Basin development with implications for Petroleum Trap Styles of the Neoprotorezoic Officer Basin, Western Australia

S.N. Apak[1], K.A.R. Ghori[1], G.M. Carlsen[1] & M.K. Stevens[1]

Abstract

Three unconformity-bounded sedimentary successions exist in most parts of the Officer Basin in Western Australia: Supersequences 1, 3, and 4. The bounding unconformities correlate with tectonic episodes, and in particular the Areyonga Movement (750 Ma) appears to be responsible for the larger structures in the Officer Basin, and separates Supersequence 1 from Supersequence 3. Structural and stratigraphic variations within the overlying Supersequences 3 and 4 are attributed to later deformation. Three main phases of hydrocarbon generation in the latest Neoproterozoic, Cambrian and Late Palaeozoic correlate well with initial migration and trap formation during the Areyonga Movement and late migration and trap formation during the later deformations.

Faults, unconformities, facies changes, and salt-associated traps occur throughout the basin but remain untested. In particular, episodic salt movement may have resulted in the formation of halokinetic traps within the younger successions. The ultimate petroleum potential of the western Officer Basin still remains to be proven but may be significant.

Introduction

The Officer Basin (Fig. 1) covers an area of 320,000 km2 in Western Australia and has a Neoproterozoic sedimentary section in excess of 6 km thick. The stratigraphy of the Officer Basin has been described by many authors (Jackson & van de Graaff, 1981; Townson, 1985; Phillips et al., 1985; Williams, 1992, 1994; Perincek, 1996, 1997; Carlsen et al., 1999; Grey, 1999; Stevens & Carlsen, 1998; Stevens & Apak, 1999; Apak & Moors, 2000a, b; 2001), and can be broadly divided into four supersequences (SS1-4, Fig. 2). Supersequence (SS) 2 is absent in the Western Australian part of the basin.

Hydrocarbons in the Officer Basin have been encountered in ten wells in the form of gas, live oil, bitumen, oil fluorescence, and oil stains. The most recent gas show, in 2002, occurred in the Geological Survey of Western Australia's stratigraphic test Vines 1 (Apak et al., 2002).

In this study, reprocessed seismic data (JNOC 1997) in the Yowalga area were reinterpreted and integrated with previous interpretations of Perincek (1997) and JNOC (1997) (Fig. 3).

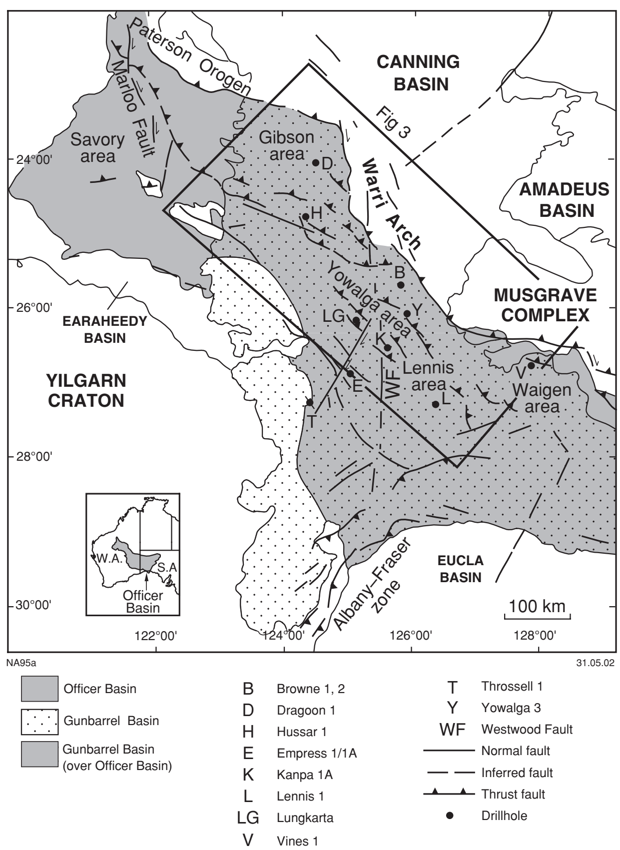

Figure 1: Regional tectonic setting of the western Officer Basin showing major structural elements and sub-areas, and surrounding tectonic units.

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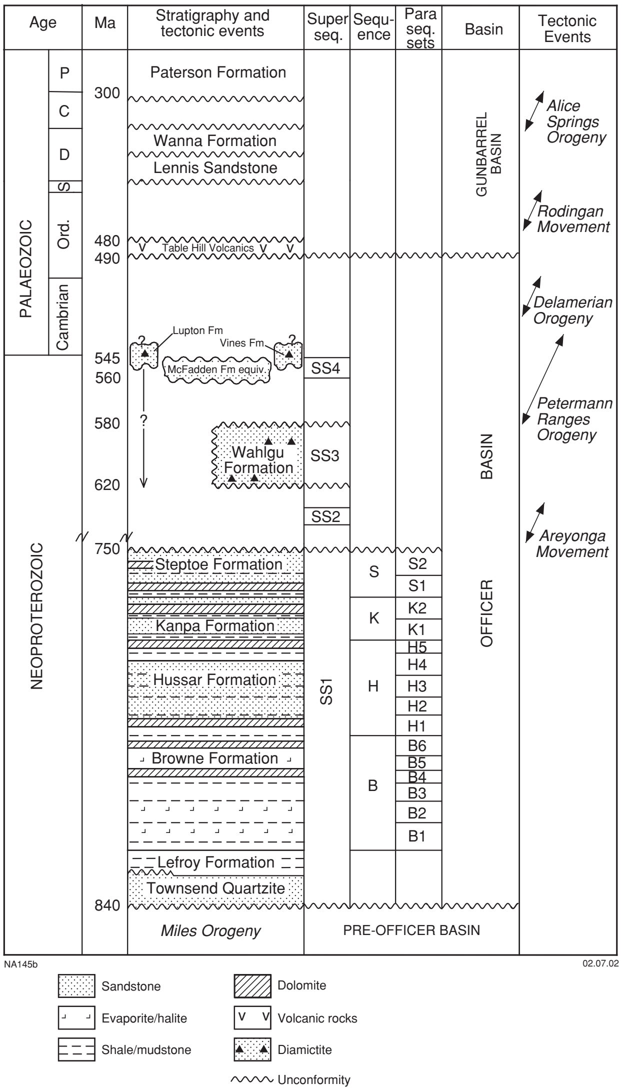

Figure 2: Stratigraphic column showing lithostratigraphy, sequence-stratigraphic units and tectonic events in the western Officer Basin.

An seismic interpretation for the Gibson and Lennis areas (Durrant & Associates, 1998), based on final stack processed sections and migrated processed sections where available in these areas, was also used in this study. A variety of traps such as faults, thrust ramp folds, drape folds, and erosive channels have been identified. Most of these traps types remain poorly tested or untested in the Officer Basin.

The objectives of this paper are to discuss the Neoproterozoic successions in relation to the structural development, and to illustrate the hydrocarbon prospectivity and play concepts within the basin.

Regional setting

The Officer Basin is bounded to the northeast by the Musgrave and Rudall complexes and the Warri Arch, a gravity ridge, which forms the boundary between the Officer and Canning basins (Fig. 1). The Officer Basin is overlain by the Phanerozoic Gunbarrel Basin, which passes north into the Canning Basin. The Cretaceous to Tertiary Eucla Basin overlies the southern flank of the Officer Basin. The adjacent older tectonic units include the Yilgarn Craton, the Albany-Fraser Orogen, and the Collier, and Earaheedy basins (Tyler & Hocking 2001).

The early division of the Officer Basin into sub-basins was based on gravity (Fig. 4) and aeromagnetic data, but seismic data do not indicate significant structural subdivision of the Neoproterozoic succession into discrete sub-basins. The Neoproterozoic succession thins towards the southern margin of the basin, but local depositional thinning and thickening are not significant enough to define discrete depositional systems in separate sub-basins (Apak & Moors, 2001). Thus we prefer to use the term areas, which coincide to what have been previously defined as the sub-basins.

The main depocentre to the north of the Officer Basin occurred along the northern edge of the basin (Apak & Moors, 2000a, b). The resultant asymmetric sediment accumulation had a long, gentle southern flank and short, steep northern flank. Due to overall poor seismic data and massive salt emplacement, the exact nature of the northern boundary of the Officer Basin is uncertain. However, in the Gibson area, seismic line N83-3A shows that interpreted Supersequence 1 strata onlap north onto the older units of the Warri-Arch (Fig. 5). The western and southern limits of the Officer Basin are defined as where the Officer Basin succession has been removed or not deposited.

Townsend (1985) identified four major fault and lineaments trends from gravity, aeromagnetic and Landsat data that reflect the structure of basement and controlled depositional patterns in the western Officer Basin (Fig. 1). These structures trend northwest, northeast, north, and east-northeast to east. Of these structural trends, the northwesterly trending faults are dominant and are reflected in major salt-associated thrusting. North and northeast-trending faults have a right lateral strike-slip component.

Sediments of the Officer Basin were deposited unconformably over variably metamorphosed Meso-Palaeoproterozoic sedimentary rocks, the Albany-Fraser Orogen, Musgrave Complex, Paterson Orogen and Yilgarn Craton. Following deposition of Supersequence 1 strata, a strong structural phase, the Areyonga Movement, caused significant folding and erosion in the basin. After the Areyonga Movement, gentle subsidence took place with the establishment of glacial conditions early in the Marinoan, and deposition of the Wahlgu Formation (Supersequence 3). Uplift or base-level change during the Petermann Ranges Orogeny (Fig. 2) resulted in partial erosion of the Wahlgu Formation and deposition of Supersequence 4 including the McFadden Formation equivalent. The Delamerian Orogeny terminated Officer Basin deposition. Extensive flows of tholeitic basalt of the Table Hill Volcanics are defined as the basal sequence of the subsequent Gunbarrel Basin.

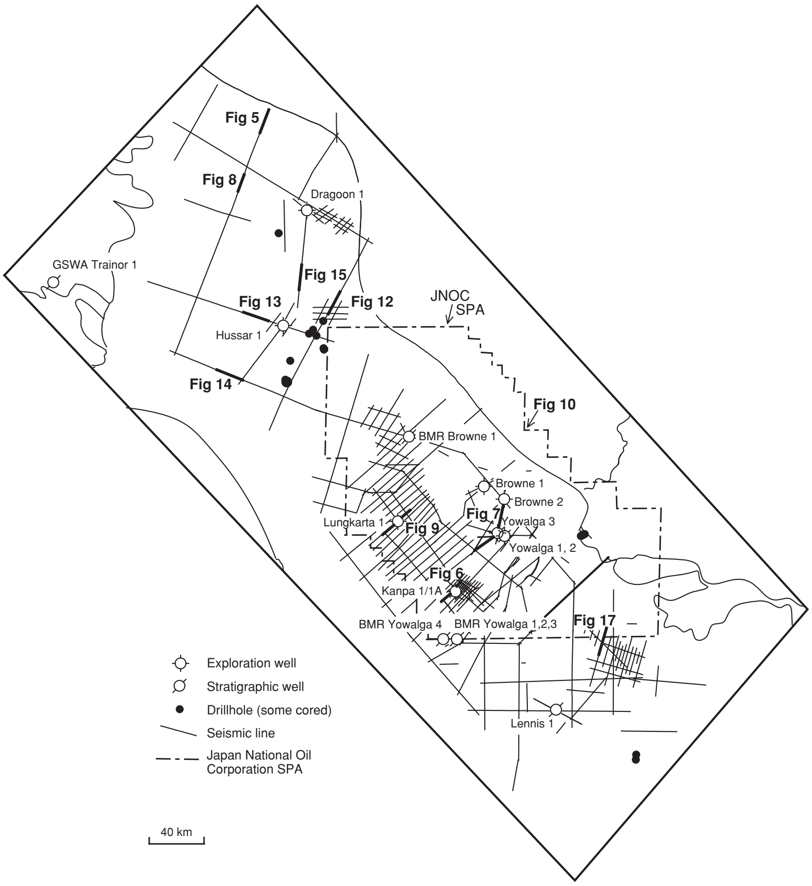

Figure 3: Location map showing seismic coverage and wells in the basin.

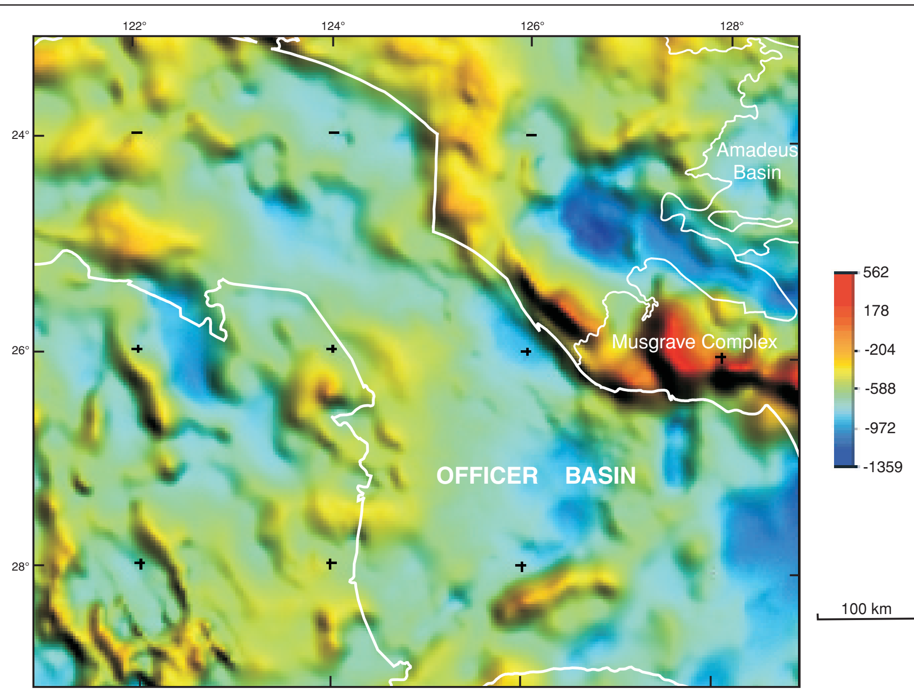

Figure 4: Bouguer gravity image of the Western Officer Basin and surrounding areas.

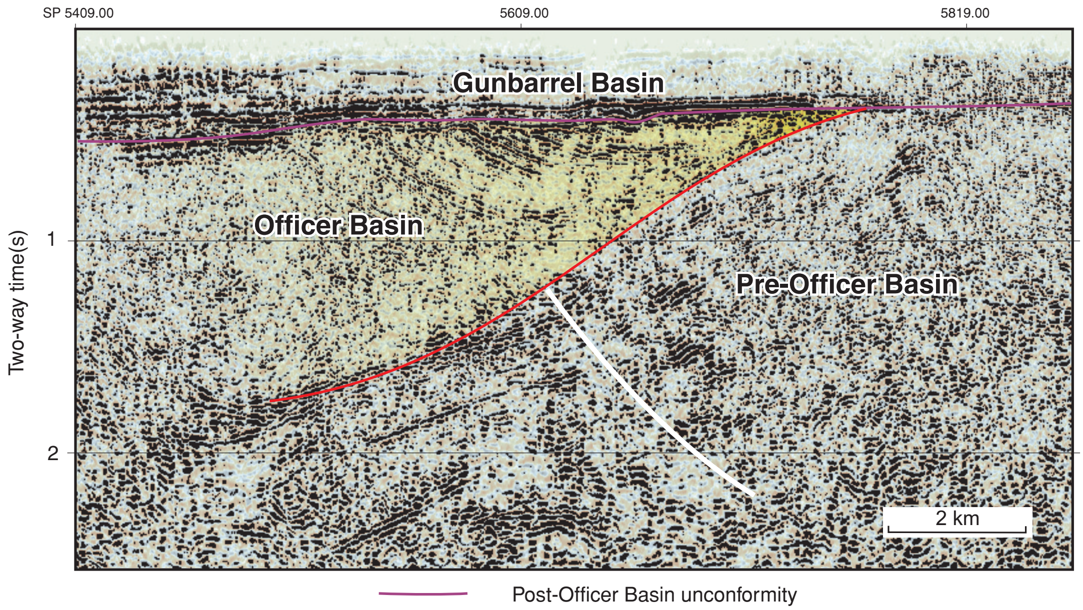

Figure 5: Seismic line N 83-03A showing the unconformable relationships between the Neoproterozoic Officer Basin and the underlying Mesoproterozoic strata. For location of seismic line see Figure 3.

Basin development

Within the Officer Basin succession in Western Australia, four major unconformities separate three stratigraphic units (Fig. 2). The four main unconformities, including the basal unconformity, and the post SS1, 3, and 4 unconformities reflect the Miles Orogeny, Areyonga Movement, Petermann Ranges Orogeny and Delamerian Orgeny respectively (Fig. 2). These features shall be discussed in stratigraphic order.

The Basal Unconformity

The basal unconformity separates the Officer Basin from the underlying Mesoproterozoic and older rocks. Because overlying massive salt commonly masks the basal unconformity, this unconformity is not a prominent reflection. However, where the contact relationship is angular, the horizon can be picked with some confidence (Fig. 5).

Supersequence 1

There is little seismic control on the lower units of Supersequence 1, the Townsend Quartzite and Lefroy Formation. However, the overlying units, the Browne, Hussar, Kanpa and Steptoe formations are better understood. Apak & Moors (2000a, b; 2001) demonstrated the presence of conformable and laterally corelative genetic units bounded by flooding surfaces. The sequence stratigraphic units of Supersequence 1 coincide closely with the previously defined lithostratigraphic subdivision of Townson (1985). In the Browne Formation (Sequence B), the dominant lithologies are mudstone, siltstone, dolomite, and halite. In general, the Hussar Formation (Sequence H), Kanpa Formation (Sequence K), and Steptoe Formation (Sequence S) consist of sandstone, dolomite, shale, and minor evaporite deposits. Secondary transgressions, observed on seismic data as high-amplitude reflections, are used to define parasequence sets (Apak & Moors, 2000a, b; 2001). Each sequence comprises numerous parasequence sets that show progradation with coarse clastic beds or tidal flat/supratidal carbonate and evaporitic deposits spread across the deeper water deposits. Sedimentary facies defined from well data indicate dominantly shallow water to sabkha and restricted hypersaline environments for the Browne Formation. Overlying formations were probably deposited within a range of restricted shallow-marine shelf, shoreface and/or lagoonal depositional environments.

Subsidence appears to have occurred intermittently, being characterised by abrupt water depth increases, followed by rapid sedimentary progradation across the basin (Apak & Moors, 2000b; 2001). The cycles are typified by flooding with a basal quiet-water facies (fine-grained lithology) followed by a shallowing with coarsening upwards facies. Major transgressions, characterised by strong amplitude events, define the base of each sequence (Fig. 2). Thick halite deposits within Sequence B were mobilised during several tectonic phases creating dramatic variations in thickness of the units, and in structural complexity. In most seismic lines Supersequence 1 strata are characterised by continuous parallel reflectors that are traceable in most parts of the basin except where the reflectors are truncated by younger unconformity (Figs 6 and 7).

Post-Supersequence 1 Unconformity

Following deposition of the Supersequence 1 strata, the Areyonga Movement caused extensive erosion prior to deposition of the Supersequence 3 strata (Wahlgu Formation).

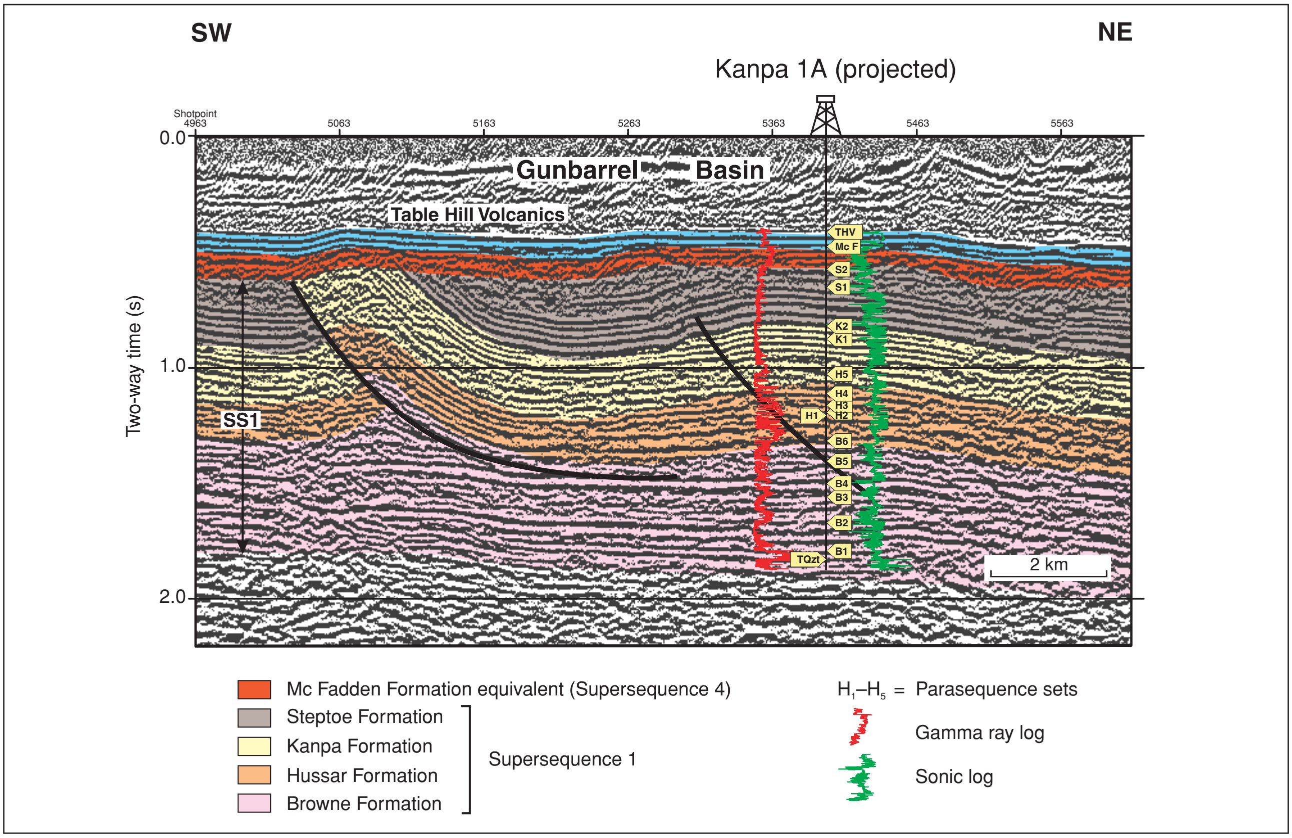

Figure 6: Seismic line T82-43 showing salt-lubricated thrust fault in the Sequence B (Browne Formation) and erosion of Supersequence 1 strata. Supersequence 3 strata is absent and Supersequence 4 strata unconformably overlies the Supersequence 1. For location of seismic line see Figure 3.

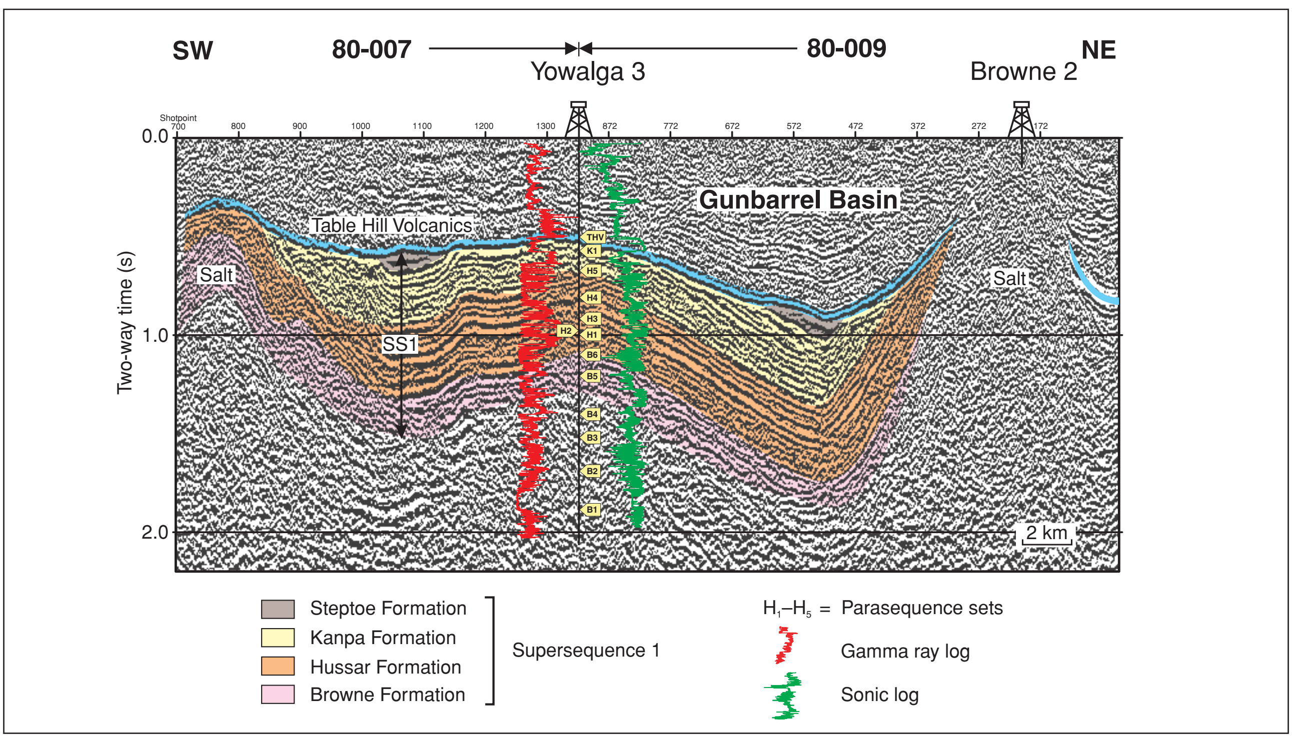

Figure 7: Composite seismic section shows Yowalga 3 and Browne 2 wells and erosion of Supersequence 1 strata between salt emplacements in the Yowalga area. For location of seismic line see Figure 3.

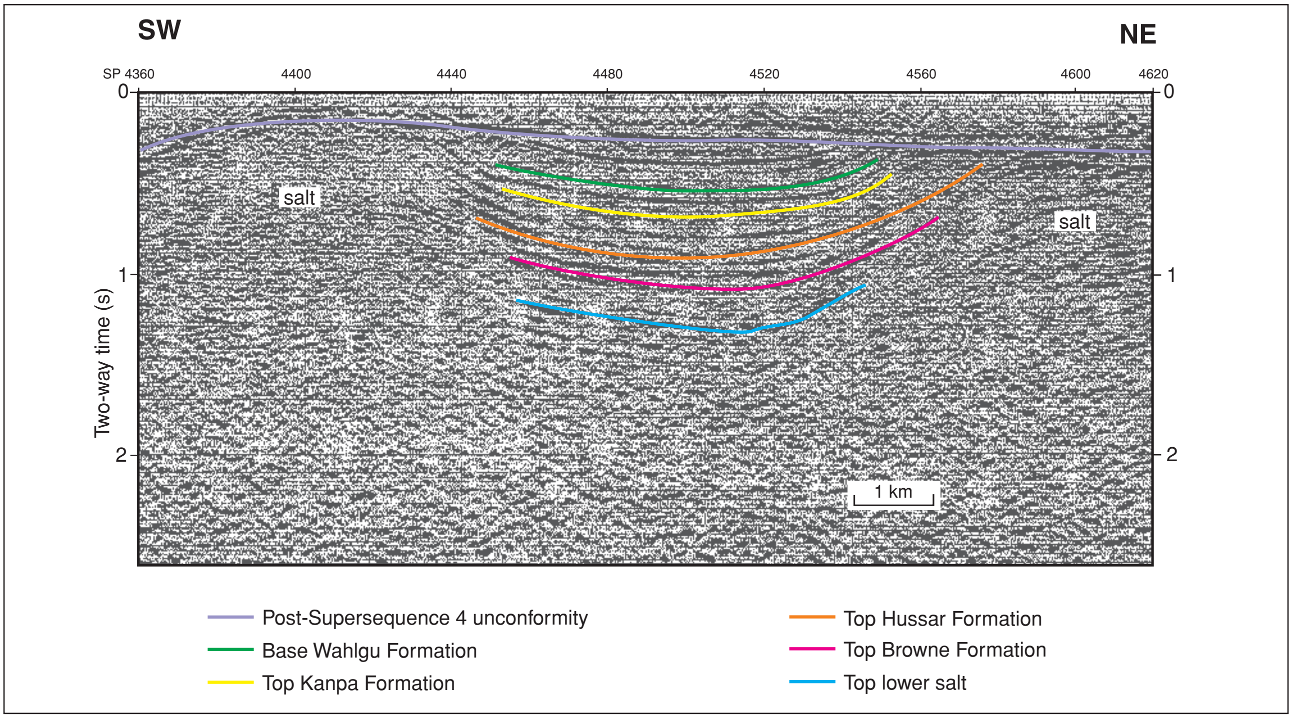

Figure 8: Seismic line N 83-03A showing residual of Supersequence 1 and Wahlgu Formations between the salt emplacements in the Gibson area. For location of seismic line see Figure 3.

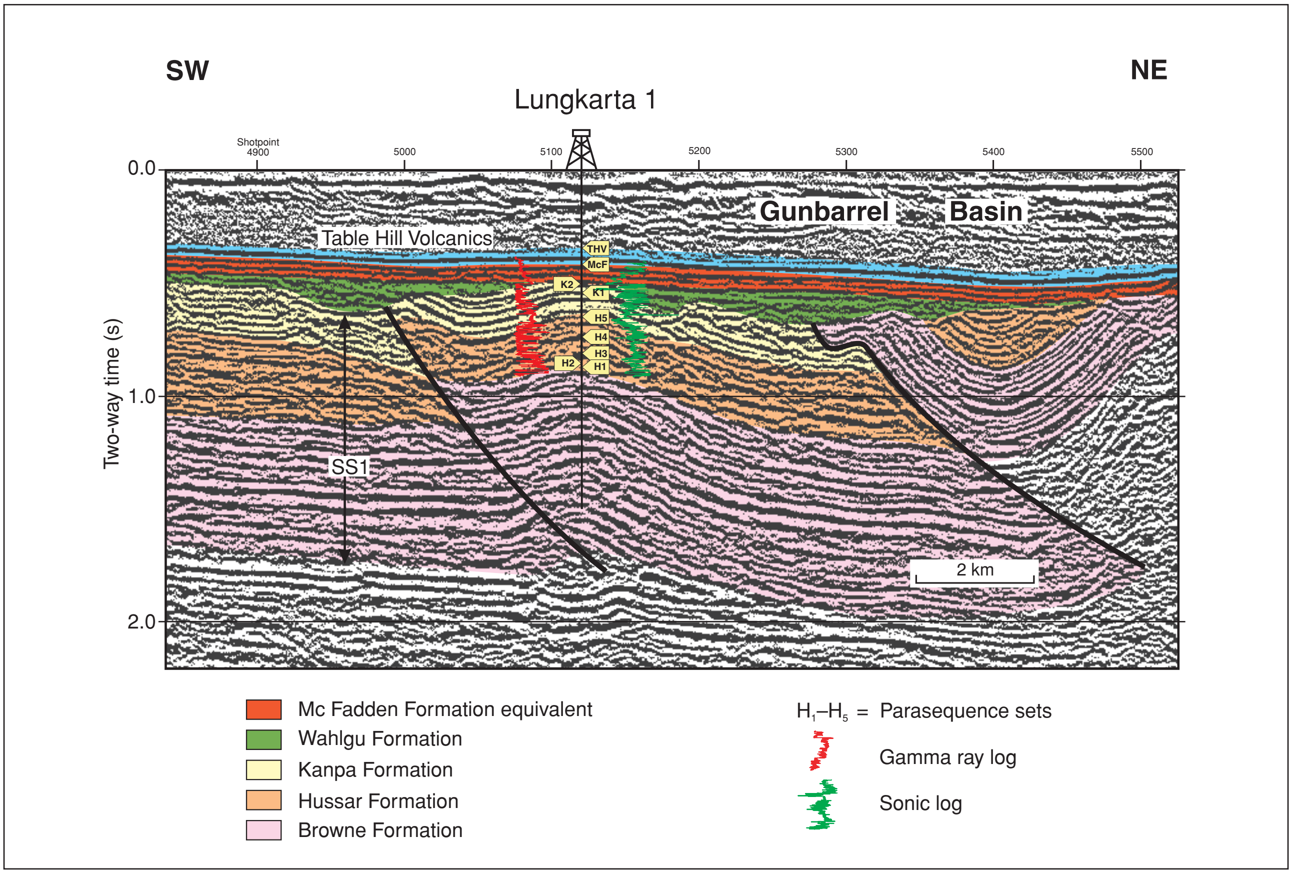

Figure 9: Seismic line T 82-57 showing Lungkarta 1 well drilled on anticline fold and deep erosional surface of the post-Supersequence 1 unconformity. For location of seismic line see Figure 3.

During this period, Supersequence 1 strata were folded and faulted and eroded, particularly over salt-emplacement highs and marginal areas (Fig. 8). This major unconformity has been influenced by salt movement and is characterised by sharply erosive valleys, and channel-like features at the base of the Wahlgu Formation (Fig. 9). The Post-Supersequence 1 unconformity is correlatable throughout most parts of the basin.

Salt Emplacements

Salt mobilisation associated with the Areyonga Movement, can be subdivided in the Yowalga area into laterally persistent zones, including the salt-ruptured zone (closest to the Musgrave Complex), the thrusted zone, and the western platform (JNOC, 1997) (Fig. 10).

In the salt-ruptured zone salt penetrated the overlying sedimentary strata. Some salt diapirs such as the Browne, Woolnough and Madley diapirs have been recognised from surface mapping. The thrusted zone is a zone of compression along thin-skinned, low-angle thrust faults, lubricated by salt within the Browne Formation (Fig. 11). The stresses responsible for these features are believed to be either compression involving the Musgrave Complex to the north or gravitational collapse of thrusted uplifts resulting from a reduction in compressional stress following the Areyonga Movement. The folded and uplifted sedimentary pile became unstable and began to glide along the salt beds toward the stable Western Platform.

Seismic line N 83-11 in the Gibson area (Fig. 12) illustrates high angle reverse faulting associated with salt emplacement. Faulting and salt movement predate or are syndepositional with the basal part of the McFadden Formation equivalent. Thinning and onlapping of the McFadden Formation equivalent over the Wahlgu Formation indicates the timing of the deformation in this area (Fig. 12). Angular contacts between the Wahlgu Formation and the McFadden Formation equivalent are only evident adjacent to the salt diapirs.

Faulting and Folding

Large-scale folds are either halokinetic or ramp anticline folds associated with tectonic and gravity-driven thrust faults. Most fault displacements are confined to the Supersequence 1 strata (Figs 6 and 9). In the Yowalga area, the most common faults are thin-skinned listric thrust faults that are detached along the salt horizon in Sequence B. Faults are often present below salt intrusions, indicating that salt movements occurred through pre-existing zones of weakness (Durrant & Associates, 1998).

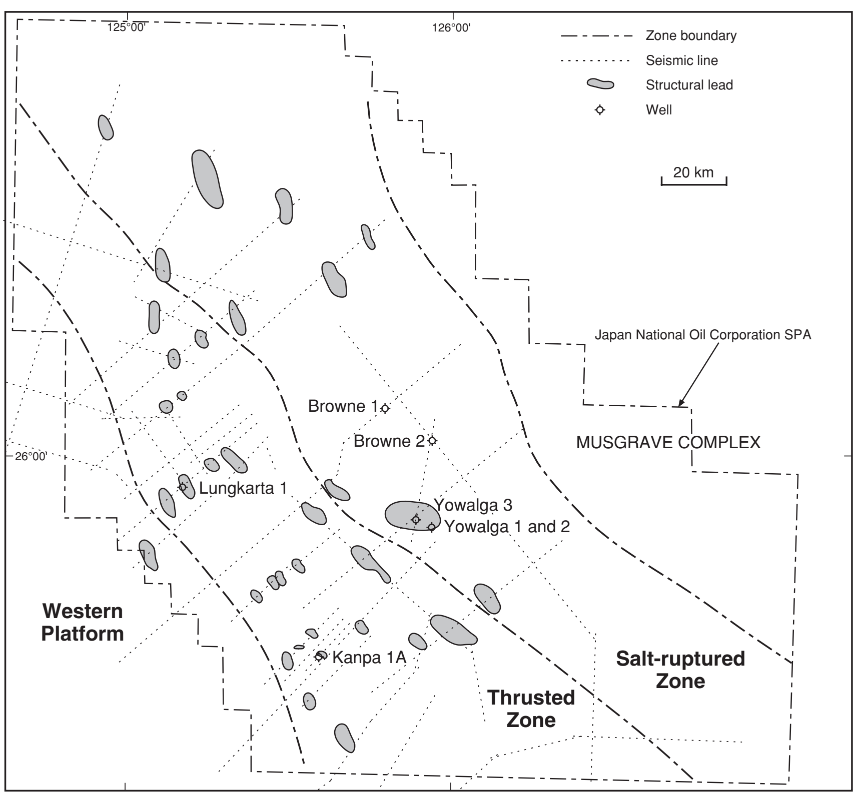

Figure 10: Distribution of structures and tectonic zoning in the Yowalga area (after JNOC 1997).

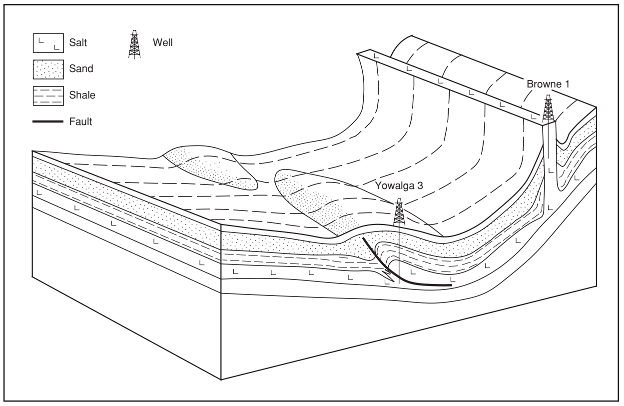

Figure 11: Schematic figure showing the relationship of salt walls and thrusts sheets. Uplift results in a raft of sediment gliding downslope on the salt, overthrusting at the leading edge, and a tension void at the trailing edge. Browne 1 tested an injection feature, and Yowalga 3 tested an anticline draped over a thrust complex.

Listric faults lubricated by salt appear to be less common in the Lennis area. Major salt walls continue their southeasterly trend from the Yowalga area. In the Gibson area, many of the thrust faults are listric and they appear as high angle reverse faults (Fig. 12). Although the reflection record below salt is poor, these faults appear to flatten with depth and probably detach near the base of salt forming basal thrust planes.

In the Gibson area, seismic line N 83-6 (Fig. 13) illustrates an apparent normal fault based on offsets in the shallow and deep section. However, erratic changes in thickness of some units, both in the hanging wall and footwall, are taken as evidence of strike-slip faulting that shows syndepositional faulting in the lower part of supersequence 1 strata (Fig. 13).

The interval from base Neoproterozoic to the base salt (the lower part of the Browne Formation) is significantly thicker on the downthrown block. In contrast, an overlying section from the base salt to the top lower salt is thicker on the upthrown block. Post Supersequence 1 reactivation of this fault has resulted in significant erosion of the Steptoe Formation on the upthrown block (between the Kanpa and Wahlgu formations). Further reactivation of this fault also resulted in minor displacement of the post-Supersequence 3 unconformity (base McFadden Formation equivalent).

Supersequence 3

Following the Areyonga Movement, gentle subsidence coincided with deposition of the glacigene Wahlgu Formation (Apak & Moors, 2001), early in the Marinoan (Grey et al., 1999). In Empress 1 and 1A, the Wahlgu Formation consists predominantly of sandstone (in part diamictitic) interbedded with mudstone and minor dolomite (Stevens & Apak, 1999). Supersequence 3 has been eroded in many places, particularly between the Gibson and Yowalga areas, but it still extends through most of the basin (Figs 9, 12). Large channels are present and in some places cut down into the Kanpa Formation (Fig. 14). There are also numerous large intraformational channels within the Wahlgu Formation.

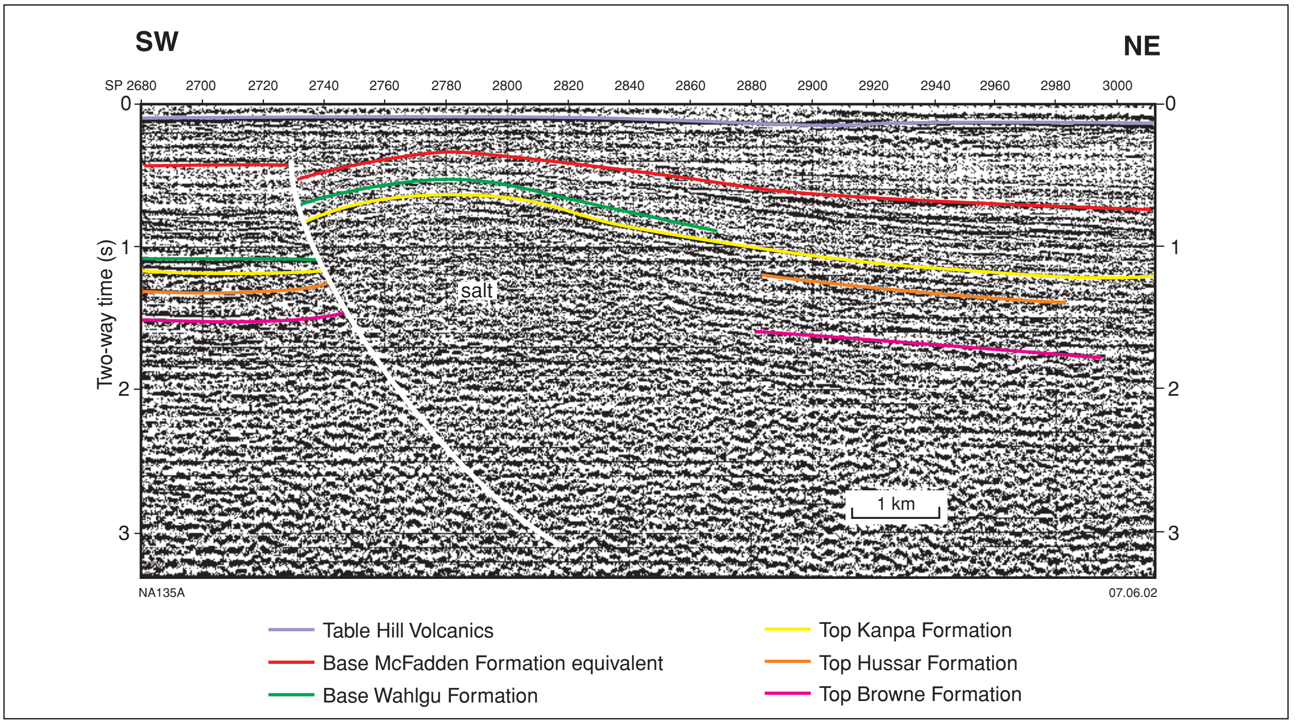

Figure 12: Seismic line N 83-11 showing an angular unconformity between the Wahlgu and the McFadden Formation equivalent. The Wahlgu Formation is deeply eroded in this location. High angle reverse faulting associated with salt emplacement resulted in minor displacement of the post-Supersequence 3 unconformity. For location of seismic line see Figure 3.

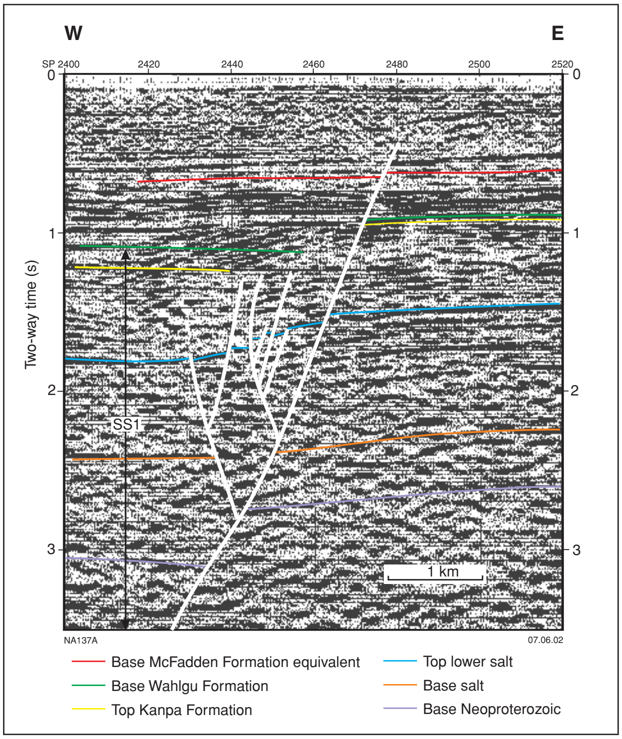

Figure 13: Seismic line N 83-6 showing late strike-slip faulting event post-dating the Wahlgu Formation and displaced the post Supersequence 3 (base McFadden Formation equivalent) unconformity. Note that the Steptoe Formation was eroded on the upthrown side of the fault block. For location of seismic line see Figure 3.

Post-Supersequence 3 Unconformity

Following deposition of Supersequence 3, the Petermann Ranges Orogeny event is interpreted to have caused the post-Supersequence 3 unconformity between the McFadden Formation equivalent and the underlying Wahlgu Formation or older units in the western Officer Basin. In areas adjacent to salt emplacements, this unconformity is angular (Fig. 12) but in other areas distant from salt walls, the contact between the Wahlgu Formation and McFadden Formation equivalent appears to be disconformable.

Supersequence 4

Supersequence 4 consists of the McFadden Formation in the Savory Basin region and a correlative unit here termed McFadden Formation equivalent in the remainder of the basin. The McFadden Formation equivalent is a siliciclastic sequence that varies from sand-dominated to shale-dominated in different parts of the western Officer Basin. The formation onlaps and thins over pre-existing structural highs (Fig. 12). Williams and Bagas (2000) suggest that the McFadden Formation in the Savory area has been weakly deformed during the closing stages of the Paterson Orogeny, which is correlated with the Petermann Ranges Orogeny of Central Australia (Bagas et al., 1995; Perincek, 1997; Tyler et al., 1998).

In Vines 1, a stratigraphic hole drilled in the Waigen area, the succession from 4 to 2017 m is a high-energy conglomeratic unit named the Vines Formation (Apak et al., 2002). The sedimentary character indicates rapid deposition of

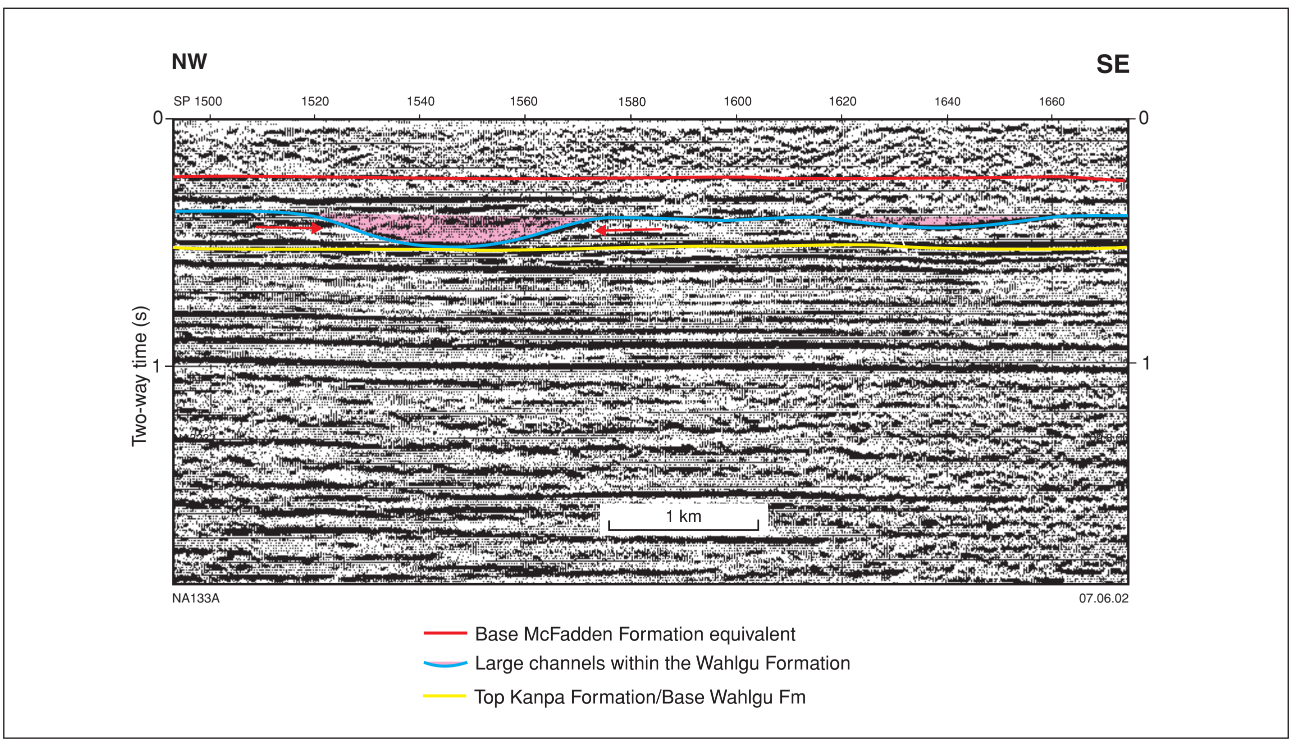

Figure 14: Seismic line N 83-8 showing a large channel development within the Wahlgu Formation. For location of seismic line see Figure 3.

over 2 km of submarine diamictites and turbidites in an actively subsiding basin. There are no seismic or other data available to define the extent or character of the formation and its relationships with other units. A gas show at 1482 m in this well is significant evidence for petroleum potential in the basin. The age of the formation is poorly constrained, but its maximum age is latest Neoproterozoic to earliest Cambrian (Apak et al., 2002).

Post-Supersequence 4 Unconformity

The Table Hill Volcanics and younger rocks unconformably overlie Supersequence 4. High amplitude reflections are generally associated with the presence of the Table Hill Volcanics. In some areas, especially in the Gibson area, the McFadden Formation equivalent and parts of the underlying successions have been truncated by the Delamerian Orogeny and younger deformation events, in particular over salt-emplacements and marginal areas (Moors & Apak, 2002).

Salt Emplacements

In the Gibson area, late salt movement in some structures penetrates Supersequences 1 through 4 (Fig. 15). Late salt movement does not effect all structures and is interpreted to be driven by overburden density imbalance. The deposition of a substantial thickness of Supersequence 3 (Wahlgu Formation) and Supersequence 4 (McFadden Formation equivalent) successions probably accounts for the continued mobility of the salt. Salt movement also displaces the Paterson Formation and even the Tertiary deposits in the Madley diapirs, suggesting that in some regions minor salt movement may have continued up to present time.

Gunbarrel Basin

The Table Hill Volcanics mark the commencement of a new depositional sequence that has been assigned to the Gunbarrel Basin (Hocking, 1994). The Table Hill Volcanics are lower Ordovician (484 ± 4 Ma) porphyritic and amygdaloidal tholeitic basalt at Empress 1 and 1A (Stevens & Apak, 1999). Volcanic rocks are present at the same stratigraphic level across WA, NT, and SA, but absent from some parts of the Gibson area due to post depositional regional and local uplift. The seismic response of the top of the Table Hill Volcanics is clear and distinct on many of the seismic lines and is used as a regional marker in the Gibson, Yowalga and Lennis areas. Salt diapirs have penetrated or folded the Table Hill Volcanics in some structures.

Petroleum Potential

Thin but organic-rich beds with excellent to fair oil generating potential together with good reservoir and seal rocks are present in the basin. Oil and gas prone source beds with fair to excellent hydrocarbon-generating potential are found in Browne 1 and 2, Empress 1/1A, Hussar 1, Kanpa 1A, LDDH 1, NJD 1, and Yowalga 3, as indicated by total organic carbon, Rock-Eval pyrolysis and rock extract analyses. The measured maturity ranges from immature to overmature as indicated by organic petrology and Rock-Eval pyrolysis. A significantly thick part of the Neoproterozoic succession in Yowalga 3 (1500-3000m) is presently within the oil window. The present-day depth to the top of the oil window in Kanpa 1A and Yowalga 3 (Yowalga area) is about 1000 m deeper than in Hussar 1 (Gibson area) (Ghori, 1998a, b).

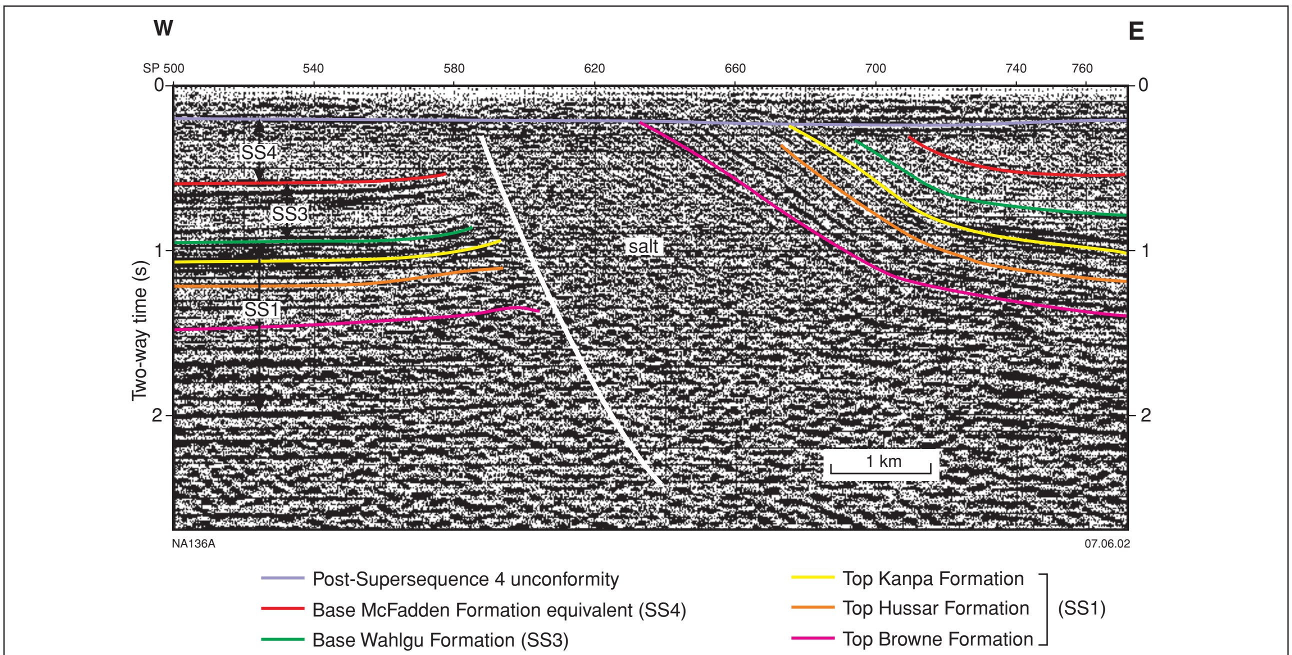

Figure 15: Seismic line N 83-07 showing late stage of salt emplacement and erosion of Supersequence 1 strata, Wahlgu Formation (Supersequence 3) and McFadden Formation equivalent (Supersequence 4). For location of seismic line see Figure 3.

The presence of both carbonate and siliciclastic sedimentary rocks in the Officer Basin has produced many opportunities for reservoir development. Potential siliciclastic reservoirs are present in the Lennis Sandstone, McFadden Formation equivalent, Wahlgu, and Lefroy formations and the Townsend Quartzite, whereas the Steptoe, Kanpa, Hussar, and Browne formations contain potential hydrocarbon reservoirs in both quartzose and carbonate lithologies.

Seals in the Officer Basin need to be considered from a number of perspectives. Local seals can be effective in four-way dip-closed traps or fault-controlled traps and as lateral seals in stratigraphic traps. However, regional seals are necessary to control the migration paths of petroleum, especially for long-range migration. Most of the formations contain lithologies that would make effective seals at all scales. Seal risk is highest for the less deeply buried sand-prone units such as the Wahlgu Formation and the McFadden Formation equivalent.

The best shale seals were deposited on flooding surfaces and form the bases of the Kanpa, Hussar and Steptoe formations. These shale units reach thicknesses of over 100 m in the Hussar Formation in Kanpa 1A.

The hydrocarbon generative history of the region, based on multi-dimensional basin modelling of geological sections drawn from wells and seismic, indicates significant differences in timing and levels of kerogen transformation to petroleum in the Brown, Hussar, Kanpa, and Steptoe formations. The main phases of oil generation within the Neoproterozoic succession were during the latest Neoproterozoic, Cambrian and Permian–Triassic. These phases vary both stratigraphically and geographically across the basin due to variable effects of at least three major tectonic events — the Neoproterozoic Areyonga Movement and Petermann Ranges Orogeny, and the Carboniferous Alice Springs Orogeny (Ghori, 2000).

Within the Browne Formation, the maximum rate of hydrocarbon generation was reached early in the basin history and most of the hydrocarbon generative potential was exhausted during the Neoproterozoic. However, the Hussar, Kanpa, and Steptoe formations were not buried so deeply and hydrocarbon generation from these units extends into the Phanerozoic. Higher maturity levels are observed at shallow depth in high amplitude folds at LDDH 1, Dragoon 1 and Brown 1 and 2. Elswhere the oil window is very deep such as at Yowalga 3. The extent and effect of Mesozoic and Tertiary tectonic events are poorly understood, because the preserved post-Alice Springs Orogeny section is thin and irregularly distributed (Ghori, 2000; 2001).

Traps

The presence of salt within the Officer Basin has resulted in a wide range of possible trap configurations. Warren (1989) defined many possible salt-related trap styles based on structure and porosity. The main play types are summarised in Figure 16 and a brief outline for each type is presented below.

Structural Traps

Thrust Faults and Folding

Thrust faults have typically initiated within the Browne Formation salt units, and penetrate upwards into the overlying formations. They may create drag rollover structures within the units they penetrate, or deform the overlying units into anticlinal features (Fig. 12). With the presence of salt on the fault plane, fault-plane sealing would be excellent. A serious risk is that tensional crestal faults may leak. Another risk is loss of hydrocarbon charge during post migration fault reactivation.

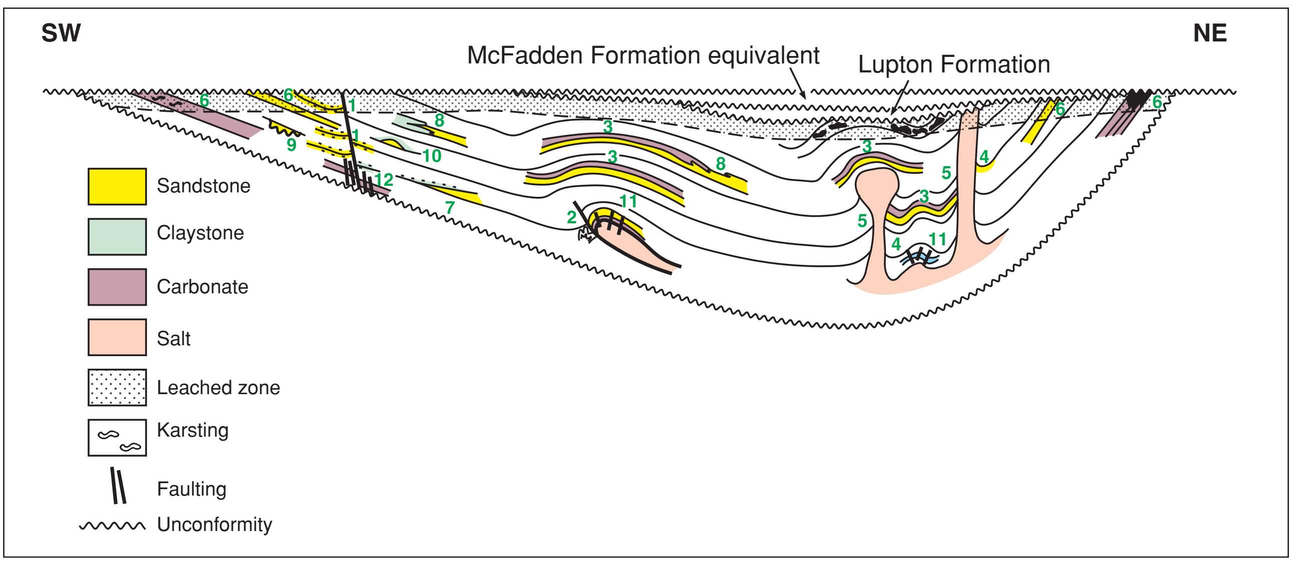

Figure 16: Schematic petroleum play types present in the Yowalga, Lennis, and Gibson areas. 1). normal fault trap; 2). drag fold on a salt-lubricated thrust; 3). drape over a salt movement high; 4). tilted salt-abutment trap; 5). salt-wall abutment trap; 6). leached zone porosity enhancement in sand and carbonate rocks; 7). stratigraphic pinchout trap; 8). stratigraphic facies change trap; 9). channel; 10). isolated off shore sand bar; 11). fractured carbonate rock.

Drape Folding and Salt Structures

Salt emplacements do not always penetrate the entire Officer Basin succession and four-way dip closure in the suprasalt section is sometimes present. The prospect of tensional crestal faults in carbonate beds may be a risk where the Supersequence 1 strata have been folded. In the salt ruptured zone (Fig. 10), salt walls create two facing salt-sealed, 3-way dip closures. These structures can be of substantial size (Fig. 12). The salt, which is able to maintain its integrity over a long period, is an effective seal and salt walls provide effective migration barriers. Timing of the diapiric phase with respect to petroleum charge is good, as the structures were available before petroleum expulsion was completed. Structures isolated from source pods by these salt walls may be in an effective migration shadow.

Fractured Reservoir

Fracture systems may be present within folded carbonates of Supersequence 1. These fractures variable associated with thrust faults crestal extension. Although the carbonates are not thick, the possibility of stacked reservoirs with pay increases the potential reserves, but these fractured reservoir fairways may be limited.

Stratigraphic Traps

Unconformity Traps

Supersequence 1 strata have been tilted and severely eroded adjacent to salt injection features (Fig. 12) and along the basin margins. Leaching of soluble components such as halite, anhydrite, and carbonate from the sandstone and carbonate, and development of karst within carbonates may create extensive secondary porosity.

A strength of the unconformity trap is the fact that unconformities are recognised to have potential as regional migration paths for fluids being expelled from compacting basins. A weakness of unconformity trap configurations below the major unconformities is that the overlying strata may not be an effective seal. For example, in the Wahlgu Formation the principal lithology is sandstone that, although glacigene, appears to be an inadequate seal as in Empress 1 and 1A. However, in Hussar 1 in the Gibson area the lower 100 m of the formation is siltstone/claystone dominated and could be an adequate top seal.

Pinchout Traps

Differential subsidence in the Officer Basin has resulted in downlap and onlap of units providing opportunities for pinch

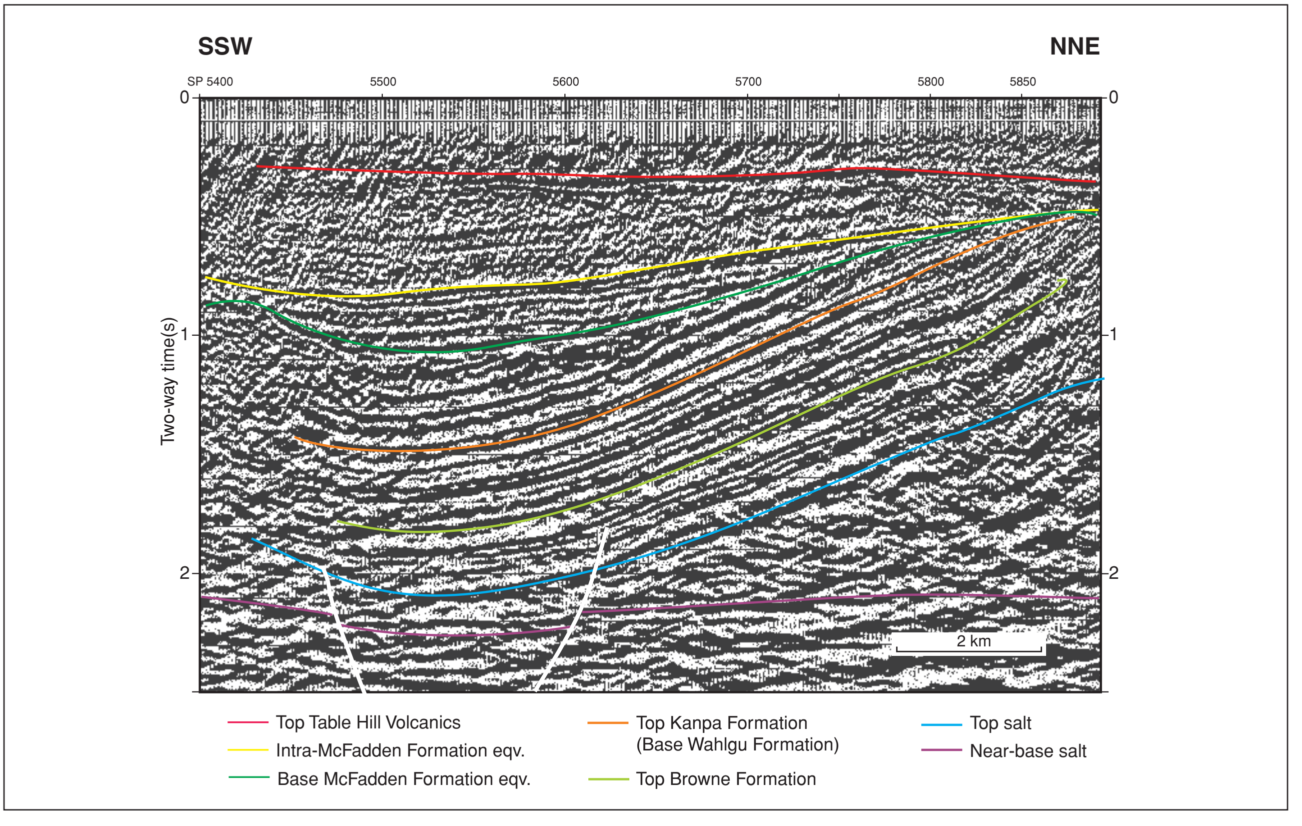

Figure 17: Seismic line T 82-139 showing a rim syncline between salt walls. The rim syncline is infilled by the Wahlgu Formation, which onlaps on to the northern salt walls. The younger McFadden Formation equivalent infills the rim syncline and onlaps on to both the northern and southern salt walls. For location of seismic line see Figure 3.

out traps. A good example occurs in the Wahlgu Formation and McFadden Formation equivalent, in the salt-withdrawal synclines adjacent to the salt walls in the Lennis area. Figure 17 shows sedimentary units onlapping against the sides of the salt rims, creating numerous potential pinchout traps. From a petroleum-charge perspective, the timing of such traps is excellent, and there is a good chance that such a configuration could be maintained over a long period, preserving any petroleum accumulation.

Facies Changes

Isolated shoreface sand bodies within fine-grained facies, such as an offshore bar, are possible stratigraphic traps. The early timing of such traps is excellent with respect to charge and the stable, low-angled ramp configuration of the area should enable the maintenance of the trap integrity over long periods of time.

There are numerous horizons where halite and anhydrite have been formed in desiccation zones, plugging the porosity of the sediments either during, or just after, deposition. Such traps are also early with respect to charge and could be expected to retain any accumulation over a long period.

Erosive Channel

Frequent emergence is well documented in the Officer Basin successions and channels filled with high-energy, reservoir-quality sediments sealed by the subsequent transgressive shale (Fig. 14) are identified exploration targets. Again the timing with respect to charge is excellent, and the retention of petroleum in this play type is likely to be good.

Prospectivity

The vast area covered by the western Officer Basin is under explored and the sparse well control precludes a complete assessment of the source-rock potential of the Neoproterozoic succession. The minor shows encountered prove that petroleum systems exist in the basin. Effective source rock units and commercially-viable petroleum systems cannot be identified from the available dataset. However, thin good-quality source units have been verified in the Browne, Hussar, Kanpa, and Steptoe Formations. A significant part of the Neoproterozoic section is presently within the oil window, and contains good reservoir and seal rocks suggesting further exploration of this frontier region is warranted.

Most units contain lithologies (salt, shale and carbonate) that would make effective seals at all scales. Thinner intervals would act as local seals. Thick regional seals formed by halite in the Browne Formation and shale in the Hussar, Kanpa and Steptoe formations have also likely controlled regional migration pathways. Thinner shale and carbonate seals are only effective locally. The presence of major evaporitic intervals further enhances the potential of the area, as evaporites are associated with large petroleum accumulations elsewhere in the world. There have been no valid tests of sub-salt plays to date in the basin. The ultimate petroleum potential of the Officer Basin is unproven but it may be significant.

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Biographies

Neil Apak holds two MSc degrees in petroleum geology, from the Istanbul University and the W. Michigan University/Colorado School of Mines. He gained a PhD. from the University of Adelaide. In 1995 Neil was employed by the Geological Survey of Western Australia as a basin analyst to evaluate hydrocarbon prospectivity in Western Australian basins, and he has been involved with the Canning and Officer basins.

Ameed Ghori is a Senior Geologist at the Geological Survey of Western Australia since 1994 and specialises in geochemical basin evaluation. He received a B. Sc. (Hons; 1967) and an M. Sc. (1968) in geology at the University of Karachi; a Postgraduate Diploma (1991) and an M. Sc. (1994) in Petroleum Geology at Curtin University of Technology, Perth. He worked as Specialist/Consultant Geologist in Pakistan at Oil and Gas Development Corporation; in Libya at Arabian Gulf Oil Company; in Australia at Lasmo Oil; SAGASCO Resources; Discovery Petroleum; and Petrochemex. Ameed is a member of AAPG, APGE, FESWA and PESA.

Greg Carlsen started his Liberal Arts and Sciences Degree at the University of Southern California and completed his Degree in Geology from Augustana College in 1976. He later completed a Master of Science Degree from Northern Illinois University in 1978. His career began as a Geophysicist with Getty Oil Company, Houston in 1978. He moved on after 2 years to join Marathon International Oil Company, Ohio, working in Libya and Egypt. Greg spent approximately 4 years (from 1982 to 1986) working for Marathon Petroleum Australia, Ltd. From 1986 until 1988 he was employed in the Indonesian Branch of Marathon. He returned to Marathon International Oil Company, Houston, as an Advanced Geophysicist working on projects in Syria. In 1990 Greg was promoted to Chief Geophysicist for Marathon and assigned to work in Ireland. He is currently employed by the Geological Survey as Manager Petroleum studies for work being carried out in sedimentary basins onshore Western Australia.

Mark Stevens completed a BSC (Geology, Hons, Australian National University) in 1975. His career began with field exploration for uranium, base metals, gold and diamonds. In 1980 he was employed as a petroleum geologist with Offshore Oil, with field mapping in the Bowen Basin and working in the Surat and Eromanga Basins. He became a Senior Geologist with Petroz in 1987, participating in exploration programs across Australia. In 1991 he joined Simon Petroleum Technology working on integrating geological and seismic data from Australia and overseas. In 1994 he was appointed to the GSWA to carry out studies of WA on-shore basins, emphasising linking outcrop and sub-surface data. Mark is currently a member of both the WABS3 and PESA (WA) Committees and was awarded the PESA (WA) Meritorious Service Award in 1999. He is married with two teenage daughters.