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Chapter 18: Lawn Hill Platform

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Chapter 18: LAWN HILL PLATFORM

M Ahmad and TJ Munson

INTRODUCTION

The Lawn Hill Platform comprises sedimentary and volcanic strata equivalent to the Tawallah and McArthur groups of the McArthur Basin. It is widely developed in the Lawn Hill region of Queensland and extends northwestward into the Northern Territory, where it occurs as narrow belts of east-trending outcrops separated by the South Nicholson Basin (**Figure 18.1**). A northern succession extends along the southern margin of the Murphy Inlier (Murphy Province) and a southern succession is exposed in areas along the southern margin of the South Nicholson Basin in the Carrara Range area. Stratigraphic correlations and nomenclature for the Lawn Hill Platform are summarised in **Figure 18.2**. The succession unconformably overlies strata (mainly Murphy Metamorphics) of the Murphy Province and is unconformably overlain by the South Nicholson Basin. A simplified regional geological map of the Lawn Hill Platform in the Northern Territory and adjacent areas of Queensland is shown in **Figure 18.3**.

The term ‘platform’ implies that this terrane evolved under relatively stable tectonic conditions. However, the Queensland portion, at least, is now known to be folded and extensively faulted, and includes significant growth faults (McConachie *et al* 1993, Scott *et al* 1998, Krassay *et al* 2000a, b). Nevertheless, the name Lawn Hill Platform has been retained here, as it is entrenched in the literature, particularly when referring to the portion in Queensland.

The Lawn Hill Platform has been described in a number of studies (eg Hutton and Sweet 1982, Blake 1987, Blake and Stewart 1992) and its extensions in the Northern Territory have been briefly discussed by Roberts *et al* (1963), Sweet (1984), Sweet *et al* (1981) and Ahmad and Wygralak (1989). More recently, Rawlings *et al* (2008) mapped the Lawn Hill Platform in MOUNT DRUMMOND[1] and described its stratigraphic and lithological settings. The Lawn Hill Platform hosts a number of base metals deposits, including the World-class Century Zn deposit in Queensland.

PALAEOPROTEROZOIC

Northern succession

The northern succession of the Lawn Hill Platform extends in discontinuous outcrop from the western end of the Murphy Inlier along the southern margins of the inlier into western Queensland (**Figure 18.3**). The succession consists of the Wire Creek Sandstone, the Peters Creek Volcanics, and the Fickling and Benmara groups (**Table 18.1**). The two lower formations (Wire Creek Sandstone and Peters Creek Volcanics) are considered to be equivalent to the Tawallah Group of the McArthur Basin and correspond to the Ᵽ6 division of Ahmad (2000). An unconformity separates these rocks from the overlying Fickling Group, which is considered to be a stratigraphic equivalent of the McArthur Group (Plumb *et al* 1990). Most outcrops previously assigned to the former Benmara beds by Smith and Roberts (1963) were referred to the redefined Benmara Group by Rawlings *et al* (2008). The Fickling and Benmara groups correspond to the Ᵽ7 division of Ahmad (2000).

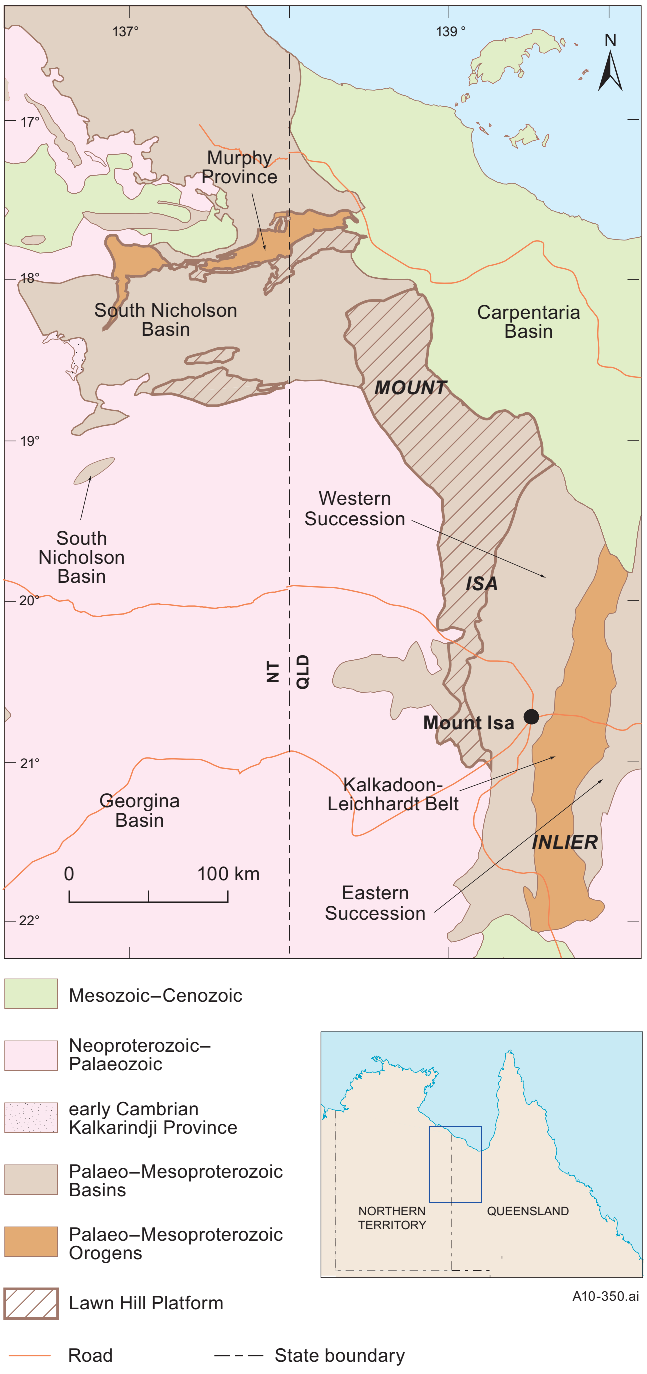

Figure 18.1. Regional geology of Lawn Hill Platform. NT geological regions from NTGS 1:2.5M geological regions GIS dataset; some small outliers/inliers omitted. Queensland geological regions simplified and slightly modified from Denaro and Dhnaram (2009) and Geoscience Australia (GA) Geological Regions National Geoscience Dataset.

[1] Names of 1:250 000 and 1:100 000 mapsheets are shown in large and small capital letters respectively, eg MOUNT DRUMMOND, CLEANSKIN.

Wire Creek Sandstone

The basal Wire Creek Sandstone (Sweet 1981) unconformably overlies igneous and metamorphic rocks of the Murphy Inlier and is probably conformably overlain by the Peters Creek Volcanics. It forms a narrow outcrop tract along the southeastern margin of the Murphy Inlier extending eastward into WESTMORELAND in Queensland. The succession is up to 70 m-thick and comprises commonly cross-bedded, medium to coarse sandstone with scattered pebbles, mostly of vein quartz and volcanic rocks. Lenticular conglomerate beds with clasts up to 30 cm in size are common. A 2–3 m-thick bed of conglomerate is often developed at the base. The Wire Creek Sandstone is correlated with the Westmoreland Conglomerate at the base of the Tawallah Group (McArthur Basin). Both formations were deposited under fluvial braided river and alluvial fan conditions. The Wire Creek Sandstone also possibly correlates with the Don Creek Sandstone at the base of the Carrara Range Group in the southern Lawn Hill Platform area. Wygralak *et al* (2009) and Hollis *et al* (2010) provided geochronological data on detrital zircons from the formation. There are several significant age peaks at ca 2510, 1950, 1900, and 1850 Ma. The youngest population at 1847 ± 13 Ma is regarded as a maximum depositional age. These youngest zircons were probably derived from the Nicholson Granite Complex/Cliffdale Volcanics, which unconformably underlie the unit.

Peters Creek Volcanics

Minor exposures of the Peters Creek Volcanics are present in the southwestern corner of CALVERT HILLS near the Queensland–NT border, where they probably conformably overlie the Wire Creek Sandstone (Ahmad and Wygralak 1989, **Figure 18.3**). A more complete succession has been mapped in WESTMORELAND in adjoining Queensland, where the Peters Creek Volcanics are exposed in a 10 km-wide, 50 km-long belt. Together with the Wire Creek Sandstone, this succession is considered to be equivalent to the whole of the Tawallah Group. The Peters Creek Volcanics has been divided into eight units with a combined thickness of about 2 km. These comprise basalt, rhyolite, rhyodacite, tuff, shale, siltstone, dolostone and conglomerate. Only the two lowermost units are exposed in the Northern Territory. The lower part of the Peters Creek Volcanics includes vesicular and massive basaltic lavas with fine to medium sandstone interbeds and is probably equivalent to the Seigal Volcanics of the Tawallah Group (Sweet *et al* 1981). Zircons from units 2 and 7 of the Peters Creek Volcanics have been dated by the SHRIMP U-Pb method at 1726 ± 2 Ma and 1724 ± 2 Ma, respectively (Page and Sweet 1998).

Fickling Group

The Fickling Group (Fickling beds of Carter 1959) outcrops along much of the southern margin of the Murphy Inlier and in the Bauhinia Dome (**Figure 18.3**). It comprises a succession of sandstone, dolostone, siltstone and shale, and is correlated with the McNamara Group of the Lawn Hill Platform to the south and with the McArthur Group of the McArthur Basin to the north.

The lowermost *Fish River Formation* is discontinuously exposed along the edge of the Murphy Inlier and comprises mainly sandstone with conglomerate lenses. It varies in thickness from between 10–20 Ma to greater than 200 m

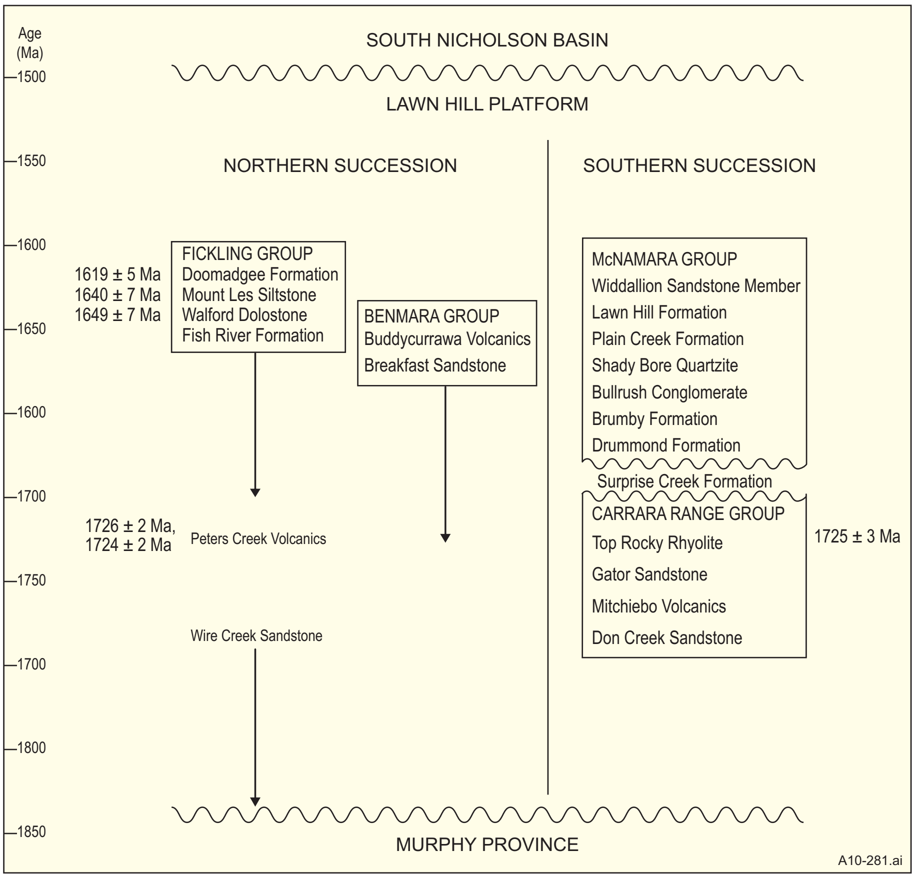

Figure 18.2. Diagrammatic correlation diagram of Lawn Hill Platform succession north and south of South Nicholson Basin and Benmarra area (constructed from Ahmad and Wygralak 1989 and Rawlings *et al* 2008).

in the Northern Territory, and reaches about 250 m in the type section in WESTMORELAND. The medium-grained quartz-rich sandstone contains ripple marks, mud cracks and herringbone cross-strata, and was deposited in a shallow-marine to tidal-flat environment of deposition, with the conglomerate suggesting a fluvial influence. Conglomerate clasts were derived from the Wire Creek Sandstone, Peters Creek Volcanics and possibly the Cliffdale Volcanics (Ahmad and Wygralak 1989). Detrital zircons from the Fish River Formation suggest a maximum depositional age of about 1770 Ma (Page *et al* 2000).

The conformably overlying *Walford Dolostone* ranges from about 250 m to 400 m thick (Sweet *et al* 1981) and forms a series of disconnected outcrops south of the Murphy Inlier. It consists of oolitic, stromatolitic and intraclastic dolostone with minor black shale and dolomitic glauconitic sandstone and is commonly silicified at the surface. The formation was deposited in shallow-marine sub- to supratidal environment (Ahmad and Wygralak 1989). Zircons from a tuffaceous bed within the Walford Dolostone have been dated by SHRIMP U-Pb method at 1649 ± 7 Ma (Page *et al* 2000).

The *Mount Les Siltstone* is discontinuously exposed in southeastern CALVERT HILLS and outcrops continue for about 30 km eastward into Queensland. It conformably overlies the Walford Dolostone and is disconformably overlain by the Doomadgee Formation. The formation consists of dolostone, siltstone, shale and minor interbeds of flaggy dolostone with gypsum and pyrite pseudomorphs. These indicate evaporitic conditions in a supratidal environment (Ahmad and Wygralak 1989). Zircons from the tuffaceous bed have been dated by the

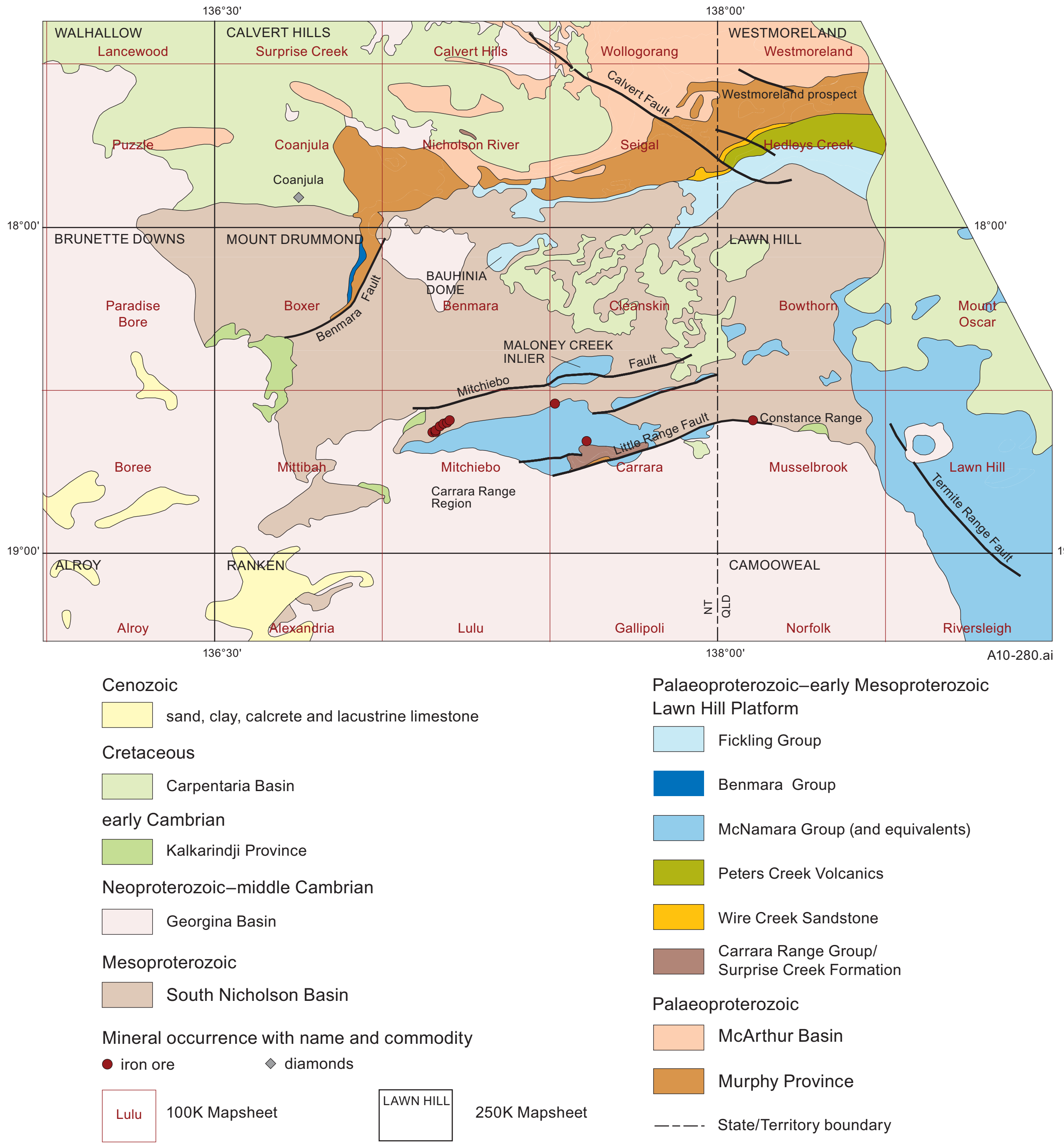

Figure 18.3. Simplified regional geology of the Lawn Hill Platform (modified from Rawlings *et al* 2008, figure 3).

SHRIMP U-Pb method at 1640 ± 7 Ma (Page and Sweet 1998, Page *et al* 2000).

The *Doomadgee Formation* disconformably overlies the Mount Les Siltstone and is unconformably overlain by the South Nicholson Group of the South Nicholson Basin. It occupies much of the southeastern corner of CALVERT HILLS and also outcrops extensively to the east in Queensland. It is about 400 m thick in the type section in WESTMORELAND (Sweet and Slater 1975). The formation consists of conglomerate, sandstone, siltstone, shale and dolostone that Rawlings *et al* (2008) described as being arranged in upward-coarsening cycles from shale to sandstone, punctuated by dolostone intervals. A variety of sedimentary structures, including abundant cross-lamination, parallel lamination, small wave ripples, trough cross-beds, hummocky cross-stratification, parting lineations, tool marks, flute, gutter and load casts (**Figure 18.4)**, and synaeresis cracks, are present and indicate deposition in a heterogeneous sedimentary environment. Rawlings *et al* (2008) interpreted that the unit represents repeated episodes of progradation across a storm-dominated shelf, culminating with shallow-water, probably intertidal sands and carbonate sediments. SHRIMP dating of detrital zircons from the Doomadgee Formation have yielded a maximum depositional age of 1619 ± 5 Ma (Page *et al* 2000).

Benmara Group

Outcrop of the Benmara Group is restricted to a northeast-trending belt in northwestern MOUNT DRUMMOND, where it unconformably overlies the Murphy Metamorphics and Connellys Volcanics of the Murphy Province. The upper contact with the South Nicholson Group is poorly exposed and may be either an unconformity or a low-angle structural (detachment) boundary (Rawlings *et al* 2008). The group includes a basal sandstone (Breakfast Sandstone) conformably overlain by a recessive interval containing a trachyte sheet and various clastic rocks (Buddycurrawa Volcanics).

The *Breakfast Sandstone* (**Table 18.1**) is a resistant, white to maroon or pink, medium to thickly bedded, medium- to coarse-grained, silicified sublithic sandstone, up to 80 m thick. The basal few metres, above the unconformity, contain abundant quartz pebbles and lesser cobbles. The unit fines upwards, and has small-scale (decimetre-wavelength) trough cross-beds, planar bedding, symmetric ripples, desiccation cracks, mudclasts, and current lineations. It also contains rare laminae or thin beds of chertified mudstone and chertified carbonate with relict domical stromatolites. Rawlings *et al* (2008) interpreted the depositional setting to have been moderate- to high-energy braided fluvial and/or shallow marine.

Unit / Thickness / Age	Lithology	Depositional environment	Stratigraphic relationships
Fickling Group			
Doomadgee Formation 200–250 m 1619 ± 5 Ma 1613 ± 5 Ma	Shale, flaggy dolomitic, micaceous, fine sandstone and siltstone, fine-grained sublithic sandstone, and medium to coarse sandstone with scattered granules and pebbles; minor lithic sandstone.	Marine shelf, ranging from basinal, through storm-dominated shoreface to shallow peritidal environments.	Base not seen, but conformable on Mount Les Siltstone to the north in Seigal. Overlain disconformably and with low-angle unconformity by South Nicholson Group
Mount Less Siltstone <90 m 1640 ± 7 Ma	Dolostone, siltstone and shale	Evaporitic supratidal	Disconformably overlain by Doomadgee Formation
Walford Dolostone <400 m 1649 ± 7 Ma	Oolitic, stromatolitic and intraclastic dolostone with interbeds of black shale and glauconitic sandstone	Shallow marine sub- to supratidal	Conformably overlain by Mount Less Siltstone
Fish River Formation 200 m <1770 Ma	Sandstone, siltstone and conglomerate	Fluvial to shallow marine tidal flat	Conformably overlain by the Walford Dolostone
Benmara Group			
Buddycurrawa Volcanics up to 300 m	Ferruginous coarse sandstone, massive and brecciated trachyte, poorly sorted immature lithic sandstone and pebble conglomerate, mature sandstone, ferruginous siltstone and fine sandstone; minor stromatolitic chert	Braided fluvial, shallow lacustrine and/or marine (fine intervals); lava flows; marginal ephemeral alluvial and debris flows (coarse intervals)	Conformable on Breakfast Sandstone; probably unconformably overlain by Bowgan Sandstone and Crow Formation
Breakfast Sandstone up to 80 m	Medium to coarse, silicified sublithic sandstone; thin basal pebble or cobble conglomerate; rare chertified stromatolitic carbonate	Braided fluvial and/or shallow marine	Unconformable on Murphy Metamorphics; conformably overlain by Buddycurrawa Volcanics
Unassigned to group			
Peters Creek Volcanics <2000 m	Vesicular basalt, rhyolite, rhyodacite; interbeds of feldspathic and glauconitic sandstone, shale, siltstone and dolostone	Subaerial to shallow marine	Conformable on Wire Creek Sandstone; angular unconformity with overlying Fish River Formation
Wire Creek Sandstone <70 m	Medium to coarse sandstone with scattered pebbles, conglomerate	Braided rivers and alluvial fans	Unconformable on Murphy Province rocks; conformably overlain by Peters Creek Volcanics

Table 18.1. Stratigraphic succession of northern Lawn Hill Platform along southern margin of Murphy Inlier, constructed from Ahmad and Wygralak (1989) and Rawlings *et al* (2008). Chronometric dates are from Page *et al* (2000).

The *Buddycurrawa Volcanics* reaches a thickness of about 300 m and consists of a basal ferruginous sandstone unit, overlain by a mixed interval of coherent trachyte, debris flow sandstone and conglomerate (**Figure 18.5**), mature sandstone, ferruginous siltstone/fine sandstone and minor stromatolitic chert (**Figure 18.6**). Rawlings *et al* (2008) interpreted a variety of depositional settings for the unit: the basal sandstone was shallow supratidal or fluvial; the trachyte was probably emplaced as lava flows with peripheral zones of peperite, where these intermingled with wet unconsolidated sediments; the debris flow sandstone was probably rapidly deposited as fluvially modified talus and debris aprons at the margins of trachyte lava bodies, during and immediately following their emplacement; other siliciclastic facies were deposited in fluvial or lacustrine settings; and the stromatolitic chert intervals are indicative of shallow, intertidal, marine depositional conditions.

The Breakfast Sandstone and Buddycurrawa Volcanics are tentatively correlated with the Shady Bore Quartzite (ca 1640 Ma) and Plain Creek Formation, respectively, of the McNamara Group (Rawlings *et al* 2008), but there is no geochronological evidence to support this. The presence of the volcanics implies an alternative possible correlation with the Peters Creek Volcanics and therefore, an age of ca 1725 Ma (Rawlings *et al* 2008). However the Buddycurrawa Volcanics are geochemically distinct from the Peters Creek Volcanics and have affinities with alkaline volcanics and shallow intrusive rocks from the Coanjula microdiamond prospect, about 20 km to the north (**Figure 18.3**), which are probably no older than ca 1665 Ma (Rawlings *et al* 2008).

Southern successions

The southern successions of the Lawn Hill Platform comprise the Carrara Range and McNamara groups, which correspond to the Ᵽ6 and Ᵽ7 divisions, respectively, of Ahmad (2000). The various elements of the Lawn Hill Platform in the southern succession are summarised in **Table 18.2**. The McNamara Group ranges in age from about 1690 Ma to 1595 Ma (Page *et al* 2000).

Figure 18.4. Load casts in flaggy facies (laminated to thinly interbedded siltstone and fine sandstone) in uppermost Doomadgee Formation. CLEANSKIN, 53K 803900mE 8002600mN, 14 km west of NT/Queensland border (after Rawlings *et al* 2008).

Carrara Range Group

The Carrara Range Group constitutes a succession of sandstone and bimodal volcanics unconformably overlying the Murphy Province succession. It is unconformably overlain by the Surprise Creek Formation and by the McNamara Group (**Table 18.2**). Sweet (1984) suggested that the Carrara Range Group is a correlative of the Peters Creek Volcanics in the eastern Murphy Inlier, and this has been confirmed on geochronological evidence by Page *et al* (2000).

The *Don Creek Sandstone,* the basal unit of the group, is unconformable on the Murphy Metamorphics, although the contact is not exposed, and is conformably overlain by the Mitchiebo Volcanics. It has been correlated with the Westmoreland Conglomerate and Yiyintyi Sandstone in the southern McArthur Basin (Ahmad and Wygralak 1989, Haines *et al* 1993). The unit comprises lithic to quartzic sandstone with pebbles or cobbles and rare conglomerate. Bedding is thick and trough cross-bedded, and beds typically coarsen upward from pebble-free sandstone to pebble/cobble-rich sandstone (**Figure 18.7**), although there is an overall upward stratigraphic trend towards finer grain size and a more lithic composition. However, cyclicity on a 10–50 m scale is also evident. These characteristics indicate

Figure 18.5. Debris-flow facies of Buddycurrawa Volcanics, comprising brown, massive to crudely bedded, poorly-sorted, coarse-grained, pebbly lithic sandstone with a distinct volcanic provenance. BOXER, 53K 703250mE 7991350mN, Whiterock Creek (after Rawlings *et al* 2008).

Figure 18.6. Chertified carbonate of Buddycurrawa Volcanics with well preserved digitate stromatolites. BOXER, 53K 702600mE 7992150mN, Whiterock Creek (after Rawlings *et al* 2008).

that the Don Creek Sandstone was probably deposited in a braided fluvial environment (Rawlings *et al* 2008).

The *Mitchiebo Volcanics* is generally conformable between the Don Creek and Gator sandstones, or is locally unconformable beneath the Surprise Creek Formation. The unit is 500–1000 m thick and is composed of massive to vesicular or microvesicular basalt and microdolerite, with interbeds of sandstone, mudstone and peperite (**Figure 18.8**). Rawlings *et al* (2008) interpreted that the basalt was probably emplaced as a series of lava flows and shallow invasive flows in a subaerial to shallow-water lacustrine setting. The Mitchiebo Volcanics is lithologically and geochemically indistinguishable from the Seigal Volcanics of the McArthur Basin, and has been correlated with this unit and with the Eastern Creek Volcanics and Buddawadda Basalt of the Mount Isa Inlier (Rawlings *et al* 2008).

The conformably overlying *Gator Sandstone* was defined by Rawlings *et al* (2008) to incorporate what was formerly mapped by Sweet *et al* (1984) as the 'upper sandstone member' of the Mitchiebo Volcanics. The formation ranges in thickness from 100 to 700 m, with a gradual increase from east to west. In the type section, in MOUNT DRUMMOND, the unit comprises lower and upper sandstone subunits separated by a thin recessive volcanic interval. In other areas, the volcanic interval is absent and

Unit / Thickness / Age	Lithology	Depositional environment	Stratigraphic relationships
McNamara Group			
Widdallion Sandstone Member (of Lawn Hill Formation) 50–370 m	Grey-red to brown, purple-weathering, highly lithic and micaceous fine to coarse sandstone; minor glauconite; siltstone and claystone	Inner shelf–high-energy shoreface environment	Conformable on lower Lawn Hill Formation; overlain disconformably or locally with angular unconformity by South Nicholson Group
Lawn Hill Formation (excluding Widdallion Sandstone Member) 125–2600 m	Interlaminated and thinly interbedded red, grey and brown siltstone and fine-grained sandstone; green to grey shale and siltstone, dolomitic siltstone, laminated and intraclastic dolostone	Storm-dominated shelf	Conformable on Plain Creek Formation; overlain disconformably or locally with angular unconformity by South Nicholson Group
Plain Creek Formation 400–1000 m	Micaceous siltstone and shale, fine to coarse lithic and sublithic sandstone; minor pebble conglomerate, graded sandstone beds, and pebble- to boulder-bearing mudstone – turbidite and mass flow sedimentary rocks	Shallow- to deep-marine basin, including fan deltas; locally emergent to shoreface	Lower and upper contacts are concordant and conformable
Shady Bore Quartzite up to 50 m	White, very fine to medium lithic and sublithic sandstone; prominently wave-rippled bedding surfaces	Shallow marine	Conformable on Brumby Formation; overlain conformably by Plain Creek Formation
Bullrush Conglomerate 50–500 m	Polymictic granule, pebble and cobble conglomerate, cross-bedded sandstone; stromatolitic chert and chert-clast conglomerate, fine-grained lithic sandstone and siltstone	Alluvial fan to fan delta	Unconformable on Top Rocky Rhyolite and Drummond Formation; conformably overlain by Plain Creek Formation
Brumby Formation 350–800 m	Interbedded fine to medium, rarer coarse to granule sandstone; laminated, brecciated and stromatolitic chert; chert-clast breccia and conglomerate with sandstone matrix; siltstone and shale dominate upper part	Intertidal to supratidal, including sabkha; deeper shelf in upper part	Lower and upper contacts are concordant and conformable
Drummond Formation 350–600 m	Dominated by sandstone, but includes minor polymictic conglomerate, chert, siltstone, claystone and dolomitic rock	Shallow marine, from shoreface to intertidal; peritidal mud- and carbonate-flats, and fluvial	Unconformable on Surprise Creek Formation; overlain conformably by Brumby Formation, and unconformably by Bullrush Conglomerate in Maloney Creek area
Unassigned to group			
Surprise Creek Formation 300–450 m	Local pebble to boulder conglomerate at base; remainder is thickly to very thickly bedded, medium to coarse sublithic to quartz sandstone	Mainly braided fluvial, with local alluvial fan deposits at base	Unconformable on Top Rocky Rhyolite, and locally on older formations of Carrara Range Group; unconformably overlain by Drummond Sandstone (McNamara Group)
Carrara Range Group			
Top Rocky Rhyolite up to 400 m 1725 ± 3 Ma	Lower: porphyritic (K-feldspar, quartz), massive to flow banded, spherulitic to microgranophyric rhyolite; local autobreccia, peperite and hyaloclastite. Upper: poorly sorted, matrix-supported, pebble to boulder conglomerate	Moderate-aspect-ratio lava flow(s); marginal ephemeral alluvial and debris flows	Unconformable on Gator Sandstone; unconformably overlain by Surprise Creek Formation and locally, by Bullrush Conglomerate
Gator Sandstone up to 700 m	Pink to purple, fine to medium, variably ferruginous, sublithic to lithic sandstone with local beds of very coarse and pebbly sandstone; minor basalt and microdolerite	Braided fluvial with sporadic intertidal marine inundation and mafic lava flows	Conformable on Mitchiebo Volcanics; unconformably overlain by Top Rocky Rhyolite
Mitchiebo Volcanics 500–1000 m	Weathered and/or altered, massive to vesicular or microvesicular basalt and microdolerite; lesser sandstone, mudstone and peperite	Subaerial lava flows and invasive flows	Conformable between Don Creek Sandstone and Gator Sandstone
Don Creek Sandstone 400–500 m	Silicified to friable, medium ± coarse, locally pebbly lithic to quartzic sandstone	Braided fluvial	Unconformable on Murphy Metamorphics; conformably overlain by Mitchiebo Volcanics

Table 18.2. Stratigraphic succession of southern Lawn Hill Platform in Carrara Range region (slightly modified after Rawlings *et al* 2008). Chronometric dates are from Page *et al* (2000).

the formation is a homogeneous sandstone throughout. In the type section, the 25 m-thick lower sandstone interval comprises fine- to medium-grained, medium to very thickly bedded sublithic sandstone, with local beds of coarse, very coarse and granule sandstone, planar bedding and low-angle planar cross-beds. The overlying, 20 m-thick recessive (volcanic) interval contains vesicular basalt and a laminated, lithic sandy mudstone (?volcaniclastic sandstone). The 100–150 m-thick upper sandstone interval is composed of thickly to very thickly bedded, medium- to very coarse-grained sublithic sandstone, with low-angle trough cross-beds, planar bedding, parallel laminations and lesser, large-scale planar cross-beds. Rawlings *et al* (2008) interpreted that the sandstones were deposited in a braided fluvial environment, with sporadic supratidal marine inundation and mafic volcanism.

Figure 18.7. Thick-bedded quartzic sandstone of Don Creek Sandstone, containing stacked, decimetre-scale, trough cross-bed sets and scattered quartz pebbles. CARRARA, 53K 783700mE 7929550mN, Boomerang Creek (after Rawlings *et al* 2008).

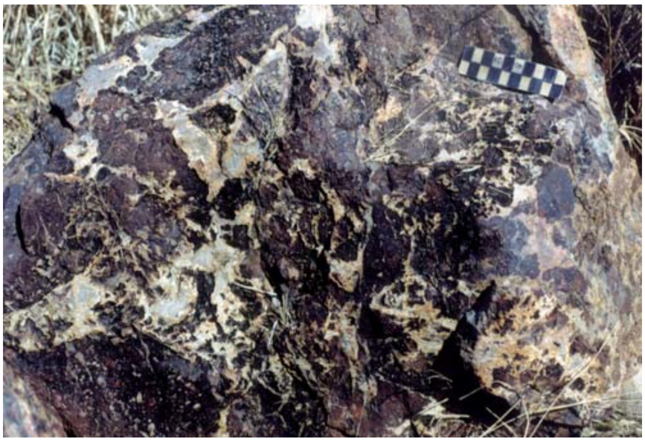

Figure 18.8. Peperite breccia in Mitchiebo Volcanics, comprising blocky to lobate vesicular basalt clasts in pale silicified red mud ± sand matrix. CARRARA, 53K 783600mE 7931100mN, Boomerang Creek (after Rawlings *et al* 2008).

Figure 18.9. Lithophysae within massive Top Rocky Rhyolite. These spherical devitrification features are up to 10 cm in diameter and form during rapid cooling of glassy felsic magmas. CARRARA, 53K 772100mE 7925900mN, Fish Hole Creek (after Rawlings *et al* 2008).

The *Top Rocky Rhyolite* unconformably overlies the Gator Sandstone and locally, the Mitchiebo Volcanics, in places where the base of the rhyolite has cut down hundreds of metres through the underlying sandstone along strike (Sweet 1983). The unit is up to 400 m thick and is unconformably overlain by the Surprise Creek Formation. It comprises a lower interval of coherent rhyolite, overlain by a conglomerate interval. The lower rhyolite interval forms bouldery to blocky outcrop of hard, silicified or crumbly, weathered pink, purple or orange porphyritic rhyolite (**Figures 18.9–18.11**), which typically contains euhedral to subhedral K-feldspar and quartz phenocrysts in a cryptocrystalline quartzofeldspathic groundmass. A SHRIMP U-Pb zircon date of 1725 ± 3 Ma has been obtained for this rhyolite (Page *et al* 2000). The conglomerate unit is up to 200 m thick and comprises matrix-supported conglomerate, with subangular to subrounded, locally imbricated clasts set in a pink lithic gravel-sand-mud matrix (Rawling *et al* 2008). At stratigraphically lower levels of the conglomerate, clasts are composed almost entirely of rhyolite-derived material (**Figure 18.12**), whereas at higher levels, the conglomerate becomes more polymictic and large silicified sandstone clasts occur. In general, the conglomerate is crudely horizontally stratified and ungraded, but there are local intervals of trough cross-bedded or planar bedded, medium to coarse lithic sandstone infilling palaeochannels and as sheets. Rawlings *et al* (2008) proposed that the Top Rocky Rhyolite was rapidly erupted as a single or composite lava dome that developed into a widespread lava sheet. Conglomerate formed at the margins of the flow, during and soon after emplacement, under the influence of sporadic and large-scale flood events.

Surprise Creek Formation

The *Surprise Creek Formation* is widespread in the Mount Isa region, where it is overlain by the Mount Isa and McNamara groups either conformably or with minor disconformity (**Table 18.2**). It was mapped by Sweet (1984) as a part of the now-obsolete Musselbrook Formation, but was subsequently distinguished as a separate unit by Rawlings *et al* (2008). The stratigraphic position of the formation is considered to be between the Carrara Range and McNamara groups. It overlies progressively older formations of the Carrara Range Group from east to west with a regional angular unconformity (Sweet 1984). The formation is up to 450 m thick and comprises basal lenses and beds of pebble to boulder conglomerate (**Figure 18.13**), intertonguing with and overlain by sublithic to quartz sandstone (**Figure 18.14**). The conglomerate ranges up to 200 m in thickness and consists mainly of sub-rounded to well rounded pebbles and cobbles, and scattered boulders of quartz, pink quartzite and quartz sandstone, set in a matrix of coarse-grained to granule lithic sandstone. The remainder of the Surprise Creek Formation consists mostly of white to pink, thickly to very thickly bedded, medium to coarse, sublithic to quartz sandstone with pebbly intervals and rare scattered cobbles. Bedforms include amalgamated small trough cross-beds, planar cross-beds, planar bedding, parallel laminations with current lineations, and hummocky cross-stratification. Rawlings *et al* (2008) interpreted the basal conglomeratic rocks to be proximal deposits of either a braided fluvial or locally an alluvial fan system. The sandstone is probably a more distal braided fluvial deposit, as it appears to grade up from, or intertongues with conglomerate, and forms a continuous sheet.

Figure 18.10. Stacked quartz folia within massive Top Rocky Rhyolite. These centimetre- to decimetre-scale, discontinuous foliated stringers of amorphous quartz are interpreted to have formed by the collapse of vesicles or the central gas cavity of lithophysae. CARRARA, 53K 792050mE 7932800mN, Don Creek (after Rawlings *et al* 2008).

Figure 18.11. Autobreccia of Top Rocky Rhyolite, composed of randomly oriented, centimetre- to decimetre-scale rhyolite clasts with variable internal textures, set in massive to crudely banded rhyolite matrix. CARRARA, 53K 771650mE 7933750mN, Carrara Range (after Rawlings *et al* 2008).

Figure 18.12. Boulder conglomerate of Top Rocky Rhyolite, composed of poorly sorted, subangular to subrounded rhyolite clasts in pink lithic sandstone matrix. CLEANSKIN, 53K 778200mE 7955800mN, Moloney Creek (after Rawlings *et al* 2008).

McNamara Group

The McNamara Group comprises sandstone, conglomerate, siltstone, shale and various carbonate rocks, which are commonly silicified to chert in outcrop. The main outcrops of the group are in LAWN HILL in Queensland, from where the stratigraphic succession was defined (Sweet and Hutton 1982, Hutton *et al* 1981, **Figure 18.2**). In the Northern Territory, the group lies disconformably, or with an angular unconformity on the Surprise Creek Formation, or is locally unconformable on the Top Rocky Rhyolite. Remapping of MOUNT DRUMMOND (Rawlings *et al* 2008) has resulted in significant modification of the older terminology of Smith and Roberts (1963) and Sweet (1984). The former

Figure 18.13 Very thick bed of coarse pebble to cobble conglomerate in the Surprise Creek Formation. CARRARA, 53K 772150mE 7934600mN, headwaters of Rocky Creek (after Rawlings *et al* 2008).

Figure 18.14. Intermediate-scale hummocky cross-stratification in fine-grained sublithic sandstone of Surprise Creek Formation. CARRARA, 53K 792300mE 7933400mN, Carrara Range (after Rawlings *et al* 2008).

Musselbrook Formation has been abandoned and split into the Surprise Creek Formation (which is excluded from the McNamara Group), the Drummond Formation, and an upper unit, the Brumby Formation.

The sandstone-dominated *Drummond Formation* reaches a thickness of 350–600 m. It comprises a variety of rock types that are referred to several informal unnamed units, including a localised, basal thin polymictic conglomerate; thinly to medium bedded, fine lithic sandstone; laminated siltstone; red beds of brown, lithic dolomitic sandstone and chertified dolostone; medium bedded, pyritic coarse sandstone; medium to thickly bedded, fine to medium sublithic to quartzic sandstone; minor chert; laminated kaolinised and chertified claystone (altered carbonate rocks?); fine ferruginous sandstone, siltstone, and stromatolitic chert; and fine sublithic siltstone and sandstone. The formation contains a variety of distinctive sedimentological features, including stromatolites, cauliflower chert, hummocky cross-stratification, mudclasts, wave and current ripple marks, herringbone cross-strata, parallel laminations, planar bedding, trough cross-beds, lenticular bedding, flute and tool marks, gutter casts and rare load casts. These characteristics indicate that the Drummond Formation was deposited in a range of environments, including shallow marine, shoreface to intertidal to peritidal mud- and carbonate flats (sabkha), and fluvial, and suggest that the formation was built up as a succession of prograding cycles across a shallow-marine shelf, culminating in largely supratidal environments (Rawlings *et al* 2008).

The *Brumby Formation* conformably overlies the Drummond Formation and ranges from about 350 to 800 m in thickness. It consists of siltstone, shale, sandstone and granule conglomerate, laminated and stromatolitic chert, dolostone, and chert-clast conglomerate and breccia, with the finer lithologies becoming more abundant up-section. Sandstones are more thinly bedded and finer grained than those in the Drummond Formation and are commonly planar or trough cross-bedded. Other sedimentary structures include sinuous-crested asymmetric ripples, pseudomorphs after gypsum, and sedimentary chert breccia and conglomerate. Rawlings *et al* (2008) interpreted the mixed siliciclastic/carbonate/chert association that characterises the lower Brumby Formation as representing a carbonate ramp environment; a proximal position relative to the sediment source is indicated by the high proportion of siliciclastic material in this part of the succession. Repeated episodes of exposure and silicification, followed by erosion and renewed inundation, indicate that the depositional environment was very shallow water, probably intertidal and supratidal. Rawlings *et al* interpreted the upper Brumby Formation, which is dominated by fine-grained rocks, to be more representative of deeper water (shelf) environments.

Figure 18.15. Alternating mudstone and sandstone beds in Plain Creek Formation. Recessive beds are laminated to thinly interbedded shale, siltstone and very fine sandstone; white to grey, well indurated beds are very fine to fine sandstone with hummocky cross-stratification. CLEANSKIN, 53K 814800mE 7956420mN, headwaters of Right Creek, 2 km west of NT/Queensland border (after Rawlings *et al* 2008).

The 40–50 m-thick *Shady Bore Quartzite* conformably overlies the Brumby Formation and has a conformable and transitional upper contact with the Plain Creek Formation. It consists of white, thinly to thickly bedded, fine- and medium-grained lithic and sublithic sandstone, and features cross-beds and prominent wave ripple marks on bedding surfaces. Rawlings *et al* (2008) interpreted the Shady Bore Quartzite to have been deposited under a wave-dominated marine shoreline environment in a series of upward-shallowing cycles.

The Brumby Formation is absent from the Maloney Creek Inlier (**Figure 18.3**), where the *Bullrush Conglomerate* unconformably overlies the Drummond Formation, or locally, the Top Rocky Rhyolite. The Bullrush Conglomerate varies considerably in thickness from about 50 m to 500 m; it is correlated with the Shady Bore Quartzite and is probably conformably overlain by the Plain Creek Formation. The conglomerate comprises polymictic granule, pebble and cobble conglomerate, alternating with cross-bedded sandstone (Sweet 1985). Minor carbonate rocks and siltstone are also present. Conglomerates are massive or crudely planar bedded, trough cross-bedded or graded, and are largely clast supported. Clasts of quartzite or quartz sandstone, quartz, chert, brown porphyritic rhyolite, and claystone (probably altered/weathered dolomitic rocks), and are set in a matrix of lithic sand to granules (Rawlings *et al* 2008). Sandstone is sublithic, white, silicified, medium- to very thickly bedded and fine to very coarse grained, with trough cross-beds and scattered pebbles and cobbles. Other sedimentary structures present in the Bullrush Conglomerate include planar lamination, current lineation,

Figure 18.16. Tool marks and flute casts on base of sandstone bed in Plain Creek Formation, Maloney Creek Inlier. CLEANSKIN, 53K 778120mE 7960770mN, 15 km northeast of Murun Murula (after Rawlings *et al* 2008).

mudclasts, symmetric ripples, and probable hummocky cross-stratification. Rawlings *et al* (2008) considered that the apparent superposition of several contrasting facies types, plus the considerable variation in clast composition between conglomerates in the succession, indicates the rapid erosion of underlying rocks and the deposition of the resultant coarse material as subaerial alluvial fans. These built out into a standing body of marine water, represented by the finer lithologies, leading to an alternation of marine and non-marine environments.

The 400–1000 m-thick *Plain Creek Formation* is conformable on the Shady Bore Quartzite and probably the Bullrush Conglomerate, and is conformably overlain by the Lawn Hill Formation. It is dominantly micaceous siltstone and shale (**Figure 18.15**), but contains several sandstone units. These sediments are arranged in cycles, a few metres thick, of stacked, upward-thickening and -coarsening beds. Sedimentary structures include ripples, hummocky and swaley cross-strata, tool marks and flute casts (**Figure 18.16**), and minor intraclast conglomerates. Thin films and veins of manganese and iron oxides are common throughout the unit. Sweet (1985) and Rawlings *et al* (2008) noted that a variety of facies were represented in the Plain Creek Formation, ranging from locally emergent, to shoreface, to storm-dominated shelf environment, to deeper marine with turbidites and mass flow (slump) deposits, and interpreted a fan delta environment of deposition for the unit. Rapid changes in water depth were possibly due to the presence of small fault-generated sub-basins, into which subaerial fans were building.

The *Lawn Hill Formation* (Sweet 1984) was previously mapped as the Bluff Range beds by Smith and Roberts (1963) and is estimated to range between 125 and 2600 m in thickness, with a northward thinning overall (Rawlings *et al* 2008). It conformably overlies the Plain Creek Formation and is the topmost unit of the McNamara Group. The upper contact of the formation is invariably unconformable; the South Nicholson Group (South Nicholson Basin) overlies the Widdallion Sandstone Member disconformably, or with angular unconformity in most outcrops. Cambrian rocks also truncate both the Lawn Hill and Plain Creek formations in some easterly areas. The formation comprises recessive, interlaminated and thinly interbedded, grey, green and red, variably leached, shale, siltstone, very fine-grained sandstone, dolostone and dolomitic siltstone. These sediments were deposited in a marine shelf environment, mainly below wave-base, although the interbedded sandstone indicates some slightly higher-energy conditions above wave base, consistent with storm influence (Rawlings *et al* 2008). The distinctive ridge-forming *Widdallion Sandstone Member*, at the top of the Lawn Hill Formation, is up to 370 m thick, and consists of lithic and micaceous, fine-, medium- and, less commonly, coarse-grained sandstone. Beds are medium to very thick and are commonly arranged in cycles from 5 to 20 m thick; cycles typically become coarser, better sorted, slightly less lithic and lighter coloured upwards (Rawlings *et al* 2008). Sedimentary structures include large low-angle cross-beds, trough cross-beds, wave and interference ripple marks, primary current lineations and rare hummocky cross-strata. The character of the sedimentary cycles and sedimentary structures in the Widdallion Sandstone Member are indicative of repeated progradational episodes in a high-energy shoreface environment. The highly lithic nature of the sandstone suggests that sedimentation was rapid and was derived from an actively uplifting source terrain (Rawlings *et al* 2008).

MINERAL RESOURCES

Other than a few minor iron ore occurrences in the southern succession in MOUNT DRUMMOND, there are no significant mineral occurrences or prospects within the Northern Territory portion of the Lawn Hill Platform succession. However, the World-class Century Zn-Pb-Ag deposit, occurs within rocks of the upper McNamara Group, 60 km to the east of the Queensland–Northern Territory border (Broadbent *et al* 1998, Hobbs *et al* 2000). The host succession for this orebody, comprising carbonate rocks, sandstone and shale of the Lawn Hill Formation, extends westward into the Northern Territory and should be considered prospective. Also in Queensland, the large low-grade pyrite-rich Walford Creek (Rohrlach *et al* 1998) and Bluebush (Maier and McGoldrick 2009) stratiform Pb-Zn prospects are hosted in a narrow east-trending belt of Fickling Group rocks exposed at the faulted northern margin of the Lawn Hill Platform. By analogy, the Lawn Hill Platform in the NT has potential for both Century and Mount Isa-McArthur River-style deposits (Rawlings *et al* 2008). It contains a reduced fine-grained, mixed carbonate-siliciclastic package similar to the McArthur Group. It is underlain by the Carrara Range Group which includes a thick oxidised sandstone package with intervals of mafic and felsic volcanic rocks. This group is equivalent to the Tawallah Group and could have acted as a source for the metalliferous brines in direct analogy to the McArthur River deposit.

Surficial manganese is locally developed in the region and is particularly common as a weathering crust on the Plain Creek Formation. Although the economic significance of the manganese occurrences has not been properly assessed by drilling, it is unlikely to extend deep into the host rock (Ferenczi 2001).

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