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Direct detection of Southeast Asian smelting sites by ASTER remote sensing imagery: technical issues and future perspectives

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ABSTRACT

Satellite-based multi-spectral remote sensing data were used in an attempt to identify control signatures for known prehistoric copper smelting sites in Thailand. It had been hoped that these characteristic signals could then be used as a reference for the detection of unknown Southeast Asian metal production sites, with the overall intention of strengthening the evidence base for early technological interactions with China and India. Regrettably, control signatures were not identified from the ASTER data due to issues of scale, chemistry, and vegetation, but we are able to offer reasons for this setback that might lead other scholars to develop successful applications of this methodology in more amenable (non-tropical) environments. Combined with ground truthing, intensive survey, excavation, and the technological analysis of metallurgical assemblages, this potentially useful and cost effective approach could lead to improved data density for the metal technology transmission discussions currently spanning Eurasia.

1. Introduction

This paper was born of a meeting of the Material Culture and Data Science research group at the UCL Institute of Archaeology in late 2007, whilst Pryce was undertaking doctoral research at UCL. This meeting was convened by Andrew Bevan and Xander Veldhuijzen, who wished to alert the research group to the potential of remote sensing for the prospection and mapping of areas of archaeometallurgical interest[1]. The application of remote sensing technologies and techniques is well established in archaeological research (e.g. Lyons and Avery, 1977; Wiseman and El-Baz, 2007), but to the best of our knowledge, this paper represents one of the first efforts to directly locate unknown mining and smelting sites. By 'directly locate' we mean the finding of a site based on the spectral signature of the typically large spoil or slag deposits produced by intensive and/or long-term metal production (though this approach does present some immediate limitations). We present a case study from Thailand, where ASTER data were used in an attempt to calibrate the spectral signature for known prehistoric mining and smelting locales in Thailand, and then apply these to unknown territories. As we will show below, the project was not a resounding success due to the inability of the spectral data to resolve relatively small targets, obscured by tropical vegetation, and insufficiently distinct from their matrices. Therefore, this paper is intended to be a technical note informing the archaeometallurgical community of the work we have done and problems we have encountered, hopefully stimulating further research and method development into what could be an effective means of archaeometallurgical site prospection in unexplored areas.

2. Archaeology

The current project was based on a very real need within Southeast Asian archaeology – more mining and smelting sites for the comparison of technological styles, and the subsequent discussion of technological transmission from neighbouring regions; predominantly China and India, though these interactions need not be unilateral (e.g. Murillo-Barosso et al., 2010; Pigott and Ciarla, 2007; Pryce, 2009; Pryce et al., 2010a; Pryce and Pigott, 2008; White and Hamilton, 2009). Since 1984, the Thailand Archaeometallurgy Project (TAP), co-directed by Vincent C. Pigott (University of Pennsylvania Museum, now UCL) and Surapol Natapintu (Thai Fine Arts Dept., now Silpakorn University) has been

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[1] Within the international collaboration of Veldhuijzen's work on ancient iron production in the Near East, a recent Masters project at Delft University of Technology in the Netherlands investigated the same problem in Jordan using remote sensing data from various satellites, including ASTER (Dentz, 2008).

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tackling the question of prehistoric regional metallurgy, based on the investigation of production locales (Pigott et al., 1992, 1997). By 1994, in two areas of Thailand, one copper mine, two copper smelting sites, and one large settlement had been excavated by TAP at either end of the Loei-Petchabun Volcanic Belt (LPVB), a metallogenic fault zone running NNE–SSW and separating the Thai Central Plains from the Khorat Plateau (Fig. 1).

The first of these two areas was Phu Lon (Bald Mountain), a 1st millennium BCE copper mine on the southern bank of the Mekong River (Fig. 2), excavated in two seasons in 1984 and 1985. The metallurgical complex extends over two hills containing substantial oxidic copper deposits, the westernmost of which was almost completely mined away in antiquity (Pigott and Weisgerber, 1998). The matrix of the site consists largely of mining debris and the surface is mostly denuded of tall vegetation.

The second area investigated by TAP was the Khao Wong Prachan Valley (henceforth 'KWPV' or 'Valley'), an igneous intrusion situated on the eastern edge of the Chao Phraya sedimentary basin (Central Plains), and about 140 km NNE of Bangkok. The Valley is of regional metallurgical interest from the beginning of the local Bronze Age (c.1300 BCE) through to the Lopburi period (c.1300 CE) (Rispoli et al., 2009). In four seasons between 1986 and 1994, TAP focused its attention on two enormous prehistoric smelting sites within the valley (Fig. 3). The earlier site, Non Pa Wai, covers 5 ha and has up to 4 m of archaeological deposits. The prehistoric metal age layers have been bracketed from c.1300 BCE to c. 300 BCE, but extractive copper metallurgy, rather than founding and consumption, is currently firmly dated post c. 6/500 BCE (Rispoli et al., 2009; Pryce et al., 2010b; cf. Natapintu, 1991; Pigott et al., 1997). The later site, Nil Kham Haeng, has a sequence dated between c. 300 BCE and c. 500 CE (Rispoli et al., 2009), and covers over 3 ha with up to 6 m of settlement and metallurgical debris. Due to past industrial-scale smelting, bioturbation, and the effects of a dynamic tropical climate, it has so far proven difficult to gain a fine-grained understanding of the stratigraphy within the industrial strata (Ciarla and Natapintu, 1992; Cremaschi et al., 1992). However, the richness of the archaeometallurgical assemblage is unparalleled, with many thousands of tonnes of slag and technical ceramic testifying to the production of large quantities of copper, presumably far in excess of local requirements (Mudar and Pigott, 2003; Pryce, 2009; Pryce et al., 2010a,b; White and Pigott, 1996). The ores for this copper are likely to have come from the three copper mineralisations recorded within the vicinity of the valley: Khao Tab Kwai, Khao Phu Kha, and Khao Pha Daeng (Fig. 3), though there is no dating evidence for any of them.

3. Project reasoning

The immediate objective of the reported remote sensing exercise was to investigate the multi-spectral visibility of the two known extractive metallurgical locales at either end of the Loei-Petchabun Volcanic Belt. It was reasoned that by defining a mining/

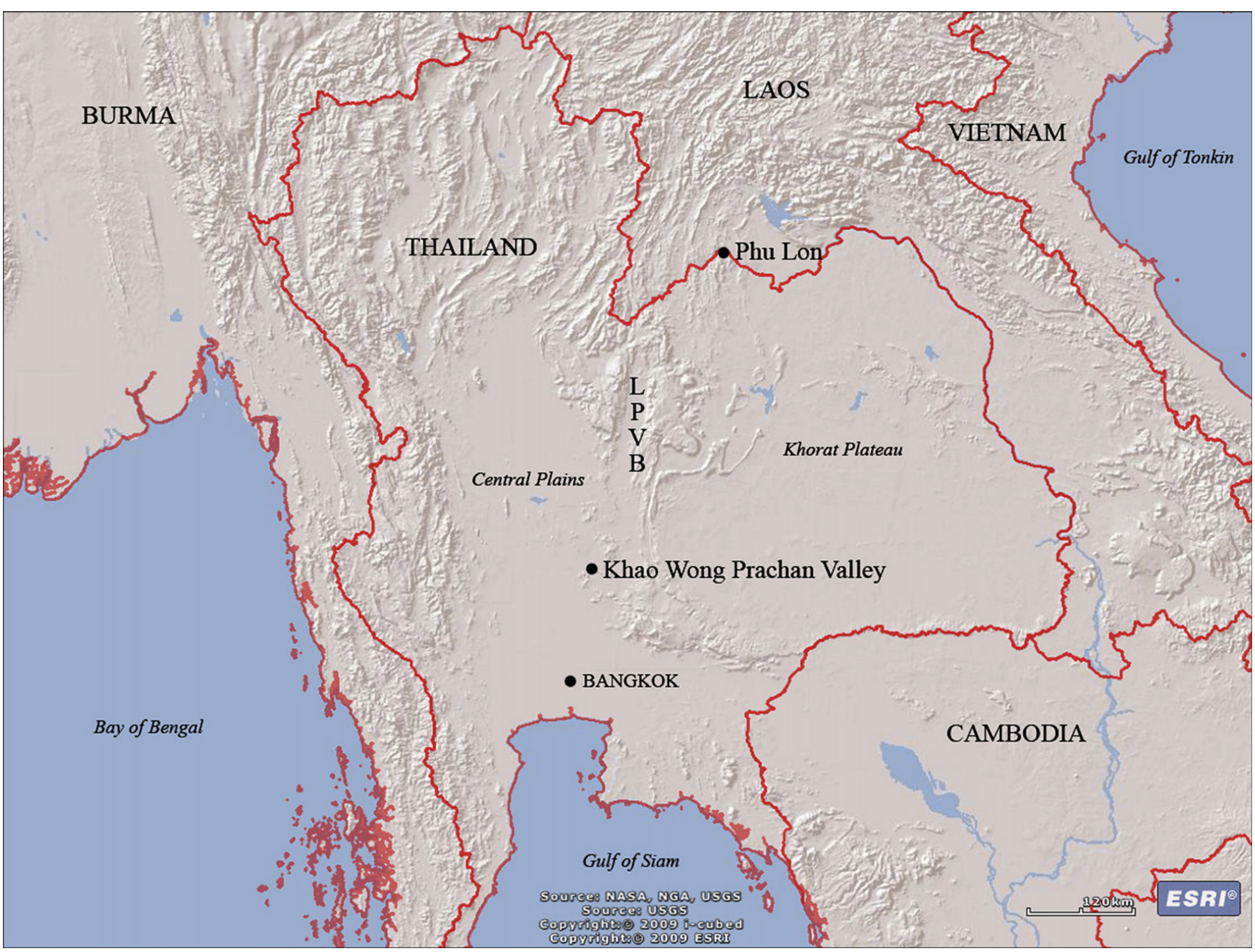

Fig. 1. Map showing the Loei-Petchabun Volcanic Belt and the principal archaeological sites mentioned in the text.