Read at the Annual Conference of the Ussher Society, January 1994

MINERALOGY AND PROVENANCE OF AIRBORNE DUST IN OPENCAST COAL MINING AREAS OF SOUTH WALES

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Merefield, J. R., Stone, I., Rees, G., Roberts, J., Dean, A. and Jones, J. 1994.
Mineralogy and provenance of airborne dust in opencast coal mining areas of South Wales.
Proceedings of the Ussher Society, **8**, 313-316.

Fugitive dust from opencast mining is a contentious issue. It has often been perceived to be a significant contributor to ambient levels of airborne particulates, even though no reliable means of dust fingerprinting has been available to regulatory authorities. To address this need, dust has been collected continuously for an eighteen month period in and around Ffos Las opencast coal mine in South Wales, over an area covering some 250 square kilometres. Samples have been analysed for mineral content by X-ray diffraction (XRD), and particle shape, size and geochemistry by scanning electron microscopy (SEM) with EDAX energy dispersive X-ray analysis. By this means it has proven possible for the first time to fingerprint dust from different sources, such as on-site and immediately off-site of the opencast coal workings, and elsewhere in the region. The results show calcite and dolomite to occur over the entire study area, indicating a significant regional component present in airborne dust in the Ffos Las locality. Local sources are recognised by an increase in day minerals such as chlorite and kaolinite over non-clay minerals such as quartz. Chlorite being detected on-site and occasionally near-site, characterises dust derived from Ffos Las opencast coal workings. Local dust generation, however, is not restricted to Ffos Las opencast site. Dust arising from quarrying, road developments and ground cover in residential properties can make a substantial contribution to the dust flux in this area. This new dust data technology has proven particularly effective and will be of considerable use in the implementation of future environmental protection legislation in Europe and world-wide.

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INTRODUCTION

After a preliminary study (Merefield and Stone, 1991), a combination of sampling and analytical techniques was devised in order to characterise dust in and around the Ffos Las opencast coal site, South Wales [SN 455 055]. The techniques were described in Merefield *et al.* (1992; 1993). The investigation sought to achieve the following objectives:

1. to set up the technology capable of characterising airborne dust samples,
2. to compile a dust database for the Ffos Las region and to,
3. use this data to evaluate dust-generating sources supplying particulates to the area.

Raw data giving single sample mineralogical analyses were stored on a personal computer (PC) after interpretation using Philips PCAPD 3.5 software for automated powder diffraction. This includes access to a total access diffraction database (TADD) stored on compact disc and the use of a ColorPro plotter for presentation of colour diffractograms and matched patterns. ARC INFO, the mapping package chosen for this application, was installed on a second PC. Being a geographical information system (GIS), it presents a sophisticated package designed specifically for spatial analysis and ideal for plotting the dust mineralogy on a regional basis. This present paper evaluates the results obtained from directional, deposit and window ledge dusts collected during the two-year study.

Location	Collector Direction	Summer	Winter
Cilferi Isaf	W	0.169	0.089
Ffos Las Entrance	E	0.179	0.167
New Perimeter	W	0.306	0.199
NE Present Void	S	0.191	0.069
SW Present Void	N	0.263	0.142

Results are from collectors facing site workings.

Table 1. Typical clay/non-clay ratios from Ffos Las on-site dust.

RESULTS

General

A range of minerals was identified in airborne dust from the fifteen British Standard four-way directional gauges monitoring the Ffos Las area (Figure 1). Quartz and the day minerals, illite, kaolinite and

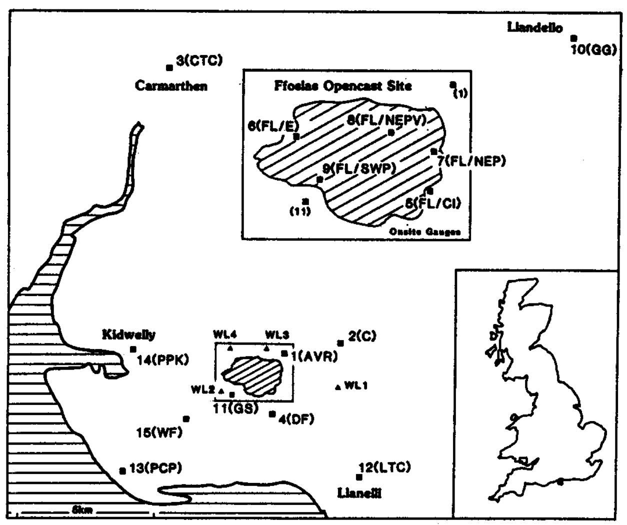

Figure 1. Location map to show positions of 4-way directional gauges and window ledge sites. Gauge numbers given with locality codes are: 1(AVR) 'Avril' Carway, 2(C) 'Mareal Villas' Cynheidre, 3(CTC) Carmarthen Technical College, 4(DF) Dythel Farm, 5(FL/CI) Cilferi Isaf 6(FL/E) Site Entrance, 7(FL/NEP) NE New Perimeter, 8(FL/NEPV) NE Present Void, 9(FI/SWP)SW Present Void, 10(GG) 'Golden Grove' Llandeilo, 11(GS) '89 Garden Suburbs' Trimsaran, 12(LTC) Llanelli Technical College, 13(PCP) Pembrey Country Path 14(PPK) 'Park Pendre' Kidwelly, 15(WF) Wern Farm, 16(UMI) Exeter University & 17(BB) Brecon Beacons (off-map). Window ledge sites given with locality codes am WL1 Llysderi, Five Roads, WL2 Culla Road, Trimsaran, WL3 Gwyn Fa, Camay, WL4 Glynmar, Trimaran, WL5 Abermarlais Caravan Park (off-map).

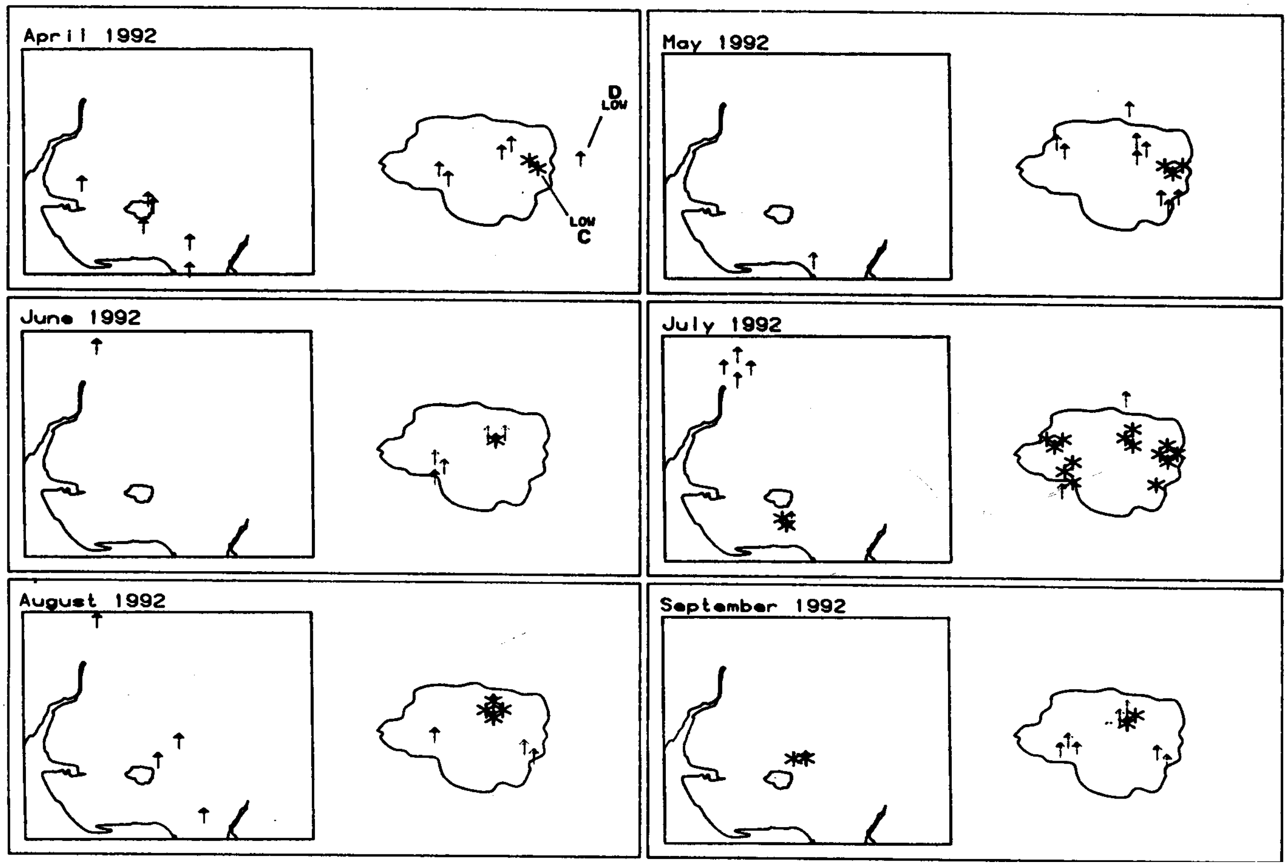

Figure 2. Seasonal variation of chlorite in airborne dust at and around Ffos las opencast coal site, UK showing most occurrence on-site.

chlorite were anticipated, as geologically the local rock outcrops are dominated by mudstones, (Strahan *et al.,* 1909; Archer, 1968; Frodsham *et al,* 1991). Less expected were the feldspars, gypsum, halite, dolomite and calcite which were also commonly trapped by the gauges. The halite was due to sea-salt-laden rainwater entering the directional gauges. As it occurred most frequently in the south and west collectors (seaward facing) it endorsed the directional efficiency of these dust collectors.

Four-way directional gauges on-site

On-site directional gauges proved valuable in characterising typical dust generated at the Ffos Las opencast coal site. The predominantly site-derived mineralogy there was dominated by clay minerals and quartz. The clay mineral assemblage is comprised of kaolinite and illite, with chlorite occurring in significant quantities (Figure 2). Feldspars occur as do calcite and dolomite but are regarded as exotic, i.e. not generated from the Ffos Las site.

In order to fingerprint these qualitative samples, a mathematical relationship was established in order to relate individual minerals within samples (Merefield *et al.,* 1994). In general terms this relates clay minerals kaolinite (K) or illite (representing the days) to quartz (Q), representing the non-clay component. Typical K/ Q ratios for on-site dust are given in Table 1. These ratios, from 0.069 - 0.306, derived from inwards-facing collectors are the highest obtained from on-site gauges. Typical values from other collectors fall as low as 0.053.

Four-way directional gauges off-Site

Off-site gauges are valuable in characterising the regional character of airborne dust. In general, non-site minerals such as calcite and dolomite are common (Figure 3) but at specific sites, dusts show roadworks, building masonry and coastal characteristics. At Carmarthen Technical College, for example, a high clay intake (ratios 0.363-0.462) apparently similar to Ffos Las, results from a period of roadworks, demonstrating that the clay to non-clay ratio alone is not always a reliable indicator of dust source. It should be used with other types of evidence such as geology, soil mineralogy, geographical position, weather conditions and ground disturbance. At Pembrey Country Park, quartz levels are moderate, halite is generated from salt spray, and calcite (possibly from beach shell debris) occurs in significant quantities at this coastal site. Geology is also reflected in the Brecon Beacons gauge where the mineral haematite (iron oxide) is recorded, indicating dust from soils developed on the Old Red Sandstone (Clayden and Hollis, 1984).

Some sites around Ffos Las do receive significantly more clays and therefore their mineralogy indicates a Ffos Las contribution. These are at Avril Carway, Garden Suburbs Trimsaran, Dythel Farm and to a lesser extent Mareal Villas Cynheidre. Nevertheless, typical clay to non-clay ratios from summer months show a wide range from 0.051 to 0.400, and for winter months from 0.039 to 0.215.

Window ledge data

The mineralogy overall from the window ledges is highly varied. All mineral types collected from the 4-way directional gauges have been trapped by the window ledge sites at one time or another. The days, illite, and kaolinite are common and occasionally chlorite occurs. Quartz is also common, calcite is often present and occasionally dolomite. Calcite and dolomite strongly suggest input from more distant limestone/roadstone workings. The more exotic minerals (for this area) such as feldspar, and particularly high concentrations of quartz, appear to signify input from the properties themselves.

At Llysderi, Five Roads, for example day to non-clay ratios show a proportion of on-site dust added to background levels, although, in the summer months, increased quartz and calcite levels modify mineral relationships and indicate separate additional dust sources.

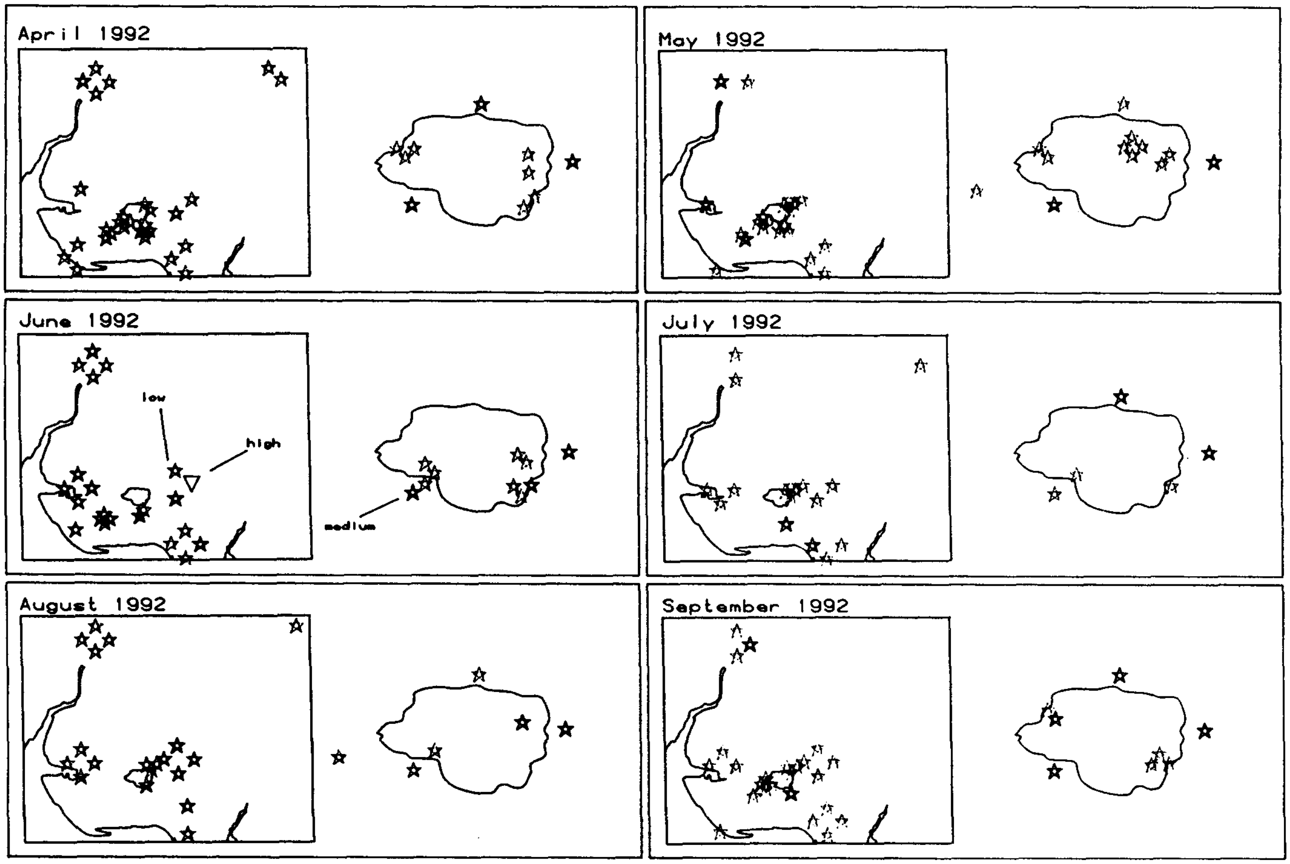

Figure 3. Calcite distribution in airborne dust of the Ffos Las region, showing ubiquitous occurrence throughout the study area.

The range of clay to non-clay ratios from 0.000 to 0.137 illustrates these variations. The regularly sampled Trimsaran and Carway window ledge sites, however, showed the most consistent presence of high clay-containing (Ffos Las type) dust with kaolinite/quartz values peaking at 0.190.

At Abermarlais, quartz and dolomite occur in abundance along with lesser amounts of calcite and the clays, illite and kaolinite. This property has a gravel drive built using dolomite and calcite and the impact of this on the window ledge sampling is emphatic.

Small amounts of coal were found on a regular basis but apparently were unrelated to other mineral components or clay to non-clay ratios. A non-Ffos Las source is implied by these findings.

The window ledge study has accurately characterised periods of relatively high dust generation and confirmed the presence of several other dust sources. This evidence is often confused, however, by the effects of other dust generators close to the sampled area, such as weathered brick and masonry.

Deposit gauge frisbee data

Data from the experimental Rees frisbee deposit collectors (Figure 4) proved very valuable in supplementing information obtained from the directional gauges. Minerals deposited included quartz, calcite, dolomite, gypsum and clays; illite, kaolinite and chlorite.

Being the least affected by local industry, roads or residential development, the University of Exeter and the Pembrey Country Park gauges gave no measurable quantities of clay without accompanying increases in quartz levels. Calcite was regularly recorded. Dust trapped at Carmarthen Technical College gave surprisingly high clay/non-clay ratios supporting the directional gauge data, with less illite than a Ffos Las-type dust.

The clay ratios obtained from the Ffos Las frisbee proved similar to the on-site directional gauges. The mineral relationships were slightly different, which might have been due to the siting of the gauge between the site workings and a near-by public road permitting two sources of local input. The frisbee does appear to be particularly effective in entrapping the finest particles. Off-site, at Rheoboth Road, there is little evidence of enrichment from Ffos Las coal workings.

CONCLUSIONS

A combination of sampling procedures by way of directional, window ledge and deposit gauges and an array of analytical techniques employing X-ray diffraction, scanning electron microscopy, energy dispersive analysis and a geographical information system have been successfully used to characterise dust at Ffos Las, South Wales, and its environs. They have also been used to evaluate sources of dust generation. Together, this combined methodology is now established as Dust Data Technology.

Local sources can be discriminated by the predominance of clay minerals such as chlorite and kaolinite, and the kaolinite/quartz relationship. Chlorite being detected largely on-site and only occasionally near-site, indicates dust derived from Ffos Las opencast coal workings. The kaolinite/quartz ratio in dust samples can support this but shows more complex origins incorporating jet stream, road, regional and Ffos Las dusts.

Calcite and dolomite occurring uniformly over the entire study area shows that regional dust is also a significant contributor to dust in the Ffos Las area.

Local dust generation is not restricted to Ffos Las opencast site. For example, airborne particulates generated from road developments, such as those near Carmarthen, have been detected and have been shown to influence the character of airborne dust in the immediate vicinity. A gravel drive at Abermarlais supplies enough quantities of dolomite to the dust flux to dominate samples collected in an adjacent property.

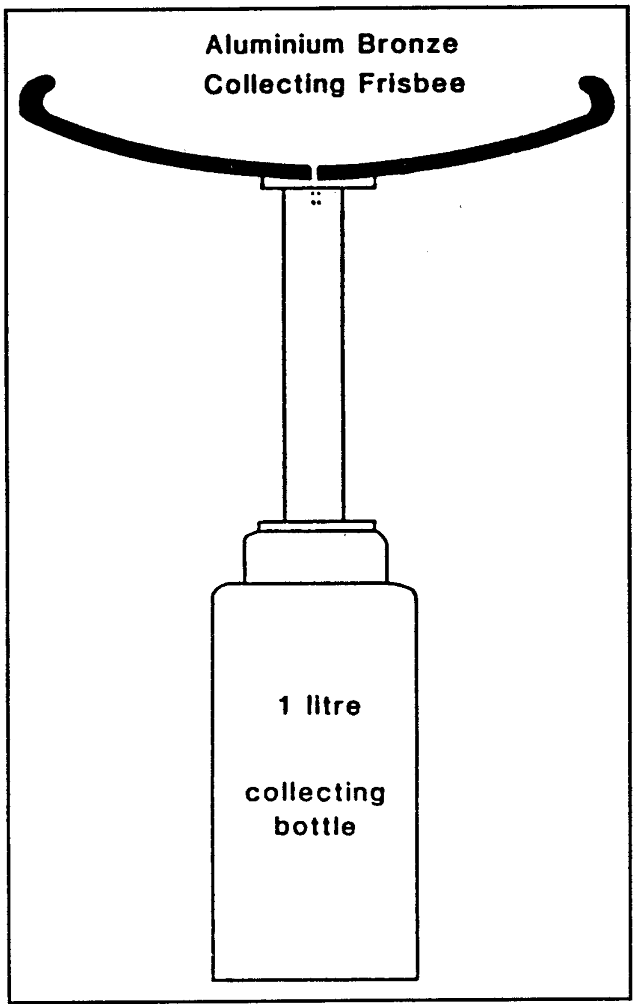

Figure 4. Experimental Rees frisbee deposit gauge, based on an original design by Hall and Upton (1988).

In conclusion, sources of dust for the Ffos Las area are several. They can be local, regional, continental, or any composite of these. Regional and continental dust provides an ambient level of airborne dust mineralogy, supplemented by local input (including road workings) when atmospheric conditions and anthropogenic activity (from opencast mining and quarrying) provide an additional supply.

ACKNOWLEDGEMENTS

Messrs R.B. Evans, K. Thomas, K. James, J. Bannister of British Coal Opencast are thanked for their support and assistance at Ffos Las opencast site. Mr L. Redmond (BCO) provided valuable data from the Ffos Las weather station data logger. Mr P.C. Jarman (BCO) is especially thanked for liaison with all cooperating groups. Mr E. Payne is acknowledged for early discussions on analytical techniques. We are also indebted to Mrs M. juster of Abermarlais Caravan Park for access to regular window ledge sampling and to Mr R. Pun of the Storey Arms Centre for enabling the siting of a 4-way directional gauge. Very grateful thanks are also extended to the residents of Trimsaran and environs who contributed much, by cheerfully making room on their properties for the dust gauges and window sampling, and who waited patiently for the outcome of this investigation. Jon Camp drafted the ERC illustrations.

This paper is published with the approval of British Coal Opencast who funded the research project.

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