

# Strontium and zinc content of the human skeletal remains from the Iron Age sites in North and South of Iran, as The paleomigration and paleodietary indicators

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This research focuses on reconstructing migration and dietary strategies of individuals in the Iron Age. Elemental analyses from archaeological skeletal remains yield an important perspective on temporal shifts in diet in relation to social and environmental circumstances. The elemental ratio data such as dietary and environmental changes have shed light on crucial issues in archaeology. The central concern of the research is about Sr, Zn and Ca compositions of teeth (N=16) from two Iron Age sites of Gohartepe and Sanjartepe, in an effort to ascertain whether this material provides reliable paleodietary and paleomigration information.

This study suggests that Sr/Ca ratio most likely demonstrates paleoecological as well as paleomigration information obtained from these sites, it is also demonstrated that geologically similar sites differ in the degree they impart certain elements to ancient enamel and Zn/Ca and Sr/Ca ratio indicates paleonutritional data. Moreover, the results obtained by trace elemental analysis were combined with the results of our previous isotopic studies on the materials of Gohartepe site northern Iran, to provide a basis to interpret variable paleodietary systems of its occupants.

**Keywords:** *Paleodietary, Paleomigration, Trace Element Analysis, Iron Age, Iran.*

## Introduction

Trace elements are normally not involved in the metabolic pathways of human beings, so bone and tooth deposits are not used in metabolic reactions and may indicate the amount ingested, therefore, both elements have been widely used as paleodietary indicators (Sillen and Kavanagh 1982; Price *et al.* 1985; Baud 1989; Lambert and Weydert-Homeyer 1993). The relative amount of the trace element strontium in bone for determination of dietary was first proposed by Toots and Voorhies (1965), who were able to discriminate between Pliocene herbivorous and carnivorous mammals by differences in the relative amount of strontium in their skeletons. Brown (1973, 1974) first applied this approach to study of human populations.

Moreover, it is citable that human diets and thus human skeletal remains from a given area tend to exhibit broadly similar Sr levels regardless of variation in the diet. This relatively large geographic

variation confounds paleodietary comparisons between different locations, requiring analyses of local fauna to adjust for these differences. In short, chemical variation between different locations can potentially exceed the variation at a single location. For example, although deer are entirely herbivorous, there is some variation in the Sr levels not only between the two regions but also within each region (Burton *et al.* 2003). Burton, Price and their colleagues have found, empirically, that soils and plants in any given location have enormous variability. Although bones reflect this variability, but they exhibit substantially less local variability than the soils and plants themselves (Burton *et al.* 1999; Price *et al.* 2002).

Besides, the analysis of <sup>13</sup>C/<sup>12</sup>C and <sup>15</sup>N/<sup>14</sup>N ratios of bone and tooth collagen is now recognized as a powerful means of reconstructing ancient human diet from the organic component. These methods are complementary to the earlier techniques of element analysis in the mineral phase of Human skeletal remains. In this research, we have used both stable Isotope and element techniques in a complementary

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fashion to provide the most complete dietary consumption model

## The study sites

### Gohartepe

Gohartepe is located on the southern coast of the Caspian Sea in the province of Mazandaran, about half a kilometer west of the Behshahr city (36°40'43"N 53°24'01"E) (Fig. 1).

The northern slopes of the Alborz Mountains lay just a few hundred meters to the south, while the shore of the Caspian Sea is less than "10 km" to the north (Mahfrouzi and Konrad Piller 2009). Extensive agriculture now characterizes the fertile coastal plain, but in antiquity, large parts of this area consisted of inhospitable marshland (Va'mbe'ry 1867; Olearius 1959; Lushey 1983; Morier 1985). According to results from  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  derived from tooth collagen of individual habitant in Gohartepe, a terrestrial herbivores diet and  $\text{C}_3$  plants is the most likely explanation for this site (Mousavi *et al.* 2012).

### Sanjartepe

Sanjartepe is located on vicinity of the Northern coast of the Persian Gulf in the province of Khuzestan, about in Andimeshk County central region (32°46'00"N 48°35'92"E), about "15 km" north of Sush city (Fig. 1).

This site is located in sedimentary Khuzestan plain. Karkhe River is located in "1 km" to the west of Sanjartepe. About this river a boscage is existed. Nowadays, it is so be dispersal of immigrant societies about this site (SardariZarchi 2007).

## Material and Method

We investigated 16 teeth of individuals from two ancient sites: 11 samples from Gohartepe in the fertile coastal plain and 5 samples from Sanjar in the sedimentary plain. It is citable that we just analyzed 11 samples of Gohartepe and 5 samples of Sanjartepe also were analyzed by this lab (Masjedi 2009: table 7-1), said as comparison.

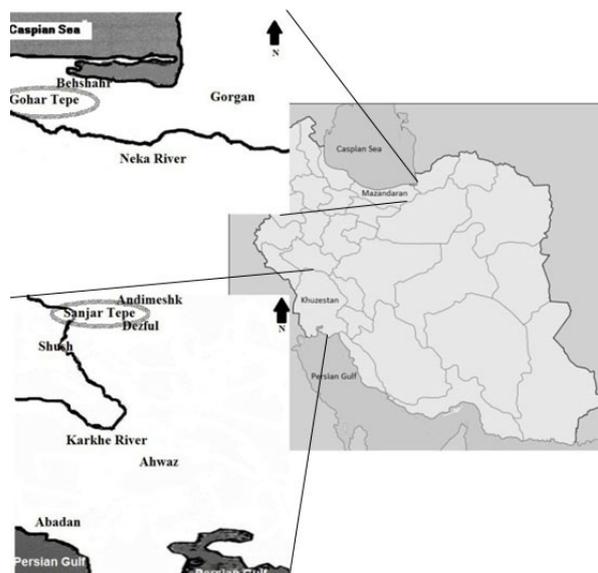


Fig. 1: Map showing the location of the Gohartepe and SanjarTepe site in North and South of Iran.

Age and sex of 6 individuals out of 11 samples of Gohartepe were identified but all 5 Individuals of Sanjartepe were still remained unknown.

The samples from Gohartepe and Sanjartepe were analyzed by proton-induced X-ray emission (PIXE) for the assay of Sr, Ca and Zn content.

First, all samples were mechanically cleaned, rinsed. Then, we amputate small piece of each sample and after fixing it on clamp that impound it, should be located in assay booth. This assay booth is set to have 10-5 vacuity. Then samples were bombard with proton berm with 2 MeV energy. For absorption the low energy X rays and repel them accession into detector, we use plastically filter namely Maylar with 175 micron third dimension that contrive a broach in the filter's central and rays special deduction will be able to transit and to enter the detector. Also, for Calcium reduction available in samples, we use other filter of silver stuff with 1/46 micron third dimension.

## Results and Discussion

Table 1 show the results of the trace elements analysis of Gohartepe and Sanjartepe samples.

The theoretical Ca/P wt ratio for hydroxyapatite is 2.16. According to the criteria of White and



Hannus (1983), bone Ca/P ratios higher than this indicate enrichment by P04 ions, and ratio slower than 1.63, indicates Ca depletion.

Our calculation in AEOI showed that the acceptable range for Ca/P ratios is about  $2.15 \pm 0.32$  thus by this range, the Ca/P ratios of 10

samples observed, fall within the standard range i.e. 7 Samples from Gohartepe (mean=2.22) and 3 Samples from SanjarTepe (mean=2.13). Mean log (Sr/Ca) ratio of Gohartepe and SanjarTepe samples are about -0.72 and -0.96 respectively (Table 2).

The results (Fig 2) are equivocal for Sr; there

**Table 1:** General results of Gohartepe: trace elemental and isotopic analyses and the element/calcium values of acceptable sample & Trace elemental results of SanjarTepe and the element/calcium values of acceptable sample.

Samples of GoharTepe		Gender	Trace elements			Isotopes		
			Sr	Zn	Ca/P	D <sup>13</sup> C	D <sup>15</sup> N	C/N
1	K	Unknown	1.54	2.34	2.52	-20	9.9	3.29
2	L	Female	2.2	0.64	2.24	-	-	-
3	M	Male	-	6.37	3.00	-	-	-
4	N	Unknown	-	1.42	2.17	-	-	-
5	O	Female	1.61	2.33	2.35	-	-	-
6	P	Female	2.82	2.69	2.73	-	-	-
7	Q	Unknown	-	1.67	2.27	-	-	-
8	R	Unknown	-	1.76	2.15	-	-	-
9	S	Female	-	2.47	2.29	19.75	8.79	3.2
10	T	Male	-	2.47	2.59	-20	10.44	3.2
11	X	Unknown	0.15	0.2	2.09	-	-	-
<b>The element/calcium values of acceptable sample</b>			<b>Sr/Ca</b>	<b>Zn/Ca</b>	<b>Ca/P</b>			
2	L	Female	0.05	0.01	2.24			
4	N	Unknown	-	0.03	2.17			
5	O	Female	0.03	0.05	2.35			
7	Q	Unknown	-	0.04	2.27			
8	R	Unknown	-	0.04	2.15			
9	S	Female	-	0.06	2.29			
11	X	Unknown	0.00	0.00	2.09			
<b>Mean of acceptable Sample</b>			0.01	0.03	2.22			
Samples of SanjarTepe		Gender	Trace Elements					
			Sr	Zn	Ca/P			
1	1S	Unknown	7.05	1.55	2.65			
2	1D	Unknown	-	1.59	2.20			
3	2S	Unknown	1.09	0.96	3.20			
4	2D	Unknown	1.26	1.9	2.01			
5	3	Unknown	1.5	1.72	2.18			
<b>The element/calcium values of acceptable sample</b>			<b>Sr/Ca</b>	<b>Zn/Ca</b>	<b>Ca/P</b>			
2	1D	Unknown	-	0.04	2.20			
4	2D	Unknown	0.03	0.05	2.01			
5	3	Unknown	0.03	0.04	2.18			
<b>Mean of acceptable Sample</b>			0.02	0.04	2.13			



is no a significant difference in the Sr content between the Gohartepe and Sanjartepe populations. It is citable that the enormous variability existed in the soils and plants of any given location can be reflected by the bones and teeth, they exhibit substantially less local variability than the soils and plants themselves (Burton *et al.* 1999; Price *et al.* 2002). Hence, according to the results achieved it may be concluded that since the sample elements of both regions in Iran are shown to be chemically similar, thus, the ‘Sanjartepe population of the southern Iran would not be assumed to have been as local individuals or comers to the area from a location that is chemically indistinguishable from the Gohartepe population in the north. This idea would strengthen the hypothesis implying that the buried population of Sanjar cemetery would have been the peoples who migrated into Khuzestan in the southern Iran from the Lake Caspian Basin of the north.

To study the mobility of human groups in history, we sample dental enamel, which develops during childhood and does not remodel, thus it retains the composition of the childhood diet during the time when the teeth were formed. Moreover, because dental enamel is much less susceptible to diagenetic contamination than bone, it is a more suitable sample for the archaeological studies.

Table 2. Calculated log (Sr/Ca) ratio for the samples mentioned in the text.

Location	Number		Log (Sr/Ca)
	Total Sample Analyzed	Standard Sample	
Iran			
Gohartepe (North)	11 (teeth)	7 Samples	-0.72
Sanjartepe (South)	5 (teeth)	3 Samples	-0.96

The different regions of Iran represent greater diversities. Archaeological evidence has long demonstrated contact between distant sites in the Iranian plateau. Theories concerning the migrations among distant sites are common. The nature of contact between the southern and northern regions of the Iranian plateau has also been a theme of

many speculations (e.g. Crossland 1971, Hemphill 1999). Our work is focused on the two Iranian Iron Age sites that show evidence of very small variation in the intrinsic levels of Sr in the two local geographical environments and long distance contact: Gohartepe and Sanjartepe. The differences are not unanticipated, but it is citable that the Gohartepe and Sanjartepe individuals consumed food grown on soils derived from fertile plain, but however, these initial results indicate that Sr levels is proven as an additional tool for discriminating local and foreign skeletons from each other as our samples from the two sites indicated.

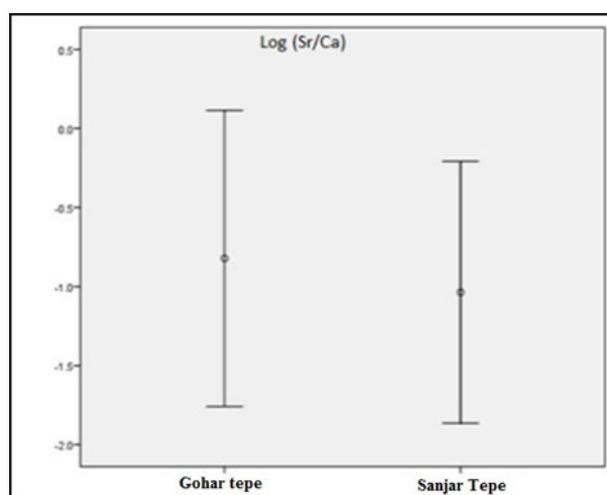


Fig. 2: Comparison of Sr/Ca from two sites of southern and northern Iran.

In addition, studies conducted on the trace elements of the ancient human group's bone (Turekian and Kulp 1956) in comparison with the living populations allowed threshold values to be fixed. These are recognized as valid by many authors (Fig. 3), and allow the dominant diet of an individual or a whole group to be discriminated (Bartoli 1995,1996). Then, comparing the results obtained in these ranges, it is possible to identify the incidence of the main categories of foodstuffs in the studied specimens diets (Giorgi *et al.* 2005: tables 1&2).

Table 3, show the element/calcium values expressed in ppm obtained from the trace elements analysis in two various groups of samples examined. For each group and for each chemical element investigated, the mean values were also calculated.



This mean values are equivocal, because this values are very fiddling and include two assumptions: 1- Considering the mean values obtained in Table 3, it is possible to state that the inhabitants diet of Gohartepe and Sanjartepe were not characterized by a considerable consumption of green vegetables,

Table 3: Reference parameters for the Sr/Ca and Zn/Ca values (Giorgi et.al. 2005: table 1&2).

Reference parameters for the Sr/Ca ratio		reference parameters for the Zn/Ca ratio	
Values in ppm	Diet	Values in ppm	Diet
> 0.57	Rich in vegetables	> 0.60	Rich in proteins
0.57-0.40	Mixed	0.60-0.35	Mixed
< 0.40	Poor in vegetables	< 0.35	Poor in proteins

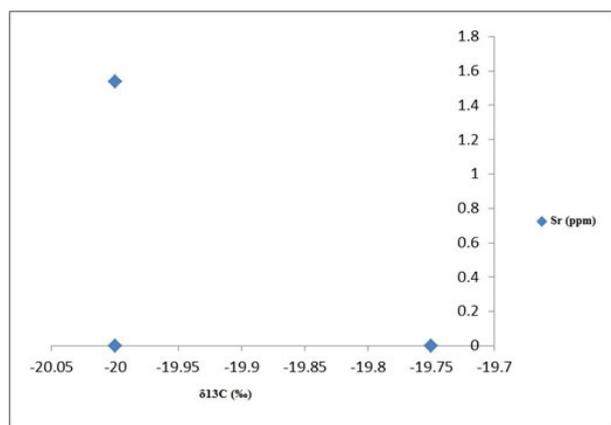


Fig. 3: Plot of strontium concentrations versus  $\delta^{13}C$ .

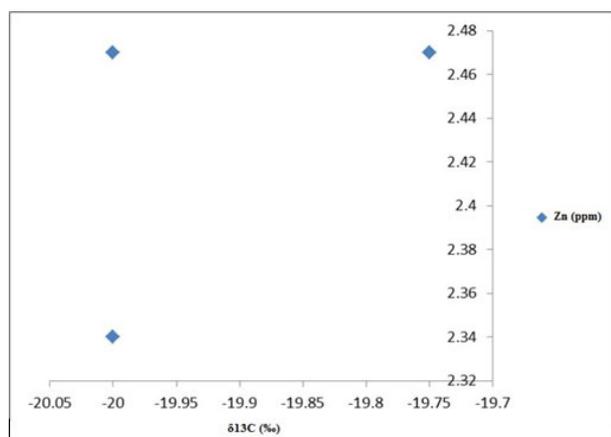


Fig. 4: Plot of zinc concentrations versus  $\delta^{13}C$ .

carbohydrates and legumes, there is also was not a minimum intake of animal protein. Owing to the Sr/Ca and Zn/Ca values are very low. 2- PIXE is not adaptable to assay trace elements in skeletal remains, perhaps pro that only acrotic layer is disposable with X ray and sample is not solved in order that it is possible assay trace element in whole sample.

### Combinational result of trace element and isotopic analyses

Our ongoing work with samples from Gohartepe and Sanjartepe is designed to test hypotheses about dietary abundance, local environmental levels reconstruction and movement between these two sites.

Hence, we also employ data from isotopes of Carbone and Nitrogen (Mousavi et.al. 2012). Stable isotope results of human teeth collagen extracted from the Gohartepe site that coordinated with trace element results, have range from  $\delta^{13}C = -20 ‰$  to  $-19.7 ‰$  with a mean of  $(-19.9 ‰)$  and from  $\delta^{15}N = 8.7 ‰$  to  $10.4 ‰$ , with a mean of  $(9.7 ‰)$ .

There is a similarity correlation between content of strontium,  $\delta^{13}C$ , zinc and  $\delta^{13}C$  for the two sexes (male and female) in inhabitant diet reconstruction of Gohartepe (Table 1). But it is important to note that though this result may be interesting but because of the very small number of male and female samples the result cannot be statically precise (Fig 3 & 4).

### Conclusions

1- According to mean log (Sr/Ca) of Gohartepe and Sanjartepe, this results indirectly indicate that this two regions in the Iranian plateau are chemically similar, and pointer that maybe the sampled ‘Sanjartepe’ at Khuzestan are not either local individuals or came from a location that is chemically indistinguishable from Gohartepe in Mazandaran. The data are consistent with a hypothesis that the ‘Sanjar’ burials at Khuzestan came from the Lake Caspian Basin.

2- These initial results that found from the trace element intrinsic levels in the two local geologic



environments indicate that Sr levels will prove an additional tool of use in discriminating foreign skeletons at the two sites.

3- According to studies conducted on the trace elements in the ancient human groups bone for paleodietary reconstruction, the Sr/Ca and Zn/Ca values of Gohartepe and Sanjartepe are very low and inhabitants of Gohartepe and Sanjartepe were not characterized by a considerable consumption of green vegetables, carbohydrates and legumes, there is also was not a minimum intake of animal protein. Beside, this very small element/calcium values may be through that PIXE is not an adaptable instrument for this type of assay.

4- There is a similarity correlation between contents of strontium,  $\delta^{13}\text{C}$ , zinc and  $\delta^{13}\text{C}$  for the two sexes (male and female) in diet inhabitant reconstruction of Gohartepe. But it is important to note that though this result may be interesting but because of the very small number of male and female samples the result cannot be statically precise.

5- Archaeological evidence indicates that shifts in human food procurement strategies are often associated with major changes in cultural orientation (Schoeninger 1979: 2). Cultural orientation is affected by factors such migration.

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