

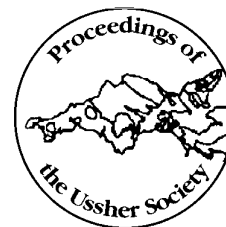
## MINERALOGICAL CHARACTERISATION OF ATMOSPHERIC DUST WITHIN AND ADJACENT TO OPENCAST COAL SITES IN SOUTH WALES

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Through a combination of analytical techniques, aeolian dust is being characterised in and around opencast coal sites in the South Wales coalfield. Subtle crystallographic variations within associated clay minerals are seen to be significant. Experimental X-ray diffraction analyses combined with scanning electron microscopy and particle size analyses of the dusts has exposed a considerable potential for 'fingerprinting' sources of dust pollution. Mineralogical analysis of rocks, soils and road dusts from the opencast sites and surrounding areas are being used to create a database. Samples are regularly collected from directional gauges with the associated meteorological data from on-site weather stations. The design of a continuous dust collector has been improved within the British Standard 1747. With the collection efficiency of clay fraction particles still low, experimental 'Frisbee' deposit gauges are also to be utilized.

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### INTRODUCTION

The characterisation of atmospheric dust and the designation of its provenance is problematic. Although a British Standard for the directional dust gauge exists, doubts have been raised on the collection efficiency of standard gauges (Ralph and Hall, 1989), calls for new designs of dust deposit gauges are made repeatedly (Hall and Upton, 1988), and no database for atmospheric dust exists in the UK.

Because opencast mine sites are potential generators of airborne dust they provide obvious targets, by way of nuisance complaints from members of the public. A reliable means for monitoring the air quality around mining operations is needed in order to address these problems.

An initial airborne dust survey for the Llanelli Borough Council, at and around the Ffos Las opencast coal site in South Wales [SN 455 055], employed X-ray diffraction (XRD) to characterise the dust (Merefield and Stone, 1991). The clay fraction was identified as well as minerals in the sand grades which are more usually analysed during atmospheric dust investigations. Although particles in the size range of 70 to 125  $\mu\text{m}$  are the most easily mobilised for wind transport (Pye and Tsoar, 1990), it was considered that detailed clay mineral analysis might well be valuable for establishing provenance. British Coal subsequently requested a research investigation into the technology required for reliable air quality monitoring of this type, and the setting up of a dust database for the Ffos Las area. This paper describes the initial investigation and the potential suggested by the preliminary findings.

### GEOLOGY AND SOILS

Stratigraphically, the coalfield comprises three major lithological units; soft argillaceous and coal-bearing strata sandwiched between Dinantian limestones below, and the Pennant sandstone above (Gayer *et al.*, 1991). The rocks exposed at Ffos Las, however, are entirely within the Middle Coal Measures of Westphalian A to C age. They are characterised by a thinly bedded and often organic-rich shale- and silt-dominated sequence with sporadic sandstone units. The resistant sandstones tend to dominate the surface exposure. Coal comprises about 5% of the total sequence (Frodsham *et al.*, 1992). Fine-grained rock types are potentially sources for dust generation, and their mineralogical and crystallinity characteristics open up possibilities for 'fingerprinting'.

The soils in the area include types with marine, river alluvium, terrestrial and man-made origins. They have been mapped in detail by the soil survey of England and Wales (Mackney *et al.*, 1983) as comprising

alluvial gley soils, Cambic stagnogley soils, brown earths and humo-ferric podzols. Those described by Clayden and Hollis (1984) as clayey contain >35% clay; fine loamy, >18% clay; and fine silty, <18% clay. All groups contain either loamy or clayey material which, on drying out, could become airborne.

### SAMPLING

Fifteen British Standard four-way directional gauges have been manufactured and installed in the field, with collector slits facing magnetic north, east, south and west. Five gauges have been sited strategically on-site at Ffos Las opencast site, one has been located at Carmarthen, off the South Wales coalfield to act as a control, and nine more have been introduced both up- and down-prevailing wind of the area under investigation (Figure 1). Although manufactured to be within BS 1747, (Figure 2) the design has been improved by strengthening the central support column, by using a thicker gauge tubing for the collector pipes and square form sample bottles. This has cut down on the degree of turbulence detected by Ralph and

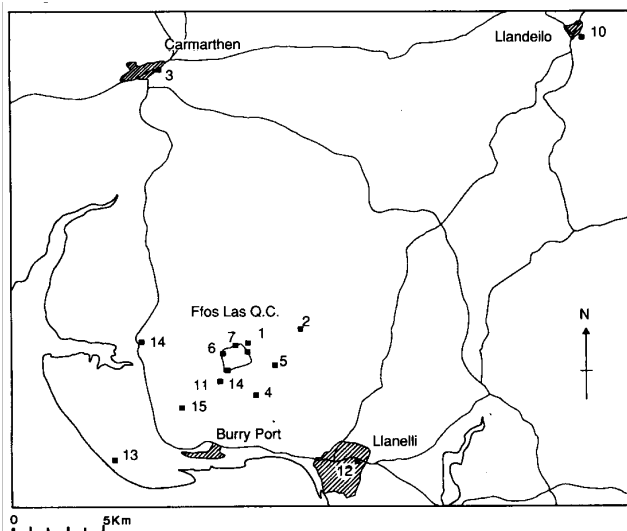


Figure 1: Location map with directional gauge sampling stations.

Hall (1989). Where possible, the gauges have been sited in open localities.

A stainless steel window ledge dust gauge has been constructed for the sampling of UPVC window sills. This is used to sample fall-out on open surfaces in residential areas, for comparison with

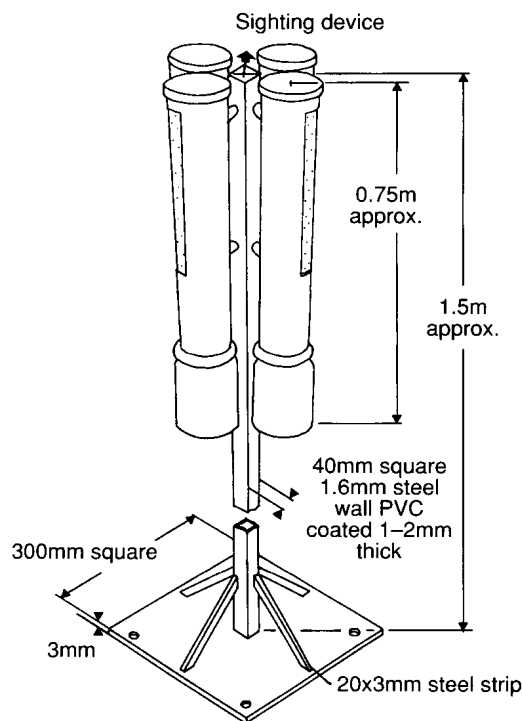


Figure 2: The British Standard Directional Dust Gauge BS 1747.

directional dust data. This sampler encloses a defined area from which the window ledge may be swept with a sable brush, making it possible to report accurately on the area sampled. The screw thread holding the bottle in place is shielded by an entry tube avoiding sample loss and contamination in the windings.

In order to provide additional material for detailed mineralogical analysis, Frisbee style deposit gauges have also been manufactured. Although largely based on the inverted Frisbee design of Hall and Upton (1988), the arm holding the collector dish to the sample bottle retainer has been lengthened to cut down on wind drag.

After experimentation, a sampling period of one calendar month has been established as the optimum for the directional gauge study. Dust remaining in the collector tubes is washed by distilled water into the sample bottle which contains dust already washed down by rain action. The four sample bottles are labelled, sealed and dispatched to the laboratory for analysis and new bottles are screwed into place.

**ANALYSIS**

Samples returned to the laboratory are dried slowly in porcelain evaporating dishes under infra-red heaters in order to minimise any induced changes in mineralogical composition. An aliquot of each is then hand ground for XRD analysis, the remainder being available for optical and scanning electron microscopy (SEM).

Samples are mounted on glass slides and step scanned from 4 to 70°2θ using 0.1° receiving and 1° divergence and scatter slits. The excitation source is Cu Kα. Where clay minerals need further discrimination tests, individual samples are heated to 550°C (kaolinite/dickite) or glycolated (smectite) as necessary (Brindley and Brown, 1980).

**DUST MINERALOGY**

The preliminary results from the 15 directional gauges (i.e. 60 individual samples) are summarised in Table 1. In general, XRD reveals that a larger clay component has been entrained by on-site gauges than by those off-site. The range of minerals present at Ffos Las is also the greatest in the study area. Quartz is ubiquitous, gypsum occurs (dehydrated to bassenite during sample preparation), as do traces of calcite. Although illite dominates the clay mineral assemblage, both kaolinite and dickite are common, chlorite also occurs and occasionally smectite. The gauge sited down-wind of the workings on the site boundary entraps most material in its south and west collectors (i.e. the sides facing the site), demonstrating the directional effectiveness of the gauge design (Figure 3). Additional proof of the resolution of the method is the presence of halite entrapped as salty spray in the south and westerly (seaward) facing collectors which re-crystallised to halite during sample drying.

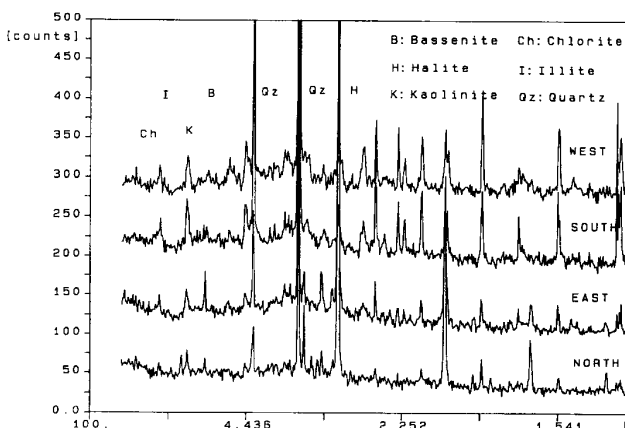


Figure 3: Composite diffractogram of dust mineralogy, from on-site four-way directional gauge.

Off-site (Table 1) the gauges entrap quartz, gypsum from all directions and halite generally from the south-west. The clay minerals present from the illite and kaolinite groups prove relatively finer and less abundant than those from on-site.

**TABLE 1: Summary of minerals present in dusts entrapped by four-way directional gauges at and around the Ffos Las site, South Wales.**

Location :	On-site	Off-site	Controls
Number :	5	7	3
Minerals :	Quartz	Quartz	Quartz
	Gypsum	Gypsum	Gypsum
	Halite	Halite	Halite
	Calcite		Calcite <sup>1</sup>
	Illite	Illite	Illite <sup>2</sup>
		Mixed-layers	
	Kaolinite/Dickite	Kaolinite	
	Chlorite		
	Smectite		Smectite <sup>2</sup>

<sup>1</sup> Calcite present only at Pembrey coastal dunes site.

<sup>2</sup> Illite and Smectite detected only from Carmarthen roadside station.

The control station at Carmarthen shows a mineralogy restricted to quartz, gypsum and halite. A small amount of illite and only a trace of smectite have been detected from the north-facing direction and are considered to originate as road dust. The Pembrey gauge, situated amongst the coastal dunes of the Severn Estuary up-

prevailing wind, collects dominant quantities of quartz and halite (most from the seaward direction), a large concentration of calcite, most probably of skeletal origin, and some gypsum but no clays. At Llandeilo, the most distant up-prevailing wind station, quartz, gypsum and halite are collected from all directions and no clays are entrapped (Table 1).

Summary data from the window ledge dust surveys carried out in nearby residential areas during October and November 1991 are given in Table 2. The first survey revealed all sites to contain quartz at varying concentrations, some to have a small amount of gypsum, some to have a trace of calcite, and very small quantities of halite. All window ledge dusts contained clay minerals of the kaolinite group but not all had illite present. The second window ledge survey gave variable amounts of quartz compared with the other mineral components, greater quantities of salt but no calcite (Table 2 and Figure 4).

**TABLE 2: Summary of minerals present in window ledge dusts in Trimsaran, Carway and Five Roads, South Wales.**

Survey :	October 1991	November 1991
Number :	6	7
Minerals :	Quartz	Quartz
	Gypsum <sup>1</sup>	Gypsum <sup>1</sup>
	Halite <sup>2</sup>	Halite <sup>2</sup>
	Calcite <sup>1</sup>	
	Illite <sup>1</sup>	Illite
	Kaolinite/Dickite	Kaolinite

<sup>1</sup> Small quantities present but not in all samples.

<sup>2</sup> Small quantities present in all samples.

#### IMPLICATIONS FOR LONG-TERM MONITORING

The directional gauges used for this investigation have proved to be considerably more efficient than those normally manufactured for atmospheric-flux monitoring. Even during the wet autumn and winter months they have entrained sufficient dust for reliable XRD analysis. The detection of halite from collectors facing seaward has also endorsed the resolution of the sampling and analysis. Although monitoring is at an early stage, detailed differences in mineralogy are evident between on- and off-site stations. In general, a greater range of mineralogy has been entrained by on-site gauges.

The mineral suite obtained from the two window ledge surveys has proved to be more complex and variable than originally could be envisaged. It is seen as prudent, therefore, to extend this aspect of the survey at least into the first six months of 1992.

Advances in design already introduced into the Frisbee deposit gauge yet to be sited in this study, should aid collector efficiency and provide valuable additional samples for detailed mineralogical investigations.

With detailed exceptions, the sampling site locations chosen for directional monitoring are yielding consistent results and demonstrating a suitability for long-term monitoring. A calendar month is seen as the optimum period for dust collection and this will be tied in with meteorological data from the on-site weather station.

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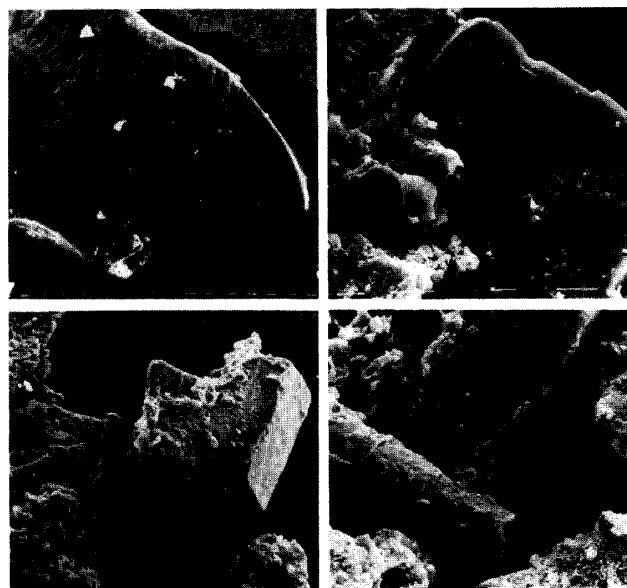


Figure 4: Scanning electron microscope images of dust captured from UPVC window ledge. Photo 1 (top left): coal sample from Ffos Las showing characteristic fracture pattern. Photos 2-4 (top right and below): associations of biogenic material, clay particles and, in some cases, absence of coal. Scale marker = 10µm.

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