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Well Completion Report, Wollongong (B.M.R.) Nos. 1, 2 and 2A Wells, Sydney Basin, N.S.W.

by

S. Ozimic

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WELL COMPLETION REPORT

WOLLONGONG (B.M.R.) NOS. 1, 2 AND 2A WELLS, SYDNEY BASIN, N S.W.

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SUMMARY

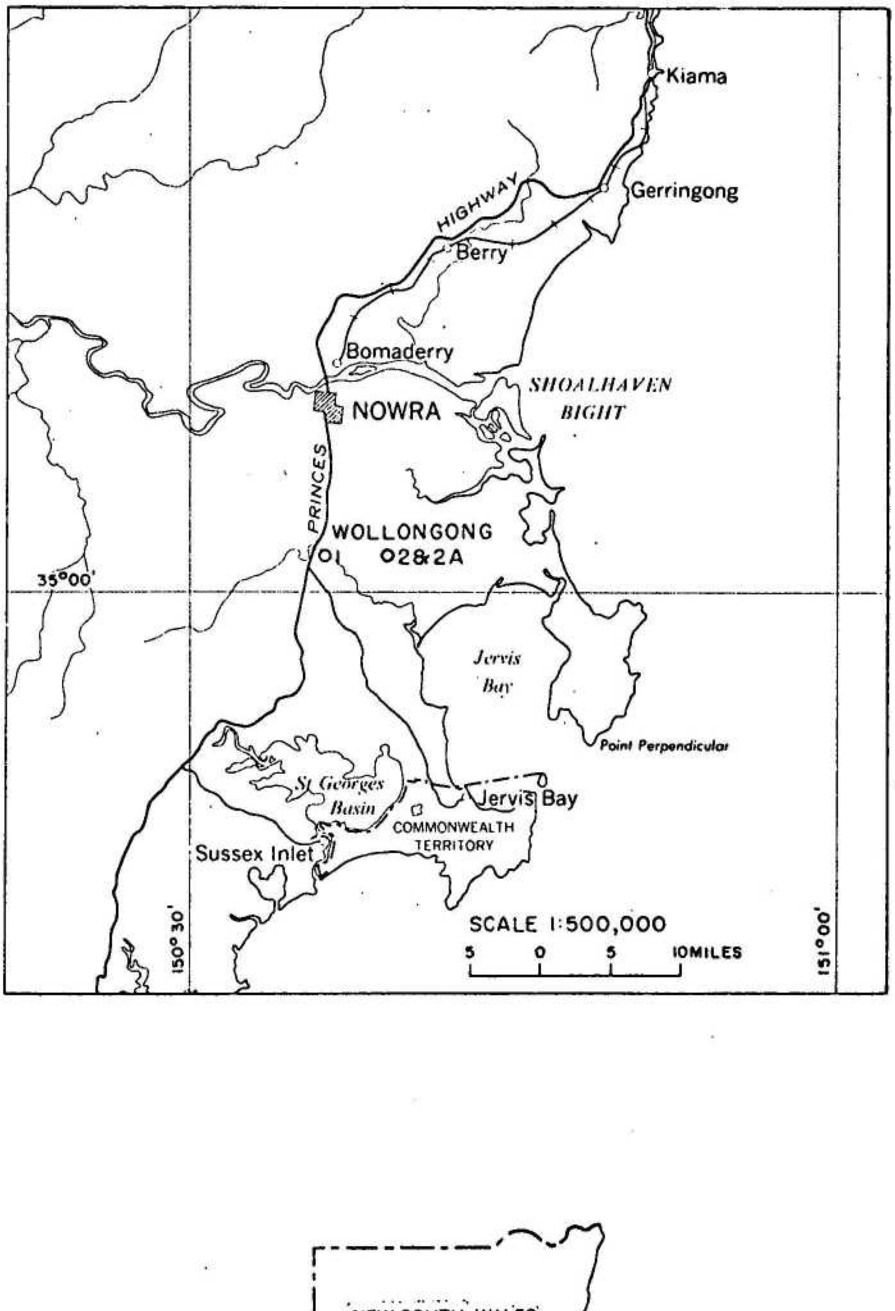
Wollongong (B.M.R.) Nos. 1, 2 and 2A wells were drilled in the southern part of the Sydney Basin N.S.W., approximately seven miles south south-east of Nowra N.S.W. The wells were drilled by the Petroleum Technology Section of the B.M.R. during March, April and May of 1970.

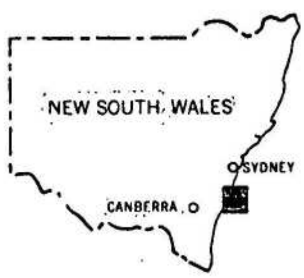
Five lithological units of the Permian Shoalhaven Group were penetrated. Wollongong (B.M.R.) No. 1 well penetrated the Nowra Sandstone, Wandrawandian Siltstone and Snapper Point Formation and was abandoned in the Pebbley Beach Formation. Wollongong (B.M.R.) No. 2 well penetrated the Berry Formation and Nowra Sandstone and was abandoned in an igneous intrusion named the Currambene Dolerite. Wollongong (B.M.R.) No. 2A well penetrated the Berry Formation, Nowra Sandstone, Currambene Dolerite and Snapper Point Formation and was abandoned in the Pebbley Beach Formation.

The wells were programmed to permit a better correlation of sub-surface stratigraphic units with surface geology. On completion of the B.M.R. drilling, it was found that revisions were necessary to the sub-surface correlations in the Nowra district and in the Sydney Basin N.S.W. as a whole.

Fig I

LOCATION OF WOLLONGONG B M R Nos. I, 2,& 2A WELLS





INTRODUCTION

The Wollongong (B.M.R.) Nos. 1, 2 and 2A wells (Fig. 1) were designed to determine the sub-surface stratigraphy and to supplement the stratigraphic information provided by Genoa Oil N.L., through the drilling of the Coonemia No. 1 well. This well had been interpreted as spudding in the Berry Formation (Genoa Oil N.L., 1969; Table 1), although the surface geology at this point on the Wollongong 1:250,000 Geological Sheet (Rose, 1966a), is shown as being Wandrawandian Siltstone.

Table 1. Correlation of sub-surface units in the Coonemia No. 1 well with surface geology (after Genoa Oil N.L., 1969)

Berry Formation	SHOALHAVEN GROUP	PERMIAN	
Nowra Sandstone			
Wandrawandian Siltstone			
Conjola Formation			
Pigeon House Creek Siltstone			
Clyde Coal Measures			
Un-named Conglomerate			
Basement		?	

To provide tight stratigraphic control, Wollongong (B.M.R.) No. 1 well was sited on a known Nowra Sandstone outcrop and the Wollongong (B.M.R.) No. 2 and 2A wells were sited half way between the Wollongong (B.M.R.) No. 1 well and the Coonemia No. 1 well.

The B.M.R. drilling showed that the sandstone unit, named Nowra Sandstone, in the Coonemia No. 1 well had been misidentified and was in fact the upper sandy unit of the Conjola Sub-Group, the Snapper Point Formation. The Nowra Sandstone itself occurs higher in the stratigraphic sequence and the unit the well spudded in is actually the Wandrawandian Siltstone (Table 2).

Table 2. Correlation of sub-surface units in the Coonemia No. 1 well with surface geology (this report).

<table>
<tr><td colspan="2">Wandrawandian Siltstone</td><td rowspan="4">Shoalhaven Group</td><td rowspan="4">Permian</td><td rowspan="4"></td></tr>
<tr><td>Snapper Point Formation</td><td rowspan="3">Conjola Sub-Gr.</td></tr>
<tr><td>Pebbley Beach Formation</td></tr>
<tr><td>Wasp Head Formation containing coal measures</td></tr>
<tr><td colspan="3">Basement</td><td>?</td><td></td></tr>
</table>

As the old correlations between surface and sub-surface stratigraphic units in the Nowra District had been applied basin-wide, the new correlations (Fig. 2, Table 3) have also to be carried throughout the Sydney Basin. These new correlations were published by Mayne et al. (1970) and are reproduced in Figure 3.

Table 3. Correlation of sub-surface stratigraphic units in the Nowra district of N.S.W.

Stratigraphy of Wollongong (B.M.R.) No. 1 well.	Stratigraphy of Wollongong (B.M.R.) Nos. 2 and 2A wells.	Stratigraphy of Coonemia No. 1 well, see Table 2.
	Berry Formation	
Nowra Sandstone	Nowra Sandstone	
Wandrawandian Siltstone	Currambene Dolerite *	Wandrawandian Siltstone
Snapper Point Formation	Snapper Point Formation	Snapper Point Formation
Pebbley Beach Formation**	Pebbley Beach Formation**	Pebbley Beach Formation
		Wasp Head Formation containing coal measures
		Basement**

* Total Depth of Wollongong (B.M.R.) No. 2 well.

** Total Depth

WELL HISTORY

General data

	Wollongong (B.M.R.) No. 1	Wollongong (B.M.R.) No. 2	Wollongong (B.M.R.) No. 2A
Location	34° 58' 00" S 150° 36' 00" E	34° 58' 40" S 150° 39' 15" E	34° 58' 40" S 150° 39' 15" E
Ground level	49 feet	245 feet	245 feet
Kelly bushing	nil	nil	nil
District	Nowra N.S.W.	Nowra N.S.W.	Nowra N.S.W.
Tenement no.	157 P.E.L.	157 P.E.L.	157 P.E.L.
Tenement holder	Genoa Oil N.L.	Genoa Oil N.L.	Genoa Oil N.L.
Drilled by	B.M.R. Pet. Tech. Section	B.M.R. Pet. Tech. Section	B.M.R. Pet. Tech. Section
Commenced drilling	12.3.1970	9.4.1970	17.4.1970
Completed drilling	8.4.1970	16.4.1970	4.5.1970
Total depth	1001 feet 8 ins	348 feet	1000 feet 6 ins
Status of the well	dry and abandoned	dry and abandoned	dry and abandoned
B.M.R. well site geologist	S.J. Mayne	S. Ozimic	S. Ozimic

Drilling data Wollongong (B.M.R.) No. 1 well

Bit size	7 ins. and 7 3/8 ins air hammer; and 4½ ins Hughes M.H. roller bits
Bit changes at	104, 232, 286, 417, 436, 698, 781, 901, 946 and 998 feet
Air drilling	surface to 104 feet
Air water injection drilling	104 feet - 417 feet
Mud drilling	417 feet to total depth
Casing	5 in. water bore casing run and cemented from 104 feet to surface

Plugs	: no. 1, 540 - 600 feet: no. 2, 240 - 300 feet, no. 3, 74 - 124 feet; and no. 4, surface to 10 feet
Abandonment procedure	: top of the well was capped, and marked "Wollongong No. 1"

Drilling data Wollongong (B.M.R.)No. 2

The well was abandoned at 348 feet, as the casing parted at 40 feet and could not be by-passed with the bit

Bit size	: 7 7/8 ins Hawthorn blade, 7 in. air hammer and 4½ in. Hughes M.H. Roller bits
Bit changes	: at 95, 145, 195, 245, and 315 feet
Casing	: 5 in. water bore casing cemented from 90 feet to surface (with 12 bags of cement)
Abandonment procedure	: top of the well was capped, and marked "Wollongong No. 2"

Drilling data Wollongong (B.M.R.) No. 2A

Bit size	: 7 3/8 ins Hawthorn blade, 7 in. air hammer and 4½ in. Hughes M.H. Roller bits
Air drilling	: surface to 105 feet
Mud drilling	: at 105 feet to total depth
Bit changes	: at 105, 155, 205, 255, 305, 355, 405, 455, 505, 555, 605, 655, 705, 755, 805, 855, 905, and 955 feet
Casing	: 5 in. water bore casing cemented from 96 feet to surface
Plugs	: no. 1, 540 - 600 feet; no. 2, 240 - 300 feet; no. 3, 70 - 120 feet and no. 4, surface to 10 feet
Abandonment procedure	: the well was plugged, capped, and marked "Wollongong No. 2A"

Wire-line log record

Wollongong (B.M.R.) No. 1 well: Spontaneous Potential, 97 - 980 feet (one run)

: Resistivity, 18 feet 8 in. lateral, 97 - 980 feet (one run)

: Gamma-Ray, 5 - 1000 feet (one run)

Wollongong (B.M.R.) No. 2A well: Spontaneous Potential, 95 - 1000 feet (one run)

: Resistivity 18 feet 8 in. lateral, 95 - 1000 feet (one run)

: Gamma-ray, 4 - 1000 feet (one run)

Cutting Samples and cores

Cutting samples were collected from the surface to total depth, at 5 - 10 feet intervals, during drilling and coring. 175 samples were collected. Cores were cut as required and a total of 20 cores were recovered from the three wells. The cutting samples and the cores are stored at the B.M.R. Core and Cuttings Laboratory, Fyshwick A.C.T.

Methods Used

All the core and cuttings samples were examined under a low power binocular microscope. Thin sections made from selected intervals were examined under a petrologic microscope. The results were plotted, with wire-line log and other information, on "petrographic well log" sheets at a scale of 1" : 100' (Plates 1, 2) and subsequently reduced to 1" : 200'.

The sedimentary rocks have been classified into conglomerate sandstone, siltstone or claystone following the Wentworth scale (Pettijohn, 1957, p. 18).

STRATIGRAPHY

Introduction

The units penetrated in the three wells and their thicknesses are listed in tables 4, 5 and 6. Petrographic well logs for the Wollongong (B.M.R.) Nos. 1, 2 and 2A wells are shown in plates 1 and 2.

Table 4. Stratigraphy of Wollongong (B.M.R.) No. 1 well

FORMATION	SUB-GROUP	GROUP	AGE	INTERVAL	THICKNESS
Nowra Sandstone	Conjola Sub-Group	Shoalhaven Group	Permian	Surface to 105'	105'
Wandrawandian Siltstone				105' - 610'	505'
Snapper Point Formation				610' - 970'	360'
Pebbley Beach Formation				970' - 1001'8" T.D.	31'8" +

Table 5. Stratigraphy of Wollongong (B.M.R.) No. 2 well

FORMATION	SUB-GROUP	GROUP	AGE	INTERVAL	THICKNESS
Superficial Deposits		Shoalhaven Group	Permian	Surface to 20'	20'
Berry Formation				20 ' - 107'	87'
Nowra Sandstone				107' - 159'	52'
Currambene Dolerite				159' - 348' T.D.	189' +

Table 6. Stratigraphy of Wollongong (B.M.R.) No. 2A well

FORMATION	SUB-GROUP	GROUP	AGE	INTERVAL	THICKNESS
Superficial Deposits	Conjola Sub-Group	Shoalhaven Group	Permian	Surface to 20'	20'
Berry Formation				20' - 107'	87'
Nowra Sandstone				107' - 159'	52'
Currambene Dolerite				159' - 616'	457'
Snapper Point Formation				616' - 918'	312'
Pebbley Beach Formation				918' - 1006'6" T.D.	72'6" +

Superficial deposits

About 20 feet of Quaternary alluvium, ferruginous sandy soil and aeolian sand was penetrated in Wollongong (B.M.R.) Nos. 2 and 2A wells.

Berry Formation

The Berry Formation (Card and Jaquet, 1903) consists of dark grey to black, massively bedded sandy siltstone conformably overlying the Nowra Sandstone. The sand sized fragments up to 1.5 mm across, comprise quartz, chert, and occasional volcanic material. Fine-grained pyrite and calcite are commonly disseminated throughout the unit. Bands of shale occur in Core 1 (B.M.R. No. 2). Slump and scour structures and micro-crossbedding were observed in Core No. 1 (B.M.R. No. 2).

Siliceous tubes, foraminiferal casts, up to 4 mm long and 1.5 mm wide, and unidentified shell fragments are distributed irregularly through parts of Core No. 1 (B.M.R. No. 2) and in most of the cuttings. Trace fossils were prominent in Core No. 1 (B.M.R. No. 2) and these comprise burrows, U-shaped tubes, and possible worm trails.

An open sea environment is postulated for this unit, on the basis of fossils and sedimentary structures.

Nowra Sandstone

The Nowra Sandstone (Joplin et al., 1952) consists of light to dark brown, poorly sorted, very fine to very coarse-grained siliceous and calcareous, sandstone and sandy siltstone, conformably overlying the Wandrawandian Siltstone in the No. 1 well, and intruded by the Currambene Dolerite in the Nos. 2 and 2A wells.

The average sandstone framework consists of quartz fragments with quartz overgrowths (43-50%), chert fragments (8-10%), feldspar fragments (5-10%, K-feldspar plagioclase), mica flakes (2-4%), volcanic rock fragments (1-2%) and calcite and siderite crystals (7%). The framework is cemented by calcite and siderite (5-8%) and an argillaceous matrix (25%).

Fossil fragments are common in the sandy siltstone beds and a few siderite pseudomorphs after thick shelled Brachiopods occur in the sandstone beds. The poor sorting of the rocks and the interbedding of sandstone with siltstone suggest a fluctuating current activity. The abundance of both, broken and intact shells suggest a near shore marine environment.

On the basis of the Gamma-Ray patterns and lithology in the Wollongong (B.M.R.) Nos. 1, 2 and 2A wells, the Stockyard Mountain No. 1 well (Alcock, 1968a), and field observation in the Nowra district, the Nowra Sandstone may be divided into three units (sand-silt-sand). Commonly only two of these occur in the central and northern Sydney Basin wells, and in parts of the Nowra district such as Crookhaven Heads and Wheelers Point. The three units observed in the Nowra district are described in Table 7. Unit A of the Nowra Sandstone crops out at Falls Creek near the Princes Highway, at the northern end of Nowra Bridge on the Princes Highway and Near Currarong Road 4.5 miles off the Princes Highway. Unit B crops out near Currarong Road 4.5 miles off the Princes Highway, at Crookhaven Heads and at Wheelers Point. Unit C is not known to outcrop. Wollongong (B.M.R.) No. 1 well and Wollongong (B.M.R.) Nos. 2 and 2A wells contain all three units.

Wandrawandian Siltstone

The Wandrawandian Siltstone (Joplin et al., 1952) consists of regularly bedded dark grey to black carbonaceous, pyritic and calcareous, poorly sorted sandy siltstone with interbeds of fine-grained lithic sandstone and laminae of shale. The unit overlies the Snapper Point Formation conformably. The lithic fragments are of volcanic and sedimentary rock.

Sedimentary structures comprise worm tubes, and probable burrow structures. Brachiopod and Pelecypod shells and traces of Polyzoa fragments occur throughout the unit.

The unit was deposited in a low to moderate energy marine environment.

The wire-line logs show a fluctuating character reflecting the interbedding. The Gamma-Ray log shows a pattern which reflects an increase in the silt content in comparison to the unit above and the unit below.

Currambene Dolerite (new name, approved)

The Currambene Dolerite is an intrusive body of dolerite lying between the Nowra Sandstone above and the Snapper Point Formation below in Wollongong (B.M.R.) Nos. 2 and 2A wells. A petrological description and a chemical analysis are given in appendix 1.

The Currambene Dolerite has been dated at 234 ± 6 million years by the Australian Mineral Laboratories, Adelaide, S.A. (See appendix 2).

Snapper Point Formation

The Snapper Point Formation (Gostin, 1968) is a massively bedded, light grey, very fine to very coarse-grained, poorly sorted sandstone, with interbeds of pebble conglomerate and of sandy siltstone, conformably overlying the Pebbley Beach Formation.

The sandstone framework consists of quartz fragments (45-60%), chert (10-15%), feldspar fragments (5-8% K-feldspar plagioclase), mica flakes (2%), calcite crystals (2%) and volcanic rock fragments (4%). The framework is cemented by silica (10-15%), unidentified clay minerals (5%) and an argillaceous matrix (5-8%).

Stringers of carbonaceous matter and finely disseminated pyrite are present in the sandy siltstone and pockets of white clay occur throughout the unit. Pebble beds, up to 5 cm thick, are common and are cemented with clay and minor quartz.

A few Brachiopod and Pelecypod shells occur throughout the unit. The presence of low angle cross-bedding, pebble beds and marine fossils suggest a high energy marine environment. A sedimentary, volcanic and granitic provenance is indicated.

The wire-line logs show a moderate to high resistivity curve and a moderate to low radiation intensity curve on the gamma-ray logs.

Pebbley Beach Formation

The Pebbley Beach Formation (Gostin, 1968) is an irregularly bedded, light grey to dark grey, sandy siltstone and very fine to very coarse-grained silty sandstone formation with thin beds of pebble conglomerate. Carbonaceous matter and pyrite crystals occur within the matrix of the pebble conglomerate.

The silty sandstone framework consists of quartz fragments (45-60%), chert fragments (10-15%), feldspar fragments (9-14%, K-feldspar plagioclase), mica flakes (4-6%), calcite crystals (2%), and volcanic rock fragments (2%). The framework contains matrix of undifferentiated clays (6-8%). Stringers of carbonaceous matter and finely disseminated pyrite are present in the sandy siltstone and pockets of white clay occur throughout the unit. Pebble beds, up to 5 cm thick, are common and are cemented with clay and minor quartz.

Table 7. Comparison of the three units in the Nowra Sandstone

UNIT	LITHOLOGY	SORTING AND GRAIN SIZE	CEMENT AND MATRIX	FOSSILS	SEDIMENTARY STRUCTURES AND BEDDING	WIRE-LINE LOGS
Unit A	Sandstone, pebbly in part.	Poor sorting, fine to very coarse sand with pebbles up to 6 mm across.	Silica, calcite and siderite.	Rare unidentified shell fragments.	Cross bedding, thick bedded.	Moderate resistivity low radiation intensity on the gamma-ray log.
Unit B	Siltstone, sandy with interbeds of shale and sandstone.	Poor sorting, mainly clay and silt with some very fine to medium sand.	Calcareous argillate.	Brachiopods, Pelecypods, Gastropods and Polyzoans.	Thin bedded.	Large increase in radiation intensity with respect to unit above and below. No significant change in resistivity with respect to unit above and below.
Unit C	Sandstone, pebbly in part.	Moderate to good sorting; very fine to coarse sand, pebbles up to 20 mm.	Calcite and siderite cement; some silt and clay matrix.	Rare shell fragments	Massive bedded.	Strong decrease in radiation intensity with respect to overlying unit and moderate decrease with respect to unit below. No significant change in resistivity with respect to unit above and below.

Figure 2

EAST-WEST SECTION – FALLS CREEK AREA

Compiled by S J Mayne, 1970

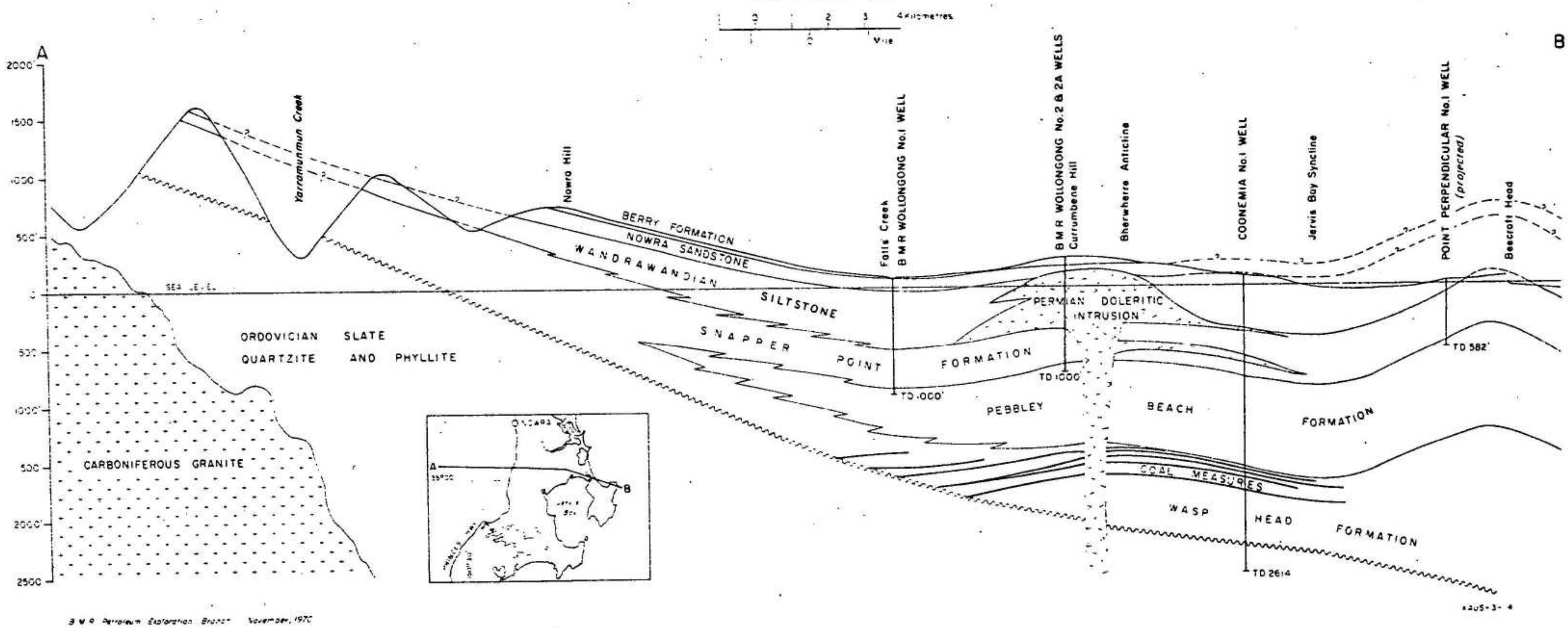


Figure 3

Modified correlation chart of Lower and Upper Permian rocks, Sydney Basin N.S.W.

		NORTHERN AREA			CENTRAL AREA			SOUTHERN AREA			NOWRA DISTRICT		
PERMIAN	Upper	Singleton Coal Measures		Newcastle Coal Measures Tomago Coal Measures	Illawarra Coal Measures			Illawarra Coal Measures					
	Lower	MAITLAND GROUP			SHOALHAVEN GROUP			SHOALHAVEN GROUP			SHOALHAVEN GROUP		Gerrigong Volcanics
				Mulbring Siltstone			Berry Formation			Berry Formation			Berry Formation
				Muree Sandstone			Nowra Sandstone			Nowra Sandstone			Nowra Sandstone
				Branxton Formation			Wandrawandian Siltstone			Wandrawandian Siltstone			Wandrawandian Siltstone
		Greta Coal Measures				CONJOLAN SUB-GROUP	Snapper Point Formation		CONJOLA SUB-GROUP	Snapper Point Formation		CONJOLA SUB-GROUP	Snapper Point Formation
		DALWOOD GROUP	GYARRAN VOLCANICS (MUSWELLBROOK)	Farley Formation			Pebbley Beach Formation			Pebbley Beach Formation			Pebbley Beach Formation
				Rutherford Formation									
				Allandale Formation			Wasp Head Formation			Wasp Head Formation			Wasp Head Formation Contouring Clyde Coal Measures
				Lochinvar Formation									

Compiled By : S.J. Mayne, E. Nicholas and S. Ozimic, 1970

A few Brachiopod and Pelecypod shells occur throughout the formation. The presence of low angle cross-bedding, pebble beds and marine fossils suggest a high energy marine environment. A sedimentary, volcanic and granitic provenance is indicated.

The wire-line logs show a moderate to high resistivity curve and a moderate to low radiation intensity curve on the gamma-ray log.

POROSITY, PERMEABILITY AND PETROLEUM PROSPECTS

Porosity and permeability of core samples were determined by the B.M.R. Petroleum Technology Laboratory. These results were extrapolated to other intervals in the section by visual comparison of lithology and examination of resistivity and gamma-ray logs.

No measurable permeability was detected. The highest measured porosity was 12%, recorded in the Snapper Point Formation (Core No. 5) in the Wollongong (B.M.R.) No. 2A well. (For detailed core analyses see appendices 3, 4 and 5). It is concluded that with the exception of a few intervals in the Snapper Point Formation the porosity is generally low throughout the section and the underlying Clyde Coal Measures. There may be pockets of permeable rock in the Nowra Sandstone or the Snapper Point Formation, but in the wells these formations were well cemented and impermeable. Most of the section penetrated should make good cap rock. The petroleum prospects are rated as low.

RESULTS OF DRILLING

A new correlation between sub-surface units and surface geology in the Nowra district has been suggested with consequent revision to the correlations with the remainder of the sub-surface in the Sydney Basin (Mayne et al., 1970). The new correlation within the Nowra district is summarized in Table 3 and Figure 2. The sequence of sedimentary rocks identified by the N.S.W. Mines Department (Rose, 1966a) as Wandrawandian Siltstone and by Genoa Oil N.L. (1969) as the Berry Formation (Table 1), is now thought to contain the Berry Formation, the Nowra Sandstone and the Wandrawandian Siltstone (Table 3 and Figure 2).

Gostin (1968) redefined the Conjola Formation into three formations, the Snapper Point Formation, the Pebbley Beach Formation and the Wasp Head Formation, together making up the Conjola Sub-Group. The units identified by the N.S.W. Mines Department (Rose, 1966 a, b) and Genoa Oil N.L. (1969; Table 1) as the Nowra Sandstone and the Wandrawandian Siltstone are now identified (Table 3 and Figure 2) as the Snapper Point Formation and Pebbley Beach Formation respectively. In consequence some revisions are necessary to the Wollongong and Ulladulla 1:250,000 geological series sheets and the respective cross-sections.

The Snapper Point Formation can be traced sub-surface through deep wells in the Sydney Basin and appears to pass into the Greta Coal Measures of the Hunter Valley. The Nowra Sandstone may be correlated with the Muree Sandstone in the northern part of the Basin and is the same stratigraphic unit, informally named Kedumba Creek sandstone e.g. A.O.G. Mulgoa No. 2, intersected in the Australian Oil & Gas Corporation Ltd wells Mulgoa No. 2 (A.O.G., 1960), Kirkham No. 1 (A.O.G., 1964a; Raine, 1969) and Woronora No. 1 (A.O.G., 1964b; Alcock, 1968b). The Nowra Sandstone is also correlated with the unnamed (S3) sandstone, intersected in the Farmount Drillers N.L. well, Stockyard Mountain No. 1 (Alcock, 1968).

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APPENDIX 1 PETROLOGY OF THE CURRAMBENE DOLERITE

SUMMARY

The upper contact of the igneous rock encountered in Wollongong No. 2 was examined in detail to determine whether the igneous material was intrusive or extrusive. The irregular nature of the contact and petrographic evidence from thin sections from immediately above and below the contact suggest that the magma was intruded into unconsolidated sediments.

The igneous intrusive, named the Currambene Dolerite (Ozimic, this report), is markedly porphyritic and contains 3 cm phenocrysts of plagioclase. Petrographic and chemical evidence differentiation of the dolerite though settling of early formed minerals (particularly plagioclase phenocrysts) producing a monzonitic residuum. The initial magma which was compositionally similar to tholeiitic magmas was enriched in K_20 and impoverished in $Si0_2$ relative to normal tholeiite and shows differentiation trends intermediate between those of tholeiite and of the calc-alkaline suite.

INTRODUCTION

The Currambene Dolerite, a 452 ft thick sill, is of interest because of its effect on the petroleum potential of the area, and because of its unusual intermediate differentiation trend.

Drill core specimens examined in thin section come from immediately above and below the upper contact, (depth 159 ft) and from 256 ft and 381ft respectively. Sepcimens from these depths have been analysed chemically along with specimens of cuttings from depths of 465 and 595 ft.

THE UPPER CONTACT

Introduction

The initial problem posed by this basic igneous mass was its mode of occurrence, whether intrusive or extrusive. A well-preserved specimen of the upper contact of the basic rock with the overlying sandstone (Nowra Sandstone, Figs 1, 2) obtained during core drilling operations, has been examined in detail to determine the mode of occurrence.

Figure 1. Contact between coarse-grained calcareous sandstone and feldsparphyric basic igneous rock. Shows colour change due to chilling and alteration near contact.
GA/3450

Macroscopic appearance

The upper part of the core consists of grey-brown medium to coarse-grained massive calcareous quartz sandstone. It contains an elongate 4 cm pebble of quartzite which is oriented with its long axis at an angle of about 80° to the general trend of the contact. Distinct "spotting" of the sandstone is apparent within 2 cm of the contact. The spots are light brown, up to 5 mm across and are surrounded by darker brown zones.

The igneous rock forming the lower part of the core is a porphyritic basalt consisting of individual phenocrysts (up to 3 cm long) and rosettes of phenocrysts of plagioclase, and equant phenocryst of a ferromagnesian mineral mostly 1 to 2 mm across, in a very fine-grained grey matrix. The colour of the matrix lightens towards the contact and plagioclase phenocrysts within about 3 to 5 cm of the contact are white and turbid due to alteration.

The contact is irregular with lobate protrusions of basalt apparently intruding the sandstone. Plagioclase phenocrysts tend to be aligned parallel to the contact.

Petrography

(a) Sandstone

The sandstone consists of poorly sorted subangular grains of quartz from 0.5 to 1 mm, and scattered rounded granules of vein quartz and of sheared quartzite up to 4 mm, in a poikiloblastic carbonate matrix. The darker areas surrounding the spots noted in hand specimen are turbid, probably due to more intense recrystallization and reaction of calcite there than in the light-coloured spots. At the contact there has been locallized recrystallation of carbonate as fibrus aggregates and veinlet infillings (probably of aragonite) with fibres oriented normhal to the contact. Quartz grains in the sandstone near the contact have abundant fractures that parallel the contact and are infilled with carbonate.

The basalt is highly altered and consists almost entirely of a very fine grained aggregate of carbonate and chlorite in which scattered pseudomorphs of the various phenocryst species can be seen.

(b) Chilled igneous rock (basalt) from contact

This thin section from immediately below the contact is notable for its high degree of alteration and fine grain-size of the groundmass. Plagioclase phenocrysts have been completely replaced by a fine-grained aggregate of a chlorite and carbonate. The groundmass consists of extremely fine-grained devitrified glass and minor disseminated carbonate, and contains microphenocrysts of carbonated material pseudomorphing probable plagioclase, pyroxene and olivine.

(c) Chilled igneous rock (basalt) from 5 cm below contact

This is similar to specimen (b) except that the plagioclase phenocrysts are unaltered (and of composition An_{50-55}) and that groundmass plagioclase is more abundant and is fresh andesine-labradorite (An_{50}). Throughout the section both olivine and pyroxene are completely replaced by carbonate accompanied locally by traces of chlorite and serpentine minerals. Small amounts of an opaque mineral (?magnetite) and traces of orange-brown biotite are also present. Devitrified, partly carbonated glass makes up 75%-80% of the groundmass.

Nature of contact and mode of occurrence

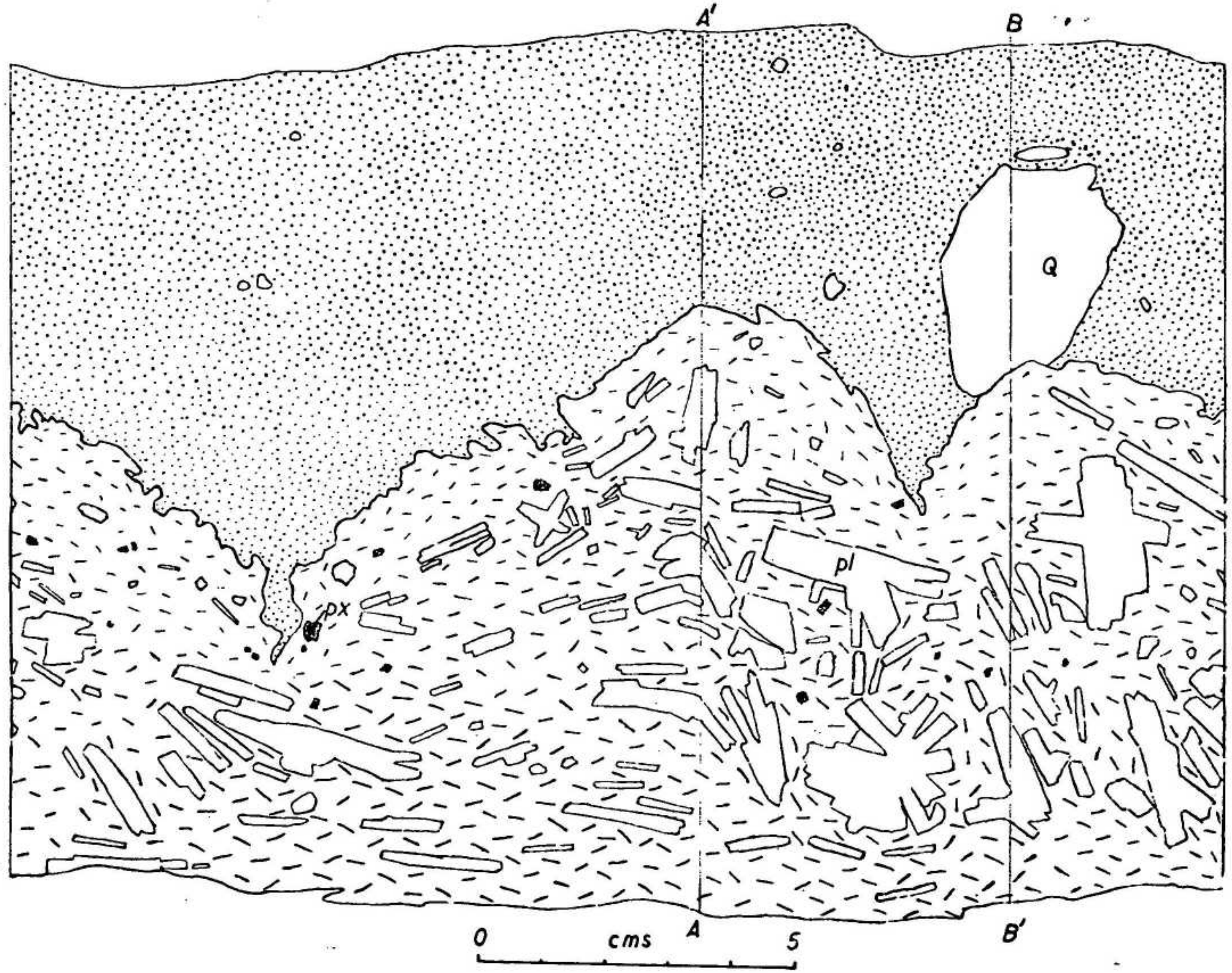
Two possibilities exist (1) that the igneous rock is extrusive and that the sediment has been deposited on top of it and (2) that it has intruded the sediment.

(1) The principal evidence for considering the igneous rock to be an extrusive is the lack of strong contact metamorphism which would normally be expected in a calcareous rock. If extrusive the marginal chilling could possibly be accounted for by sub-aerial cooling or sub-marine intrusion, but the lack of definite pillow form tends to preclude the latter.

The reasonably constant thickness of the chilled and altered margin the flow-foliation of the phenocrysts parallel to the contact, and the intertonguing of igneous rock and sandstone indicate that there has been no erosion of the igneous rock, which would be unlikely if it were extrusive. Also a quartzite pebble is oriented with its long axis normal to the contact and is in contact with the top of a lobe rather than lying in the hollow between lobes which would be expected if it were extrusive.

(2) The spotting of the sandstone noted above, although slight, is strongly suggestive of contact metamorphism, and the calcification of the igneous rock near the contact suggests reaction between the calcareous sandstone and an intrusive. In this there is a close anology with "white trap" formed by intrusion of basaltic magma into calcareous sediments e.g. in the Coal Measures of Scotland.

The absence of weathering products of the basalt in the overlying sandstone is considered supporting evidence for an intrusive origin.



Sketch of contact between Currambene Dolerite and Nowra Sandstone. Shows intertonguing of intrusive and sandstone and flow alignment of plagioclase phenocrysts parallel to the contact.

FIGURE 2.

The shape of the contact, especially broad lobes and small subsidiary tongues of basalt in sandstone, and of sandstone in basalt suggest either intrusion into unconsolidated sediment or mobilization of the sediment adjacent to the contact.

Since the calcite cement of the rock shows "spotting", i.e. evidence of contact metamorphism, the sediment must have contained some interstitial calcite cement prior to intrusion, and the intertonguing of basalt and sandstone at the contact could be due to mobilization of the sediment. Intrusion into freshly deposited aqueous sediment appears to be unlikely in view of the lack of phreatic activity in the area, although time relationships indicated by the age determination are consistent with intrusion into unconsolidated or only partly consolidated sediment.

THE CURRAMBENE DOLERITE

Macroscopic appearance and variations

Specimens from the Currambene Dolerite are mostly dark- grey coarse grained rocks containing about 15% of 2 to 3 cm plagioclase phenocrysts which commonly form rosettes (Fig. 1). Apart from effects of chilling and alteration at the contacts the only macroscopic variations are a change in colour from dark grey to pale grey-brown, and a decrease in the content of plagioclase phenocrysts, upwards towards the 260 ft level.

Petrography

The macroscopic variations noted above are a reflection of variation from rocks with dominant plagioclase (both as phenocrysts and groundmass) in the lower part and dominant potash feldspar (microperthite) in the upper part. This is a reflection of the normal type of fractionation found in tholeiitic intrusives, the principal difference here being the paucity of quartz in the residuum. Three apparently typical specimens are described below.

Porphyritic syenogabbro 381 ft (Sp 744)

This rock is representative of the lower part of the sill. It is a medium-grained porphyritic rock with a hypidiomorphic granular texture. Phenocrysts of plagioclase up to about 3 mm long make up about one third of the rock. Ophitic texture is absent. The rock consists of plagioclase (phenocrysts 35% groundmass 25%), potash feldspar (13%), pyroxene (12%), olivine pseudomorphs (6%), chlorite (6%), titanomagnetic (3%), K feldspar (3%) and sphene and apatite each less than (1%).

Plagioclase phenocrysts are tabular and exceed 1 cm in length. Most phenocrysts present extend beyond the confines of the thin section and their size is uncertain. Most of the phenocrysts are partly clear and unaltered, and partly intensely sericitized. Both albita and Carlsbad twinning is well displayed. Composition is around An_{65}. Groundmass plagioclase occurs as a felted aggregate of 1 mm tabular grains. All grains are slightly turbid to incipient sericitization. Composition, based on albite Carlsbad twins, is An_{32}.

Potash feldspar, which is turbid and microperthitic, forms a narrow border round most plagioclase phenocrysts and round many plagioclase crystals in the groundmass.

Pyroxene is a very pale brown pigeonite with low 2V and Z'c=31° Some grains of augite are also present but can be distinguished with certainty only by their high 2V and high extinction angle (up to 43°) Olivine pseudomorphs are mainly euhedral to subhedral and contain inclusions of magnetite. They consist of pale green lamellar antigorite and patches of very pale grey brown to green serpophite. Interstitial patches of pale green lamellar length-slow chlorite showing weak (.004) birefringence and anomalous blue-grey colours. It is associated with minor amounts of a turbid colourless lenth-fast ?chlorite forming lamellar and radiating aggregates. Titanomagnetite occurs as scattered 0.2 mm to 0.5 mm non-skeletal, equidimensional subhedral grains. Sphene is present as very small discrete grains in chlorite aggregates and locally forms a thin border between titanomagnetite and chlorite. Apatite forms small elongate interstitial grains.

Hypersolvus monzonite 256 ft (Sp743)

This rock is representative of the residuum forming the upper part of the sill. It is a medium to coarse-grained non-porphyritic rock with a hypidiomorphic granular texture. Ophitic texture is developed locally. It consists essentially of microperthite (45%) plagioclase (35%) chlorite (8%) and pyroxene (5%). Quartz (2-3%) titanamagnetite (2-3%) apatite and sphene each less than (1%) are minor accessories.

Turbid microperthite, the most abundant mineral phase, occurs as discrete equidimensional and thick tabular grains up to 2 mm and as broad overgrowths on plagioclase crystals. 2V is around 62° (direct measurement) indicating that the potash feldspar phase is intermediate microcline. Plagioclase forms thin tabular crystals up to 2 mm long which tend to occur in clusters and locally show ophitic relationships with pyroxene. It is slightly turbid due to sericitization, unzoned, and has composition around An_{35}. Pyroxene is a very pale brown non-pleochroic pigeonite, with low 2V and Z'c=28°. Chlorite is mostly a moderately deep green, pleochroic, length-slow variety with birefringence of around 0.011. It occurs as discrete patches that probably pseudomorph an earlier ferromagnesian mineral in interstices between feldspar crystals, as a marginal alteration product of pyroxene, and as small scattered patches within feldspars. It generally contains inclusions of sphene and iron oxide. A reaction rim of sphene is generally present where the chlorite is in contact with ?titanomagnetite. An opaque oxide probably titanomagnetite, forms 1 mm equidimensional skeletal grains and thin flakes disseminated throughout the rock. It is locally intergrown with pyroxene. Quartz forms discrete interstitial grains up to 1 mm. Micropegmatite is absent. Apatite occurs as very elongate, locally acicular crystals with a length/breadth ratio of up to 20.

Trachybasalt — 165 ft (6 ft below upper contact)

This rock is fine-grained, porphyritic, and holocrystalline. It contains scattered tabular phenocrysts of plagioclase up to 1.5 cm and small scattered phenocrysts of pyroxene in a fine-grained groundmass of thin tabular labradorite, small equant grains of pyroxene, scattered grains of magnetite and altered olivine.

Plagioclase phenocrysts ranging from 1.5 cm long to 0.5 mm are fresh and make up about 10% of the rock. It variously shows albite, Carlsbad, and pericline twinning and has composition of An_{64} (assuming high temperature optics) based on universal stage determinations on Carlsbad-albite twins. Groundmass plagioclase forms thin fresh tabular crystals around 0.3 mm in length. Composition based on universal stage determinations on albite twins is around An_{50} to $_{55}$. Clinopyroxene occurs as small euhedral to subhedral equidimensional 0.1 to 0.2 mm grains and rare phenocrysts up to 3 mm, and makes up about 15% to 20%of the rock. Z'c=ca 32° and 2V is low suggesting that it is pigeonitic. Olivine pseudomorphs up to 1 mm are mostly completely replaced by pale olive-green ?bowlingite. A few patches of radiating and random aggregates of (?)antigorite probably also pseudomorph olivine. Magnetite grains, some of them skeletal, up to 0.2 mm make up about 3% of the rock. Minor amounts of turbid pink-brown sphene are associated with some opaque grains.

Interstitial material between plagioclase laths is partly potash feldspar but mostly a very pale green unidentifiable microcrystalline mineral. Both stain readily with sodium cobaltinitrite indicating a high potash content.

Rock nomenclature

The formal stratigraphic name Currambene Dolerite has been chosen because of the essentially tholeiitic nature of the rocks, their proximity to the dolerite compositional field, and their occurrence as a hypabyssal sill. In strict petrographic nomenclatural terms, most of the rocks are syenogabbro

(Johannsen, 1937) but this rock name has not achieved sufficient acceptance for it to be suitable as a stratigraphic name. The syenogabbros from the Currambene. Dolerite are similar to the more basic varieties (syenogabbros) of "monzonite" from Monzoni (Johannsen 1937, p 127). The differentiate is petrographically a monzonite (sensu stricto) in that potash feldspar/plagioclase exceeds the limiting ratio 35/65, but because the potash feldspar is cryptoperthitic microperthite, its norm contains less potash feldspar and it lies at the potassic side of the syenogabbro field. The fine-grained chilled margins contain labradorite and are trachybasalt (usage of Johannsen 1937, p. 128; Hatch, Wells, and Wells, 1961, p. 353) rather than latite (the name allotted locally to extrusives similar in age to the Currambene Dolerite).

CHEMISTRY

Composition of the original magma

Chemical analyses and CIPW norms of rocks from the Currambene Dolerite are presented in Table 1 where they are compared with the norm of the average latite (average of 17 analyses) from the Sydney Basin (Joplin 1963, pp 177-187).

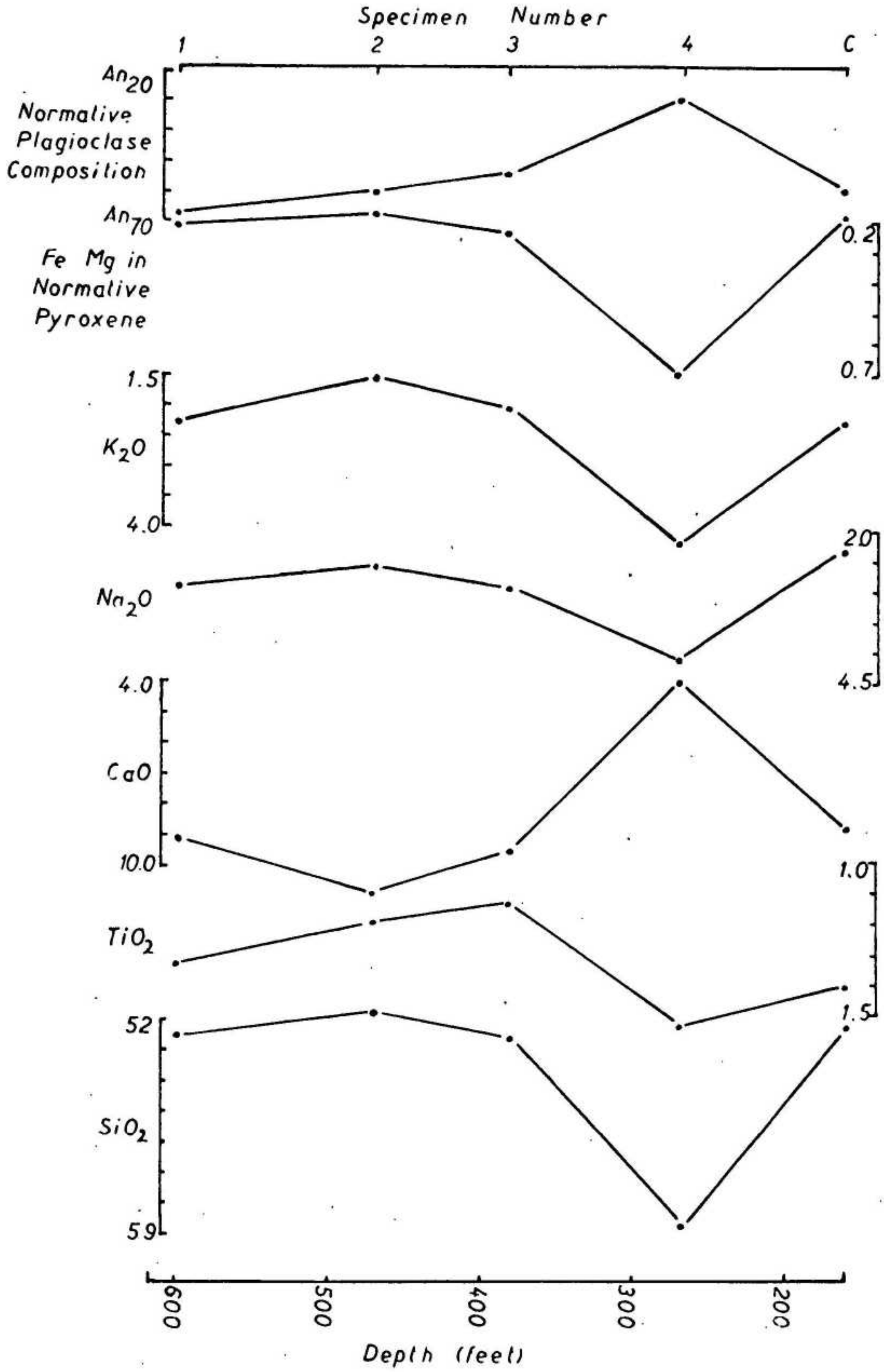
There is a close similarity between the composition of some latite extrusives (e.g. Joplin, 1963; Table M, and 7, 9, 11, 20, 22) from this area and that of the original magma of the Currambene Dolerite. Compared with these rocks of similar SiO_2 content (and also with the average latite which is more siliceous) the Currambene Dolerite magma appears to be more basic and less well differentiated, having higher contents of those constituents which are depleted in the later stages of fractionation (MgO, CaO) and lower contents of those which increase with fractionation (Fe, Na_2O, K_2O, MnO, P_2O_5).

This primary composition may be regarded as transitional between mormal tholeiite and trachybasalt (as used above) but closer to the latter. In particular the high initial K_2O content and high oxidation state distinguishes it from most basaltic magmas. Both these features are characteristic of the latite magma of this area.

Differentiation

The differentiation trend shown by a particular magma depends partly on its composition and cooling history, and partly on pressure, particularly on the partial pressure of oxygen in the system (Osborn 1959).

FIGURE 3.



Specimen Number
1
2
3
4
C
An20
Normative
Plagioclase
Composition
An70
Fe Mg in
Normative
Pyroxene
0.2
0.7
1.5
K2O
4.0
2.0
Na2O
4.5
4.0
CaO
10.0
1.0
TiO2
1.5
52
SiO2
59
600
500
400
300
200
Depth (feet)

TABLE 1

CHEMICAL ANALYSES[1] AND C.I.P.W. NORMS OF SPECIMENS FROM THE CURRAMBENE DOLERITE

	1	2	3	4	C	L
SiO_2	52.5	51.7	52.2	58.71	52.32	54.19
TiO_2	1.31	1.17	1.14	1.53	1.42	0.99
Al_2O_3	17.5	18.0	18.7	17.2	17.2	16.70
Fe_2O_3	4.16	4.45	3.97	2.69	4.80	4.19
FeO	4.88	4.45	4.74	4.74	4.88	3.80
MnO	0.15	0.17	0.15	0.18	0.14	0.18
MgO	5.6	6.5	5.6	2.5	5.9	3.17
CaO	9.23	10.96	9.63	3.95	8.78	6.02
Na_2O	2.9	2.6	3.0	4.2	2.5	3.78
K_2O	2.24	1.52	2.12	4.24	2.32	3.88
P_2O_5	0.48	0.25	0.41	0.77	0.55	0.63
Total	101.0	101.8	101.7	100.7	100.8	97.44 [2]
Q	1.44	1.38	0.30	5.58	3.78	2.28
or	13.34	8.90	12.23	25.02	13.90	22.80
ab	24.63	22.01	25.15	35.63	20.96	31.96
an	28.08	32.80	31.41	15.57	28.91	17.24
di (fs	1.19	1.06	1.06	-	0.79	0.79
di (en	4.50	6.40	4.20	-	3.50	2.70
di (wo	6.38	8.35	5.80	-	4.76	3.83
hy (fs	2.51	1.72	2.77	4.36	2.11	1.32
hy (en	9.50	9.80	9.80	6.20	11.30	5.20
mt	6.03	6.50	5.80	3.94	6.96	6.03
il	2.43	2.28	2.13	2.89	2.58	1.82
ap	1.01	0.67	1.01	1.68	1.34	1.34
	101.0	101.9	101.7	100.8	100.9	97.3

Normative Plagioclase	An_{68}	An_{60}	An_{55}	An_{30}	An_{58}	An_{35}

[1] X.R.F. analyses by J. Sheraton. FeO determined by titration with $K_2Cr_2O_7$. Specimens from Wollongong No. 2: 1-600 ft; 2-470 ft; 3-384 ft; 4-267 ft; C-upper chilled contact zone.

L - Average of 17 latites from Sydney Basin (data from Joplin 1963)

[2] Other constituents, mainly H_2O, average 2.79%.

FIGURE 4.

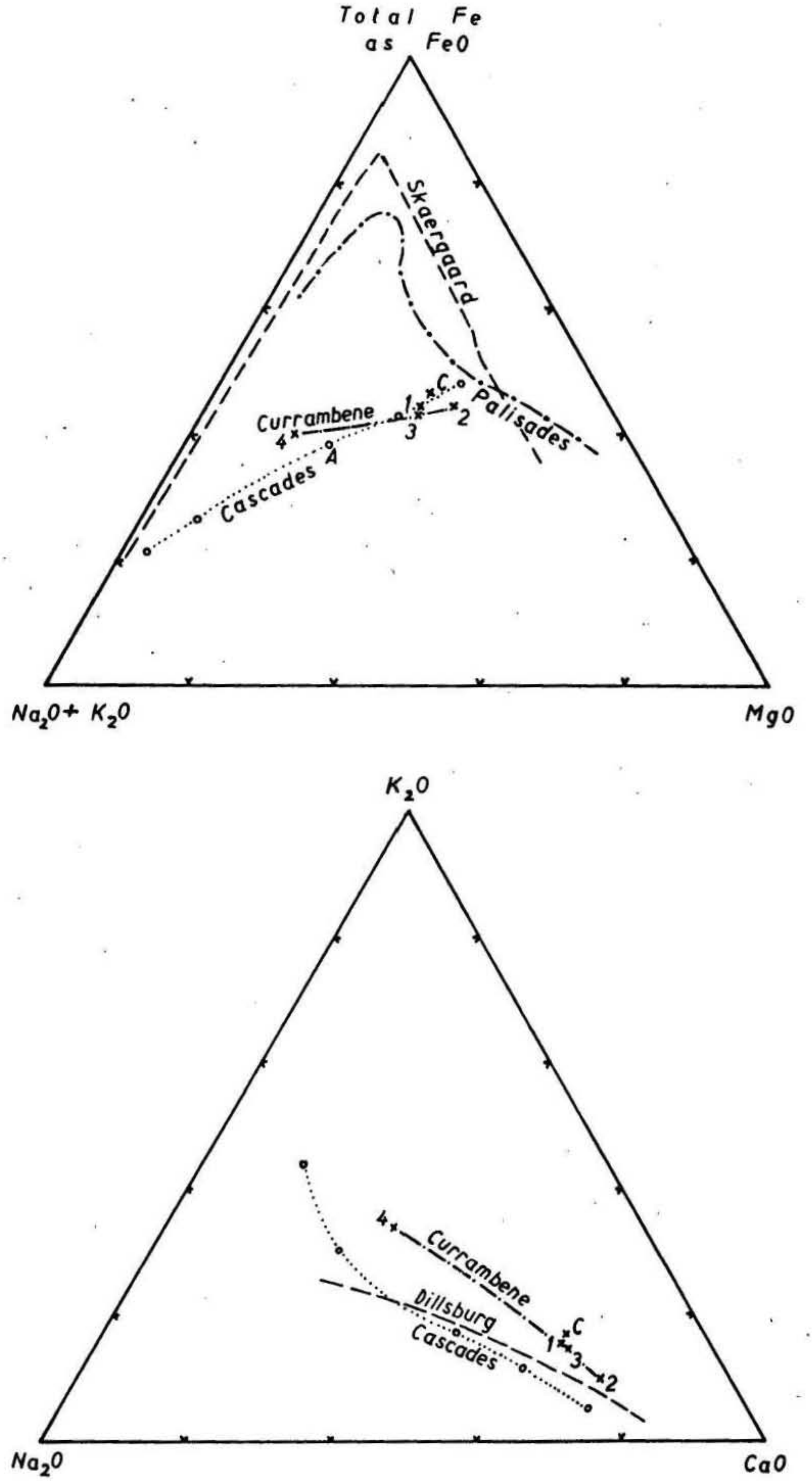
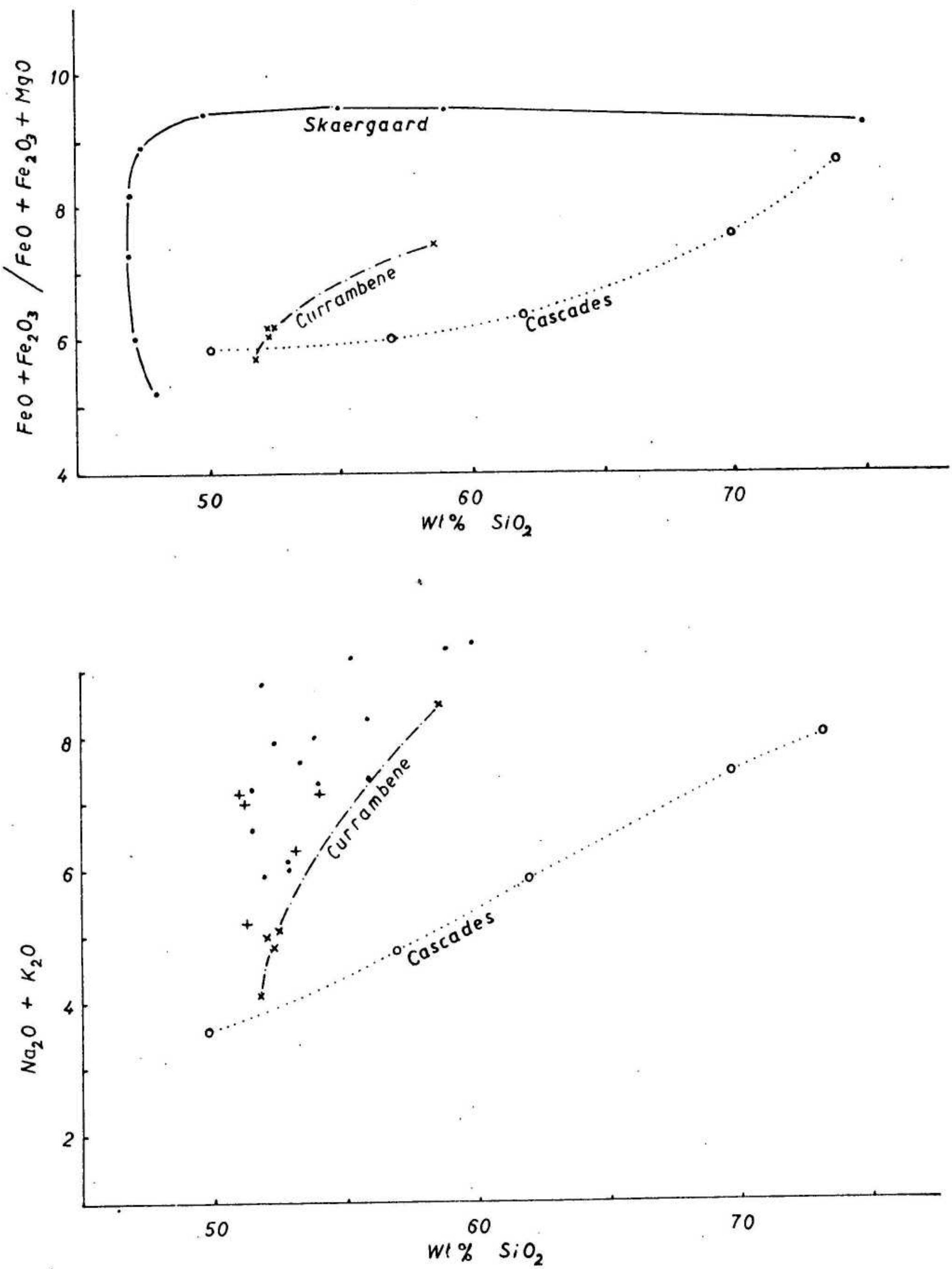

Total Fe as FeO
Skaergaard
Currambene
Palisades
Cascades
1
2
3
4
C
A
$Na_2O + K_2O$
MgO
K_2O
Currambene
Dillsburg
Cascades
4
C
1
3
2
Na_2O
CaO

FIGURE 5.



10
8
6
4
FeO + Fe2O3 / FeO + Fe2O3 + MgO
Skaergaard
Currambene
Cascades
50
60
70
Wt% SiO2
8
6
4
2
Na2O + K2O
Currambene
Cascades
50
60
70
Wt% SiO2

The partial pressure of oxygen may vary during crystallization depending on the rate of crystallization of magnetite. In the Currambene Dolerite (and in the latites of this region) a high initial partial pressure of oxygen has resulted in early crystallization of magnetite and a subsequent reduction in the Fe'''/Fe'' ratio. The high partial pressure of oxygen and consequent crystallization of Fe as magnetite (rather than olivine and pyroxene) has resulted in slight oversaturation (Table 1) whereas a lower partial pressure of oxygen would probably have resulted in saturated or slightly undersaturated rocks.

In addition to the high Fe'''/Fe'' ratio, differentiation trends of the Currambene Dolerite, shown in Figs 3, 4, 5 are controlled largely by the relatively high initial K_2O content, and by the presence of plagioclase phenocrysts.

Notable features of the differentiation of the Currambene Dolerite are an initial reversal of the eventual differentiation trend (4a, b, 5a, b) due to initial settling of plagioclase phenocrysts causing initial enrichment of both CaO and Na_2O (Figs 3, 4a, b), and a subsequent settling of mafic constituents (Fig. 4a) along with further plagioclase.

Although the variations in composition with depth (Fig. 3) show the general trends expected from a differentiated tholeiite, binary and ternary chemical variation diagrams indicate some marked differences.

The trends displayed are in general closer to the calc-alkaline differentiation trends (e.g. Cascades-Carmichael, 1964) than to the normal tholeiitic trends (Figs 4, 5), but differences arise mainly though the higher K_2O and lower SiO_2 in the Currambene Dolerite. Whereas the end-product of differentiation in both the tholeiitic and calc-alkaline suites is of granitic composition that of the Currambene Dolerite is a monzonite.

Failure to develop the Fe enrichment in intermediate stages of fractionation formed e.g. in Skaergaard and the Palisades is well demonstrated in Figs 4a, 5a. This feature of the Currambene Dolerite is attributed to early removal of Fe as magnetite.

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APPENDIX 2. POTASSIUM-ARGON AGE REPORT ON CURRAMBENE DOLERITE MINERALOGY

by

K.J. Henley

(The Australian Mineral Development Laboratories)

Thin Section

Phenocrysts of andesine are generally 3-5 mm long but some exceed 10 mm. Most are finely compositionally zoned, the most basic types appear to fall in the labradorite range, but it is thought that the bulk of the material is more sodic, being andesine. The phenocrysts form about 10% of the rock. Subordinate amounts of phenocrystic clinopyroxene occur, forming less than 1% of the rock. Other phenocrysts, probably pyroxene or amphibole, have been replaced by calcite and/or green biotite. Other rounded masses of chlorite and calcite may represent infilled vesicles.
The groundmass consists of intergrown plagioclase (andesine) laths, pyroxene grains, chlorite and magnetite. Grain size is uniform and averages 0.1 mm.

Suitability for age determination

Plagioclase phenocrysts are unaltered and should yield reliable data. The extreme alteration of some of the mafic phenocrysts and the widespread occurrence of chlorite in the groundmass render the rock unsuited to whole rock determination.

Separation

The rock was crushed and the -25 +120 mesh fraction collected. After sieving at 44 mesh and examining the two size fractions it was concluded that liberation of the -44 +120 mesh fraction was far superior to that of the -25 + 44 fraction. The former was separated in TBE and the heavy fraction collected. Magnetite was removed using a hand magnet and the plagioclase was purified using magnetic separation techniques.

GEOCHRONOLOGY

by

A.W. Webb

(The Australian Mineral Development Laboratories)

Analytical Data

% Potassium:	0.5279, 0.5279
Radiogenic ^{40}Argon:	23.371×10^{-10} moles/gram
$^{40}Ar^{*}/^{40}K$:	0.01455
% ^{40}Ar atmos:	11.4
Age:	234×10^{6} yrs $\pm$ 6×10^{6} yrs

Constants used

$^{40}K = 0.0119$ atom. %

$= 4.72 \times 10^{-10}/yr$

$= 0.584 \times 10^{-10}/yr$

APPENDIX 3. LIST OF CORES, DESCRIPTION OF CORES AND CORE ANALYSES RESULTS, WOLLONGONG (B.M.R.) NO.1 WELL

LIST OF CORES

Core No.	Cored Interval (in feet)	Recovery (in feet)	Recovery %
1	60'02" - 62'05"	2'03"	100
2	74'06" - 75'09½"	1'03½"	100
3	88'06" - 89'03"	0'07½"	83
4	148'00" - 151'04½"	3'04½"	100
5	232'00" - 236'03"	4'03"	100
6	285'04" - 286'06"	0'08"	55
7	435'00" - 438'01½"	3'02½"	100
8	698'06" - 698'10"	0'04"	100
9	781'00" - 789'10"	8'10"	100
10	901'06" - 909'06"	8'00"	100
11	946'06" - 957'05½"	10'11½"	100
12	998'06" -1001'08"	3'01"	98

DESCRIPTION OF CORES, WOLLONGONG B.M.R. No. 1

Core No. 1 60'02" - 62'05" (recovered 2'03")

Top 4" - Light grey, poorly sorted, very fine to pebbly, quartz rich sandstone with fragments of Pelecypod and Brachiopod shells. Thin laminae of siderite are common.

7" - Dark grey to black, fissile shale with traces of Bryozoa remains and some unidentified shell fragments.

1'4" - Light grey, poorly sorted, very fine to pebbly, quartz rich sandstone; Brachiopod (Productoid) shells and spines are abundant. Calcite crystals occur throughout the core; veins of siderite and some calcite are present.

The bedding is generally poorly defined, except for the shale parting.

Core No. 2 74'06" - 75'09½" (recovered 1'03½")

Light grey, poorly sorted, very fine to pebbly, calcite cemented quartz rich sandstone; traces of carbonaceous matter are present throughout the core; lenses of pyrite and pockets of very finely disseminated pyrite are common. Parts of the core are brownish, hematite stained. Broken fragments of Brachiopod shells are rare.

Core No. 3 88'06" - 89'03" (recovered 7½")

Light grey to brown, moderately sorted, calcite and siderite cemented quartz rich sandstone; traces of broken shell fragments are present.

Core No. 4 148'00" - 151'04½" (recovered 3'04½")

Light grey to dark grey, sandy siltstone with abundant fossil fragments of Brachiopod and Pelecypod shells.

Sedimentary structures are of micro-cross bedding, slump and scour structures.

Core No. 5 232'00" - 236'03" (recovered 4'03")

Top 2'06" - Dark grey, strongly reworked, sandy siltstone with an abundance of shell fragments of Brachiopods, Pelecypods and occasional Gastropods. Trace fossils are abundant. The sedimentary structures comprise slump and scour structures and micro cross-bedding.

The sandstone shows no apparent bedding but some thin layers of pebbles up to 7 cm thick show horizontal bedding.

Bottom 1'09" - Dark grey to black, pebbly in parts, strongly reworked, sandy siltstone. Shell fragments of Brachiopods are common but Pelecypod shells are rare. Thin laminae of white sandstone are found throughout the core, the sandstone is calcite cemented.

Sedimentary structures are mainly slump and scour structures, burrows and micro-bedding.

Core No. 6 285'04" - 286'06" (recovered 8")

Dark grey to black, strongly reworked sandy siltstone with abundance of broken Brachiopod and Pelecypod shell fragments. Trace fossils are abundant together with sedimentary structures as in Core No. 5.

Core No. 7 435'00" - 438'01½" (recovered 3'01½")

Light grey to dark grey, strongly reworked, pebbly in parts sandy siltstone; Brachiopods and Pelecypod shell fragments are rare, but trace fossils are abundant. Thin calcite and siderite veins are common. Traces of very finely disseminated pyrite occur throughout the core.

Pebbles, up to 25 mm, of greenish grey phyllite are common in parts of the core.

Core No. 8 698'06" - 698'10" (recovered 4")

Light grey, poorly sorted, coarse to pebbly, siliceous to calcareous sandstone with traces of carbonaceous material. Lenses of siderite are common.

Core No. 9 781'00" - 789'10" (recovered 8'10")

Light grey to dark grey, poorly sorted, pebbly, calcareous and siliceous quartz rich sandstone; pockets of white clay occur throughout the core. Pebbles of greenish and grey metamorphic rock are common.

Traces of shale fragments occur. Layers of dark grey to black bands, up to 5 mm thick of micaceous (? graphite) shale are present. Traces of carbonaceous and pyrite material are present.

The core shows massive bedding.

Core No. 10 901'06" - 909'05½" (recovered 8')

Top 3' - Light to dark grey, poorly sorted, very fine to pebbly sandstone. Carbonaceous material is common together with fragments of thick shelled Brachiopods. Trace fossils are rare.

5' - Dark grey sandy siltstone and silty sandstone with abundant thick shelled Brachiopods. Fragments of carbonaceous material and pebbles of greenish metamorphic rock occur throughout the core interval. Lenses of calcite and siderite are rare.

Core No. 11 946'06" - 957'05½" (recovered 10'11½")

Light grey to dark grey sandy siltstone and silty sandstone. Fragments of broken shells occur throughout the core together with laminae of coaly material. Trace fossils are common and their presence indicates an abundance of bottom dwellers and burrowers.

Lenses of siderite and calcite together with pebbles of quartz, chert and metamorphic rock occur throughout the core.

Core No. 12 998'06" - 1001'08" (recovered 3'01")

Dark grey to brownish grey poorly sorted silty sandstone and sandy siltstone, with an abundance of thick shelled Brachiopods and some Pelecypod shells. Trace fossils are present.

Fragments of woody material and coaly lenses are common. Pebbles of quartz and chert are scattered throughout the core together with pebbles of metamorphic rock. Veins of siderite and calcite are common.

APPENDIX 4. LIST OF CORES, DESCRIPTION OF CORES AND CORE ANALYSES RESULTS, WOLLONGONG (B.M.R.) No. 2 WELL

LIST OF CORES

Core No.	Cored Interval (in feet)	Recovery (in feet)	Recovery %
1	95' - 104'½"	9'½"	100
2	158' - 167'11"	9'5"	100
3	266'6" - 271'5"	4'11"	100

DESCRIPTION OF CORES, WOLLONGONG B.M.R. No. 2

Core No. 1 95' - 104'½" (recovered 9'½")

Dark grey to black, sandy siltstone with occasional shale partings. Bands of pebbles occur in the top part of the core. Traces of siliceous casts thought to be foraminifera occur in the core together with traces of brachiopod shells. The sediments show strong churning, slump and scour structures are common.

Core No. 2 158'06" - 167'11" (recovered 9'5")

Top 18" Light brown to grey calcareous and sideritic, massively bedded, in parts argillaceous sandstone with Brachiopod shells that are entirely sideritized.

8'11" Greenish grey, porphyritic basic intrusive rock with plagioclase crystals up to 3 cm long. The contact zone shows a 2 inch wide chilling margin, highly calcareous.

Core No. 3 266'6" - 271'5" (recovered 4'11")

Greenish brown, medium grained Holocystaline doleritic intrusive rock.

Laminae of coaly material are present, and show horizontal bedding. Outlines of bi-valve fossils occur but are filled with clayey material.

APPENDIX 5. LIST OF CORES, DESCRIPTION OF CORES AND CORE ANALYSES RESULTS, WOLLONGONG (B.M.R.) No. 2A WELL

LIST OF CORES

Core No.	Cored Interval (in feet)	Recovery (in feet)	Recovery %
1	380'6" - 384'6"	4'	100
2	622'6" - 626'10"	4'4"	100
3	760'0" - 764'7"	4'7"	100
4	846'0" - 847'1"	2'1"	100
5	900'0" - 905'2"	5'2"	100
6	995'0" - 998'0"	3'	100

DESCRIPTION OF CORES, WOLLONGONG B.M.R. No. 2A

Core No. 1 380'06" - 384'06" (recovered)

Greenish grey to slightly brown, porphyritic igneous intrusive rock.

Light grey to white plagioclase crystals dominate the rocks composition and are up to 3 cm long; some rosettes are formed from the plagioclase crystals.

Core No. 2 622'06" - 626'10" (recovered 4'4")

Light grey to white, poorly sorted, very fine to coarse-grained quartz rich sandstone with occasional pebbles of quartz and chert; pockets of whitish to grey clay are common. Traces of carbonaceous material occur throughout the core. Only slight traces of calcareous matter are present. The bedding is very massive.

Core No. 3 760'00" - 764'07" (recovered 4'7")

Light grey to dark grey, poorly sorted, massively bedded, calcareous in parts, argillaceous sandstone with pebble bands. Laminae of coaly matter are common throughout the core, together with very finely disseminated pyrite.

Core No. 4 845'00" - 847'01" (recovered 2'1")

Light grey to dark grey, poorly sorted, very fine to very coarse-grained quartz rich sandstone; pockets of clay as in Core No. 2 are common.

Laminae of coaly material are present, and show horizontal bedding.

Outlines of bi-valve fossils occur but are filled with clayey material.

Core No. 5 900'00" - 905'02" (recovered 5'2")

Same as Core No. 4

Core No. 6 995'00" - 998'00" (recovered 3')

Light grey to dark grey, poorly sorted, thick bedded quartz rich sandstone with interbeds of sandy siltstone and shale. Coaly laminae are limited to sandy parts only, however both sandstone and siltstone are calcareous and pyritic.

Traces of broken shells occur throughout the core.

The silty portion of the core shows bioturbation.

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. WOLLONGONG NO. 1

DATE ANALYSIS COMPLETED June 1, 1970

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
1	60'11"	61'8"	Sh; aren slty	4.7	<0.1	<0.1	2.59	2.71	54	Nil	N.D.	Neg.	Nil
2	75'6"	75'9"	Sst; m.gr to c.gr.	7.4	<0.1	<0.1	2.48	2.67	14	Nil	N.D.	Neg.	Nil
3	88'6"	88'11"	Sst; m.gr to c.gr.	9.9	0.16	0.15	2.41	2.67	7.9	Nil	N.D.	Neg.	Nil
4	149'10"	150'6"	Slst; aren	4.0	<0.1	<0.1	2.61	2.72	34	Nil	N.D.	Neg.	Nil
5	232'0"	232'6"	Slst; mic calc.	3.1	<0.1	<0.1	2.65	2.73	13	Nil	N.D.	Neg.	Nil
6	285'4"	286'0"	Sst;v.f.gr calc.	2.5	<0.1	<0.1	2.63	2.70	36	Nil	N.D.	Neg.	Nil
7	436'10"	437'5"	Slst; aren.	3.2	<0.1	<0.1	2.62	2.70	60	Nil	N.D.	Neg.	Nil
8	698'6"	698'10"	Sst;m.grto v.c.gr. calc	4.8	<0.1	<0.1	2.55	2.68	2.2	Nil	N.D.	Neg.	Irregular blue yell spotted

Remarks: -

General File No. 69/1414

Well File No.

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. WOLLONGONG NO. 1

DATE ANALYSIS COMPLETED June 1, 1970

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
9	784'7"	784'11"	Sst; m.gr sl. calc.	9.3	0.14	0.14	2.43	2.68	2.9	Nil	N.D.	Neg.	irregular blue yell spotted
9	789'1"	789'5"	as above	11	0.25	0.23	2.38	2.67	2.3	Nil	N.D.	Neg.	"
10	906'3"	906'9"	Sst;f.gr.to m.gr. carb	3.5	<0.1	<0.1	2.60	2.68	22	Nil	N.D.	Neg.	Very dull even blue
11	946'10"	947'2"	Sst; m.gr.	9.4	0.10	0.12	2.46	2.71	4.0	Nil	N.D.	Neg.	irregular dull yell spotted
12	1001'1" ~~999'7"~~	1001'7" ~~1000'2"~~	Sst; f.grto m.gr. arg	5.9	<0.1	<0.1	2.56	2.73	15	Nil	N.D.	Neg.	"

Remarks: -

General File No. 69/1414
Well File No.

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. VOLLONGONG (BMR) NO. 2

DATE ANALYSIS COMPLETED 29 May, 1970

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
1	98'8"	99'4"	Slst; arg.	4.7	<0.1	<0.1	2.62	2.75	35	Nil	N.D.	Neg.	Nil
2	166'7"	167'0"	Slst.	1.9	<0.1	<0.1	2.72	2.77	100	Nil	N.D.	Neg.	Nil
3	269'11"	270'4"	Volcan intrus.	2.9	<0.1	<0.1	2.62	2.70	68	Nil	N.D.	Neg.	Nil

Remarks: -

General File No. 69/1414

Well File No.

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. WOLLONGONG NO. 2A

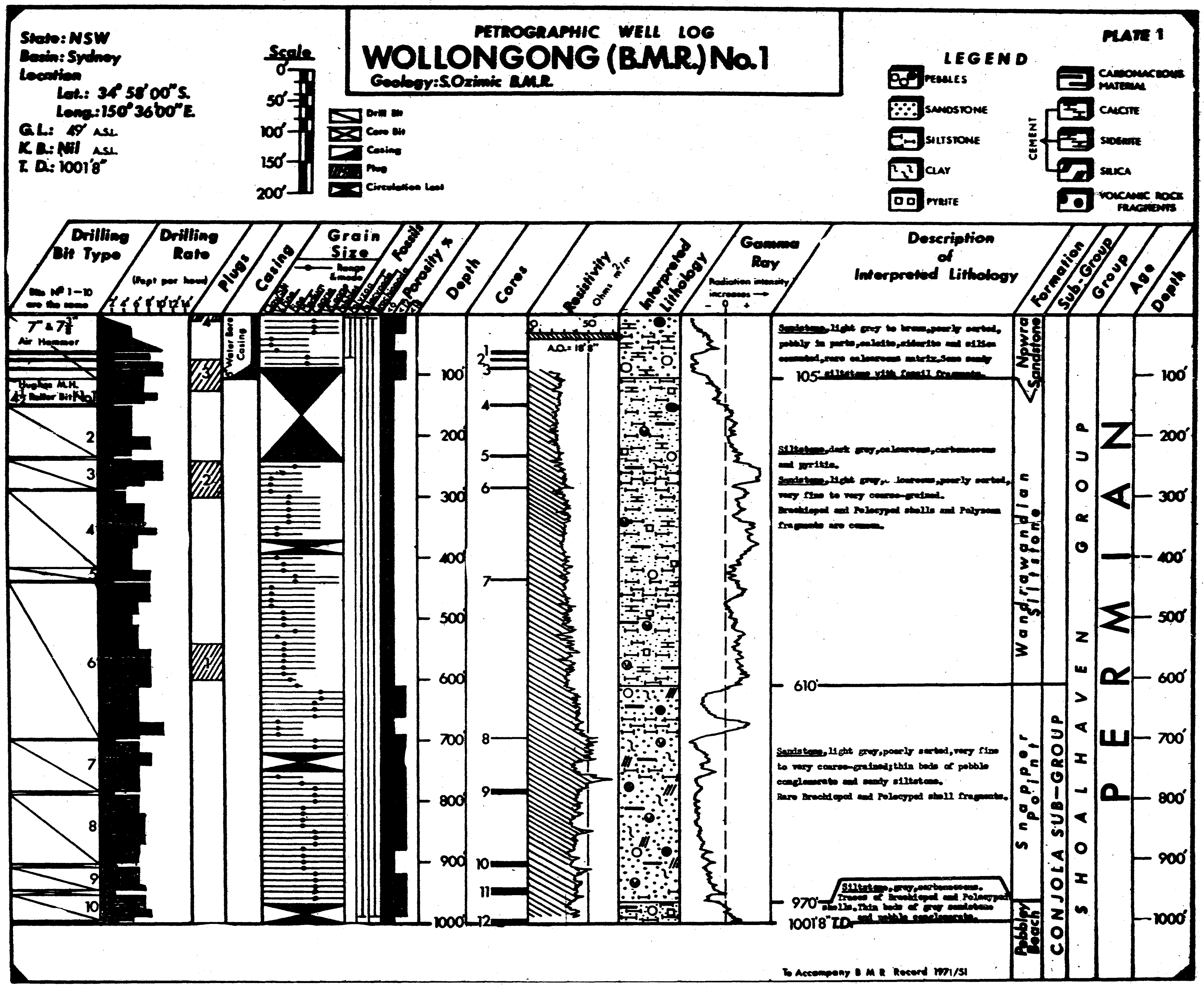
DATE ANALYSIS COMPLETED May 29, 1970

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
1	383'9"	384'4"	Volcan intrus	2.3	<0.1	<0.1	2.78	2.85	86	Nil	N.D.	Neg.	Nil
2	624'2"	624'9"	Sst; m.gr. to v.c.gr	10	0.19	0.10	2.38	2.65	6.7	Nil	N.D.	Neg.	Dull even yellow spotted
3	663'5"	664'1"	Sst; m.gr. to v.c.gr. carb	11	0.12	0.14	2.36	2.69	8.3.	Nil	N.D.	Neg.	Nil
4	846'5"	846'9"	Sst; m.gr to c.gr	8.9	0.13	0.14	2.43	2.67	6.2	Nil	N.D.	Neg.	Dull even blue
5	901'8"	902'3"	Sst; m.gr	12	0.13	0.13	2.35	2.66	5.0	Nil	N.D.	Neg.	Dull even yellow spotted
6	996'7"	997'0"	Sst; m.gr slty, arg.	5.7	<0.1	0.1	2.56	2.71	27	Nil	N.D.	Neg.	irregular dull yell spotted

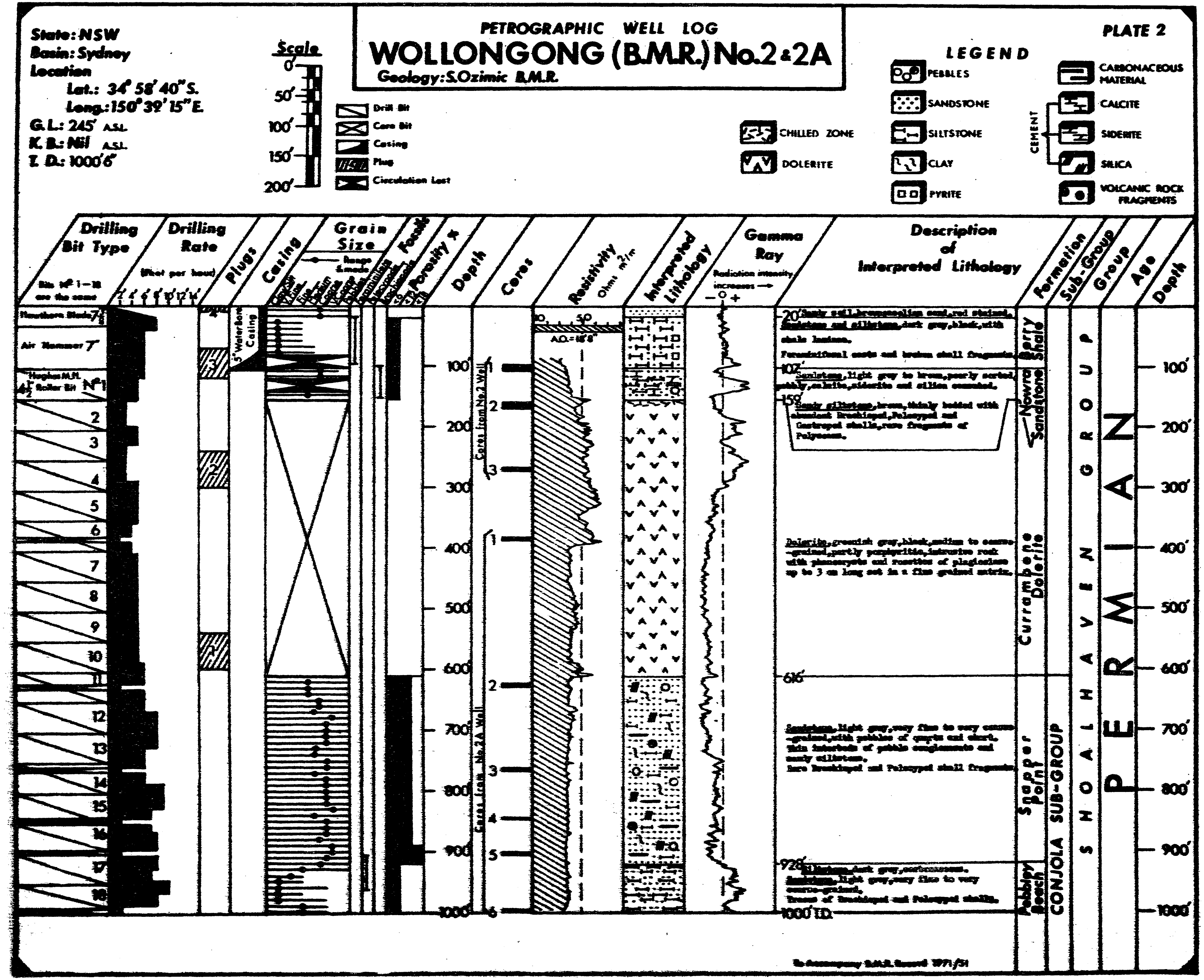
Remarks: -

General File No. 69/1414

Well File No.



PETROGRAPHIC WELL LOG
WOLLONGONG (B.M.R.) No.1
Geology: S.Ozimic B.M.R.
PLATE 1
State: NSW
Basin: Sydney
Location
Lat.: 34° 58' 00" S.
Long.: 150° 36' 00" E.
G.L.: 49' A.S.L.
K.B.: Nil A.S.L.
T.D.: 1001'8"
Scale
0'
50'
100'
150'
200'
Drill Bit
Core Bit
Casing
Plug
Circulation Lost
LEGEND
PEBBLES
SANDSTONE
SILTSTONE
CLAY
PYRITE
CARBONACEOUS MATERIAL
CEMENT
CALCITE
SIDERITE
SILICA
VOLCANIC ROCK FRAGMENTS
Drilling Bit Type
Bits No 1–10 are the same
Drilling Rate
(Feet per hour)
Plugs
Casing
Grain Size
Range
Fossils
Porosity %
Depth
Cores
Resistivity Ohms m²/m
Interpreted Lithology
Gamma Ray
Radiation intensity increases →
Description of Interpreted Lithology
Formation
Sub-Group
Group
Age
Depth
7" & 7 3/8" Air Hammer
Hughes M.H. 4 3/4" Button Bit No 1
Water Bore Casing
A.O.= 18'8"
105'
Sandstone, light grey to brown, poorly sorted, pebbly in parts, calcite, siderite and silica cemented, rare calcareous matrix. Some sandy siltstone with fossil fragments.
Siltstone, dark grey, calcareous, carbonaceous and pyritic.
Sandstone, light grey, calcareous, poorly sorted, very fine to very coarse-grained.
Brachiopod and Pelecypod shells and Polyzoan fragments are common.
610'
Sandstone, light grey, poorly sorted, very fine to very coarse-grained; thin beds of pebble conglomerate and sandy siltstone.
Rare Brachiopod and Pelecypod shell fragments.
970'
Siltstone, grey, carbonaceous. Traces of Brachiopod and Pelecypod shells. Thin beds of grey sandstone and pebble conglomerate.
1001'8" T.D.
Nowra Sandstone
Wandrawandian Siltstone
Snapper Point
Pebbley Beach
CONJOLA SUB-GROUP
SHOALHAVEN GROUP
PERMIAN
100'
200'
300'
400'
500'
600'
700'
800'
900'
1000'
To Accompany B M R Record 1971/51


PETROGRAPHIC WELL LOG
WOLLONGONG (B.M.R.) No.2 & 2A
Geology: S.Ozimic B.M.R.
PLATE 2
State: NSW
Basin: Sydney
Location
Lat.: 34° 58' 40" S.
Long.: 150° 39' 15" E.
G.L.: 245' A.S.L.
K.B.: Nil A.S.L.
T.D.: 1000'6"
Scale
0'
50'
100'
150'
200'
Drill Bit
Core Bit
Casing
Plug
Circulation Lost
LEGEND
CHILLED ZONE
DOLERITE
PEBBLES
SANDSTONE
SILTSTONE
CLAY
PYRITE
CARBONACEOUS MATERIAL
CEMENT
CALCITE
SIDERITE
SILICA
VOLCANIC ROCK FRAGMENTS
Drilling Bit Type
Drilling Rate
Plugs
Casing
Grain Size
Fossils
Porosity %
Depth
Cores
Resistivity Ohms m²/m
Interpreted Lithology
Gamma Ray
Radiation intensity increases →
Description of Interpreted Lithology
Formation
Sub-Group
Group
Age
Depth
Hawthorn Blade
Air Hammer 7"
Hughes M.H. Roller Bit
N°1
5" Water Bore Casing
A.O. = 18'8"
Cores from No.2 Well
Cores from No.2A Well
20' Sandy soil, brown, aeolian sand, red stained.
Sandstone and siltstone, dark grey, black, with shale laminae.
Foraminiferal casts and broken shell fragments.
107' Sandstone, light grey to brown, poorly sorted, pebbly, calcite, siderite and silica cemented.
150' Sandy siltstone, brown, thinly bedded with abundant Brachiopod, Pelecypod and Gastropod shells, rare fragments of Polyzoans.
Dolerite, greenish grey, black, medium to coarse-grained, partly porphyritic, intrusive rock with phenocrysts and rosettes of plagioclase up to 3 cm long set in a fine grained matrix.
616'
Sandstone, light grey, very fine to very coarse-grained, with pebbles of quartz and chert. Thin interbeds of pebble conglomerate and sandy siltstone.
Rare Brachiopod and Pelecypod shell fragments.
928' Siltstone, dark grey, carbonaceous.
Sandstone, light grey, very fine to very coarse-grained.
Traces of Brachiopod and Pelecypod shells.
1000' T.D.
Berry Shale
Nowra Sandstone
Currambene Dolerite
Snapper Point
Pebbley Beach
CONJOLA SUB-GROUP
SHOALHAVEN GROUP
PERMIAN
100'
200'
300'
400'
500'
600'
700'
800'
900'
1000'
To Accompany B.M.R. Record 1971/51