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Chemical Study of Basaltic Hopper-Rubber (Olynthus) Mills from Naḥal Tut and 'En Ḥofez

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Four basalt stones of 'hopper-rubber' or 'Olynthus' mills[1] were sampled for chemical composition. Samples 1 and 2 are upper (*meta*) and lower (*catillus*) stones of a complete Olynthus mill found during the excavations of Naḥal Tut (Nos. 224/2065, 299/2467; Alexandre, this volume: Fig. 59). Sample 3 is the upper stone (*meta*) of an Olynthus mill (No. surface/3222) and Sample 4 is a piece of an unrelated flat lower stone (*catillus*), both from the excavations at 'En Ḥofez (No. 368/3872; see Alexandre 1997 for a brief summary of the excavation). All have been dated on stratigraphic evidence to the second half of the fourth century BCE. The aim of the present study was to define the source of the basalt. A simple visual examination of the four samples indicated that the first three were produced from a fine, dense basalt and the fourth from a considerably rougher, more porous stone.

The analytical laboratory received samples that had been taken from the mills by sawing the stones and pulverizing the debris. In one case (Sample 3), both powder and a piece of stone were submitted for analysis, enabling comparison for the purpose of determining whether any contaminations had taken place during sample collection. The piece of stone was ground in an agate mortar in the analytical lab. Chemical analyses of major elements were performed using fusion with lithium metaborate followed by measuring concentration with an inductively coupled plasma atomic emission spectrometer (ICP-AES), Perkin Elmer Optima 3300. Elements Rb, Nb, Mo, Pb, Th and U were determined using sintering with sodium peroxide and measuring with an ICP-mass spectrometer (ICP-MS), Perkin Elmer Sciex Elan 6000. The other elements were analyzed by an ICP-AES Jobin Yvon JY-48 (See Tables 1 and 2 for the chemical composition of the samples).

Unfortunately, the results obtained for zinc (Zn), cobalt (Co), nickel (Ni) and copper (Cu)

Table 1. Chemical Composition of Basalt Objects

Trace Elements (in ppm)

Sample No.		Zn	Co	Ni	Ba	Cr	V	Be	Cu	Yb	La
1	224/2065	218	100	128	320	46	202	1.22	728	2.8	17
2	299/2467	226	323	388	321	53	179	1.18	3036	2.6	17
3*	Surface/3222	232 (80)	331 (60)	407 (55)	324	48	200	1.24	3103 (30)	2.9	14
4	368/3872	255	252	955	530	253	235	1.34	2793	2.5	18

Trace Elements (in ppm) (cont.)

Sample No.		Y	Eu	Sr	Rb	Nb	Mo	Ce	Pb	Th	U	Zr
1	224/2065	21	0.74	496	30	17	5.3	40	7	4.2	1.10	162
2	299/2467	21	0.57	473	31	15	2.0	39	11	3.5	1.08	156
3	Surface/3222	22	0.12	497	34	16	2.1	42	9	3.7	1.15	161
4	368/3872	21	0.70	626	11	40	2.5	44	4	1.9	0.80	172

* Results in brackets are from the stone pulverized in the analytical laboratory.

Table 2. Chemical Composition of Basalt Objects

Major Elements (in wt%)												
Sample No.		SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	MnO_2	Na_2O	K_2O	P_2O_5	L.O.I.
1	224/2065	54.67	19.01	7.37	0.97	9.02	4.74	0.12	3.50	1.12	0.3	<0.01
2	299/2467	53.86	18.17	7.28	0.94	9.46	4.64	0.12	3.30	1.11	0.2	<0.01
3	Surface/3222	54.77	18.59	7.43	0.95	8.86	4.94	0.12	3.40	1.16	0.3	0.07
4	368/3872	43.04	14.81	13.34	2.56	10.30	9.68	0.18	2.63	1.07	0.5	0.39

in the powders were not useful because of the contaminations caused by the saw during the sampling (compare results for Sample 3, carried out from the powder and from the stone, in Table 1). As demonstrated in Tables 1 and 2, Samples 1–3, all hopper-rubbers, are similar in composition, while Sample 4, the flat stone, has a higher content of Fe, Ti, Mg, Ba, Cr, Sr, and Nb and a lower content of Si, Al, Na, Rb and Th.

The comprehensive data published by Williams-Thorpe and Thorpe (1993) were used to establish the provenance of the objects studied. The flow diagram (see Williams-Thorpe and Thorpe 1993: Fig. 8) and the calculated ratios for the elements determined in our samples are shown in Fig. 1. A comparison of our results with the geological fields defined in Williams-Thorpe and Thorpe (1993: Figs. 10–17) yielded several conclusions. In the plot TiO_2 vs. Zr, Samples 1–3 are located in the Island Arc lavas and Sample 4, in the Within-Plate fields. Plot K_2O vs. SiO_2 was used in order to determine the relationship between Samples 1–3 and Aegean or Anatolian fields. Our results fall in the Hellenic Island Arc zone. The graph of Sr vs. Ba also shows that these three samples originated in the area of the Aegean islands. Finally, plots Ba vs. Th and Rb vs. Sr show further that the samples correspond to the basalt found on the Island of Nisyros.

Sample 4 was determined to be Within-Plate, and further examination using TiO_2 vs. Zr revealed compatibility with the Levant, rather than with the Egypt zone. The Fe_2O_3 and TiO_2 contents in this sample correspond to both Israel and the northern Syria fields. At the same time, plot Nb vs. Sr helps elucidate the exact provenance of this sample: the area west of Tiberias.

In conclusion, the chemical examination has established that three of the four hopper-rubber millstone samples (the lower and the upper stones from Naḥal Tut and the upper stone from ‘En Ḥofez) were manufactured in the area of Nisyros in the Aegean region. This is compatible with the research carried out by Williams-Thorpe and Thorpe, which has indicated that the quarries at Nisyros specialized in the manufacture of hopper-rubbers (Williams-Thorpe and Thorpe 1991:57). The lower mill stone from ‘En Ḥofez, on the other hand, is of local manufacture.

NOTE

[1] For a comprehensive article on this type of mill, see Frankel 2003.

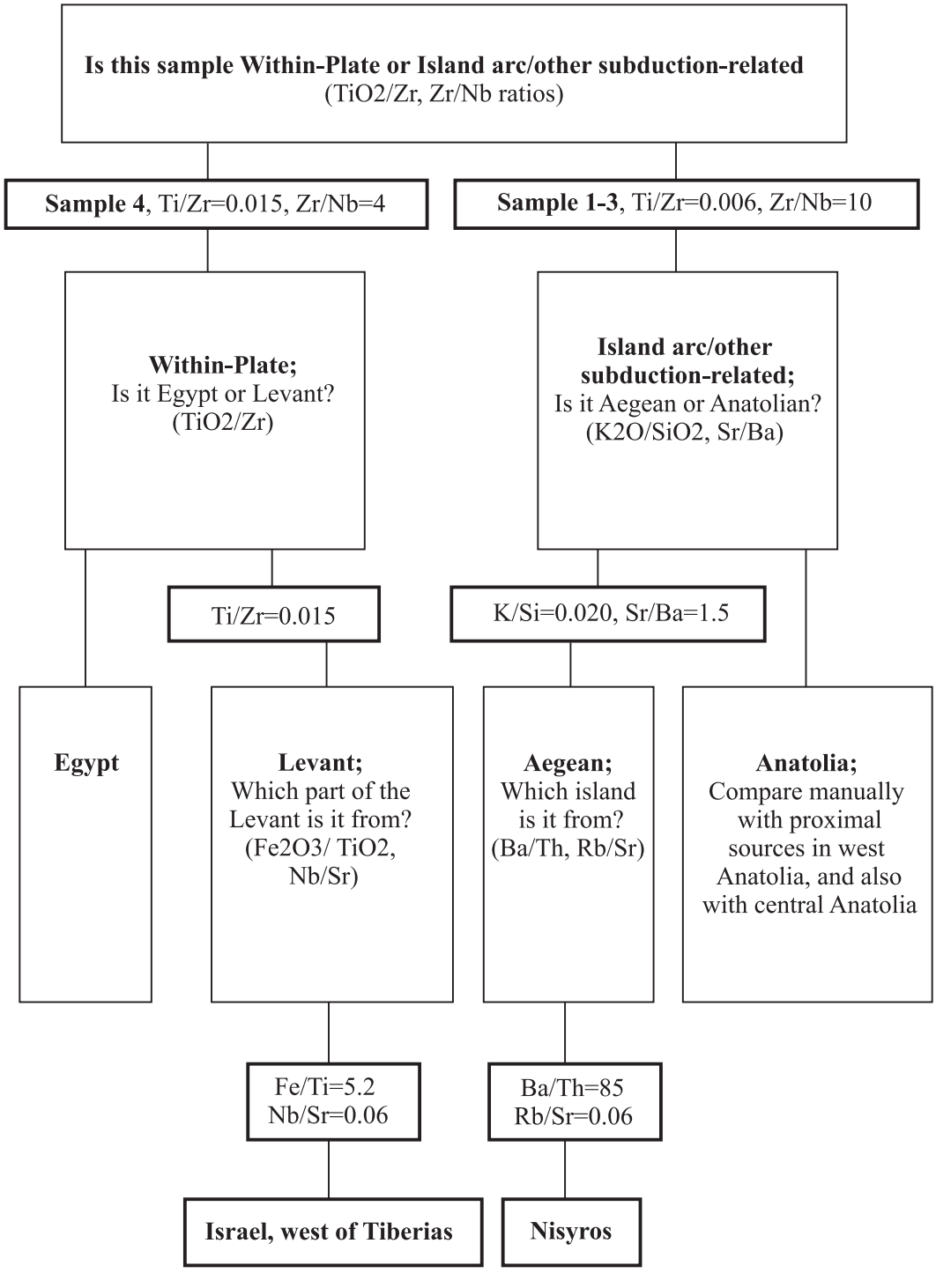

Fig. 1. Flow diagram showing the procedure for the provenancing of millstones to geological sources in the Mediterranean region (after Williams-Thorpe and Thorpe 1993). Our data are presented in the bold frames.

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