COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1966/83

A PETROLOGICAL STUDY OF THE SEDIMENTS FROM HIGHWAY ANTICLINE NO.1 WELL AMADEUS BASIN, NORTHERN TERRITORY.

by

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Institut Français du Petrole

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CONTENTS

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SUMMARY

The Highway Anticline No. 1 well was drilled by Exoil (N.T.) as a stratigraphic and structural test of the Highway James Range Anticline. The well is 3725 feet deep.

Petrological studies show that the total thickness of sediments can be correlated with Cambrian formations as follows:

2952 feet (true thickness) of Jay Creek Limestone, overlain by 436 feet (true thickness) of Goyder Formation.

With the exception of the dolomitic, cherty and stromatolitic limestone in the lower unit of the Jay Creek Limestone, the sediments represent typical sections of Jay Creek Limestone and Goyder Formation.

Strong diagenetic and post-diagenetic changes have taken place throughout the total thickness.

INTRODUCTION

The Highway Anticline No. 1 well was drilled by Exoil (N.T.) Pty. Ltd. and partners as a stratigraphic and structural test of the Highway Anticline.

This well is approximately 50 miles south of Alice Springs on the Stuart Highway in the Northern Territory of Australia. Further details of the well history are given in the well completion report on Highway Anticline No. 1 by Exoil (N.T.) Pty. Ltd. (1965) which is the principal reference for this study.

This detailed petrological study has been undertaken to establish a finer lithological subdivision of the Cambrian sediments by comparing them with the lithologies of surface samples. Another purpose was to determine whether or not the unit between the bottom of the well and 2842 feet is equivalent to the Proterozoic, Bitter Springs Formation, or Cambrian formations.

In order to obtain a more precise idea of the lithologies, cuttings were examined at 10 foot intervals. Thin sections were prepared from the cores. The cuttings were thin-sectioned at every lithological change and at 30 foot intervals between the bottom and 2842 feet. Some thin sections have been treated with silver nitrate to distinguish calcite from dolomite. A calcilog with an interval of 40 feet for each sample has been prepared. Palaeontological examination for conodonts has been undertaken on cores 5 and 6. Heavy mineral separation has been made on 3 samples; one of them represents a composite cuttings sample from several sandstone horizons of the Goyder Formation. All petrological results have been described on the attached composite log.

DESCRIPTION OF LITHOLOGICAL UNITS

Equivalent of Jay Creek Limestone

This formation has been intersected in the Highway Anticline No. 1 well from the total depth of 3735 feet (E.L. depth 3725 feet; driller depth 3770 feet) to 480 feet.

This composite lithological sequence has been divided into 2 units: a lower part, between 3725 and 2842 feet with dolomite predominant and an upper part, between 2842 feet and 480 feet with a slight predominance of siltstone over dolomite and limestone.

The lower part has been considered by Exoil as an equivalent of the Bitter Springs Formation or possibly as Chandler Limestone.

The upper part has been correlated by the geologists of Exoil as Hugh River Shale.

Lower unit (3725 to 2842 feet)

This unit is characterized, mainly by a dolomite sequence with some siltstone and sandstone horizons.

Dolomite

The dolomites are white to grey, pink to brownish-red, very compact and dense, in places finely laminated, microcrystalline and more rarely cryptocrystalline, slightly calcareous. Characteristic of the whole interval is coarse to very coarse, quartz-chalcedony-chert, generally in nodules, and exceptionally, in fine laminae as in core 6 (3760-3763^{+} feet). The chert includes several cryptocrystalline calcite crystals.

Below 3300 feet the dolomite has numerous calcarenitic and oolitic horizons with algal structures. Characteristic of this interval are small globules of strongly recrystallized radiant calcite. These "rosettes", observed for the first time in Alice No. 1 well by A. Fehr, have been recognized throughout the whole formation in this well. These structures are always recrystallized, mostly silicified with a cryptocrystalline chalcedony centre and an external concentric band of microcrystalline quartz. They do not allow a precise correlation. In cores 5 and 6 numerous stromatolites have been recognized; all are strongly inclined at steep angles between 35° and 50°, to the long axis of the core. Haematite, in spots, diffused and intergranular is common and colours the rock red; the green and grey-green coloration is probably due to a lower oxidation state of the iron. Black and hard interstitial masses, vug linings or very small pellets occur throughout this unit, especially between 3650' - 3660' and 3740' and 3750 feet, mostly in association with pyrite crystals. A dissolution test with carbon tetrachloride did not give any results.

Locally the dolomites grade into silty or very fine sandy dolomites with a variable content of detrital quartz, feldspar, lithic fragments, chert and muscovite.

Sandstone and Siltstone

These rocks are generally brownish-red to pink, fine to coarse grained, medium sorting, angular to rounded, very quartzitic with rare muscovite, and with single rounded quartz pebbles at 3560 feet. The sandstones have a haematitic and rarely a calcareous cement. They grade either into sandy dolomite or into brownish-red and green haematitic and chloritic siltstone.

Upper contact

This limit was picked at the change to massive, dense carbonate rock in the cuttings and at the marked shoulders on the gamma-acoustic logs.

Age determinations

A dissolution test for conodonts was carried out on cores 5 and 6. The result was negative.

Lithification

In this carbonate rock unit the changes that have taken place have been primarily due to the lithifications by compaction, although diagenetic recrystallization, dolomitization and silicification have occurred. In order we can distinguish:

Growth of chalcedonic chert which has replaced fossils in the lower part of the formation, or is present as rounded nodules throughout.

The absence of dolomite rhombs in the chert shows that the silicification occurred before dolomitization.

At the time of the recrystallization, chalcedony in contact with carbonate rock was recrystallized into microcrystalline quartz.

Porosity

This unit is characterized by a general lack of porosity; only minor vugular porosity was noticed. Fine fractures are often filled with white calcite.

Environment

The presence of algae and oolites would seem to indicate a very shallow water environment where limestone was laid down with rare detrital material together with a small unvarying amount of iron.

Conclusions for this unit

The petrological study of this unit has shown some pertinent characters such as the presence of algal structures and "rosettes" which occur throughout the whole formation, the shape of rounded quartz-chalcedony-chert, the predominantly reddish colouration, and the absence of glauconite which do not allow correlation of this unit with the Bitter Springs Formation or the Chandler Limestone.

No traces of unconformity and intense erosion (involving the removal of the Chandler Limestone and Areyonga Formation, and all formations between) have been observed and sedimentation seems to be continuous with the overlying sediments, and therefore I consider this unit as an equivalent of Jay Creek Limestone or preferably lying in a transition-zone between the Jay Creek Limestone and Giles Creek Dolomite.

Upper unit

This unit has been recognized between 2842 feet and 480 feet. It overlies conformably the lower carbonate rock unit.

This upper unit may be divided into three subunits characterized by the proportion of carbonate rocks which alternate with monotonous, generally brownish-red and green siltstone.

Subunit I : 2840' to 1574' : dolomite

Subunit II : 1574' to 1060' : siltstone with rare beds of carbonate rock

Subunit III : 1060' to 480' : calcareous, calcarenitic and algal carbonate rock.

Subunit I (2840 to 1574 feet)

This sequence is composed of thin dolomite horizons alternating with siltstone which in places grades into fine sandstone. Siltstone and the minor sandstone represent about 75% of the total thickness.

Dolomite

The dolomites are white to light grey, pink to red, saccharoidal to microcrystalline, often haematitic, silty to sandy, locally pelletic and have between 10% and 25% calcite.

Detrital material varies between 1% and 40% throughout the total thickness; there is always angular to subrounded silty to fine grained, quartz, rare feldspar, metamorphic rock fragments and some muscovite flakes. Finely disseminated pyrite is present. Between 2300' and 2274' there is a chalcedonic-quartz horizon. Also between 2680' and 1615' a persistance of transparent to white, fibrous gypsum and anhydrite has been noticed in the cuttings. In thin section anhydrite (very rare gypsum) occurs in lenses, nests, and often in very coarse crystals with inclusions of well developed dolomite rhombs. A similar type of fibrous gypsum and anhydrite fills irregular anastomosing veins and some fissures, between 10 and 20 mm thick in core 3.

Subunit II (1574 feet to 1060 feet)

This subunit is mainly a brownish red and green siltstone with some very thin beds of dolomitic limestone and calcitic dolomite. Siltstone comprises about 95% of the total thickness.

The dolomitic horizons are white to grey, rarely red, microcrystalline and grade into silty, micaceous calcitic dolomite.

Subunit III (1060 feet to 480 feet)

In this interval siltstone and sandy siltstone are slightly predominant over the carbonate rocks which represent 40% of the total thickness.

Limestone

The limestone and dolomitized limestone are white to grey, also brownish-red, cryptocrystalline to microcrystalline, silty to finely sandy, and haematitic. Characteristic of this interval is the presence of numerous algal structures, like "rosettes" (see above), lumps* and some calcarenitic horizons; these strongly recrystallized structures are locally silicified by fine grained quartz.

Through the total thickness of the upper unit the siltstones are practically homogeneous. They grade into silty shale, rarely shale and some sandstone lenses. The siltstone is generally brownish-red, also green, grey with very rare blackish-grey bands, fissile, and micaceous. They have numerous pebbly zones characterized by red, rounded to subrounded, coarse to very coarse grained quartz and some lithic grains. The cementing media is variable; haematite is dominant in red siltstone with some poorly defined clay matter, and chlorite in green siltstone, with pyrite and black matter (altered pyrite?) throughout. Cryptocrystalline calcite and dolomite pseudorhombs occur in minor amount, locally increasing at 50%.

The quartz sandstone occurs in fine interlaminations or in lenses, and is red to brownish-red, green, white to grey, medium sorted, angular to rounded and fine to coarse grained. The framework is quartz, rare microcline, and lithic fragments (3 to 10 mm across) locally including variable amounts of pellets and some limestone pebbles. Muscovite and green to brownish-green biotite altered to chlorite is always less than 5%. Accessory minerals are rounded tourmaline, zircon, apatite, and garnet. Two heavy mineral tests gave the following results:

	Tourmaline	Zircon	Almandine	Actinolite	Opaques
594'-4"	55%	10%	23%	2%	Pyrite and magnetite
598'-4"	76%	13%	10%	1%	" "

It seems that any apatite has been dissolved in hot HCl acid.

The cement is principally haematite (never in coatings) or chlorite, and some silica overgrowths, calcite and dolomite.

Anhydrite and gypsum cement occurs locally between 2680' and 1615'.

Contacts of the upper unit

The lower limit is distinguished as much by the sharp change in the

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*Lumps: "composite grains typically possessing surficial irregularities and believed to have formed by a process of aggregation" M.W. Leighton and C. Pendexter 1962.

lithology as by the electric logs and gamma-acoustic logs. Between 2842' and 2755' there is a silty, sandy and pebbly zone which is indicated on the resistivity log by a very strong positive deflection. The upper limit of the unit is a transition zone corresponding to a decrease in the regular rythmic interbedding of carbonate and siltstone and an increase in detrital content. The limit has been picked at the first appearance of a clean sandstone horizon, well documented in cuttings and on the S.P. log.

Porosity

Negligible intergramular porosity is to be expected from this interval.

Lithification

Diagenesis has been strong in this interval especially by compaction in the siltstone and silicification in the carbonate rock. Recrystallization and dolomitization are particularly important in the lower subunit where all structures have disappeared and limestone is completely dolomitized.

Anhydrite and gypsum have filled veins, and fractures in the lower subunit after dolomitization.

Environment

A shallow marine to coastal depositional environment for these sediments seems most likely. The source area of the episodic coarse clastics was probably a continental area composed of metamorphic rocks.

General conclusions for the Jay Creek Limestone

The Jay Creek Limestone can be characterized by:

the algae and chert content of the lower unit

~~the~~ fossils, rounded coarse quartz pebbles and garnet content in the upper unit.

Goyder Formation

This formation, which has been recognized between 480 feet and the top of the well, is characterized mainly by quartz- and feldspathic sandstone grading into siltstone and interbedded with some limestone horizons.

Sandstone

This quartzitic or feldspathic sandstone is variegated but mainly reddish, very fine to medium and rarely coarse grained, angular to subrounded, medium to well sorted and is characterized by a detrital content which varies greatly in amount. Quartz, orthoclase, microcline commonly with crystal faces, metamorphic or igneous lithic chert, muscovite and minor green to brownish-green biotite altered to chlorite make the framework of the rock.

Accessory minerals are pyrite, tourmaline, zircon and apatite. A test for heavy minerals has been carried out on a mixed cuttings sample, with the following results -

Tourmaline	Garnet	Barite	Andalusite	Pyrite
5%	1%	10%	1%	85%

The percentage of heavy minerals is low but the presence of rounded barite, andalusite and garnet is interesting as an indication of a strongly metamorphosed source area. The matrix cement is represented by all stages of silicification such as silica overgrowths commonly with crystal faces, intergranular silica. Rare feldspathisation has also been recorded which tends to recrystallise to forms with rhombic x-sections. Haematite, filling intergranular spaces, seems to be locally weathered. Kaolinite and clay are very rare but calcite and dolomite are present in variable amount.

Limestone

The limestones are generally white, also reddish, silty to sandy with quartz, microcline and muscovite. They are locally dolomitized but very often occur in algal structures, oolites and lumps.

Some limestone horizons located between 300 feet and the top are very pure. It seems possible that dedolomitisation has taken place by circulation of meteoric water from the surface.

Siltstone and some silty shale, commonly grading onto one another, red-brown, grey, green, ochreous, and in part micaceous increase in proportion towards the base of the formation.

The lower limit is picked at the first appearance of a sandstone horizon marked by the S.P. log only.

Porosity

The sandstone horizons show a light intergranular porosity which is reduced by cementation.

Lithification

Silicification, feldspathisation, calcification and dolomitization seem the principal diagenetic changes.

Environment

The Goyder Formation was deposited in a shallow marine neritic environment with predominantly detrital deposits.

THICKNESS OF THE FORMATIONS

The total depth of Highway Anticline No. 1 well has been determined by the electric logs. Nevertheless in the thickness evaluation of the different formations the dip of the beds has to be taken into account.

A study of the dipmeter shows an average dip of 15° - 20° between the top and 3000 feet and 50° - 70° between 3000 feet and the bottom.

Elsewhere these steeply dipping beds are emphasized also by the study of the stromatolites in core 5 and 6 which indicate an average dip of 45° and by the problems caused by deviation of the well.

The average dip adopted here will be of 25°.

- Thickness of Jay Creek Limestone
  3245' x cos 25° = 2952 feet

- Thickness of Goyder Formation
  480' x cos 25° = 436 feet

CONCLUSIONS

The petrological study of Highway Anticline No. 1 well has shown that the three formations previously correlated with the Bitter Springs Formation, Hugh River Shale and Goyder Formation by Exoil have to be reinterpreted.

- For the lower part as a thick cherty dolomite unit, rich in algae correlated with the Jay Creek Limestone.

- For the middle part as an interbedded siltstone, dolomite and limestone unit, strongly dolomitized at the bottom, rich in algae and calcarenitic, with garnet in the upper part. This unit represents a typical section of Jay Creek Limestone.

- For the upper part as a gradational change in the lithology, becoming more sandy and containing rhombic quartz and feldspar overgrowths, andalusite, rounded barite and rare garnet. This unit is correlated with the Goyder Formation:

Silicification, dolomitization, recrystallization and development of gypsum and anhydrite have strongly affected the rocks.

References

Forman, D.J., Milligan, E.N., and McCarthy, W.R., 1965 - Regional Geology and structure of the north-east margin, Amadeus basin, Northern Territory. Bur. Min. Resour. Aust. Rec., 1965/44.

McTiggart N.T., Pemberton R.L., - Well completion report Exoil (N.T.) Highway Anticline No. 1 1965.

Wells, A.T., Ranford, L.C., Stewart, A.J., Cook P.J., Shaw R.D., 1965 - The Geology of the north-eastern part of the Amadeus basin, Northern Territory. Bur. Min. Resour. Aust. Rec. 1965/108.

Core analysis sample description

Jay Creek Limestone

Core 1 : 592' - 92' - 4" Siltstone and Sandstone grade into each other
Greenish-grey, finely laminated, wavy, locally cross bedded siltstone with shaly interlaminae and grey to light greyish-white sandstone lenses.

50% quartz, angular, silt sized, rare orthoclase, microcline and sodic plagioclase, 2-20% muscovite in fine streaks emphasizing bedding, biotite green to brownish green altered; accessory minerals are tourmaline, haematite and black matter. Cement :
40% cryptocrystalline and microcrystalline calcite, illite ? in shale laminations.

594' - 94' - 4" Sandstone
Brownish-red, compact and dense
40-50% quartz, angular to subrounded, very fine to coarse grained, poorly sorted, rare microcline, metamorphic or igneous lithics; 2% parallel muscovite and rare green biotite altered to chlorite; accessory minerals are tourmaline, garnet. Cement:
30% cryptocrystalline calcite and subhedral dolomite crystals; haematite in variable amount.

596' - 96' - 4" Calcitic sandstone
Similar to 594'4": but amount of haematite and carbonate minerals increasing, very micaceous in bedding-planes.

598' - 98' - 4" Siltstone grading into sandstone
Brownish-red, compact to wavy, with sandstone interlaminae or lenses.
50 to 75% quartz, very fine to coarse grained, angular to rounded poor sorting, rare microcline, metamorphic or igneous chert, pellets and some limestone pebbles (diameter 3 to 4 mm), 5% muscovite and some altered biotite; accessory minerals are garnet - tourmaline - zircon - black matter. Cement:
20-30% calcite, haematite and a small amount of illite?

600' - 600' - 4" Siltstone and sandstone in fine wavy interlaminae grading locally to silty, very micaceous, haematitic and calcareous shale.

Core 2 : 1251' - 51' 4" Siltstone

Red to brownish red, finely laminated siltstone, very micaceous with quartz, microcline, 10% muscovite and green altered biotite. Cement: 30% haematite and 5% subhedral dolomite.

1253' - 53' 4"
Similar to 1251' 4" but the rock body seems more disturbed

1257' - 57' 4" Siltstone

Red to brownish-red, compact to laminated with some grey, green, very fine sandstone lenses. Geodes filled with euhedral calcite. 50 to 60% quartz, silt sized, angular with rare microcline, plagioclase, 10% muscovite and green biotite. Cement : haematite and subhedral dolomite.

Core 3 : 1776' - 76' 4" dolomitized limestone
Reddish to green, grey, ferruginous, compact and dense dolomitized cryptocrystalline limestone with 5% quartz, strongly corroded by carbonate minerals, some muscovite flakes, some dolomite and anhydrite. The core shows a strong fracturation filled with white, crystalline and fibrous gypsum. Intergranular haematite is abundant.

1778' - 78' 4" Siltstone
Brownish red, micaceous with lenses of grey-greenish very fine sandstone, haematitic, calcareous and some gypsum and anhydrite nests.

1782' - 82' 4"
Similar to 1778' 4", but richer in clay-matter.

1784' - 84' 4" dolomitized limestone
Green-grey cryptocrystalline carbonate rock, strongly dolomitized, with silt-sized dolomite rhombs, 10% quartz, silt-sized, corroded and muscovite in fine flakes.

Fissures and veins filled with white gypsum and anhydrite.

Core 4 : 2428' - 28' 4" Siltstone
Greenish-grey, poorly laminated, siltstone, very rich in muscovite and green biotite. Chlorite and dolomite cement is present in variable amount.

2429' - 29' 4" Similar to 2428' 4" but bedding is very disturbed.

Core 5 : 3150' - 50' 4" Dolomite
Pink, white and light grey microcrystalline and haematitic dolomite, very dense, fractured, massive.
Core is crowded with strongly recrystallised stromatolites, indicating a dip of between 30° and 60°.

Core 6 : 3760 - $63^{\pm}$ Dolomite
Variegated, microcrystalline, massive and compact dolomite with cryptocrystalline chalcedonic-chert laminae, finely fractured.

3769'6' - 3770' Dolomite
Variegated, microcrystalline, massive and compact dolomite with stromatolites and minor amounts of silt sized, angular quartz, and muscovite. Numerous chalcedony laminae = Haematite occurs.

Lat. 24° 20' 23" S
Long. 133° 27' 06" E
Elevation: GROUND 1,603' A.S.L.
K.B. 1,616' A.S.L.
B.M.R. INDEX No. 429

HIGHWAY ANTICLINE No.1

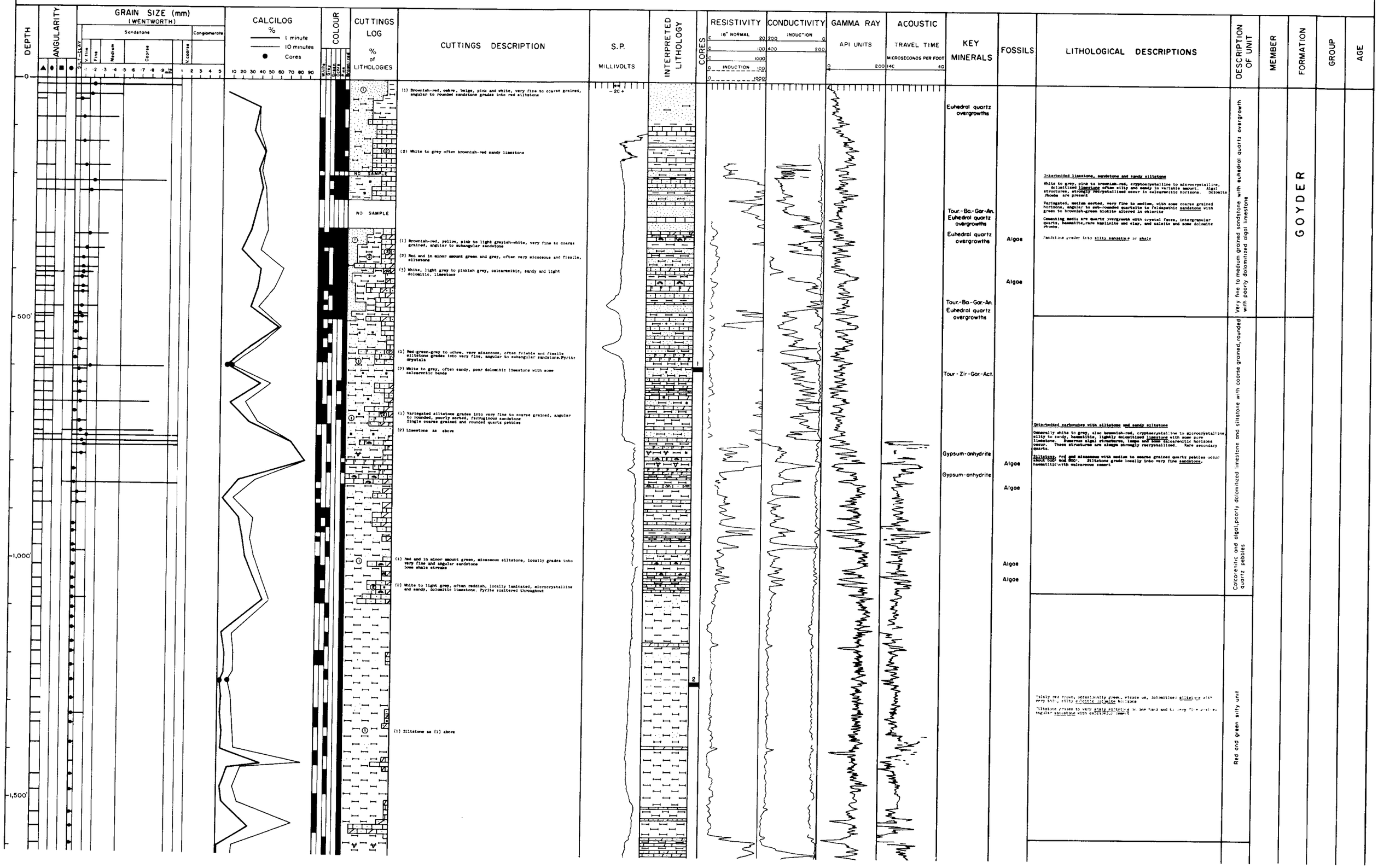
PLATE 1 (SHEET 1)
EXOIL (N.T.) PTY. LTD.
AMADEUS BASIN
NORTHERN TERRITORY

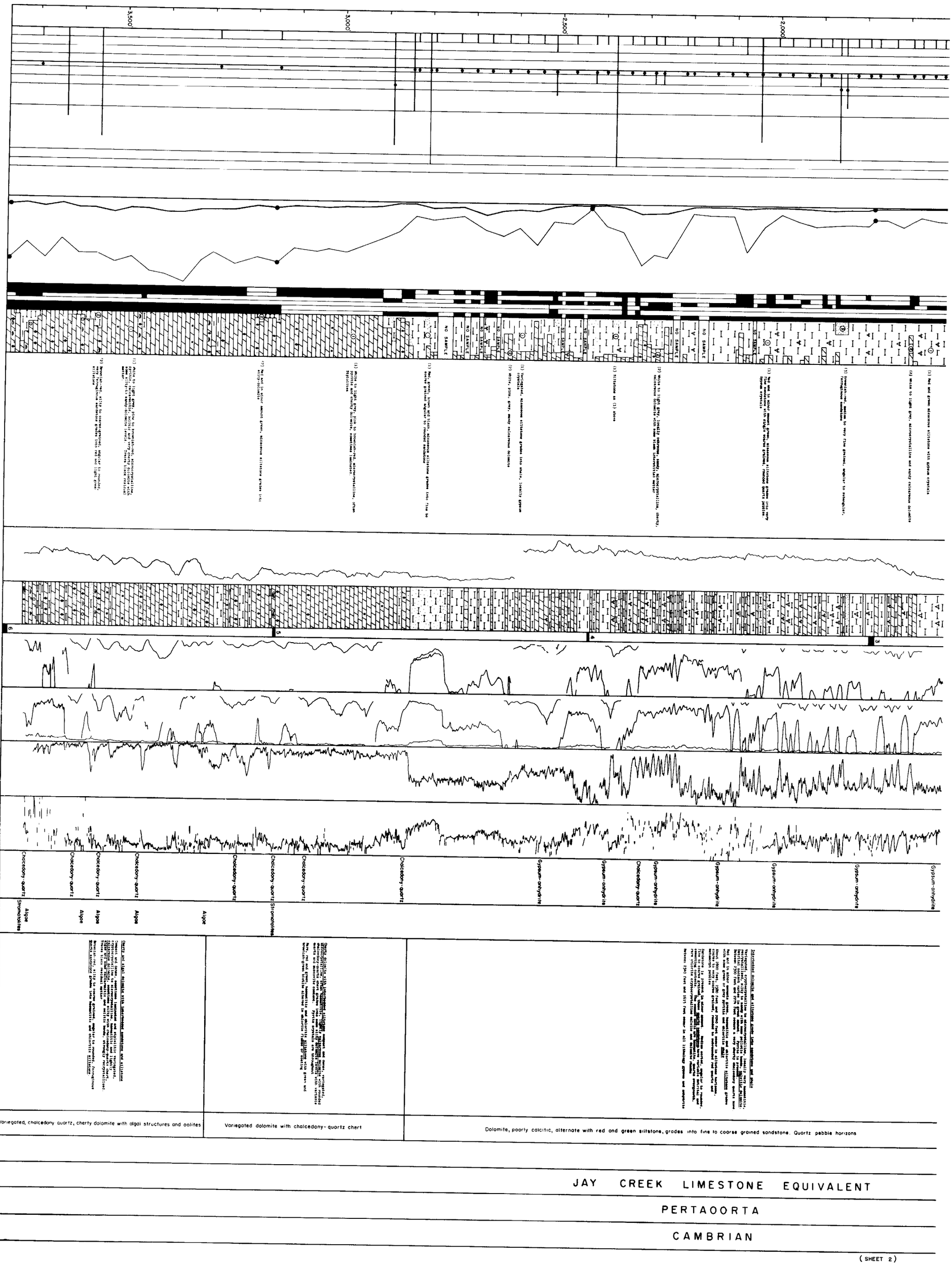
SCALE
FEET 100 50 0 100 200 300 FEET

Reference

- Sandstone
- Siltstone
- Shale
- Calcarenitic limestone
- Dolomite
- Dolomitized limestone
- Pyrite
- Gypsum and anhydrite
- Chalcedony-quartz chert
- Algae
- Stromatolites
- Oolites

Act. Actinolite
An. Andalusite
Ba. Baryte
Tour Tourmaline
Zir. Zircon




3,500'
3,000'
2,500'
2,000'
Dolomite, poorly calcitic, alternate with red and green siltstone, grades into fine to coarse grained sandstone. Quartz pebble horizons
Variegated dolomite with chalcedony-quartz chert
Variegated, chalcedony quartz, cherty dolomite with algal structures and oolites
Gypsum-anhydrite
Chalcedony-quartz
Stromatolites
Algae
NO SAMPLE
JAY CREEK LIMESTONE EQUIVALENT
PERTAOORTA
CAMBRIAN
Geologist: G SCHMEARER I.F.P
G53/A1/17
R G W
T.D. E log 3,725
Driller 3,770'
TD: Secondary Record 1966/83
(SHEET 2)