

RESEARCH REPORT SERIES no. 42-2014

# TANKERVILLE LEAD MINE, TANKERVILLE, WORTHEN WITH SHELVE, SHROPSHIRE GEOCHEMICAL SURVEY

TECHNOLOGY REPORT

David Dungworth



INTERVENTION  
AND ANALYSIS



ENGLISH HERITAGE

*This report has been prepared for use on the internet and the images within it have been down-sampled to optimise downloading and printing speeds.*

*Please note that as a result of this down-sampling the images are not of the highest quality and some of the fine detail may be lost. Any person wishing to obtain a high resolution copy of this report should refer to the ordering information on the following page.*

# Tankerville Lead Mine, Tankerville, Worthen with Shelve, Shropshire

## Geochemical survey

David Dungworth

NGR: SO 355 299

© English Heritage

ISSN 2046-9799 (Print)

ISSN 2046-9802 (Online)

*The Research Report Series incorporates reports by the expert teams within the Investigation & Analysis Division of the Heritage Protection Department of English Heritage, alongside contributions from other parts of the organisation. It replaces the former Centre for Archaeology Reports Series, the Archaeological Investigation Report Series, the Architectural Investigation Report Series, and the Research Department Report Series.*

*Many of the Research Reports are of an interim nature and serve to make available the results of specialist investigations in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation. Where no final project report is available, readers must consult the author before citing these reports in any publication. Opinions expressed in Research Reports are those of the author(s) and are not necessarily those of English Heritage.*

*Requests for further hard copies, after the initial print run, can be made by emailing:*

*Res.reports@english-heritage.org.uk*

*or by writing to:*

*English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD*

*Please note that a charge will be made to cover printing and postage.*

## **SUMMARY**

This report explores the use of portable X-Ray Fluorescence (pXRF) spectroscopy as a means to characterise the degree and nature of contamination at a historical lead mine. It was possible to take 40 *in situ* readings within a period of less than 2.5 hours. Lead (and other elements, including zinc, barium and arsenic) were detected at levels of as much as 100 times above normal background levels. The limited nature of the survey prevents a detailed exploration of spatial variation in heavy metal contamination and how this might be related to specific mining and ore processing activities. The collection of data from exposed deposits within two excavated trenches shows that the degree of contamination varies with depth and that this variation is not predictable. This situation is likely to be related to the variety of different activities that took place and the complex site formation processes which give rise to the deposits of mining waste,

## **ACKNOWLEDGEMENTS**

I would like to thank the Heritage at Risk Architect (John Tieman) and the building contractors who facilitated access.

## **ARCHIVE LOCATION**

Fort Cumberland, Portsmouth, PO4 9LD

## **DATE OF SURVEY**

May 2014

## **CONTACT DETAILS**

Fort Cumberland, Portsmouth, PO4 9LD

David Dungworth; 023 9285 6783; [david.dungworth@english-heritage.org.uk](mailto:david.dungworth@english-heritage.org.uk)

## INTRODUCTION

Techniques of non-invasive survey play an important role in characterising of the historic environment (Clark 1990). Methods which determine the chemistry of soils and sediments (geochemical survey) are increasingly being deployed to supplement more traditional approaches. Geochemical survey undertaken using portable X-ray fluorescence (eg Dunster *et al*/2012; Dungworth *et al*/2013) have the added advantage that survey data can be acquired and reported on quickly. The survey reported on in this report took place at a historic lead mine in order to better understand risks associated with the conservation management of the site.

## THE SITE

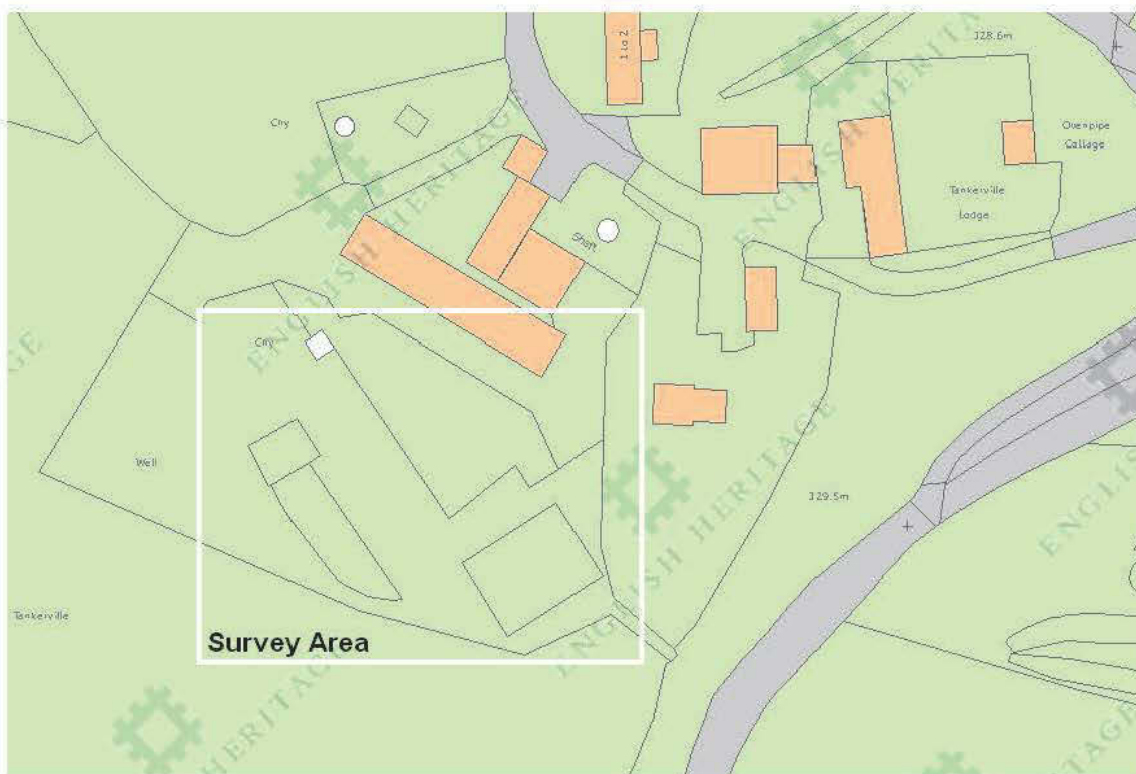


Figure 1. Ordnance Survey map of the Tankerville Lead Mine site showing the location of the survey area (see Figure 2)

© Crown Copyright and database right 2014. All rights reserved. Ordnance Survey Licence number 100024900. © Crown Copyright and database right 2014. All rights reserved. Ordnance Survey Licence number 100024900.

Tankerville lead mine lies within a historic lead mining district in the west of Shropshire, and was established in the middle of the 19th century.

In 1864 the shaft was deepened to locate the richest lead vein in Shropshire. In the early 1870s the mine was considerably expanded with the sinking of a new shaft, known as Watson's, and an engine was installed for pumping and winding. In 1875 a new engine house was constructed to house a Cornish steam engine. With the mine operating at a loss after 1878, it closed in May 1884.

National Record of the Historic Environment (UID 871041).

The site is currently owned by the Shropshire Mines Trust and various conservation works have been undertaken, the most recent of which have received funding from English Heritage. The current work aims to improve water drainage to prevent erosion of stone-built features.

## METHODOLOGY

A Niton XL3t portable X-Ray Fluorescence (pXRF) spectrometer was used and the optimum settings were selected to allow useful limits of detection for key elements (in particular Pb), that is close to the average crustal abundance of these elements, within a reasonably short analysis time (90 seconds). Elements associated with lead ores (Ba, Zn and As) were also sought.

The pXRF was used with the Mining Mode setting and the results compared for five Certified Reference Soils. The results provided information on the limits of detection, allowed calibration of the raw data and indicated the degree of instrumental precision, shown in Table 1. This indicated accuracies of 20–100ppm (varying between different elements) and precision which was correlated with measured concentration. The background levels for lead were expected to be in the range 20–50ppm (Dunster *et al* 2012).

Table 1. Accuracy, precision and limits of detection (LoD) for selected elements (in ppm)

Element	Accuracy (ppm, one standard deviation)	Precision (one standard deviation, relative)	LoD
Zn	20	±5%	10
As	50	±5%	200
Ba	100	±5%	50
Pb	30	±5%	20

The pXRF geochemical survey was undertaken along the line of two trenches excavated for drainage pipes. Water within a reservoir (marked on the plan in Figure 2) has been leaking out and has caused damage to the terrace wall to the north. This is being addressed through the two drainage pipes: Trench 1 and Trench 2. Five survey points were taken within the excavated portion of Trench 1 (TIP1–TIP5, see Figure 2) and a further four points along the projected line of the trench (TIP6–TIP9). Four survey points were taken within the then excavated portions of Trench 2 and a further four

points along the projected line of the trench. For the survey points taken within the excavated trench, the opportunity was taken to analyse sediment at various depths (depending on stratigraphy) as well as the current land surface immediately adjacent to the trench.

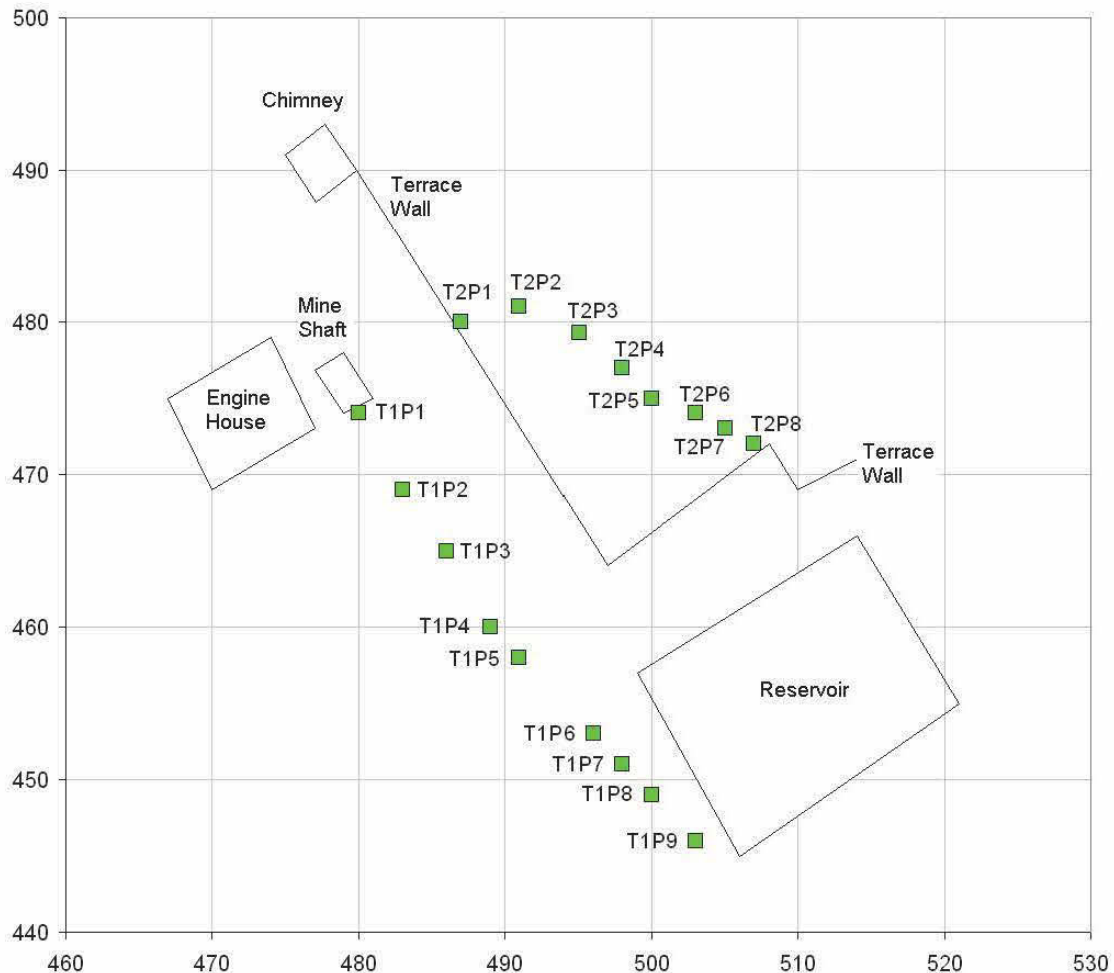


Figure 2. Sketch plan of the survey area (see Figure 1) showing the survey points taken along the line of the trenches dug for the drainage pipes (Trenches 1 and 2)

## RESULTS

The survey included 41 separate readings at 17 survey points (Figure 2) taken over a period of 2 hours and 22 minutes. Lead, zinc and barium were detected in all readings during the survey and arsenic was detected 15 times (in part due to the relatively high limit of detection for arsenic caused by interference from lead in the readings). All four elements (but especially lead, zinc and barium) are commonly associated with lead mining, ore processing and lead smelting. The lowest readings for barium were close to (or

slightly below) the global background values, but lead and zinc were elevated above the background concentrations in all readings (Table 2). The average readings were all relatively high and are consistent with the mining and treatment of lead ores.

Table 2. Summary of readings for lead, zinc and barium (ppm). Sources for global background levels = Rudnick and Gao (2005); Taylor and McLennan (1985)

Element	Symbol	Minimum	Average	SD	Max	Global Background
Lead	Pb	177	7822	6633	32990	17
Barium	Ba	370	15195	38108	200145	450
Zinc	Zn	150	3159	5468	31836	74

The readings obtained at or close to the current ground surface show some spatial variations (Figure 3). The unexcavated line of Trench 1 shows rather low values for lead, zinc and barium and these elements are generally found at higher levels elsewhere. Barium and zinc are most consistently elevated along the line of Trench 2 (compared to Trench 1). This may be due to differences in the techniques used to treat ores in the two areas.

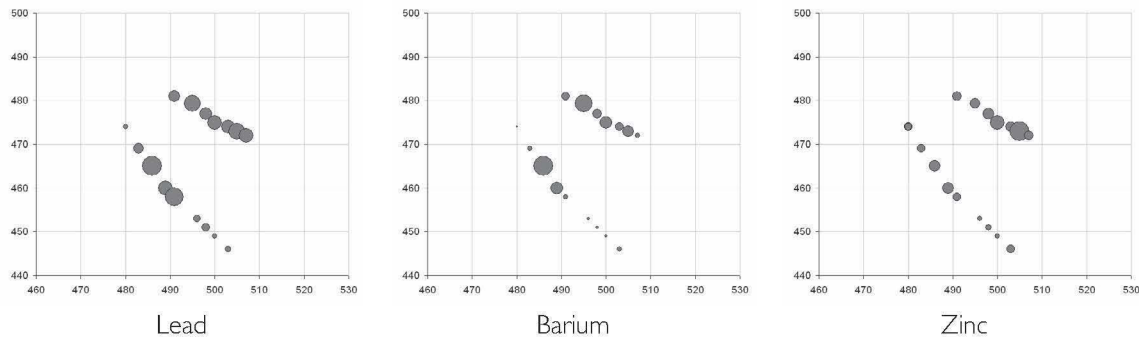


Figure 3. Plots of concentrations of lead, barium and zinc at the surface (size of circles proportional to concentration).

There were eight points within the excavated trenches where it was possible to take a reading from the current ground surface and from several layers of sediment exposed within the trench and thereby examine how element concentration varied with depth.

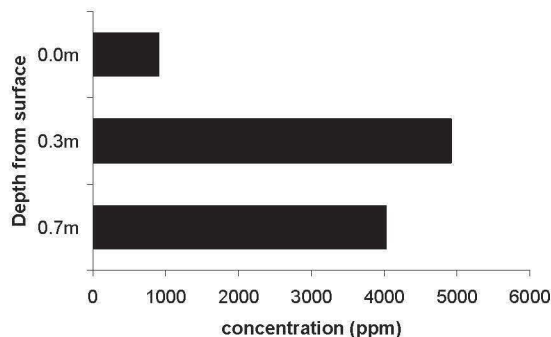


Figure 4. Trench 1, Point 1, changes in zinc concentration with depth

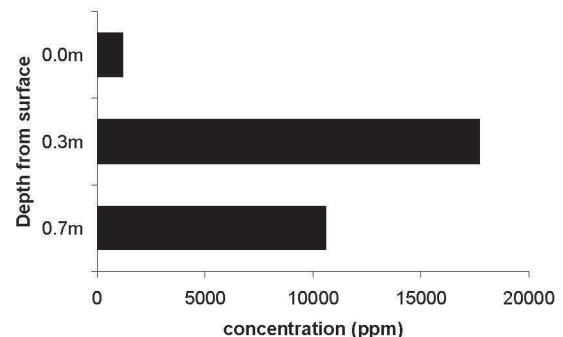


Figure 5. Trench 1, Point 1, changes in lead concentration with depth



Figures 4 and 5 show the variations in the zinc and lead with depth at Point 1 in Trench 1: the surface values for these two elements are substantially lower than those for the buried sediments.

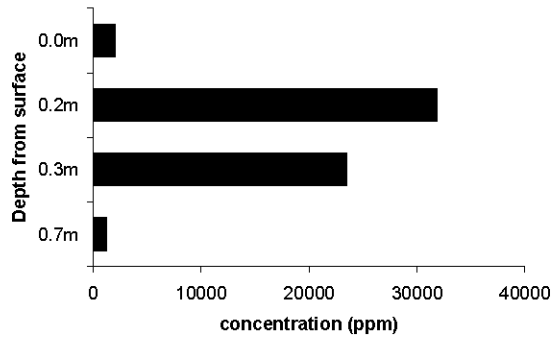


Figure 6. Trench 1, Point 3, changes in zinc concentration with depth

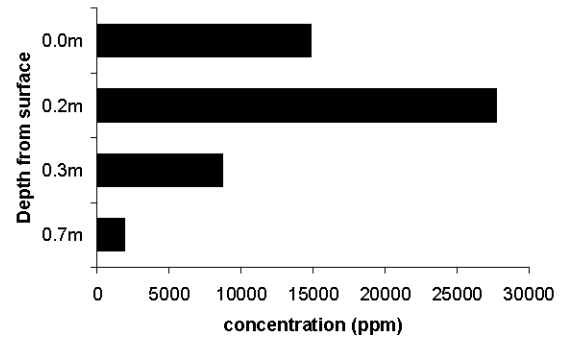


Figure 7. Trench 1, Point 3, changes in lead concentration with depth

At Point 3 in Trench 1 the surface value for zinc is low compared to most of the buried deposits but at 0.7m the zinc concentration is less than at the surface (Figure 6). At the same point the lead concentration displays considerable variation; first increasing with depth and then decreasing (Figure 7). The two deposits encountered at 0.2m and 0.3m below the current ground (a beige clay and a pale sand, respectively) also contained elevated levels of barium. The presence of barium suggests that these two deposits are associated with ore dressing (barium sulphate minerals are frequently associated with lead ores).

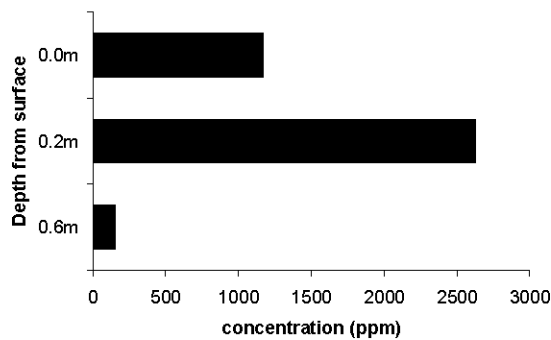


Figure 8. Trench 1, Point 5, changes in zinc concentration with depth

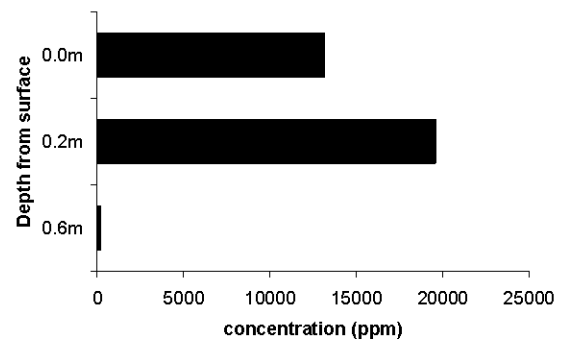


Figure 9. Trench 1, Point 5, changes in lead concentration with depth

The southern end of the excavated portion of Trench 1 (Point 5) was dug through what appeared to a natural clay sub-soil deposit (0.6m readings, shown in Figures 8 and 9). While the surface and topsoil both show elevated levels of zinc and lead, the apparently natural clay contains concentrations of these two elements which are only slightly elevated (150 and 177ppm) above the global background values. The slightly elevated values might be due to contamination from the overly deposits but could also be a natural consequence of the clay forming within an area with outcropping lead ores.

Readings for two points in Trench 2 are shown in Figures 10–13.

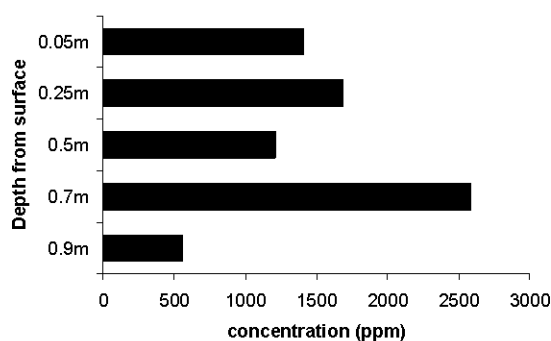


Figure 10. Trench 2, Point 2, changes in zinc concentration with depth

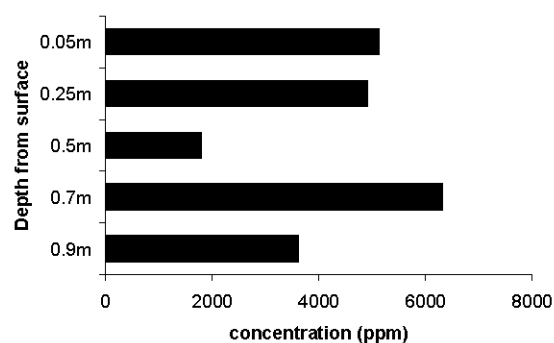


Figure 11. Trench 2, Point 2, changes in lead concentration with depth

The measurements of zinc and lead concentrations at different depths in Trench 2 exhibit the same overall aspects of those in Trench 1: the concentration of an element at the surface is not always a reliable indicator of the concentration at depth. Some buried deposits contain much lower concentrations of lead or zinc compared to the surface but in other cases the opposite is true.

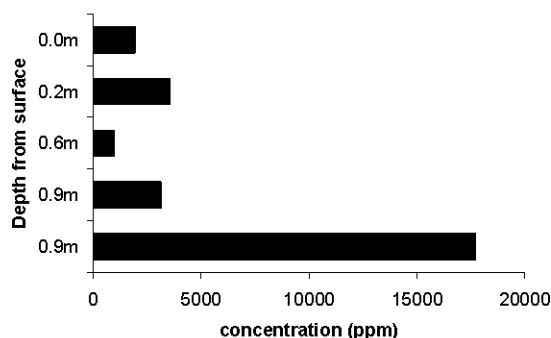


Figure 12. Trench 2, Point 4, changes in zinc concentration with depth

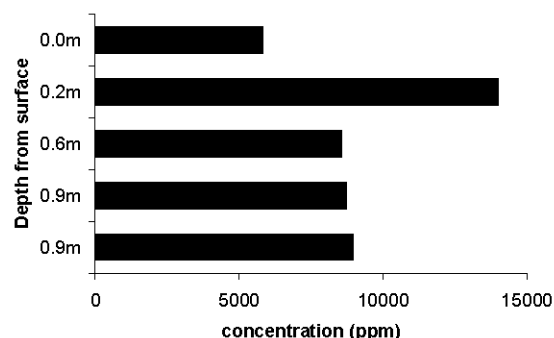


Figure 13. Trench 2, Point 4, changes in lead concentration with depth

## DISCUSSION

Geochemical survey is being increasingly applied in archaeology (see Dunster *et al* 2012 for a literature review). The use of pXRF allows data to be acquired rapidly and made available almost instantly as there is little (or no) sample preparation required. This approach has been used very successfully for a recent survey of the small Roman settlement at St Algar's Farm, Somerset (Dungworth *et al* 2013) where geochemical anomalies generally correlated with the geophysical anomalies and excavated archaeological remains.

The Tankerville lead mine survey involved far fewer sampling points and was undertaken to assess the nature and degree of land contamination. As the trenches for the drainage pipe had already been partially excavated when the survey started, the opportunity was taken to analyse exposed sub-surface deposits as well as the current land surface.

The concentrations of lead, and other elements associated with lead mining, were above the normal background levels. The elevation of these elements is entirely consistent with the previous use of the area as a lead mine. The limited geographical extent of the survey (all within 30–40m of the mine shaft) provides little scope for a detailed spatial examination of the data. A wider survey, possibly linked to the examination of any surviving historic maps or plans, might provide more information on the extent and arrangement of different activities, such as ore crushing and sorting. The concentrations of lead and zinc in deposits at Tankerville are considerably greater than those identified during other surveys (Table 3). This is probably due, at least in part, because the other surveys were extensive (covering up to 300km<sup>2</sup> in one case) while the Tankerville survey was intensively focussed on a single mining site.

*Table 3. Comparative data (ppm) for geochemical surveys of lead mining and lead working areas (Sources: Mendips, Davies and Ballinger 1990; Derbyshire, Wild and Eastwood 1992; St Algar's Farm, Dungworth et al 2013; Tankerville, this report)*

Element	Mendips		Derbyshire		St Algar's Farm		Tankerville	
	Pb	Zn	Pb	Zn	Pb	Zn	Pb	Zn
mean	183	267	339	196	573	61	7,822	3,159
sd	798	668	1,063	257	605	28	6,633	5,468
min	8	14	30	10	28	19	177	150
max	10,200	8,344	16,460	4,261	4,283	383	32,990	31,836

The survey at Tankerville identified significant variations in lead and zinc concentrations with depth: while the surface values were *generally* correlated with those obtained from sub-surface deposits there were many occasions where buried deposits contained much greater (or much lower) concentrations of these elements. While a detailed examination of the various processes which give rise to geochemical anomalies is beyond the scope of this report, some general principles can be explored.

The mining of metallic ores and the processing of these ores will give rise to varying degrees of contamination of the surface from mining waste. The nature and extent of the contamination will depend on the nature of the ore that is mined, the scale of such mining and the technologies employed for processing the ore. Metallic ores are often accompanied by a range of other minerals which may be rejected at the ore processing stage (Paynter 2009). The very high levels of barium detected in some deposits at Tankerville is consistent with an ore processing regime which aimed to recover lead ores but which rejected barium ores. If the miners employed a completely efficient ore processing technology they would leave no trace of the metal they sought, however, ore processing regimes face diminishing returns and economic factors will often dictate that

some of the desired metal will be left in mining waste. In the case of Tankerville the waste deposits typically contain 0.7wt% lead.

Where heavy metal contamination arises through airborne pollution (*eg* from a smelter or possibly an ore processor) the contamination should form a fairly simple distribution which will be highest at the source area (smelter or ore processor) and diminish with distance (this could be further moderated by prevailing winds). Where contamination falls on stratigraphically simple deposits (*eg* ploughsoil or pasture land) the contamination would initially be highest at the surface and decrease with depth. Anthropogenic and natural soil formation and mixing processes will tend to draw some contamination down from the surface over time. Where contamination arises from fragments of mining waste that are too large to be airborne the spatial distribution of subsequent geochemical anomalies is likely to be more complex. Relatively coarse fractions of mining and ore processing waste (>2mm?) will in most cases be dumped in particular locations through human agency, although these dumps may be subject to subsequent natural erosion processes. Where mining and ore processing requires several distinct steps or processes (*eg* ore crushing may initially be by stamping with additional reduction carried out using a rotary crusher), several different types of waste may be generated in different areas and the waste from each stage may be managed and disposed of in quite different ways. This could give rise to very complex spatial distributions of different metals and minerals associated with the historic mining. This may be further complicated on long-lived sites where technological developments may lead to old mining waste being reworked to recover some of the metal that it still contains. The re-working of existing deposits of mining waste also has the potential to contribute to the formation of complex stratigraphy where the concentration of heavy metals varies with depth.

The concentrations of lead (and other elements) at the surface and in buried deposits at Tankerville are at most 100 times greater than the normal background levels. Such high concentrations of heavy metals are potentially hazardous to health. Any works which disturb these deposits should take into account their contaminated nature and carefully assess the relevant risks.

## CONCLUSIONS

The rapid geochemical survey of surface and exposed deposits of mining waste at the historic lead mine at Tankerville has shown that these deposits contain elevated concentrations of lead (and other elements associated with lead mining). The variations in metal concentrations (both spatially and with depth) are complex: a simple explanation cannot be advanced on the basis of such a small survey. Nevertheless, it is clear that pXRF is well suited for the geochemical survey of mining and smelting sites and it is hoped that the approach can be extended in the future.

## REFERENCES

- Clark, A 1990 *Seeing Beneath the Soil*. London: Batsford
- Davies, B E and Ballinger, R C 1990 'Heavy metals in soils in north Somerset, England, with special reference to contamination from base metal mining in the Mendips'. *Environmental Geochemistry and Health* 12, 29–300
- Dungworth, D, Comeau, B and Lowerre, A 2013 *St Algar's Farm, Selwood, Somerset. Geochemical survey*. Research Report 28/2013. Portsmouth: English Heritage
- Dunster, J, Dungworth, D and Lowerre, A 2012 *Rendlesham, Suffolk. Characterising metalworking through a geochemical survey*. Research Report 30/2012. Portsmouth: English Heritage
- Paynter, S 2009 *Hilton Mine, Scordale, Cumbria: Identification of Mineral Samples*. Research Report 20/2009. Portsmouth: English Heritage
- Rudnick, R L and Gao, S 2005 'Composition of the continental crust' in R L Rudnick (ed) *The Crust*. Oxford: Elsevier, 1–64
- Taylor, S R and McLennan, S M 1985 *The Continental Crust: its composition and evolution*. Oxford: Blackwell
- Wild, M and Eastwood, I 1992 'Soil contamination and smelting sites', in L Willies and D Cranstone (eds) *Boles and Smeltermills* (London: Historical Metallurgy Society), 54–57

## APPENDIX

Calibrated values for the concentration of selected elements

<b>SAMPLE</b>	<b>Easting</b>	<b>Northing</b>	<b>Zn</b>	<b>As</b>	<b>Pb</b>	<b>Ba</b>
TIP1 0m ground surface	335481	299475	995	<200	1289	597
TIP1 0m ground surface	335481	299475	808	<200	1086	370
TIP1 0.3m deep dark grey brown sediment	335481	299475	4920	<200	17710	5175
TIP1 0.7m deep ditto	335481	299475	4028	<200	10601	4694
TIP2 0m ground surface	335483	299469	1039	231	3849	1835
TIP2 0.7m rock	335483	299469	225	<200	338	5029
TIP3 0m ground surface	335486	299465	2000	<200	14828	28481
TIP3 0.2m deep beige clay	335486	299465	31836	487	27725	191937
TIP3 0.3m deep pale sand	335486	299465	23525	<200	8683	200145
TIP3 0.7m deep grey brown clay loam	335486	299465	1241	<200	1881	3358
TIP4 0m ground surface	335489	299460	2013	<200	7702	11160
TIP4 0.3m deep grey clay loam with rocks	335489	299460	5202	<200	32990	102753
TIP5 0m ground surface	335491	299458	1167	<200	13176	2193
TIP5 0.2m deep dark humic soil	335491	299458	2626	<200	19571	3190
TIP5 0.6m deep beige clay (natural)	335491	299458	150	<200	177	945
TIP*6 22m	335496	299453	533	<200	2047	729
TIP*7 25m	335498	299451	601	<200	2703	891
TIP*8 31m	335500	299449	379	<200	1087	673
TIP*9 38m	335503	299446	1092	<200	1761	1890
T2P1 0.5m white powder (mortar?)	335487	299480	1285	214	8186	6389
T2P1 0.8m grey loam and rocks	335487	299480	1427	320	7710	4549
T2P2 0.05m grey loam	335491	299481	1408	<200	5127	5565
T2P2 0.25m grey loam	335491	299481	1684	<200	4911	10303
T2P2 0.5m black humic soil	335491	299481	1207	<200	1786	4122
T2P2 0.7m powdery beige sandy loam	335491	299481	2581	273	6314	6823
T2P2 0.9m beige clay	335491	299481	556	<200	3614	4033
T2P3 0m ground surface	335495	299479	1769	<200	10174	21066
T2P3 0.3m grey loamy clay	335495	299479	6439	<200	12314	12635
T2P3 0.7m powdery cream sediment	335495	299479	3947	<200	4391	4060
T2P3 0.9m grey gravelly loam	335495	299479	2358	2126	21472	4875
T2P3 0.9m black humic soil	335495	299479	1320	<200	2634	856
T2P4 0m ground surface	335498	299477	1933	211	5814	7129
T2P4 0.2m grey clay loam	335498	299477	3566	363	13998	31469
T2P4 0.6m loose powdery sediment with rocks	335498	299477	989	<200	8551	19015
T2P4 0.9m reddish brown humic soil?	335498	299477	3138	<200	8721	3488
T2P4 0.9m black humic soil	335498	299477	17698	677	8945	768
T2P*5	335500	299475	3239	<200	7446	11254
T2P*6	335503	299474	1634	333	6907	5671
T2P*7	335505	299473	5848	<200	9693	8903
T2P*8	335507	299472	1480	569	8304	1988



## ENGLISH HERITAGE RESEARCH AND THE HISTORIC ENVIRONMENT

English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for the protection and sustainable management of the resource, and to promote the widest access, appreciation and enjoyment of our heritage. Much of this work is conceived and implemented in the context of the National Heritage Protection Plan. For more information on the NHPP please go to <http://www.english-heritage.org.uk/professional/protection/national-heritage-protection-plan/>.

The Heritage Protection Department provides English Heritage with this capacity in the fields of building history, archaeology, archaeological science, imaging and visualisation, landscape history, and remote sensing. It brings together four teams with complementary investigative, analytical and technical skills to provide integrated applied research expertise across the range of the historic environment. These are:

- \* Intervention and Analysis (including Archaeology Projects, Archives, Environmental Studies, Archaeological Conservation and Technology, and Scientific Dating)
- \* Assessment (including Archaeological and Architectural Investigation, the Blue Plaques Team and the Survey of London)
- \* Imaging and Visualisation (including Technical Survey, Graphics and Photography)
- \* Remote Sensing (including Mapping, Photogrammetry and Geophysics)

The Heritage Protection Department undertakes a wide range of investigative and analytical projects, and provides quality assurance and management support for externally-commissioned research. We aim for innovative work of the highest quality which will set agendas and standards for the historic environment sector. In support of this, and to build capacity and promote best practice in the sector; we also publish guidance and provide advice and training. We support community engagement and build this in to our projects and programmes wherever possible.

We make the results of our work available through the Research Report Series, and through journal publications and monographs. Our newsletter *Research News*, which appears twice a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities.

A full list of Research Reports, with abstracts and information on how to obtain copies, may be found on [www.english-heritage.org.uk/researchreports](http://www.english-heritage.org.uk/researchreports)

*For further information visit [www.english-heritage.org.uk](http://www.english-heritage.org.uk)*

