The Tectonic Framework of the Canning Basin, WA, including 1:2 million Structural Elements Map of the Canning Basin

Record 1994/48

by R.D. Shaw, M.J. Sexton & I. Zeilinger

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: Hon. David Beddall, MP
Secretary: Greg Taylor

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Neil Williams

ISSN: 1039-0073
ISBN: 0 642 22354 8

CONTENTS

PLATES (Continued)

Structural elements, Canning Basin and surrounding region

SUMMARY

The Canning Basin is a complex, composite, long-lived, pericratonic basin that has experienced several extensional episodes: in the Ordovician, the Mid-Devonian, the latest Devonian-Carboniferous and possibly in the earliest Permian. Later extension, in the latest Permian, the Mid-Jurassic and the Cretaceous, was centred offshore. The basin also experienced transpressional faulting in the Mid-Carboniferous (early Namurian, here termed the Meda Movement) and major right-lateral strike-slip faulting in the Late Triassic to Early Jurassic Fitzroy Movement. A less well defined compressional movement, the Prices Creek Movement, took place in the Early Devonian. These extensional and compressional events divide the basin into a number of successor sub-basins.

A mid-basinal basement arch, with a thin sedimentary cover, separates two deep northwest-trending complex troughs. The main part of the northern trough, the Fitzroy Trough is up to 15 km deep, and is separated by a basement high, the Jones Arch, from its southeastern extension, the Gregory Sub-basin. The southern trough contains about 4-5 km of mainly Ordovician to Silurian deposits, covered by less than one kilometre of Devonian and younger sedimentary rocks. It is divided into a narrower and more extensively faulted western part, the Willara Sub-basin, and a broader much less faulted eastern part, the Kidson Sub-basin.

Two bounding-fault complexes controlled the tectonic development of the Fitzroy Trough. The northern margin was controlled by the Beagle Bay-Pinnacle Fault Complex and the southern margin by the Fenton Fault Complex. Many of the Devonian reef complexes developed within these fault complexes. Both these fault complexes are shown to be listric, at least locally. Each fault complex appears to be linked, at least in part, to zones of detachment faulting localised at or near the base of the sedimentary succession. Locally, the two complexes, including their linked detachment zones, may merge across the basin. The northern fault complex branches eastwards into a series of faults, some of which controlled development of a separate depocentre to the southeast, the Gregory Sub-basin. Within the central western part of the Fitzroy Trough, other more - westerly trending faults also appear to have also influenced deposition.

The Fenton Fault Complex also controlled development of the southern margin of the Gregory Sub-basin. The eastern margin of this sub-basin was controlled by a separate and more complex array of faults resulting from the influence of northerly trending features such as the Billiluna Fault.

The faults in the southern Willara and Kidson Sub-basin differ from those controlling the northern trough. Here, the main fault features, the Admiral Bay and Munro Fault Zones, form a array of sub-parallel normal faults.

Pre-existing basement province boundaries, interpreted from geophysical domain boundaries, appear to have exercised an important and recurring control on the localisation of major Palaeozoic extensional structures. For example, the southern margin of the Lennard Shelf approximates the magnetic domain boundary that may represent the southern limit of the King Leopold Orogen. In its central part the shelf appears to correspond to a major gravity feature sourced in the basement. A second basement province boundary, interpreted from the regional Bouguer gravity pattern, roughly corresponds to the southern margin of the Jurgurra Terrace. The same boundary appears to continue to the southeast, approximately along the southern margin of the Crossland Platform.

Within the Fitzroy Trough, major transverse accommodation zones separate segments of the main linked fault systems into partially separate depositional compartments. Each compartment appears to have undergone varying amounts of extension in two or more episodes. Along the northern margin of the Fitzroy Trough, these transverse zones appear to cut and offset the reef complex on the Lennard Shelf, but they do not extend far into the basement to the north. That is, these orthogonal zones are not obviously related to pre-existing basement structures. Thus, although several of the master faults controlling the margins of the Fitzroy Trough reveal some degree of control by pre-existing basement structures, the extensional accommodation zones show no marked control. Accommodation Zones are less apparent in the Gregory Sub-basin.

In contrast, transverse accommodation zones are uncommon in the south of the basin and appear to coincide with basement arches, that may reflect basement inheritance. This contrast in the style of deformation may be a feature of older Ordovician tectonism evidence of which has largely been destroyed

by later movements in the north. Here the main fault zones, such as the Admiral Bay Fault Zone, are made up of closely spaced, sub-parallel faults. Weak linkage between these fault segments is by means of relay zones (transverse ramps).

The basins' episodic history is well illustrated both by the seismic record and by the geohistories derived from well data. In the Ordovician, extensional faulting commenced at the northern margin of the Fitzroy Trough and along the northern margin of the Willara Sub-basin (Admiral Bay Fault Zone) and the Kidson Sub-basin subsided. In the mid-Devonian, the compressional Prices Creek Movement produced a new topography. Renewed subsidence, possibly driven by extension located deep in the lithosphere, started in the Early Devonian (Mid-Emsian) and resulted in deposition of the Tandalgoo and Poulton Formations. The main rifting episode, producing the space to accommodate much of the fill in the Fitzroy Trough, lasted from the mid-Givetian to Early Carboniferous. This episode, known as the Pillara Extension, occurred in three or more pulses (or extensional movements). The first two major pulses of extension, the Gogo Movement (Mid-Givetian to Frasnian) and the Van Emmerick pulse, (latest Frasnian to Famennian) resulted in rapid subsidence of the Fitzroy Trough, thereby accommodating thick carbonate buildups and thick lowstand clastic wedges. The interleaved carbonate reef complexes rapidly became the deposits dominant on the Lennard Shelf. After the second pulse of extension, the Van Emmerick pulse, there appears to have been a major shift in the faults controlling subsidence. As a result, sites of deposition shifted away from the northern margin of the Fitzroy Trough and the region of deposition appears to have widened. This rearrangement may explain the transgressive nature of the Pillara reef-building cycle versus the regressive nature of the Nullara reef-building cycle on the Lennard Shelf. The third renewal of extension, termed the Red Bluffs Extension, started in the late Famennian and continued into the Carboniferous. This movement, is suggested by the rapid accumulation of slope conglomerates and the progressive thickening of the Laurel and Anderson Formations towards the Fenton Fault System.

In the Mid-Carboniferous, limited transpressional fault movement, caused the inversion of some pre-existing extensional structures in the northeastern part of the Fitzroy Trough. The transpression coincided with an emergence of the region above sea level, expressed as the unconformity at the base of the Grant Group. This episode of emergence and local inversions, the Meda Movement, correlates with the peak of the Alice Springs Orogeny in central Australia. In the Late Carboniferous, pockets of lower Grant Group deposition, occurred in foreland-like synclinal depressions along the northern margin of the Fitzroy Trough.

A resurgence of extension in the earliest Permian, the Point Moody Movement, is indicated by a marked thickening of the clastic upper Grant Group towards the Fenton Fault System.

In the earliest Permian, the Lagrange Extensional Movement (centred offshore), may represent a thermal sag phase, during which the Blina Shale was deposited unconformably on the Liveringa Group.

The last major tectonism, the Fitzroy Transpressional movement, was during the Late Triassic to Early Jurassic. It produced dextral shear that reactivated the faulted margins of the Fitzroy Trough, inverting earlier extensional structures. Within the trough, broad east-trending anticlines and arrays of small shear faults formed obliquely to margins of the basin.

INTRODUCTION

AIMS OF REPORT

This report presents the 1:2 000 000 Structural Elements Map of the Canning Basin (Plate 1 by describing the various elements, their controlling faults and their affect on basin development. The map incorporates the results of AGSO's Canning Basin Project carried out between 1990 and 1994. This report also attempts to rationalise previously published structural and tectonic terminology and to clarify the definition and naming of individual tectonic elements and structures. The limits of the structural elements are not always well defined due to poor outcrop and limited seismic coverage; in Plate 1 the faults are positioned where they are estimated to intersect the surface. In order to provide a 3D-picture of the basin, and present preliminary new interpretations of deep-seismic sections BMR 88-01 and BMR 88-03, (Plates 2 and 3).

The report has three parts. The first discusses basement structures and tectonic events. The second, following a general outline of the basin as a whole, briefly describes individual structural elements in the basin. The third part presents a reconstruction of the tectonic history in an attempt to understand the subsidence history of the basin in terms of the movement on the major structures. The report concludes by commenting on some of the characteristic and unique features of the Canning Basin, emphasising the importance of reactivation of basement structures.

DATA SOURCES

The published sources used to define each element are listed in the **Appendix**. Each element is also given an identification number and a recommended abbreviation. The main references defining the tectonic elements include those by Gorter et al. (1979), Foreman & Wales (1981), Purcell & Poll (1984), Yeates et al. (1984), Begg (1987) and Goldstein (1989). The starting point for compilation of the map was the 1:1 000 000 geological map of Towner & Gibson (1983). Reconnaissance field work was carried out in support of the project at the northern margin of the basin by R.D. Shaw in 1989 and 1990. Early definitions of the structural elements were reassessed in terms of current data, and some were redefined to achieve consistency and compatibility with current subdivision of the sedimentary basins of Western Australia compiled by Hocking et al. 1993, based on Geological Survey of Western Australia maps of the base of the Permian Grant Group (Taylor et al. 1990) and the top of the Ordovician succession (Iasky et al. 1991). For the structural elements in the offshore Canning Basin, this report adopts the recent usage of Passmore (1991 and Hocking et al., 1994). The tectonic elements for the surrounding basement region to the south of the basin are mainly derived from the recent review of the geology and mineral resources of Western Australia (Geological Survey of Western Australia, 1990).

Surface 1:250 000 geological maps, Bouguer gravity maps and aeromagnetic TMI maps have formed an important source of basic data in the compilation.

PREVIOUS INTERPRETATION OF DEEP SEISMIC DATA

Two deep seismic profiles, recorded in 1988 by AGSO (then BMR), were designed to test various models of basin formation (Plates 2 and 3). Most previously published sections across the Fitzroy Trough show symmetrically distributed normal faults controlling the basin margins. However, a review of selected exploration seismic data (Drummond et al. 1991) suggests that the rifting is, in fact, asymmetrical with normal faults along one side only. In the BMR deep seismic profile, (BMR88-03, Plate 2a, 2b) the southwestern margin of the Fitzroy Trough is bounded by normal faults that appear to detach at about 7 s two-way-travel time (15-17 km for a mean velocity near the base of the sedimentary succession of about 4.3 km/s). In contrast, normal syn-rift faults formed during the Devonian on the northern margin appear to have relatively small displacements.

A surprising result of the 1988 BMR deep seismic profile across the Canning Basin was the discovery of two complex crust-cutting bands of reflectors, one of which extends to mantle depths (Drummond et al. 1991). The most prominent of these seismic events is interpreted to be a basement fault system that dips gently to the southwest from the northern margin of the basin (Plate 2a, 2b). As this feature is not readily explained by current models for the development of the basin it may be a largely passive basement feature.

The two deep seismic profiles across the trough are sufficiently different in seismic character to suggest that, during Devonian extension, the basin was segmented into compartments separated by orthogonal fault zones, which accommodated to different degrees of extension.

TERMINOLOGY

The terms adopted for tectonic and structural elements in the Canning Basin generally follow the recent summary of terms explained and illustrated by Hocking et al., 1994. They are based on precedent and local usage, as in other basins around the world The term *shelf* is used in the sense of a palaeo-continental shelf, where a wide and substantially cratonic region has been onlapped by shallow marine deposits. *Platform* is commonly applied to an isolated shelf region not attached to the cratonic landmass. In the Canning Basin the platforms represent more restricted, isolated regions within the main basin where limited, but episodic, subsidence implies some tectonic instability. *Embayment* is used for a downwarped re-entrant containing a thin succession, into an adjacent shallower or older structural element: for example, a region of shallow basement landward of a trough. Such regions commonly contain strata resting directly on basement or lying at the basement margin. Examples are the Pender, Napier, Margaret

River, Wallal and Samphire Embayments. These features are best considered to be marginal components showing enhanced subsidence within the wider shelf regions. *Terrace* is applied to those parts of the inferred palaeo-continental shelf that have either been more submerged or undergone greater amounts of subsidence than the main part of the shelf. They occupy part of the slope between the main shelf region and the basin floor. The Laurel Downs Terrace, for example, is considered to be part of the Lennard Shelf, as it is capped by shelf carbonate deposition; other examples are the Jurgurra and Barbwire Terraces. Because these terraces are generally bounded by normal faults, they are not part of the craton. They mark the edges to the main *troughs*, *deeps* or *sub-basins*. The Kidson Sub-basin differs from the other sub-basins in that it is not surrounded by terraces and contains few obvious extensional structures, (see Romine et al, 1994). Following current usage in the basin, *Highs* are elongate, basin-parallel regions of shallow basement, whereas *arches* are similar features separating sub-basins.

Following recent models of faulting tectonics in basins (e.g. Gibbs 1984), we began, like Begg (1987), by attempting to map linked extensional fault systems that emphasise three-dimensional fault-components such as splays, listric fans, flats, ramps and sidewall structures such as transfers. We recognised a series of fault blocks or compartments, formed by the interaction of extensional and transfer faults. As the fault mapping progressed, it became convenient to adopt a procedure started by Begg, and give a different name to each fault system lies between major accommodation (transfer) zones.

It turns out that the sets of normal faults bordering the Fitzroy Trough, the most prominent feature in the Canning Basin, are unusually complex. For this reason, a hierarchy of terms was developed to describe, at different scales, these composite fault features and their individual elements. We use four terms for these hieratical features.

1. The term *Fault Complex* is applied to each of the two belts of interconnected fault systems, and auxiliary faults, that border each side of the Fitzroy Trough.

2. For the Canning Basin, the term *Fault System* is used for semi-continuous master faults and their linked accommodation/ transfer structures, together with linked minor faults. Interaction of these faults and accommodation structures allows a consistent amount of extension within a particular region. So, the pattern of minor faulting within each compartment is distinctive, and related to the amount and direction of displacement on the master fault. Each fault system is separated from its neighbours by a major accommodation (or transfer) zone. Minor changes in normal and transfer fault pattern, reflecting small adjustments to the amount of extension, are grouped within the one fault system.

3. The term *Fault Zone* is applied to narrow zones of closely spaced, sub-parallel faults that may or may not be linked or joined at depth. These zones are not divided into compartments by accommodation zones.

4. The term *Fault Segment* is used to refer to either an individual fault within a discontinuous or en echelon fault zone, or those parts of one long fault that are broken up to some degree by one or more transfers or accommodation zones.

In the recommendations at the end of this report, we suggest how this scheme for naming extensional faults can be simplified in future studies. In this region the naming of other fault types, such as strike-slip faults, and contractional thrust faults and shear zones, is more straight forward.

The term *Accommodation Zones* (see Rosendahl 1987, Ebinger 1989, Morley et al. 1990) is a general term for structures that separate regions showing different fault geometry or spacing, thereby implying changes in the amount or direction of extension. It includes specific features such as transfer and relay zones (see below) as well as more complex features. Many of the accommodation zones at the margins of the Fitzroy Trough lie transverse to the basin margins and show a complex geometry as a result of a multi-phase history. In other regions of the world such zones can also trend oblique to the main border faults of basins or half grabens (Morley 1990).

Transfer Faults (see Gibbs 1984), a category of accommodation zones, are single cross-faults that are an integral part of a linked extensional fault system.

Relay zones are very different to transfer faults. Within some zones of sup-parallel faults, displacement between overlapping en-echelon fault segments is accommodated largely by lateral ramps (Larsen 1988, Morley et al. 1990, Peacock & Sanderson 1991, Schlische 1993). Variable, but minor, degrees of faulting and/or folding allow for further strain adjustment within the zones.

One other term needs clarification. The blocks between parallel arrays of faults within *fault zones* are termed *riders* (Schlische 1993). Gibbs (1984 p. 613) suggests that such riders are small rotated blocks that sit on a master detachment zone. They are seen to accommodate localised strains, especially those generated as a result of the curvature on the listric part of a detachment zone.

STRATIGRAPHY

This report adopts the stratigraphic framework published by Kennard et al. (1994a) and illustrated in Figure 1. The tectonic events identified in this report that correspond to or closely follow stratigraphic breaks are also shown Figure 1 and summarised in Table 1. The Palaeozoic stratigraphy is outlined further in Table 2, and the basement stratigraphy in Table 3.

REGIONAL GEOLOGICAL SETTING

The regional setting of the Canning Basin is illustrated in Plate 1 and summarised in Figure 2. The Canning Basin consists of two deep, northwest-trending troughs, separated by a mid-basinal arch, where less than two kilometres of sediment are preserved. The northern trough is filled largely by Devonian to Carboniferous rocks and comprises the Fitzroy Trough and its south-easterly continuation as the Gregory Sub-Basin. The southern trough is filled largely by Ordovician rocks and is divided into the Willara and Kidson Sub-Basins. The arch, made up of the Barbwire and Crossland Platforms, is covered by a reduced section that includes both Ordovician and Devonian rocks. Younger successions, dominated by Permian rocks, cover much of the basin and are thickest in the Fitzroy Trough.

The deepest part of the basin is the Fitzroy Trough, which is more than 15 km deep and 850 km long by 100 km wide. The trough is a complex halt-graben that thickens towards the Fenton Fault, the dominant feature of a listric fault complex. To the north, it is separated from the Precambrian basement rocks of the King Leopold Orogen by the Lennard Shelf and the Pender and Margaret Embayments. The boundary between these terraces and the trough is marked by the Beagle Bay-Pinnacle Fault Complex. To the south, the trough is separated from the Broome and Crossland Platforms by the Fenton Fault Complex (see insert in Plate 1 showing Principal Structural Elements).

In the far southeast, the Canning Basin is weakly connected with the generally older Amadeus and Officer Basins. The connection with the Amadeus Basin mainly involves Ordovician strata. The connection with the Officer Basin is dominated by Permian strata, although Neoproterozoic strata, more typical of the Officer Basin, are present but largely deeply buried in the far southeastern part of the Canning Basin.

The general form of the central Fitzroy Trough is shown in cross-section in Figure 3, and in two regional deep-seismic lines across the central and eastern parts of the Trough plates 2 and 3).

GRAVITY EXPRESSION OF THE CANNING BASIN

The gross shape of the basin, and underlying basement structure is reflected in Bouguer gravity anomaly maps. Figure 4 displays the basement tectonic elements and their positions relative to the pattern of the Bouguer gravity anomalies in the region.

A close correlation exits between gravity features (shown in Fig. 5) and the main Structural Elements (compare with Plate 1). A comparison of Figures 4 and 5 shows that many of the basement tectonic elements ("provinces") broadly correspond to areas with different structural style. This image also illustrates that, in many cases, both the major extensional fault system of the Fitzroy Trough and the associated accommodation zones appear to correspond to discordant, linear features in the regional gravity (Bouguer anomalies). This is illustrated further in Figure 6, where the change from positive to negative gravity values is emphasised.

At a more regional scale, the postulated position of the regional zones of accommodation separating the Canning and Amadeus Basins at various times, such as in the Mid-Devonian (compare with Anfiloff & Shaw 1973, Forman & Shaw 1973, Braun et al. 1991), appears to correspond to discordant gravity lineaments (see Fig. 4). However, accommodation cannot be ascribed to any one single zone. In addition, the sigmoidal bend in the gravity feature corresponding to the Paterson Orogen (compare with Mathur & Shaw 1982) is consistent with an overall sense of apparent distributed dextral 'shear' across a region lying between the Canning and Amadeus Basins.

PART 1: BASEMENT STRUCTURES AND TECTONIC EVENTS

Several features, inherited from Proterozoic to earliest Palaeozoic basement, exercise an important and recurring control on Phanerozoic basin development. The stratigraphy of the Proterozoic basement, summarised in Table 3, forms a backdrop to understanding the basement evolution and, hence, basin development.

Linked, northwest-trending shear zones in the King Leopold Orogen to the north of the basin form an anastomosing network and are of more than one age. The oldest of these shear zones succeeded earlier folding events and formed part of the D_3 Yampie Event (Tyler & Griffin 1990, Shaw et al. 1992). The shears commonly strike 110°-115° and their S-C fabrics, preserved where these zones cut granite, indicate northward transport (Tyler & Griffin 1990). The shears are younger than the age of the 1890-1850 Ma Barramundi Orogeny (Page & Williams 1988) and older than the youngest of the Late Proterozoic glacial successions, which are thought to have been deposited at about 650-640 Ma (Bofinger 1967, Plumb 1980). Thus, they are Mid-Proterozoic in age, probably 1000 Ma or older (Shaw et al. 1992),

A younger D_4 event, the Precipice Event, is evident in the Precipice Fold Belt (Griffin & Myers, 1988) at the southern margin of the Kimberley Basin. Here, Tyler & Griffin (1990) observed that the D_4 axial-plane cleavage cuts through the unconformity separating the Kimberley Basin succession from the overlying Late Proterozoic glacigene sediments, indicating that the D_4 cleavage postdates these sediments. In the Precipice Range in the north of the King Leopold Orogen, the thrusting is south-directed, whereas in the Louisa Basin (Plate 1, LSB) the thrusting is east-directed (Shaw et al. 1992). Based on limited K-Ar and Rb-Sr isotopic data, the age of D4 is estimated at about 530-560 Ma (Shaw et al. 1992, compare with earlier work of Bennett & Gellatley 1970).

During the subsequent D_5 Spielers deformation, north-directed thrusting and folding took place in the southern King Leopold Orogen and in the Oscar and Pillara Inliers. Shearing, accompanied by quartz-veining and post-shearing annealing recrystallization took place under low-grade greenschist metamorphic conditions. This shearing is considered to be the same age as thrusting affecting nearby Late Proterozoic glacial successions.

One Proterozoic shear zone of particular importance is the Spielers Shear Zone in the southern Oscar Inlier (north of the Djowi Fault in Plate 1), as this shear zone became the locus of subsequent normal faulting during development of the Phanerozoic Fitzroy Trough. The shear zone marks a major thrust boundary between the Mid-Proterozoic Proterozoic Whitewater Volcanics and Marboo Formation to the south, and younger metasediments to the north that include rocks which are arguably glacigene and, therefore, possibly Late Proterozoic in age (Griffin et al. 1992). The thrusting direction, indicated by the oblique mylonitic stretching lineation, suggests dextral transpression along the Spielers Shear, whereas the shortening direction indicated by the overfold system implies sinistral transpression on the main fault system during folding. These relationships indicate two movements separated in time. It is suggested that the D_4 dextral strike-slip movement on the main zone in the north of the Inlier was followed, somewhat later, by north-directed thrusting in the Spielers Shear Zone. This later, more localised, event is referred to as the Spielers Event (D_5). The dominant shear fabric produced by movement on the Spielers Shear Zone is older than the Late Devonian Pillara Limestone of the Canning Basin succession, which overlaps these sheared rocks.

West of the Louisa Basin, east-directed thrusts are assigned to D_4, since they formed during regional overfolding and cleavage formation and they cut Late Proterozoic glacigene units, but not the Antrim Plateau Volcanics. Northeasterly and easterly trending faults such as the Glidden and Pinnacle Faults, which are apparently linked to the thrust fault system, do cut the Antrim Plateau Volcanics, which are considered to be of probable Early Cambrian age (Mory & Beere 1985; compare with Muir 1980). Thus, some post-Early Cambrian movement has occurred on this fault system and is younger than the D4 event. Basement faulting and shearing along a splay of the Pinnacle Fault show gossanous quartz veining, suggesting a similar style, and possibly a similar age, of movement to the Spielers Shear.

TIMING AND TECTONIC IMPLICATIONS OF THE FINAL PRE-BASIN BASEMENT DEFORMATION

The basement rocks in the King Leopold Orogen have undergone three or more deformational phases (Tyler & Griffin 1990).The last widespread deformation to affect the King Leopold Orogen as a whole is the Precipice Event (Shaw et al., 1992). The overfolding and shearing in the Oscar Inlier produced

Spielers Shear Zone and is considered to have formed in the final stages of this event. It overprints structures of the Precipice Event in the Oscar Inlier.

Within the Spielers Shear Zone, two muscovite samples (Fig. 2) yield Middle Cambrian K-Ar ages of 504 ± 4 Ma and 514 ± 4 Ma (Shaw et al. 1992). Similarly, muscovite, from a north-trending schist zone within the southern part of the King Leopold Orogen, gave an age of 506 ± 4 Ma. Deformed actinolite-biotite schist from basement core in Langoora 1 Well on the northwest margin of the Lennard Shelf gave a younger age of 473 ± 3 Ma.

Although these K-Ar results are of a reconnaissance nature, their consistency points to a major period of fault movement in the Latest Precambrian (the Precipice Movement 530 - 560 Ma), and more localised uplift in the Middle Cambrian (*c.* 500 Ma). The latest Precambrian compressional tectonism, evident at the margin of the King Leopold Orogen, may have been more widespread to the south in the region occupied by the Canning Basin (see Myers 1990). If Late Precambrian tectonism was widespread it would explain the apparent lack of Cambrian deposition in the Canning Basin as a whole. The *c.* 500 Ma final compressional deformation, although probably a more localised event, is older than the earliest known sediments in the basin (latest Tremadocian at about 490 Ma), and helps in defining the age of onset of subsidence in the basin (Shaw et al. 1992).

BASEMENT CONTROL - LENNARD SHELF

Is the Beagle Bay-Pinnacle Fault Complex a reactivated basement-province boundary? We have shown that the northern margin of the Fitzroy Trough dates from the Proterozoic and lies on or close to the edge of the southeastern exposed margin of the King Leopold Orogen, extended to include the older schists in the Oscar Inlier. This margin also corresponds to a major magnetic domain boundary (Fig. 4). Equivalents of the Marboo Formation (Table 3), the earliest unit in the King Leopold Orogen, are present in each of three basement inliers/highs exposed along the Beagle Bay-Pinnacle Fault Complex.

Rocks that make up most of the Oscar Inlier are considered to represent the remnants of a younger, elongate basin lying at the southwestern margin of the King Leopold Orogen. These rocks apparently overlie those showing 1880-1850 Ma igneous activity in the Pillara Inlier, which is related to Barramundi tectonism in the Kimberley region (Wyborn 1988). The main rocks of the Oscar Inlier are a quartz sandstone and conglomeratic succession and they overlie rocks of the King Leopold Orogen (Marboo Formation) at its southwestern margin. They differ from the extensional 1800-1840 Ma Kimberley Group succession, in that the Hart Dolerite is absent (Table 3). Griffin et al. (1992) consider that the Oscar Range succession is possibly equivalent to the Carr Boyd and Glidden Groups (~900-1200 Ma), because they lack the Hart Dolerite and show only one folding episode (unlike the rest of the orogen where two phases are well developed). A more localised, younger, but folded sedimentary package in the Oscar Inlier is correlated with 700-800 Ma Sturtian deposits, as it includes a unit considered to be glacigene. Thus, these two younger Proterozoic sedimentary successions were most likely deposited in the period 1200 Ma to 700 Ma. Deposition may well have been localised at the southern edge of the major crustal province boundary dating from the 1850-1880 Ma Barramundi Orogeny.

These younger basement sedimentary successions are missing from the May River and Sixty-Seven Mile Highs, as well as the Pillara Inlier. These inliers consist of basement schists (Marboo Formation), intruded, in the case of the Pillara Inlier, by granite (probably 1860 Ma in age). Limited drilling in the Sixty-Seven Mile High (BHP-UTAH DBD-1), suggests that Devonian carbonates are thin (less than 320 m) or absent over all or part of the basement high. Basement intersected in DBD-1 consists of partly crenulated muscovite-quartz-chlorite schist (Marboo Formation, see Tyler & Griffin 1990; see Table 3). Breccia at the base of the sedimentary section in DBD-1 (mainly Grant Group) may represent debris flow material, possibly produced by Mid-Carboniferous tilting.

PART 2: STRUCTURAL ELEMENTS OF THE CANNING BASIN

GENERAL OUTLINE

The main structural elements of the onshore Canning Basin, (Plate 1 and Fig. 2) are :

1) the northern shelf region, made up of the Lennard Shelf and its disrupted eastwards extension as the Bulka Hills and Billiluna shelves;
2) a northern segmented basin, the Fitzroy Trough and its eastwards extension as the Gregory Sub-basin, flanked by a series of terraces and embayments. The Oobacooma Sub-basin represents the off-shore extension of the Fitzroy Trough. The terraces and embayments at the northern margin of the northern basin mark the transition to the basin slope. They include (i) the Laurel Downs Terrace and the Moogana Terrace, as well as the Pender, Napier and Margaret River Embayments along the northern margin, (ii) the Balgo and Betty Terraces in the northeast and (iii) the Jurgurra, Dampier and Barbwire Terraces in the south;
3) a central basement arch comprising a reduced sedimentary succession, referred to as the Broome Platform in the west and the Crossland Platform in the east;
4) the southern basins, consisting of the Willara Sub-basin in the west and the Kidson Sub-basin in the east; and
5) a southern shelf region, comprising the Anketell, Table Top and Ryan Shelves, together with the Wallal Platform, and the Samphire, Wallal, Oakover and Cobb Embayments.

Northern shelf region

The *Lennard Shelf* occurs along most of the northeastern side of the Basin. The Shelf is a shallow basement feature overlain by up to 5 km of sediments of predominantly Ordovician, Devonian and Permian age. The northeastern boundary of the Canning Basin is the exposed unconformity between the Phanerozoic sediments of the Basin and the Precambrian rocks of the Halls Creek Orogen. The southwestern margin of the Lennard Shelf as adopted by Forman and Wales (1981) is extended south of the Beagle Bay-Pinnacle Fault System to the Harvey Fault System, as this latter system aligns with the Pinnacle Fault System farther to the southwest. Consequently, the Laurel Downs Terrace is included in the Lennard Shelf.

A number of distinctive elements are recognised within the Lennard Shelf (Plate 1); the Laurel Downs, Moogana Terraces, and the Margaret River, Pender, and Napier Embayments. The *Napier* and *Margaret River Embayments* represent depressions where thicker successions were preserved along the northern margin of the Lennard Shelf (limits are marked by fine black lines in Plate 1).

The *Margaret River Embayment* is a structurally complex region made up mainly of Middle to Late Devonian sedimentary rocks lying northeast of Fitzroy Crossing. The Embayment corresponds to the western part of the area defined as the Margaret River Terrace by Forman and Wales (1981). Subsidence in the embayment was mainly during the Nullara reef-building cycle. Within the Margaret River Embayment, where it borders the Laurel Downs Terrace, there is a 10-15 km-wide zone of transtensional structures, sometimes refer to as the Fossil Downs graben.

As redefined in this report, the *Laurel Downs Terrace* approximates the Laurel Downs Embayment outlined by Purcell and Poll (1984). The terrace is bounded to the south by the Harvey Fault System and to the north by a segmented, composite fault system made up of the May River, Sixty-Seven Mile and Oscar Fault Systems (ie. part of the Beagle Bay-Pinnacle Fault Complex). It incorporates the eastern part of the Margaret River Terrace as defined by Forman and Wales (1981) and extends from the Fraser River Accommodation Zone in the west to the Colombo Fault in the east (Plate 1).

A series of basement highs and inliers lie between the Napier and Margaret River Embayments and the main terrace regions. These include the *May River High* (MH, Plate 1), the *Sixty-Seven Mile High* (SH), the *Oscar Inlier* (OI) and the *Pillara Inlier* (PI). A fifth (unnamed) high, interpreted from magnetic data, occurs in the Napier Embayment area north of the May River High. It is bounded to the east by a normal fault adapted from a geological sketch map by Kufpec Australia Pty Ltd (unpublished report 1986).

The eastern extension of the Fitzroy Trough is referred to as the *Gregory Sub-basin* because it is a separate depocentre with a somewhat unique history. This sub-basin is bordered to the north by the Balgo and Betty Terraces, which pass into the Billiluna Shelf to the far northeast.

The *Balgo Terrace* (Smith 1984) is bordered by the Landrigan and Mueller Faults in the north and northeast and by the Hinge Fault in the southwest. Together, the Balgo and Betty Terraces form a composite feature similar to those on the Lennard Shelf bordering the northern margin of the Fitzroy Trough.

The *Betty Terrace* (WAPET 1970) lies between the Hinge and Stansmore Faults. It forms a series of structural high and low features within the basement. The Betty Terrace varies in depth from 3 to 6 km. Seismic evidence supported by drilling indicates that the overlying sedimentary section, which thickens south towards the Gregory Sub-basin, is composed of Ordovician to Permian rocks. Displacement on The Stansmore Fault appears to decrease to the northwest.

The *Billiluna Shelf* is separated from the Lennard Shelf by the Precambrian basement rocks around Bulka Hills. Seismic data show that it is an extensively faulted basement feature. The shelf is overlain by about 3 km of mainly Ordovician and Devonian sedimentary rocks. The shelf's southwestern boundary is the Mueller Fault, and its northwestern, northern and eastern boundaries substantially correspond to the exposed unconformities between Phanerozoic rocks of the Canning Basin and Precambrian basement rocks of the Halls Creek Orogen and The Granites-Tanami Block.

Fitzroy Trough

The *Fitzroy Trough*, is situated southwest of the Lennard Shelf and Betty Terrace. Seismic and magnetic evidence suggests a sedimentary succession about 15 km thick (Drummond et al. 1991, Towner & Gibson 1983) and possibly up to 18 km in the southeast. The Fitzroy Trough contains sedimentary sequences of Ordovician, Devonian, Carboniferous and Permian age. The correlatives of the Ordovician rocks are the same thickness outside the trough (in the Willara Basin and on the Jurgurra Terrace), but the correlatives of the Devonian, Carboniferous and Early Permian rocks outside the trough are much thinner.

The southwestern boundary of the Fitzroy Trough is the Fenton Fault Complex made up of the Fenton, Dampier and Dummer Fault System. The maximum movement on the Fenton Fault System, the dominant fault in the complex, is about 4 km down to the northeast. However, the northwestern and southeastern ends of the Fenton Fault System are poorly defined. In fact, seismic evidence suggests that the throw on the Fenton Fault System decreases to the southeast, where displacement is taken up by a steep monoclinal flexure (WAPET 1970).

All the major faults paralleling the northwest-trending Fitzroy Trough are steeply dipping towards their downthrown sides, and all of them appear to be major faults with long histories of growth (Forman *in* Gorter et al. 1979). Seismic evidence has shown that anticlines parallel to the faults may be present on their down-dip sides, together with antithetic faulting.

The *Gregory Sub-basin* represents the southeastern extension of the Fitzroy Trough. It is separated from the thicker part of the Fitzroy Trough to the northwest by the *Jones Arch*: a basement high, largely inferred from the thinning of the succession above the base-Grant unconformity (see Taylor et al. 1990).

The *Oobacooma Sub-basin* represents the offshore extension of the Fitzroy Trough. The northwestern boundary between it and the Fitzroy Trough is arbitrarily taken to be where the base of the Mesozoic-Cainozoic succession exceeds 1000 ms TWT (Luck, 1991a, 2b; Hocking et al., 1994).

The *Barbwire* and *Jurgurra Terraces* are two relatively narrow fault bounded regions in which thin shelf-like deposits overlie, basement at shallow depths. They are separated from the Fitzroy Trough by the Fenton Fault System. The southwestern boundary of the Jurgurra Terrace is the Dampier Fault System; whereas the southern boundary of the Barbwire Terrace is the Dummer Fault System. The Dampier and Dummer Fault Systems are not exposed, and it appears from limited seismic information that they overlap each other in an en-echelon fashion. Seismic data indicate that both terraces are underlain at shallow depth by basement and have been subjected to block faulting. The sediments on the Jurgurra Terrace are commonly 2-4.5 km thick, locally up to 7 km (Begg 1987), and those on the Barbwire Terrace are 1.5 km thick in the northwest, increasing up to 7 km in the southeast (Begg 1987, WAPET 1970). The fill on these terraces comprises Palaeozoic rocks covered by a veneer of Mesozoic rocks. The Jurgurra and Barbwire Terraces are unusual in showing salt domes and pillow structures in the Late Ordovician Carribuddy Formation (Mallowa Salt in Fig. 1, e.g., salt in Mirbelia 2).

The *Dampier Terrace* is a complexly faulted region with an intermediate depth of sediment at the northern margin of the Broome Platform where the Jurgurra and Barbwire Terraces overlap. Its northern margin is marked by segments of the Dampier and Dummer Fault System, and its southern margin is partly outlined by the Collins Fault and partly poorly outlined by a thick wedge of Permian clastics (see Hocking 1993, Taylor et al., 1990). The Collins Fault, previously taken to define its southern margin, breaks up in the region between Pictor 1 Well and Thangoo 1 Well. The Dampier Terrace is roughly equivalent to what Connolly et al. (1984) called the Collins Terrace and what several authors (Bentley 1984, Hocking 1993) have referred to as the Mowla Terrace. However, this feature is poorly defined and is part of what some other authors (e.g., Karajas & Kernick 1984, Begg 1987) incorporated into the Broome Platform (see below). Hocking et al. (1994) prefer the name Mowla Terrace to Dampier Terrace. The northwestern extension of the Dampier Terrace, previously mapped in the Broome area beyond the mappable limit of the Collins Fault (Karajes & Kernick 1984, Begg 1987, Goldstein 1989), is even more poorly defined and has been deleted from the mapped extent of the Dampier Terrace.

Central basement arch

The *Broome Platform* ('Broome Swell' of Veevers & Wells 1961, 'Broome Platform' of Koop (1966; and 'Crossland Platform' of WAPET 1970), centrally located in the Canning Basin, is a broad region of relatively shallow basement, overlain by 1-3 km of sedimentary rocks of predominantly Ordovician and Permian age, although it contains a thin Devonian succession and thin Mesozoic rocks in the northwest. The regional dip of the sediments on the platform is to the southwest. Its southwestern margin is marked by the Admiral Bay Fault Zone, which is defined largely on seismic data. Locally this fault zone shows normal displacement of about 500 m down to the south, but is more generally expressed as a zone of distributed faulting across a hinge zone. The fault essentially affects the Ordovician and basement rocks; farther to the southeast, no clear boundary exists between the platform and the sub-basins to the south. Thus, the Broome Platform marks a region of restricted deposition that did not downwarp as rapidly as the Fitzroy Trough and the surrounding terraces, and that underwent several episodes of episodic uplift and erosion, the most pronounced of which were the Mid- Late Carboniferous Meda Movement and the Late Triassic to Early Jurassic transpressional Fitzroy Movement (see section below on Tectonic History).

The *Crossland Platform* is the southeastward extension of the Broome Platform, from which it is separated by a northerly embayment of the Kidson Sub-basin. Hocking et al., (1994) extend the Crossland Platform northwestwards to what is termed the McLarty Embayment in this report. It is separated from the Gregory Sub-basin to the north by the Barbwire Terrace. Its boundary with the Kidson Sub-basin is gradual, being outlined in Plate 1 at the 3.5 km depth contour. It forms a broad drape and its structure is dominated by weak extensional faults. As on the Broome Platform, salt dissolution structures are a noteworthy feature.

Southern basins

The Kidson and Willara Sub-Basins to the southwest of the Broome Platform are two contiguous basement depressions filled largely with Ordovician and Permo-Carboniferous sequences.

The *Willara Sub-basin*, which has a maximum estimated depth of 4.5 km, is filled dominantly by a shale, carbonate and evaporite succession of Ordovician to earliest Silurian age (Jones & Young 1993). Thin covers of Devonian, Permian and Mesozoic overlie the Ordovician-Silurian deposits. The shape of this dominantly Ordovician sub-basin has been controlled by extensional faulting and shows local thickening towards the Admiral Bay and Munro Fault Zones (Romine et al. 1994, see also Conolly et al. 1984).

The *Kidson Sub-basin* exhibits negligible faulting and forms a broadly oval depression that may be as deep as 5 km (Middleton in GSWA 1990). Its succession is like that of the Willara Basin and has been outlined by Conolly et al. (1984) and Romine et al. (1994).

The *Munro Terrace* (the Munro Arch of previous workers) is a low, poorly defined and relatively extensive basement rise separating these sub-basins. It was thought to date from the end of the Ordovician, but the recent correlations of Romine et al. (1994 see fig. 11) suggest it dates from the Emsian/Eifelian following the Prices Creek Movement.

The *McLarty Embayment*, previously regarded as part of the southeastern Broome Platform, is a depression that borders the Munro Terrace to the north and is connected to the Willara Sub-basin.

Conolly et al. (1994), referred to it as the McClarty Sub-basin and saw it as a Carribuddy Group 'salt basin', forming a re-entrant from the Kidson Sub-basin. It became an important feature in the Permian, when it was connected to the Willara Sub-basin (see Taylor et al., 1990). The spelling *McLarty* is preferred, in agreement with naming of McLarty 1 well.

Southern shelf region

The *Samphire Embayment* is a small basement depression lying near the coastline to the southwest of the Willara Sub-basin. It is separated from the Willara Sub-basin by an area of relatively shallow basement. Limited seismic evidence, together with aeromagnetic results, confirm that the embayment is bounded along its southwestern margin by a northwest-trending fault of pre-Permian age. The southern extension of the Samphire Embayment, south of the Anketell Shelf, is referred to as the Wackarlcarty Embayment by Hocking et al., (1994).

The *Anketell*, *Tabletop*, and *Ryan Shelves* occupy regions where thinning Canning Basin deposits onlap the basement to the south (Gorter et al. 1979, Conolly et al. 1984). This composite shelf region is covered by a veneer of Late Palaeozoic and Mesozoic rocks less than 700 m thick. Although these names have been retained here, the accuracy of their boundaries may be questioned because of the paucity of information. Hocking et al. (1994) incorporate the Tabletop Shelf into the Anketell Shelf. They introduce another term, the Warri Arch, for what is effectively an extension of the Tabletop Shelf (their Anketell Shelf) to the southeast. Their Warri Arch includes the Clutterbuck Inlier. This inlier and the basement to the Warri Arch may represent an extension of the Musgrave Block. These revisions seem reasonable and will be incorporated into future additions of the map.

The *Wallal Embayment* is defined from seismic and drilling data as a small, shallow, northwest trending half-graben bounded in the northeast by a faulted narrow *Wallal Platform*, and in the southeast by the pinching out of the sedimentary succession. The embayment contains Ordovician, Permian and thin Triassic rocks.

The *Oakover Embayment* (OKE in Plate 1) is a valley, cut into basement, that has been subsequently filled with Permian to Carboniferous glacigene sediments (Taylor et al., 1990, Hocking 1993).

The *Lucas Basin* (LB in Plate 1) refers to the region of overlapping, but separate Devonian, Permian-Carboniferous and Triassic successions within basement along the boundary between The Granites-Tanami Block and the Arunta Block. These successions also overlie a thin Mid-Proterozoic cover sequence, the *Birrindudu Basin*.

The *Cobb Embayment* (Plate 1), also known as the Cobb Depression, is occupied by Permian clastics. It overlaps the boundary between the Musgrave Block and the Amadeus Basin and extends eastwards from the eastern margin of the Ryan Shelf.

FOLDS

Folds are common in the northwest of the Fitzroy Trough and are arranged in en-echelon fashion with axes generally orientated west to west-northwest. Some appear to be slightly asymmetrically, and their axial planes dip slightly to the south. In some cases the major anticlines appear to overlie pre-existing depressions (Galloway & Howell 1975). An example of such a feature is in the axial region of the St George Ranges and Poole Range Anticlines, where the Poole Sandstone is markedly thicker than to the north and south. In the Gregory Sub-basin folds of similar style and age (see Smith 1984), swing to an east-west orientation in the southern part where, due to more convergent strike-slip faulting, they become asymmetrical with south-dipping, shallow, listric reverse faults on their flanks. These folds date from the Fitzroy Movement, but a few show earlier growth related to the Meda Movement. There is little folding in the Willara and Kidson Sub-basins.

FAULTS AND ACCOMMODATION ZONES

Mesozoic Faults — Fitzroy Trough

The Fitzroy Trough contains numerous short north-northwest-trending transverse *faults*, arranged en-echelon between boundary fault systems (not shown on Fig. 2, Plate 1). These en-echelon faults show only small displacements of less than 10 m. They are predominantly normal faults, although a few reverse faults occur and there are several minor low-angle thrust faults in the Poole Range in the upper part of the Grant Group that may mark the soles of gravity slide blocks. Commonly the normal faults have an average dip of 70°. Slickensides indicate that movements were essentially vertical. The throw on any one of these en-echelon faults is seldom more than 100 m and the maximum throw recorded in the St George Ranges is 200 m. These faults date from the Fitzroy Transpressional Movement during the Late Triassic to Early Jurassic (see Section on Tectonic History).

The Beagle Bay-Pinnacle Fault Complex

This fault complex controls the northern margin of the Fitzroy Trough and extends east-southeast from Beagle Bay, to the Bulka Hills Shelf (see inset in Plate 1). It marks the southern margin of the Devonian reefs on the Lennard Shelf, separating platform carbonates and clastics of the Lennard Shelf (including Pender Embayment, and Napier Embayment) from a thick succession of deeper marine shales and carbonates of the Fitzroy Trough. The fault complex includes the Beagle Bay, May River, Sixty-Seven Mile, Oscar, Harvey and Pinnacle Fault Systems (Plate 1). As such, it incorporates the Moogana and the Laurel Downs Terraces. Each fault system is separated by accommodation zones and controlled the accumulation of fill in that particular compartment. The Geike Fault Zones (GKFZ), and the Stoney Creek Fault Zone are not part of the fault complex.

These major faults appear to have undergone a long and complex tectonic history. For example, compressional reactivation of the extensional fault system at the northern Fitzroy Trough margin has produced variable dips, including upturned dips in the hanging-wall of faults. They have probably also been affected by Late Triassic - Early Jurassic, dextral strike-slip movements (Fitzroy Transpressional Movement).

The Beagle Bay Fault System (Plate 1, Fig. 2) has been delineated from various data sources including surface geology, Landsat imagery and selected sub-surface seismic data. It forms the western most part of the Beagle Bay-Pinnacle Fault Complex. The fault system corresponds to both the southern limit of the Devonian reef (Begg 1987) and southern edge of an Ordovician 'basement' ridge (Purcell & Poll 1984). The northern boundary of the fault system in the far west is the Pender Bay Fault. At its western end, the intervening belt between these faults is an Ordovician high corresponding to the Pender Embayment (Lehmann 1986, Forman & Wales 1981). The Beagle Bay Fault System is comparable in style to the Oscar Fault System (see below) in that it was a major control on the location of the carbonate shelf edge in the Devonian. The Beagle Bay Fault System is offset slightly by the Fraser Accommodation Zone (FAZ) to the north to the May River Fault System. Together these features are en-echelon from the Harvey Fault System. The Beagle Bay and May River Fault Systems differ from the Harvey Fault System in appearing to show more fault control on sedimentation in the Devonian.

May River Fault System (Plate 1) represents the segment of the Beagle Bay-Pinnacle Fault Complex lying south of the May River High. Seismic mapping by Jackson et al. (1993) has shown it to dip steeply at 80 degrees to the southwest. They suggest that faulting was initiated in the Givetian on a deep basement arch forming part of the May River High. A thick older ? Ordovician to Givetian section is preserved on the downthrown side of the fault. The fault system underwent reactivation in the Mid-Carboniferous prior to deposition of the Grant Group in the Permian. Poorly defined local thickening of the Upper Anderson Sequence (the unit Y of Jackson et al. 1993) may be the result of the initial development of anticlinal flower structures such as the Meda Structure (seismic line H 84-10.5) along the axis of the Fault System and sympathetic synclinal depressions.

The *Sixty-Seven Mile Fault System* (SFS in Plate 1) is known only from seismic data and is listric in character (as shown by both time and preliminary depth migrated sections). It occurs just south of the Sixty-Seven Mile (basement) High in the region northeast of the Blina Oilfield. It represents the displaced continuation of the May River Fault System east of the Sundown Accommodation Zone, and is offset from the Oscar Fault System to the east by the Mount Percy Accommodation Zone (PAZ). As shown by Jackson et al. (1993 p. 9-10; see also Taylor 1992), it dips to the southwest at about 30 degrees, and shows major structural growth during the Mid-Devonian (Givetian to Frasnian). These authors have used seismical data to map the fault, including its offset by small step-transfer faults in the footwall, and show its relationship to antithetic faults in the hanging wall. This mapping (e.g. lines H81-51.2, H84-19.6, 22, ED84-439) indicates a complex history of emergence in the late Frasnian and subsequent subsidence.

The fault system was intersected in BMR seismic line 88-03 where it is linked to a major listric fault system near the base of the sedimentary section (see Fig. 2; Jackson et al. 1993, Taylor 1992).

To the north of the Sixty-Seven Mile basement high is the *Napier Fault*, a conjugate north-dipping normal fault

The *Oscar Fault System* (Plate 1; Brown et al. 1984, Griffin et al 1992) consists of two or more sub-parallel, steeply south-dipping (up to 70°-80°) normal faults. Later-stage fault movements have produced steepened dips within the fault zone, a relationship consistent with compressional or transpressional movement during the tilting of fault blocks. Intraformational unconformities involving local structural discontinuities of up to 30° in Devonian carbonates suggest that some of the steepening of dips may be the result of syn-depositional faulting during reef development. Alternatively, the oversteepening of dips may reflect slope development on the reef margin (compare with Alberta Basin, North America; see Begg 1987). Marginal conglomeratic facies exposed in the nearby Devonian carbonates contain locally derived basement clasts, indicating that the Oscar Inlier was emergent.

The Oscar Fault System seems to have been controlled by basement inheritance and developed along and to the south of, a major basement shear zone, the Spielers Shear Zone (Shaw et al. 1992): a greenschist (sericite-epidote-chlorite) shear zone which dips southwards at 40-70°. Weak fabric asymmetry within the zone suggests a south-block-up (ie. upthrust) sense of shear. North of the shear zone is a high-strain zone of intense flattening and upfaulting. Exposure of the zone is masked by overlapping Devonian carbonates. Farther north again, an overfold zone in the axial region of the Oscar inlier also shows progressive north-directed structures within a predominantly flattening strain field, with a subsequent dextral component.

The *Harvey Fault System*, (Plate 1, Fig. 2) recognised as a distinct feature by Purcell and Poll (1984) and Begg (1987), marks the southern margin of the Laurel Downs Terrace between the Kora Transfer Zone in the west, where it links with the partly overlapping May River Fault Zone, and the Colombo Fault Zone in the east. There is an abrupt angular bend in the fault trace where it intersects the Sundown Accommodation Zone: to the northwest of this zone, it is a relatively simple southeast-dipping normal fault, locally forming two anastomosing splays; whereas to the southeast, where it cuts a structural high made up of Ordovician and basement rocks, it comprises a complex system of both southwest- and northeast-dipping faults forming numerous positive and negative flower structures. In this southeast area the fault system seems to have formed a set of local horst and graben structures following the Van Emmerick pulse in the Famennian. In the Early and Mid-Carboniferous, following the Red Bluffs Movement (see succeeding Tectonic History Section), it seems to have acted as a major growth structure. Growth had ended by the time of the succeeding Permian Grant Group which overlaps the fault. The flower structures related to strike-slip fault movements,lying immediately southwest of the fault formed during the dextral transpressional Fitzroy Movement (Rattigan 1967). All these features are detailed in a set of seismic and map folios by Jackson et al. (1993).

At shallow depth on BMR line 88-03 the Harvey Fault system appears to be comprised of two separate steep, sub-parallel faults about 1.5 km apart. Detailed seismic mapping (Jackson et al. 1993, map 2) show that the BMR line crosses the Harvey Fault System in a relay zone where the major offset on the fault is transferred from one fault trace to the other. The main fault displacement is post-Anderson Formation in age, but pre-Lower Grant Group in age (ie. mid Carboniferous)

The *Pinnacle Fault System* (Plate 1, Fig. 2; Craig et al. 1984), and closely related *Cadjebut Fault* (JF, Plate 1), lie 15-20 km to the south of the Virgin Hills Fault Zone (VFZ); however, they may all form part of a wide region of related south-dipping, linked normal faults. The absence of Late Ordovician and Silurian rocks at the unconformity between the Ordovician and Devonian successions north of the Cadjebut Fault is consistent with exhumation during the Late Ordovician and/or the Silurian (see below). The eastward extension of the Pinnacle Fault is well displayed in the regional magnetic data, and confirms that it cuts both the western extension of the Stansmore and Landrigan Faults (in the Gregory Sub-basin).

The Pinnacle Fault System, like the Virgin Hills Fault Zone, is downthrown on the southern side and has a southerly dip of about 60° in outcrop. From seismic data, the Pinnacle Fault System appears as three sub-parallel, steep faults which are progressively downthrown to the south (Purcell & Poll 1984, fig. 6 WAPET Line B. In structural style, it is comparable to the Harvey Fault System and lies roughly along strike from that system. However, fault continuity is disrupted by two northerly trending fault zones the Colombo Fault Zone and further east, the Outcamp Hill Accommodation Zones (OAZ, Plate 1). The region south of the Pinnacle Fault System, west of the Jones Arch and east of the Outcamp Accommodation Zone (see below), is informally referred to as the Poole compartment (after the anticline), as sediment accumulation there is complex and not related only to activity on the Pinnacle Fault System.

The *Cadjebut Fault* (JF in Plate 1) branches from a major bend in the Pinnacle Fault System, where it swings in strike from northeast to east-northeast. Although it is essentially a normal fault dipping southwards, it is sigmoidal in plan and has undergone a complex history involving post-extension compression and, even later, a minor component of sinistral shear (P. Muhling, BHP-UTAH, pers. comm. 1989).

Other faults at the northern margin of the Fitzroy Trough.

The *Virgin Hills Fault Zone* (Crowe & Towner 1981) is made up of the Virgin Hills Fault (VFZ in Plate 1) and nearby Home Range Faults at the southern flank of, and within, the Pillara Inlier (PI), respectively. Both these faults are downthrown to the south by at least 600 m and 300 m, respectively. A crude foliation in brecciated basement suggests a southerly dip to the Virgin Hills Fault of 55-65°, consistent with the dip of brecciation and calcite veining in the Devonian carbonates alongside the fault. Complex dip variations along this fault typically involve steep southerly dips, consistent with late-stage compressional fault reactivation. The faults appear to have reactivated two of several south-dipping greenschist (sericite-chlorite) shear zones in the basement. These shear zones are commonly outlined by lenticular vein quartz and dip southwards at 35°- 85°. However in seismic section the Virgin Hills Fault Zone appears as a single fault which flattens at depth to the south (Purcell & Poll 1984, fig. 6 WAPET Line B.

Important differences between the Oscar Range Fault System and Virgin Hills Fault Zone, such as the spacing between individual normal faults, may be due to variations in the rheology of the basement sub-strate. For example, the Pillara basement in the region of the Virgin Hills Zone consists predominantly of Proterozoic granitoid, whereas the Oscar System is localised mainly in schistose metasediment.

The *Geike Fault Zone* (GKFZ, Plate 1) is located southeast of the Oscar Inlier and northwest of the Virgin Hills Inlier, immediately north of Fossil Downs homestead. It is a discontinuous, locally en-echelon, transtensional west-northwest-trending fault system, in which the general sense of movement was north-block down combined with a dextral component. This distinctive, and somewhat localised, fault system was active in the latest Givetian to Frasnian (as indicated by patterns of brecciation and fault-related calcite veining in the Pillara Formation, see Table 2). Clasts of Pillara Formation in debris flows within the Famennian Napier Formation imply fault reactivation in the latest Frasnian-early Famennian.

Local reactivation within the Geike Fault Zone may date from the Mid-Carboniferous when many of the inversion structures formed (Begg 1987).

The *Stoney Creek Fault Zone*, 20 km north of the Geike Fault Zone (Plate 1), is a reactivated basement shear zone. In part it is expressed as a sharp photo-lineament at the contact between basement and the Devonian cover succession. The fault appears to have reactivated the southern edge of the Stoney Creek Shear Zone, a basement feature formed in the latest Cambrian (Tyler & Griffin 1990, Shaw et al. 1992). The sharpness of the photo-lineament is presumed to be the result of post-Devonian fault movement. Frasnian carbonate debris is profuse alongside the fault and contains abundant clasts of locally derived basement, suggesting that either fault movement took place during the Frasnian or that the fault-scarp persisted after faulting in the Givetian.

Accommodation zones - northern Fitzroy Trough

Northeasterly-trending faults and transverse lineaments in the Canning Basin that are approximately orthogonal to the basin-bounding structures have been interpreted as transfer faults (Begg 1987, Etheridge et al. 1988, White & Muir 1989, compare with Craig et al. 1984). However, many of these transverse features are more complex than simple cross-structures that link parts of an extensional fault system, so the more general term *accommodation zone* is adopted in this report.

An example of an accommocation zone, the Doran Zone is figured in Plate 3b. The zone is expressed in seismic data as a wide zone of fracturing and faulting. These accommodation zones subdivide the northern margin of the basin into a series of rectangular compartments, which show similar normal fault patterns and sediment packages. This is well illustrated by the major differences evident on BMR 88-01 and 88-03 seismic lines (Plates 2 and 3).

Based on field examinations these northeasterly-trending accommodation zones do not appear to extend northward beyond Devonian reefs at the northern margin of the Lennard Shelf. However, as shown on Plate 1, some of them do line up with lineaments on Landsat data which have been traced into the basement northeast of Derby. Basement faults and shear zones, pre-dating basin development in the Precambrian King Leopold Orogen, form an anastomosing network and show little, if any, sign of reactivation during the Palaeozoic extensional episodes which are characterised by an orthogonal fault network. However, many, if not most, of these accommodation zones appear to be part of the fault systems that make up the Beagle Bay-Pinnacle Fault Complex.

The *Fraser River Accommodation Zone* (FAZ, Plate 1) is a relatively minor zone proposed by Begg (1987) in the onshore part of the Fitzroy Trough at its northwestern end. Located immediately east of the Fraser River 1 Well, it is assumed to mark the northwestern edge of the Fraser River combined gravity-magnetic 'bulls eye'-styled anomaly.

The *Kora Transfer Fault*, (KTF, Plate 1) is a type of accommodation zone made up of a single cross-fault that is an integral part of the complex linked Beagle Bay-Pinnacle extensional fault system. It was first highlighted by Begg (1987, and unpublished map at 1:250 000) and parallels the nearby Yarrada Transfer Fault to the southeast.

It is at this point that the Harvey Fault System begins to develop as an en-echelon feature, forming a more southerly parallel component of Beagle Bay-Pinnacle Fault Complex. The Beagle Bay Fault System aligns more closely with the May River Fault System to the east.

The *Yarrada Transfer Fault* (YTF, Plate 1) is poorly defined and corresponds approximately to zone of disruption and apparent offset of the Beagle Bay Fault System. The zone corresponds to May River Transfer Fault, referred to by Begg (1987, and unpublished map by him at 1:250 000) and parallels the nearby Kora Transfer Fault to the northwest. Both the Yarrada and Kora transfer faults appear to be simple, orthogonal features linking normal fault segments of the main fault complex and as such, represent a special type of accommodation zone.

The *Sundown Accommodation Zone* (SAZ, Plate 1) is outlined by a shift in the carbonate shelf edge (Drummond et al. 1988, fig. 6) and may represent the major accommodation zone that results in the change in the seismic character between BMR lines 88-01 and 88-03. For example, west of the zone the northern margin of the Fitzroy Trough appears to be flexed into a broad hinge, whereas to the east of the zone the trough margin is marked by well-developed normal faulting (Drummond et al. 1988, compare with BMR seismic sections 88-01 and 88-03 in Plate 2). Thus, the accommodation zone represents a complex adjustment zone between two different groups of normal fault systems: the Sixty-Seven Mile and Oscar Fault System in the east, and the May River and the Beagle Bay Fault System in the west. It roughly corresponds to a gravity lineament marking the eastern limit of the prominent gravity ridge centred on Yarrada 1 Well.

The accommodation zone is marked by a zone of structural disruption giving rise to a zone of poor reflectivity. Faults bordering the zone show displacement dating from the Givetian that decrease in magnitude from the Frasnian to the Tournaisian (Jackson et al. 1993).

The *Blackstone Accommodation Zone* (BAZ, Plate 1) is parallel to, and about 18 km southeast of, the Sundown Accommodation. It cuts the northwestern part of the Sixty-Seven Mile basement high. It appears to align with the southeastern end of the Markam Fault (KF, Plate 1). Immediately to the west of the Blackstone Zone, two spatially distinct Devonian reef trends appear to merge into the carbonate platform of the Lennard Shelf.

The *Mount Percy Accommodation Zone* (PAZ, Plate 1) is an accommodation zone corresponding to a northward back-stepping of the Oscar Inlier relative to the Sixty-Seven Mile basement high. Gravity highs mirror the back-stepping of the basement highs. The zone also corresponds to a local gravity gradient at the eastern end of the gravity ridge. North of Mount Percy, the zone is expressed at the surface as a strike discordance in beds of carbonate, which appears to coincide with aeromagnetic discordance. The zone terminates before the outcropping Devonian reefs at the northern margin of the Lennard Shelf; however lineaments derived from Landsat data are evident in basement along strike from this accommodation zone.

Extension in the Mid-Givetian to Frasnian led to an influx of spectacular submarine fan conglomerates in the overlap region between normal fault systems in the region of the Mount Percy Accommodation

Zone (across the Napier Embayment, see Goldstein 1989, p. 481). The conglomerate may have been derived from uplifted footwall crests on normal faults (predicted farther north at the northern margin of the Lennard Shelf).

The *Colombo Fault Zone* (Plate 1) corresponds approximately to that figured by Craig et al. (1984). It is a steep southeast-dipping normal fault showing evidence of sinistral displacement, at the northwestern margin of a complex transtensional zone that is sometimes referred to as the Fossil Downs graben (Kemp & Wilson 1990, Vearncombe et al. 1994). It forms an accommodation zone between the combined Oscar and Harvey Fault Systems to the west and the Pinnacle Fault System to the east. It also cuts off the Geike Fault Zone (GKFZ). Half-graben structures are locally developed on the southeastern down-throw side of the Colombo Fault Zone. These may have acted as channel-ways for Late Devonian to Early Carboniferous conglomerate (unit DPc), such as seen in outcrop along Boab Creek.

The *Outcamp Accommodation Zone* (OAZ, Plate 1), also referred to as the Albatross Fault, marks the southeastern margin of a complex transtensional zone known as the Fossil Downs graben (Kemp & Wilson 1990, Vearncombe et al. 1994). It is a northeast-trending zone of sinistral offset at the margin of the transtensional zone that is made up of steep north-northeast trending normal and sinistral strike-slip faults. At the regional-scale, the transtensional zone accommodates the back-stepping of the Beagle Bay-Pinnacle Fault Complex, leading to an apparent dextral offset between the reef complexes of the Pillara and Oscar Inliers. A set of northwest-trending horst and graben structures, spaced at intervals of 3 to 5 km, lie immediately southeast of the Albatross Fault. The Pillara Inlier forms an asymmetrical horst within this set of structures. A thick wedge of mid- to late Devonian clastics occur at depth alongside the fault at its southwestern-most end (Kufpec Australia Pty Ltd, unpublished data, 1986).

These structures show evidence of two or more pulses of movement in the mid- to late Devonian (Kemp & Wilson 1990, Vearncombe et al. 1994). The transtensional zone is complex, having developed as a result of extension on a north-northeast axis, combined with internal strike-slip offsets, the whole zone being bounded by steep sinistral faults, the Colombo Fault in the northwest and the Albatross Fault (Outcamp Accommodation Zone) in the southeast.

Basement highs, which correspond very approximately to gravity highs, lie on the central-eastern, western and southwestern flanks of the transtensional zone.

Kemp and Wilson (1990) have examined seismic data in the region of Needle Eye Rocks 1 and Margaret 1 wells, and they record a Givetian to early Famennian succession in excess of 1.5 km. The succession is thickest in a north northeast-trending 'central graben', located between the two wells and extending north-northeast from the northwestern tip of the Pillara Inlier.

Intrabasinal faults - Fitzroy Trough

The Mount Wynne Fault Zone is made up of poorly defined north-dipping, normal fault segments that lie north of the Mount Wynne structure (seen on BMR line 3) and may continue westwards passing along the south of the Grant Range Anticline. On BMR 88-03 it dips steeply to the north with minor post-Permian normal displacement and appears to sole-out at about 6.5 secs (Jackson pers. comm.). Its trend follows that of a major gravity feature. This and other sub-parallel faults within the Fitzroy Trough may explain the lack of alignment of accommodation on either side of the Trough.

Faults — southern Fitzroy Trough

The Fenton Fault Complex has four principal components (inset to Plate 1): (1) The main Fenton (West) Fault System bordering the Jurgurra Terrace, (2) The Fenton (East) Fault System bordering the Barbwire Terrace, (3) The Dampier Fault System lying between the Jurgurra Terrace and the Dampier Terrace, and (4) The Dummer Fault System, and (5) The Collins Fault.

The *Fenton Fault System, Western Segment* (Plate 1) is a moderately north-dipping normal fault system that separates the Jurgurra Terrace from the much deeper Fitzroy Trough. Many of these faults show listric geometry and together have been estimated to account for up to 60 km of extension (Warren 1974, unpublished in Begg 1987) and, like the Dampier Fault System, the Fenton Fault System seems to breakup into a series of disconnected, more northwesterly-trending, normal faults at its western end. During the Emsian- Eifelian, there seems to have been uplift of the Terrace at the same time as subsidence of the trough, accompanied by a transgression in the Fitzroy Trough (Poulton Formation).

The *Fenton Fault System, Eastern Segment* (Plate 1) represents the eastern continuation of the West Fenton Fault System, east of the Camelgooda Accommodation Zone (CAZ in Plate 1) and the Barbwire Terrace. In the BMR 88-03 seismic section it is shown to be markedly listric in nature. It continues to the southeast to form the southern margin of the Gregory Sub-basin.

The Dampier Fault System is a set of semi-continuous north-dipping normal faults that separates the Jurgurra Terrace from the Dampier Terrace (Foreman & Wales 1981, Brown et al. 1984, Begg 1987, Romine et al. 1994). Within the Fenton Fault Complex, the extensional displacement is transferred from the Dampier Fault System in the west to the Dummer Fault System in the west, across an unnamed accommodation zone (compare with Begg 1987). The Dampier Fault System marks a hinge zone at the southern edge of the Jurgurra Terrace (Purcell & Poll. 1984 fig. 16) that was initiated during the Gogo of the Pillara Extension (compare with Forman & Wales 1981, Brown et al. 1984, Kennard et al., 1994a).

The *Dummer Fault System* (Lehmann 1986) lies at the southern margin of the Barbwire Terrace, where the succession thins rapidly. It is made up of normal faults that dip at moderate angles northwards. At it northwestern end its component faults are linked by several apparent transfer faults. This fault system was active in the period from the Mid-Devonian to the Early Carboniferous, as units of this age thicken into the fault system (Foman & Wales 1981, fig. 65).

The *Collins Fault* (Plate 1) is a north-dipping normal fault within the Broome Platform, marking part of the southern margin of the eastern part of the Dampier Terrace. It is of short length; to the southeast (near Canopus 1), it appears to pass into a hinge zone. South of the fault sedimentary thickness decreases rapidly to less than 2 km (compare with Begg 1987). The fault dates from the Mid-Devonian.

Accommodation zones — southern Fitzroy Trough and Broome Platform

The *Camelgooda Accommodation Zone* (CAZ in Plate 1) is a diffuse zone, orthogonal to the main Fitzroy Trough. It is highlighted by discontinuous seismic reflectors, whereas the bordering blocks display more continuous reflections.

The *Doran Accommodation Zone* (DAZ in Plate 1); figured in (Plate 3b and Taylor et al., 1990), corresponds to an abrupt shift in the position of the Fenton Fault System. It may also affect the Mount Wynne Fault Zone, a feature positioned only very approximately in Plate 1.

Faults — Gregory Sub-Basin

The Gregory Sub-basin (Smith 1984) is the easternmost extension of the Fitzroy Trough (Plate 1, Fig. 2). It has been influenced by fault interaction with the adjoining Hall Creek Orogen in the north and The Granites-Tanami Block in the east, thereby making it distinct from the main part of the Fitzroy Trough. The Gregory Sub-basin and the Fitzroy Trough experienced similar depositional histories; they were initially filled with Early Ordovician clastics, and accumulated a thick fill following major rifting in the Mid-Devonian to Early Carboniferous. However, in the Gregory Sub-basin this succession has been more severely eroded along its flanking terraces, the Bulka Hills Shelf in the north and the Barbwire Terrace in the south. This increased erosion probably reflects the greater influence of the Meda Movement in this eastern part of the basin, which is correlated with the massive uplift accompanying thrusting at the peak of the Alice Springs Orogeny in Central Australia. These effects are most apparent at the easternmost boundary, the Billiluna Fault. In addition, the eastern portion of the central arch (Barbwire Terrace and Crossland Platform) was less of a major barrier to various transgressions so that the Gregory Sub-Basin was connected to the Kidson Basin, especially in the Mid-Devonian (see Lehmann 1984).

The *Billiluna Fault Zone* (Plate 1) was referred to as the Eastern Margin Fault System by Smith (1984). It consists mainly of west-dipping normal faults showing evidence of activity during the Middle Palaeozoic, displacing Ordovician deposits. Probable transtensional reactivation in the latest Devonian can be linked to delta-complex deposition of the Knobby Sandstone. Sinistral movement on the fault may have been the result of a clockwise rotation of the Kimberley Block and the Canning Basin relative to The Granites-Tanami Block, as suggested by Smith (1984).

The *Landrigan Fault* (Plate 1, Fig. 2) named after Landrigan Cliffs in MOUNT RAMSAY, is equivalent to an unnamed east-west fault along the northern margin of the Balgo Terrace figured by Smith (1984, fig 5). It appears to extend northwestwards to join the Pinnacle Fault, close to that fault's junction with the Cadjebut Fault (JF in Plate 1). The Landrigan Fault is cut off in the east by the more northerly trending Mueller Fault System. Both faults grew mainly during the Middle Devonian to Carboniferous and are listric in nature.

The *Mueller Fault System* (Plate 1, Fig. 2) is a set of sub-parallel, southwest-dipping normal faults that seem to be listric and show surface dips as high as 69° and pass into a decollement at the basement interface (see Smith 1984). Some of these faults show displacements in excess of 1000 m. As with the Landrigan Fault, fault growth was mainly during the Mid-Devonian to Early Carboniferous period.

The *Hinge Fault System* (Plate 1) is sub-parallel to and structurally similar to the Mueller Fault. It defines the southwest margin of the Balgo Terrace. It and discontinuous faults in the Balgo Terrace show maximum growth during the Devonian to Early Carboniferous. These faults show little activity after the time of the Grant Group. The fault system changes in style along stoke; in the northwest it is a series of normal faults down-stepping towards the sub-basin in the southwest; it is a single large growth fault in the central part, and it forms a series of step-faults in the southern part.

The *Stansmore Fault* (Plate 1, Fig. 2) is a southwest-dipping normal fault at the margin of the Gregory Sub-Basin and with the Betty Terrace. It offsets the southern end of the Hinge Fault System. This offset has been attributed to dextral transcurrent movement antithetic to that along the Billiluna Fault and the Stansmore Fault during the Red Bluffs extensional movement (compare with Smith 1984).

The *eastern part of the Fenton Fault System* defines the southwestern margin of the Gregory Sub-basin. It was an active normal fault in the Mid Devonian to Early Carboniferous and possibly also in the Early Ordovician. During the Fitzroy Movement, flower structures formed locally along the fault system as a result of right-lateral strike-slip faulting.

The *Dummer Fault System* (Plate 1, Fig. 2) is a north-dipping normal fault at the southern margin of the Barbwire Terrace which is a feature common to the southern margins of both the Fitzroy Trough and the Gregory Sub-Basin. Reactivation of the fault during the late Triassic and Early Jurassic Fitzroy Movement is considered by Smith (1984) to have produced up to 40 km of right-lateral offset.

The *Tina Springs Fault* is a steeply dipping offshoot of the Dummer Fault System. It was an active normal fault in the Mid-Devonian to Early Carboniferous. It was locally reactivated to produce flower structures during the Fitzroy Movement. These movements involve right-lateral displacements.

Faults — Willara and Kidson Sub-Basins

The *Admiral Bay Fault Zone* (Plate 1, Forman & Wales 1981) marks the southern central edge of the Broome Platform and the northern margin of the Willara Sub-Basin. This Sub-Basin is an asymmetrically half-graben, filled mainly with Ordovician clastics, that thicken northwards towards the faulted northern margin, where a series of depocentres border the downthrown side south of the fault zone. The structure and stratigraphic evolution of the sub-basin is discussed in much more detail in Romine et al. (1994). The basin shallows to the south and southwest, into a shelf-like region, where several moderately south-dipping, disconnected, normal faults are developed, the largest being the *Munro Fault Zone* (Forman & Wales 1981). The faults in the southern Willara and Kidson Sub-basin differ from those controlling the northern trough in that they form an array of sub-parallel normal faults, separated by narrow rider-like fault blocks, and weakly linked by relay zones (fault parallel ramps).

The *Chirit and Frankenstein Fault Zones* (Plate 1, Fig. 2) described (see Gibbs 1984, p.613) by Romine et al. (1994), mark the northern edge of two narrow half-grabens on the Anketell Shelf. These half-grabens extend to the southeast into an area that has been previously placed within the Kidson Sub-basin. The Chirit Fault had been noted earlier by Brown et al. (1984, fig. 3; see also Conolly et al. 1984), who also recorded the *Saturn Fault*, a north-dipping normal fault near the boundary between the Kidson Sub-basin and the Tabletop Shelf.

Accommodation features — Willara and Kidson Sub-Basins.

Just as the style of faulting differs between the northern and southern troughs of the Canning Basin, so do the accommodation structures. In the Willara and Kidson Sub-Basins the main fault zones are made up of narrow rider-like fault blocks. Linkage between these fault blocks is accommodated by lateral ramps and related structures in relay zones. These features have been extensively described by Romine et al. (1994). In these zones the displacement between overlapping, en echelon fault segments is adjusted continuously, allowing connection along ramps between the hanging-wall of one fault segment and the footwall of the next. At the regional scale, abrupt back-stepping of the main fault zones corresponds to basement highs that permit a relay-style transfer of extensional strain. The largest example is the *Great Sandy Accommodation Zone* (not figured in Plate 1, see Romine et al. 1994), a basement arch separating the two principal displacements of the Willara Trough, both of which show thickening into distinct segments of the Admiral Bay Fault Zone. The eastern extension of the fault zone back-steps northwards and widens across the Great Sandy Accommodation Zone.

PART 3: TECTONIC HISTORY

BASEMENT

The Beagle Bay- Pinnacle Fault Complex lies on or close to a south-dipping basement thrust zone marking a major Proterozoic province boundary at the southern margin of an emergent King Leopold Orogen (see Section on Basement Structures). This thrust zone is shown to have been active at about 500 Ma (Shaw et al. 1992), immediately before the onset of subsidence in the Canning Basin.

Deformations of similar age are likely to have affected the southern margin of the proto-Canning Basin overlying the northern margin of the Paterson Province (Myers 1990), as this was part of a major trans-continental zone of deformation that was active at the end of the Cambrian (e.g., 530-550 Ma Petermann Ranges Orogeny in the Musgrave Block, Maboko et al. 1992) and at the close of the Cambrian in the Officer Basin (Priess 1987) and the Kanmantoo Trough in South Australia (Parker 1986).

CANNING BASIN

An assessment of the various episodes in the development of the Canning Basin in general, and the Fitzroy Trough in particular, is outlined in Table 1 and Figure 1.

Evidence for these episodes comes from analysis of outcrop, seismic and well data. The results of a geohistory analysis (Kennard et al. 1994 b), completed after our structural project, provides supporting evidence for the episodes established from other data sets. Their analysis uses the WinBury 1.4 geohistory modelling software. Figure 6, adapted from the geohistory study, shows back-stripped basement subsidence curves for wells in the region of the mid-basinal arch. The main extensional and compressional events are well expressed by these curves. Other pertinent results from the geohistory analysis, including estimates of maximum recorded subsidence for each episode, are summarised in Table 7.

Samphire Marsh Extensional Movement

The tectonic movement takes it name from Samphire Marsh 1 well where some of the oldest dated Ordovician sediments are recorded (see Niccol et al. 1993). Extremely rapid basement tectonic subsidence calculated by Kennard et al. (1994b) from well data, is in excess of 1.4 km in the central Kidson and northern Willara Sub-basins and the northwest margin of the Fitzroy Trough, bordering the Lennard Shelf. More moderate tectonic subsidence of the order of 0.6 - 1.0 km is estimated for the Broome Platform and Dampier and Barbwire Terraces (cf. Table 6).

The late Tremadoc Nambeet Formation shows growth towards the Admiral Bay Fault Zone (see Romine et al. 1994), but in much of the central part of the basin the initial depocentre had more the form of an intracratonic sag basin. The inundation of this depression, probably from the west, is seen to be a response to the Kelly Creek Eustatic Event identified by Niccol et al. (1993). The resulting transgression spread relatively rapidly and led to establishment of the Larpintine sea-way, connecting the Canning and Amadeus Basins. By the Late Arenigian, growth against the Admiral Bay and Munro Fault Zones was more apparent and subsidence rapidly increased in the Willara Sub-basin (Willara and Goldwyer Formations, see Romine et al. 1994).

A similar pattern of thickening into southwest-dipping normal faults is also evident on the northern Broome Platform and along the northern margins of the Fitzroy Trough at Blackstone and Gap Creek (see Romine et al. 1994, fig. 5). Current seismic interpretation suggests that the interval affected by the movement appears to extend from the Arenigian, when the Willara Formation was deposited, to the early Llanvirnian, represented by the early part of the Goldwyer Formation. An apparent increase in subsidence in the early stages of deposition of the Goldwyer Formation may be a consequence of a rise in relative sea-level with the advent of the Maloney Creek Eustatic Event (Nicoll 1993).

Ordovician carbonates and shales accumulated in several depocentres, especially in the southern sub-basins. As mentioned above, remnants of these are also preserved along the northern margins of the Fitzroy Trough where locally the Ordovician succession thickens towards the Beagle Bay-Pinnacle Fault Complex, thereby suggesting extensional movement along this zone (e.g. Ordovician thickening towards the Virgin Hills Fault System, Purcell & Poll 1984, fig. 6 WAPET line B; and towards the Sixty-Seven Mile Fault System section north of Blackstone 1 Well, the so-called Blackstone half-graben).

Carribuddy Sag Phase

The fact that growth faults like the Admiral Bay Fault Zone die out up-section before reaching the late Llanvirnian Nita Formation suggests that by this stage the Tectonic driving force was related to thermal relaxation in a sag phase. The same sag phase may have continued throughout the period of increasingly restricted deposition represented by the Carribuddy Group that incorporates thick halite deposits. The timing of events is constrained by revised biostratigraphic dating and stratigraphic subdivision of the sediments in the upper part of Carribuddy described by Foster and Williams (1991), Nicoll et al. (1994) and Romine et al. (1994). The sag phase may have spanned the period from about 465 Ma to at least about 435 Ma.

Unnamed period of Late Ordovician to Silurian Hiatuses

An enigmatic Silurian event, marked by a phase of thinning and onlap, within the middle 300 m section of the Sahara Formation Romine et al. (1994). The onlap is placed above, but not immediately above, the Mallowa Salt (see Figure 1, Tables 1 & 2), starting after the deposition of the basal Sahara Formation which was dated by conodonts as Early Silurian (Llandovery, Nicoll et al. 1994). This event corresponds with a period of basin-wide tilting, resulting in uplift and minor erosion to the northwest in the region of the Barbwire Terrace and subsidence centred in the Kidson Sub-basin (Romine et al. 1994, Romine pers. comm.).

This depositional picture is similar to that of the Mereenie Sandstone in the Amadeus Basin. It is likely that this event may correlate, in part, with the Rodingan Movement, highlighted by unconformities within and at the base Mereenie Sandstone, as well as at the base of the underlying Carmichael Sandstone. The age of the Rodingan Movement(s?) is very poorly constrained. It possibly started at about 430 Ma (Shaw 1991, compare with Shaw et al. 1991a) as did the onlap phase in the Sahara Formation. As the time of deposition of the Mallowa salt appears to correspond to that of Carmichael Sandstone deposition, the breaking up of the Larpintine sea-way connecting the Amadeus and Canning Basins started somewhat earlier in the Caradoc, (see Nicoll et al. 1991, cf. Fig. 1).

Prices Creek Compressional Movement

In the Gap Creek area at the northeast margin of the Fitzroy Trough, Middle Devonian sedimentary rocks (Poulton Formation) unconformably overlie Ordovician rocks. Locally (e.g., at Gap Creek), an angular unconformity is evident, which amounts to a 20° difference in strike and a 5-15° difference in dip. Minor folding is apparent along the Ordovician/Devonian boundary in both the Gap Creek and Give-and-Take Creek areas. Folding is also observed on seismic data (see Middleton in GSWA 1992, fig. 4-116). The minor folding does not affect the overlying Frasnian limestone units (Pillara reef complex), suggesting that a mild compressional event occurred between the Ordovician and the Devonian. A new name, the Prices Creek Movement, is applied to this deformation, which consists of minor folding and uplift that affected the Early Ordovician Gap Creek Formation.

Following this event, extensive erosion occurred on the Barbwire Terrace and in the west of the Canning Basin. Geohistory analysis of well data (Kennard et al. 1994b) shows that tectonic uplift resulted in erosion of at least 700 - 800 m of the Ordovician-Silurian succession on the northern Broome Platform and the outer margin of the Lennard Shelf (Table 6).

A minimum age for the event is provided by the Emsian/Eifelian age for ostracods from the base of the equivalents of the lower Tandalgoo Formation on the Barbwire Terrace (Elsa Sandstone Member of the

Worral Formation, Niccoll et al., 1994). The correlation of the lower Tandalgoo Formation with the Worral Formation, based on an analysis of sequence stratigraphy by Romine et al. (1994), allows us to establish a maximum age for the Prices Creek Movement, as the Tandalgoo Formation rests on Lower Silurian of the Sahara Formation in the Kidson Basin (see Romine et al. 1994). The preferred correlative of the Prices Creek Movement is the Emsian Pertnjara Compressional Movement in central Australia, at about 390 Ma (Shaw et al. 1991b). However, given the long time-gap indicated, of perhaps as much as 20 Ma, it is not impossible that there were two erosional events that converged to produce one unconformity in most areas.

Tandalgoo Sag Phase

This is called a sag phase because it is thought to reflect the thermal response to a phase of extension centred in the lower crust and sub-crustal lithosphere, as explained below. The developing and progressively widening late Early Devonian to the Middle Devonian basin, represented by the Emsian to Eifelian Tandalgoo Sandstone and the younger to partly equivalent Poulton Formation, is suggestive of a thermal sag basin, especially as little faulting appears to be associated with it. This depositional stage may represent the first stages of Devonian extensional or transtensional strain in the lower not the upper crust. Subsidence was centred on the Willara and Kidson Sub-basins and, to a lesser extent, on the Barbwire Terrace. One speculative explanation for the onset of this subsidence, mainly recorded by the Tandalgoo Formation, is that it was driven by the thermal relaxation of the lithosphere following deep-seated extension that was concentrated in the lower crust and upper mantle, in a manner similar to that suggested by Shaw et al. (1991a) for latest Neoproterozoic to earliest Cambrian subsidence in the Amadeus Basin.

Pillara Extensional Movement

The major extensional event to affect the Fitzroy Trough started in the Mid-Givetian (~375 Ma, Kennard et al. 1992), and was well established by the Frasnian (Goldstein 1989). Subsidence was at a maximum along the southern margin of the Fitzroy Trough, bordering the Fenton Fault System where tectonic subsidence in excess of 3.5 km has been estimated from well data (Kennard et al. 1994). It appears to have started with extension in a south-southwest direction, centred on both the Beagle Bay Pinnacles, and Fenton Fault Fault Complexes. Initially, the extension appears to have been distributed over a wide region that included the southern terraces to the Fitzroy Trough (see subsidence analysis of Kennard et al. 1994 b). Fault movements rapidly became centred on the Beagle-Bay - Pinnacles Fault Complex, the Fenton Fault Complex and possibly a fault lying at the southern margin of the Mount Wynne Fault Zone (Plate 1), the controlling feature for the Mount Wynne Anticlinal Structure (Plate 2b).

Major orthogonal accommodation zones formed between these main normal fault systems to allow for marked differences in the amount of extension in each compartment. This event started with rapid and sustained subsidence, the Gogo extensional pulse, in the period extending from Mid-Givetian to the Frasnian. Within the Fitzroy Trough, it was followed by two other recognisable pulses of extension, the Van Emmerick and Red Bluffs pulses marked by tilting and block faulting. The timing of these pulses is established by the stratigraphic position of conglomeratic clastic fans that locally blanket the faulted rocks. The consequences of the last extensional pulse continued through to the Carboniferous.

Gogo extensional pulse The earliest phase of the Pillara Extension in the Mid-Givetian is referred to as the Gogo Extensional Movement. Several depositional units of this age thicken towards segments of the Beagle Bay-Pinnacle Fault Complex (see below). Although the normal faulting led to increased subsidence in the Fitzroy Trough, it, and the Gregory Sub-Basin, were still connected to the Kidson Sub-Basin across the Barbwire Terrace (e.g., see Brown et al. 1984).

Within the trough, the start of growth on the Fenton Fault System and possibly a fault at the northern margin of the Mount Wynne Anticlinal Structure is evidence by thickening (of unit D) against these faults (Plates 2 and 3). Downthrow on the Fenton Fault System allowed for an estimated 3.5-4 km of tectonic subsidence (Table 6, Kennard et al. 1994 b). Tectonic subsidence ranged from 500-700 m on the outer margin of the Dampier Terrace (e.g. Matches Springs 1, Pictor 1: Table 6) to less than 500 m on the Lennard Shelf, the Dampier and Barbwire Terraces, and the Kidson Sub-basin (Fig. 7). Subsidence on the Laurel Downs Terrace is estimated at 1.5-2.0 km (Blina 1, Mimosa 1; see Kennard et al., 1994 b) and drops to 900 m on the outer margin of the Lennard Shelf (Table 6). The amount of subsidence drops off rapildly once the middle of the Lennard Shelf is reached (see Kennard et al., 1994b).

Reef development there in the Pillara Cycle may have been largely controlled by eustatic sea-level rise. Reef growth was characterised by vertical platform growth, widespread drowning of the platform and backstepping along the edge of the Lennard Shelf (Kennard et al. 1992, compare with Begg 1987). Reef development was accompanied, at least locally, by dolomitization and extensive sparry-calcite veining (e.g. Geike Fault Zone).

As suggested by Romine (pers. comm; see also Romine et al. 1994), the "Mirbelia Dolomite" may represent the initial deposits on the Barbwire Terrrace following the Pillara Movement, whereas the overlying "Boab Sandstone" may reflect early effects of erosion as a result of uplift along a ramp on the southern flanks of the Fitzroy Trough (e.g., region of Boab 1). As such, the 'Boab Sandstone" may be analogous to the fan conglomerates that later spill into the trough along its northern flanks during the Van Emmerick pulse (see below).

Some localised post-Poulton Formation uplift and erosion is implied by the disconformity above the overlying Poulton Formation. For example, the Frasnian carbonates of the Pillara cycle of reef development disconformably overlie the Poulton Formation in the Gap Creek area (reconnaissance by R.D.S.; see also Nicoll et al. 1993).

Givetian-Frasnian Fault growth, shown by thickening sedimentary packages, is seen along the south-dipping Oscar Fault System (e.g. BMR 88-03, Drummond et al. 1991), the Sixty-Seven Mile and the May River Fault Systems (Jackson et al. 1993), and probably along other segments of the Beagle Bay-Pinnacle Fault Complex. These packages are seen on seismic data to thicken obliquely towards the Oscar Fault System (e.g., in seismic profile BMR 88-03), where they are interpreted to represent submarine fan complexes. Thin wedges of Givetian clastic sediments onlaps the Sixty-Seven Mile and May River Highs on the up-thrown blocks. There was also coeval relative displacement across the Sundown Accommodation Zone (Jackson et al., 1993).

Van Emmerick extensional pulse The influx of conglomerates and debris flows that reached a peak in the Late Frasnian suggests rapid upward tilting of the hinterland. This tilting is known as the Van Emmerick Pulse. We suggest that this movement records a shift in normal faulting activity away from the Beagle Bay Pinnacle Fault Complex to the Fenton Fault System. A northwesterly shift in the position of the main depocentres in the Fitzroy Trough (see Brown et al. fig 11) and a contraction of deposition to the northern troughs appears to have occurred at this time towards the end of the Frasnian. Although conclusive evidence for this shift is not yet available, it appears that the Famennian succession thickens gradually against the Fenton Fault System (Drummond et al. 1991, BMR line 88-03, fig. 3, section BB'-north; Purcell & Poll, 1984, fig. 7, profile D, WAPET line AF; see also Plate 2a, b). There was also either a rapid fall in relative sea-level or uplift along the southern margin of the trough, thereby increasing the angle of the depositional slope there. In the region south of the Fenton Fault System, the amount of emergence above sea-level implies hanging-wall uplift on that fault. The extension was marked by an increase in the rate of subsidence on the floor of the Fitzroy Trough, allowing a thick sedimentary pile to accumulate (compare with Kennard et al., 1994b). Whereas it is difficult to differentiate the relative effects of general sea-level change from changes in subsidence rate on the platform, continued subsidence is implied in the trough, in order to accommodate the total thickness of the late Frasnian-Famennian lowstand deposits Jackson et al. (1992). Thicknesses reached in excess of 2 km (>1.0 sec TWT in Plate 2b; see also subsidence evidence in Kennard et al., 1994b).

Fault reactivation seems to have been short-lived and to have peaked in the latest Frasnian-Early Famennian. It can account for much of the stratigraphic complexity and facies variation recorded as this time. The best example of the movement is a major influx of molasse-like sediment known as Van Emmerick Conglomerate, the deposition of which commenced in the late Frasnian. Outcrop of the conglomerate is localised to sections along the northwestern margin of the Napier Embayment. The deposition is possibly related to uplift along unmapped normal faults in the region of the Duck Hole Shear (DHS in Plate 1). Equivalent conglomerates have been intersected in Meda 1 and Yarrada 1, and coeval lowstand deposits mapped on seismic data throughout the Meda Embayment (Kennard et al. 1992, Southgate et al. 1193) Late Frasnian uplift, emergence and erosion of the rotated Laurel Downs Terrace Block to form the Blackstone high, as demonstrated by Blina 1, also occurred during the Van Emmerick pulse (Jackson et al 1993). East-west extension evident in the McWhae Ridge area of the Margaret Terrace, marked by the Bobs Bore Conglomerate, can also be assigned to the Van Emmerick pulse (compare with Playford 1981 figs 33 & 34).

A period of erosion and/or non-deposition, that apparently corresponds to this event, affected the whole of the Broome Platform, as well as the southern Canning Basin (Begg 1987, p. 145). Unfortunately, Permian erosion has remove much of the critical section. Emergence, implied by this hiatus in the south, may partly reflect isostatic adjustment to rifting of the Fenton Fault. Egan (1991) has pointed out that such foot wall uplift can be one of the best indicators for the timing of rifting.

Submergence of the eroded Blackstone High in the mid-Famennian, indicates localised renewed extension along the northern margin of the Fitzroy Trough. Extensional movement on the Sixty-Seven Mile Fault (region near Blackstone 1 and Blina 1) led to the formation of an embayment within this compartment (locally known as the Kimberley Downs Embayment) and the formation of the Blina carbonate platform (Famennian Sequences 1 and 2 of Jackson et al. 1993; Kennard et al. 1992, Southgate et al. 1993). The Harvey Fault System and possibly the May River Fault were initiated at this time. This extension, which continued into the Late Famennian, resulted in the onlapping units at Blina and Crab Creek wells (see Goldstein 1989, figs 16 & 17). The fault movements along the northern margin of the Fitzroy Trough appear to be minor adjustments, the largest normal fault displacements being concentrated along the Fenton Fault System.

Red Bluffs extensional pulse

Starting in the very latest Devonian and continuing into the Early Carboniferous, there was renewed extension as evidenced by the progressive thickening of the upper Laurel and Anderson Formations towards the Fenton Fault System (Drummond et al. 1991, BMR line 3, compare with Begg 1987, p. 148) and towards the Stansmore Fault in the Gregory Sub-basin. Indications of growth on the faults within the Fenton Fault System is also provided by seismic evidence of fan deltas developing across the active fault scarp (noted by Brown et al. 1984, also see below). Extension is similarly implied by localised thickening of these units elsewhere, such as immediately south of Hakea 1 well (P. O'Brien, pers. comm.). Variable dips in and between inferred fault blocks in the back-reef succession of the eastern Margaret Embayment (e.g., observed during reconnaissance by R.D.S. in the Bugle Gap, Lawford Range and Hull Range) can be attributed to east-west and northeast directed extension during the Red Bluffs Movement as well as the earlier Van Emmerick pulse (see above, compare with Playford 1981). Similarly, in the Gregory Sub-basin, up to about 6 km of Early Carboniferous sediment, mainly of Laurel and Anderson Formations (Smith 1984), accumulated at a sufficiently sustained rate (240 m/Ma) that extensional tectonism is implied, in the obvious absence of foreland loading (compare with Schwab 1986).

The pulse is marked by the spectacular influx of coarse clastics (conglomerate and sandstone) on both the northeastern margin of the Margaret Embayment and the Billiluna Shelf. The locality from which the movement has been named, Red Bluffs, is where *Leptophloem australe* has been identified (Veevers et al. 1967) in a coarse sandstone that directly and disconformably overlies both Late Devonian rocks of the Gum Hole Formation (and the Nullara Limestone, compare with Druce & Radke 1979, fig. 6). The contact follows sharp ridges and valleys in the latter limestone. The current palaeontological view (Jones 1994) is that the *L. australe* fauna can be placed in the very latest Devonian or, less probably, in the earliest Carboniferous. Shallowly dipping (less than 15°) sandstone and conglomerate discordantly overlying the Devonian reef complex between Red Cliff and the Sparke and Barramundi Ranges, and the continuity of facies suggests all these semi-continuous exposures are linked. These stratigraphic relationships imply that much of this discontinuous sandstone unit is latest Devonian to earliest Carboniferous in age. The Knobby Sandstone, exposed on the Billiluna Shelf, also contains *L. australe*, and represents a similar coeval sedimentary facies, regarded by Smith (1984) as a delta complex.

This resurgence of normal-faulting movements that accompanied the extension appears to have led to a steepening of dips, in units of Famennian age, towards the footwall of several normal faults. The faulting may also explain the formation of debris flows in the Nullara Formation (also of early Famennian age exposed within the Geikie Fault Zone), in addition to the tilting , and inferred faulting of Famennian strata, in the McWhae Ridge region (this tilting post-dates onlap of the reef spine as documented by Playford 1980). A rise in relative sea-level following the extension may also explain onlapping units of earliest Carboniferous age (upper equivalent to the Yellow Drum and Laurel Formations, cf. Begg 1987).

The conglomerates in the Sparke Range post-date probable equivalents of the Gum Hole and lower Yellow Drum Formations (ie., latest Devonian units of the Fairfield Group; see Roberts et al. 1968). Deposition of these conglomerates can be linked to normal faulting that climaxed at the time corresponding to the Devonian - Carboniferous boundary. The conglomerates have sub-horizontal dips and are strewn across an eroded and tilted succession of Devonian carbonates. The conglomerates are preserved plastered to parts of the Mount Emma and Mount Winifred Faults (MEF & WF in Plate 1; T. Griffin & I. Tyler, GSWA, pers. comm., 1990). The conglomerates are sub-horizontal dipping, molasse-like, matrix-supported, pebble and boulder conglomerates which are unlike any unit in the flat-lying latest Carboniferous to Early Permian Grant Group, which, in turn, onlaps the Devonian carbonates to the south. Thus, these conglomerates are of very latest Devonian or Carboniferous age, like those at Red Bluffs, as they post-date equivalents of the Gumhole and lower Yellow Drum Formations and pre-date the Grant Group.

Thus, deposition of conglomerates of unit D-Pc (notes on MOUNT RAMSAY by Roberts et al. 1968) at the northeastern edge of the Margaret Embayment in the Sparke and Barramundi Ranges also date from the same extensional pulse. Minor displacement on the faults in the Margaret River Embayment continued after deposition of unit D-Pc. White & Muir (1989) proposed a Devonian thrust (inversion) event to account for this major influx of molasse-like sediment, but they are more readily accounted for by a resurgence of normal faulting.

The movement can also account for main influx of the molasse-like Mount Behn Conglomerate, the deposition of which starts in the late Famennian. This deposition is very localised and may be related to footwall uplift on unmapped normal faults at the northern margin of the Napier Embayment. Very localised, linear, deeply entrenched valleys were incised into marginal slope deposits and were filled with coarse clastics such as those of the Mount Behn Conglomerate.

Following the tectonic instability indicated on the northeastern margin of the Fitzroy Trough by the conglomerates, a major sedimentary ramp complex (see Fig. 3, Jackson et al., p217) formed on the northern margin of the Fitzroy Trough (Jackson et al. 1992). This ramp complex represents the distal edge of a wide extensional wedge that thickened into the Fenton Fault System. The wedge, made up of carbonates and shales of the Laurel Formation passing upwards into siltstones and sandstones of the Anderson Formation, spread across a large part of the Lennard Shelf, under conditions of falling rates of subsidence. A delta complex spread cross the northern troughs from the Gregory Sub-Basin, detritus being sourced from highlands to the east, which were emerging as a result of the Alice Springs Orogeny. This phase of deposition continued in the Fitzroy Trough, with minimal interruption, until the *G. maculosa Zone* in the early Namurian; (a possible depositional break suggested by Jones and Young 1993).

The extensive and even deposition of much of the Laurel and Anderson Formations in the Fitzroy Trough implies that either (i) the extension was accommodated on a limited number of faults, such as the Fenton Fault System, (ii) the extension was substantially sub-crustal with the result that most of the subsidence occurred in a post-rift thermal sag phase, as proposed to explain the Cambrian subsidence in the Amadeus Basin (see Shaw et al. 1991a), or (iii) that the extension took place very slowly, with the result that thermal equilibrium was continuously maintained and, consequently, there is no marked separation between a rift phase and a thermal sag phase, as in 'instantaneous' stretching models such as that of McKenzie (1978).

Evidence of subsidence derived from wells in the trough (Yulleroo 1, Myroodah 1; Kennard et al., 1994 b) suggests that continued subsidence was driven by downthrow on the Fenton Fault. This subsidence masked that due to lithospheric cooling. This conclusion is confirmed by the thickening of the Laurel and Anderson Formations against the Fenton Fault System and their absence from the southern terraces, bordering the trough to the south.

MEDA TRANSPRESSIONAL MOVEMENT

Variable but slight inversion of Devonian normal faults is inferred to have taken place in the Mid- to Late Carboniferous, concurrent with a period of sustained uplift and erosion. It is likely that some of the uplift implied by the regional unconformity at the base of the Grant Group, may have continued during deposition of the Grant Group in the earliest Permian (Fig. 1, Table 2). Continued uplift and erosion at the northern margin of the Fitzroy Trough in the Late Carboniferous is also supported by apatite fission track results (Arne et al. 1989). Widespread uplift and erosion of the order of 200 - 300 m over much of the basin is estimated from well data (Kennard et al. 1994b). Uplift and erosion appears to have been a maximum (800 m in Calamia 1) towards the southern margin of the basin. However, much of this uplift and erosion can be attributed to the Drosera Erosional Event related to the development of ice sheets in the Late Carboniferous.

The unconformity at base of the lower Grant Group has been correlated with the final phase of the Alice Springs Orogeny in central Australia (eg.Goldstein 1989). Recent $^{40}Ar/^{39}Ar$ geochronology in upthrust basement north of the Amadeus Basin in central Australia (Shaw et al. 1989, Shaw et al. 1991b) confirms that the last phase (Mount Eclipse Movement) of the Alice Springs Orogeny continued into the Late Carboniferous (about 300-320 Ma). In the Canning Basin, the equivalent pulse of the Alice Springs Orogeny, may correlate with uplift and erosion immediately before and during deposition of the lower Grant Group, and the subsequent Drosera Erosion which, marks the break between the lower and upper Grant Group; the estimated age span of this uplift is 326 Ma to 298 Ma (see Fig. 1; Tables 1, 2 & 4; Jones & Young 1993).

The tectonic history in the Canning Basin is, however, different from that of the Amadeus Basin in central Australia. In central Australia, the main pulse of the Alice Springs Orogeny occurred in the early Frasnian-Famennian and led to the deposition of syn-orogenic conglomerates (Table 4, e.g. Hermannsburg Sandstone and Brewer Conglomerate). This pulse appears to correlate with the main phase of extension during the Frasnian to the Tournaisian time-interval in the Fitzroy Trough (ie., Pillara and Nullara Cycles). Further work is required to test these correlations and deductions (see table 4 for a tentative scheme). Some of the tectonic implications of the contrasting behaviours between the Canning and Amadeus Basins have been discussed by Braun et al. (1991) in terms of movements on what they refer to as the Lassiter Shear Zone.

Available biostratigraphic age constraints indicate that the uplift, and the seismic unconformity at the base of the Grant Group across the outer portion of the Lennard Shelf pre-dates the deposition of the *S.yberti* bearing Lower Grant Group intersected in Meda 1 well. This unconformity (illustrated in Fig. 8) is preserved only in a narrow corridor on the outer-margin of the Lennard Shelf. This corridor runs from near the Sisters Terrace 1 to the region of Wapet May River 1 (compare with Jones & Young 1993). This unconformity truncates the multicoloured unit at the top of the Anderson Formation (see Jackson et al. 1992, 1993); see Table 2). The geographic extent of this break, placed at about 320-326 Ma (early Namurian), is uncertain because it appears to extend across on the Lennard Shelf, but is not evident in the Fitzroy Trough, where a more complete succession is preserved (Fraser 1, Grant Range 1 and St George Range 1 wells).

The pockets of deposition represented by the lower Grant Group are interpreted as foreland-like deposits concentrated in synclinal depressions along the northern margin of the Fitzroy Trough, where transpressional movement appears to have been focused. The movement on reactivated faults produced positive and negative flower structures along the boundary between the Fitzroy Trough and the Lennard Shelf, particularly along segments of the Harvey and May River Fault Systems. Some reversal also took place within the transverse Sundown Accommodation Zone and the Outcamp Accommodation Zone much further to the east. There are hints in the seismic data that incipient growth of some of the anticlines within the Fitzroy Trough, and the Gregory Sub-basin (see Smith 1984, Kufpec Australia Pty Ltd, unpublished data 1986) started at this time.

A positive flower structures formed during this movement is illustrated in the interpretation of seismic data for line H84-12.3, southeast of Meda 1 (Fig. 8, after Jackson et al. 1993). The structure, a faulted anticline, represents the reactivation of the May River Fault System. Growth on the structure was essentially complete by the time of deposition of the Lower Grant Group (horizon ybe in Fig. 8). However, sufficient movement continued on the structure to give rise to an angular unconformity between the Lower and Upper Grant Group (indicated by discordant arrows, which are reflector terminations). Post-Grant movement on the structure is slight compared with the earlier movements and is largely a result of the Fitzroy Movement. The same structure is also illustrated by seismic line H84-10.5 that passes through Meda 1 well (see Southgate et al. 1993, Fig. 3). The best record for an erosional break at the base of the Lower grant Group is to be found in Blackstone 1 well (see Jones & Young 1993).

Another feature that can be attributed to the Meda Movement is the tilting of the Anderson Formation in synclinal features against a monoclinal upturn developed along segments of the Harvey Fault System. Interpretation of this thickening is complicated by post-Meda Movement erosion during the Drosera Erosion Event (see below). Some reactivation of normal faults appears to have led to a steepening of dips in Devonian strata against the footwall of several Devonian normal faults (eg. parts of Virgin Hills Fault Zone, field observations by R.D.S.)

Thus, the formation of the contractional structures and the subsequent uplift and erosion are correlated with the culmination of the Mid-Carboniferous phase of the Alice Springs Orogeny in central Australia (Table 4). In the Canning Basin region, local up-thrusting may have continued into the Permian (e.g., Upper Grant Formation in Kora 1 Well). Alternatively, such structures cutting the Permian succession are the result of reactivation during the Fitzroy Movement (see below). Erosion attributed to mid Carboniferous uplift varies from scant to in excess of about 1 km (Lehmann 1986, fig. 12). For example, much of the Early Carboniferous (Tournaisian-Visean) Fairfield Group was eroded from the northern part of the Broome Platform (previously the Dampier Terrace) on the southern margin of the Fitzroy Trough, and only scattered outcrops of the Fairfield Group are preserved on the Laurel Downs (Margaret) Terrace. The more deformed section of the Bargo Terrace and Billiluna Shelf may potentially reflect this tectonism. The reduced section on the Billiluna Shelf is ascribed to removal of section as a result of erosion following Meda Movement uplift (compare with Yeates & Muhling 1977).

The Meda Movement in the Canning Basin differs significantly in character from the large uplifts and thrusting that accompanied the peak of the Alice Springs Orogeny in Central Australia. The early phases of the Alice Springs Orogeny that start in the Late Devonian appear to be absent from the Canning Basin except for the Prices Creek Compressional Movement that appears to correlate with the Pertnjara Movement in central Australia (see Table 4). The amount of uplift resulting in the marked steepening of dips is, for the most part, localised along pre-existing Devonian normal faults, such as the Virgin Hills and Cadjebut Faults. There was minor folding of beds around the Virgin Hills Inlier and the Emmanuel Ordovician High. Also assigned to the Meda Movement are minor west-northwest (~120-130°) folds that distort the Ordovician-Devonian boundary, south of the Pillara Inlier in the region of Gap Creek Spring and in the headwaters of Emmanuel Creek.

Mild right-lateral, strike-slip faulting is postulated to account for locally developed flower structures developed in places along the northern margin of the Fitzroy Trough (e.g. May River Fault, seismic line H84-10.5). Mild doming over these flower structures did not affect the basal unit of the Grant Group (containing the *S. ybertii Zone* or younger units).

The lack of widespread syn-orogenic deposition suggests that the Meda Movement was of limited magnitude for the most part or that it was dominated by oblique-slip and strike-slip movements. Detailed mapping by BHP-UTAH in the Cadjebut area (P. Muhling pers. comm. 1989, 1990) has demonstrated minor component of left-lateral strike-slip movement on the Cadjebut Fault which may be ascribed to this event. Sinistral strike-slip faulting can also explain features such as local pop-up structures, steep (48°) dips against the Virgin Hills Fault, sharp bends in the Cadjebut Fault near Pinnacle Spring, and the obliquity of minor folds in the Ordovician-Devonian contact in the Cadjebut region. Activity on northerly trending faults, such as those south of Guppy Hills, suggest an orthogonal pattern of faulting, which may be a reactivation of Devonian and earlier structures.

Apatite fission track results for basement samples immediately north of Devonian carbonates on the Lennard Shelf suggest that these samples had cooled through temperatures of about 100 ± 20 °C by about 300 Ma and subsequently underwent protracted cooling (compare with Arne et al. 1989). The samples may have reached peak temperatures during maximum burial in the Late Devonian and Early Carboniferous. It is considered that most of the sustained uplift and erosion north and east of the Lennard Shelf was a consequence of the Meda Movement.

The skewness in the distributions of apatite fission track lengths in other basement samples north of the Lennard Shelf suggests mixed ages, possibly reflecting incomplete resetting, which implies that the temperatures during maximum burial were less than 70-80°C. This fission track age result, plus the evidence of erosion of basement during deposition of the Grant Group (Arne et al. 1989, p. 505) and the limited preservation of the Grant Group on the Lennard Shelf north of the Oscar and Napier Ranges, suggests that little, if any, Grant Group was deposited in the region now occupied by basement. Nevertheless, these basement samples at the northern margin of the basin may have undergone as much as 3 km of slow, long-lived uplift and erosion since the time of maximum burial, assuming a geothermal gradient similar to that at present of about 30°C/km. This compares with uplift and erosion on the Lennard Shelf of about 1.5 to 2 km, assuming the same geothermal gradient. Much of this uplift may have taken place in the mid-to late-Carboniferous and may be due to both the Meda Movement and the subsequent Drosera Erosion Event which immediately followed deposition of the lower Grant Group and preceded deposition of the Upper Grant Group.

Drosera Erosion Event

This event is proposed to explain a gap in the biostratigraphic sedimentary record between the basal "pre-glacial" Grant Group and the Upper "glacial" or main Grant Group (Jones & Young 1993). This hiatus may represent about 10-12 Ma, extending from the Late Westphalian through to the Stephanian (from about 298-310 Ma). The movement is seen as substantially a continuation of the Meda Movement, complicated by rapidly enhanced erosion as a result of the encroaching glacial period that started in the Late Carboniferous. Alternatively, the absence of Late Westphalian-Stephanian sediments may simply result from erosion at the base of the advancing continental ice sheet.

Point Moody Extensional Movement

The marked, progressive thickening of the Upper Grant Group towards the Fenton Fault, at the southern margin of Fitzroy Trough, suggests a major recurrence of extension in the Early Permian (compare with Drummond et al. 1991). Such a thickening is indicated south of Myroodah 1 on BMR line 88-03 and is suggested south of Millyit Range and Point Moody 1 in the preliminary isopach data of Forman & Wales (1981). Similar thickening, implying growth of intrabasinal faults, is suggested by the same data set south of Fraser River 1 well and in the St. George Range region. Rapid tectonic subsidence generated by rifting is a maximum along the southern margin of the Fitzroy Trough bordering the Fenton Fault.

Tectonic subsidence curves, such as those for the Jurgurra-Dampier-Barbwire Terraces (Fig. 7), provide evidence for the widespread nature of the rifting event. The rifting is seen to be synchronous with deposition of the Upper Grant Group from about 298 to 290 Ma. Maximum subsidence noted is in the Fitzroy Trough (600 m in Yulleroo 1, 1100 m in Myroodah 1), while 600-800 m of subsidence is estimated for parts of the Broome Platform (e.g. Aquila 1, Thangoo 1A; Table 6). The subsequent sag phase, corresponding to the rapid decline in the rate of subsidence, is recorded by the units of the Liveringa Group.

These presumed syn-extensional units may correlate with syn-rift fill of probable Early Permian age recently identified offshore in the Edel Sub-basin of the Northern Perth Basin (Marshall & Lee 1989). Here, the rift phase of the Northern Perth Basin appears to end with an unconformity (a short-lived erosional break?) of late Early Permian (? base of Artinskian) age.

The Point Moody Extension correlates with a subsidence phase recognised offshore in the North West Shelf, where it is taken to mark the onset of the Westralian Basin (AGSO North West Shelf Study Group, 1994).

Nura Nura Transgression

The widespread marine transgression marked by the incoming of the Nura Nura Member of the Poole Sandstone in the Earliest Sakmarian (at about 290 Ma) is referred to the Nura Nura Transgression. It records a rise in relative sea-level that may result from the development of a widespread sag that may represent thermal subsidence following the extensional movement.

Lagrange Extensional Movement

This movement is defined in the Bedout Sub-basin as that extension marked by basaltic volcanism, with a minimum K - Ar age 253 Ma ± 5 Ma, detected in Lagrange 1 (Colwell & Stagg, 1994). Normal faulting in the Late Permian is widespread on the Northwest Shelf; for example, rifting is well documented in the Perth Basin (Quaife et al., 1994) where alkali basalts have been recorded with an age (250 ± 40 Ma) similar to those on the Bedout High. Basalts are also interpreted in the Permian section in the Offshore Fitzroy Trough (Cowell & Stagg, 1994). Onshore, dolerites intruding the Grant Group at Perindi 1 well on the Moogana Terrace probably date from the same event (see Reeckmann & Mebberson 1984). The movement is tentatively placed in the Late Permian. It may correlate with a period of minor uplift and erosion which produced the unconformity between the Liveringa Formation and the Blina Shale (base Blina unconformity).

A reason why this event corresponds to a hiatus (regression) in the Canning Basin, rather than subsidence related to rifting, is enigmatic. It could reflect magmatic underplating of the lower crust associated with the intrusion of the dolerites.

The Bedout Movement is considered by us to be a compressional movement that produced folding over the faulted core of the Bedout High and extensive erosion there and in the surrounding area (Colwell & Stagg, 1994). Latest Permian basalts assigned to the Lagrange Movement are considered to have been uplifted and eroded during the movement. Transpressional faulting in the Bedout Sub-basin has been linked to the same tectonism. The timing of the movement is possibly earliest Triassic, following the Lagrange Extensional Movement. It does not appear to have been an important event in the Canning Basin. Further work is required to sort out the tectonic events in the Bedout region.

Fitzroy Transpressional Movement

This movement originally defined as the Fitzroy Movement by Forman & Wales (1981). Its timing is placed in the Late Triassic to Early Jurassic (Colwell & Stagg, 1994); early Jurassic (180-200 Ma) being preferred. produced the large divergent, anticlines and synclines in the central region of the Fitzroy Trough. These structures have been ascribed to regional dextral strike-slip (wrench) movements of the 'cratonic' blocks bounding the Fitzroy Trough (Rattigan 1967, Smith 1968, Gorter et al. 1979). They range in trend from northwest to west-northwest. Some, such as that shown on seismic line H84-10.5 near Meda 1 Well (Kennard et al. 1992, fig. 2), are wrench anticlines. Synclinal depressions formed in the region of the Gregory Sub-Basin and the largely off-shore Oobacooma Sub-basin. Variations in the pattern of deformation reflect the main depositional compartments of the northern trough, which, in turn were inherited from major features in the basement. The trends of the fold implies northerly to northwesterly compression parallel to a closely-spaced set of sub-vertical shear faults of small displacement, which are particularly prolific in the region of the St George and Poole Anticlines. A component of major dextral shear affected the fault complexes at the margins of the Fitzroy Trough, resulting in local inversion of extensional structures. By way of comparison, the overall pattern of deformation is analogous to that affecting the Cainozoic Taranaki graben in New Zealand (Naylor et al. 1986, fig. 5c).

During the movement, strata in the region of the Broome and Crossland Platforms, and bordering terraces to the north, were formed into a broad arch. Uplift in the region of the Fitzroy Trough was variable and complex. During this movement the region of the Willara and Kidson sub-basins underwent slight regional uplift with negligible, if any, faulting. In the offshore Fitzroy Trough (Oobacooma Sub-basin), the Triassic to earliest Jurassic section is missing, possibly as a consequence of the Fitzroy Movement (Colwell & Stagg 1994).

Horstman (1984) estimated up to about 3 km of uplift and erosion in the centre of the Fitzroy Trough and up to 1 km on the Lennard Shelf, based on vitrinite reflectance values. This result is supported by an estimated 1.5 km uplift and erosion from apatite fission track data from Grevillea 1 well on the Lennard Shelf (Arne et al. 1989), uplift beginning at about 200 Ma.

Kennard et al. (1994 b) have also estimated uplift and erosion, using the WinBury geohistory model. Their estimates are generally lower than Horstman's, by variable amounts ranging from over 2 km to 50 m. The WinBury model is considered to be based on more consistent and up-to-date CAI maturity and stratigraphic data. It also adopts a more realistic palaeogeotherm (15-20% higher than present day) in its estimates. Kennard et all's modelling suggests that uplift and erosion affected most of the Canning Basin and were greatest in the northern Broome Platform and bordering Fitzroy Trough, where about 1 km (locally more) was eroded.

This transpressional tectonism appears to have been most intense in those regions previously most affected by extension in the Devonian. Presumably this was because the crust there, dominated by a thick sedimentary package, was weaker than that in the adjoining regions, dominated by more stable basement provinces. For example, the Lennard Shelf escaped deformation, as it was a region of thin sedimentary cover overlying basement.

Mesozoic Extensional Events Offshore

Major periods of extension started in the Middle Jurassic with a northwest-southeast directed movement (Goldstein 1989) and were mainly restricted to offshore regions. The earliest phase of Gondwana breakup started adjacent to in the northern Carnarvon Basin in the abyssal plane in the Callovian-Oxfordian later, in the Early Cretaceous (Neocomian - Valanginian renewed breakup took place to the west and southwest of the Exmouth Plateau. -see Table 2).

Tertiary Compressional Events

Some post-Permian erosion is also attributed to the Tertiary collision of the Australian and Indian sub-plates (Goldstein 1989). Compressional events affected much of the Australian plate in the Middle Eocene (*c.* 40-45 Ma) and in the Mid- to late Miocene (*c.* 10 Ma) (Etheridge et al. 1991).

CONCLUDING COMMENTS

Main crustal-scale features

The regional significance of particular structural features becomes more apparent when we examine the structural elements map (Plate 1, Fig. 2) after the new basement tectonic elements map of Australia being produced by AGSO, became available. These geophysically-defined basement elements show a broad correspondence to the structural elements discussed here, but differ from them in detail (Fig. 5). From these correlations we can assess the degree of basement control on basin development. The following basin structures show some degree of basement inheritance.

1. The western segment of the *Beagle Bay - Pinnacle Fault Complex* corresponds to the southern boundary of the King Leopold (Ko in Figs. 4 & 5). The correspondence between these features ends just east of the Colombo Fault (at the eastern end of the basement feature labelled O and N in Fig. 5). In the images of the deep seismic data for the line BMR 88-03 (Plate 2a, 2b), a discontinuous set of quasi-planar reflectors appears to track a major southwest-dipping fault zone that extends deep into the mantle (Drummond et al. 1991). At the surface, the fault zone aligns with the Spielers Shear, a late Cambrian thrust (Shaw et al. 1992). The Oscar (normal) Fault System is parallel to but a few kilometres basinward (south) of, the Spielers Shear. It seems likely that this composite feature marks a more ancient Proterozoic province boundary that has undergone several phases of reactivation. However, the main Oscar Fault and it's westwards extension as the Sixty-Seven Mile Fault System form listric faults that sole at or near the basement-cover interface. The listric nature of these faults is illustrated in several seismic sections including BMR 88-03 (Plate 2b) and that figured by Taylor (1992).

The Beagle Bay - Pinnacle Fault Complex is segmented by a series of prominent orthogonal accommodation zones. Most of these zones do not appear to be simple transfer faults. Rather, they appear to be wide, and in places discontinuous, zones of accommodation separating distinct segments of normal faulting with variable amounts of displacement (compare with Lehmann 1986, Begg 1987). Several of these zones show strong basement evolvement, as illustrated by their marked gravity expression (see, Fig. 6). These accommodation zones extend well out into the Fitzroy Trough, but do not cross the trough. Their southerly limit is thought to mark the southern extent of the listric faulting that also involved the basement.

2. The *Fenton Fault Complex* is seen on the BMR lines 88-03 and 88-01 (Plate 2a, b & 3a, b) to form a northeast-dipping listric fault that soles into the basement-cover interface (Drummond et al. 1991). A second north-east dipping listric fault, surfacing near Mount Wynne, soles into the same interface. The Fenton Fault system tracks the northern boundary of an elongate basement element (Br in Fig. 5). This element corresponds to a prominent Bouguer anomaly ridge that indicates a narrow crustal zone having

excess mass relative to its neighbouring regions. As such, this basement zone may represent a regional-scale Proterozoic rift feature, not unlike the continental rift zone in eastern North America. Furthermore, the basement zone is discordant with respect to a series of basement elements lying both to the north (O, N and Ho in Fig. 5) and the south (La and R, Fig. 5). The southern margin of the basement zone corresponds to the boundary between the southern terraces of the Fitzroy Trough and the Broome Platform.

Density interfaces of the type that outline this basement feature will tend to amplify gravitationally induced lithospheric stresses imposed during tectonism. As a result, boundaries of this type are likely to become zones of failure due to the spatial focussing of stresses (compare with Braun 1992).

Accommodation zones are less common along this fault system compared to that forming part of the Beagle Bay - Pinnacle Fault Complex. Some accommodation between normal fault segments also involves relay ramps (see Romine et al. 1994). The Camelgooda Accommodation Zone lies in the region of, but does not align with, a major angular disruption in the main basement element.

3. The *Admiral Bay Fault Zone* is a set of sub-parallel normal faults which form a series of narrow step-like terraces at the northern margin of the Willara Sub-Basin (Fig. 2). The lower part of the Ordovician succession thins in a step-wise pattern across this fault zone onto the Broome Platform. The contact between the Willara Sub-basin and the Broome Platform aligns with a basement boundary. This boundary separates a well-defined relatively stable basement feature to the north (Br in Fig. 5) from a more segmented, and so more mobile, basement region to the south (La in Fig. 5).

The normal faults in the southern sub-basins form sub-parallel arrays. Relay ramps link the overlapping fault segments (see Romine et al. 1994). This contrasts with normal faults at the northern margin of the Fitzroy Trough. Where, orthogonal accommodation zones link the faults systems. One exception in the southern sub-basins is the Great Sandy Accommodation Zone, a wide zone associated with a basement high that marks a northward-backstepping of the Admiral Bay Fault Zone as it passes eastwards.

The Admiral Bay Fault Zone is not as strongly expressed in the magnetic and gravity data, as the faults controlling the margins of the Fitzroy Trough. The different styles of response to accommodation evident in these two regions of normal faulting may reflect the larger and more focused displacements involved in the development of the Devonian Fitzroy Trough compared with the Admiral Bay Fault which is essentially and Ordovician feature. Renewed normal fault displacements in the Carboniferous and Permian accentuated these features in both sub-basins.

As suggested by Peacock and Sanderson (1994) in general, and noted as potentially relevant to the Canning Basins' development by Romine et al. (1994), relay ramps may represent the initial step in a progressive evolution to oblique transfer zones linking normal fault segments. The more complex orthogonal accommodation zones of the Beagle Bay-Pinnacle Fault Complex may represent a more advanced step in extensional processes that involved listric normal faults with larger displacements.

4. At the *southern margin of the Canning Basin* the Anketell and Tabletop Shelves preserve thin sedimentary cover over shallow basement of the substantially Neoproterozoic Paterson Province. The buried northern margin of the Province lies near the southern limits of the Kidson and Willara sub-basins. It seems likely that the southern margin of the Canning Basin was controlled by a basement slope, representing relict topography dating from the last period of thrusting in the Paterson Province in the Neoproterozoic.

5. At *south-eastern margin of the Canning Basin* there is a gradual zone between the thick deposits of Kidson Sub-basin and the thin deposits of the Ryan Shelf. It aligns with the boundary of a stable basement feature underlying the Kidson Sub-basin (R in Fig. 5) and a discordant north-south feature (A in Fig. 5). The younger north-trending basement feature is characterised by relatively high Bouguer gravity anomaly values (basement feature A in Fig. 4) that corresponds to the Ryan Shelf. The Ryan Shelf appears to be underlain by Neoproterozoic rocks of the Amadeus Basin succession. Relative uplift of this basement ridge may be a relict from Neoproterozoic tectonism, possibly the Petermann Ranges Orogeny. The Billiluna Fault, marking the eastern limit of the Canning Basin, lies within this north-trending elongate feature.

Patterns of episodic uplift and subsidence.

An interesting aspect in the development of the onshore Canning Basin is that the major periods of extension, leading to rapid subsidence, are preceded by episodes of compression (Fig. 1). This sequence of events occurred on three separate occasions. (1) The latest Cambrian Spielers Compressional Event was followed by the basin-wide Samphire Marsh Extension in the early Ordovician. (2) The Prices Creek Compressional Movement led to development of a widespread hiatus throughout the basin. It was followed in the Emsian/Eifelian by the Tandalgoo Sag Phase, regarded as pre-rift phase of extension that was seated in the lower crust and lithospheric mantle. It heralded the Pillara Extension that produced the most spectacular rifting in the Fitzroy Trough in the Givetian. (3) The Media Transpression, leading to small foreland-like basins concentrated at the northern margins of the Fitzroy Trough and the Gregory Sub-basin, was followed, after a period of erosion, by the Point Moody Extension. What might have been the cause of this pattern of uplift followed by subsidence? Basically, a period of transpressional tectonism could have weakened the crust and locally accentuated stress concentrations in the lithosphere, thereby producing zones of potential tectonic instability. Stresses needed to induce strike-slip or transpressional reactivation of older strucutres could be lower than those needed for reactivation in extension or compression, as higher levels of stress concentration are possible.

It is well known that extensional stresses, generated while stretching the continental lithosphere, will be at a maximum in regions of relative weakness inherited from previous tectonic events (see White et al. 1986, Braun and Beaumont 1989, Dunbar and Sawyers, 1988). Such weaknesses might take the form of a crustal or lithospheric-scale fault, a region of thickened crust, or a province boundary that is a density discontinuity. These weak regions will progressively become the loci for deformation as stretching proceeds. What are the implications of these concepts for the evolution of the Canning Basins?

The Samphire Marsh extension seems to have been a basin-wide event involving activity on several widely spaced extensional faults. Of these, the Admiral Bay Fault Zone and segments of the Beagle Bay-Pinnacle Fault Complex lie on major boundaries and, therefore, zones of weakness between basement elements.

During the Pillara extension, the locus of initial deformation driving foot-wall uplift may have been a basement thrust zone imaged in BMR line 88-03; the Spielers Shear Zone. The main visible initial Devonian displacement was on the Beagle Bay - Pinnacle Fault Complex that appears to closely follow this basement thrust zone.

Why is the region of the Fenton Fault Complex (controlling the terraces at the southern margins of the northern basins) so unstable? The reason may be because its northern and southern components align with the discordant northern and southern boundaries of an unusual basement zone (Br in Fig. 5, see above). Not only do these boundaries represent major boundaries in the basement, but they also represent major density discontinuities. Both these features can potentially induce crustal failure by spatially focussing lithospheric stresses.

Both the Beagle Bay-Pinnacle Fault Complex and the Fenton Fault System were also active during the Point Moody Extension in the Permian.

A Scenario for Evolution of the Canning Basin

It is envisaged that during the Spielers Event in the Late Cambrian (500 Ma), the crust in north-western Australia was further shortened and thickened by thrusting (see Shaw et al., 1992). The crust had already been thickened and weakened by faulting during the earlier (compressional) Petermann Ranges Orogeny at 530-560 Ma. The extension produced half-grabens like that at Blackstone. The basement controls on the Admiral Bay Fault and other structures in the Willara Sub-basin are not so well understoond. Significantly, the compressional Spielers Event was separated from the Samphire Marsh Extension by a short period of time, possibly less than 10 million years. The inversion of thrusts to form extensional faults has been recorded in other basins. For example, similar inversion is proposed by Seguret et al. (1989) for initiation of a Devonian basin in Norway.

During the Samphire Marsh Extension in the Ordovician, posterior collapse of the thickened crust at the northern margin of the basin was achieved by inversion of thrusts, like the Spielers Shear, as ductile shear zones.

During the Pillara Extension in the Devonian, the extensional forces were much greater and longer-lived than those in the Ordovician. Stretching of the mantle lithosphere started in the region of the Kidson and Willara sub-basins. Stretching did not breach the upper crust possibly because the lower crust was too strong. Whether this strength was due to post-extensional mantle healing after an initial burst of Devonian stretching as suggested by Braun (1992), is open to conjecture. The time-span between the Tandalgoo Sag Phase and the Pillara Extension, possibly 15 Ma, was probably too short for the newly underplated lower crust to cool down and strengthen by a process like post-extensional mantle healing.

With renewed or increasing lithospheric extension (Pillara Extension), stresses became localised along major zone of crustal weakness, such as the fault marked at the surface by the Spielers Shear. The developing upper-crustal extension rapidly expanded to incorporate the region now occupied by the Fitzroy Trough and the Gregory Sub-basin. This was also a region already weakened by repeated tectonism during the Ordovician and in several episodes during the evolution of the basement.

As the magnitude of the extension became extreme, stretching spread to encompass much of the lower crust in the region of the developing Fitzroy Trough. Listric faults formed at the southern and northern margins. At the time of the Van Emmerick Extensional Pulse most of the upper crustal extension was localised on the Fenton Fault System. However, most of the subsidence was driven by downward loads generated by both the basin infill and thinning of the lower crust. It was this thinning of the lower crust that allowed the extensional strains to be balanced on the scale of the crust (see physical modelling by Braun & Beaumont 1989, and Egan 1992). Minor foot-wall uplift occurred, and is now represented by the basement inliers within the Lennard Shelf and emergent regions on the Broome Platform. Foot-wall uplift on the Fenton Fault System was greatest following the Van Emmerick pulse and was followed by erosion. This pattern of uplift and erosion on active rift flanks has been by modelled by Braun and Beaumont (1989) and Egan (1992). Their modelling predicts that exhumation on the rift flank is a consequence of the flexural response of a lithosphere of moderate flexural rigidity to extension involving pure shear (thinning) of the lower crust.

Repeated extension during the Moody Point Event in the Permian may have followed a similar pattern of development. Again, it can be hypothesised that early deep extension in the lower crust and lithospheric mantle produced a widespread sag basin and that, as the extension progressed, extension moved to become concentrated in the crust, focussing on the Fenton Fault.

RECOMMENDATIONS FOR FUTURE WORK

This study has highlighted several issues, the approach to which needs to be reassessed in future research. These include:

1) How the Canning Basin is named and subdivided. The Canning Basin may be better regarded as a Superbasin that is divisible into four or more stacked successor basins. The successor basins would correspond, more or less, to the megasequences recognised by several authors (Table 7). Basins A and B (Table 7) would refer to the Ordovician-Silurian Megasequence and Devonian to Early Carboniferous Megasequence, respectively. The Late Carboniferous to Permian Megasequence could be amalgamated into the Westralian Superbasin as the onset of deposition in each appears to be coeval (see Kennard et al. 1994 b, AGSO North West Shelf Study Group 1994).

2) How to name and map complex fault systems like those of the Canning Basin. In hindsight the system we used to manage the complex hierarchy of fault systems that controlled development of the Fitzroy Trough could be simplified. The term, *fault complex* could be downgraded to the term, *fault system*. What we termed *fault systems* could be called *fault segments*. For example, the May River Fault System within the Beagle Bay - Pinnacles Fault Complex would become the May River segment of the Beagle Bay - Pinnacles Fault System. A set of faults separated by major accommodation/ transfer zones could be referenced by linking them to a fault compartment. For

example, the Sixty Seven Mile compartment (ID 35C in Appendix 3A) could included: (i) all the faults bounded by Sixty Seven Mile fault segment, (ii) part of the Harvey fault segment, (iii) the Blackstone Accommodation Zone and (iv) the Mount Percy Accommodation Zone. The Fitzroy Trough, itself, could be subdivided by this mechanism if it were found, by further mapping, to be transected by features such as the Mount Wynne Fault Zone.

ACKNOWLEDGMENTS

This report is very much a joint effort by the various members of the Canning Basin Team, including M J Jackson, J M Kennard, P E O'Brien, P N Southgate and K R Romine. The AGSO Land Seismic Group acquired and processed the deep seimic data. Principal contributors were M J Sexton, T B Barton, B J Drummond and D W Johnstone. Some drafting by M Moffat; including work from our Cartographic Services Unit in production of the enclosed Structural Elements Map.

These notes have benefited from numerous comments and advice from personnel of both the Geological Survey of Western Australia, particularly R M Hocking and I.M. Tyler, and several petroleum and mineral exploration companies. (including KUFPEC Australia Pty Ltd, Petroleum Securities Australia Ltd, Shell Company of Australia Ltd, Billington Exploration Australia, BHP-UTAH Minerals International, and CRA Exploration Pty Ltd.)

The manuscript has been revised following comment by M J Jackson, J M Kennard, R Korsch, T Loutit, R S Nicoll K K Romine and P Symonds.

REFERENCES
(Including those in the Lexicon of Structural and Tectonic Features)

AGSO North West Shelf Study Group, 1994, Deep reflections on the North West Shelf: Changing perceptions of basin formation. In Purcell, P.G. and Purcell, R.R. (editors), The Canning Basin, Western Australia; Proceedings of the West Australian Basins Symposium, 1994. The Petroleum Exploration Society of Australia, Limited, Perth, Western Australia, 63-76.

Anfiloff, W. & Shaw, R.D., 1973, The gravity effects of three large uplifted granulite blocks in separate Australian shield areas. *Symposium on the Earth's Gravity Field and Secular Variations in Position, Proceedings*. New South Wales University Publication, 273-289.

Arne, D.C., Green P.F., Duddy, I.R., Gleadow, A.J.W., Lambert, I.B. & Lovering, J.F., 1989, Regional thermal history of the Lennard Shelf, Canning Basin, from apatite fission track analysis: implications for the formation of Pb-Zn deposits. *Australian Journal of Earth Sciences*, 36, 495-513.

Begg, J., 1987, Structuring and controls on Devonian reef development, implications for petroleum exploration. *Australian Petroleum Exploration Association Journal*, 27, (1), 137-151.

Bentley, J., 1984, Petroleum Geology of the Central Broome Platform. *In* Purcell, P.G., (ed.) *The Canning Basin, Western Australia*. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, Western, Australia, 157-168.

Bennett, R. & Gellatly, D.C., 1970, Rb-Sr determinations of some rocks from the western Kimberley region. *Bureau of Mineral Resources, Australia, Record*, 1970/20.

Blake, D.B., Hodgson, I.M. & Muhling, P.C., 1979, Geology of the Granites-Tanami region, Northern Territory and Western Australia. *Bureau of Mineral Resources, Australia, Bulletin*, 197, 91 pp.

Bofinger, V.M. 1967, Geochronology in the east Kimberley area of Western Australia. Ph. D. Thesis, Australian National University (unpublished).

Braun, J., 1992, Post-extensional mantle healing and episodic extension in the Canning Basin. *Journal of Geophyscial Research*, 97, (B6), 8927-8936.

Braun, J. & Beaumont C., 1989, A physical explanation of the relationship between flank-uplift and the breakup unconformity at passive continental margins. *Geology*, 17, 760-764.

Braun, J., McQueen, H. & Etheridge 1991, A fresh look at the Late Palaeozoic tectonic history of west-central Australia. *Exploration Geophysics*, 22, 49-54.

Brown, S.A., Boserio, I.M., Jackson, K.S. & Spence, K.W., 1984, The geological evolution of the Canning Basin - implications for petroleum exploration. *In* Purcell P.G. (ed.). *The Canning Basin, Western Australia*, Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 85-96.

Colwell J.B. & Stagg, H.M.J., 1994, Structure of the Offshore Canning Basin: First Impressions from a New Regional Deep-seismic Data Set, *In* Purcell P.G. & Purcell R.R. (eds) *The Sedimentary Basins of Western Australia* proceedings West Australian Basins Symposium, The Petroleum Exploration Society of Australia Limited, Perth, Western Australia, 757-767.

Compston, W. 1974. The Table Hills Volcanics: Precambrian or Palaeozoic? *Journal of the Geological Society of Australia* 21, 403-412.

Connolly, J., Falvey, M., Kingsley, D., Melton, B. & Russell, T., 1984, Geology and petroleum potential of the Southern Canning Basin, Western Australia. In Purcell, P.G., (ed.), *The Canning Basin, Western Australia.* Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 137-146.

Craig, J., Downey, J.W., Gibbs, A.D. & Russell, J.R., 1984, The application of Landsat imagery in structural interpretation of the Canning Basin, Western Australia. *In* Purcell, P.G. (ed.) , *The Canning Basin, Western Australia.*, Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 57-72.

Crowe, R.W.A. & Towner, R.R., 1981, Noonkanbah, Western Austalia, 1:250 000 Geological Series. *Bureau of Mineral Resources, Australia & Geological Survey of Western Australia, Explanatory Notes* SE/51-12.

Daniels, J.L., 1974, The geology of the Blackstone region, Western Australia. *Geological Survey of Western Australia Bulletin*, 123.

Diekman, L.J., 1988, Regional structure and isochron mapping in the Meda Embayment, EP129, Canning Basin. Internal Report, Eromanga Energy Limited (unpublished).

Derrick, G.M. & Gellatly, D.C., 1971, The Precambrian geology of the Oscar Range Inlier, Lennard River 1:250 000 Sheet area, SE 51-8, Western Australia. *Bureau of Mineral Resources, Australia, Record*, 1971/61.

Derrick, G.M. & Playford, P.E., 1973, Lennard River, Western Australia, 1:250 000 Geological Series (2nd edition). *Bureau of Mineral Resources, Australia, Explanatory Notes*, SE/58-8.

Dow, D.H., & Gemuts, I., 1969, Geology of the Kimberley Region, Western Australia, The East Kimberley. *Bureau of Mineral Resources, Australia, Bulletin* 106, 935 pp.

Druce, E.C. & Radke, B.M., 1979. The geology of the Fairfield Group, Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin*, 200, 1-62.

Drummond, B.J., Etheridge, M.A., Davies, P.J. & Middleton, M.F., 1988, Half-graben model for the structural evolution of the Fitzroy Trough, Canning Basin, and implications for resource exploration. *The Australian Petroleum Exploration Association Journal*, 28, (1), 76-86.

Drummond, B.J., Sexton, M.J., Barton, T.J. & Shaw, R.D., 1991, The nature of faulting along the margins of the Fitzroy Trough, Canning Basin, and implications for the tectonic development of the trough. *Exploration Geophysics*, 22, 111-116.

Dunbar, J.A. & Sawyer D.S., 1988, Contintental rifting at pre-existing lithospheric weaknesses. *Nature*, 333, 450-452.

Ebinger, C.J., 1989, Geometric and kinematic, development of border faults and accommodation zones, Kivu-Rusizi rift, Africa. *Tectonics*, 8, 117-133.

Egan, S. S., 1992, The flexural response of the lithosphere to extensional tectonics, *Tectonophysics*, 202, 291-308.

Etheridge, M.A.,McQueen, H. & Lambeck,K., 1991, The role of intraplate stresses in Tertiary (and Mesozoic) deformation of the Australain continent and its margins: a factor in petroleum trap formation. *Exploration Geophysics* 22, (1), 123-128.

Etheridge, M.A., Symonds, P.A. & Powell, T.G., 1988, Application of the detachment model for continental extension to hydrocarbon exploration in extensional basins. *The Australian Petroleum Exploration Association Journal*, 28, (1), 167-187.

Forman, D.J. & Shaw, R.D., 1973, Deformation of crust and mantle in central Australia. *Bureau of Mineral Resources, Australia, Bulletin*, 144, 20 pp.

Forman, D.J. & Wales, D.W., 1981, Geological evolution of the Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin*, 210, 91 pp.

Foster, C.B. & Williams, G.E., 1991, Late Ordovician-Early Silurian age of the Mallowa Salt of the Carribuddy Group, Canning Basin, Western Australia, based on of *Tetrahedraletes medinensis* Stroth & Traverse 1979. *Australian Journal of Earth and Sciences*, 38, 223-228.

Galloway, M.C. & Howell, D.J., 1975, Relinquishment Report of TR 5851H to 5856H, 5878H to 5880H, Fitzroy Trough, Western Australia. *Esso Exploration and Production Incorporated, and Dampier Mining Company of Australia, Company Report* (unpublished).

Gellatly, D.C., Sofoulis, J., Derrick, G.M. & Morgan, C.M., 1974, The older Precambrian of the Lennard River 1:250 000 sheet area, Western Australia. *Bureau of Mineral Resources, Australia, Record*, 73/144.

Geological Survey of Western Australia, 1990, Geology and mineral resources of Western Australia. *Geological Survey of Western Australia Memoir*, 3, 827 pp.

Gibbs, A.D., 1984, Stuctural evolution of extensional basin margins. *Journal of the Geological Society, London*, 141, 609-620.

Goldstein, B.A., 1989, Waxings and wanings in stratigraphy, play concepts and the prospectivity in the Canning Basin. *The Australian Petroleum Exploration Association Journal*, 29, (1), 466-508.

Gorter, J.D., Rasidi, J.S., Tucker, D.H., Burne, R.V., Passmore, V.L., Wales, D.W. & Forman, D.J., 1979, Petroleum geology of the Canning Basin. *Bureau of Mineral Resources, Australia, Record*, 1979/32.

Griffin, T.J. & Myers, J.S., 1988, Geological note - A Proterozoic terrane boundary in the King Leopold Orogen, Western Australia. *Australian Journal of Earth Sciences*, 35, 131-132.

Griffin, T.J., Tyler, I.M. & Playford, P.E., 1992, Explanatory notes on the Lennard River 1:250 000 geological sheet, Western Australia (3rd edition). *Geological Survey of Western Australia Record* 1992/5.

Harland, W.B., Armstrong, R.L., Cox, A.V., Craig, L.E., Smith, A.G., & Smith, D.G., 1989, *A geologic Time-scale.* Cambridge University Press, Cambridge.

Hocking, R.M., 1994, Explanatory notes on Phanernozoic Basin subdivision, *Geological Survey of Western Australia Record* 1994/4.

Hocking, R.M., Mory A.J. & Williams I.R., 1994, Atlas of Neoproterozoic and Phanerozoic Basins of Western Australia. *In* Purcell P.G. & Purcell R.R. (eds) *The Sedimentary Basins of Western Australia* proceedings West Australian Basins Symposium, The Petroleum Exploration Society of Australia Limited, Perth, Western Australia, 23-43.

Horstman, E.L., 1984, Evidence of post-Permian epeirogenic uplift in the Canning Basin from vitrinite reflectance data. *In* Purcell, P.G., (ed.), *The Canning Basin, Western Australia.* Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 401-409.

Ingersoll, R.V., 1988, Tectonics of sedimentary basins. *Geological Society of America,* Bulletin, 100, 1704-1719.

Iasky, R.P., Middleton, M.F. & Taylor D.D., 1991, Top Ordovician Structure - Seismic Time, *Canning Basin, 1:1 000 000 Subsurface Compilation,* Geological Survey Western Australian (unpublished map).

Jackson, M.J., Diekman, L.J., Kennard, J.M., Southgate, P.N., O'Brien, P.E. & Sexton, M.J., 1992, Sequence stratigraphy, basin-floor fans and petroleum plays in the Devonian - Carboniferous of the northern Canning Basin. *The Australian Petroleum Exploration Association Journal,* 32, (1), 214-230.

Jackson, M.J., Kennard, J.M., Moffat, M., O'Brien, P.E., Sexton, M.J., Southgate, P.N. & Zeilinger, I., 1993, Canning Basin Project Stage 1, Lennard Shelf: Explanatory Notes for seismic and map folios. *Australian Geological Survey Organisation Record,* 1993/1.

Jones, B.G., 1988, Fluviatile and lacustrine facies in the Middle to Late Pertnjara Group, Amadeus Basin, Northern Territory. *In* Korsch, R.J. & Kennard, J., (eds), Geological & Geophysical Studies of the Amadeus Basin. Central Australia, *Bureau of Mineral Resources, Australia, Bulletin,* 236, 333-348.

Jones, P.J., 1988, Comments on some Australian, British and German isotopic age data for the Carboniferous System. *IUGS Subcommission on the Carboniferous, Stratigraphic Newsletter,* 6, 26-29.

Jones, P.J., 1989, Australian Phanerozoic Timescales. Carboniferous. Biostratigraphic charts and explanatory notes. *Bureau of Mineral Resources, Australia, Record,* 1989/35.

Jones, P.J., 1994, Australian Phanerozoic Timescales 5. The Carboniferous Period (2nd edition). *Australian Geological Survey Organisation Record,* 1994/**.

Jones, P.J. & Young, G.C., 1993, Summary of Phanerozoic biostratigraphy and palaeontology of the Canning Basin (Lennard Shelf). *Australian Geological Survey Record,* 1993/4.

Kennard, J.M., Southgate, P.N., Jackson, M.J., O'Brien, P.E., Christie- Blick, N., Holmes, A.E. & Sarg, J.F., 1992, New sequence perspective on the Devonian reef complex and the Frasnian - Famennian boundary, Canning Basin, Australia. *Geology,* 20, 1135-1138.

Kennard, J.M., Jackson, M.J., Romine, K.K., Shaw, R.D. & Southgate, P.N., 1994 a, Depositional sequences and associated petroleum systems of the Canning Basin. In Purcell, P.G. and Purcell, R.R. (editors), The Canning Basin, Western Australia; Proceedings of the West Australian Basins Symposium. The Petroleum Exploration Society of Australia, Limited, Perth, Western Australia, 657-676.

Kennard, J.M., Jackson, M.J., Romine, R.R. & Southgate, P.N., 1994 b, Canning Basin Project Stage II - Geohistory Modelling. Australian Geological Survey Organisation, Record, 1994/67, 243 pp.

Middleton, M.J., 1990, Canning Basin. In (editors), Geology and mineral resources of Western Australia. Geological Survey of Western Australia Memoir, Perth, 3, 425-457.

Kennard, J.M., Jackson, M.J., Romine, R.R. & Southgate, P.N., 1994, Canning Basin Project Stage II - Geohistory Modelling. Australian Geological Survey Organisation, Record, 1994/67, 243 pp.

Kemp, G.J. & Wilson, B.L., 1990, The seismic expression of Middle to Upper Devonian reef complexes, Canning Basin. *The Australian Petroleum Exploration Association Journal*, 30, (1), 280-289.

Koop, W.J., 1966, Recent contributions to the Palaeozoic geology in the southern Canning Basin, Western Australia. *Australian Petroleum Exploration Association Journal*, 6, 105-109.

Larsen, P.H., 1988, Relay strucures in the lower Permian basement-involved extensional system, East Greenland. *Journal of Structural Geology*, 10 (1), 3-8.

Lehmann, P.R., 1984, The stratigraphy, palaeogeography and petroleum potential of the Lower to lower Upper Devonian sequence in the Canning Basin. *In* Purcell, P.G., (ed.), *The Canning Basin, Western Australia*. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth,Western Australia, 253-275.

Lehmann, P.R., 1986, The geology and hydrocarbon potential of the EP 104 Permit, northwest Canning Basin, Western Australia. *The Australian Petroleum Exploration Association Journal*, 26(1), 261-284.

Luck, G.R. (compiler), 1991a, Bedout Island, Broome, Lacepede, Mandora, Phoenix, Rowley Shoals, Tasman, and Visscher - Top Middle Jurassic structure - seismic time *1:250 000 Subsurface compilation series, Western Geological Survey.*

Luck, G.R. (compiler), 1991b, Broome, Lacepede, Pender and Tasman - Top Lower Carboniferous structure - seismic time *1:250 000 Subsurface compilation series, Western Geological Survey.*

Maboko, M.A.H., McDougall, I., Zeitler, P.K. & Williams I.S., 1992, Geochronological evidence for ~ 530-550 Ma juxtaposition of two Proterozoic metamorphic terranes in the Musgrave Ranges, central Australia. *Australian Journal of Earth Sciences*, 39, 457-471.

McKenzie, D.P., 1978, Some remarks on the development of sedimentary basins. *Earth and Planetary Science Letters*, 40, 25-32.

Marshall, J.F. & Lee, C.S., 1989, Project 131.07: Basin framework and resource potential of the Abrolhos Sub-basin. *Wolf, K.H., et al. BMR 89: Year Book of the Bureau of Mineral Resources, Australia*, 62-67.

Mathur, S.P. & Shaw, R.D., 1982, Australian orogenic belts: evidence of evolving plate tectonics? *Earth Evolution Science*, 4, 281-308.

Middleton, M.J., 1990, Canning Basin. In (editors), Geology and mineral resources of Western Australia. Geological Survey of Western Australia Memoir, Perth, 3, 425-457.

Morley, C.K., Nelson, R.A., Patton, T.L. & Munn, S.G., 1990, Transfer zones in the East African rift system and their relevence to hydrocarbon exploration in rifts, *American Association of Petroleum Geologists Bulletin*, 74, 1234-1253.

Mory, A.J., & Beere, G.M., 1985, Palaeozoic stratigraphy of the Ord Basin, Western Australia and Northern Territory. In Professional papers for 1993. *Geological Survey of Western Australia Report* 14, 36-45, Report 14, 3-45.

Myers, J.S., 1990, Precambrian tectonic evolution of part of Gondwana, southwestern Australia. *Geology*, 18, 537-540.

Naylor, M.A., Mandl, G. & Sijpesteijn, C.H.K., 1986, Fault geometries in basement-induced wrench faulting under differnent initial stress states. *Journal of Structural Geology*, 8 (7), 737-752.

Nicoll, R.S., 1993, Ordovician conodont distribution in selected petroleum exploration areas, Canning Basin, Western Australia. *Australian Geological Survey Organisation Record* 1993/17.

Nicoll, R.S., Laurie J.R. & Roche, M.T., 1993, Revised stratigraphy of the Ordovician (Late Tremadoc-Arenig) Prices Creek Group and Devonian Poulton Formation, Lennard Shelf, Canning Basin, Western Australia. *AGSO Journal of Australian Geology & Geophysics*, 14, 65-76.

Nicoll, R.S., Romine , K.K. & Watson, S.T., 1994, Early Silurian (Llandovery) conodonts from the Barbwire Terrace, Canning Basin, Western Australia. *AGSO Journal of Australian Geology and Geophysics*, 15 (2), 247-255.

Page, R.W., 1988, Geochronology of Early to Middle Proterozoic fold belts in northern Australia. *Precambrian Research*, 40/41, 1-19.

Page, R.W. & Williams, I.S., 1988. Age of the Barramundi Orogeny in northern Australia by means of ion probe and conventional U-Pb studies. *Precambrian Research*, 40/41, 21-36.

Parker, A.J., 1986, Tectonic development and metallogeny of the Kanmantoo Trough in South Australia. *Ore Geology Reviews*, 1, 203-212.

Passmore, V., 1991, Hydrocarbon prospectivity of the offshore Canning Basin. *Bureau of Mineral Resources, Australia, Record*, 1991/11.

Peacock, D.C. & Sanderson, D.J., 1991, Displacement, segments linkage and relay ramps in normal fault zones. *Journal of Structural Geology*, 13, 712-733.

Peacock, D.C. P. & Sanderson, D.J., 1994, Geometry and development of relay ramps in normal fault systems. *American Association of Petroleum Geologists Bulletin*, 78(2), 147-165.

Playford, P.E. & Johnstone, M.H., 1959, Oil exploration in Australia. *American Association of Petroleum Geologists Memoir*, 57, 157-179.

Playford, P.E., 1980, Devonian "Great Barrier Reef" of the Canning Basin, Western Australia. American Association of Petroleum Geologists, 64 (6), 814-840.

Playford, P.E., 1981, Devonian Reef Complexes of the Canning Basin, Western Australia. Field Excursion Guidebook, Fifth Australian Geological Convention, 1981, Geological Society of Australia.

Preiss, W.V. 1987, The Adelaide Geosyncline. *Geological Survey of South Australia, Bulletin*, 53, 438 pp.

Purcell, P.G. & Poll, J., 1984, The seismic definition of the main structural elements of the Canning Basin. *In* Purcell, P.G., (Ed.), *The Canning Basin, Western Australia*. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 389-400.

Quaife, P., Rosser, R. & Pagnozzi, S., 1994, Structural Architecture and Stratigraphy of Offshore Northern Perth Basin, Western Australia. *In* Purcell P.G. & Purcell R.R. (eds) *The Sedimentary Basins of Western Australia* proceedings West Australian Basins Symposium, The Petroleum Exploration Society of Australia Limited, Perth, Western Australia, 813-827.

Rattigan, J.H., 1967, Fold and fracture patterns resulting from basement wrenching in the Canning Depression. *Australian Institute of Mining & Metallurgy, Proceedings*, 223, 17-22.

Reeckmann, S.A. & Mebberson, A.J., 1984, Igneous intrusions in the North-West Canning basin and their impact on oil exploration. *In* Purcell, P.G., (Ed.), *The Canning Basin, Western Australia*. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 389-399.

Roberts, H.G., Halligan, R. & Playford, P.E., 1968, Mount Ramsay, Western Australia, 1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/52-9.

Roberts, J., Claoue-Long, J. & Jones, P.J., 1993, SHRIMP zircon dating and Australian Carboniferous Time. *Compte Rendu of the 12th International Congress of Carboniferous and Permian Stratigraphy and Geology* Buenos Aires, 1991, 2, 319-338.

Romine, K.K., Southgate, P.N., Kennard, J.K. & Jackson, M.J., 1994, The Ordovician to Silurian phase of the Canning Basin, WA: Structure and sequence evolution. In Purcell, P.G. and Purcell, R.R. (editors), The Canning Basin, Western Australia; Proceedings of the West Australian Basins Symposium. The Petroleum Exploration Society of Australia, Limited, Perth, Western Australia, 677-696.

Rosendahl, B.R., 1987, Architecture of continental rifts with special reference to East Africa. *Annual Review, Earth and Planetary Sciences*, 15, 445-503.

Schlische, R.W., 1993, Anatomy and evolution of the Triassic-Jurassic continental rift system, eastern North America, *Tectonics*, 12, 1026-1042.

Schwab, F.L., 1986, Sedimentary signatures of foreland basin assemblages: real or counterfeit? *Special Publication of the International Association of Sedimentologists*, 8, 395-410.

Seguret, M., Seranne, A. & Brunel, Chauvet, M., 1989, Collapse basin: A new type of extensional sedimentary basin from the Devonian of Norway. *Geology*, 17, 127-130.

Shaw, R.D., 1991, The tectonic evolution of the Amadeus Basin, central Australia. *In* Korsch, R.J. & Kennard, J., (eds), Geological & Geophysical Studies of the Amadeus Basin, Central Australia. *Bureau of Mineral Resources, Australia, Bulletin*, 236, 429-461.

Shaw, R.D., Etheridge, M.A. & Lambeck, K., 1991a, Development of the Late Proterozoic to Mid-Palaeozoic, intracratonic Amadeus Basin in central Australia: a key to understanding tectonic forces in plate interiors. *Tectonics*, 10 (4), 68-721.

Shaw, R.D., Stewart A.J. & Black L., 1984, The Arunta Inlier: a complex ensialic mobile belt in Central Australia. Part 2: tectonic history. *Australian Journal of Earth Sciences*, 31, 457-484.

Shaw, R.D., Tyler, I.M., Griffin, T.J. & Webb, A., 1992, New K-Ar constraints on the onset of subsidence in the Canning Basin, Western Australia. *BMR Journal of Australian Geology and Geophysics*, 13, 31-35.

Shaw, R.D., Zeitler, P., Black, L.P. & McDougall, I., 1989, The unroofing history of the Arunta Block in the region of the Redbank Thrust Zone, central Australia, based on $^{40}Ar/^{39}Ar$, Rb-Sr and K-Ar dating methods. *IGCP-235 Conference on Metamorphism and Geodynamics*, IGCP /IUGS/ UNESCO/ Department. Applied Geology, University of New South Wales, 3-4 July.

Shaw, R.D., Zeitler, P. & McDougall, I., 1991b, The Palaeozoic history of an unusual intracratonic thrust belt in central Australia based on $^{40}Ar/^{39}Ar$ and K-Ar and fission track dating. *Journal of the Geological Society, London* , 149, 937-954.

Shergold, J.H., 1989, Australian Phanerozoic Timescales. Cambrian. Biostratigraphic charts and explanatory notes. *Bureau of Mineral Resources, Australia, Record,* 1989/33.

Shergold, J.H., Jago, J.B., Cooper, R.A. & Laurie, J.R., 1985, The Cambrian System in Australia, Antarctica and New Zealand. *International Union of Geological Sciences, Publication* 19.

Smith, J.G., 1968, Tectonics of the Fitzroy wrench trough, Western Australia. *American Journal of Science*, 226, 766-776.

Smith, G., 1984, The tectonic development of the Gregory Sub-basin and adjacent areas, northeastern Canning Basin. *In* Purcell, P.G., (ed.), *The Canning Basin, Western Australia.* Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 109-120.

Southgate, P.N., Kennard, J.M., Jackson, M.J., O'Brien, P.E. & Sexton, M.J, 1993, Reciprocal lowstand clastic and highstand carbonate sedimentation, subsurface Devonian Reef Complex, Canning Basin, Western Australia. *In* R.J. Loucks & J.F. Sarg (eds), Carbonate sequence stratigraphy, developments and application. *American Association of Petroleum Geologists Memoir*, 57, 157-179.

Stewart, A.J., 1992, Structural Map of the Amadeus Basin (1:1 000 000 scale) 1992. *In* Lindsay, J.H., (ed.), *Geological Atlas of the Amadeus Basin.* Bureau of Mineral Resources, Canberra, Australia.

Strusz, D.L., 1989, Australian Phanerozoic Timescales 3: Silurian. *Bureau of Mineral Resources, Australia, Record,* 1989/33.

Sweet, I.P., 1977, Precambrian geology of the Victoria River region. *Bureau of Mineral Resources, Australia, Bulletin,* 168, 73 pp.

Sylvester, A.G., 1988, Strike-slip faults. *Geological Society of America,* Bulletin, 100, 1666-1703.

Taylor, D.D., Middleton, M.F. & Luck, G.R., (compilers), 1990, Base Grant Group, structure-seismic time. *Canning Basin 1:1 000 000 subsurface compilation.* Geological Survey Western Australia. (unpublished map).

Taylor, D.D., 1992, Blina Oilfield, Canning Basin, Case History, *Exploration Geophysics,* 23, 467-480.

Towner, R.R. & Gibson, D.L., 1983, Geology of the Onshore Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin,* 215, 51pp.

Tucker, R.D., Krogh, T.E., Ross, R.J. & Williams, S.H., 1990, Time-scale calibration by high-precision U-Pb zircon dating of interstratified volcanic ashes in the Ordovician and Lower Silurian stratotypes of Britain. *Earth and Planetary Science Letters,* 100, 51-58.

Tyler I.M. & Griffin, T.J., 1990, Structural development of the King Leopold Orogen, Western Australia. *Journal of Structural Geology,* 12, 685-701.

Tyler I.M. & Griffin, T.J., 1992, Explanatory notes on the Yampi 1:250 000 geological sheet (Second Edition). *Western Australian Geological Survey Record* 1992/28.

Vearncombe, J.R., Dentith, M., Doring, S., Reed, A., Cooper, R., Hart, J., Muling, P., Windrim, D., & Woad, G., 1994, Regional and Prospect-scale Fault Controls on Mississippi Valley-type Zn-Pb Mineralization at Blendevale, Canning Basin, Western Australia. *Economic Geology* (in press).

Veevers, J.J. & Wells, A.T., 1961, The geology of the Canning Basin, Western Australia. *Bureau of Mineral Resources, Bulletin* 60.

Veevers, J.J., Roberts, J., White, Mary E. & Gemuts, I., 1967, Sandstone of probable lower Carboniferous age in the northeastern Canning Basin, Western Australia. *The Australian Journal of Science,* 29, (9), 330-331.

WAPET, 1970, Helen (267) reconnaisance seismic survey, final report. *Bureau of Mineral Resources, Australia,* File 70/504.

Webby, B.D. & Nicoll, R.S., 1989, Australian Phanerozoic Time Scales 2: Ordovician. *Bureau of Mineral Resources, Australia, Record,* 1989/32.

White, S.H. & Muir, M.D., 1989, Multiple reactivation of coupled orthogonal fault systems: an example from the Kimberley region in northern Western Australia. *Geology,* 17, 618-621.

White, S.H., Bretan, P.G. & Rutter, E.H., 1986, Fault zone reactivation: Kinematics and mechanisms: *Royal Society of London, Philosophical Transactions,* Series. A, 317, 81-97.

Yeates, A.N., Gibson, D.L., Towner, R.R. & Crowe, R.W.A., 1984, Regional geology of the Onshore Canning Basin, W.A. *In* Purcell, P.G., (ed.), *The Canning Basin, Western Australia.* Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 23-56.

Yeates, A.N. & Muhling, P.C., 1977, Mount Bannerman, Western Australia, 1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes,* SE/52-13.

Young, G.C., 1989, Australian Phanerozoic Timescales 4: Devonian. *Bureau of Mineral Resources, Record,* 1989/34.

TABLE 1

LIST OF THIRTEEN TECTONIC EPISODES IDENTIFIED IN THE CANNING BASIN

A **Basin initiation - Samphire Marsh Extensional Movement**
* Extension; series of half grabens
  (e.g. Willara Sub-basin, and Blackstone half-graben in 'proto' Fitzroy Trough)
* Early Ordovician (~490 Ma) to latest Arenigian/earliest Llanvirnian (~470 Ma)

B **Carribuddy Sag Phase**
* Starts near base of Carribuddy Group
* Possibly preceded by mild tectonism at about 470 Ma (end supersequence A1)
* Subsidence accentuated by Maloney Creek Eustatic Event
* Continued until the end of the Mallowa Salt at close of Ordovician (~434 Ma)

C **Unnamed - Hiatus**
* Base of onlapping succession within Sahara Formation
* Followed by minor renewed subsidence in the Kidson Basin
* Early Silurian
* May correlate with Rodingan Movement in Amadeus Basin

D **Prices Creek Compressional Movement**
* Minor folding and uplift in Gap Creek Area
* Early Devonian movement (410-390 Ma)
* Erosion on the Barbwire Terrace and in the west of the basin
* Correlates with Pertnjara Movement at start of Alice Springs Orogeny

E **Tandalgoo Sag Phase**
* Subsidence recorded by Tandalgoo, Worral and Poulton Formations
* Subsidence centred on Willara and Kidson Sub-basins, and Barbwire Terrace
* Onset is in Emsian/ Eifelian (~390 Ma)
* May relate to thermal relaxation of lithosphere following deep-seated extension

F **Initiation of Pillara Extension, Gogo Extensional Movement**
* NNE-SSW extension
* Beagle Bay - Pinnacle Fault Complex
* Active orthogonal accommodation zones are part of fault complex
* Rapid Givetian-Frasnian subsidence in three pulses:
  i.e. Initial phase then Van Emmerick and Red Bluffs Extensional Movements
* Started with Gogo Formation and Boab Sandstone in mid-Givetian (~375 Ma)

G **Van Emmerick Extensional Movement, a resurgence of the Pillara Extension**
* Tilting, uplift and erosion of Blackstone, May River and Sixty-Seven Mile Highs
* Late Frasnian to early Famennian (366-363 Ma)
* Followed by (i.e., reversal of polarity of extension within the Fitzroy Trough
  from north-directed to south-directed growth)

H **Red Bluffs Extensional Movement, a resurgence of the Pillara Extension**
* Tilting and uplift of NE edge of Margaret Embayment
* Deposition of units D-Pc, and Knobby Sandstone (in NE Gregory Sub-Basin)
* Started in very latest Devonian (~354.5 Ma, break within Yellow Drum Formation)
* Laurel/ early Anderson Formations thickening into Fenton Fault System
* Similar thickening into Stansmore Fault (Gregory Sub-basin)
* Laurel Formation transgression on Lennard Shelf
* Latest Devonian (354.5 Ma) to late Visean (~340 Ma)

I **Meda Transpressional Movement**

* Uplift and erosion at base of Lower Grant Group
* Positive and negative flower structures along northern margin of Fitzroy Trough
* Preservational/growth thickening of Anderson Formation along Harvey Fault System
* Development of foreland-like depressions of Lower 'Grant Group' followed
* Correlates with peak of Alice Springs Orogeny
* Mid-Carboniferous (326-320 Ma)

J **Drosera Hiatus/Erosional Event**

* Non-deposition/erosion to form Lower-Upper Grant Group biostratigraphic break
* Late Westphalian-Stephanian (310-298 Ma)

K **Point Moody Extensional Movement**

* Thickening of Upper Grant Group into Fenton Fault System
* Started about 298 Ma
* Widespread sag (thermal sag with sediment loading) followed
* Marine transgression at base of Nura Nura Member of Poole Sandstone
* Transgression starts in Earliest Sakmarian (~290 Ma)

L **Lagrange Extensional Movement**

* Offshore Bedout Sub-basin and NW Shelf
* Expressed as thermal sag phase onshore (base Blina Shale unconformity)
* Leading to minor uplift and erosion (onshore Canning Basin)
* Dolerite intrusion
* Latest Late Permian (~253-251 Ma)

M **Fitzroy Transpressional Movement**

* Dextral wrench
* Divergent anticlines in Fitzroy Trough
* Uplift and erosion (up to 3 km wthin Fitzroy Trough;
  1 km on Lennard Shelf)
* Timing is imprecise: Late Triassic to Early Jurassic (200-180 Ma)

Table 2 Stratigraphy of selected Mesozoic and Palaeozoic units in the Canning Basin

PERIOD	EPOCH	SERIES/ STAGE	AGE § base STAGE ~ Ma 1	AGE § base-unit (~ Ma±)2 STAGE ~ Ma 3	ROCK UNIT	ROCK UNIT	LITHOLOGY & FACIES	BASIN EVOLUTION
CRETACEOUS	LOWER	VALANGINIAN BERRIASIAN	146	(138) **144+**	BROOME SANDSTONE		Shallow marine sandstone	
JURASSIC	LATE	TITHONIAN		(148) **152+**	JARLEMAI SILTSTONE		Subtidal marine siltstone	Rifting offshore
	LATE - MIDDLE	KIMMERIDGIAN	155	(153) **156+**	ALEXANDER FORMATION		Shallow marine siltstone & sandstone	
	MIDDLE	OXFORDIAN- (CALLOVIAN) - BAJOCIAN	174	(180)	WALLAL SANDSTONE		Continental -shallow marine sandstone	Start of break-up in Callovian?
					MAJOR	**UNCONFORMITY**		
		FITZROY			**MOVEMENT**	**(180 - 200 Ma)**		Right-lateral strike-slip; E-anticlines; numerous, minor NE- tensional faults
TRIASSIC	EARLY	ANISIAN - SCYTHIAN	241	(245)	ERSKINE SANDSTONE	CULVIDA SANDSTONE	Fluvial sandstone	Rifting offshore
		SCYTHIAN		***245-251*** (251±)	BLINA SHALE	MILLYIT SANDSTONE	Shallow marine shale	
				(251+)	MINOR e.g. base	UNCONFORMITY Blina Shale		**LAGRANGE EXTENSIONAL MOVEMENT (250-253 Ma)**
PERMIAN	LATE -	DORASHAMIAN/ .M. KUNGURIAN		(275)	LIVERINGA GROUP		Fluvio-deltaic siltstone & sandstone	Rifting offshore
	EARLY	KUNGURIAN -L. ARTINSKIAN	260/	***272-283*** (?285)	NOONKINBAH FORMATION		Deep marine shale	

	EARLY	ARTINSKIAN/ L. SAKMARIAN	269/	***283-290*** (290)	POOLE SANDSTONE	NURA NURA MEMBER	Sandstone, start major marine transgression	
				(290)		UNCONFORMITY	Major transgressive sequence follows	**Nura Nura deglaciaton**
	EARLY	E. SAKMARIAN ASSELLIAN	282/	***290-298*** (300) **c. 298**	UPPER GRANT GROUP		Continental-marine glacial sediments	**Point Moody Extension (starts about 298 Ma)**
CARBONIFEROUS	LATE	E.STEPHANIAN-MID-WESTPHALIAN		(298-315) **c. 315**	MAJOR	UNCONFORMITY		Tectonic or related to glaciation?

DROSERA EROSION c. 298-310 Ma

May reflect onset of glaciation and tectonism that correlates with closing stages of the Alice Spring Orogeny

	LATE	?NAMURIAN	333	(c. 312-329) **327**	'Lower Grant Group'	Unnnamed Unit, with *Yberti*	Alluvial-deltaic sediments	Foreland-like depression
	LATE	E. NAMURIAM		(c. 320-327) **c. 343**		UNCONFORMITY	Sedimentation continuous on basin floor in west	

MEDA TRANSPRESSIONAL MOVEMENT (325-315 Ma)

Onset of transtrensional tectonism may correlate with peak of the Alice Spring Orogeny

	EARLY	EARLY VISEAN/ LATE TOURNASIAN	350	(348)		ANDERSON FORMATION	Fluvio-deltaic clastics, influx from est?	Renewed rifting centred on Fenton Fault
				(C. 350)	MINOR	UNCONFORMITY		
		MIDDLE-EARLY TOURNAISIAN		*T1-6¢* (352+) **354**	FAIRFIELD GROUP	LAUREL FORMATION	Transgressive shelf-trough carbonates & clastics	Sedimentary ramp setting, continued extension
		UNCONFORMITY	AT		MARGIN		Major transgression	**Laurel Flooding**

DEVONIAN	LATE	TOURNAISIAN/ FAMENNIAN	363	*353/* *F3-4* (354)	FAIRFIELD GROUP Mt Behn Conglom.	YELLOW DRUM FORMATION, uppermost Laurel Fm	Regressive shelf-shallow marine carb-clastics	**Red Bluffs Extensional Movement ~ 354.5 Ma**
		Latest FAMENNIAN		*F2* (356)	GUMHOLE FORMATION			Sedimentary ramp setting from F3A, start thermal sag phase
				(358)	MAY RIVER SHALE	LULUIGI FM, CLANMEYER FM .	Marine shales and carbonates	Tectonic rearrangement, max. ext. in Gregory Sub-basin
		FAMENNIAN	367	*F1* (364) **364**	NULLARA FORMATION	NAPIER FM.	Reef fringe carbonate, (base Nullara Cycle)	Continued extension, arguably in two episodes
		?Latest FRASNIAN		*F-F*-top (364 +)	VAN EMMERICK CONGL.	UPPER VIRGIN HILLS FORMATION (unit has long time range)	Carbonate-clastic fill, major Influx of conglomerates	**Van Emmerick Extensional Movement 363-366 Ma** Rifting on S. margin of Fitzroy Trough; tilting - up to Nth on N. margin
				FR5	LOCAL	UNCONFORMITY		Minor tectonic rearrrangement; rifting switches to Fenton Fault Complex
DEVONIAN	LATE/ MIDDLE	FRASNIAN-LATE GIVETIAN		*FR1-4* **370** *G-F* (375)	PILLARA FORMATION, GOGO FORMATION, Fan Conglomerates		Fringe reef carbs/ deep marine shale, basin-floor conglomerate	Rifting centred on northern margin of Fitzroy Trough
		MID-GIVETIAN		(375)	Boab Sandstone on Barbwire Terrace	?GOGO FM, i.e. base Pillara cycle	Marine shale	**Start of Gogo Extensional Movement** centred on Beagle Bay-Pinnacles Fault Complex

START OF PILLARA EXTENSION (375 Ma)

	LATE/ MIDDLE	FRASNIAN-LATE GIVETIAN	380	(375) **381**		Kidston Sub-basin MELLINJERI FM (Frasnian/Givetian)		Correlate of syn-rift deposits in Fitzroy trough, end of Tandangoo Sag Phase
					Local	Unconformity (e.g. Gap Creek)		Change in basin dynamics
		EARLY GIVETIAN	380	(381) **381**	DOMINIC SHALE, ?TRANS MARINE BEDS	MIRABELLA DOLOMITE (Barbwire Terrace)		Pre-rift 'hard-pan' units
	MIDDLE	EIFELIAN/ LATE EMSIAN	386/	(393+)	POULTON FORMATION (top Givetian), MAY RIVER CONGL.	TANDALGOO SANDSTONE, WORRAL FM (contains Eif./Ems. Fish)	Shallow marine clastics in Fitzroy Trough, evaporites then red continental sandstone to south; anhydrites in Mellinjeri Fm	**Tandalgoo Sag Phase:** may represent thermal response of extension deep in lithosphere

Start TANDALGOO SAG PHASE (390 Ma)

DEVONIAN	EARLY	EMSIAN/ LOCHKOVIAN	408	(390-410) **410**	MAJOR	UNCONFORMITY		Mild uplift in narrow zones following compressional tectonism

PRICES CREEK COMPRESSIONAL MOVEMENT (390-410 Ma)

				c. 410-425?	CARRIBUDDY GROUP	Mid-upper SAHARA FORMATION	Regional onlap recorded in claystones of middle Sahara Formation	Titiing up to NE, minor subsidence in Kidston Sub-Basin
SILURIAN	EARLY	WENLOCK	430	(430?) **430**	CARRIBUDDY GROUP	?HIATUS above LOWER SAHARA FORMATION		May correlate with hiatus at base of Mereenie andstone, Amadeus Basin (i.e., Rodingan Movement)

CARRIBUDY SAG PHASE (434-c. 470 Ma)

SILURIAN	**EARLY**	LLANDOVERY	439	(434) **434**	CARRIBUDDY GROUP	lowest 'WORRAL FORMATION'	Shelf carbonates & clastics, shale in eqiv. 'Sahara Fm'.	Closing stage of thermal sag phase
ORDOVICIAN		?ASHGILIAN - LLANEILIAN (Upper Darrivilian)	443/ 469	***449*** (462) **464**	CARRIBUDDY GROUP	Malllowa Salt, Nibil Fm, Minjoo Salt, Bongabinni Fm	Intertidal carbonates & evaporites	Early stage of thermal sag phase
ORDOVICIAN		LLANVIRNIAN		(466)	NITA FORMATION	Upper Goldwyer Fm in Kidston Sub-basin	Subtidal-supratidal sabka	Transitional phase
		LLANVIRNIAN	476	(468) **470**	GOLDWYER FORMATION		Subtidal shale, mnr limestone	Transitional phase, Maloney Creek Eustatic Event
		LATE ARENIGIAN		(?472)	WILLARA FORMATION	GAP CREEK FORMATION (top eroded), WHITE CLIFFS SST	Shelf carbonates - subtidal shales	Renewed extension
	EARLIEST	E. ARENIGIAN to Latest TREMADOCIAN (WARENDIAN)	493 510	***474/*** (?482) **490**	NAMBEET FORMATION	EMANUEL FORMATION, & unnamed dol/sst	Intertidal - subtidal carbonates & shales	**Samphire Marsh Extension:** Initial extension, activity on Harvey and Admiral Bay Faults Zones

FOOTNOTES:

§ Age range of formation in bold/italics ***290-298*** ; age of base in parenthesis, e.g. (364); age at the base of the Stage in bold type, e.g. **364 Ma**

¢ *T1-6* Stratal units of Southgate et al. (1993) and Kennard et al. (1992).

1. Estimated age - **Ma** - for the base of each Biostratigraphic Stage taken from Harland et al., 1989.

2. Estimated age (Ma) for the base of each stratigraphic unit (very approximate).

3. Estimated age - **Ma** - for the base of each Biostratigraphic Stage taken from the 'BMR' time scale subsequently adjusted
(Cambrian after Shergold, 1989; Ordovician after Webby & Nicoll , 1989 - revised after Tucker et al. 1990; Silurian, after Strusz, 1989;
Devonian, after Jones, 1989;
Carboniferous after Jones, 1988 and Roberts et al. 1992; Permian and younger after Harland et al., 1989)

Table 3. Precambrian-Early Cambrian stratigraphy of the northern margin of the Canning Basin

PERIOD	AGE (Ma)[1]	ROCK UNIT	ROCK UNIT	LITHOLOGY	BASEMENT EVOLUTION
		Spielers Event 500-510 Ma[6]			
EARLY CAMBRIAN	possibly 520[1] compare with		ANTRIM PLATEAU BASALT	Basalt	
		Precipice Event 530-560 Ma[6]			
LATE PROTEROZOIC	*ca* 670[2]	MOUNT HOUSE GROUP	THROSELL SHALE	Shale, sandstone	
		LOUISA DOWNS GROUP	EGAN FORMATION (TILLITE)	Tillite, arkose, carbonate	
	ca 725[2]	KUNIANDI GROUP	LANDRIGAN TILLITE	Tillite, sandstone, siltstone	
		DOLERITE (*ca* 730 Ma[3]			
		UNCONFORMITY			
		OSCAR RANGE GROUP	NINETY SEVEN MILE BEDS	Quartzite, conglonerate, sandstone	
			ELIMBERRIE BEDS	Sandstone, conglomerate, siltstone	
		UNCONFORMITY			
			LINESMAN BEDS	Siltstone, shale, sandstone, boulder beds	
			HART DOLERITE (*ca* 1800[4] Ma)	Dolerite	
	ca 1840-1800	KIMBERLEY GROUP	PENTECOST SANDSTONE	Sandstone, shale	

		ELGEE SILTSTONE	Siltstone
		CARSON VOLCANICS	Basalt
		Sandstone, conglomerate	
ca 1840-1760	SPEEWAH GROUP	e.g. LANSDOWN ARKOSE	Sandstone, minor arkose
	UNCONFORMITY? - MAJOR PERIOD OF EROSION		
	LAMBOO COMPLEX		Granite, granodiorite, gabbro, metamorphics
		UNIT Pbp1	Granite
		LENNARD GRANITE	Granite
		McSHERRYS GRANODIORITE	Granodiorite
ca 1850[5]		WHITEWATER VOLCANICS	Rhyodacitic ash flow tuff
1850[5]		TICKALARA METS	Paragneiss, amphibolite, migmatite
		McINTOSH GABBRO	Uralitised gabbro, amphibolite
	UNCONFORMITY? - MAJOR PERIOD OF EROSION		
	BARRAMUNDI OROGENY (*ca* 1885-1870[5])		
		WOODWARD DOLERITE	Uralitised dolerite
	HALLS CREEK GROUP	MARBOO FORMATION	Greywacke, phyllite
ca 1880[5]		BISCAY FM.	Mafic and felsic volcanics, sediments
ca 1990[4]		DING DONG DOWNS VOLCS	Mafic and felsic volcanics

Footnotes:

1: Rb-Sr age of Compston (1974) for Kulyung Volcanices in Officer Basin
2: Rb-Sr age of Bofinger (1967)
3: K-Ar age from C.B. Smith in White & Muir (1989)
4. Preliminary unpublished U-Pb zircon data by R.W. Page, BMR
5: U-Pb zircon ages from Page (1988) amd Page & Williams (1988).
6: K-Ar ages from Shaw et al (1992).

Table 4. Correlation of Silurian to Permian units between the Canning, Amadeus and Ngalia basins and corresponding tectonism in Amadeus Basin

PERIOD	AGE (Ma)	CANNING BASIN UNITS	AGE (Ma)§	AMADEUS BASIN UNITS	LITHOLOGY, AMADEUS BASIN	NGALIA BASIN UNITS	TECTONISM in Central Australia	ACTIVE STRUCTURE	DEPOSITIONAL FEATURE
PERMIAN	c. *290-298*	Upper Grant Group (Carlyon Formation) ?Unconformity		Buck Formation, Crown Point Formation	Sandstone, conglomerate with erratics; plus tillite, siltstone			Thrusts N. of Ngalia Basin, uplift N. of Amadeus Basin	Brewer Trough full
CARBONIFEROUS									
	(c. 298-315)	Major Unconformity							
	c. 298 - 310	**DROSERA EROSION**		**Closing stages,**	**ALICE**	**SPRINGS**	**OROGENY**	**300 Ma**	
	(c.310-320) **Nam. 327**	Lower Grant Group (Winifred & Betty Fms)		Eroded		Mt Eclipse Sst	**MT ECLIPSE MOVEMENT**		
	c. 320-326	Unconformity							
	c. 320 - 326	**MEDA MOVEMENT**		**Peak of ALICE**	**SPRINGS**	**OROGENY**	**320 Ma**	Thrusts N. of Ngalia Basin	Brewer Trough full
	(348)	Anderson Formation		Eroded		Mt Eclipse Sst	Movement continues		
	(352+) **Tour. 354**	Laurel Formation		(Brewer Congl. removed by erosion?)					
	?340-354.5	**RED BLUFFS EXTENSIONAL MOVEMENT**				Mt Eclipse Sst	Precursor to Mt. Eclipse Movement	Gardiner-Kernot Thrust Complex	Thrust overrides Trough

DEVONIAN	(355)	Yellow Drum Formation, Gumhole Formation		Brewer Conglomerate	Polymictic conglomerate, conglomeratic sandstone	**KERRIDY MOVEMENT**	**BREWER MOVEMENT**	Thrusting moved to Ormiston Thrust Zone & MacDonnell Homocline	Narrowing & deepening of trough
	(363)	Nullara Formation		Brewer Conglomerate	As above	Erosion	Movement continues		
	Fram. 364 (364+)	Virgin Hills Formation, Brenn Conglomerate	(365)	Brewer Conglomerate	As Above	Uplift & erosion of Kerridy Sandstone	Start of Brewer Movement	Rapid narrowing of trough	
	363-366	**VAN EMMERICK EXTENSIONAL MOVEMENT**							
		Local Unconformity							
		Gogo Formation, Pillara Formation		Hermannsburg Sandstone - Ljitera Member	Conglomeratic sandstone	Kerridy Sandstone		Erosional enhancement of flexure	Deepening trough
		Gogo Formation, Pillara Formation		Rare local unconformity					
		Gogo Formation, Pillara Formation		Hermannsburg Sandstone - sandstone unit	Sandstone	Kerridy Sandstone		Redbank Thrust Zone	A wide, assymetrical trough
	(375) **Fras.** ***370-375?*** (376±)	Gogo Formation, Pillara Formation (Extension starts in Late Givetian)	(370-377)	:		Kerridy Sandstone		Upward propagation of Redbank Thrust Zone	Flexural downwarp

	375	**GOGO EXTENSIONAL MOVEMENT**		Local Unconformity		Uplift, precursor to Kerridy Movement	**HENBURY MOVEMENT** ***375-377/***	Early thrusting on Redbank Thrust Zone	
		?Local Unconformity							
	(381) **Giv. 380**	Dominic Shale, Transitional marine beds	380	Parke Siltstone	Siltstone, aeolian sandstone over Fluvial sandstone, overbank siltstone	Kerridy Sandstone		Basement uplift	As above
	381+			Local Unconformity			(base Park Siltn, Pertnjara Movement of Jones, 1991)¢	Basement uplift to N of Redbank Thrust Zone.	
	Eif. (392) **387/ 390**	Poulton Formation, Tandalgoo Sandstone Worral Form.	(?392)	Parke Siltstone 1: N'Dhala Member, Deering Siltstone Member	Siltstone; fluvial clastics	Kerridy Sandstone		As above	As above
	Ems. ***390-410***	Unconformity	(380/ 400)¢	Unconformity		Unconformity		Embyronic Redbank Thrust Zone	Lacuna
	c *390-410*	**GAP CREEK MOVEMENT**	**390-410**	**PERTNJARA MOVEMENT**	Erosion		**PERTNJARA MOVEMENT**	Regional upwarping to NE & S of basin	
EARLY DEVONIAN		Erosion		Mereenie Sandstone	Aeolian & fluvial sandstone				Transpressional? basin development Numerous depositional breaks
SILURIAN	(410-434) **Land. 434**	Sahara Formation	(?415/? 435)	?Mereenie Sandstone					
	c. 410-434	Tilting, then onlap within middle Sahara Formation	**430 ± 20**	**RODINGAN MOVEMENT**					

(434)	Carribuddy Fm., e.g., Mallowa Salt Lowest 'Worral Formation'		Unconformity	Unconformity
(463)	Lower Carribuddy Fm	(?455)	?Carmichael Sst	

* RTZ: Redbank Thrust Zone

§ Age range: ***410-434***, age in parenthesis, e.g. (364), is estimated age at base of formation, whereas age in bold type, e.g. **364 Ma**, is age at the base of the Stage

¢ Unconformity placed by Jones (1991) at c.380-?374 ? (Givetian to earliest Frasnian) and by Shaw & others (1992) at c. 380-400 Ma (? Pragian) assuming that the oldest basement mineral age ascribed to the Alice Spring Orogeny

Table 5. Key to unconformities and supersequences shown on Plates 2b and 3b.

UNCONFORMITY	*SUPER-SEQUENCE*	*UNIT AT BASE*	*UNIT AT TOP*	*SERIES STAGE*
13	K	Wallah Sandstone	Jarlemai Siltstone	Tithonian to Bajacian (Jurassic)
12	J	Blina Shale	Erskine Sandstone	Scythian (Triassic)
11	I	Poole Sandstone and Nura Nura Member	Liveringa Group	Dorashamian to Late Sakmarian (Permian)
10	H	Grant Group	Grant Group	Early Sakmarian to Late Assellian
9	G	'Lower Grant Group'	'Lower Grant Group'	Namurian (Permian)
8	F	Mount Behn Conglomerate below lower shale of Laurel Formation	Anderson Formation	Early Visean to latest Famennian (Carboniferous)
7	Eu	Gum Hole Formation (upper Nullara Reef cycle)	lower Yellow Drum Limestone	Late Famennian (Devonian)
6	El	Van Emmerick Conglomerate (lower Nullara Reef cycle)	Nullara Limestone	Famennian to latest Frasnian
5	D	Boab Sandstone, Gogo Formation (Pillara Reef cycle)	Pillara Limestone, Napier Formation	Frasnian to mid-Givetian
4	C	Tandalgoo Formation, Mellinjerie Limestone	Poulton Formation	Mid-Givetian to Emsian (Devonian)
	B	Bongabinni Formation (Carribuddy Group)	Sahara Formation (Carribuddy Group)	Llandovery to Llandelian (Ordovician)
3	A2	Goldwyer Formation	Nita Formation	Llanvirnian
2	A1	Willara Formation, Emanuel Formation	Willara Formation,	Arenigian
1	A0	Nambeet Formation, Unnamed dolomite & sandstone unit	Nambeet Formation	Tremadocian (Ordovician)
0	X	Basement		Proterozoic

Table 6. Summary of geohistory Analysis (after Kennard et al. 1994 b), showing maximum estimates, in metres, of tectonic subsidence (-) and exhumation (+ ; uplift and erosion)

Episode	**Lennard Shelf**	**Fitzroy Trough**	**Dampier & Barbwire Terraces**	**Broome Platform**	**Willara & Kidson Sub-basins**
Fitzroy Transpression	+ 500 Mimosa 1	+ 2600 Yulleroo 1	+ 850 Edgar Range 1	+ 1200 Thangoo 1A	+ 650 Willlara 1
Point Moody Subsidence-Sag Phase	- 350 Langoora 1	- 1100 Myrroodah 1	- 300 Edgar Range 1	- 600-800 Aquila 1, Thangoo 1A	- 450 Willara
Meda transpresssion & Drosera Erosion	+ 400 Blackstone 1	+ 250 Yulleroo 1	+ 350 Dodonea 1	+ 200 Thangoo 1A	+ 300 in Kidson 1, + 800 in Calamia 1
Pillara Subsidence-Sag Phase	- 900 in Meda 1 - 2000 in Minosa 1	- 4000 Yulleroo 1	- 700 Pictor 1, Matches Spring 1	Not recognised	Not recognised
Tandalgoo Sag Phase	- 200-400 metres basin-wide				
Prices Creek Movement	+ 750	Unknown	+ 350 Dodonea 1	+ 800 Hedonia 1	+ 300 Willara 1
Samphire Mash Subsidence-Sag Phase	- 1700 Mimosa 1	Unknown	- 800 Matches Spring 1	- 800 McLarty 1	- 2300 Vela 1

Table 7. Megasequences in the Canning Basin

Age Range (Ma) approx.	Stage	Megasequences of Kennard et al. (1994 b)	Megasequences of Warris (1993)	Sequences of Middleton (1993)	Proposed Successor Basin
~ 160	Start of continental break-up				
160-180	Mid-Jurassic	K	---	---	---
180-200 +	Transpressional Fitzroy Movement: producing basin inversion				
< 250	Early Triassic	J	III	---	---
250 - ~ 253 +/-	Bedout Movement: widespread hiatus				
253-320	Permian - Late Carboniferous	G, H & I	III	Pz5	Start of Westralian Superbasin
320-326	Transpressional Meda Movement: widespread hiatus				
326-390 +/-	Early Carboniferous - Devonian	C, D, El, Eu, & F	II	Pz4	Basin B
390-410	Compressional Prices Creek Movement				
410-488 +/-	Ordovician-Silurian	A0 to B2	I	Pz2, Pz3	Basin A
500-510 +/-	Compressional Spielers Event				
~ 520 (estimate)	Early Cambrian	Antrim Plateau Basalt	---	---	Ord Basin
530-560	Compressional Precipice Event				
730? - < 670 +/-		Glacigene units	---	---	Louisa Basin

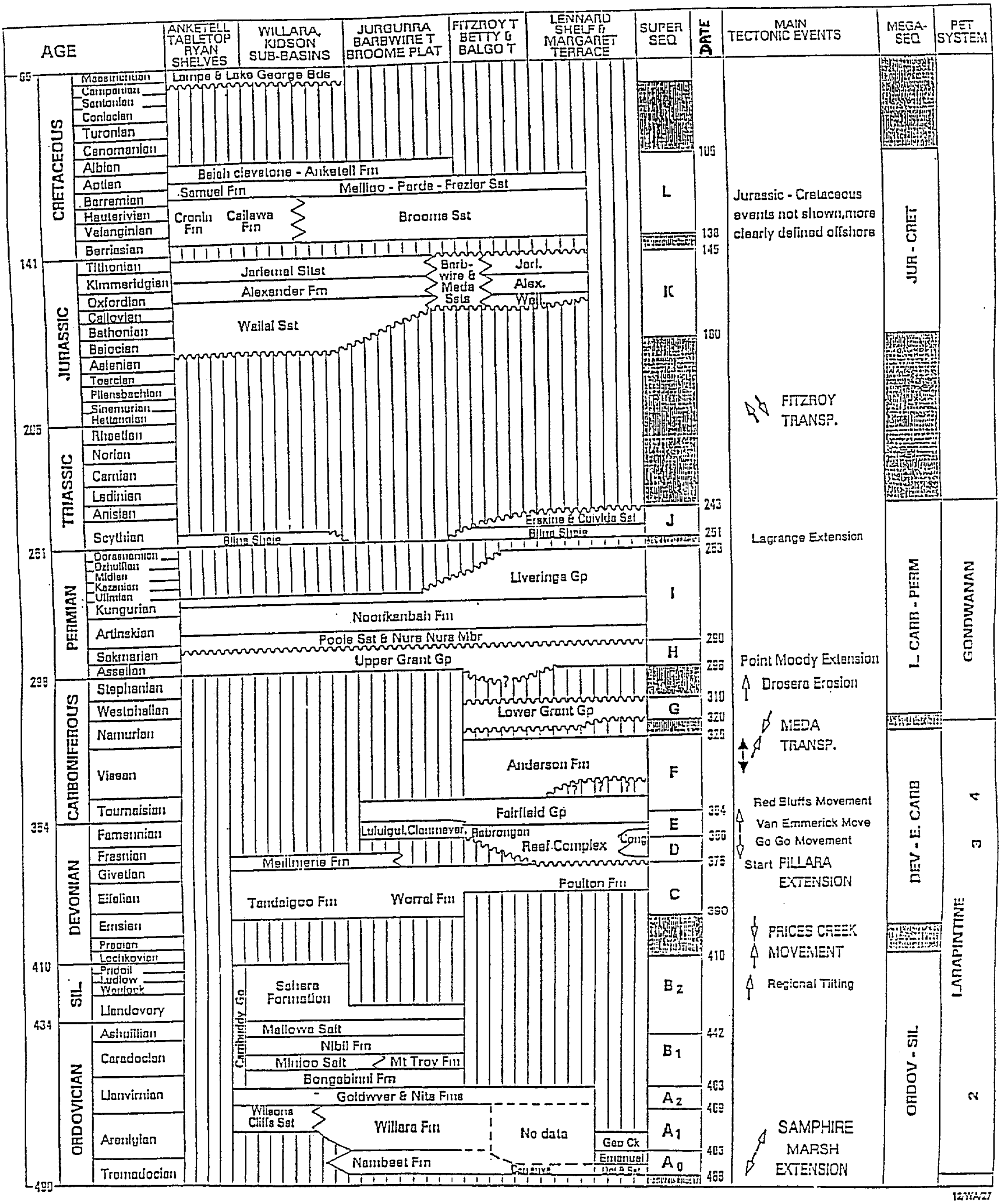


Figure1. Generalised stratigraphic column for lithostratigraphic units in the Canning Basin, illustrating their relationship to tectonic events (from Kennard et al. 1994).

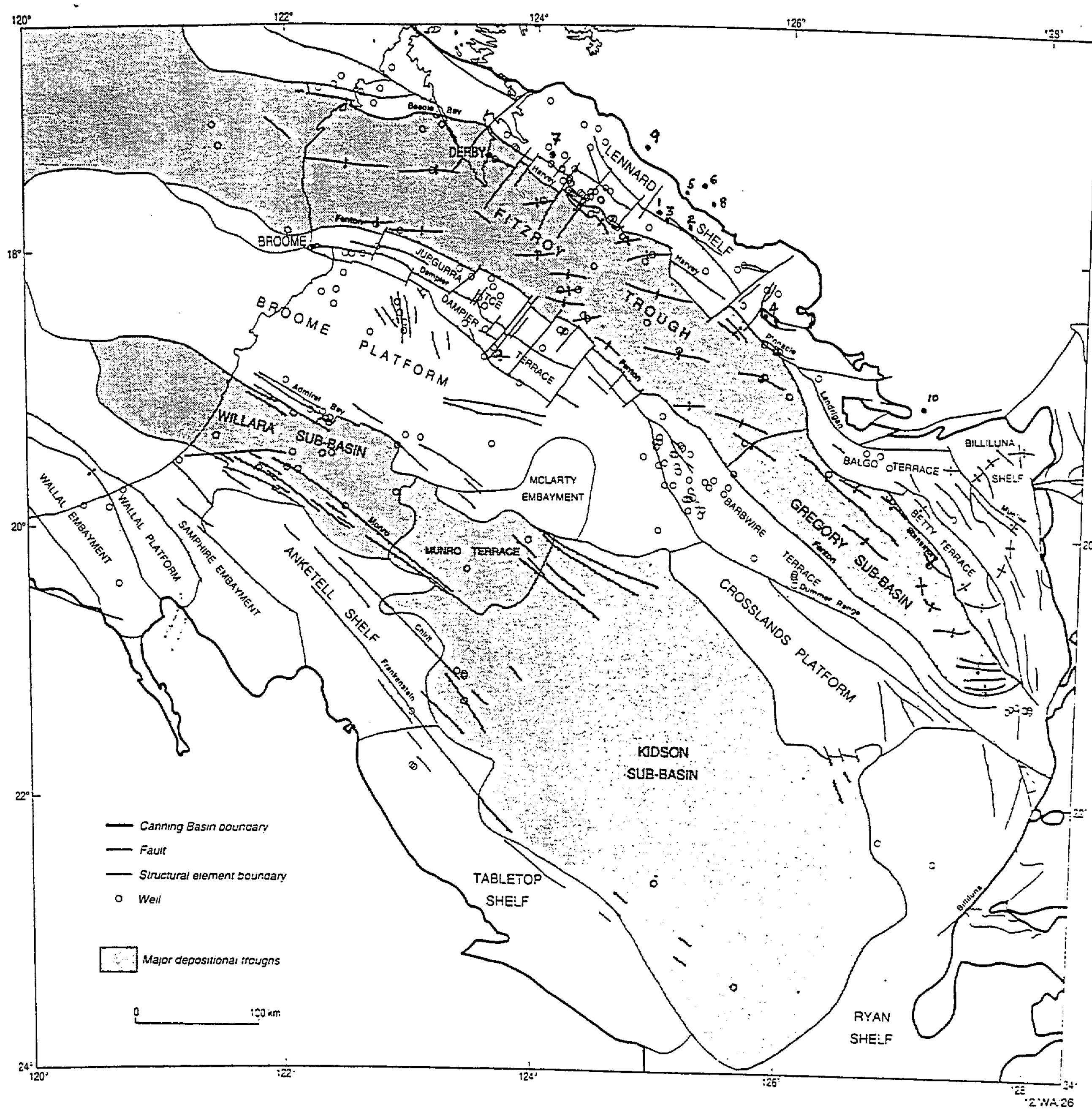


Figure 2. Simplified structural elements map of the Canning Basin showing the position of deep seismic lines BMR88-01 and BMR88-03. Also, shown is the distribution of exploration wells (open circles) in relation to the main structures and dated basement samples (dots); approximate age are 1 532 Ma, 2 504 Ma, 3 514 Ma, 4 557 Ma, 5 506 Ma, 6 700 Ma, 7 473Ma, 8 1475 Ma, 9 1000 Ma and 10 1725 Ma.

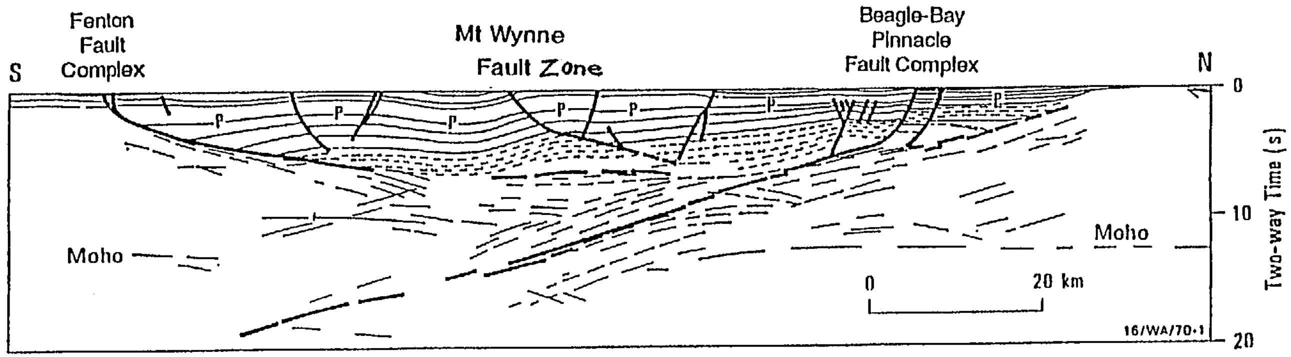


Figure 3. Simplified cross-section across the Fitzroy Trough based on a preliminary interpretation of the BMR deep seismic reflection images.

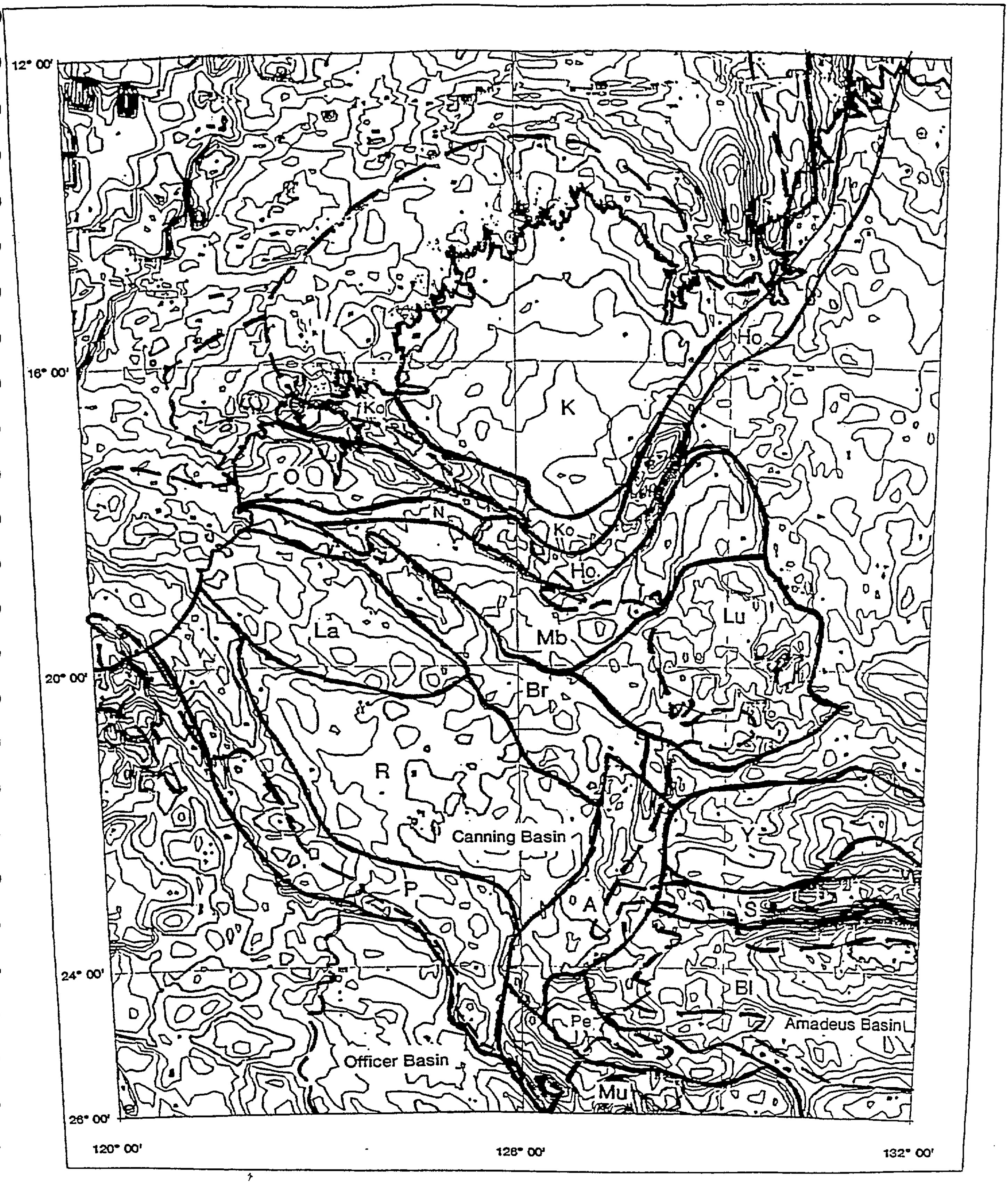


Figure 4.The distribution of the main basement tectonic elements relative to the pattern of Bouguer gravity anomalies. A Angus, Bl Bloods Range, Br Broome, K Kimberley, Ko Kings Leopold, La Lagrange, Lu Lucas, Mb Mount Bannermann, Mu Musgrave, N Noonkanbah, Ho Halls Creek, O Oscar, P Paterson, Pe Petermann, R Roeves, S Strangways, Y Yuendumu. The limits of the Canning, Officer and Amadeus basins are also shown, as dashed lines.

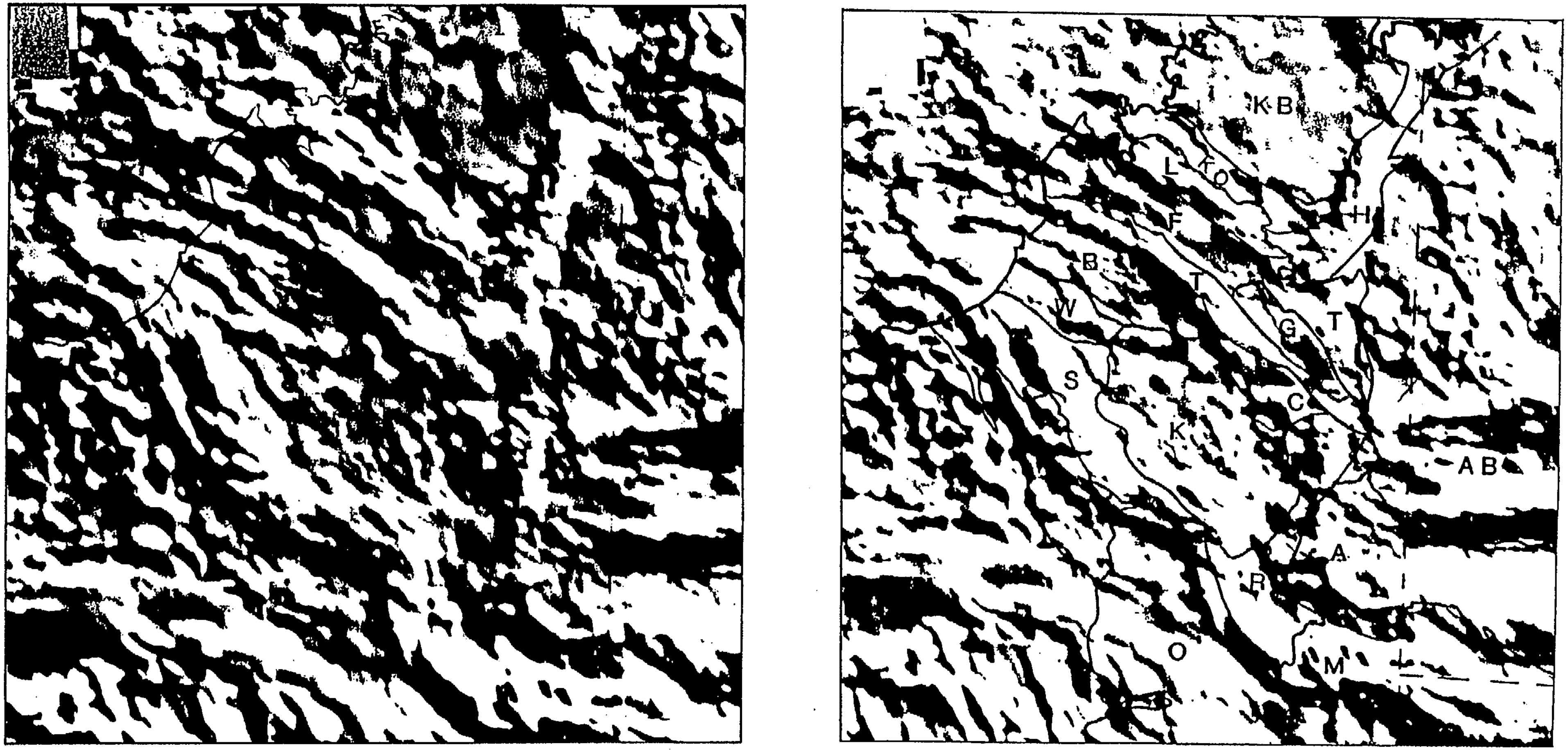


Figure 5.

a. An image of gridded Bouguer gravity data of the Canning Basin region, portrayed as pseudo-topography obliquely illuminated from the northeast.

b. Above image with an overlay of the structural elements as follows:

A - Amadeus Basin
AB - Arunta Block (basement)
B - Broome Platform
C - Crossland Platform
F - Fitzroy Trough
G - Gregory Sub-basin,
H - Halls Creek Orogen (basement)
KB - Kimberley Basin (basement)
KO - King Leopold Orogen (basement),
K - Kidson Sub-basin
L - Lennard Shelf
M - Musgrave Block (basement)
P - Paterson Province
R - Ryan Shelf
S - Southern Shelves and embayments
T - Terraces
W - Willara Sub-basin

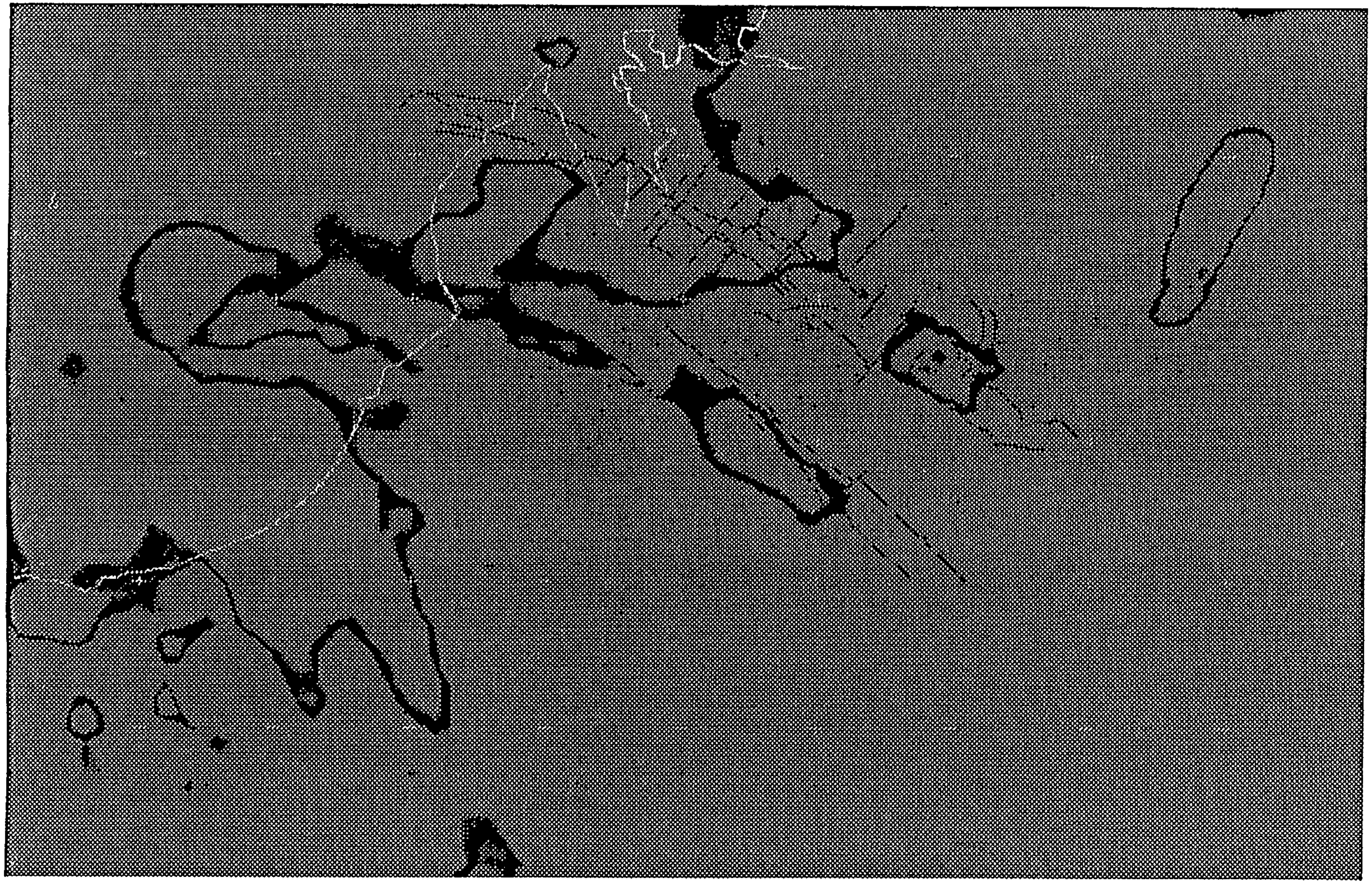


Figure 6. Simplified, enhanced image of Bouguer gravity anomaly data, accentuating the boundary between positive and negative anomaly values. Some of the main faults and accommodation zones of the Fitzroy Trough are draped over the image.

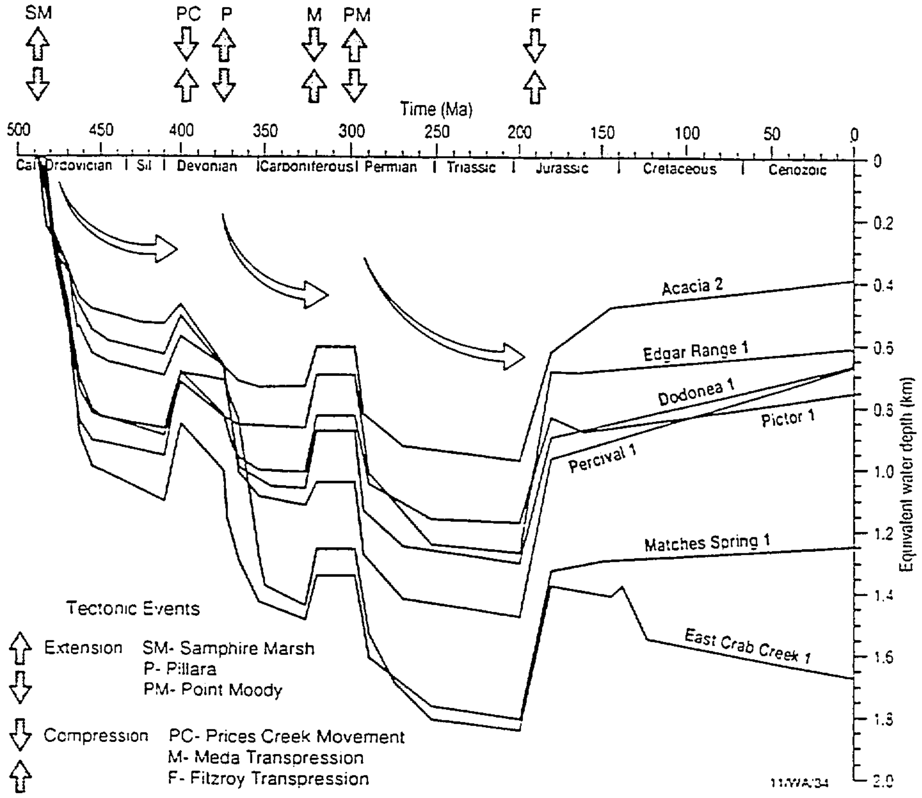


Figure 7. Tectonic subsidence curves for wells on the Jurgurra, Dampier and Barbwire Terraces.

H84-12.3

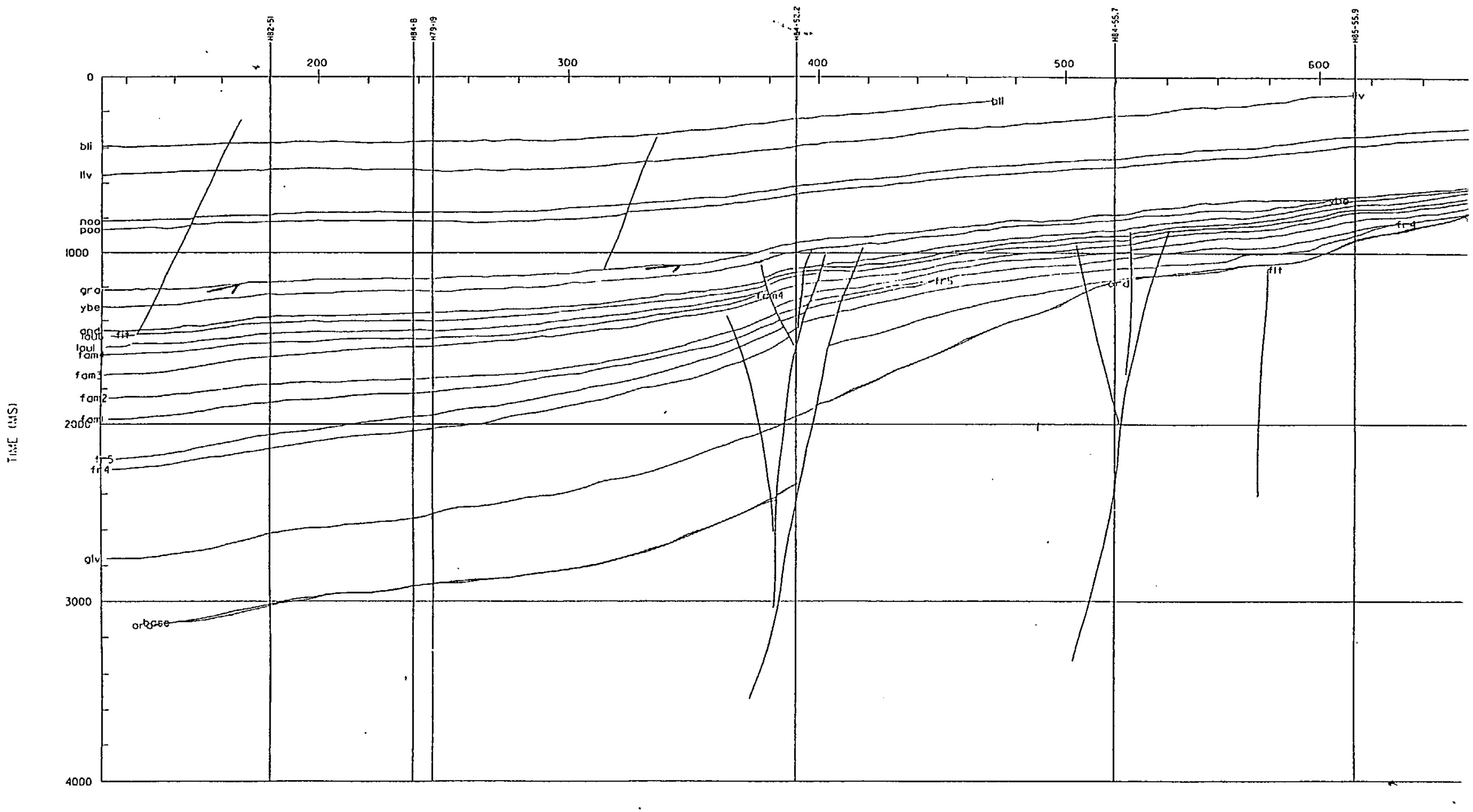


Figure 8. Interpreted seismic section H84-12.3 showing Late Carboniferous reactivation of the May River Fault System.

Plate 1 Structural Elements of the Canning Basin. The key to the abbreviations is given in the map reference.

See enclosure

Plate 2a. Uninterpreted standard stacked section to 20 seconds, BMR 88-03 Central Fitzroy Trough

See over

LINE 3 CANNING

PLATE 2A

PLATE 2A

R9404802

Plate 2b Preliminary interpretation of deep-seismic line BMR 88-03

See over

PLATE 2B

PLATE 2B

Plate 3a Uninterpreted standard stacked section to 20 seconds, BMR 88-01, Fitzroy Trough to Willara Sub-basin

See over

PLATE 3A

AGSO GARP 21-JUL-1994 17:26

USERNAME: LSEXTON PLOT ENTRY: 0 SEGMENT/PANEL NO: 1/1

DISCO VERSION 9.0.8
DISCO JOB : 4865
PROJECT : CANNING
LINE : 1
USER : MIKE
TITLE : LINE 1 - BOW VALLEY
INPUT FILE : /ONSHORE/CANNING/LINE1.DIR/RUSSPLT1
SITE : GARP
AP TYPE : (CPU)
OPTIONS : /LIST/NOCHECK/NODUMP/NOMEMCHK/WARN/NOACCT/APMASK= -1

SECPLOT
LINE 1 CANNING
POLARITY NORMAL - POSITIVE FILL (20000 MS @ 4.000 MS SAMPLE RATE)
SECOND AVERAGE USING 4 WINDOWS OVER ENTIRE TRACE INCLUDING ZERO SAMPLES
RMS = 0.931852E+08 GAIN = 1.00 DIRECTION = LR

PLATE 3A

PLATE 3A

Plate 3b Preliminary interpretation of deep-seismic line BMR 88-01

See over

PLATE 3B

```
AGSO                                   GARP          21-JUL-1994 17:26
USERNAME: LSEXTON                      PLOT ENTRY: 0        SEGMENT/PANEL NO: 1/1
DISCO VERSION 9.0.8
DISCO JOB     :   4865
PROJECT       :  CANNING
LINE          :  1
USER          :  MIKE
TITLE         :  LINE 1 - BOW VALLEY
INPUT FILE    :  /ONSHORE/CANNING/LINE1.DIR/RUSSPLT1
SITE          :  GARP
AP TYPE       :     (CPU)
OPTIONS       : /LIST/NOCHECK/NODUMP/NOMEMCHK/WARN/NOACCT/APMASK= -1
SECPLOT
LINE 1 CANNING
POLARITY  NORMAL  - POSITIVE  FILL ( 20000 MS @ 4.000 MS SAMPLE RATE)
SECOND AVERAGE USING 4 WINDOWS OVER ENTIRE TRACE          INCLUDING ZERO SAMPLES
RMS =  0.931852E+08  GAIN =   1.80  DIRECTION = LR
```

TWT

PLATE 3B

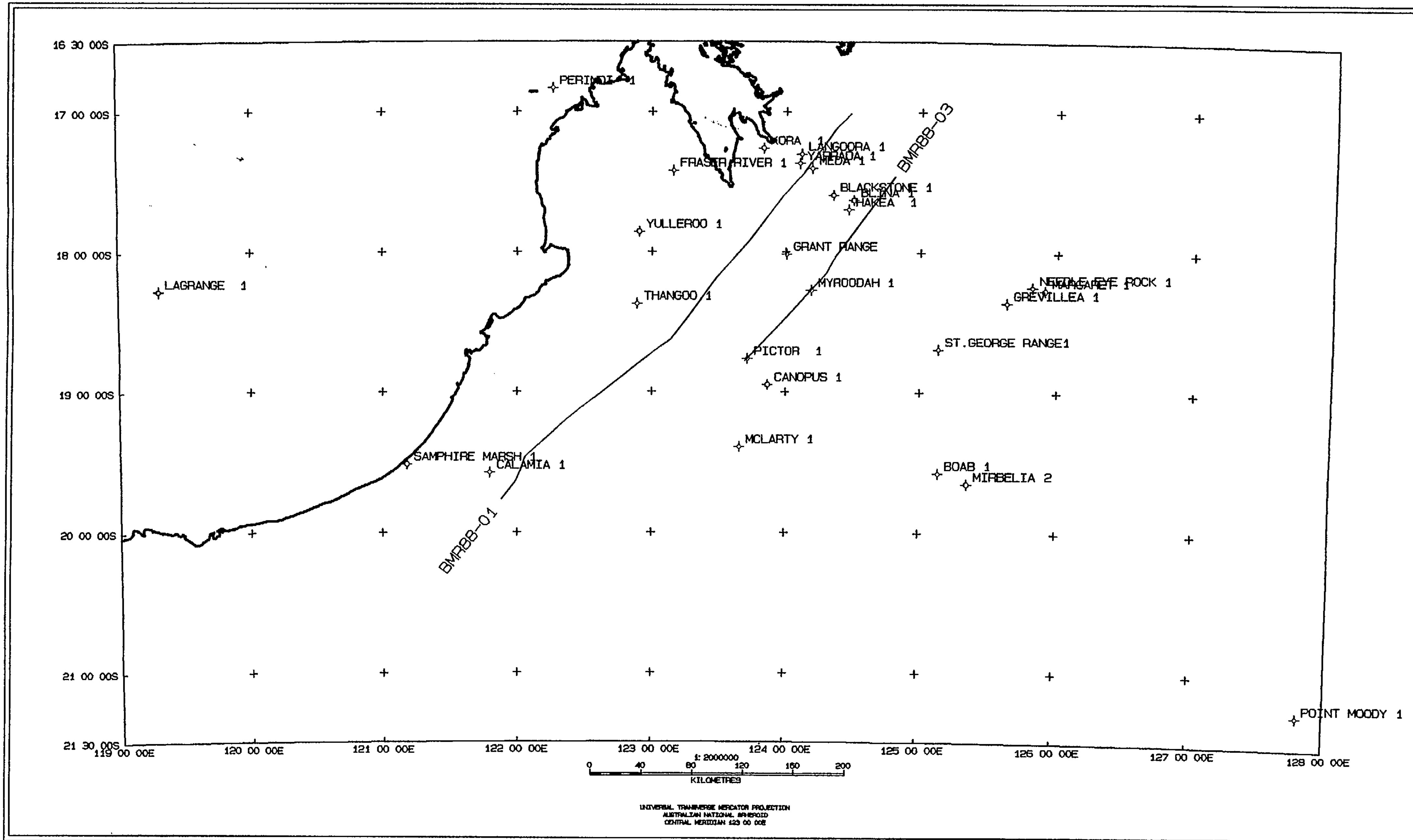


Plate 4 Location of Wells

APPENDIX.

Tectonic Elements, Canning Basin and surrounding region
(Parts 1 to 10)

Index of Elements

1	Blocks/provinces/orogens/terranes
2a	Inliers/basement/domes
2b	Inliers/basement/domes/highs (buried)
3a	Dominantly Phanersozoic basin/sub-basins
3b	Dominantly Precambrian basin/sub-basins
4	Terraces/platforms/embayments
5	Arches
6	Fault complexes
7	Fault systems/fault zones/faults
8	Hinge lines
9	Transverse accommodation zones and transfer faults
10	Anticlines/synclines

Note: ID numbers are an acquisition number used in a structural database that is in preparation.

1) BLOCKS/ PROVINCES/ OROGENS/TERRANES

ID	Feature	Abbrev.	Reference
1	Arunta Block (Arunta Inlier)	AK	3
2	Musgrave Block	MK	4
2B	Clutterbuck Inlier	CI	5
3	The Granites-Tanami Block (Arunta Inlier)	GK	2
4	Yilgarn Province	YP	2
4A	Western Gneiss Terrane	4A	2
4B	Murchison Province	4B	2
4C	Southern Cross province	4C	2
4D	Eastern Goldfields province	4D	2
5	Halls Creek Orogen	HCO	1
7	King Leopold Orogen	KLO	1
8	Paterson Orogen/ Province includes:	PP	2
(99)	Yeneena Basin, subdivided into Western (W), Central (C) & Eastern (E) Zones, & Fore 99 see section 5B, below)	YEB	2
9	Pilbara granite-greenstone Terrane/ Block	PK	2
9A	Milli Milli Dome	9A	2
9B	Rat Hill Inlier	9B	2
9C	Turkey, Rooney & Dingo Inliers	9C	2
9D	Coonninia Inlier; Billinnooka Inlier to SW	9D	2
10	Rudall Complex	RC	2

REFERENCES:

1 Tyler & Griffin, 1990

2 Geological Survey of Western Australia 1990 - including contribution on the Inliers of granite-greenstone terrane by I.M. Tyler; the Nabberu Basin by R.D. Gee; the Paterson Orogen by I.R. Williams & J.S. Myers; the Bangemall Basin by I.R. Williams; the Savory Basin by I.R. Williams, and the Birrindudu Basin by Kathleen Grey.

3 Blake et al., 1979; see also Shaw et al., 1984

4 Stewart, 1992; see also Forman & Shaw, 1984 and Daniels 1974.

5 Hocking et al., 1994 (see note in References 5B)

2A) INLIERS/ BASEMENT/ DOMES

- surrounding Canning & Officer Basins

ID	Name	Feature	Abbrev.
11	Minor Precambrian domes		
12	Marymia	Dome	MD
13	Sylvania	Dome/Inlier	SD

REFERENCE:

Geological Survey of Western Australia 1990 - including contribution on the Inliers of granite-greenstone terrane by I.M. Tyler; the Nabberu Basin by R.D. Gee; the Paterson Orogen by I.R. Williams & J.S. Myers; the Bangemall Basin by I.R. Williams; the Savory Basin by I.R. Williams; the Karara Basin by I.R Williams; and the Birrindudu Basin by Kathleen Grey.

2B) INLIERS/ BASEMENT/ DOMES/ HIGHS (buried)

- within Canning & Officer Basins

ID	Name	Feature	Abbrev.	Refs
2b	Clutterbuck	Inlier	CI	27*
14	May River	High	MH	9*, 13
15	Oscar (Range)	Inlier	OI	6, 9, 13*, 25
17	Pillara	Inlier	PI	10, 13*
18	Sixty Seven Mile	High	SH	13*, 24
19	Madley (Officer Basin)	High	YH	14
20	Neale (Officer Basin)	Ridge	NH	14
21b	Baron	Inlier	BI	27*

REFERENCES:

See next page, after section 3B

3A) DOMINANTLY PHANEROZOIC BASINS/ SUB-BASINS

& composite basins with Phanerozoic elements (for depocentre see Structural Features, below)

ID	Name	Feature	Abbrev.	Refs
21	Amadeus	Basin	AB	1, 18*, 27
21B	Baron	Inlier	BI	27*
23	Bedout	Sub-Basin	DB	1, 5, 17*, 23
24	Beagle	Sub-Basin	EB	17*, 23
25	Browse	Basin	BB	1*, 23
27	Canning	Basin	CB	1*, 23
29	Carnarvon	Basin	CRB	1*, 23
33	Exmouth	Plateau	EX	1*, 17
35	Fitzroy	Trough	FT	1*, 2, 3, 4, 5, 6, 11, 23
35A	Beagle Bay	Compartment	BC	13
35B	May River	Compartment	MC	13
35C	Sixty Seven Mile	Compartment	OC	13
35D	Oscar	Compartment	SC	13
35E	Poole	Compartment	PC	13
40	Gibson	Sub-Basin	IB	15g
41	Gregory	Sub-Basin	GB	1*, 2, 5, 7*, 23
43	Kidson	Sub-Basin[@]	KB	1*, 3, 5, 23*, 20, 26
(50)	Lucas	Basin	LB	16
	includes:			
44C	Triassic	Succession	LB$_C$	8, 16
44B	Permian-Carboniferous	Succession	LB$_B$	8, 16
44A	Devonian	Succession	LB$_A$	8, 16
45	Officer	Basin	OB	1*, 3
46	Oobcooma	Sub-Basin	OOB	13, 21*, 22, 23, 27
47	Ord	Basin	ORB	19
	includes:			
47B	Devonian			19
47A	Cambrian[$]			19
48	Rowley	Sub-Basin	RB	1*, 5, 17

ID	Name	Feature	Abbrev.	Refs
49	Waigen	Basin	WAB	159
	(Officer	Basin)		
(50)	Lucas	Basin	LB	16
	includes:			
51	Willara	Sub-Basin	WB	1*, 3, 5, 20, 21, 22, 23, 26
53	Wiso	Basin	WSB	1*
55	Yowalga	Sub-Basin	YOB	14
	(in Officer	Basin)		

@ Outlined at 3.5 km depth contour, but transitional onto adjacent shelves

$ Includes ?Early Cambrian Antrim Plateau Volcanics in the Ord Basin

REFERENCES: after section 3B

3B) DOMINANTLY PRECAMBRIAN BASINS/ SUB-BASINS

ID	Name	Feature	Abbrev.	Refs
70	Ashburton	Basin	ASB	15d
71	Bangemall	Basin	BAB	15f
	includes:			
71B	Kahiban	Basin		
71C	Trainor	Inlier		
72	Birrindudu	Basin++	BIB	16
	includes:			
72B	Late Proterozoic	Succession		
72A	Mid-Proterozoic	Succession		
76	Bresnahan	Basin	BRB	15a
80	Hamersley	Basin	HAB	15e
	(Pilbara Craton)			
83	Karara	Basin	KAB	15f
85	Kimberley	Basin	KYB	15c
88	Lousia	Basin$	LDB	12, 13
90	Nabberu	Basin	NAB	15b
90A	Glengary region			
90B	Earaheedy region			
93	Savory	Basin	SAB	15f
95	Victoria River	Basin	VRB	14*
96	Wolf Creek	Basin #	WCB	13*
	Waigen	Sub-basin		15g
	(Officer	Basin)		
99	Yeneena	Basin	YEB	15f
	(Paterson	Orogen/Province)		

$ Equivalent Neoproterozoic glacigene and older rocks lie between the Halls Creek Orogen and the 1.4 -1.6 Ga Birrindudu Basin.

++ Excludes Antrim Plateau Volcanics which are placed in the Ord Basin. Overlying Amadeus Basin equivalents not distinguished

overlying Louisa Basin equivalents not distinguished

*** Principal reference**

PRINCIPAL REFERENCES:

1 Forman & Wales, 1981
2 Purcell & Poll, 1984
3 Yeates et al., 1984
4 Begg, 1987
5 Craig et al., 1984
6 Goldstein, 1989
7 Smith, 1984
8 Towner & Gibson, 1983
9 Lehmann, 1986
10 Crowe & Towner, 1981
11 Begg, 1989 (unpubl. map)
12 Roberts et al., 1968
13 This report
14 Sweet, 1977
15 Geological Survey of Western Australia, 1990:
15a Hunter
15b Gee
15c Griffin & Grey
15d Thorne
15e Trendall
15f Williams
15g Iasky, 1990
16 Blake et al., 1979
17 Passmore, 1991
18 Stewart, 1992 - see also Forman & Shaw , 1993
19 Mory & Beere, 1985
20 Taylor et al., 1990
21 Iasky et al., 1991
22 Luck, (1991a, b) also in Hocking 1993
23 Hocking, 1993
24 Taylor, 1992
25 Griffin et al., 1992
26 Romine et al., 1994
27 Hocking et al., 1994 show two addtional features (i) Baron Inlier (21b) a part of the Amadeus Basin within the Ryan Shelf, and (ii) Clutterbuck Inlier (2b) that may represent an extension of the Musgrave Block.

4) TERRACES/ PLATFORMS/ EMBAYMENTS

ID	Name	Feature	Abbrev.	Refs
133	Anketell/LAMBERT	SHELF	AS	1, 3, 13, 16, 19*
136	Balgo	Terrace	AT	6, 7*
137	Barbwire	Terrace	BT	1*, 3, 4, 5, 7, 19
138	Bedout	High	ET	1*, 5, 16, 19, 27
139	Betty	Terrace (Arch)	TT	1, 3, 5, 6*, 7, 19
140	Blackstone	High	BH	13, 22*
141	BILLILUNA	SHELF	BS	1, 3, 5, 7*, 19
142	BROOME	PLATFORM @ (ARCH)	BP	4, 6*, 15,
143	BULKA HILLS	SHELF/ Terrace	KT	6*
145	CROSSLAND	PLATFORM@	CP	4*, 6, 7, 20, 21, 19
146	Cobb	Embayment	CE	26
147	Dampier	Terrace	DT	4*, 6, 19, 27
155	Jurgurra	Terrace	JT	4*, 6, 19
157	Kingston (Officer	Shelf Basin)	KS	14
159	Laurel Downs	Terrace§	LDT	2 cf. 1
133	LAMBERT/Anketell (Carnarvon	SHELF Basin)	AS	1*, 3, 19
161	LENNARD (Undivided,	SHELF see also§)	LS	1*, 3, 5, 15, 19
162	LEVEQUE	SHELF	VS	1*, 3, 5, 19
163	Leveque	Platform	VT	4
165	McLarthy	Embayment	MLE	10, 13, 21
166	Margaret River	Embayment§	ME	4, 13*, 17
167	Moogana	Terrace§	MT	4, 9*
169	Munro	Terrace	MUT	13*,18, 19, 27/1
171	Napier	Embayment§	NE	4, 6, 9*
175	Oakover	Embayment	OKE	13, 19, 21*
176	Pender	Embayment§	PE	1, 9*
177	PENDER disused	TERRACE§	PT	1, 5, 6, 9, 13*, 19, 27/2
179	PILLARA	SHELF+		16

ID	Name	Feature	Abbrev.	Refs
180	RYAN	SHELF@	RS	1*, 3, 5, 19, 25*, 27/3
184	Samphire	Embayment	SE	5, 6*, 8, 16, 19, 27/4
185	TABLETOP	SHELF@	TS	1, 5, 25*, 19
190	Wallal	Embayment	WAE	5, 6*, 16, 20
191	Westwood (Officer	Terrace Basin)	WT	14
	Wallal	Platform	WAT	16*, 20

* **Principal reference**

§ Part of Lennard Shelf

+ used for eastern part of Anketell Shelf

@ Outlined at 3.5 km depth contour, grading into adjacent shelves. A shallower depth is used by Hocking (1993).

REFERENCES:

1 Forman & Wales, 1981
2 Purcell & Poll, 1984
3 Yeates et al., 1984
4 Begg, 1987
5 Craig et al., 1984
6 Goldstein, 1983
7 Smith, 1984
8 Towner & Gibson, 1983
9 Lehmann, 1986
10 Brown et al., 1981
11 Begg, 1989 (unpubl. map)
12 Roberts et al., 1968
13 This report,
14 Iasky, in GSWA, 1990
15 Middleton, in GSWA 1990
16 Passmore, 1991
17 Kemp & Wilson, 1990
18 Connolly et al., 1984
19 Hocking, 1993
20 Taylor et al., 1990
21 Iasky et al., 1991
22 Jackson et al., 1959
23 Veevers & Wells, 1961
24 Koop, 1966
25 Gorter et al., 1979
26 Daniels, 1974
27 Hocking et al., GSWA 1994

Notes: 1. adopts the term Mowla Terrace for Dampier & Munro Terraces

2. uses term, Pender Terrace for combined feature made up of Pender Embayment and Moogana Terrace.

3. Places western margin of Ryans Shelf into the Warrie Arch.

4. Splits the Samphire Embayment into a northern Samphire Graben and a southern Waukarlcarty Embayment (south of Wallal Platform).

5) ARCHES

ID	Name	Feature	Abbrev.	Refs
202	Anketell	Ridge	AR	5*
204	Bulka	Arch +	BA	5*
210	Jones	Arch	JR	3, 5, 10, 11
220	Leveque	Arch	LR	1*
(169)	Munro	Arch/ Terrace	MUT	2, 3, 5, 6, 7, 10, 11, 12/1
224	Neale (Officer	Ridge Basin)	NR	8, 12/2
225	North Turtle	Arch	TR	1, 5, 8, 9
248	Warri (continues into Officer	Arch/ Hinge Basin as Warri Hinge)	WR	1*, 5, 12
300				

Footnote: +Part of Bulka Hills Shelf

REFERENCES:

*** Principal reference**

1 Forman & Wales, 1981
2 Purcell & Poll, 1984
3 Yeates et al., 1984
5 Craig et al., 1984
6 Goldstein, 1989
7 Connolly et al., 1984
8 Iasky, 1990
9 Passmore, 1991
10 Taylor et al., 1990
11 Iasky et al., 1991
12 Hocking et al., 1994

Note: 1. GSWA's new term Warri Arch incorporates the Clutterbuck Inlier and is effectively an extension of the shelf, occupying the western margin of the Ryan Shelf

2. Neale Ridge renamed Neale Arch.

6) FAULT COMPLEXES

That is a complex belt of interconnected faults and fault systems-components

Faults within a fault complex are named individually:

1) BEAGLE BAY-PINNACLE COMPLEX (This report)

2) FENTON-FAULT COMPLEX (This report)

7) FAULT SYSTEMS/ FAULT ZONES/ FAULTS

FAULT SYSTEMS: A set of linked faults, typically made up of ramps, flats and side wall transfer faults or zones of accommodation (Gibb, 1980).

FAULT ZONE: A narrow zone of closely spaced, sub-parallel faults which may or may not be linked.

ID	Name	Feature	Abbrev.	Refs
1001	Admiral Bay	Fault Zone	AFS	1*, 2, 3, 5, 21
1001.1		master fault	AF	
1003	Abutilon	Fault	ABF	17*
1004	Albatross	Fault	ALF	22, 23*
1005	Beagle Bay	Fault System	BFS	1, 3, 4*, 9
1005.1		master fault	BF	
1009	Bedout	Fault Zone	BZ	1*5
1010	Billiluna	Fault Zone	NF	13*, 15
1057.2	Cadjebut	Fault	JF	10*
	(part of	PFS)		
1017	Chirit	Fault Zone	CHFZ	21*
1015	Collins	Fault	CF	4*
1016	Colombo	Fault	COF	5*, 23
1019	Dampier	Fault System	DFS	1, 2, 3, 4, 9, 13*
1019.1		master fault	DF	9, 13*
1020	Djowi	Fault	DJF	24
1021	Dummer (Range)	Fault System	RFS	1, 3, 4, 9, 13*
1021.1		master fault	RF	3, 4, 13*
1021.1020		faults east of Barbwire 1		
1026	Fenton West	Fault System	FFS	1, 3, 4*, 11
1026.1		master fault	FF	13*
1027	Fenton East	Fault System	FEF	2, 7, 11, 13*
1027.1		master fault		13*
1028	Frankenstein	Fault Zone	FRFZ	21*
1030	Geike	Fault Zone	GKFZ	8, 13*
	Glidden	Fault	GRF	4, 12*, 13
1036	Harvey	Fault System	HFS	4, 13*, 26
1036.1		master fault	HF	13*
1037	Hinge	Fault	GF	7*

ID	Name	Feature	Abbrev.	Refs
1038	Landrigan	Fault	LF	13*
1042	Markam	Fault	KF	1*
1063	May River	Fault System	MRFS	13*, 26
1043	Mermaid	Fault	MF	1*, 5
1044	Mount Elma	Fault	MEF	13*
1045	Mt Winifred	Fault	WF	12, 13*
1046	Mt Wynne	Fault Zone	WNF	12, 13*
1047	Mueller	Fault	EF	7*
1048	Munro	Fault	UF	1*, 2, 3, 5, 21
1050	Napier	Fault	NF	4, 13*
1053	Oscar (Range)	Fault System	OFS	2, 4, 13*, 24
1053.1		master fault		13*
1056	Pender Bay	Fault	PBF	1, 4, 5, 9*
1057	Pinnacle	Fault System	PFS	1, 3, 4, 5, 11, 13*
1057.1		master fault	PF	13*
1063	May River	Fault System	MRFS	13*
1064	Sixty Seven Mile	Fault System	SFS	4, 13*, 26
1064.1		master fault		13*
1065	Saturn	Fault	SF	2*
1067	Sparke Range	Fault	SRF	12, 13*
1068	Stansmore	Fault System	TFS	1, 3, 5, 7*
1068.1		master fault	TF	
1070	Tina Springs	Fault	IF	5, 7*
1075	Virgin Hills	Fault Zone	VFS	4, 10, 13*
1075.1		master fault	VF	
	Unnamed Basement	**Faults**		
	Basement Faults			
	Angelo	Fault	ANF	18?
ID	**Name**	**Feature**	**Abbrev.**	**Refs**
	Djowi	Fault	DJF	18
1435	Halls Creek	Fault (Zone)	HCF	7, 20*
1435.1		master fault		20*, 25
1440	Glidden	Fault	GRF	16, 19, 20*

ID	Name	Feature	Abbrev.	Refs
1442	Greenvale	Fault	GVF	16, 19, 20
1467	Springvale	Fault	SGF	16, 19, 20, 25
1475	Woodward	Fault	WOF	16, 19, 20, 25
	Unnamed Basement	**Faults**		
	Named	**Thrust Faults/ Shear**		
1500-	Duck Hole	Shear Zone	DHT	18
1600				
1630	Inglis	Fault	INT	16
	Mondooma	Thrust	MOT	18
	Sandy Creek	Shear	SAT	12, 13*, 14
1645	Spielers	Shear	SPT	12, 13*, 14, 24
1661	Stoney Creek	Shear (Fault)	STT	12, 13*, 14
1665				
	Named	**Thrust Faults/ Shear**		

REFERENCES:

*** Principal reference**

1 Forman & Wales, 1981
2 Brown et al., 1984
3 Yeates et al., 1984
4 Begg, 1987
5 Craig et al., 1984
6 Goldstein, 1989
7 Smith, 1984
8 Towner & Gibson, 1983
9 Lehmann, 1986
10 Crowe & Towner, 1981
11 Playford & Johnston, 1959
12 Roberts et al., 1968
13 This report
14 Shaw et al., 1992
15 Myers & Hocking, 1988
16 Tyler & Griffin, 1990
17 Pasminco Exploration unpubl. information, 1993
18 Tyler & Griffin, 1992
19 Roberts et al., 1968
20 Griffin & Grey in GSWA, 1990
21 Romine et al., 1994
22 Kemp & Wilson., 1990
23 Verncombe et al., 1994
24 Griffin et al., 1992
25 Dow & Gemuts, 1969
27 Jackson et al., 1993

8) HINGE LINES; stratigraphic pinchout

ID	Name	Feature	Abbrev.	Refs
401	Admiral Bay	Hinge-line	AH	2, 5*
	(Ramp on Fault Zone)			
403	Leveque	Hinge-line	LH	1*, 5
410	Tobin	Hinge-line	TH	5*
420-500	Unnamed	Hinge-lines		

* References, see above for explanation

9) TRANSVERSE ACCOMMODATION ZONES AND TRANSFER FAULTS

ID	Name	Feature	Abbrev.	Refs
1805	Blackstone	Transfer Fault	BAF	4, 10, 13*
1807	Brooking	Accommodation Zone	RAZ	13*
	(Colombo F. is	part of RTZ above)		
1810	Camelgooda	Accommodation Zone	CAZ	4*, 9, 13
1815	Doran	Accommodation Zone	DAZ	4*, 9, 13
1820	Fraser River	Accommodation Zone	FAZ	4, 9, 13*
1830	Kora	Accommodation Zone	KTF	4, 10, 13*
1850	Yarrada	Transfer Fault	YTF	4, 10, 13*
	(May T F	of Begg 1987)		
1860	Outcamp	Accommodation Zone	OAZ	13*, 14, 15, 16
	(Albatross F. is	part of OTZ)		
1865	Percy	Accommodation Zone	PAZ	4, 13*
1880	Sundown	Accommodation Zone	SAZ	4, 9, 13*
1900				
1901-2000	Unnamed	Transfer Fault/ Accommodation Zone	tz	

*** Principal reference**

REFERENCES:

1 Forman & Wales, 1981

2 Purcell & Poll, 1984

3 Yeates et al., 1984

4 Begg, 1987

5 Craig et al., 1984

6 Goldstein, 1989

7 Smith, 1984

8 Towner & Gibson, 1983

9 Lehmann, 1986

10 Crowe & Towner, 1981

11 Begg, 1989 (unpubl)

12 Roberts et al., 1968

13 This report

14 Kemp & Wilson, 1990

15 Verncombe et al., 1994

16 Kufpec, unpublished data

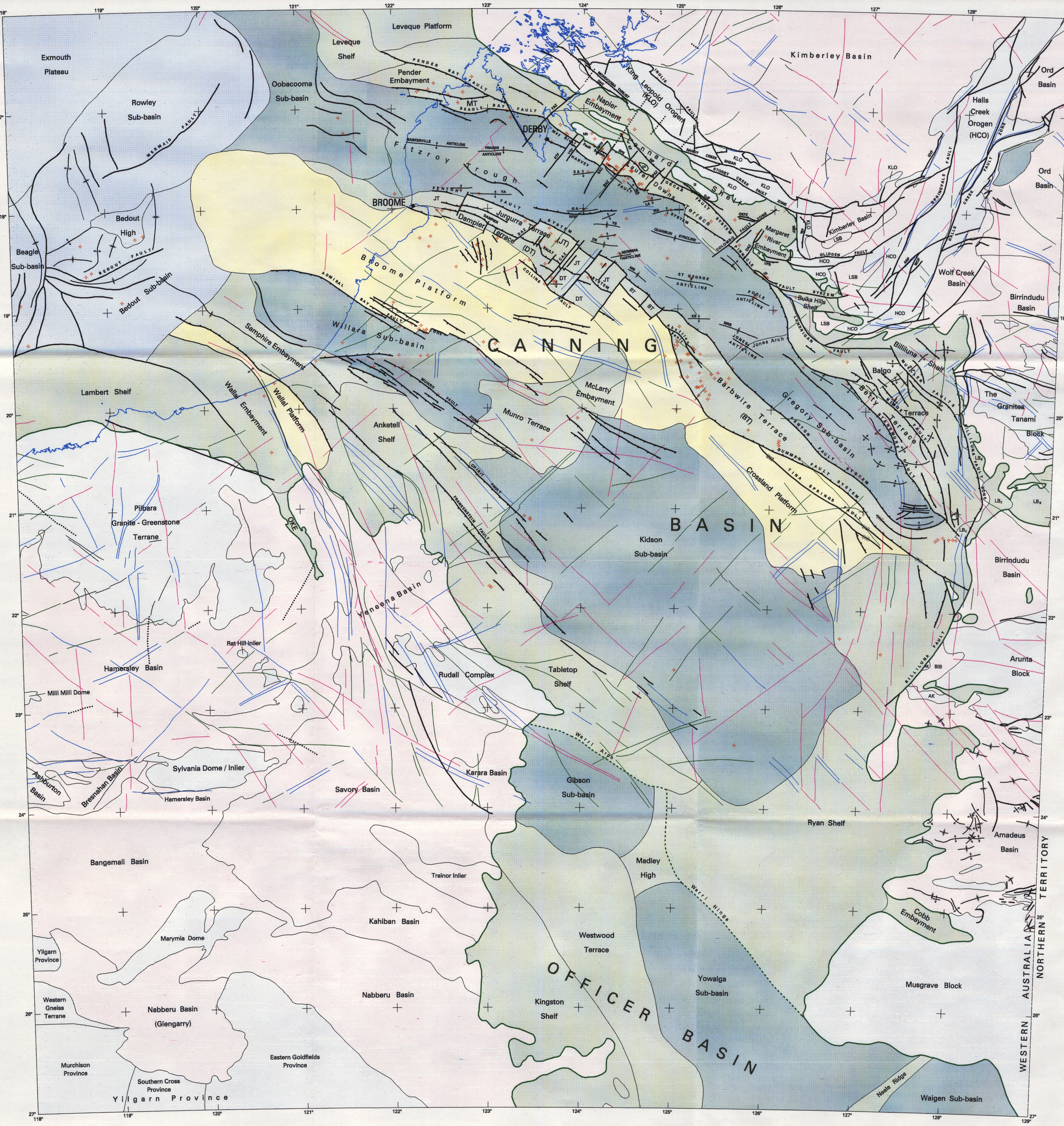
10) ANTICLINES/SYNCLINES

ID	Name	Feature	Abbrev.	Refs
2010	Baskerville	Anticline	BA	1
2015	Deep Well	Anticline	DA	1
2020	East Yeeda	Anticline	EA	2
2030	Ellendale	Anticline	LA	2
2035	Grant Range	Anticline	GA	1*, 2
2040	Fraser	Anticline	FA	2
2060	Jones	Anticline	JA	2
2070	Mt Hardman	Anticline	MA	2
2090	Nerrima	Anticline	NA	2
2100	Poole	Anticline	PA	1*, 2
2120	St George	Anticline	SA	1*, 2
2125	Warrawedda	Structure	WA	2
2130	Yulleroo	Anticline	YA	2
2201-2500	**Unnamed**	**Anticlines**		
2500	Dry Corner	Syncline	DS	1
2520	Kirby Range	Syncline	KS	1
2530	McLarty	Syncline	MS	1
2540	Millwt Range	Syncline	MRS	1
2550	Myroodah	Syncline	YS	1
2560	Quanbun	Syncline	QS	1
2701-3000	**Unnamed**	**Synclines**	s	1

REFERENCES:

1 Towner & Gibson, 1983

2 Lehmann, 1986



STRUCTURAL ELEMENTS OF THE CANNING BASIN

WESTERN AUSTRALIA

by R.D.Shaw, M.J.Sexton, I.Zeilinger 1994

Scale 1:2 000 000

0 40 80 120 160 200 kilometres

SIMPLE CONIC PROJECTION WITH TWO STANDARD PARALLELS 17°20′ AND 25°40′
CENTRAL MERIDIAN 132°30′

BASEMENT

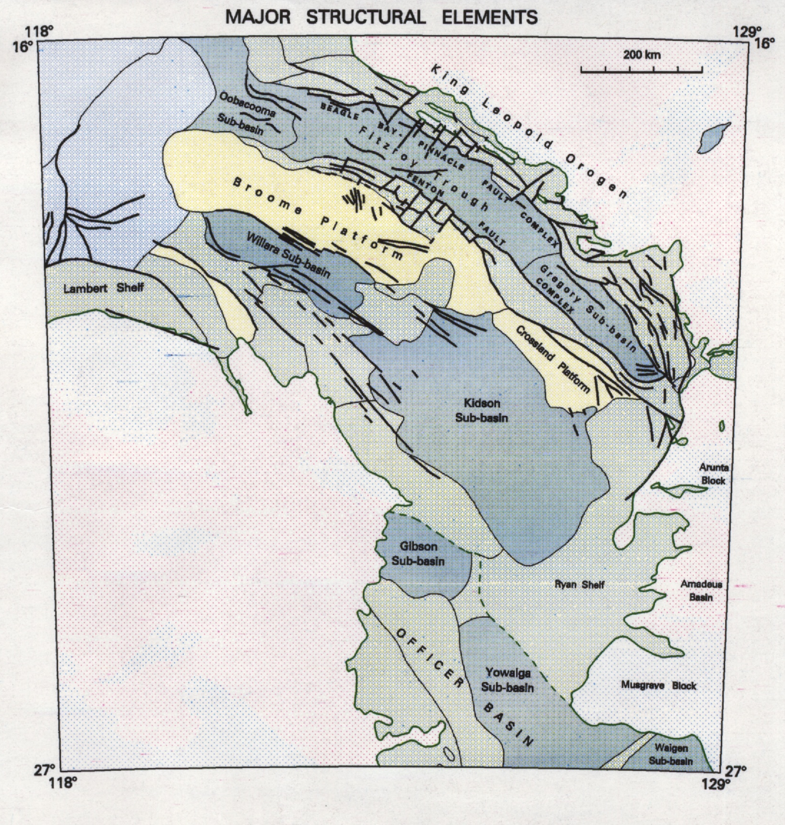
- *Crystalline rocks*
- *Precambrian /older basins*

BASINS

- *Arch or platform*
- *Terrace or shelf*
- *Trough or sub-basin*
- *Younger offshore features*

- *Major basin boundary*
- *Major basin boundary, approximate*
- *Basin boundary*
- *Fault*
- *Fault showing relative displacement*
- *Normal fault, square on younger rocks*
- *Thrust-fault, triangle on older rocks*
- *Anticline*
- *Syncline*
- *Lineament derived from onshore geological mapping*
- *Lineament derived from gravity data*
- *Lineament derived from aeromagnetic data*
- *Lineament derived from Landsat data*
- *Lineament derived from the coincidence of at least two of the above lineaments*
- *Petroleum exploration well*

MAJOR STRUCTURAL ELEMENTS



LIST OF ABBREVIATIONS

FAULTS

ANF	ANGELO FAULT (basement)
DJF	DJOWI FAULT
DHT	DUCK HOLE SHEAR (basement)
GVF	GREENVALE FAULT (basement)
GKFZ	GEIKE FAULT ZONE
JF	CADJEBUT FAULT
KF	MARKAM FAULT
MEF	MOUNT ELMA FAULT
NF	NAPIER FAULT
SFS	SIXTY-SEVEN MILE FAULT SYSTEM
VFS	VIRGIN HILLS FAULT ZONE
WF	MT WINIFRED FAULT (basement)
WOF	WOODWARD FAULT (basement)
WNF	MOUNT WYNNE FAULT ZONE

ACCOMMODATION ZONES

BAZ	BLACKSTONE ACCOMMODATION ZONE
CAZ	CAMELGOODA ACCOMMODATION ZONE
DAZ	DORAN ACCOMMODATION ZONE
FAZ	FRASER RIVER ACCOMMODATION ZONE
KTF	KORA TRANSFER ZONE
MTF	MEDIA TRANSFER FAULT
OAZ	OUTCAMP HILL ACCOMMODATION ZONE
PAZ	MT PERCY ACCOMMODATION ZONE
SAZ	SUNDOWN ACCOMMODATION ZONE
YTF	YARRADA TRANSFER ZONE

ANTICLINES

EA	EAST YEEDA ANTICLINE
GA	GRANT RANGE ANTICLINE
LA	ELLENDALE ANTICLINE
MA	MOUNT HARDMAN ANTICLINE
YA	YULLEROO ANTICLINE
WA	WARRAWADDA STRUCTURE

SYNCLINES

DS	DRY CORNER SYNCLINE
KS	KIRBY RANGE SYNCLINE
MS	McLARTY SYNCLINE
MRS	MILLWT SYNCLINE
YS	MYROODAH SYNCLINE

STRUCTURAL ELEMENTS

AK	ARUNTA BLOCK (basement)
BIB	BIRRINDUDU BASIN
HCO	HALLS CREEK OROGEN (basement)
KLO	KING LEOPOLD OROGEN (basement)
DT	DAMPIER TERRACE
LB_B	LUCAS BASIN (Permian succession)
LB_C	LUCAS BASIN (Triassic succession)
LSB	LOUSIA BASIN (Neoproterozoic succession)
MH	MAY RIVER HIGH (Shallow basement feature)
MT	MOOGANA TERRACE
OKE	OAKOVER EMBAYMENT (basement inlier)
OI	OSCAR INLIER (Permian succession)
PI	PILLARA INLIER (basement inlier)
SH	SIXTY-SEVEN MILE HIGH (shallow basement feature)

Source of data :
Various small-scale published structural maps

Geological map of Western Australia (1:250 000 scale map)
Compilers Myers,J.S., and Hocking,R.M., 1988.
Geological Survey of Western Australia (GSWA)

Unpublished data from recent mapping by GSWA

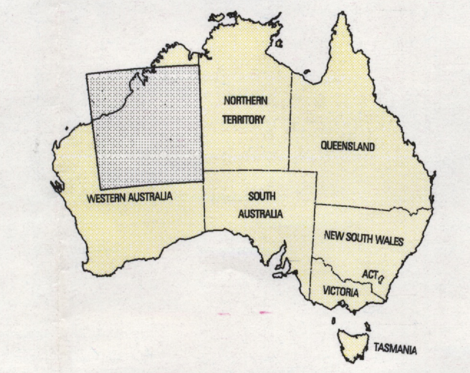
Onshore Lineaments : Derived from Tectonic Elements of the North West Shelf (1:250 000 scale map) by Etheridge & Henley Geoscience Consultants for GPS Nopec Pty Ltd Shelf'

Compiled 1994 by : R.D.Shaw, M.Sexton, I.Zeilinger, Australian Geological Survey Organisation (AGSO)

Cartography by : A.J.Retter, AGSO

Copies of this map and the accompanying Record may be obtained from : AGSO Sales Centre, GPO Box 378, Canberra, ACT 2601, Australia
phone : (06)2499519 fax : (06)2499982

MAP LOCALITY



Produced by the Australian Geological Survey Organisation, Department of Primary Industries and Energy. Issued under the authority of the Minister for Primary Industries and Energy

It is recommended that this map be referred to as :
Shaw,R.D., et al 1994 - *Structural Elements of The Canning Basin* (1:2 000 000 scale map). Australian Geological Survey Organisation

This map is accompanied by a text publication :
Shaw,R.D., Sexton,M.J. & Zeilinger,I., 1994 - The Tectonic Framework of the Canning Basin, WA, including 1:2million Structural Elements Map of the Canning Basin.
Record 1994/48

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

STRUCTURAL ELEMENTS OF THE CANNING BASIN

Date printed : 08-NOV-1995