Neutron Activation Analysis of a bichrome sherd excavated at Tell Kabri, Palestine

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A bichrome wheel made pottery sherd excavated at Tell Kabri (Area D, No B 2114, L611)has been submitted to the Bonn archaeometry laboratory for analysis to determine its production place. According to archaeological research, this sherd was made in Cyprus which had to be ascertained archaeometrically.

It is well accepted today (Mommsen 2007), and already since many years (Perlman and Asaro 1969) that the minor and trace elemental abundances in pottery are characteristic for the clay paste that was prepared by the ancient potters using a certain, fixed recipe. All products of such a production series of one or of several workshops in a pottery centre using the same clay and recipe may be recognized comparing their elemental composition. For workshops in different regions and even for different production series in a single pottery workshop these patterns are assumed to show measurable differences. This is the so-called provenience postulate formulated by Weigand et al. 1977 for clay sources and by Mommsen 2004 for pastes. This assumption of the uniqueness of the elemental pattern has certainly a high probability to be true, if as many elemental concentrations as possible are measured with small experimental uncertainties.

To locate the geographical origin of a pattern in a pottery sherd reference material of known provenance for comparison must have been analysed before. The database of the Bonn laboratory holds now more than 8000 samples from the Eastern Mediterranean, among them many reference pieces, so that the chances to find an already known pattern in a sherd that can be assigned to a certain production place are high.

The analysis method in use here since more than 20 years is the Neutron Activation Analysis (NAA)which is well suited for provenancing of pottery. The analytical procedure is described at length in Mommsen et al. 1990. 80 mg of pottery powder is usually sufficient for a measurement. After irradiation with thermal neutrons each sample is measured four times to increase the reliability of the data. As concentration standard a pottery standard prepared in Bonn and calibrated with the Berkeley pottery standard (Perlman and Asaro 1969) is used. About 30 elemental concentrations can be determined, if present above the detection limit. The pattern comparison is done with a statistical package developed in Bonn (Beier and Mommsen 1994). It is able to take the experimental uncertainties which are different for each elemental value, as well as possible dilutions of the clay paste by varying amounts of e. g. pure sand or calcite into account. A higher amount of sand admixed to the clay paste will lower the concentration values of all elements except for Si and O, both not measured by NAA in Bonn. Without this correction diluted members of a group will not be recognized (Mommsen and Sjöberg 2007). The elements As, Ba, Ca, and Na are not considered during the best relative fit calculation and during the pattern comparison, since they often vary in products of a workshop due to differences in the preparation or firing procedures or due to burial conditions.

In Table 1 the concentration data of the sherd from Tell Kabri named TeKa 6 are given together with the experimental counting uncertainties (Column 1 and 2). This pattern matches statistically for many elements a pattern of now 61 samples assigned to a general Cypriot origin called CYPH, shown in Table 1, column 3 and 4. Pattern CYPH, published already by Mountjoy and Mommsen 2001, D'Agata et al. 2005, and Mommsen et al. 2005, varies for some elements which can be measured with high precision as e. g. Co with a spread (root mean square deviation)of 12 % or Cs with a spread of 17 %. Therefore it must be assumed that several different, but still geochemical related patterns corresponding to slightly different pastes are summed up in this large group CYPH. Eighteen members of this group stem from the finding site Sinda, Cyprus (Mommsen and Sjöberg 2007), and, due to distribution arguments only, may point to an origin of this pattern from there. But since we have no other material for Cyprus, let alone good reference material, other production sites in that area cannot be excluded. The remaining samples of this group are all from finding sites outside Cyprus, from Egypt or Palestine like the sherd TeKa 6. They represent according to the status of current research Cypriot exports and, therefore, cannot be used to locate the sites of the producing workshops at Cyprus. A second pattern CHKR with 6 members also from the site Sinda and not very different from CYPH is shown in Table 1, column 5 and 6. If the concentrations of CHKR are lowered by a best relative fit factor with respect to CYPH of 0.88, differences in the concentrations of K and Rb, which are lower, and Cs which is higher, are seen. These are the elements which also vary for sample TeKa 6 compared to group CYPH. More samples from other sites in Cyprus have to be analysed to explain this variation of the alkali elements in the Cypriot groups. Nevertheless, the statistical assignment of the pattern of sherd TeKa 6 to a Cypriot origin is unquestionable. No other patterns in our databank are close in composition except the Cypriot groups.

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Table 1:
Concentrations C of elements measured by NAA for sample TeKa 6 and concentration averages M for reference groups CYPH and CHKR in µg/g (ppm), if not indicated otherwise, and errors δ and spreads σ, respectively, in percent of M. Factor is the best relative fir factor with respect to group CYPH.

	TeKa 6		**CYPH**		**CHKR**	
	1 sample		61 samples		9 samples	
	factor 0.98		factor 1.00		factor 0.88	
	M ± δ(%)		M ± σ(%)		M ± σ(%)	
As	9.48	(0.8)	11.7	(82.)	5.54	(32.)
Ba	603.	(2.5)	551.	(38.)	316.	(39.)
Ca%	11.4	(1.5)	12.1	(39.)	11.0	(12.)
Ce	40.2	(1.6)	39.2	(4.8)	38.4	(1.6)
Co	25.1	(0.5)	20.4	(12.)	20.4	(6.9)
Cr	304.	(0.4)	287.	(13.)	294.	(12.)
Cs	1.90	(3.9)	3.36	(17.)	4.67	(11.)
Eu	0.97	(2.1)	0.97	(5.3)	0.93	(2.1)
Fe%	4.76	(0.3)	4.15	(5.7)	4.37	(4.0)
Ga	9.04	(14.)	13.1	(29.)	15.0	(17.)
Hf	2.96	(1.7)	2.99	(6.8)	2.87	(2.5)
K %	1.07	(1.2)	1.71	(10.)	0.94	(33.)
La	18.9	(0.6)	19.8	(3.7)	20.3	(1.7)
Lu	0.34	(3.7)	0.34	(6.8)	0.33	(5.6)
Na%	0.81	(0.5)	1.10	(24.)	1.31	(12.)
Nd	17.2	(3.8)	17.5	(8.9)	20.4	(6.7)
Rb	39.5	(4.3)	61.0	(13.)	35.6	(31.)
Sb	0.55	(10.)	0.73	(28.)	0.77	(41.)
Sc	19.0	(0.1)	18.0	(5.4)	18.5	(2.8)
Sm	3.65	(0.2)	3.50	(8.4)	3.83	(3.5)
Ta	0.58	(4.6)	0.58	(6.2)	0.58	(4.2)
Tb	0.56	(7.6)	0.56	(7.6)	0.55	(7.8)
Th	6.10	(0.8)	6.05	(6.8)	6.60	(3.2)
U	1.63	(5.4)	2.46	(24.)	2.97	(6.7)
W	1.34	(8.1)	1.41	(17.)	1.19	(22.)
Yb	2.07	(2.3)	2.15	(5.8)	2.09	(3.0)
Zn	83.6	(2.2)	103.	(29.)	80.7	(25.)