

# Improvements to the analytical protocol of lapis lazuli provenance: First study on Myanmar rock samples\*

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**Abstract.** The study of lapis lazuli is important to find out information about the provenance of a material used since the Neolithic Age for the manufacturing of precious carved artefacts. The Badakhshan deposits in Afghanistan are commonly considered as the main source of lapis lazuli in ancient times. However, other quarries could have possibly been exploited since antiquity. A protocol to distinguish the provenance of lapis lazuli rocks among four known source areas (located in present-day Afghanistan, Tajikistan, Siberia and Chile) by means of non-invasive techniques was set up in the last years. It is based on differences in the physical-chemical properties measured in 45 lapis lazuli rocks that constitute our reference database. The aim of the present paper is to extend the protocol analysing, by means of a multi-analytical approach, 10 lapis lazuli rock samples, coming from the quarry district of Mandalay in Myanmar, to find out significant petrographic and mineralogical markers. Optical microscopy and scanning electron microscopy were used to perform a detailed petrographic and mineralogical characterisation allowing to distinguish the Myanmar lapis lazuli in three main groups. SEM-EDX analyses on selected mineral phases were performed.

## 1 Introduction

Lapis lazuli is a semi-precious blue stone. It was used as decorative material by ancient civilizations since the Neolithic Age (VII millennium BC) for the manufacturing of precious carved artefacts [1]. Despite its extensive employment in palaces, temples and tombs, the knowledge on the geographical provenance of lapis lazuli rock is still incomplete. The possibility to associate the raw material to man-made objects could be helpful to reconstruct trade routes in specific historical periods.

The wide employment of lapis lazuli is related to its unique blue colour which is due to the occurrence of lazurite: a sulphur-bearing member of the sodalite group which can be also defined as sulphur-bearing haiyune (in the past, lazurite was considered as a variety of haiyune rich in sulphur [2,3] containing both sulfate and sulfide sulphur).

Lapis lazuli is generically classified as a metamorphic rock, even if this definition could not be considered exhaustive, due to the complexity of mechanisms involved in its genesis (more details in the following section: “Geological settings of lapis lazuli occurrences”).

Due to the relative rarity of geological conditions in which it can be formed, only few sources of lapis lazuli exist in the world [4,5]. In antiquity just one source, the Sar-e-Sang deposits in the Badakhshan Region (in present-day Afghanistan), seems to have supplied the whole Middle East, South Asia and Central Asia civilizations, among which, particularly, the Indus Valley, the Syro-Mesopotamian and the ancient Egyptian civilizations can be considered [6–10].

However, the early exploitation of the other geologically documented sources in the area, as in Lyadzhuar Dara (Pamir Mountains in present-day Tajikistan) and in Swat Valley (present-day Pakistan), or in more distant

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