Nuclear Instruments and Methods in Physics Research B 269 (2011) 2373–2377

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Lapis lazuli provenance study by means of micro-PIXE

Alessandro Re [a,b,*], Alessandro Lo Giudice [a,b], Debora Angelici [a], Silvia Calusi [c], Lorenzo Giuntini [c], Mirko Massi [c], Giovanni Pratesi [d]

[a] Dipartimento di Fisica Sperimentale, Università di Torino, Via Giuria 1, 10125 Torino, Italy
[b] INFN Sezione di Torino and Centre of Excellence "Nanostructured Interfaces and Surfaces", Università di Torino, Via P. Giuria 1, 10125 Torino, Italy
[c] Dipartimento di Fisica, Università and INFN Sezione di Firenze, Via Sansone 1, 50019 Sesto Fiorentino, Firenze, Italy
[d] Dipartimento di Scienze della Terra and Museo di Storia Naturale, Università di Firenze, Via G. La Pira 4, 50121 Firenze, Italy

ARTICLE INFO

Article history:
Available online 27 February 2011

Keywords:
Lapis lazuli
Provenance
PIXE
Archaeometry
External microbeam

ABSTRACT

In this paper we report about the micro-PIXE characterisation of lapis lazuli, for a provenance study of this semi-precious stone, used for glyptic as early as 7000 years ago. The final aim is to find markers permitting to identify the origin of the raw material coming from three quarries in regions of historical importance: Afghanistan, Pamir Mountains and Siberia. This may help to reconstruct trade routes, especially for ancient objects for which written testimonies are scanty or absent at all.

Due to the heterogeneity of lapis lazuli we concentrate our attention on single phases instead of the whole stone; in particular we focused on two of the main phases: lazurite, responsible for the blue colour, and diopside, the most frequent accessory mineral. This study was preceded and completed by means of microanalysis with Scanning Electron Microscopy (SEM-EDX) and Cold-Cathodoluminescence (cold-CL) analysis.

Despite the limited number of analysed samples, results are sufficient to exclude/suggest a few features as provenance markers, partly confirming what has been previously published in literature.

1. Introduction

External ion beam analyses have been widely used in cultural heritage investigations owing to the possibility to work in air on large objects without any pre-treatment. IBA techniques, exploiting proton beams, can be used in most materials without damaging. Moreover, the availability of scanning micro-beams allows the investigation of details down to the micrometer scale, which proved to be very useful in many cases [1]. Particle-Induced Gamma ray Emission (PIGE), Backscattering Spectrometry (BS) and especially Particle-Induced X-ray Emission (PIXE) can be considered as the chief IBA techniques, but also Ion Beam Induced Luminescence (IBIL) has been successfully employed in this field [2–4].

The IBA techniques can be applied to the study of the provenance of the raw material used in the object making, which can help to reconstruct ancient trade routes. A promising material in this context is the semi-precious stone lapis lazuli, used for glyptic as early as 7000 years ago and for painting starting from the Medieval Age. Only few sources of lapis lazuli exist in the world, due to the low probability of geological conditions in which it can form [5]. Historical sources are in very inaccessible places, such as Afghan and Pamir Mountains, and stones were transported for thousand of kilometres, in times for which the knowledge of trade routes is still largely incomplete. Although presently the mines in Afghanistan are widely considered as the only sources of the lapis lazuli in ancient times [6–8], other sources have been proposed [6,7,9,10], so that the provenance of ancient lapis lazuli is still an open question.

Lapis lazuli is a metamorphic rock characterised by the presence of the mineral lazurite (responsible for its blue colour), combined with other types of minerals whose presence and relative amount varies from and within deposits. Lazurite is traversed by grey–white or yellowish veins, due to the presence of various accessory minerals such as calcite, wollastonite, phlogopite, plagioclase, diopside and others. There may be also other feldspathoids of the same lazurite family such as haüyne, sodalite or nosean. Furthermore, lapis lazuli of all deposits contains small inclusions of pyrite, mistaken in the past for gold inclusions. Due to the rocks heterogeneity, it is very difficult to identify provenance markers by analysing elemental composition of the whole rocks or works of art. Hence, a campaign to individually analyse mineral phases in lapis lazuli stone by means of ion beam techniques was started. Samples from four quarries of historical importance were analysed: three samples from Afghanistan, four samples from Pamir Mountains, one sample from Siberia and four samples from Chile.

* Corresponding author at: Dipartimento di Fisica Sperimentale, Università di Torino, Via Giuria 1, 10125 Torino, Italy. Tel.: +39 0116707366; fax: +39 0116691104.
E-mail address: alessandro.re@to.infn.it (A. Re).

0168-583X/$ - see front matter
doi:10.1016/j.nimb.2011.02.070