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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1968/49

JURASSIC BENTONITE FROM THE MILES DISTRICT, QUEENSLAND

by

N.F. Exon & P.G. Duff

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CONTENTS

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SUMMARY

Five seams of good-quality bentonite crop out in a scarp north of Miles in southern Queensland, and another on the plain 1000 feet to the west. Bentonite in the same general interval was also intersected in shallow drill holes nearby.

These outcrops are part of an Upper Jurassic sequence in which bentonite has previously been found further west. The bentonites are ash-fall deposits which have been preserved only in back-swamps away from Jurassic stream channels. They may be widespread in the Upper Jurassic sequence of the Surat Basin.

Laboratory testing has shown that some of the bentonite has commercial potential.

INTRODUCTION

During the mapping of the Chinchilla 1:250,000 Sheet area in 1967, by a joint Bureau of Mineral Resources/Geological Survey of Queensland field party, bentonite was collected from a road cutting on the Miles/Wandoan road 24 miles north of Miles. R.R. Vine took the sample to Canberra where it was tested by Duff in the Petroleum Technology Laboratory. It turned out to be a swelling bentonite of excellent quality, and a further 8 samples were collected by Exon from different levels in the vicinity; two other clays from near Chinchilla were also submitted. Most of the samples from the locality tested as good quality swelling bentonites; the other two samples were not bentonitic. Three shallow holes were drilled nearby to collect unweathered core from the whole interval of interest. Only two levels of good swelling bentonite were penetrated in the bores, compared to at least five in outcrop. However, the test results show that the deposit is of economic interest. Further work in the area could lead to the discovery of a workable deposit near a railway only 200 miles from Brisbane.

PART I - GEOLOGY AND CHEMISTRY

by

N.F. Exon

This is the third discovery of good-quality bentonite in south-east Queensland (see Fig. 1) as the result of regional geological mapping by Bureau of Mineral Resources/Geological Survey of Queensland field parties.

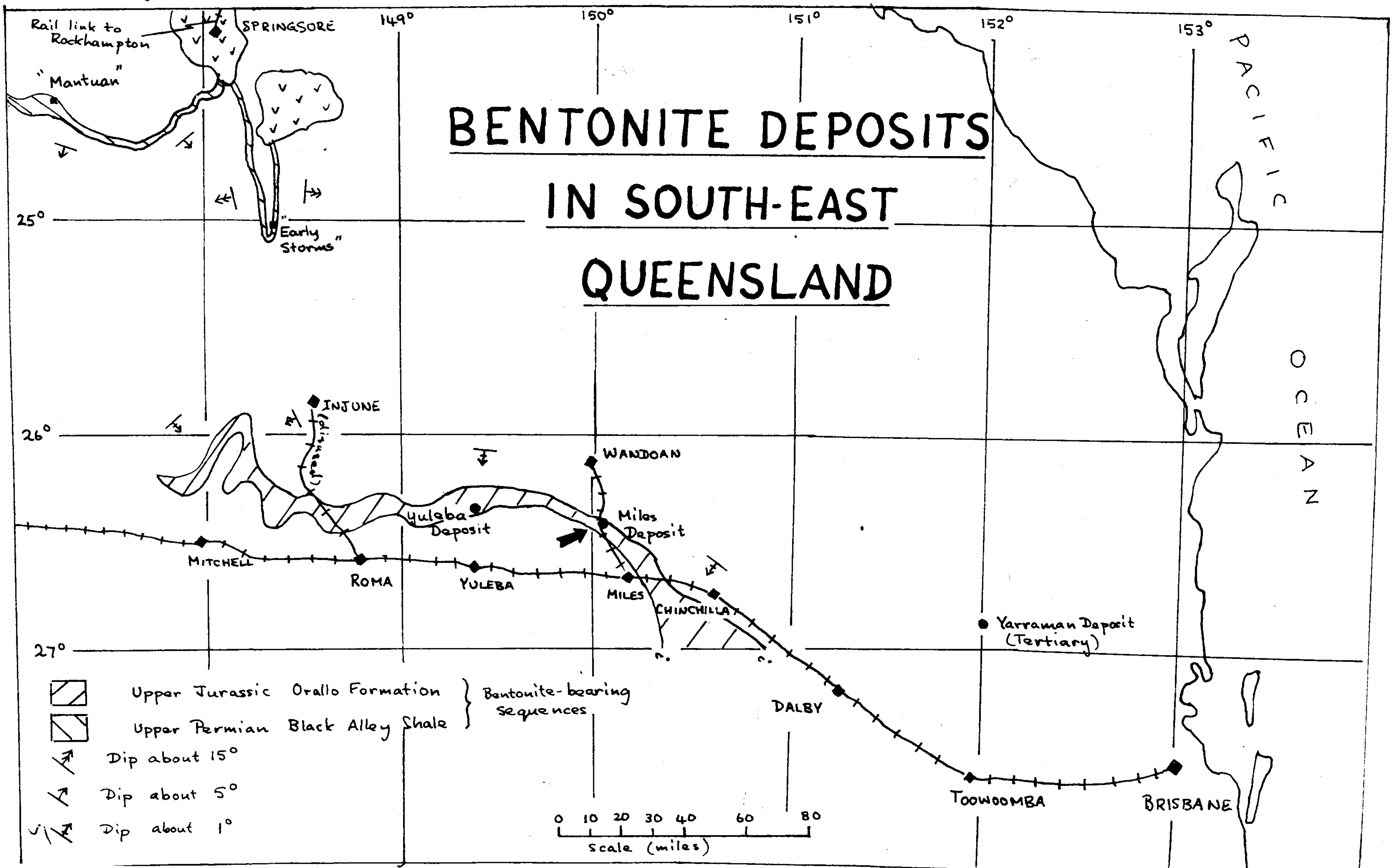
The first (Thompson and Duff, 1965) was in the Upper Permian Black Alley Shale in the Springsure area. This has since been extensively prospected and large tonnage of good quality material proved in the Mantuan area.

The second was in the upper part of the Upper Jurassic Orallo Formation in the Yuleba area. This discovery, described by Duff and Milligan (1967), gave test results which compared "favourably with those obtained from testing of the Black Alley Shale .... and even surpass the latter material in respect of the wall-holding characteristics". However, it did "not meet the A.P.I. specifications for bentonite for use in drilling muds but could possibly be used, after alkaline treatment, for iron ore pelletising". The deposit was not considered economic in the area tested in detail, but suggestions as to further exploration were made. Milligan stated that "small outcrops of claystone and 'clay' have been recognized in the unit throughout its mapped extent". However, despite the fairly good chance of finding further good bentonite deposits in the Orallo Formation in the Roma Sheet area, no further work has been done.

The Miles deposit is probably related to the same period of volcanism as the Yuleba deposit but is somewhat older. The sediments containing this bentonite are equivalent to either the uppermost Injune Creek Group or the lowermost Orallo Formation but are not lithologically typical of either unit. Mapping in the area is hampered by poor outcrop and some faulting. Spore information (Appendix 1) slightly favours equivalence to the upper Injune Creek Group. In either case the age of the deposit is Upper Jurassic.

To accompany Record 1968/49

Fig. 1.



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Both the Injune Creek Group and the Orallo Formation are of fresh-water origin and consist of fluviatile and paludal sediments derived largely from contemporaneous andesitic volcanism, which extended through Middle and Upper Jurassic times.

The location of the bentonite outcrops is shown, and they and the containing sequence are described, in Figure 2, which also shows the position of the drill holes. Due to drilling difficulties three holes had to be drilled at the one site. Figure 3 is a composite log of the continuously cored sequence in the drill holes. Core recovery averaged 80%. The ground surface in Figure 3 and the plateau top in Figure 2 are roughly the same level. Appendix 2 contains the petrography of thin sections from drill cores. Three bentonite samples (see Fig. 2) from outcrop were processed for forams and diatoms, but none were found.

It is probable that bentonite occurs elsewhere in the upper Injune Creek Group. Cracking clays, which could be bentonitic, crop out in this sequence just west of the Roma/Injune road (Roma 1:250,000 Sheet; grid reference 150738). As regards the bentonite in the Orallo Formation it is of interest that thick claystone crops out well west of the Roma Sheet, in the equivalent position in the Hooray Sandstone. On the Mungallala/Mount Elliott Homestead road (Mitchell Sheet, g.r. 572747) there is 35 feet of massive white claystone which proved to be largely kaolinite with lesser illite (Exon, Milligan, Casey and Galloway, 1967). This could easily be a deep-weathered alteration product of an originally bentonitic clay.

General sequence near Miles deposit

About 150 feet of sediments crop out in a north-facing scarp formed by the erosion of a plateau which represents an old, probably early Tertiary, land surface. The upper 80 feet of this sequence was deeply weathered (and toughened as compared to normal recently weathered material) during formation of this land surface. The sequence consists of fluviatile sandstone with silt, coal and clay bands. Bentonitic clays only crop out below the deeply weathered zone, but one bentonite band occurs at 55 feet (i.e. low in the deeply weathered zone) in the drill holes, which were sited on the plateau.

Nearby, on the plain to the north-west, the same sequence is present on low rises (e.g. SB375 in Fig. 2). A mile or two north there are typical outcrops of calcareous lithic sandstone of the Injune Creek Group.

The area lies in the eastern limb of the Mimosa Syncline which is a major south-plunging downwarp between the Roma Shelf in the west and an area of shelf sediments lapping onto the older granites, volcanics and metamorphics of the Auburn Massif and Yarraman Block to the east. The eastern limb of the syncline is block faulted by north-trending faults as shown by seismic work by Union-Kern-A.O.G. The trace of one major seismic fault is 4 miles east of this locality. At the surface there are numerous north-west and north-east trending lineaments which apparently represent small faults caused by late movements on the older faults (which have little displacement after early Jurassic times). A dip of about $\frac{1}{2}^{\circ}$ to the south-west is indicated for the bentonitic sediments in this area.

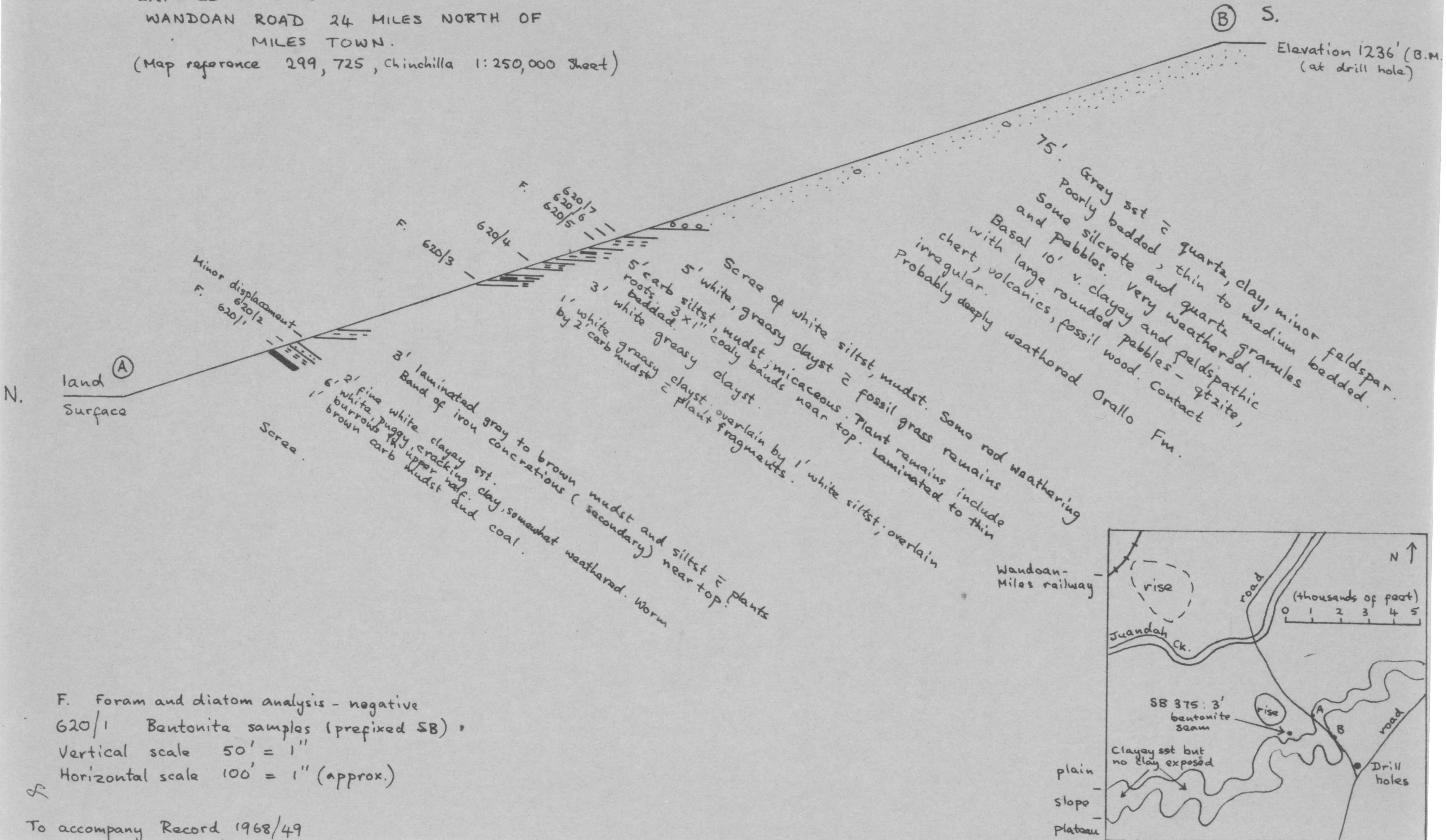
The sequence consists largely of thickly bedded, cross-bedded, labile sandstone which appears to be a clayey feldspathic sandstone in hand specimen. However, in thin section (Appendix 2) fine volcanic rock fragments and fresh angular labradorite are the main constituents, with lesser quartz, montmorillonitic clay matrix, biotite and carbonaceous material, and minor apatite. The clay matrix was shown to be bentonitic during water drilling of the sandstone, as it formed an excellent drilling mud. Thinly bedded grey siltstone and mudstone is fairly common in beds up to several feet thick. A number of greasy white bentonite seams up to 6 feet thick are exposed in the cutting on the main Wandoan/Miles road (see Fig. 2 and Plate 1), and thinner seams are present in the subsurface 1500 feet to the south-east (Fig. 3). In many places these are associated with coal and carbonaceous mudstone beds of varying thickness.

Elsewhere in the scarp, outcrop is quite good but consists of sandstone, siltstone and mudstone. In about 2 days work over several miles to east and west no bentonite was found, and it seems that the road position is fortuitous in that it cuts the most abundantly bentonitic sequence in the immediate area. However, there is bentonite away from the scarp at SB375.

MILES BENTONITE DEPOSIT

Fig. 2

EXPOSED IN ROAD CUTTING ON MAIN MILES-WANDOAN ROAD 24 MILES NORTH OF MILES TOWN.
(Map reference 299, 725, Chinchilla 1:250,000 Sheet)



F. Foram and diatom analysis - negative
620/1 Bentonite samples (prefixed SB).
Vertical scale 50' = 1"
Horizontal scale 100' = 1" (approx.)

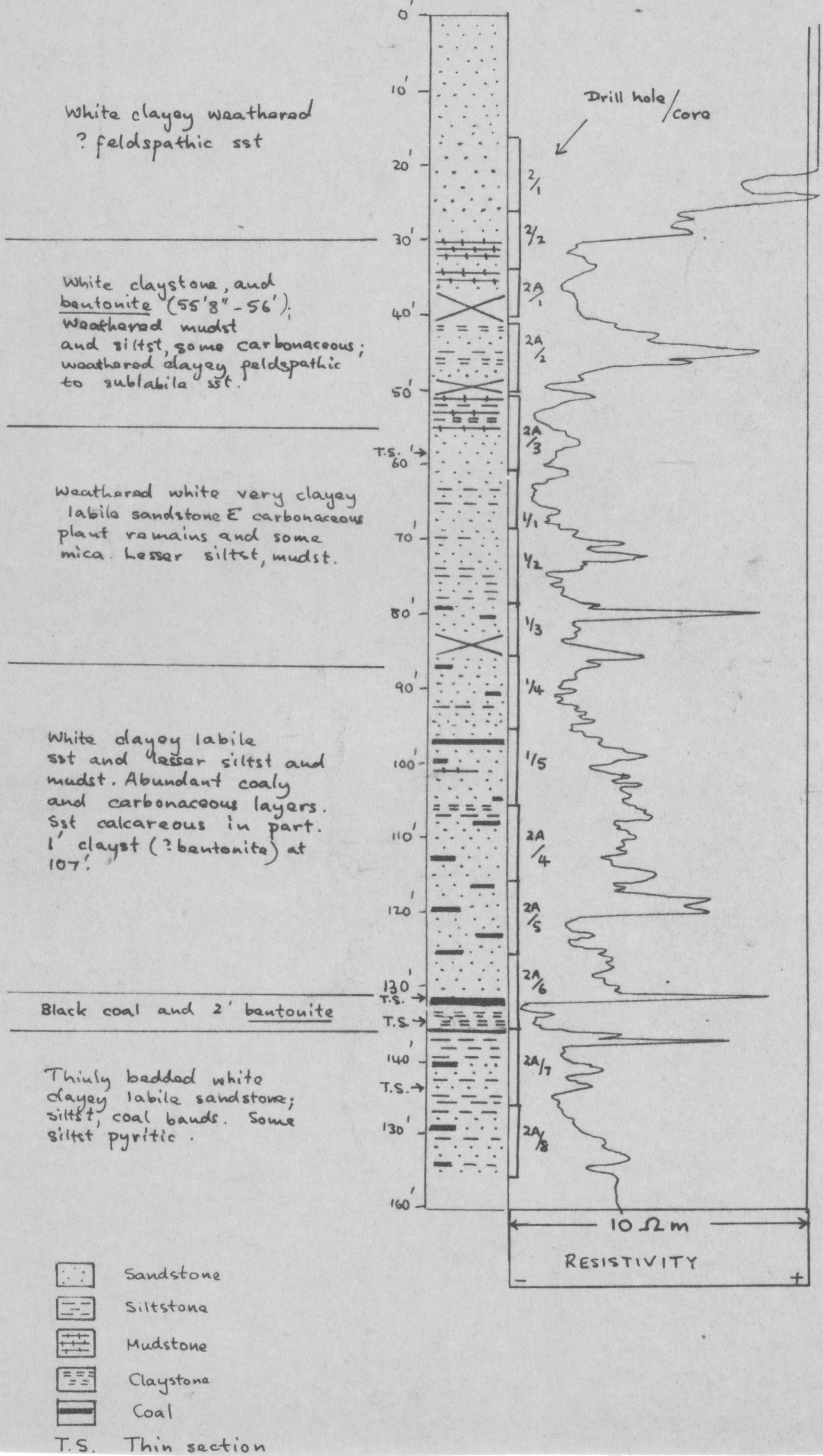
To accompany Record 1968/49

G56/A9/4

Fig.3

COMPOSITE LOG OF DRILL HOLES
BMR CHINCHILLA Nos 1, 2, 2A

(Drilled on plateau above bentonite outcrops, about 500 yards S of slope and within 10 yards of each other. G.L. 1236')



The Bentonite

In outcrop this forms a white greasy cracking clay (Plate 1). In some cases it contains plant remains, including fossil grass in its living position (White, 1968). At the surface it is often iron stained. A thin section of fresh bentonite from a drill core (Appendix 2) showed the clay to consist of great numbers of fine glass shards and ash, which had been clay-altered. Impurities made up less than 2% of this specimen which is thus an unworked ash-fall deposit.

Table A shows the results of X-ray diffraction examination of the outcrop samples, mostly carried out by C. Branch of the B.M.R. All the bentonitic samples consist dominantly of montmorillonite group clays, generally with abundant α-cristobalite, some quartz and minor kaolin. SB375 departs from this type in that quartz is very abundant and α-crystobalite absent. As SB375 is probably more heavily weathered than the other samples, this could be a weathering phenomenon, the metastable α-cristobalite breaking down to give stable quartz.

The analysis of SB620/4, which is not the best sample but was the first collected, is shown in Table B, and compared with other Queensland analyses and that of typical Wyoming bentonite. It can be seen that it is much higher in silica than the other samples, and considerably lower in most other constituents than the Wyoming bentonite. However, it is a sodium bentonite, unlike other Australian examples listed. It has a total base exchange capacity of 31.5 me (milliequivalents) % compared with 81 me% for the Black Alley Shale bentonite. Thus it should be less susceptible to improvement by treatment with sodium carbonate, but as it is already a sodium bentonite this probably does not matter.

In rheological properties several of these samples are as good as the best of Australian bentonites (Part 2), but not as good as Wyoming bentonite as a base for dilling mud.

Deposition and Alteration

During deposition of this sequence the environment was dominated by south to south-west flowing streams of moderate energy. Andesitic volcanics and some acid volcanics (as shown by the presence of angular quartz) provided the vast bulk of the detritus. At this locality sand sized debris was carried in the streams, and fine ash rained from above.

The extreme angularity and freshness of the feldspar suggests derivation from a fairly local source, probably within the syncline. As there are major faults in the area it is quite likely that vents were located along them, but none have been found.

Ash falling into the stream channels probably provided the montmorillonitic matrix of the sandstones, but no shards were preserved. However, in back swamp areas ash falls were preserved. Vegetation thrived in these areas between falls as shown by the abundance of coal and carbonaceous mudstone between ash beds. Some grasses grew on the ash itself and were commonly preserved in their growth position by the next fall. From time to time stream channels swept over former backswamp areas causing some erosion of fine material, and sand deposition.

The shards devitrified to give montmorillonite and α-cristobalite. The chemical composition of the resulting clay is more siliceous than for a normal bentonite, which suggests a more acid than typical volcanism. In areas subjected to the early Tertiary deep-weathering the metastable α-cristobalite probably changed to quartz, and montmorillonite to kaolinite. * However, recent weathering has left the montmorillonite unchanged.

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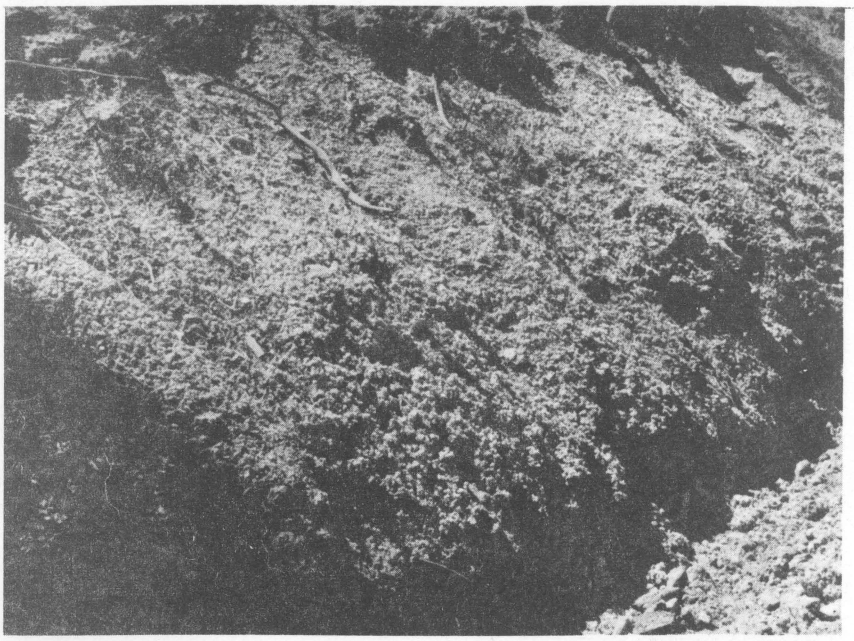
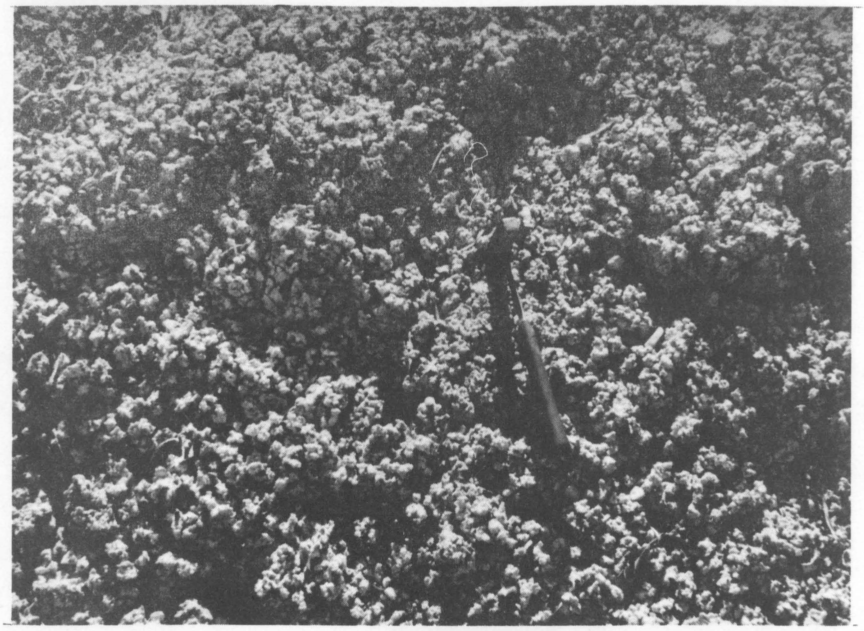
* That deep weathering will convert montmorillonite to kaolinite is shown in a shallow drill hole in the Canterbury Sheet area in the Eromanga Basin (Gregory and Vine, in prep.). In this continuously cored hole, analysis for clay minerals was carried out every ten feet. The matrix of the rock low in the profile was greatly dominated by montmorillonite, in the middle part it varied at random from montmorillonite to kaolinite, and in the upper part it was greatly dominated by kaolinite.

OUTCROPS OF MILES BENTONITE IN SCARP



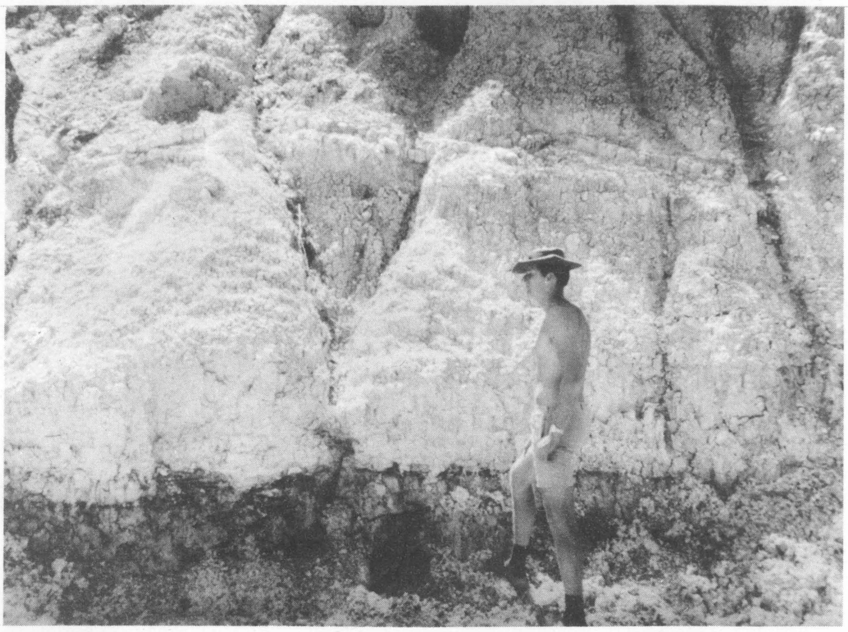
General view of one seam

(Neg. no. GA 860)



Close-up of bentonite

(Neg. no. GA 858)



Seam overlying coal and carbonaceous mudstone

(Neg. no. GA 859)

RELATIVE ABUNDANCE OF VARIOUS MINERALS

TABLE A

(X-RAY DIFFRACTION)

SAMPLE		MONTMORILLONITE GP.	KAOLINITE GP.	CRISTOBALITE	QUARTZ	ILLITE
SB 620/2	o	very abundant	absent	abundant	minor	
620/3		"	"	"	trace	
620/4		"	trace	"	minor	
620/4	*	"	minor	absent	absent	trace
620/5		"	"	abundant	trace	
620/6		"	"	"	abundant	
620/7		"	"	"	"	
SB 374	x	"	"	absent	very abundant	
375	o	"	absent	"	"	
SB 900	+	minor	very abundant	absent	very abundant	
901	+	"	abundant	"	"	

Note: All samples except that marked * examined by Dr. C. Branch at B.M.R.

* sample examined by E.C. Stock at A.M.D.L.

\+ non bentonitic clays from Upper Jurassic in Chinchilla area

x non bentonitic sample from slope above SB 375 (Fig. 2)

o best bentonites from physical properties

TOTAL SILICATE ANALYSES OF VARIOUS BENTONITES

TABLE B

		SB 620/4 o	Bentonite "E" * Black Alley Shale	Meandu Creek + Bentonite	Wyoming x bentonite
Silica	SiO_2	74.0	47.3	52.6	66.90
Aluminium oxide	Al_2O_3	15.2	18.3	16.1	15.26
Ferric oxide	Fe_2O_3	0.87	3.8	2.3	2.80
Ferrous oxide	FeO	0.05	0.25		0.12
Magnesium oxide	MgO	1.27	2.2	3.8	2.26
Calcium oxide	CaO	0.08	6.1	0.8	0.46
Sodium oxide	Na_2O	0.37	1.44	0.1	2.12
Potassium oxide	K_2O	0.11	0.35	0.1	0.42
Water over 100°C	H_2O^+	5.65	5.60	10.6	3.67
Water at 100°C	H_2O^-	2.25	10.4	13.6	5.80
Carbonate	CO_2	0.02	4.00		0.05
Titanium oxide	TiO_2	0.11	0.27	0.2	0.11
Phosphorus pentoxide	P_2O_5	0.01	0.04	-	0.04
Manganese oxide	MnO	< 0.01	0.21	Trace	
		99.99			

* Haldane, Appendix in Thompson and Duff (1965)

\+ Croft and Zeissink (1967)

x Analysis 9, Page 12 in Silica Products Company (1930)

o A.M.D.L. report AN 1122/68

f

Suggestions for further prospecting

One of the most favourable aspects of this deposit is that it is only 2 miles from a railway line which links this area with Brisbane 200 miles away.

The material in the scarp itself cannot be regarded as an economic prospect due to the great thickness of overburden. It is probable that to be economic a deposit would have to consist of a 3 foot seam with probably less than 10 feet of overburden (Thompson and Duff, 1965). The thicker the seam the greater the permissible overburden. Fortunately the scarp deposit shows that seams of about 6 feet can be expected. Another favourable point is that dips are negligible and that the relief in the area is generally not high.

The immediate area of interest must be that around SB375 where there is bentonite among low rises on the plain of the Injune Creek Group. A detailed mapping, and truck-mounted auger or shallow drilling programme, in this area is suggested. This could also shed light on the true stratigraphic position of this bentonite. There would be little point in extending the search to the south and east, as Cainozoic cover is extensive and most older rocks are deeply weathered, and clays would probably be kaolinite-altered (e.g. SB900, 901 in Table A).

However, mapping and drilling below the scarp of the basal Orallo Formation north-west of SB375 is suggested. Perhaps initially this could be carried as far westwards as the first appearance of the Gubberamunda Sandstone between the Injune Creek Group and Orallo Formation (10 miles). It is emphasized though that there is a possibility of finding workable bentonite in the upper Injune Creek Group as far west as Roma at least.

The Orallo Formation is also prospective on the Roma Sheet, but (as with the Injune Creek Group) not on Chinchilla Sheet south and east of this find.

The fluviatile environment of deposition leads to some problems which would apply equally to any areas where bentonite occurred in such an environment. Workable deposits would have to be in old back swamp areas; some method of defining stream channels and point bar deposits would be invaluable but probably this can only be done by drilling, and extrapolation from that drilling and cross-bedding information in nearby outcrops. Electric logs of holes taken with a small portable logger could be useful (see Fig. 3; 130' to 140') in that bentonite has a very low resistivity and coal, which is commonly associated with the bentonite in the backswamp environment, has very high resistivity. Thus if logged holes gave levels of sharply fluctuating resistivity these levels could well contain bentonite seams.

In all this work the appropriate 1:250,000 preliminary geological maps held at the Bureau of Mineral Resources and the Geological Survey of Queensland and the appropriate air photographs would be invaluable. From the maps the general areas of outcrop are apparent, and from the photographs areas where topography and overburden made economic deposits unlikely could be ruled out.

It is apparent that the quality and quantity of bentonite in this area is very encouraging. Problems of stratigraphy remain but these would be resolved as exploration proceeded.

PART 2 - LABORATORY TESTING FOR SUITABILITY AS A DRILLING MUD ADDITIVE

by

P.G. Duff

Ten surface samples of bentonitic claystone were evaluated in the Petroleum Technology Laboratory for their suitability as a drilling mud additive.

As some of these samples exhibited fair rheological properties, cores were taken to intercept an extension of these bentonitic layers at depth. From these cores a further ten samples were selected for testing.

A description of these samples and their position and method of sampling is given elsewhere in this report.

Testing was carried out in accordance with procedure laid down by the American Petroleum Institute (A.P.I.) using apparatus approved by that authority.

Explanation of Terms and Tests

1. The term "viscosity" in relation to drilling mud refers to the overall or Apparent Viscosity (A.V.) measured on a variable speed, rotational viscometer. The A.V. is measured in centipoise units and is made up from two distinct components, namely, the Plastic Viscosity, (P.V.) and the Bingham Yield, (Y).

(a) The P.V. may be simply described as that part of the A.V. which is created by mechanical friction between the solid particles in the slurry, between the solids and the liquid which surrounds them, and by the shearing of the liquid itself. The measurement of P.V. is made in centipoise units.

(b) The Y. value is that part of the A.V. which is produced by electrochemical action between unsatisfied charges on the clay particles; it is measured as a shear force in pounds per 100 square feet.

2. The Expressed Filtrate or "water loss" is the volume, in millilitres, of clear liquid which can be forced out of the slurry under test, during a period of 30 minutes, with a pressure of 100 psig. (pounds per square inch, gauge), through a filter paper 7 square inches in area.

3. The gelling properties of a slurry are determined on the rotational viscometer where the shearing force, acting on a rotor moving slowly in the slurry is measured immediately after agitation for the "Initial" gel and, after 10 minutes quiescent standing for the "Ten Minute" gel. These gel values are measured in pounds per 100 square feet.

4. All the slurries were prepared using dry bentonite in distilled water and were high-speed mixed for 30 minutes to give maximum dispersion. Slurries were then allowed to stand for 24 hours to ensure complete hydration of all bentonitic material. Finally, each slurry was given a further 30 minutes high-speed mix before testing.

5. A simple test to determine whether a crude sample is bentonitic is the Benzidine Test. In this test the dried sample is treated with an aqueous solution of benzidine base. If the sample contains a significant amount of swelling bentonite the mixture turns blue <u>immediately</u>. Samples containing minor amounts of bentonite produce very pale shades of blue after time intervals depending roughly on the percentage of bentonite present.

Colours listed in Table 1 were read 30 seconds after benzidine addition.

A.P.I. Specifications for Bentonite as a Drilling Mud Additive

The relevant section from the "A.P.I. Specifications for Oil Well Drilling Fluid Materials (Tentative), A.P.I. Standard 13.A., 1st Addition March 1965", reads:

Section 3. Bentonite

Bentonite Physical and Chemical Requirements

Requirement	Numerical Value
Plastic Viscosity	8 cp. minimum
Filtrate	14 ml. maximum
Wet Screen Analysis Residue on U.S. Sieve No. 200	2.5 % maximum
Moisture	12 % maximum

Filtrate and Plastic Viscosity are for a suspension of 21 gm. of bentonite in 350 ml. of distilled water.

Specification for Bentonite to be Used in Iron Ore Pelletizing

A more recent application for bentonite has been in the iron ore pelletizing process. However, specifications for bentonite to be used in pelletizing cannot be given as each company using bentonite for this purpose issues a different set of requirements. It appears, however, that the closer the sample tests are to the A.P.I. specifications for bentonite suitable for drilling mud purposes, the more efficient it is in pelletizing operations.

At present some Australian bentonites are being investigated for possible use in the pelletizing of Western Australian iron ore. However, only one inconclusive report, by Broken Hill Pty Ltd, Shortland Research Laboratory, has been issued to date.

Discussion of Results

Table 1 lists the results of initial testing of all the surface samples submitted. Based on these results samples which showed fair rheological properties were selected for further testing; those selected were marked 620/1, 620/2 and S.B. 375.

No further testing was carried out on the remaining samples either because their P.V. values were too low even after treatment with soda ash or because the filtrate values were too high or a combination of both.

Table 2 shows the effect of various concentrations of soda ash on sample 620/1; it may be seen that the alkaline addition has had some effect on the P.V. indicating that this sample is susceptible to ionic base exchange.

Table 3. Results of alkaline treatment of sample 620/2 shown in this table indicate that the P.V. may be increased appreciably by the addition of only a small quantity of soda ash. The filtrate has also been lowered effectively.

Table 4. Sample S.B. 375 exhibits only a small increase in P.V. but a fair drop in filtrate after alkaline treatment. The addition of soda ash above 1% continued to increase the overall viscosity (A.V.) but this is due to a rise in yield only, indicating that contamination and not base exchange is taking place.

Table 5. Test results on 10 samples selected from cores cut in the B.M.R. wells, Chinchilla Nos. 1, 2 and 2A are shown in this table.

The two samples from Chinchilla No. 1 had very poor rheological properties and further testing of these was discontinued.

Two segments selected from Chinchilla No. 2 cores proved to be very poor in as much as only 19%, in one case, and 26% in the other case, of the solid material, could be made to disperse, the residue remaining as hard lumps. No further work was carried out on these samples.

The only samples of interest came from Chinchilla No. 2A at depths of 55'3" to 56'0" and 134'8" to 136'3".

Two slurries were prepared from the 55'3" to 56'0" interval because of the heterogenous nature of the sample; the first slurry consisting of a mixture of brown-red and buff coloured material, the second slurry consisting of buff coloured material only.

The sample from the 134'8" to 136'3" interval was uniformly bluish-grey and two portions were selected from this for slurry preparation; the duplicate test results are shown in the table.

Table 6. The two samples from Chinchilla 2A; (55'3" to 56'0" and 134'8" to 136'3") were treated with varying amount of soda ash as shown in the table.

No improvement, of any consequence, was noted in any of these tests and in some cases deterioration of properties occurred.

Table 7. This table is included for easy comparison of the quality of some bentonites tested in the Petroleum Technology laboratory, compared with a premium grade, commercial, Wyoming bentonite.

Considering P.V. values in this table, it can be seen that the two Chinchilla bentonites, one a surface sample, the other from depth, are amongst some of the best Australian bentonites found to date.

We may grade those bentonites, which we have tested, in respect of this property, as shown below:

Untreated Sample		Treated Sample
Chinchilla 2A. (135' - 136')	Best P.V.	Chinchilla 2A. (135' - 136')
Yuleba Creek (Qld)	↓	Chinchilla S.B. 375
Chinchilla S.B. 375		Yuleba Creek (Qld)
Early Storms (Qld)		Early Storms (Qld)
Gellibrand (Vic.) Mantuan (Qld)		Mantuan (Qld)
	Poorest P.V.	Gellibrand (Vic.)

If we now consider one other important characteristic of bentonite slurries, expressed filtrate, we may grade these Australian bentonites as follows:

Untreated Sample		Treated Sample
Early Storms (Qld)	Best Filtrate	Early Storms (Qld)
Yuleba Creek (Qld)	↓	Yuleba Creek (Qld)
Chinchilla 2A (135' - 136')		Chinchilla S.B. 375
Chinchilla S.B. 375		Gellibrand (Vic.)
Gellibrand (Vic.)		Chinchilla 2A (135' - 136')
Mantuan (Qld)	Poorest Filtrate	Mantuan (Qld)

Conclusions

Some of the bentonitic material from the Chinchilla area has potential as a commercial bentonite according to the good rheological and expressed filtrate values obtained on testing.

This potential would be further enhanced if material which had not been contaminated with iron compounds etc. could be found in flat lying beds and if relatively little overburden had to be removed before mining.

A.P.I. TESTS OF SURFACE SAMPLES OF MILES BENTONITES — TABLE 1

All slurries 6% by weight of dry bentonite in distilled water.

Sample No.	620/1		620/2		620/3		620/4		620/5		620/6		620/7		SB 374		SB 375		901	
Treatment A.P.I. Tests	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Benzidine test	Mid blue	–	Mid blue	–	Pale blue	–	Pale blue	–	Very pale blue	–	Very pale blue	–	Very pale blue	–	Trace blue	–	Pale blue	–	Pale blue	–
Moisture content (% by wt.)	31	–	20	–	28	–	30	–	29	–	24	–	9	–	15	–	21	–	5	–
Apparent Viscosity (cp.)	3	5.5	4	7.3	3	4.3	2	5	2	4.3	1.8	2.5	1.8	1.3	1.5	1.5	5.5	5	1	1
Plastic Viscosity (cp.)	2	5	3	6	2.5	3	1.5	3	1.5	3.5	1	2	1	1	1	1	4.5	4	0.5	1
Yield (lb./100 sq.ft.)	2	1	2	2.5	1	2.5	1	4	1	1.5	1.5	1	1.5	0.5	1	1	2	2	1	0
Initial Gel (lb./100 sq.ft.)	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Ten Minute Gel (lb./100 sq.ft.)	1	2	1	2	1	5	2	4	1	1	0	1	0	0	0	0	2	9	0	2
Expressed Filtrate (cc.)	22	18	18	15	25	24	48	20	37	26	46	28	96	71	66	45	17	15	91	70
pH (Lovibond comparator)	8	–	8	–	8	–	7.5	–	7	–	7	–	7	–	7	–	8	–	7	–
Sand Content (% by vol.)	Tr.	–	0.4	–	Tr.	–	Tr.	–	0.8	–	0.5	–		–	Tr.	–	0.5	–	Nil	–

A = Original sample air-dried only

B = Original sample treated with 2% by weight of sodium carbonate

SAMPLE 620/1 TABLE 2

All slurries 6% by weight of dry bentonite in distilled water

A.P.I. TEST	Original sample Air dried only	Sodium Carbonate Addition % by wt. 0.5	1	2	4
A.V. (cp.)	3	5.5	5.5	5.5	8.5
P.V. (cp.)	2	4.3	5	5	5
Y (lb./100sq.ft.)	2	2.5	1	1	8
Init. Gel (lb./100sq.ft.)	0	1	1	1	5
Ten. Min. Gel. (lb./100sq.ft.)	1	3	2	2	23
Filtrate (cc.)	22	21	18	18	18

SAMPLE 620/2

TABLE 3

All slurried 6% by weight of dry bentonite in distilled water

A.P.I. TEST	Original sample Air dried only	Sodium Carbonate Addition % by wt.							
		0.1	0.2	0.5	0.6	1	2	4	8
A.V. (cp.)	4	4.3	4.8	8.5	8.3	6.3	7.3	13	18.5
P.V. (cp.)	3	3.5	4.5	7	4.5	6	6	6	6
Y. (lb./100 sq.ft.)	2	1.5	0.5	3	7.5	0.5	2.5	14	25
Init. Gel (lb./100 sq.ft.)	0	0	0	0	1	0	0	10	25
Ten Min. Gel. (lb./100 sq.ft.)	1	0	1	1	20	1	2	31	45
Filtrate (cc.)	18	18	18	17	21	16	15	14	12

SAMPLE SB 375 TABLE 4

All slurries 6% by weight dry bentonite in distilled water

A.P.I. TEST	Original sample Air dried only	Sodium Carbonate Addition % by wt.							
		0.1	0.2	0.5	0.6	1	2	4	8
A.V. (cp.)	4	6.3	6.8	7	5.8	7.8	8.5	9.3	13
P.V. (cp.)	3.5	5	6	5.5	5	6	6	5	5
Y. (lb./100 sq. ft.)	1	2.5	1.5	3	1.5	3.5	5	8.5	16
Init. Gel. (lb./100 sq. ft.)	1	0	0	1	0	1	1	5	12
Ten Min. Gel. (lb./100 sq. ft.)	1	0	1	1	1	1	1	22	26
Filtrate (cc.)	18	14	15	18	14	13	13	15	17

A.P.I. TESTS OF SUBSURFACE SAMPLES OF MILES BENTONITES FROM B.M.R. SCOUT DRILLING

TABLE 5

All slurries 6% by weight of dry bentonite in distilled water

A.P.I. TEST	Well No. 1 66'2"	Well No. 1 68'3" 69'0"	Well No. 2 25'10" 26' 3"	Well No. 2 33'6" 34'6"	Well No. 2A 42'0" 43'0"	Well No. 2A 44'6" 45'6"	Well No. 2A 45'6" 47'2"	Well No. 2A 55'3" 56'0"	Well No. 2A 55'3" 56'0" selected	Well No. 2A 107'0" 108'0"	Well No. 2A 134'8" 136'3"	Well No. 2A 134'8" 136'3" Repeat
A.V. (cp.)	2	2	would not		2	1.3	2.5	3.5	4.5	1.8	6	5.5
P.V. (cp.)	1.5	1.5	yield.		1.5	1	1.5	3	4	1.5	5.5	5
Y. (lb./100 sq.ft.)	1	1	Large		1	0.5	2	1	1	0.5	1	1
Init. Gel. (lb./100 sq.ft.)	0	0	volume		0	0	0	0	0	0	0	0
Ten Min. Gel. (lb./100 sq.ft.)	0	0	not		0	0	0	0	0	0	1	7
Filtrate (cc.)	24	25	dispersed		25	40	22	19	16	25	17	18
pH (by Lovibond comparator)	7	7			7	7	7	7	-	7	8.5	-
Sand (% by vol.)	0.3	0.5			0.5	Nil	0.5	Trace	-	0.3	Trace	-
Benzidine Test	Pale blue	Pale blue	Pale blue	Pale blue	Mid blue	Pale blue	Mid blue	Mid blue	Mid blue	Pale blue	Dark blue	Dark blue

EFFECT OF SODIUM CARBONATE ON SELECTED SUBSURFACE BENTONITES — TABLE 6

All slurries 6% by weight of dry bentonite in distilled water

A.P.I. TEST	Sodium Carbonate Addition % by wt.											
	Well No. 2A 55'3" to 56'0"						Well No. 2A 134'8" to 136'3"					
	Air dried only	0.5	1	2	4	8	Air dried only	0.5	1	2	4	8
A.V. (cp.)	3.5	3.5	3.8	3.8	5.8	6.5	6	5.3	8.3	11.5	13.5	14.5
P.V. (cp.)	3	3	3	3	3	4	5.5	3.5	5	6	5	4
Y. (lb./100 sq.ft.)	1	1	1.5	1.5	5.5	5	1	3.5	6.5	11	17	21
Init. Gel. (lb./100 sq.ft.)	0	0	0	1	4	4	0	0	2	7	15	18
Ten Min. Gel. (lb./100 sq.ft.)	0	0	0	6	11	16	1	11	18	23	26	27
Filtrate (cc.)	19	17	17	18	20	23	17	18	20	18	20	23
pH (by Lovibond comparator)	7	-	-	-	-	-	8.5	-	-	-	-	-
Sand (% by vol.)	Trace	-	-	-	-	-	Trace	-	-	-	-	-

COMPARISON OF VARIOUS BENTONITES — TABLE 7

All slurries 6% by weight of dry bentonite in distilled water

A.P.I. TEST	Wyoming bentonite "Volclay"	Yuleba Creek area Qld.		Gellibrand Vic.		Early Storms area Qld.		Mantuan Downs area Qld.		Chinchilla area Qld. S.B. 375		Chinchilla area Qld. Well 2A 135'-136'	
		Orig.	+2% Na	Orig.	+2% Na	Orig.	+2% Na	Orig.	+2% Na	Orig.	+2% Na	Orig.	+2% Na
A.V. (cp.)	18	5	5.8	1.8	2.5	3.3	8	1.8	3.5	4	8.5	6	11.5
P.V. (cp.)	10	4	4	1	1.5	3	5	1	2.5	3.5	6	5.5	6
Y. (lb./100 sq.ft.)	15	2	3.5	1.5	1	0.5	6	1.8	2	1	5	1	11
Init. Gel. (lb./100 sq.ft.)	3	0	1	0	0	0	1	0	1	1	1	0	7
Ten Min. Gel. (lb./100 sq.ft.)	33	1	12	0	2	0	23	2	8	1	1	1	23
Filtrate (cc.)	12	14	13	24	15	16	12	48	20	18	13	17	18
pH (by Lovibond comparator)	9	9	-	8.5	-	9	-	8	-	7	-	8.5	-

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APPENDIX 1

PALYNOLOGY OF SAMPLES FROM BMR CHINCHILLA NOS. 2 AND 2a SCOUT HOLES

by D. Burger

Samples from shallow holes, penetrating the Jurassic Orallo Formation in the western part of the Chinchilla Sheet area and continuously cored in search for bentonite, were examined for spores and microplankton. The following levels were selected:

Bore	Sample No. (MFP)	Depth	Spore Unit
Chinchilla No. 2a	4668	132'5-6"	J 5-6
Chinchilla No. 2a	4669	139'11"-140'	J 5-6
Chinchilla No. 2	4670	158'11"-159'	barren

The samples consist of clayey sandstone. Deep-weathering had to some degree affected the whole interval penetrated by the holes, so that most of the core material was unsuitable for palynological examination.

Sample No. 4668

Recovery moderate, microfossils poorly preserved.

Spores:
- Cyathidites australis
- Baculatisporites comaumensis
- Osmundacidites wellmanii
- Leptolepidites verrucatus
- Vitreisporites pallidus
- Lycopodiumsporites austroclavatidites
- Nevesisporites vallatus
- Classopollis spp.
- Contignisporites fornicatus
- Perotrilites pseudoreticulatus (1 specimen)
- Coronatispora perforata
- Tsugaepollenites segmentatus

Microplankton: None

31

Sample No. 4669

Recovery abundant, microfossils well preserved.

Spores: Cyathidites australis, minor
Alisporites grandis, similis
Lycopodiumsporites spp.
Applanopsis dampieri (common)
A. trilobatus (Rare)
Classopollis spp.
Microcachryidites antarcticus
Neoraistrickia truncata
Leptolepidites verrucatus
Polycingulatisporites densatus
Klukisporites scaberis
Inaperturopollenites turbatus (common)
Nevesisporites vallatus
cf. Murospora florida (1 specimen)
Contignisporites fornicatus (common)
Matonisporites cooksonii
Coronatispora perforata
Stereisporites perforatus
cf. Biretisporites spectabilis
Ischyosporites punctatus

Microplankton: None

Both microfloras must be assigned to spore units J 5-6, characterized by the co-occurrence of Classopollis spp. and Contignisporites spp., prior to the appearance of Cicatricosisporites australiensis (Evans, 1966).

The upper part of the J 5-6 interval can probably be distinguished by the first appearance of Aequitriradites spp. and has tentatively been defined as unit J 6 (Burger, 1968). The absence of this type in both assemblages, notably in the very rich microflora of sample 4669, indicates that the spores may belong to unit J 5. The presence in sample 4668 of one spore, attributed to Perotrilites pseudoreticulatus Couper 1953 might also point to a J 5 age, as this type was noticed only in J 4-5 microfloras and seems to be restricted to the Injune Creek Group, at least in the Surat Basin (Burger, 1968).

32

Microfloras of J 5 age are known to occur only in the upper part of the Birkhead Formation and also in the Westbourne Formation. The Gubberamunda Sandstone disappears in outcrop near the boundary between the Roma and Chinchilla Sheet areas, so that in the region where Chinchilla Nos. 2 and 2a were drilled, the Orallo Formation directly overlies the Injune Creek Group. The holes penetrated the lower part of the formation, and the age of the microfloras suggests that samples 4668 and 4669 may be as old as the uppermost Injune Creek Group.

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APPENDIX 2

PETROGRAPHY OF THIN SECTIONS FROM SHALLOW DRILLING

by

N.F. Exon

Four thin sections from cores from the shallow drill holes were examined. Their positions are shown in Figure 3. All are from Chinchilla 2A. Percentages mentioned are estimates only. All are products of intermediate with lesser acid volcanism.

Core 7, 143'5" - 143'6"

Very fresh labile volcanic sandstone with average grainsize 0.05 to 0.1 mm. Very fine grained rock fragments of probable volcanic origin make up 55% of the rock. These contain iron ore or mica and are often iron stained. Fresh angular labradorite (30%), angular quartz (5%), and montmorillonitic clay matrix (5%) are the other major constituents. Carbonaceous debris, often as ovoid masses, lies in the bedding and cross-bedding. Minor constituents are detrital iron ore, biotite and rounded and euhedral epidote. Accessories are muscovite, euhedral apatite, chloritoid fragments and secondary sparry calcite.

Core 6, 134'8" - 136'3"

Clay-altered tuff. Its rheological properties are excellent (see Section 2 in body of record). It consists almost entirely of altered glass shards and fine ash. Minor impurities ($<$ 2%) are angular feldspar, very fine-grained volcanics and iron ore.

Core 6, 132' - 132'1"

Very fresh volcanic lithic sandstone of grainsize 0.2 to 0.5 mm. Very fine grained subrounded intermediate volcanic rock fragments, many of which contain acicular or lath-like feldspar, and which are often iron altered, make up 70% of the rock. Very angular labradorite (15%) commonly consisting of broken euhedral crystals, some of which are zoned, angular quartz (5%) and montrmorillonitic matrix (5%) are the other major constituents. There is minor rounded iron ore, micrite carbonate grains, carbonaceous debris and very minor biotite and apatite.

<u>Core 3, 58'0" - 58'1"</u>

Weathered clayey sandstone of grainsize 0.2 mm. Consists largely (75%) of montmorillonitic clay matrix which may represent altered rock fragments. Other common constituents are altered very fine grained rock fragments (10%) which are often heavily iron stained or chlorite altered, angular quartz (10%)and subhedral feldspar (5%). The feldspar is a plagioclase but shows very little twinning. Minor constituents are bleached biotite and detrital iron ore.