Synchrotron Radiation in Archaeometry

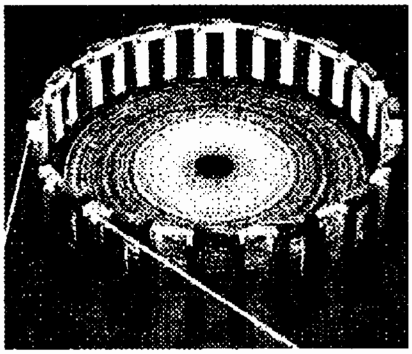

Figure 1. SR in Archaeometry logo.

Despite its name, archaeological science is one of the youngest sciences when compared with the more ancient studies of medicine, astronomy, mathematics and physics. It came of age with the invention of carbon–14 dating by W.F. Libby in the 1940s and with the application of standard mineralogical analytical techniques in the second half of the 20th century. A host of other material science methods and techniques are now used routinely for the examination of ancient objects. They supply valuable information to archaeologists as they piece together our picture of the ancient world.

This cross-disciplinary approach has led to the foundation of the discipline of archaeometry. Detailed information of which archaeologists have previously only dreamed can now be obtained by exploiting the unique properties of synchrotron radiation. There are many SR techniques developed for materials and biological science research that can be utilized for archaeological science.

A workshop, sponsored by the SR Round Table and DARTS (Daresbury Analytical Research Services), was hosted by Daresbury Laboratory from November 19 to 20, 1999, with the aim of bringing together archaeological and synchrotron scientists to cross-fertilize ideas from these two broad research areas. The program, abstracts and references to work involving SR techniques may be found at http://srs.dl.ac.uk/arch/.

At the close of the meeting, Professor Mark Pollard, Bradford University, member of the editorial board of the *Journal of Archaeological Science*, emphatically removed the question mark from "Is SR relevant in AS?" and urged the participants to pursue ideas generated during the workshop by submitting research grants to appropriate funding bodies. He also suggested that key papers presented at the workshop be published in a special issue of the other leading journal in the field, *Archaeometry*. The editor, Professor Mike Tite, Oxford Research Lab for Archaeology and History of Art, has commissioned six papers scheduled to be printed in a future issue.

Daresbury Laboratory is not the only SR center where such work is carried out. The first papers to appear in the literature were by Izumo Nakai et al. ("Chemical speciation of archaeological objects by XRF/XANES Analysis using synchrotron radiation," 1991) and Hans Mommsen et al. ("X-ray fluorescence analysis on inks and papers of incunabula with synchrotron radiation," 1996), at the Photon Factory and the Bonn University's ELSA-II source, respectively, reporting work which started in the late 1980s. Other elegant applications of SR have been carried out at ESRF (K. Janssens et al. 1996,

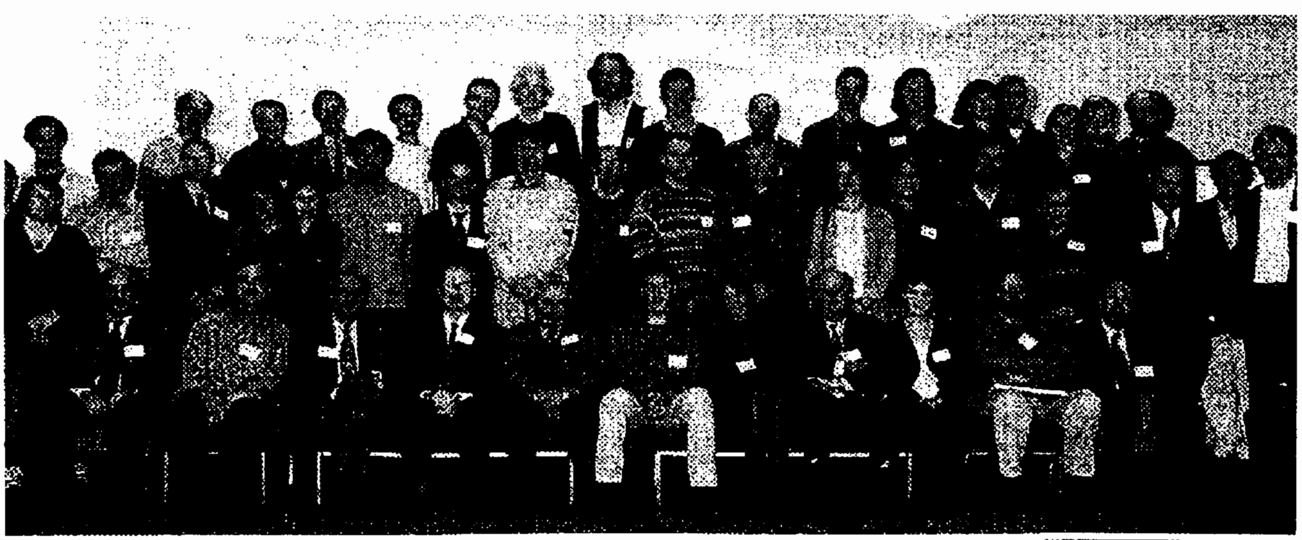

Figure 2. Workshop participants gather for the traditional group photo.

P. Walter et al., 1999), LURE (P. Dillmann et al., 1998), and APS (E.S. Friedman et al., 1999), while parallel activities are in progress at HASYLAB, ALS and elsewhere.

It is perhaps important to note that this cross-disciplinary research is not one-way only. To quote Dr. John Prag of The Manchester Museum, co-organizer of the workshop: *"While archaeological science may at first blush seem a somewhat recondite discipline, [seemingly] irrelevant to the day-to-day needs of the country and its economy in the twenty-first century, it is worth saying that an interdisciplinary project where an archaeologist and a medical artist [...] were involved has led from working with old bones to advances in plastic surgery."* (see *Making Faces* by John Prag and Richard Neave, British Museum Press, 1997).

Such unexpected links and lateral technology transfer between scientific disciplines is a familiar happening to practicing scientists, whatever their background and motivation. The study of Sumerian vessels may not be of high priority in cutting-edge materials science research but the intellectual stimulus may lead, for all one can tell, to insights into archaeoproteins, the extinction of species following the onset of the ceramic period or microbial life in hostile environments.

Such a link, totally unexpected by the participating parties until a short time ago, was made with the SESAME project (see Herman Winick's editorial in *SRN* Vol. 12, No. 6, 1999 and http://www.weizmann.ac.il/home/sesame/). Readers are reminded that SESAME arose out of the peace negotiations in the Middle East, aiming at developing the scientific capability of countries in the Middle East and the Mediterranean region. Dr Engin Ozdas from the Advanced Research Materials Lab, Haceteppe University, Ankara, is sponsored by SESAME to work at DL on topics of relevance to the archaeology of the region, the "anvil of civilization." By the grace of Athena, goddess of science, and Apollo, god of light, SR might even get at the Engin marbles. ■

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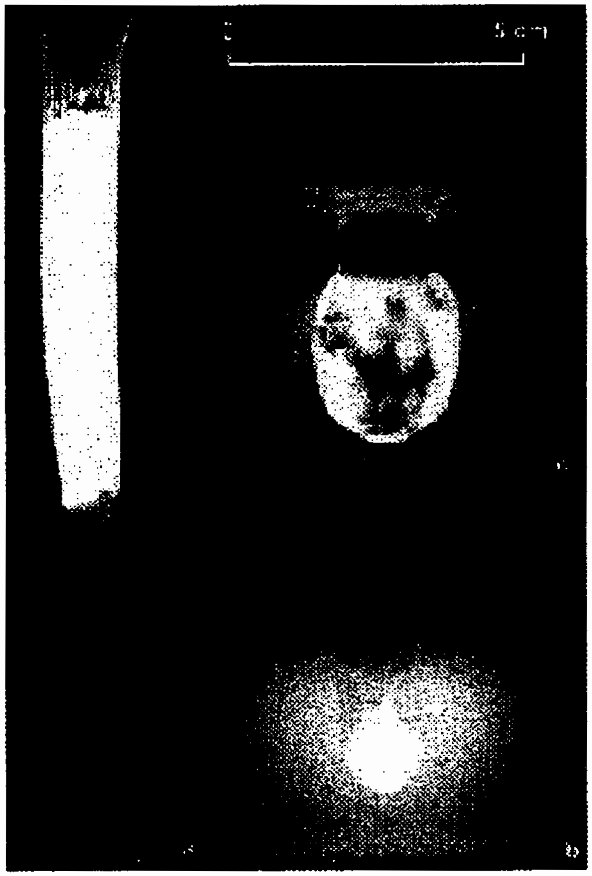

Figure 3a. X-ray radiography of different makeup receptacles from the Egyptian collection of the Louvre Museum. The white areas show the distribution of the X-ray-absorbing lead powders present in the make-up. (a) reed case E, still full of makeup; (b) alabaster recipient with a fabric lid; (c) alabaster recipient and cover. It contains a small amount of makeup attached on the inner wall.

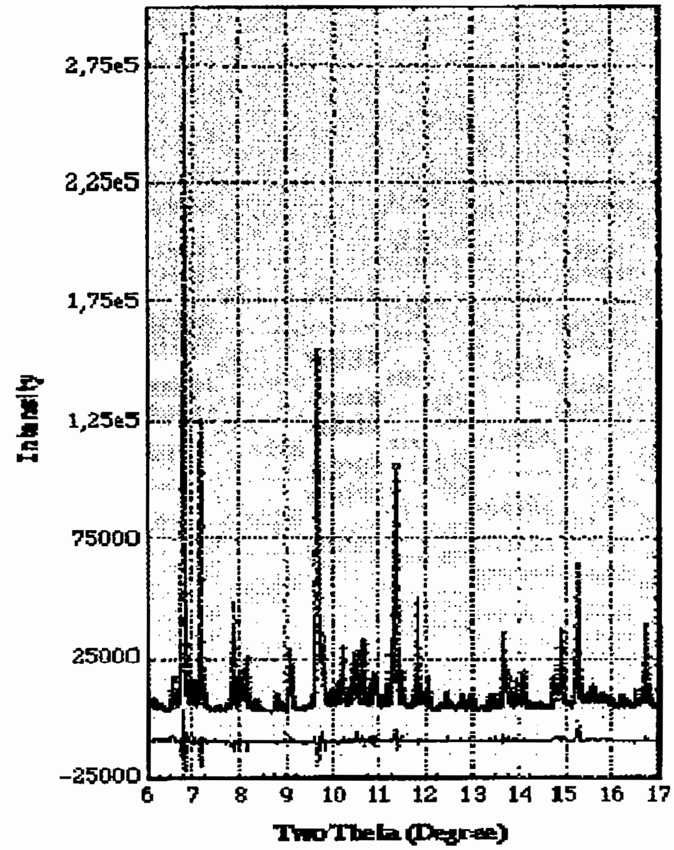

Figure 3b. Powder diffraction pattern of crystalline material in the alabaster cosmetic powder container, shown above, dated from the Tutankhamon reign. It was measured on BM16 of ESRF by Eric Doorybee and Pauline Martinetto. Phase analysis by Rietveld refinement has shown that wet chemistry was employed to produce a powder with cosmetic as well as eye-decease preventing properties. Photos from ESRF Newsletter, *32, 1999.*

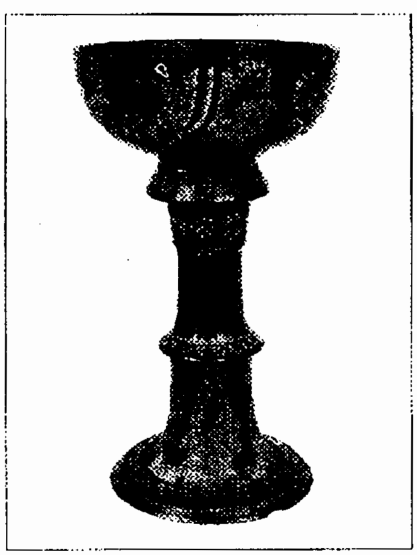

Figure 4a. *A thymiaterion (incense burner) from Apulia, Italy, late 4th century BC, in The Manchester Museum. Stylistic differences between the bowl and stem and a neat repair joining them gave reasons to suspect that the object was a 19th century pastiche, a fake bowl set upon an ancient stem. The two parts had separated while in storage. Non-destructive SR-XRD (γ=0.52Å at SRS station 16.2) from underneath the glossed surface indicated that the clays from the two pieces are practically identical. In order to confirm that differences in the diffraction patterns were due to crystalline orientation effects, 20mgr of powder was scraped from the undecorated bottom of the stem and of the bowl, loaded in 500micron capillaries and examined by HRPD in stepping mode (station 9.1) and at the protein diffraction station 9.6, which uses a CCD image detector to collect the full pattern.*

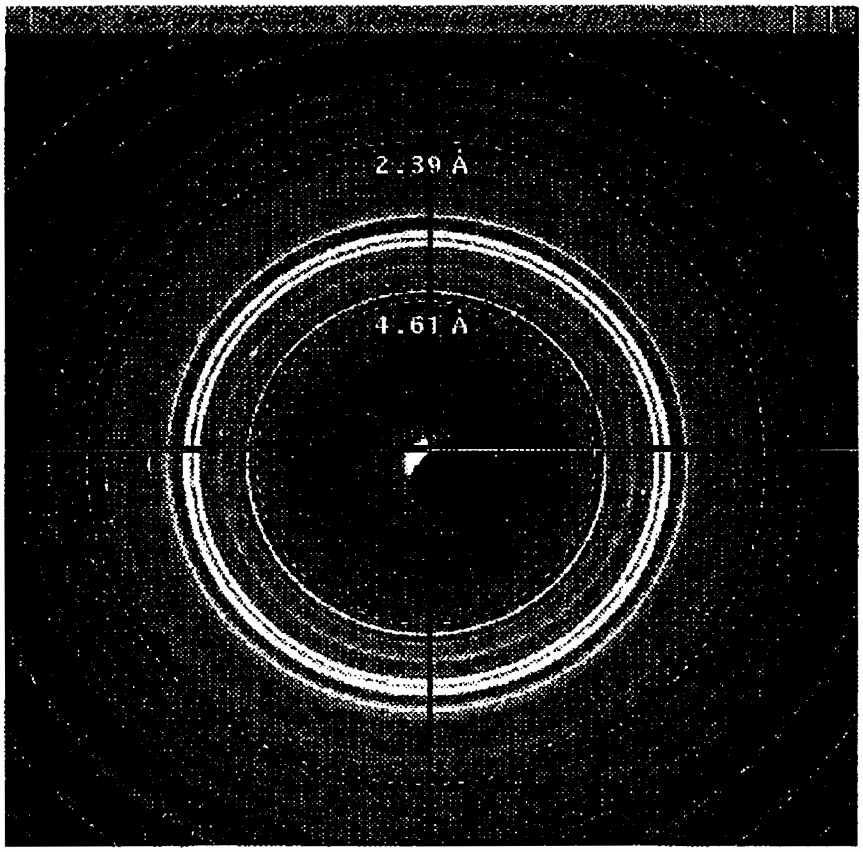

Figure 4b. The powder diffraction patterns from bowl (top) and stem (bottom), collected in 60 seconds during single bunch (±90deg osc., 20mA at 2GeV).

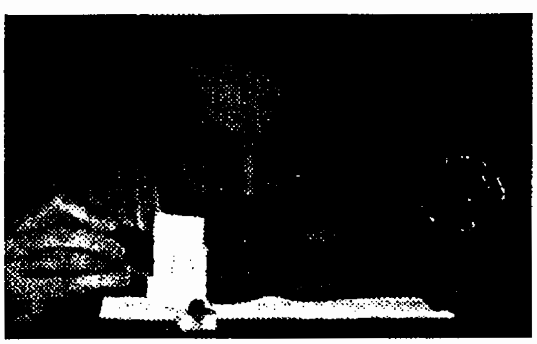

Figure 5a. Ercan Alp oversees analysis of a Judaidah figurine at Argonne National Laboratory's Advanced Photon Source.

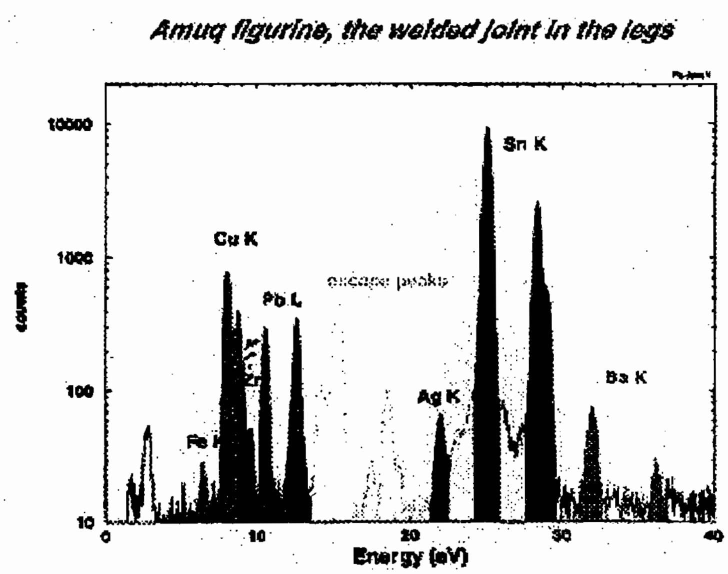

Figure 5b. Elemental analysis of the Judaidah figurine showing peaks corresponding to tin, copper and lead. Figures from Oriental Institute, University of Chicago, 1997-98 Annual Report, "Amuq Valley Project."

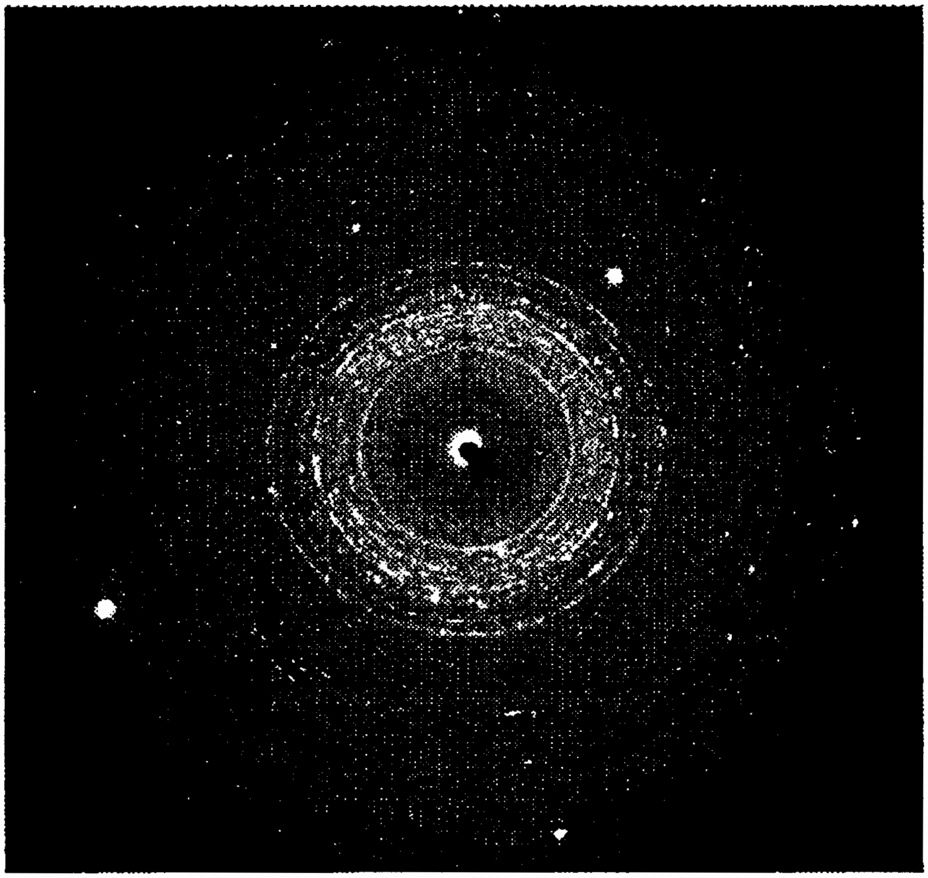

Figure 6a. Diffraction pattern from a 10-micron-thick section of a potsherd from the Bronze Age site of Iktanu, Jordan, showing diffraction from specific mineral inclusions. Beam footprint 10 microns at the ESRF ID13 beamline. Data collected on the day of the workshop by Bridget Murphy, Martin Müller, Manfried Burghammer and Christian Riekel.

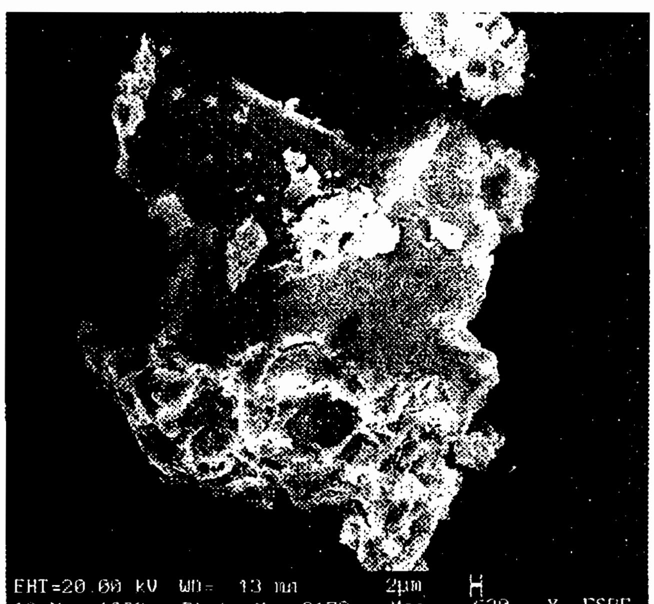

Figure 6b. SEM image of the slice, field 100 microns, collected by Irena Snigireva.