ABRASIVE SUPPLY FOR ANCIENT EGYPT REVEALED

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In the framework of the major research scheme "Synchronization of Civilizations in the Eastern Mediterranean Region in the 2nd Millenium B.C" instrumental neutron activation analysis (INAA) was used to determine 30 elements in pumice from archaeological excavations to reveal their specific volcanic origin. In ancient time, the widespread pumiceous products of several eruptions in the Aegean region have been used as abrasive tools and were therefore popular trade objects. The correlation of such archaeological findings to a specific eruption of known age would therefore allow to certify a maximum age of the respective stratum ("dating by first appearance").

Eruptions that produced relevant pumice quantitites took place on Santorini (Thera), Kos, Gyali, Nisyros and Milos. The youngest and of highest interest for archaeological purposes is the "Minoan Eruption" at Santorini, which is assumed to have happened between 1450 and 1650 B.C.[1,2]. The huge explosive character of this eruption, and the large amount of erupted material (several km^3) provide earth scientists and archaeologists with an important time-synchronous stratigraphic marker horizon of pumice and pumiceous tephra that allows to correlate sites across entire regions[3].

Essential to an identification of the primary volcanic source is the knowledge that pumices from the Aegean region can easily be distinguished by their trace element distribution patterns. This has been shown by previous studies of our working group[4-6]. The elements Al, Ba, Ca, Ce, Co, Cr, Cs, Dy, Eu, Fe, Hf, K, La, Lu, Mn, Na, Nd, Rb, Sb, Sc, Sm, Ta, Tb, Th, Ti, U, V, Yb, Zr and Zn were determined in 16 samples of pumice lumps from excavations in Tell-el-Dab`a and Tell-el-Herr (Egypt). Two irradiation cycles and five measurement runs were applied. To show the accuracy of the results obtained, typical samples of the most important pumice sources in the Aegean region, particulary from Milos, Nisyros, Kos and Thera were analyzed together with the Egyptian samples of unknown origin. A reliable identification of the samples is achivied by comparing these results to the database compiled in previous studies[4,5]. The geographical positions of these islands are shown in Fig. 1.

Fig. 1: Geographical situation

Sampling

The main objects of investigation were 15 samples of pumice found in archaeological context during excavations in Tell-el-Dab`a and 1 sample from Tell-el-Herr (Egypt). After surface cleaning with distilled water in an ultrasonic bath, the samples were crushed exclusively with PE tools, transferred to PP beakers, dried for 96 hours at 110°C and homogenized by grinding in an agate mortar to a grain size <3µm followed by drying to constant weight at the same temperature.

Table 1. Activation products, half-lives and gamma-energies used for pumice analyses

element	activation product	half-life	γ-energy keV
Al	^{28}Al	2.2 min	1779
Ba	^{131}Ba	11.5 d	496
Ca	^{49}Ca	8.7 min	3084
Ce	^{141}Ce	32.5 d	145
Co	^{60}Co	5.27 a	1173
Cr	^{51}Cr	27.7 d	320
Cs	^{134}Cs	2.07 a	796
Dy	^{165}Dy	2.3 h	95
Eu	^{152}Eu	13.5 a	1408
Fe	^{59}Fe	44.5 d	1099
Hf	^{181}Hf	42.4 d	482
K	^{42}K	12.4 h	1525
La	^{140}La	40.3 h	1596
Lu	^{177}Lu	6.7 d	208
Mn	^{56}Mn	2.6 h	1811
Na	^{24}Na	15.0 h	1369
Nd	^{147}Nd	11.0 d	531
Rb	^{86}Rb	18.6 d	1077
Sb	^{124}Sb	60.2 d	1691
Sc	^{46}Sc	83.8 d	1120
Sm	^{153}Sm	46.3 h	103
Ta	^{182}Ta	114.4 d	1189
Tb	^{160}Tb	72.3 d	879
Th	^{233}Pa [a)]	27.0 d	312
Ti	^{51}Ti	5.8 min	320
U	^{239}Np [a)]	56.6 h	278
V	^{52}V	3.7 min	1434
Yb	^{169}Yb	32.0 d	177
Zn	^{65}Zn	244.3 d	1116
Zr	^{95}Zr	64.0 d	757

a) ^{233}Pa and ^{239}Np are produced by the β-decay of ^{233}Th (half-life 22.3min) and ^{239}U (half-life 23.5min), which were formed by neutron capture of ^{232}Th and ^{238}U, respectively.

Analysis

For activation of short- and medium lived radionuclides, the samples were weighed into PE capsules, about 150 mg each. They were irradiated for 1 minute in the irradiation position of the General Atomic pneumatic transfer system of the Triga Mk2 reactor of the Atominstitut der Österreichischen Universitäten at a thermal neutron flux of $3.3 \cdot 10^{12}$ $n \cdot cm^{-2} \cdot s^{-1}$. A first measurement (counting time 5 minutes) was performed after a decay of 5 minutes to determine Al, Ca, Ti and V. About 3 hours later, a second gamma spectrum was measured for 8 minutes to quantify Dy, K, Mn and Na. For the determination of Al, the reaction

$^{27}Al(n,\gamma)^{28}Al$ was used. The additional production of ^{28}Al by the reaction $^{28}Si(n,\gamma)^{28}Al$ was corrected for. The amount produced was determined by the irradiation of high purity quartz, the respective peak area was calculated from the known Si concentrations of the samples and subracted from the ^{28}Al peak. A list of the radionuclides and the gamma-peaks used is given in Table 1. For the activation of long-lived radionuclides, about 150 mg of each sample were sealed into Suprasil^{TM} quartz glass vials. The samples were irradiated together with standards for 91 hours in the ASTRA-reactor of the Austrian Research Centre Seibersdorf at a neutron flux of $7 \cdot 10^{13}$ $n \cdot cm^{-2} \cdot s^{-1}$. After a decay of 10 days, a first gamma-spectrum was measured to obtain the activities of the medium-lived nuclides (La, Lu, Sm, and U). After 32 and 110 days a second resp. third spectrum was taken to detect the long-lived nuclides (Ba, Ce, Co, Cr, Cs, Fe, Hf, Nd, Rb, Sb, Sc, Ta, Th, Yb, Zr resp. Eu, Tb and Zn) the measuring time was 1800 seconds for the first, 10000 seconds for the second and 10000 seconds for the third run. All measurements were performed with a 151 cm^3 HPGe-detector connected to a PC-based multichannel analyzer. A preloaded filter and loss free counting system improved the quality of the spectra obtained[7,8].

Results

The reference materials soil standard BCR No. 142, CANMET reference soil SO1, NIST SRM 1633b Coal fly ash and Rhyolith GBW-07113 were activated together with the samples and used as standards. Blank values for the PE and Suprasil^{TM} quartz glass irradiation vials were measured and found negligible. To show the accuracy of the results obtained, typical samples of the most important pumice sources in the Aegean region, particulary from Milos, Nisyros, Kos and Thera were analyzed together with the Egyptian samples of unknown origin. The results are given in Table 2. Detection limits ($<5\sigma$) depend on the measuring time and the γ-background of the samples. Errors due to counting statistics are calculated by $\pm\sigma$.

The basic knowledge obtained by previous studies, where pairs of elements were chosen to characterize the most important groups of pumice in the Aegean region, by the formation of typical clusters, provides an unmistakable relation of the pumice samples from excavations in Tell-el-Dab`a and Tell-el-Herr (Egypt) to their specific volcanic origin.

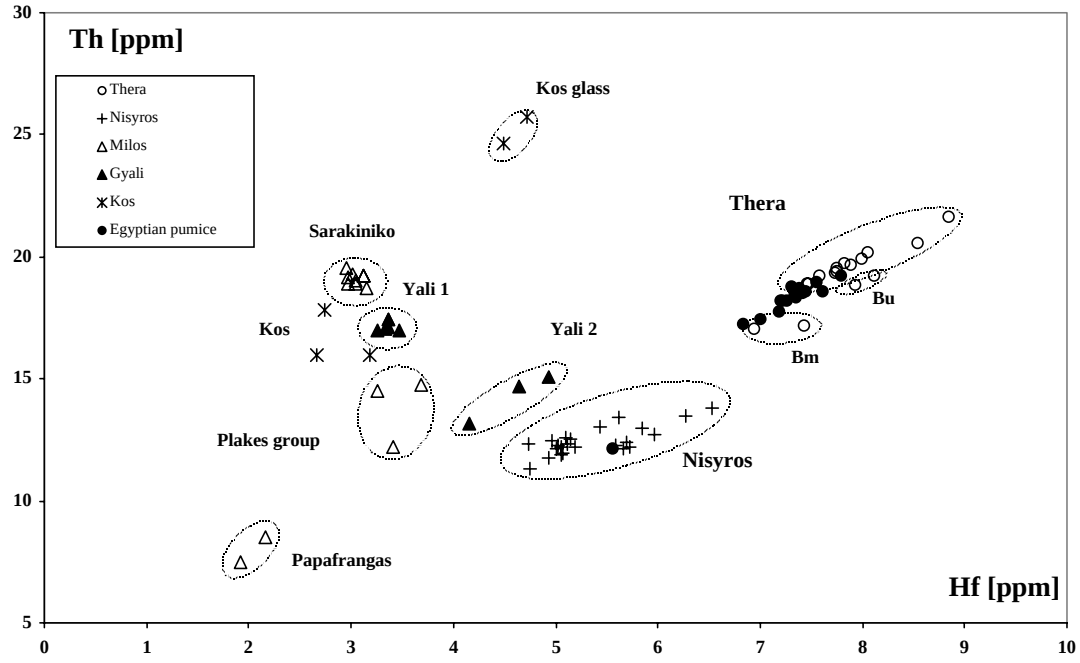

Fig. 2a Concentrations of Th and Hf in pumice from Aegean islands and excavations in Egypt

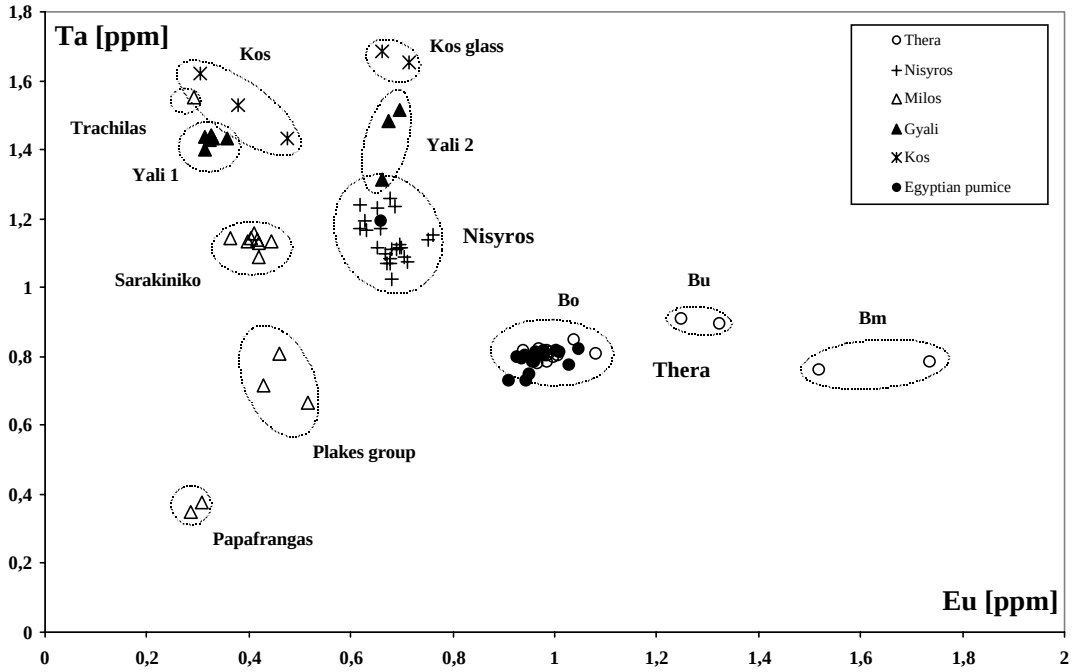

Fig. 2b Concentrations of Ta and Eu in pumice from Aegean islands and excavations in Egypt

Conclusions

Within the error range, most of the elements determined in typical reprepresentatives of Milos, Nisyros, Kos and Santorini were in perfekt agreement with values from the literature[4,5,9-14] . On the basis of the Cluster graphics presented, it is possible to relate unkown pumice to its primary source, just by comparing the relation of a few elements, like Ta-Eu and Th-Hf (Fig. 2a, 2b). We conclude that all samples except one can be related to the Minoan eruption of Thera, while this one leaves no doubt to have its origin in Nisyros.

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References

1. W.L. FRIEDRICH, Feuer im Meer-Vulkanismus und Naturgeschichte der Insel Santorin, Spektrum Akademischer Verlag, Heidelberg-Berlin-Oxford, 1994.
2. A. BOND, Multiple sources of pumice in the Aegean, Nature 259, (1976) 194-195.
3. H. SIGURDSSON, S. CAREY, J: D. DEVINE, in D. A. HARDY et al. (Eds.), Assessment of Mass, Dynamics and Enviromental Effects of the Minoan Eruption of Santorini Volcano, in D.A. HARDY et al (Ed.s)
   Thera and the Aegaean World III, Vol. 2, The Thera Foundation, London, 1990.
4 M. BICHLER, H. EGGER, A. PREISINGER, D. RITTER, P. STASTNY, NAA of the „Minoan pumice“ at Thera and comparsion to alluvial pumice deposits in the Eastern Mediterranean region, J. Radioanal. Nucl. Chem. 224 (1997) 7.

5. C. PELTZ, P. SCHMID, M. BICHLER, INAA of Aegean pumices for the classification of archaeological findings, J. Radioanal. Nucl. Chem., Vol. 242, No. 2 (1999) 361.
6. H. PICHLER, W. SCHIERING, Der spätbronzezeitliche Ausbruch des Thera-Vulkans und seine Auswirkungen auf Kreta, Archäolog. Anzeiger (1980) 1.
7. G. P. WESTPHAL, Digital implementation of the preloaded filter pulse processor J. Radioanal. Nucl. Chem., 193 (1995) 81.
8. G. P. WESTPHAL, Time correction of counting losses in nuclear spectroscopy J. Radioanal. Nucl. Chem., 70 (1982) 387.
9. C.J. VITALIANO, S.R. TAYLOR, M.D. NORMAN, M.T. McCULLOCH and I.A. NICHOLLS, Ash layers of the Thera volcanic series: Stratigraphy, Petrology and Geochemistry, in D.A. HARDY et al (Eds.),Thera and the Aegaean World III, Vol. 2, The Thera Foundation, London, 1990, 53-78.
10. V. FRANCAVIGLIA, B. DI SABATINO, Statistical study on Santorini pumice falls, in D.A. HARDY et al (Eds.) Thera and the Aegaean World III, Vol. 2, The Thera Foundation, London, 1990, 29-52.
11. J. KELLER, Prehistorc pumice tephra on Aegean islands, in C. DOUMAS (Ed) Thera and the Aegaean World II, Thera and the Aegaean World, London, 1980.
12. M. FYTIKAS, Volcanology and petrology of volcanic products from the island of Milos and neighbouring islets, J. Volcanol. Geotherm. Res. 28 (1986) 297.
13. L. FRANCALANCI, J.C. VAREKAMP, Crystal retention, fractionation and crustal assimilation in a convecting magma chamber, Nisyros volcano, Greece, Bull. Volcanol. 56 (1995) 601.
14. T. REHREN, Geochemie und Petrologie von Nisyros, östliche Ägäis, Ph.D. Thesis, Freiburg, Germany, 1988.