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New markers to identify the provenance of lapis lazuli: trace elements in pyrite by means of micro-PIXE

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Abstract Lapis lazuli has been used for glyptics and carving since the fifth millennium BC to produce jewels, amulets, seals, inlays, etc; the identification of the origin of the stone used for carving artworks may be valuable for reconstructing old trade routes. Since ancient lapis lazuli art objects are precious, only non-destructive techniques can be used to identify their provenance, and ion beam analysis (IBA) techniques allow us to characterise this stone in a fully non-invasive way. In addition, by using an ion microprobe, we have been able to focus the analysis on single crystals, as their typical dimensions may range from a few microns to hundreds of microns.

Provenance markers, identified in previous IBA studies and already presented elsewhere, were based on the presence/absence of mineral phases, on the presence/quantity of trace elements inside a phase and on characteristic features of the luminescence spectra. In this work, a systematic study on pyrite crystals, a common accessory mineral in lapis lazuli, was carried out, following a multi-technique approach: optical microscopy and SEM-EDX to select crystals for successive trace element micro-PIXE measurements at two Italian facilities, the INFN Laboratori Nazionali di Legnaro and the INFN LABEC laboratory in Firenze. The results of this work allowed us to obtain new markers for lapis lazuli provenance identification.

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1 Introduction

Lapis lazuli is a blue semi-precious stone used for glyptics and carving by different civilisations as early as 7000 years ago. The identification of the provenance of raw material used for man-made objects can provide valuable help in the reconstruction of ancient trade routes. This task is simplified by the fact that only a few sources of lapis lazuli exist in the world, due to the low probability of geological conditions in which it can form. In recent years, there has been an increasing interest in the study of the provenance of this stone, both in artefacts and in lapis lazuli blue pigment, and results have been obtained using different analytical techniques and approaches [1–5]. We started to work in this field in 2007 [6, 7], and we have been developing a fully non-invasive analysis procedure, exploiting ex-vacuo ion beam analysis (IBA) techniques [8]. Due to the paragenetic mineralogical heterogeneity of lapis lazuli stone, we

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