NEUTRON ACTIVATION ANALYSIS. WHERE WAS THE DOLPHIN JAR MADE?

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Chemical analysis of trace and minor elements of archaeological pottery will give an elemental concentration pattern that is characteristic of the clay paste an ancient potter prepared and used to produce his wares. If a large number of concentration values is measured, at least 20 elements, better more, this pattern can be assumed to be unique for each paste or production series of a workshop and, therefore, points not only to the producing workshop, but, more specifically, to each of the possible different clay pastes prepared at this workshop. Provenance can be established by comparing the chemical pattern of a pottery sample with the measured data of reference material of known provenance. This method to determine provenance and to distinguish locally produced wares from imports is well accepted today and used especially for fine wares poor in temper and inclusions and, therefore, difficult to classify by other methods as e. g. petrographic analysis.

A sample (SIDO 20) of 80 mg of pottery powder from the dolphin jar vessel (S/1785) (see Doumet-Serhal, p. 40 in this issue), taken by a clean sapphire drill, was subjected to the routine Bonn Neutron Activation Analysis (NAA) procedure described at length in Mommsen *et al.* 1991. As standard the Bonn pottery standard was used which is calibrated with the well-known Berkeley pottery standard (Perlman and Asaro 1969). Therefore, our data can be compared directly to the published concentration patterns of this and the Perlman Jerusalem archaeometry laboratories.

The measured elemental concentrations C in the sample of the dolphin jar, together with the measurement errors δ, are shown in Table 1, 2nd and 3rd column. This pattern was then compared with our own databank of known patterns from the eastern Mediterranean and, in addition, with published NAA patterns of the Berkeley and Jerusalem laboratories using the Bonn statistical filter program to sort out similar patterns (Beier and Mommsen 1994). No statistically good match could be found in our databank that mainly holds Greek and East-Greek reference patterns and only a few data sets from other regions of the eastern Mediterranean. But a number of not very different patterns, all pointing to the Levant, have been found in publications of the Berkeley and Jerusalem laboratories. Before the comparison, the old literature values have been corrected for Cr (11.4 /% up) and Yb (5.7 /% down), if given, according to a re-calibration of the Berkeley pottery standard (Strange *et al.* 1995, p. 186).

As examples, the three patterns found in publications that statistically match the dolphin jar sample best are presented in Table 1. The values of a pattern formed of 14 samples from Iron Age II pottery (BEER SHEBA) and assumed to be produced in the area of Beer Sheba is shown in columns 3 and 4 (from Gunneweg and Mommsen 1990, Table 2, last column, adjusted by a best relative fit factor of 0.80 with respect to the dolphin jar sample). Given are the average concentration values M and their spreads (root mean square deviation) σ for 16 elements. A larger concentration difference is found only for the element Hf. This element is also different for the two other patterns from Palestine shown in Table 1. In columns 5 and 6 the 19 elemental values of nine pottery pieces of plain-coarse wares (MEVORAKH-CW, Iron Age cooking pots and Iron Age jars), made presumably at or near Tell Mevorakh are listed (from Yellin and Perlman 1978, Table 3, column 2, multiplied here with fit factor 0.92). As further example, the pattern of five sherds excavated at Tell Qasile, stratum VII, 7th century B. C., is shown in columns 7 and 8 (QASILE-VII, from Yellin and Gunneweg 1985, Table 16, column 1 and repeated in Table 17, column 6, here with fit factor 0.90 [in the text these tables are named Table 10 and 11, respectively]). This pattern has been reported to be not very different from patterns of several sites situated south of Tell Qasile (patterns also given in Table 17 of this reference: Deir el-Balah, Ajjul, Ashkelon, Ashdod). The five Iron Age sherds are therefore assumed to be imports from some southern site to Tell Qasile.

The general similarity of the dolphin jar pattern with these and other patterns from Palestine suggests a local provenance from this area, especially, since all available patterns from Greece, Turkey and Cyprus are very different in many elements. As shown by the best relative fit factors given in Table 1, the clay paste used for the dolphin jar vessel has 10 – 20 % lower concentrations for all elements compared to the other Palestine patterns except for Ca, it seems to be diluted mainly by Ca-carbonate. To determine the producing workshop of the fish jar exactly - was it made locally at Sidon or imported from some other site in Palestine to Sidon - is not yet possible. More reference material from Palestine is needed.

Table 1:

Concentrations of 29 elements C in µg/g (ppm), if not indicated otherwise, and relative measurement errors δ (in %) measured by NAA in Bonn for the fish jar sample compared with some concentration patterns from literature (see text). The average concentrations M from literature have been corrected by a best relative fit factor (factor) with respect to C and are also given in µg/g (ppm) or %, if indicated. Their spreads (root mean square deviations) σ are in % of M.

	SIDO 20 (fish jar) 1 sample factor 1.00		BEER SHEBA 14 samples factor 0.80		MEVORAKH-CW 9 samples factor 0.92		QASILE-VII 5 samples factor 0.90	
	C	+/- δ (%)	M	+/- σ (%)	M	+/- σ (%)	M	+/- σ (%)
As	14.6	0.9	-		-		-	
Ba	711.	2.2	-		-		-	
Ca %	13.5	1.7	6.16	40.	12.1	18.	4.05	76.
Ce	72.4	1.2	-		65.0	9.3	-	
Co	18.2	0.6	19.1	7.9	18.7	15.	19.2	11.
Cr	109.	0.7	111.	12.	104.	9.4	94.1	5.9
Cs	2.86	2.5	1.84	26.	1.33	22.	1.90	23.
Eu	1.28	1.8	-		1.44	8.3	-	
Fe %	3.89	0.4	3.69	6.7	3.52	8.9	4.13	14.
Hf	4.75	1.2	10.8	16.	8.28	29.	8.46	16.
K %	0.76	3.2	-		-		-	
La	29.6	0.3	29.0	4.7	31.9	4.6	30.5	4.4
Lu	0.41	3.5	0.42	7.5	0.48	12.	0.43	4.2
Na %	0.12	2.2	0.40	18.	0.37	23.	0.45	21.
Nd	27.6	2.9	-		-		-	
Ni	82.0	35.	55.2	20.	84.6	17.	90.0	15.
Rb	53.9	3.4	55.2	19.	-		47.7	15.
Sb	0.69	7.9	-		-		-	
Sc	12.8	0.2	12.4	5.2	12.1	5.3	3.5	13.
Sm	5.01	0.2	-		5.91	7.2	-	
Ta	1.05	2.8	1.20	10.	1.13	8.9	1.12	4.8
Tb	0.68	6.0	-		-		-	
Th	7.59	0.7	7.84	7.1	7.47	12.	7.10	8.1
Ti %	-		0.59	16.	0.38	22.	-	
U	1.60	6.5	2.08	15.	1.76	10.	1.51	15.
W	1.25	15.	-		-		-	
Yb	2.70	2.3	-		3.38	11.	-	
Zn	65.8	2.8	-		-		-	
Zr	112.	22.	-		-		-	

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