DEPARTMENT OF MINES AND ENERGY

SOUTH AUSTRALIA

THE COMPILATION OF COAL BOREHOLE DATA FOR COMPUTER PROCESSING: SUMMARY OF AN INDUSTRY METHOD

BY

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INTRODUCTION

The author worked as well site geologist for a large exploration company during 1977. This report summarises the operational methods employed, and describes a system of encoding borehole data for computer processing. The report may serve as a basis for possible Departmental establishment of a similar data-processing system.

Exploratory and delineation drilling was carried out on a brown coal deposit which locally was upgraded by thermal metamorphism to a semi-anthracite. Seven coal seams were developed, averaging fifty metres in total thickness. Individual seams were laterally extensive and contained numerous tonstein bands and silicified lenses.

All coal borehole data were compiled and filed using the COGEO computer system (summarised in Figure 1).

Personnel were based at a well-appointed field camp including offices and coreshed located within the lease holdings.

DRILLING OPERATIONS AND INITIAL CORE HANDLING

Drill rigs used were three Longyear 38's equipped with triple-valve Bean pumps, a combination designed specifically for core drilling: few holes were rotary-drilled. Operations continued on a 24-hr basis with two twelve-hour shifts. Drilling ceased for twelve hours every Sunday to facilitate machinery maintenance and drilling crews' rotation.

Core was cut in three-metre lengths where possible, following standard diamond-coring practices. Although the drilling company was contracted to recover a minimum of 90% of the coal core cut, otherwise being required to redrill at their cost, 80% recovery often was accepted (as determined by the well site geologist). All core was extruded onto split PVC pipe halves with perforations at regular intervals to enable drainage. The pipe halves were 3.5 m in length, in groups of three, each group being supported by a strong wooden tray.

A geologist's assistant was available at the rig site. His duties were to remove excess drilling mud from the coal, mark the base of driller's runs with enscribed wooden blocks, wrap fresh samples for analysis (total moisture, sodium and geotechnical) as directed, cover all core trays with canvas, and add water when appropriate to prevent core desiccation.

For rotary-drilled holes the assistant collected cuttings samples at three-metre intervals.

WELL SITE GEOLOGY

A well site geologist was assigned to each drilling rig in operation. For exploratory holes (which were always cored) the geologist was required to remain on site for the duration of the day shift. Core was not logged at night. For delineation holes the geologist was required on site only to log the accumulated core from each drilling shift. Although the geologist remained on site if stratigraphic problems were apparent, he otherwise returned to the project site office to compile borehole data.

For the occasional rotary-drilled hole the geologist would only visit the site each day to check progress.

Field core descriptions were made on a standard borehole log sheet (Figure 2) using COGEO (computerised geology) nomenclature (abbreviated in Appendix I). The following geological and geotechnical parameters were recorded:

1. drillers depth
2. unit thickness
3. R.Q.D. (recovered quality determination: the length of core recovered in sticks longer than 10 cm).
4. % lithology, qualifiers, and colour
5. weathering
6. permeability
7. plasticity
8. durability, resistance to abrasion
9. strength
10. bedding
11. jointing
12. sedimentary-tectonic structure
13. accessory minerals
14. sample number
15. remarks

All coal core was wrapped in plastic, water was added, the plastic sealed and the core boxed. Core for sodium analysis initially was wrapped in aluminium foil, bound with Scotch tape and then wrapped in plastic, but it was discovered that the foil contaminated the sample. Thereafter samples were wrapped first in plastic, bound with cellotape, then secondly in aluminium foil, bound with tape then immersed in molten wax inside a suitable length of PVC tubing to ensure that the sample remained undisturbed. A representative 10% of non-coal core also was boxed. The remaining 90% of non-coal core was discarded.

Assistants placed core into wooden core boxes 1.1 m long with five internal divisions. Foam rubber commonly was used to pack on top of the core, to minimise the risk of damage during transportation to the coreshed.

GEOPHYSICAL BOREHOLE LOGGING

All boreholes were logged by BPB Industries Ltd. Geophysical logs used were:-

1. gamma-long spacing density-caliper 1:200 scale general log
2. point resistivity, neutron-neutron 1:200 scale general log
3. gamma 1:20 scale detail log
4. long spacing density 1:20 scale detail log
5. high resolution density 1:20 scale detail log (resolution 20 cm)
6. caliper 1:20 scale detail log
7. resistivity and/or focused electric 1:20 scale detail log.

The detail logs Nos. 3-7 inclusive were run over the coal seam intervals only. All log data were recorded both digitally and as analogues, and logs were presented to the client as sepias after preparation at the field office. General 1:200 scale field-copy logs also were available at the well site.

COAL SAMPLING

Boxed coal core was laid sequentially onto the core-shed tables. The recovered core was correlated with the geophysical logs. Such units as silicified coal, tonstein bands and resin bands were excellent markers enabling the core to be "pegged" against the logs: intervals of core loss commonly could be determined with an accuracy of ± 1 cm. Many transitional lithologic boundaries too subtle to identify macroscopically at the well site (eg. carbonaceous clay to clayey coal) could be identified by careful comparison with logs at the core shed.

This procedure also provided a check on field - recorded lithologic thickness.

Thus, coal core selected for bulk density, total moisture and sodium analysis was accurately located relative to the geophysical logs; this is critical if computer crossplots of core data are to be used correctly for calibrating geophysical logs and subsequently determining coal ash contents in rotary-drilled holes.

Intervals of homogeneous lithology or transitional lithology between two homogeneous lithologies were sampled. Generally coal sample intervals were restricted to a maximum length of two metres.

Bulk density was determined for all total-moisture-analysis samples and tonstein samples (if preserved as a stick). Samples were weighed; wholly crushed; a portion sent to the laboratory for analysis (chemical, ash fusion, crucible, swelling index, volatiles etc); and the remainder kept as a reserve.
Core for sodium analysis was specially prepared. Only core available in sticks of approximately 60 cm lengths was selected. Each stick was separated into four samples - 10 cm from either end; the central core portion; and an outer layer from the entire stick comprising about one third of the core radius. This method was followed to determine whether the sodium content was inherent, or due to contamination from drilling muds. In addition, at some locations three separate holes were drilled using respectively water, CMC or bentonite as drilling mud, to determine relative mud-contamination effects.

A sample-interval log was constructed on the Gamma Detail Log. A reference depth for each coal seam was ruled on the Gamma-LSD-Caliper 1:200 General Reference Log. Subsequently, coal core interval depths were read from the gamma logs.

A Sample Submission Sheet (Figure 3) was compiled for each borehole. One copy remained on file at the core shed and the original was sent with the coal samples to the laboratory.

The core recovery percentage from a given interval could be roughly checked by dividing the gross weight of the coal sample by its represented thickness and comparing it with the known average weight per centimetre of core for coal from that area. This check proved very useful, especially when chemical analysis conflicted with geophysical log characteristics, e.g. relatively high ash-content from analysis but low gamma count from logs. Such conflicts commonly occurred for samples immediately above and below clay bands. If the core weight/length was greater than the known average, it then was assumed that the core was "telescoped" or that a clay band may have been included in the sample. The sample interval then was adjusted appropriately after rechecking all data.

After sampling, the residual non-coal core was telescoped, reboxed and stacked in a core library.

BOREHOLE DATA PRESENTATION

All borehole data were compiled on standard sheets, termed "blocks". These were used for both cored and rotary-drilled holes.

CL Geology Block

Non-coal core was correlated with the Gamma-LSD-Caliper 1:200 General Log and Resistivity, Neutron-Neutron 1:200 log, and using the former as the depth standard, field core descriptions were transferred to the CL Geology Block (Figure 4A,4B). The Gamma Detail Log provided the depth standard for coal-seam intervals, descriptions for which were similarly entered.

The CL Block is basically an expanded borehole field log. Drilling data also could be recorded - weight on bit, flush returns, rpm, penetration rate, mud weight, mud temperature and resistivity - but appropriate columns are not shown on Figure 4A. Other columns on that enclosure relate to:

- entry number eg. line 0001, 0002 etc.
- interval, eg. depth recorded in metres
- stratigraphic unit names, eg. group, formation
- unit, eg. seam 2
- subunit, eg. tonstein 3
- information type, coded: 1 - cuttings only
  2 - logs only
  3 - core only
  4 - sidewall core only
  5 - logs & core
  6 - logs & cuttings
  7 - logs & sidewall core
  8 - driller only

Other Blocks

Additional data were presented on appropriate survey, chemical analysis and geotechnical analysis code sheets.

Lithologs

A generalised percentage litholog was drawn in a 10 cm wide column on the Gamma-LSD-Caliper 1:200 General Log.

COMPUTER PROCESSING APPLICATIONS

All data were filed on computer tape. The computer was programmed to:

1) adjust all analyses for core loss, calculate an interval weighted average, and ultimately calculate a reconstituted bulk coal seam analysis.

2) prepare plots of contourable data eg. seam thickness, depth to roof, depth to floor, interseam thickness.

3) calculate coal reserves

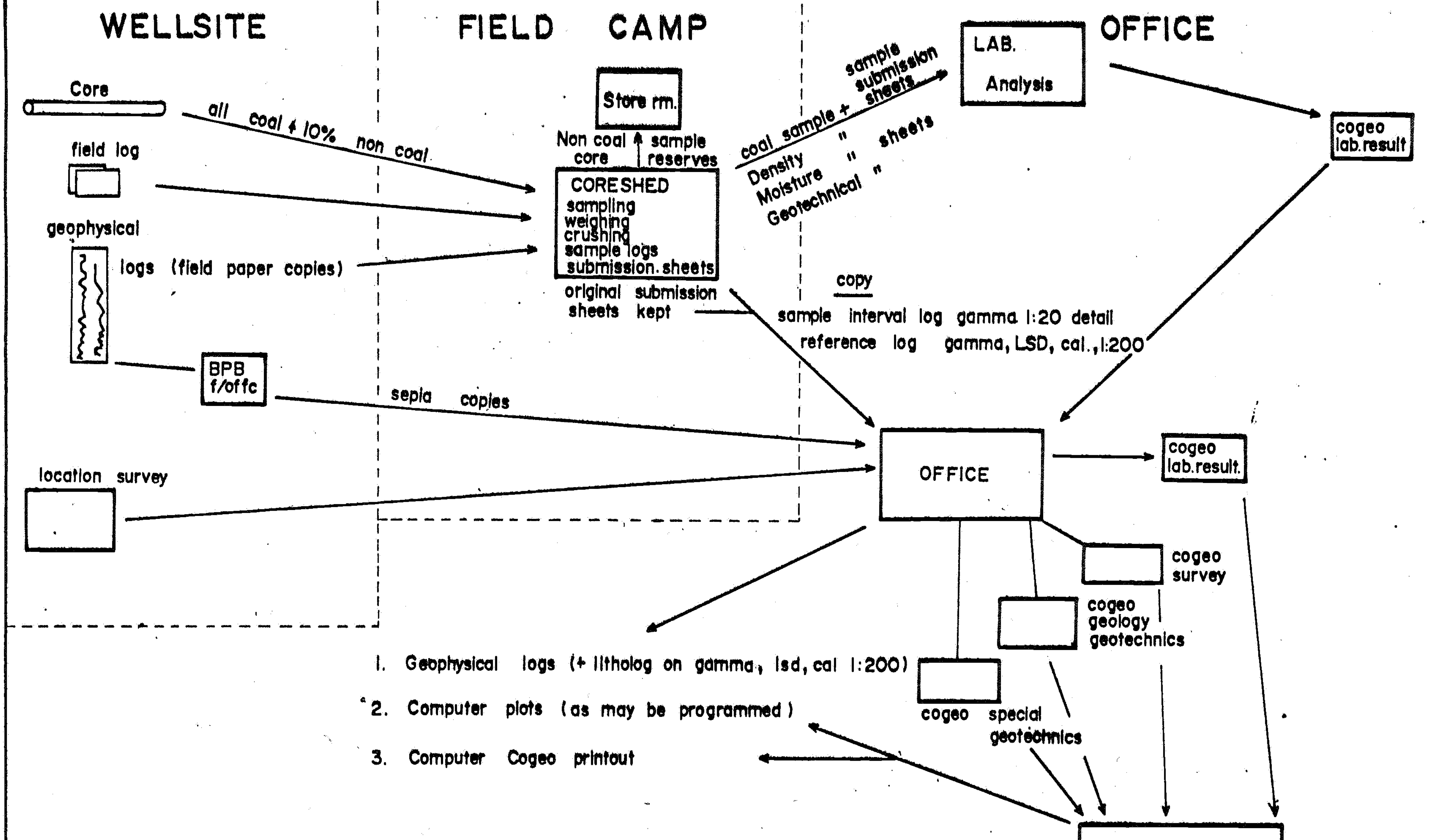
4) calculate overburden/coal ratios

5) calculate ash determination from geophysical borehole data crossplots.

Computer applications to coal exploration and delineation are further discussed in Peeters and Kempton (1977).

REFERENCE

Peeters, M. and Kempton, N.H., 1977. Wireline Logging for Coal Exploration in Australia. <u>The Log Analyst</u>, 18: 24 - 29.



FLOW DIAGRAM : COGEO

FIG. 1

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BOREHOLE FIELD LOG

PAGE GEOLOGIST DATE AREA BOREHOLE

DEPTH	T/NES.	RQD	%	lithology main	Q1	Q2	colour	wethg		plast.	durab.	strgh	Bedding	JOINTING	sed.tect.stru.	acces. mins.	sample no.	REMARKS
01 02 03 04 05	06 07 08	09 10 11	12 13	14 15 16	17 18	19 20	21 22	23 24	25	26 27	28 29	30 31	32 33 34 35 36 37 38	39 40 41 42 43 44 45 46 47	48 49 50 51	52 53 54 55	56 57 58 59 60	

SAMPLE SUBMISSION SHEET No:

DATE: GEOLOGIST: BOREHOLE: AREA:

interval from	to	t/ness M.	recov. M.	%	sample wt. gms.	lab. sam. wt. gms.	res. sam. wt. gms.	bulk density	lithology	sample no	remarks
etc.											

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FIG. 3

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COGEO CL BLOCK

COUNTRY	STATE	AREA

COUNTRY
STATE
AREA
DATE
AUTHOR
Page of

GEOLOGICAL DATA																															GEOTECHNICAL DATA																	
BOREHOLE	SEQUENCE	DEPTH		INTERVL	GROUP	FORMN.	UNIT	SUBUNIT	SA TYPE	RECOV.	RQD	SAMPLE		LITHOLOGY 1					LITHOLOGY 2					LITHOLOGY3					WEATHG.	PLASTY.	DURABY.	STRENGTH		BEDDING			JOINTING				SAMPLE No.	SED./TEC. STRUCTURE	ACCESSORY MINERALS
	No.	from	to									No.		%	Main	Q 1	Q 2	Colour	%	Main	Q 1	Q 2	Colour	%	Main	Q 1	Q 2	Colour				Soil	Rock	Spacg	Dip	Azimuth	Spacg	Descn	Dip	Azimuth			
01 02 03 04	05 06 07 08	09 10 11 12 13	14 15 16 17 18	19	20 21	22 23	24	25	26	27 28 29	30 31 32	33 34 35 36 37	38	39 40 41	42 43	44 45	46 47	48 49	50 51	52 53	54 55	56 57	58 59	60 61	62 63	64 65	66 67	68 69	70 71	72 73	74 75	76 77	78 79	80 81	82 83	84 85 86	87 88	89 90	91 92	93 94 95	96 97 98 99 100	101 102 103 104	05 106 107 108 109 110 111 112
etc.																																											

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CL REMARKS BLOCK

country	state	area	borehole	sequence number	Remarks
		etc.			

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APPENDIX 1

Abbreviated COGEO Nomenclature

MAIN LITHOLOGY

COMPONENT SIZE	SUPERFICIAL DEPOSITS	
>20 cm	BØ	Boulders
6 - 20 cm	CB	Cobbles
0.2 - 6 cm	GV	Gravel
>50% - 0.06 - 2 mm	SA	Sand
50 - 80% 2 - 60 μ	SL	Silt non plastic v. sl. gritty when wet shows dilatancy sl. cohesive when dry.
>80% is <2μ	CL	Clay individual grains not visible with x10. Cohesive when dry rolls into 3 mm threads. Plastic and smooth when wet.
	ØG	Organic, fibrous elements visible with x10 lens usually compressible, usually dark.
	SØ	Soil SI in situ SR transported.
	LA	Laterite

IGNEOUS ROCKS

AS Andesite
TF Tuff

CONSOLIDATED SEDIMENTARY DEPOSITS

BC	Boulder Conglomerate
CC	Cobble Conglomerate
PC	Pebble Conglomerate
SS (SC, SM, SF)	Sandstone looks rough feels granular, individual grains visible with naked eye.
ST	Siltstone reflection on surface not increased by rubbing with same material for few secs. No listric surfaces.
CS	Claystone - reflection on surface increased by rubbing with same material, may have listric surface.
SH	Shale Fissile claystone.
CØ	Coal C1-27
DM	Dolomite
FG	Ironstone
GY	Gypsum
RS	Resin Rock
SD	Siderite
LM	Limestone
CR	Carbonate unspecified
SU	Sulphide Rocks

MAIN LITHOLOGY QUALIFIERS - in addition to above

Coal - Brown

EA Earthy
FB Fibrous
LF Leafy
RS Resinous
SB Sub-Bit
WO Woody
WX Waxy

COAL-Bituminous

B Bright
D Dull
HD Heavy Dull
L Lustrous
CI 90% bright
C2 80-90% "
C3 60-80% "
C4 40-60% "
C5 20-40% "
C6 10-20% "
C7 <10% "

Rock Type

AK Arkose
TØ Tonstein

ROCK FORMING COMPONENTS

BE Bentonitic Clay
FD Felspar
GC Glauconite
KL Kaolinite Clay
LI Limonite
MC Mica
MU Muscovite
BI Biotite
QZ Quartz
RF Rock Fragments
PY Pyrite
SI Silicified

GRAINSIZE

CM Coarse 2-0.5 mm
MD Medium 0.5-0.25 mm
FN Fine 0.25-0.06 mm

Occurrence

CN Concretions
CT on cleats
DS Disseminated
GØ Globular
EX Extrusive
IN Intrusive
IC Intercalated
LN Lenses
LM Laminae <1 cm
ND Nodules
SK Streaks
GR Granules
PE Pelletal
PS Pisolitic
VS Vesicular
MM Metamorphosed
CD Conchoidal
BR Breccia
MS Massive
F Fossiliferous

Texture

FI Fissile <.2 mm
FR Fragmental
RW Reworked
AG Angular
RN Rounded
HG Homogeneous
DE Detrital
AU Authogenic
CY Crystalline
HT Heterogeneous

Mineral and Qualifiers

When present in accessory amounts the Rock-forming-components here can be coded as minerals and Nature of Occurrence and Texture codes used to qualify.

SEDIMENTARY STRUCTURES

BORED	BØ	FLASER BEDDING	FB
BIOTURBATED	Bu	RIPPLES	R
CONVOLUTED BEDDING (B'G)	CV	RIPPLES ASSYMMETRICAL	RS
CARB WISPS	CW	RIPPLES LINGUOID	RL
GRADED B'G NORMAL	GN	RIPPLES SYMMETRICAL	RS
GRADED B'G INVERSE	GI	SCOUR AND FILL	SC
FLAME STRUCTURE	FM	SAND LINEATION	SN
LOAD CASTS	LD	SORTING GOOD	SG
MUD CRACKS	MU	SORTING FAIR	SF
PRODCAST BOUNCE MARKS	PC	SORTING POOR	SP
		SLUMP STRUCTURE	SR
PLANT FRAGMENTS	PF	SUBAQUEOUS SHRINK	SZ
CROSS BEDDING	XB	TRACE FOSSIL	TF

TECTONIC STRUCTURE

CLEATED	CT
CLEAVAGE	CE
BOUDINAGE	BN
FAULT ZONE	FZ
NON CLEATED	NC
STYLOLITE	ST

WEATHERING

SØ	Soil discoloured, changed to soil. Original fabric destroyed.
WC	Completely weathered - discoloured, changed to soil-original fabric remains.
WH	Highly weathered, discoloured, discontinuous discoloured surfaces, alteration penetrates deeply. Fabric altered near discolouration surfaces.
WE	Mod. weathered, discoloured discontinuities have discoloured surfaces, alteration penetrates slightly. Intact rock weaker than rock.
WX	Slightly weathered may be discoloured, discontinuities have discoloured surfaces.
FH	Fresh, no discolouration, max strength.
BT	Burnt, scoria, naturally coked coal.

STRENGTH

Rock

R7	extremely strong requires many hammer blows to break.
R6	very strong requires several hammer blows to break intact material.
R5	strong requires hammer blow to break hand held sample.
R4	moderately strong can't be cut with knife. Pick indents to 0.5 cm.
R3	moderately weak difficult to obtain shallow cuts - Pick indents deeply.
R2	weak - knife cuts deeply crumbles under pick blows.
R1	very weak brittle or tough, difficult to break in hand.

COHESIVE SOIL

C4	Stiff cannot be moulded with fingers, but nail indents
C3	Firm moulded by strong fingers pressure
C2	Soft easily moulded with fingers
C1	V. soft exudes between fingers when squeezed

NON COHESIVE SOIL

G4	weakly cemented lumps of soil can be abraded with thumbs
C3	compact non cemented requires pick for excavation
G2	loose could be excavated with a spade
G1	v. loose hand penetrates easily

PLASTICITY

LE	Lean silty and/or non sticky when wet, doesn't roll easily into 3 mm diam. threads when moist. Marked dilatancy, low dry strength.
IN	Intermediate. Slightly sticky clays. Rolls into 3 mm dia. threads when moist. Some shrinkage in drying.
FA	Fatty very sticky clays. Usually swelling. Rolls easily into 3 mm threads when moist. High dry strength, considerable shrinkage in drying.

COLOUR

BUFF	BF	GREY	GY
BLACK GREEN	BG	LIGHT BROWN	LB
BLACK	BK	LIGHT GREEN	LG
BLUE	BL	ORANGE BROWN	ØB
BROWN	BN	ORANGE	ØR
CREAM	CR	ORANGE YELLOW	ØY
DARK BROWN	DB	PINK	PK
GREY BROWN	GB	PURPLE	PP
GREY DARK	GD	RED	RD
GREY GREEN	GG	WHITE	WH
LIGHT GREY	GL	YELLOW BROWN	YB
GREEN	GN	YELLOW	YW
		VARIEGATED	VG

BEDDING AND JOINTING SPACING

01	<2 m	Add 10 for slickenside on bedding surface
02	0.6-2 m	Add these numbers for separation at bedding surface
03	20-60 cm	00 little or no separation
04	6-20 cm	20 some separation
05	2-6 cm	30 separation at many or all surfaces.
06	0.6-2 cm	
07	<0.6 cm	

DESCRIPTION OF JOINTING

08	Tight non planar
07	Tight planar rough
06	Tight planar smooth
05	Open non planar
04	Open planar rough
03	Open planar smooth
02	Infilled with soil <1 cm
01	Infilled with soil >1 cm

Add No's below to indicate

10	slickenslide
20	infilled with calcite
30	infilled with quartz
40	infilled with resin

PERMEABILITY

Codes are based on discontinuity spacing in rocks and granularity in soils. Increase code if discontinuity is >0.2 mm wide.

Rock discontinuity		Soil grainsize
8	high <6 cm	clean gravels
6	Mod. 6-60 cm	clean sands
4	Slight 60-200 cm	fine sands-silts
2	impermeable >200 cm	intact clay