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PROGRESS GEOLOGICAL REPORT, PERMIT NO. 3, BONAPARTE GULF BASIN.

E.P. UTTING.

WESTRALIAN OIL LTD.,

16.10.-58.

C O N T E N T S.

PROGRESS GEOLOGICAL REPORT, PERMIT NO.3, BONAPARTE GULF BASIN.

SUMMARY.

The Bonaparte Gulf Basin on the north-western margin of the Australian continent is divided into at least two embayments in which Palaeozoic strata outcrop. The present report describes the south-eastern, or Burt Range embayment.

Investigations have included detailed geological reconnaissance with some instrumental control, shallow subsurface drilling, palaeontological studies, gravity surveys and limited seismic reflection traverses.

The Palaeozoic strata occupy an area of about 350 square miles within the permit and consist of 9,000-10,000 feet of marine sediments the bulk of which are Upper Devonian to Lower Carboniferous in age. The sediments are highly fossiliferous over substantial portions of the sequence and include limestones, dark pyritic shales and siltstones, and porous sandstone beds.

The structure is a broad syncline with anticlines developed on the eastern limb. The large high angle Cockatoo Fault occurs to the east of the anticlinal areas and small components are partly involved with the anticlines. Cross folding has formed structurally 'high' areas, with one definite closure and several possible closures.

Oil prospects are considered to be encouraging because of the relatively thick sedimentary column and the presence of potential source, reservoir and cap rocks, and structure.

Other than the shallow drilling by Westralian Oil Limited within its permit area, the deepest being to 510 feet, there has not been a test hole in any portion of the Bonaparte Gulf Basin. The shallow drilling produced most useful stratigraphical results and it is recommended that the programme be continued. Holes to a depth of 2,000-3,000 feet should verify the existence of the Upper Devonian Burt Range Formation basinwards and penetrate the upper section, which in outcrop contains porous horizons. Drilling of this nature is considered to be a preliminary necessity prior to the major project of drilling a deep hole 6,000-10,000 feet deep to test the full section.

The site for the first hole is selected in structural area 1(A) and discussion and criticism by the Oil Advisory Committee as to the position of this and other holes will be appreciated.

INTRODUCTION.

This report describes the present state of knowledge of the geology of the Burt Range embayment of the Bonaparte Gulf Basin, Northern Territory. It follows on the investigations carried out in previous field seasons, as described in detail by Utting (1957 a) and recently reviewed by Stach (1958 a) and Thomas (1958 c).

Where necessary, reference is made to the adjacent Carlton embayment which is outside and west of the Permit, but few details are discussed. Traves (1955 a) is the main reference for this area.

(...2/.)

The field work during 1957 consisted of gravity survey, reconnaissance geology and the sampling of all outcropping calcareous materials for microfossil examination.

The gravity survey was carried out by J. Burbury, geophysicist of Mines Administration Pty. (Appendix 5). Conodont examinations were by Dr. B.F. Glenister (Appendix 1) and microflora by B.E. Balme (Appendix 2), of the University of Western Australia.

J. Rade, of Westralian Oil Limited, undertook the sampling of calcareous materials and prepared stratigraphic columns of the localities. The sampling was carried out on a systematic basis, 20 lbs of chips being taken to represent an average over each 50 feet (maximum) of strata. Due care was taken to include any specifically calcareous shale or other likely material, but little was obtained. A total of 130 samples was taken and these were examined later by Dr. Glenister, who selected the most suitable materials for his determinations.

Representative portions of the samples were forwarded to the Bureau of Mineral Resources, Canberra, to augment material previously examined. Reports were received recently from G.A. Thomas (Appendix 3) and P.J. Jones (1958 b), the latter including preliminary determinations of Carboniferous foraminifera by Miss I. Crespin. Important new aspects were indicated from these reports.

Unfortunately much of the limestone proved unfossiliferous and there are still unanswered questions of correlation and succession within the area, because outcrops are sparse and dislocations by faulting are known. Considerable progress has been made, but it is now clear that at least one stratigraphic bore-hole is required to confirm interpretations, which at the present time lend encouragement for oil prospects.

The Devonian-Lower Carboniferous succession can be followed with a reasonable degree of certainty in the south-western portion of the embayment. Elsewhere its distribution, as shown, is partly interpretive and the basinward facies are in particular need of confirmation.

SUMMARY OF STRATIGRAPHY.

T h e following strata have been recorded within the Bonaparte Gulf Basin. Reference is made to the table on Figure 1 for closer detail of ages within the Burt Range embayment.

QUATERNARY		Sands, clays and gravels cover extensive areas.
U. PERMIAN	Port Keats Basin. Separate basin to north	
Port Keats Group	1500(+)'	Sandstone, shale and limestone (marine and fresh water beds).
L. PERMIAN	Bonaparte Gulf Basin just north of Permit 3	
Keep Inlet Beds.	(?)	Sandstones and glacial boulders, relationship to underlying beds unknown.

(...3/.)

U. CARBONIFEROUS (?)	Burt Range embayment in Permit 3	
Border Creek Sandstone.	1500'	Sandstones and conglomerates (one plant fossil only).

Disconformity

L. CARBONIFEROUS		
Point Spring Sandstone.	250'	Sandstones, limestone, minor siltstone and shale (dominantly marine, some plant stems).
Milligans Beds.	350(+)' 200'	dark pyritic shales (marine) Sandstone (marine).

? Disconformity

Septimus Limestone) Spirit Hill Limestone)	100 to 650'	limestone, minor sandstone. siltstone and shale,(marine).
Enga Sandstone.	400'	Sandstone (marine).
U. DEVONIAN		
Burt Range Formation.	600(+)'	Sandstones, limestones, siltstones and shales (marine)
(may extend into L. Carboniferous)	2500'	dark pyritic sandstones, siltstone and shales with interbedded limestones (marine).
	600'	limestone (marine).
	4000'	total.
Cockatoo Sandstone.	3800'	Sandstones and minor conglomerates. (marine and plant fossils).

Unconformity

L. ORDOVICIAN	Carlton embayment west of Permit 3	
	550(+)'	Glauconite sandstone.
M. & U. CAMBRIAN	2200(+)'	Sandstones, some limestones (marine).

BASEMENT of Proterozoic sediments and metamorphics with some L. Cambrian volcanics.

(...4/.)

TENTATIVE STRATIGRAPHIC TABLE.

EUROPEAN STANDARD			THOMAS and others	GLENISTER in press	NORTH AMERICAN STANDARD		COMPARISION FITZROY BASIN
PART LOWER PERMIAN			KEEP INLET BEDS — ? — ? — ? —				GRANT FORMATION
UPPER CARBONIFEROUS	STEPHANIAN		BORDER CREEK SANDSTONE (limits unknown)			PENNSYLVANIAN	ANDERSON FORMATION (Correlation and upper limit uncertain)
	WESTPHALIAN (Moscovian)						
	UPPER NAMURIAN		— ? — ? — ? —				
LOWER CARBONIFEROUS	LOWER NAMURIAN		POINT SPRING SANDSTONE and MILLIGANS BEDS		CHESTERIAN	MISSISSIPPIAN	— ? — ? —
	DINANTEAN	VISÉAN			MERAMECIAN		
		TOURNASIAN	SPIRIT HILL and SEPTIMUS LIMESTONES (CENGA SANDSTONE) — ? — ? — ? — UPPER PORTION BURT RANGE FORMATION	SPIRIT HILL and SEPTIMUS LIMESTONES — ? — BURT RANGE FORMATION	OSAGIAN		LAUREL BEDS — ? — FAIRFIELD BEDS
U. DEVONIAN	(FAMENNIAN)		POSITION OF BASE OF BURT RA. FORMATION and UNDERLYING COCKATOO SANDSTONE IS INDEFINITE	COCKATOO SANDSTONE	KINDERHOOKN		NAPIER FORMN. (Behn etc. congl.) PILLARA — ? — ?
	(FRASNIAN)						
M. DEVONIAN							

COMPILED LARGELY FROM THE PRELIMINARY FOSSIL DETERMINATIONS OF THOMAS, PLUS INFORMATION FROM JONES and GLOVER GLENISTER'S WORK, and FITZROY BASIN DATA (McWHAE et al. 1958d) FOR COMPARION

STRATIGRAPHIC DETAIL.

BASEMENT.

Basement rocks are largely Upper Proterozoic sandstones, locally quartzitic, and siltstones of considerable total thickness.

In the south-western portion of the Burt Range embayment the basement consists of minor remnants of the Lower Cambrian Antrim Plateau Volcanics. In the same general locality, but on the eastern side of the Cockatoo Fault, the Palaeozoics lie directly on Lower Proterozoic metamorphics.

CAMBRIAN AND ORDOVICIAN.

It is relevant to refer briefly to the known sedimentation during these periods as, although no outcrops occur within the Burt Range embayment, structural conditions suggest the possibility of some representation down-pitch to the north.

From 20 to 160 miles south of the embayment there are three shallow basins in which sediments of (?) Middle Cambrian Age have been developed. Matheson and Teichert (1948) estimate in the Hardman Basin 2,000 feet of shales and sandstones overlying a maximum of 1,000 feet of fossiliferous and cherty limestones interbedded with calcareous shales.

The presence of asphaltum (mineral pitch) at several localities within the Lower Cambrian basalts near these basins is of interest and has prompted theories that the material is derived from overlying sediments of Cambrian age or younger. There is also the remoter possibility that the source of origin is from massive algal reefs that are known to occur within the Upper Proterozoic sediments and which presumably underlie the basalts.

Ten miles to the west of the Burt Range embayment is the Carlton embayment, where Traves (1955 a) has estimated 2,750 (+) feet of fossiliferous sandstones and limestones of Cambrian to Lower Ordovician age, which were tilted and eroded prior to deposition of Cockatoo Sandstone.

COCKATOO SANDSTONE.

In the southwestern margin of the Burt Range embayment, about 3800 feet of shallow water sandstones form a broad overlap over the basement of Lower Cambrian volcanics and Precambrian rocks.

The beds are friable fine to coarse grained sandstones containing minor conglomerates, and are typically cross-bedded. Fossils are scarce but one plant and several marine forms have been recorded.

An Upper Devonian age has been attributed on slender evidence (Matheson and Teichert, 1948 a; Traves, 1955 a) and there is some possibility of a Middle Devonian age.

Shales are known near the top of the Cockatoo Sandstone, but outcrops of the upper portion of the beds are practically non-existent and the relation to the overlying Burt Range Formation

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is not clear. At the north-east end of the Pincombe Range, Burt Range Formation rests directly and discordantly upon Proterozoic sediments, so that the following possibilities exist:

(i) The Pincombe Range was an island during deposition of Cockatoo Sandstone, and sedimentation shelved out towards its present north-eastern end.

(ii) There was an erosional period between deposition of Cockatoo Sandstone and Burt Range Formation.

Both alternatives have points in their favour, but the first is preferred as the sequence up to a late stage of the Burt Range Formation suggests gradual subsidence.

Cockatoo Sandstone is a porous formation of considerable potential importance for oil migration and accumulation, provided that it persists basinwards. In common with the Burt Range Formation, there are no outcrops in the eastern or northern portions of the embayment, the surface there being occupied by younger sediments. Because of the depth of sediments shown by seismic survey and the indications that the embayment has occupied a structural 'low', it is thought that Cockatoo Sandstone will exist in the deeper portions, but its thickness may be diminished.

BURT RANGE FORMATION.

This formation outcrops poorly, but is broadly divisible into the following sections:

(i) An upper section consisting of fine to medium grained sandstone, interbedded with fossiliferous calcareous sandstone and minor limestone beds. Several non-outcropping areas are considered to represent limestone, calcareous siltstone and possibly shale. The uppermost of these contains fossil locality 'E', from which many complete fossils have weathered out of an apparently shaley matrix.

The beds are at least 600 feet thick, and are reasonably well exposed on the western slope of Enga Ridge.

(ii) A poorly outcropping central section which shows narrow fossiliferous limestone outcrops, two to ten feet thick, interspersed with extensive soil covered areas. Two holes l_1 and l_2, drilled by the Ivanhoe Pastoral Company to approximately 180 feet depth, gave cuttings of grey fine grained calcareous sandstone, siltstone and some shale. Fine pyrite is present as a minor constituent. Matheson and Teichert (1948a) noted many highly fossiliferous beds of limestone, and a belt of fossiliferous shales half a mile wide.

This section represents approximately 2,500 feet of beds and in the lack of more finite outcrop information it is presumed that the lithology is essentially as described, i.e. fine grained calcareous pyritic sediments and shales with thin limestone interbeds.

(iii) Approximately 600 feet of thin bedded limestone, in which no fossils have been found, occur at the base of the formation.

(...6/.)

The total thickness represented in the outcropping area is 4,000 feet. Seismic reflection traces (Robertson 1957 b) suggest that this thickness is maintained in the centre of the basin and may increase down-pitch to the north of Spirit Hill. At the extreme southern end of the basin, in the vicinity of the Cockatoo Fault, the thickness is diminished considerably.

In the writer's opinion, the term Burt Range Limestone (Traves, 1955 a) is misleading because of the variety of the contained sediments. For the purposes of the present report Burt Range Formation is substituted. It may be preferable at a future date to form a Group of three formations, the upper to include the Enga Sandstone.

A late Upper Devonian age has been well established by Teichert (Matheson and Teichert, 1948) and Opik (in Traves, 1955). Thomas (Appendix 3) considers the assemblage at Locality 'E' to be suggestive of late Devonian to very early Carboniferous. Locality 'E' is 50 feet below the base of the Enga Sandstone and can be conveniently regarded as the top of the Burt Range Formation.

During the current field season fossils and samples are being taken over the full spread of the formation which, incidentally, outcrops outside the Permit Area.

The largely unfossiliferous limestones and calcareous sandstones of the Burt Amphitheatre have been regarded as Upper Devonian on rather flimsy evidence. (See discussion in Utting, 1957 a). The lithology of the area is very similar to the Spirit Hill Limestone. Most of the samples taken for microfossil determination proved unfossiliferous but Glenister (Appendix 1) obtained one diagnostic conodont, Pseudopolygnathus sp., which 'strongly suggests an early Carboniferous age for the containing beds'. The fossil was obtained from a section 150 feet below the top of the formation at locality 'H'. The result tends to confirm the correlation of the beds of Amphitheatre with the Burt Range Formation but is not conclusive. If the correlation is correct, it adds weight to Thomas' suggestion that the Burt Range Formation could possibly range into the very early Carboniferous.

The Burt Range Formation is regarded as providing the major source rock possibilities of the area. The fossiliferous central section shows evidence of a reducing environment under quiet conditions of deposition and can be regarded as source beds. Sandstone beds of appreciable thickness occur near the top of the sequence and are overlain by formations in which sandstone, limestone and shale are well represented.

The characteristics of the formation basinward are a matter of conjecture. In the lack of drilling or outcrop data the assumption is that shaley facies will be more fully represented.

ENGA SANDSTONE.

Enga Sandstone is known with certainty only in the southern portion of the basin, where it occurs in a conformable sequence between Burt Range Formation and the Septimus Limestone. It is the uppermost and the most strongly developed of a succession of sandstone members that occur in the upper beds of the Burt Range Formation. The thickness is approximately 400 feet but is difficult to estimate precisely as the beds are contained in an extensive dip slope.

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The presence of abundant worm burrows in some of the beds indicates a shallow water environment at this stage of the sedimentary record.

Opik, (in Traves, 1955 a) placed the Enga Sandstone at the base of the Carboniferous. The recent palaeontological work suggests that it should be raised slightly higher in the Lower Carboniferous.

It will be seen from a later discussion that the Septimus and Spirit Hill Limestones are now considered to be contemporaneous. There is therefore a probable correlation between Enga Sandstone and the fine to coarse sandstones that grade upward into the Spirit Hill Limestone at Spirit Hill and Fossil Locality 'B'. These represent a portion of Traves' (1955 a) Nigli Gap Sandstone. Other isolated outcrops in this locality are in the zone of the Cockatoo Fault and are of problematical correlation (see Discussion of Terminology 'Weaber Group').

SEPTIMUS AND SPIRIT HILL LIMESTONES.

The Septimus and Spirit Hill Limestones are similar in thickness and in their relation to overlying and underlying sandstone beds. Each contains sandy facies, coarse detrital quartz within the limestones and are in part cross-bedded. They differ in that the main development at Spirit Hill is dolomitic and practically devoid of fossils except for crinoid stems, whereas Septimus Limestone contains many highly fossiliferous horizons.

During 1956 the writer could find only two areas with identifiable fossils in the Spirit Hill locality.

Locality 'A' : A low isolated outcrop, 100 feet square, projecting barely one foot above plain level. This patch is most difficult to find. It represents the upper portion of the Spirit Hill Limestone.

Locality 'B' : A small and probably faulted zone approximately three miles north-east of the main limestone mass of Spirit Hill. This is Locality 19 of Traves (1955 a) and 8 of Glover (1955 b). Here 100 feet of highly fossiliferous soft silty limestone alternate with hard limestone interbeds. The beds are overlain by 100 feet of medium grained friable sandstone, locally silicified, and underlain by 120 feet of calcareous sandstone, followed by 150(+) feet of cross-bedded medium grained sandstone with floating pebbles.

Glenister (Appendix 1) and Thomas (Appendix 3 and 1958 c) consider 'B' to be the equivalent of Septimus Limestone. Locality 'A' has similarities, but is described by Thomas as 'inadequate for precise correlation, however it is probably also equivalent to the Septimus fauna in a general way.' Thomas indicates a correlation with the main fossiliferous part of the Laurel Beds of the Fitzroy Basin of W.A. Jones (1958 b) correlates 'B' with the Laurel Beds on the basis of ostracods.

The evidence, although not conclusive because of the isolated position of 'B', favours the correlation of the Spirit Hill and Septimus Limestones, and serves to simplify the stratigraphy within the Burt Range embayment. Until new information is available and this now seems possible only by stratigraphic drilling, the correlation is accepted and the age, after Thomas and Glenister, as Upper Tournaisian or equivalent Osagean.

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The lack of fossils, and the dolomitic nature of the main mass of limestone at Spirit Hill may be due to diagenesis or to later recrystallisation. It is noteworthy that a thin bed of marble occurs within the Point Spring Sandstone in this area.

The limestones are considered to be near shore deposits, from evidence of grain size, detrital quartz, cross-bedding and the variable thickness (100 to 650 feet). However, the presence of two very small occurrences of galena in the upper beds of Spirit Hill suggests some tendency towards a reducing environment, which was present during deposition of the succeeding Milligans Beds.

There is considerable thinning of the limestones in the north-eastern portion of the embayment and the formation is unknown in the north-west and in the Carlton embayment where there may have been non-deposition, or facies changes not yet recognised.

Jones (1958 b) noted shale beds at seismic shot hole 449. Minor silty beds are known in the Burt Range and a degree of gradation to shales basinwards is to be expected.

MILLIGANS BEDS.

The name Milligans Beds is proposed for the subsurface shales of the Keep River plain. The sandstones that are interpreted below them and which overlie the Spirit Hill Limestone are tentatively included within the Milligans Beds.

The best-known locality is at Milligans No.1 bore (129° 01' E, 15° 38' S), where 354 feet of shales occur from 146 to 510 feet, which is the bottom of the hole. The upper beds are transitional into the Point Spring Sandstone at this locality and in Milligans No.3 bore. At Spirit Hill No.1 bore, 295 feet of shale (unbottomed) was disclosed, including a section of fine grained limestone and calcareous sandstone from 268 to 280 feet. In seismic traverse 'A', just north of Spirit Hill, shales occur from shot holes 308 to 331 and are followed to the east (i.e. underlain) by limestones with some shale and finally by sandstones at shot hole 335.

The shale is dark-grey, commonly calcareous and locally pyritic and gypseous.

Jones (1958 b) showed interesting results from microfaunal investigations, and reports: 'a rich marine fauna. Foraminifera, bryozoa, ostracods and crinoid columnals are abundant; small brachiopods, gastropods, pelecypods, holothurian sclerites and echinoid remains are common; sponge spicules, cephalopods, annelids, and conodonts are poorly represented.' He also suggests that the fossiliferous section of Milligans No.1 (185-472 feet) and the lower part of Milligans No.2 (123-186 feet) are slightly older than the upper part of No.2 (111-123 feet), the seismic shot holes 306-307 just north of Spirit Hill, and seismic shot holes 76 to 87 in the Carlton embayment. Jones (written communication) equates the shales of Milligans No.1 with one of the limestone outcrops of Milligans Hill (Point Spring Sandstone) on the basis of the same ostracod assemblages, and can distinguish these from the older Septimus Limestone. Jones has also advised that endothyroid foraminifera havebeen examined

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by Dr. D.N. Zellar, an American specialist on these forms, who has tentatively assigned an Upper Mississippian to Lower Pennsylvanian age to them.

The writer (1957 a) considered the shales as probably within the Burt Range Formation, being guided by lithology, geologic structure and Glenister's indication of the conodont Polygnathus in Milligans No.1 as probably Upper Devonian (Appendix 1, Report No. 1). Jones' report indicated the need for review and subsequently Blame (personal communication) drew attention to the close similarity of microflora from Milligans No.1 with a section immediately overlying the Lower Carboniferous Laurel Beds in the current Meda No.1 bore (Fitzroy Basin, W.A.). In the light of this evidence and of new information from abroad, Glenister (personal communication) has modified the range of the Polygnathids examined and states that these could extend into the Chesterian.

In this report, therefore, the shales of Milligans Beds are regarded as of similar age to the Point Spring Sandstone i.e. Visean to possible Namurian.

The sandstones and minor conglomerates that overlie the Spirit Hill Limestone on the eastern portion of Spirit Hill are interpreted as underlying the shales, in the manner shown on Figure 2. The contact between the beds has not been seen in the field but may be present under the extensive talus of Spirit Hill. Sandstone at approximately this horizon has been noted in seismic shot holes 335, 405 and 442. It is possible that the sandstone grades laterally into the shales, but the interpretation presented is preferred on present evidence.

There is approximately 200 feet of fine to coarse sandstone in this unit, but a full section has not been measured because of faulting and lack of suitable exposures. There are local conglomeratic beds near the base. At one place on Spirit Hill there is a suggestion of unconformity at the base, but this feature may be due to slumping over an irregular top of the Spirit Hill Limestone. Elsewhere the contact appears conformable.

Thomas (Appendix 4) suggests that there might not be a very great age difference between the sandstone and the Spirit Hill (Septimus) Limestone, but the fauna is very sparse and is inconclusive.

In the present report the unit is grouped together with the shales as a temporary measure in preference to creating a new formation name. It is desired to keep the identity of the sandstone separate from the Spirit Hill and Septimus Limestones, near the top of which there is a sandy interbed.

Total thickness of the Milligans Beds is over 550 feet, being 350(+) feet of shales and approximately 200 feet of sandstones.

The suggestion of a depositional break at the base may be significant, particularly in view of the (at present) obscure relationship of previously recorded Devonian sediments (Traves 1955 a) to the Carboniferous shales which Jones has shown to be present in the Carlton embayment. There is a possibility of disconformity there, due perhaps to non-deposition of the Septimus, Enga and portions of the Burt Range Formation.

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A similar tendency seems indicated in the western portion of the Burt Range embayment (Plate 2), and between the Pincombe and Weaber Ranges, but there is insufficient sub-surface information for clarity. Disconformity may also exist between the plunges of the main syncline in the vicinity of Milligans Lagoon, as discussed further under 'Structure', and the features may be due to separate periods of folding.

The 200-300 feet of sandstones that overlie the Septimus Limestone at Mt. Septimus and the Burt Range may represent the Milligans Beds sandstone or the Point Spring Sandstone. No limestones or fossils have been found but there are sparse wood impressions. The unit has been shown as unclassified on Plates 1 and 2.

The Milligans beds are of considerable significance in the oil prospects of the area. The shales should be an ideal caprock and appear of sufficient thickness to be effective in areas of moderate faulting. They occur in a stratigraphically high position above a sequence of sandstones and limestones with which they have been folded, and within which there are adequate porous horizons. The shales have an extensive spread laterally and should persist down pitch to the north, possibly thickening in that direction. A reducing environment was present during deposition and they can, therefore, be regarded as source rocks, particularly basinwards.

POINT SPRING SANDSTONE.

The name Point Spring Sandstone was first used by Opik (1950) to describe the fossiliferous sandstones near Point Spring in the Weaber Range. Traves (1955 a) widened its scope to include all the outcropping sediments of the Weaber Range. Utting (1957 a) used the lower section, which is partly fossiliferous, as a mappable unit over most of the embayment under the name of Keep River Sandstone; the upper and major portion of the beds was retained as the Point Spring Sandstone.

It appears that Keep River Sandstone is not a suitable term in view of the prior usage of Keep Inlet Beds by Glover (1955 b) for a later formation in the Bonaparte Gulf region. In this report, therefore, the writer follows Thomas (1958 c) in reverting to Point Spring Sandstone for the fossiliferous lower section and introduces a new name, the Border Creek Sandstone, for the overlying beds.

The type location of Point Spring Sandstone can be regarded as in the lower portion of the Weaber Range scarp 4 miles north-west of the W.A.-N.T. boundary (195° 23', S, 128° 57' E), being 5 miles east of Point Spring. Reeves (1948 b) recorded the following section at this place, the upper portion being basal Border Creek Sandstone.

30 - 40'	cross-bedded pebble conglomerate; pebbles chiefly quartzite, 1"-2" in diameter;
10'	boulder conglomerate, with cemented boulders of quartzite, 1"-6" in diameter. This conglomerate with overlying members weathers into high castle rocks at the east end of Weaber Range;
150'	Well bedded, massive to cross-bedded, fine to medium ferruginous sandstone; (? basal Border Creek Sandstone or Upper Point Spring Sandstone, but the beds listed below are Point Spring Sandstone,- E.P.U.)

(...11/.)

10 - 30'	Concealed;
5'	Grey, pitted sandstone, with casts of Productid;
60'	Shaley, ferruginous sandstone;
25'	Shaley sandstone; forms cliffs 125' above flats at base of range;
100'	Talus, no exposure.

Portions of these beds occur at other localities along the Weaber Range scarp and Thomas (Appendix 3 and 1958 c) lists the fossil content.

The following section at Milligans Hill is compiled by the writer from his own observations and the log of Milligans No.1 bore :

-	Loose conglomerate pebbles of Border Creek Sandstone at top.
15'	Grits with some shale at top.
60'	Mainly calcareous grits, with gritty fossiliferous limestone beds of extremely variable thickness, and some fine grained sandstone.
30'	Fine grained sandstone, some worm tracks.
25'	Blank at top of drill hole. Possibly sandstone.
39'	Fine grained sandstone with approx. 3' bed of sandy limestone.
82'	to 146' depth in drill hole. Passage beds of calcareous, pyritic, gypseous siltstones and shales, interbedded with fine grained sandstone. Milligans Beds below.
251'	Total thickness estimated in this area, appears relatively consistent throughout the embayment.

At Spirit Hill approximately 260 feet of strata occur, but because of much sandstone talus details cannot be recorded. A high proportion of sandstone is present, some of which shows worm tracks and wood impressions; a little siltstone and shale is known; a bed of unfossiliferous recrystallised limestone, two feet thick, has been noted.

Between Milligans and Spirit Hills, at the site of Milligans No.3 bore, a low hill of medium grained sandstone exhibits many wood impressions. Extensions of this outcrop can be traced northwards across the Keep River towards Spirit Hill.

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Similar sandstones, but with no limestone and with very sparse wood impressions occur above Septimus Limestone in the Burt Range and Mount Septimus. Because there is a possibility of these being correlated with the Milligans Beds, they are shown as unclassified in the accompanyint Plates.

Thomas (Appendix 3) considers the Milligans Hill and Weaber Scarp (near Point Spring) localities to be Visean to possibly Namurian in age.

The Point Spring Sandstone is transitional into the Milligans Beds shales below. There can be little age difference and Jones (written communication) has noted a similar ostracod assemblage within both formations in the Milligans Hill area.

It is clear that the beds were deposited in a shallowing marine environment, and near paralic conditions were attained. There may have been emergence at the close of deposition, but the uniform spread to the west of the Cockatoo Fault suggests that there was no significant erosion on that side of the fault. A period of movement followed by erosion on the east side of the Cockatoo Fault is inferred, in order to explain the extensive overlap there of probable Border Creek Sandstone over Precambrian rocks.

BORDER CREEK SANDSTONE

The name Border Creek Sandstone is proposed for the sandstones and conglomerates that overlie the Point Spring Sandstone. Traves (1955 a) included this sequence within the Point Spring Sandstone. Because of the distinctive lithology indicating a new environment, and an indefinite age owing to lack of fossils, a restriction of Traves' nomenclature is recommended.

The type locality is in the Weaber Range, commencing near Border Creek (at 15°23' S, 128°57' E) and extending northwards for two miles. It represents the greatest development of the beds, approximately 1,500 feet being estimated from air photos, but only the base has been studied in the field. Reeves' (1948 b) record of 40-50 feet of conglomerate (read under Point Spring Sandstone) is accepted as the base, but it is uncertain whether the underlying 150 feet of cross-bedded sandstone should be included in the formation. About 300 feet of similar sandstone overlies Point Spring Sandstone at Point Spring and no conglomerate has been noted there.

The type section of Border Creek Sandstone is in the cliff faces of the western portion of Spirit Hill (15° 34' S, 129° 03' E) where it is best known. Allen (1956 a) followed by Rade (1956 b) have measured the thickness of the members and during their work the writer examined the sequence. Allen included the basal conglomerates within the underlying sandstones (Point Spring Sandstone).

	Allen.	Rade.
Upper Beehive Sandstone: medium grained quartz sandstone with thin pebble beds.	170'(+)	170'
Fine to medium grained sandstone with minor pebble beds. A little siltstone.	80'	70'

(...13/.)

	Allen.	Rade.
Lower Beehive sandstone: medium grained quartz sandstone with floating pebbles.	80'	80'
Basal Conglomerate: cobbles up to 10inch size. Minor sandstone lenses.	20'(+)	50'

A total of 370 feet occurs in this section and the thickness removed by weathering is unknown.

The sandstone members exhibit strong joint sets which have been eroded to leave huge beehive shaped outcrops, easily recognisable on air photos. Similar features are evident in most of the Border Creek Sandstone occurrences, and appear characteristic of the Upper members, but are known to a lesser degree in the Cockatoo Sandstone.

The typical basal conglomerate occurs at Milligans Hill and at 1/2 mile north of Milligans No..3 bore.

At Mount Septimus and in the Burt Range, beds with a lithology similar to the Border Creek Sandstone occur above unfossiliferous sandstones which overlie the Septimus Limestone. A basal conglomerate, 15-40 feet thick, occurs at Mount Septimus and the western and southern portions of Burt Range, but is not present in the northern tip of Burt Range.

The broad and apparently shallow overlap of sandstones and conglomerates over Precambrian rocks to the east of Burt Range and the Cockatoo Fault has not been examined in its entirety by the writer, but was described by Traves (1955 a) and Rade (1955 c). This includes the type locality of the Nigli Gap Sandstone of Traves, who described it as follows :

'The sediments are essentially arenaceous, and most of the formation is of sandstone with numerous rafted pebbles. The unit also includes conglomerate members throughout the sequence, although the most significant conglomerate member occurs at the base.'

The detail of Traves' various descriptions, together with a report received from Rade who is currently investigating this locality, suggests that the sequence is quite similar to that of Spirit Hill, including the large size of boulders (up to two feet) in the basal member. The upper members are strongly jointed and show the characteristic weathering.

About six miles to the south is an isolated remnant of heavy conglomerate, possibly over 500 feet thick, overlying Precambrian rocks.

In the lack of fossil evidence, the writer considers that these occurrences within the southern portion of the embayment are more suitably correlated within the Border Creek Sandstone than in any other horizon in the Bonaparte Gulf area. The lithological similarities are quite remarkable in view of the shallow water conditions obtaining throughout, and the whole is consistent with a change of environment and rapid overlap at the commencement of Border Creek time.

(...14/.)

There is no recognisable unconformity with the underlying Point Spring Sandstone. No representatives of that formation have been seen within the conglomerates of the Border Creek Sandstone. The Point Spring Sandstone is persistent over most of the area west of the Cockatoo Fault and hence does not appear to have been eroded.

The available evidence suggests, therefore, that there has been no prolonged period of emergence, if any, between Point Spring and Border Creek deposition on the western side of the Cockatoo Fault. Faulting is inferred, with a movement east block up along the main Cockatoo Fault and erosion to the east of it. Rejuvenation of the sedimentation is inferred. There may have been movements in the Spirit Hill area at this time, with associated folding, but these could have occurred in post-Border Creek time.

There have been movements at an unknown time subsequent to Border Creek deposition, mainly within the Cockatoo Fault zone. These are particularly evident in the Amphitheatre locality and the Spirit Hill faulting could be contemporaneous. A period of folding may have occurred at this time, as there seems to be a relation of folds to faults at Amphitheatre and Spirit Hill. Faulting of Border Creek strata is shown near Ninbing in the Carlton embayment on Plate 1 of Traves (1955 a).

The Border Creek Sandstone is unfossiliferous except for the record of Equisetales stems at Nigli Gap (Traves 1955). Its age is older than Permian and younger than the Point Spring Sandstone and in the present report is referred to as Upper Carboniferous.

SANDY CREEK AND FLAPPER HILLS BEDS:

Traves (1955 a) described the isolated outcrops near Sandy Creek on the north-eastern flank of the embayment. In a restricted section 200(+)feet of fossiliferous sandstone overlies 20(+)feet of fossiliferous limestone. Traves included the beds within the Spirit Hill Limestone. Thomas (Appendix 3 and 1958 c) indicates a fauna with Dinantian affinities, except for choristites species which closely resembles a Moscovian type.

Thomas provisionally regards the age as early Moscovian, which is younger than the Point Spring Sandstone, but might be the age of the unfossiliferous Border Creek Sandstone.

Several average samples showed no microfossils.

The geographic position of these beds suggests they occur in the horizon of the Spirit Hill Limestone, but could possibly be as high as the Point Spring Sandstone. However the location, in common with several isolated unfossiliferous sandstone out-crops to the south, could be influenced by Cockatoo Fault movements. The correct stratigraphical position remains problematical.

The Flapper Hill Sandstone of Traves is another isolated outcrop 12 miles north-east of the Sandy Creek occurrence and is not shown on the present mapping. Traves described at least 100 feet of sandstone containing a rich marine fauna. Thomas (1958 c) states that the faunal affinities are Dinantian and the beds could possibly be part of the Point Spring Sandstones or the higher Border Creek Sandstone.

The field position of the Flapper Hill Sandstone with relation to the sedimentary basin is much the same as the Sandy Creek beds. The stratigraphic position is problematical, but possibly Point Spring Sandstone.

(...15/.)

To avoid ambiguity, the beds described in this section are not shown on the Stratigraphic Table.

KEEP INLET BEDS.

The Border Creek Sandstones of the Weaber Range dip gently northwards below the tidal mud flats of the Keep Inlet. In an area 25 miles north of Border Creek, Glover (1955 b) described isolated outcrops of sandstone containing clay pellets and heterogenous boulders of glacial origin, under the name Keep Inlet Beds. Although no contacts have been observed, the rocks are considered to be younger than the Border Creek Sandstone and from the evidence of one fossil, to be possibly Permo-Carboniferous, but more probably Lower Permian in age.

These are probably the equivalent of the Grant Formation and Lyons Group of Western Australia.

DISCUSSION OF TERMINOLOGY 'WEABER GROUP'.

Traves (1955 a) introduced the term 'Wéaber Group' to embrace four formations: Nigli Gap Sandstone at the base, Spirit Hill Limestone, Point Spring Sandstone and Flapper Hill Sandstone.

Inview of the probable contemporaneity of the Septimus and Spirit Hill Limestones, and the apparent continuous sedimentation over most of the embayment from Upper Devonian to at least the top of Septimus Limestone, the grouping must be revised or discontinued, and is not used in the present report.

Nigli Gap Sandstone is also a dubious name in view of the interpretations set out. If this formation is to be retained as an existing unit it would have to be inserted near or at the Enga Sandstone horizon. Some problematical occurrences of sandstones with floating stones flank and partly overlap the main Cockatoo Fault to the east of Spirit Hill. These might be referable to the Nigli Gap Sandstone as originally envisaged, but because the periods and degrees of various movements in the zone of the Cockatoo Fault are relatively unknown, the beds are problematical and could represent other horizons including the Border Creek Sandstone.

GEOPHYSICAL RESULTS.

SEISMIC.

During 1956 the Bureau of Mineral Resources undertook limited seismic reflection surveys (Robertson, 1957 b) along traverses shown on Plate 1. The results were applied by Utting (1957 a) to cross sections which are included in the geological sections of Plate 2.

Most of the reflections were of poor quality but extended over the greater part of the traverses, except to the east of the main suspected anticlinal crests where they were non-existent. Consequently the strike extensions of the main Spirit Hill anticline were not located. Minor reversals and terrace effects on the eastern limb of the main syncline were indicated. A well defined unconformity was suggested along traverse 'C' at a little over 9,000 feet depth and from the general trend of outcrop dips, is probably the Proterozoic basement. The plunge at this place is nearly horizontal.

In the northern traverse 'A', reflections were obtained to a depth of 20,000 feet. Robertson states that there is evidence of unconformities at 6,000 feet and 14,000 feet, and suggests that the latter may be the base of the Palaeozoic section.

(...16/.)

In view of the reversal in gravity gradient near traverse 'A', and a similar though not identical structural tendency, there are some grounds for assuming bedrock at the suggested 6,000 feet unconformity, if it exists. The evidence is not positive and depth to bed rock can be inferred no closer than 6,000-14,000 feet, with no strong discordance at the contact.

GRAVITY

Gravity surveys have been carried out as follows:

(i) In 1955, by Mines Administration Pty. Ltd. on behalf of Associated Australian Oilfields N.L. and Westralian Oil Limited (Glover 1955 b).

(ii) In 1956, by the B.M.R. along seismic traverses and across a portion of the Carlton embayment. (Refer map entitled 'Gravity Survey 1955-56, Bonaparte Gulf Basin, W.A./N.T.'- not in this report).

(iii) In 1957, by J. Burbury of Mines Administration Pty.Ltd. on behalf of Westralian Oil Limited. (Appendix 5 and Plate 3 of this report).

Burbury indicated a deepening and broadening of the sedimentary trough south from Milligans Lagoon towards the Burt Range. Graphical interpretation showed that the displacement of the Cockatoo Fault in the Amphitheatre would be in excess of 5,000 feet, while further north, east of Milligans Hill and Spirit Hill, an even greater displacement was indicated.

The gravity contours have been consolidated in Plate 1 of this report, so that comparison can be made with known geology. The map of (ii) should be compared with Traves' (1955 a) geological plan. The following features are noted:

(i) The close correspondence of gravity highs with Upper Proterozoic inliers, shown by the B.M.R's regional gravity reconnaissance.

(ii) The association of the main synclinal axis of the Burt Range embayment with the low axis of gravity contours, and a similar association in the Carlton Basin, west and south-west of the Pincombe Range.

(iii) The 'high' at the +5 and +6 milligal contours just north of Spirit Hill, in the vicinity of seismic traverse 'A', and the gradient to north and south from it. This supports one of the main structural reversals, but is opposed to the northerly pitch of the younger sediments between Milligans Hill and Spirit Hill.

From the above considerations it is apparent that gravity is a most useful guide to broad structures in the area, but that probably the deeper sediments or basement tendencies are indicated rather than the shallow structures.

(iv) The gravity contours continue to depress to the north and reach a closed 'low' at the -3 milligal contour 6 miles north of Plate 1, outside of the permit area. Contours of the Carlton embayment also converge to the same closure, which on the present limited evidence is presumed to indicate the approximate centre of the main basin of deposition.

(...17/.)

(v) Burbury's indication of a possible displacement of at least 5,000 feet on the Cockatoo Fault supports the general degree of displacement shown on the geological sections of Plate 2.

It is interesting that the contours swing across the fault in the southern portion of the area. A considerable depth of Palaeozoic rocks was suspected and checking of the area was therefore carried out by J. Rade during the current field season. Rade hasnot advised the presence of fossiliferous rocks or beds other than sandstones and conglomerates, which is in accordance with the shallow overlap previously conceived. It seems therefore that the gravity results in this locality indicate structure within Proterozoic basement sediments, which pitch gently southwards.

STRUCTURE.

The limits and nature of all depositional areas within the Bonaparte Gulf Basin are not known, but to the south of the present shore line there is considered to be a relatively large basin which is divisible into two embayments.

The distribution of strata within the Burt Range embayment is controlled by a broad syncline, trending and plunging generally northwards, and flanked by parallel Proterozoic ridges. The western ridge is the Pincombe Range which divides the main basin into its two embayments, and the eastern ridge flanks the Cockatoo Fault. Both ridges were in existence during deposition of the Palaeozoic strata which took place within the intervening structural 'low'.

Seismic results indicated an unconformity in traverse 'C' (Section D-D1) at a depth of 9,000 feet, which is accepted as the Proterozoic basement, but the depth is problematical in the northern traverse 'A' as possible unconformities were indicated at 6,000 feet and 14,000 feet.

The high angle Cockatoo fault is a regional feature which dates at least from the Proterozoic and has a profound effect on Precambrian geology over a known distance of 250 miles southwards. The periods of movements are not known precisely, but some occurred during and after deposition of the Devonian-Carboniferous succession with a total displacement (west block down) of the order of 5,000 feet.

The main Cockatoo Fault is flanked on the west for two miles by a zone of faults which anastomose with the major fracture and have had varying degrees of movement, mainly west block down. The largest of these is probably the central Spirit Hill fault, to which the writer attributes a vertical displacement of 800 feet (Figure 2) in the southern portion of the hill.

Minor parallel faults occur on the western edge of the embayment near its overlap on the Pincombe Range, but no displacements of major nature are in evidence there or in the central portions of the embayment.

(...18/.)

There are folded reversals in the main syncline and these have important bearing on oil prospects. The eastern limb flattens and anticlinal structures are developed, partly within the Cockatoo Fault zone. Anticlines occur at Spirit Hill and Amphitheatre, and intervening soil covers other potential areas. Unfortunately the limited seismic traverses failed to show reflections over suspected anticlines.

A broad anticlinal cross fold is evident at about the latitude of Milligans Lagoon, to the south of which there is a tendency for all sediments older than Milligans Beds to pitch flatly south, causing possible closure at area C, Plate 1. The apparent discordance of Milligans Beds is interesting in view of a similar feature shown by seismic dip traces along east-west sections (refer Sections A-A1, D-D1) where the axis of the upper formations tends to be displaced to the west.

A cross fold of considerable significance is interpreted in the plain country two miles north of Spirit Hill, largely from the existence there of Milligans Beds, as shown by shallow drilling. Gravity contours support the structure, in fact the locality is at the major reversal of gravity contours and a basement ridge may occur in this area. Outcrops nearby at Spirit Hill are known to be faulted and it is possible that the structure is more complicated than shown. Closure is considered probable at area A and possible at B.

A third anticlinal cross fold occurs in the faulted Amphitheatre block but does not extend significantly into adjacent areas. Complete closure is obtained.

Further detail of the anticlinal areas is given under 'Oil Possibilities'.

The history of folding is not known with certainty owing to the gentle degree of dips and the lack of well defined unconformities. Generally the older beds show steeper dips. Possible fold periods are after the Septimus Limestone, Point Spring and Border Creek Sandstone depositions, but the process may have been more or less continuous. It has been pointed out that some discordance may be present in the younger strata, but verification will require prolonged stratigraphic drilling or seismic work. It is possible that Milligans Beds and younger formations, particularly Border Creek Sandstone, mask structures within older beds.

OIL POSSIBILITIES.

The geological history, structure and rock types within the Burt Range embayment offer considerable encouragement for the prospects of generation and accumulation of oil deposits.

There has accumulated an appreciable thickness of marine beds, portions of which contain a rich and diverse fauna, under conditions usually regarded as most suitable for petroleum generation. The indications of substantial proportions of shale are encouraging from a cap-rock aspect and there are proved or near-proven folded prospects, in addition to possible fault and stratigraphic traps.

(...19/.)

The embayment is portion of an apparently more extensive marine basin to the north, the limits and contents of which are not clearly known owing to negligible outcrops and a complete lack of drilling. There are similarities with the Fitzroy Basin of Western Australia, where oil traces have been encountered in Devonian and Ordovician strata under conditions which have encouraged continued drilling.

The remoter prospects lie in the possible deposition of Older Palaeozoic marine sediments (which are represented in the Carlton embayment) in the deeper portions of the main basin, and in migration southward up-pitch into the Burt Range embayment. Here the strong development of Cockatoo Sandstone would be a most suitable horizon for migration and accumulation, and the siltstones and shales of the Burt Range Formation a suitable cap rock.

Much more finite and encouraging prospects can be seen in the continuous or near-continuous succession of Upper Devonian and Lower Carboniferous marine sediments, which are 5,000-6,000 feet thick within the embayment (possibly increasing northwards) and rest on 3,800 feet of probably Upper Devonian Cockatoo Sandstones (Refer to Plate 2 and Figure 2).

During the deposition of these sediments, which range from the base of the Burt Range Formation to the top of the Point Spring Sandstone, there is evidence of a rich marine fauna and a reducing environment at several horizons. Although shallow drilling has only tested portions of the sequence, dark fossiliferous calcareous and pyritic shales or siltstones have been found in the boreholes, with a thickness of at least 350 feet at one place. A large proportion of similar sediments is suspected throughout the 5,000-6,000 feet of the succession, particularly in the basin facies, and therefore the existence of suitable source beds seems proven. Burt Range Formation limestone at Button's Crossing in the Carlton embayment, which smells slightly of petroleum when broken, is of some interest in this connection (Allen- 1956 a).

The existence of interbeds of sandstone, fossiliferous limestones and sandy limestones, from the upper portion of the Burt Range Formation to the top of the Point Spring Sandstone, suggests partial near-shore or shallowing conditions and provides suitable reservoir rocks.

The stratigraphically high shales of the Milligans Beds, which are at least 350 feet thickness, will provide a suitable caprock in the central and deeper portion of the embayment. These could also contribute to the source rocks in depth basinwards.

The following table of strata characteristics is set out with due appreciation of the possibilities of facies and unforeseen changes in the deeper portions of the embayment, which is untested by drilling. There are no outcropping Devonian rocks in the central and northern portions but their presence at depth is assumed from geologic structure supported by geophysics.

	Cap Rock. (and probable source bed.)	Thickness. (feet.)	Reservoir Rock.
(i)		1,500	Border Creek Sandstone (no cap rock known)

(...20/.)

	Cap Rock. (and probable source bed.)	Thickness. (feet.)	Reservoir Rock.
(ii)		250	Point Spring Sandstone: Limestones, minor shales and siltstones (no definite cap rock known)
(iii)	Milligans Beds shales	350(+)	
(iv)		200	Milligans Beds lower sandstones
(v)		up to 100	calcareous sandstones interbedded near top of Septimus-Spirit Hill limestone.
(vi)	? Silty facies within limestone or replacing limestone basinward	100-650	? Septimus-Spirit Hill Limestone (bedding planes and fractures)
(vii)		400±	Enga Sandstone
(viii)	? Interbedded thin shales and siltstones	600+	Burt Ra. Formation upper sandstones and thin limestones.
(ix)	Burt Ra. Formation central siltstones and shales	2,500	
(x)	? Dense thin bedded limestone	600	Dense thin bedded limestone
(xi)		3,800	Cockatoo Sandstone, possibly decreasing basinwards.

There are two structural 'highs' (refer Plates and Figure 2) which are controlled by folding and in part by faulting. A third is inferred from gravity data. The various areas are outlined in red on Plate 1.

Area 1. A gentle elongate high centred on the eastern portion of Spirit Hill. Indicated by geology, gravity and in part seismic results. Three possibilities of closure are indicated on present information.

The most encouraging possibility is at (A).

(A) Folded closure probable on all sides except southeast, where an inferred fault (an extension of the central Spirit Hill Fault- west block down), near S.P.329 may assist the closure. Shales were shown in seismic shot holes on both sides of the fault. In addition, the poor record seismic traces at S.P's. 329 and 330 suggest a possible closure to the east of the fault. (Plate 2, section A-A1). Gravity contours show a regional high. The area may be more highly faulted than shown.

(...2/1 ...)

Indicated strata are (iii) to (xi) and possibly older Palaeozoics.

A hole 2,000-3,000 feet deep should penetrate the upper section of the Burt Range Formation and would provide most interesting stratigraphic information in addition to prospects of oil.

A depth of from 6,000 to 10,000 feet may be necessary to penetrate the full succession.

(B) Regional dips to west and north; possible dip to east where there is a fault of unknown displacement; structure to the south is indefinite but suggests a local pitch change or fault reversal; gravity contours pitch broadly north and south from a regional high; seismic work gave no reflections.

Indicated strata are (vi) to (xi).

(C) From geology, this is structurally the highest locality within Area (1). Situated on the southern extension of a well defined anticline at Spirit Hill, there is closure to north, north-east and west. Possible closure to the south is suggested from dips recorded in the scarp 1-2 miles to the south and the general trend of gravity contours.

Indicated strata are possibly portion of (vii) to (xi).

Area 2. A local gravity high of apparently appreciable dimensions occurs in the northern part of the area in both Permit 3 (W.O.L.) and Permit 1 (A.O.O.). This is near the mouth of the embayment and representatives of all formations should be present including possibly older Palaeozoics. There is no outcrop.

The high was indicated by gravity observations of widely spaced traverses and a close grid of gravity and seismic work should give most interesting information.

Area 3. The Amphitheatre Anticline is closed in sediments of probable Burt Range Formation. The structure is within a faulted block of the Cockatoo Fault zone. There has been no seismic work. Gravity results show the regional basin tendency and do not indicate the obvious anticlinal structure.

Strata available are (ix) to (xi) and a hole 3,500 feet deep would probably penetrate well into the Cockatoo Sandstone.

No attempt is made to list pure fault traps at the present time as the movements and locations are not properly known. In general it is assumed that displacements increase in proximity of the main Cockatoo Fault. The present of substantial thicknesses of shale in at least two horizons is considered important for these prospects and may account for the lack of known seepages.

(...22/.)

An example of a stratigraphic trap tendency is the lensing out of the Cockatoo Sandstone towards the Pincombe Range. As some shale has been recorded near the top of this formation and as the overlying Burt Range Formation contains appreciable shales, the possibilities are considered to be quite useful.

CONCLUSION AND RECOMMENDATIONS.

From the various evidence described it is considered that the area holds encouraging oil prospects and warrants serious consideration, particularly as there has been no test drilling within the Bonaparte Gulf Basin.

Little more can be gained from geological survey as outcrops are very scarce and much of the evidence for the possible closures is from regional deduction.

More detail could be obtained from close gravity surveys and specialised seismic methods, and this would be the normal approach to the drilling of a deep well to a depth of 6,000 - 10,000 feet, which is necessary to test the bulk or all the succession.

As the present time economic considerations and the lack of full knowledge of the oil potential warrant preliminary testing on a more modest scale.

The main structural tendencies are sufficiently located and understood to obtain maximum information from stratigraphic holes, 2,000-3,000 feet deep, in suitably selected localities.

It is considered that a fundamental requirement is a stratigraphic hole situated so as to confirm the presence of the main potential source beds of Upper Devonian Burt Range Formation in the Spirit Hill area or northwards. The most suitable locality is considered to be at (A) in structural high No.1. A hole there would confirm the interpretations made of thickness, lithology and stratigraphic position from Milligans Beds through the upper section of the Burt Range Formation. Correlations between Septimus-Spirit Hill Limestones and Enga-'Nigli Gap' Sandstone would be confirmed or otherwise. Being in a structural 'high' with possible closure, and situated closely 'up pitch' from the deeper northern basin, the hole should also give useful information on the shallower oil prospects.

A hole at site 1(A) is recommended, in the first instance, and for economical reasons it could be drilled with light plant capable of reaching 2,000-3,000 feet depth.

Consideration should be given to drilling a similar hole at either 1(B) or 1(C) where the Burt Range Formation should exist at shallower depths, possibly of the order of 1,000 feet.

A site on the closed gravity +3 milligal contour (area 2) would give most interesting stratigraphic information for correlation purposes after the drilling of 1(A). There is no outcrop or structural control but the top of the Burt Range Formation might be present at 2,500-3,000 feet.

(...23/.)

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E.P. Utting.

E.P. UTTING.

Westralian Oil Ltd.,
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PERTH, West.Aust.

16th October, 1958.

APPENDIX 1.

COPY REPORTS RECEIVED FROM DR. B.F. GLENISTER, UNIVERSITY OF WESTERN AUSTRALIA, DEPARTMENT OF GEOLOGY.

Report No.1, April 28, 1957.

Devonian and Carboniferous Conodonts from the Bonaparte Gulf Basin.

by

Brian F. Glenister.

The samples listed below were submitted for conodont analysis. Limestones were digested in a 20% concentration of acetic acid. Shale samples were broken down by means of the kerosene technique, and their residues were separated by the use of heavy liquids.

No.8- Burt Range Limestone- about 1/4 way up section - The fauna recovered from this sample is as follows :

Bore I1.

Holmesella sp.
conodont gen.ind.

This small sample failed to yield any diagnostic material. Holmesella is common in several of the Upper Devonian formations of the Fitzroy Basin, and is also known from the Gneudna Limestone of the Carnarvon Basin. However, the known range of this genus does not permit the sample to be aged within the Upper Devonian. Further samples should allow a more accurate determination of the age of this formation.

Milligan Hills- Fragmentary conodonts were recovered from this specimen, but their preservation does not permit identification.

Milligan's No.1- Numerous ostracods occur throughout this section. At present they are not particularly reliable as guide fossils, for little is known of Australian Palaeozoic ostracod faunas. The following is a list of the conodont occurrences:

0- 68'	Barren
68-140'	Lonchodus sp.
140-191'	Polygnathus sp.
191-242'	barren
242-290'	barren
290-341'	Polygnathus sp.
341-392'	conodonts, gen.ind.

Polygnathus is the most diagnostic of the forms in this section.

The range of the genus is from Middle Devonian to Middle Mississippian. However, the species in question is unlike Middle Devonian forms, whereas it closely resembles some of the forms from the Upper Devonian of the Fitzroy Basin. It thus seems probable that the containing beds are of Upper Devonian age, but the possibility of a Lower or Middle Mississippian age should not be overlooked.

No.3- Septimus Limestone- base of N. end of hill - 1/2 way up formation - Conodonts were not found in this sample, but three specimens of the bryozoan genus Archimedes were recovered from the residues. This genus first occurs in the Mississippian and its presence thus supports the Carboniferous age assumed for the formation.

Spirit Hill - Locality A- The following conodonts were recovered from this sample :

(...2/.)

Cavusgnathus sp.
Gnathodus sp.
Hindeodella sp.

Cavusgnathus is the index genus of this group. Representatives range in age from Upper Mississippian (Namurian) to Lower Permian, but are most common in the Pennsylvanian. A form which is probably conspecific with the species under consideration occurs in the Carboniferous Laurel Beds of the Fitzroy Basin. The genus is widespread geographically, but is nowhere known from beds older than the Upper Mississippian.

Spirit Hill - Locality B -

Barren

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Report No.2, May 11, 1957

Carboniferous Conodonts from the Bonaparte Gulf Basin.

by

Brian F. Glenister.

The samples listed below were submitted for conodont analysis. Limestones were digested in a 20% concentration of acetic acid. Shale samples were broken down by means of the Kerosene-Capillarity Technique, and their residues were separated by the use of heavy liquids.

Spirit Hill No.1.

51 -102'	barren
102 -151'	"
151 -202'	"
202 -253'	"
253 -295'	"

Despite the fact that these samples appeared to resemble closely those from Milligan's No.1 Bore, they are almost completely unfossiliferous. The only fossils recovered in the residues were several fragmentary ostracods.

Spirit Hill B- 3 miles NNE of Spirit Hill - J.E. Glover Locality 9.

Cavusgnathus sp.
Lonchodus sp.
cf. Ozarkodina sp.
Polygnathus n. sp.

The overlap of specimens of Cavusgnathus sp. and Polygnathus sp. enables the age of the fauna to be fixed within narrow limits. Cavusgnathus is not known below the Chesterian (Lower Namurian) (and Upper Visean) of North America. Polygnathus does not normally occur above the Middle Mississippian (Meramecian or Lower Visean), although the species under consideration is an advance form and can be expected near the top of the generic range. The overlap of these two ranges is at the Meramecian-Chesterian boundary. The age of the fauna is thus either Upper Visean or Lower Namurian. Both Ozarkodina and Lonchodus have long ranges, and they add nothing to the biostratigraphic value of the fauna.

Spirit Hill d - barren.

Locality D - Spirit Hill - barren.

Amphitheatre Anticline - Burt Range Limestone - barren.

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(...3/.)

Report No.3, Jan. 3, 1958

Devonian and Carboniferous Microfossils from the Bonaparte Gulf Basin

by

Brian F. Glenister

The samples listed below were selected for conodont analysis from bulk samples stored at Millenden. Each sample was digested in a 20% concentration of acetic acid and the residues were picked without concentration by heavy fluids. Three samples of black shale were submitted to Balme for palynological examination, and his report is appended.

None of the samples examined from the Bonaparte Gulf Basin contains conodont faunas nearly as prolific as those almost invariably encountered in the Devonian and Carboniferous strata of the Fitzroy Basin. The reason for the paucity of conodont faunas is difficult to determine, but it is probably connected with the detrital nature of the limestones in the Bonaparte Gulf Basin. Sampling techniques used in the collection of the samples were apparently satisfactory. It therefore seems improbable that sufficient conodonts exist in the area covered by Westralian Oil Ltd. leases to permit extensive use of these fossils as a sensitive stratigraphic tool.

Amphitheatre area - Burt Range Limestone -

A00 This sample contains the richest conodont assemblage of the entire collection. It includes the following forms:

Fossil Locality "H"

Ozarkodina sp.	M. Ord. - L. Trias.
Pseudopolygnathus sp.	L. Miss.
Ctenognathus sp.	M. Sil. - L. Trias.
Ligonodina sp.	M. Sil. - L. Perm.
Lonchodina sp.	M. Sil. - L. Perm.

Three of the genera in this fauna are long ranging, but Pseudopolygnathus is geographically widespread and is restricted stratigraphically to the Lower Mississippian (Kinderhookian) of North America and its time equivalents (early Tournaisian). The occurrence of this genus strongly suggests an early Carboniferous age for the containing beds. This is considerably older than the Septimus Limestone but younger than the late Devonian (Famennian) conodont-bearing strata of the Fitzroy Basin (Virgin Hills Formation).

AR1	? Ozarkodina sp.	M. Ord. - L. Trias.
AR2	Barren	
AR3	Barren	
AR4	Barren	
A1	Barren	
A3	Barren	
A5	Barren	
A7	Barren	
A9	Barren	

(...4/.)

Septimus Limestone .-

BBT 1 Barren

BBT 4 *Hindeodella* sp. U. Ord. - L. Trias.
Holmesella sp.
"fish plates"

None of the forms in this fauna provides unmistakable evidence for the age of the containing beds, but the "fish plates" are of a type which is unknown in the Devonian but is common in the early Carboniferous of the Fitzroy Basin.

BBT 8 "fish plates"

Plates of this type are known from both Upper Devonian and Carboniferous strata.

BBT 10 *Cavusgnathus* sp. U. Miss. - L. Perm.
Holmesella sp.

This representative of Cavusgnathus is not conspecific with the forms previously recorded from Spirit Hill Section A (Report No.1) and Spirit Hill Section B - 3 miles NNE of Spirit Hill (Report No.2), although the representatives from the three areas are closely related and probably do not differ greatly in age. The presence of *Cavusgnathus* indicates that the containing beds can not be older than the Upper Mississippian (Chesterian or Upper Visean - Lower Namurian), although they may belong higher in the Carboniferous.

B1 *Ctenognathus* cf. *C. aciendentatus*

Ctenognathus ranges from the Middle Silurian to the Lower Triassic, but *C. aciendentatus* is a Tournaisian species and the closely similar Australian form is probably of this age.

B4 *Archimedes* sp. Carb. - Perm.
Ostracoda

A restricted age can not be determined from these forms, although the presence of the bryozoan suggests that the strata are not as old as the Devonian.

B6 Ostracoda

B12 Barren

B18 *Archimedes* sp.
Ostracoda

B24 *Archimedes* sp.
Ostracoda

B30 *Archimedes* sp.
Ostracoda

B36 *Archimedes* sp.

B42 Barren

(...5/.)

B48	Archimedes sp. Ostracoda	
B54	Barren	
B60	Barren	
B67	Holmesella sp. "fish plates"	

"Fish plates" are of Carboniferous aspect.

Milligans.-

C1	Archimedes sp. Ostracoda	
C2	Archimedes sp.	
CX1	Prioniodina sp. Archimedes sp. Ostracoda	U. Dev. - U. Perm.
CX2	Archimedes sp.	
CX3	Barren	

None of the forms from Milligans permits a restricted age determination.

Spirit Hill.-

D1	Barren	
D2	Barren	
D3	Barren	
D4	Ctenognathus sp.	M. Sil. - L. Trias.
D5	Barren	
D6	Barren	
D7	Barren	
D8	Barren	

The single specimen of Ctenognathus does not permit a restricted age assignment.

E.No.1	Barren	
E1	Barren	
F1A	Barren	
F2	Barren	
F4	Barren	

Sandy Creek.-

G1	Barren	
G1A	Hindeodella sp.	U. Ord. - L. Perm.
G2	Barren	

The single imperfect specimen of Hindeodella does not permit the designation of a restricted age.

(...6/.)

SE end of Weaber Range.-

H1	Barren
H1A	Barren
H2	Barren
H3	Barren

Macrofossils in H1A proved to be gastropods, not ammonoids, and are of no value in the designation of a restricted age.

NE of Spirit Hill.-

SS1	Barren
SS3	*Cavusgnathus* sp.

The single specimen of Cavusgnathus from SS3 is reworked, and proves only that the containing beds are Upper Mississippian or younger in age.

Foothills near Cockatoo Scarp.-

Samples KU1-8 (conodonts), and KX1-3 were submitted in bulk for inspection and selection of most likely material. In view of the extremely poor recovery of conodonts in other samples from the Bonaparte Gulf Basin, only two further samples were washed. They are the following:

KU2	Barren
KU8	Barren

The following is a palynological report by Mr. B.E. Balme on three shale samples submitted earlier for conodont studies.

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APPENDIX 2.

COPY OF REPORT FROM B.E. BALME, GEOLOGY DEPARTMENT, UNIVERSITY OF WESTERN AUSTRALIA.

Report on Samples from Milligans and Spirit Hill Boreholes.

by

B.E. Balme.

I have carried out palynological examinations on three samples of sediments from the above bores. The samples tested were :

Spirit Hill No.1 Bore	51' - 102'
Milligans Bore	191' - 242'
Milligans Bore	391' - 442'

These samples all contained carbonaceous material and spores were plentiful in the maceration residues. The microfloras were diverse and well-preserved, composed almost entirely of undescribed species.

Pteridophyte spores dominated the assemblages. The main elements of the flora are probably lycopods but the ferns may also be represented by heavily cutinised tetrahedral spores of varying ornament. Such a microflora is undoubtedly a primitive one, but it is difficult to date it precisely in the absence of comparative material from dated sediments elsewhere. The following comments are therefore tentative.

(a) In my opinion the sample from Spirit Hill is of the same general age as those from Milligans Bore. There are some differences between the assemblages but they have a number of species in common.

(b) The three assemblages do not resemble any previously found in Western Australian sediments. Perhaps the closest similarities are to be found in the microfloras from the upper 1,500 feet of the Laurel Downs Bore (Fitzroy Basin) from sediments said to be uppermost Devonian or Lower Carboniferous in age.

(c) Little published information exists on Devonian spores from overseas, but the present assemblages seem clearly younger than microfloras from the Old Red Sandstone of Scotland. Some of the forms recorded in the three samples seem close to types described from the Lower Carboniferous of Scotland and Germany, although it is difficult to determine how much significance should be attached to this.

On the balance of evidence I favour a Lower Carboniferous age for the three samples, although they could be of late Devonian age.

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3-1-58.

APPENDIX 3.

COPY OF REPORT BY G. A. THOMAS, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, CANBERRA.

PRELIMINARY DETERMINATION WESTRALIAN OIL LIMITED

FOSSIL COLLECTIONS

Westralian Locality E - Burt Range Limestone, 50' below (base of) Enga Sandstone.

Brachiopods : Composita? sp. (1 specimen only)

Camarotoechia sp. nov.

'Lentaena' sp. cf. L. analoga (Phillips)

Athyris sp.

Rhipidomella sp. cf. R. michelini (L'evelle)

Avonia sp. nov. productid indet.

Spiriferid (small, lamellate)
~~Tylothyris? cf. T. laminosa (McCoy)~~ (1 incomplete specimen only).

This assemblage is suggestive of a late Devonian or possibly very early Carboniferous age. Two of the species are closely related to species occurring in the undoubtedly Carboniferous Septimus Limestone. Avonia sp. nov = a species in the Upper Devonian Fairfield Beds. The assemblage is reminiscent of the Zone d'Etroeungt of Europe.

Septimus Limestone Localities G and F.

Loc G = zone 'd'

Brachiopods: Rhipidomella sp.

Productid indet.

Bryozoan indet.

Crinoid stems

+ Ostracods determined by P.J. Jones

Macrocypris sp. A.

Paraparchites sp.

Bairdia sp. F? and B

Loc. F, zone 'c'

Brachiopods: Reticularia sp. nov. A.

Camarotoechia sp.

Brachythyris sp. nov. A (cf B. ovalis (Phillips)).

(...2/.)

Rhipidomella sp. nov. (cf.R.Michelini (L'Eveille)).

'Leptaena' cf. L. analoga (Phillips)

Schellwienella sp. nov. A.

Unispirifer sp. nov. A.

" ? sp. nov.B.

Mollusca (determined by J.M. Dickins)

Pterinopectinidae gen. et sp. ind.

Straparolus? spp.

Sphaerodoma? sp.

Pelecypoda gen. et sp. ind.

Ostracods (P.J. Jones) Bairdia sp.F.)

Locality F, zone 'b'

Brachiopods: Unispirifer sp. nov. A.

" ? sp. nov.B.

Punctospirifer sp. nov.A.

Brachythyris sp. nov. A.

Reticularia sp. nov. A.

Cleiothyridina? sp. nov.

Camarotoechia sp.

Rhipidomella sp. cf. R. michelini

Schellwienella sp. nov. A.

Linoproductus sp.

Buxtonia? sp., Pustula sp.

'Leptaena' sp. cf. L. analoga

Molluscs : (J.M. Dickins)

Allorisma? sp.

Baylea sp. cf. B. yvanii (L'eveille)

Trilobites: Several small pygidia.

Locality F, zone 'a'

Unispirifer sp. nov. A (small individuals)

Cleiothyridina sp. nov. A.

Rhipidomella cf. R. michelini

Composita sp. nov. A.

~~Reticularia sp. nov.~~ A

Brachythyris sp. nov. A

(...3/)

Punctospirifer sp. nov.A.

Punctospirifer cf. plicatosulcatus (Glenister)

'Leptaeana' sp. cf. L. analoga.

Schuchertella sp.

Mollusca: (J.M. Dickins)

Platyceratidae gen. et sp.

Bellerophontidae gen. et sp.

Pseudozygopleura? sp.

Echinoderms: Pentremites? sp.

Crinoid stems

Sponges: Numerous triaxon spicules

Corals: Syringopora sp.

cf. Michelinia sp.

Rugose corals

The above fossils are of Lower Carboniferous age. From the affinity of the brachiopod species listed and the absence of distinctive Visean species an early Dinantian, i.e. Tournaisian age is suggested as probable. A correlation with the main fossiliferous part of the Laurel Beds of the Fitzroy Basin is indicated by the brachiopods and also by the small ostracod fauna so far recorded. The Moogooree Limestone is also in general, of the same age. The available collections indicate a zonation of the brachiopod species at Mt. Septimus.

Westralian Locality B =WA (A) 9. Spirit Hill area.

This locality has a fauna of brachiopods which indicates an age equivalent to the upper part of the Septimus Limestone.

Brachiopods: Unispirifer sp. nov. A.

" ? sp. nov. B.

Rhipidomella sp. cf. R. michelini.

Cleiothyridina ~~Camarotoechia~~ sp.

Buxtonia? sp.

Composita sp. nov.

Corals : Syringopora sp.

small rugose form.

(...4/.)

Ostracods: (P.J. Jones)

Acratia sp. B

Bairdia sp. B,C,D,E,F.

Glyptopleura sp.

Jonesina
~~Loehriella~~ sp.

Paraparchites sp. B.

Euklœdenella? sp.

The ostracods indicate approximate contemporaneity with the Laurel Beds and thus indirectly with the Septimus Limestone.

Westralian Locality A

This collection is very poor but does indicate a Lower Carboniferous assemblage

Spirifer? sp.

Rhipidomella sp.

Syringopora sp.

Gastropoda 3 gen. et sp.

Bellerophontidae gen. et sp. ind.

Crinoid stems.

This collection is inadequate for precise correlation, however it is probably also equivalent to the Septimus fauna in a general way.

Other Collections

(1) Weaber Range area. 1 mile east of Point Spring in a gritty calcareous rock.

Brachiopods : Syringothyris sp. aff. S. spissus Glenister

Dictyoclostus sp. A

Cleiothyridina sp. nov. B

Ectochoristites? sp.

Schellwienella sp. nov. B

Mollusca : Bellerophon sp.

Bucanopsis sp.

Straparolus? sp.

Large high spired gastropod.

Coral : Syringopora sp.

The above species in general indicate an age ranging from Visean

(...5/.)

to possibly Namurian, i.e. late Lower to early Upper Carboniferous.

(2) Milligans Hills

Several collections come from here, some are in gritty limestone and are all probably of the same age.

WA (A) 6 : Mines Admin. Ltd., in fine grained brown sandstone.

Dictyoclostus sp. B.

Spirifer sp. nov. aff. S. bisulcatus Sowerby

WA (A) 3 : Schellwienella sp. nov. B.

Ectochoristites? sp.

Cleiothyridina sp. nov. B

WA (A) 4 : In gritty calcareous rock

Cleiothyridina? cf. sp. B

Ectochoristites? sp.

Dictyoclostus sp. B.

Miscellaneous collection of D.M. Traves, 1955, from Milligans Hills- 'hill few miles north of Mt. Septimus'.

'Spirifer' sp. nov. aff. S. bisulcatus.

Dictyoclostus sp. B?

All the Milligans Hills localities are assumed to be of the same approximate age although some of the specimens are poorly preserved.

WA (A) 3: Contains three of the Point Springs species and is therefore to be correlated with it.

WA(A) 4, WA(A) 6 and the D.M. Traves 1955 collection are all probably of a general Visean to Namurian age and though the species are not certainly identical they could be contemporary with WA(A) 3 and the Point Springs bed. It is thus possible that all the above localities could represent one general horizon.

Sandy Creek Beds

The fossils from here are in a partly silicified and ferruginized limestone. Internal details are poorly preserved.

Brachiopods: Choristites sp. nov. A

" sp. nov. B

" sp. nov. C

(...6/.)

Composita sp. nov. B

Camarotoechia sp.

cf. Prospira sp. nov.

Dictyoclostus? sp.

Cleiothyridina? sp. nov. C

Chonetes sp.

Coral : Syringopora

This fauna is distinctive from the others in the group. The presence of Choristites, the species of which seem allied to Russian forms, suggests a Moscovian age, however the Composita sp. and cf. Prospira appear to be allied to earlier species. Provisionally therefore the age is regarded as early Moscovian.

The poorly known Flapper Hills fauna is possibly of the same age since two of the few forms there are apparently conspecific with those from Sandy Creek, however the record of Rhipidomella suggests it may be older and perhaps nearer the Point Springs beds or Keep River Sandstones in age.

General

The conclusion therefore is that the Septimus Limestone is Lower Carboniferous and ranges probably to late Tournaisian or possibly earliest Visean. The Spirit Hills localities A and B are of the same age.

The Point Spring and Milligans Hills localities contain faunas of Visean to possibly Namurian age. Since a major unconformity is said to separate Weaber Group and Septimus Limestone a late Visean to Namurian age may be considered more likely. It should however be remembered that the European Age names Tournaisian, Visean, etc. cover very considerable periods of time since the Carboniferous is a very long Period.

I understand that Dr. Glenister has indicated that Early Carboniferous conodonts occur in beds referred to the upper part of the Burt Range Limestone, at the north end of the Burt Range

(...7/.)

Amphitheatre. Is this identification of the rocks as Burt Range Limestone undoubted? The brachiopods of locality E near the top of the Burt Range Limestone, although probably near the Carboniferous/Devonian boundary, do not suggest an age ranging very far into the Lower Carboniferous. Of course the Burt Range Limestone may range higher in age away from Locality E but the possibility that the Amphitheatre beds are a higher formation could be considered.

Dr. Glenister considers that the Spirit Hill limestone (presumably Locality B) is of Middle Mississippian age. This is in accord with my identification of the brachiopods with species from the upper part of the Septimus type section. Therefore Spirit Hill limestone in part, at least, is contemporary with the Septimus Limestone and may be only a facies variant. Thus the sandstones below the Spirit Hill limestone could be approximately equivalent to the Enga sandstone.

Further the shaly to sandy rocks encountered in the Milligans Hills bores could also be approximately equivalent to the Enga-Septimus Limestone succession, although decisive faunal evidence is not yet available.

If the provisional Early Moscovian age for the Sandy Creek beds is correct these beds ought to occur within the Point Spring Sandstone succession higher than the beds near the Point Spring.

The assemblage is quite different from the other faunas in the area which makes local correlation difficult.

(signed) G. A. THOMAS.

4-3-58.

A P P E N D I X 4.

Report of G.A. Thomas to Mines Administration Pty. Ltd., on fossils taken by Allen (1956 a).

The specimens from Spirit Hill and Enga Ridge were unfortunately not very much help in determining ages. The following more or less identifiable fossils were observed.

Spirit Hill Limestone :

F1)
F10)+ Camarotoechia sp. ind.
F11)

F2)
F3) Indeterminate spiriferids

F13 Syringopora sp. ind.

Sandstone above Spirit Hill Limestone : (Allen's locality 3).

F4 Spiriferid indet.
F6 Rhipidomella cf. michelini L'ev.
F9 Rhipidomella ? sp. ind.
F8 Orthotetid gen. et sp. ind. (A dorsal valve which possibly is referable to Schellwienella sp.)

Schellwienella sp. nov. occurs in the Septimus Limestone and another species occurs near Point Spring and also in WAA3 in the Milligans Hills.

Although the above fossils do not help much, the presence of Rhipidomella cf. michelini which is very common in the Septimus Limestone suggests that there may not be a very great age difference between the two formations.

The Enga Ridge specimen is not identifiable.

The above specimens do not provide very much evidence for correlation of the Spirit Hill limestone. However, a re-examination of the collection from WAA9 plus some good specimens collected by Westralian Oil Ltd. from the same locality yielded some interesting results.

The brachiopods from locality WAA9 are now seen to be conspecific with species from the upper beds from the Septimus Limestone at Mt. Septimus and are of about the same age, i.e. about Upper Tournaisian. The other collections from the Spirit Hills area are not good enough to indicate their proper correlation. The general opinion seems to be that all the limestones near Spirit Hill are of the same formation and if this is correct, the Spirit Hill Limestone could be a lateral equivalent of the Septimus Limestone or part of it. Even if it should be demonstrated that the Spirit Hill Limestone overlies the Septimus Limestone, they must be both of nearly the same age.

B.F. Glenister has found that the conodonts from the WAA9 locality are of early Mississippian age and this agrees with my brachiopod evidence.

I now consider from further study of the specimens from the Weaber Range, about 1 mile east of Point Spring, that they are probably of Lower Carboniferous to possibly early Upper Carboniferous age, i.e. Visean to possibly Namurian age. Some of the Milligans Hills localities can be closely correlated with Point Springs notably WAA3 and probably the other collections from the same area, although the collections are insufficient for certainty.

The Sandy Creek specimens still suggest to me an early Moscovian age though they could possibly be older. However, the species of choristites are nearest to the Moscovian representatives of this genus.

(signed) G.A. THOMAS.

17.3.'58.

A P P E N D I X 5.

GRAVITY SURVEY

BURT RANGE BASIN, NORTHERN TERRITORY.

By-

J.E. Burbury.

(Submitted to Westralian Oil Limited by Mines Administration Pty. Ltd., October, 1957).

METHOD AND ACCURACIES :

Seventy-one gravity stations were established along 35 miles of surveyed line in the Burt Range Basin.

The instrument used was a Worden Gravity Meter No.216 with a scale constant of 0.09095 milligals and a reading accuracy of 0.1 scale divisions.

Repeat readings were taken within two hours to check for the drift of the meter, which, throughout the survey, did not exceed 3 scale divisions per hour.

A closure error of 0.14 milligals in the observed gravity values was found in the 22 mile traverse encircling the Central Burt Range. This error was distributed around the traverse, the necessary correction per half-mile-station being approximately 0.003 milligals.

Corrections for latitude and elevation were applied to all observed gravity values. The combined Free-Air and Bouguer correction factor for elevation used was 0.06826 milligals per foot, corresponding to a density of 2.1 gms/c.c. for the near-surface rocks.

The corrected gravity values were tied-in to the gravity values established by the Bureau of Mineral Resources, 1956 at stations SP.415 and SP.448.

The accuracy of the survey can be determined by considering the respective accuracies of the gravity observation, and latitude and elevation corrections. These have been estimated to be 0.02, 0.01 and 0.03 milligals respectively. These give a standard error of -

$$\left((0.02)^2 + (0.01)^2 + (0.03)^2 \right)^{\frac{1}{2}} = 0.04 \text{ milligals}$$

The Bouguer gravity values were plotted at a scale of 1" = 1/2 mile and contoured at an interval of 1.0 milligals.

INTERPRETATION :

The contours indicate a deepening and broadening of the sedimentary trough south from Milligans Lagoon towards the Central Burt Range, where the deepest part of the trough occurs immediately to the west of the Amphitheatre Fault in the vicinity of gravity station R.37.

To the east of the axis of this trough a line of steep gravity gradient runs from pegs R.54 and R.55 in the north, through pegs R.1 and R.2, to pegs R.39 and R.40 in the south. This line of steep gravity gradient closely follows the line of the Cockatoo Fault and is considered to be an expression of this fault.

The gradient across the fault varies- being approximately 5 milligals in half a mile in the north, and approximately 2 milligals in half a mile in the south. The steep gravity gradient observed in the north between pegs R.54 and R.55 is similar to that observed in the gravity traverse by the Bureau of Mineral Resources, in 1956, across the northern extension of the Cockatoo Fault, east of Spirit Hill.

The gravity profile over the Cockatoo Fault in the Amphitheatre area indicates the downthrown side of the fault to be to the west, while surface geology shows the Burt Range limestone, on the west, faulted against the Nigli Gap sandstone, indicating the western side to be upthrown. It is considered that only minor movements of the fault, after deposition of the Nigli Gap sandstone, have brought about this phenomenon, the major movement of the fault having been prior to or during deposition of the Burt Range limestone, when the western side was strongly downthrown.

Graphical interpretation has shown that the displacement of the Cockatoo Fault in the Amphitheatre area would be in excess of 5,000 feet, while further north, east of Milligans Lagoon and Spirit Hill, the steeper gravity gradient could indicate an even greater displacement. It is possible that along the northern extension of the Cockatoo Fault subsequent uplift of the western block after deposition of the Nigli Gap sandstone did not take place or that the movement was less than that on the Cockatoo Fault in the Amphitheatre area. Also in the north, low density Carboniferous sandstones are faulted against the Upper Proterozoic rocks, giving a large density break and hence a large effect on the gravity across the fault, while in the south, higher density Devonian Limestone is faulted against Lower Proterozoic rocks, making the density break and hence the gravity effect smaller.

No other structural elements are expressed by the gravity in its present form. There appears to be no expression of the Amphitheatre Fault and no structural highs were delineated by the survey.

However, more detailed gravity work in the Amphitheatre area may delineate structural elements that cannot be resolved from the gravity map in its present form.

(Signed) J.E. BURBURY,
Geophysicist.