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Assessing the changing condition of industrial archaeological remains on Alston Moor, UK, using multisensor remote sensing

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A B S T R A C T

Upland environments have the potential to preserve relatively undisturbed multi-period archaeological remains due to reduced anthropogenic impacts such as intensive agriculture. However, these environments can also be extremely fragile and susceptible to alternative pressures from insensitive land-use practices and their dynamic geomorphological setting. This paper presents the results of research focussing on the interactions between industrial heritage sites and their semi-natural landscape context within the upland landscapes of Alston Moor, North Pennines, UK. Change detection using multispectral Landsat data was combined with detailed mapping from airborne lidar, aerial photographs and fieldwork to quantify the rate and nature of the changing condition of selected industrial archaeological sites. Results indicate that extensive degradation has been occurring at a number of former lead mining sites over recent decades, primarily due to fluvial erosion in the form of gullying but with slope and aeolian processes also of significance in particular locations. Soil samples taken from actively eroding areas within Fletcheras Rake, one of the earliest documented lead mines in the area, suggest that the reworking and redistribution of sediments from former mining sites are releasing heavily contaminated sediments into the wider hydrological catchment. It is argued that a more complete understanding of the complex interrelationships and linkages between archaeological sites and the semi-natural environments in which they are situated can only be achieved through the combined application of research methods employed by both the archaeological and geomorphological disciplines.

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1. Introduction

The potential for archaeological remains within upland environments to survive relatively undisturbed by recent pressures such as intensive agriculture or urban development is now widely acknowledged (Tunnicliffe, 2006; Whyte and Winchester, 2004). Uplands such as the North Pennines have the potential to retain important archaeological sites as upstanding monuments or earthworks; features that would often have been destroyed through activities such as long-term intensive ploughing in corresponding lowland contexts (Coggins, 1986; Darvill, 1986a; Manby and Turnbull, 1986). The extensive peat deposits occurring within many upland environments also provide an excellent archive of palaeoenvironmental data and organic archaeological remains (Gearey et al., 2010; Simmons, 2003).

However, it has also been recognised for several decades that the archaeology within upland environments faces a diverse range of other pressures, both natural and anthropogenic, that threaten the survival of this important resource (e.g. Darvill, 1986b). Insensitive land-use practices coupled with indirect anthropogenic effects such as global climate change are impacting directly and indirectly on environments where thin soils, harsh climates and short growing seasons often predominate, making upland environments overwhelmingly dynamic and fragile. Implementing policies and management practices that maintain or improve core upland ecosystem services can therefore be particularly difficult,

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with the need to maintain the appropriate balance between the requirements of the direct 'users' of upland landscapes, whether inhabitants or periodic visitors, and associated priorities such as carbon sequestration and biodiversity (Bonn et al., 2009; Burt et al., 2002). Within this context, the need to determine practical and effective heritage management strategies is paramount.

Remote sensing has already been used effectively to investigate a wide range of environmental and anthropogenic pressures in upland landscapes, including gully erosion (Evans and Lindsay, 2010), peatland hydrology (Harris and Bryant, 2009), habitat mapping (Poulin et al., 2002), carbon fluxes (Becker et al., 2008) and the effectiveness of peatland restoration (Lowe et al., 2009). Nevertheless, there have been few studies that have attempted to specifically investigate the potential of remote sensing techniques for managing upland archaeological remains, particularly in reference to their wider semi-natural environment (cf. Kincey and Challis, 2010).

1.1. Context to the research

This paper discusses the results of remote sensing analyses and fieldwork undertaken to assess the changing condition of industrial archaeological remains on Alston Moor in the North Pennines, UK. Although analysis was designed to focus on the historic industrial remains of the area and so primarily medieval and post-medieval in date, many of the wider implications will equally apply to remains from other periods and site types. The condition of the archaeological resource was assessed in relation to evidence for erosion processes within the surrounding landscape, such as the presence of landforms such as gullies, debris fans and relict stream channels. Multi-temporal imagery was used to quantify the extent of change over time through an assessment of how the form and nature of the archaeological sites has altered through recent decades.

The extent and severity of erosion in upland environments is often driven by complex interrelationships between a wide range of contributing factors. The nature of the sediments and their vegetation cover provide the context against which a variety of erosion processes, including fluvial, aeolian, slope and frost are constantly acting (Burt et al., 2002; Evans and Warburton, 2010). The sensitivity of upland peatlands to change and degradation in particular is well understood (Charman, 2002; Tallis et al., 1997); with considerable research focussing specifically on peat erosion within the Pennine Chain (Bower, 1960; Evans and Warburton, 2005; Yeloff et al., 2005). The nature and severity of the erosion and its impact on the archaeological resource varies depending on the local situation and specific conditions, with landform evidence such as gullies or arcuate tears providing indirect insights into which particular geomorphological processes are dominating.

The situation in this area of the North Pennines is complicated further by the potential for these processes to cause remobilisation of metal contaminants stored in the archaeological deposits; a long-term legacy of the area's industrial heritage. The role of archaeological remains within the broader source-pathway-receptor framework for assessing land contamination is already widely acknowledged (McCaffrey et al., 2005), with such remains able to act as the source of pollutant mobilisation, the pathway linkages along which mobilisation occurs, or the receptor sites for deposited contaminants. Therefore targeted fieldwork to collect samples for testing the levels of these contaminants and their bioavailability to the wider catchment was also conducted, with the results of this analysis being considered in relation to their likely geomorphological context. The conclusions of the work are discussed in relation to this particular landscape in the UK but are equally applicable to other environments where similar anthropogenic and geomorphological factors co-exist.

The work was part of wider English Heritage research aimed at investigating the archaeological landscapes of the North Pennines Area of Outstanding Natural Beauty (AONB) (Ainsworth, 2008). This multidisciplinary research aimed to use diverse techniques including remote sensing, field survey and historic area assessments to better understand the historic environment of the area. Emphasis was placed on recording evidence for the exploitation of mineral resources, principally lead extraction and processing, and farming; the twin practices that have historically dominated the economy of the area. The recording of these 'miner-farmer' industries went alongside research into the complex interplay between historic land-use practices and the surrounding semi-natural environment, with the intention being to generate an assessment of potential future impacts. This paper outlines the results of one aspect of the overall project, the use of multisensor remote sensing techniques to record and assess the condition of archaeological sites within the Alston Moor landscape (Kincey et al., 2011).

1.2. Study area

Analysis focused on a 32 km^2 area of Alston Moor (central NGR: NY755440), incorporating sections of the valleys of the River South Tyne to the south and the River Nent to the north, as well as a sizeable area of upland moor crossing Middle Fell and Flinty Fell; an altitudinal range of 250–670 m AOD (Fig. 1).

Alston Moor is located within the Northern Pennine Orefield, a geological area bounded by the faults marking the Tyne Gap and Stainmore Gap to the north and south respectively, the Pennine escarpment to the west and the former West Durham Coalfield to the east. The geology of the Alston Block consists primarily of Carboniferous age sedimentary rocks that form a series of repeating sequences of limestones, sandstones, interbedded shales and coal measures, known as the Yoredale cyclothems. Igneous intrusions into the network of faults and veins within the Carboniferous rocks resulted in the rich mineral deposits that have driven the industrial exploitation of the area, in particular lead and zinc ores and the associated gangue minerals such as fluorite and barytes (Dunham, 1990). The overall topography of the landscape developed during the last glaciation and through subsequent Holocene processes. The north- to north-east-facing valley slopes were typically covered by boulder clay as the glaciers retreated and are therefore smooth in profile, whilst the south- to south-west-facing slopes tend to have a profile consisting of stepped benches caused by the differential weathering of exposed Carboniferous strata with varying hardness characteristics (Bulman, 2004; Clarke, 2008). Soils in the area are typical of other upland environments with similar geology, comprising slowly permeable acidic loams and clays on the lower valley slopes and blanket bog peat soils on the higher fells.

The landscape is sparsely populated, with the exception of relatively small nucleated settlements at Nenthead and Garrigill, and includes fields on the lower slopes of the two valleys that have been improved with fertilisers and historically kept in constant use primarily for pasture grassland, known locally as 'in-bye' land. At higher elevations the land grades into open heathland, moorland and blanket bog on the fell tops.

The archaeological mapping covered the entire study area but with two locations selected for more detailed analyses in order to better characterise detailed process interactions and patterns of change: the surface lead workings and hush at Redgroves (NY734448) (Fig. 2) and the lead workings at the Scheduled Monument site of Fletcheras Rake (NY745434) (Fig. 3). The main workings at Redgroves were opencast along Redgroves Hush, an artificial ravine caused by the repeated discharge of water from an upstream reservoir in order to clear overburden from surface

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