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Chapter 32: Wiso Basin

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Chapter 32: WISO BASIN

PD Kruse and TJ Munson

INTRODUCTION

The Wiso Basin is a large (160 000 km^2) intracratonic sedimentary basin located in the central northwestern Northern Territory (**Figure 32.1**). It is bounded to the east by the Palaeo–Mesoproterozoic Tomkinson, Warramunga and Davenport provinces of the Tennant Region and to the west by the Palaeoproterozoic Tanami Region and Palaeo-Mesoproterozoic Victoria and Birrindudu basins. To the south, the contact with the Palaeoproterozoic Aileron Province of the Arunta Region is a steep south-side-up thrust fault system. Northward, the Wiso Basin links with the Daly and Georgina basins beneath Cretaceous cover of the onshore Carpentaria Basin. These neighbouring basins contain stratigraphic successions of similar age to the Wiso Basin and form distinct depocentres that are separated from the Wiso Basin by basement ridges formed by basaltic rocks of the Kalkarindji Province (Tickell 2005, see **Daly Basin: figure 31.2**). In the southeast, there is also a poorly defined connection with the southern Georgina Basin across a basement high (Dunster *et al* 2007, **Figure 32.1**). In the middle Cambrian, the interconnected Wiso, Daly and Georgina basins collectively formed part of a vast depositional area that extended across northern, central and southern Australia; contiguous portions of this depositional system in northern and central Australia are referred to in this volume as the Centralian B Superbasin (see **Centralian Superbasin**).

Proterozoic rocks underlie and form the basement for the generally flat-lying basin and inliers of Proterozoic rocks that are correlated with the Tomkinson Creek Group and upper Hatches Creek Group of the Tennant Region are scattered throughout SOUTH LAKE WOODS[1] and WINNECKE CREEK (Kennewell 1977, Huleatt 1977, see **Other Palaeoproterozoic inliers**). In the north of the basin, almost flat-lying rocks of the early Cambrian Antrim Plateau Volcanics (Kalkarindji Province) form basement for the Palaeozoic succession (see **Daly Basin: figure 31.2**), above Proterozoic rocks.

About 80% of the basin is very shallow, containing less than 300 m of platformal middle Cambrian rocks. The main basin depocentre is the Lander Trough along the southern margin (**Figure 32.1**), which includes a much thicker succession of Cambrian, Ordovician and ?Devonian rocks (**Table 32.1**). The succession there is estimated to be up to 2000–3000 m thick and may reach a maximum of 4500 m (Questa 1989, Ambrose 2006). Away from the northwestern margin, outcrop is patchy to non-existent.

The basin contains elements of two successive sedimentary successions that have been recognised from sequence stratigraphic studies of middle Cambrian strata in the adjacent Georgina Basin (Shergold *et al* 1988, Southgate and Shergold 1991, Laurie 2006): sequence 1 (Ordian) and

[1] Names of 1:250 000 mapsheets are in capital letters, eg SOUTH LAKE WOODS.

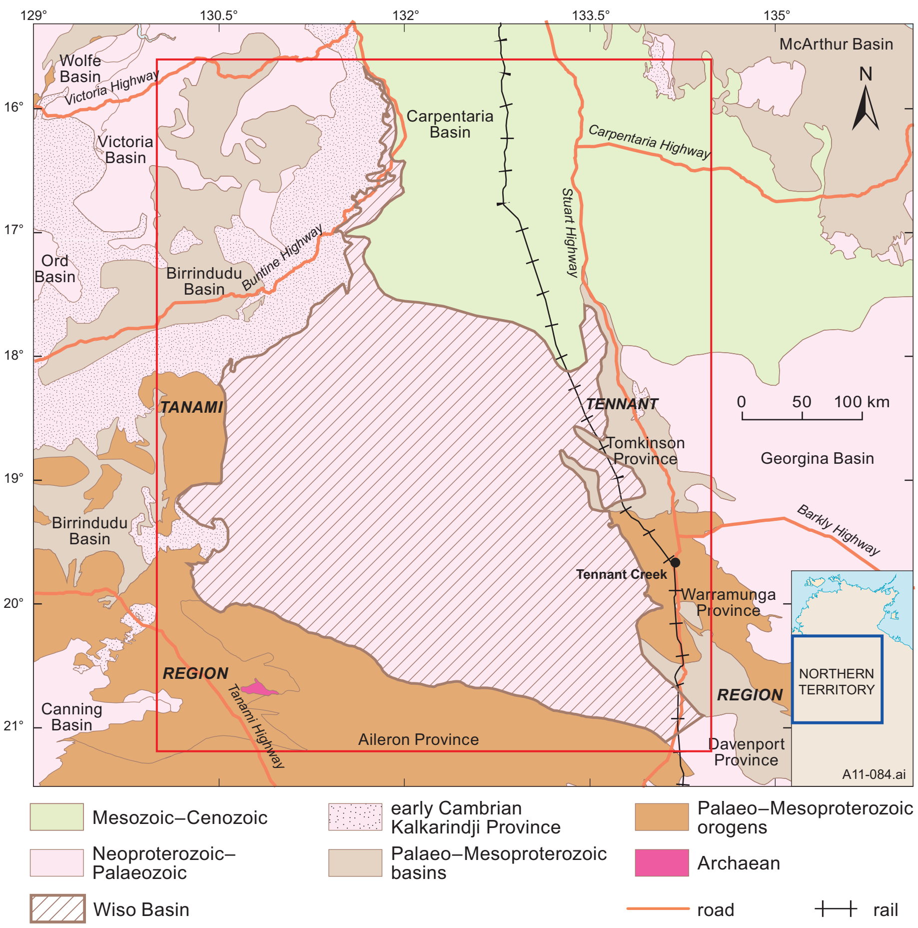

Figure 32.1. Regional geological setting of Wiso Basin. NT geological regions slightly modified from NTGS 1:2.5M geological regions GIS dataset. Box shows area of **Figure 32.2**.

sequence 2 (latest Ordian–early Mindyallan). These are overlain by sedimentary units of Early–Middle Ordovician and ?Devonian age.

Significant studies of the basin include Milligan *et al* (1966), Randal and Brown (1967), Kennewell *et al* (1977), Kennewell and Huleatt (1980), Questa Australia (1989), Pegum and Loeliger (1990) and Gorter *et al* (1998). A stratigraphic correlation chart for the Wiso and other NT basins of similar age is in **Centralian Superbasin: figure 22.6**.

MIDDLE CAMBRIAN

Middle Cambrian units assigned to sequence 1 include, in ascending stratigraphic order, Montejinni Limestone, Hooker Creek Formation and Lothari Hill Sandstone (**Table 32.1**). Marine limestone beds in the first two formations are fossiliferous, yielding an Ordian fauna of trilobites (including *Redlichia*), bradoriides, brachiopods, hyoliths, molluscs, echinoderm plates, sponge spicules and chancelloriids (Traves 1955, Milligan *et al* 1966, Huleatt 1977, Kennewell 1977, Kruse 1998), with strong species-level similarity to correlative faunas of the Linnekar Limestone and Panton Formation (Ord Basin) and Tindall Limestone (Daly Basin). The succession is also equivalent in age to the Top Springs Limestone, Gum Ridge Formation, Thorntonia Limestone and Border Waterhole Formation of the Georgina Basin.

Only one unit is assigned to sequence 2: the Point Wakefield beds of Templetonian age (Jell in Kennewell 1977, Kruse 1998). This unit is broadly correlated with the Anthony Lagoon Formation and Wonarah Formation of the Georgina Basin, with the Jinduckin Formation of the Daly Basin, and with the Eagle Hawk Sandstone of the Ord Basin.

Montejinni Limestone

The oldest unit recognised in the Wiso Basin is the Montejinni Limestone (Traves 1955), which is best exposed in the northwest of the basin (**Figure 32.2**), where the main outcrop tract forms a rugged dissected terrace flanking a plateau. It is also exposed as isolated mesas to the west of the plateau and terrace, and as sparse low rises or boulder fields elsewhere in the north and in the east of the basin. This unit generally thickens southwards from outcrops in the north; it is 38.7 m thick in BMR Larrimah-2, exposures are in the range ca 40–100 m thickness in VICTORIA RIVER DOWNS (Kennewell and Huleatt 1980, Beier *et al* 2002), and a maximum known thickness of at least 151 m (incomplete section) is reached in drillhole BMR Green Swamp Well-6 (Kennewell 1978). The Montejinni Limestone is unconformable on the early Cambrian Antrim Plateau Volcanics (Kalkarindji Province) along the northwestern margins of the basin, and on Proterozoic basement rocks further towards the south; the latter contact is not exposed. It is unconformably overlain by Cretaceous strata of the onshore Carpentaria Basin in the north and by the Point Wakefield beds near the eastern basin margin. Elsewhere, throughout the central and southern parts of the basin, the unit is overlain conformably and with a gradational contact by the Hooker Creek Formation. Rock types include limestone and dolostone (including microbial (dolo)laminite and mottled, bioclast, oncoid and ribbon types), maroon-green siltstone and minor dolomitic quartz sandstone (**Figures 32.3**, **32.4**). An overall tripartite limestone-mudstone-limestone subdivision of the formation, recognised by Randal and Brown (1967), appears to be typical across the entire basin, being also evident in some cored drillholes in the southeastern portion (Kruse 1998).

Unit, max thickness	Lithology	Depositional environment	Stratigraphic relationships
Devonian?			
Lake Surprise Sandstone <150 m	White to light brown, fine to medium quartz sandstone; low-angle cross-beds, slumps.	Shallow marine, shoreface, ?fluviatile.	Unconformable on Hanson River beds, Lothari Hill Sandstone.
Early–Middle Ordovician			
Hanson River beds 170–<800 m	Fine to medium sandstone, siltstone, micaceous claystone, limestone, glauconitic dolostone, microbialite; fossiliferous (trilobites, brachiopods, molluscs, conodonts, ichnofossils); ooids.	Shallow marine to ?fluviatile.	Unconformable on Point Wakefield beds.
middle Cambrian: sequence 2			
Point Wakefield beds 41.1+ m	White and brown, locally calcareous claystone, ?overlain by interbedded claystone and sandstone; fossiliferous (trilobites, brachiopods, sponge spicules, stromatolites); cross-beds in sandstone.	Shallow marine to ?fluviatile.	Unconformable on Lothari Hill Sandstone, Hooker Creek Formation, Montejinni Limestone.
middle Cambrian: sequence 1			
Lothari Hill Sandstone 94+ m	Pale- to red-brown, fine quartz sandstone, locally micaceous or dolomitic; minor claystone, dolostone; desiccation cracks, vertical ?burrows, minor low-angle cross-beds, symmetric ripples.	Intertidal to ?shoreface.	Conformable and gradational on Hooker Creek Formation.
Hooker Creek Formation 162 m	Maroon-green siltstone, minor limestone, quartz sandstone; limestone beds fossiliferous (trilobites including *Redlichia*, brachiopods, hyoliths, echinoderm plates).	Peritidal to restricted marine.	Conformable and gradational on Montejinni Limestone.
Montejinni Limestone 151 m	Limestone and dolostone (including microbial (dolo)laminite and mottled, bioclast, oncoid and ribbon types), maroon-green siltstone; minor dolomitic quartz sandstone; local basal polymict breccia; nodular evaporites, hot and cold seep structures; fossiliferous (trilobites including *Redlichia*, bradoriides, brachiopods, hyoliths, molluscs, echinoderm plates, sponge spicules and chancelloriids).	Peritidal to restricted marine.	Unconformable on Antrim Plateau Volcanics.

Table 32.1. Summary of Palaeozoic stratigraphic succession of Wiso Basin.

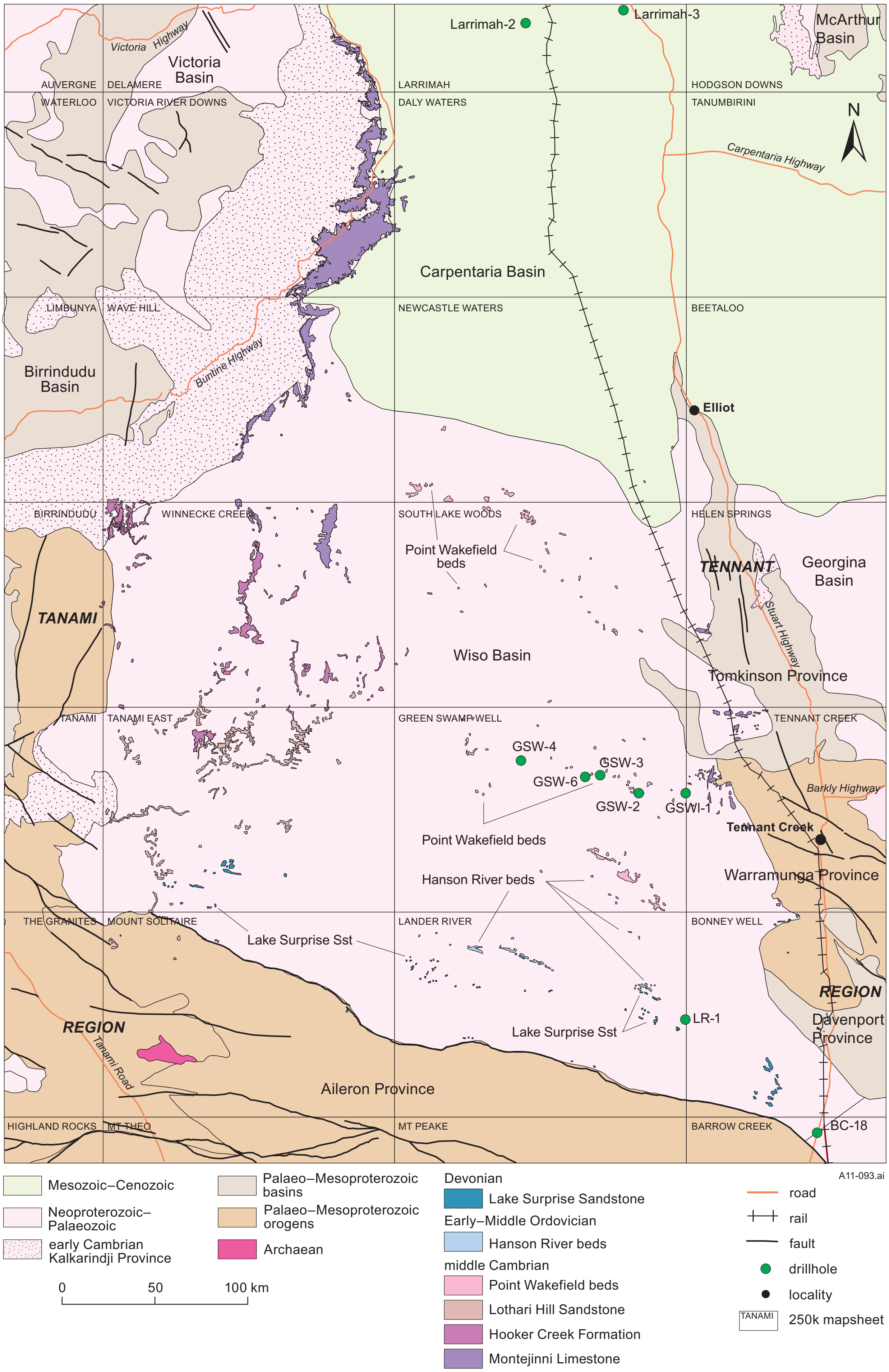

Figure 32.2. Simplified geology of Wiso Basin, derived from GA 1:1M geology and NTGS 1:2.5M geological regions GIS datasets. Some smaller exposures are labelled on mapface. Abbreviations: GSW = Green Swamp Well; LR = Lander River; BC = Barrow Creek; Sst = Sandstone.

The Montejinni Limestone was deposited on an extensive, restricted but oxygenated marine platform with episodic high salinities and tidally influenced open marine settings (Kennewell and Huleatt 1980, Beier *et al* 2002). Microbial laminite with nodular chert dominates basal beds along the northwestern margin, and basal polymict breccias have been intersected in drillholes in the southeast. By analogy with the Ord and Daly basins, the locally evaporitic siliciclastic rocks are taken to indicate recurring peritidal sedimentation.

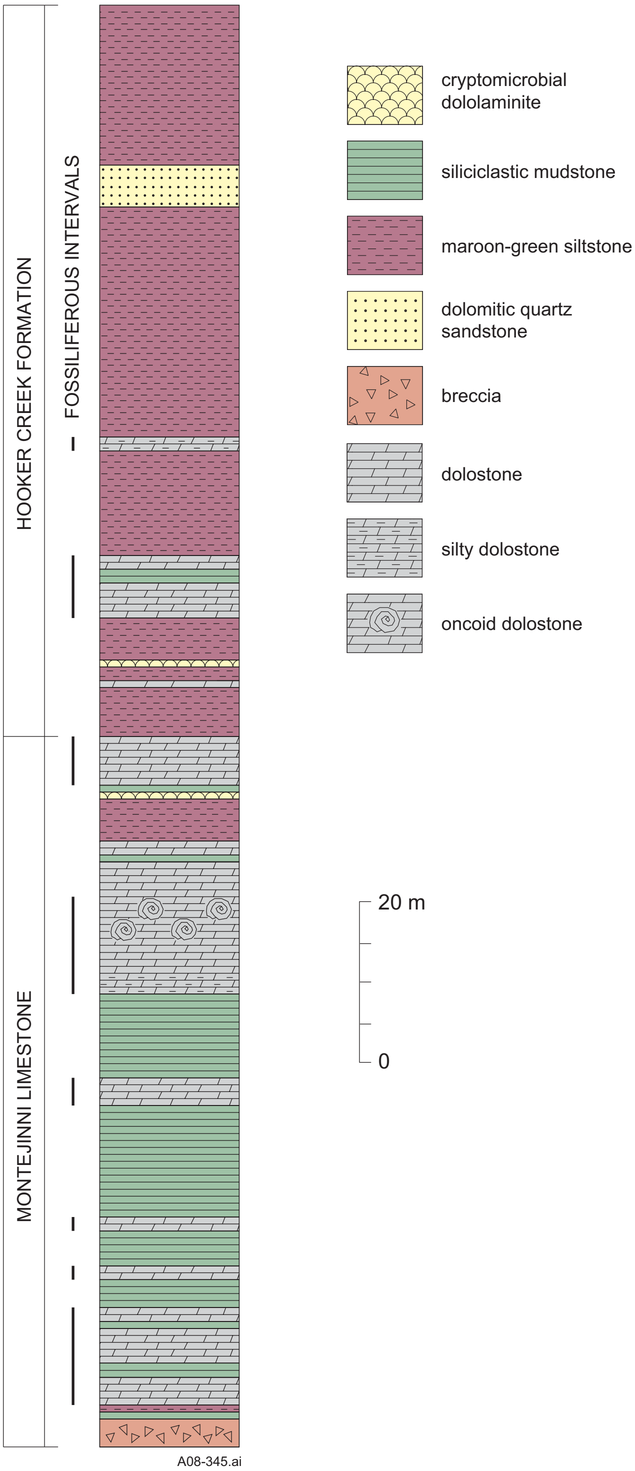

Figure 32.3. Schematic stratigraphic section of Montejinni Limestone and Hooker Creek Formation in southeastern Wiso Basin, based on data from several cored drillholes in southeast of basin (after Kruse 1998). Note broad, tripartite limestone-mudstone-limestone subdivision of Montejinni Limestone, with mudstone dominating medial part of section and limestone/dolostone more common towards base and top.

Hooker Creek Formation

The Hooker Creek Formation (Kennewell and Huleatt 1980) is exposed as low rises or thin caps on scarps in the western Wiso Basin (**Figure 32.2**). It has been intersected in drillholes in the east and southeast of the basin, indicating a widespread distribution across the central and southern parts, but is not recognised in the north of the basin. The formation reaches a maximum known thickness of 161.5 m in the type section in BMR Green Swamp Well-6, and intervals of 45 m and 51.8 m were described by Kennewell and Huleatt (1980) from WINNECKE CREEK. Drill sections in the southeastern Wiso Basin range from 80 m to over 120 m in thickness (Kruse 1998, **Figure 32.3**). The formation has conformable and gradational contacts with the Montejinni Limestone (below) and Lothari Hill Sandstone (above). Where the latter unit is absent, the Hooker Creek Formation is unconformably overlain by the Point Wakefield beds or by Cretaceous strata of the Buchanan Hills beds. The formation consists almost entirely of red-brown to maroon-green, laminated, bioturbated micaceous siltstone and grey dolomitic mudstone, with a few thin marine dolomitic limestone beds, particularly toward the base, and minor fine-grained dolomitic quartz sandstone towards the top (Kennewell and Huleatt 1980, Kruse 1998). These rock types and the presence of marine fossils indicate that the depositional environment ranged from

Figure 32.4. Montejinni Limestone at Chowyung Waterhole [LARRIMAH, WESTERN CREEK, 53L 243770mE 8276250mN; photos courtesy of D Karp, Water Resources Branch, NT Department of Natural Resources, Environment, The Arts and Sport (NRETAS)]. (**a**) Exposures of thinly bedded dolostone. (**b**) Detail of vuggy dolostone, showing poorly defined thin bedding (above hammer).

peritidal to shallow marine with restricted circulation (Kennewell and Huleatt 1980).

Lothari Hill Sandstone

The unfossiliferous Lothari Hill Sandstone is best exposed as scarps surrounding low rises in the southwestern part of the basin, in TANAMI EAST and southern WINNECKE CREEK (**Figure 32.2**). It conformably overlies the Hooker Creek Formation in most parts of the basin, with a gradational contact (Kennewell and Huleatt 1980). The formation reaches a maximum thickness of 93.9 m in the type section in BMR Green Swamp Well-4, but the top of this section is eroded and the unit may be thicker elsewhere in the basin. The Lothari Hill Sandstone is overlain with a slight angular unconformity by the Point Wakefield beds, or where that unit is absent, is unconformably overlain by the Lake Surprise Sandstone or by Cretaceous strata of the Buchanan Hills beds. The formation is thickly bedded and consists of white to more typically light brown or red-brown, locally dolomitic, fine quartz sandstone and minor claystone, dolostone and chert. Sedimentary structures include desiccation cracks, vertical ?burrows, low-angle cross-beds and symmetric ripples, and these indicate deposition in an intermittently desiccated, wave and tidally influenced regime (Kennewell and Huleatt 1980).

Point Wakefield beds

The Point Wakefield beds are typically poorly exposed as rubble-strewn slopes and small scarps on the margins of low rises in the eastern half of the Wiso Basin, particularly in southern WINNECKE CREEK, SOUTH LAKE WOODS and GREEN SWAMP WELL (**Figure 32.3**). The unit thins towards and is probably absent in the north of the basin, and is overlain by younger rocks in the south, where it probably extends into the Lander Trough (Kennewell and Huleatt 1980). No complete section has been measured, but exposures of the unit are generally estimated to be >20–25 m thick and a maximum known (incomplete) thickness of 41.1 m has been recorded in stratigraphic drillhole BMR Barrow Creek-18 (Milligan 1963). The Point Wakefield beds unconformably overlie all three sequence 1 formations of the Wiso Basin (**Table 32.1**). This erosive relationship is demonstrated in drillholes BMR Green Swamp Well-1, -2 and -3, in which the unit rests on the Montejinni Limestone, Hooker Creek Formation and Lothari Hill Sandstone, respectively (Kennewell and Huleatt 1980). The unit is overlain by probable Hanson River beds in southeastern GREEN SWAMP WELL, although the contact is not exposed, and is unconformably overlain by Cretaceous rocks in other areas. Kennewell and Huleatt (1980) considered the boundary with the Hanson River beds to be probably gradational, whereas Gorter *et al* (1998) suggested that it may be unconformable.

In GREEN SWAMP WELL, a lower, white/brown, calcareous claystone subunit is apparently overlain by an upper subunit consisting of metre-scale interbeds of well sorted, generally fine-grained, occasionally cross-bedded sandstone and laminated claystone. A low-diversity fauna from the lower subunit (Jell in Kennewell and Huleatt 1980), of the trilobite *Xingrenaspis alroiensis* (Etheridge) and three brachiopod species, was described by Kruse (1998). The trilobite species has alternatively been assigned to *Eosoptychoparia (Eosoptychoparia)* Chang by Yuan *et al* (2002). The species is also known from the Wonarah Formation (Shergold *et al* 1985), of late Templetonian-Floran (lower sequence 2) age. The marine fauna and fine calcareous rocks of this subunit suggest a shallow marine setting. Silicified stromatolites have been recorded from the upper subunit at one locality, which suggests an intertidal or restricted shallow marine environment, at least in part. Cross-bedded sandstone and claystone might have been deposited under shallow marine conditions, or alternatively may represent a fluviatile setting (Kennewell and Huleatt 1980).

EARLY–MIDDLE ORDOVICIAN

A single Ordovician unit, the Hanson River beds, is recognised in the Wiso Basin, although seismic data indicate that younger Ordovician rocks may be present in the subsurface in the Lander Trough (Questa 1989).

Hanson River beds

The Hanson River beds (Milligan *et al* 1966) rim the northern flank of the Lander Trough (**Table 32.1**, **Figure 32.2**) and presumably extend into it, there thickening up to a maximum 800 m inclusive of Cambrian rocks (Kennewell *et al* 1977). They have not been recognised in more northern parts of the basin. Exposures of the Hanson River beds are poor and mostly consist of rubbly rises, except in northern LANDER RIVER, where they form low scarps between areas of calcrete (Kennewell and Huleatt 1980). The succession is therefore uncertain, but Kennewell and Huleatt (1980) recognised four informal constituent units, from top to bottom:

- Unit 4 (5+ m): Limestone and dolostone bearing conodonts of latest Arenigian (Darriwilian) age (Druce in Kennewell and Huleatt 1980), together with minor white micaceous claystone and well sorted sandstone yielding molluscs, brachiopods, trilobites and ichnofossils, the molluscs with affinity to faunas in the Stairway Sandstone and Stokes Siltstone of the Amadeus Basin (Pojeta and Gilbert-Tomlinson in Kennewell and Huleatt 1980). Calcrete capping.
- Unit 3 (22+ m): Dolostone and white, crystalline laminated limestone with minor, dark brown to dark grey laminated and bioturbated mudstone and siltstone interbeds; calcrete capping. Gorter *et al* (1998) described four upward-shallowing cycles, consisting of black shale overlain by oolitic ironstone, from within this unit in BMR Lander River-1. Conodonts from unit 3 indicate a middle Arenigian (Dapingian) age (Druce in Kennewell and Huleatt 1980); brachiopods are indeterminate.
- Unit 2 (75+ m): Well sorted fine sandstone and poorly sorted sandstone grading to siltstone, with minor grey to brown dolostone and light green, locally micaceous and glauconitic, fissile claystone. Ichnofossils (‘tracks and burrows’) are abundant. Ooids, microbial structures and occasional brachiopods are also present.
- Unit 1 (<67 m): Unfossiliferous, fine to medium, moderately sorted sandstone interbedded with orange-

brown and green, slightly micaceous siltstone and claystone. The stratigraphic relationship of unit 1 to the other units is inferred from its geographical location to the north of unit 2 in a generally south-dipping succession, but it is also possible that these beds may be of Mesozoic or Cenozoic age and therefore unrelated to other units of the Hanson River beds.

The depositional environment of unit 1 is uncertain, although the poorly sorted sandstone suggests a continental, perhaps fluviatile regime. Shallow marine depositional conditions are indicated for the other three units, from the presence of marine fossils, ichnofossils, microbial structures and ooids. On the biostratigraphic evidence and lithological similarities, Kennewell and Huleatt (1980) correlated these beds with the Pacoota Sandstone–Stokes Siltstone interval of the Amadeus Basin.

?DEVONIAN

Lake Surprise Sandstone

The Lake Surprise Sandstone (Kennewell and Huleatt 1980) caps the Wiso Basin succession. This formation is confined to the Lander Trough and is poorly exposed in a west-northwest-trending area extending from LANDER RIVER to MOUNT SOLITAIRE (**Table 32.1**, **Figure 32.2**). The unfossiliferous quartz sandstone is white to brown, very fine to medium to coarse (Kennewell and Offe 1979, Kennewell and Huleatt 1980), well sorted and well rounded, and contains abundant low-angle cross-beds. At some localities, the sandstone contains a matrix of silt and clay. Probable soft-sediment slump structures are also present. Kennewell and Offe (1979) indicated a thickness for the unit of 250 m from seismic data and estimated a maximum thickness of up to 350 m, but a lesser thickness of up to 150 m was reported by Kennewell and Huleatt (1980). The Lake Surprise Sandstone is unconformable on the Hanson River beds, or where this is absent, on the Lothari Hill Sandstone and possibly other middle Cambrian units. Seismic evidence (Ray Geophysics 1967) indicates that the unit transgresses the southern marginal faults of the basin, so that it is also unconformable on, rather than faulted against Aileron Province rocks. Large-scale slumps in the formation possibly represent structural disturbance contemporaneous with movement on these faults (Kennewell and Huleatt 1980). The Lake Surprise Sandstone is unconformably overlain by Cenozoic strata in many areas.

The Lake Surprise Sandstone is undated, but must be younger than the underlying Early–Middle Ordovician Hanson River beds. It is lithologically similar to the Dulcie Sandstone of the Georgina Basin; both units are interpreted to have been deposited in a similar tectonic setting, as synorogenic deposits at about the time of the Early Devonian Pertnjara-Brewer events of the Alice Springs Orogeny (Pegum and Loeliger 1990, Haines *et al* 2001). Kennewell and Huleatt (1980) suggested that the depositional environment may have been shallow marine or a beach, or alternatively may have been fluviatile, with the good sorting and rounding in the sandstone explained by derivation from a provenance that comprised mature sandstone or quartzite with these characteristics. A fluviatile, braided stream or fan setting has been favoured by subsequent workers (eg Questa Australia 1989, Pegum and Loeliger 1990, Haines *et al* 2001). The maturity of the sandstone and lack of very coarse components suggests a relatively low-relief, distant source area. High levels of sediment transport and low thresholds of bank erosion may have resulted in the braided-stream characteristics, even in this relatively fine-grained deposit.

STRUCTURE

Overall, the Wiso Basin comprises a west-northwest-trending, thick depocentre, the Lander Trough (**Figure 32.5**), and an extensive, much thinner and less deformed area flanking the trough to the north. Over much of the basin, the flat-lying succession is little affected by tectonism. Drilling has outlined broad, gentle downwarps north and south of the northwesterly basement extension of the Tennant Region transecting SOUTH LAKE WOODS, and photopatterns suggest some gentle flexure of Cambrian rocks. Several major northeast-trending faults have been interpreted in Proterozoic basement rocks, but these do not have any significant surface expression (Kennewell and Huleatt 1980).

The Lander Trough, along the southern basin margin, is on trend with the Dulcie and Toko troughs (synclines) of the Georgina Basin to the southeast, all three of which are separated from Proterozoic rocks of the Aileron Province by a series of thrust fault systems (**Figure 32.5**). Questa (1989) used aeromagnetic and gravity data to identify significant en echelon depocentres in the trough, separated by a pronounced but low-relief cross-axial high. Regional dip steepens to an estimated 2º or more in the trough and limited seismic data indicate that the Palaeozoic succession thickens considerably southwards (Mathur in Kennewell and Huleatt 1980), giving an overall asymmetry to the basin fill. This suggests that the original structure of the trough was that of a half-graben, with subsidence presumably controlled by a master detachment fault system forming the southern depositional margin and probably underlying the trough.

The present faulted southern margin with the adjacent Arunta Region is a series of east-southeast-trending, southwest-dipping thrust faults with a total displacement of over 2000 m (Kennewell *et al* 1977). It is unclear whether or not the depositional margins of the basin originally coincided with these present-day faults. No marginal basin facies has been reported from the vicinity of the structures and the sense of movement (south-side-up thrusting) is opposite to that of inferred, north-side-down, normal listric faults that would have originally bounded the half-graben. It is therefore possible that early Palaeozoic deposits may have extended southwards across the present southern margin of the basin, but have subsequently been uplifted and eroded. The Lake Surprise Sandstone was noted by Kennewell and Huleatt (1980) to extend across a thrust fault, indicating that major movements must have occurred prior to deposition of this unit. Large-scale slumps in the Lake Surprise Sandstone possibly represent contemporaneous structural disturbance. If so, the Devonian Pertnjara-Brewer events of the Alice Springs

Orogeny (Haines *et al* 2001) were most likely responsible for this slumping.

MINERAL RESOURCES

The Wiso Basin is virtually unexplored, but has potential for phosphate, base metals, diamonds, uranium and petroleum. Current exploration is focused on phosphate, uranium and petroleum.

Phosphate

Traces of phosphorite have been found in middle Cambrian sedimentary rocks over large areas of the interconnected Georgina, Wiso and Daly basins, and the Georgina Basin is host to several significant deposits, including the world-class Wonarah deposit (see Dunster *et al* 2007, Khan *et al* 2007). In the Georgina Basin, phosphate is associated with both sequence 1 and sequence 2 units (Southgate and Shergold 1991). Currently accepted exploration models (eg Cook and McElhinney 1979, Donnelly *et al* 1988), target organic-rich carbonate rocks on depositional basin margins and areas of onlap onto basement highs, where upwelling and favourable palaeogeography would have brought cold phosphate-rich waters onto the shallower marine shelf. Phosphate minerals form close to the sediment–water interface during times of low overall sedimentation and are intimately connected with the dynamics of diagenetic redox fronts (Shields 2002).

The *Lady Judith* prospect (Howard 1990) is located in the western Wiso Basin (**Figure 32.6**) and was originally investigated by Howard (1984). The prospect was formerly named Buchanan Hill by Smith (2000), who noted the presence of 31% P_2O_5 over a 6 m-thick section. Khan *et al* (2007) obtained a maximum of 28.2% P_2O_5 at 15–18 m depth, and 2.2% P_2O_5 at 72–75 m depth in waterbore RN020989. The upper phosphatic intersection is most likely to be in Hooker Creek Formation, although Howard (1990) considered it to be in medial Montejinni Limestone, and the deeper occurrence is probably in Montejinni Limestone.

In western TENNANT CREEK, the *Warrego West* prospect is recognised from phosphate occurrences in two waterbores intersecting Montejinni Limestone (Khan *et al* 2007). In waterbore RN016930, thick phosphatic zones spanning the depth interval 27–47 m (EOH) have yielded values in the range 1–5.5% P_2O_5. Phosphate mineralisation is in light grey silty claystone/mudstone and cherty mudstone. Waterbore RN016930 is 5 km along strike to the south of RN016930 and has assayed 3.2% P_2O_5 from 39.62–42.67 m depth. These two occurrences are within 25 km of the Adelaide–Darwin railway line. The *Kunayangku* occurrence, in a single waterbore (RN011609) in the southwest of the same sheet area, appears to lie stratigraphically at about the Montejinni Limestone–Hooker Creek Formation contact. Phosphate mineralisation is present in silty sandstone and calcareous siltstone. A maximum of 2.43% P_2O_5 has been reported from the depth interval 84–87 m (Khan *et al* 2007).

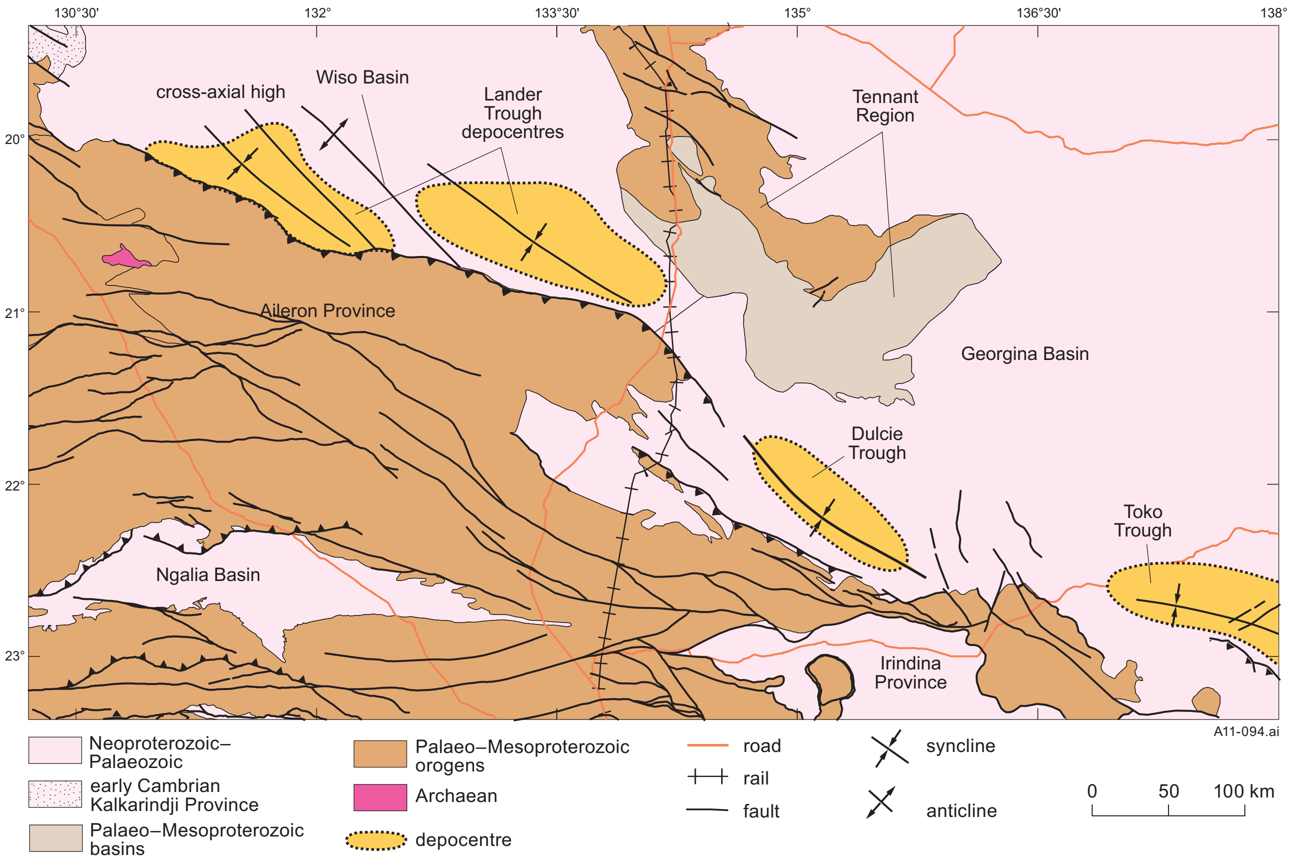

Figure 32.5. Schematic map of southern Wiso and Georgina basins showing locations of Palaeozoic depositional troughs (modified from Questa 1989, Gorter *et al* 1998). Lander Trough, along southern Wiso Basin margin, is on trend with Dulcie and Toko troughs of Georgina Basin to southeast, all three of which are separated from Proterozoic rocks of Aileron Province by a series of thrust fault systems. Basemap is 1:2.5M geological regions overlain by interpreted major faults (from NTGS GIS datasets).

Two dolostone samples from the Hanson River beds in north-central LANDER RIVER in the southern Wiso Basin have yielded analyses of 10.6% and 3.2% P_2O_5 (Milligan *et al* 1966). In the northern Wiso Basin, analyses of 1–7% P_2O_5 were obtained from pale mudstone at 36.6–39.6 m depth in percussion drillhole BMR Larrimah-3, immediately underlying basal Cretaceous rocks. The phosphate is surmised to have been concentrated by pre-Cretaceous weathering (Kennewell and Huleatt 1980).

Base metals

Economically insignificant copper occurrences are widespread at and adjacent to the unconformable contact between the Antrim Plateau Volcanics and overlying sedimentary units within the western Wiso and Ord basins. These are discussed more fully in **Kalkarindji Province**. Randal and Brown (1967) reported occurrences of copper in the basal Montejinni Limestone immediately above the Antrim Plateau Volcanics along the northwestern Wiso Basin margin, and Kennewell and Huleatt (1980) also reported copper from undivided Montejinni Limestone and Hooker Creek Formation in a similar stratigraphic position in southwestern TANAMI EAST. The best known copper occurrence is *Crowsons Prospect*, located 11 km west of Montejinni homestead. Native copper, cuprite, malachite, chalcocite and traces of covellite were reported from the Antrim Plateau Volcanics near the contact with the Montejinni Limestone (Zimmerman 1968, Sweet 1973), and malachite also occurs as a fine dissemination or as thin veinlets in the limestone. Specimens assaying better than 20% Cu were said to have been collected from the surface (Sampey Exploration Services 1968), but individual costeans have returned best assays of 4.5% to 7.24% Cu (Sakurai 1991).

The Wiso Basin may be prospective for Mississippi Valley-type carbonate-hosted lead-zinc deposits, although there has been little exploration for this type of mineralisation within the basin. The widespread Montejinni Limestone at the base of the succession probably has the best host-rock potential. This unit has enhanced secondary porosity and permeability, which may have facilitated fluid flow and provided favourable sites for sulfide deposition. Suitable ore controls at local and regional scales might have been provided by extensional structures, such as normal, transtensional and strike-slip faults, and by associated fractures and dilatancy zones.

Diamonds

Few diamond exploration programs have been conducted in the Wiso Basin. An Aberfoyle Resources Ltd–Ashton Mining Ltd–AOG Minerals Ltd joint venture in the early 1980s recovered four small diamonds in the northeastern part of the basin in BEETALOO (Ashton Mining 1986). Stockdale Prospecting Ltd also conducted exploration for diamonds in the western Wiso Basin in WAVE HILL and VICTORIA RIVER DOWNS in the late 1990s (Berryman 1998).

Uranium

There is some potential for sandstone-type uranium deposits in the Wiso Basin analogous to the Angela (Amadeus Basin) and Bigrlyi (Ngalia Basin) deposits. A possible source of leachable uranium is provided by radiogenic basement rocks, particularly the Aileron Province to the south. Reductants that may have facilitated the deposition of uranium oxides are present as organic-rich intervals at various levels within the succession and as hydrocarbons. Permeable aquifer sandstone intervals enable fluid flow within the basin, and the lateral and vertical variations in permeability that are needed to focus fluid flow and enable fluid mixing are provided by heterogeneous rock units,

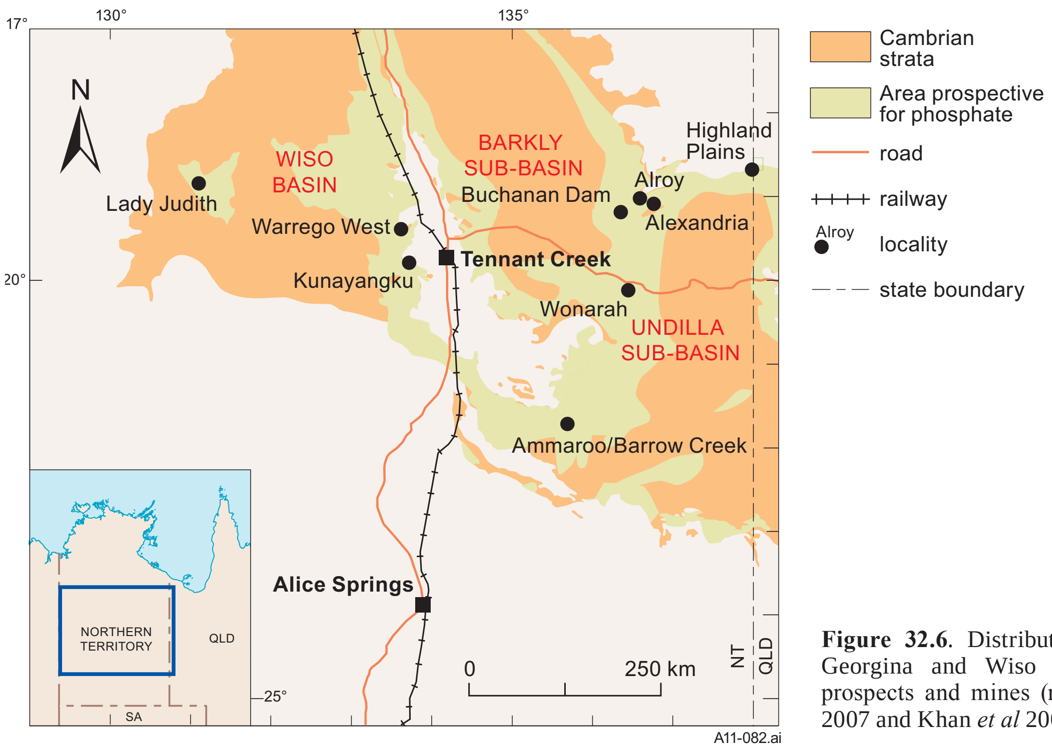

Figure 32.6. Distribution of phosphatic strata in Georgina and Wiso basins, showing phosphate prospects and mines (modified from Dunster *et al* 2007 and Khan *et al* 2007).

unconformities and other structures. The Wiso Basin is extensive enough to host a large uranium resource and Toro Energy Ltd is currently exploring for tabular, palaeochannel and roll-front uranium deposits in the southeast, using a combination of airborne TEM and drilling (Toro Energy Ltd website: http://www.toroenergy.com.au/_webapp_386443/Wiso,__NT, accessed June 2011).

Petroleum

The Wiso Basin is virtually unexplored for petroleum, although much of the basin is currently covered by exploration permit applications. No petroleum or deep stratigraphic wells have been drilled anywhere in the basin, although there are a number of shallow mineral exploration and BMR stratigraphic drillholes. Minor hydrocarbon shows have been noted in two of the BMR drillholes. The most prospective area, the Lander Trough, has not been drill tested, greatly limiting geological interpretations of this feature. A reconnaissance seismic survey was undertaken in the southeast of the basin in the late 1960s (Ray Geophysics 1967), but there is otherwise no seismic coverage of the basin. Airborne geophysics, including a modern grid of aeromagnetic data at a line spacing of 400 m or better, is available over the whole of the basin. Useful appraisals of the petroleum potential of the basin are by Kennewell and Huleatt (1980), Questa (1989), Pegum and Loeliger (1990), Gorter *et al* (1998) and Ambrose (2006).

Source rocks

The most promising source rock intervals in the Wiso Basin succession are the Montejinni Limestone and unit 3 of the Hanson River beds. Rock-Eval pyrolysis indicates that these units have fair to good oil source rock potential (Gorter *et al* 1998). The Montejinni Limestone contains marine fossils and stromatolites, and is the only formation in the succession from which hydrocarbon shows have been recorded: these include tarry residue at 72 m depth in BMR Green Swamp Well-1 (Milligan *et al* 1966) and residual hydrocarbons at 259 m in Green Swamp Well-6 (Watson 1987). TOC values from 0.10% to 0.85% have also been recorded from samples of the limestone (Watson 1987). Unit 3 of the Hanson River beds contains marine fossils and dark brown shale and mudstone intervals at several levels that are potential source rocks (Questa 1989, Gorter *et al* 1998). Other intervals in the Wiso Basin succession also have source potential, and good source rocks may be present in the subsurface within the Lander Trough, in areas that have not been drill tested. Questa (1989) noted that any evaporitic successions that might be present within the Wiso Basin should be regarded as potentially rich oil-prone source rocks.

Reservoirs and seals

A number of Cambrian and Ordovician sandstone and carbonate intervals within the Wiso Basin succession have good reservoir potential and either underlie effective sealing strata or contain intraformational seals (Kennewell and Huleatt 1980, Questa 1989, Pegum and Loeliger 1990, Gorter *et al* 1998). Fractured and vuggy carbonate rocks in the Montejinni Limestone (**Figure 32.4b**), which is the main producing aquifer in the western Wiso Basin, have particularly good potential. The overlying Hooker Creek Formation has produced good groundwater flows in some waterbores and some parts of this formation may therefore form effective reservoirs. The Lothari Hill Sandstone has only poor to fair reservoir potential, but could have received hydrocarbons migrating from older source intervals. Intraformational siltstone and claystone in the Hooker Creek Formation and Lothari Hill Sandstone might provide seals (Kennewell and Huleatt 1980). Vuggy dolostone in the Point Wakefield beds may also have reservoir potential and interbedded claystone may form effective seals. The two basal units of the Hanson River beds have well sorted, porous fine-grained sandstones that may have subsurface reservoir potential (Gorter *et al* 1998), and Questa (1989) and Pegum and Loeliger (1990) suggested that these may have the best reservoir potential in the succession. Intraformational beds of claystone are possible seals (Kennewell and Huleatt 1980). The Lake Surprise Sandstone is thin and permeable; this unit may have reservoir potential, but it apparently lacks an effective seal, so is less prospective (Kennewell and Huleatt 1980, Gorter *et al* 1998).

Thermal maturity

Much of the Wiso Basin succession is too thin and shallow to be thermally mature, except in the Lander Trough where modelled depths of 3000 m or greater indicate that the succession there should be more mature. Questa (1989) noted that the Cambrian Montejinni Limestone and Ordovician Hanson River beds should be moderately to optimally mature within the Lander Trough, but that possible Ordovician source rocks were probably immature for significant hydrocarbon generation, or at an early generative stage. Gorter *et al* (1998) considered that is unlikely that any of the Palaeozoic section within the trough will be beyond the oil and wet gas/condensate window. They reported that samples of Montejinni Limestone and Hooker Creek Formation from BMR Green Swamp Well-1 and -6 had relatively low maturity, but tarry residues in samples from the former well indicate that mature source rocks must be present in the vicinity. More recent maturation modelling by Central Petroleum Ltd has indicated that source rocks in the Lander Trough may range from the early oil window to the early gas window, depending on the depth of burial (Central Petroleum Ltd, ASX announcement, 26 May 2011).

Prospectivity

About 80% of the Wiso Basin (central and northern parts) contains generally less than 500 m of section and is therefore not considered very prospective for hydrocarbons (Randal and Brown 1967, Kennewell and Huleatt 1980, Questa 1989, Gorter *et al* 1998). Long-distance migration from possible source rocks in thicker successions would be required to charge any existing structures in these areas. However, the Lander Trough, with a modelled depth of 2000–3000 m up to a maximum of 4500 m (Questa 1989), is much more prospective for petroleum, and adjacent shallower parts of the basin may also have received hydrocarbons migrating northwards from more deeply buried sources. The Lander Trough is on trend with and is analogous to the Dulcie and Toko troughs of the southern Georgina Basin (**Figure 32.5**), where significant oil and gas shows have been encountered (Gorter *et al* 1998, Ambrose 2006, Dunster *et al* 2007). It features significant en echelon depocentres, separated by a cross-axial high (Questa 1989). The succession in these offset depocentres is unknown, but has potential to include: (a) middle Cambrian petroleum systems equivalent to the Arthur Creek/Thorntonia petroleum system of the Georgina Basin; and (b) Ordovician petroleum systems equivalent to the prolific Horn Valley Siltstone of the Amadeus Basin (Ambrose 2006). Hydrocarbon generation is likely to have commenced in the Ordovician and may have also occurred during the Devonian–Carboniferous Alice Springs Orogeny (Central Petroleum Ltd, ASX announcement, 26 May 2011).

A variety of possible conventional structural and stratigraphic traps may be present within the basin. Structural traps are possible in areas adjacent to the southern marginal faults (Pegum and Loeliger 1990), and Questa (1989) indicated that these might include horst blocks. Structural traps associated with compressional folding during the Alice Springs Orogeny may also be present. Stratigraphic traps are possible in the vicinity of palaeo-shorelines (Ambrose 2006), and at pinchouts of the Lander Trough onto shallower parts of the basin in the north and onto the cross-basin high within the trough (Questa 1989). Other stratigraphic traps may be present in middle Cambrian dolostones (Gorter *et al* 1998), and in any coarse siliciclastic units that might be present at the base of the succession (Questa 1989) or adjacent to basin-marginal faults. Landsat-based structural analysis has shown the presence of a number of circular structures, several kilometres in diameter, that have been tentatively identified as potential diapiric salt structures or domes associated with possible buried equivalents of the Bitter Springs Formation of the Amadeus Basin (Central Petroleum Ltd, Exploration document: http://www.centralpetroleum.com.au/files/exploration.pdf, accessed May 2011). If present, these would provide potential for various types of diapiric traps. There is also potential for unconventional basin-centred gas and oil plays over large areas of the basin (Central Petroleum Ltd, ASX announcement, 26 May 2011).

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