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# ASSESSMENT OF EARLY LEAD WORKING SITES IN THE YORKSHIRE DALES BY GEOPHYSICAL PROSPECTION

by Kenneth Hamilton, J.G. McDonnell and A. Schmidt

## ABSTRACT

Although lead was a major source of economic wealth in antiquity, there have been few studies of lead smelting sites in Britain. This study presents an assessment of mediæval lead smelting sites (bales) in Swaledale by archæological geophysics. Sites were surveyed using a fluxgate gradiometer. Bale sites appear to have consisted of several small areas of burning, often with associated fuel stores. The results suggest that the difference between bales and blackwork ovens is less clear than was previously thought. In addition, it appears that the terms bale and bole refer to two similar but separate technologies, and that the terms are not interchangeable.

## LEAD PRODUCTION

Lead appears early on in the metallurgical world, as one of Britain's earliest metal objects and later as an alloying agent in copper alloys.[1,2] The majority of lead produced from the Roman period to the post-mediæval period was used in construction and in the pewter industry.[3]

Lead was worked in antiquity in various areas of the British Isles, e.g. in Teesdale, the Yorkshire Dales, Derbyshire, the Mendips and the south west of England.[4] The ore is present as galena (PbS, lead sulphide), which occasionally weathered to cerussite ($PbCO_3$, lead carbonate).

Lead smelting is possible at relatively low temperatures (600 to 800°C), hence early lead smelting furnaces are assumed to have been simple hearths.[5] In Yorkshire, the smelting was carried out in so-called bales, a form of wind-fired furnace, similar to the Westphalian lead smelting furnaces described by Agricola.[6,7] Wind-fired lead furnaces are also found in Derbyshire, as boles. Indeed, the terms are often used interchangeably (e.g. Raistrick and Jennings, Tylecote, Willies & Morrison).[8-12]

While the existence of bales was known from documentary evidence, the first archæological recording of one was by Raistrick in 1919, published in 1927.[13] He wrote:-

> "*Situate* [sic] *on a low hill usually facing west or south-west, the direction of the prevailing wind. A small space, not more than a few feet in diameter, was surrounded by stones built in a low wall, with an opening to the west; the loose soil was scooped out in a hollow from which a shallow trench led to a place outside the wall. A layer of brushwood and peat was built up inside, the ore to be smelted heaped on top, and when a good steady wind was blowing from the south-west the fire was lighted. With the steady draught so obtained a temperature sufficient to reduce the soft ores was easily obtained.*"

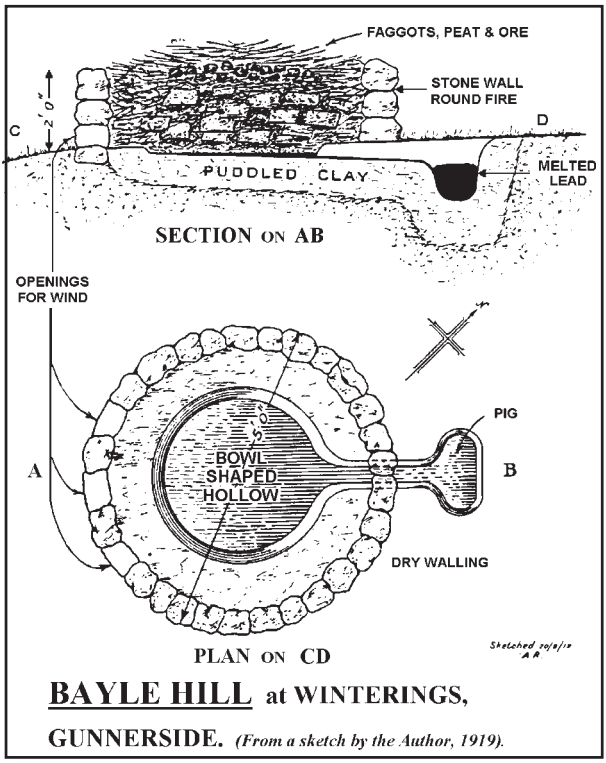


Figure 1. Putative reconstruction of a bale (from Raistrick, 1927).

Boles, however, are described as:-14

> "*builded upon a hill and walled with stonne on the owt sydes and the back about xx foote* [6m] *wyde wherein was laied vj great trees called Blockes for the first foundacon and uppon these blockes was layed certen smolton ewer about halfe a yarde* [46cm] *thycke and upon that ewer theyr was layed tenne or twelve trees called shankerds upon these shankerds next layed or builded certen fyer trees where in the workemen set in the ewer iij or iiij courses to smelt theyr ewer on if the winde stande right an for burning downe of the Bole aforesaid they do build and set before the face of that Boole certen great trees to the number of xxtie or xxxtie with great quantitie of smale woodde to the value of ccc seeme of wodde where of tenne seeme is a weane loade.*"

On the face of it, the differences between these two types of furnace are minimal, and chiefly a question of scale. There is, however, a wooden platform in the Derbyshire bole, allowing a better draught throughout the furnace and raising the temperature at lower levels within the furnace.

Due to the low temperatures involved, bale smelting is a particularly inefficient method of smelting ore, yielding a slag that could consist of up to 50% lead, as unreduced ore and partially reduced oxides.[4] In the late mediæval period, the slags produced by bale smelting were resmelted in separate hearths, called blackwork ovens.[8] Blackwork ovens (slag hearths) were small, bellows-driven hearths, fired with charcoal to achieve a higher temperature and more reducing conditions.[9] Blackwork ovens produced a black, glassy slag, compared to the white, porous slags of the bales.[5] Blackwork ovens were usually situated adjacent to bales, to take advantage of a ready supply of raw material. As bales and blackwork ovens are very similar structures, and frequently occur together, accurate identification of one or the other is difficult (e.g. Raistrick compared with Blanchard).[13,15] Unfortunately, there is no real way to differentiate between them, except by reference to slag samples. Often, however, both types of slag occur together, as at Grinton Smeltings or on Calver Hill.[16,17] Whether this is indicative of a certain type of blackwork oven, a bale site with associated blackwork oven or a bale run at an unusually high temperature is, at present, unknown.

## GEOPHYSICAL SURVEYS

The majority of published bale sites in Yorkshire have been located by Lawrence Barker, by a combination of place name evidence, areas of little or no vegetation and surface finds of bale slags.[6,18] Differentiation between areas of lead contamination and areas of heather burning on aerial photographs has proved difficult.[6] To date, only three bales have been surveyed using geophysical techniques, all using magnetometer surveys.[16,19,20]

In this study, Calver Hill Site 1 and Grinton Smeltings were surveyed in 10 metre square grids, walking along parallel traverses from west to east, at a traverse interval of 0.5 metre and with a sampling interval of 0.5 metre. Magnetometer data were collected using a Geoscan Research FM36 fluxgate gradiometer with an ST1 automatic sample trigger. Magnetometer survey was chosen to detect thermoremanent magnetisation associated with areas of fierce heating (e.g. within a bale) (Hamilton *et al.* in prep).

Calver Hill Site 1, published by Barker and White, is a 950m$^2$ area of slag scatter in several discrete areas, along with an area of burnt material and an area of large stones (Plate I).[6,17]

The site consists of two probable bales, indicated in Figure 3. Slag and burnt material have spread downhill, creating a large bare area downhill of the western bale (although the bale is partially covered by vegetation). To the north-east lies an area of dumping, either from this bale site or from another bale further uphill, which is now covered by heather. Downhill is a semicircular feature, possibly the remains of a ditch or turf bank. This feature may represent the remains of a shelter or store.

*Plate I: Area of bale on Calver Hill Site 1, looking North (K. Hamilton).*

Grinton Smeltings (Barker Site 5) was previously surveyed by McDonnell *et al*.[16] The site consists of a probable bale, indicated in Figure 3. Downhill is a semicircular feature, possibly the remains of a ditch or bank. The shape of the anomaly suggests that the feature has been subjected to intense burning, and may represent the remains of a burnt-down shelter or store. The current course of the stream can be plotted on the results. When the current course of the stream is compared with the magnetometer results, it seems likely that the course has changed over time. The results of the survey by McDonnell *et al.* suggest at least one other bale further west.

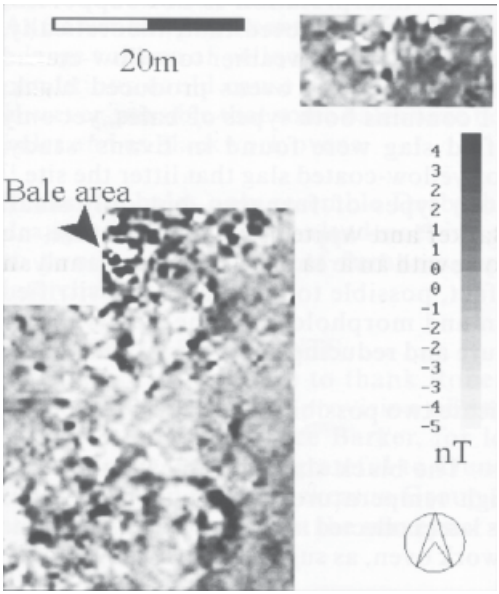


Figure 2: Magnetometer data from Calver Hill Site 1.

On both sites, slag finds were mainly white-coated lead slag, with occasional finds of black vitreous slag. The presence of large quantities of white-coated

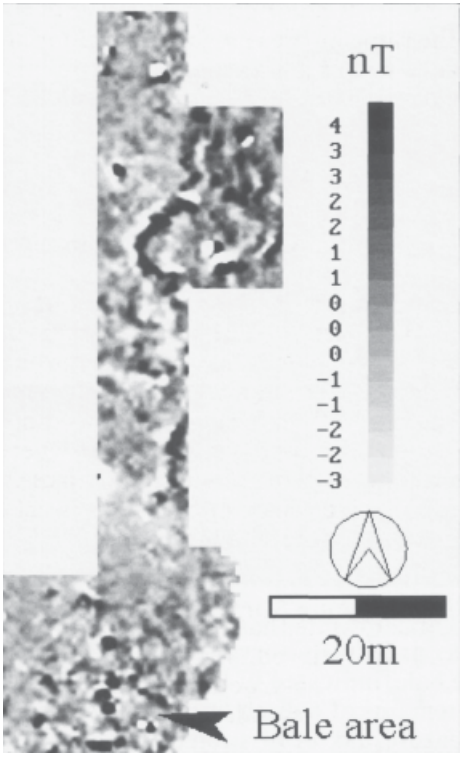


Figure 3: Magnetometer data from Grinton Smeltings.

slag makes the presence of bales highly likely, while the presence of small amounts of black vitreous slag on Calver Hill Site 1 and Grinton Smeltings suggests that slag hearths may have been operative in the area.[5]

**DISCUSSION**

From the results of these surveys, it appears that the investigated bale sites consist of an area used for several smelting events, sometimes involving separate bales, and some using smaller furnaces. The larger sites contain one large, stone-walled bale, with several smaller smelting areas scattered in the vicinity, while the smaller sites involve only small bales. It would be tempting to interpret one feature as a bale, with the others being blackwork ovens. This interpretation is not supported, however, by slag finds on the site. Claughton noted that, theoretically, the lower temperature bale produced slags which weather to yellow-coated slags, while the higher temperature blackwork ovens produced black, vitrified slags.[21] Calver Hill Site 1 contains both types of bales, yet only two small pieces of black vitrified slag were found in Evans' study, compared with the vast amounts of yellow-coated slag that litter the site.[17] Grinton Smeltings contained both types of furnaces, but only small quantities of black vitrified slag.[16] There appears to be, therefore, no direct correlation between slag type and bale shape. Chemical analysis of bale slag showed that it is, in fact, possible to produce black vitrified slag in a bale, as the composition and morphology of the slag is linked to a combination of the temperature and reducing conditions in the bale.[5]

The sites surveyed, therefore, indicate two possibilities:-

1. All smelting events are bales. The black slag was created in a bale which reached a particularly high temperature, due to ideal weather conditions. Yellow-coated slag was later collected and removed to a separate location for resmelting in a blackwork oven, as suggested by Claughton.

2. There is no structural difference between a bale and a blackwork oven. Indeed, the two may have performed the same purpose, by using a different fuel and the addition of bellows. This would create the least work for the smelters, as they would not need to build a separate furnace, and would not need to move slag.

In fact, it may be that both of the above explanations are true. Documentary evidence (cited by Claughton), combined with the evidence from Grinton Smeltings, however, suggests that the first option was the more common.

From the strength of the magnetic responses, it is likely that the walled bales were lined with clay, as suggested by Raistrick. The size and shape of the features indicates that bales were small (diameter 1-2m), probably round features, some of which were surrounded by a stone wall, although some remained as merely big bonfires. The industry, therefore, appears far more haphazard and opportunistic in Yorkshire, as opposed to Derbyshire, where the industry appears to have been organised, with regular, reusable furnaces.[14] Because of the differences in construction, size, shape and pattern of use, the two terms bale and bole should not be used interchangeably.

## CONCLUSIONS

From the geophysical results, it is possible to state that bale smelting was a much more haphazard affair than previously believed. Bale sites consist of several smelting areas of differing size and construction, and possibly utilising different fuels. Many bale sites had semi-circular structures, which may have been used as shelters or fuel stores.

As Calver Hill Site 1 contained small traces of black vitrified slag in amongst a large volume of yellow-coated slag, it is highly likely that ideal smelting conditions could cause black vitrified slag to be created in bales. It is, however, possible that some bales were being used both as primary smelting bales and as blackwork ovens.

Yorkshire bales only resemble Derbyshire boles in that they are natural draught furnaces used for lead smelting. The two terms bale and bole refer to two separate types of furnaces, and can no longer be considered interchangeable.

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**BIBLIOGRAPHY**

1. Hunter, F. & Davis, M. "Early Bronze Age Lead - a Unique Necklace from Southeast Scotland" *Antiquity*, Vol.68 (1994), pp.824-830.

2. Bayley, J. "Non Ferrous Metal Working: Continuity and Change" In Slater, E.A. and J.O. Tate (Eds.) *Science and Archæology Glasgow 1987. Proceedings of a Conference on the Application of Scientific Techniques to Archæology, Glasgow, September 1987.* BAR British Series 196 (i) (1988), pp.193-207.

3. Nriagu, J.O. *Lead and Lead Poisoning in Antiquity* (New York: John Wiley and Sons, 1983).

4. Tylecote, R.F. *The Early History of Metallurgy in Europe* (London: Longman, 1987).

5. Murphy, S. "Smelting Residues from Boles and Simple Smeltmills". In Willies, L. & Cranstone, D. (Eds.) *Boles and Smeltmills*. (Matlock Bath: Historical Metallurgy Society Ltd, 1992), pp.43-47.

6. Barker, L. & White, R. "Early Smelting in Swaledale and Arkengarthdale: A Further Look" In Willies, L. & Cranstone, D. (Eds.) *Boles and Smeltmills* (Matlock Bath: Historical Metallurgy Society Ltd, 1992), pp.15-18.

7. Agricola, G. *De Re Metallica* (translated by H.C. Hoover & L.H. Hoover) (New York: 1950).

8. Raistrick, A. & Jennings, B. *A history of Lead Mining in the Pennines* (London: Longmans, 1965).

9. Tylecote, R.F. *The Prehistory of Metallurgy in the British Isles* (London: The Institute of Metals, 1990).

10. Willies, L. "Introduction" In Willies, L. & Cranstone, D. (Eds.) *Boles and Smeltmills* (Matlock Bath: Historical Metallurgy Society Ltd, 1992), p.1.

11. Willies, L. *Lead and Lead Mining* (Princes Risborough: Shire Album 85, 1994).

12. Morrison, J. *Lead Mining in the Yorkshire Dales* (Skipton: Dalesman Publishing Company, 1998).

13. Raistrick, A. "Notes on Lead Mining and Smelting in West Yorkshire" *Transactions of the Newcomen Society*, Vol.7 (1927), pp.81–96.

14. Kiernan, D. & Van De Noort, R. "Bole Smelting in Derbyshire" In Willies, L. & Cranstone, D. (Eds.) *Boles and Smeltmills.* (Matlock Bath: Historical Metallurgy Society Ltd, 1992), pp.19-21. Citing Public Records Office E134/24.

15. Blanchard, I.S.W. "Lead Mining and Smelting in Medieval England and Wales" In Crossley, D.W. (Ed.) *Medieval Industry* (London: Council for British Archæology Research Report No.40, 1981), pp.72-84

16. McDonnell, J.G., S. Dockrill, C. Heron, D. Starley and J. Tirpak "Geophysics and Slag Analysis at Grinton Smeltings". In Willies, L. & Cranstone, D. (Eds.) *Boles and Smeltmills*. (Matlock Bath: Historical Metallurgy Society Ltd, 1992), pp.48-50.

17. Evans, B. *The Electronic Surface Survey of Early Lead Smelting Sites In Swaledale* (Unpublished Undergraduate Dissertation, University of Bradford, 1993).

18. Barker, L. "Bale Hills in Swaledale and Arkengarthdale" *British Mining*, Vol. 8 (1978), pp.49-54.

19. EDAS *Hagg Farm Archæological Survey.* Yorkshire Dales National Park Report (1997).

20. Vernon, R. *Report on a Geophysical Survey at the Dacre Lead Smelting Site near Pateley Bridge North Yorkshire* (University of Bradford Internal Report, 1998).

21. Claughton, P. "Notes on the Development of Bole Smelting" *British Mining.* Vol. 55 (1995), pp.127-138

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