GeoArch

Report 2023/07

Iron ores from the Mansell Raceway, Dunkeswell Airfield, Dunkeswell, Devon

Dr Tim Young
12th April 2023

Iron ores from the Mansell Raceway, Dunkeswell Airfield, Dunkeswell, Devon

Dr T.P. Young

Abstract

This report describes iron ores encountered during a watching brief and excavation of ore extraction pits at Dunkeswell by AC Archaeology. The project provided two opportunities: firstly to examine the nature of the ore present in a geological section equivalent to that worked in the pits and secondly to undertake elemental analysis of specific textures of ore to help understand the variation previously observed in various bulk analyses of ore. The project also provided an opportunity to re-examine the analyses of iron ores from five previous pieces of work in the Blackdown Hills area.

The ore was extracted at the Mansell Raceway site at an uncertain date, using pits dug into the Clay-with-flints, a geological unit with a complex and not-fully understood origin. The ores observed in this project comprised crusts generated during box-stone-weathering of the precursor lithology. These crusts comprised two components – a remnant of the precursor impregnated with iron oxides and an external overgrowth with, at least in part, a botryoidal structure. The precursor materials included some with a fine silty nature and some that were ferruginous grainstones, with millimetre scale coated grains, probably formerly of glauconite. The samples analysed in detail spanned these microstructures and demonstrated a coherent pattern of variation in the content of trace elements, particularly of the rare earth elements.

Despite the dominant sedimentary precursor material in the deposit being derived from the Upper Greensand, current evidence suggests that the deposit is chaotic and is classifiable as Clay-with-flints, generated through intense weathering and dissolution of the Upper Greensand during the early Tertiary. The Clay-with-flints probably suffered further deformation during the Pleistocene. Despite the name, the absence of chalk in this area (it had been eroded before the onset of the deep weathering) means that the siliceous component of the deposit is chert derived from the Upper Greensand rather than flint derived from the chalk.

It is argued that had-picking of larger ore fragments would probably have been undertaken during quarrying, as the finer fractions of the deposit are rich in chert fragments that would have required separation if quarried in bulk.

Contents

Abstract 1

Contents 2

Methods
- Project rational and history 2
- Analytical methods 2
- Archaeological and geological background 2

Results
- Description of iron ores 3
  - General 3
  - Details of sampled materials 3
- Elemental composition of iron ores 4
- Composition of a natural assemblage 4

Interpretation 4

Discussion 4

Illustration captions 6

References 7

Table 1: Submitted material 8
Table 2: Analyses of selected samples 9
Table 3: Key comparative compositional data ... 10

Figure 1 11
Figure 2 12
Figure 3 13

Methods

Project rationale and history

The material described here derives from excavations and a watching brief undertaken by AC Archaeology in 2018 at Mansell Raceway, Dunkeswell Airfield, Dunkeswell, Devon [ST 1301 0838] (ACD1746; Etheridge 2019).

This analytical programme has been designed to address the investigation of the iron ores in two ways: firstly, to examine the nature of the ore present in a section of the natural, untouched geology in a section equivalent to that worked in the pits and secondly to undertake elemental analysis of specific textures of ore to help understand the variation that had previously been observed in bulk analyses of ore from the area.

The work was undertaken during the winter of 2022/23 with reporting concluded in April 2023.

Analytical methods

Samples were selected from the assemblage for further analysis to pursue the various identified aims. The selected samples were slabbed on a diamond saw and subsamples were taken for preparation of whole-sample elemental analyses.

Bulk elemental analysis was undertaken using two techniques. The major and minor elements (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, P and S) were determined on a fused bead using wavelength-dispersive X-Ray-fluorescence (WD-XRF). Whole-specimen chemical analysis for thirty-six trace elements (Be, Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Mo, Sn, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Th, and U) were undertaken using a sample in solution by Inductively-coupled Plasma Mass Spectrometry (ICP-MS). Both XRF and ICP-MS analyses were commissioned from X-Ray Mineral Services Ltd.

For major element analysis, samples were ground using a tungsten carbide shatter mill, dried at 105 C overnight and then 0.5 g was mixed with 6.5g of 50:50 LiT/LiM flux and fused to produce a glass disk using a Claisse M4 Fluxy automatic fused disk maker. The samples were analysed using a Bruker S4 WD-XRF using the default wavelengths for the elements identified. Calibration was via a selection of iron slag reference materials and geological reference materials.

Samples for trace-element analysis were drawn from a second aliquot of the powdered material to establish trace element using the alkali fusion method (Jarvis & Jarvis 1992a and 1992b; Pearce *et al*. 1999). These samples were prepared using an automated, flame-based fluxer and LiM/LiBr 98.5/1.5 flux. QC data for Pb and Rb indicate that a small loss of these elements occurred during fusion, data for Zn and Cs were a little erratic. Once prepared, the samples were then all subjected to ICP-MS analysis using a Thermo Scientific XSERIES 2 ICP-MS. Data quality was strictly monitored in terms of precision and accuracy by five international rock standards of known concentration and varying compositions which are run after every 20 unknown samples. In addition, external monitoring of data quality is carried out four times a year via the GeoPt round robin proficiency testing program (http://www.geoanalyst.org/ overview.html).

The results of the chemical analyses are presented in Table 2 of this report. The GeoArch site code used for the samples is MRW.

Archaeological and geological background

The Blackdown Hills provided a source for iron ore that constituted a major regional resource from the Iron Age until the medieval period. This resource appears to have been of particular significance during the early medieval with five smelting sites dating to between the 7th and 11th centuries having been excavated in recent years (Burlescombe, Reed *et a*l. 2006; Culmstock Road South, Rainbird & Young 2015; Churchills Farm, Smart 2018; Culmstock Road North, Young *et al*. in press; Langford, Rainbird 2020, Young 2021). The smelting sites have produced very little iron ore and what has been recovered was generally in very small fragments. The exception to this was at Culmstock Road South, which produced a moderate amount of ore, but of a grade too low to be compatible with the slags generated; these materials have been interpreted as deliberate discards.

Reed (1997) reported on ores from extraction pits at a location 3.4km WSW of the present site and illustrated 'nodules' of up to approximately 400mm and weighing 30kg.

A further round of investigation of the ore resources resulted from work undertaken by Cotswold Archaeology (Nichol 2015) in the NE part of Dunkeswell airfield (approximately 600m east of the present site). Analysis of ores from that site focused on bulk analyses of a suite of very high grade box-stone crusts. Box-stones are zones of iron enrichment formed when reduced iron released by weathering reactions passes into oxidised zones around joints or the outside of concretions (typically zones influenced by meteoric waters) where the iron II oxidises to

insoluble iron III and precipitates. Such textures may form along the joints in a well-jointed rock or may form around the outside of individual concretions. Thus iron migrates from the interior to form a box-like rim or crust around the outside (sometimes impregnating the outer section of the rock, sometimes as a precipitate into void space).

The accumulation of evidence from the previous sites enabled modelling of the iron ore as a mixture of very high-grade ore (Group 1; such as is seen in the box-stone crusts) and lower grade material including more of the precursor lithology (Group 2). This modelling was presented in the archive report for Culmstock Road North (Young 2020), but is not in the final, shorter published account of the site (Young *et al*. in press). This mixture is envisaged as being the product of the natural range of compositions within the ore, rather than resulting from deliberate blending.

Electron microscopy of iron ore fines from the furnace at Langford (Young 2021) produced further evidence for the incorporation of a wide range of lithologies, including laminated box-stone crusts, sphaerosiderite and iron oxide-replaced sandstones, these latter lithologies probably indicating an input from the Upper Greensand.

Understanding of the geological succession in the Dunkeswell area from which these materials were produced is, however, very imperfect. The unit mapped at outcrop is the Tertiary Clay-with-flints, which lies unconformably on the Cretaceous Upper Greensand.

Detailed geological interpretation of the Clay-with-flints has focused more on the better exposed areas near the coast than on the inland zones, perhaps leading to a bias towards the significance of the role of the dissolution of chalk (which overlies the Upper Greensand in those areas) in its generation.

A major study by Isaac (1981) demonstrated that, at least locally, the unit includes a Tertiary sedimentary succession including soil horizons dating to the Paleocene and Eocene.

Later studies by Gallois (2009; by which date many of the localities described by Isaac were no longer accessible) emphasised the role of dissolution of the Chalk as well as Tertiary deposition in the formation of the 'Clay-with-flints. Importantly however, Gallois (2004b) demonstrated that the Upper Greensand was also affected by dissolution.

The stratigraphy of the Upper Greensand itself is also better known in the coastal zone, where it has been the subject of several detailed studies (Hart & Williams 1990; Gallois 2004a; Gallois & Owen 2018, 2019).

In the Blackdown Hills, not only is the Chalk absent, but the Upper Greensand differs from its development in the coastal belt. Trerise (1960) assigned the Upper Greensand of the Blackdown Hills to its own facies, 'The Blackdown Facies'. The succession in the Blackdown Hills probably only includes the lower part of the succession observed at the coast (mainly the Foxmould Member), but this differs from its typical exposure on the coast in being heavily leached and decalcified. Trerise commented (1960, 22) that 'the non-calcareous sediments are more richly ferruginous than usual, suggesting that the leaching may have been accompanied by the decomposition of glauconite to limonite'. The intensity of this weathering in the Blackdown Hills has been linked to the absence of the Chalk below the sub-Tertiary unconformity in this area.

Chert is also a recognised significant component in the Upper Greensand (e.g. Trerise 1961) and is specifically noted as being a component of 'The Backdown Facies'.

To complicate the geological context still further, the Clay-with-flints was further disturbed during the Pleistocene. In areas with a topographic gradient, such disturbance resulted in the formation of deposits mappable as head. The influence of Pleistocene cryoturbation on other sections of the Clay-with-flints may be more cryptic.

Results

Description of iron ores

General
The supplied material included approximately 200 hand-picked fragments of ore weighing almost 21kg recovered from the fills of various features, mostly extraction pits. In addition, there were 3 hand-picked fragments (572g) and 5276g of residues resulting from the processing of a bulk sample taken from the natural (context (402)).

The iron ores are box-stone structures, with the recovered material mostly in a highly fragmented state. The ores show a varied style of development, with some neat simple box-stones, some with a higher degree of iron oxide infill, some with chert fragments entrained in the outer crusts, and some with cracking that might indicate that the precursor rock showed septarian structures.

The most common texture shows the iron-oxide crusts surfaced with a slightly porous, iron oxide impregnated, slightly micaceous, siltstone. Others show seams of fine sandstone. Still others show evidence for the precursor being a grainstone formed of iron-rich millimetre-scale particles, perhaps weathered grains of glauconite.

The main facies of ore are crudely quantified in Table 1, with subdivision into box-stones with simple or botryoidal crusts, box-stones with elements showing grainstone texture suggestive of glauconite, box-stones with chert clasts and box-stones with yellow/brown cores surviving, rather than being empty.

Details of sampled material:
MRW1 (from a 174g piece from context (472)) is a piece of complex anastomosing dense iron oxide rich layers from a box-stone crust. The dense layers are a dark brown, but the surfaces are of a porous brownish yellow material, locally with small amounts of mica.

MRW2 (from a 36g piece from context (430)) is a laminated crust of very dense, dark reddish brown iron oxides. The massive laminae are up to 3mm in thickness. They locally merge with a thin paler, often yellow brown parting. Where not merged, one surface of the denser layers shows a thin (millimetre-scale) layer of almost black fibrous crystals with a botryoidal surface.

MRW3 (from an 86g piece from context (430) is a dense dark brown iron oxide-rich crust formed within a lithology formed of clay-rich grains of up to 1mm diameter. The grains (where not over-printed by the dense crust) show a yellow-brown colour where oxidised, becoming distinctly greener in some areas,

possibly hinting at the presence of an iron bearing aluminosilicate mineral (such as berthierine or glauconite). The granular material is porous, with shrinkage cracking having developed, forming a polygonal network between the grains.

Elemental composition of iron ores

The elemental composition of the three samples is provide in Table 2. All three samples are high grade, with the determinations of Fe_2O_3 being between 83.3% and 88.4%. The analytical totals are a little high, and the error is likely to be poor calibration for iron at these high values. Another estimate would be by subtraction of the other elemental oxides and the LOI from 100%, which gives estimates of 79.1% to 85.6% for Fe_2O_3.

The measured total for other elemental oxides alone (excluding the LOI; effectively the gangue) ranges from 4.0 to 8.5%. The measured LOI is slightly greater than the effect of the dehydroxylation of goethite (FeO.OH), so it is likely there is a small proportion of combined water in the iron minerals.

The highest-grade sample was MRW2, the layered crust with botryoidal overgrowths, the lowest MRW3, the altered grainstone.

The contents of the alkali and alkaline earth elements are very low. Manganese is present in rather variable concentrations and is only really elevated in MRW1. In contrast phosphorus is only elevated in MRW2.

The trace element content is generally extremely low, with only cobalt and zinc showing moderate values. This is reflected in the total rare earth element content (Σ REE) which varies from 24ppm to 86ppm with the total gangue content. The upper crust normalised REE profiles (Figure 1; normalisation factors after Taylor & MacLennan 1981) show not only lower totals but the relative depletion of the light REE (LREE) and increasing negative cerium anomalies with increasing iron content. Sample MRW2, the most LREE depleted, can be placed confidently with Group 1 and MRW3, the least depleted, within the Group 2 ores (*sensu* Young 2020). Sample, MRW1, lies intermediate between the two groups.

Composition of the natural assemblage

The natural (context (402)) was sampled (as sample <6>) in an attempt to clarify the nature of the resource being worked by the extraction pits.

The >10mm fraction of this material contained abundant iron-rich box-stone fragments.

The unsorted 4-10mm fraction showed a significant proportion (approximately 13% by weight) of pale, commonly almost white, angular fragments of chert accompanied by a very small amount of silicified fossil shells (including both brachiopods and bivalve molluscs). The chips commonly have a morphology suggestive of derivation from very thin (perhaps typically c.5mm) layers. One large block of iron ore from elsewhere (context (428)) appears to show large amounts of similar chert encased in its outer layers and small fragments of chert are moderately common as inclusions in the iron oxide dominated lumps. The cherts typically have remnants of original surfaces with a cream-coloured soft material, probably the remains of an original limestone. They are opaque and locally show evidence for an internal structure, probably reflecting grains (e.g. bioclasts) or burrows in the precursor.

This fraction contained a very small proportion (<2%) of other materials, including tiny chips of red siltstone and sandstone, together with some rounded fragments of possible vein quartz. Whether these materials were present within the Upper Greensand, or whether they indicated some later addition is unclear, but the chips of relatively fresh red sandstone at least suggest that fresh material derived from the Triassic became incorporated long after the weathering event, most likely during the Pleistocene.

Full sorting of the finer fractions was not undertaken, but visual inspection shows a broadly similar proportion of chert within dominantly iron-rich material.

Interpretation

The elemental analyses from the present study add further evidence for the two groups of iron-rich materials as defined by Young (2020): Group 1 of rich iron-ores (with a more strongly relatively depleted LREE) and Group 2 of leaner ores (with less depleted LREE). Table 3 provides comparative data from other analyses of Blackdown Hills ores.

Sample MRW3 adds to the body of samples that shows a relict grainstone texture, with grains formed of variably oxidised green clay. Previous samples showing similar textures included HCR8 and possibly HCR9, as well as some of the microscopic debris from Langford. The most likely interpretation of these lithologies is that they represent altered glauconitic grainstones, but the state of the weathered samples does not preclude an origin from a berthierinic material or perhaps a lateritic one. Despite this doubt, the most likely geological origin for such a lithology would be within the Upper Greensand.

The cherts present within the natural are also suggestive of derivation from the Upper Greensand. Despite the name of the geological unit as ‘Clay with Flints’, the sample of natural examined in this project contained no flint. The siliceous components all appear to be of chert, most likely from the Upper Greensand. This would be compatible with the deposits being generated during weathering and perhaps dissolutional collapse, rather than containing a significant fresh Tertiary sedimentary component.

A very small proportion of fresh red sandstone and siltstone fragments have probably been incorporated at a later date – perhaps by cryoturbation during the Pleistocene.

Discussion

This site supplements the existing evidence surrounding of the exploitation of box-stone iron ores within the Clay-with-flints for the early iron smelting around the Blackdown Hills.

The ore resource was variable, being formed of weathering crusts formed on different precursor lithologies. The available evidence does not point towards a well-bedded geological source and the box-stone weathering crusts appear to be largely

fragmented, rather than forming intact structures (apart from at the locality investigated by Reed, 1997).

In this lack of a strong geological framework, it appears that the Dunkeswell deposits represent a facies of the Clay-with-flints dominated by weathered and disturbed (perhaps during the dissolution induced subsidence), Upper Greensand. It appears unlikely that the materials recorded here result from deposition in the Tertiary.

It is unclear, in detail, what part(s) of the Upper Greensand might be present within the Clay-with-flints of Dunkeswell. If the dissolution was particularly intense then a considerable degree of mixing may have occurred. If some semblance of the original stratigraphic succession survives, then perhaps levels in the upper part of the Foxmould Member, where sediments are often more glauconitic and include cherty materials, might be indicated.

The redistribution of iron during weathering has resulted in a large variability in composition on small scales of distance. Thus, individual pieces of ore will represent varying mixtures of different textural components.

The iron oxide crusts generated by precipitation into void space (the Group 1 ores with botryoidal textures, e.g. sample MRW2) show a marked degree of depletion of the LREE. This appears to be an example of a wider phenomenon in similarly textured rocks, with, for instance, the late-stage botryoidal ores in the Forest of Dean and Worcester Graben sectors of the Bristol Channel Orefield showing a similar effect (e.g. Young & Thomas 1998 Fig 111, 1999 Fig 5; Young 2000 Fig 10.6). The precise mechanism involved has not been identified.

The increased understanding of the nature of the ore at Dunkeswell also permits some further consideration of the nature of the quarrying. The available evidence makes it unlikely that the extraction pits were dug to exploit a particular bed of ore – and the profile of the pits also indicates this. Rather, they appear to have been dug to extract ore from a general mix of fragmented ore in a finer matrix. The significant proportion of chert in the sub-10mm fraction would make this fraction undesirable to employ for smelting. Hand-picking of larger pieces of larger pieces of ore during quarrying would be more practical, with either the rejection of any substantial pieces containing chert (potentially the reason for the almost 6kg block of ore in the backfill of F426) or their crushing and picking.

Several of the analyses of ore pieces listed in Table 3 deriving from the smelting sites show high values for LOI and were therefore not roasted. Although it is possible that these are simply materials rejected for not having been roasted properly, they may be indicative that raw ores were transported to the smelting sites (either for smelting raw or more likely for roasting there).

Illustration Captions

Figure 1: Photographs of the analysed samples,

Figure 2. Upper Crust-normalised REE data for samples of iron ores from the Blackdown Hills area. The normalisation factors are after Taylor & McLennan 1981.

Figure 3: samples from Mansell Raceway illustrated in the context of samples allocated to Group 1 and Group 2 ores.

Upper: binary plot of Dy_N/Pr_N against Dy_N/Lu_N (the upper crust normalised concentrations of those elements) which describes the form of the REE profiles

Lower: binary plot of Dy_N/Pr_N against Σ REE which illustrating the increasing relative depletion of the LREE in the Group 1 samples with very low total REE.

References

ETHERIDGE, T. 2019. Mansell Raceway, Dunkeswell Airfield, Dunkeswell, Devon.. AC Archaeology Report ACD1746/2/0.

GALLOIS, R.W. 2004a. The stratigraphy of the Upper Greensand (Cretaceous) of south-west England. *Geoscience in south-west England*, **11**, 21–29.

GALLOIS, R.W., 2004b. Large-scale dissolution features in the Upper Greensand (Cretaceous) in south-west England. *Geoscience in south-west England,* **11**, 30–36.

GALLOIS, R. W. 2009. The origin of the Clay-with flints: the missing link. *Geoscience in southwest England*, **12**, 153-161.

GALLOIS, R. & OWEN, H. 2018. The stratigraphy of the mid Cretaceous (Albian) Upper Greensand Formation of the Wessex Basin and South West England, UK. *Acta Geologica Polonica*, **68**, 161-180.

GALLOIS, R. & OWEN, H. 2019. The stratigraphy of the Gault and Upper Greensand Formations (Albian stage, Cretaceous) of the Dorset and East Devon Coast World Heritage Site, U.K. *Proceedings of the Geologists' Association*, **130**, 390-405.

GRIFFITH, F, & WEDDELL, P, 1996. Ironworking in the Blackdown Hills: results of recent survey, *Mining History*, **13**, 27–34

HART, M.B. & WILLIAMS, C.L. 1990. The Upper Greensand in East Devon: new data but old problems. *Proceedings of the Ussher Society*, **7**, 273-278.

ISAAC, K.P. 1981. Tertiary weathering profiles in the plateau deposits of east Devon. *Proceedings of the Geologists' Association*, **92**, 159-168.

JARVIS, I. & JARVIS, K. E., 1992a. Inductively coupled plasma-atomic emission spectrometry in exploration geochemistry. In: Hall, G. E. M. & Vaughlin, B. (eds), *Analytical Methods in Geochemical Exploration*. Journal of Geochemical Exploration Special Issue.

JARVIS, I. & JARVIS, K. E., 1992b. Plasma spectrometry in earth sciences: techniques, applications and future trends. In: Jarvis, I. & Jarvis, K. E. (eds), Plasma Spectrometry in Earth Sciences. *Chemical Geology*. **95**, 1 - 33.

NICHOL, M. 2015. Land at Dunkeswell Airfield, Dunkeswell, Devon; archaeological strip, map and sample excavation report. CA report 14418.

PEARCE, T. J., BESLY B. M., WRAY D., & WRIGHT D. K. 1999. Chemostratigraphy: a method to improve interwell correlation in barren sequences - a case study using onshore Duckmantian/Stephanian sequences (West Midlands, UK*). Sedimentary Geology* **124**, 197- 220.

RAINBIRD, P. 2020. Land at Langford (Areas 12, 13 & 15), near Cullompton, Devon (centred on NGR ST 0337 0311); results of an archaeological trench evaluation. AC Archaeology report ACD2168/2/1.

RAINBIRD, P. & YOUNG, T.P. 2015. Saxon iron smelting furnaces at Culmstock Road, Hemyock, Devon. *Proceedings of the Devon Archaeological Society*, **73**, 279-314.

REED, S.J. 1997. Blackdown Hills Ironworking Project, Archaeological recording of an iron extraction pit, Broadhembury, Devon. Exeter Archaeology, Unpublished Report 97.38.

REED, S.J., JULEFF, G. & BAYER, O.J. 2006. Three late Saxon iron-smelting furnaces at Burlescombe, Devon. *Proceedings of the Devon Archaeological Society*, **64**, 71-122.

SMART, C. YOUNG, T., ALLAN, J. DAWSON, D., TAYLOR, R.T., ANDERSEN, J., ROLLINSON, G., CHALLINOR, D., JONES, J., MARSHALL, P., TOMPKINS, M., COLLINGS, T., KEEN, L., LANGHAM, G., KENT, O, BRONK RAMSEY, C., DUNBAR., E. & REIMER, P. 2018*. Industry and the making of a rural landscape: iron and pottery production at Churchill's Farm, Hemyock, Devon*. BAR British Series 636.

TAYLOR, S.R. & McLENNAN, S.M. 1981. The composition and evolution of the continental crust: rare earth element evidence from sedimentary rocks. *Philosophical Transactions of the Royal Society*, **A301**, 381-399.

TRERISE, G.R., 1960. Aspects of the Lithology of the Wessex Upper Greensand. *Proceedings of the Geologists' Association*, **71**, 316–3339.

TRERISE, G.R., 1961. The nature and origin of chert in the Upper Greensand of Wessex. *Proceedings of the Geologists' Association*, **72**, 333–356.

YOUNG, T.P. 2000. Chapter 10. The Paviland Ochres: characterisation and sourcing. *In:* ALDHOUSE-GREEN, S., *Paviland Cave and the 'Red Lady': a definitive report*. Western Academic and Specialist Press Limited, 205-225.

YOUNG, T.P. 2014. Archaeometallurgical residues from Culmstock Road, Hemyock, Devon (ACD591). *GeoArch Report 2014-11.* 43pp.

YOUNG, T.P. 2015a. Analyses of ores and residues from Dunkeswell, Devon. GeoArch Report 2014-31.

YOUNG, T.P. 2015b. Archaeometallurgical residues from Churchills Farm, Hemyock, Devon. *GeoArch Report 2015-31*. 77pp.

YOUNG, T.P. 2020. Archaeometallurgical residues from north of Culmstock Road, Hemyock. *GeoArch Report 2020/20*, 51pp.

YOUNG, T.P. 2021. Archaeometallurgical residues from Langford, Devon. *GeoArch Report 2021/01*, 50pp.

YOUNG, T.P., ORELLANA, J. & MUDD, A. *in press.* Early medieval iron smelting north of Culmstock Road, Hemyock, and its regional significance. *Proceedings of the Devon Archaeological Society,* forthcoming.

YOUNG, T.P. & THOMAS, G.R. 1998. The cargo: iron ore analysis. pp. 105-111 *In:* Nayling, N. *The Magor Pill Medieval Wreck*, CBA Research Report 115, Council for British Archaeology.

YOUNG, T.P. & THOMAS G.R. 1999. Provenancing iron ore from the Bristol Channel Orefield: the cargo of the Magor Pill Boat. *In:* POLLARD, A.M. (ed) *Geoarchaeology: exploration, environments, resources*, Geological Society of London, Special Publication, 165, 103-121.

Table 1: summary catalogue of submitted lump materials.

Context	Description	Feature no.	Weight	No.	box-stones with simple or botryoidal crust		box-stone with grainstones		box-stones with chert clasts		box-stones with yellow/brown cores		notes
					no	wt g	no	wt g	no	wt g	no	wt g	
402	Natural		572	3							3	572	adherence is mainly fine silt with tiny moulds
404	Fill of pit F403	403	124	2	1	118					1	6	
407	Lower fill of pit F406	406	730	15	14	448					1	282	9/300 crusts are polished, 1/282 crusts hosted in medium sand
			2	1									1/2 burnt chert
409	Upper fill of pit F406	406	440	5	5	440							
410	Cut no. for pit	410	516	8	6	344					2	172	possibly fine sand in places
411	Lower fill of pit F410	410	954	3	1	142					2	796	large pieces are of low-grade concretion in khaki coloured silt/fine sand
412	Middle fill of pit F410	410	684	10	7	176	1	34			2	474	120/5 show polish, 2/474 dense ores with leathery brown exteriors - sst??
413	Upper fill of pit F410	410	520	1							1	520	yellow brown matrix possibly fine sand?
417	Lower fill of pit F416	416	402	1							1	402	1/402 fine silt with small occasional moulds and poor crusts
418	Upper fill of pit F416	416	254	4	3	152	1	102					1/102 shows both coated grains and white chert/limestone fragments
421	Upper fill of pit F419	419	66	1	1	66							1/66 is weathered ochreous concretion
423	Single fill of pit F422	422	2	1	1	2							
428	Lower fill of pit F426	426	128	2			1	10	1	118			
			5850	1					1	5850			large block of box-stone ore with white inclusions
430	Upper fill of pit F429	429	402	5	2	62	2	172	1	168			
433	Upper fill of pit F432	432	48	6	5	48							plus 14/1 porous ferruginous fine sandstone
437	Third fill of pit F435	435	642	12	12	642							178/2 broken thin complex sheet - mouldic silt on surface
444	Single fill of pit F443	443	652	1							1	652	low grade, but very dense, central sheet dark with highly porous both sides
446	Single fill of pit F445	445	92	2	2	92							1/44 outer material is highly porous yellow-brown, 1/48 may be fragmental
449	Upper fill of pit F447	447	54	1	1	54							
451	Single fill of pit F450	450	812	4	1	156					3	656	3/656 are highly porous on a fine scale in both dark and yellow bands
454	Lower fill of pit F453	453	532	6	4	428	1	48			1	52	
456	Lower fill of pit F452	452	48	1			1	48					grains largely mouldic, outside dehydration cracked and possibly reddened
457	Second fill of pit F452	452	870	5	1	118					4	752	1/118 very dense polished crust, 4/752 highly porous
468	Main fill of pit F466	466	30	3	3	30							
472	Main fill of pit F470	470	484	5	5	484	tr		tr				
485	Fill of ? tree throw F476	476	300	9	9	300							1/20 is roasted ore
487	Single fill of pit F486	486	290	7	5	238	2	52					2/52 are dense polished oxide
489	Lower fill of pit F488	488	1590	3							3	1590	thin dark crust large soft yellowish cores. Small fossil moulds
492	Upper fill of pit F491	491	1805	54	46	992			6	742	2	68	10/184 of crusts show polish
494	Lower fill of pit F491	491	1470	20	18	956					2	506	dense box-stone crusts

Table 2: major element analyses by XRF expressed as wt% oxides, trace element analyses by ICP-MS in ppm, both raw measured values. < = below detection.

		SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	SO3	LOI
MRW1	dense crust on fine siltstone?	3.39	1.34	84.69	1.09	<0.01	<0.01	0.33	0.11	0.04	0.62	0.09	12.59
MRW2	crust with botryoidal laminae	1.84	0.19	88.44	0.31	0.39	0.19	0.06	<0.015	0.01	1.03	0.03	10.42
MRW3	crust on grainstone ore	4.34	2.28	83.25	0.56	0.32	0.15	0.12	<0.015	0.09	0.67	0.05	12.41

	Be	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Mo	Sn	Cs	Ba
MRW1	2.96	36.46	18.75	73.72	42.52	26.92	225.73	2.52	4.86	8.55	13.66	53.36	1.73	0.76	0.41	0.74	126.77
MRW2	3.04	34.38	42.30	186.18	32.04	49.09	105.94	0.80	0.87	3.63	12.52	22.31	0.48	4.47	0.34	0.09	14.04
MRW3	3.06	49.08	32.41	105.34	64.50	34.56	468.87	3.52	4.79	11.14	19.45	17.04	1.69	0.31	0.67	1.24	36.54

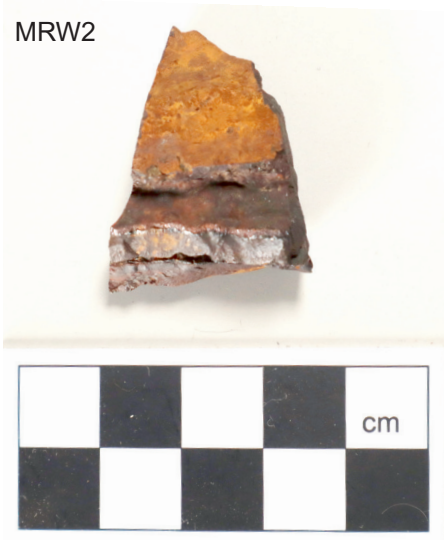
	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Pb	Th	U
MRW1	10.31	13.06	2.25	9.61	2.17	0.54	2.54	0.39	2.40	0.45	1.42	0.20	1.30	0.18	1.20	7.40	1.25	2.63
MRW2	6.28	4.91	1.03	4.42	0.98	0.26	1.48	0.23	1.54	0.29	1.03	0.14	1.00	0.15	0.45	2.39	0.31	1.83
MRW3	20.02	26.08	4.31	17.62	3.73	0.87	3.99	0.59	3.58	0.63	1.91	0.29	1.71	0.24	0.40	5.63	1.55	2.94

*Table 3: summary of key compositional parameters for samples from the Mansell Raceway and other sites. LOI = loss on ignition, Σ = total, E_N = concentration of element E normalised against the Upper Crust standard (Taylor & MacLennan 1981), values in parenthesis with * show EDS analyses recalculated on the basis of 12% LOI to permit comparison.*

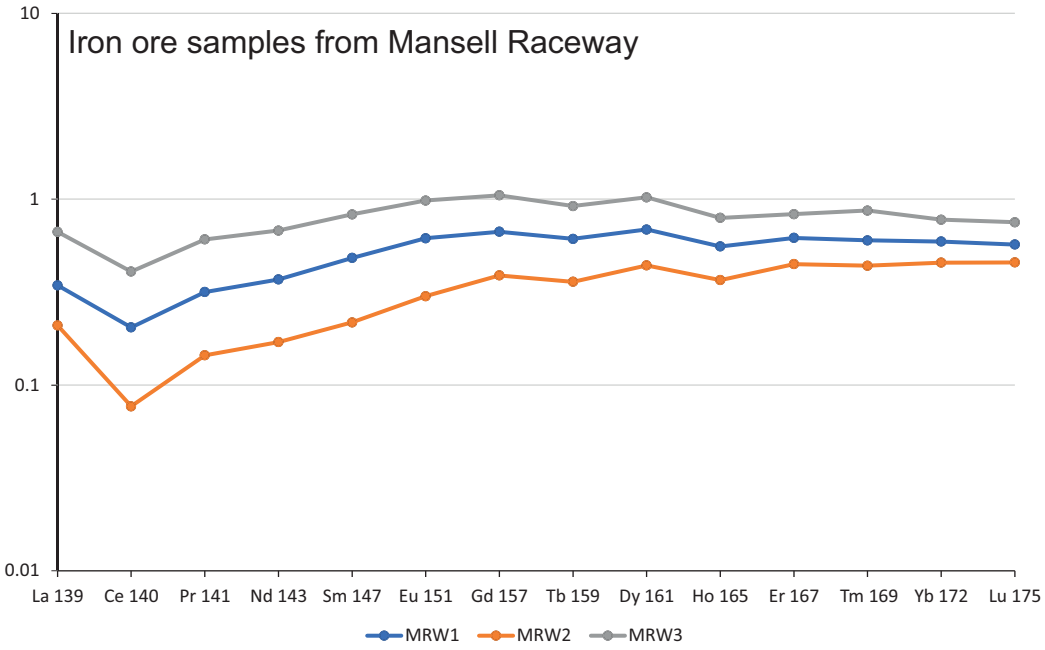
Sample	Report	Lithology	P_2O_5 %	SiO_2/Al_2O_3	Σ Gangue (%)	LOI (%)	Σ REE ppm	U/Th	Dy_N/Lu_N	Dy_N/Pr_N
Mansell Raceway, Dunkeswell Airfield										
MRW1	This report	dense crust on fine siltstone?	0.62	2.53	6.91	12.59	46.83	2.10	1.20	2.17
MRW2	This report	crust with botryoidal laminae	1.03	9.68	4.02	10.42	23.75	5.83	0.96	3.05
MRW3	This report	crust on grainstone ore	0.67	1.90	8.52	12.41	85.56	1.90	1.36	1.68
Dunkeswell Airfield										
DUNK1	Young 2015a	box-stone	1.10	1.64	4.19	12.22	58.98	1.99	1.08	2.74
DUNK2	Young 2015a	box-stone	0.56	1.93	3.34	12.73	36.63	2.47	1.01	3.11
DUNK3	Young 2015a	ferruginous rock with crusts	0.69	1.49	3.34	12.47	32.44	2.57	0.99	3.20
DUNK4	Young 2015a	porous crust	1.11	0.57	3.25	12.87	27.18	5.62	1.01	3.45
Culmstock Road, South										
HCR8	Young 2014	low-density, yellow/brown pelletal ore	1.21	1.67	13.59	12.83	122.68	0.86	1.11	1.60
HCR9	Young 2014	roasted with thin dark skins around red, clay with pellets.	0.70	1.69	23.39	3.52	301.40	1.51	1.36	1.30
Churchills Farm										
HCF24	Young 2015b		1.23	1.90	11.66	12.09	92.07	0.53	0.95	1.34
Culmstock Road, North										
HCN11	Young 2020	box-stone with fibrous goethite	0.44	4.26	5.51	4.30	109.15	2.36	1.34	2.86
HCN12	Young 2020	roasted box-stone.	0.28	3.13	9.42	-0.69	48.68	1.04	1.35	1.74
Langford										
mean	Young 2021	Mixed	0.74 (0.65*)	3.21	13.33 (11.73*)					
mean no sst	Young 2021	mixed	0.75 (0.66*)	1.42	8.05 (7.08*)					

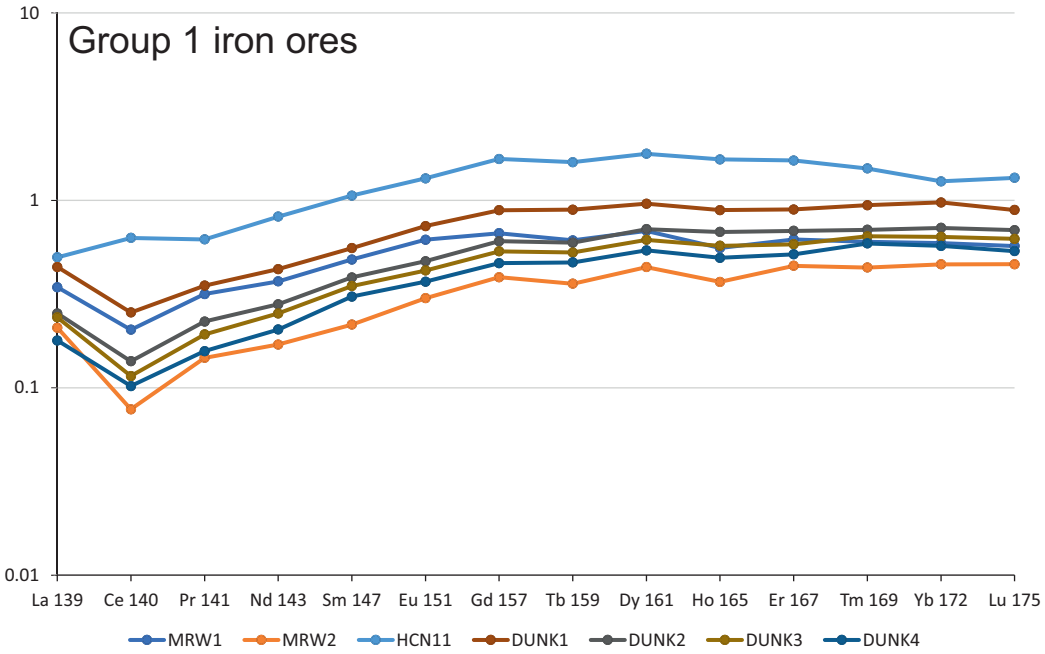
MRW1

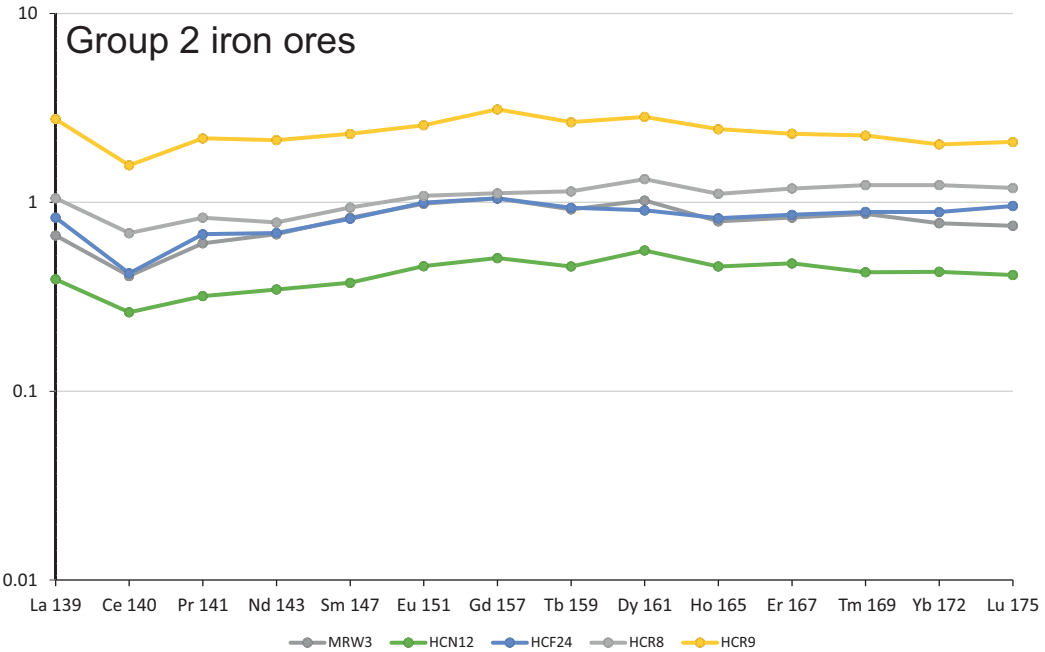
MRW2



MRW3


Iron ore samples from Mansell Raceway
10
1
0.1
0.01
La 139
Ce 140
Pr 141
Nd 143
Sm 147
Eu 151
Gd 157
Tb 159
Dy 161
Ho 165
Er 167
Tm 169
Yb 172
Lu 175
MRW1
MRW2
MRW3


Group 1 iron ores
10
1
0.1
0.01
La 139
Ce 140
Pr 141
Nd 143
Sm 147
Eu 151
Gd 157
Tb 159
Dy 161
Ho 165
Er 167
Tm 169
Yb 172
Lu 175
MRW1
MRW2
HCN11
DUNK1
DUNK2
DUNK3
DUNK4


Group 2 iron ores
10
1
0.1
0.01
La 139
Ce 140
Pr 141
Nd 143
Sm 147
Eu 151
Gd 157
Tb 159
Dy 161
Ho 165
Er 167
Tm 169
Yb 172
Lu 175
MRW3
HCN12
HCF24
HCR8
HCR9

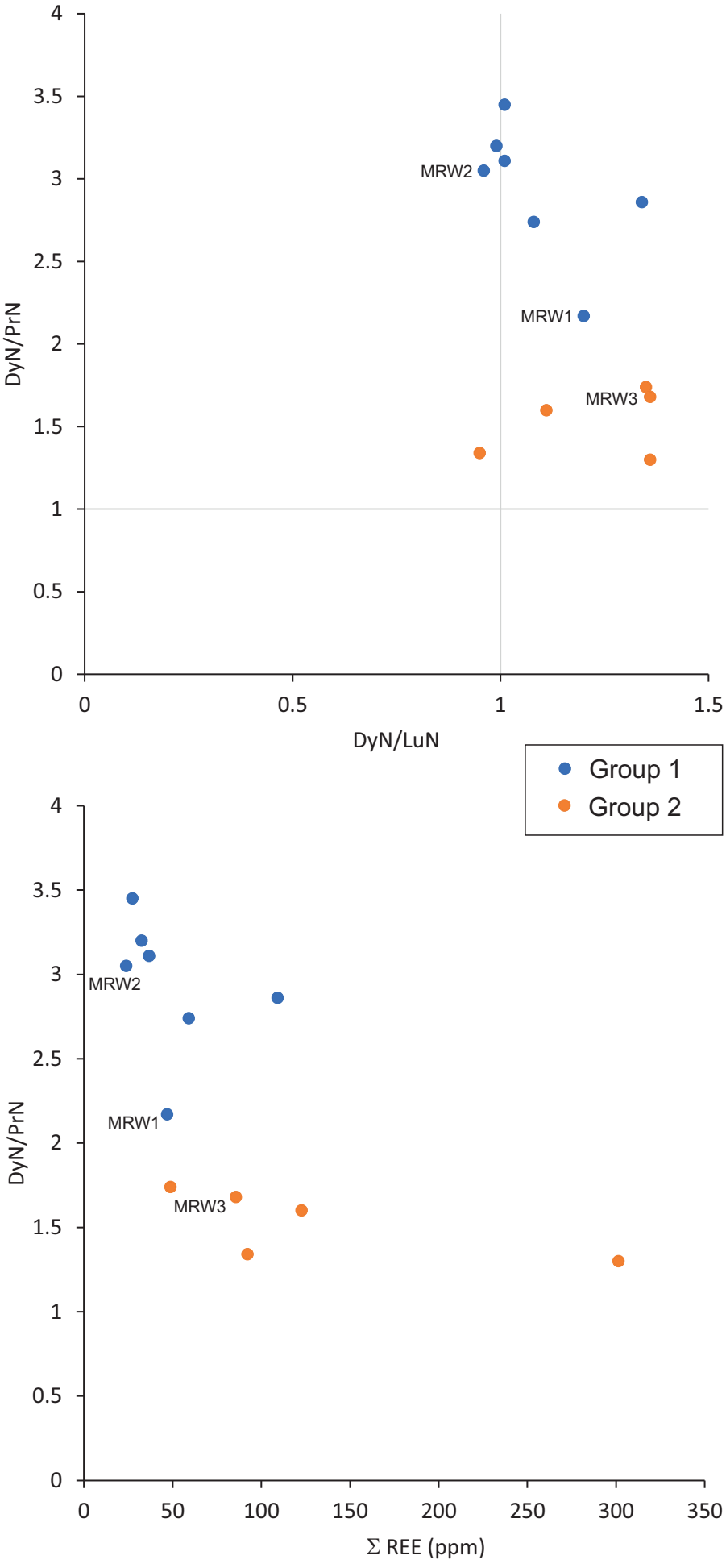



Figure 3