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THE BONAPARTE BASIN, NORTH-WESTERN AUSTRALIA

A Stratigraphic Summary with Special Reference to the Gondwanaland System

by

L. C. Noakes, A.A. Öpik, and Irene Crespin

Chief Geologist

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ILLUSTRATIONS.

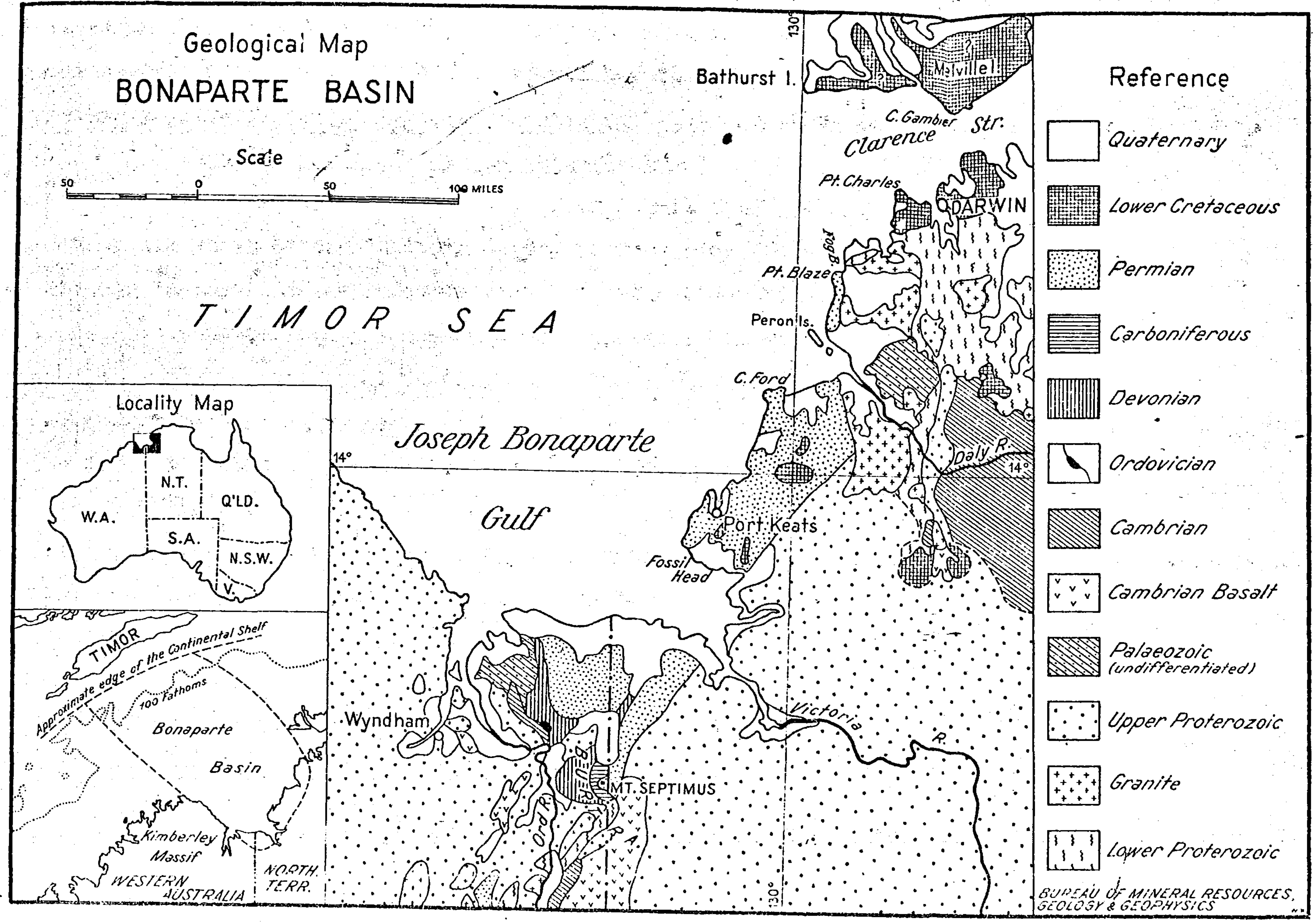
INTRODUCTION.

The Palaeozoic rocks of the Bonaparte Basin outcrop at the head and along the western side of Joseph Bonaparte Gulf and extend across the border between Western Australia and the Northern Territory. For the most part, these Palaeozoic rocks are submerged beneath the waters of the Timor Sea and those which remain above sea level are restricted to a zone 210 miles long and averaging approximately 30 miles wide which extends from the Burt Range north-east to within 60 miles of Darwin (see Plate 1). Although the Palaeozoic rocks now occupy a very restricted area above sea level, the Bonaparte Basin as a structural unit probably extends north-westerly from the present coast line to the edge of the continental shelf - a distance of perhaps 400 miles from the head of Joseph Bonaparte Gulf (Plate 1). The configuration of the basin on the continental shelf has been discussed by Fairbridge (1951) in his study of the Sahul shelf. The Bonaparte Basin is therefore roughly comparable in size to the Desert Basin in the Kimberley Division of Western Australia, with the difference that the Bonaparte Basin is largely submerged and many of its geological features consequently obscured.

Although the occurrence of Permian sediments along the shores of Bonaparte Gulf has been known since 1894, knowledge of the stratigraphy of the Basin is still very incomplete. Indeed, the Bonaparte Basin is the least known Palaeozoic basin in Australia, due partly to the remoteness of the area and the discouraging results of early coal explorations, and partly to the fact that the stratigraphical extent of the Palaeozoic sequence was only discovered in the last ten years.

The Palaeozoic sequence so far established includes Cambrian, Ordovician, Devonian, Carboniferous and Permian sediments which rest on a pre-Cambrian basement and which are overlain in places by a mantle of Lower Cretaceous sediments.

The authors intend in this paper to give an account of Carboniferous and Permian sediments of the Basin, as far as present knowledge permits, with briefer mention of the Lower Palaeozoic and Mesozoic sediments of the area. Stratigraphical nomenclature has been revised to conform to the Australian Code of STRATIGRAPHIC Nomenclature



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iferous strata in the same area, collected by Brown in 1894 and

(Raggatt, 1950) (~~Glaessner, Raggatt, Teichert and Thomas, 1948~~) and formational names used in this paper have been, or will be, formally established in other publications.

REVIEW OF GEOLOGICAL INVESTIGATIONS.

Fossils were reported from Fossil Head, 30 miles north of the mouth of the Victoria River, by Commander Stokes in 1839 and, in 1894, H.Y.L. Brown collected fossils from the same locality which Etheridge described as Carboniferous (Brown 1895). Brown visited the area again in 1905 and collected from fossiliferous strata from several points along the coast between Fossil Head and Cape Ford, 80 miles to the north(Brown 1906). Etheridge (1907) examined the collection and regarded the fossils as Permo-Carboniferous.

Between 1905 and 1911 a search for coal deposits in these sediments was carried out by the Government of South Australia, who then administered the Northern Territory, and ten bores were drilled - six near Cape Ford and four in the vicinity of Port Keats, midway between Cape Ford and Fossil Head. The bores indicated only traces of coal, but established a sequence of at least ~~1,000~~ 1,500 ft. of Upper Palaeozoic sediments.

Earlier explorations also established the occurrence of Mesozoic sediments in the Darwin district. Radiolarian shale was collected from the Darwin area by Hinde (1893), and from fossiliferous strata in the same area, collected by Brown in 1894 and again in 1905, Etheridge established a Cretaceous and subsequently a Lower-Cretaceous age for the sediments (Etheridge, 1895, 1907).

Jack (1906) made a traverse south from Wyndham and mapped areas of Carboniferous and Devonian sediments south of Bonaparte Gulf, but subsequent work has shown that his Palaeozoic units were, in fact, little-folded Upper Pre-Cambrian sediments, although by chance the area shown as Devonian on his map covers part of the area in which Devonian sediments were subsequently found.

Wade (1924) made a reconnaissance of some of the country between the Ord and Victoria Rivers, but had little chance to identify the Palaeozoic rocks where he crossed them. Sediments which he regarded as Cambrian have been subsequently proved to be Upper Pre-Cambrian. In 1941, F.G. Foreman, then Government Geologist of Wyndham, which Teichert (1943) identified as Devonian in age. This discovery was followed by a survey of the area by Matheson and Teichert in 1945 (the results of which were published in 1948), who mapped the Devonian and an overlying sequence of Carboniferous and Permian sediments which they discovered in the Burt Range. L. C. Noakes (1949) produced a reconnaissance map of the Katherine-Darwin region in 1946 which outlined the Lower Cretaceous sediments and helped to define the north end of the Bonaparte Basin, and Reeves (1948) defined the Basin as a whole and compiled an account of the stratigraphy from his own work and that of previous workers in a review of oil possibilities within the Basin.

The most recent work carried out in the area was that of the Land Research and National Survey, Commonwealth Scientific and Industrial Research Organization who, aided by geologists from the Bureau of Mineral Resources, carried out a survey of natural resources of the area south of the Victoria River in 1949. This work will be completed in 1952, but the Palaeozoic sequence at the southern end of the Basin has already been mapped in more detail than heretofore, Cambrian sediments discovered by Reeves in the vicinity of Wyndham have been traced over a wider area and Ordovician strata have been added to the sequence.

STRATIGRAPHY.

The Pre-Cambrian basement rocks on which the Palaeozoic sediments rest consist mainly of Upper Proterozoic sediments which have been only gently folded. Older metamorphic and granitic rocks of Lower Proterozoic or Archaeozoic age form the floor of the Basin in some places, particularly towards the north end.

The Palaeozoic rocks occur in two areas - the southern and northern portions of the Basin - which are ~~divided~~ separated by the estuary of the Victoria River, and it is convenient to refer to these sub-divisions in discussing the stratigraphy, because the full succession discovered in the southern portion of the basin has not yet been found north of the Victoria River.

Lower Palaeozoic.

Both Cambrian and Ordovician sediments are represented in the Basin, but as yet there is no evidence of Silurian deposits. In Cambrian time, transgressive seas extended

TABLE I.

STRATIGRAPHY OF THE BONAPARTE BASIN.

SYSTEM	SERIES	STRATIGRAPHICAL UNITS		LITHOLOGY	THICKNESS	CORRELATION.
Cretaceous	Lower Cretaceous (Albian)	Southern Portion of the Basin. ?	Northern Portion of the Basin. Mullaman Group	Radiolarian shales, shale and sand-stone altered by lateritisation in Miocene (?) Time.	Up to 100'	Rome Series, Qld. } in part. Blythesdale Series Qld. (?) Winning Radiolarite, W.A.
		disconformity or slight unconformity.				
Permian	Lower Kungurian to upper Artinskian	Weaber Range Group		Bedded and massive sandstone with conglomerate, shale and limestone. Both marine and terrestrial fossils.	2000'+	Liveringa Group) Kimberley Noonkanbah Group) Div. W. Aust.
			Pt. Keats Group	Shale and sandstone with some conglomerate. Both marine and terrestrial fossils and streaks of coal.	1500'	Liveringa Group (lower)) Kimberley Noonkanbah Group) W. Aust. Poole Sandstone.)
		disconformity				
Carboniferous	Lower Carboniferous	Mt. Septimus Limestone		Fossiliferous limestone, sandy limestone and calcareous sandstone with bands of crinoidal limestone.	approx. 355	
		Snowie Sandstone	?	Fine-grained sandstone characterised by worm burrows.	1800±	?
Devonian	Upper Devonian	Burt Range Limestone		Limestone, sandy limestone and calcareous sandstone with bands of crinoidal limestone.	4000'	
		(Cockatoo Sandstone	?	Friable, well-bedded sandstone and conglomerate.	4800'	?
		(Onslow Beds		Sandstones with thin beds of limestone	?	
		Unconformity				
Ordovician	Lower Ordovician	Pander Sandstone	?	Glauconitic sandstone	?	?
Cambrian	Middle (and Upper?) Cambrian	Carlton Formation		Sandstone and oolitic limestone	3500±	?
	Middle Cambrian ?		Elliott Ck. Formation.	Sandstone, shale and limestone.	500±	(Negri Limestone, W. Aust., Daly (River Group, N.T.?
	Lower Cambrian	Antrim Plateau Volcanics				Volcanics of the Katherine-Darwin region.
		Unconformity				
			PRE-CAMBRIAN BASEMENT.			

north-east Western Australia and sediments deposited in these seas are still preserved in a number of isolated basins south and east of the Bonaparte Basin, along the valleys of the Ord and Daly Rivers.

Within the confines of the Basin itself, Cambrian sandstones/oolitic limestone of the Carlton Formation (Traves,1949) outcrop 35 miles east of Wyndham and, in the northern portion of the Basin, sandstone, shale and limestone of the Elliott Creek Formation, near the lower Daly River (Noakes 1949), may be Cambrian in age although no fossils have yet been found. The age of the known fossiliferous beds in the Carlton Formation is the top of Middle Cambrian. Overlying sediments in which fossils have not yet been found probably represent Upper Cambrian. The Formation is reputed to be at least 3500' in thickness.* (?)

/and

The only Ordovician sediments found in the Basin occur in the southern portion, 35 miles east of Wyndham, where fossiliferous, glauconitic sandstones of Lower Ordovician age, (the ~~Pandas~~ Sandstone (Öpik 1950)), overly the Cambrian, Carlton Formation without apparent break in sequence.

/a

Upper Palaeozoic.

Devonian.

Devonian rocks have not been found in the northern portion of the Basin but at least 8,800 feet of Devonian sediments have been examined in several places between the Ord and Victoria Rivers and particularly in the Burt Range, about 65 miles east-south of Wyndham. In the Burt Range section, the Cockatoo Sandstone, at least 4,800 ft. in thickness, rests unconformably on Pre-Cambrian sediments or on Lower Cambrian volcanics and is conformably overlain by the Burt Range Limestone (formerly "Series") which is at least 4,000 ft. thick (Matheson and Teichert,1948). Both of these units are regarded as Upper Devonian from fossil content.

?east

?and

Upper Devonian sediments have also been mapped in the Onslow Hills, 30 miles east-north-east of Wyndham where sandstone and limestone of the Onslow Beds are approximately equivalents of the Cockatoo Sandstone and are conformably overlain by the Burt Range Limestone.

Carboniferous.

Carboniferous sediments were first recognized by

* Personal communication (D.M. Traves)

Matheson and Teichert in the Burt Range in 1945. Reeves (1948) mapped, in reconnaissance, two additional exposures of Carboniferous sediments between the Burt Range and the estuary of the Victoria River but subsequent work by Traves and Öpik proved these sediments to be Permian.

No Carboniferous sediments have been observed in the northern portion of the Basin but they may be found on closer examination.

The Burt Range, in the vicinity of Mt. Septimus, provides the best known section of Carboniferous strata in the Basin. The sequence has been divided into two units - the Snowie Sandstone and Mt. Septimus Limestone. In their original mapping of the sequence in the Burt Range, Matheson and Teichert included in the Carboniferous succession only the limestone - since named Mt. Septimus "Series" by Reeves (1948) and changed to Mt. Septimus Limestone by Traves (1949) - and placed the underlying, unfossiliferous sandstone at the top of the Upper Devonian, Burt Range "Series". This sandstone, Snowie Sandstone of Traves (1949), is apparently conformable with both the underlying Upper Devonian and overlying Carboniferous and has been tentatively placed into the Carboniferous by Öpik (1950).

The Snowie Sandstone consists of fine-grained, well-bedded sandstone which is characterized by vertical worm burrows up to one to two inches in diameter and 10 to 15 inches long. These occur on many horizons within the sandstone. In places the rock shows ripple marks and current bedding, but these occurrences are rare. The sandstone is remarkably uniform and is approximately 1,000 ft. in thickness.

According to Matheson and Teichert (1948) "it is obviously a shallow water deposit which represents the closing stage of the Devonian cycle of sedimentation" but the Snowie Sandstone can be regarded equally well as the beginning of Carboniferous sedimentation because the highest limestone beds of the Burt Range Limestone, immediately below the Snowie Sandstone, contain a fauna closely related to that of the Carboniferous limestone, at Mt. Septimus. At a locality 3.7 miles west of Mt. Septimus, in Devonian Limestone

Septimus Limestone.

Furthermore, as suggested in Table II below, the Mt. Septimus Limestone probably does not represent the lowermost Carboniferous in the area. Since the sequence from the Upper Devonian into the Carboniferous is conformable with no lacunas observed, the Snowie Sandstone seems to be the initial deposit of the Lower Carboniferous rather than the top of the Devonian. If the Snowie Sandstone were placed in the Devonian a lacuna at the base of Mt. Septimus limestone has to be postulated.

The Mt. Septimus Limestone conformably overlies the Snowie Sandstone, and, in the vicinity of Mt. Septimus, includes pure limestone and all gradations from limestone to calcareous sandstone (Öpik 1950). Except for a few bands of pure crinoidal limestone, all of the rocks contain some quartz sand. Current bedding is common throughout and ripple marks occur in some places. Traves and Smith* measured the following section at the north-eastern end of Mt. Septimus, in which the Mt. Septimus Limestone is at least 355 feet thick:-

Permian (?) (280'+)	280'	Gritty dark brown sandstone with some conglomerate.
	6'	Obscured.
Carboniferous (355')	90'	Massive crinoidal limestone with numerous brachiopods at top and earthy bands near base.
	20'	Sandstone with thin crinoidal bands
	5'	Crinoidal limestone.
	60'	Current-bedded sandstone with thin crinoidal bands at top.
	20'	Calcareous sandstone with thin crinoidal bands.
	20'	Sandy limestone with crinoids and brachiopods
	50'	Bedded crinoidal limestone with brachiopods *Camarotoechia* less common at top.
	15'	Thinly bedded limestone rich in spirifers.
	30'	Crinoidal limestone with rich *Camarotoechia* band at top
	45'	Bedded granular limestone with mainly fragmental fossils.

Matheson and Teichert (1948) examined the limestone sequence about 6 miles south of Mt. Septimus and record 350 ft. of limestone, which is mostly crystalline and very fossiliferous.

The fauna at Mt. Septimus has not yet been described, but it contains over twenty five genera, amongst them Syringopora, Michelinia, a solitary rugose coral, crinoids, Fenestrellina, Chaetetes, Trepostomata, Rhipidomella cf. australis (McCoy), Leptaena analoga Phillips, Productus (Marginirugus) n. sp., four genera of spiriferids, amongst them Spirifer s. st., Tylothyris, and perhaps a new genus; Reticularia (?), Athyris, Composita, Camarotoechia aff. pleurodon Phillips, Euomphalus, Orthonychia, fragments of trilobites and three genera of ostracods. Leptaena analoga is present over the total thickness (355 feet) of the Mt. Septimus Limestone. Camarotoechia, the spiriferids (except Tylothyris) and productids are most numerous over eight feet of the strata commencing above the lowermost 75 feet of the section. Composita, Rhipidomella, Tylothyris are abundant in the upper 90 feet of the sequence.

Bioherms and biostromes are absent. The limestones are sandy and are interbedded with sandstone. Limestones as well as sandstones show extensive current bedding as evidence of an epicontinental, marine, shallow water environment.

The presence of Leptaena analoga indicates a definite Lower Carboniferous (Mississippian) age for the Mt. Septimus Limestone. The presence of Productus (Marginirugus) is perhaps even more significant. A.H. Sutton (1938, p.576) states that Marginirugus is confined to the Keokuk and Warsaw formations of the Mississippian of the Mississippi Valley. Until further work is done the position of the Mt. Septimus Limestone can be summarised as shown in the following table:

TABLE II.

Correlation of the Carboniferous Strata in the Bonaparte Basin with formations in the Mississippi Valley. USA

General Time Unit.	Formations in Mississippi Valley (Sutton 1938).	Burt Range, N.W. Australia.
Mississippian	11. N. Chester	
(Lower	10. M. Chester	
Carboniferous)	9. L. Chester	
	8. Ste.Genevieve	
	7. St. Louis	
	6. Salem	
	5. Warsaw (Marginirugus)	Mt. Septimus
	4. Keokuk	Limestone
	3. Burlington	
	2. Fern Glen	Snowie Sandstone

PERMIAN.

Permian strata have been found in both the northern and southern portions of the Basin, although much field work remains to be done, particularly in the northern portion of the Basin, before the Permian succession can be clearly established.

Northern Portion of the Basin.

Except for small mesa- cappings of Lower Cretaceous sediments and areas of alluvium, Permian rocks occupy the entire coastal strip, about 35 miles wide, extending from the Fitzmaurice River in the south to the Daly River in the north. A smaller area of Permian (?) sediments has been mapped along the coast between the Daly River and Point Blaze.

? The sediments rest on Pre-Cambrian granite or Upper Pre-Cambrian sediments along the eastern margin of the Basin, although it is not definitely known whether pre-Permian sediments may be preserved at the base of the Palaeozoic sequence. No glacial or fluvio-glacial beds have been identified yet.

Although known for many years, Permian sediments in the northern portion of the Basin were not formally named until Noakes (1949) proposed "Port Keats Group" for the whole conformable sequence. No formal names have yet been given to sub-divisions of the Group.

The best outcrops of the Group occur in the cliffs along the coast and in a number of mesas inland. Brown (1905) cites exposures at Fossil Head as the most typical of the Permian rocks along the coast. The section consists of about 100 feet of sandstone, ? shale and sandrock and is apparently capped by laterite judging by Brown's description. The sandstone is micaceous; it ranges in texture from fine to gritty and the lower beds are richly fossiliferous. Current bedding and ripple marks with a wave length of three to four inches were also observed by Brown. The beds are horizontal with a slight seaward dip.

At other places along the coast between Fossil Head and the Daly River Brown (1905) records sandstone, sandrock or shale beds but the cliffs are lower than at Fossil Head and it is clear from his description that most of these sections consists of deeply lateritized sediments. At Cape Ford and particularly at Red Cliff, ... shallow areas of "arenaceous and argillaceous deposits of Tertiary age" resting on Permian strata, which could represent either completely laterized Permian sediments or lateritised Lower Cretaceous beds. ?

A northerly extension of Port Keats Group, along the coast between the Daly River and Point Blaze, was mapped by Noakes (1949). Most of the outcrops in this area consist of laterite derived from shale, sandy-shale and sandstone. Noakes records that "argillaceous rocks appear to be predominant and most of the shales are calcareous, particularly in the western part of the area. Fragments of shale and sandstone were found under laterite in one locality near the eastern margin of the area, but these gave no clue to structure and contained no palaeontological evidence beyond occasional worm tracks. The age of the sediments in this area is therefore in doubt but they have been provisionally mapped as part of the Port Keats Group because of their lithology and geographical position."

The Elliott Creek Formation in the Daly River area has already been mentioned. In lithology and degree of metamorphism it resembles both the Daly River Group (Cambrian) and the Port Keats Group (Permian) and the authors tentatively regard the Formation as Cambrian.

Several stratigraphical sections of the Port Keats Group have been examined in mesas occurring inland from the coast between Fossil Head and the Daly River. At Mt. Greenwood, 25 miles south-south-east of Cape Ford, Noakes (1949) recorded approximately 130 ft. of sandstone, with intercalations of sandy shale, dipping south-west at an average of 5 degrees. No fossils were found in the section but most of the sandstone, particularly that exposed at the base of the section is noticeably friable and appears comparable with the "friable, sugary, sandy rock" recorded by Brown (1905) from Fossil Head. Between Mt. Greenwood and the eastern limit of the Port Keats Group, Noakes found only rare outcrops of sandstone which, judging by the composition of the soils, is the dominant rock type.

Inland from Port Keats, H.J. Evans (Reeves, 1946) examined and measured seven sections in mesas and knolls between Mt. Goodwin and Table Hill. In one of ~~which~~ the sections, Permian fossils were discovered. In each section, Permian sediments up to a maximum thickness of 400 feet were found below a thin capping of lateritized, Lower sandstone and shale of various types with a slight preponderance of sandstone. Evans describes the sediments south-east of Port Keats as follows :- "In general the Permian consists of shales, sandstone and ~~sandy sanctone~~ silty sandstone with shale-conglomerates in places. The shales are white to pink in colour sometimes massive but very well bedded. The sandstones, range from massive to thinly bedded and commonly exhibit extensive cross-bedding. The shale-conglomerates formed by channelling in the beds during deposition. No definite lithographic markers suitable for structural interpretation were noticed in the Permian of the area".

The deepest section of the Port Keats Group was explored by bores drilled in search of coal between 1905-1911. Two of these bores - one at Port Keats and one near Cape Ford - reached the limit of the drill at approximately 1500 feet below the surface and were entirely in Permian sediments. The shallowest bore at Cliff Head proved 700 ft. of sediments, presumably Permian, before granite bed-rock was struck. In general, the section exposed by the bores consists of alternating shale and sandstone of various types with a clear indication of changing conditions of sedimentation by the occurrence at different horizons within the sequence of marine fossils, plant remains and streaks of coal.

Brown (1908) noted that in one bore (Bore No.4, Port Keats) some of the samples logged as sandstone or shale were calcareous and included limestone.

Etheridge (1907), who described the fossils collected from Bore No. 4 Port Keats, suggested that sediments down to a depth of about 550 ft. may be Mesozoic because of the occurrence of Estheria, but Teichert (Reeves, 1948, p.9) has pointed out that Estheria is found in Permian as well as in Mesozoic strata. It is apparent that any Lower Cretaceous sediments present in the section would be restricted to 25 to 50 feet at the top of the section.

Unfortunately, neither palaeontological or stratigraphical data are sufficient to define the Permian sequence in the northern portion of the basin, but the total thickness of the Port Keats Group is at least 1,500-2,000 feet.

Approximately forty species of Permian fossils have been identified by Etheridge (1907), Crockford (1943), Crespin(19..

and by Teichert (in the report by Reeves, 1948) from seven various localities in the northern portion of the Basin. It is interesting to note that each of the seven known fossil localities shows a completely differenct faunal assemblage with practically no fossils common to any other locality. This may be the result of incomplete collecting, or may indicate that the Port Keats Group shows finer palaeontological subdivisions than are usual in other areas of Permian sediments.

However, two distinct stages are recognized. A lower one, with Glossopteris browniana Brongniart and other plants in Bore No. 4, representing the Poole Sandstone (formerly known as the Lower Ferruginous) of the Kimberley Division and an upper horizon, with a marine fauna correlated to the Noonkanbah Group and the lower part of the Liveringa Group (Upper Ferruginous). This sequence in the Kimberleys is regarded as Artinskian in age so that practically the whole of the Artinskian seems to be represented by fossiliferous deposits in the Port Keats area.

Southern Portion of the Basin.

Permian sediments have been identified in four separate areas between Wyndham and the mouth of the Victoria River, and sediments which may be Permian in age have been mapped in the Burt Range and in country farther south.

Permian East of Wyndham.

West of Keep Inlet a large area of Permian rocks overlaying Devonian sediments has been mapped by Reeves. At the southern edge of this area lies the Weaber Range, 55 miles east by north from Wyndham, where fossils have been collected at Point Spring. Between Keep Inlet and the estuary of the Victoria River a smaller area of Permian deposits occurs which has been examined in less detail. South-east of Keep Inlet, fossiliferous Upper Palaeozoic rocks are found in the fault blocks of Sandy Creek and Flapper Hills. The fauna of Sandy Creek has been interpreted by Teichert (Reeves 1948) as possibly Carboniferous in age.

All the occurrences (Point Springs, Sandy Creek and Flapper Hills) are now regarded as Permian in age and parts of the Weaber Range Group (Reeves, 1948), which Traves* reports as at least 2000' thick.

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TABLE III.

Correlation of Permian Strata in the Bonaparte Basin
with Permian Sediments in the Kimberley Division, W.A.

General Time Scale.	Desert Basin Kimberley Division	Bonaparte Basin (Southern Portion)		
Kungurian (lower)	Erskine Sandstone; Liveringa Group.	Point Spring Sandstone	Weaber Range Group: Upper beds lacustrine, with plants	
			Lower beds, marine, with Dictyoclostus	
Artinskian (Upper)	Noonkanbah Group		Sandy Creek Limestone, marine	Flapper Hills Sandstone, marine.

~~It~~ This is a tentative correlation only because the few fossils of the Weaber Range Group ~~which~~ are not well preserved, and cannot be correlated with certainty with the rich fauna of the Kimberley Division.

Permian of the Burt Range.

To the south-east of Wyndham, Matheson and Teichert mapped conglomerates, sandstones and slates as probable Permian strata overlying Lower Carboniferous beds in the Burt Range, near Mt. Septimus, and in the southern portion of the Range and farther south they mapped beds, presumably of the same age, occurring in fault-blocks and not in contact with fossiliferous Palaeozoic rocks.

Reeves, Öpik and Traves agree that the sandstone and conglomerates overlying the Carboniferous sediments in the northern portion of the Burt Range are probably Permian although no fossils have been found and no evidence for glaciation has been observed. Traves (1948) regards the sediments as part of the Weaber Range Group and the section at Mt. Septimus has been reproduced above. Conglomerates outcropping some 5 miles south of Mt. Septimus were examined by Traves in 1949 but they do not include any features to suggest glacial or fluvio-glacial origin. Moreover, their relationship to the Permian (?) sandstone capping Mt. Septimus is not evident because the outcrops are separated by a fault, trending south-south-west, mapped by Matheson and Teichert (1948). The sandstones at Mt. Septimus dip 2½ degrees to the north-east, in apparent conformity very slight angular unconformity as Matheson and Teichert (1948) have pointed out.

However, the southern and south-eastern extension of these beds, mapped by Matheson and Teichert as possible Permian (the Mt. Booking Series) has not been confirmed by subsequent workers. Reeves (1948)and Traves (1949) regard the white and grey shales and sandstones and the unsorted conglomerates which may be of glacial origin, as part of the Victoria River Group of Upper Proterozoic (Nullagine) age.

No fossils have been found in any of these beds, and it seems very likely that most of these rocks are Pre-Cambrian and that there is, so far, no evidence of fluvo-glacial deposits of Permian age in the Bonaparte Basin.

Lower Cretaceous.

Lower Cretaceous sediments are the youngest marine deposits known in the Bonaparte Basin. After a considerable interval of erosion, from Permian to Lower Cretaceous time, sediments were laid down in a shallow, transgressive sea which followed much the same pattern as its Cambrian predecessor. It covered a large area of the Northern Territory and was linked up with the Roma Sea of Central Queensland.

This sea probably covered the greater part of the Bonaparte Basin although, so far, remnants of Lower Cretaceous sediments have been found only in the northern portion. The massif which lies to the south of Bonaparte Gulf, ~~and~~ consisting mainly of Pre-Cambrian rocks, apparently formed the southern shore line for the Lower Cretaceous sea in this region.

Within the Bonaparte Basin and in the area to the north of it, the Lower Cretaceous sediments consist only of shale and sandstone of the Darwin Formation (Noakes 1949), although, south-east of Darwin, these marine beds are underlain apparently conformably by lacustrine deposits with plant remains. Originally, they were regarded as Upper Jurassic (Hossfeld, 1937, Voisey, 1939) but Noakes and Crespin now believe that they are Lower Cretaceous. Noakes named the full lacustrine and marine sequence the Mullaman Group and this name has been used for sediments near the coast south of Darwin because it is not definitely known how far west the lower lacustrine

Sediments of the Group outcrop along the coast from Darwin to the south-west as far as Fog Bay. Farther south they appear only as cappings on mesas, with the possible exception of the cliff section in the vicinity of Cape Ford to which reference has already been made. These sediments are sub-horizontal and range from fine shale to sandstone with, in places, coarse sandstone and fine conglomerate at the base of the section. A characteristic of these beds is the occurrence of radiolarian shale in many places not only in the Katherine-Darwin region but also in the Barkly Tableland and in Queensland. In all known outcrops, the sediments have been strongly lateritized, probably in the Miocene Epoch, and in most places the process has affected the complete section of 50 feet or more.

Secondary silification brought about by lateritization has in many places altered radiolarian shales into a fine-grained tough rock ("porcellanite") or sandy shales or sandstones into quartzite ("billy") and it is to these hard bands that the mesas in the northern portion of the Bonaparte Basin owe their preservation.

The maximum observed thickness of the Mullaman Group in the area south-east of Darwin, including both marine and lacustrine beds, is 210 ft. but south of Darwin the maximum observed thickness is 90-100 ft. at Mt. Greenwood (Noakes, 1949). The sediments are 40-50 ft. thick in the vicinity of Darwin, at least 20 ft. thick at Fog Bay, about 50 ft. in the presumed Lower Cretaceous section at Cape Ford, and up to 60 ft. thick at the top of mesas examined by Evans (Reeves, 1948) south-east of Port Keats.

Fossils of Lower Cretaceous age in the Mullaman Group are present in the Bonaparte Basin and in the area around Darwin. They have been recognized at Mt. Greenwood, south of the Daly River; Point Charles, 16 miles west of Darwin; Fanny Bay, Shoal Bay and Gun Point at Darwin; and in the vicinity of Cape Gambier on Melville Island.

Apparently there are two horizons of Lower Cretaceous fossils within the Mullaman Group, one containing an assemblage of mega-fossils such as Pelecypoda and Cephalopoda as at Point Charles, and the other containing microfossils such as Radiolaria, as for instance, at Fanny Bay, Darwin.

The first reference to megafossils in the area

A later collection was made by Etheridge (1907) from the same locality. He noted that the fossils were all replaced by limonite. The Pelecypoda included Aucellina incurva Etheridge and Nuculana sejuncta Etheridge. Whitehouse (1926) revised the list of ammonites which included the genera Desmoceras, Boudanticeras, Spathoceras, Hamites, Anisoceras, Scaphites and Trilocoleras. More recently (Noakes, 1949) a cast of Dimitobolus was found in the silicified cap rock at Mt. Greenwood.

The beds containing the Radiolaria are more widely distributed and form caps to mesa-like outcrops throughout the area. However, the first record of Radiolaria was made by Hinde (1893) from Fanny Bay, Darwin and the genera and even species described by him have been identified in "porcellanites", shales and sandy shales from many localities. These forms described by Hinde include Spongodiscus expansus, Lithocyclina exilis, Lithocampe fusiformis, Amphibrachium crassum, A. truncatum, A. fragilis, Dictyomitra australis, D. triangularis, Spongolena symmetrica, Stichocapsa pinguis and S. chrysalis. The commonest genus is Cenosphaera. Investigations overseas by W. Reidel (personal communication 1951) suggest that this assemblage of Radiolaria in the Lower Cretaceous rocks of Australia is unique.

Hinde (1893) did not suggest an age for the radiolarian beds at Fanny Bay, but Etheridge (1907) regarded the megafossils at Point Charles as Lower Cretaceous and recognised the similarity of some species to those in the Lower Cretaceous of Queensland. Whitehouse (1926) does not mention the Fanny Bay radiolarian deposits in his correlation of the marine Cretaceous of Australia. However, he regards the Point Charles beds as the equivalent of the "Tambo Series" of Upper Albian age. Investigations of the microfaunas of the beds in the Roma area shows that in the sequence there the ammonite-Foraminifera-bearing rocks underlie the radiolaria-bearing siltstone and sandy siltstone. This sequence is also present at Point Charles and it is suggested that the beds containing the larger fossils at Point Charles, Gun Point, Darwin, Shoal Bay and Maclear Creek in the vicinity of Darwin and on Melville Island are of Upper Aptian or Lower Albian and the radiolarian beds, of Upper Albian age. It is suggested also that the Point Charles Beds are probably the equivalent of the "Roma Series". However, until the type sections for the "Roma Series" and

STRUCTURE OF THE BASIN.

Geological mapping of the Palaeozoic sediments of the Bonaparte Basin has been insufficient to provide a comprehensive structural picture but a number of main structural features are known.

Cambrian and Ordovician sediments have been folded, but Upper Palaeozoic strata, apart from faulting, have been little disturbed. Matheson and Teichert(1948) have described the folding of the Middle and Upper Cambrian sediments and underlying Lower Cambrian volcanics in isolated Cambrian basins south of the Bonaparte Basin. Within the Bonaparte Basin the apparently conformable Cambrian-Lower Ordovician sequence shows dips of up to 40 degrees mainly to the north-east. This provides evidence of moderate regional folding. On the other hand, Devonian, Carboniferous and Permian sediments do not show regional folding and at most places, apart from tilting in the vicinity of faults, show dips rarely above 15 degrees. Some steeper dips have been mapped towards the base of the Upper Devonian sequence east of Wyndham and local doming appears in the Burt Range Limestone in the same area, but these structures may be due mainly to conditions of deposition and consolidation (Reeves 1948).

In the southern portions of the Basin, Upper Palaeozoic sediments dip gently to the east or north-east and Reeves has suggested that the mild uniform easterly dip of the Upper Devonian sediments in the extreme south of the Basin could be due to "fore set beds built out into the sea by Palaeozoic rivers".

In the northern portion of the Basin, no evidence of folding has been noted in any of the Palaeozoic rocks and even in the Elliott Creek Formation, which may be Cambrian in age, the beds are sub-horizontal. The Port Keats Group shows gentle dips of about 5 - 10 degrees in a general west or north-west direction which may indicate a gentle and uniform depositional slope.

The fact that both the sedimentary succession and accompanying structures are more fully developed to the south indicates that the southern portion of the Basin has been less stable, with movement and deposition particularly concentrated in a zone of re-adjustment, resembling a foredeep, bordering the Kimberley massif. Fairbridge (1951) from physiographic evidence has postulated major faulting with throw to the north-east along the north-eastern margin of the Kimberley massif, west of Wyndham. At least on two occasions, from this marginal zone to submerge the more stable northern portion of the Basin.

Faulting has played an important part in the attitude and distribution of the Palaeozoic sediments of the Basin and provides the most striking structural features of the region. Matheson and Teichert (1948), referring to the Burt Range and to the country farther south, describe a system of faulting, mostly of the block type which they believe is definitely post-Permian in age, but, within the Bonaparte Basin, not all major faults are post-Permian. Some faults in both the northern and southern portions of the Basin appear to have originated during the period of mild orogeny between Lower Ordovician and Upper Devonian time (Caledonian of Reeves (1948), although in some places movement was repeated in later periods of instability. Certainly, nearly all faults mapped are normal and commonly strike north-east or north-west. Many show movement in post-Permian time, probably in Tertiary time. As Reeves has pointed out, the east side of the Basin seems to have been determined by faulting.

The structural environment of the Basin, the epi-continental character of its sediments and its structural history classify it as a discordant basin in the sense of Umbgrove (1947). Its origin is obscure as in many basins of this kind, but the earliest phases of subsidence occurred in early Cambrian and possibly even in Upper Pre-Cambrian time. The sedimentary record shows that parts of the Basin were submerged intermittently from Cambrian to Cretaceous time and that during these submergences the Basin was linked with an open sea to the west and north-west - conditions which were again produced by the flooding of the continental shelf in Pleistocene time.

THE BONAPARTE BASIN AND GONDWANALAND.

Teichert (1941) has already pointed out the significance of the records of Palaeozoic sedimentation along the western coast of Australia in relation to the problems of reconstructing Gondwanaland or of tracing its subsequent foundering or disruption. Certainly, any reconstruction of the ~~old~~ Gondwanaland continent must allow for at least an ancient and wide embayment, although not a geosyncline, ~~which extended~~ along the West Australian littoral far south of the Bonaparte Basin.

Teichert in 1941, found "no evidence in western Australia to support either Dr. Toit's supposed 'northerly creep' of Australia in Tertiary time or Kuenen's 'anti-clockwise rotation' of this continent." The authors agree with Teichert and believe that these hypotheses, at least as far as they involve the Australian continent, should be refuted.

Viewing the Australian Continent as a whole, we find that the environment along the west and north-west margin, at least since Pre-Cambrian time, has been fairly consistently one of quiet sedimentation on a continental shelf which, although subject to some movement, has been a relatively stable area. This is in strong contrast to the consistent easterly and north-easterly growth of the eastern portion of the Continent. The general persistence of these two tectonic environments - geosynclinal deposits and shield-growth in the east and north-east and stable conditions with persistent epi-continental basins in the west and north-west - surely ~~infers~~ indicates that the relationship between the Australian Shield and crustal units to east and west must have followed a consistent pattern, at least since Pre-Cambrian time. Although these conditions may not, per se, preclude any continental drift, they can hardly be reconciled with the wanderings of the Australian continent as postulated by Du Toit (1947) and modified by King (1950).

On the other hand, Fairbridge's reconstruction of the floor of the Indian Ocean (1948) (which suggests an ancient embayment, or sea, north-west of the Australian continent and foundered, continental fragments in the western and southern portions of the Indian Ocean) lends new emphasis to the idea that the problems of the propagation of the Gondwanaland flora can be adequately explained with little recourse to the concept of continental drift.

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