Appendix 5.2 – X-Ray Diffraction Analyses

Bore No/ Depth (m)	Landslide No.	Stratigraphy	Clay Mineral Constituents				
			Dominant or Co-dominant	Sub-dominant (>20%)	Accessory (5-20%)	Trace (<5%)	Other Major and (Minor) Mineral Constituents
2/3.10	15	Childers Formation	Kaolinite with halloysite admixed			Mica/illite	Quartz (goethite) (hematite?)
2/5.80	15	Lower Cretaceous	Montmorillonite*		Kaolinite	Mica/illite	Quartz (Na feldspar) (alunite?)
4/5.90	10	Tertiary Older Volcanics	Kaolinite with halloysite admixed	Hydrated halloysite			(goethite) (hematite?)
5/6.00	10	Tertiary Older Volcanics	Kaolinite with halloysite admixed	Hydrated halloysite montmorillonite			(goethite)
14/3.00	9	Tertiary Older Volcanics	Halloysite (dehydrated-metahalloysite) montmorillonite*				(K feldspar)
14/5.00	9	Childers Formation	Kaolinite	Illite-montmorillonite (regularly mixed layers)			Quartz
15/4.50	10	Childers Formation	Kaolinite	Mica/illite	Illite-montmorillonite (randomly mixed layers)		Quartz
16/5.00	10	Tertiary Older Volcanics	Kaolinite with halloysite admixed	Hydrated halloysite	Randomly layered mixed clays		(goethite)
17/6.40	9	Tertiary Older Volcanics	Kaolinite with halloysite admixed	Randomly layered mixed clays			(goethite) (quartz) (hematite?)

Bore No/ Depth (m)	Landslide No.	Stratigraphy	Clay Mineral Constituents				
			Dominant or Co-dominant	Sub-dominant (>20%)	Accessory (5-20%)	Trace (<5%)	Other Major and (Minor) Mineral Constituents
18/2.00	17	Childers Formation	Kaolinite with halloysite admixed	Randomly layered mixed clays			(goethite) (hematite?) (quartz) (K feldspar) (dolomite?) (anatase?)
20/1.90	Klevans	Lower Cretaceous	Montmorillonite*		Kaolinite	Mica/illite	Quartz (Na feldspar)
21/5.33	20	Childers Formation	Kaolinite Randomly layered mixed clays	Mica/illite			Quartz
22/4.30	20	Childers Formation	Layered montmorillonite-vermiculite-illite?	Kaolinite	Illite-montmorillonite* (randomly mixed layers) Mica/illite	Mica/illite	Quartz (alunite?) (anatase?)
27/5.62	7	Lower Cretaceous	Montmorillonite*		Mica/illite	Kaolinite Chlorite	Quartz Na feldspar (alunite?)

* Inhibited montmorillonite: Inert interlayered material such as gibbsite or brucite present

MINERALOGY OF 15 SOIL SAMPLES

1. Introduction

A batch of fifteen samples received from the Victorian Department of Minerals & Energy (Mr J Brumley) were soils from various depths (up to 6.4 m) from thirteen boreholes. They were to be examined by X-ray diffraction methods to determine their clay and non-clay mineralogies, according to AMDEL Code MC2. This consists of a diffractometric examination of the bulk sample, plus the separation of a -2μ 'clay' fraction and the examination of samples prepared from this fraction.

2. Procedure

The samples, which were damp, were removed from their plastic bags and air-dried at rom temperature. Sub-samples were taken, ground finely by hand, and used to prepare X-ray diffractometer traces which were interpreted by standard procedures.

Further weighed sub-samples were taken and dispersed in water with the aid of deflocculants and an electric blender, and allowed sediment to produce -2μm esd 'clay fraction' material by the pipette method. The resulting dispersions were examined in a plummet balance to determine their solids contents, and were then used to produced oriented clay preparations on ceramic plates. Two plates were prepared per sample, both being saturated with Mg^{++} ions and one in addition being treated with glycerol. When air-dry, these were examined in the diffractometer. Various additional diagnostic examinations were carried out as required, including examination of the glycerol-free hot (130^{o}C) and after heating for 1 hour at 550^{o}C.

3. Results

The results are given in Table 1, which lists the following:

(a) The mineralogy of the total sample, as derived from XRD scan of the bulk material, with supporting evidence as available. The minerals found are listed in approximate order of decreasing abundance, using the semi-quantitative abbreviations given. Coverage of clay minerals may be incomplete, and for the full clay mineralogy the section on the clay fraction (c) should always be consulted. This section (a) should be used for information on non-clay minerals, and to give a general idea of the proportions and make-up.

(b) The proportion of the sample found to separate into the -2μm size fraction, as determined by plummet balance. The figure obtained may be variable according to the pre-treatment and dispersion conditions used.

(c) The mineralogy of the -2μm fraction, given in the same way as (a).

4. Remarks

In general, the minerals are typical of those in soils in that they are poorly crystalline and poorly defined, and the interpretation is consequently sometimes difficult.

Goethite and hematite are invariably very poorly crystalline and give XRD patterns difficult to identify. In general, the reported presence of these minerals corresponds well with those samples identifiable as iron-bearing from their colour.

Kaolinite and halloysite. The two closely-related minerals are widely present. It is difficult to identify moderate amounts of metahalloysite in the presence of kaolinite; hence they are often reported together as K/H in the table where there are indications of the presence of halloysite. If halloysite identification is of great importance in these or other instances the use of electron microscopy is recommended. In some cases hydrated halloysite, which has a 10Å rather than a 7Å basal spacing, has been definitely detected and is reported separately.

Montmorillonite (smectite). In some cases this has been reported as 'inhibited'. This refers to the presence of inert interlayer material, probably gibbsitic or brucitic, which inhibits the collapse of the clay layers when the Mg-saturated clay is heated to low temperatures (e.g. 110-150^{o}C). The inhibited montmorillonites reported here collapse to about 13.5Å (from 15Å) at such temperatures, instead of to a more usual spacing of about 12-12.5Å. Heating to 550^{o} promoted a fully collapse to about 10Å. This is unlikely to be of practical importance, but is reported for completeness.

Interstratified materials. Various types of interstratified or 'mixed-layer' clays are reported, as listed in the mineral key. The material found in BH22 4.30 m appears to be very unusual, and may consist of a 3-component interstratification. It is tentatively identified as a montmorillonite-vermiculite-illite.

Mineral Key

AL	Alunite
An	Anatase
C	Chlorite
Dol	Dolomite
F	Na feldspar
F'	K feldspar
G	Goethite, very poorly crystalline
H	Halloysite, dehydrated (metahalloysite)
HH	Hydrated halloysite
Hm	Hematite, very poorly crystalline
K	Kaolinite
K/H	Kaolinite with probable or definite admixed halloysite
M	Mica/illite
$(M\text{-}Mo)_{ran}$	Illite-montmorillonite mixed-layer clay, more or less randomly interstratified
$(M\text{-}Mo)_{reg}$	Illite-montmorillonite mixed-layer clay, more or less regularly interstratified
ML	(Sample BH22) – mixed-layer clay of complicated type, possibly montmorillonite-vermiculite-illite
Mo	Montmorillonite (smectite)
Mo'	'Inhibited' montmorillonite – see text
Q	Quartz
RI	Randomly-interstratified clay material of indeterminate type. Likely to contain montmorillonite.

Semi-quantitative abbreviations

These are defined as follows:

D = Dominant. Used for the component apparently most abundant, regardless of its probable percentage level.

CD = Co-dominant. Used for two (or more) predominating components, both or all of which are judged to be present in roughly equal amounts.

SD = Sub-dominant. The next most abundant component(s) providing its percentage level is judged above about 20.

A = Accessory. Components judged to be present between the levels of roughly 5 and 20%.

Tr = Trace. Components judged to be below about 5%.

Table 1 – Bulk and -2µm mineralogies of 15 soils

Sample	BH2	3.10m	BH2	5.80m	BH4	5.90m	BH5	6.0m	BH14	3.0m	BH14	5.00m	BH15	4.50m	BH16	5.0m	BH17	6.40m
Bulk Mineralogy	K/H	D	Mo	D	K/H	D	K/H	D	H	D	Q	D	Q	D	K/H	D	K/H	D
	Q	SD	Q	A-SD	G	A	HH	SD	Mo	SD	K	SD	K	SD	HH	SD	G	A
	G	A	F	A	Hm?	A	G	A	F'	Tr	M	A	M	SD	G	A	Hm?	A
	Hm?	A	K	A			Mo	A			Mo?	A					Q	A
	M	Tr	M	Tr														
			Al?	Tr														
-2 µm fract. % of total	62		20		50		20		24		36		28		19		73	
Mineralogy	K/H	D	Mo'	D	K/H	D	K/H	D	H	CD	K	D	K	D	K/H	D	K/H	D
	G	A	K	Tr-A	HH	SD	HH	SD	Mo'	CD	(M-Mo)reg	SD	M	A-SD	HH	SD	RI	SD
	M	Tr	Q	Tr-A	G	A	Mo	SD			Mo	A	(M-Mo)ran	A	RI	A	G	A
	Q	Tr	M	Tr			G	A			M	A	Q	Tr				
											Q	Tr						

Sample	BH18	2.0m	BH20	1.90m	BH21	5.33m	BH22	4.30m	BH24	3.00m	BH27	5.62m
Bulk Mineralogy	K/H	D	Mo	D	K	D	K	CD	Q	D	Mo	CD
	Q	SD	Q	SD	Q	SD	ML	CD	K	SD	Q	CD
	Hm?	A	F	A	M	A	Q	A-SD	M	A	F	A-SD
	F'	Tr	M	Tr			M	Tr	C?	Tr	M	Tr-A
	Dol?	Tr	K	Tr			Al?	Tr	F	Tr	C	Tr
	Ana?	Tr					Ana?	Tr			Al?	Tr
-2 µm fract. % of total	37		30		75		67		45		18	
Mineralogy	K/H	D	Mo'	D	K	CD	ML	D	K	D	Mo'	D
	RI	SD	Q	A-SD	RI	CD	K	SD	(M-Mo)ran	A	M	A
	G	A	K	A	M	A-SD	M	Tr	M	A	Q	Tr
	Q	Tr	M	Tr-A	Q	A	Q	Tr	Q	Tr-A	K	Tr
			F	Tr							C	Tr
											F	Tr

Mineral Key (see separate page)