Non-destructive characterization: from biogenic residues on stone tools to sediments on skeletal remains

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All archaeological study is inherently destructive (Barker, 1993). Archaeological remains are finite, irreplaceable archives demanding matching caution, even more so for human remains, whose destructive analysis requires prior ethical and legal authorisation. This calls for complementary, minimally invasive techniques tailored to each material. I will present Palaeolithic case studies in which microscopy (OM/SEM) is integrated with FTIR imaging, including synchrotron infrared sources, to characterise Ancient Starch Candidates (ASC) at single-grain level on stone tools, while synchrotron X-ray microtomography (SR-μCT/μCT) and neutron imaging (ISIS, INES/IMAT beamlines) allow compositional mapping of skeletal and sedimentary remains before any physical sampling.

STARCH. Chemically authenticated ancient starch, mainly from underground storage organs, on 36 ka BP ground stones across the Pontic steppe, identified by combining FTIR spectroscopy at the SISSI beamline (Elettra, Trieste) with OM/SEM.

DYES. Elusive use of dyes such as indigotin from *Isatis tinctoria*, identified through microscopy, Raman and FTIR spectroscopy, and SR-μCT on six pebbles from Dzudzuana Cave (Caucasus): the earliest known evidence of blue-dye extraction, around 40 ka.

GRAVE GOODS. μCT, archaeometry and neutron imaging of sediment adhering to the skull of a pregnant woman buried with her 34–36-week-old foetus, revealing pigments and animal residues linked to everyday activities, alongside perforated shell beads used as funerary ornaments.

None of this would be possible without coordinated access to large-scale infrastructures. EU-funded access through CERIC to synchrotron (Elettra), neutron (ISIS) and Ion Beam Analysis facilities underpins this non-invasive pipeline. It also demands a shift in field and museum conservation protocols,

designing sampling and storage around these facilities' requirements to avoid compromising the bioarchive potential of finds before analysis begins.

G. Birarda, E. Badetti, C. Cagnato et al. *Morpho-chemical characterization of individual ancient starches retrieved on ground stone tools from Palaeolithic sites in the Pontic steppe*, Scientific Reports, 13 (2023), https://doi.org/10.1038/s41598-023-46970-8

Longo L, Veronese M, Cagnato C, et al. *Direct evidence for processing Isatis tinctoria L., a non-nutritional plant, 32– 34,000 years ago.* (2025), PLoS One 20(5): e0321262. https://doi.org/10.1371/journal.pone.0321262

Short bio:

Laura Longo (PhD Anthropology; postdoc Earth Sciences) is a Palaeolithic archaeologist specialising in techno-functional and residue analysis of stone tools. Former Prehistory curator at the Verona and Florence museums and Associate Professor at NTU Singapore, she is Vice President of the UISPP Functional Analysis Commission. She contributed to early Neanderthal mtDNA research and pioneered the chemoprofiling of the earliest known dye molecule (indigotin, ~40 ka), integrating microscopy and FTIR. Repeatedly awarded EU beamtime (CERIC-ERIC, EXCITE2, LINXS) at Elettra, SOLEIL, CEITEC and ISIS, she now combines synchrotron, neutron and IBA techniques with biomolecular analyses (omics).