DEPARTMENT OF
MINERALS AND ENERGY



# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1973/74

# SEDIMENTARY BASINS OF THE SAHUL SHELF



by

L.W. Williams, D.J. Forman, and P.J. Hawkins

RECORD NO. 1973/74

# SEDIMENTARY BASINS OF THE SAHUL SHELF

by

L.W. Williams, D.J. Forman, and P.J. Hawkins

## CONTENTS



## FIGURES

ABSTRACT

The Bonaparte Gulf Basin and parts of the Browse and Money Shoal Basins occur beneath the Australian continental shelf in the area bounded by longitudes 121°E and 132°E and extending to the southwest to latitude 15°S.

The Australian coastline, except in the Bonaparte Gulf, is bounded by areas of thin generally flat-lying Mesozoic sediments overlying basement. These areas are separated by hinge zones from areas of thicker Mesozoic and Palaeozoic sediments.

The Mesozoic and Tertiary sediments, at least, are typical of those expected on a continental shelf subjected to periodic transgressions and regressions of the sea.

The most common diastrophism is faulting which has formed the hinge lines, the Rob Roy Graben in the Browse Basin, a pre-Mesozoic graben in the Money Shoal Basin, and the Ashmore-Sahul Block, Sahul Ridge, and Cartier Trough in the Bonaparte Gulf Basin. Salt diapirs intrude part of the sequence in the Bonaparte Gulf Basin.

## INTRODUCTION

Water depths in the area between Australia and Indonesia are mostly less than 200 m, with the depth increasing gradually from the Australian coast towards the Timor Trough. Greater depths occur in the Timor Trough, where depths reach 3000 m, and in the extensions of the Trough, towards the Indian Ocean and Arafura Sea.

In the area of the Timor Sea bounded by longitudes 121°E and 132°E and extending to the southwest to latitude 15°S, an area of approximately 730 000 km$^2$, 25 petroleum exploration wells have been drilled (Fig. 1). In the same area about 80 000 km of seismic traverse and 50 000 km of aeromagnetic traverse have been surveyed by companies and about 35 000 km of geophysical traverse employing seismic, gravity, and magnetic methods have been surveyed by the Australian Bureau of Mineral Resources (BMR).

The results of much of this work are available and have yielded a good general knowledge of the geology of the area. This knowledge includes the present day structure of the area and the age and lithology of many of the sediments. It has also allowed a provisional subdivision of the area into three sedimentary basins.

## SEDIMENTARY BASINS

Three sedimentary basins are recognized in the area under consideration: the Browse, Bonaparte Gulf, and Money Shoal Basins. Money Shoal Basin, as used here, is roughly coextensive with Arafura Basin as used by Shell Development (Aust.) Pty Ltd (Balke et al., 1973). The name 'Arafura Basin' has been used previously (Rix, 1964; Plumb, 1965; Dunnet, 1965) for a Proterozoic basin offshore and onshore in the northeastern part of Arnhem Land and that use is preferred.

The eastern margin of the Browse Basin is the seafloor outcrop of the unconformity separating Upper Cretaceous to Holocene sediments from Precambrian rocks. The northern margin - the boundary between the Browse and Bonaparte Gulf Basins - follows the crest of the Londonderry Arch, then trends west-northwest via the crests of discontinuous rises in the ocean floor and continues along the southern edge of the Ashmore-Sahul Block to the edge of the continental shelf.

The southern margin of the Bonaparte Gulf Basin continues east and southeast from the crest of the Londonderry Arch along the seafloor outcrop of the unconformity between Phanerozoic and Precambrian rocks and joins onshore with the exposed unconformity between Palaeozoic and Proterozoic rocks of the Kimberley Basin. The eastern margin of the Basin, onshore, is a partly faulted and partly unconformable contact between Palaeozoic and Precambrian rocks. Offshore the eastern limit of Permian or Triassic subcrop defines the margin as far north as Bathurst Island. This line, together with an arbitrary line running north-northwest from Bathurst Island along Van Diemen Rise and through Sunset Shoal, separates the Bonaparte Gulf Basin from the Money Shoal Basin.

The southern margin of the Money Shoal Basin, in the area being considered, abuts the Pine Creek Geosyncline onshore.

## STRUCTURAL SUBDIVISIONS

The sediments have been folded, faulted, and intruded by salt diapirs. No compressional folding is known and anticlines were caused by drape and differential compaction or by arching of sediments over growing diapirs.

Diapiric salt intrusions are known only in the Bonaparte Gulf Basin. Halite intrudes Lower Carboniferous sediments in Pelican Island No. 1 and other diapirs are interpreted on seismic sections.

The area may be divided into several large structural subdivisions each covering thousands of square kilometres and incorporating smaller characteristic subdivisions - folds and fractures of local importance - which are related geometrically, temporally, and genetically to the larger unit (Fig. 2). The main criteria for this subdivision is structural relief and the main mechanism is faulting.

Faulting during sedimentation in some areas has produced trends referred to as hinge zones across which the rate of thickening of sediments changes markedly. Areas of comparatively thin, flat-lying Mesozoic and Cainozoic sediments occur on the inshore parts of all three basins, where Palaeozoic rocks are generally missing. Hinge zones mark the boundary of areas of thicker sediments farther offshore.

The most southwesterly of the structural subdivisions in the area is the Buccaneer Nose, which is interpreted on seismic sections as a fault-bounded area of elevated basement over which Mesozoic and Tertiary sediments are arched.

A north-trending graben (Rob Roy Graben) containing late Carboniferous and Permian sediments beneath Mesozoic sediments adjacent to a hinge zone has been interpreted on seismic records and from drilling results. Three sides of the graben are faulted. Two sides trend northerly and a third northeasterly, with the northeasterly trending fault forming part of the hinge zone.

The axis of the Bonaparte Gulf Basin bifurcates offshore; the northwesterly extension is the Sahul Syncline, the northeasterly extension is unnamed. The so-called Sahul Ridge is a fault block, an elevated area of basement overlain by thinner sediments (less than 4500 m thick), between the two axes, and with physiographic expression as a rise in the ocean floor. The elevated area corresponds approximately to the southwestern part of the Sahul regional gravity high; it contains several domes and basins and is bounded by hingelines.

The Ashmore-Sahul Block lies within the western part of the basin. The structural province contains block-faulted Triassic sediments overlain by Jurassic and Cretaceous sediments thinner than in neighbouring areas of the Bonaparte Gulf and Browse Basins, and a normal thickness of Tertiary sediments. The southern and southeastern margins are a hingeline and the eastern margin is a normal fault.

The Londonderry Arch, which separates the Bonaparte Gulf and Browse Basins, is an elevated area of basement rocks extending northwestwards from the Kimberley Basin. A thinner sequence of sediments occurs over the arch and the sea floor rises above it (Londonderry Rise).

The Northeast Londonderry Ridge is an elevated area of basement covered by thinner sediments that extend northeast from the shallower Londonderry Arch. The northwestern margin of the ridge is a normal fault.

The Cartier Trough is a graben lying between two sets of northeasterly trending faults near the outer edge of the continental shelf. Calculations of depth to magnetic basement suggest that up to 6000 m of sediments is present in the Trough.

The hinge zone in the Money Shoal Basin extends farther offshore and into deeper water than those in the other Basins. Also the sediments on the inshore side of the zone are up to 4500 m thick and are partly of Palaeozoic age. The faults in the zone appear, from seismic sections, to displace the basal Mesozoic strata more than those higher in the section.

A pre-Mesozoic graben, mainly east of 132°E, contains a sedimentary fill of the order of 6000 m shoreward of the hinge zone.

## STRATIGRAPHY

Extensive geophysical surveys by petroleum exploration companies and the Bureau of Mineral Resources, together with drilling and mapping, provide the basis for a regional geological framework.

Cambrian to Lower Carboniferous

Palaeozoic sedimentary rocks, unconformable on basement, crop out mainly south of latitude 15°S in the Bonaparte Gulf Basin and extend offshore beneath the Mesozoic sediments. They are also identified on marine seismic sections extending from the Canning Basin into the south of the Browse Basin.

As no well has been drilled in the Money Shoal Basin west of 132°E, information on the sediments in that part of the Basin must be obtained from the few outcrops, geophysics and wells drilled outside the area. The most relevant well is Money Shoal No. 1 (10°18'57"S; 132°44'11"E), which intersected thin Silurian terrigenous clastics (Fig. 3).

A pre-Mesozoic graben, interpreted from seismic records, extends into the area from the east. Although good reflections are recorded from within the graben, the age of the infilling sediments is not known.

The oldest rocks in the Bonaparte Gulf Basin are up to 1000 m of Lower Cambrian continental basalt, tuff, and agglomerate with minor interbedded sandstone. The volcanics crop out extensively in the south and east of the basin, where they overlie the Precambrian basement with an angular unconformity. Up to 1200 m of Cambrian and Lower Ordovician marine sandstone, sandy dolomite, and stromatolitic dolomite unconformably overlie the volcanics onshore.

Onshore, at least 3000 m of Upper Devonian and Lower Carboniferous marine deepwater shale, siltstone, and minor sandstone are rimmed on the southeast by shallow water sediments consisting of up to 3100 m of conglomerate, sandstone, dolomite, limestone (including reef complex), and shale, and on the southwest by up to 1980 m of shallow-water sandstone, dolomite, marl, limestone (including reef complex), and shale. Offshore, 935 m of Lower Carboniferous shallow marine siltstone, shale, and minor oolitic limestone were penetrated in Pelican Island No. 1.

Upper Carboniferous to Upper Triassic

Major regional angular unconformities developed as a partial consequence of folding and faulting in the Lower (?) Carboniferous and in the Upper Triassic. The sedimentary section between these unconformities has been drilled in the Bonaparte Gulf Basin and in the Browse Basin.

Late Carboniferous (?) and lowermost Permian marine claystone, shoreline sandstone, and minor limestone, 713 m thick, unconformably overlie probable Precambrian sedimentary basement in the Rob Roy Graben (Fig. 5). Scott Reef No. 1 reached total depth after penetrating 375 m of Upper Triassic deltaic and shallow marine claystone with dolomitic sandstone and recrystallized limestone immediately beneath a major regional angular unconformity.

The Upper Devonian and Lower Carboniferous sequence in the Bonaparte Gulf Basin is disconformably overlain onshore by 100 m of Upper Carboniferous fluviatile quartz sandstone with minor conglomerate and siltstone. Offshore, Lower Carboniferous sediments are overlain unconformably by Upper Carboniferous marine and shoreline pyritic and calcareous quartz sandstone, siltstone, and dolomite in Lacrosse No. 1 and conformably by up to 830 m of dominantly fluviatile sediments in Pelican Island No. 1.

Onshore, Lower Permian rocks disconformably overlie the Upper Carboniferous and unconformably overlie the Precambrian basement in the east. Offshore they overlie Upper Carboniferous sediments with a possible disconformity. They consist of continental silicified sandstone (in places containing phenoclasts of glacial origin), siltstone, and shale, overlain by deltaic sandstone with interbeds of coal and marine shale and sandstone, and are up to 1750 m thick.

Offshore 510 m of Upper Permian shallow marine and fluviatile quartz sandstone, siltstone, and shale occur in Petrel No. 1, and 375 m of similar sediments with minor coal occur in Lacrosse No. 1.

Triassic estuarine laminated siltstone and fine-grained sandstone (up to 110 m thick) conformably overlie the Permian sediments in the north-eastern part of the Basin onshore.

Offshore, up to 1950 m of Triassic sediments conformably overlie the Permian. They consist of Lower Triassic marine shale and siltstone in Sahul Shoals No. 1, Lower Triassic fluviatile carbonaceous sandstone, siltstone, and shale in Petrel No. 1, and Middle Triassic marine sandstone, shale, and limestone, and Upper Triassic deltaic sandstone and shale with minor beds of marine calcarenite, calcilutite, and marl in Sahul Shoals No. 1.

Interpretation of seismic records and well data shows a westward thickening of Triassic sediments from Petrel No. 1 to Sahul Shoals No. 1.

Permian sedimentary rocks probably extend from the Bonaparte Gulf Basin into the Money Shoal Basin. Triassic sediments have not been identified in the area, but their presence in the deeper parts can be inferred from seismic evidence and a thick Triassic section in Petrel No. 1.

Upper Triassic to Recent

The stratigraphy of rocks above the Upper Triassic regional unconformity is much better known. A number of less prominent unconformities and disconformities occur within the sequence, which is typical of that expected on a continental shelf subjected to periodic transgressions and regressions of the sea. Fluviatile and deltaic coastal plain sediments are common near the depositional margins, and outer to inner shelf marine sediments predominate near the depocentres of the basins.

Upper Triassic sediments are present, south of latitude 15°S, above the unconformity at Lynher No. 1. At Rob Roy No. 1, 93 m of Lower Jurassic deltaic sediments (Fig. 5) unconformably overlie Lower Permian sediments, and in the west at Scott Reef 96 m of Lower and Middle Jurassic near shore marine sandstone and claystone unconformably overlie Upper Triassic sediments.

Interpretation of seismic records with the available well control indicates that probable Upper Cretaceous sediments unconformably overlie basement in the Londonderry Arch and that a more complete Cretaceous sequence over 3300 m thick and an Upper Jurassic sequence occur in the depocentre of the basin.

Upper Jurassic marine shale, 30 m thick at Scott Reef No. 1, probably thickens towards the depocentre, but does not occur at Rob Roy No. 1.

In Scott Reef No. 1, 762 m of Upper and Lower Cretaceous marine sediments disconformably overlie the Upper Jurassic sediments. Claystone and sandstone are overlain by calcilutite and marl. Two disconformities occur within the sequence.

In Rob Roy No. 1, 780 m of Cretaceous marine claystone, sandstone, and minor siltstone disconformably overlie the Lower Jurassic sediments. Minor disconformities occur within the Neocomian, between the Neocomian and Aptian, and between the Aptian and Albian.

The thickest Tertiary sequence penetrated was 3460 m of calcilutite, marl, calcarenite, calcisiltite, and reefal limestone (1411 m thick) in Scott Reef No. 1, disconformable on Cretaceous rocks. Rob Roy No. 1 penetrated 130 m of Paleocene marginal marine sandstone with minor coal and claystone, conformably overlying Cretaceous sediments. In the same well thin Pliocene to Recent calcarenite, minor calcisiltite, sandstone, and dolomite disconformably overlie the Paleocene rocks.

Wells subsidised by the Australian Government and drilled in the Bonaparte Gulf Basin give a clear picture of the Upper Triassic to Recent sediments (Fig. 4).

Offshore, in Gull No. 1, 239 m of probable Lower Jurassic sediments unconformably overlie the Triassic. Elsewhere Triassic sediments are disconformably overlain by Middle and Upper Jurassic sediments consisting of 900 m of non-marine multicoloured sandstone, siltstone, and shale in Petrel No. 1, 35 m of Upper Jurassic volcanics and thin marine calcarenite, lithic sandstone, and shale in Ashmore Reef No. 1, and Upper Jurassic marine shale and marginal marine sandstone at Heron No. 1 (Fig. 4).

Interpretation of seismic records shows that the Jurassic sediments maintain a constant thickness within the Cartier Trough and over the Northeast Londonderry Ridge.

Onshore, up to 30 m of Cretaceous marine sandstone, siltstone, and conglomerate unconformably overlie Triassic and older rocks.

Offshore, up to 2125 m of Cretaceous marine quartz sandstone, shale, and minor limestone conformably overlie the Jurassic, except on the Ashmore-Sahul Block, where up to 130 m of Lower and Upper Cretaceous marine calcilutite, shale, and marl unconformably overlie the Upper Triassic. In Petrel No. 1, an unconformity occurs within the Lower Cretaceous rocks and in Sahul Shoals No. 1 a disconformity separates the Lower and Upper Cretaceous rocks.

The Upper Cretaceous sediments thin westward from 576 m in Gull No. 1, via the Northeast Londonderry Ridge and Cartier Trough, to 290 m in Ashmore Reef No. 1.

Offshore up to 2000 m of Tertiary calcilutite, marl, and calcarenite conformably and unconformably overlie the Cretaceous rocks.

Interpretation of seismic records shows that Tertiary sediments are thickest in the Cartier Trough.

Cainozoic deposits onshore consist of alluviam, travertine, laterite, soil, and sand. Offshore they consist of calcarenite, calcareous quartz sandstone, and calcilutite.

Balke et al. (1973) report an almost complete lack of mappable seismic reflections in a large part of the Money Shoal Basin below a seismic event in the Lower Cretaceous sediments. Nevertheless they believe that the hinge zone developed during the Jurassic and predict that the predominantly fluviatile and paralic Mesozoic sediments drilled in Money Shoal No. 1 (Fig. 3) will change abruptly at the hinge zone into deeper water marine shale. The effects of the structural hinge zone on stratigraphy becomes less pronounced in the Upper Cretaceous and has had little effect on the Cainozoic and Recent sediments.

The Tertiary sediments are divided into an upper carbonate sequence and a lower carbonate and clastic sequence by a disconformity that also occurs in the Bonaparte Gulf and Browse Basins.

## CONCLUSIONS

Thick sequences of Cainozoic, Mesozoic, and Palaeozoic sediments are preserved within the Browse, Bonaparte Gulf, and Money Shoal Basins on the Sahul Shelf. The sediments have been tilted regionally and faulted at various times and have been intruded locally by salt diapirs, but no compressional anticlines are recognized. The faulting has been responsible for rapid changes in the rate of thickening of sediments and for differential uplift of several large areas.

Little is known of the stratigraphy of the Palaeozoic sediments, but the Mesozoic and Tertiary sediments at least are typical of those expected on a continental shelf subjected to periodic inundations by the sea. Fluviatile and deltaic coastal plain sediments are common near the depositional margins, and outer to inner shelf marine sediments predominate near the depocentres of the basins.

Exploration for petroleum has proceeded at a moderate rate since 1965 and is expected to continue at the same rate for the foreseeable future. To date the search has been rewarded by the discovery of gas in Scott Reef No. 1 and an uneconomic flow of gas at Petrel No. 1. Only minor hydrocarbon shows have been reported from other wells.

## ACKNOWLEDGMENTS

In addition to data supplied by BMR, much of the information contained in this paper has been compiled from the well completion reports of drilling subsidised by the Australian Government. Most were submitted by B O C of Australia Limited and Arco Australia Limited. We have also made liberal use of published papers by Balke et al. (1973) and Martison et al. (1972) and of an unpublished manuscript 'Summary of Sedimentary Basins in Australia and Papua New Guinea, 1973' in preparation by the Sedimentary Basins Study Group of BMR.

## REFERENCES

BALKE, B., PAGE, C., HARRISON, R. and ROUSSOPOULOUS, G., 1973 - Exploration in the Arafura Sea - APEA J., 13 (1)

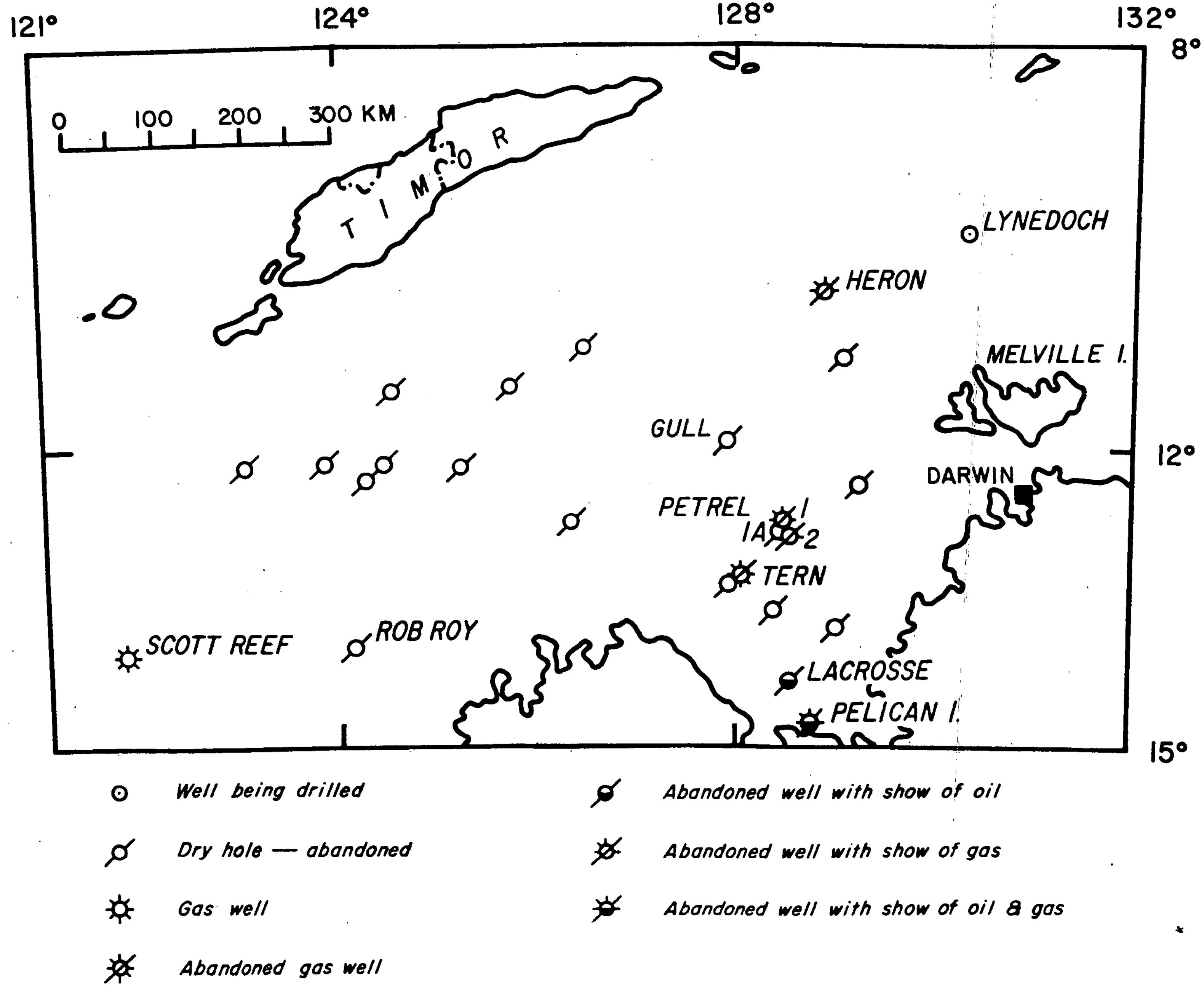
DUNNET, D., 1965 - Arnhem Bay/Gove, N.T. - 1:250,000 Series. Bur. Miner. Resour. Aust. explan. Notes SD/53-3, 4

MARTISON, N.W., McDONALD, D.R., and KAYE, P., 1972 - Exploration on the continental shelf off northwest Australia. Aust. Oil Gas Rev 19 (3), 8-18

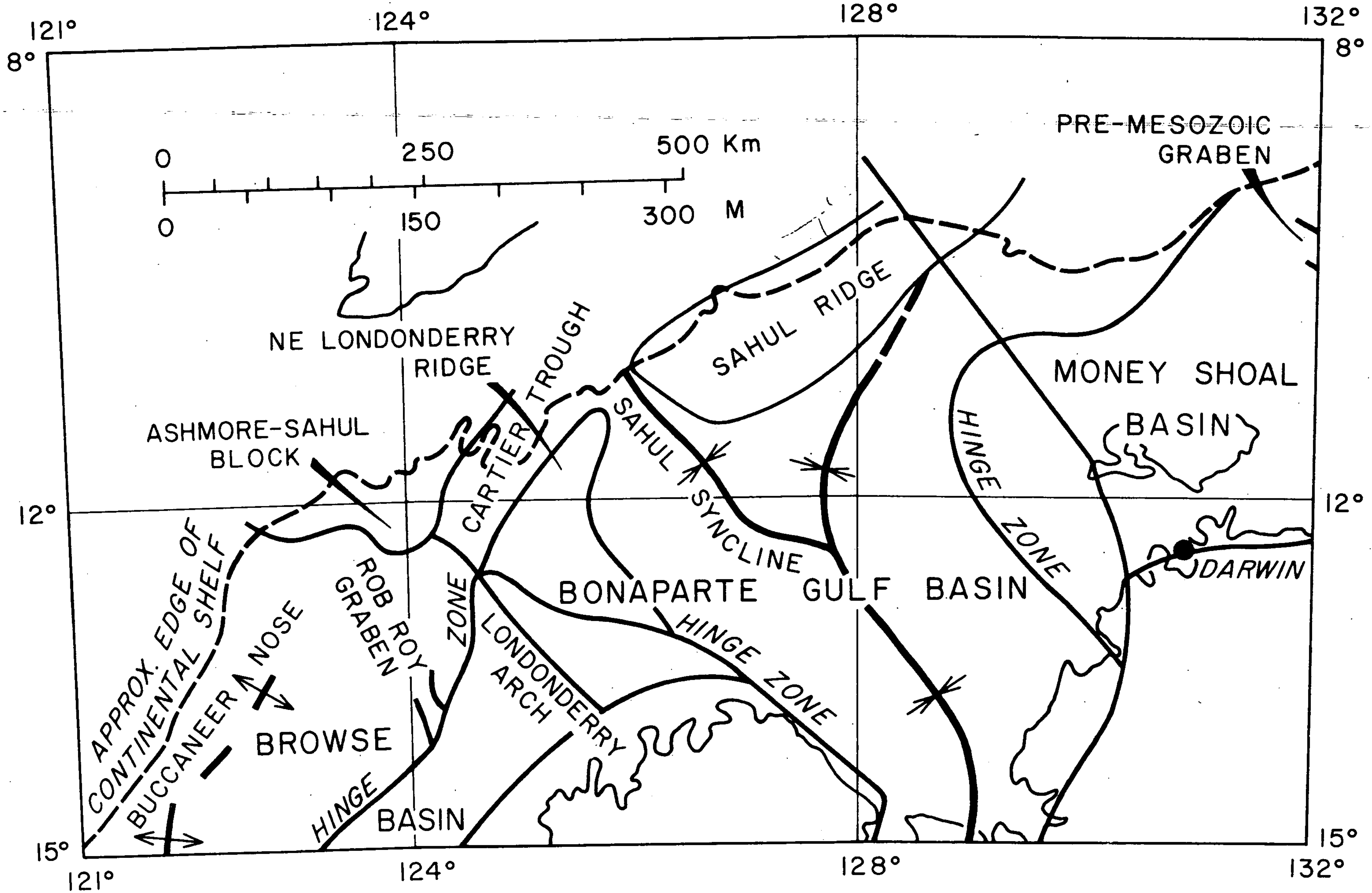
PLUMB, K.A., 1965 - Wessel Islands/Truant Island, N.T. - 1:250,000 Series. Bur. Miner. Resour. Aust. explan. Notes SC/53-15, 16

RIX, P., 1964 - Junction Bay, N.T. - 1:250,000 Series. Bur. Miner. Resour. Aust. explan. Notes SC/53-14

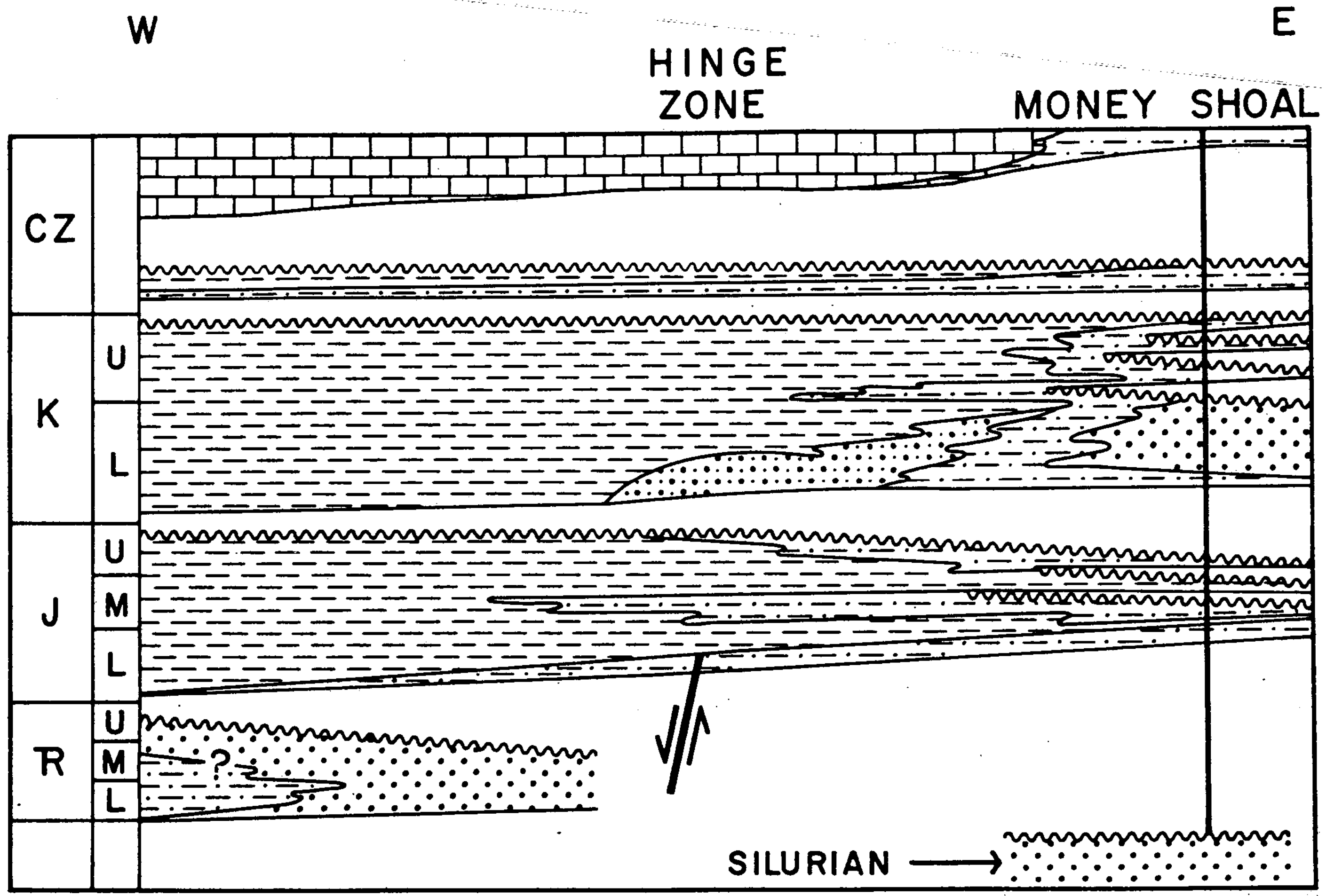
FIG.1 WELL LOCATIONS



# FIG.2 STRUCTURAL SUBDIVISIONS



# FIG. 3 TIME CORRELATION - MONEY SHOAL BASIN




(AFTER BALKE ET. AL. 1973)

OUTER AND INNER SHELF CARBONATES

OUTER AND INNER SHELF SHALE

COASTAL PLAIN

DELTAIC

FLUVIATILE

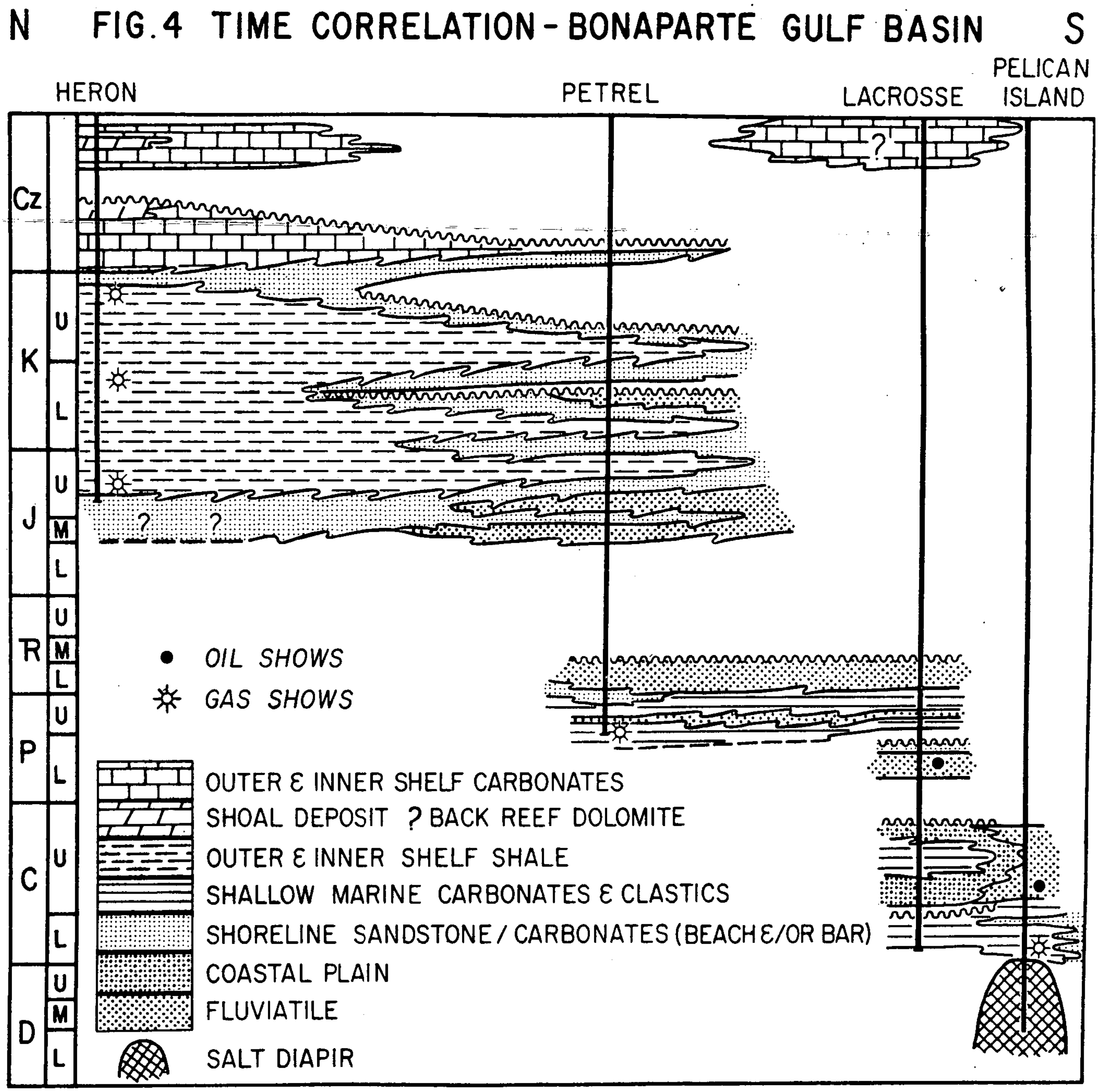

N
FIG.4 TIME CORRELATION - BONAPARTE GULF BASIN
S
HERON
PETREL
LACROSSE
PELICAN ISLAND
Cz
K
U
L
J
U
M
L
Ʀ
U
M
L
P
U
L
C
U
L
D
U
M
L
?
?
?
OIL SHOWS
GAS SHOWS
OUTER & INNER SHELF CARBONATES
SHOAL DEPOSIT ? BACK REEF DOLOMITE
OUTER & INNER SHELF SHALE
SHALLOW MARINE CARBONATES & CLASTICS
SHORELINE SANDSTONE / CARBONATES (BEACH &/OR BAR)
COASTAL PLAIN
FLUVIATILE
SALT DIAPIR

FIG. 5 TIME CORRELATION - BROWSE BASIN