DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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SOUTH AUSTRALIAN COMMERCIAL CLAYS, GEOLOGY, MINING AND USE.

A TALK, AND FIELD EXCURSION PRESENTED TO THE 8TH. BIENNIAL CONFERENCE OF THE AUSTRALIAN CLAY MINERAL SOCIETY, ADELAIDE
AUGUST 1982

GEOLOGICAL SURVEY

by

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and

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MINERAL RESOURCES SECTION

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STOP 3: Williamstown kaolin-sillimanite-mica deposits.

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DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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SOUTH AUSTRALIAN COMMERCIAL CLAYS

Geology, Mining and Use.

A talk, and field excursion presented to the 8th Biennial Conference of the Australian Clay Minerals Society.

Adelaide-August 1982

INTRODUCTION

The Australian Clay Minerals Society is an informal grouping of mineralogists, geologists, chemists, physicists geomorphologists and soil scientists interested in clay minerals, the last group being predominant. The only organised function of the society is a biennial conference.

The 8th Biennial Conference was held in Adelaide at the Charles Hawker Conference Centre, Waite Agricultural Research Institute, from 18 to 20 August 1982.

The Conference had two themes -

- Clays in Soils and Sediments
- Clays in Industry.

Most papers presented were in the first category.

The authors presented the following paper, and were responsible for organising a field excursion on Thursday 19 August.

As many delegates were from interstate, and few had formal geological training, the paper was designed as preparation for the field excursion, introducing the audience to the geological environments of South Australia's commercial clays, their mining and use.

Slides illustrating the talk have been reproduced here as colour prints. One set of 35 mm transparencies is held by Minerals Resources Section, with a duplicate set filed in Technical Information Section.

The Conference programme, and abstracts of all papers comprise Appendix A, and names and addresses of the 76 registered delegates are listed in Appendix B.

The 9th Conference will be in Canberra in 1983 on dates to be fixed. It is recommended that at least one Departmental delegate attend.

TALK (TEXT)

SLIDE 1

This map shows the geology of the Adelaide area. More detail is shown on the State 1:1 000 000 Geological Map on display.

The core of the Mount Lofty Ranges consists of Precambrian rocks, Lower Proterozoic Barossa Complex inliers of gneiss and schist shown in RED, overlain by a sequence of Adelaidean quartzite, dolomite, silstone and shale shown in BROWN.

SLIDE 2

These sediments were folded, faulted and metamorphosed in Lower Palaeozoic times. The metamorphism was generally low grade, greenschist facies, but higher grades of metamorphism were reached in some localities with the development of sillimanite bearing rocks.

A long period with little tectonic activity followed this metamorphism, and a deep weathering profile developed, represented on this schematic cross section by the deeper brown colour.

This weathering profile is very important economically, being the source of almost all of South Australia's commercial clay. The bulk of this weathered shale is used in the brick industry, but significant amounts are also used in cement manufacture, refractories, and for a variety of industrial applications.

SLIDE 3

Relatively fresh Adelaidean shale and siltstone in the Mount Lofty Ranges. The rocks have been folded, as shown by the moderate dip, and faulted.

Where Adelaidean sediments have been affected by deep weathering, feldspar, mica and chlorite have been weathered to clay minerals, and the rock has been wholly or partly leached of iron. Argillaceous rocks alter to white or varicoloured weathered shale, depending on iron content.

SLIDE 4

White weathered shale is used to make cream and ivory bricks, and coloured weathered shale is used for red and earthy-coloured bricks.

SLIDE 5

Generally the white weathered shale is higher in the weathering profile, such as here at Hallett weathered shale pit at Golden Grove.

Note: Overburden - Tertiary clayey sand.
White weathered Shale.
Red weathered Shale.

Both red and white firing weathered shale are produced from this pit by selective mining.

SLIDE 6

This pit at Anstey Hill has been an important source of white-firing weathered shale for many years. As in most pits, the weathered shale is mined by scrapers, dumped in horizontally layered stockpiles and picked up from a vertical face by front-end loader to ensure uniform blending.

SLIDE 7

This pit at Golden Grove produces red-firing weathered shale. Brick shale is a relatively low-cost commodity, with transport representing a significant proportion of the overall cost. Cost savings are achieved by siting the brickworks close to the clay source, as they are here.

SLIDE 8

Baker Gully clay deposit south of Adelaide produces both red and white firing weathered shale, and is also an important source of weathered shale for use in the cement industry. Shale from this particular pit is notable for its very low alkali (Na + K) content which make it suitable for the production of low alkali cement at the Adelaide Brighton Cement Company's Birkenhead plant near Port Adelaide. In recent years, significant amounts of low alkali cement have been exported to the West Coast of U.S.A. where reactive aggregates have caused deterioration in concrete structures built using conventional cement. Golden Grove however, is the most important source of ordinary cement shale for which alkali content is less critical.

SLIDE 9

Birdwood clay pit, operated by Kaiser Aluminium and Chemical Corporation (Australia), produces a range of clay products with a number of industrial applications.

Deeply weathered aluminous shale, which is overlain by weathered sandstone, varies from, pure white kaolin to white weathered shale to red, brown and grey laminated weathered shale.

SLIDE 10

Mining at Birdwood is generally carried out over a limited period during summer months - the various grades of clay being pushed up into stockpiles and used as required, whilst the high purity white kaolin is selectively mined using a small front end loader.

M grade clay, pure white kaolin (approx. 42% $Al_2 O_3$), is selectively mined and sold to milling companies who market the kaolin as an industrial filler.

C grade clay is more siliceous clay (approx. 35% $Al_2 O_3$) with low iron content, sold to Adelaide Brighton Cement for manufacture of white cement.

R grade clay, with nominal 36% Al_2O_3 content contains up to 2% iron and is used as fireclay at the company's Beverley plant. A small amount of this clay is also milled and used as an industrial filler in applications where the whiteness of M grade kaolin is not required.

SLIDE 11

The unique Williamstown orebody is Australia's only commercial source of mica and sillimanite, as well as being an important source of high purity kaolin. The deposit is in Adelaidean metasediments which reached sillimanite grade during metamorphism.

SLIDE 12

The orebody was originally a pipe-like mass of sillimanite, kyanite, quartz, and rutile, developed within mica shist and sillimanite gneiss during metamorphism. Subsequent hydrothermal activity has altered much of the sillimanite to kaolin, and kyanite to green muscovite mica, so that the orebody, shown here, is now a mixture of kaolinised sillimanite and kaolin, with scattered boulders of unaltered sillimanite, and mica rich zones. The ore, composed of kaolin and kaolinised sillimanite, was previously marketed as 'kaosil' and contains between 40 and 55% $Al_2 O_3$.

SLIDE 13

The orebody is mined by front-end loader, then tipped over a screen to separate unaltered sillimanite boulder from the clay. Both sillimanite and highly aluminous clay are used for the manufacture of high temperature refractories, clay also being exported to Japan and England.

Approximately 1 500 to 2 000 tonnes of white kaolin from Williamstown are milled annually for use as an industrial filler in paint, rubber, vinyl, plastics and paper, although like all other South Australian kaolin, Williamstown material is too coarse for paper coating.

SLIDE 14

At present little clay is produced for ceramic and pottery industries, but this has not always been the case. At Longwood, in the Adelaide Hills, deeply weathered kaolinised sandstone was quarried, and treated to produce high purity white kaolin.

SLIDE 15

This clay, which is probably the closest of any South Australian clay to a traditional English china clay, has also been mined by underground methods. Only very small quantities have been produced in the last ten years.

SLIDE 16

Kaolinised sandstone was crushed and washed. Upcurrent classifiers separated silica from kaolin, and overflow from the classifiers gravitated into a series of levigating ponds, shown here, where kaolin settled out and dried. Two grades of kaolin were produced for use in pigments, water based paints, cosmetics, pottery ware and glazes for tiles. The separated silica was also used for manufacture of sodium silicate and fire bricks, and finely ground silica was used in polishes, cleansers and abrasives.

Similar levigation ponds were also used at Williamstown.

SLIDE 17

Immediately south of the kaolin quarry, the Longwood acid shale deposit produced weathered shale suitable for use in acid resistant bricks and pottery ware.

SLIDE 18

After the long period of tectonic stability, during which Precambrian rocks were weathered and some Permo-Carboniferous glacigene sediments were deposited, the next major episode of sedimentation in the Adelaide area was during Tertiary times. With the beginning of uplift of the Mt. Lofty Ranges, lacustrine and fluviatile sediments were deposited in three main basins.

- Barossa.
- Golden Grove.
- Maslin Beach.

SLIDE 19

These Tertiary basins are the source of almost all of Adelaide's construction sand, from deposits up to 30 m thick. They also contain white sedimentary clay, derived by erosion of weathered Adelaidean shale and deposited in lenses within the sand. This clay generally has finer particle size and lower silt content than the weathered source material. They consequently exhibit much more plastic behaviour than weathered shale and can be used as bond clay in building bricks and refractory bricks.

SLIDE 20

Gravel beds at the base of the dominantly sandy Tertiary succession, overlying weathered Adelaidean shale.

SLIDE 21

A thin lens of white plastic clay within Tertiary sand at One Tree Hill. This lens is about 25 across and 4 m thick.

SLIDE 22

At McLaren Vale, two white plastic clay lenses are mined. The upper lens is separated from the lower one by a bed of sand. Sand is stripped by scrapers, and clay mined from the face by front end loader.

SLIDE 23

This pit at Golden Grove is Adelaide's most important source of white plastic clay. Clayey sand overburden 10 to 15 m thick is stripped by elevating scrapers.

SLIDE 24

The exposed clay bed is then mined by power shovel.

SLIDE 25

Within most of the inland non-marine, Tertiary basins and palaeo-drainage channels there are extensive deposits of palygorskite (or attapulgite) clay. Palygorskite generally crops out on the margins of playa lakes, here being overlain by Pleistocene sand and gypsum.

SLIDE 26

Palygorskite is invariably associated with beds of dolomite. Although generally only about 1-3 m thick, palygorskite beds extend over many square kilometres and huge reserves of easily mineable clay are available.

Preliminary testing of palygorskite from Lake Frome has indicated slightly inferior absorbency to clay marketed at present, but recent sampling suggests that palygorskite near Coober Pedy may be marketable as an industrial absorbent, and for agricultural purposes.

Montmorillonitic clay, of Early Cretaceous age was deposited throughout the Great Artesian Basin in South Australia. Although in outcrop the clay is generally weathered to kaolin, fresh material is exposed in opal workings at Andamooka, Stuart Creek and near Coober Pedy. Samples tested to date have all been calcium rich and sub bentonitic, but further testing is warranted.

SLIDE 27

Returning to the geological map of the Adelaide area, areas shown in green are underlain by Holocene alluvial sediments containing beds of red firing plastic clay.

The early brick industry in Adelaide was founded on deposits of this material on the Adelaide plains near Brompton and Allenby Gardens and in the Torrens river valley. Urban expansion has resulted in closure of most of these clay pits although small quantities are still mined at Allenby Gardens today.

SLIDE 28

However, a number of red plastic clay deposits have been opened in Holocene alluvial sediments infilling valleys in the Adelaide Hills. This pit is near Cudlee Creek.

Another, potentially huge, source of red plastic clay is the fine tailings, or slimes, produced by sand washing operations.

SLIDE 29

Most sand producers operate washing plants, such as this one, to wash clay and silt from the sand. The fine tailings are then pumped into dams...

SLIDE 30...which contain water when in use and dry out after they are abandoned.

SLIDE 31

These dry dams are deceptive, the drying out being restricted to a thin surface layer...

SLIDE 32...beneath which is a soupy mixture of clay and water. Although research has shown that tailings up to 0.5 m thick can be dried out in shallow dams during summer months, this is not done on a routine basis by sand producers. Current production of tailings around Adelaide exceeds total plastic clay consumption, so that there is little hope of economically re-claiming tailings in abandoned dams and making available additional sand reserves at present sterilised by tailings.

SLIDE 33

In cases where the fine tailings have been dried out, as in Readymix's Highbury pit, the tailings have been used successfully in brick blends.

SLIDE 34

In closing, we'd like to give you an idea of the size of the clay mining industry in the Adelaide area.

Under the South Australian Mining Act, clay used for construction purposes, that is for the manufacture of clay bricks, tiles or pipes is classed as an extractive mineral. Clay which because of physical and chemical properties is suitable for specific purposes prescribed under the Mining Act such as the manufacture of cement, or as a refractory or filler is classed as a mineral.

Heavy clay industries use the bulk of clay produced in the Adelaide area, about 750 000 tonnes being mined in 1980.

Almost all production shown on this chart was used for the manufacture of clay bricks, with tile and pipe industries using very little in comparison.

Of this total, over 650 000 tonnes was weathered shale, with much lesser amounts, namely 95 000 tonnes and 7 000 tonnes being white plastic and red plastic clay respectively.

You will note the importance of Golden Grove as the major source of both white plastic clay and weathered shale.

SLIDE 35

Slightly less than 150 000 tonnes of industrial clay was mined in 1980, about one fifth the amount of construction clay but in contrast to construction clay where almost all production is used in the one industry, industrial clays are used for a wide variety of purposes.

About 135 000 tonnes of clay was used for cement manufacture. In 1980, all production was from weathered shale pits. With the exception of the Truro quarry, which is operated by Adelaide Brighton Cement Company solely as a cement shale pit, production is from pits which also supply other industries, mainly the brick manufacturers.

Golden Grove is the largest producer of cement shale, all production going to the Birkenhead cement plant, closely followed by Truro which supplies all the shale to Angaston works.

A little over 10 000 tonnes of clay are used annually as fire clay and for production of refractories. With the exception of the unique Williamstown orebody all recorded production is from weathered shale pits. Woodside, Birdwood and Williamstown quarries produce refractory clay of various grades, the latter two quarries also supplying approximately 2 000 tonnes of high purity white kaolin for use as a filler in a number of industrial applications.

Tregolana quarry near Whyalla is operated by BHP, and supplies fire clay to the Whyalla steel works.

In summary it may be said that a number of industries are dependant upon clay minerals, and clays are in fact...

SLIDE 36

...the building blocks of today's society.

L Barnes

LCB/AMP/GU

L.C. BARNES,

AM Pain

A.M. PAIN

MINERAL RESOURCES SECTION

SLIDES AND NOTES TO ACCOMPANY TALK

Slide 1 Generalised Geological Plan - Adelaide Metropolitan Area.

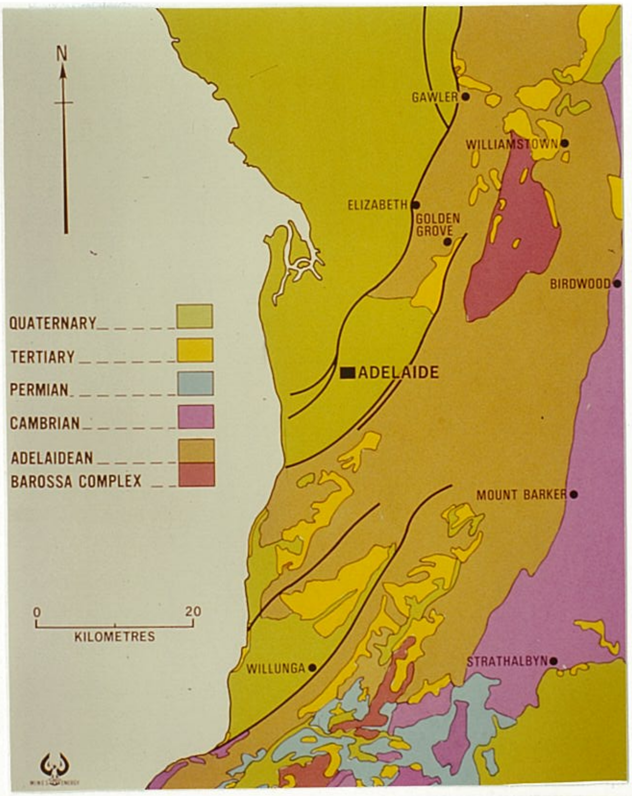
Highlight: Mount Lofty Ranges.
Core of Precambrian rocks.
Lower Proterozoic Barossa Complex in red.
Adelaidean sediments in brown.

Slide 2 Schematic Geological Cross-Section of the Adelaide area showing geological environment of clay deposits.

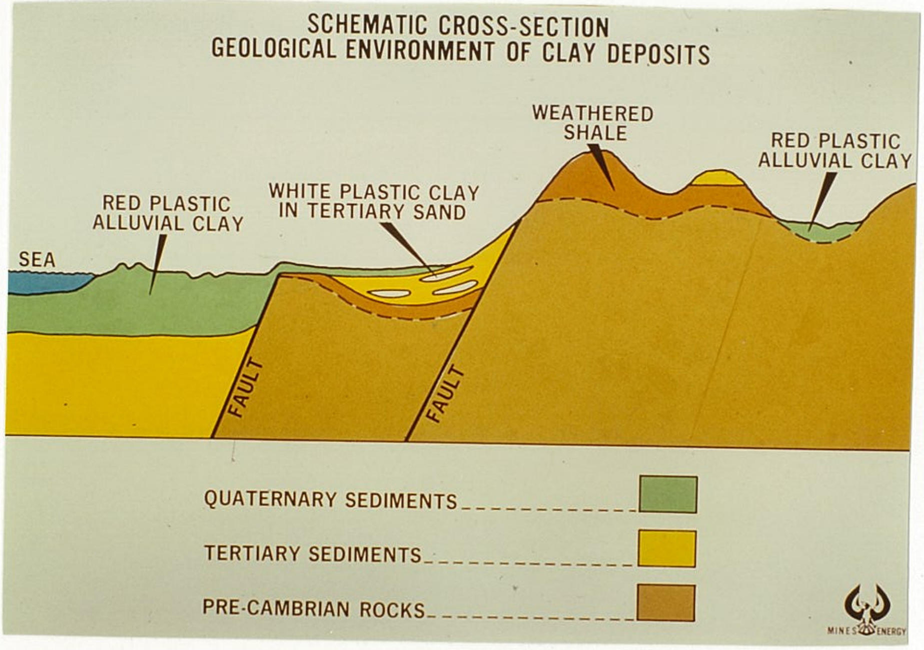
Highlight: Folded and faulted Adelaidean sediments, keeply weathered in upper part to form weathered shale.

Slide 3 Folded and faulted Adelaidean sediments - Mylor, Mount Lofty Ranges.

Highlight: Well bedded nature of moderately fresh sediments.
Moderate dip resulting from folding.
Fault zones to right of figure and on right hand side.



SLIDE 1
No. 23148



SLIDE 2
No. 23149

SLIDE 3
No. 23150

Slide 4 Baker Gully weathered shale deposit - contact of white weathered shale with red weathered shale.

Highlight: Variation in iron content of weathered shale produces either white firing, or red firing weathered shale.

Slide 5 Hallett weathered shale pit Golden Grove.

Highlight: Tertiary sand overburden, upper bench, has to be scraped off before mining. Weathered shale, white in upper part used for cream or ivory bricks, red to brown in lower part used for red and earthy coloured bricks.

SLIDE 4
No. 23151

SLIDE 5
No. 23152

Slide 6 Anstey Hill weathered shale deposit.
General view easterly, working pit in foreground, stockpiles in centre.

Highlight: Weathered shale mined by scraper, carted to stockpile to build up horizontally layered stockpiles. Front end loader loads from a vertical face onto trucks for cartage to brickworks. Method ensures thorough blending of weathered shale.

Slide 7 Hallett weathered shale pit and brickworks, Golden Grove - general view southwesterly.

Highlight: Pit produces red firing weathered shale, mined by scraper, stockpiles centre. Stockpiles of white firing weathered shale trucked in from other deposits. Brickworks adjacent to quarry to minimise transportation of low cost clay.

Slide 8 Baker Gully weathered shale deposit - general view northeasterly.

Highlight: Mining and loading red firing weathered shale.

SLIDE 6
No. 23153

SLIDE 7
No. 23154

SLIDE 8
No. 23155

Slide 9 Birdwood kaolin - silica deposit, general veiw northeasterly.

Highlight: Moderately weathered siltstone in foreground (brown) passing up into deeply weathered shale (white) overlain by weathered sandstone (orange).
Basinal structure - contact of shale and sandstone obscured by clay stockpiles centre and right.
Thin Tertiary sand on uppermost bench.

Slide 10 Birdwood kaolin - silica deposit, close up of working face.

Highlight: Pockets of high grade white kaolin selectively mined by small front-end loader.

SLIDE 9
No. 23156

SLIDE 10
No. 23157

Slide 11 Williamstown kaolin-sillimanite-mica deposits, Mt. Crawford Mine - aerial view westerly. Quarry and mine buildings in foreground, waste dump in background.

Highlight: Orebody in floor of quarry plunges steeply to north (right of photo). Ever increasing amounts of overburden have to be removed to mine orebody. New overburden removal program visible in rear face of quarry.

Slide 12 Williamstown kaolin-sillimanite-mica deposits, Mt. Crawford Mine - close up of working face, view northerly.

Highlight: High grade white kaolin orebody separated from weathered Adelaidean sediments by major fault (left centre of photo).

Note: photograph printed in reverse. This is eastern margin of orebody, fault dips steeply east.

Slide 13 Williamstown kaolin-sillimanite-mica deposits, Mt. Crawford Mine. Screening plant to separate boulders of unaltered massive sillimanite from kaolin and kaolinised sillimanite. Kaolin stockpile in shed.

SLIDE 11
No. 23158

SLIDE 12
No. 23159

SLIDE 13
No. 23160

Slide 14 Longwood clay deposit - general view southeasterly. Disused open cut workings. Underground workings out of view to left. Weathered Aldgate Sandstone overlain by weathered Skillogalee Dolomite.

Slide 15 Longwood clay deposit - underground workings.

Drive in completely kaolinised Aldgate Sandstone (white) ending in iron stained weathered sandstone.

Slide 16 Longwood clay deposit - general view southwesterly, of disused levigating ponds. Shallow concrete ponds into which kaolin water slurry was piped and kaolin allowed to settle out. When dried out the white koalin was scraped from the ponds.

SLIDE 14
No. 23161

SLIDE 15
No. 23162

SLIDE 16
No. 23163

Slide 17 Longwood clay deposit, Longwood acid shale quarry, general view northwesterly. Deeply weathered Woolshed Flat Shale used for production of acid resistant bricks. Kaolin quarry behind dump left background.

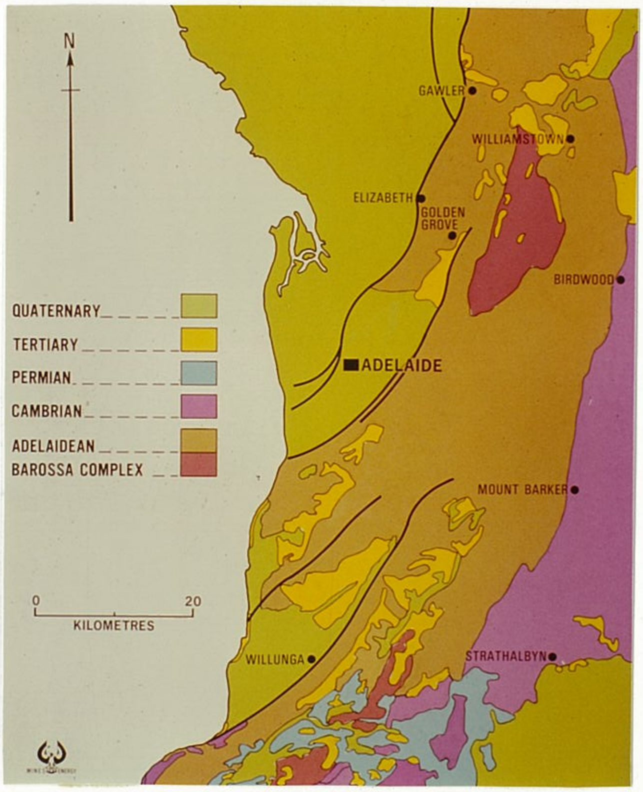
Slide 18 Generalised geological map - Adelaide Metropolitan Area.

Highlight: areas of Tertiary deposition, in fault bounded embayments on western side of Mount Lofty Ranges e.g. Willunga Embayment and in lacustrine basins within ranges e.g. Golden Grove, Gawler, Barossa. Main areas of white plastic clay accumulation on margins of embayments e.g. McLaren Vale or in lacustrine basins, Golden Grove, Gawler. One Tree Hill.

Slide 19 Schematic geological cross-section Adelaide area showing geological environments of clay deposits.

Highlight: Areas of Tertiary deposition St Vincent Basin and restricted basins in ranges. White plastic clay lenses, derived by erosion of weathered Adelaidean shale, in thick sand accumulations.

SLIDE 17
No. 23164



SLIDE 18
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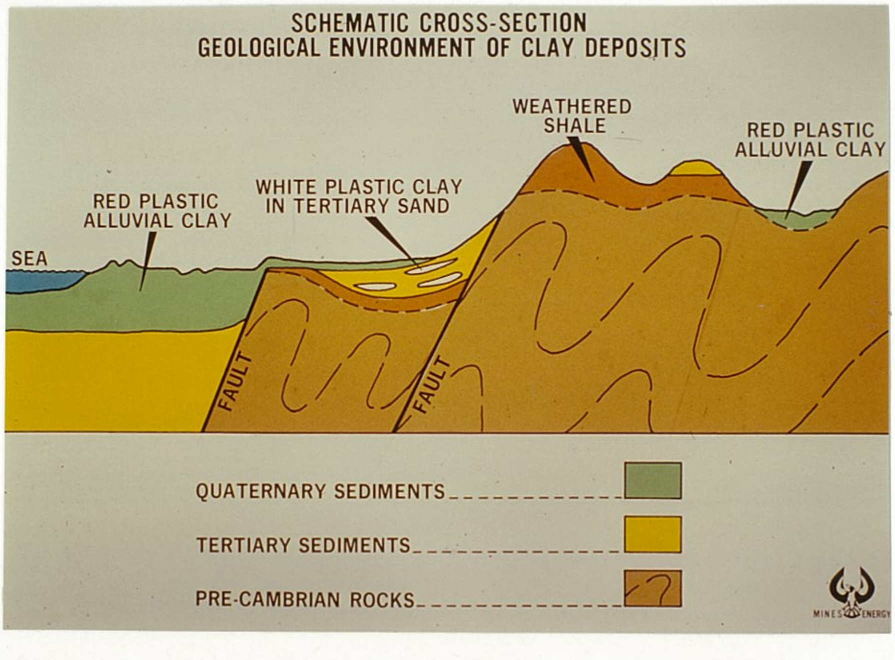
SLIDE 19
No. 23149



SCHEMATIC CROSS-SECTION
GEOLOGICAL ENVIRONMENT OF CLAY DEPOSITS

Slide 20 Tertiary gravel beds unconformably overlying brilliant white weathered Adelaidean shale, Lyndoch. The gravel passes rapidly upwards into the dominantly sandy Tertiary sequence.

Slide 21 One Tree Hill clay deposit - view easterly. White plastic clay lens in orange brown Tertiary sand. Sand rests unconformably on weathered Adelaidean shale (white). Contact is high in quarry face on left and dips down to be near floor of quarry in the centre.

Slide 22 McLaren Vale white plastic clay deposit - general view easterly. Two lenses of white plastic clay separated by orange brown sand which is being stripped by elevating scrapers. Clay is mined by front-end loader.

SLIDE 20
No. 23165

SLIDE 21
No. 23166

SLIDE 22
No. 23167

Slide 23 Fricker white plastic clay deposit Golden Grove - general view southerly. White plastic clay bed is about 10 m thick overlain by clayey sand overburden. Contact between clay and sand is prominent bench on top of clay bed.

Slide 24 Fricker white plastic clay deposit Golden Grove - close up to working face. Plastic clay is mined by power shovel.

SLIDE 23

No. 23168

SLIDE 24

No. 23169

Slide 25 Playgorskite clay outcrop in Garford Palaeochannel, COOBER PEDY. Palygorskitic and dolomitic clay (white) crop out in cliff face, overlain by gypseous sand and gypcrete. Palygorskite is also in playa lake, obscured by a thin veneer of Holocene sediment.

Slide 26 Cliff section on edge of Lake Millyera, CURNAMONA. Two thin beds of palygorskite clay (dark olive green) separated by clayey sand beneath a cap of white dolomite about 1 m thick.

SLIDE 25
No. 23170

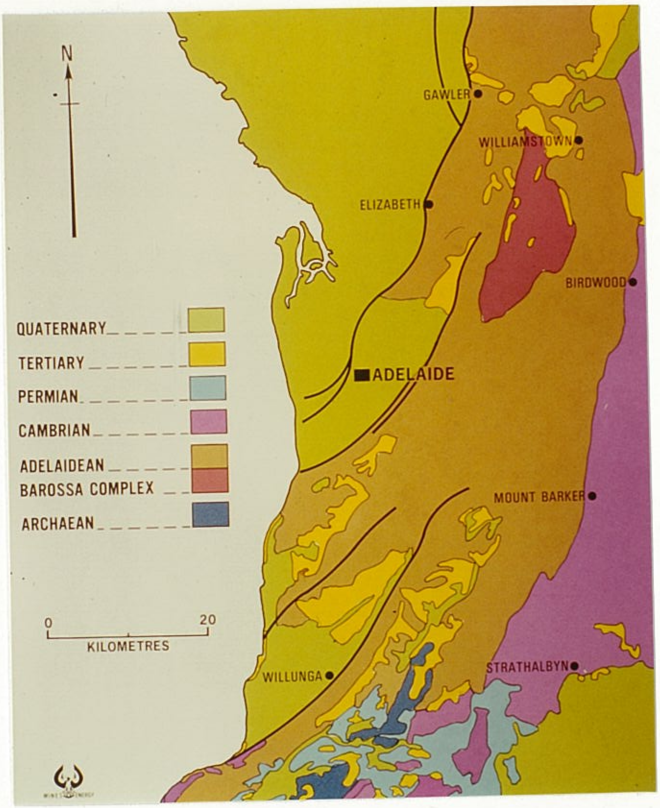
SLIDE 26
NO. 23171

Slide 27 Generalised Geological Map - Adelaide Metropolitan Area.

Highlight: Areas of Quaternary deposition on the Adelaide Plains on the western side of the Mount Lofty Ranges, and in valleys and drainage channels within the ranges.

Slide 28 Hannaford red plastic clay deposit - Cudlee Creek. Alluvial clay and silt deposited in valleys provides bulk of Adelaide's red plastic clay requirements.

Slide 29 Sand washing plant - Maslin Beach. All major sand pits operate sand washing plants to wash clay and silt from Tertiary sand. Stockpile of washed sand on left, clay water slurry pumped to slimes dam.



SLIDE 27
NO. 23148

SLIDE 28
No. 23172

SLIDE 29
NO. 23173

<u>Slide 30</u> Slimes dams, Q.I. (formerly L R and M) sand pit Gawler. Clay - water slurry pumped into ponds where clay slowly settles and some water reclaimed. In many cases, dams are located in sand pits, sterilising sand reserves.

Highlight: Quarry face showing varicoloured Tertiary sand in background.

<u>Slide 31</u> Surface crust on partially dried out slimes dam Golden Grove. Department of Mines and Energy pontoon mounted drill rig used in Department program to establish clay reserves within slime dams.

Highlight: Shrinkage cracks in surface crust attest to very high shrinkage rates of clay contained within slimes dams.

SLIDE 30

No. 23174

SLIDE 31

No. 23175

Slide 32 Clay water slurry beneath dried surface crust - slimes dam Golden Grove. Once surface crust forms slurry beneath dries extremely slowly and may remain in fluid state for many years. For effective drying of slimes ponds should be a maximum of 0.5 m deep.

Slide 33 Old slimes dam - Highbury. The clay water slurry has completely dried out and the clay dug out and used successfully in red brick blends.

SLIDE 32
No. 23176

SLIDE 33
No. 23177

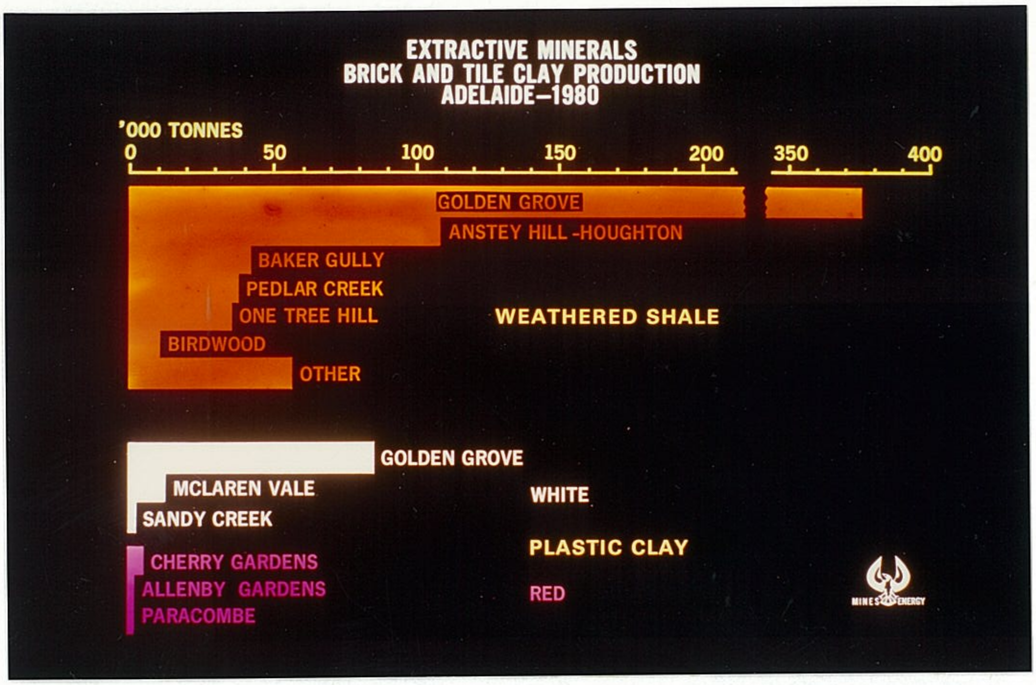
Slide 34 Chart of Brick and Tile Clay Production Adelaide 1980.

Highlight: 650 000 tonnes out of 750 000 tonnes total production is weathered shale, of which 375 000 tonnes from Golden Grove.
Golden Grove also principal producer of white plastic clay about 80 000 tonnes out of total of 95 000 tonnes.
Total red plastic clay production only about 8 000 tonnes.

Slide 35 Chart of South Australian Industrial Clay Production - 1980.

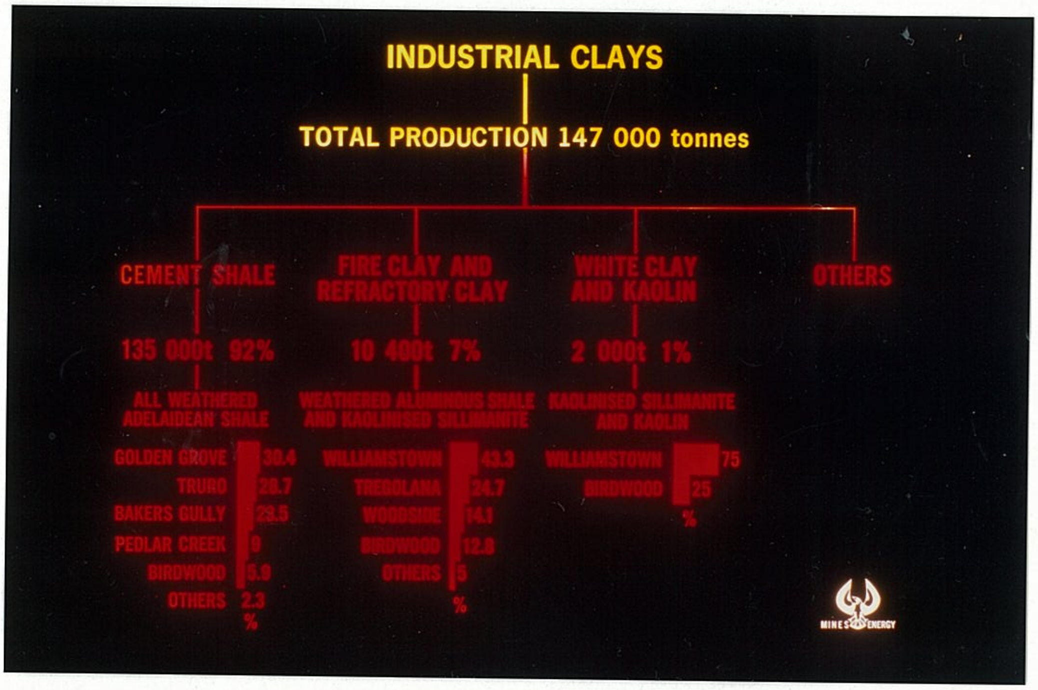
Highlight: 92% of industrial clay is used for cement manufacture, all of which is weathered shale. Apart from Truro, production is from pits which also supply brick manufacturers.
Williamstown is biggest producer of refactory clay followed by Tregolana, operated by the BHP Company, all output being used at the company's steelworks at nearby Whyalla.
Williamstown also biggest producer of white clay and kaolin.
No recorded production of pottery, ceramic or absorbent clays in 1980.

Slide 36 House bricks emerging from tunnel kiln, lined with refractory bricks.



EXTRACTIVE MINERALS
BRICK AND TILE CLAY PRODUCTION
ADELAIDE—1980

SLIDE 34
No. 23178



INDUSTRIAL CLAYS

TOTAL PRODUCTION 147 000 tonnes

SLIDE 35
No. 23179

SLIDE 36
No. 23180

FURTHER READING

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GEOLOGICAL MAPS

1: 250 000	ADELAIDE
	ANDAMOOKA
	BARKER
	COOBER PEDY
	FROME
	TORRENS
1: 63 360	Adelaide
	Mannum
	Gawler
	Echunga
1: 50 000	Preliminary Map - Resources Series
	Adelaide
	Onkaparinga

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Longwood: - Kaolin and weathered shale deposit

Olliver, J.G., and Nichol, D., 1978. Longwood Clay Deposits. Mineral Resour. Rev., S. Aust., 142: 119-132.

One Tree Hill: - White plastic clay and weathered shale deposits

Pain, A.M., and Scott, D.C. (in preparation). One Tree Hill Clay Deposits. S. Aust. Dept. of Mines and Energy report.

McLaren Vale: - White plastic clay deposit

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Barnes, L.C., Olliver, J.G., and Spencer, W.G., 1978. Reconnaissance Sampling of Palygorskite Deposits Lake Frome Area, South Australia. Mineral Resour. Rev., S. Aust., 149: 22-31.

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Cromer "C" - Kaolin deposit

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FIELD EXCURSION GUIDE

ITINERARY

8.45	a.m.	Depart CSIRO, Netherby.
8.55	a.m.	Depart Gatehouse Motel, Glen Osmond. Travel via Freeway.
9.45	a.m.	Arrive Stop 1 - Woodside fireclay deposit.
10.10	a.m.	Depart Woodside. Travel to Birdwood.
10.30	a.m.	Arrive Stop 2 -Birdwood clay and silica deposit.
11.30	a.m.	Depart Birdwood. Travel to Williamstown.
11.50	a.m.	Arrive Stop 3 - Williamstown kaolin - sillimanite - mica deposits.
12.50	p.m.	Depart Williamstown. Travel to Lyndoch.
1.05	p.m.	Lyndoch Hotel, Lunch.
1.45	p.m.	1 bus to Karrawirra Winery for tasting and sales - Return to Lyndoch Hotel.
2.45	p.m.	Depart Lyndoch. Travel via Gawler to One Tree Hill.
3.15	p.m.	Arrive Stop 4 - One Tree Hill clay deposit.
3.40	p.m.	Depart One Tree Hill. Travel via Golden Grove to Adelaide.
4.45	p.m.	Arrive Glen Osmond.

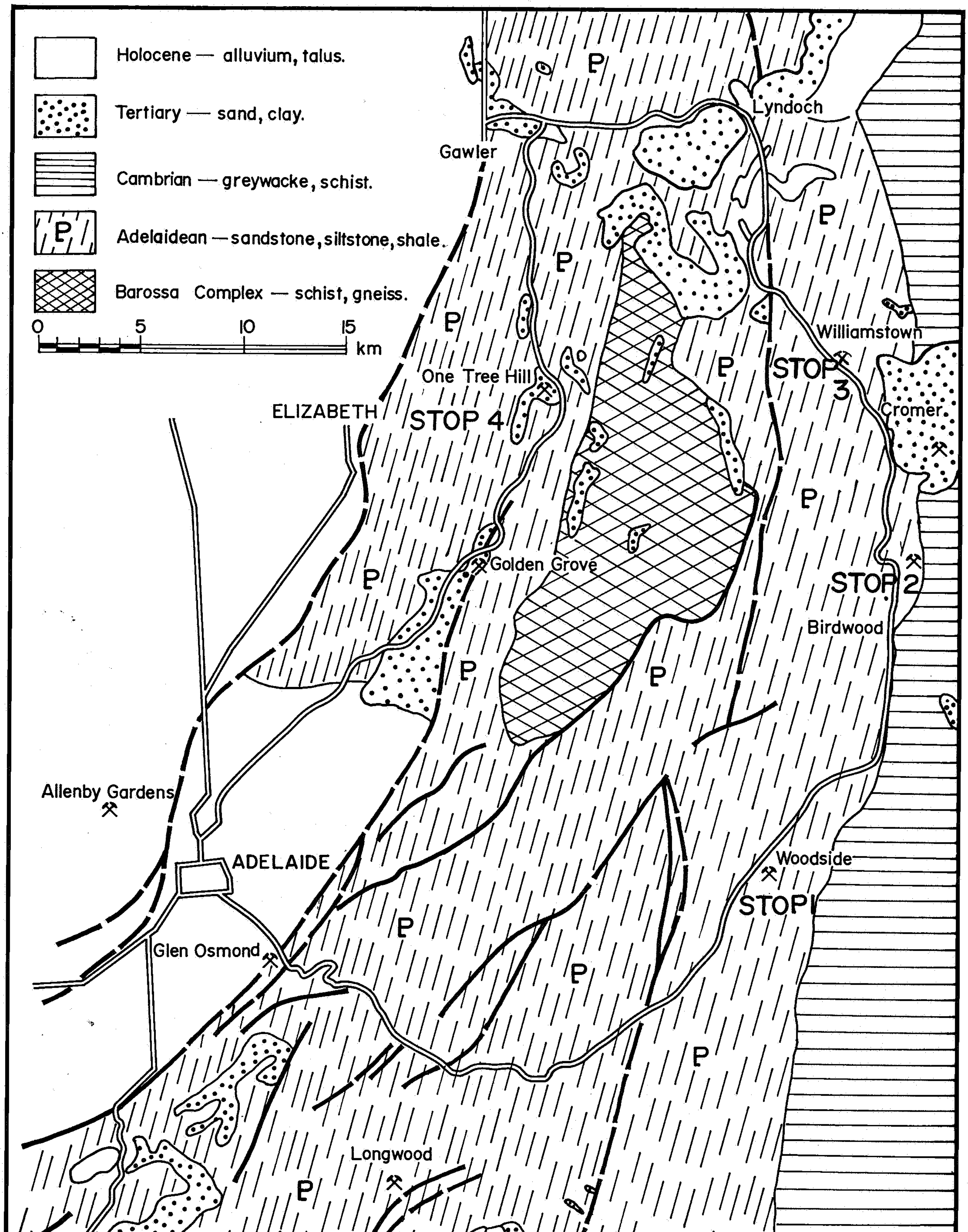


Fig. 1

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

AUSTRALIAN CLAY MINERALS SOCIETY
EXCURSION LOCALITY PLAN
(August 1982)

COMPILED

CDO 8-3-83
DATE

DRAWN D.W.W.

DATE 24·2·83

CHECKED

SCALE

PLAN NUMBER S16613

3062

STOP 1 - WOODSIDE FIRECLAY DEPOSIT, GEORGEFF'S QUARRY

Location

Section 4240, hundred Onkaparinga, 3 km north northeast of Woodside.

Mineral Tenure Private Mine No. 189. E.G. Bell

Operator D. Georgeff and Co.

History and Production

Georgeff's pit has been worked since about 1970 with production totalling 10 600 tonnes to the middle of 1980. Average production for the last few years has been about 1 500 - 2 000 tonnes/year.

Originally Mr. P. Morony, then Langbein Transport P/L., worked the fireclay pit on the southern side of the road from 1958 to 1978.

Geology (Fig. 1)

Adelaidean: Belair Subgroup - interbedded phyllite, schist and feldspathic quartzite.

The central part of the quarry is deeply weathered, laminated grey and white clay-shale and massive white claystone, which was probably originally slate. The eastern and western walls of the quarry are in weathered muscovite schist and phyllite, whilst less weathered mica schist crops out on the slopes east of the quarry. The ridge to the west is underlain by weathered feldspathic sandstone, which crops out poorly. An old building stone quarry on the edge of the road is in weathered mica schist underlying this sandstone.

All rocks strike slightly east of north and dip about 50^0 easterly. A tight synclinal fold, with small scale parasitic folds is exposed in the northern face of the quarry.

In Langbein's quarry south of the road, Tertiary conglomerate and sand unconformably overlie Adelaidean sediments.

Mineralogy and Chemistry

Weathered claystone consists of 65% kaolinite ($Al_4Si_4O_{10}(OH)_8$), 20-30% quartz and accessory muscovite. The kaolinite is primarily in the form of hallosyite.

Mineralogical analyses of claystone, and weathered mica schist are shown in Table I.

TABLE I

CLAY MINERALOGY, WOODSIDE FIRECLAY DEPOSIT

Sample 1		Sample 2	
Claystone		Weathered Schist	
Kaolinite *	Dominant	Kaolinite **	Dominant
Halite	Accessory	Quartz	Sub Dominant
Quartz	Trace-Accessory	Tourmaline?	Trace
Anatase?	Trace		
Gypsum	Trace		

* Includes abundant halloysite, some of which is hydrated halloysite.
** Includes detectable halloysite, apparently not as abundant as indicated by *. Some hydrated halloysite is present.

Recent chemical analyses of claystone and weathered mica schist are given in Table II. Sample locations are shown on Figure 1.

TABLE II

CHEMICAL ANALYSES, WOODSIDE FIRECLAY DEPOSIT

	Sample 1	Sample 2
Oxide (%)	Claystone	Weathered schist
SiO_2	47.0	68.3
TiO_2	2.15	1.12
Al_2O_3	27.9	20.3
Fe_2O_3	0.80	0.31
FeO	<0.02	0.04
MnO	<0.01	<0.01
MgO	0.35	0.09
CaO	0.08	0.05
Na_2O	1.30	0.25
K_2O	0.25	<0.10
P_2O_5	0.17	0.05
H_2O+	9.40	8.10
H_2O-	9.40	1.10
Cl	1.59	
	100.39	
Oxygen equiv. to chlorine	0.36	
TOTAL	100.0	99.7

Firing Test

See Data sheet 4.

Use

The clay is purchased by Kaiser Refractories Ltd. and is used in

1) Standard refractory bricks - 26% Al_2O_3. (37% Al_2O_3 bricks and 42% Al_2O_3 bricks, require Birdwood or Williamstown kaolin).

2) Insulating bricks - other components are sawdust and One Tree Hill clay.

3) Ladle cements.

Georgeff's clay is milled and used by Mitsubishi in foundry bond clay, as a partial replacement of expensive, imported bentonite. The crystal structure of halloysite clay is thought to be the reason this clay is suitable.

Clay and weathered schist are low in alkali (Na_2O and K_2O) content and have potential as a low alkali cement component. Adelaide Brighton Cement Co. is exporting low alkali cement to America.

STOP 2 - BIRDWOOD CLAY AND SILICA DEPOSIT

Location

Section 6397, hundred Talunga, 3 km north of Birdwood.

Mineral Tenements

ML 2917, EML 4346; ML 2951, EML 4347; ML 2994, EML 4348 - Kaiser Aluminium and Chemical Corporation (Australia) Ltd.

Mining Contractor - David Linke Contractor.

Mining History

The first mining was for alluvial gold in 1870-74, south and west of the present clay pit. Underground mining of gold bearing quartz reefs commenced in the mid 1890's and an extensive system of underground workings were developed.

Clay mining by the South Australian Portland Cement Co. Ltd. began before 1938, probably in the old open cut (Fig. 2). By 1950, high purity white clay was being mined from underground workings about 100 m west of Wickham Shaft - see Figure 2.

By 1953, operations had shifted to the area of the present pit, with several adits being driven into the hillside exploiting white clay immediately adjacent to and beneath sandstone.

All production has been from the present pit since opening in 1954.

Geology (Fig. 2)

Adelaidean: Belair Subgroup - Deeply weathered schist and siltstone overlain by friable sandstone and quartzite. The contact between deeply weathered argillaceous rocks and sandstone may be an erosional unconformity.

Regional trend of Adelaidean rocks is north-south, with moderate easterly dips, but near the clay quarry, the sediments are folded into a broad basinal structure (Fig. 3). A minor, northerly plunging, synclinal fold is exposed on the western side of the quarry.

Numerous quartz and quartz ironstone veins, up to 1 m wide, many of which are gold bearing, intrude the clay sequence.

Unconformably overlying Adelaidean sandstone is a variable thickness, generally only a few metres, of partially ferruginised Tertiary sand, which is in turn overlain in places by up to 6 m of Holocene pebbly clay.

As elsewhere in the Adelaide Hills, the degree of weathering of the argillaceous rocks is variable, although in general the deepest weathering, and hence the whitest clay is immediately beneath the sandstone. This white clay crops out very poorly around the edge of the sandstone outcrop and all exploration has been by drilling.

Chemical Analyses, Mineralogy and Firing Tests

See Data sheets 5 and 6.

Recent chemical analyses of the clay products are shown in Table III.

TABLE III

CHEMICAL ANALYSES - CLAY PRODUCTS, BIRDWOOD CLAY DEPOSIT

%	M GRADE	C GRADE	R GRADE
moisture	-=	27.0	26.6
LOI	14.8	13.3	12.9
Al_2O_3	35.4	32.0	32.9
SiO_2	46.9	51.0	51.3
Fe_2O_3	0.24	0.80	1.12
TiO_2	2.00	2.30	1.60
CaO	0.05	0.01	0.04
MgO	0.02	0.02	0.02
Na_2O	0.06	0.01	0.04
K_2O	0.02	0.01	0.02

Production

Mining is carried out by contractors over 2-4 months during the summer, with the clay being stockpiled and removed as required.

The southern part of the open cut has been worked out and rehabilitation has commenced. Further quarry development will be north northeasterly and downwards, as drilling in the pit indicates additional reserves of good quality clay at depth.

Increasing amounts of sandstone overburden will have to be removed to reach the clay and markets are required for this material.

Output comprises 3 clay products and 2 silica products. Total production has been about 10 000 tonnes per annum for many years.

Clay Products

1. M GRADE CLAY (nominally 35-40% Alumina) formerly K2 Grade - supplied to ACI - Tennant at Beverley. This, the purest kaolin, is extremely clean and white. In 1980, production was about 550 tonnes. This finely milled white clay is used as a filler in the manufacture of paper and rubber, and also in the paint-making industry.

2. C GRADE CLAY (nominally 35% Alumina) formerly Kl Grade or R (A) Grade - Supplied to Adelaide Brighton Cement Ltd (ABC), Angaston, South Australia.

Semi-blended cream to buff coloured clay with an iron content of 0.8%. More siliceous than M Grade clay, evident when the clay is chewed. 1980 production was slightly more than 8 000 tonnes. This clay is used in the production of white cement and grout.

3. R GRADE CLAY (36% Alumina) formerly Kl Grade or R (B) Grade).

This clay is stockpiled and blended for use as a refractory grade clay at Kaiser Refractories' Beverley plant. It is similar to C Grade clay except that iron contents up to 2% are tolerated. This may occasionally result in a slightly higher alumina content. Annual production varies between nil and 10 000 tonnes, dependent on availability and demand for material. 1980 production was about 1 300 tonnes. Often, it is stockpiled during C Grade extraction when iron content becomes unsuitable for ABC. The clay is used by Kaiser Refractories Ltd as one of the basic ingredients in the manufacture of refractory bricks.

Finally milled R grade clay is used as filler in applications where pure white clay is not required, such as in rubber and vinyl, and up to 1 000 tonnes is sold to ACI - Tennant for this purpose.

Low grade, (22-27% Alumina) cream coloured miaceous and siliceous clay is found adjacent to M, C and R grade clays, both laterally and at depth, and markets are being sought for this clay.

Silica Products

1. Refractory Silica

Small quantities of silica sand are used by Kaiser Refractories for silica refractory bricks. Production in 1980 totalled nearly 700 tonnes.

2. Sand and Rubble

Local councils purchase small amounts of sand each year for road repairs.

The sand is suitable for building purposes and with treatment may be suitable for glass sand. The possibility of marketing large quantities of sand is at present being investigated.

STOP 3 - WILLIAMSTOWN KAOLIN - SILLIMANITE - MICA DEPOSITS

Location

Sections 941, 942, 950 and 3101, hundred Barossa, county Adelaide, 3 km SE of Williamstown.

Mineral Tenure

Private Mine No. 13 - B.H. MacLachlan Pty. Ltd.

Operator

Australian Industrial Minerals N.L.

History and Production

The Williamstown deposits comprise four separate ore bodies.

- Mt. Crawford Mine, section 950, the main quarry.
- Springfield Mine, section 3101.
- Warren Mine, section 942.
- Small unnamed deposit, section 941.

White kaolinitic clay, previously referred to as dickite, was discovered at Williamstown on the Warren property in the early 1900's. Broken Hill Proprietary Limited (BHP) commenced mining in section 941 under an agreement with the landowner, probably in 1904 and 1905, but soon transferred operations to section 950, the Mt. Crawford Mine. The clay was used in the manufacture of zinc retorts.

BHP, and, after 1915, Broken Hill Associated Smelters (BHAS) worked the mine up to 1936, when operations were taken over by Industrial Metals, a company set up initially to mine rutile, but under the terms of its agreement had to supply 500 tons of clay per year to BHAS.

Industrial Metals changed their name to Australian Industrial Minerals N.L. (AIM) in 1948 and worked Mt. Crawford Mine and Springfield Mine.

Operations ceased at Springfield Mine in about 1960, but the deposit was recently reopened, principally to supply a growing market for mica.

Production from Mt. Crawford and Springfield Mines is not differentiated in Departmental records. Together, these two deposits have produced nearly 222 000 tonnes of fireclay and kaolin, nearly 28 000 tonnes of sillimanite and over 26 000 tonnes of mica up to 1981.

Warren Mine was worked by Torrens Mining Company (who were also mining talc at Gumeracha) from 1933 to 1960, producing fireclay initially, and later sillimanite and mica. The deposit was subsequently held by Newbold Refractories, but little work was done, that company preferring to purchase their fireclay requirements from AIM. 15 600 tonnes of fireclay and 350 tonnes of sillimanite have been produced from Warren Mine.

Small quantities of kyanite are also produced, notably from Springfield Mine, although production is generally grouped with sillimanite, and about 1 000 tonnes of weathered shale, Warren Shale, have been produced from Mount Crawford Mine for use in bricks.

Geology (Fig. 4)

Adelaidean: Burra Group shale, siltstone and feldspathic quartzite has been metamorphosed and metasomatised, resulting in formation of muscovite and biotite quartz schist, quartz sillimanite gneiss and sillimanite quartzite. Accessory minerals include kyanite, rutile and garnet.

Large pipe like segregations of sillimanite, kyanite, rutile and quartz developed within the schist sequence. Hydrothermal activity, probably associated with late stage pegmatite intrusion, has altered much of the sillimanite to kaolin, and kyanite to green muscovite mica. Faulting has resulted in formation of muscovite shear zones.

At Mt. Crawford Mine the orebody is in two parts, both roughly elliptical and plunging northerly at about 70°, see Figure 3.

The northern, or main orebody, comprises kaolin and kaolinised sillimanite (kaosil), with scattered masses and pods of unreplaced sillimanite. This massive sillimanite, or 'rock' as it is called, comprises about 5% to 10% of the orebody.

The southern orebody contains less sillimanite and more mica, and the kaolin is discoloured by iron staining.

East of the main orebody, deeply weathered schist is exposed. This clay (called Warren Shale) contains between 25% and 35% Al_2O_3 and is moderately plastic. Small quantities have been mined and used for brick manufacture, and as a bond clay in refractories.

At Springfield Mine, the orebody is a steeply northerly plunging kaolin mica mass, with several broad mica rich zones, contained within complexly folded biotite schist. There is little massive sillimanite within the orebody, but some sillimanite has been mined from sillimanite quartzite adjacent to the kaolin-mica orebody.

Chemical analyses and firing tests of

- kaolinised sillimanite (kaosil)
- white kaolin
- Warren Shale

from Mt. Crawford Mine, and clay from Springfield Mine are given in data sheets 8, 9, 10 and 11.

Production and Use

Williamstown kaolin and kaolinised sillimanite, with alumina content ranging from 35% to nearly 50% is used extensively for the production of refractories, and is exported to both England and Japan for this purpose. About 6 500 tonnes of clay was produced in 1980, of which about 70% was used as fireclay.

'Rock' sillimanite (60% Al_2O_3) is also used for production of high temperature refractories, all production being sold to Nonporite in Melbourne. The massive, tough, rock has to be broken up by calcining before use. Production averaged about 600 tonnes/annum for many years but has fallen recently to 330 tonnes in 1981.

White kaolin, which generally contains some mica, is sold to both ACI-Tenement and Steetley Industries who mill the clay for use as filler in paint, plastic, rubber, paper, floor coverings, glass, cosmetics, adhesives and inks. Kaolin is too coarse grained for use in paper coating. About 2 000 tonnes of Williamstown kaolin is used annually as filler.

Fine grained muscovite mica is also used as filler, predominantly in paint, where mica flakes align on the surface giving added protection. Mica is also used in welding rods, and in plaster board, and as a dusting agent between two surfaces likely to adhere, such as in foundry moulds and rolled adhesives, and for Christmas decorations, 'Santa Snow' etc.

About 3 200 tonnes of mica were produced from Williamstown in 1980. Small amounts of clay are tolerated in the mica product, being an aid to milling.

STOP 4 - ONE TREE HILL CLAY AND SHALE PIT

Location

Section 4357, hundred Munno Para. 30 km northeast of Adelaide, and 4 km northeast of One Tree Hill.

Mineral Tenure

Private Mine 133 - Kaiser Aluminium and Chemical Corporation (Aust.) Ltd.

Operator

Kaiser.

Production

Annual production of 1-2 000 tonnes of white plastic clay ceased in 1978, alternative supplies being obtained from Clay and Mineral Sales white plastic clay pit at Golden Grove.

Between 1979 and 1981, approximately 80 000 tonnes of white weathered shale was sold to P.G.H. for brick manufacture. Recently, P.G.H. has negotiated access to an alternative source of One Tree Hill shale in Private Mine 88, immediately west of Kaiser's pit.

Geology

Adelaidean unconformably overlain by Tertiary: Interbedded quartzite, siltstone and shale were deeply weathered and leached in Late Palaeozoic and Mesozoic times. A sequence of lacustrine sand, gravel, sandy clay and locally developed lenses of white plastic clay was deposited during the Tertiary Period. Although carbonaceous clays have been found in the area, they have failed to yield palynological samples. Age of the Tertiary sediments is presumed to be similar to those in the Golden Grove basin 8 km to the southeast, where palynological samples suggest an Upper Middle Eocene age.

Tertiary sediments at One tree Hill reached thicknesses in excess of 50 m and were deposited on a land surface with relief comparable to present day topography.

The extent of Tertiary sediments is shown on the accompanying plan and cross-section (Fig. 5).

Extensive drilling by Kaiser Aluminium and Chemical Corporation has shown that the plastic clay lens, which reaches maximum thickness of 16 m in section 4357, extends southwards into section 4363, which is held under EML 4493.

Uses

1. White plastic clay was used formerly at Kaiser's Beverley plant as bond clay for refractory products. This clay has also been used in ivory brick and pipe manufacture.

2. Substantial quantities of weathered shale have been used in brick manufacture.

Firing Tests

Firing test of weathered shale is presented in data sheet 12. No firing test on One Tree Hill white plastic clay have been done by S.A. Department of Mines and Energy, but a firing test on Golden Grove white plastic clay is included, see data sheet 13.

CLAY FIRING TEST

DATA SHEETS

P.G.H. GLEN OSMOND SHALE - CR 617

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
800	1.2	20.1		Red Buff	Very Soft
850	1.7	20.1		"	"
900	1.8	19.7		"	"
950	2.1	18.9		"	Soft
1000	2.9	16.7		Light Red	Soft
1050	5.0	11.0		"	Slightly harder
1100	9.2	1.3		Dark Brown	Very Hard
1150	7.1	0.1		V. dr. Brown	Vitrified, bloating starting.

SIZING ANALYSIS

Less than (micron)	%
1	4.3
2	15.2
3	24.6
4	34.3
5	43.3
6	51.5
7	60.7
8	67.0
10	74.7
15	82.0
20	87.9
25	100.0
50	100.0

GRIT + 300# BSS 44.2%

CHEMICAL ANALYSIS

SiO_2	63.70
Al_2O_3	12.90
Fe_2O_3	4.90
FeO	1.80
MgO	4.80
CaO	0.75
MnO	0.10
Na_2O	1.60
K_2O	3.00
TiO_2	1.35
SO_3	0.14
Cl	0.08
CO_2	0.45
H_2O+	3.25
LOI	4.50

MINERALOGICAL COMPOSITION

Feldspar	
Quartz	25
Mica	
Vermiculite	
Chlorite	
Kaolin	
Geothite	

LONGWOOD KAOLIN - CR 119

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
1000				SL. Pink	Friable
1200	14.3			SL. Buff	Friable
1300	15.3			Off. White	
1500				White	No sign of fusion

SIZING ANALYSIS

GRIT
+ 15 mic. 32%

Less than (micron)	%
1	2.0
2	4.0
5	26.0
10	49.0
15	68.0

CHEMICAL ANALYSIS

SiO_2	49.1
Al_2O_3	36.4
Fe_2O_3	0.38
MgO	0.48
CaO	0.18
Na_2O	0.48
K_2O	0.28
TiO_2	0.33
Cl	0.07
H_2O+	12.3

MINERALOGICAL COMPOSITION

- Kaolinite
- Quartz
- Mica
- Tourmaline

LONGWOOD ACID SHALE CR 118

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
1000	1.7			Light Buff	Friable
1200	14.9			Gr-Yellow	Hard, Apparently vitrifing
1300	8.4			Black-Wh.	Spotted, hard rough surface. Well vitrified. Slight bloating

SIZING ANALYSIS

GRIT
+ 15 mic 20%

Less than (micron)	%
1	6.0
2	8.0
5	24.0
10	51.0
15	80.0

CHEMICAL ANALYSIS

No Chemical analysis available.

MINERALOGICAL COMPOSITION

Kaolinite	Coarse
Mica	
Quartz	Fine
Tourmaline	
Zircon	
Calcite	

Key

D	Dominant
CD	Co-Dominant
SD	Sub-Dominant (15-30%)
A	Accessory (5-15%)
Tr	Trace (5%)

GEORGEFF WOODSIDE FIRECLAY - A396/77

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
40	6.3	-	-	Greyish white N9/N8	Satisfactory
105	6.2	-	-	Greyish white N9/N8	Satisfactory
850	6.9	25.1	Soft	Greyish pink 5R 8/2	Satisfactory
900	7.4	24.8	Soft	" "	"
950	8.3	23.6	"	" "	"
1000	9.1	23.6	"	" "	Slight yellow efflorescence
1050	8.9	23.6	"	" "	"
1100	9.2	22.8	Moderate	Pinkish grey 5yr 8/1	"
1150	10.4	19.8	"	" "	"
1200	12.2	16.6	"	White N9	"
1250	12.5	14.6	Hard	White N9	"

SIZING ANALYSIS

CHEMICAL ANALYSIS

SiO_2	56.66
TiO_2	1.82
Al_2O_3	27.01
Fe_2O_3	1.17
FeO	.04
MnO	$<$ .01
MgO	.23
CaO	.22
Na_2O	.25
K_2O	.39
P_2O_5	.11
H_2O+	8.42
H_2O-	1.59
TOTAL	97.91

MINERALOGICAL COMPOSITION

Kaolinite	D
Quartz	SD
Muscovite	A
Talc	Tr
Tourmaline	Tr

Key

D Dominant
SD Sub-Dominant (15-30%)
A Accessory (5-15%)
Tr Trace (5%)

Halloysite detected by electron microscopy

KAISER'S BIRDWOOD M. GRADE KAOLIN - CR 727

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments	
40	2.9	-	-	White N9	Ext. Cracking	Slight scumming
105	2.5	-	-	"	"	"
800	5.0	36.2	Soft	"	"	Yellow scumming
850	6.0	35.7	Soft	"	"	Slight yellow scumming
900	6.8	33.2	Soft	"	"	"
950	7.1	31.3	Soft	"	"	"
1000	7.5	31.1	Soft	"	"	"
1050	7.8	30.4	Soft	"	"	"
1100	8.3	29.0	Soft	"	"	
1150	9.3	25.1	Moderate	"	"	
1200	11.0	21.3	Moderate	"	"	

SIZING ANALYSIS

GRIT

+ 53 um (+ 300 #)	12

SEDIMENTATION

wt % finer than

44 um	88
31 um	85
22 um	75
1~~5~~6 um	67
8 um	57
4 um	38
2 um	31
1 um	25

CHEMICAL ANALYSIS

SiO_2	44.48
TiO_2	1.48
Al_2O_3	36.45
Fe_2O_3	0.18
FeO	0.02
MnO	< 0.01
MgO	0.03
CaO	1.64
Na_2O	0.01
K_2O	0.09
P_2O_5	0.07
H_2O+	13.72
H_2O-	0.48
V_2O_5	0.030
TOTAL	98.68
TOTAL SOLUBLE SALTS	0.09

MINERALOGICAL COMPOSITION

KAOLINITE	D
MUSCOVITE	Tr
QUARTZ	Tr
CALCITE	Tr-A

- 2 micron Mineralogy

% of total Mineralogy	46
Kaolinite	D

Key

D	Dominant
CD	Co-Dominant
SD	Sub-Dominant (15-30%)
A	Accessory (5-15%)
Tr	Trace (<5%)

KAISER'S BIRDWOOD R. GRADE KAOLIN CR709

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments	
40	0.9	-	-	Very pale orange 10 yr 8/2	External cracking	
105	0.6	-	-	" "	"	"
800	1.7	30.6	Moderate	Light orange pink 5 yr 9/4	"	"
850	1.8	30.6	"	" "	"	"
900	2.3	29.6	"	" "	"	"
950	3.4	28.8	"	Greyish orange pink 10 r 8/2	"	"
1000	2.1	28.6	"	" "	"	"
1050	3.9	28.3	"	" "	"	"
1100	4.0	27.7	"	White N9	"	"
1150	4.2	21.8	F. Hard	" "	"	"
1200	7.3	16.2	Hard	" "	"	"Scummed

SIZING ANALYSIS

GRIT + 53 μm (300 #)	40.4
SEDIMENTATION wt % finer than	
44 μm	66.2
31 μm	66.2
22 μm	61.6
16 μm	56.7
8 μm	48.7
4 μm	43.8
2 μm	34.6
1 μm	28.3

CHEMICAL ANALYSIS

SiO_2	52.33
TiO_2	1.51
Al_2O_3	31.81
Fe_2O_3	.73
FeO	.41
MnO	< .01
MgO	.08
CaO	.10
Na_2O	.03
K_2O	.11
P_2O_5	.01
H_2O+	12.06
H_2O-	.08
CO_2	.09
TOTAL	99.44
V_2O_5(ppm)	375.

MINERALOGICAL COMPOSITION

Quartz	A
Kaolinite	D
Mica/illite (muscovite type)	A
Talc	Tr
Calcite	Tr

- 2 micron Mineralogy

% of total Mineralogy 35

Kaolinite	D

Key

D	Dominant
CD	Co-Dominant
SD	Sub-Dominant (15-30%)
A	Accessory (5-15%)
Tr	Trace (<5%)

CROMER C. KAOLIN CR 606

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
800	8.9	40.0		Off white	Soft
850	9.1	39.8		"	"
900	9.2	39.8		"	"
950	9.2	39.6		"	"
1000	9.2	39.6		"	"
1050	9.3	39.5		"	"
1100	9.3	39.5		"	"
1150	9.4	39.4		"	Still friable
1200	9.6	38.6		"	

SIZING ANALYSIS

GRIT
+ 50 mic 45%

less than (micron)	%
1	3.0
2	9.0
3	16.0
4	22.0
5	28.0
6	35.0
7	41.0
8	47.0
10	58.0
15	73.0
20	84.0
25	89.0
50	100.0

CHEMICAL ANALYSIS

- 200 mesh

SiO_2	46.10
Al_2O_3	37.30
Fe_2O_3	1.50
FeO	0.35
MgO	0.29
CaO	0.17
MnO	<0.01
Na_2O	<0.01
K_2O	<0.25
TiO_2	0.14
SO_3	0.13
Cl	0.02
CO_2	0.20
H_2O+	14.40
H_2O-	0.74

MINERALOGICAL COMPOSITION

- 200 mesh

Kaolinite	Dom
Quartz	2.3

WILLIAMSTOWN - MT. CRAWFORD MINE - Highly Aluminous Fireclay (Kaosil) CR 130/3

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
1200	8.4			White	No gain in strength
1300	13.1			"	No sign of vitrifying
1400	17.1			"	No sign of vitrifying
1500				"	No sign of vitrifying

SIZING ANALYSIS

GRIT

+ 15 mic 42%

less than (micron)	%
1	7.0
2	9.0
5	23.0
10	38.0
15	58.0

CHEMICAL ANALYSIS

SiO_2	43.1
Al_2O_3	48.2
Fe_2O_3	0.30
MgO	0.12
CaO	0.04
Na_2O	0.18
K_2O	0.41
TiO_2	0.04
Cl	0.01
H_2O+	8.05

MINERALOGICAL COMPOSITION

Kaolinite
Dickite
Sillimanite
Quartz
Damourite
Rutile
Kyanite
Diaspore
Limonite

WILLIAMSTOWN - MT. CRAWFORD MINE - WHITE KAOLIN - CR 592

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
800	3.4	29.8		light brown	Very soft
850	3.9	29.8		"	"
900	4.1	29.8		"	"
950	4.2	29.2		Off white	"
1000	4.2	29.2		"	"
1050	4.6	29.2		"	"
1100	4.9	29.0		White	"
1150	5.6	28.2		"	"
1200	6.6	26.2		"	"

SIZING ANALYSIS

GRIT
+ 50 mic 56%

Less than (micron)	%
1	2.0
2	7.0
3	13.0
4	17.0
5	18.0
6	20.0
7	32.0
8	41.0
10	47.0
15	64.0
20	72.0
25	92.0
50	100.0

CHEMICAL ANALYSIS

SiO_2	45.40
Al_2O_3	43.50
Fe_2O_3	0.48
FeO	0.13
MgO	0.08
CaO	0.11
MnO	< 0.01
Na_2O	0.26
K_2O	0.21
TiO_2	1.11
SO_3	< 0.01
Cl	< 0.01
CO_2	0.36
H_2O+	8.45
H_2O-	0.23

MINERALOGICAL COMPOSITION

- 2 micron

Quartz	15
Kaolinite	> 50
Chlorite	5-20
Illite	< 5

WILLIAMSTOWN - MT CRAWFORD MINE - WARREN SHALE   CR 593

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
800	8.4	26.1		Fawn	Soft
850	8.6	26.1		"	"
900	9.8	25.2		"	"
950	8.2	23.7		"	Still friable
1000	10.6	23.3		Light fawn	" "
1050	10.9	23.0		" "	" "
1100	11.1	21.8		" "	" "
1150	12.8	17.7		Brownish	Harder
1200	15.7	14.1		"	"

SIZING ANALYSIS

GRIT
+ 50 mic 21%

Less than (micron)	%
1	2.0
2	7.0
3	9.0
4	14.0
5	18.0
6	20.0
7	23.0
8	28.0
10	36.0
15	50.0
20	56.0
25	70.0
50	100.0

CHEMICAL ANALYSIS

SiO_2	60.3
Al_2O_3	25.9
Fe_2O_3	0.75
FeO	0.07
MgO	0.45
CaO	0.12
MnO	< 0.01
Na_2O	0.50
K_2O	0.41
TiO_2	1.14
SO_3	0.07
Cl	0.75
CO_2	0.21
H_2O+	9.55
H_2O-	1.30

MINERALOGICAL COMPOSITION

- 2 microns

Quartz	< 3
Kaolinite	> 50
Illite	< 5
Chlorite	5-20

WILLIAMSTOWN - SPRINGFIELD MINE - ALUMINOUS FIRE CLAY - CR130/1

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative Hardness	Munsell Colour	Comments
1200	8.4			White	No gain in strength
1300	13.1			"	No sign of vitrifying
1400	17.1			"	No sign of vitrifying
1500				"	"

SIZING ANALYSIS

GRIT
+ 15 mic. 42%

less than (micron)	%
1	7.0
2	9.0
5	23.0
10	38.0
15	58.0

CHEMICAL ANALYSIS

SiO_2	44.1
Al_2O_3	42.0
Fe_2O_3	0.63
MgO	0.14
CaO	0.02
Na_2O	0.08
K_2O	0.02
TiO_2	0.05
H_2O+	13.0

MINERALOGICAL COMPOSITION

Kaolinite
Dickite
Silli.
Quartz
Damourite
Rutile
Kyanite
Diaspore
Limonite

KAISER'S REFRACTORIES WEATHERED SHALE - ONE TREE HILL CR 737

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
40	2.6	-	-	Very pale orange 10 yr 8/2	External cracking
105	2.6	-	-	" "	" "
800	2.5	19.2	Moderate	Moderate orange pink 5 yr 8/4	" "
850	3.~~8~~3	19.3	"	" "	" "
900	3.1	19.2	"	" "	" "
950	3.3	18.8	"	" "	" "
1000	3.7	17.7	"	Light orange pink 5 yr 9/4	" "
1050	4.3	16.0	Hard	" "	" "
1100	5.6	12.9	"	Light greyish orange 10 yr 8/4	" "
1150	6.4	10.7	"	Greyish yellow 5 y 8/4	" "
1200	6.7	9.8	"	Yellowish grey 5 y 7/2	" "

SIZING ANALYSIS

GRIT + 53 um (300 #)	34

Sedimentation
wt % finer than

44 um	66
31 um	64
22 um	63
16 um	59
8 um	53
4 um	44
2 um	35
1 um	29

S.G. 2.59

CHEMICAL ANALYSIS

SiO_2	67.3
TiO_2	1.41
Al_2O_3	19.9
Fe_2O_3	1.10
MnO	< 0.01
MgO	0.48
CaO	0.06
Na_2O	0.08
K_2O	1.60
P_2O_5	0.04
V_2O_5	0.026
L.O.I.	7.46
TOTAL	99.5

MINERALOGICAL COMPOSITION

Quartz	SD
Mica/illite	A
Kaolinite	D

- 2 micron Mineralogy

% of total mineralogy 35

Mica/illite	Tr-A
Kaolinite	D
Montmorillonite (poorly defined interstratified material)	Tr

Key
D Dominant
CD Co-Dominant
SD Sub-Dominant (20%)
A Accessory (approx. 5-20%)
Tr Trace (<5%)

FRICKER'S GOLDEN GROVE PLASTIC CLAY - CR705

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
40	5.1	-	-	White N9	Satisfactory
105	4.9	-	-	Very light grey N8	Scummed
800	4.7	18.1	Moderate	Moderate orange pink 5 yr 8/4	"
850	5.2	17.8	"	" "	"
900	5.3	17.2	"	" "	"
950	5.4	16.5	F. Hard	" "	"
1000	6.2	14.5	Hard	" "	"
1050	8.4	12.3	"	Dark orange pink 5 yr 7/4	"
1100	10.3	6.0	"	Greyish orange 10 yr 7/4	Scummed self glazing
1150	10.7	4.6	"	Yellowish grey 5 y 7/2	" "
1200	10.9	3.1	"	" "	" "

SIZING ANALYSIS

GRIT	
+ 53 μm (300#)	7.2

SEDIMENTATION

wt % finer than

44 μm	93.2
31 μm	86.9
22 μm	81.2
16 μm	76.7
8 μm	70.7
4 μm	62.9
2 μm	54.9
1 μm	46.9

CHEMICAL ANALYSIS

SiO_2	58.64
TiO_2	2.15
Al_2O_3	24.40
Fe_2O_3	1.31
FeO	.17
MnO	< .01
MgO	.69
CaO	.16
Na_2O	.30
K_2O	1.93
P_2O_5	.04
H_2O+	9.02
H_2O-	.09
CO_2	.11
TOTAL	99.01
V_2O_5 (ppm)	295.

MINERALOGICAL COMPOSITION

Quartz	SD
Kaolinite	D
Mica/illite muscovite type	SD
Feldspar	Tr
Gypsum	Tr
Talc	Tr

- 2 micron Mineralogy

% of total Mineralogy 55

Kaolinite	D
Mica/illite (muscovite type) with some montmorillonite interstratifraction	SD

Key

D	Dominant
CD	Co-Dominant
SD	Sub-Dominant (15-30%)
A	Accessroy (5-15%)
Tr	Trace (<5%)

HALLETTS ALLENBY GARDENS RED PLASTIC CLAY CR87

DRYING AND FIRING PROPERTIES

Temp. °C	% Total Shrinkage	% Absorption	Relative. Hardness	Munsell Colour	Comments
850	6.0	10.5			
900	7.0	9.9			
950	7.0	9.6			
1000	8.0	9.1			
1050	8.0	7.5			

SIZING ANALYSIS

GRIT
+ 50 mic 26%

Less than (micron)	%
10	65.0
25	69.0
50	74.0

CHEMICAL ANALYSIS

SiO_2	64.1
Al_2O_3	15.1
Fe_2O_3	5.81
FeO	0.37
MgO	2.16
CaO	1.82
Na_2O	1.01
K_2O	2.19
TiO_2	1.03
SO_3	0.04
Cl	0.03
CO_2	1.33
H_2O+	4.75

MINERALOGICAL COMPOSITION

PLANS TO ACCOMPANY
EXCURSION GUIDE

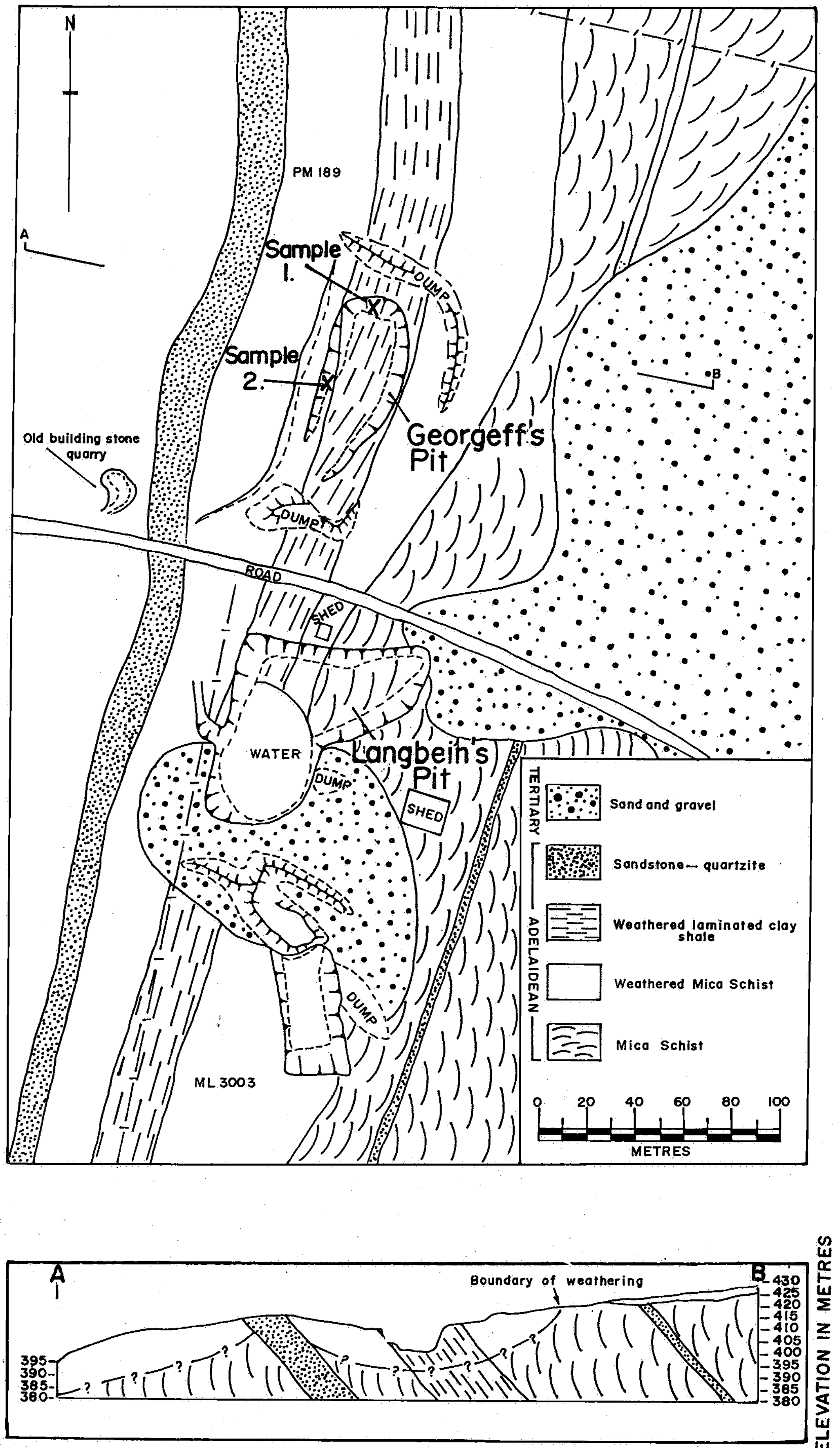


Fig. 2

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

WOODSIDE FIRECLAY DEPOSIT
SECS. 4140, 4141 : HD. ONKAPARINGA
GEOLOGICAL PLAN AND SECTION

COMPILED	WR C.D.O	8.3.83 DATE
DRAWN D.W.W.	SCALE	
DATE 24.2.83	PLAN NUMBER	
CHECKED	S 16614	

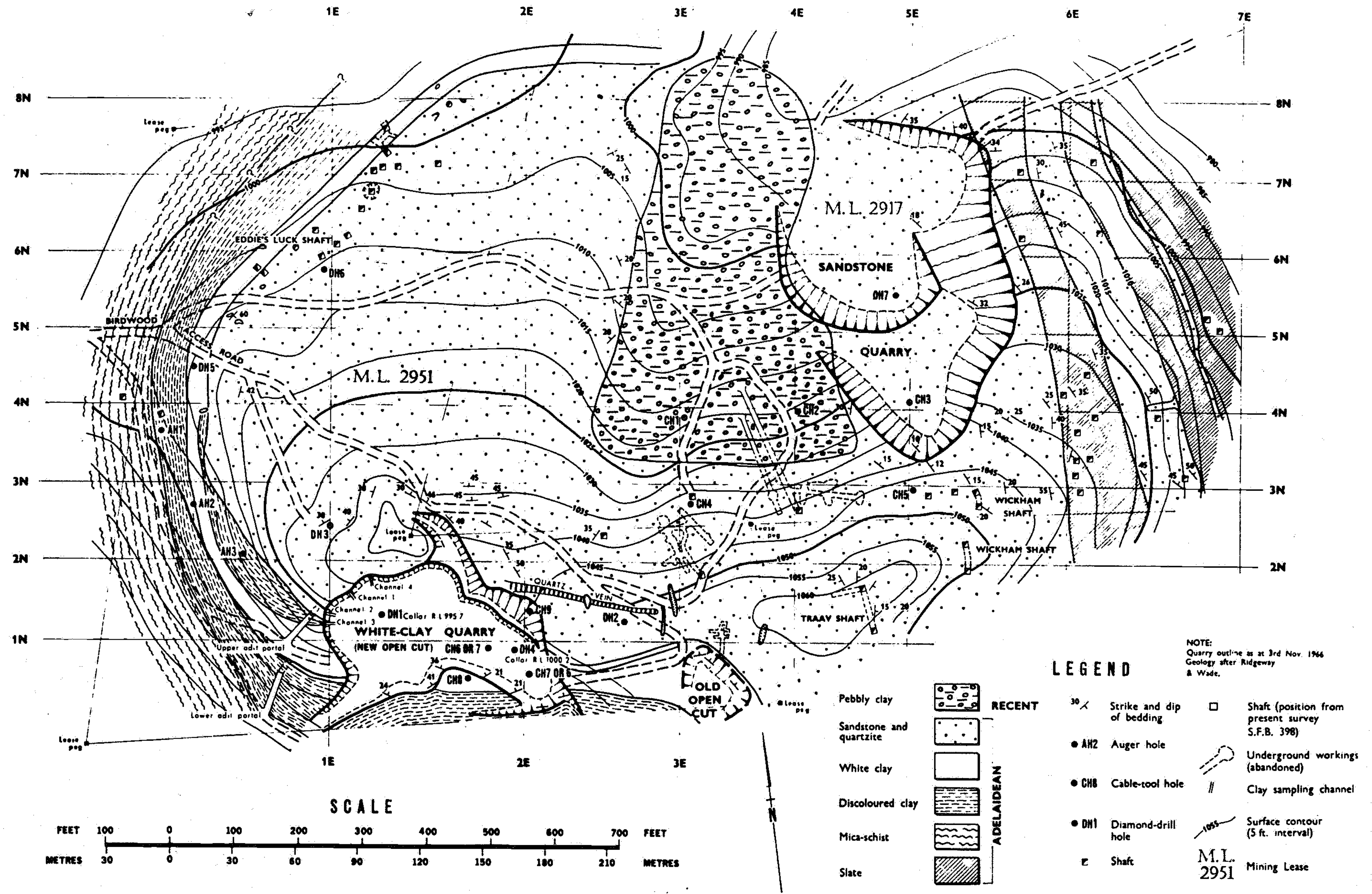
3062

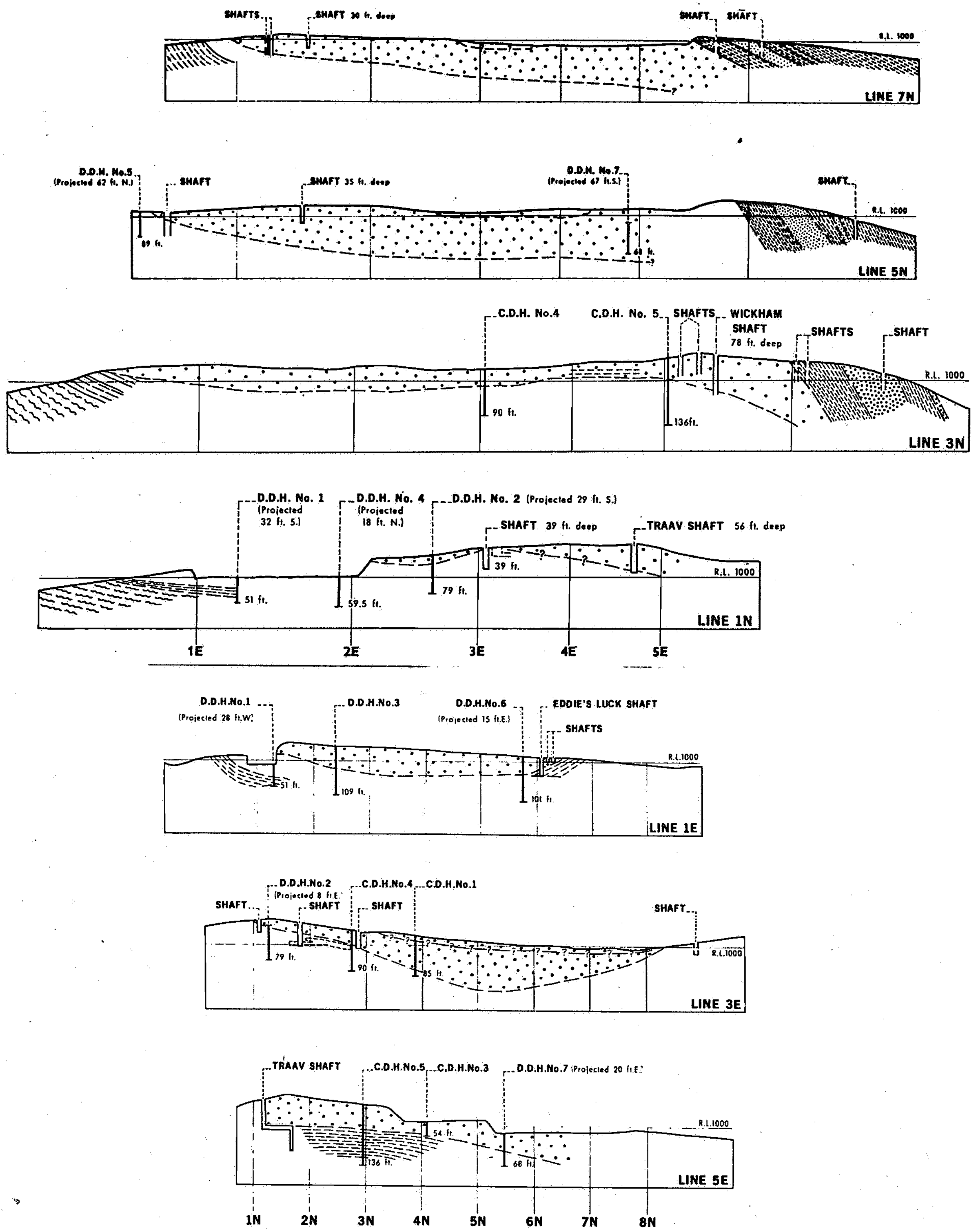
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

BIRDWOOD KAOLIN-SILICA DEPOSIT
SEC. 6397 : HD. TALUNGA
GEOLOGICAL PLAN

COMPILED	C.D.O.	DATE 8.3.65
DRAWN	D.W.W.	SCALE
DATE 24.2.63		PLAN NUMBER
CHECKED		S16615

Fig.3





LEGEND

▨	Mica schists	⁘	Quartzite
▨	Discoloured clay	▒	Sandstone
▨	Slate	☐	White clay
▨	Brown or ferruginous clay		

SCALE

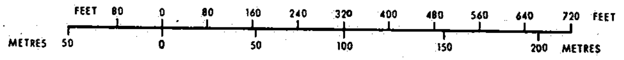


Fig. 4

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

BIRDWOOD KAOLIN-SILICA DEPOSIT
SEC. 6397 : HD. TALUNGA
GEOLOGICAL SECTIONS

COMPILED	LR	8-3-83	
	C.D.O.	DATE	
DRAWN D.W.W.	SCALE		
DATE 24.2.83	PLAN NUMBER		
CHECKED	S16616		

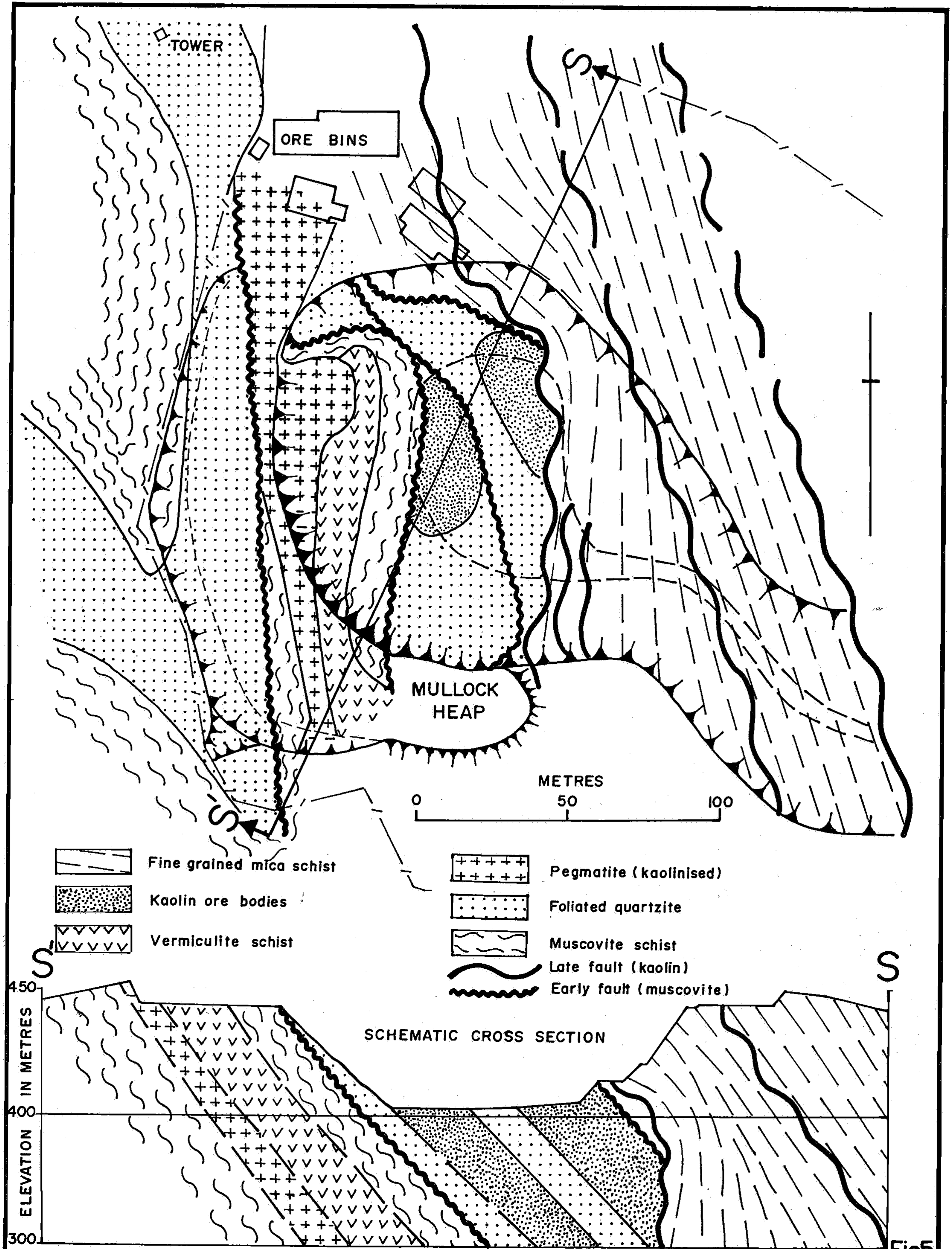


Fig5

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

WILLIAMSTOWN KAOLIN-SILLIMANITE-MICA DEPOSITS - MT. CRAWFORD MINE
SEC. 950 : HD. BAROSSA
GEOLOGICAL PLAN AND SECTION

COMPILED: C.D.O
DATE: 8.3.83
DRAWN: D.W.W.
SCALE
DATE
CHECKED
PLAN NUMBER: S 16617

3062

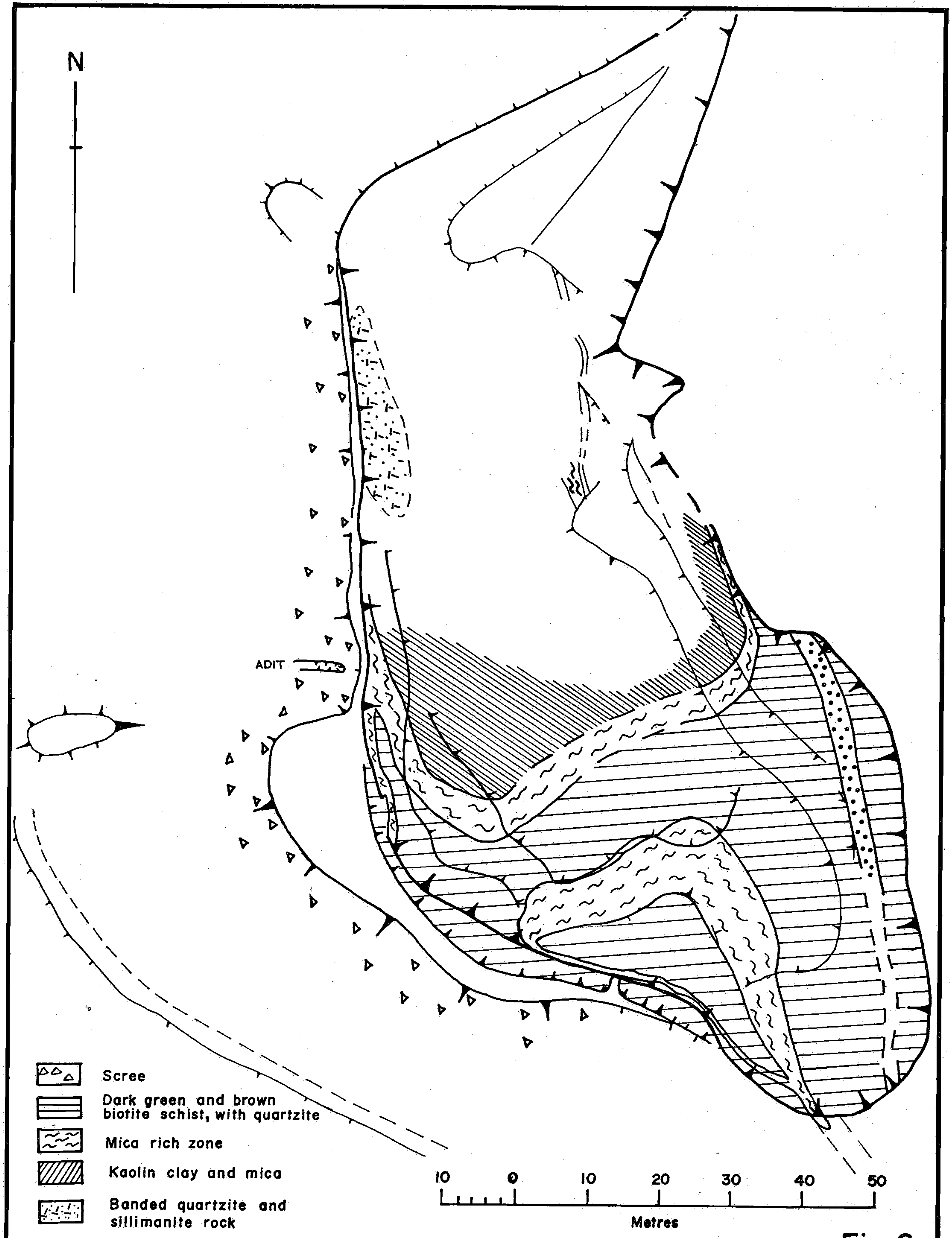
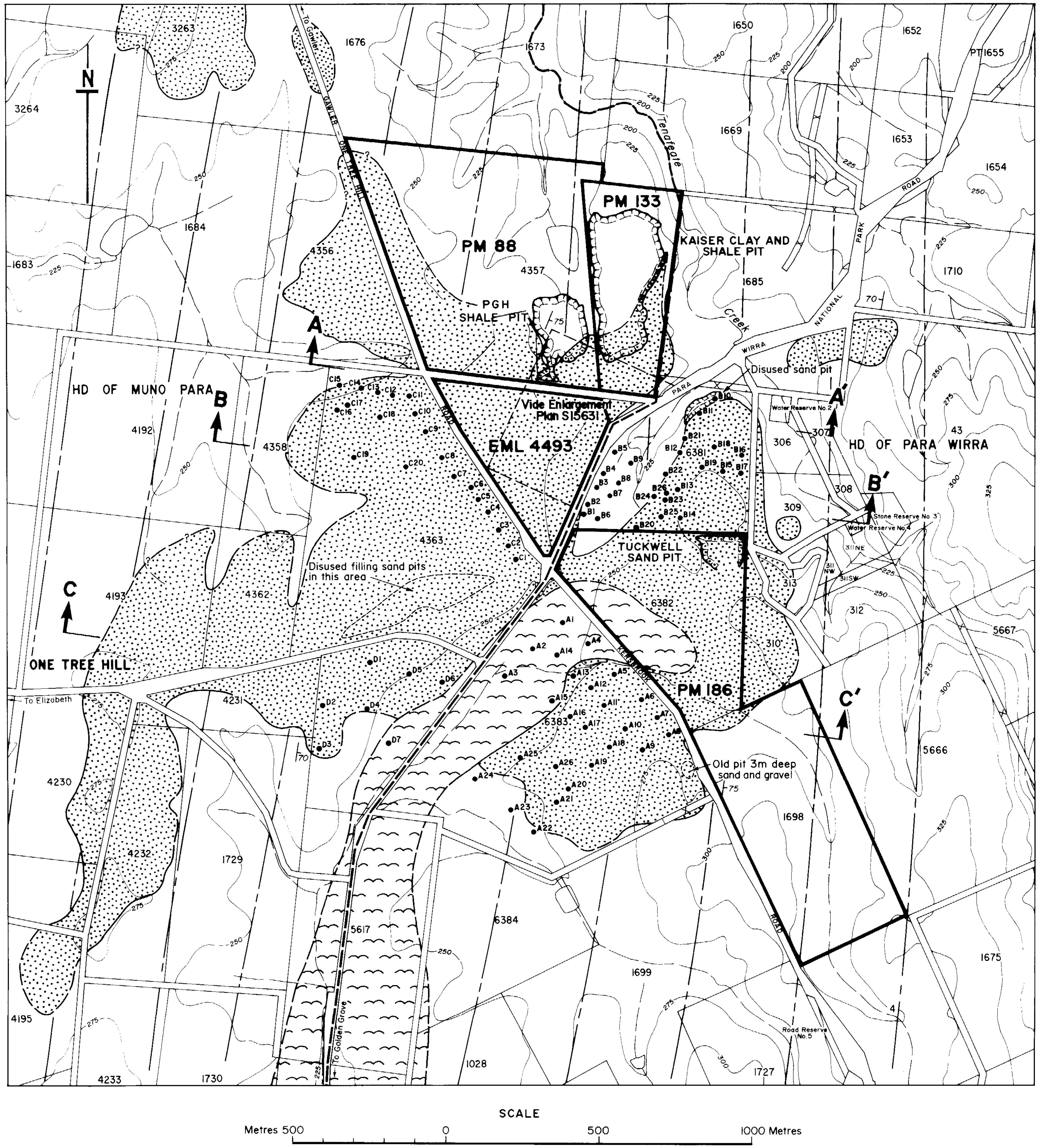


Fig. 6

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

WILLIAMSTOWN KAOLIN-SILLIMANITE-MICA DEPOSITS - SPRINGFIELD MINE
SEC. 3101 HD. BAROSSA
GEOLOGICAL PLAN

COMPILED	CDO 8.3.83 DATE
DRAWN D.W.W.	SCALE
DATE	PLAN NUMBER
CHECKED	S16618



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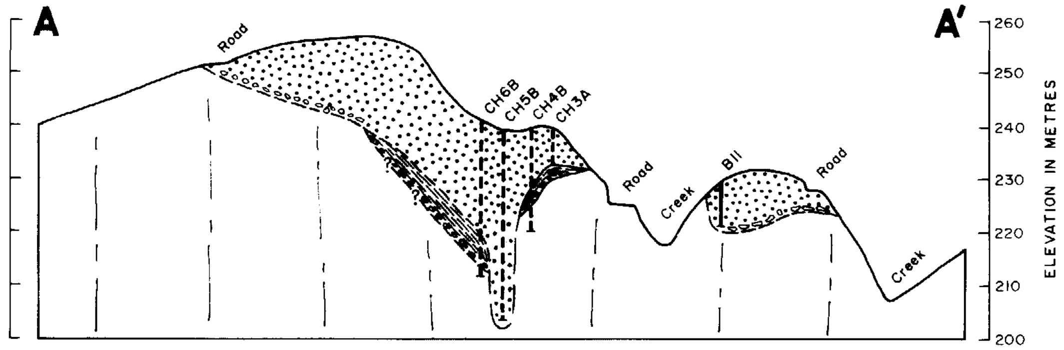

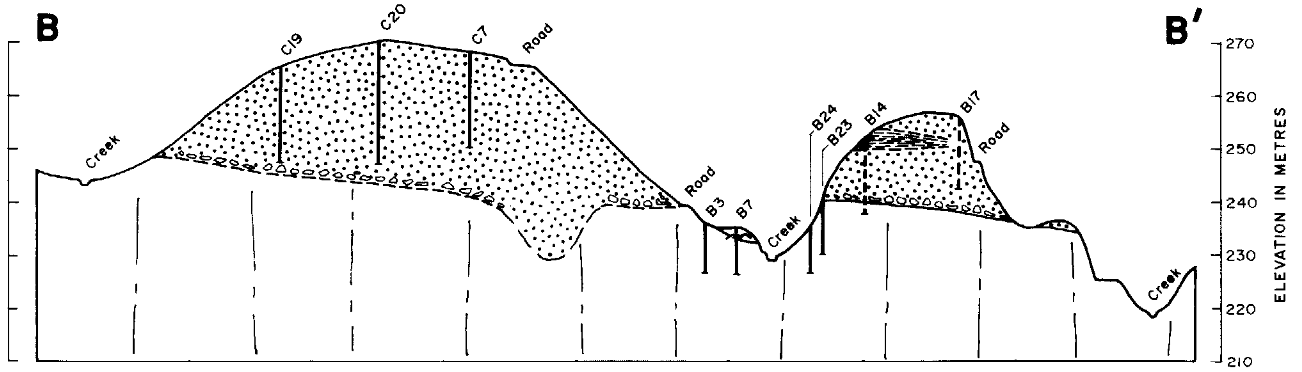

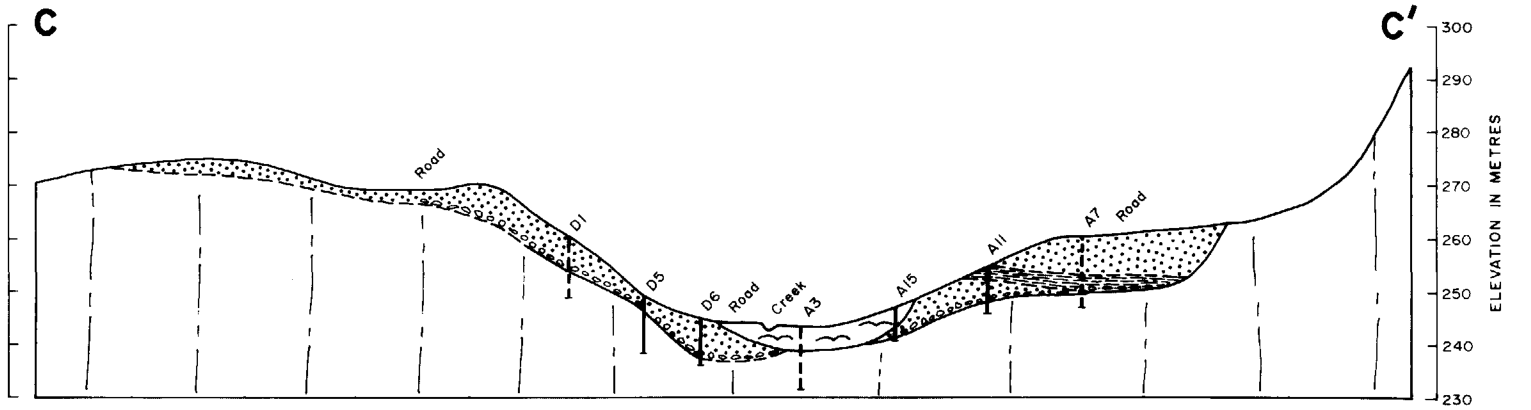

Quaternary

▨	Alluvium. Brown sandy clay and gravel.

Tertiary

▨	White sand with white and yellow clay lenses. Gravel at base.

Pre-Cambrian

▨	Shale with narrow quartzite interbeds showing trend lines.

Geological boundaries

——	Observed
— — —	Approximate
—?—	Inferred
↗75	Strike and dip of bedding

● A8	Drillhole location and number.
PM88	Tenement boundary.
⊤ ⊥	Drillhole, projected drillhole on section line.
275	Surface contour in metres. A.H.D.

Fig. 7

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

CLAY AND SAND RESOURCES
ONE TREE HILL
GEOLOGICAL PLAN AND SECTIONS

COMPILED D.C. Scott
DRAWN A.F.
DATE July 1980
CHECKED
8.3.93
CDO DATE
SCALE
PLAN NUMBER
81-517

APPENDIX A

PROGRAMME AND ABSTRACTS OF PAPERS

8th BIENNIAL CONFERENCE
of the
AUSTRALIAN CLAY MINERAL SOCIETY

PROGRAMME

Wednesday, 18th August

9.00 - 9.30	Registration
9.30 - 9.45	Opening address by Dr. A.E. Martin Chief, C.S.I.R.O. Division of Soils
9.45 - 10.45	Session 1. Chairman Dr. K. Norrish
9.45 - 10.05	Clays of Lake Bunyan, Near Cooma G. Taylor and P.H. Walker
10.05 - 10.25	Physical and Mineralogical Properties of Lateritic Pallid Zone from Jarrahdale, South West of Western Australia A.F. McCrea and R.J. Gilkes
10.25 - 10.45	The Regional Distribution of Minerals in Lateritic Duricrust in South Western Australia P. Agyili, R.J. Gilkes and H.M. Churchward
10.45 - 11.15	Morning Tea
11.15 - 12.15	Session 2. Chairman Dr. K.G. Tiller
11.15 - 11.35	Weathering Effects on some Clay Minerals around Eleura Zn-Pb-Ag Deposit, N.S.W. Y. Togashi and G. Taylor
11.35 - 11.55	Electron Microscopic Study of Alteration Products of Feldspars R. Anand and R.J. Gilkes
11.55 - 12.15	Clay Forming Reactions in Silicates R.A. Eggleton
12.15-13.45	Lunch
13.45 - 14.45	Session 3. Chairman Dr. R. Brown
13.45 - 14.05	South Australian Clays and their Uses L.C. Barnes and A.M. Pain
1405 - 14.25	The Kaolin Profile at Birdwood Clay Quarry, South Australia J.H. Callender, J.M. Fetherston and D. Nichol

14.25 - 14.45	The Ceramic and Refactory Properties of Natural Chamotte from Wingen, New South Wales D. Nichol and L.J. Day
14.45 - 15.15	Afternoon Tea
15.15 - 16.15	Session 4. Chairman Dr. O.G. Ingles
15.15 - 15.35	The Breakdown of Clay-rich Rocks During Coal Mining W.W. Emerson and R.W. Seedsman
15.35 - 15.55	Formation Damage to Clays in Pore Spaces - A Problem in Oil Exploration P.G. Duff
15.55 - 16.15	Desalinisation and Water Transport in Compacted Clays L.A.G. Aylmore and B. Thornton

Thursday 19th August

8.30 - 17.00	FIELD EXCURSION Visits to quarries at Woodside, Birdwood, Williamstown and One Tree Hill.

Friday 20th August

9.00 - 10.00	Session 5. Chairman Dr R.M. Taylor
9.00 - 9.20	The Reaction of Activated Clays with Alkaline Ferric Oxide O.G. Ingles
9.20 - 9.40	High Resolution TEM Study of some Goethites Kath. Smith and R.A. Eggleton
9.40 - 10.00	Alumina-rich Siliceous Cementation of Duricrusts and Saprolites C.R.M. Butt and P.J. Darragh
10.00 - 10.30	Morning Tea
10.30 - 11.30	Session 6. Chairman Dr. E.W. Radoslovich
10.30 - 10.50	A Structural Model for Aniline Vermiculite P.G. Slade
10.50 - 11.10	Reactions of Aromatic Ring Systems with Clay Surfaces M. Raupach
11.10 - 11.30	Factors Influencing the Intercalation of Organic Compounds in Halloysites and Kaolinites G.J. Churchmann and B.K.G. Theng

CLAYS OF LAKE BUNYAN, NEAR COOMA

G.Taylor, Canberra College of Advanced Education;
P.H.Walker, CSIRO Division of Soils, Canberra.

Lake Bunyan covered at least 300 km^2 of the northern Monaro, N.S.W. during the late Tertiary. Its lacustrine sediments rest unconformably on deep weathering profiles in Palaeozoic sedimentary, volcanic and metamorphic rocks and early Tertiary basalts of the Monaro Province (53-36m A).

In the Lake Bunyan sedimentary sequence, five facies have been recognised which have a total thickness of about 180m. These facies are:-

(a) Lake marginal facies - medium to coarse quartz sand with minor clay and coaly laminae.

(b) Volcanic facies - conglomerates and sands of basic volcanic ejecta and crystals with pebbles of Palaeozoic bedrock. These are generally weathered to clay-size material.

(c) Clay facies - ultra fine grained clays.

(d) Coaly facies - pyritic coal seams interbedded with clay.

(e) Diatomite facies - massive to finely laminated diatomite with minor interbedded clay.

Facies a, b and d usually occur low in the sequence; facies c occurs in the upper part of the sequence; facies e is restricted to the uppermost part of the sequence.

The clay facies is the largest component of the Lake Bunyan sequence and is up to 50m thick. Fine laminae occur, but the clay often shows evidence of deformations of biotic and physical origin. Pronounced grey, red and yellow mottles are common and the clay is variably gypseous, sesquioxidic, sideritic and jarositic with minor lenses of diatomite. The clays show a high degree of multi-directional fabric orientation (bimasepic with minor skelsepic) which is reflected in a high degree of megascopic slickenside development.

Clays of this facies generally have a mean particle size <0.5μm and frequently more than 80% by weight is <0.2μm. Coarse components are rare and in some cases consist of secondary minerals. The particle size of the clays is relatively uniform with depth.

The clay minerals are dominated by kaolinite with a high degree of crystallinity. Minor components include smectite, halloysite and a trace of 1nm mineral. The smectite tends to occur in the upper part of the sequence. X-ray diffraction peaks of the kaolinite are sharp and for smectite are broad. T.E.M. photographs confirm that the smectites are only a few d-spacings thick.

Two origins seem possible for the clay facies. They may be the fine fraction of erosion products of deep Tertiary weathering of the Monaro landscape which were deposited in the lake. Alternatively they may be syngenetic and formed from the mix of solutes and colloids derived from Tertiary weathering.

PHYSICAL AND MINERALOGICAL PROPERTIES OF LATERITIC PALLID ZONE FROM JARRAHDALE, SOUTH WEST OF WESTERN AUSTRALIA.

A.F.McCrea and R.J.Gilkes,
Department of Soil Science and Plant Nutrition,
University of Western Australia.

Lateritic pallid zone materials formed from meta-quartz dolerite contained 45-80% clay. Granite pallid zone consisted of clay (50% clay), clay loam (40% clay), or sandy clay loam (30% clay). The clays from granite pallid zone contained more than 85% coarse clay (5-0.2μ) while clays from dolerite pallid zone contained less than 60% coarse clay. Dolerite pallid zone retained 35-50% total water by weight at maximum retentive capacity and granite 20-35%. Although there was a large range in total soil water, the proportion of total available water (pF 2.0-4.2) was similar for granite (15-30%) and dolerite pallid zone (19%).

Pore size distribution determined by mercury injection porosimetry showed dolerite pallid zone to contain 50% more pore volume at suctions greater than wilting point than did granite pallid zone. This observation accounts for the higher total water percentage for dolerite pallid zone. Total porosity (kerosene technique) was 0.25-0.35 cc/g for dolerite, 0.20 cc/g for finer (1.8% greater than 1mm) and 0.14-0.18 cc/g for very coarse to coarse grained (5.6-24.2% greater than 1mm) granite pallid zones. Bulk densities of dolerite pallid zones ranged from 1.20-1.50 g/cc with fine grained granite and coarse grained granite pallid zones having values of 1.90 g/cc and 1.95-2.10 g/cc respectively.

Strength measurements of pallid zone were measured with a pocket penetrometer having a 40° hardened steel tip, 1.0mm diameter, penetrating 5.0mm into 30.0mm diameter clods at pF's 2.0 and 5.1. Dolerite pallid zone mean strengths increased by 47% from 0.32 Kg to 60.0 Kg and granite pallid zone strengths by 71% from 0.25 Kg to 0.86 Kg at pF's 2.0 and 5.1 respectively.

/contd...

XRD showed granite pallid zone to consist of quartz and kaolinite with lesser amounts of feldspar, halloysite, and gibbsite. Most dolerite pallid zones were dominantly halloysite with minor kaolin and quartz. Rutile and ilmenite were present at concentrations of 2-5% in the 0.25-0.03mm fraction of some dolerite pallid zones giving them a steel grey colour. These particular dolerite pallid zones showed a dominance of kaolin over halloysite.

SEM photos showed areas of preferred orientation of halloysite crystals in some samples. Plots on polar graph paper showed that parallel orientation of halloysite was more prevalent in dolerite than in granite pallid zone, and occurred not only on ped surfaces but also within peds. TEM photos of the less than 1μ fraction showed similar halloysite crystal lengths for some granite and dolerite pallid zones. However, coarser grained pallid materials exhibited a larger range of halloysite crystal widths. Ratios of kaolin versus halloysite content of the less than 1μ fraction determined from TEM photographs showed granite pallid zone to have an average of five times greater K/K+H ratio than dolerite pallid zone. Pore volume may be influenced by K/K+H as dolerite pallid zones generally show lower K/K+H ratios and higher pore volumes than granite pallid zone material.

THE REGIONAL DISTRIBUTION OF MINERALS IN LATERITIC DURICRUST IN SOUTH WESTERN AUSTRALIA

P. Agyili*, R.J.Gilkes* and H.M.Churchward**

*Dept. Soil Science and Plant Nutririon, University of Western Australia

**CSIRO Division of Land Resources Management, Floreat Park, Western Australia

A quantitative X-ray diffraction technique using calcium fluoride as an internal standard was developed and was used to analyse 300 samples of lateritic duricrust. The samples came from sites between 10-260 Km east of the Darling Scarp and included various pisolitic, massive and saprolitic materials. Quartz (range 0-90%), gibbsite (0-90%) and kaolin (0-100%) were generally the major constituents with lesser goethite (2-100%) and hematite (0-14%) and minor anatase (0-3%). Rutile (0-3%) and boehmite (0-6%) were only rarely detected. Quartz was common throughout the study area and was least common in the west. Gibbsite was present in all types of duricrust with the exception of saprolitic material. It was most abundant in the west (0-90%) and less abundant in the east (0-50%). It was most abundant in pisolitic materials. Kaolin contents ranged from 0-100% and increased from west to east. Kaolin was most abundant in non-pisolitic materials, i.e. in massive, incipient and mottled materials. Goethite occurred in every sample and was most abundant in the west and east of the study area. Amounts ranged from 0-80% in the west, and 0-60% in the east. It was much less abundant (0-20%) in the central part of the area even though the frequency of occurrence remained high. Hematite showed a pattern of occurrence that was similar to that of goethite. It was most abundant in pisolitic material. Anatase was most common in pisolitic material and occurred only infrequently in the east. Rutile only occurred in a few samples. Boehmite was also rarely detected and occurrences were predominantly in the west and very rare in the east. The mineral was more common in pisolitic materials. This distribution pattern has been related to morphological properties of duricrust, parent materials and rainfall distribution in the region.

CLAY MINERALS AROUND THE ELURA ZN-PB-AG DEPOSIT, NSW

Y. Togashi and G.F. Taylor, CSIRO Division of Mineralogy, Sydney

The Elura Zn-Pb-Ag orebody occurs about 43km NNW of Cobar in the lower Devonian C.S.A. siltstone unit of the Cobar Supergroup as a discrete vertical pipe-like body elongated north-south with maximum dimensions 200m x 120m. Above -98m, the orebody has been completely oxidised producing porous gossans.

The mineralogy of the unaltered Cobar Supergroup sedimentary rocks is essentially quartz + muscovite + chlorite ± carbonate ± albite. The mineralogy of the freshest C.S.A. siltstone examined in this study, is quartz + muscovite + Fe-rich chlorite + ankerite + siderite + K-feldspar + pyrite + anatase. Quartz and muscovite are also common in weathered and/or mineralised siltstone.

Within the weathered profile three zones are recognised:

(1) Completely weathered zone (surface to -84m), where kaolinite and ferrugineous bands of goethite and hematite are formed at the expense of chlorite, carbonates and pyrite. Traces of halite also occur.

(2) Partly weathered zone (-84m to -130m), where chlorite, carbonates and pyrite coexist with such weathering products as kaolinite, goethite halite. Hematite is absent from this zone.

(3) Unweathered zone (below 130m).

A zone forming an envelope about 20m wide around the orebody to a depth of -232m, in which chlorite and ankerite are replaced by kaolinite and siderite, is also considered to be due to weathering. It coincides with deeper weathering around the orebody.

Muscovite shows no systematic variation in its $2M_1$ dominant polytype composition with minor 1M association througout the studied area. Its expandable layer content is also uniformly negligible, except for a minor increase at points at 8m from the wall of the orebody along crosscut at the -232m level.

Kaolinite often occurs in the outer siliceous zone of the orebody and the wallrocks as veinlets with traces of base metal sulfides. Some of the veinlets are composed of monomineralic kaolinite, while others are associated with significant amounts of alunite. The relationship of the kaolinite veinlets to sulfide mineralization at Elura is unclear at this stage.

ELECTRON MICROSCOPIC STUDY OF ALTERATION PRODUCTS OF FELDSPARS.

R.R.Anand and R.J.Gilkes
Dept. Soil Science and Plant Nutrition, University of Western Australia

Weathering of feldspars in a saprolite zone of a soil profile in deeply weathered granite in south Western Australia was studied by a variety of techniques. Transmission electron microscopy including selected area electron diffraction and dark field imaging, optical microscopy and XRD indicated that the transformation to halloysite, kaolin and gibbsite is direct, without any intermediate poorly crystalline or amorphous phase. Alteration of feldspars uniquely consisted of congruent dissolution which proceeded via networks of cracks, twin plane boundaries, cleavage and exsolution lamellae. Selected area electron diffraction has shown that the maximum possible size of an amorphous zone on feldspar surfaces is about 10A^{o} (i.e. the limit of resolution of dark field imaging). Halloysite, kaolin and gibbsite appear uniquely to have crystallized from solution in etchpits on the feldspar surface. Highly weathered feldspar grains are coated with a porous framework of flat euhedral kaolinite and gibbsite and radiating spherical aggregates of tubular halloysite. SAD pattern of halloysites showed that they are all elongated along their b axis with average lengths of 0.40±0.16 μm and diameters of 0.07±0.025 μm. Kaolinite crystals had an average major axis length of 0.12±0.06 μm and a minor axis length of 0.09±0.04 μm. In the other profile the feldspar had mostly altered to halloysite which occurred as longer tubes with an average length of 0.73±0.28 μm and a diameter of 0.08±0.02 μm.

CLAY FORMING REACTIONS IN SILICATES

R.A.Eggleton, Dept. of Geology, Australian National University, Canberra

The mechanism of silicate mineral weathering is determined by the structural similarity between the primary silicate and its secondary weathered product. The rate of weathering is also affected by this structural relation and by the extent of misfit between primary and secondary lattices. If a secondary clay mineral inherits structural elements directly from the parent silicate, a topotactic transformation is possible. This mechanism is particularly favoured if a high proportion of the cations in both structures do not change coordination (e.g. Al in octahedral coordination in both), and the reaction may proceed rapidly. The rate of alteration after an initial topotactic transformation is affected by the development of voids and tunnels as a result of a volume difference between primary and secondary phases. The different weathering susceptibilities of olivine, orthopyroxene, and clinopyroxene can be explained by these mechanisms.

Mineral structures which do not share polyhedral elements, such as feldspars (Al^{iv}) and clays (Al^{vi}) cannot be related by a topotactic transformation. Instead, they pass through an amorphous phase which develops a bubble-like structure of roughly packed spheres. The rate of nucleation of clay layers on the surface of such spheres is affected by the sphere diameter; 1:1 layers can form on 50Å spheres (allophane → halloysite), whereas 2:1 layers cannot nucleate on spheres smaller than 200Å in diameter.

SOUTH AUSTRALIAN CLAYS AND THEIR USES

L. C. Barnes and A. M. Pain
South Australian Dept of Mines and Energy.

Adelaide's annual consumption of clay is approximately 0.9 million tonnes.

About 85% of the 0.75 million tonnes used in the heavy clay industries for the production of clay bricks, tiles and pipes is mined from deposits of weathered Adelaidean shale and siltstone. The most important quarries are at Golden Grove and Anstey Hill. Other deposits are at Pedlar Creek and Baker Gully in the south, Birdwood to the east and Gawler to the north.

Red plastic clay is mined from alluvial deposits in valleys within the Mount Lofty Ranges. White plastic clay is restricted to lenses in Tertiary fluvio - lacustrine sand deposits at Golden Grove, McLaren Vale and One Tree Hill.

Industrial clay consumption approximates 0.15 million tonnes annually, most is weathered Adelaidean shale and siltstone for cement manufacture. Major quarries are situated near Truro and at Baker Gully, the latter supplying shale suitable for manufacture of low alkali cement. Birdwood kaolin deposit supplies white clay suitable for white cement and grout.

The most important refractory grade kaolin deposit is at Williamstown where the unusual kaolinised sillimanite orebody has been worked to depths of 80 m. Because of the presence of partially altered sillimanite, kaolin from this deposit has abnormally high Al_2O_3 content, and has been exported.

Other refractory clay deposits at present being mined include Birdwood, where highly aluminous shale has been deeply weathered to white kaolin; Woodside, where deeply weathered shale contains a high proportion of halloystite, and Tregolana near Whyalla.

White clay for general purpose filler is mined from Williamstown and Birdwood. White kaolin suitable for ceramic purposes has been mined previously from weathered pegmatite at Cromer and near Penneshaw on Kangaroo Island, from weathered shale at Woocalla north of Pt Augusta, and at Longwood in the Mount Lofty Ranges where a levigating plant produced various grades of kaolin and quartz from weathered sandstone.

Deposits of palygorskite (attapulgite) widespread through inland Tertiary basins and ancient drainage channels are being evaluated. Mesozoic sediments of the Great Artesian Basin offer some potential for economic deposits of bentonite and montmorillonite.

THE KAOLIN PROFILE AT BIRDWOOD CLAY QUARRY, SOUTH AUSTRALIA

J. H. Callender*, J. M. Fetherston** and D. Nichol
*   Kaiser Aluminium and Chemical Corp. (Australia) Ltd., Sydney
**   Kaiser Refractories, Sydney
***   Steetley Industries Ltd., Sydney

A kaolin deposit at Birdwood in the Mount Lofty Ranges, South Australia, is currently exploited for refractory and filler grades of clay. The deposit forms part of an extensive zone of kaolinitic shales and lies within the Saddleworth Formation (Burra Group) of Precambrian (Adelaidean) age.

The origin of the kaolinite at Birdwood has provoked much discussion in the geological literature and controversy still persists. Alteration of argillite in the Saddleworth Formation from a chlorite-illite-quartz mineral assemblage to a kaolinite-quartz assemblage undoubtedly occurred during a cycle of deep-weathering which took place in the Tertiary period. However, the presence of pods of pure kaolinite, as well as thin discordant veins of kaolinite in the Birdwood deposit have led some workers to suggest that metasomatic processes, possibly in the early Palæozoic have also been active and the effect of the Tertiary weathering cycle is overprinted.

The profile thickness generally exceeds 50 metres and five distinct zones have been recognised within the clay quarry. The parent rocks are overlain by a ferruginous zone composed of relict-banded, red-brown kaolinitic material (1). This grades upwards over a short interval into off-white (2A), then white (2B), kaolinitic shale. In the central part of the profile, relict sedimentary banding becomes progressively less distinct and the free quartz content diminishes (3). Kaolinite with minor ferruginous mottles (4A), gradates upwards into a prominent mottled zone (4B). In the uppermost part of the altered sequence, relict banding is almost completely obliterated, massive kaolinite ranges from off-white (5A), to white (5B), in colour and irregular pods of veined kaolinite-breccia (5C) are common.

	1	2A	2B	3	4A	4B	5A	5B	5C
SiO_2	61.6	69.5	63.8	50.6	43.8	43.6	46.3	45.5	44.2
Al_2O_3	23.7	20.5	24.6	32.6	38.1	38.7	36.9	38.8	37.9
Fe_2O_3	3.23	0.25	0.13	0.23	0.96	1.08	0.21	0.17	0.09
CaO	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
MgO	0.05	0.04	0.04	0.02	0.02	0.04	0.04	0.04	0.05
Na_2O	0.03	0.07	0.04	0.02	0.03	0.05	0.02	0.06	0.04
K_2O	0.07	0.28	0.09	0.01	0.03	0.02	0.05	0.03	0.08
TiO_2	0.98	0.94	1.15	1.99	1.49	0.98	1.10	0.47	2.34
MnO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
P_2O_5	0.036	0.023	0.054	0.110	0.194	0.160	0.160	0.005	0.015
Kaolinite	60	55	65	85	97	97	98	99	100
Quartz	35	40	35	15	1	1	2	1	-
Illite	-	5	-	-	-	-	-	-	-
Iron Minerals	5	-	-	-	2	2	-	-	-
Kaolinite crystallinity	med.	med.	high	med.	high	high	high	high	high

Kaolinite crystallinity increases towards the top of the profile and vein kaolinite is unusually well-ordered. The veins are not only discordant and thin, but also discontinuous and restricted in distribution to the highly leached zone at the top of the profile. As such it seems reasonable to conclude that the veins formed by the infilling of joints, tension gashes and collapse-breccias during the deep-weathering event in the Tertiary period and that a non-metasomatic vein-forming process applies.

It is suggested that intense leaching caused partial desilicification of kaolinite leaving an aluminous residuum which preferentially migrated from the clay zone into open fractures and eventually crystallised through resilicification into well-ordered kaolinite.

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THE CERAMIC AND REFRACTORY PROPERTIES OF NATURAL CHAMOTTE FROM WINGEN, NEW SOUTH WALES

D. Nichol * and L. J. Day **

* Steetley Industries Limited, Sydney

** The Australian Mineral Development Laboratories, Adelaide

At Wingen, New South Wales, kaolinite clayrocks (flint clays) of the Permian Koogah Formation have been metamorphosed to chamotte by heat from the natural combustion of coal seams. The natural chamotte is selectively mined, processed and supplied to manufacturers of refractory and ceramic products. Chamotte is an extremely volume-stable refractory aggregate and important applications include not only medium-alumina brick but also ramming mixes and castables.

Industrially, chamotte is usually prepared by calcination of aluminosilicate raw materials and the typical representative energy required to calcine flint clay is about 7,000 MJ per net tonne of chamotte with burning temperatures in the range from 1400°C to 1600°C, and an Al_2O_3 content of 45 per cent on a calcined basis. Not surprisingly, the commercial sector has shown considerable interest in natural chamotte due to its inbuilt energy component.

Mineralogically, the natural chamotte consists of approximately 60 per cent mullite, 35 per cent cristobalite and traces of tridymite and rutile. The cristobalite is generally present in the alpha form. Typical chemical analysis comprises 43.0 per cent Al_2O_3, 52.7 per cent SiO_2, 1.4 per cent Fe_2O_3, and 0.5 per cent L.O.I.

The pyrometric cone equivalent (P.C.E.) or refractoriness of the natural chamotte was determined and the material was found to have an end point of Orton Cone 32-33 which is equivalent to 1717-1743°C.

Bulk specific gravity and apparent porosity values of 2.58 gm/cm^3 and 10.6 per cent respectively are comparable with synthetic chamottes.

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THE BREAKDOWN OF CLAY-RICH ROCKS DURING COAL MINING

R.W.Seedsman* and W.W.Emerson**
* CSIRO Division of Applied Geomechanics, Syndal, Victoria.
**CSIRO Division of Soils, Glen Osmond, South Australia.

The presence of clay rich rocks may cause highwall and spoil pile failures in open-cut mines. The basic cause is the further uptake of water by such rocks due to the mechanical break-up during mining and also by the changes in hydrology caused by mining. Simple tests have been developed for qualitatively assessing those rocks which can take up sufficient water to become dangerously weak. The tests are based on the degree of dispersion of materials in water. Such tests have been coupled with Na-saturation tests in order to help determine the various factors which control water uptake.

The tests have been applied to materials occurring in the coal mines of the Bowen Basin. The dominant clay mineral present is a lath shaped interstratified illite-montmorillonite. The main factors weakening the bonds between the clay particles are exchangeable sodium (and magnesium) and moderate amounts of organic matter. The strengthening factors are the electrostatic forces due to the high surface density of charge, large amounts of organic matter and cement.

In one mine, where the strata have an average ESP of 35, failure of highwalls occurs due to weakening of narrow clay bands containing up to 6% C. Failure of spoil piles also occurs if dispersive material is placed in the base of the spoil pile. Such material may be spontaneously dispersive (the surface Tertiary clays) or made so by mechanical reworking. (mudstones and claystones near the coal). At another mine, the ESP of the strata is less than 5 yet spoil pile failure still occurs. In this case there is a band of dispersive clay within 1 metre of the base of the spoil pile along which failure may be occuring.

So far, the simple dispersion tests have been able to diagnose why failures occurred. Work is continuing to refine dispersion limits for known dangerous material by the examination of material from different mine sites and after different degrees of mechanical comminution.

FORMATION DAMAGE DUE TO CLAYS IN PORE SPACE - A PROBLEM IN OIL EXPLORATON

P G Duff
to be given by B A McKay

Authigenic clays lining permeable pore space in sandstone reservoirs often present problems in the locating and production of hydrocarbons.

The effect on such clays may be either physical or chemical and, in most instances, can be avoided or, in the case of electric logging, compensated for.

Diagnostic laboratory methods used to determine the clay content and attitude and possible deterioration or movement entails the use of X-ray diffraction of < 5 μm material (as well as bulk analysis), S E M with EDAX, clay bound determinations and other BMR devised, chemical, flow and pressure tests.

A project has been initiated within the BMR where core material from possible production zones in Australia's sedimentary basins is being investigated with reference to clay problems that may arise during drilling, electric logging, production and enhanced oil recovery operations.

DESALINATION AND WATER TRANSPORT IN COMPACTED CLAYS

L. A. G. Aylmore and B. K. Thornton
Dept. Soil Science and Plant Nutrition, University of Western Australia

When an electrolyte solution is forced through a charged porous membrane the relative transport of water and ions is determined by a number of factors including pore size, solution concentration, cation exchange capacity and the nature of the exchangeable cations. Theoretical treatments based on DLVO concepts predict that the salt sieving coefficient should increase with flow pressure gradient to a maximum and that electroviscous retardation (or an apparent increase in viscosity) will occur to an extent determined largely by the development of the double layer distribution within the pore volume.

Experimental measurements of the permeability and salt sieving coefficient for a rigid porous membrane formed from a highly compacted illite clay demonstrated that marked deviations from theoretical predictions occurred. In particular the three to four fold variations in the permeability of the clay membrane which occurred between different electrolytes and different concentrations, far exceed those attributable to variation in the diffuse double layer development. Similarly in contrast to previous theoretical predictions, salt sieving was observed to decrease rapidly with increasing flow pressure over the pressure range examined.

More recent work has helped to elucidate these effects. The decrease in salt sieving with increasing flow pressure has been shown to arise from the development of a concentration polarization gradient and non-laminar flow conditions at the ingoing face of the membrane, both of which are in turn related to the rate of flushing of the ingoing face by the by-pass system. When an optimum rate of flushing is achieved desalination conforms more closely to theoretical predictions. On the other hand the variations in permeability with nature of the electrolyte and its concentration, demonstrate that the mobility of water adjacent to the clay mineral surfaces is determined predominantly by the influence of cationic size, charge and concentration on the viscosity of the preferred or unique water structure developed in proximity to the clay surface.

The nature of this preferred or coerced water structure has been further examined by studies of the change in effective viscosity with change in temperature for a number of different electrolytes and concentrations. The discrete changes in the permeability of the clay membrane observed with changes in temperature are regarded as indicative of first order phase transitions in the preferred structural configuration of the coerced water layers.

THE REACTION OF ACTIVATED CLAYS WITH ALKALINE FERRIC OXIDE

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This paper describes the theoretical background to a new method of clay stabilization which is seemingly applicable to all clays and clay soils. The method resembles closely an accelerated laterization of the soil in its end effects, though the means by which it is achieved are strictly chemical.

The method involves firstly an activation of the clay by low temperature heating appropriate to the particular clay mineral/s present, followed by chemical attack on the activated clay in the presence of ferric oxide. This results in the formation of a series of new compounds with crystalline habits and zeolitic-type structures (inter alia) which incorporate iron in their lattice and possess considerable weathering resistance as well as conferring strength on the soil/clay mass. The formation of these new compounds may be very rapid (major "laterization" occurring within 7 days, given favorable air access to the samples).

Discussion centres on the nature of the medium necessary to promote the reactions leading to this accelerated laterization, and possible links with the natural laterization processes.

HIGH RESOLUTION TEM STUDY OF SOME GOETHITES

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The microstructures of some goethites (α - FeOOH) were investigated using high resolution transmission electron microscopy. Electron images of individual goethites varied immensely with thickness and focus. It was found that bands of "fingerprints" sometimes delineated areas of different thickness. None of the goethites investigated showed radiation damage even after prolonged exposure to the electron beam. Goethites which have fibrous morphologies in hand specimen were found to be composed of euhedral needles with radii of $\sim$ 200Å. It is possible that the silica present in probe analyses of fibrous goethites is located between these needles.

ALUMINA-RICH SILICEOUS CEMENTATION OF DURICRUSTS AND SAPROLITES

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A siliceous allophane – like material is a widely distributed and apparently abundant cementing agent in gritty sandstones and saprolites in the granitic terrain of the Yilgarn Block of Western Australia. The material closely resembles the siliceous cementing agents but it is softer than opaline and chalcedonic silica.

The presence of a significant amount of alumina in the cement was established with the electon microprobe. The analyses show a fairly wide range of compositions with mean atomic Al/Si ratios of 0.35 - 0.78. The ratios of normal allophanes have ratios of 1.0 -2.0.

The structure of the material is generally amorphous to X-ray and electron diffration, but may show kaolinite and opal CT patterns due to contamination or incipient crystallization.

This material also occurs deep in the saprolite of some profiles where it not only in-fills the voids but also permeates the clay matrix.

A STRUCTURAL MODEL FOR ANILINE VERMICULITE

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Abstract - A vermiculite-aniline intercalate with a basal spacing of 14.7Å has been investigated by one-dimensional and two-dimensional X-ray diffraction methods. The intercalate, prepared by ion exchange between Na-saturated Llano vermiculite and a 1% aniline hydrochloride solution, contains only one aniline molecule per single layer cell. A reduced effective cell charge is believed to be responsible for this. Structure factor calculations were made in space group C2/c and with a unit cell *a*=5.33, *b*=9.18, *c*=29.78Å, β=97.0°. However, extra reflections in the a*b* plane, which are similar to those in a vermiculite-benzidine intercalate, showed that after aniline intercalation the true unit cell became primitive. The aniline molecules are distributed statistically over the equivalent crystallographic sites in the interlayer space. The organic molecules are orientated with their planes vertical and their nitrogen atoms over the projected centres of the ditrigonal cavities into which they key. A model for the packing of organic molecules on a silicate layer will be discussed and its relationship to that for benzidine-vermiculite pointed out.

REACTIONS OF AROMATIC RING SYSTEMS WITH CLAY SURFACES

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Several modifying influences affect the properties of aromatic ring compounds bound at clay surfaces. These amount to the presence of various coupling phenomena which may be between the organic molecules themselves, or between the organic molecules and the clay. Modifications of IR spectra resulting from these influences will be discussed. The results are of importance to the reactivity of the organic molecules as in catalysis as well as to clay-organic-clay interactions as in soil aggregation studies.

FACTORS INFLUENCING THE INTERCALATION OF ORGANIC COMPOUNDS IN HALLOYSITES AND KAOLINITES

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The rates and extents of formation of intercalation complexes between a series of amides and a number of halloysites were related to some chemical, structural and morphological properties of the halloysites. The reactions of one of these amides with a number of kaolinites were also studied for comparison

Results include :

(1) All the amides gave single-layer complexes with halloysites that had basal spacings between 10.4 A^o (with formamide) and 12.4 A^o (with N,N - dimethylacetamide).

(2) The presence of interlayer water in halloysites brought about an increase in the rate and extent of formation of complexes with all of the amides.

(3) When interlayer water contents of halloysites were equal, the ease of complex formation was closely related to crystallinity, as given by indices using data from X-ray diffraction, infrared spectra and differential thermal analysis.

(4) The reactivity of halloysite with amides corresponded closely to the length of tubes or laths while halloysites having spheroidal particles had intermediate reactivities.

(5) There appeared to be a relationship between iron contents of the halloysites and each of reactivity, crystallinity and morphology.

(6) The mechanism of formation of amide intercalation complexes is different for halloysites and kaolinites. This can be explained by the interstratification of layers which occurs in halloysites but not in kaolinites.

(7) Amides intercalate in kaolinites much more slowly and usually less completely than in dehydrated halloysites; this difference can be used to distinguish halloysites and kaolinites when they occur together.

HIGH CHARGE FINE GRAINED KAOLINS IN S.E. QUEENSLAND

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In soil samples from 11 profiles derived from basaltic material in S.E. Queensland, fine grained kaolin is the dominant clay mineral. TEM examination of the clay (<2µm) fraction showed that the particles are usually thin, of good hexagonal shape, and the width of the platy surface is commonly 0.05-0.1µm with a range of 0.005-0.3µm. There is no evidence from the TEM study of any other layer silicate type.

The shape of the 001 kaolin peak on the XRD diffractograms varies between samples from short and broad to long and thin for equal amounts of clay. In some samples there is evidence (XRD, SiO_2/Al_2O_3 ratio, and I.R.) for small amounts of 2:1 minerals. These 2:1 minerals may be a separate phase and/or interstratified with the kaolin. Both cases may contribute to the broad 001 kaolin peak. In other samples (N=11), there is little or no evidence for 2:1 minerals and in this case it seems that the broad and asymmetrical 001 kaolin peak is mainly due to fine particle size. These 11 kaolin samples have a permanent negative charge (variable negative charge is small) ranging from 5.3-20.3 (mean 12.4) meq/100g, and surface area (determined by EGME) ranging from 109-188 (mean 127) m^2/g.

The surface charge distribution calculated from CEC measurements at pH7 on 11 samples below 40cm (to minimise organic matter effects) ranges from 0.9-4.0 (mean 1.8) nm^2/unit charge. The surface charge density of the kaolin component is higher if the surface area of iron oxide minerals is taken into account, and approaches that of smectite (about 1.4nm^2/unit charge). Thus the high charge of these clays may be explained by the kaolins possessing a degree of isomorphous substitution on the surface and fine particle size.

AN UNUSUAL HALLOYSITE

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A clay from 'The Patch Pit' north of Kalgoorlie was investigated. Preliminary studies showed that the clay was mono-mineralic, consisting of lathes ~ 33Å wide, ~ 70Å thick, and many microns in length. The chemistry of the clay corresponded precisely to that of kaolin. The (h k o) part of its diffraction pattern was the same as that of kaolin, but it gave a broad, multiple series of (00ℓ) peaks. The latter peaks varied a little with hydration, but typically peaks could be measured at 23, 17, 14, 10, 8.4 and 7 Å.

A subsequent sampling of the wet clay showed it to be pure hydrated (10Å) halloysite. A diffractometer trace of the wet clay showed a high frequency ripple running over the (00ℓ) spacings. This ripple was attributed to interference between the opposite sides of each cylindrical tube. The observed and calculated diffraction patterns agreed well, and the 300Å diameter corresponded to that observed in the electron microscope. All halloysite tubes should show such interference, but it is not observed if the tube diameter varies. In the case of the above halloysite, the tube diameter must vary by no more than a few percent. The wall thickness is 5 unit cells. The ribbons observed in the original sample are due to collapse of the tubes on drying. Then diffraction results from opposing 35Å thick kaolin crystals. Calculated diffraction effects agree moderately well with those observed.

HALLOYSITE IN A WEATHERED PROFILE AT Pt. MACQUARIE, N.S.W.

E. Slansky. Geological Survey of New South Wales, Geological and Mining Museum.

Along the beaches at Port Macquarie on the northern coast of New South Wales outcrops a suite of ophiolitic rocks which are highly altered. The mineral assemblages are characteristic of prehnite - pumpellyite, greenschist and glaucophane schist facies of metamorphism. At places, soft argillaceous rocks occur which are constituted predominantly of clay minerals, mainly kaolinite and/or chlorite with a micaceous mineral. These rocks were originally shales and slates. Argillized mafic volcanic rocks outcrop at Shelly Beach and Tacking Point. Their main, and sometimes sole, constituent is smectite.

The most significant clay mineral occurrence was found on a slope above Rocky Beach. There, halloysite occurs in a prominent horizon of blue clay about 2 m thick which is part of a deeply weathered profile. The profile is situated above serpentinite which contains nearby two lenses of glaucophane-bearing schists. Insignificant local concentrations of magnesite and rare macroscopic chromite were found in the serpentinite. The profile comprises six lithological units in which four clay mineral assemblages were distinguished. These are, from the bottom to the top: (i) mainly smectite with some illite and serpentine mineral, (ii) halloysite, (iii) kaolinite, and (iv) kaolinite and illite. The halloysitic clay is grey with a bluish and a purple tint. It has a prominent parallel structure which is due to dark, very small, red-brown or dark grey grains arranged in thin beds and embedded in a light coloured white and grey massive matrix. Halloysite occurs in the clayey matrix. In the white matrix which forms lenses within the grey matrix halloysite tubes as seen under SEM, are well developed with an aspect ratio mostly higher than 10:1, thus suggesting unrestricted crystallization. In the grey matrix halloysite particles are arranged in a much denser aggregate and their aspect ratio is less than 10:1. The chemical composition of the halloysite corresponds to

$$(Al_{3.77}Fe^{3+}_{0.04}Mg_{0.01})_{3.82}Si_{3.81}O_{10}(OH)_8 \cdot 1.3\ H_2O.$$

This composition points to a partly hydrated form. X-ray study of chips cut from untreated natural clay showed the halloysite to be the 10 Å form originally. Later, due to storage and handling partial to complete dehydration took place as shown by XRD traces. The mineral reacts with potassium acetate and ethylene glycol. The expansion of its lattice after glycolation is, however, incomplete and an effect similar to a partial dehydration is produced. The 001 reflections appear in two ranges of spacings within a band of increased intensity. As the diffraction effects caused by water loss in halloysite are generally related to interstratification of two layers (7 and 10 Å), Allegra's mixing function for various degrees of randomness and segregation was calculated. It was found that even for a moderate segregation there is a tendency for the reflections to be grouped near the spacings of the two layers. The peak position of the prevailing form (hydrated or dehydrated) is only slightly influenced by the presence of the other one. A partially dehydrated natural sample was interpreted with the aid of the calculated mixing function as a 4:6 assemblage of hydrated and dehydrated halloysite with segregation around 0.3.

The halloysite clay and the smectite underneath were derived most likely from serpentine although the origin of halloysite clay from glaucophane schist cannot be entirely ruled out. Above the halloysite clay the clay mineral assemblages dominated by kaolinite indicate a different parentage, possibly from a metagraywacke which was found close by.

CALCULATION OF EXPECTED X-RAY POWDER DIFFRACTION PATTERNS OF MINERALS

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The Joint Committee on Powder Diffraction Standards (JCPDS) has, for some years, sponsored the development of a suite of powerful computer programmes. The purpose of these programs is to enable the user to calculate the powder diffraction pattern to be expected from a given structure, or a mixture of up to seven structures. There are several reasons why it may be highly desirable to be able to simulate a diffraction pattern in this way.

This paper will review some of the uses of the JCPDS programs, point out the basic assumptions and options available in the current version, give some experience in the ease and costs of using these facilities, and discuss how such calculations may be of particular interest in clay mineralogy.

CHEMISTRY AND MINERALOGY OF CLAYS IN STREAMS

D.J. Chittleborough and J.M. Oades

The effect of land use on the yield and nature of clay (especially fine clay) in streams is being studied in four catchments in the South Mount Lofty Ranges. The catchments have a relatively uniform land use and compass urban, intensive horticulture, virgin scrub and grazing on unimproved pasture.

The chemistry and mineralogy of the colloid, and the proportion of nutrients in solution compared with that associated with particulate matter, is discussed in relation to discharge. The relationship between the nature of the clay in the stream and the soils from which the clay was derived is described for the catchments with horticultural and grazing land uses.

APPENDIX B

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LIST OF CONFERENCE DELEGATES

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