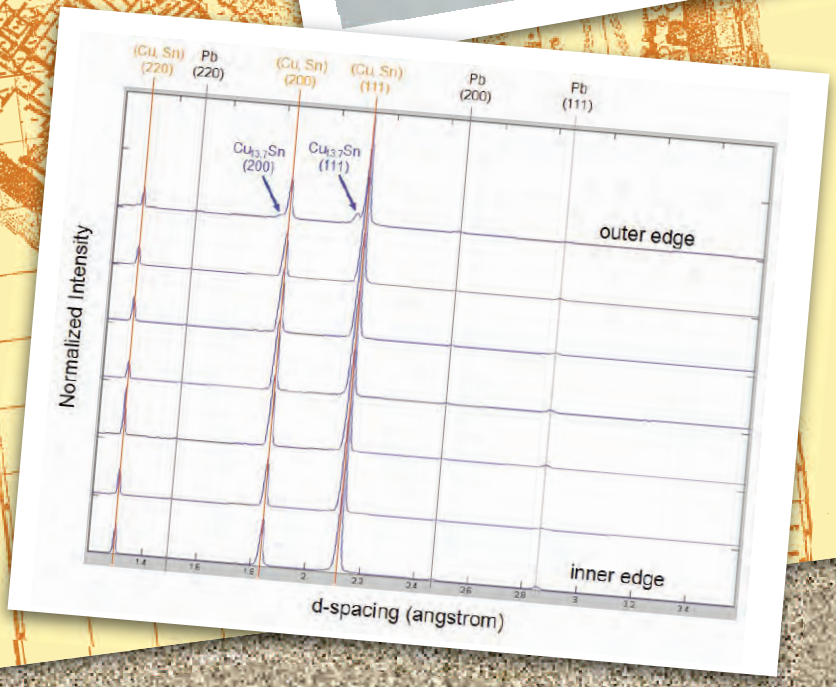

Photograph above: Excavating near the recently revealed city wall at Tell en-Nasbeh, 1927 (courtesy of the Badè Museum of Biblical Archaeology, Pacific School of Religion).

Fig. 1 (right top): O-shaped bangle 2665c from the Badè Museum collection at the Pacific School of Religion, 7 mm. diameter, 74.40 g, dating to the 10-6th century BCE.

Fig 2 (bottom right): Normalized intensity as a function of d-spacing for a typical bangle (2665c) at seven different positions from the inner edge to the outer edge of the bangle in 1 mm steps. Beam size: 100 x 100 μm^2.

Map of Tell en-Nasbeh (courtesy of Aaron J. Brody, Badè Museum of Biblical Archaeology, Pacific School of Religion).

BRINGING ANCIENT CULTURES TO LIGHT

An interdisciplinary team of researchers utilized two APS beamlines and a variety of synchrotron techniques to analyze the bronze alloys of Iron Age bracelets excavated in the 1930s at Tell en-Nasbeh, an archaeological site 12-km north of Jerusalem, which is associated with the Biblical town of Mizpah in Judah. The bracelets were used as mediums of exchange, symbols of wealth, and at times as utilitarian objects. The results of this journey back in time indicate that commerce often trumped hostilities in those ancient hills.

In the 1980s, Garman Harbottle, a senior chemist at Brookhaven National Laboratory, foresaw that synchrotron radiation could be used to solve questions about the composition, origins, and method of fabrication of ancient artifacts. In recent years, beamlines at the APS have been used to study ancient Chinese bronzes; astrolabes from Lahore, Pakistan; and now, these Iron Age bronze bracelets.

The non-destructive research at the APS revealed not only the composition and mode of fabrication of the original alloy, but when placed in an archeological and socioeconomic perspective, the findings also suggest that despite enmity between Judah and nearby Edom, trade between the warring kingdoms was thriving (Fig. 1).

The bracelets are part of a larger collection housed in the Badè Museum at the Pacific School of Religion in Berkeley, California. Five O-shaped bangles from Iron Age II (1,000-586 BCE) from family tombs outside the walls of the site were tested, while two C-shaped bangles tested were found on the tell itself and date from the late Iron Age (IIB) to the early Persian era (8-5th centuries BCE).

Chemical analysis of a bangle fragment performed in 1930-31 was deemed unreliable because drilling through the bangle's surface to the core introduced bits of corroded exterior material into the interior bulk material. Non-invasive, high-energy x-ray diffraction and x-ray fluorescence (XRF) at XOR beamline 1-ID allowed analysis in discrete steps from the corroded surface to the interior, revealing the composition of the original alloy. Most of the bangles were found to consist of lead, tin, and copper in four phases—Cu; Sn; an intermetallic phase, Cu13.7Sn; and Pb (Fig. 2).

The presence of lead in the bronze suggests that the metal workers may have discovered a means to create a strong, easily molded alloy while lowering the cost of production, as tin was a rare and costly metal imported from afar. The transition in composition from the surface to the core indicates that the molten alloy was subjected to rapid cooling. The bangles were formed in either rod-shaped molds, and then hammered into shape, or in circular-shaped molds. Residual strain in the bulk alloy could be the result of bending after casting, or from annealing after casting in a circular mold.

The research team used energy-dependent XRF at MR-CAT beamline 10-ID to detect the presence of arsenic, which has an energy level so close to that of Pb that traditional XRF measurements cannot distinguish between the two. None of the bangles contained more than trace amounts of arsenic, a likely indication that they were fabricated from a regional source. There were no mining activities at Nasbeh, but in the Iron Age, extensive mining and smelting took place at Wadi Feinan, a site in Edom about 300 kilometers SE from Nasbeh and a possible source of the leaded-tin bronze bangles. Thus, despite ongoing hostilities between Edom and Judah, economic trade between the two tribes likely occurred along well-established routes. — *Elise LeQuire*

See: Elizabeth S. Friedman[1], Aaron J. Brody[2], Marcus L. Young[3], Jon D. Almer[4], Carlo U. Segre[1], Susan M. Mini[4,5], "Synchrotron radiation-based x-ray analysis of bronze artifacts from an Iron Age site in the Judean Hills," J. Archaeo. Sci. **35,** 1951 (2008). DOI: 10.1016/j.jas.2007.12.006
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1-ID • XOR • Materials science, physics, chemistry • High-energy x-ray diffraction • 3.3-cm Undulator A • Accepting general users

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