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Destructive and nondestructive geochemical analysis of vesicular basalt from bedrock outcrops in the Salt-Gila Basin, Arizona: Evaluating the potential of nondestructive portable X-ray fluorescence spectroscopy for archaeological provenance analyses

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ABSTRACT

Researchers have long been interested in tracing the movement of vesicular basalt from natural source areas to archaeological contexts in the Salt-Gila Basin of southern Arizona. However, this effort has been hampered by the lack of a reliable and practical analytical technique for characterizing the composition of individual artifacts and specimens from geological sources. This paper summarizes an assessment of the efficacy of nondestructive portable X-ray fluorescence spectrometry (pXRF) for vesicular basalt provenance analyses. Specifically, the nondestructive technique was evaluated by comparing its performance in the analysis of 100 geological samples to an independent study that utilized destructive XRF and Neutron Activation Analysis (NAA). Additionally, nondestructive pXRF was used to analyze 900 vesicular basalt samples from 18 different volcanic outcrops in the study region. The results of these analyses indicated that nondestructive pXRF is capable of generating sufficiently reliable data for select elements and also that there is considerable geochemical variability among the material source areas. Therefore, pXRF may be both a reliable and practical analytical technique for vesicular basalt provenance studies in the Salt-Gila Basin.

1. Introduction

A study was conducted to evaluate the efficacy of nondestructive portable X-ray fluorescence spectrometry (pXRF) for vesicular basalt provenance studies in the Salt-Gila (i.e., Phoenix) Basin of southern Arizona (Figs. 1 and 2). Nondestructive XRF is a reliable method for characterizing compositionally heterogonous materials to a degree acceptable for geographic provenance analyses (Bernadini et al., 2015; Forster et al., 2011; Grave et al., 2012; Johnson, 2011; Kahn et al., 2013; Lundblad et al., 2008; Lundblad et al., 2011; Markowicz, 2008; Mintmier et al., 2012; Mills et al., 2008). The portable and nondestructive qualities of most pXRF devices also confer practical advantages for extensive archaeological research. However, three analytical challenges obstruct application of nondestructive pXRF for vesicular basalt provenance analyses in the study region: the reliability of the technique for quantitative analysis of vesicular material, the impact that the reduced elemental sensitivity of pXRF devices has on discerning meaningful geochemical patterning, and uncertainty regarding the extent of geochemical variability among basaltic outcrops in the Salt-Gila Basin.

Three tests were conducted to address each analytical concern. First, 100 vesicular basalt samples from select bedrock outcrops were split, with one half subjected to destructive XRF and Neutron Activation Analyses (NAA) by the Archaeometry Laboratory at the University of Missouri Research Reactor (MURR). The other half was analyzed using nondestructive pXRF by the Gila River Indian Community – Cultural Resource Management Program (GRIC-CRMP). The objective of the independent laboratory analyses was to assess the reliability of the nondestructive technique for characterizing vesicular basalt sample composition. In the second analysis, the multivariate structure of the MURR and GRIC-CRMP datasets were examined to determine if the reduced elemental sensitivity of the nondestructive technique adversely affected its utility for identifying geochemical patterning pertinent to provenance analyses. In the third study, 900 vesicular basalt samples from 18 different volcanic outcrops in the Salt-Gila Basin were assayed using nondestructive pXRF (Table 1; see Fig. 2). The resultant geochemical data were examined to assess if there was sufficient geochemical variability among the sampled source areas to permit

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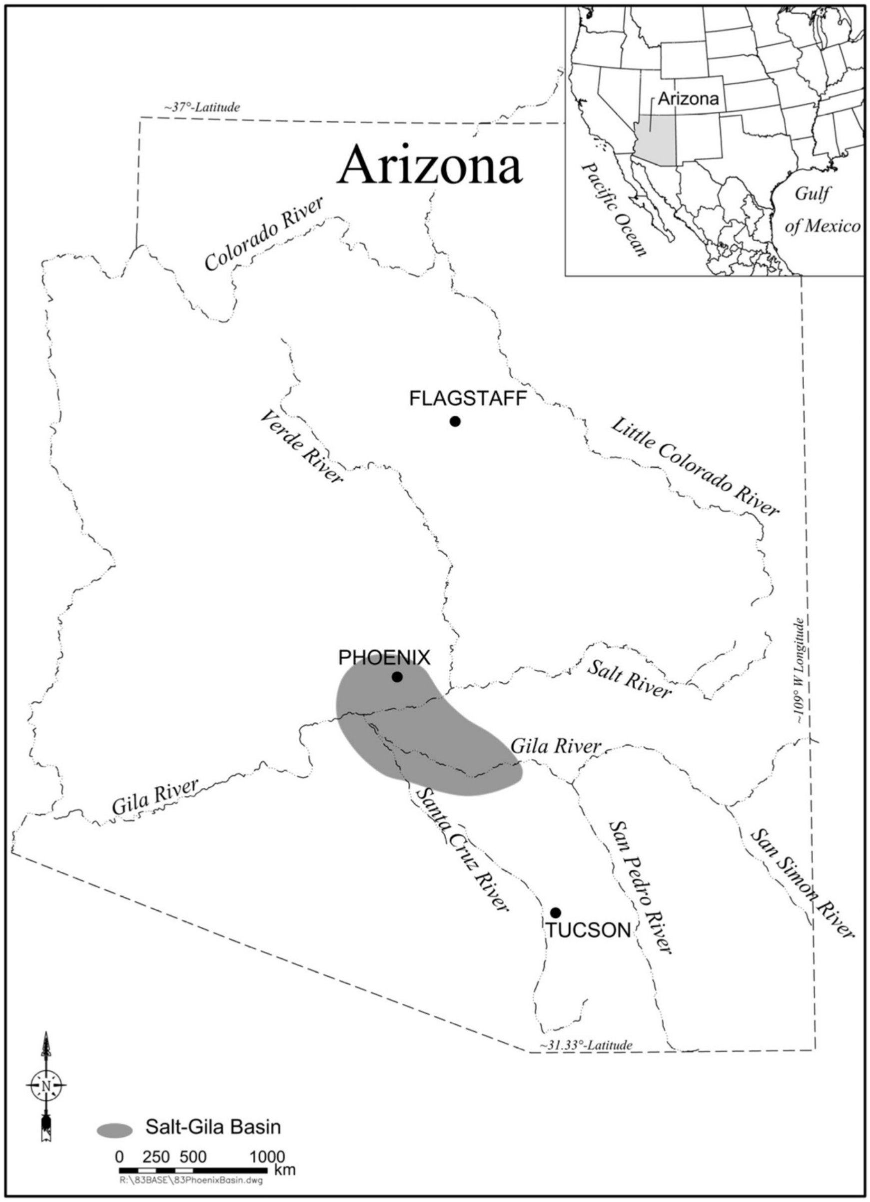

Fig. 1. Map of the Salt-Gila Basin in southern Arizona.

vesicular basalt provenance studies.

The first test identified measurement comparability among the destructive and nondestructive methods for multiple elements, including a suite of incompatible elements important for characterizing volcanic rock. The second analysis found that the reduced elemental sensitivity of pXRF had no adverse impact on the geochemical data structure. The third study revealed that there is ample geochemical variability in the nondestructive dataset to consistently distinguish material from several basaltic outcrops in the Salt-Gila Basin. Together, these findings suggested that nondestructive pXRF offers an effective means for characterizing the composition of individual vesicular basalt specimens and also discerning the geographic provenance of vesicular basalt from the study region.

2. Background

Vesicular basalt is a mafic volcanic rock characterized by several exterior and internal cavities. These voids are the relics of gas bubbles that were present in lava during solidification of the rock. Vesicular basalt occurs naturally in the Salt-Gila Basin at several bedrock outcrops (see Fig. 2; Table 1). Prominent exposures include the Santan Mountains in the middle Gila Valley, the McDowell Mountains in the Salt River Valley, and a collection of smaller hills (e.g., Adobe Mountain, Hedgpeth Hills, and West Wing Mountains) in the New River area north of Phoenix (Richard et al., 2000; Leighty, 1997). The vast majority of these outcrops were formed during the late Oligocene (29–23 mya) and Miocene (23–5 mya) epochs, with some early Pliocene (12–4 mya) basalt present in the eastern part of the study area (Leighty, 1997). The formations are generally composed of material from a single volcanic episode. However, in some cases, fault-block tilting during the Late Tertiary Basin and Range Disturbance (ca.15–8 mya) has resulted in the exposure of different petrogenetic units at single bedrock outcrops. The Deem Hills, Ludden Mountain, Robbins Butte, and the Santan Mountains, for example, all feature mixed talus of mafic and intermediate material.

Throughout prehistory and well into the historical era, the volcanic bedrock outcrops of the Salt-Gila Basin provided the Akimel O'Odham and their *Huhugam* ancestors (i.e., Hohokam) raw material preferable for the manufacture of food-grinding tools (e.g., manos and metates) and other stone implements (Bostwick and Burton, 1993). Today,