Tracing the provenance of lapis lazuli: a multi-technique approach based on IBA

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Lapis lazuli is a semi-precious blue stone used since antiquity for the manufacturing of carved artifacts. Although the Badakhshan mines (Afghanistan) are considered its primary source, other deposits exist (Tajikistan, Siberia, Myanmar), with their potential contribution to ancient supply still under debate. The limited number of provenance studies conducted in literature so far have shown that the question of the lapis lazuli origin remains only partially resolved.

Over the past 15 years, our group has developed a multi-technique provenance protocol, primarily based on Ion Beam Analysis (IBA), applied non-destructively to almost 100 lapis lazuli artifacts and almost 70 reference rocks. The protocol exploits proton microprobes to search for physical-chemical markers inside single mineral species (e.g., diopside, pyrite, calcite), a necessary approach due to the material's strong heterogeneity. In particular, μ-Proton Induced X-ray Emission (μ-PIXE) and μ-Ion Beam Induced Luminescence (μ-IBIL) have proven highly effective in identifying markers within reference geological rocks, allowing us to distinguish among five distinct geographical origins: Afghanistan, Tajikistan, Siberia, Chile, and Myanmar.

The protocol methodology, including its recent upgrades, will be presented alongside selected case studies. These examples involve artifacts dated from the 3rd to the 1st millennium BCE, recovered across different ancient sites in the Middle East (including the Indus Valley, Iran, Mesopotamia, Ancient Egypt, and Oman).

Short bio:

Marta Magalini is an INFN research fellow. An experimental physicist with a PhD in Technology for Cultural Heritage (University of Turin), she specializes in nuclear and spectroscopic techniques for cultural heritage. Her research focuses on Ion Beam Analysis applied to provenance studies (lapis lazuli); she has led experimental campaigns at major European facilities and contributed to several research projects on the developemnet of analytical techniques for

the characterisation of cultural heritage (CHNet-NICHE, PITCH, Horizon 2020 BE-ARCHAEO). Her current work blends advanced diagnostics and machine learning for data treatment.