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THE PORTONACCIO MATERIALS FROM VEII: A SCIENTIFIC ANALYSIS *

Since 1976 a variety of materials from the Portonaccio site at Veii have been tested at San José State University in California to determine their physical characteristics, and from these to ascertain how accurate ancient assertions are concerning Etruscan technology and culture. In obtaining samples for the study, no damage was done to monuments; the specimens were discarded fragments.

Tests included macroscopic examination, thermoluminescence measurements, infrared spectral and spectrochemical analyses, and chemical analysis using proton induced x-ray emission [1].

The sculptural group found at Veii in the vicinity of the Portonaccio temple remains, of which the Apollo is the best known (*tav.* I *a*), is important not only because of the role it plays in the development of Etruscan art, but also because it may provide evidence for the appearance of the lost sculptures from the first Roman temple of Jupiter Capitolinus erected during the reign of Tarquinius Superbus, and dedicated in the first year of the Roman Republic, 509 B.C. [2].

Of particular interest is the fact that the famous Etruscan sculptor, Vulca of Veii, was given the commission by Tarquin to complete the cult image of Jupiter Optimus Maximus for the temple at Rome [3]. The same artist, or his workshop, may have been responsible for the creation of the Portonaccio statuary, as has been suggested by Professors Giglioli [4] and Pallottino [5].

While original sources inform us that the earliest temple of Jupiter Capitolinus was destroyed by fire in 83 B.C. [6], ancient texts tell us nothing about the fate of the Portonaccio temple (*tav.* II *a*).

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* The authors wish to dedicate this paper to the memory of Professoressa Luisa Banti.

[1] Our thanks to Prof. Thomas A. Cahill at the Crocker Nuclear Laboratory of the University of California at Davis for the PIXE analysis of our clay sample.

[2] Polyb. 3. 22; Liv. 2, 8; 7. 3; Plut., *Publ.* 14.

[3] Plin., *HN* 35. 157. According to Pliny it is Tarquinius Priscus who gave Vulca the contract; this would place the commission prior to 579 B.C., or some seventy years before the temple of Jupiter Capitolinus was dedicated.

[4] G. Giglioli, *Statue fittili di età arcaica*, in *NS* 1919, 33.

[5] M. Pallottino, *La scuola di Vulca* (1945).

[6] Cic., *Cat.* 3. 9; Sall., *Cat.* 47.2; Tac., *Hist.* 3. 72.

I

Analysis of a clay sample from one of the Portonaccio sculptural fragments provided information regarding the source of the clay, the firing temperature, and the use of cinnabar as a coloring agent. To aid in polishing the surface, the specimen was set in a cold plastic mount.

Macroscopic examination of the sample revealed that it consists of rock fragments and mineral grains in a fine – grained, buff – colored matrix; one surface of the specimen is coated with a thin polychrome layer.

Observed in thin section (*tav.* I *b*) under the microscope the sample was seen to include plagioclase feldspar, quartz, opaque oxide, leucite, biotite, rock fragments, glass, and groundmass. The abundance of euhedral minerals with strong optical zoning (*tav.* II *b*) indicates volcanic origin; the presence of unaltered euhedral mineral grains and glass particles in a fine-grained matrix is perfectly compatible with a pyroclastic rock type.

The fresh condition and euhedral form of mineral grains in the specimen prove that they were not subjected to chemical or mechanical weathering. From this it seems likely that the clay was local, and employed without the addition of fillers. And from the euhedral form of the mineral grains it may be further deduced that the upper limit of the temperature during firing was less than 1100 degrees centigrade [7].

The polychrome layer on the sample appears to contain hematite applied in a slip, and fired with the statue (*tav.* III *a*). But the presence of sulphur on the surface, and absence of it in the body, indicates that some parts of the sculpture may have been coated, after firing, with a coloring agent, presumably cinnabar. Had this been applied before firing, it would have been lost with the elevation of the temperature during heating of the statue. The sulphur confirms the ancient tradition that flesh-colored areas on certain sculptures were painted with cinnabar [8].

II

While literary sources provide an exact date for consecration of the temple of Jupiter Capitolinus, the Portonaccio statuary has been dated until the present time, solely on the basis of style, between 515 and 490 B.C. [9].

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[7] Feldspar crystals, for example, will melt at temperatures higher than 1100 degrees centigrade.

[8] PLIN., *HN* 33. 111-112; PLUT., *Quaest. Rom.* 98.

[9] L. BANTI, for instance, in *Il mondo degli etruschi* (1969), dates the Apollo of Veii to around 490 B.C.; M. MORETTI and G. MAETZKE in *Terra e arte degli etruschi* (1969), to the late 6th

To establish an absolute date range a clay specimen was tested for thermoluminescence. This revealed a firing date between 503 and 257 B.C. Given the upper limit of the date range, it is likely that the statue from which the sample comes did not suffer fire damage during the sack of Veii in 396 B.C. According to this information it would appear to postdate the terracotta sculptures commissioned for the temple of Jupiter Capitolinus, thought, perhaps, by only a few years.

III

It is commonly accepted that when clay is heated it will shrink in size. Yet Pliny the Elder [10] and Plutarch [11] report an unusual case in which clay increased, rather than decreased, in volume after firing. In Plutarch's version of the story Tarquinius commissioned artisans from Veii to create a terracotta chariot for the roof of the temple of Jupiter Capitolinus. During the firing a remarkable thing occurred: the chariot increased in size, and could only be extracted from the kiln with considerable difficulty, even after the roof and sides of the kiln had been removed.

Since clay generally shrinks during firing, controlled experiments were conducted to determine whether a volume increase is possible [12].

In the initial phase of the study, 149 samples of various clay mixtures were fired at different temperatures to observe their behavior. Specimens of clay containing 50 per cent spodumene exhibited an average increase in size of 5.8 per cent when fired at 1100 degrees centigrade, and an average decrease in size of 2.9 per cent when fired at 1300 degrees centigrade. It appeared that spodumene, or the lithium contained therein, was the agent responsible for the volume increase.

In the next phase of the experiment two hundred and twenty-four samples with various concentrations of lithium were fired at temperatures of 1100, 1150, 1200, and 1250 degrees centigrade [13]. From this it appeared that lithium, in the

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or early 5th century B.C.; M. Pallottino in *Civiltà artistica etrusco-italica* (1974), to around 500 B.C.; and O. Brendel in *Etruscan Art* (1978), between 515 and 490 B.C.

[10] Plin., *HN* 28. 16.

[11] Plut., *Publ.* 13.

[12] All research and conclusions concerning clay expansion were contributed by Dr. Arlan E. S. Smith.

[13] The volume increase obtained with spodumene was repeated, and tests were made to determine whether or not the size increase could be ascribed to the presence of a lithium compound; and an attempt was made to fix the concentration of lithium (spodumene or lithium carbonate) required to bring about the increase, and to narrow the temperature range at which maximum volume increase would occur. In these tests a chemically defined clay, kaolin, and a naturally occurring clay, Kentucky Ball No. 4, were employed.

form of naturally occurring minerals, was the element responsible for the increase in volume observed in the clay specimens; that a concentration of lithium in the range of two to four per cent was necessary to achieve increase in size; and that maximum expansion occurred at 1100 degrees centigrade.

The size increase in the clay samples containing lithium can be attributed to the oxygen released from lithium oxide at the time the temperature of the clay approaches 1100 degrees centigrade [14].

From these experiments it is evident that there is a chemical explanation for the expansion that occurred during the firing of the clay chariot at Veii.

IV

The pool adjacent to the Portonaccio temple at Veii (*tav.* III *b*) is believed in antiquity to have contained water regarded by the ancients as having curative properties, and perhaps to have been associated with a cult of Minerva Medica [15].

To determine whether or not the water contained compounds believed to be medically effective, residue specimens were analyzed by infrared spectral analysis and spectrochemical analysis. The analyses revealed high levels of potassium and sulphur, and in order of decreasing concentration, the five major trace elements, barium, vanadium, boron, lead and nickel.

Judging by this information, it seems probable that the water in the Portonaccio pool was used for treatment of heart and circulatory problems, and for skin and hair disorders during the Etruscan and Roman time periods [16].

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[14] At 1100 degrees centigrade the clay softens and forms silicon dioxide polymers, at the same time combining with the lithium. The oxygen is released from lithium oxide and trapped in the heat-softened clay, thus resulting in expansion. At higher temperatures the trapped oxygen is released into the atmosphere, and the volume increase, consequently, reduced.

[15] L. BANTI, *Il culto del cosiddetto 'tempio dell'Apollo' a Veii*, in *StEtr* 17, 1943, 187 ff.

[16] Potassium salts can be used in place of sodium salt by heart patients, while sulphur may be employed in the treatment of skin diseases. Barium and boron appear to have no known biological effect at the concentration levels found in the samples. Lead seems to be deleterious in all concentrations, but was probably tied up by sulphur as an insoluble sulfide. Vanadium at low concentration appears to lower cholesterol and increase iron absorption in the blood. Nickel at low concentration may improve skin tone and promote healthy membranes in the body. See I. DAVIES, *The Clinical Significance of the Essential Biological Metals* (1972); A. S. PRASAD, ed., *Trace Elements in Human Health and Disease*, 2 (1976); A. S. PRASAD, *Trace Elements and Iron in Human Metabolism* (1978); N. KHARASCH, ed., *Trace Metals in Health and Disease* (1979); R. B. ALFIN-SLATER *et al.*, *Nutrition and the Adult: Macronutrients* (1980); A. OSOL *et al.*, *Remington's Pharmaceutical Sciences* (1980[6]); J. E. REYNOLDS, ed., *Martindale: The Extra Pharmacopoeia* (1982[28]); M. WINDHOLZ *et al.*, *The Merck Index* (1983[10]); W. MODELL, ed., *Drugs of Choice 1984/1985* (1984).

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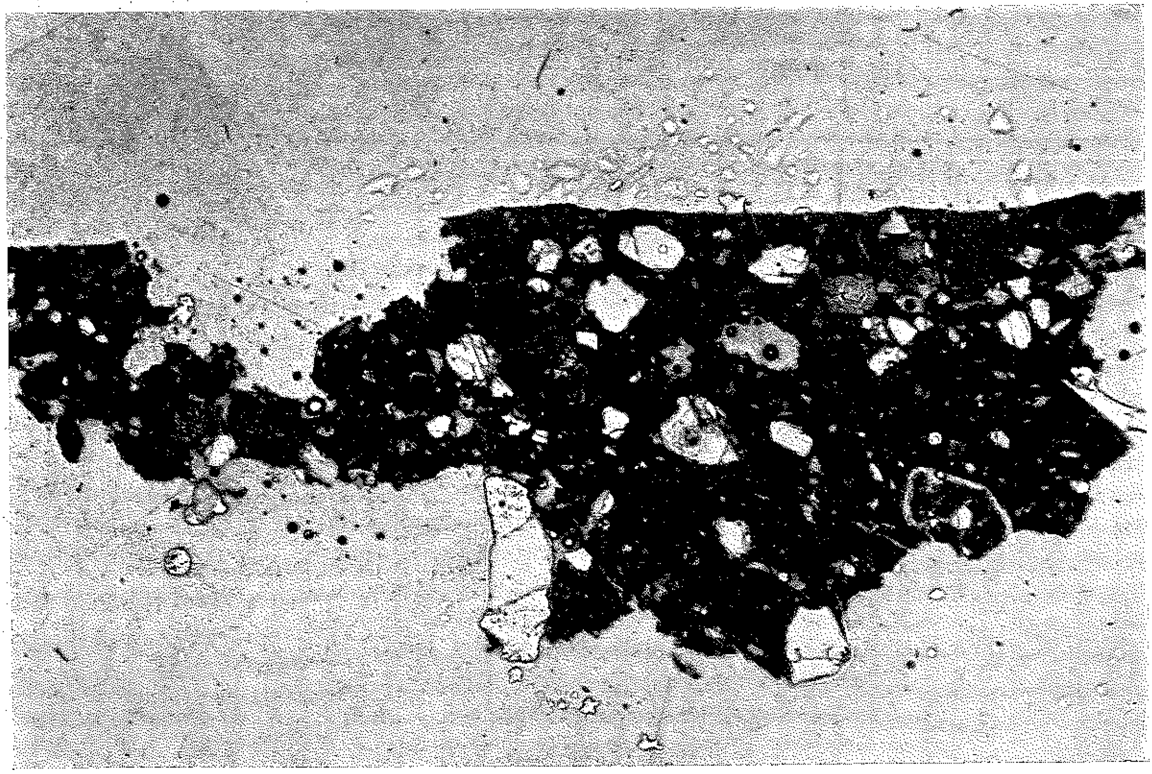

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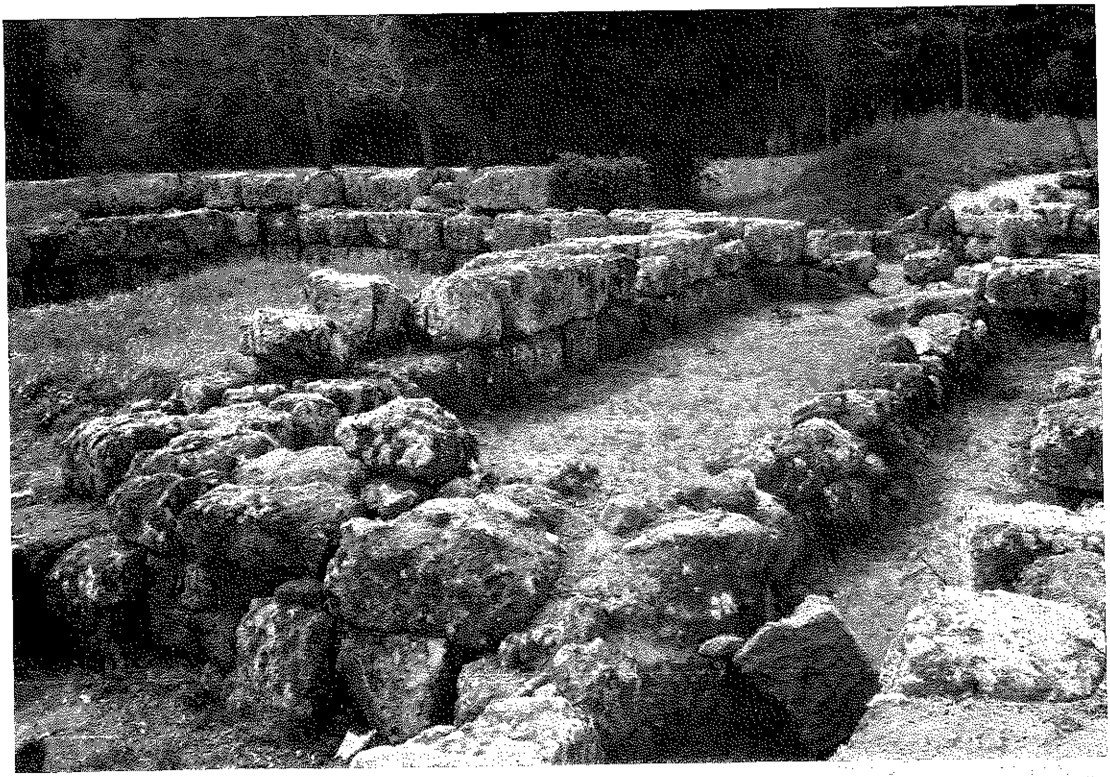

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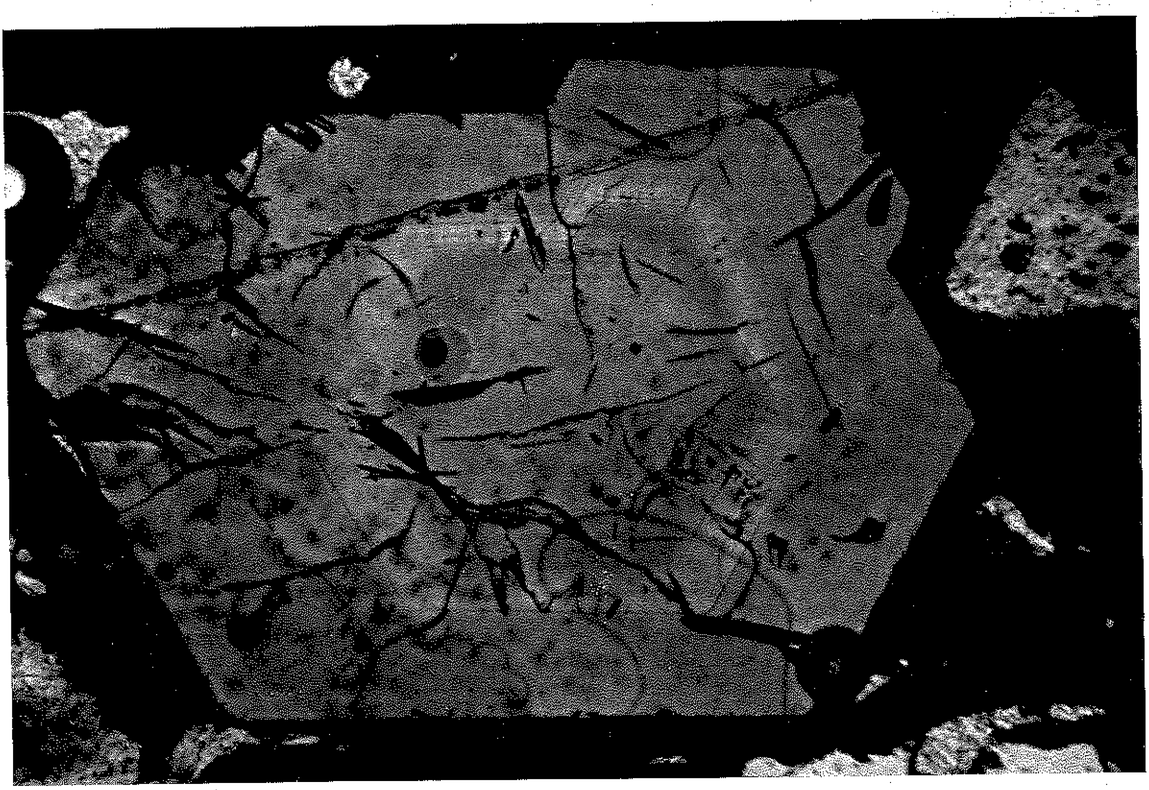

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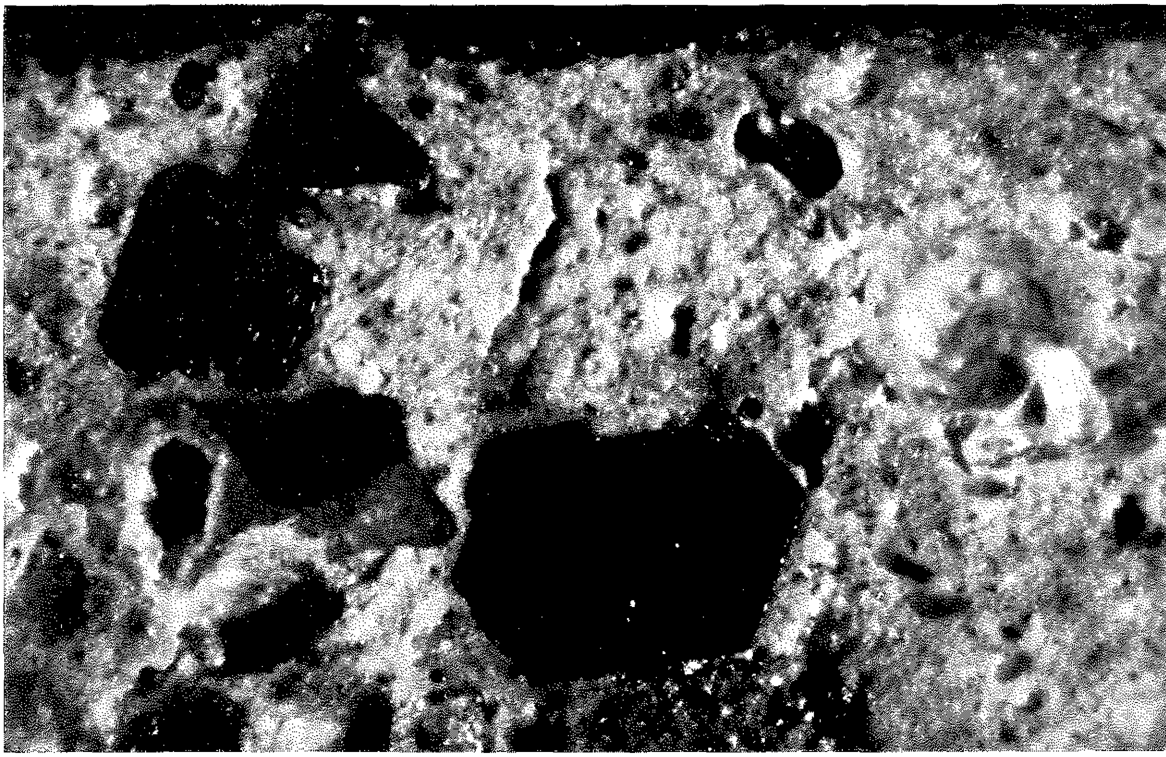

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