CHAPTER 1: INTRODUCTION

1.1 Introduction

This research is an investigation into medieval and post-medieval high temperature primary production industries in order to obtain a better understanding of their magnetic characteristics and thus improve geophysical survey interpretation of the features associated with these industries. Investigations into secondary production industries, such as iron smithing, have not been undertaken due to the rarity of such sites being identified in the archaeological record and consequently not being available for geophysical survey and sample analysis. Originally, the study was confined to the primary industries of iron smelting, lead smelting, and glass production, but as the research programme developed, the study was extended to include charcoal production due to its close association with iron smelting. The production technologies of these primary industries are known to have improved significantly during the later medieval and post-medieval periods, particularly with respect to iron and lead smelting. This research specifically investigates the technologies carried out at ground level. In addition to researching the geophysical responses of the industries studied, the use of magnetic characteristics for dating purposes is investigated.

1.2 Research Background

Geophysical prospection is an invaluable technique in the location of high temperature processes in the landscape, either as part of routine large scale surveys or as targeted surveys in the investigation of surface features or finds; examples are Corney *et al.* (1994), Gaffney *et al.* (2000) and Walker *et al.* (2005). However, geophysical surveys, particularly using magnetometry and magnetic susceptibility techniques, have not

necessarily located the main components of primary production industrial sites with a high degree of precision.

Few surveys over iron smelting sites have been conducted in a manner other than to record the furnace and slag deposit features; any fine detail is usually uncovered during excavation (Vernon *et al*. 1998b). The interpretation of geophysical data derived from iron smelting sites and the separate identification of the areas of ore processing and fuel storage, the furnace and its associated features, and slag deposits have been complicated by the different magnetic responses from each of these features; the furnace and slag heap magnetic anomalies between them can easily mask other anomalies (Vernon *et al*. 1998b; Powell, 1999). The interpretation is further complicated by the wide range of geophysical responses that iron smelting sites can produce. Magnetometer surveys of typical archaeological sites often record data values in the range ±10nT, whereas iron smelting site data can easily be ±1000nT or more, and as a result subtle features may be missed (Vernon *et al*. 1998b).

A review of the literature indicates that geophysical prospection and archaeomagnetic dating have not been carried out at many iron smelting sites excavated in the 20th Century, or at least not adequately documented; there are exceptions, such as Millbrook, Sussex (Tebbutt 1982), Woolaston, Gloucestershire (Fulford and Allen 1992) and Llwyn Du, Snowdonia (Crew and Crew 1995). It is only recently that geophysical survey techniques have been employed for enhanced, systematic detection and recording of early iron smelting sites (Abrahamsen *et al*. 1998b; Crew 2002; McDonnell 1995a; Photos-Jones *et al*. 1998; Vernon 1995; Vernon and McDonnell 1996; Vernon *et al.* 1998a, b and 1999). The magnetic response of an iron smelting site has been shown

by these authors and others to be a combination of the responses from the anomalies associated with the individual features of the site and the underlying geology.

Very few, if any, geophysical surveys have been undertaken at lead smelting, glass production and charcoal production sites: the interpretations of these sites through geophysical survey is consequently sparse. According to R. Vernon (pers. comm.) the earliest known geophysical survey of a British lead smelting site was carried out at Grinton in Swaledale (McDonnell *et al.* 1992) with a follow-up investigation at Grinton and elsewhere in Swaledale by Hamilton (1998), all with varying degrees of success in identifying features. Magnetic geophysical survey appears not to have been used in the majority of glass production site investigations. Kenyon (1967, 147) states that more than half the known sites in the Weald were found as a result of following up a field name clue by fieldwalking. At the glass production sites of Bagot's Park, Staffordshire (Crossley 1967), and Hutton Common and Rosedale in North Yorkshire (Crossley and Aberg 1972), proton magnetometer surveys were carried out before excavation, more as a test of the survey technique but in each case confirming the initial visual site impressions. As far as can be ascertained, only two charcoal production sites have been geophysically surveyed: in Eskdale, Cumbria (Leigh 1999) and on the Gower, South Wales (Kissock and Wright 2001).

In recent investigations, such as Vernon *et al*. (1999) and Powell *et al*. (2002), detailed surveys followed by limited excavation and laboratory analysis of excavated materials have shown that it is possible to obtain a much improved interpretation of the geophysical data. The specific research of the Kyloe Cow Beck iron smelting site in Bilsdale, North Yorkshire (Powell *et al*. 2002), focused on the interpretation of magnetometry and magnetic susceptibility surveys, through the comparison of the

survey data with the excavated site features and the analysis of the magnetic characteristics of excavated samples from the furnace, slag deposits, and adjoining soil and heat affected clay. Analysis of the remanent magnetic properties of the furnace also allowed the feature to be dated by conventional archaeomagnetic methods (cf. the magnetic mapping technique used by Crew (2002)).

By improving the interpretation of magnetic geophysical survey data, through the investigation of the magnetic characteristics of the individual features or components of iron smelting, lead smelting, glass production and charcoal production sites, it should be possible to identify and locate these features with greater precision. This will be important for comparing sites of the same industry and discriminating between them to allow sites or features within sites to be targeted for excavation. Where excavation is not possible because preservation *in situ* is considered the best option, geophysical survey techniques are essential due to their non-destructive nature and precise interpretation of survey data is imperative.

1.3 Aims and objectives

In summary, this research is an investigation into the magnetic characteristics of medieval and post-medieval ground level iron smelting, lead smelting, glass production and charcoal production sites. The aims of the research are:

(a) to enhance the interpretation of these industrial production sites by improved analysis of the geophysical magnetic survey data through detailed characterisation of the magnetic signature of individual components within the sites; this will allow:

(i) the individual components of an industrial site to be distinguished, e.g. furnace or similar structures, charcoal pitsteads or platforms, ore processing areas and slag or other waste product deposits, and

(ii) discrimination between the industries based on the types of components identified and the landscapes in which the sites are found;

(b) to develop a means of quantifying the temperatures achieved in site structures and the immediate surrounding area, through the measurement of the changing magnetic properties of the heat affected zones;

(c) to carry out the archaeomagnetic dating (AMD) procedure at those industrial sites where thermoremanence has been acquired, in order to determine the suitability of the heat affected site material for AMD sampling, i.e. whether one type of material is more appropriate than another; the stability of sample material, both physical and magnetic, will be tested as part of the process of calculating the archaeomagnetic date.

The investigations are divided between the practical evaluation of potential sites using geophysical survey and trial excavation, and laboratory analysis of sample material from sites. To achieve the above aims the following objectives have been identified:

(a) for each of the four specified industries, representative samples of soil, natural clay, furnace or similar material, heat affected clay, ores, products, waste products and miscellaneous material directly associated with the industrial process, e.g. crucibles, will be obtained. Sampling will require either identification of sites where limited trial excavations can be undertaken to obtain samples, or identification and retrieval of material from previous excavations, held in museums or other archives. It is recognised

that this archival material may only be a small proportion of the excavated finds but would none the less provide valuable data;

(b) for each of the representative samples noted above, the morphological, mineralogical and magnetic properties will be determined using, as appropriate, optical and scanning electron microscopy, X-ray diffraction, and magnetic susceptibility and viscosity measurements; the magnetic properties will allow comparison with and interpretation of the geophysical survey data;

(c) where practicable, the archaeomagnetic characteristics and date of high temperature structures will be determined. To achieve this objective, some excavation has to be undertaken, but where this is not possible, it is recognised that a significant amount of data regarding the thermoremanent properties of a structure would be unobtainable;

(d) the thermal properties of natural clay samples obtained from the industrial sites noted above will be investigated and compared with the corresponding magnetic properties of samples obtained from site working surfaces; this will determine any temperature/susceptibility relationship which could be used to estimate the operating temperature of a furnace or similar structure.

1.4 Wider implications

Whilst originally directed at the iron smelting industry associated with Rievaulx Abbey, and the impact that the monastic activities had on the landscape on and around the North York Moors, by implication the research can be applied elsewhere and extended to include other high temperature industries of the medieval and post-medieval periods, where the processes were carried out at or below ground level, e.g. brick and tile making. Although this research has been deliberately restricted to the medieval and

post-medieval periods, it is considered feasible for the analyses described within to be applied to other periods providing there is sufficient evidence of a process remaining in the archaeological record.