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Elemental analysis and characterization of ochre sources from Southern Arizona

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Abstract

Iron oxides and other associated minerals (ochre) were widely used in ancient times, however, the use and procurement of these materials is not well understood and there has been little research on the elemental characterization of the material compared to other artifact classes. To assess the possibility of identifying ochre differences between locations, the original potential geological sources should be thoroughly characterized. This paper describes the collection of potential geologic sources of ochre in the Tucson basin of Arizona, sampling of those sources, instrumental neutron activation analysis (INAA), and subsequent multivariate analysis of the data. This paper has several goals, including characterizing geochemical trends within and between ochre sources, identifying the important elements in geochemical characterization of ochre, and establishing a database for further investigations. This preliminary study indicates that the inter- and intra-source variations in geological sources of ochre in the Tucson basin region can be differentiated. Future analysis of iron oxide artifacts will be performed to examine correlations between artifacts and sources and provide a basis for further deductions concerning ancient ochre procurement.

Keywords: Ochre; Elemental analysis; INAA; Arizona; Tucson basin; Iron oxide; Pigments

1. Introduction

Over the decades, many archaeological materials from ceramics to obsidian have been characterized by trace element analysis methods. From these analyses, information on ancient exchange of trade goods and interactions between groups can sometimes be deduced. Iron oxides and other associated minerals (“ochre”) were widely used as pigments in several archaeological contexts, however, there has been far less research on the elemental characterization of ochre compared to ceramics, stone tools, and other archaeological materials. Known prehistoric ochre sources are few, and the sites have not been systematically recorded by archaeologists.

As used by archaeologists, the term “ochre” covers a multitude of materials in a geological or geochemical sense. In general, it means a red pigment rich in iron oxides. The term ochre has been applied to materials as diverse as soil lumps with as little as 3% iron and iron-rich ore minerals with 30% iron or more. Every provenance study necessarily begins with the basic evaluation of the degree of variation in potential sources. Without some compositional measure, and assurance that sources vary on a scale appropriate to the study

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in question, it is not possible to proceed with a valid provenance characterization (Rands and Bishop, 1980; Stein, 1993). In the Tucson basin, thousands of artifacts have been identified as ochre and potential geologic sources have been identified, yet there has been no systematic mineralogical or geochemical study to characterize potential sources. The work presented here is the first step towards characterizing ochre sources in the Tucson area. This paper describes the sampling and instrumental neutron activation analysis (INAA) of ochre limited to geological sources from the western Tucson basin, Arizona and the subsequent multivariate analysis of the data. It was designed to test the hypothesis that these sources have the variation necessary to proceed with artifact-based provenance studies. The characterization of sources from a region helps to provide information about local or regional exchange in raw materials, in this case, iron oxide minerals. Because artifacts identified as ''ochre'' have frequently been ground up or added to vehicles for use as paint, it is often difficult to even determine the type of deposit that was collected much less the collection point. Elemental analysis provides a highly precise ''fingerprint'' of geologic deposits, thus was chosen as a starting point for this provenance study. Characterization of the degree of variation in ochre geochemistry both within and between sources, identification of the important elements in ochre characterization, and development of a comparative compositional database are important first steps toward the goal of conducting a full-scale ochre provenance study. The overall objectives are to better understand the source geochemistry of ochre in the region of Tucson, Arizona, and ancient ochre procurement patterns. This study is limited to three known geological sources in the Tucson basin to establish a foundation for characterization of iron oxides in the region.

2. Previous research

Previous studies of ochre sourcing from around the world have primarily focused on identifying the mineralogical content of paints, pigments, and ochre, without elemental composition. In addition, many are focused on artifact analysis rather than raw material characterization. Exceptions to this include sourcing of the Paviland ochre by XRF and petrography (Young, 2000), and possible sourcing of ochre from the El-Wad cave in Israel by SEM-EDS (scanning electron microscopy with energy dispersive spectrometry (Weinstein-Evron and Ilani, 1994)). David et al. (1993) used PIXE (particle induced x-ray emission) to study 69 ochre samples from Northern Australia. Clarke (1976) analyzed ochre from the Wilgie Mia ochre mine to study particle size and elemental composition. He also interviewed local Aboriginal people concerning the uses of ochre from this particular source.

Very few studies have been performed on the characterization of ochre sources in North America. Mrzlack (2003) used PIXE to analyze the source of ochre artifacts from an Alaskan cave site, and Ellis et al. (1997) characterized ochre sources from Texas by instrumental neutron activation analysis (INAA). Elemental characterization studies are fundamental to understanding ochre geochemistry and are the foundation for possible ochre sourcing in the future. Other recent studies include the analysis of ochre sources in Missouri and North America by Popelka-Filcoff (2006) Popelka-Filcoff et al. (2007a) by INAA, and elemental analysis of ochre from eight North American sites by Erlandson et al. (1999) by PIXE.

Erlandson et al. (1999) studied ochre from eight locations around the United States. Although based on a limited analysis of a single (in some cases a few) sample per source, their paper suggested that differences between ochre sources could be identified. In this example, compositional differences are expressed by the elemental signatures of the sources (Weigand et al., 1977; Wilson and Pollard, 2001; Neff and Glascock, 1995). In contrast to the Erlandson paper, the study presented here characterizes the sources through examination of multiple sampling locations per source. From a literature search, the results presented in this study represent the only elemental and trace elemental analyses of ochre from the Tucson basin region performed to date, and contribute to a growing database of ochre elemental analyses from other regions (Popelka-Filcoff, 2006 Popelka-Filcoff et al., in press-a; Popelka-Filcoff et al., 2007a; Popelka-Filcoff et al., 2007b).

3. Archaeological and geological background

Red ochre is a relatively common find in prehistoric settlements in southern and central Arizona where it has been found in securely dated contexts at least 2300 years old (Mabry, 1998; Miksa and Tompkins, 1998) (Fig. 1). Known uses include paint for pottery, basketry, arrows, and pictographs, and possibly for body and wall painting. It was also used in mortuary contexts where it was sprinkled over inhumations at certain times in prehistory. Ochre is found on Archaic and Hohokam sites in southern Arizona in a variety of forms, from unmodified red rocks or earthy lumps, to abraded rocks, powder on grinding tools, and even in the form of processed large lumps or ''cakes'' that were purified and made ready for use (Miksa and Tompkins, 1998). It is particularly abundant on several sites near the Beehive Peak and Rattlesnake Pass source areas discussed in this paper. In particular, Beehive Peak is adjacent to the West Branch site, which has produced large quantities of ochre and ochre-stained artifacts. West Branch is known for its abundant evidence for the large-scale production of painted pottery (Heidke, 2000). The Los Morteros site adjacent to Rattlesnake Pass was not a pottery production center in prehistory, however, the widespread ochre processing evidence at the site suggests its inhabitants may have processed the ochre for use as a trade item (Wallace, 1995).

Ochre in the greater Tucson basin potentially comes from three types of geological formations (Fig. 1). The first are soil profiles that are enriched in iron formed during the Pleistocene epoch (Jackson, 1989; McKittrick, 1988). The Beehive Peak sampling area represents this type of source. Soils forming just above bedrock have enriched iron in the B horizon. Second, iron oxide formations occur as near-surface supergene mineralization from hydrothermal ore-producing fluids,