



# ENVIRONMENTAL LEGACY OF 19<sup>th</sup> CENTURY LEAD MINING AND MINERAL PROCESSING AT THE NEWTOWNARDS LEAD MINES

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**Abstract:** Ireland's largest 19<sup>th</sup> century mining site, the Newtownards Lead Mines at Conlig and Whitespots, County Down, may present significant human and animal health and environmental risks such as exhibited by other abandoned mine sites of similar size. We present information on the distribution of lead enrichment in tailings, spoil, soil and vegetation in the mine sett and adjacent areas, and make outline recommendations for improving site management. The risks are partially mitigated by the absence of smelting on site, the enclosed topography of the ore processing area, and the abundance of carbonate gangue resulting in neutralisation of acid generated during oxidation of the spoil and tailings. Tailings and associated soils in the southern part of the main sett contain remarkably high concentrations of lead. The tailings material has been dispersed by erosion enhanced by motorbike scrambling and similar recreational activities. The site is a Country Park and a designated Area of Special Scientific Interest for its unusual mineralogical and botanical features, but without active management, continued deterioration will compromise its scientific and mining heritage value. The surviving mine buildings should be actively conserved and measures taken to preserve landscape features associated with former ore processing. We recommend that responsible parties should implement a site specific hazard-risk management plan, sympathetic to the site's ASSI designation and use as a Country Park, particularly to alleviate the primary hazard, namely the lead-rich tailings impoundments and adjacent downslope area into which tailings material has been redistributed. *Journal of the Mining Heritage Trust of Ireland* 15, 2015, 41-53.

## INTRODUCTION

In a recent volume of this Journal, Schwartz and Critchley (2013) provided a full account of the history and industrial archaeology of the Newtownards Lead Mines and other small-scale mine trials in County Down, Northern Ireland. Their account extends and revises the previous 'definitive' account of the Newtownards Mines by Woodrow (1978). One aspect that Schwartz and Critchley only briefly discuss in their report is the environmental legacy and possible human health implications of lead mining and ore processing at the site. This legacy comprises lead-enriched spoil and tailings, and soil enriched by lead dispersed from these materials since the closure of the mines.

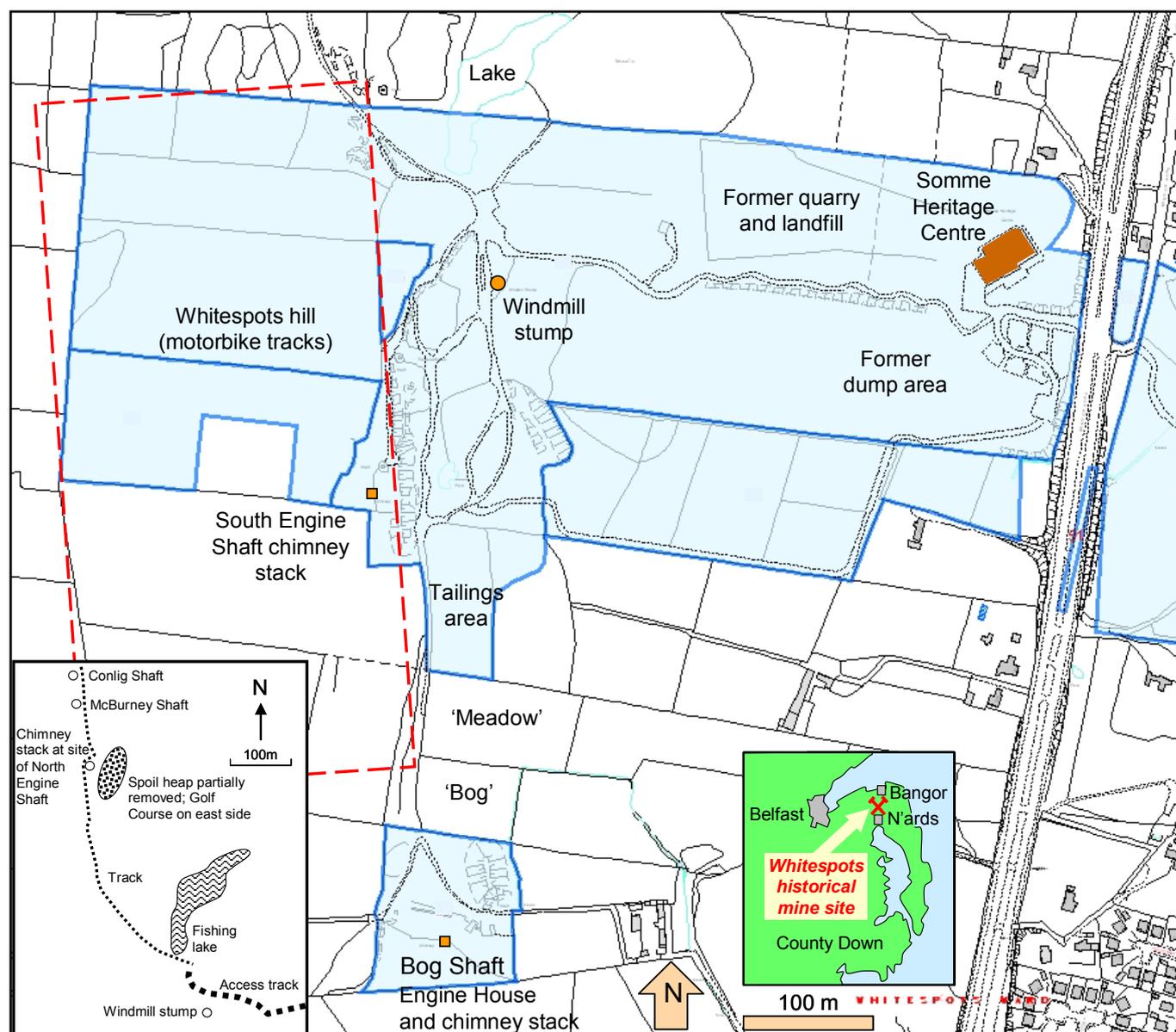
Stemming from an invited talk at the AGM Weekend meeting in May 2015 held at North Down Museum, Bangor, the current article brings together results from several research projects, undertaken intermittently since the mid-1990s involving postgraduate students from two universities and survey work commissioned by the Ards Motor Cycle Club (Ards MCC) Ltd. The aim of this article is to illustrate and inform the readership of the distribution of lead enrichment in tailings, spoil, soil and vegetation in the mine setts and

adjacent areas, and to make outline recommendations for the future (improved) management of potential hazards and risks to the environment and health.

## GEOLOGY, GEOMORPHOLOGY AND LAND USE

The Newtownards Lead Mines exploited a mineralized vein-breccia structure in a north-south fault zone extending from 1.5 to 3 km north of Newtownards (Smith *et al.*, 1991). The host rocks are Silurian greywackes and shales that are part of the Southern Uplands – Longford-Down turbidite belt. There is no accessible exposure of the mineralization, and detailed descriptions were not recorded during the period of mining; therefore, the nature of the ore material and its formation are inferred from collections of samples from the spoil heaps.

The mineralized breccias comprise angular rock fragments cemented by quartz, dolomite and baryte, within which the ore minerals occurred as coarsely crystalline masses. Early-formed silica-cemented breccias that are barren of metallic minerals were re-brecciated and cemented by dolomite, baryte and metallic minerals, primarily galena, chalcopyrite, and sphalerite. As far as we are aware, only the galena was



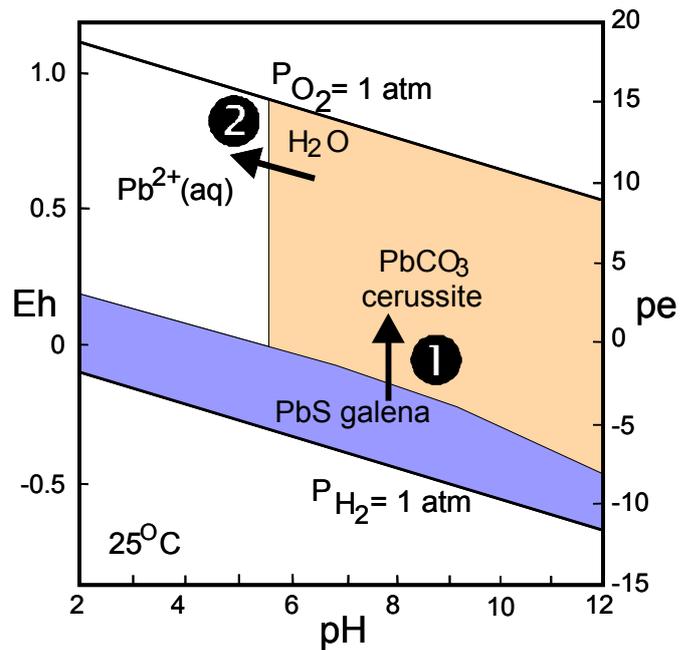
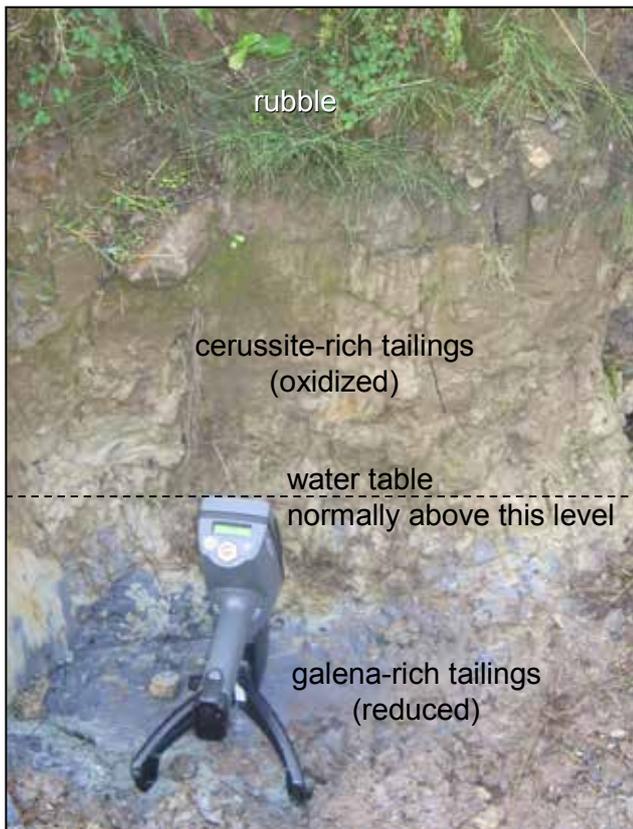
**Fig. 1: Field boundary map of the Whitespots area showing in blue the land owned by Ards and North Down Borough Council. Crown Copyright reserved. Red dashed box indicates the area shown in Fig. 6. On the right of the map is the Newtownards–Bangor road. The mine site is easiest to access from car parks located southeast of the Somme Heritage Centre. Inset maps show the location within eastern Northern Ireland, and a northwestern extension of the main map to show location of the Conlig Lead Mine sett. Base map provided by Ordnance Survey of Northern Ireland: Crown Copyright reserved**

recovered during 19<sup>th</sup> century processing of the ore. Other associated gangue minerals are chalcedony, calcite, and clay minerals. Secondary carbonate minerals such as malachite and cerussite occur in oxidised ore which is fairly scarce in the spoil heaps. Of particular mineralogical interest are rare occurrences of the barium zeolite minerals harmotome and edingtonite. These paragenetically late minerals may have crystallized following intrusion of a dolerite dyke through the breccias in the early Cenozoic (Tertiary) era, long after the main mineralization events in the Carboniferous Period (Moles and Nawaz, 1996; Moles, 2007). Schwartz and Critchley (2013, 23) provide a broader plate tectonics context for these geological events.

The geomorphology of the mine sett is important as it

influenced the location of mine infrastructure and ore processing, as well as the current environmental legacy. The northern part of the mineralized structure, the Conlig Mine sett, lies within undulating woodland of the Cladeboye Estate and adjacent greens of the Cladeboye Golf Course. The trace of the concealed mineralized structure is expressed as an elongate depression. This is likely due to a combination of pre-Holocene erosion and dissolution and surface mining and/or subsidence into shallow underground workings. South of the estate boundary, the Whitespots Mine sett lies on an east-facing escarpment on Whitespots Hill (Fig. 1).

With the exception of small, eastwards flowing field drains at the south of the Whitespots Mine sett, there are no permanent surface watercourses in the area. However, straddling the



**Fig. 2:** Left: Vertical section through tailings at the southern edge of the fishing lake (located in the north part of Fig. 1) exposed during a prolonged dry period. An Innov-X alpha PXRF spectrometer is set up for in situ measurement. The lower part of the profile comprises unoxidised tailings that are blue-grey coloured due to finely comminuted galena. The beige-coloured upper part comprises oxidised tailings in which the original galena has been replaced by the lead carbonate cerussite. Right: Simplified acidity-oxidation diagram for Pb compounds, adapted from Drever (1997). ①: oxidation of tailings in presence of excess carbonate forming cerussite. ②: cerussite dissolution due to physical transfer to a lower pH environment such as moderately acidic soil, or a mammal's stomach

boundary between the Conlig and Whitespots Mine setts is a small lake, used for fishing, occupying a depression surrounded by bedrock exposures. This depression had been occupied by a bog prior to the construction of a dam during development of the mine. The resulting lake provided water for ore processing activities in the vicinity of the windmill about 100m south of the dam (Fig. 1). The lake may be recharged by water from the flooded underground workings. During prolonged dry periods when the water level is low, galena-rich tailings are exposed at the south edge of the lake (Fig. 2) – the significance of this will be discussed later. Except where exposed in the bank of the lake at its southernmost point, these tailings are capped by building rubble which may have been placed here to further raise the water level.

At Whitespots, the deeper shafts that were sunk to gain access to ore at depth (Schwartz and Critchley, 2013) are located on the escarpment and consequently the South Engine Shaft chimney stack is a visually prominent feature of the mine site. Spoil heaps flank the escarpment below the level of the former engine house (Fig. 1). Much of the spoil material was removed in the first half of the 20th century for use as fill and foundation material, notably for Newtownards airport which was constructed on former estuarine mudflats. Photographs of the Whitespots Mine Sett taken around the turn of the 20th

century, featured on the front cover of volume 13 of the MHTI Journal and as Figure 19 in the article by Schwartz and Critchley (2013), illustrate the former height of the spoil heaps that extended some 200m south from the windmill stump.

A valley, presently densely vegetated, extends for about 100m southwards from the southern edge of the Whitespots spoil heaps. In its upper (northern) part the valley contains a cluster of deep roughly circular depressions, some 3 m in diameter, which may have been buddling pits. Downslope to the south are a series of tailings terraces, their flat tops indicating the original top surface of infilled tailings dams (impoundments). Lines of cobbles transverse to the valley axis are the remains of the impounding walls. The oxidised tailings are characterised by pale-coloured and compact silty material, and where undisturbed are capped by a thin organic-rich soil and vigorous growth of bracken. Tailings material is also stacked against the escarpment on the west side of the valley. In total there were at least four tailings impoundments, now variably eroded (Fig. 3) as will be discussed later.

The southern boundary of this 'tailings area' is a prominent hedgerow, south of which the valley opens out to the east at a former pasture field, hereafter referred to as the 'meadow' (Fig. 1). South of this is a bog which floods in wet weather and



**Fig. 3: Eroded tailings impoundment in the area southeast of the South Engine Shaft chimney stack, looking south with the Bog Shaft engine house, chimney stack and (gorse-covered) spoil heap visible in the distance. During periods of rain, cerussite-rich tailings material is washed downslope through the gap in the hedge into the 'meadow' beyond. The meadow and hedge are the subjects of biogeochemical analyses reported here**

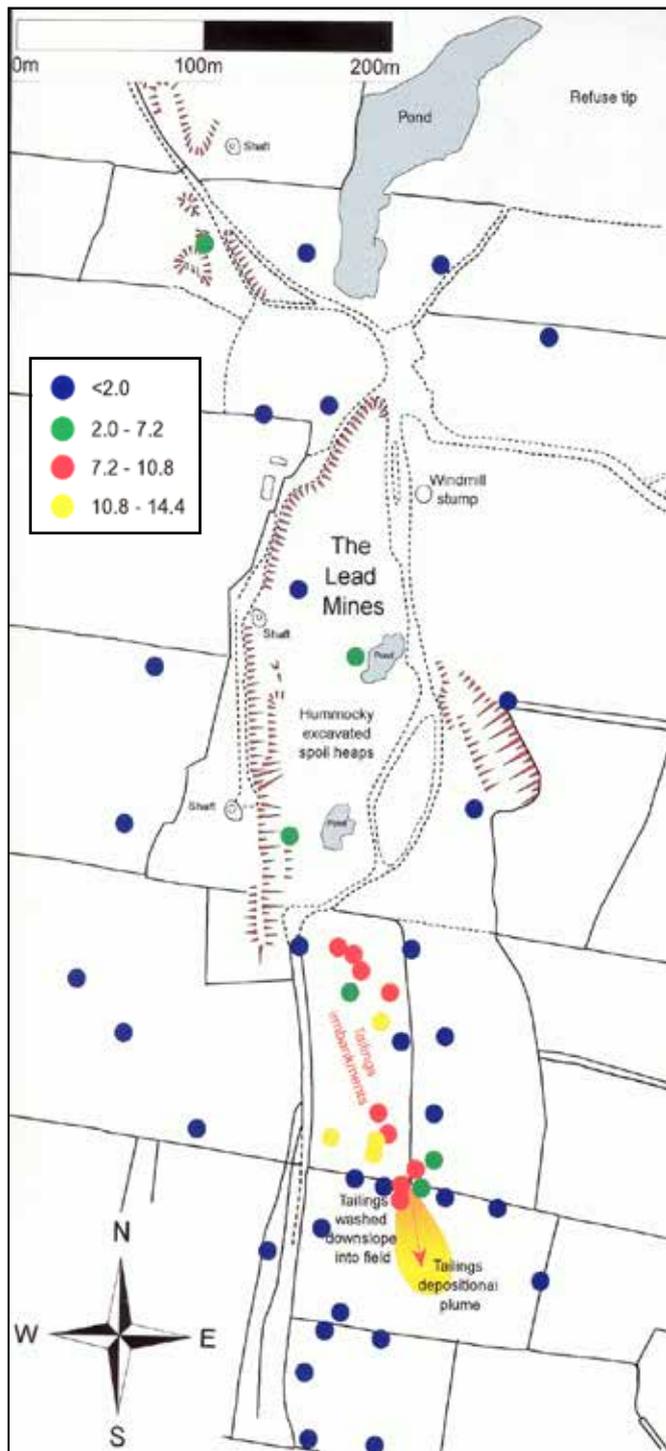
gives its name to the Bog Shaft, the southernmost relict of the Newtownards Lead Mines. The largely intact engine house and chimney stack (described by Schwartz and Critchley, 2013) sit on slightly elevated ground and the intact spoil heap forms a prominent, gorse-covered hill adjacent to the bog (Fig. 3). As the Bog Shaft was sunk primarily for mine drainage purposes, the spoil is predominantly greywacke and shale devoid of mineralized material. It is not known whether the bog might have been used for ore washing/processing.

Drainage eastwards from the bog and meadow is by means of stagnant ditches alongside hedgerows: there is currently no known fluvial transportation of sediment away from this part of the mine site. As it is noted that spoil was removed from the site for the construction of the Newtownards Airfield, it is plausible that the site has had an impact beyond its boundaries. The Tellus Programme stream sediment map for Pb (Lister *et al.* 2007) shows lead enrichment in stream sediments in the areas south of Bangor and Newtownards. This is likely due to contamination of watercourses from former mines and prospects in the area and from relocated spoil used as fill material. However, from mineralogical studies of metalliferous materials identified in stream, canal and estuarine sediments in Newtownards, Moles *et al.* (2003) reported that the metals are predominantly from industrial (manufacturing) and urban sources rather than from mining activities.

In the late 1990s much of the mine area was designated as a country park by the Department of the Environment for Northern Ireland. Potentially dangerous shafts were fenced off, paths were laid, lead contamination warning signs put up and interpretive boards erected to explain the significance of buildings and other features of the site. The Whitespots Country Park occupies land owned by the Ards and North Down Borough Council ('ANDBC'), shown in Fig. 1. However, as reported by Schwartz and Critchley (2013), negligence and vandalism have degraded the appearance and appeal of the mine site, despite its designated status and being a Country Park.

### **LEAD ENRICHMENT IN SOIL AROUND THE MINE SITE**

In 1995, for his MSc dissertation at Queen's University Belfast (QUB), Mark Kelly undertook geochemical analyses of an initial set of 17 samples of spoil, tailings and shallow soil taken from various locations in the Lead Mines area, 5 samples of vegetation (grasses, foliar) taken from just beyond the 'meadow' hedgerow and 3 samples of surface water taken from the northern lake, an ephemeral pond in the spoil area and from an issues c. 20 m south-east from the Bog Shaft. He found relatively low concentrations of lead in spoil and nearby soil at the North Engine Shaft, which is the largest surface



**Fig. 4: Dermot Smyth's map of Pb concentrations (classified into 4 class intervals with values in weight percent) in <2 mm soil or other substrates collected from 53 locations in the Whitespots area**

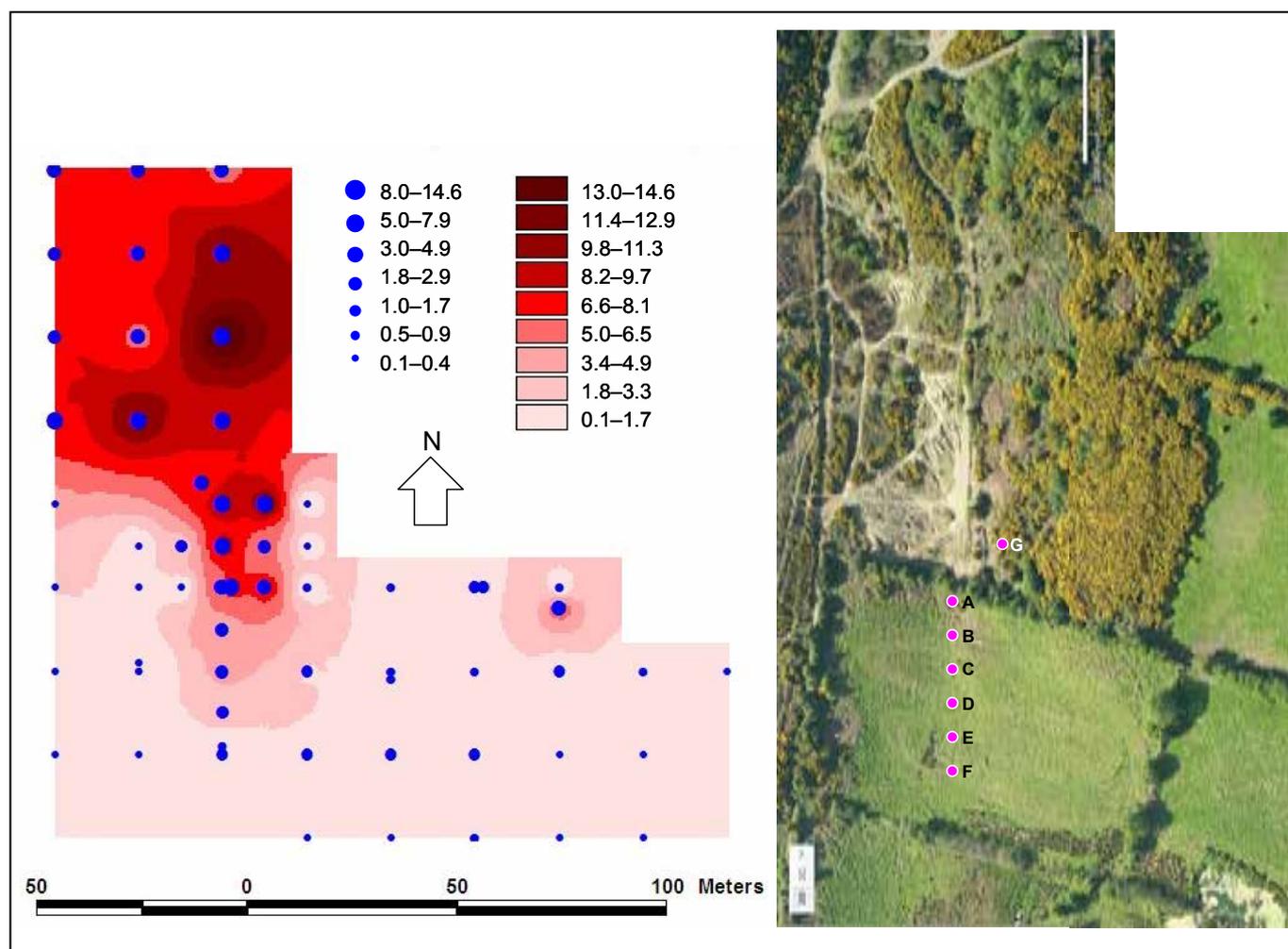
feature of the Conlig Lead Mine site (Fig. 1 inset). Mark's work revealed the remarkably high lead content – over 8 and up to 14 % – in tailings and soil containing redeposited tailings material in the south of the Whitespots Mine site. He found lead concentrations of maximum 0.38 % in ashed meadow vegetation samples. Lead concentrations in the water samples were unfortunately not measurable with the analytical technique used. Consequently, further investigations focussed

on the main tailings area and meadow, described below. In the meadow, surface soil contains typically 2–8 % Pb due to contamination from redeposited tailings material.

In the late 1990s as part of a PhD research project at QUB on biogeochemical prospecting methods, Dermot Smyth undertook sampling and analysis of soil and vegetation from throughout the Whitespots Mine site and adjacent area, although this was not reported in his final thesis (Smyth, 2001). Considering the widespread occurrence of bracken (*Pteridium aquilinum*) at the site, Dermot chose this plant as a sampling medium. He collected samples of bracken leaves and associated root-zone soil or other substrate such as tailings from 53 sites across an area of about one third of a square kilometre (Fig. 4). The <2 mm sieved soil and ashed vegetation were analysed at OMAC Laboratories using an Aqua Regia digest and an ICP Emission Spectrometry multi-element method. Lead concentrations ranged from <300 ppm to >1.9 % in 'background' soil and from 8.0 % to 14.4 % in tailings. Bracken ash Pb values ranged up to 0.28 % and showed a weak correlation with substrate Pb values. The soil Pb analysis results are shown in Fig. 4 using four class intervals, the lowest being <2 % Pb which includes most soil and mine spoil samples. Confirming the outcome of Mark Kelly's initial work, Dermot found that relatively high Pb values in soil are confined to the main tailings area and redeposited tailings in the meadow downslope (Fig. 4 inset).

With regard to hazardous elements other than lead, Dermot found low levels of As, Cd and Hg in his geochemical results from 53 soil/substrate samples, consistent with the pilot study by Mark. In all cases, mercury was below the 1 ppm detection limit of the ICP-ES. Cadmium is above the 1 ppm detection limit in a few soil samples with values up to 4.5 ppm whereas Cd concentrations are typically 6–12 ppm in tailings. Arsenic concentrations are in the range 7–22 ppm with no distinction between background soil and spoil/tailings; however subsequent PXRf analyses of tailings indicate higher amounts with locally high As values up to 900 ppm. The sulphur content of tailings and spoil samples is 0.16–0.6 %. Antimony, copper and zinc are relatively enriched in spoil and tailings: these contain up to 37 ppm Sb, 0.1 % Cu, and 0.22 % Zn.

In 2006 an Innov-X portable x-ray fluorescence metals analyser (PXRf) then recently purchased by the University of Brighton was deployed in the south Whitespots area to obtain in situ elemental analysis of exposed tailings and near-surface soil (Moles *et al.* 2006). The PXRf instrument and procedure used was the same as reported in Carr *et al.* (2008). Measurements were taken on a 20 m grid, and infill on a 10 m grid in areas of steep gradients in Pb concentration. Fig. 5 shows the distribution of measured Pb concentrations interpolated to create a contoured map. The redeposited tailings plume is clearly defined extending at least 50 m south of the entry point at the field boundary – this will be discussed in more detail later. Also visible in Fig. 5 is a discrete soil Pb anomaly at the northeast corner of the meadow some 80 m east of the entry point. The source of this was identified as tailings material that had apparently been taken here, perhaps a century ago, to cement the stonework of a low drystone wall marking the field boundary. This relocation of tailings material



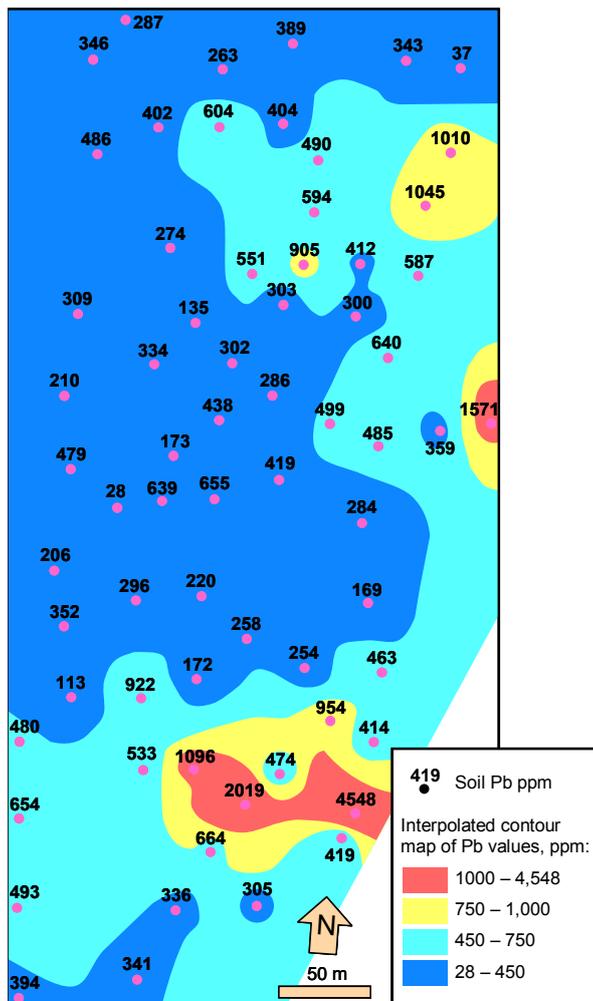
**Fig. 5: Spatial distribution of Pb, determined by in situ PXRF, in topsoil in the tailings area and meadow alongside an aerial photograph of approximately the same area (Microsoft Virtual Earth™, 2006). Data collected by the author. Map produced by Osric Forton using ArcGIS (Moles *et al.*, 2006). Circles labelled A–G are the locations of soil pits for geochemical profiles (Fig. 9)**

has resulted in intermittent Pb-rich soils along the field boundary, dispersing downslope in the eastern part of the meadow. It is likely that tailings material has been deployed in a similar way elsewhere around the Whitespots area.

During fieldwork in 2006, one of the authors (NRM) met a committee member of Ards MCC Ltd. and subsequently a contract was agreed for in situ PXRF analysis of soil exposed in paths and motorbike tracks in the hilly area west of the Whitespots mine sett. Fieldwork was undertaken in October 2007 during dry weather conditions. In one 12 hour day, 83 measurements were collected at 67 sites across an area measuring approximately 650m (north-south) by 250m (east-west). The results shown in Fig. 6 indicate that the paths and tracks used by motorcyclists expose soil that, by and large, does not have elevated levels of lead or other metals. At two locations in the southeast corner of the surveyed area, near the South Engine Shaft, lead concentrations were found to be comparatively high with values in the range 0.2–0.5 %. Elsewhere in the surveyed area, Pb values are less than 1000 ppm (0.1 %) and in much of the area less than 450 ppm. At that time, 450 ppm was the threshold guideline value for residential land use (with and without plant uptake) as defined

by the Department of the Environment Food and Rural Affairs (DEFRA) when undertaking Contaminated Land Exposure Assessments. Since then, new assessment criteria have been published - Category 4 Screening Levels - which include provisional threshold levels for lead of between 270 mg/kg to 1,400 mg/kg for the land use category 'Parks and Open Spaces'.

Combining datasets from the Ards MCC report, and from the work of Mark Kelly, Dermot Smyth and other postgraduate students whose projects the first author supervised at Queen's University (co-authors of Moles *et al.* 2004), enables production of a generalised map showing the known distribution of Pb-enriched soil/substrates in the Whitespots Mine area (Fig. 7). A simple, arbitrary 3-fold classification has been adopted using thresholds of ~0.5 % for moderately enriched and ~2 % Pb for highly enriched substrates. Based on the surveys described above, the western and southern boundaries of the area of 'moderate' contamination are well defined, whereas the eastern boundary is speculative. Geochemical surveying of the land to the east of the open area of spoil and ponds (south of the windmill) is hampered by impenetrable dense vegetation. The area of 'very high' lead



**Fig. 6: Interpolated contour map of lead concentrations, showing in situ PXRF measurement points and values in parts per million, in surface soil along paths and tracks on Whitespots hill west of the mine sett. Coloured map area corresponds to the dashed-line red box in Figs. 1 and 7**

content in surface material is restricted to the tailings valley, the adjoining meadow with redeposited tailings, and the tailings-cemented field wall extending eastwards. However, as noted earlier, tailings material is present beneath a ~1 m layer of rubble at the south end of the lake (Fig. 2) and there may well be other, as yet undiscovered, occurrences of lead-rich surface materials around the mine site and surrounding area.

It is worth mentioning here that metal enrichment of the ground at Whitespots is not exclusively due to mine spoil and tailings: in some places contamination is due to metalliferous waste dumped at the site during a period of about 40 years from the 1940s. A scrap metal collector apparently dwelt on the site and stockpiled metallic waste in an area c. 25 m in diameter located c. 80 m west of the windmill. Although the stockpile has gone, the ground here comprises metal-rich waste which inhibits growth of shallow-rooting vegetation; it is now carpeted with moss. Dermot Smyth analysed two samples from this ground and confirmed its enrichment in a distinctively wide range of metals including cadmium up to 20

ppm. Elsewhere, vehicles have been abandoned and set alight, melting their lead batteries. Even after removal of the burnt cars, the resulting slag-like pieces of metallic lead remain on the ground, for example in the southern part of the spoil area adjacent to the North Engine Shaft. This is unsightly and unpleasant in the context of the area's use as a Country Park, but is localised in comparison to the extensive area of lead-rich tailings and tailings enriched soil that pose potential environmental and health risks.

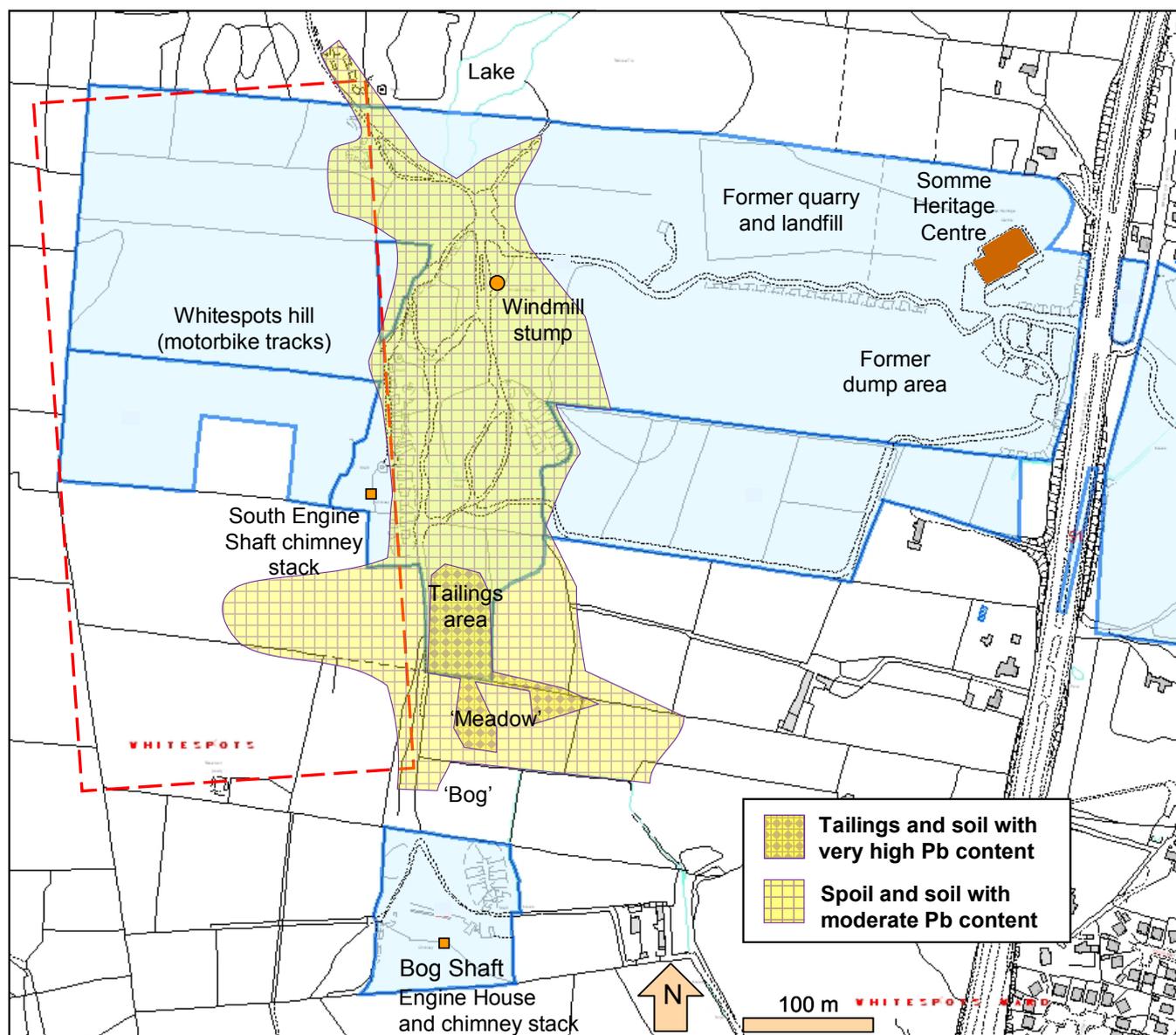
## LEAD-RICH TAILINGS, SOIL AND PLANT UPTAKE

This section considers in more detail the distribution and composition of tailings and tailings-enriched soils in the southern part of the Whitespots mine site, outside of the ANDBC landholding (Figs. 1, 3 and 8), and the issues arising from their very high lead contents. We will also consider evidence for plant uptake of lead and whether this poses a hazard to people visiting this area.

As noted above, in the tailings lead occurs mainly as very fine-grained cerussite (lead carbonate,  $PbCO_3$ ) except where waterlogged conditions have preserved galena (Fig. 2). Cerussite is not present in the primary ore and its origin is attributed to reactions involving the decomposition of fine-grained galena in the presence of oxygen and excess carbonate, and the release of sulphate in solution (Fig. 2). The excess carbonate is provided by calcite and dolomite which are, fortuitously, major constituents of the ore material and therefore abundant in the tailings as shown by X-Ray Diffraction (XRD) analyses. The oxidation-carbonation process probably occurred during the first few decades after filling of the impoundments, during which time large amounts of dissolved sulphate were presumably transported away from the tailings in groundwater and overland flow.

In her 1998 MSc project on the composition of tailings in the main tailings area, Kirsty Kerr identified spatial variations in the particle size and bulk mineralogy using XRD analysis, with varying proportions of clay, quartz and carbonate minerals. The central tailings impoundment has the highest proportion of cerussite, up to 22 %, and also the finest particle size with 80–97 % in the clay-silt range (<63 microns). This variation suggests that, during operation of the mines, the impoundments had been filled sequentially and during this time there were changes in the ore composition and/or the processing methods and efficiency of recovery of galena.

In the main tailings area, the covering of shallow soil and surface vegetation has been stripped by human activities, specifically the recreational use of 4x4 off-road vehicles, quad bikes and motorbikes. These have incised gulleys through the impoundments (Fig. 3). This has exposed the impermeable tailings to erosion by rain and wind. Rainwash and overland flow has relocated much of the tailings material from the original impoundments, downslope through gaps in the hedge into the topographically lower meadow. Here, inundation of the meadow grass and growth of distinctive calcium-looking plants (including orchids) formed a visible plume across the field (Fig. 8). Depth probing indicates that half a metre or



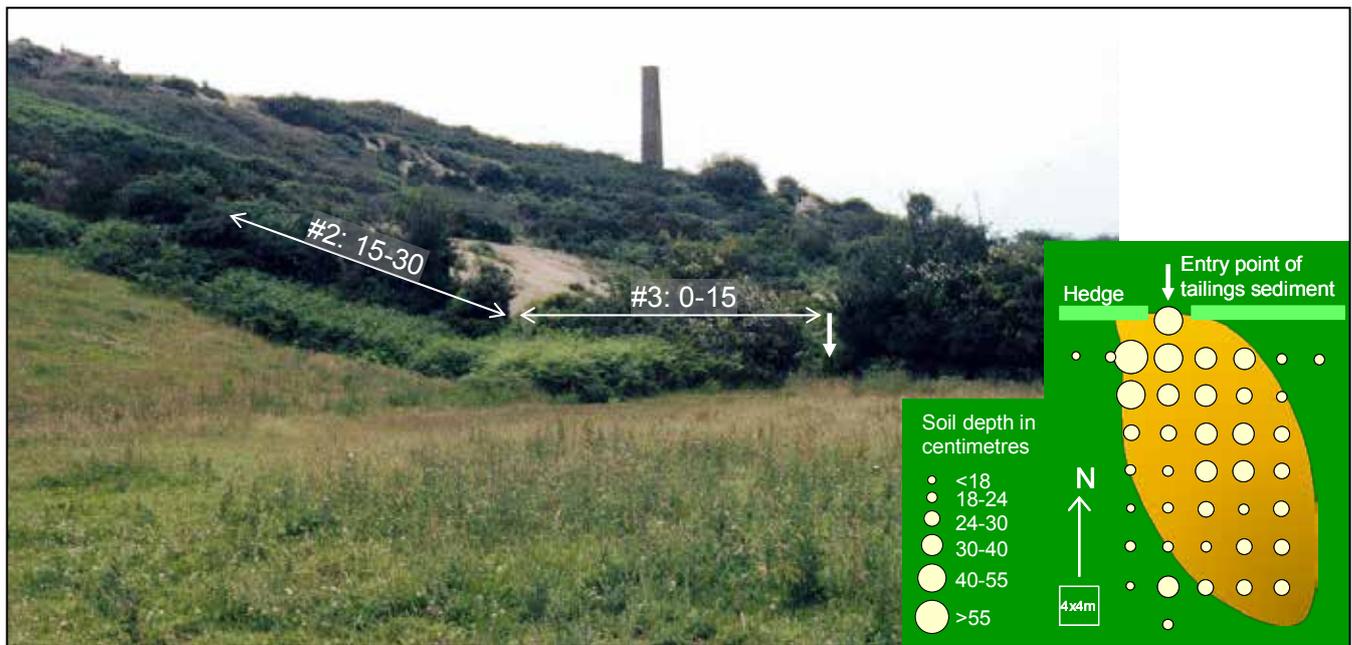
**Fig. 7: Distribution of soil Pb enrichment based on various surveys reported here, outlined on the OSNI base map (see Fig. 1): Crown Copyright reserved. ‘Very high Pb content’ indicates over ~2 % and ‘moderate Pb content’ indicates c. 0.5 to 2 %. The western and southern boundaries of the ‘moderate’ Pb content are well defined, whereas the eastern boundary is speculative**

more of redeposited tailings has accumulated in the proximal part of this plume (Fig. 8) where overland flow passes through the hedge, which has been partially buried by the sediment.

In situ analysis of surface materials by PXRf confirmed Pb levels in the range 6.2–14.6 % in the tailings area and 0.1–11.9 % in the meadow soil (Fig. 5) (Moles *et al.* 2006). Lab analyses (AAS and ICP-MS) showed excellent agreement with PXRf analyses of dried and homogenised samples (for Pb,  $R^2 = 0.9989$ ). Lead concentrations decrease linearly along the axis of the ‘plume’ for a distance of 60 m from the tailings ingress point, but decrease rapidly over a few metres perpendicular to the plume axis. Pb levels of 1–2 % extend for 60–80 m eastwards of the plume axis, probably due to vehicular dispersion of enriched soil in the meadow. ‘Background’ levels of Pb in the meadow soil are ~0.1–0.2% (~1000–2000 ppm) which are considerably above current Soil

Guideline Values for residential and commercial/ industrial and allotment land-use types and the provisional C4SLs for Parks and Open Spaces (270 mg/kg to 1400 mg/kg range). Further dispersal of Pb-enriched soil probably occurred between 2006 and 2013 due to continued use of the meadow and adjoining fields for motorbike and quad bike scrambling.

As probing had demonstrated a considerable depth of probably redeposited tailings in the proximal part of the plume (Fig. 8), in 2011 the lead author supervised University of Brighton MSc student Boli Ajibola in a project to gain more information on the tailings influx by means of geochemical depth profiles. Six soil pits 10 m apart were excavated in an approximately north–south transect across the meadow, plus a control site 20 m north of the hedge. Sets of contiguous samples from the vertical profiles were analysed by PXRf (Fig. 9) with validation by ICP Mass Spectrometry. Pit A, located in the



**Fig.8: Photograph taken in 2000 of the meadow looking northwest with the prominent South Engine Shaft chimney stack on the escarpment. Central in the photograph, the pale area bare of vegetation is an eroded tailings impoundment. Extending left to right is the hedgerow through which eroded tailings are washed into the meadow. Vigorous growth of pale green bracken is visible in an area where sandy, calcite-rich tailings have been deposited. Arrowed lines labelled 0-15 and 15-30 indicate lengths of hedge from which vegetation samples were taken for analysis (Fig. 11). Inset: map of the redeposited tailings plume in the meadow showing soil depths estimated by probing on a 4 m grid with an iron rod. The south-eastern extremity of the plume corresponds to the location of the photographer**

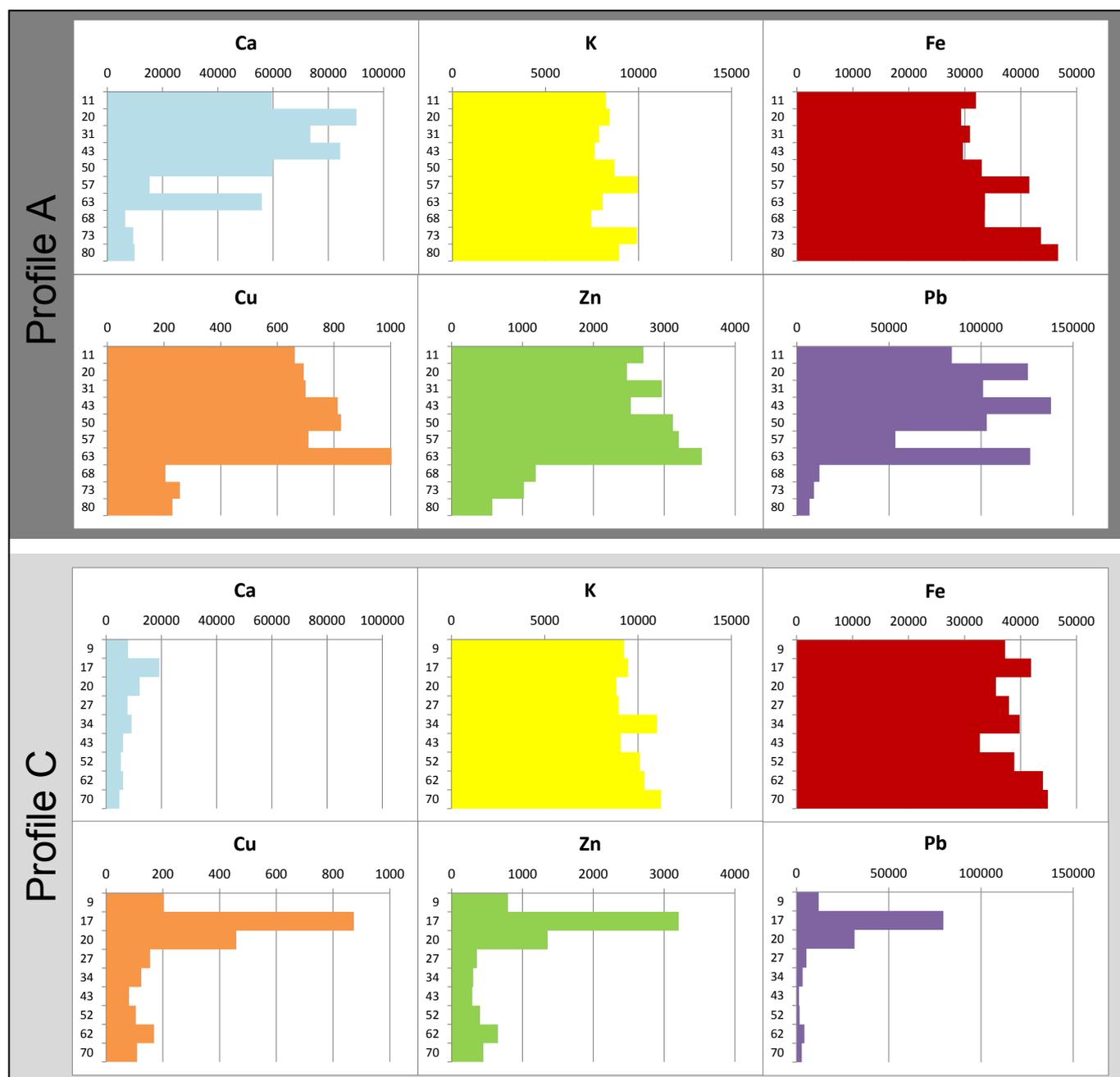
proximal plume area 5 m south of the field boundary, revealed tailings-rich material containing c.  $10 \pm 3$  % Pb to a depth of 63 cm. At this depth, there was a visibly sharp boundary with relatively normal soil containing 0.7–1.2 % Pb. Calcium shows a very similar profile to Pb. The redeposited tailings are enriched in Cu and Zn. Pit B 10 m to the south showed a similar geochemical profile but with tailings-rich material only in the upper 25 cm. Pit C a further 10 m south showed a tailings influence only in the depth interval 9–20 cm (Fig. 9) with similar Cu, Zn and Pb concentrations to the upper part of Pit A but much lower Ca concentrations. Pits D, E and F showed much lower levels of Pb (<5000 ppm) and also much lower Ca, Cu and Zn suggesting that an insignificant amount of tailings material had reached their location by overland flow.

The low calcium in profile C corresponds with a paucity of calcite and dolomite. This could be because the coarser particles of these minerals were not transported as far as cerussite by the overland flow, or because calcite and dolomite have dissolved after deposition (or both processes in combination). As noted by Moles *et al.* (2004), cerussite is the least soluble of these carbonate minerals in neutral pH conditions.

Cerussite concentration in surface soil from the meadow was measured using semi-quantitative XRD by Cecilia Maher in her QUB MSc project in 2000 (Fig. 10 B). In this study, the meadow area was divided into 10 sectors and composite soil samples were collected representing the average of each

sector. In the proximal part of the plume the soil contains around 12 wt% cerussite plus abundant calcite and dolomite, as also indicated by the alkaline pH of the soil (Fig. 10 A). Further across the field the average cerussite is around 9 wt%, and concentrations of around 2 wt% are found on the far (south) side of the field. This is at odds with the aforementioned soil pit analyses of Pb <0.5 %, perhaps due to the XRD over-estimating low abundances of cerussite. In her laboratory work Cecilia used a reagent named DTPA in solution to leach metals from homogenised soil samples: this extraction provides an estimation of the bio-available metal content i.e. that which can be taken up by plant roots. The results (Fig. 10 C) show a similar pattern to cerussite abundance with over 300 ppm Pb extractable in the proximal part of the plume. Cecilia investigated the correlation between DTPA-extractable (bio-available) soil metal content and metal enrichment in dock and plantain roots and leaves from the meadow sectors. She found positive correlations which are stronger in dock than in plantain and stronger in roots than in leaves, as reported in Moles *et al.* (2004).

Cecilia's MSc project also involved chemical (ICP-MS) analysis of plant material collected from the hedge bordering the meadow. We had noticed chlorosis and stunting of gorse and hawthorn where the hedge had been inundated by redeposited tailings, and wondered if this might be due to toxicity. Representative samples of ivy, hawthorn and bramble were collected along three 15 m lengths of hedge, sample 1 being a control sample from the south side of the meadow, on the opposite side to the tailings entry point. Sample 2 was

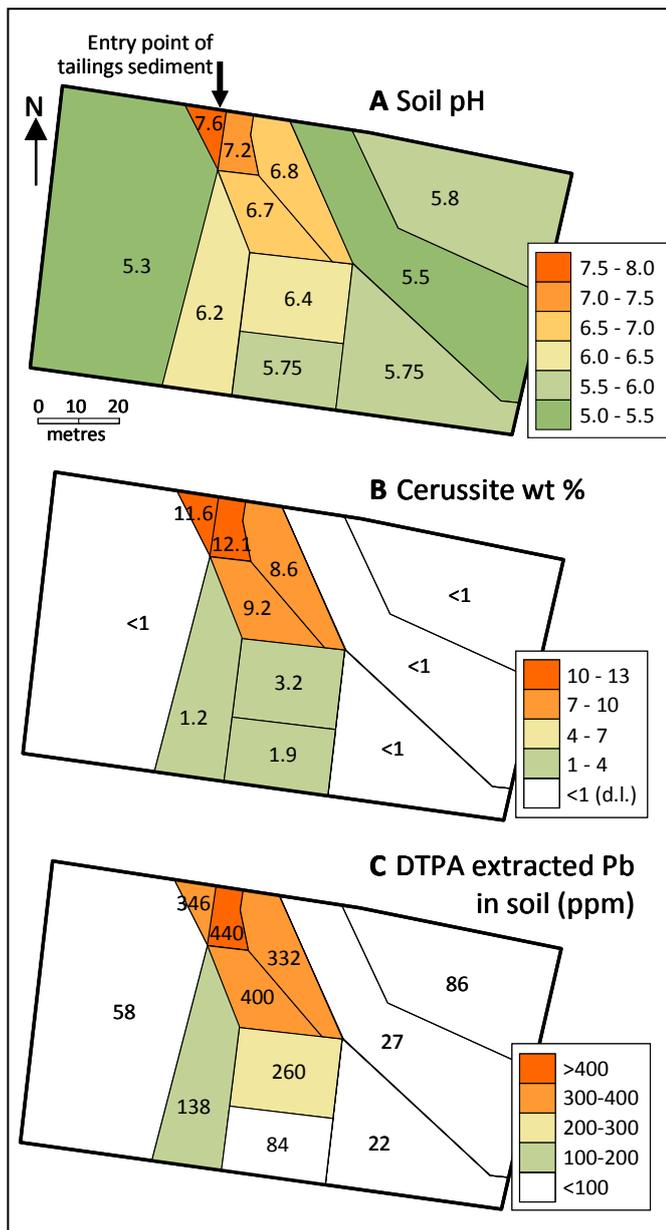


**Fig. 9:** Soil geochemical profiles for pits A and C in the meadow field, located on Fig. 5. Vertical axis is depth in centimetres. Horizontal axes are element concentrations in ppm measured by PXRF in homogenised samples representing each depth interval. Profile A is located 5 m south of the field boundary intersection, close to the tailings entry point. Profile C is located 20 m south of A

gathered from hedge 15–30 m upslope from the tailings entry point, and sample 3 from the partially inundated hedge adjacent to the tailings entry point (Fig. 8). For each plant type the twigs and leaves were ashed and analysed separately. The results for P, Mn, Pb, Zn and Cu are shown in Fig. 11. Phosphorus (P) values in sample 1 vegetation (the control) are much higher than in samples 2 and 3, whereas Pb values in sample 1 are much lower, as expected. Hawthorn twigs carry the highest concentrations of Pb, Zn and Cu in samples 2 and 3. In leaves, the highest Pb values are found in bramble in sample 2, and the highest Zn in ivy in sample 3. Vegetation in sample 3 contains lower concentrations of Pb and Mn than sample 2. We interpret this as lower metal uptake by the stressed plants in the tailings-inundated hedge, compared with

healthy plants nearby. Mn deficiency in plants is known to be associated with chlorosis (Maher 2000).

Cecilia also analysed soil from the meadow for available phosphorus (using Olsen’s extraction method) and found that soils are deficient in P with concentrations in the range 5–12 ppm. Therefore, rather than due to metal toxicity, the stunting and chlorosis of vegetation rooted in tailings-dominated soil appears to reflect the comparatively low bio-availability of nutrient elements particularly P and Mn. Dermot Smyth came to a similar conclusion from his study of bracken biogeochemistry in the same area. From a human health perspective, it would appear from these studies, that in this part of the site, plants are enriched with lead, and therefore



**Fig. 10: Maps of the tailings-enriched meadow showing sectors in which composite soil samples were analysed with results for: A. soil pH; B. cerussite content; and C. bio-available Pb content, from the MSc dissertation by Cecilia Maher in 2000. A version of the figures was published in greytone in Moles et al. 2004**

probably their fruits such as blackberries, although we have not specifically analysed these fruits.

The meadow has until fairly recently been grazed by horses and occasionally cattle. Although plants have relative low concentrations of toxic metals which is unlikely to have posed a significant risk to animal or human health, grazing animals are known to ingest soil which may have posed a more significant potential animal and human health risk. For decades, the ground had remained undisturbed such that re-deposited tailings accumulated largely on top of the pre-existing soil profile, forming a visible plume across the field as reported by Moles et al. (2004). However, starting early in

2006 motorbike scramblers in effect ploughed the field, unintentionally dispersing the tailings-rich topsoil. In recent years the western part of the field has been fenced off, presumably to prevent livestock from gaining access, and gorse is spreading across the tailings-enriched area of the meadow. For as long as this is the case, this is viewed as a benefit in that disturbance of the lead-enriched soil will be inhibited.

### SITE MANAGEMENT AND URGENT RECOMMENDATIONS

Based on the occurrence of lead-enriched tailings and soils and the use of the site by the general public and other recreational users, the site may present significant hazards and resultant environmental and health risks such as exhibited by other abandoned metalliferous mine sites of similar size, for example Leadhills-Wanlockhead, Avoca and Parys Mountain. Fortunately, Newtownards does not have a legacy of on-site smelting or acid mine drainage, as the abundance of carbonate gangue has neutralised acid generated during oxidation of sulphides in the tailings and spoil. Also fortunately, and unlike the aforementioned historical mine sites, long-distance fluvial dispersion of the mine wastes has been inhibited by the enclosed topography of the principal mineral processing area in the south of the Newtownards mine sett.

To the best of the authors' knowledge, detailed animal, human and environmental risk assessments have not been undertaken in the wider area of the Newtownards mine site. Source – pathway – receptor links need to be considered in order to define appropriate remedial measures. The following exposure routes for lead and potentially other toxic metals are not exhaustive and are intended only for illustration:

- Ingestion of soil enriched with the principal lead-bearing mineral, cerussite, which is readily soluble in the acid conditions of the stomachs of humans or animals (Fig. 2);
- Consumption of blackberries from bramble plants growing in the vicinity of the tailings;
- Outdoor inhalation of respirable dust, particularly in dry weather when dust is raised by vehicle tyres;
- Indoor inhalation of respirable dust from metal enriched soil/ tailings material that site users may unknowingly transfer to their homes via footwear and clothing, or for example from adherence to the fur of pet dogs.

Of particular concern are children who may be encouraged, for their safety (*sic*), to use the 'soft' ground of the tailings area for scrambling, instead of the perceived 'less safe' steep rocky areas on the east flank of Whitespots Hill.

In the summer of 2012 motorbike and quad bike access to the Whitespots Country Park was banned, as noted by Schwartz and Critchley (2013, 81). A consequence of this ban was that scrambling activity was displaced from the Country Park to the adjoining woodlands of the Clandeboye Estate and fields south of the ANDBC landholding. This included the tailings area which, when visited by NRM and MHTI members in

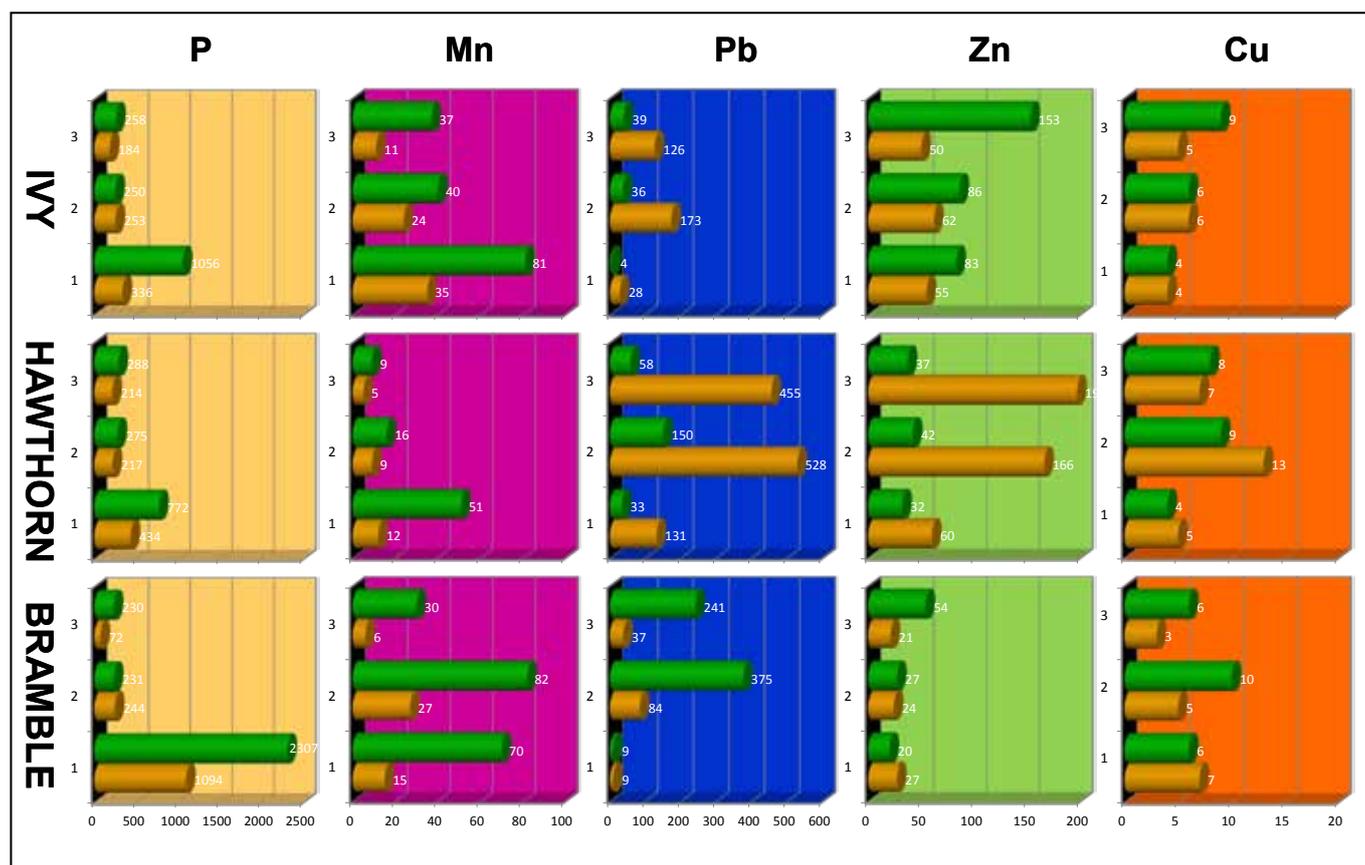


Fig. 11: Phosphorus and heavy metal content of ashed vegetation samples from the hedge between the tailings area and meadow. Data from Cecilia Maher's MSc dissertation (2000). All values in ppm (mg/kg). Orange bars = twigs; green bars = leaves of the respective plant. Numbers on vertical axes indicate sample location (see Fig. 8): 1 = control sample from hedge on the other (south) side of the field from the tailings entry point, 2 = hedge 15-30m upslope from the tailings entry point, 3 = hedge 0-15m from (adjacent to) the tailings entry point

May 2015, showed more severe and extensive erosion than observed previously. The total ban seems unreasonable considering the low levels of lead ascertained in the Whitespots hill tracks (Figs. 6 and 7) and it appears that organised trial events within this area have been reinstated since 2014.

With regards to the existence of potential hazards and risks to the environment, human health and animal health, the main issue is that the tailings area and meadow south of the Whitespots Country Park are in private ownership and therefore not deemed to be the responsibility of the Council. This situation, combined with lack of knowledge of the tailings and the hazards and risks they pose, seems to have prevented implementation of appropriate remediation. During the MHTI visit to the site in May 2015, a sizeable stream was flowing across the tailings on the escarpment side of the tailings area, continuing to erode the impoundments and transport Pb-rich sediment into the meadow. As a precautionary approach, we suggest that until more detailed environmental and health risk assessments are undertaken and preferred remedial option(s) identified, measures are put into place to manage hazards associated with the tailings and meadow areas. Recommended urgent remedial measures are: (a) proper control of all vehicular access; (b) capping/ encapsulating and stabilisation of the exposed tailings; and (c) improved drainage to divert overland water flows away from the tailings area.

On the other hand, there does not appear to be as great a potential environmental and/ or animal and human health risk associated with motorbike or quad bike activities on the hill and wooded area west of the Whitespots Mine Sett. Subject to further discussions between interested parties, these activities may be permitted to continue providing that, en route to and from this area, vehicles do not traverse across areas containing tailings or spoil material. Acceptable routes would include the north-westwards continuation of the main track between the Somme Heritage Centre and the windmill stump (Fig. 1) or a new access route via roads to residences north of Whitespots Country Park. The track that lies along the southern boundary of the Country Park (Fig. 1) should definitely NOT be used for vehicles going to and from Whitespots Hill, as the vehicles would traverse spoil material and lead-rich ground.

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