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The application of soil survey data in opencast coal sites in Scotland

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Abstract

A commitment by the National Coal Board Opencast Executive to restore opencast coal areas to agricultural use as efficiently as possible recognizes the need for continual improvement in techniques. The Department of Agriculture and Fisheries for Scotland, as agents to the National Coal Board Opencast Executive, share a similar objective. Both organizations appreciate the need for a comprehensive soil survey, but experience has shown that general-purpose maps and reports are not always adequate for use in opencast mining operations.

A soil survey of a proposed site at Keirsbeath is described and, on the basis of results from the use of improved survey methodology, and computer techniques to analyse the data, interpretative maps have been produced. The procedures, together with an examination of soil quantities available for restoration, and of critical moisture levels in soil stripping, are an improvement with significance for the planning and development work stage. A scheme of soil operations has been presented and the relevance of soil data to the forthcoming restoration and rehabilitation stages is discussed.

Introduction

Several areas in the Midland Valley of Scotland have been developed extensively for the extraction of coal by opencast mining. This mining technique was begun in 1942 and has proved, in many instances, to be more cost-effective than traditional deep mining operations. During the period 1982–92 it is estimated that 2600 ha will be disturbed for opencast coal extraction and subsequently restored (Barrett, pers. comm.). The successful recovery of coal has been frequently offset by unsatisfactory reinstatement of the site, a situation common between 1942 and 1960. This is less prevalent now following mounting concern about the increasing acreage of despoiled land and the consequential loss of agricultural land, which focused attention on the need for proper restoration to reinstate land to agricultural use. In accepting responsibility for opencast mining, the National Coal Board Opencast Executive (NCBOE) has earned high regard for its responsible approach to improving techniques of restoration. Furthermore, work by staff of the Ministry of Agriculture, Fisheries and Food (1982) has been highly significant in England, and much of the current restoration work being carried out in Scotland is based on their experimental work.

Within Scotland close liaison is maintained between NCBOE and the Department of Agriculture and Fisheries for Scotland (DAFS), which is concerned with opencast coalmining in two distinct roles. Firstly, before planning permission to extract is granted, DAFS must advise on the agricultural capability of the proposed site and, if extraction is approved, DAFS ensures that the NCBOE complies with the terms of the Authorization granted by the Secretary of State for Scotland to work the site. Secondly, agricultural rehabilitation of restored sites is managed by DAFS on behalf of NCBOE for a five-year period, after which, with the agreement of the parties concerned, the land is returned to the owners.

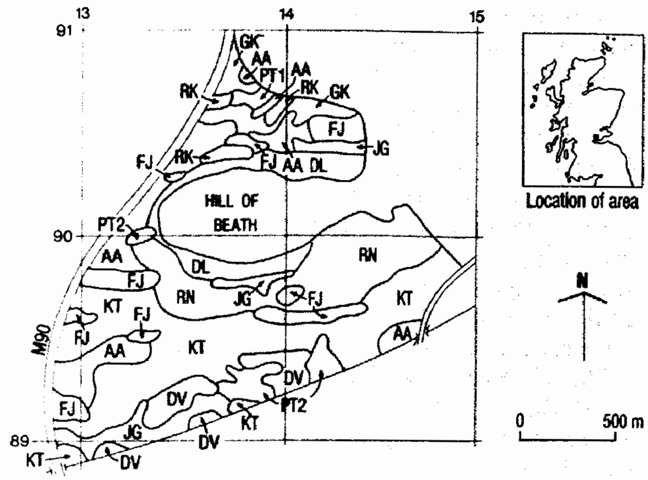
Prior to the late 1970s, the Soil Survey of Scotland (SSS) was not concerned with opencast mining operations unless requested to advise on specific soil problems. Romans (1954) examined the agricultural rehabilitation of several sites in West Fife, and Robertson (pers. comm.) investigated problems associated with the storage of topsoil and soil profile development on reinstated sites at Westfield, Fife. When a shortage of topsoil was discovered on the Blindwells, Phase 1, site in East Lothian, Shipley (pers. comm.) undertook soil survey investigations and located suitable material to mix with the existing topsoil and rectify the deficit. For subsequent opencast proposals at Blindwells, Phase 3, and Ponesk and Roughhill in the west of Scotland, detailed soil maps and accompanying pedological reports have been produced, but with little attempt to interpret the soil data for site management. The soil survey of a 240 ha site at Wallyford, Midlothian was an exception (Shipley, pers. comm.) because it was designed to provide both a detailed soil map and interpretative data. Using a 100 m grid survey, manually drawn interpretative maps were compiled of the depth of topsoil and subsoil (to 1 m), with a further map of the nature and depth of the underlying parent material being produced from a combination of soil survey data and additional data collected by NCB geologists from bore-hole logs.

Western (1978) suggests that the benefit of any soil survey can be measured by its relevance to the project under consideration and highlights the particular benefits of 'special-purpose surveys' or surveys with a practical objective over 'general-purpose surveys', which provide only a basic scientific inventory of the study area. A critical review of the literature revealed that soil surveys are more useful to site investigation and development planning if an interpretative assessment of the soil data is undertaken. For example, systematic interpretation of pedological data has shown the usefulness of soil surveys to the soil engineer (McGown and Iley 1973; Pettry and Coleman 1973), the highway engineer (Allemeier 1973), in site investigation (Dumbleton and West 1971) and in the broader aspects of land use for many purposes in engineering or planning (Hartnup and Jarvis 1979). An opportunity to study the possible potential of soil survey data to opencast mining arose during a survey of the proposed Keirsbeath opencast site, Fife. The principal aims of the study are to demonstrate the value and adaptability of soil data and maps at the particular stage of planning and development of an opencast mine, and to study the potential use of a computer in processing soil data and producing computer graphics of single-factor or interpretative maps.

Extraction at Keirsbeath will take place in two distinct phases, the first of which began immediately the reported soil survey was completed. Most emphasis will be on the production of potentially useful site management data for the development of the site, bearing in mind the restoration and subsequent rehabilitation requirements.

The study area

The designated Keirsbeath opencast coal site occupies approximately 172 ha within the Dunfermline district of Fife region (Fig. 1). Centred around the Hill of Beath, the area forms a distinct 'L' shape with the western boundary represented by the M90



		Brown Forest Soils		Non-Calcareous Gleys	
ASSOCIATION	**PARENT MATERIAL**	**SOIL SERIES**			
		Freely Drained	Imperfectly Drained	Poorly Drained	Very Poorly Drained
DARLEITH	Drifts derived from basaltic lavas and basic intrusive rocks	DL Darleith			
DARVEL	Fluvioglacial sands and gravels derived mainly from Lower Carb. igneous and sedimentary rocks	DV Darvel			
HINDSWARD	Till derived from Carboniferous sandstones & shales with a varying admixture of basic igneous material		RN Reidston		
GIFFNOCK	Till derived mainly from Carboniferous sandstones with some shales, coals and limestones		AA Aberdona	GK Giffnock	RK Rouken
	Till derived from the above named rocks with partially sorted surface layers		KT Kennet		
	Carboniferous sandstone (residual)	FJ Forestmill			

ALLUVIAL SOILS

TEXTURE	Very Poorly Drained
PEATY	JG Geanies

ORGANIC SOILS

BASIN PEAT	50-100 cm	PT1
	>100 cm	PT2

Figure 1. The soils of Keirsbeath.

motorway and the southern boundary by the Dunfermline–Cowdenbeath railway.

Most of the area is part of an undulating till plain of gentle to moderately sloping drumlin-like mounds and intervening large and small depressions. Regular, steep slopes are characteristic of the mounds which occur in the extreme south with intervening hollows of alluvial tracts or peat basins, usually less than 200 m wide. In the north, steep slopes formed from colluvial deposits on till, or from residual basalt deposits, skirt the Hill of Beath, an old volcanic plug.

Procedures

Survey methodology

During the systematic soil survey of combined Sheets 40/41 (Kinross/Elie), the soils had been mapped by the Soil Survey using 1:25000 field maps for eventual publication at a scale of 1:63 360 (Laing *et al.* 1974). Free survey techniques were employed whereby the surveyor combined observations of the soil profile with those of the site geomorphology, geology and vegetation. Extensive use was made of aerial photographs because environmental and soil factors (e.g. breaks in slope, changes in vegetation and topsoil colour) could all be correlated with tonal pattern changes on the photographs, and major soil types could be quickly and accurately delineated. Regular ground inspection was necessary to establish and maintain these correlations and to (a) confirm soil boundaries or (b) establish the range in soil properties within a particular mapping unit.

To satisfy previous requests from DAFS for detailed soils information, SSS had produced detailed soil maps at 1:10 000 scale where the minimum soil area represented by one square centimetre on the map would be one hectare (2·5 acres) rather than 6·25 ha (15·5 acres) at 1:25 000 scale. This is achieved by a more intensive survey which, using free survey techniques, attempts to define the soil boundaries more accurately and thereby increase the purity of the mapping units. However, Avery (1970) and Western (1978) suggest that where there is much variability within landform units, grid mapping is likely to be more effective than free survey as statistical techniques can be applied to the data. Furthermore, by careful choice of the grid interval the final map should compare favourably with the conventional 1:10 000 map and the systematic soil information could be easily referenced, located in the field and utilized to assess the graphical output of soil data by computer. The decision to undertake a grid survey of Keirsbeath was therefore taken and, bearing in mind the time and staff resources available for the job, a grid interval of 100 m was considered practical.

The grid intersections, which correspond to the Ordnance Survey grid on a 1:25 000 map, were transferred to aerial photographs (1:5000 scale) using a Zeiss sketchmaster to aid location in the field. Profile and environmental characteristics at 174 grid intersections were examined and the data recorded on specially designed field cards. The inspection pits were dug to approximately 60 cm and thereafter augered to 1 m, unless an impenetrable horizon was encountered first. Full peat depth observations were made, both at the intersection of grid lines and at random points within the area of the deposit. A soil map at 1:10 000 scale was drawn using the information from the 174 grid intersections and data from additional profiles. This map was intended for comparison with the single-factor maps, which were to be produced from the computer-processed grid survey data. The distribution of the soils and the appropriate map legend are shown in Fig. 1.

Computer methodology

Using a Data General Eclipse C/150 minicomputer, the data from each of the 174 grid points was keyed into two sequential computer disk files and verified. The first dataset contained the reference data for each grid point and was recorded as follows:

1. Observation no.	grid intersection no. (e.g. 1)	column 1
2. Slope	slope in degrees (e.g. 3)	5
3. Slope	slope type (e.g. st)	8
4. Map reference	grid ref. (NT) (e.g. 137908)	11
5. Aspect	from compass (e.g. 350 degrees)	18
6. Land-use capability	Class and subclass (e.g. 3sg)	22

7.	Altitude	e.g. 175 m	26
8.	Association	e.g. GK—Giffnock	30
9.	Series	e.g. KT—Kennet	35
10.	Drainage	e.g. P (free)	38
11.	Topsoil depth	e.g. 30 cm	40
12.	Subsoil depth	e.g. 15 cm	46

The second dataset contained the data for each horizon as follows:

1.	Observation no.	link with reference dataset	column 1
2.	Horizon	master and qualifier (e.g. Ap)	5
3.	Depth	from surface to 100 cm	10
4.	Mottle	frequency and chroma (e.g. F4)	14
5.	Texture	qualifier and texture (e.g. F.SL.)	17
6.	Structure	strength, size and shape (e.g. M.M.ab.)	22
7.	Root frequency	e.g. M	28
8.	Stone frequency	e.g. F	29

These datasets, which were linked by a common field (grid number) and corresponded to a database as defined by Hyman (1976) (albeit a very small database), were then read into a database using the INFOS system for data management (Data General Corporation 1981). Indexes were created of the following key fields: grid number, association, series and horizons, so that records could be accessed quickly using these keys rather than running through the key fields within each record.

Computer graphics

By accessing the computer-stored data to a Tetronix 4027 high resolution colour graphics display (part of the Macaulay Institute hybrid system), an interactive classification facility was developed, based on man/machine control at the Tetronix terminal (Stove and Ritchie 1982). Through this development it was possible to achieve data capture, display, editing and processing from the source databank, as a result of which interpretative maps were produced.

A scheme of soil survey operations

It is essential that inspectors from DAFS and site managers from NCBOE should have sufficient soil information so that they can predict and provide against difficulties that may arise during any particular phase in the management of an opencast mine. The successive operations must be assessed carefully to ensure that maximum benefit is derived from the soil data. Table 1 details the scheme followed by the NCBOE in accordance with the Opencast Coal Act (1958) and indicates the need to synchronize the collection of different types of soil data with the work schedule of the specialist. The following three sections examine the use of soil survey information in relation to this scheme.

Use of soil survey information in planning and development

Site investigation prior to the drawing up of documents of authorization is not necessary because no firm commitment has, at this stage, been taken by NCBOE to

Table 1. Suggested scheme of work to optimize cooperation

Present NCBOE role	Present DAFS role	SSS work role
1. *Planning and development*		
1.1 NCB geologists discover area of potential coal deposit—study of 1:10 000 geological maps/old records		
1.2 NCB geologists drill and confirm potential		
1.3 NCB planners fulfil statutory obligations pre-drilling		1.3 Provide NCB planners with site information
1.4 NCB Deep Mines Section confirm drilling will not affect operations		
1.5 Preparation of contract documents/application for authorization:		
1.51 estimaters (NCBOE) calculate coal quantities, provision costs and draw up mining contract		1.51 Carry out detailed soil survey
1.52 planners (NCBOE) conduct pre-application consultations prior to drawing up authorization	1.52 DAFS inspectors inform Secretary of State of agricultural potential	1.52 Assist DAFS inspectors if requested
1.6 If authorization is granted: contract documents completed, tenders sought, contract let		
2. *Opencast mining process*		
2.1 Stripping and storage of topsoil 2.2 Stripping and storage of subsoil 2.3 Stripping and storage of overburden/identification of soil-making material	DAFS inspectors represent Secretary of State to ensure conditions of authorization are carried out	Advise DAFS on proper identification of soil-making materials
2.4 Restoration of overburden/subsoil/topsoil		2.4 Carry out soil survey to monitor performance of restoration
3. *Rehabilitation*		
3.1 Replacement of fixed farm equipment	DAFS inspectors act as agents to NCBOE in all rehabilitation work—pass land back to owner	Advise DAFS throughout field operations of restoration
3.2 Rehabilitation of site over period not less than 5 years, management and drainage		3.2 Advise DAFS/NCBOE of soil problems during rehabilitation

work a particular area. However, some preliminary work by SSS during the pre-application stages (stage 1.3) will allow both DAFS and NCBOE to assess soil and land capability conditions; for many areas in the Midland Valley of Scotland information should be available on existing maps or can be interpreted from the newly completed 1:250 000 soil and LCA maps.

If this information had been requested for the Keirsbeath area, the storage of topsoil on deep peat and the siting of the plant yard on peat alluvium with a high groundwater table could have been avoided. When there are indications that mining will proceed (stage 1.5), the surveyor can effectively organize his survey, thereby anticipating and solving problems which may occur during the survey execution. Current guidelines by DAFS are that soil surveys should be carried out only on good-quality arable land and not for areas under rough grazing or moorland. As a general guide, the good-quality arable land is found within the east and central areas of the Midland Valley and equates with Land Capability Classes 2 to 4 (Bibby and Mackney 1969), whereas in the wetter west the soils have less agricultural significance and equate with Classes 4 and 5. DAFS is currently considering revising guidelines to suggest soil surveys for all the potential opencast coal sites, the extent and details of which should be at the discretion of the local DAFS official. When one considers that soil surveys are cheap in relation to the total costs of development, this can only help to improve the chances of optimum management of opencast coal sites.

The interpretation of soil data

It is essential that the style and language of the soil report should be in a form which is meaningful to both NCBOE and DAFS staff. Too often soil surveyors fail to interpret data properly and present the user with complex, scientific, jargon (MacRae 1982). For a special-purpose survey, Western (1978) recommends that a summary of the main soil characteristics, rather than detailed text, be provided. Using the INFOS Query/Report Writer (Data General Corporation 1980) this can be achieved, and by retrieval and analysis of a selection of records, any table can be produced to answer the precise questions of the map user. For example, the distribution of the drainage class within each soil mapping unit can be assessed (Fig. 2) from the reference data, and by analysis of the Ap horizon only, the average depth, dominant texture, mode and range of stoniness of the same horizon can be tabulated (Fig. 3).

Land capability for agriculture classification

To assist in agricultural advisory work, farm planning and defining land quality in connection with land restoration, the soil data can be interpreted into the Land Capability Classification (Bibby and Mackney 1969), which is an accepted system of presenting soil data in terms of the flexibility of land for cropping. The capability of the soil, prior to coal extraction, should be determined so that a comparison with conditions after reinstatement can be made. Furthermore, the possibility of rectifying any existing limitations during reinstatement can be examined.

On Keirsbeath the majority of the arable soils have been assigned to Land Capability Class 3s and 3sw. Excluding the Darvel and, to a lesser extent, the Kennet series, waterlogging of the upper soil horizons occurs at times of high rainfall, so that great care is needed to avoid structural damage by machinery. The coarse texture, which results in low moisture and nutrient retention capacity, often

Distribution of Drainage within each Mapping Unit

Association	Mapping Unit	Code	Total Frequency	Drainage V.Poor	Poor	Imperfect	Moderate	Free
Alluvial Soil	GEANIES	JG	7	-	5	2	-	-
Darleith	AMLAIRD	AM	1	-	1	-	-	-
Darleith	DRUMAIN	DM	2	-	-	-	2	-
Darvel	DARVEL	DV	7	-	-	2	4	1
*Darleith	DARLEITH	DL	12	-	-	-	6	3
Giffnock	ABERDONA	AA	25	-	-	25	-	-
Giffnock	FORESTMILL	FJ	14	-	-	4	3	7
Giffnock	GIFFNOCK	GK	13	-	13	-	-	-
*Giffnock	KENNET	KT	50	-	-	39	10	-
Hindsward	REIDSTON	RN	26	-	-	20	6	-
Peat	PEAT	PT	1	1	-	-	-	-
*Series not recorded			16	6	-	2	1	-
Totals			174	7	19	94	32	11

*Drainage records not complete

Figure 2. Example of computer analysis of reference data.

Characteristics of Ap Horizons in each Mapping Unit

Mapping Unit	Code	Ap Horizon Frequency	Average Depth (cms)	Dominant Texture (occurrences)	Stoniness Mode	Range
GEANIES	JG	4	31.5	Loam(3)	None,Few	None - few
DARLEITH	DL	6	26.5	Loam(6)	Few	None - many
DRUMAIN	DM	2	20.0	Loam(2)	Common	All common
DARVEL	DV	7	30.7	Sandy loam(6)	Few	None - common
ABERDONA	AA	23	28.1	Loam(19)	Few	None - common
FORESTMILL	FJ	14	29.3	Sandy loam(10)	Few	Few - many
GIFFNOCK	GK	4	30.0	Loam(3)	Few	All few
KENNET	KT	48	29.4	Loam(25)	Few	None - many
REIDSTON	RN	26	27.3	Loam(23)	Few	None - common
Total,mean & modes		134	28.6	Loam(85)	Few	None - many

Figure 3. Example of computer analysis of horizon data.

combined with the added restriction imposed by uneven topography, are the main limitations to agriculture for the Darvel series. The fine texture of the till deposits and consequent longer period of wetness of the poorly drained series make successful cultivation very difficult and such soils are included in Class 4ws, along with other areas where, despite the presence of good-quality soils, steep slopes are a major impediment to agriculture. In the latter areas, cultivations must be performed in only one direction. Where steepness of slope and degree of waterlogging are so severe that arable agriculture is no longer possible, the soils have been placed in Land Capability Classes 5g and 5ws because grassland improvement is still feasible if a drainage scheme is implemented and mechanical operations are carefully managed.

Interpretative maps

In all but one case, previous work by SSS for DAFS and NCBOE has provided only a pedologic soil map and report, there being no attempt to produce derived interpretative maps showing the potential of the land for the range of uses which the specialist may consider. Western (1978) stresses that the surveyor rather than the user should carry out interpretative assessment of the soil data. The data for Keirsbeath are open to different interpretations using different criteria because the use of a grid survey means that there were no decisions taken or constraints adopted at the start of fieldwork. When these interpretations are converted to graphic form they provide a useful predictive tool in the initial planning phase. For example, maps were produced to illustrate the distribution of topsoil (Ap horizon or peat) depth (Fig. 4a) and texture (Fig. 4c), both of which have significance for soil stripping operations. All subsoil horizons beneath the plough horizon were examined with respect to their potential as 'soil-making material' and the decision taken that if textures were finer than sandy clay loam (e.g. silty clay, clay loam), the soil material ought to be regarded as 'overburden'. An interpretative map (Fig. 4b) was constructed to indicate the variable depth of subsoil or 'soil-making material'. Other interpretations are currently being investigated jointly by DAFS, NCBOE and SSS staff.

Quantities

Current specifications by NCBOE and DAFS are that 300 mm topsoil and 600 mm subsoil should be replaced on the reinstated site, although current trends (Barrett, pers. comm.) may be to increase the subsoil or 'soil-making' material to 900 mm. Only the results of a soil survey will confirm whether or not materials are available on the site to satisfy these requirements. If a shortfall exists, the specifications in the contract document can be amended or steps taken to identify other suitable 'soil-making material' on or near the site. In these circumstances, the significance of the interpreted maps (Figs 4a and 4b), to the site engineer becomes apparent and substantial quantities of material, which might otherwise have been ignored and discarded, can be retained during stripping operations.

The coaling area at Keirsbeath measures 112·5 ha so that there is a need to find 337 500 m^3 topsoil and 675 000 m^3 subsoil. One method of calculating the possible quantities of topsoil and subsoil was to compute the average depth of topsoil (Ap horizon), excluding peat, and subsoil or 'soil-making material' from the recorded profiles within the coaling area. Computer analysis of the 174 sample sites indicated the average topsoil and subsoil depth was 28·0 cm and 50·8 cm, respectively, and, by calculation, 315 225 m^3 topsoil and 571 275 m^3 subsoil were available. A second method was considered to be more accurate because it took into account the soil variability on the site. Interpretation of the soil data indicated that each mapping unit had a differing potential to provide soil-making material.

Darvel series > Kennet series > Forestmill series (if highly weathered) > Reidston series > Aberdona series

By computing the topsoil, subsoil and peat quantities according to the relevant 100 m grid for each soil series and summing over the whole site, the following figures were obtained:

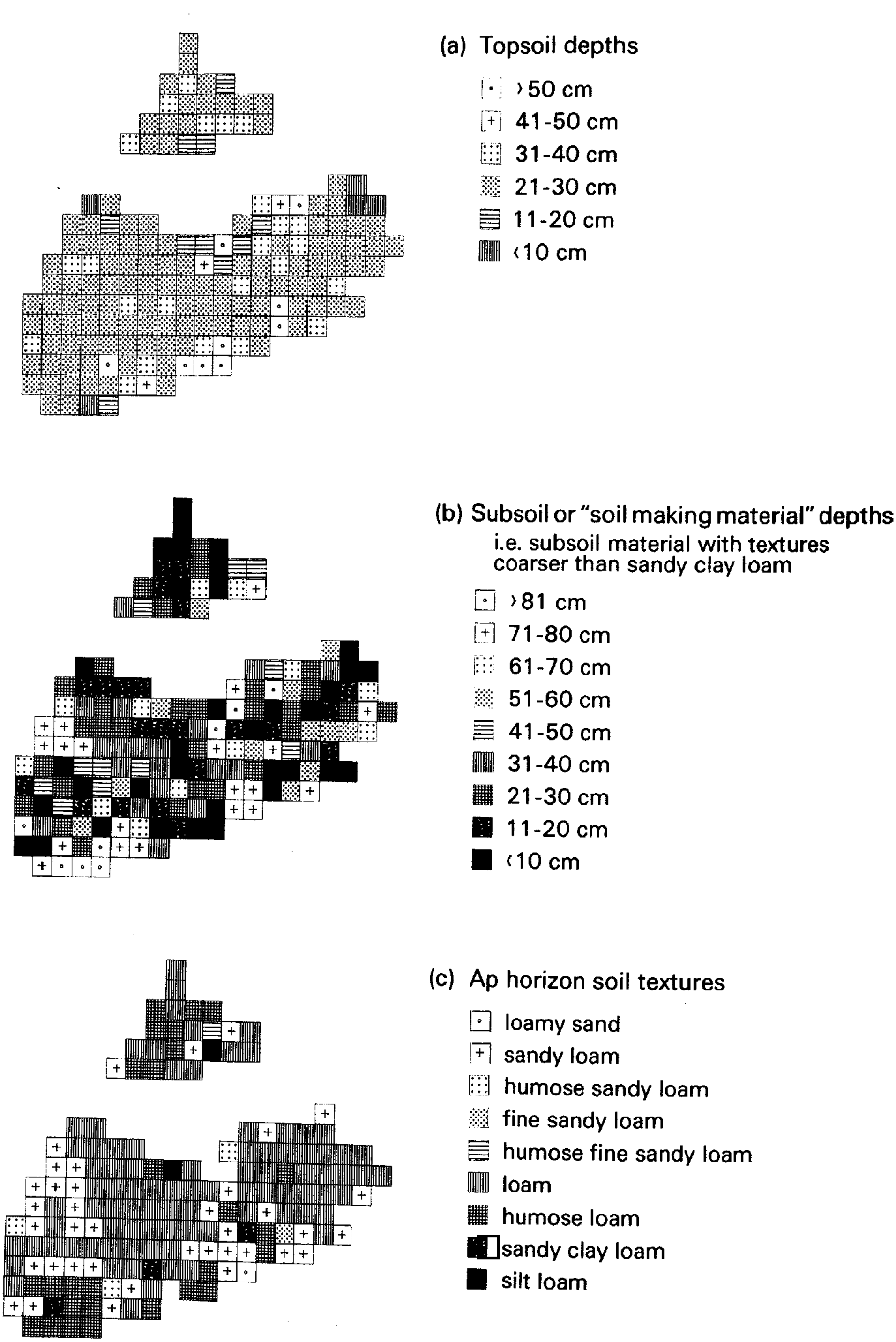


Figure 4. Interpretative maps derived from Keirsbeath data.

Potential topsoil quantity	304 579 m^3	if mixed provides 364 074 m^3
Potential peat quantity (calculated to 1 m depth)	59 495 m^3	
Potential subsoil quantity	551 144 m^3	

Even allowing for shrinkage of the peat during storage and mixing, there would appear to be sufficient topsoil to satisfy the 300 mm requirement. Indications of a shortfall of subsoil by both methods of calculation are incorrect when it is remembered that the soil survey only examined the regolith to 1 m. Research confirmed that if reports by NCB geologists and geotechnical engineers were interpreted correctly, the deficiencies in subsoil quantities could be rectified. Study of drift maps and bore-hole reports prepared by NCB geologists revealed that sand and gravel deposits of the Darvel Association extended to depths up to 15 m and that much of the residual sandstone of the Forestmill series was of a soft nature. The latter material equates closely with the highly weathered sandstone exposed in a 5 m section behind Keirsbeath farm; such material would rip easily during excavation and provide a workable, stone-free, sandy medium. Therefore, with the knowledge that the Darvel series occupies 7·08 ha, one extra metre of sand and gravel should provide 70 800 m^3 and almost satisfy the apparent shortfall of 123 856 m^3. Although not carried out on Keirsbeath, NCBOE intend conducting a geotechnical survey of all proposed opencast sites to formulate plans for earthwork design and possible realignment of streams etc. Representative undisturbed samples from these studies can provide the soil surveyor with invaluable information on the nature of strata between 1 m and rockhead, making careful placing of bore-holes and collaboration between respective survey teams an important factor to be considered seriously in the future. Such collaboration will involve the soil surveyor becoming more familiar with civil engineering terminology (BSI 1975), particularly at sites likely to contain insufficient subsoil or 'soil-making material' to satisfy the 600 mm specification. Previous SSS investigation into the realignment of the A9 Trunk Road (Walker and Gauld 1975) has shown the benefit to be derived from the examination of deep pits excavated by mechanical digger. The investigations by McGown and Iley (1973) into road design in Ayrshire, by Hartnup and Jarvis (1979) in West Yorkshire and Jarvis *et al.* (1979) in southern England have demonstrated the value of close liaison between engineer and pedologist.

Use of soil survey information during the opencast extraction process

Information derived from interpretative maps aids the site engineer in planning his stripping operations and allows him to achieve greater efficiency, both by the avoiding of soil structural damage as a result of working the soil when it is too wet, and by ensuring the capture of all potential 'soil-making material'. Soil movement should never take place when the soil moisture limit is in excess of the plastic limit; indeed, it should be considerably less than the figure obtained by the standard Casagrande method, which is the basis of current British Standard Methods (BSI 1975). Recent work by Campbell (1976) on arable topsoils and by Sherwood and Ryley (1970) on civil engineering soils have shown that the drop-cone penetrometer test offers a distinct improvement over the Casagrande device. Examination of 18 soils by Campbell *et al.* (1980) demonstrated that the Casagrande and drop-cone penetrometer plastic limits differed by a mean of 8 per cent w/w with a range of 3–12 per cent w/w. The potential use of the commercially available drop-cone penetrometer in the field along with portable moisture-reading probes suggest that new techniques for dealing with soil moisture contents for soil movement are worthy of examination.

Rather than collecting samples for the determination of the lower plastic limit on a soil series basis, the surveyor should sample according to the specific topsoil and subsoil texture so that suitable recommendations can be applied to the interpretative maps (e.g. Fig. 4b). No calculations were undertaken for Keirsbeath because soil stripping began immediately after the soil survey was completed and a review of analytical techniques had revealed that meaningful results could be provided only after more detailed investigations into this problem.

The early soil survey provides sufficient information to formulate a realistic restoration programme. In brief, the careful storage of all subsoil or 'soil-making material' will enable a permeable subsoil to be replaced over the overburden so that, together with a general levelling of the previously steep slopes, the current limitations to successful agriculture (i.e. gradient and soil texture problems) can be alleviated. If a comparative survey is undertaken after soil replacement has occurred, the specialist can assess how successful the restoration has been. Such an assessment is almost mandatory because, under the Town and Country Planning (Minerals) Act 1981, 'land in use for agriculture must be restored, in so far as it is practicable to do so, to the physical characteristics it possessed when last used for agriculture'. The second soil record can also be used as a consultative document because it predicts problems which may arise after restoration (e.g. excessive compaction of soil layers, problems relating to drainage or water supply, alignment of final field boundaries, siting of ditches, etc.). Soil nutrient analyses for the topsoil, and possibly subsoil, are invaluable. They provide a useful indication of the lime and fertilizer inputs which must be supplied immediately after restoration. Comparison with pre-mining soil nutrient levels would provide meaningful results if the earlier studies had been carried out.

Use of soil survey information during rehabilitation

Soil studies should continue throughout the five-year rehabilitation period prior to the site being released by NCBOE and returned to the landowner. Through the use of comparative soil surveys and practical research into alternative rehabilitation techniques for particular soil conditions, the landowner will be reassured that the performance of his land has not deteriorated following extraction. Where the soils have been handled correctly during removal, storage and replacement, the five-year period may be sufficient, but conversely, where errors have been made, farmers may be offered an additional three-year agreement with financial assistance on approved treatments (Hope 1982). The soil surveyor should continue to liaise with agronomists to review the best rehabilitation techniques for the particular soil types, climate, farming practice and restoration success on a site. Examination of previously reinstated sites and the long-term results of restoration methods can make a valuable contribution in the studies (Swain 1982).

Practical conclusions

Because the information shown on soil maps and in their accompanying reports is mainly of a pedological nature, it has, as yet, not been fully utilized by staff of DAFS and NCBOE with respect to opencast mining operations. A change of presentation of data to a more practical approach is recommended. Through cooperation between the organizations concerned, the value of soil survey has been increased by the production of interpretative maps which help in the application of the soils data to a specificed purpose. By modifying survey methodology and using computer techniques to produce these maps quickly and cheaply, the soil data are now in a form which both DAFS and NCBOE can easily assimilate and from which they can acrrue benefit.

Great emphasis must be given to the timing of soil investigations and the fieldwork carried out on Keirsbeath has provided valuable lessons to test a possible scheme of soil operations. If the initial soil survey of Keirsbeath had been carried out at the proper stage, additional information could have been incorporated within the application for authorization and subsequent contract document. In this case the soil survey provided confirmation that sufficient topsoil and subsoil were present to comply with the restoration scheme practised by NCBOE and supervised by DAFS. However, the soil data were supplemented by geological information which gave a complete insight into the volumes of potential subsoil and 'soil-making material' beneath the surface 1 m. If sufficient quantities had not been available, as is often the case, a realistic restoration programme is often impossible unless satisfactory soil-making material (e.g. crushed sandstone) is identified and carefully stored during mining operations. In this way, stony but highly permeable material can be placed at normal drainage depth rather than heavy-textured glacial till which might have been there prior to mining (Thomasson 1982).

It is concluded that soil survey is directly relevant to the wide range of possible needs by DAFS and NCBOE specialists during all stages of opencast coal extraction. On the Keirsbeath site the time has not yet arrived to test the usefulness of interpretative work at the restoration and rehabilitation stages. Further studies on the soil moisture contents for soil movement during stripping and restoration are being made and considerable scope exists for an interchange of ideas to improve existing rehabilitation techniques. The findings of the study support the hypothesis postulated by Western (1978) that 'survey in isolation is undesirable; interpretation in isolation is unacceptable'.

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