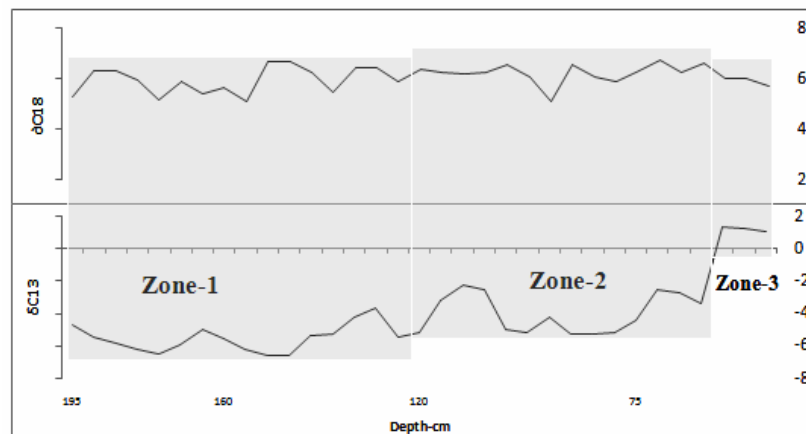


Fig. 4. Variation of δO^{18}_{carb} (up) and δC^{13}_{carb} (down) in Difference Depth Values of δC^{13}_{carb} Showed Three Remarkable Zones.

Table 2. Result of the Isotopes Analyzing of Parishan Lake Carbonates

Sample ID	Depth-cm	Delta 13C x 1000	Delta 18O x 1000
		vpdb	vpdb
LK-	190-195	4.68	5.31
LK-	185-190	5.42	6.30
LK-	180-185	5.83	6.32
LK-	175-180	6.19	5.95
LK-	170-175	6.44	5.13
LK-	165-170	5.95	5.98
LK-	160-165	5.01	5.38
LK-	155-160	5.56	5.64
LK-	150-155	6.23	5.10
LK-	145-150	6.54	6.65
LK-	145-150	6.61	6.69
LK-	140-145	5.39	6.26
LK-	135-140	5.28	5.48
LK-	130-135	4.25	6.44
LK-	125-130	3.67	6.44
LK-	120-125	5.40	5.88
LK-	115-120	4.12	6.35
LK-	110-115	3.15	6.23
LK-	105-110	2.21	6.17
LK-	100-105	2.49	6.24
LK-	96-100	5.01	6.54
LK-	96-100	5.16	6.07
LK-	92-96	4.25	5.12
LK-	84-88	5.26	6.55
LK-	80-84	5.28	6.07
LK-	75-80	5.17	5.90
LK-	70-75	4.44	6.33
LK-	65-70	2.53	6.74
LK-	60-65	2.76	6.24
LK-	55-60	3.34	6.61
LK-	40-45	1.3	6.01
LK-	40-45	1.22	5.99
LK-	30-35	1.08	5.73

Discussion

Oxygen Isotopic Composition of Carbonate (δO^{18}_{carb})

Many factors can be considered as the controller of isotopic values of Lake Carbonate. We cannot attribute δO^{18}_{carb} changes to only one factor. It's usually

interpreted in this way that in the lake environment, the oxygen isotope value changes are related to temperature variability and the ratio of precipitation/evaporation (Leng and Marshall, 2004). Yet, attributing δO^{18}_{carb} changes to different factors in spatial conditions of studies is different. So, It should be considered that measured isotopic changes in sediment can be related to the vast extend of environmental process. So, in these researches, surveying all of the possible affecting factors is essential. In lake environments, different factors can determine swing oxygen isotope of lake sediment, yet the most important factors can be substance source, water temperature, period of settlement and quantities of output and input of the lake (Benson *et al.*, 1996). Studies show that variation of δO^{18}_{carb} value of rain water at the middle and high latitude has a respective relation with the surface temperature (Rozanski and Conifantini, 1992). Epstein studied tentative relation between temperature and δO^{18}_{carb} values of carbonate known as equation of paleo temperature by Greek (Hu *et al.*, 2006; Epstein *et al.*, 1953). In current conditions, in Europe, the isotopic composition of rain shows a near relation with the variations of air surface mean temperature. In lakes with closed systems, such temperature dependence can provide useful information for paleo temperature of area (Wang *et al.*, 2002).

In open hydrological systems, the isotope compositions of lake water oxygen clearly reflect isotopic composition of precipitation (rain and snow) value of the lake (Leng and Marshall, 2004). Overflow and time of water resident time are reduced or sometimes reached to zero. Then, at this time, isotopic composition of lake water is near to the input value of lake. (Wang *et al.*, 2002). Yet, sometimes, we can't attribute variation of δO^{18}_{carb} values of lake water to the only one factor (Fan *et al.*, 2007). The relation of calcite detachment with the 4.3 temperature changes only one

in thousand at $\delta\text{o}^{18}_{\text{carb}}$ values of calcite. (kim and o, Neil, 1997). In some lake environments, $\delta\text{o}^{18}_{\text{carb}}$ values of lake water are not clearly related to mean annual precipitation. When period of lake water resident time is long, isotopic variation of lake water oxygen is controlled by basin and efficient hydrological process of lake. In this case, evaporation has more important effect on the isotopic composition of lake water. Totally, evaporation can be most the important affecting factor on isotopic composition of stationary water extend and closed systems, especially in the arid area, evaporation causes lack of water. (Wang *et al.*, 2002). Also, we should note that dynamic evaporation of lake waters is related to the value of relative humidity of air (mark Buhay *et al.*, 2009). So, we can use $\delta\text{o}^{18}_{\text{carb}}$ values of close system for rehabilitating hydrological conditions of lakes. Of course, this point is also important that existence of fundamental upheaval in hydrological systems of lake leads to the change of controlling factors of $\delta\text{o}^{18}_{\text{carb}}$ values. In this situation, $\delta\text{o}^{18}_{\text{carb}}$ value of sediments can be a function of input value of lake because in this case in contrast with input and output of Water Lake, evaporation becomes too little. Also, if water settlement time reaches to near of zero, the $\delta\text{o}^{18}_{\text{carb}}$ values are reflecting evaporation value in the area (Wang *et al.*, 2002). So, the existence of an arid period results to the reduction of input and increasing settlement time of lake. At this time, as a result of increasing surface evaporation, the ratio of evaporation /input (E/I) of lake water becomes richer than $\delta\text{o}^{18}_{\text{carb}}$. Parishan lake is located in southern semi arid area of Iran. Currently, correlation of water surface variation with the ratio of (P-E) is near to 0.86 (Fig. 4). This shows that now, the main value of lake input is provided from precipitation. So, it seems that some values of Water Lake result from underground waters but there is a little accurate information about it. Now, lake does not have main output in

the form of runoff and it seems that most of the water lack is caused by evaporation. Then, lake is settled in a dip that water of lake to overflow. So, lake is in almost closed condition and morphological situation. High mean value of oxygen isotope in this lake rather than lakes of west of the country (Zeribar and mirabad) represents the evaporation in controlling isotopic values of this lake, because most of time, small quantities of $\delta\text{o}^{18}_{\text{carb}}$ represent open systems and high value represent closed systems. (Fan *et al.*, 2007). So, it seems that the ratio of E/I is an important controller of Parishan lake $\delta\text{o}^{18}_{\text{carb}}$. Variation of Isotopic evidences is interpreted as a result of variation of seasonal precipitations. So, the low values of oxygen isotope of lake carbonates at early Holocene are because of enhancing winter precipitations and high values of oxygen isotope at middle Holocene is because of enhancing spring precipitation (stevens *et al.*, 2006). Also, Variation of Isotopic evidences of Zeribar lake is because of seasonal precipitation changes. Lighter values of oxygen Isotope cause more negating Isotopic evidence of Zeribar lake (Stevens *et al.*, 2001) while Jones knows evaporation as a main controller of Isotopic values of Zeribar lake. Also, controlling function of isotopic values of Zeribar Lake is variation of precipitation source area (Jones and Robert, 2007). Also, in the east south of turkey, changes of $\delta\text{o}^{18}_{\text{carb}}$ values in a closed hydrological system are attributed to the changes of evaporation in the area (Eastwood *et al.*, 2007). Isotopic variation of carbonates of a lake in the west of Poland is interpreted as a result of climatic changes and hydrological variations of lake (Apolinarska, 2009). In a study in the east of Canada about Isotopic evidence of a lake, variation of E/I Ratio was used for reconstruction of past hydrological changes (Mark buhay *et al.*, 2009). Considering that precipitation is the most important source for water of Parishan lake, the Ratio of E/I can be

changed to E/p. so, the changes of $\delta\text{o}^{18}_{\text{carb}}$ can represent a history of drought of the area. The value of $\delta\text{o}^{18}_{\text{carb}}$ during the study period shows low oscillation conditions. Leveling of these values implies this fact that during the study period, any important changes did not occur in precipitation values, the value of $\delta\text{o}^{18}_{\text{carb}}$ did not show a firm correlation with the value of $\delta\text{C}^{13}_{\text{carb}}$ and this correlation became firm only at upper part of the core in zone 3. It seems that only in this period, controlling factors affect the isotopic

values of carbon and oxygen equally and a gradual increasing procedure is visible in the $\delta\text{o}^{18}_{\text{carb}}$ value of lake. This procedure shows the gradual drying of area. This procedure of gradual dryness is totally known throughout the zone of morocco to India at late Holocene (Schilman *et al.*, 2001). Yet, evidences show the enhancement of precipitation and transcending level of lake in southern zone such as Sudan (Hammarland *et al.*, 2003).

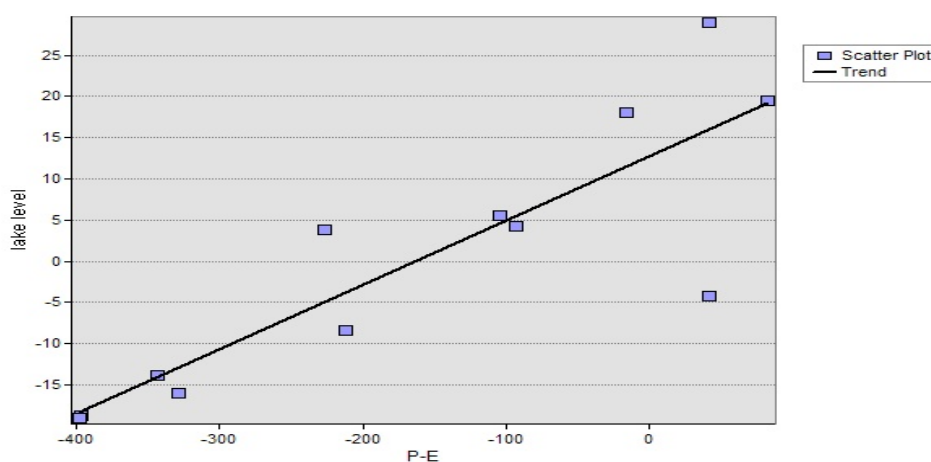


Fig. 5. Graph of Strong Correlation between P-E Ratio and Lake Level

Carbon Isotopic Composition of Carbonate ($\text{C}^{13}_{\text{carb}}$)

In Lake environment, the effective function on $\delta\text{o}^{13}_{\text{DIC}}$ are variable. The important factors of determining these changes are generally $\delta\text{o}^{13}_{\text{DIC}}$ of input water of lakes and exchanging CO_2 , respiration and photosynthesis of aquatic plant of the lake (Hu *et al.*, 2006).

The inputs of soft water into the lake almost lead to lower pH of Water Lake that will result to decreasing Alkali nature of Water Lake. Lowing of Alkali nature totally leads to negating δC^{13} of Water Lake. In closed basins, high evaporation increases Alkali nature of water lake that is accompanied with enhancement of δo^{18} (Fan *et al.*, 2007). Underground waters and river flows have generally low values of δo^{13} , for example in north of Europe these

values at calcite are between -10 and -15, but higher values of δC^{13} (-3 to +3) are seen in underground waters of karstic zones where carbon atoms are formed with breaking up lime stones (Andrews *et al.*, 1997). In addition to this, aquatic plants of lake generally use carbonates during photosynthesis. When producing and growing of lake plants are high, δC^{13} value of lake is affected by this action, so that aquatic plants prefer taking C^{12} during operation that increases value of δC^{13} in the lake (Hue *et al.*, 2006). Planktons also use C^{12} values that leads to enrichment of C^{13} over left in the water of lake and finally, enriches δC^{13} (Schwalb *et al.*, 1999). Indeed, lake water's $\delta\text{C}^{13}_{\text{DIC}}$ changes with biological production of lakes. During life of lakes when rich biomass conditions

and enhancement of production occur, C^{12} of carbon supplies is decreased and value of C^{13} increases. In lake environment with closed hydrological systems, especially in Non karstic basin, high values of δC^{13} show different degrees of balance of δC^{13}_{DIC} with CO_2 of atmosphere (Wang *et al.*, 2002). Intensive evaporation of water of lakes will release $C^{12}O_2$ to the atmosphere and there upon δC^{13}_{DIC} of lake will become richer (Xu *et al.*, 2006). Under conditions of atmosphere CO_2 balance with δC^{13} , lake water will generally experience some values between +1 to +3 (Wang *et al.*, 2002). There are some big lakes with closed hydrological systems, especially in arid areas in which both δO^{18} and δC^{13} are high and positive. In these cases, values show near correlation. This correlation almost is useful for measuring hydrological closing of the lake. In closed lakes, values of δO^{18} and δC^{13} because of evaporation and atmospheric exchanges show high covariance. (Tanner, 2009). Indeed, high correlation between δC^{13} and δO^{18} can represent a common practical mechanism on the lake water and dissolved inorganic carbon (Eastwood *et al.*, 2006). During the study period, value of δC^{13}_{carb} of Parishan Lake shows more variations rather than δO^{18}_{carb} . The observed increasing procedure in the value of oxygen isotope is more intensive and full of variations. Changes of δC^{13}_{carb} values from -6 to near of -2 portend that intensive variations occur in the controller source of these values. These changes represent that possibly during the study, this lake was affected by different controller factors. So, three separate zones are determined for surveying these factors in different terms.

Zone 1 (120 to 195 cm) (1800-900 ¹⁴ c years BP)

This zone includes lowest part of the core and is almost longest zone of this core. Data of δC^{13}_{carb} are at the lowest values of this zone. Also, the least observed δC^{13}_{carb} at the whole of study term is in this zone

and the average of the carbon isotope is -5.41. δC^{13}_{carb} value of the lake in this zone probably is not in balance with CO_2 . Low correlation of δC^{13}_{carb} and δO^{18}_{carb} values show that the lake experiences more open conditions. In these cases, especially in karstic areas, these low values could be because of more recharge of underground waters to the lake. With respect to karstic stones of area, more recharge of underground waters can result in lowering of δC^{13}_{carb} values. Existence of Gypsum crystals shows more intensive of underground flows to the lake. So, more underground recharge possibly is the main factor of lowering δC^{13}_{carb} values.

Zone 2 (55 to 125 cm) (900-175¹⁴ C years BP)

δC^{13}_{carb} values of carbon at this term have higher values. Average of values in this term is -3.93. After this zone, the increasing process of δC^{13}_{carb} values becomes more intensive. Incremental process of δC^{13}_{carb} values during this period is interpreted as a result of gradual decrease of underground water recharge. Decreasing underground water recharge in the area could follow gradual procedure of area dryness. These changes of underground water are more intensive than climatic phenomenon. So, it seems that a kind of intensifier factor is effective on depletion and falling of underground waters. The archaeological evidences of Lake Border and existence of old aqueduct in the area show long record of exploiting underground waters in the area. It seems that increasing procedure of δC^{13}_{carb} values of Parishan Lake in this zone was coincided with start of exploitation of underground waters and agricultural consumption.

Zone 3 (40 cm to surface sediment) (about 150 recent years)

This zone is determined with a sudden shift of δC^{13}_{carb} values up to zero. Most of correlations between values of δC^{13}_{carb} and δO^{18}_{carb} were seen in this zone showing

complete closing of the lake. Most probably, swift incensement of values of δC^{13}_{carb} in this zone is because of high reduction in recharge of underground waters. This causes those values of δC^{13}_{carb} set in more balance with CO_2 of atmosphere. High reduction of underground water recharge is most possibly because of pickup underground waters by well and aqueduct. Actually, these changes do not show any harmony with gradual procedure of drought in the area.

Conclusion

Gradual enhancement of δO^{18}_{carb} values during the study term of Parishan Lake represents a week drought procedure in the area. In the final part of the study term, that is zone 3, changes in the values of δO^{18}_{carb} of the carbon Isotope show human's effect rather than environmental factors. Throughout the study term, high variations are not seen in the values of input and output of the lak. Values of δC^{13}_{carb} show more intensive changes during the study term. Assessment of the carbon Isotope's results shows that main changes in the values of δC^{13}_{carb} of Parishan Lake occur as a result of changes in the underground water's recharge. Variation of underground water's recharge in the area shows unusual harmony with the drought procedure of the area, because underground water usually shows less sensitivity to the climatic changes rather than surface waters. With respect to the severity of underground water's reduction in the area, it seems that the role of human factors is more important for these changes. Archeological evidences at the margin of the lake portended that habitancy and use of underground aquifers in the form of aqueduct around the lake have a long background. So, intensifier factor of underground water changes is anthropogenic factor. Sudden and intense shift of the values of δC^{13}_{carb} in zone 3 represents hard reduction of underground recharge. It seems that this term is

accompanied by adding system of well and more picking of underground waters. After this term, with respect to high correlation of values of δC^{13}_{carb} and δO^{18}_{carb} , lake has experienced complete close conditions and main input values of lake are resulted from precipitation and evaporation. In this term, hard evaporation of surface water of the lake is the controller of both values of δO^{18}_{carb} and δC^{13}_{carb} causing that values of δC^{13}_{carb} set in exchange with the CO_2 of the atmosphere.

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