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Analysis of Red Paint and Filling Material from the Sarcophagus of Queen Hatshepsut and King Thutmose I

Red Paint

The reddish color of the sarcophagus exterior is due to red-colored paint; thick deposits can be seen in hieroglyphs and other recessed areas, while only thin washes occur on polished stone surfaces. Six samples from the left (east) side were analyzed by electron microprobe,¹ Fourier transform infrared microscopy (FTIR),² and gas chromatography/mass spectrometry (GC/MS),³ to identify the pigments and binder(s). The analyses indicate that the red paint, which is of similar if not identical composition in all of the samples, contains red earth (or ochre), the only red pigment that has been found to date in ancient Egyptian paints. Kaolinite (a clay mineral) and quartz are components of this earth pigment, as indicated by the FTIR spectra (fig. 1). The spectra also suggest that the pigment was bound with a plant gum, a type of binder that was common in ancient Egypt.⁴

Plant gums can be hydrolyzed to yield simple sugars, the types and relative amounts of which vary somewhat from one gum to another.⁵ Two samples of paint were analyzed for simple sugars by GC/MS. The samples gave virtually identical results, showing the presence of large amounts of xylose and glucose, and smaller amounts of fucose, rhamnose, galactose, and possibly arabinose (fig. 2). These results suggest that more than one sugar-containing material is present in the paint. One component may be gum tragacanth, a gum that could have been available in ancient Egypt (xylose and fucose are important sugars in this gum). Glucose is not usually found in plant gums, although it is present in honey, plant juices, sugar, and some seeds; perhaps some sugar (in the form of plant juice or honey) was added to make the paint a little stickier.

Exactly why this red paint is present on the surface is not certain. As speculated in the preceding article,⁶ it may simply have been brushed or smeared over the surface as a guide for the stoneworkers polishing the stone. Thus the thicker deposits found in the hieroglyphs and other recessed areas of the design may be fortuitous rather than indicating intentional filling of these design elements with red paint. There are no indications of other colors anywhere on the exterior of the sarcophagus, although paint does remain on the figures on the inside ends (these figures were added during alteration of the sarcophagus).⁷

Filling Material in Altered Inscriptions

During alteration of the sarcophagus, portions of many inscriptions were filled with a brownish-black material. One sample from a character on the top edge of the left (east) side was analyzed by a combination

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Fig. 1. Fourier transform infrared absorption spectra of two red paint samples from the sarcophagus exterior. Peaks marked "Kao" are due to kaolinite, those marked "Qtz" to quartz, both of which are components of the red pigment. Peaks due to the paint binder are also marked.

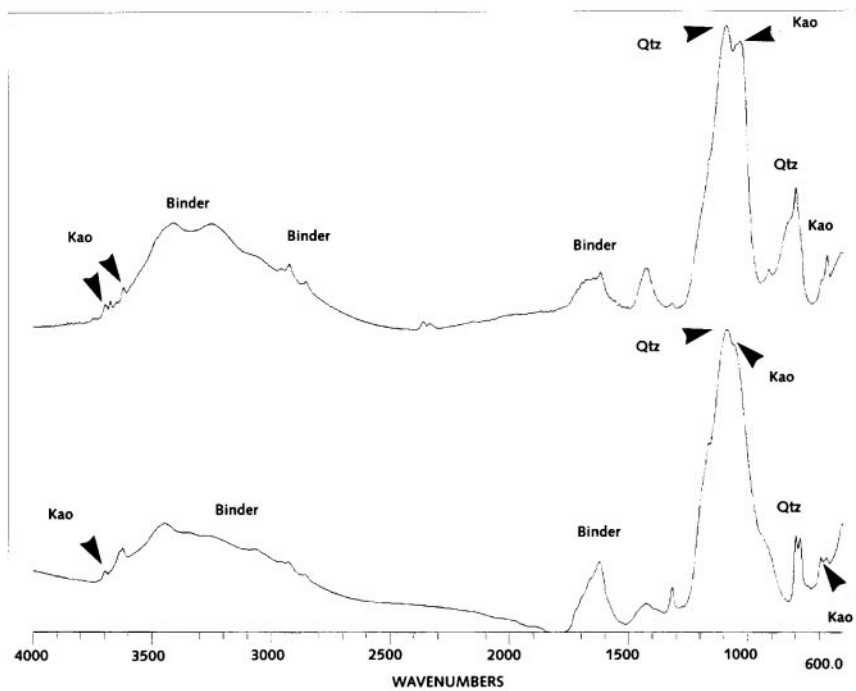
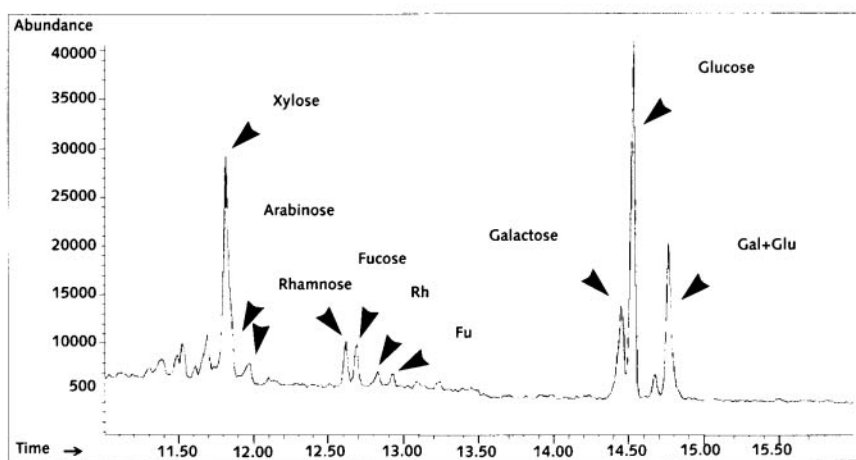


Fig. 2. Portion of total ion chromatogram from hydrolyzed sample of red paint from a recessed area of the design on the sarcophagus exterior. Simple sugars, analyzed as oxime-trimethylsilyl derivatives, are labeled (most give rise to two separate peaks, as indicated).



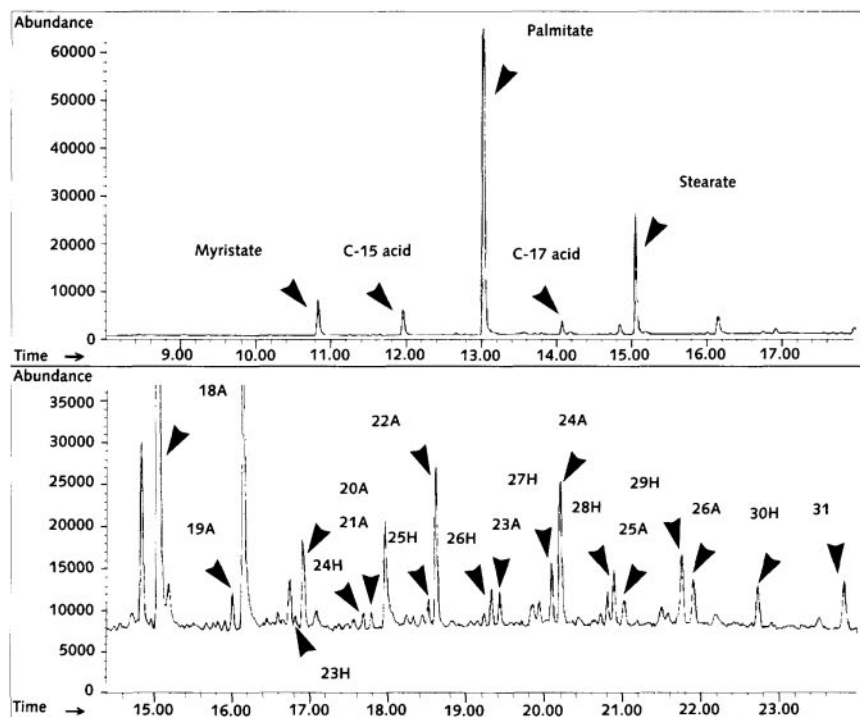


Fig. 3. Portions of total ion chromatogram from methylated methylene chloride extract of a sample of fill from an altered inscription. Upper trace shows major peaks, all due to fatty acids as indicated. Lower trace is an expanded portion of the chromatogram, showing some of the less abundant compounds detected, which mainly consist of straight-chain hydrocarbons (labeled "H," preceded by number of carbon atoms) and fatty acids (labeled "A," again preceded by number of carbon atoms).

of the same techniques used with the red paint. The sample is mostly organic in nature, and contains little or no inorganic filler (a very small amount of calcium carbonate was detected). The principal compounds detected by GC/MS were fatty acids (fig. 3, top). These are present as free fatty acids in the sample, rather than in the form of triglycerides (the form in which they occur in vegetable oils).⁸ The source of these fatty acids may be an animal source, given the relative abundance of myristic acid.

Among the minor peaks in the chromatogram is a series due to hydrocarbons (fig. 3, bottom); the source of these is not clear, but does not appear to a plant wax or beeswax, nor does the pattern resemble that of the hydrocarbons found in bitumen or asphaltum. GC/MS analysis detected traces of two compounds indicative of mastic resin, a type of resin that would have been available in ancient Egypt.⁹ No sugars were detected by GC/MS in a different portion of the sample, so no gum is apparently present. The FTIR spectrum suggested that a protein-containing material, such as animal glue, could also be present. Thus the fill was made from a mixture of materials, which included mastic resin and a fatty substance, perhaps animal fat.

NOTES

1. The elemental compositions of small portions of the samples were analyzed by qualitative energy-dispersive X-ray fluorescence in a Cameca MBX microprobe (Dept. of Earth and Planetary Sciences, Harvard University).
2. Samples were pressed in a diamond anvil cell and analyzed on a Nicolet 510P FT-IR spectrometer with an attached Nic-Plan infrared microscope at a resolution of 8 wavenumbers; 300 scans were co-added.
3. Samples were hydrolyzed and derivatized following the procedure described by D. Erhardt, W. Hopwood, M. Baker, and D. von Endt ("A Systematic Approach to the Instrumental Analysis of Natural Finishes and Binding Media," *American Institute for Conservation Preprints of Papers Presented at the Sixteenth Annual Meeting, New Orleans, Louisiana, June 1-5, 1988* [Washington, D.C., 1988], pp. 67-84), except derivatization was carried out with 30 microliters of a lab-prepared oxime reagent (8.5 mg hydroxylamine hydrochloride/ml in pyridine) and 10 microliters of trimethylsilylimidazole. Analyses were carried out on a Hewlett Packard 5890 capillary gas chromatograph with an HP 5971A mass selective detector. Split sampling was utilized, with a non-polar column. The mass spectrometer was operated in selected ion monitoring mode, using a program that included the five major ions of each of eight common simple sugars. Identifications were made on the basis of retention time and mass spectra with reference to simple sugar and gum standards prepared and analyzed by the same procedures.
4. A. Lucas and J. R. Harris, *Ancient Egyptian Materials and Industries* (London, 1962, 1989 reprint), pp. 5-6; and Catherine Vieillescazes and Daniel Lefur, "Identification du liant dans la peinture murale égyptienne (temple de Karnak), *Bulletin de la Société d'Égyptologie Genève* 15 (1991), pp. 95-100.
5. See, for example, J. Twilley, "The Analysis of Exudate Plant Gums and Their Artistic Applications: an Interim Report," in *Archaeological Chemistry III*, ACS Advances in Chemistry Series, No. 205 (Washington, D.C., 1984), pp. 357-394.
6. See preceding article, p. 37.
7. *Ibid.*, p. 49.
8. A crushed sample was saponified and extracted following a procedure described by D. Erhardt et al. (note 3). Methylation was carried out with 10 microliters of dimethylformamide dimethyl acetal. GC/MS analysis

was carried out both with the mass spectrometer in scan mode (50-500 amu) and selected ion monitoring mode, utilizing a program that includes characteristic ions for fatty acids, wax hydrocarbons, hopanes of asphaltum and bitumen, and some of the compounds found in pine and mastic resins. A second portion of the sample was extracted by heating in methylene chloride and then methylated before analysis by GC/MS. The profiles of fatty acids in the saponified sample and methylene chloride solution were essentially identical, indicating that the fatty acids are not present in the form of esters (as in triglycerides), which the FTIR spectrum also indicated.

9. The compounds, detected by selected ion monitoring in the methylated methylene chloride extract, were methyl moronate (base peak, m/z 189; molecular ion, m/z 468) and methyl oleanonate (base peak, m/z 203; molecular ion, m/z 468). For a discussion of the source(s) of this resin in antiquity, see J. Mills and R. White, "The Identity of the Resins from the Late Bronze Age Shipwreck at Ulu Burun (Kas)," *Archaeometry* 31 (1989), pp. 37-44.