DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
NON METALLIC RESOURCES DIVISION

OODLA WIRRA PALYGORSKITE DEPOSIT
(Sec. 132 Hd. Coglin Co. Herbert

by

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Rept.Bk.No. 77/15
G.S. No. 5844
D.M. No. 466/76

CONTENTS

PLANS ACCOMPANYING REPORT

DEPARTMENT OF MINES
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(MC 789 - Rocla Industries Pty. Ltd.)

Sec.132 Hd. Coglin Co. Herbert

ABSTRACT

Palygorskite of pedogenic origin has formed above dolomitic Callana Beds in the Mt. Grainger Diapir near Oodla Wirra.

Palygorskite with varying amounts of montmorillonite produced satisfactory water absorbent material after calcination but is not suitable for use in drilling muds.

No further work is required as reserves are limited.

INTRODUCTION

Rocla Industries Pty. Ltd. are seeking a raw material that is capable of being treated to produce an absorbent clay. Both montmorillonite and palygorskite are used commercially overseas. The process involves shredding, calcining, roll crushing and screening.

The three size fractions produced are used as follows:

+19 mm oversize - Landscaping.

-19 mm + 0.25 mm - oil soakage, pet litter.

-0.25 mm fines - pesticide carrier.

The Australian market approximates 10 000 tonnes per year.

The palygorskite occurrence previously recorded by Jack (1913) and Crawford (1956) was inspected on 21st September, 1976 by J.G. Olliver (Supervising Geologist) accompanied by D.C. Scott (Geologist), P. Cocking (Technical Manager, Rocla Ceramics) and R. Hockey (Land owner). Four samples were collected and submitted to The Australian Mineral Development Laboratories (AMDEL) for testing.

Results were sufficiently encouraging that the deposit was surveyed by stadia theodolite on 3-4 November, 1976 by S.G. Carr (Geologist) and R.J. Harris (Technical Assistant). The accompanying geological plan (Fig. 2) is based on this survey. A further 11 samples were submitted to AMDEL.

Petrographic descriptions and X-ray diffraction analysis comprise Appendix A and the chemical analysis of 4 of the samples are detailed in Appendix B. The results of absorbency and rheological tests are included in the report.

DEFINITION

Palygorskite is an hydrated Mg-Al-silicate, of limited occurrence, often referred to as attapulgite. The descriptive terms - mountain cork and mountain leather are also used.

Palygorskite together with related sepiolite form the hormite group of clay minerals which are characterised by an amphibole-like chain structure.

Chemical composition varies within the following range:

SiO_2	52 - 62%
Al_2O_3	6 - 18%
Fe_2O_3	1 - 7%
CaO	0 - 3%
MgO	6 - 14%
H_2O+	10 - 13%

Five modes of formation of palygorskite are discussed by Wiersma (1970).

LOCATION AND ACCESS

The deposit is located on section 132, Hd. Coglin, Co. Herbert within the District Council of Peterborough part of the Mid North Planning Area.

Access from Oodla Wirra, about 260 km from Adelaide on the Barrier Highway, is northwards along the well graded Dawson road for 9.6 km to a dam, thence eastwards along a poorly defined track for a further 1.8 km (see Fig. 1). The Mt. Grainger Goldfield is 2-3 km to the north.

Terrain is gently undulating with relatively deeply incised gullies draining easterly into the Nackara Creek, a major tree lined stream channel.

The deposit is situated in mainly uncleared moderately dense eucalyptus scrub. Land use is low intensity grazing.

MINERAL TENURE

Mineral Claim 789 was registered by Rocla Industries Ltd. on 1st November, 1976 over an area of 8.5 ha and abandoned on 20th July 1977.

MINING ACTIVITY

Three shafts were sunk in the 1890's on or near the palygorskite (Crawford, 1956). Shaft A, on the southern bank of the southern creek, is still open to 3.5 m but Shafts B and C have been filled in.

Small stockpiles of palygorskite remain at Shaft A, Pit D (washed in, see Plate 1) and Pit E (open to 0.5 m). Pits F and G do not expose palygorskite.

GEOLOGICAL SETTING

Regional geology and the stratigraphic table as shown on Fig. 1 have been adapted from ORROROO (Binks, 1968).

The palygorskite deposit is located within the Mt. Grainger Diapir near the western contact with grey and green laminated siltstones and dolomites of the Saddleworth Formation Equivalent, a unit of the Burra Group of Adelaidean age.

The Mt. Grainger Diapir occupies the core of an anticline in the Adelaidean sediments. Several "diorite" dykes are shown on ORROROO intruding the diapir.

The nature of the carbonate breccia occupying the anticlinal cores is disputed by Johnson and von Sanden (1969). The shales, cherts and dolomites in the core are considered to be Callanna Beds in normal stratigraphic context. The heavy fracturing and deep weathering are believed to be a consequence of the position in the anticlinal core.

More detailed investigations beyond the scope of this report are required to clarify the situation.

SITE GEOLOGY

Outcrop is poor throughout MC 789, with bedrock mantled by soil and gravel units (see Plate 1).

The six samples of country rock submitted for petrographic description (See Appendix A) are described in Table 1. Sample locations are shown on Fig. 2.

TABLE I

Samples of Country Rock

Field No.	Dept. No.	Description
P1	P540/76	Recrystallized massive sandy dolomite or dolomitic sandstone.
P2	P541/76	Fine grained weakly laminated ferruginous, calcareous sandstone with clayey interbeds.
P6	P545/76	Recrystallized quartzose dolomite.
P7	P546/76	Weathered clayey ironstone.
P10	P549/76	Weathered andesite dyke.
P11	P550/76	Heavily dolomitized andesite.

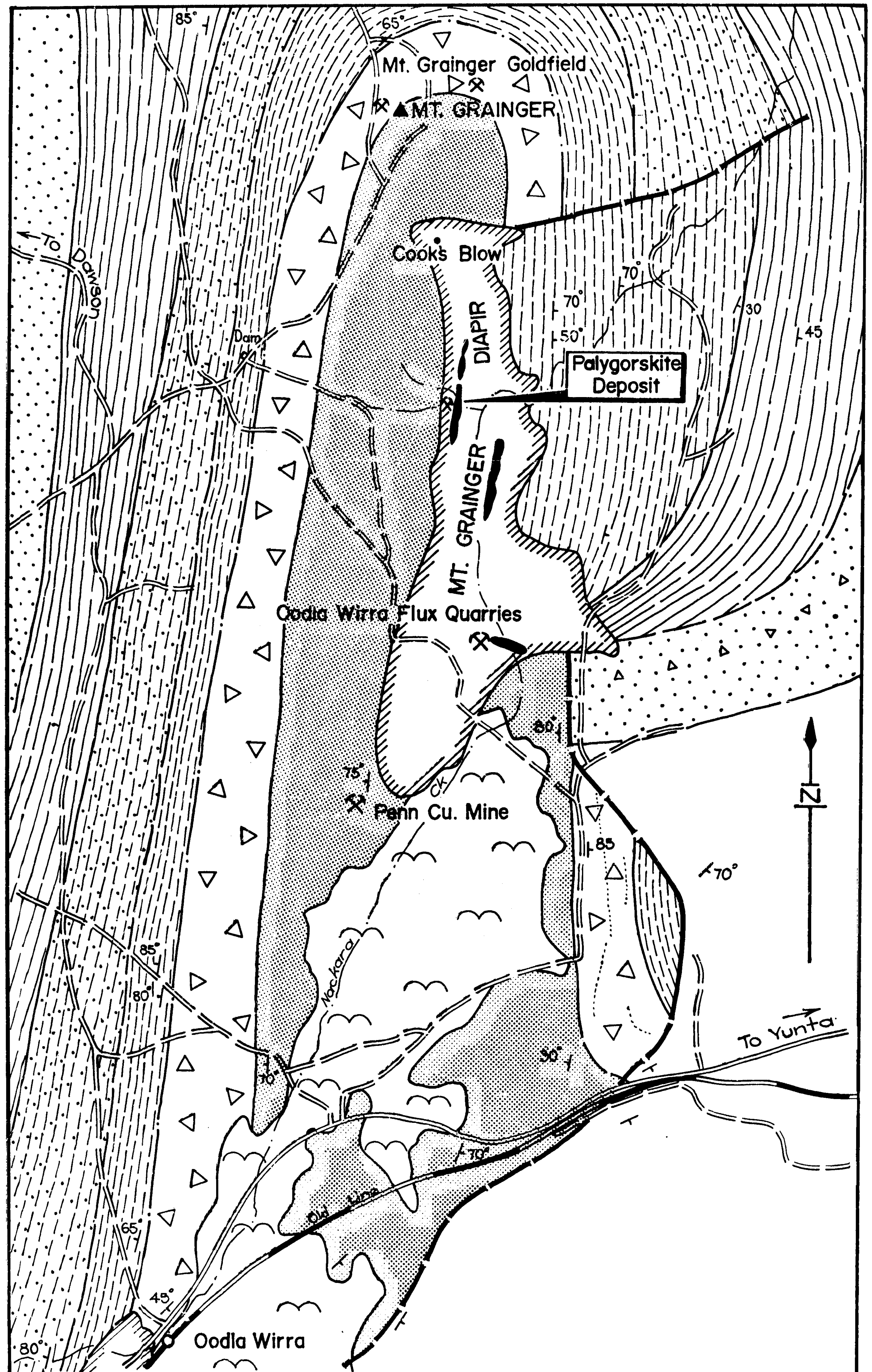
The country rock in the area mapped consists of

- outcropping laminated recrystallised sandy dolomite (P540/76 and P545/76) in bedsup to 10 m wide with an occasional narrow intrusive quartz vein.
- poorly exposed highly fractured and cleaved quartzose dolomite (P541/76). Apart from the stream channels, this unit is exposed only where ferruginised near the fence along the western boundary of MC 789.

  A pronounced vertical cleavage strikes about 120°.

In general, the beds strike north-south with vertical to steep easterly dips. Small scale folding is evident near Pit F.

At the junction of the two gullies, a vertical andesite dyke up



LEGEND

Age	Group	Unit
QUATERNARY		Alluvial Deposits.
PRECAMBRIAN	WILPENA GROUP	Ulupa Siltstone - Red-brown Weathering, Grey Green Siltstone and minor Sandstone.
	UMBERATANA GROUP	Grampus Quartzite - Feldspathic Off-White Sandstone, Locally Arenaceous Tillite. Pepuarta Tillite - Grey Green Massive Siltstone Local Boulder Tillite. Gumbowie Arkose Member - White Feldspathic Sandstone
		Enorama Shale - Green, Well Laminated Calcareous Shale and siltstone.
		Tarcowie Siltstone - Grey Green, well bedded siltstone and Minor Sandstone, Frequently Ripple Marked.
		Tapley Hill Fm. - Flaggy, Well Laminated Blue Grey Siltstone. Calcareous Near Top With Thin Bands of Interbedded Limestone. At Base, Tindelpina Shale Member Finely Laminated Carbonaceous & Pyritic Shale with Thin Dolomite Interbeds Near Base.
		Appila Tillite - Massive Boulder Tillite with Interbedded Siltstones and Sandstones.
	BURRA GROUP	Saddleworth Fm. Equivalent - Grey, Green Grey Laminated Siltstone and Dolomite.
	CALLANA BEDS	Diapiric Breccia with Carbonate Matrix Rafts of contorted Siltstones, Sandstones & Dolomites of Callana Beds.
		Andesite Dyke.

Fault.

70° Strike and Dip of Bedding.

SCALE

Metres 0 1000 2000 3000 4000 Metres

FIG. 1

DEPARTMENT OF MINES - SOUTH AUSTRALIA

PALYGORSKITE OCCURRENCE M.C.789
SEC. 132 HD. COGLIN
REGIONAL GEOLOGY

INDUSTRIAL MINERALS SECTION	COMPILED S.G.Carr.	DRN J.W.	SCALE 1:50,000	PLAN NUMBER
DIRECTOR OF MINES		CKD A.F.	DATE 13-4-77	77-349

6732-III

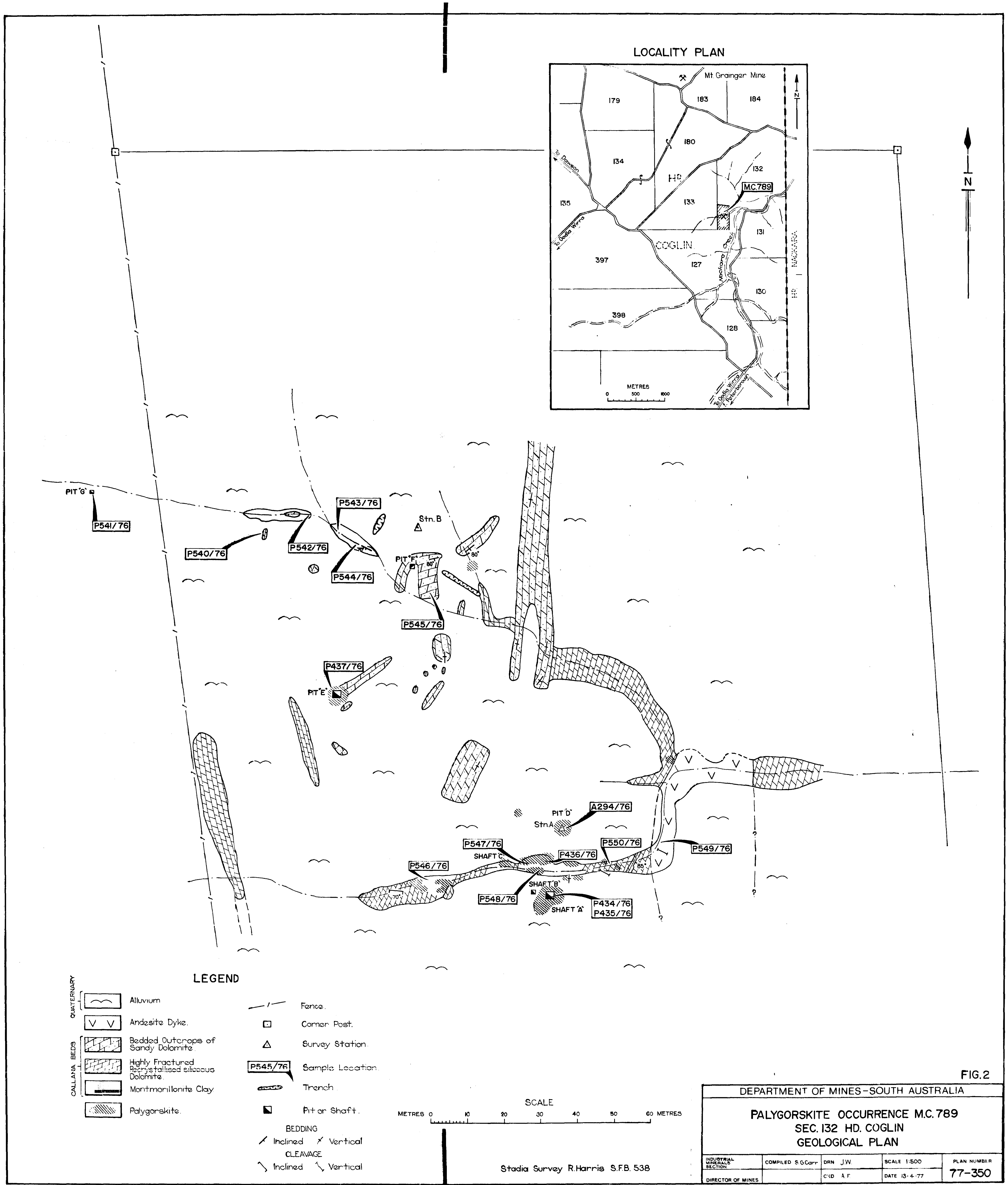


FIG.2

DEPARTMENT OF MINES-SOUTH AUSTRALIA

PALYGORSKITE OCCURRENCE M.C.789
SEC. 132 HD. COGLIN
GEOLOGICAL PLAN

INDUSTRIAL MINERALS SECTION	COMPILED S.G.Carr	DRN J.W.	SCALE 1:500	PLAN NUMBER
DIRECTOR OF MINES		CKD A.F.	DATE 13-4-77	77-350

to 29 m wide is aligned with the bedding of the country rock. The grey-green andesite (referred to as a lamprophyric rock in Crawford, 1956) which is weathered and slightly to heavily dolomitized, consists mainly of plagioclase (see P549/76 in Appendix A). In places, a strong vertical cleavage has developed trending 115° - 120° as in the dolomitic rocks. The contact is irregular. The dyke appears to lens out northwards as dolomitic breccia with lenses and tongues of andesite are exposed in the northern bank of the gully.

Veinlets of andesite, less than 1 m wide, intrude fractured dolomite up to 30 m west of the main dyke.

PALYGORSKITE OCCURRENCE AND ORIGIN

The five samples of palygorskite and five samples of yellow clay submitted to AMDEL are described in Table 2. Sample locations are shown on Fig. 2.

The palygorskite has formed as distinctive flaky lumps up to 0.5 m in diameter and 0.2 m thick (see Plates 1 and 2).

TABLE 2

Samples of Palygorskite and Clay

FIELD NO.	SAMPLE NO.	DESCRIPTION
Palygorskite		
-	A294/76	Stock pile of palygorskite at Pit D. (See Plate 1).
B	P435/76	Pod of palygorskite 0.2 m by 0.1 m in Shaft A, southern wall 1.5 m below ground surface.
C	P436/76	Relatively fresh, yellow Palygorskite dug from creek bank opposite Shaft A.
D	P437/76	Stockpile of palygorskite at Pit E.
P9	P548/76	Weathered lump of palygorskite in creek bank.
Yellow Clay		
A	P434/76	Yellow-brown friable clay with harder black iron rich nodules enclosing palygorskite pod (P435/76) on southern wall of Shaft A.
P3	P542/76	Pale brown unconsolidated clayey soil.
P4	P543/76	" " " " "
P5	P544/76	" " " " "
P8	P547/76	Pale yellow-brown clay enclosing pods of palygorskite in creek bank opposite Shaft A.

Narrow veins, pods and aggregates of palygorskite are exposed for 55 m along the southern creek near Shafts A, B and C. Country rock is invariably fractured quartzose dolomite. No palygorskite was observed in the more massive recrystallized dolomite.

In the creek bank opposite Shaft A, sheet-like masses of palygorskite up to 0.5 m x 0.5 m x 0.15 m are enclosed in yellow montmorillonitic clay. Montmorillonite is dominant in all 5 samples of clay both in the bulk sample and in the 2 micron fraction (see Appendix A). Palygorskite was detected in only P547/76 as an accessary (5-20%). The clay does not contain the kimberlite "indicator minerals" ilmenite and pyrope garnet (see P434/76 Appendix A) and therefore has not been derived from weathering of kimberlite.

Isolated pods and veins of palygorskite are exposed in

- relatively massive but fractured dolomite in Pit E,
- in the gully 15 m east of Pit F,
- near the north western margin of the andesite dyke
- 170 m northwest of Pit D outside MC 789.

Pale green-brown palygorskite has formed as a felted mass of poorly aligned flakes. Individual flakes vary greatly in size up to 0.6 mm long (see P548/76 in Appendix A).

X-ray diffraction analysis shows a wide variation in palygorskite content with rapid transition from palygorskite-rich zones to carbonate-rich zones particularly in P548/76.

For the bulk samples, A294/76 contained less than 30% palygorskite with about 66% calcite and P436/76 was also dominantly calcite. P435/76 was dominant montmorillonite and only P437/76 was dominant palygorskite.

For the 2 micron fraction, palygorskite was dominant in all samples except P435/76 where palygorskite was subdominant.

In general, agreement was good between X-ray diffraction analyses and optical estimates. Non-crystalline or poorly crystalline components such as goethite are reported in greater amounts in optical estimates.

The chemical analysis in Appendix B of four palygorskite samples generally fell outside the theoretical range because of the presence of significant amounts of other minerals.

All Palygorskite occurs

- in fractured quartz-dolomite
- within the soil profile
- associated with montmorillonitic clay
- within 100 m of the andesite dyke

Hence, a pedogenic origin as outlined by Singer & Norrish (1974) is proposed. They had investigated crusts or cutans of palygorskite coating soil aggregates in calcareous red earths under arid conditions near Alice

Springs and in red earths and red brown earth soils in a warm temperature climate in Eastern Riverina, N.S.W. R. Cooper concluded in AMDEL Report MP 1541/77 that the alkaline conditions and magnesium ions necessary for palygorskite to form have been provided by the breakdown of dolomite of possible ferroan variety and that the andesite dyke may have restricted leaching as required by Singer & Norrish (1974).

ABSORBENCY

Procedure

Preparation of the samples by AMDEL so that their absorbencies could be determined involved milling, moistening the resulting fine powders with water and kneading to maximum workability, calcining at 650°C and crushing the resulting lumps to a size fraction of -5 mm to +1 mm. The granules were soaked in water for 24 hours, drained under standardised conditions and their water contents determined. The absorbency figures quoted are a percentage of the dry clay weights.

Results

Absorbency of samples of palygorskite are compared in Table 3 with two proprietary cat litters available in Adelaide. The dominant mineral as determined by X-ray diffraction analysis is also tabulated.

TABLE 3

Water Absorbency

Sample No.	%	Dominant Mineral Bulk	 2 micron
A294/76	105.5	Calcite	Palygorskite
P435/76	100	Montmorillonite	Montmorillonite
P436/76	145	Calcite	Palygorskite
P437/76	187	Palygorskite	Palygorskite
P548/76	not tested	-	-
Tydee Tom	99.6	-	-
Embassy	114	-	-

The four samples tested compare favourably with the proprietary materials and further testing to Australian Standard AS K9P is warranted. Sample P437/76, the only sample with dominant palygorskite in bulk recorded the highest absorbency.

RHEOLOGICAL PROPERTIES

Sample A294/76 was submitted for an evaluation of rheological properties. Dr. W.G. Spencer in AMDEL Report MT 479/77 reports that:

> "A Suspension of 45 grams of clay in 350 mls of distilled water produced a very thick gel. The suspension was highly thixotropic. The apparent viscosity (steady state) was 30 centipoise, the immediate apparent viscosity being very much higher.
>
> Interpretation of rheological results is complicated by the high time-and shear-thixotropy. The barrel yield of the material, that is, number of barrels of 15 centipoise mud produced from one ton of clay, is approximately 60-80. Barrel yields of over 80 are normally required for drilling muds. Furthermore these yields are required in water saturated with sodium chloride. In view of the low result obtained in distilled water, the more stringent test using salt water was not carried out".

These results do not meet specification. However, the sample was only one piece relatively low in palygorskite content and therefore not representative of the deposit.

RESERVES

The deposit had been considered to have some potential as Crawford (1956) showed the palygorskite in a zone 11 m wide probably as a vertical bed conformable to the dolomitic sediments.

Less than 5 tonnes of palygorskite is readily available either from stockpiles (See Plate 1) or by gouging the creek banks. Palygorskite is erratically distributed near the base of the soil profile and does not exceed 0.2 m in thickness in exposures to date.

Therefore, far less than 100 tonnes of relatively pure palygorskite is expected within MC 789.

Reserves of mixed palygorskite-montmorillonite are somewhat greater but confined to two known areas

- at Shaft A, extending over an area of 30 m x 30 m
- west of Pit F, possibly of similar extent.

A total of 9 000 tonnes is inferred based on a thickness of 2 m and S.G. of 2.5.

Mineable reserves are expected to be considerably less due to the need to reject zones rich in calcite or dolomite.

Trenching by backhoe or bulldozing is required to delineate reserves and to test soil covered areas for obscured pockets of palygorskite.

CONCLUSIONS

Palygorskite has formed by the alteration of dolomitic sediments within the Mt. Grainger Diapir adjacent to an intrusive andesite dyke.

Petrology and field relationships are compatible with a pedogenic origin in an area of restricted leaching.

Water absorbencies of calcined palygorskite are superior to the commercial absorbents tested. Absorbency increased significantly with increase in palygorskite content.

Results of testing of a low grade sample for use as a drilling mud were unfavourable.

Reserves of relatively pure palygorskite are negligible and reserves of palygorskite-montmorillonite are probably limited to several thousand tonnes.

With a potential market of 10 000 tonnes/year, no further investigation is warranted.

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APPENDIX A

PETROGRAPHIC DESCRIPTIONS AND

X-RAY DIFFRACTION ANALYSIS

-extracted from AMDEL Reports

MT 479/77 .. by Dr. W.G. Spencer

MP1035/77 & 1541/77 by R. Cooper

Sample: P1, P540/76; TS37107

Location:
11 km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
Recrystallized sandy dolomite or dolomitic sandstone.

Hand Specimen:
This sample consists of at least ten lumps of rock which are pale brown with goethite-limonite staining, have in most cases a relatively coarse grain size of between 1 and 4 mm and appear to be composed of varying amounts of quartz and dolomite. Those lumps which are strongly dolomitic are generally pitted and often contain veins which consist of dolomite crystals and goethite-filled cavities. In the more quartzose samples there are usually some veins or joints which contain quartz with little or no dolomite.

The thin section was prepared from a lump which was possibly slightly more quartzose than the bulk of the lumps.

Thin Section:
An optical estimate of the constituents gives the following:-

	%
Dolomite	50-70
Calcite	trace-1
Quartz	30-50
Opaques	1-3

This sample is composed essentially of dolomite and quartz and has a sedimentary texture which has been considerably modified by recrystallization. Although there are crystals of both quartz and dolomite present which are several millimetres across the original grain size of the rock was probably once considerably finer.

Quartz crystals occurring as inclusions in larger dolomite crystals are rarely more than 0.2 mm across and possibly have not changed in size since the rock was deposited. There is one patch of finely crystalline quartz which is at least 3 mm long which is possibly a more quartzite ?pebble of primary detrital origin.

The dolomite forms equant subidioblastic crystals which range in size up to at least 3 mm across. There are areas/?bands where the crystal size of the dolomite is considerably finer and the average size of the crystals is about 0.2 mm. It is probable that such bands represent former sedimentary bedding. Twinning is common in the dolomite crystals and the carbonate was recognized to be dolomite by its general appearance and because a microchemical staining test for calcite gave negative results. Opaque inclusions up to 0.1 mm across are dispersed through the dolomite crystals. These inclusions probably consist of hematite or goethite. There are some fairly well defined areas where a considerable amount of goethite and limonite is associated with the dolomite and these areas, which have straight, regular outlines, possibly represent crystals or crystal aggregates of ferroan dolomite, or possibly even siderite, which have recrystallized. There is often a minor amount of calcite also present in these areas.

Quartz occurs as equant subidiomorphic and xenomorphic crystals/grains which range in size up to several millimetres across. A few of the quartz crystals show pronounced undulose (strain) extinction but most extinguish evenly. Some of the quartz crystals are sieved with minute opaque inclusions, some are perfectly free of inclusions and some contain both inclusion-filled and inclusion-free areas. Where inclusion-free quartz occurs the crystal boundaries commonly suggest that quartz is replacing dolomite but where dolomite crystals with straight crystal outlines are in contact with inclusion-filled quartz there is in a few places the suggestion that the dolomite has been replacing the quartz.

This is a sample of sandy dolomite or dolomitic sandstone. Recrystallizat appears to have caused a coarsening of crystal size especially in the dolomite. However, it is not certain whether the presence of iron oxides inhibits the recrystallization of the dolomite, whether quartz has a synergistic effect, or whether differences in crystal size in various parts of the sample are related to the size of the detritus in the initially formed sediment.

Sample: P2, P54/76; TS37110

Location:
11 km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
Fine-grained, weakly layered, ferruginized calcareous sandstone interleaved with clayey (kaolinitic) layers.

Hand Specimen:
This sample is yellow-brown, fine-grained and layered with the laminations varying in thickness from less than 1 mm to several millimetres. The sample is friable and easily broken and the colour is mainly due to limonitic alteration.

X-ray diffraction results: (key to abundance categories on P14)

Bulk Mineralogy

Quartz	Dominant
Potash feldspar	Sub-dominant
Kaolinite	Accessory
Goethite	Accessory

Clay Fraction (<2 μm) 12%

Kaolinite	Dominant
Goethite	Accessory
Quartz	Trace
Potash feldspar	Trace

Thin Section:
An optical estimate of the constituents gives the following:-

	%
Quartz	20-30
Carbonate (mainly calcite)	5-10
Goethite/limonite	40-50
Clay	10-20
?Feldspar	5-10

This sample has a clastic sedimentary texture but has suffered extensive alteration and in many places the texture and mineralogy is obscured by the presence of goethite-limonite. Quartz and carbonate-rich layers are interleaved with clay-rich layers and the thickness of the layers varies from less than 0.3 mm up to at least 2 mm.

Quartz is present as angular to rounded grains which are well sorted and typically between 0.03 mm and 0.1 mm across with a few larger grains up to 0.6 mm across. In a few places there appears to have been reaction between quartz and carbonate but generally the shape of the quartz grains appears to be a primary feature which has not been significantly altered through reaction with the other minerals present.

The carbonate in the sample is mainly calcite and this was established with a microchemical staining test. The calcite occurs as irregularly shaped grains/crystals which range in size up to 0.2 mm across. In some places the calcite appears to form a matrix for the quartz grains and it is evident that the phase has recrystallized extensively since the rock was deposited.

Goethite is present throughout the sample and is in many areas the dominant mineral present. The clay in the sample is yellow-brown and this is thought to be due to limonite staining.

The X-ray diffraction results indicate that the clay in this sample is kaolinite. Clay-rich layers are up to 0.3 mm across and as mentioned the clay is yellow-brown due to limonite staining. It is finely crystalline and in places appears to have migrated through the sample in vein-like structures disrupting the surrounding bedding units.

In the quartz and carbonate-rich layers there are numerous small interstitial areas which have low relief and are sieved with minute opaque inclusions. The mineral(s) in this interstitial material could not be positively identified and is probably the potash feldspar detected in the X-ray diffraction analysis.

The quartz and calcite-rich layers in this rock may once have consisted of fine dolomitic sandstone. Alteration/replacement since the rock was deposited although leaving the quartz grains largely unaltered could possibly have resulted in the dolomite (a ferroan variety) changing to a mixture of goethite-limonite and calcite. Generally the clay layers follow the bedding and their origin is thought to be related to the primary detrital mineralogy. However, exactly how and from what the kaolin formed is not certain.

Sample: P6, P545/76; TS37108

Location:

11km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:

Recrystallized quartzose dolomite.

Hand Specimen:

On sawn surfaces this sample appears pale brown and generally fine and even-grained with a crystal size of less than 0.5 mm. A pattern of ?fractures can be distinguished and along these there are concentrations of iron oxides (goethite-limonite) the largest of which are up to 1 mm across. On external surfaces the sample is brown (limonite-stained) and complexly corroded/pitted.

Thin Sectin Section:

An optical estimate of the constituents gives the following:-

	%
Dolomite	60-80
Quartz	15-30
Opaques (goethite-limonite)	3-6

This sample has a granoblastic texture and is composed principally of dolomite and quartz. Although it was undoutedly once a sediment the detrital shapes of the grains/crystals have been completely modified.

Dolomite is present as equant subidiomorphic crystals which range in size from 0.06 mm to at least 0.5 mm across. The largest dolomite crystals are usually adjacent to/associated with crystals of quartz and the smallest dolomite crystals occur in areas where there are significant amounts of goethite-limonite.

Quartz occurs as equant subidiomorphic and xenomorphic crystals which range in size up to 1 mm across. The crystals of quartz generally extinguish evenly and are clear although most contain a few "trails" of minute opaque inclusions. There are a few places in the rock where quartz, dolomite and goethite-limonite are complexly intergrown. These patches, which are up to 2 mm across, are more finely crystalline than the rest of the rock and often the quartz crystals in these areas are heavily sieved with goethite-limonite.

This is a sample of recrystallized quartzose dolomite. Although undoubtedly of sedimentary origin clastic textures have been completely obliterated. Dolomite crystals are coarsest where they are adjacent to/associated with quartz crystals and are smallest where there are concentrations of goethite-limonite. Much of the goethite-limonite occurs close to fractures and has probably been introduced as the rock weathered but there are also patches which appear unconnected with the fractures in the rock and these have possibly formed through the recrystallization of dolomite which was formerly more ferroan than it is at present.

Sample: P7, P546/76; TS36903

Location:
11km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
Clayey ironstone.

Hand Specimen:
This sample consists of lumps of brown, porous, weakly layered friable material. On sawn surfaces the material is seen to be finely crystalline and to contain patches varying in colour from off-white to dark brown with most of the material being yellow-brown. The colour appears to be caused by goethite/limonite.

X-ray diffraction results: (key to abundance categories on P14)

Bulk Mineralogy

Goethite	Dominant
Montmorillonite	Sub-dominant
Mica	Accessory
Kaolinite	Accessory
Quartz	Accessory
Calcite	Trace

Clay Fraction (<2 μm 19%)

Montmorillonite	Dominant
Goethite	Accessory
Kaolinite	Accessory
Quartz	Trace

Thin Section:
An optical estimate of the constituents gives the following:-

	%
Goethite	70-90
Quartz	10-20
Muscovite-sericite	trace-2
Clay	1-4

This sample is largely opaque and apparently composed mainly of an open structure of goethite-rich granules. These granules are typically 0.06 mm in diameter and the interstices between them are filled predominantly with limonite-stained clay. Also present in the sample are grains of quartz, flakes of muscovite-sericite and a few patches of clay and muscovite-sericite which are relatively free of goethite-limonite and probably correspond to thelighter coloured areas in the hand specimen. The quartz grains are up to at least 1 mm across and have finely irregular (corroded) margins. The muscovite-sericite flakes are up to 0.2 mm long and, are similar to quartz in that t occur throughout the sample. Although calcite was detected in the X-ray diffraction analysis of this sample it could not be located in the thin section.

This sample is a highly ferruginous clayey ironstone. It has formed by replacement/alteration and these processes have occurred to an extent that the texture and mineralogy of the original rock type has been completely obliterated.

Sample: P10, P549/76; TS36904

Location:
11 km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
Weathered andesite.

Hand Specimen:
This sample is grey-green, homogeneous and appears to consist of phenocrysts of quartz and plagioclase seated in a finely crystalline ?feldspathic matrix. In the portion of the sample from which the thin section was prepared there are two veins each about 2 mm across which are filled with goethite and ?carbonate. The sample appears to have broken along widely spaced joints and external surfaces are coated with a carbonate "scale" and are stained by goethite-limonite.

Thin Section:
An optical estimate of the constituents gives the following:-

	%
Host rock	
Plagioclase (phenocrysts)	4-8
Plagioclase (matrix)	70-80
Dolomite	5-15
Opaques	5-15
?Biotite	2-4
Vein	
Hematite-goethite	60-70
Quartz	5-15
Clay-filled voids	10-20

This sample has a trachytic texture and consists essentially of plagioclase phenocrysts in a matrix of smaller, aligned plagioclase laths. Also present in the matrix are opaque grains and dispersed through the sample are patches of dolomite and patches of biotite.

The plagioclase phenocrysts are up to 5 mm long, are somewhat irregular in shape and have smooth and often embayed margins. The plagioclase phenocrysts are either untwinned or simply twinned, are generally slightly altered by sericite and carbonate and from their general appearance are thought to be either andesine or oligoclase in composition. The matrix plagioclase occurs as subhedral laths which are up to 0.2 mm long. These laths are aligned, twinned and appear to be oligoclase in composition.

Throughout the matrix plagioclase there are opaque grains which range in size from less than 0.01 mm up to 0.06 mm and are sub-idiomorphic (cubic) in shape. They appear to consist of iron oxides, mainly ?hematite and goethite which have probably formed from magnetite.

Dolomite occurs as equant subhedral and anhedral patches which range in size up to 1 mm across. The dolomite was identified by its general appearance and because a microchemical staining test for calcite gave negative results. There are usually opaque grains and in a few places some biotite flakes associated with the dolomite. The dolomite has probably replaced a former phenocrystal phase but the nature of this is not known.

The biotite is green, pleochroic and occurs as flakes which are up to 0.2 mm across. These occur singly and in patches up to 1 mm across and invariably the biotite is slightly altered. Some of the larger patches of biotite have probably replaced a former phenocrystal phase but the nature of this is not known.

The vein is up to 4 mm across and consists mainly of interlocked flakes/blades of iron oxides. These probably once consisted of specular hematite but this appears to have been largely or completely altered to goethite and limonite. Between the blades/flakes there is a considerable amount of void space which has been infilled by clay and quartz.

This is a sample of weathered andesite (which has been dolomotized to a minor extent) and it contains several narrow veins which probably once contained specular hematite.

<u>Sample: P11, P550/76; TS37101</u>

Location:
11 km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
<u>Heavily dolomitized ?andesite.</u>

Hand Specimen:
This is a light coloured, carbonate-rich rock which has an apparent grain size varying from less than 1 mm up to at least 5 mm. No bedding is apparent and staining by goethite-limonite is confined to joint planes which are widely spaced.

Thin Section:
An optical estimate of the constituents gives the following:-

	%
Dolomite	70-80
Plagioclase	15-25
Opaques	3-6

This sample has a granoblastic texture and consists mainly of dolomite with lesser amounts of plagioclase and opaques.

The dolomite occurs as equant xenoblastic grains which range in size up to at least 1 mm across although most are between 0.1 and

0.3 mm across.

The plagioclase occurs as stumpy lath-like crystals which range in size up to 0.3 mm long. The plagioclase crystals do not appear to be aligned and from their general appearance appear to be fairly sodic, probably oligoclase in composition.

The opaques occur as equant subidiomorphic (cubic) grains which range in size up to 0.1 mm across and occur as inclusions in the dolomite and plagioclase. The opaques appear to consist of iron oxides, probably goethite with some hematite.

This rock is thought to be an andesite which has been heavily dolomitized.

X-RAY DIFFRACTION ANALYSIS OF PALYGORSKITE SAMPLES

Sample No.	A294/76	P435/76	P436/76	P437/76	P548/76 Palygorskite Zone	P548/76 Carbonate Zone
(1) Bulk Material						
Mineral						
Palygorskite	CD	A	SD	D	D	-
Montmorillonite	-	D	A	A	A	-
Calcite	CD	A	D	A	A	SD
Quartz	Tr	A	A	A	A	A
Mica	-	A	A	A	-	-
Kaolinite	-	Tr-A	A	A	A	A
Goethite	-	Tr-A	-	A	-	A
Feldspar	-	Tr-A	-	-	-	Tr
Halite	-	Tr	-	-	-	-
Gypsum	-	Tr	-	-	-	-
Dolomite	-	-	-	-	-	D
(2) -2 μm Fraction (% less than 2 μm)						
% of Bulk Sample	36	46	56	60	50	78
Mineral						
Palygorskite	D	SD	D	D	D	D
Montmorillonite	-	D	A	A-SD	A	A
Calcite	SD	Tr	A-SD	Tr-A	A	A
Goethite	-	A	A	A	A	A
Kaolinite	Tr-A	A	-	A	A	A
Chlorite?	-	-	A	-	-	-
Quartz	-	-	Tr	Tr	Tr	Tr
Vermiculite?	-	-	-	-	A	A

D - Dominant - most abundant component, regardless of probable percentage level.
CD - Co-dominant - components with equal abundance.
SD - Sub-dominant - next most abundant component provided percentage level above 20%.
A - Accessory - 5-20%
Tr - Trace - less than 5%.

Sample: P9, P548/76; TS37111 and TS37112

Location:
11 km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
Impure palygorskite.

Hand Specimen:
This sample consists largely of light, brown, finely crystalline banded material. On the sawn surface the layers are seen to be typically between 1 to 2 mm across, finely crumpled and partings between the layers up to 2 mm across are common. In one part of the sample there is a gradation from the material described above to material which is yellow-brown with more ?clay and carbonate.

Thin Section:
An optical estimate of the constituents gives the following:-

Palygorskite-rich area (TS37111)

	%
Palygorskite (and clay)	70-90
Quartz	5-15
Goethite-limonite	5-15
Calcite	5-15

Carbonate-rich area (TS37112)

Palygorskite (and clay)	20-30
Quartz	2-4
Goethite-limonite	5-15
Calcite	50-70

Two thin sections were prepared from this sample; one to show the structure and textures present in the palygorskite-rich area and the other to show the transition between the palygorskite-rich area and the carbonate-rich portion. It was not possible microscopically to distinguish between palygorskite and the other clay minerals detected by X-ray diffraction analysis.

The palygorskite is a pale green-brown colour, has a fibrous-flaky texture and individual flakes vary greatly in size with a few being up to at least 0.6 mm long. The palygorskite flakes are not strongly aligned and in most parts appear as felted masses. Finely granular goethite is intimately associated with the palygorskite and in a few places staining with limonite is quite intense.

Rhomb-shaped structures are preserved in the palygorskite in a few places and these rhombs are filled with either ?chalcedony or goethite-limonite. These are thought to be former dolomite rhombs but the carbonate in this sample is definitely calcite. The nature of the carbonate has been confirmed both by X-ray diffraction analysis and by a microchemical staining test. The calcite occurs as equant xenomorphic crystals which are typically about 0.05 mm in diameter and these are aggregated into irregularly shaped patches up to 0.6 mm across in the palygorskite-rich areas of the rock and larger masses up to several millimetres across in the carbonate-rich portion of the sample. Quartz, palygorskite and goethite-limonite areintimately intergrown with the carbonate in different portions of the sample.

Many of the quartz grains in this sample have a distinctive cigar-shape and may be authigenic. There are also some round-ovoid grains which generally have a radial extinction pattern although undulose (strain) extinction is a feature of most of the grains. The quartz grains tend to be concentrated in patches/layers in the sample some of which are palygorskite-rich and some of which are carbonate-rich. The largest quartz grains are up to 0.6 mm long but most are between 0.1 and 0.3 mm in diameter.

The transition from the palygorskite-rich to the carbonate-rich portion of the sample is fairly abrupt although small patches of carbonate occur in the palygorskite-rich area and foliae/crumpled layers of palygorskite occur in the carbonate-rich portion of the sample. Minor amounts of quartz are present in both areas and this quartz is probably authigenic or at least recrystallized if of detrital origin. Goethite-limonite is ubiquitous throughout the sample.

Sample: A, P434/76; TS36654

Rock Name:
Yellow-brown clayey soil

Hand Specimen:
This sample consists of yellow-brown, friable clayey material. There is some darker flecking (?manganese concentrations) and some lighter-coloured patches.

X-ray Diffraction Analysis Results:

Table 1. X-ray Diffraction Analysis of Sample P434/76

Bulk Material

Montmorillonite	Dominant
Feldspar	Accessory
Quartz	Accessory
Goethite	Accessory
Kaolin	Accessory
Mica	Accessory
Dolomite	Accessory
Halite	Trace

-2μm Fraction (%<2μm 26%)

Montmorillonite	Dominant
Goethite	Accessory
Kaolin	Trace-Accessory

The procedure followed during the X-ray diffraction examination of this sample is the same as that for samples P435/76 to P437/76 and is given at the foot of Table 4. A key to the abundance categories employed is given in Table 4.

Thin Section:
One of the more coherent lumps in the sample was thin sectioned and in texture, and possibly mineralogy, probably differs somewhat from the material as a whole. The thin-sectioned sample consists essentially of small (up to 0.02 mm in diameter) highly-corroded quartz grains in a mixture of finely-crystallized clay and iron oxides (goethite). Also recognisable are small flakes of mica and a few irregularly-shaped plagioclase crystals of altered appearance. Overall the texture appears granular but it is not certain whether this has been inherited or has developed during the weathering of the material.

Heavy Mineral Separation Results:

The results of crushing a portion of the sample to 0.42 mm, desliming it at 0.045 mm and separating the -0.042+0.045 mm fraction in tetrabromoethane (sp.gr. 2.96) are as follows:

Table 2: Heavy Liquid Separation of Sample P434/76

Size-fraction	Weight %
+0.045 mm >2.96 sp.gr.	0.1
+0.045 mm <2.96 sp.gr.	47.5
-0.045 mm (unseparated)	52.4
Total	100.0

Reflected light microscope examination of a polished section (PS25135) of the "sinks" product showed it consists of goethite, limonite, manganese minerals and trace amounts of rutile, pyrite and non-opaque minerals.

Discussion:

Fairbairn and Robertson (1966) have investigated the stages in the tropical weathering of kimberlite. From their paper it is fairly clear that unless ilmenite and pyrope garnet are present ("kimberlitic minerals") it is difficult, if not impossible, by laboratory methods to ascertain if highly weathered, clay samples like this one are derived from kimberlite.

In their paper, in Table 13, they give the mineralogical analyses of seven samples of kimberlite which are at various stages of weathering. None of their samples has a mineralogical composition which corresponds to the mineralogical composition of this sample.

Sample: P3, P542/76

Location:
11km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
Pale brown, unconsolidated clayey soil.

X-ray diffraction results: (key to abundance categories on P14)

Bulk Mineralogy

Feldspar (albitic)	Dominant
Montmorillonite	Sub-dominant
Dolomite	Accessory
Calcite	Accessory
Quartz	Accessory
Mica (illite)	Trace

Clay Fraction (<2 μm) 19%

Montmorillonite	Dominant
Calcite	Accessory
Kaolinite	Trace

Sample: P4, P543/76

Location:
11km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
Brown unconsolidated clayey soil.

X-ray diffraction results: (key to abundance categories on P14)

Bulk Mineralogy

Montmorillonite	Dominant
Quartz	Sub-dominant
Calcite	Accessory to sub-dominant
Dolomite	Accessory
Mica	Accessory
Goethite	Accessory

Clay Fraction (<2 μm 27%)

Montmorillonite	Dominant
Goethite	Trace to accessory
Kaolinite	Trace
Quartz	Trace

Sample: P5, P544/76

Location:
11km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
Brown unconsolidated clayey soil.

X-ray diffraction results: (key to abundance categories on P14)

Bulk Mineralogy

Montmorillonite	Dominant
Calcite	Sub-dominant
Kaolinite	Accessory
Feldspar (albitic)	Accessory
Goethite	Accessory
Dolomite	Trace to accessory
Quartz	Trace
Talc	Trace

Clay Fraction (<2 μm 26%)

Montmorillonite	Dominant
Vermiculite	Accessory
Calcite	Accessory
Goethite	Accessory
Kaolinite	Accessory
Quartz	Trace

Sample: P8, P547/76

Location:
11 km north of Oodlawirra. Section 132 in the hundred of Coglin.

Rock Name:
Unconsolidated brown clayey soil.

X-ray diffraction results: (key to abundance categories on P14)

Bulk Mineralogy

Quartz	Co-dominant
Goethite	Co-dominant
Montmorillonite	Co-dominant
Palygorskite	Accessory
Mica/illite	Accessory
Kaolinite	Accessory
Feldspar (albitic)	Trace

Clay Fraction (<2 µm 39%)

Montmorillonite	Dominant
Palygorskite	Accessory
Goethite	Accessory
Kaolinite	Trace
Mica-illite	Trace

4. REFERENCES

Fairbairn, P.E. and Robertston, R.H.S. (1966) Stages in the Tropical Weathering of Kimberlite. Clay Minerals, Vol 6, p351-370.

APPENDIX B

CHEMICAL ANALYSIS

- extracted from AMDEL Reports

MT 479/77 and MP1035/77

Sample No.	A294/76	P435/76	P436/76	P437/76
SiO_2	15.23	31.98	42.93	39.22
TiO_2	0.03	0.20	0.04	0.05
Al_2O_3	2.82	7.94	8.97	7.76
Fe_2O_3	4.27	12.51	15.08	18.14
FeO	< 0.55	< 0.05	< 0.05	0.05
MnO	0.06	1.84	0.13	0.14
MgO	3.35	3.98	7.13	5.64
CaO	36.6	12.13	0.63	6.67
Na_2O	0.04	1.37	0.67	0.06
K_2O	0.11	0.26	0.08	0.14
P_2O_5	0.11	0.11	0.12	0.19
H_2O+	3.82	7.81	10.75	10.33
H_2O-	2.43	9.19	11.45	5.32
CO_2	29.10	9.10	0.45	5.40
TOTAL	98.52	98.42	98.42	99.56