BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

RECORD 1980/42

BROWSE BASIN REGION

EXPLANATORY NOTES AND STRATIGRAPHIC COLUMNS

by

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CONTENTS

ABSTRACT

The Browse Basin Region covers the offshore areas of the Northwest Shelf and Slope west of the Kimberley Block, Western Australia. Most of the region is occupied by the large and economically important Browse Basin, an elongate downwarp, and the adjacent submarine Scott Plateau, which have areas of 100 000 km^2 and 80 000 km^2, respectively. Sediments ranging in age from Carboniferous to Holocene are known in the region from drilling; evidence from adjacent basins suggests that older Palaeozoic sediments may also be present. Basement composition is known only from wells on the eastern margin of the Browse Basin that intersected Precambrian rocks of the Kimberley Block, and from a DSDP hole on the Argo Abyssal Plain that penetrated to oceanic basement.

An intracratonic basin existed over the region until the late Palaeozoic. The history of this basin is largely speculative. During the Permian and early Mesozoic, sediments that were largely non-marine, paralic, and fluvio-deltaic were deposited in troughs and rift valleys in a horst-and-graben regime formed by sporadic tectonic movement associated with the early phase of continental rifting. Tectonism climaxed in the Jurassic when a major rift developed at the western margin of the region. Plate separation in the late Mesozoic was accompanied by the establishment of marine conditions and the development of a peripheral basin on the site of the horst-and-graben zone. Marine clastics were succeeded by largely carbonate sediments when the region was tilted westward in the Late Cretaceous.

The small non-producing Scott Reef gas/condensate field in the Browse Basin contains the only proven hydrocarbon resources in the region. All present exploration is concentrated in the Browse Basin, where known source rocks, reservoir rocks, and oil and gas shows make it the most prospective area in the region.

INTRODUCTION

The name Browse Basin Region is an informal term used in this study for the area west of the Kimberley Block that underlies the Northwest Shelf and Slope of offshore Western Australia, shown in Figure 1. Several formally defined structural and geographic features are contained within the region.

The Browse Basin, which is wholly within the region, is an elongate downwarp underlying approximately 100 000 km^2 (Allen & others, 1978) of the continental shelf and slope. The basin lies wholly offshore between, and partly contiguous with, the Canning Basin to the south and Bonaparte Gulf Basin to the north (Fig. 1). The Londonderry High and Ashmore Platform partly mark its northern margin, and the Leveque Shelf is part of its southeastern margin (Halse & Hayes, 1971). The Kimberley Block in Western Australia forms the eastern limit, which is onlapped by the basin's Permian and younger sediments (Fig. 2). The basin is bounded to the west by the Scott Plateau, a submarine plateau that occupies about 80 000 km^2 of the continental slope and lies in an average water depth of 2500 m (Stagg & Exon, in prep.).

Main structural trends of the Browse Basin are generally northeast, parallel to the present coastline. Faulting (Fig. 2) subdivides the basin into two unequal portions. The smaller eastern portion, consisting of the Yampi Shelf and Prudhoe Terrace (Figs.1, 2) and their extensions, has a relatively shallow basement and little structural relief. The larger western portion contains several large Mesozoic structural lineaments such as the Scott Reef Trend (Figs.1, 2). The basin's evolution and its present structural form may be related to events associated with the breakup of eastern Gondwanaland.

The total thickness of sediments in the Browse Basin and on the Scott Plateau is unknown, as the only wells to reach basement are those drilled on the shallow eastern edge of the basin which penetrated Precambrian rock, and on the Argo Abyssal Plain (Fig. Au7b). The oldest

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Figures Au7a and Au7b and these explanatory notes were prepared as a contribution for the United Nations ESCAP Atlas of Stratigraphy.

basin sediments so far penetrated by drilling are Carboniferous. Allen & others (1978) estimated the thickness of Carboniferous and younger sediments is at least 11 000 m in the central part of the basin; Crostella (1976) suggested a maximum thickness of at least 12 000 m.

The 15 wells in the basin have intersected sediments ranging in age from Holocene to Late Carboniferous. Regional geological relations suggest that earlier Palaeozoic sedimentary rocks, possibly as old as Cambrian or Ordovician, may have been deposited west of the Prudhoe Terrace. Cretaceous and Cainozoic sediments thicken seaward from the Yampi Shelf; the Cretaceous sequence thins over the Scott Reef and Seringapatam Trends near the western edge of the basin (Figs.2, 3), and the Cainozoic thins on the western part of the Scott Plateau (Fig. 3).

The Scott Reef gas field is the only significant hydrocarbon discovery to date. It has not yet been developed for production.

DATA COMPILATION

Direct geological information on the region is sparse; much of the Browse Basin and its adjacent areas lies in water depths greater than 200 m (Fig. 4), beyond the continental shelf. Exploration drilling has been largely confined to the shallower eastern part of the Browse Basin and to the present-day reefs along the western edge of this basin. Regional geological interpretations over the rest of the largely untested region are based chiefly on geophysical data, mainly seismic.

The best explored part of the Browse Basin Region is the Browse Basin itself. Most of the Browse Basin data come from work carried out by Woodside Petroleum Development Pty Ltd (formerly BOC of Australia Ltd and BOCAL Pty Ltd), which conducted most of the geophysical surveys and drilled all the wells in the basin (Halse & Hayes, 1971; Warris, 1973; Crostella, 1976; Allen & others, 1978).

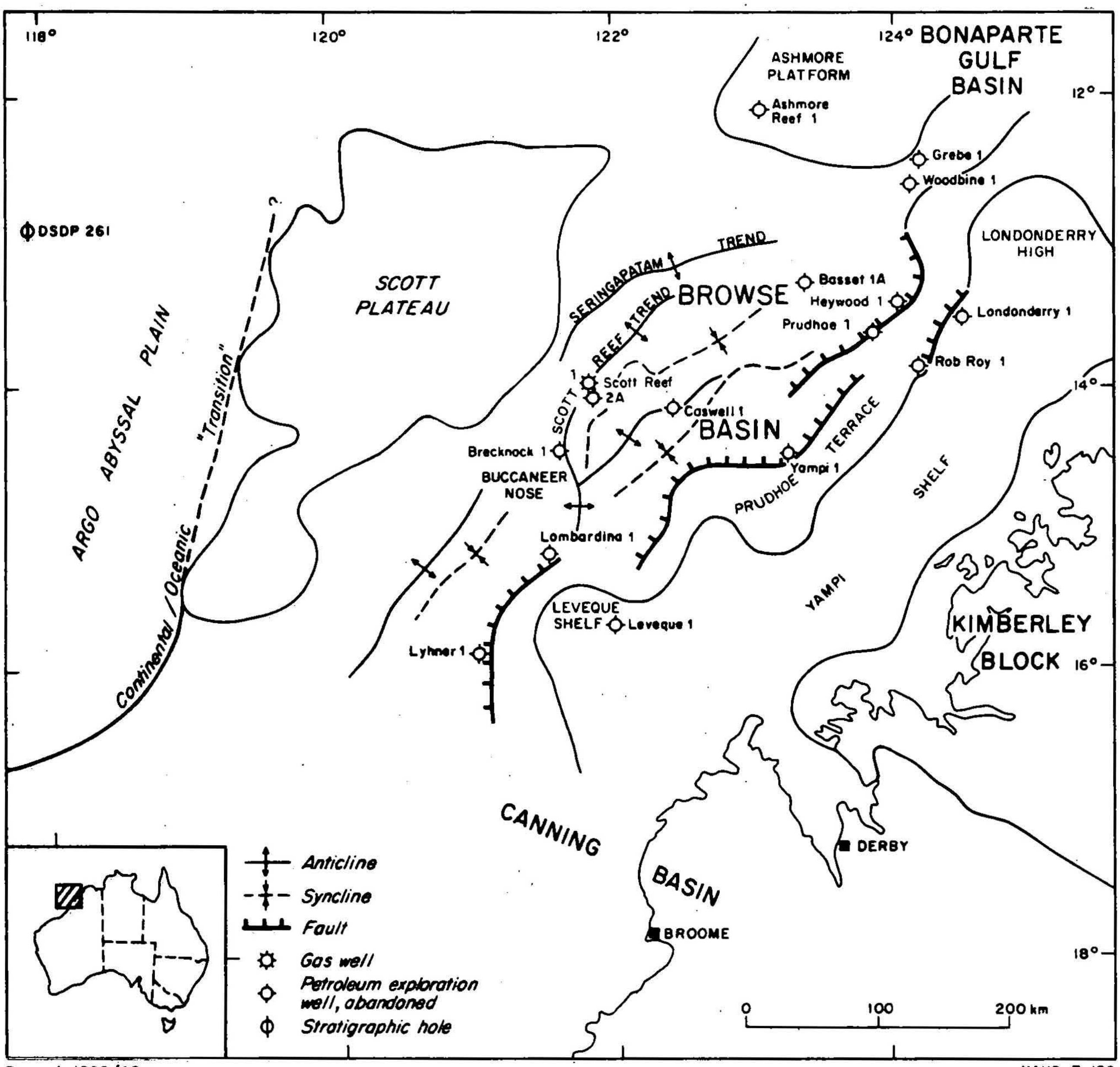

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Fig. I Regional setting Browse Basin and adjacent areas

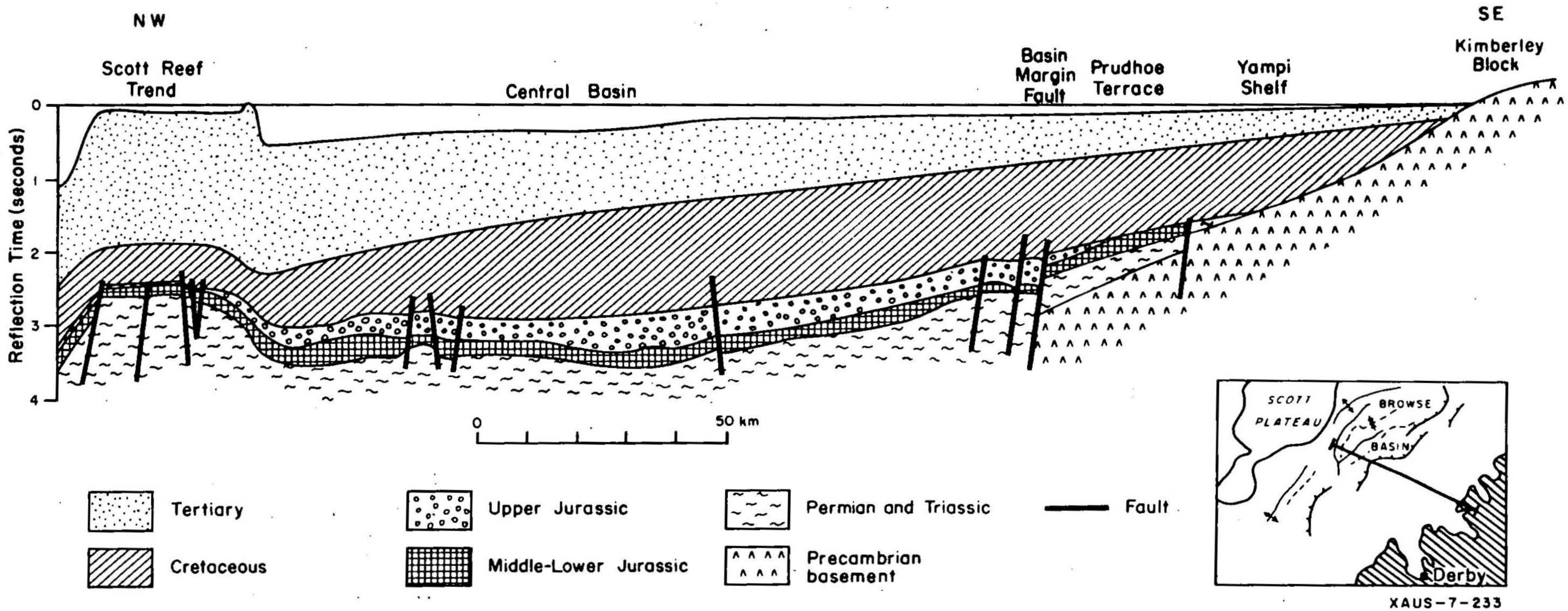

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Fig.2 Browse Basin structural cross-section (after Allen and others, 1978)

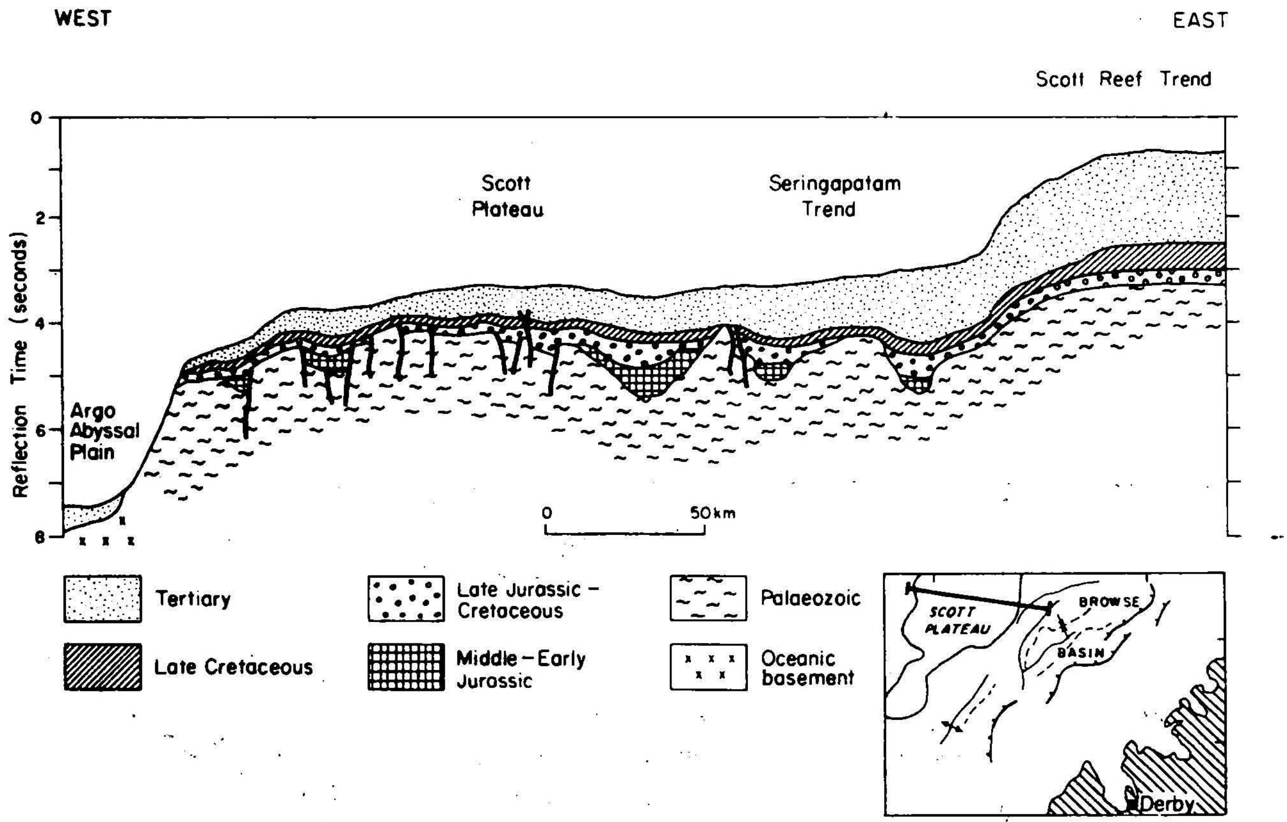

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Fig.3 Scott Plateau structural cross-section (after Stagg, 1978)

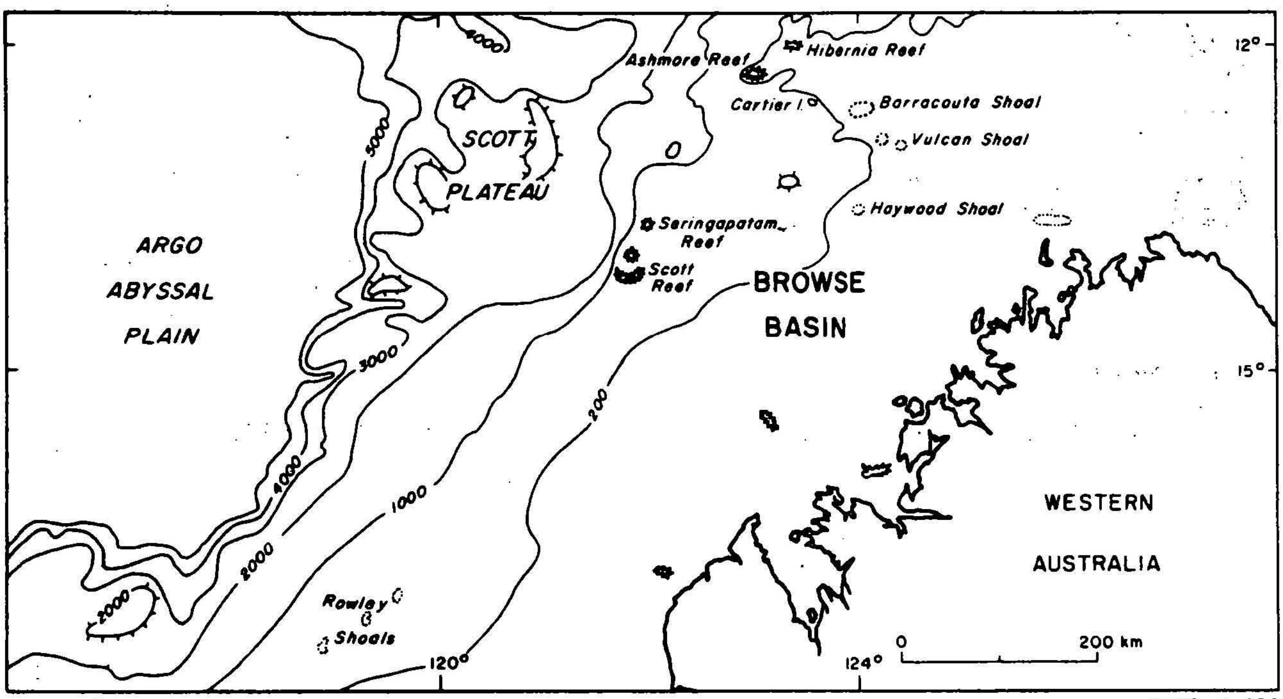

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Fig. 4 Bathymetric map

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Information in this report on areas west of the Browse Basin was largely compiled by the author from published studies of the geophysical surveys of the continental margin conducted by the Australian Bureau of Mineral Resources, and from the deep sea surveys, stratigraphic drilling, coring, and dredging by other scientific organisations (Veevers, Heirtzler & others, 1974; Hogan & Jacobson, 1975; Hinz & others, 1978; Stagg, 1978; Stagg & Exon, in prep.).

The stratigraphy, ages, and time breaks used for the well columns in Figures Au7a and Au7b were compiled from interpretative company data in well completion reports and environmental analysis reports (Woodside Petroleum Development Pty Ltd for the Browse Basin wells and Leg 27 of the JOIDES Deep Sea Drilling Project for the Argo Abyssal Plain). The unconformities and disconformities shown largely represent faunal breaks determined from micropalaeontology. No formal stratigraphic names have been proposed; the formation names used for the Cretaceous and Tertiary strata in Ashmore Reef 1 are informal names and no attempt has been made to extend these names into the Browse Basin. The depths and time breaks for the Scott Plateau (Fig. Au7b) represent seismic reflectors which have been tied to wells in the surrounding basins (Stagg & Exon, in prep.) - no wells have yet been drilled on the Scott Plateau.

REGIONAL TECTONIC EVOLUTION

The Phanerozoic tectonic evolution of the western margin of Australia can re related to two separate phases: a speculative, early to middle Palaeozoic phase in which local development of the Tethys Sea was critical; and a better known latest Palaeozoic to Mesozoic phase which has been related, in terms of plate tectonic theory, to the separation of the 'Indian' and Australian parts of Gondwanaland, the pattern of development being similar to that of the 'Atlantic type' margin model (Falvey, 1974).

The first apparent local development of the Tethys Sea at the northern end of the present western margin of Australia was reflected in Early Cambrian volcanism and the development of a northwest-trending aulacogene, north of the Browse Basin (Veevers, 1976). This aulacogene became the site of shallow marine deposition in the Middle Cambrian. Subsequent epeirogenic movements south of this aulacogene progressively initiated 'intracratonic' basins from north to south across the site of the present west coast of Australia. An arm of the Tethys Sea gradually transgressed southward inundating all except the southernmost of these basins by the Late Silurian. Renewed movement in the Middle Palaeozoic created northwest-trending rifts within some of the northern basins (Warris, 1973) and deep northwest trends in the Browse Basin Region.

The Late Palaeozoic to Mesozoic phase of activity consisted of continental rifting movements that eventually led to the splitting off of the 'Indian' part of Gondwanaland from the Australian part. Along most of the present Northwest Shelf of Australia this activity began in the Late Palaeozoic with major tensional movement that produced troughs parallel to the present coastline (Powell, 1976). The troughs were superimposed on the Palaeozoic 'intracratonic' basins, and were apparently open to the sea. The accumulation of thick sediments in the troughs was locally interrupted by tensional movements in the Late Permian, Late Triassic, and Early and Middle Jurassic. These movements produced structural trends, generally at right angles and adjacent to northwest trends that had formed earlier in the Palaeozoic; in the Browse Basin most such movements occurred in the Late Triassic and Jurassic (Allen & others, 1978). Within the complex continental margin development, including the intracratonic basins, a series of parallel horsts and grabens formed east of and parallel to a main rift along which continental separation later took place. Seafloor spreading commenced in the northwest in the late Middle Jurassic but did not progress to the more southern basins until the Cretaceous (Larson, 1975; Powell, 1976).

As the 'Indian' and Australian plates drifted apart in the Cretaceous a marine transgression inundated the remains of the old basins, which were now peripheral to the Australian craton, and eventually submerged their horst blocks. This part of the initial Indian Ocean passed through an early ocean phase, characterised by clastic sedimentation that lasted into the Late Cretaceous (Veevers, Heirtzler & others, 1974). A change to dominantly carbonate deposition in the latest Cretaceous began in the northern end of the Northwest Shelf and progressed southward, marking the beginning of the present ocean phase.

BASIN EVOLUTION

The pre-Permian history of the Browse Basin Region is speculative. Regional geological evidence suggests that an intracratonic basin developed over the area in the early Palaeozoic; its eastern boundary appears to have bordered on the present Prudhoe Terrace. Sediments in the adjacent Canning and Bonaparte Gulf Basins imply that the region was probably inundated by an arm of the Tethys Sea in the early Palaeozoic and again in the Devonian (Veevers, 1971). Stagg (1978) believes that northwest-trending faults along the outer part of the Scott Plateau were initiated early in the basin's existence. The whole region was probably uplifted and eroded in the Carboniferous.

Late Carboniferous-Permian doming of the Scott Plateau area was accompanied by downwarping and marine inundation of the Browse Basin. Along the eastern side of the basin a sequence of paralic clastics and carbonates succeeded by non-marine sand and silt (Figs.Au7a, 7b) shows that the sea regressed westward towards the centre of the basin in the Early Permian. Climatic conditions which had been sub-equatorial throughout most of the Palaeozoic became colder as the Australian continent moved closer to the south pole in the Permian (Embleton, 1973); however, glacigene sediments of Early Permian age in the adjacent Canning and Bonaparte Gulf Basins (Veevers, 1971) have no known counterpart in the Browse Basin.

Block faulting in the Late Permian or Early Triassic left the Scott Plateau and the eastern portion of the Browse Basin (Yampi Shelf and Prudhoe Terrace) upstanding (Fig. 5), and resulted in an erosional wedging out of Permian and Triassic sediments along the eastern side of the Browse Basin (Figs.Au7a, 7b). The same effect may also have been produced along the basin's western flank. No late Permian or Early to Middle Triassic sediments have been intersected in the Browse Basin but Powell (1976) has suggested the basin was probably inundated in the Early Triassic by a sea transgressing southward into the central Browse Basin and gradually regressing northward in the Late Triassic. During the Permian and Triassic the Scott Plateau probably remained largely an emergent, erosional land mass, apart from local structural depressions that appear to have received Triassic fill (Stagg, 1978).

Rifting in the Late Triassic terminated Triassic sedimentation over much of the Browse Basin and marked the start of a period of intense tectonism which culminated in the Early Cretaceous in the onset of seafloor spreading along a rift zone west of the Scott Plateau. The structural evolution of the region during this period is illustrated in Figure 5. Most of the development of the horsts and grabens took place during the Jurassic. The Ashmore Platform was also uplifted at much the same time. Evidence of these movements is provided by the change from a marine to a non-marine environment of deposition (Fig. 6) in Scott Reef 1 and by a major hiatus covering much of the Jurassic in Ashmore Reef 1 (Fig. Au7a). The central part of the basin and related grabens continued to subside and receive thick sequences of fluvio-deltaic to paralic clastics (Fig. 6). The Kimberley Block, the major sediment source during most of the basin's history, continued to supply sediment, but dipmeter data from Scott Reef 1 indicate that the Scott Plateau also provided sediment (Allen & others, 1978). Basic lavas were extruded within the Browse Basin (Fig. 6) and over the Scott Plateau (Fig. 5) during the latter part of the rift valley stage.

There appears to have been little tectonic activity from the Late Triassic to the Late Jurassic at the southern end of the Browse Basin, where sedimentation continued uninterrupted (Fig. Au7a). Results of the deep sea drilling project hole (DSDP 261) west of the Scott Plateau, indicate that final rupture of the 'Indian' and Australian plates in this region occurred early in the Late Jurassic (Veevers, Heirtzler, & others, 1974). Separation of the two plates was followed by foundering of the Australian margin and the

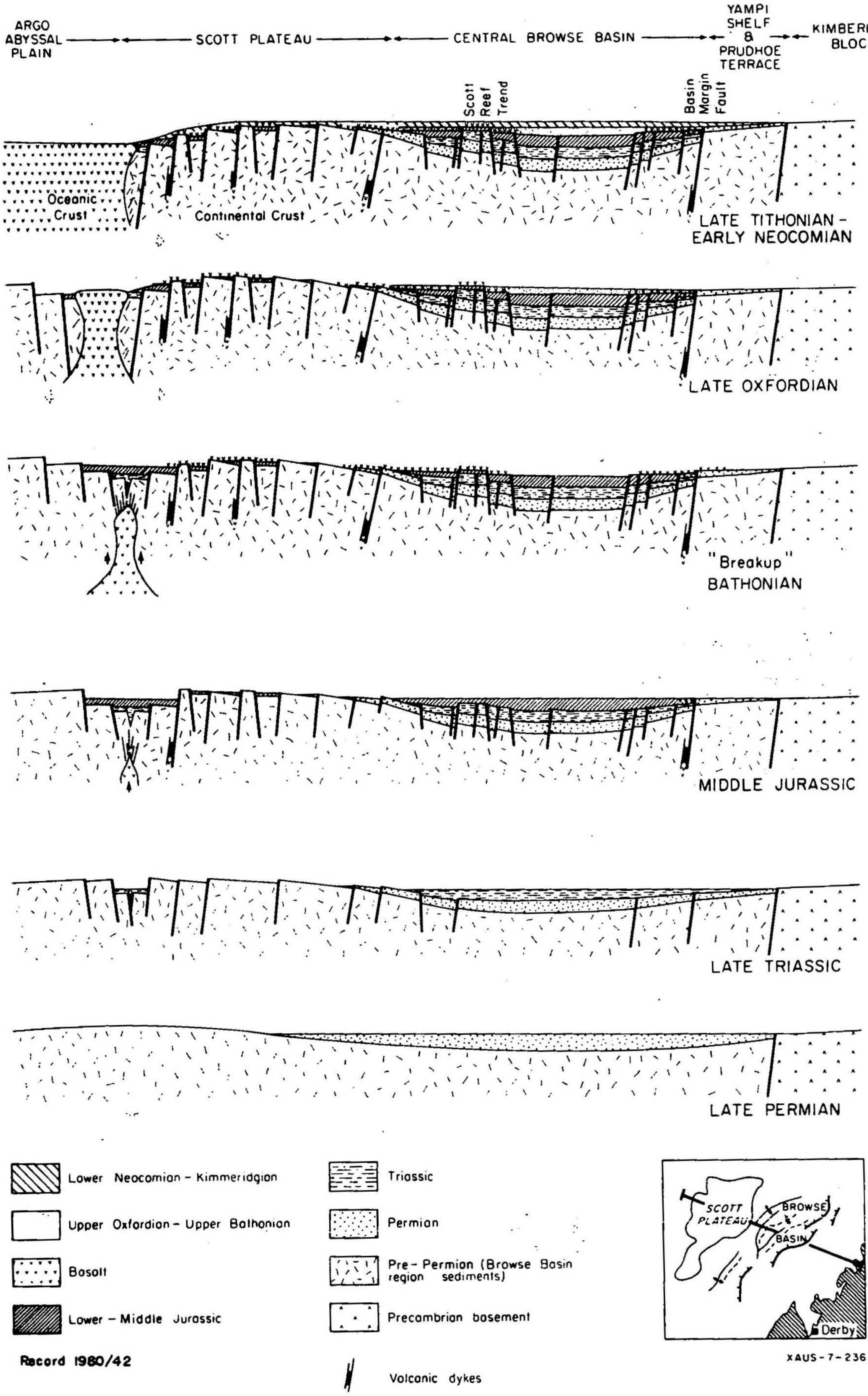

Fig.5 Structural evolution (Allen and others, 1978)

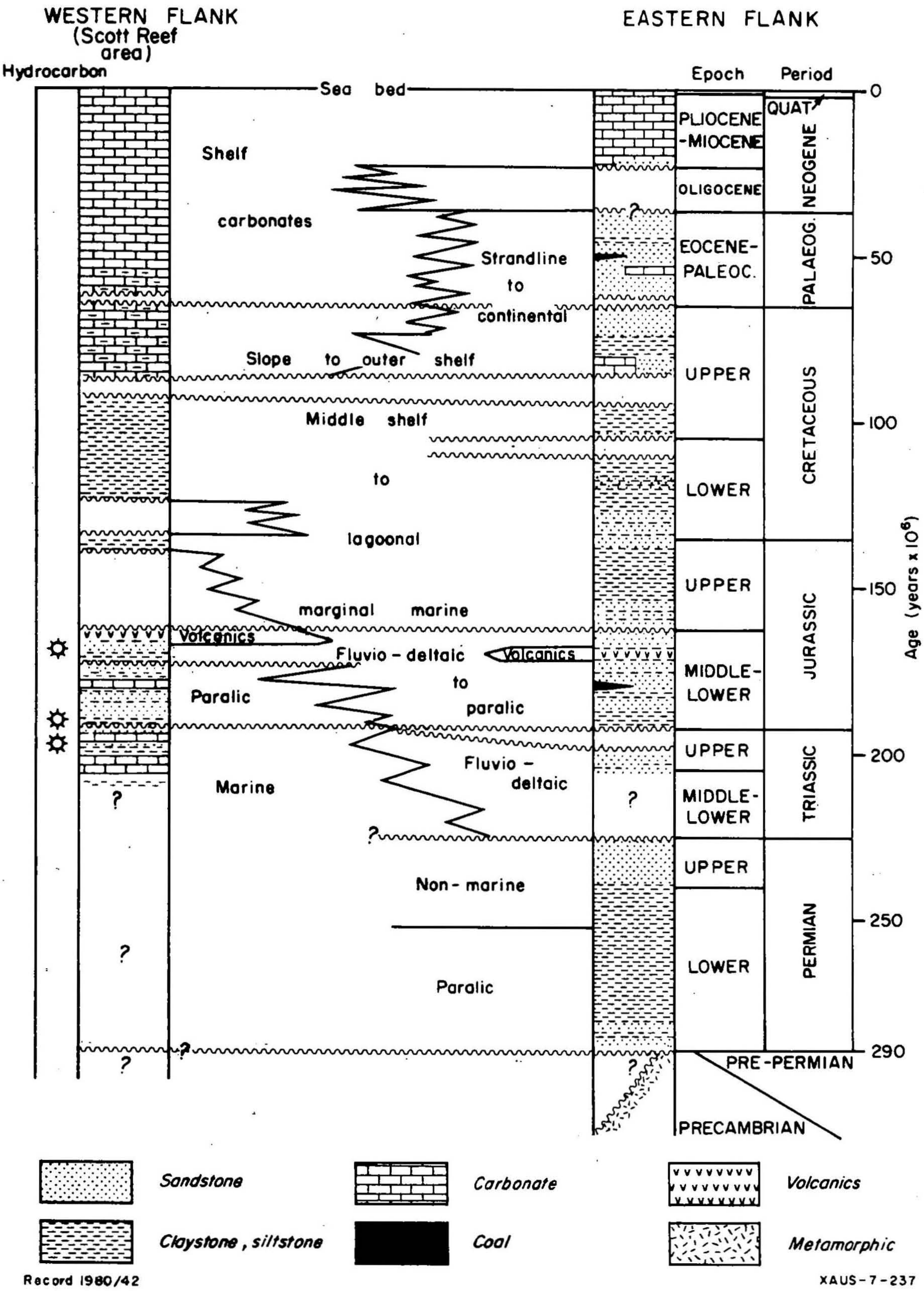

Fig. 6 Generalised stratigraphy Browse Basin (after Allen and others, 1978)

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establishment of shallow marine conditions over the Scott Plateau and Browse Basin during the Latest Jurassic and the Early Cretaceous, when a thick blanket of marine claystone and coarser clastics covered all except parts of the Yampi Shelf.

Parts of the Scott Plateau remained emergent until the Late Cretaceous (Stagg, 1978) when the whole region was tilted westward. This tilting was accompanied by a change from predominantly clastic to predominantly carbonate sedimentation in the western part of the Browse Basin (Fig. Au7b) and temporary subaerial exposure of its eastern part (Fig. 6) (Apthorpe, 1979).

The Late Cretaceous and Cainozoic were generally times of tectonic stability. Sedimentary breaks in the stratigraphy (Fig. 6) are the result of eustacy or local regressions rather than tectonic activity. However, late Tertiary faulting in the northern part of the basin (Allen & others, 1978) may be related to adjustments of the continental margin during collision of the Australian plate with the Indonesian Arc in the late Cainozoic. Gradual sagging of the continental margin since the Late Cretaceous has resulted in the build-up of a prograding wedge of shelf sediments (Fig. 2).

RESOURCES

Hydrocarbons

The small, gas/condensate Scott Reef field is the only proven hydrocarbon accumulation in the Browse Basin region. This field is located near the western margin of the basin, on the Scott Reef Trend, largely beneath Cainozoic atolls on the outer margin of the continental shelf (Martison & others, 1973). Only two wells, the discovery well Scott Reef 1 and a step-out well Scott Reef 2A, have been drilled in or near the field. The discovery well flowed up to 515×10^3 m^3/day and 58 m^3 of condensate (Crostella, 1976) with an API gravity of 49^o-54^o (Allen & others, 1978). There has been no production from the field. Reserves have been estimated at 0.068 trillion m^3 for gas and 6.36 million kL for condensate (Beddoes, 1973).

The only proven hydrocarbon reservoirs (Fig. 6) in the Browse Basin are the rift valley sediments - Late Triassic and Early to Middle Jurassic fluvial/deltaic and paralic sands and carbonates - below the Late Jurassic (breakup) unconformity (Crostella, 1976). The overlying Late Jurassic to Early Cretaceous marine claystone acts as both the seal and the major source rock; Triassic and Early-Middle Jurassic claystones interbedded with the reservoir rocks are also thought to have source rock potential (Allen & others, 1978). Hydrocarbons contained in the fluvial/deltaic sediments may have suffered delayed maturation relative to marine source rocks as a result of the terrestrial nature of the organic material. Hydrocarbon shows recorded from sandstones within Late Jurassic and Early Cretaceous porous clastics suggest that these rocks also have some reservoir potential. The thick Late Cretaceous and Early Tertiary sandstones along the eastern flank of the basin have good reservoir characteristics but, where tested, lack a vertical seal.

Hydrocarbon traps in the Browse Basin are predominantly structural. The trap forming the Scott Reef field consists of a horst block, the Permian to Jurassic sediments of which have been draped and sealed by Jurassic-Cretaceous marine shales (Fig. 2), and is analogous to traps along the Rankin Trend (Carnarvon Basin) which contain commercial quantities of gas (Powell, 1976).

The Scott Reef field discovery well, drilled in 1971, was one of the early wells in the Browse Basin. Subsequent drilling has been generally disappointing. Some encouragement, however, came in 1978 from a strong oil show in Caswell 1 in the central Browse Basin; this well established the presence of oil as well as gas in the basin, but details have not been made public. Future exploration will probably concentrate on deep-water structures (Playford, 1975).

The hydrocarbon potential of the Scott Plateau is not rated highly. Over much of the plateau the potential source rocks are probably of Palaeozoic age, and any hydrocarbons generated have most likely been lost during Late Palaeozoic and Mesozoic emergence and erosion (Stagg, 1978; Stagg & Exon, in prep.). However, pinch-outs of the thicker Mesozoic sequence to the east against the older rocks of the plateau may form possible targets. The great water depth (Fig. 4) would make any exploitation a costly venture.

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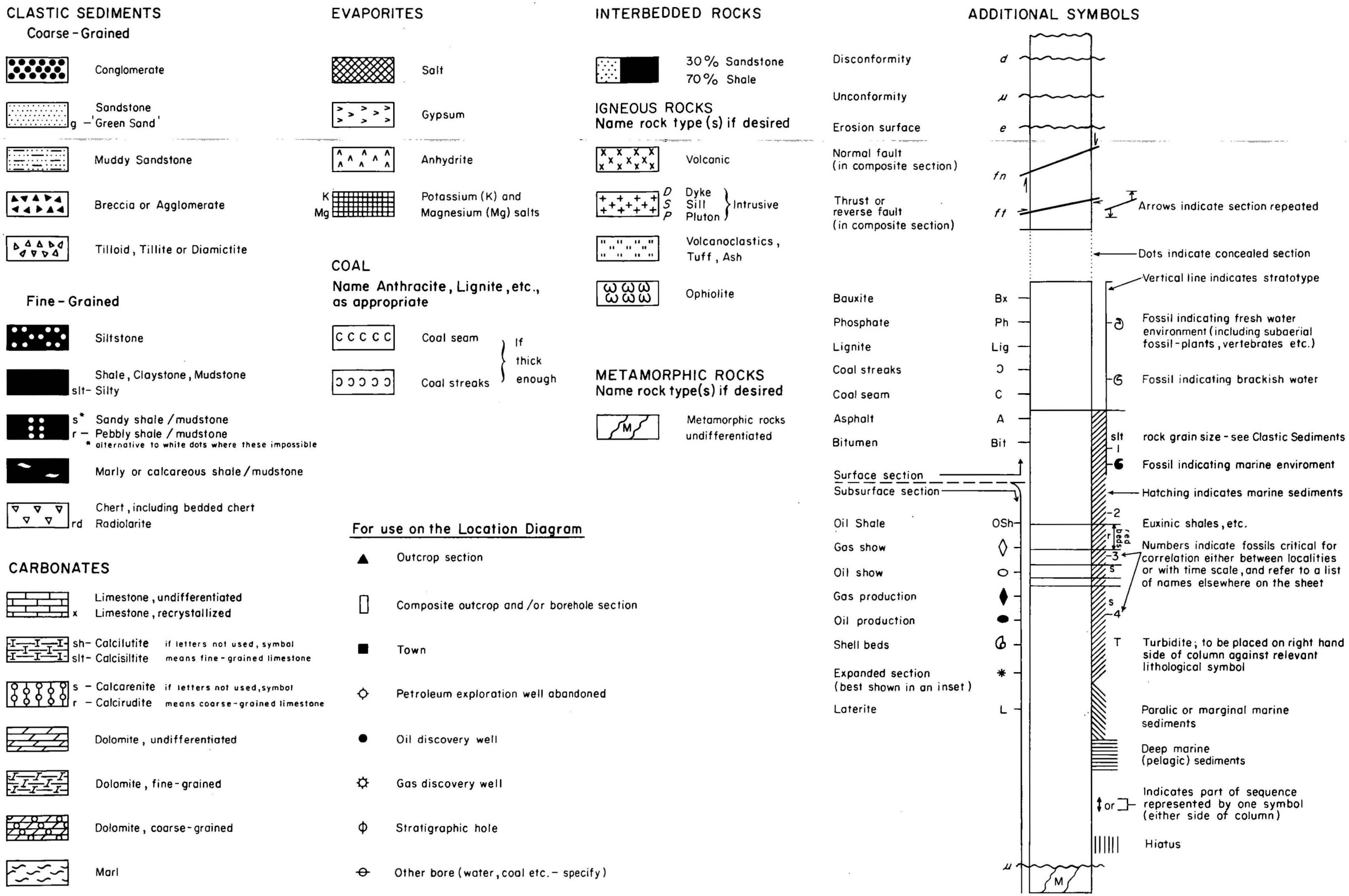
Fig. Au 7



Standard Legend for Stratigraphic Columns

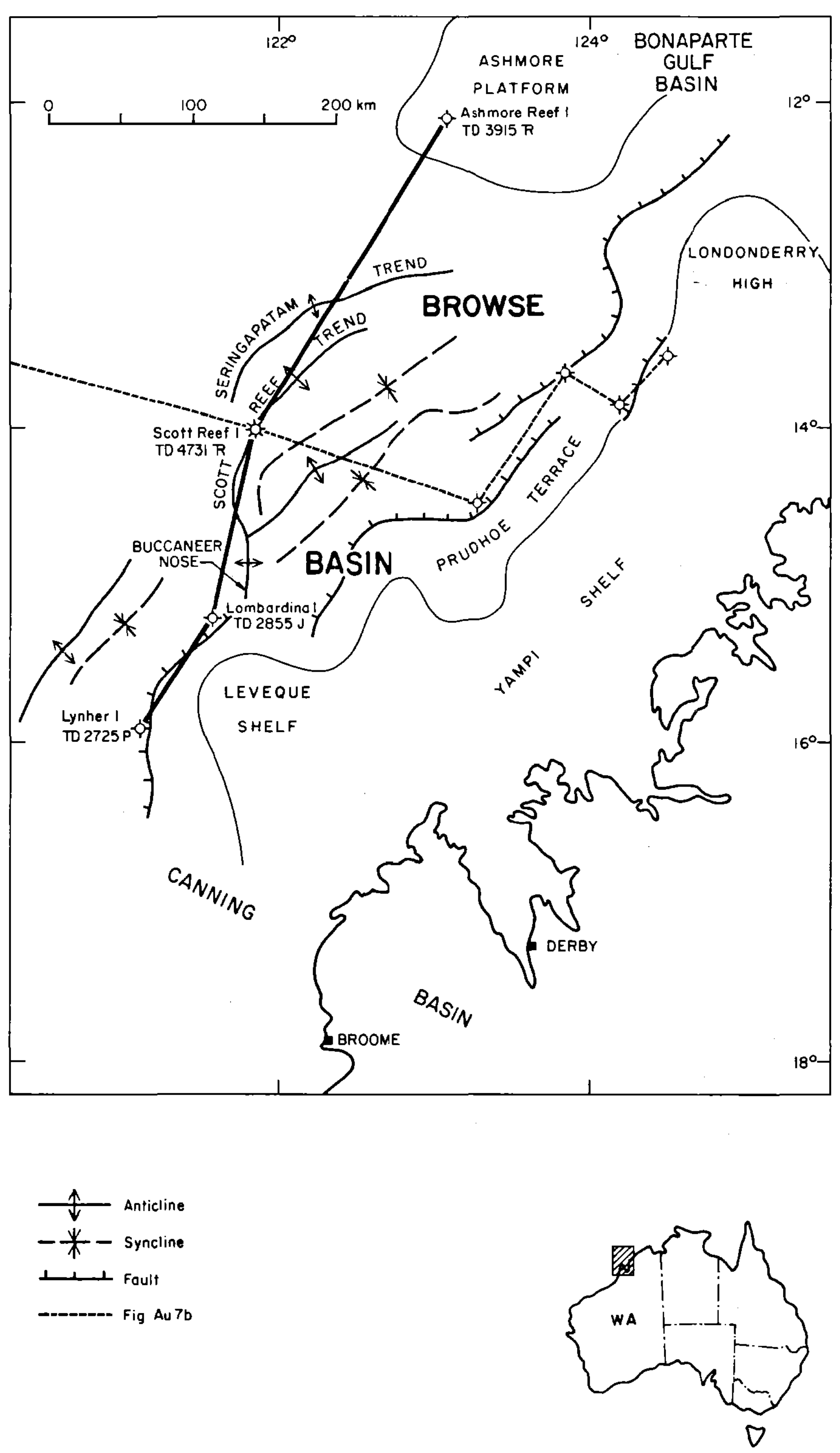
AUSTRALIA

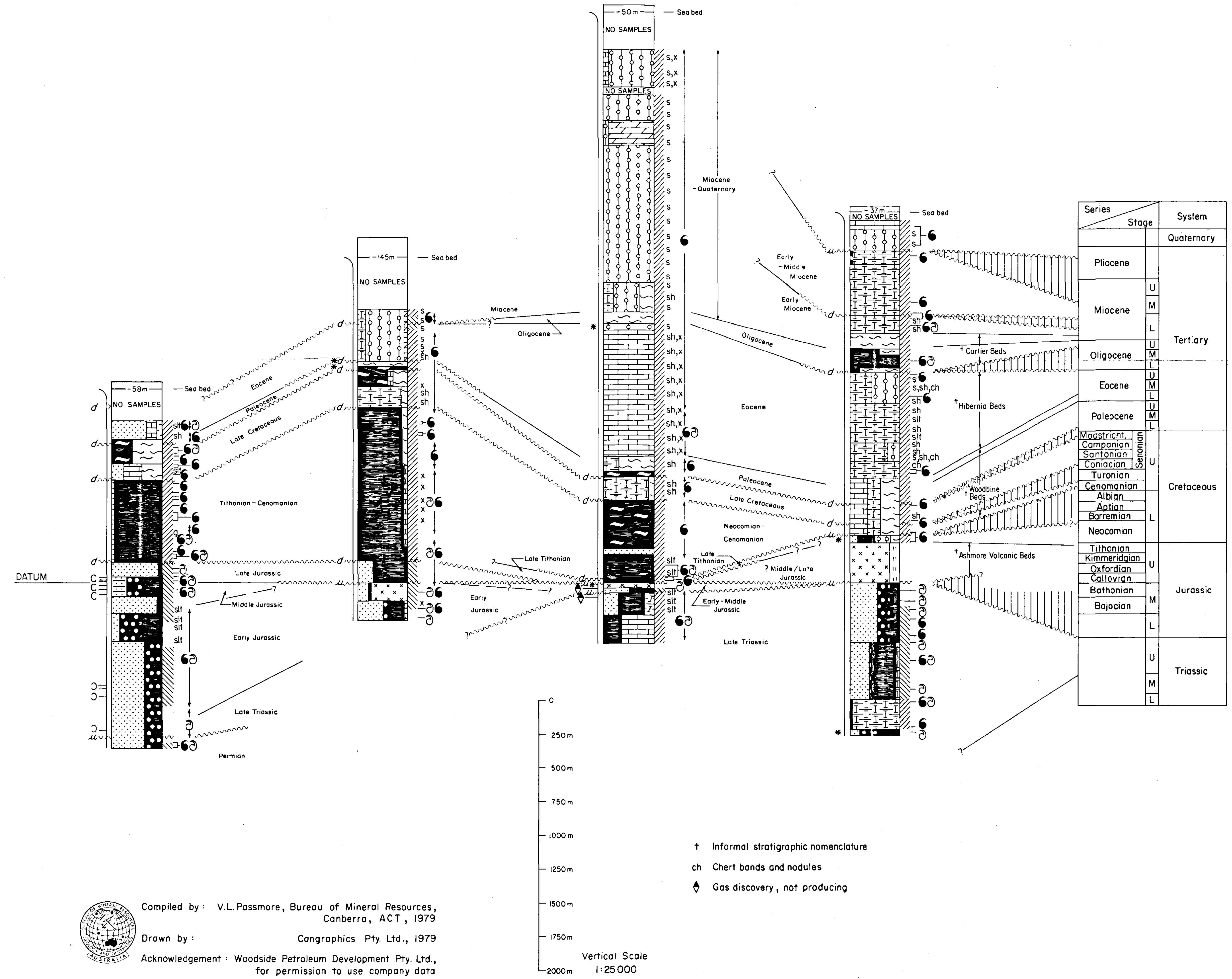
BROWSE BASIN: NORTHWESTERN WESTERN AUSTRALIA

Fig. Au 7a

ESCAP ATLAS OF STRATIGRAPHY (IGCP PROJECT No. 32)

LOCATION DIAGRAM





† Informal stratigraphic nomenclature

ch Chert bands and nodules

Gas discovery, not producing

Compiled by: V.L. Passmore, Bureau of Mineral Resources, Canberra, ACT, 1979

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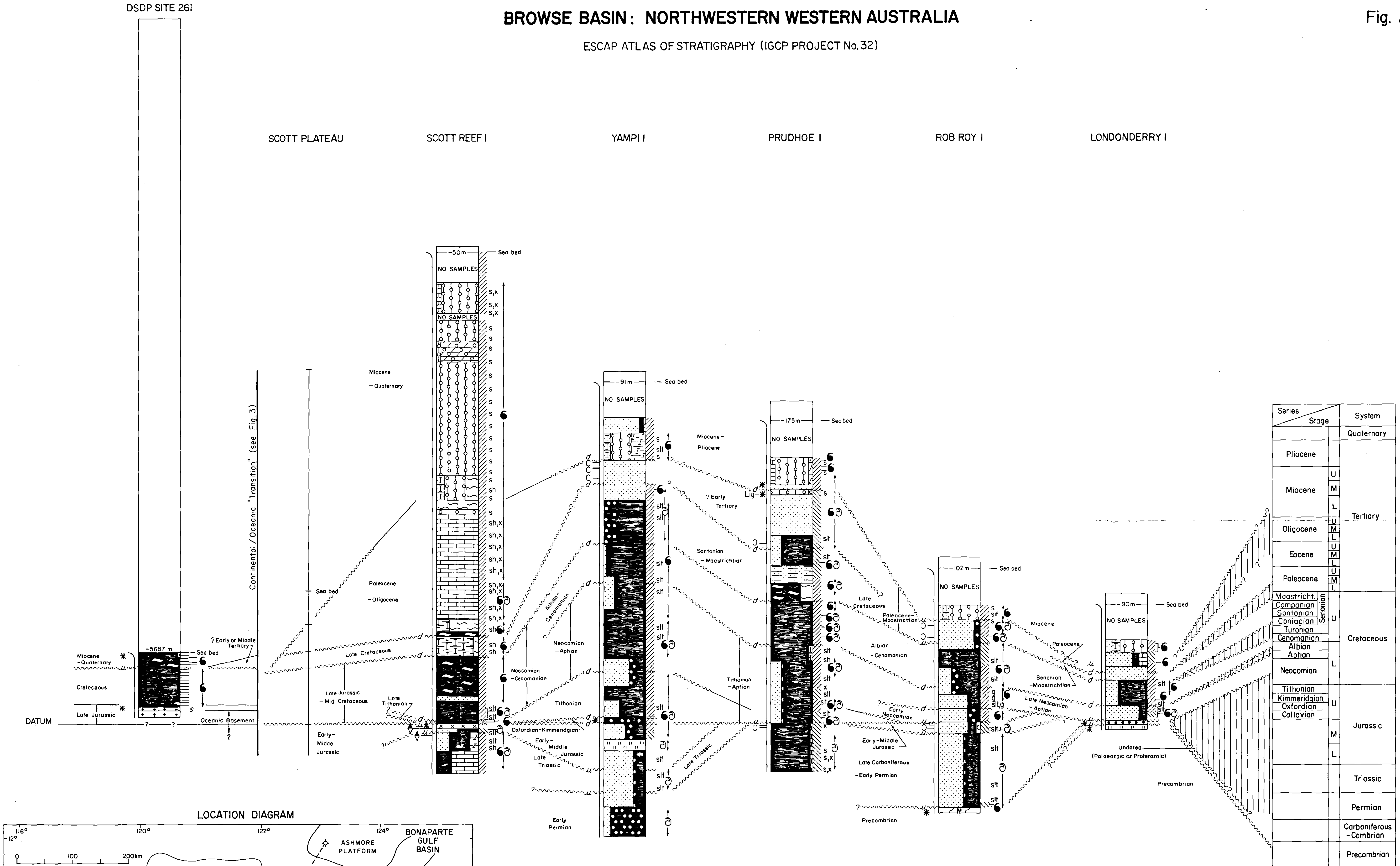
Acknowledgement: Woodside Petroleum Development Pty. Ltd., for permission to use company data

AUSTRALIA

BROWSE BASIN: NORTHWESTERN WESTERN AUSTRALIA

ESCAP ATLAS OF STRATIGRAPHY (IGCP PROJECT No. 32)



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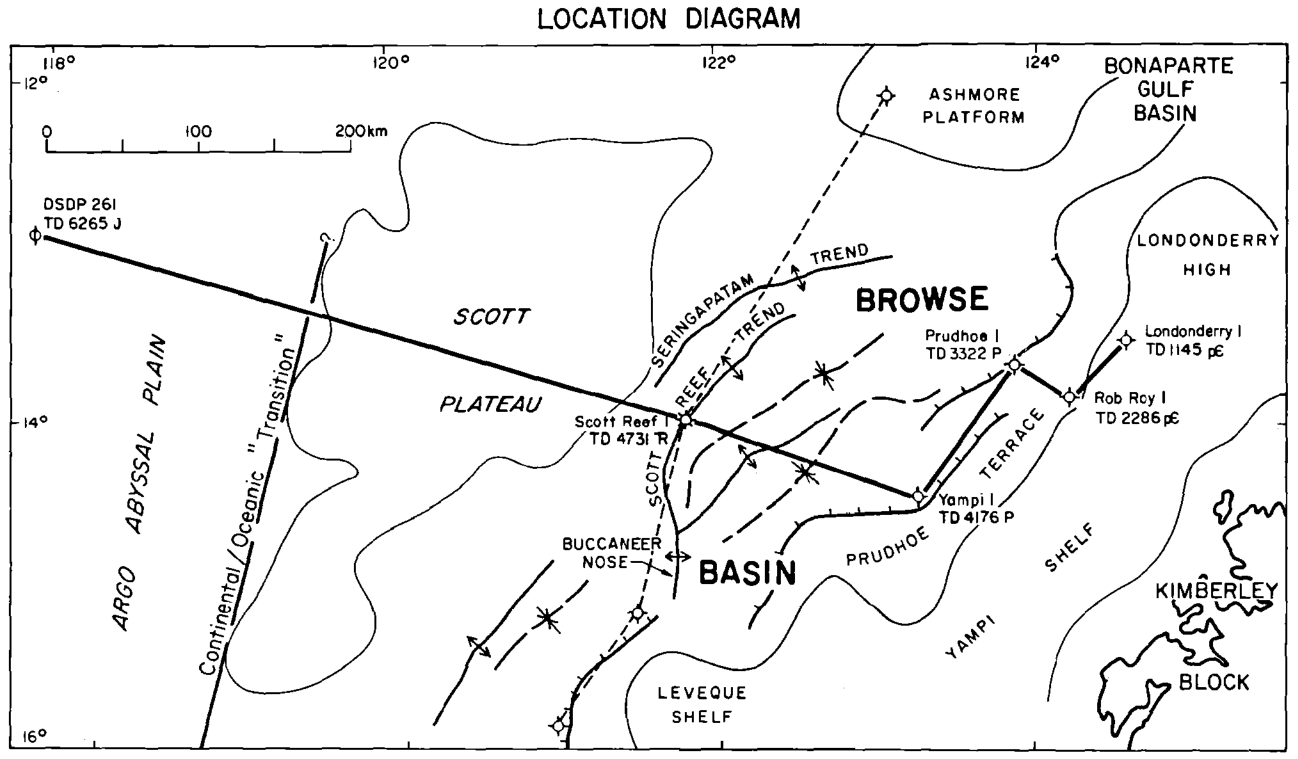

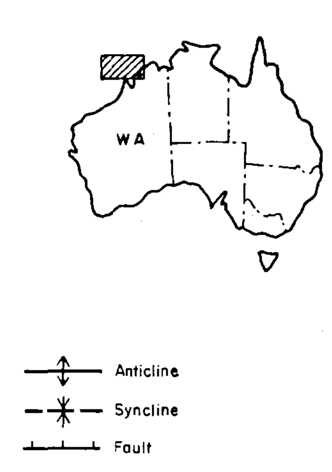

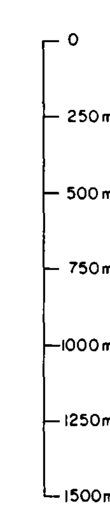

Vertical Scale 1:25 000

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