Preliminary Archaeometallurgical Investigations of Bronze Age Metal Finds from Shahdad and Tepe Yahya[1]

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Shahdad and Yahya which are two important prehistoric sites in the Kerman Province, are of most important for Archaeometallurgical studies. During excavations at these sites a number of metal objects have been discovered. Moreover, evidence of metal working on the surface testify to manifacturing of metal objects. This also shows that the site might have experienced craft specialization.

The following contribution is representing results of archaeometallurgical investigations on several metal artifacts from prehistoric contexts from the sites of Tepe Yahya and Shahdad which are situated in Kerman Province. The aim of this research is to investigate the provenance of the raw materials which had been used. Further some new observations concerning the distribution of artifacts will be presented.

Keywords: *Bronze Age; Shahdad; Tepe Yahya; Ur, Metal Artifacts*

Introduction

During the find registration in the National Museum of Iran in Tehran (May-June 2006), nineteen metal artifacts from the Bronze Age settlements of Shahdad[2] and Tepe Yahya[3] in southeast Iran were sampled. Three of them came from prehistoric layers IVC2-IVB at TepeYahya[4],and sixteen came from graves of periods TAK III_2-TAKII_1 from Shahdad (Hakemi 1997: 83, Table 2).

This paper presents research results reached by utilizing energy dispersive X-ray fluorescence (EDXRF), which determines the chemical content in order to assess the origin of raw materials (Lutz & Pernicka 1996: 313-23). The main requirement is that the artifacts analyzed are primary artifacts and not made from reused metal. The analysis was conducted at the Curt Engelhorn-Zentrum Archäometrie in Mannheim, Germany.

Sampling[5]

The metal artifacts from Tepe Yahya are referred to here as MT01-MT03. MT01 (fig. 1) is a copper shaft-hole axe from layer IVB5 (Lamberg-Karlovsky & Potts 2001: 115, fig.4.44 (SF3756); Lamberg-Karlovsky and Thornton 2004: 52; Stöllner et al. 2004: 582, no.55). It has parallels with other copper axes from Shahdad (Hakemi 1997: 636, Gp.3), Damin (Tosi 1970: 46-47, fig.17a) and Susa (Tallon 1987: vol. I, 96, no.73[Sb821]). MT02 (fig. 2) is a remarkable theriomorphic figurine, first described as a capride.[6] Subsequent to the recent examination, it seems more likely to represent a felid. The dating of this figurine is unclear, because the results of the archaeometallurgical investigations contradict the previous dating to layer IVB. MT03 (fig. 3) is an unregistered copper spearhead (Lamberg-Karlovsky and Potts 2001: 9, fig.1.26) from layer IVC2, which shows some parallels with Susa III artifacts from Susa (LeBrun 1971: fig. 67.1-3).

The artifacts from Shahdad are referred to as

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[1] This is a revised version of the archaeometallurgical chapter from my Masters thesis, first presented at the "Second International Workshop on Early Iranian Metallurgy (19-21 September 2007)" at the Department of Archaeology, University of Nottingham, England.

[2] Shahdad is located on the western margins of Dasht-e Lut, about 75 km east of Kerman.

[3] Tepe Yahya lies in the Soghun Valley, approximately 225 km south of Kerman and 30 km northeast of Doulatabad.

[4] Unanimity regarding the dating of Strata IVC-IVB is summarized in Lamberg-Karlovsky & Potts 2001, ch. 8 and following.

[5] All photos of sampled artifacts were taken by the author in June 2006, at the National Museum of Iran.

[6]This artifact was first presented as a steatite animal head (Lamberg-Karlovsky 1970: Fig. 21W). After the find registration at the National Museum of Iran and the subsequent archaeometallurgical analysis, it became obvious that this animal figurine was made of a copper alloy.

MT04-MT19. MT04 and MT05 (figs. 4,5) are copper adzes, which can be compared to type Gp.12 (Hakemi 1997: 638, Gp.12); on this basis, they are dated to TAKIII$_2$-TAKIII$_1$ the second half of the third millennium B.C. MT06 (fig. 6) is a copper dagger roughly dated to the period of TAKIII$_2$-TAKIII$_1$, due to other finds from Grave 142 (Hakemi 1997: 301, object no. 1494; 639, Gp. 2). The tapering bar MT07 (fig. 7), which was first presented in an unpublished Doctoral dissertation (Vatandoost-Haghighi 1977: 92, no.12; 1999: 128, no.12), and in the catalogue of the Bochum exhibit catalogue *Persiens Antike Pracht,* also dates to this period (Stöllner et al. 2004: 591, no. 63). Samples

Fig.1: *MT01 Shaft-hole axe from Tepe Yahya.*

Fig. 2: *MT02 Theriomorphic figurine from Tepe Yahya.*

Fig. 3: *MT03 Spear head from Tepe Yahya.*

Fig. 4: *MT04 Adze from Shahdad.*

Fig. 5: *MT05 Adze from Shahdad*

Fig. 6: *MT06 Dagger from Shahdad.*

MT08 (fig. 8) and MT19 (fig. 19) are derived from small copper shaft-hole axes which have parallels at Mundigak Level III6, the transition from the Late Chalcolithic to the Early Bronze Age (Casal 1961: vol. I, 249; Vol. II, plate XXXIX.B.10a). MT09 (fig. 9) likewise derives from a copper shaft-hole axe, which based on its shape, can be compared to MT01 from Tepe Yahya and to the above-mentioned parallels from Shahdad, Damin and Susa. A previously unpublished sickle blade-shaped knife, MT10 (fig. 10), has some parallels at Susa, although they lack such elaborate hilts (Tallon 1987: vol. I, 181, 595 [Sb9627]). An almost identical knife with a thickened hilt was found in Grave 80 in Cemetery A at Kiš and is dated to the end of the third millennium B.C. (Hauptmann and Pernicka 2004: plate 39, 657). MT11 (fig. 11) and 18 (fig 18) are copper chisels with parallels at Susa, from the transition from the third-second millennium B.C. (Tallon 1987: vol. I, 163, 462-70). Parallel finds of copper chisels are documented in Mesopotamia (Hauptmann and Pernicka 2004: plate 32, no. 498, 499; plate 86, 1321, 1322). MT12 (fig. 12), MT13 (fig. 13), MT14 (fig. 14), MT15 (fig. 15) and MT16 (fig. 16) are from copper pins, which correspond with the form variant I.1.3. MT17 (fig. 17), likewise a copper pin, belongs to the variant I.1.2. [1]

Fig. 7: *MT07 Tapering bar from Shahdad.*

Fig. 8: *MT08 Shaft-hole axe from Shahdad.*

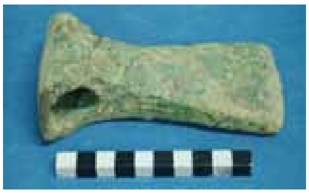

Fig. 9: *MT09 Shaft-hole axe from Shahdad.*

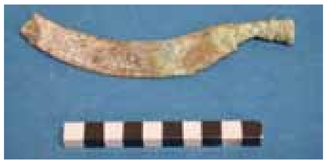

Fig. 10: *MT10 Knive from Shahdad.*

Fig. 11: *MT11 Chisel from Shahdad.*

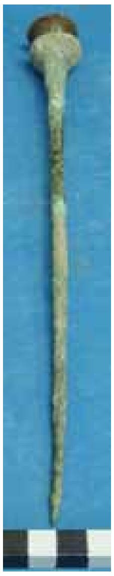

Fig. 12: *MT12 Needle from Shahdad.*

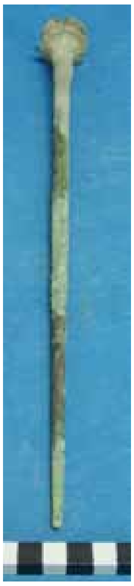

Fig. 13: *MT13 Needle from Shahdad.*

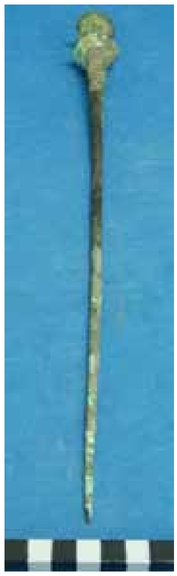

Fig. 14: *MT14 Needle from Shahdad.*

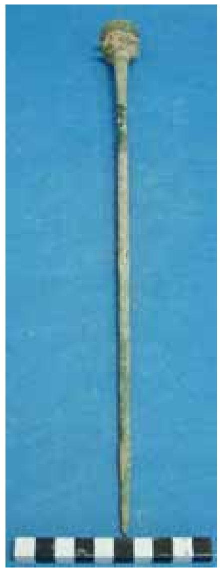

Fig. 15: *MT15 Needle from Shahdad.*

Archaeometallurgical Results (Table. 1):

Copper (Cu):

The highest copper content measured was 98%, in samples MT01 and MT10; the lowest was 85%, in MT02. The following discusses whether this should be considered pure copper or arsenic copper.

Tin (Sn):

The highest content of tin was measured in

[1] These classifications follow those of my unpublished Masters thesis, *Metal Needles and Pins from Shahdad: A Function Typological Approach* (Meier 2008).

Fig. 16: *MT16 Needle from Shahdad.*

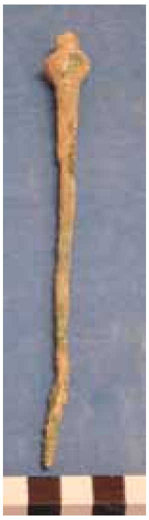

Fig. 17: *MT17 Needle from Shahdad.*

Fig. 18: *MT18 Chisel from Shahdad.*

Fig. 19: *MT19 Shaft-hole axe from Shahdad.*

Sample	Object	Exc. No.	Dating (B.C.)	Cu	Sn	Pb	As	Sb	Ni	Fe	Bi	Zn	Ag	Co
				%	%	%	%	%	%	%	%	%	%	%
MT 01	axe	3756	IV B5	98	0,009	0,13	0,64	0,014	0,05	0,53	0,01	0,2	0,029	0,29
MT 02	figurine	?	IV B	85	0,96	11,6	0,22	0,200	0,05	1,04	0,01	0,7	0,088	0,01
MT 03	spearhead	11571-54	IV C2	97	0,005	1,60	0,85	0,017	0,01	0,16	0,01	0,2	0,42	0,01
MT 04	adze	54-1356	2500-2000	96	0,005	0,36	2,84	0,031	0,02	0,39	0,01	0,2	0,015	0,01
MT 05	adze	298-1355	2500-2000	95	0,005	0,02	0,41	0,010	0,15	4,7	0,01	0,2	0,047	0,03
MT 06	dagger	169-1350	2500-2000	96	0,010	0,16	3,2	0,011	0,03	0,23	0,01	0,2	0,047	0,01
MT 07	tap.bar	170-1350	2500-2000	97	0,005	0,16	3,1	0,021	0,04	0,1	0,01	0,2	0,061	0,01
MT 08	axe	521-1350	2500-2000	96	0,005	0,26	3,8	0,017	0,06	0,18	0,01	0,2	0,063	0,01
MT 09	axe	522-1350	2500-2000	95	0,005	0,23	4,1	0,045	0,05	0,18	0,01	0,2	0,040	0,01
MT 10	blade	525-1350	2500-2000	94	0,84	0,13	2,41	0,119	2,31	0,2	0,01	0,2	0,014	0,02
MT 11	chisel	378-1350	2500-2000	96	0,071	0,79	1,12	0,045	0,52	1,03	0,01	0,2	0,018	0,05
MT 12	pin	515-1350	2500-2000	96	0,029	0,10	3,3	0,025	0,16	0,32	0,01	0,2	0,046	0,01
MT 13	pin	509-1350	2500-2000	95	0,005	0,02	4,3	0,005	0,09	0,45	0,02	0,2	0,049	0,01
MT 14	pin	405-1350	2500-2000	92	0,005	0,13	6,5	0,008	0,01	1,35	0,01	0,2	0,079	0,01
MT 15	pin	282-1350	2500-2000	94	0,005	0,05	4,5	0,005	0,03	0,91	0,01	0,2	0,005	0,01
MT 16	pin	242-1352	2500-2000	96	0,008	0,24	3,4	0,006	0,01	0,16	0,01	0,2	0,002	0,01
MT 17	pin	250-1352	2500-2000	94	0,006	0,13	5,0	0,010	0,13	0,25	0,01	0,2	0,103	0,01
MT 18	chisel	220-1352	2500-2000	97	0,005	0,09	2,45	0,012	0,03	0,75	0,01	0,2	0,009	0,01
MT 19	axe	208-1352	2500-2000	98	0,012	0,41	1,13	0,094	0,01	0,17	0,02	0,2	0,34	0,01

Table 1: *The results of the EDXRF-analysis 2007.*

MT02 with 0.96%. In the majority of the sampled items (MT03, MT04, MT05, MT07, MT08, MT09, MT13, MT14, MT15, and MT18), no trace of tin measured above 0.005%. The lack of tin in the other objects was also remarkable. Only two objects, each with a tin content of nearly 1%, can be called bronze, although such small amounts of tin do not measurably affect the properties of alloys.

Lead (Pb):

The highest content of lead, 11.6%, was measured in MT02. This strongly indicates that this artifact did not originate in Bronze Age cultural horizons. The use of lead to improve liquidity already began during the Late Uruk Period, and was very common in Mesopotamia (Rapp 1988: 24; Pernicka 1995: 54; Reiter 1997: 113-14).

Arsenic (As):

The highest content of arsenic is 6.5%, from MT14; the lowest is 0.22%, from MT02. The low content is associated with a lead content of 11.6% and a tin content of 0.96%. The analysis of MT02 differs in many aspects from that of the other sampled artifacts. The majority of artifacts contain arsenic copper, in strongly diverging patterns. A similar pattern can be observed with the bronze finds from Ilıpınar (Begemann et al. 1994: 205-9). The arsenic was not added for its deoxidant properties (Northover 1989: 111-112). E. Pernicka observes that arsenic is a common element in copper ores, and that such small concentrations can be considered unintended or natural impurities (Pernicka 1999: 47-56).

Antimony (Sb):

The highest concentration of antimony was measured in MT02 (0.2%); the lowest in MT13 and MT15 (0.005%). The results for antimony are consistently low. The mean is 0.028%, with a standard deviation of 0.031%.

Nickel (Ni):

MT10 stands out of the corpus with 2.31%. With the exception of MT11 (0.52%), all other concentrations were lower than 0.2%.

Silver (Ag):

The highest silver content was measured in MT03 (0.42%); the lowest was in MT16 (0.002%).

Evaluation of the Archaeometallurgical Results:

All artifacts other than MT02 can be designated as arsenic copper, because their average copper content is over 95%, with the arsenic content varying from 0.5%-6.5%. This is considered an unintentional addition of arsenic, or else natural impurities. There is no unanimity among scholars about the highest amount of arsenic allowable in arsenic copper (Charles 1971: 21-24; Lechtman 1996: 481, 501; Pernicka 1995: 47-56).

MT02 has an unusually high lead content (11,6%), which was added to improve the flowing of the copper (Rapp 1988: 24; Reiter 1997: 113). This artifact also has a tin content of almost 1%, which is a typical for locally produced artifacts, copper with lead added in such a high concentration was very common in Mesopotamia and Susiana in this period, and is unknown in locally produced south Iranian metal artifacts, suggesting that MT02 was an import. MT10 and MT11 differ from the remaining samples, which were taken because of their high concentration of nickel in combination with their high arsenic content. This leads to the assumption that the ore body was As-Ni-minerals, like Gersdorffit (NiAsS; Pernicka 1999: 164). MT10 also contains tin (0.84%).

With regard to MT12-MT16, and all the variants I.1.3., only one well stratified parallel was found outside Shahdad, in Pit X, Grave B.64 in the Royal Cemetery of Ur (Wolley 1955: 131, 201, Table 29, U19191). Archaeometallurgical investigations conducted by E. Pernicka and J. Lutz (Hauptmann and Pernicka 2004: 76, 1864, table 120) indicate that the needle found at Ur might be imported. Beyond the technical and formal similarities and the uniqueness of that item at Ur and other Mesopotamian sites, the comparison of their chemical contents is most striking. The “Ur”-needle (fig. 20)[1] is about 98% copper and 1.38% arsenic (Hauptmann and Pernicka 2004: 138), which fits perfectly with the average values of 95% copper and 4.4% arsenic in the samples from MT12-MT16. The differences are negligible, supporting the hypothesis that it was imported. Based on the logarithmic table of all sampled items based on their arsenic and nickel content, a division of the “Shahdad”(MT04, MT06, MT08, MT09, MT10, MT12, MT13, MT14, MT15, MT16, MT17, MT18) and “Tepe Yahya“ material (MT 01, MT03) can be discerned. This suggests that the raw materials needed for the production of the metal artifacts belong to one deposit area. However, due to the comparatively small sample of artifacts and our limited knowledge about the situation of mining archeology in

[1] This drawing is reproduced with the permission of E. Pernicka.

Southeast Iran, this hypothesis remains unproven.

The results of the analysis of MT02 from Tepe Yahya emphasize its exceptionality and suggest that it was imported.

MT05, MT11 and MT19, all from Shahdad, appear outside the cluster of Shahdad artifacts on the right of the diagram (fig. 21). This suggests that these artifacts were not made of local raw materials, but the provenience of the deposits from which they were made remains uncertain.

Data comparable to the Shahdad material was published in 1999 by A. Vatandoost-Haghighi (Vatandoost-Haghighi 1999: 128-131, table 2, 1-16d); the first presentation of this material was in his 1977 doctoral dissertation. In it, he analyzed 164 Bronze and Iron Age metal artifacts from Iran (Vatandoost-Haghighi 1977: 81-96, table 1, 225-226). The results of his nineteen analyses on needles and axes from Shahdad support the recent analysis, as there is no deviation. The only difference is due to limitations in the earlier methods of measurement. Cobalt, zinc and gold could not be detected; antimony and tin could only occasionally be detected. It is, therefore, hardly surprising to find just a few of Vatandoost-Haghighi´s results displayed in the plotted diagram (see figs. 22, 23). Instead, all results of analyzed artifacts from Shahdad are shown on the diagram that presents the relation between the elements Ag and Sb. This confirms the homogeneous character of the Shahdad metal materials.

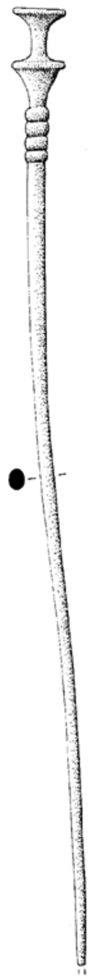

Fig. 20: *Needle from Ur.*

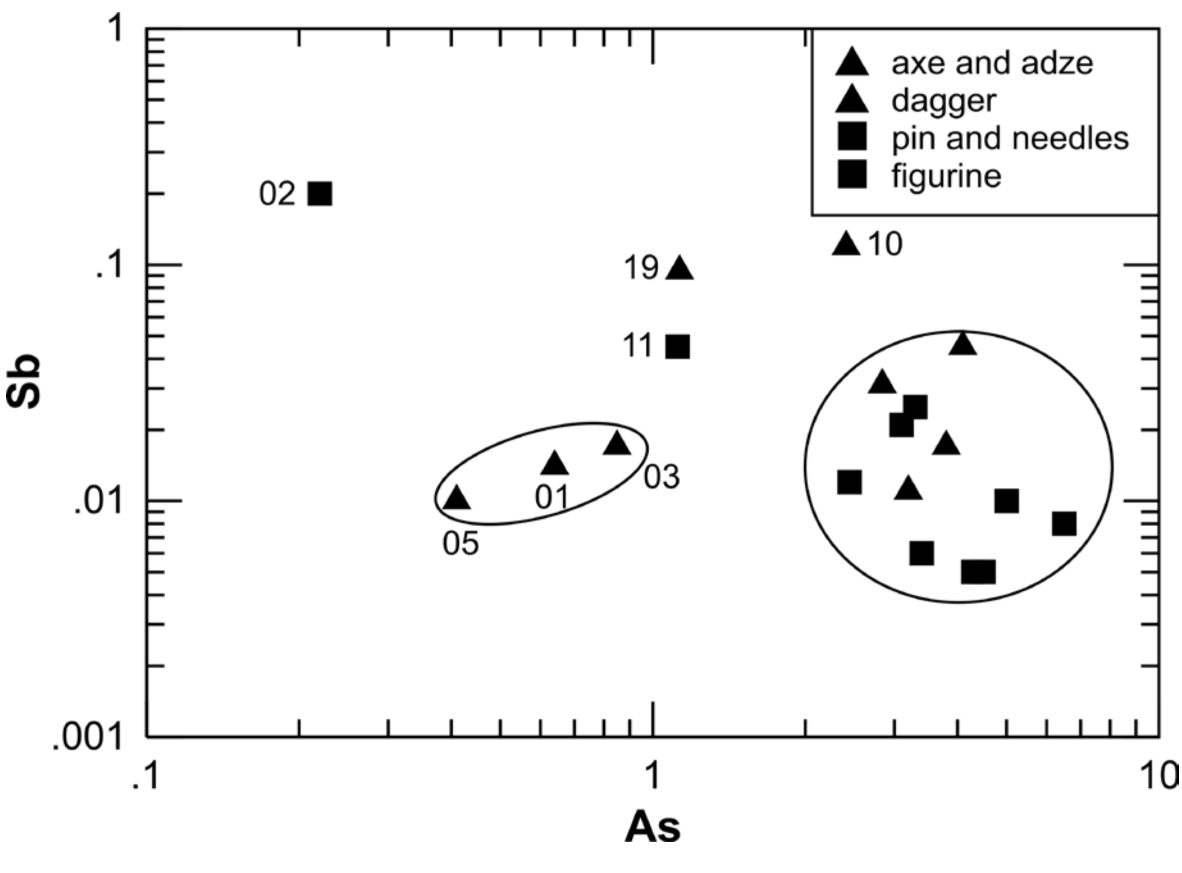

Fig. 21: *As vs. Sb scatter diagram of samples MT01 to MT19 from Tepe Yahya and Shahdad in Southeast Iran.*

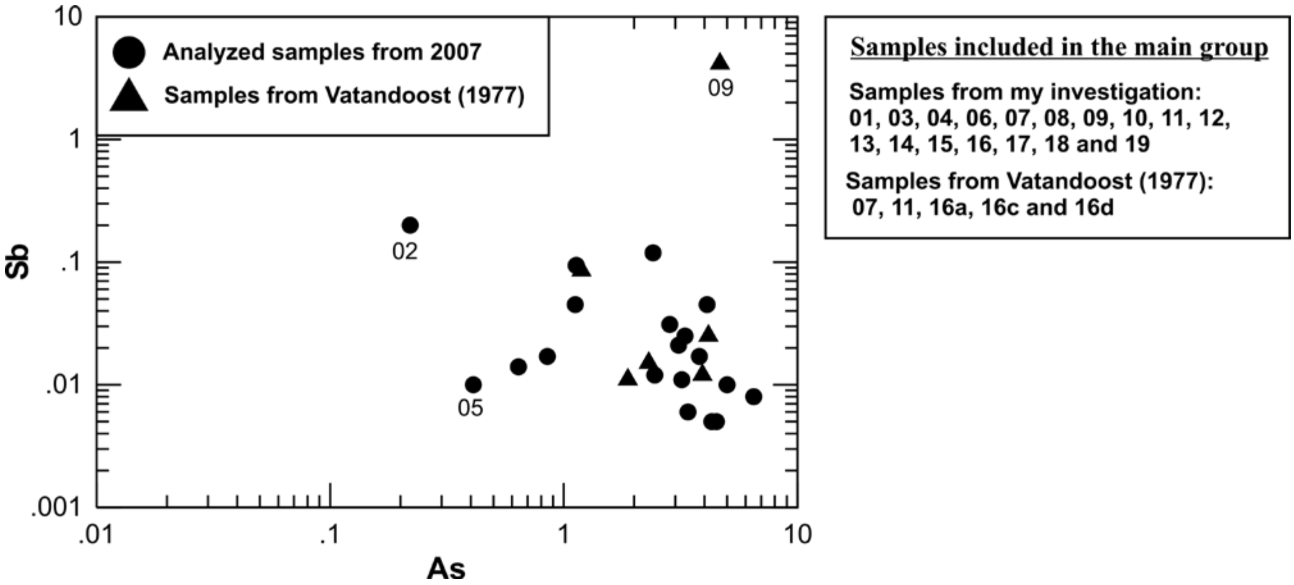

Fig.22: *As vs. Sb scatter diagram of samples from Tepe Yahya and Shahdad. Analysis conducted by Vatandoost-Haghighi (1977) and the author in 2007.*

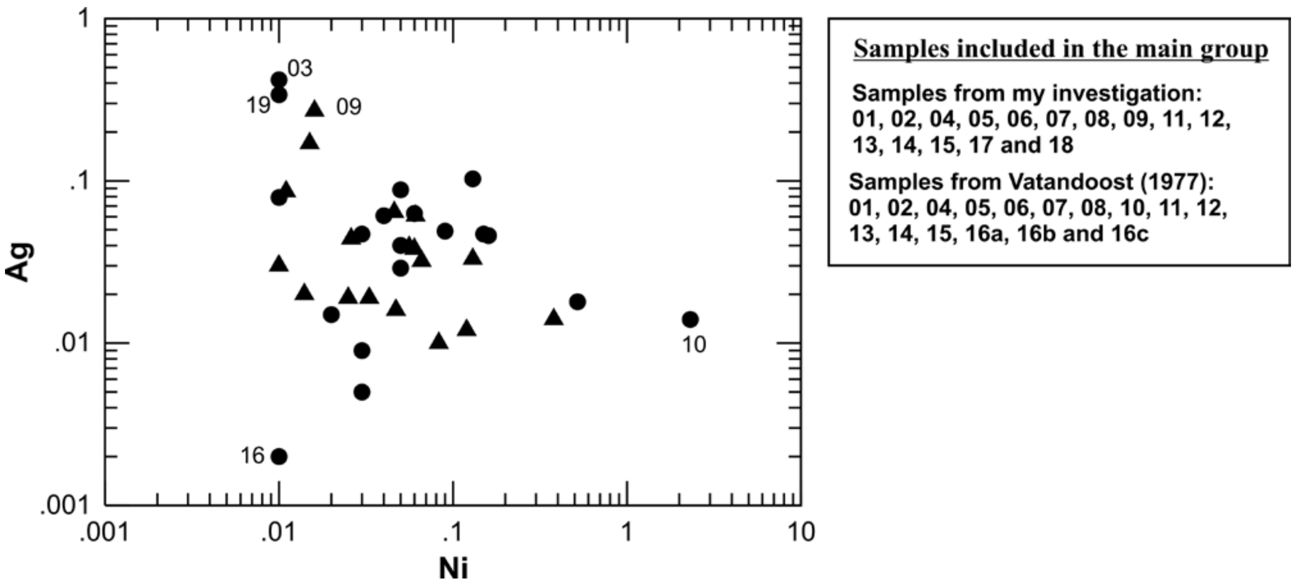

Fig. 23: *Ag vs. Ni scatter diagram of the analysis results from Tepe Yahya and Shahdad conducted by Vatandoost-Haghighi (1977) and the author in 2007.*

Conclusion:

Since the investigations of D. Bazin and H. Hübner, T. Berthoud and more **(**Bazin and Hübner 1969; Berthoud et al. 1982; Pigott 1999: 113-14; Schürenberg 1963: 200-30), scientists have determined that the copper ore deposits from Talmessi and Meskani in the region of Anarak contain arsenic-enriched copper minerals like Domeykite (Cu_3As) and Algodonite($Cu_{5.2\text{-}8}As$), which had been exploited in prehistoric periods (Pigott 2004: 30; Heskel and Lamberg-Karlovsky 1980: 258-59). Dasht-e Lut is surrounded by rich copper ore deposits, at which traces of ancient metallurgical activities can be documented (Abbasnejad-Sereshti 2003/1382: 68-72). It seems likely that the people of the Shahdad region exploited nearby deposits rather than traveling hundreds of kilometers through the desert to the copper deposits from Talmessi and Meskani.

Unfortunately, most of the more recently discovered areas of mining and metallurgical activities in the region of Dasht-e Lut have not been studied. Only R. Abbasnejad-Sereshti, an archaeologist from the University of Mazandaran (Iran), utilized a new approach to southeast Iranian archaeometallurgy. For his Masters thesis, he surveyed the area, investigating prehistoric metallurgical activities at sites with traces of mining, or with traces of workshops, or with traces of both activities (Abbasnejad-Sereshti 1994). Further archaeometallurgical research is desirable.[1] Recent studies of the deposits from Sheikh Ali, in the region surrounding Tepe Yahya, confirm the occurrence of copper minerals exploited during prehistoric periods (Rastad et al. 2002). Lead isotope analysis of this material is not complete and the connections between the metal artifacts from Tepe Yahya and the ore deposits from Sheikh Ali remain uncertain.

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[1]See, too, Momenzadeh 2004: 20.

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