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Chapter 19: South Nicholson Basin

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Chapter 19: SOUTH NICHOLSON BASIN

M Ahmad and TJ Munson

INTRODUCTION

The South Nicholson Basin (Smith and Roberts 1963, Sweet *et al* 1981) represents a succession of predominantly sandstone and siltstone in an up to 50 km-wide and 200 km-long, east-trending belt outcropping to the south of the Murphy Inlier (Murphy Province). This succession has moderate to near horizontal dips and is little deformed. It has a total thickness of about 7 km (Rawlings *et al* 2008), unconformably overlies rocks of the Murphy Province and Lawn Hill Platform in western Queensland and the eastern Northern Territory, and has been correlated with the Roper Group in the McArthur Basin (Plumb *et al* 1990). Subsurface, the South Nicholson Basin succession extends southward to the west of the Mount Isa Inlier beneath covering strata of the Georgina Basin. It was intersected in NTGS drillholes NTGS00/1 and NTGS01/1 in southern RANKEN[1] (Kruse 2003) and Shergold and Druce (1980) speculated that it might continue beyond 22°S as far south as TOBERMORY and adjacent GLENORMISTON (Queensland).

Rawlings *et al* (2008) have redefined the various units of the South Nicholson Basin and this publication follows their terminology. The stratigraphic succession is given in **Table 19.1** and the general geological setting is given in **Figures 19.1** and **19.2**. The South Nicholson Basin succession corresponds to the Ᵽ9 division of Ahmad (2000).

LATE PALAEOPROTEROZOIC OR MESOPROTEROZOIC

Unassigned to group

Caulfield beds

The Caulfield beds outcrops in a relatively small area in the central north of the South Nicholson Basin (**Figure 19.2**). It was formerly mapped as a part of the Fickling Group of the Lawn Hill Platform by Smith and Roberts (1963), but was distinguished as a separate unit by Rawlings *et al* (2008). The formation is flat lying to gently dipping and is not metamorphosed or significantly deformed. The basal relationships of the unit with underlying strata are unknown, as contacts are not exposed. It is unconformably overlain by the Constance Sandstone of the South Nicholson Group with only minor discordance. The Caulfield beds (**Figure 19.3**) has a cumulative thickness of at least 600 m and the unit has been informally divided into lower and upper parts. The lower part is at least 500 m thick and comprises coarse lithic sandstone and conglomerate with minor intercalated carbonate rocks and siltstone. Coarser beds generally lack internal stratification, whereas finer beds feature small- to medium-scale trough cross-beds, planar bedding, parting lineations and interference ripples. Clasts within the conglomerate are subrounded, up to 40 cm in diameter, and are consistent with a sedimentary and low-grade metamorphic-felsic igneous provenance. The upper part of the formation is approximately 100 m thick and consists of interlayered 10–30 m-thick units of sandstone, chert and siltstone (Rawlings *et al* 2008). The main sources of siliciclastic material were the Murphy Metamorphics, Nicholson Granite Complex and Cliffdale Volcanics

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

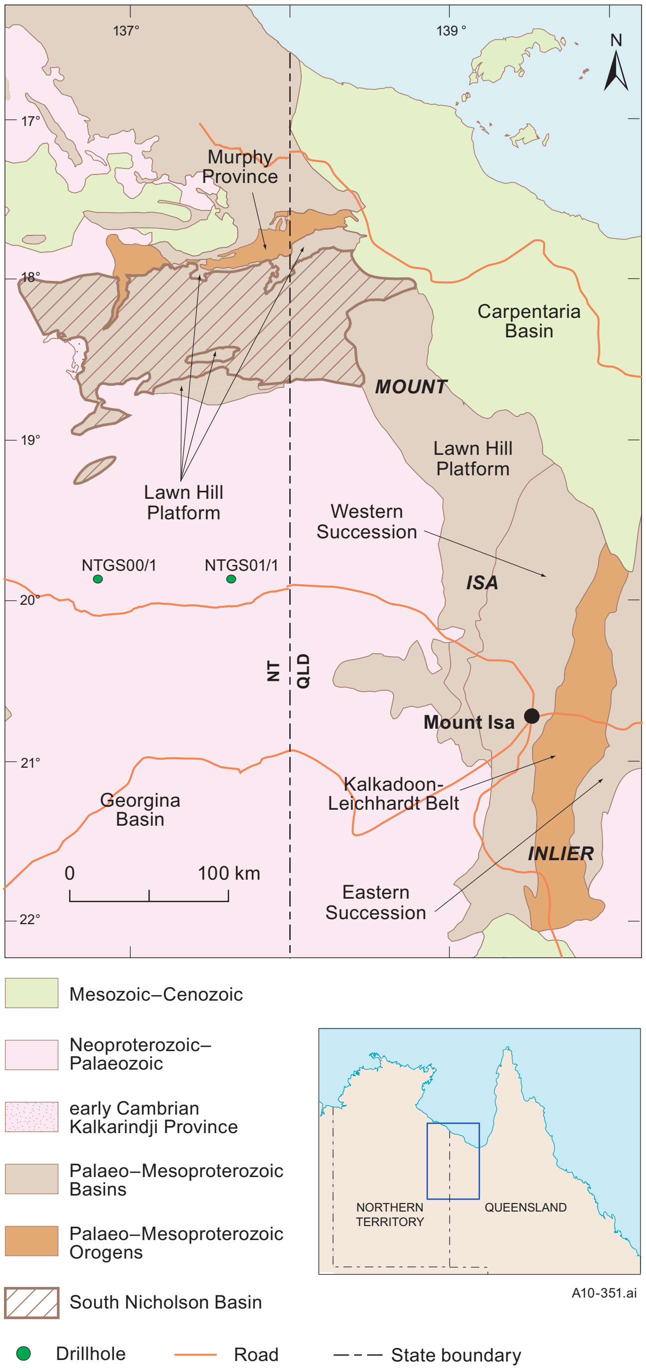

Figure 19.1. Regional setting of the South Nicholson Basin. NT geological regions from NTGS 1:2.5M geological regions GIS dataset; some small outliers/inliers omitted. Queensland geological regions simplified and slightly modified from Denaro and Dhnaram (2009) and Geoscience Australia (GA) Geological Regions National Geoscience Dataset.

Unit, thickness	Lithology	Depositional environment	Stratigraphic relationships
South Nicholson Group			
Accident Subgroup			
Mullera Formation >1100 m (includes Middle Creek Sandstone Member)	Micaceous, locally ferruginous siltstone, shale and lithic to quartzic fine sandstone; minor ironstone, organic-rich shale and medium quartzic sandstone.	Shallow-marine shelf, partly above storm wave-base ('tempestite facies') and partly below ('organic' and 'shale-rich facies').	Conformable on Constance Sandstone; top not exposed, but unconformably overlain by Georgina Basin.
Middle Creek Sandstone Member up to 70 m	Silicified, fine ± medium, sublithic glauconitic sandstone with distinctive decimetre-scale amalgamated trough cross-beds defined by haematite dustings on foresets.	Shallow-marine intertidal and shoreface, above fair-weather wave base.	Conformable within Mullera Formation.
Constance Sandstone 75–1100 m; subdivided into five members			
Schultz Sandstone Member 120–600+ m	Friable, medium, coarse and very coarse to granule sandstone; thick intercalated unit of platy, thinly laminated, very fine sandstone.	Shallow marine: upper shoreface to intertidal; may include braided fluvial.	Disconformable on Wallis Siltstone Member; overlain conformably by Mullera Formation.
Wallis Siltstone Member 0–200 m	Green-brown-weathering, laminated very fine to fine sandstone with micaceous partings; minor siltstone and shale; interbed of white, well sorted, coarse to very coarse quartz sandstone with large mudstone intraclasts.	Deeper marine: lower shoreface and storm-dominated shelf.	Conformable on Burangoo Sandstone Member; overlain disconformably, and locally with subtle angular unconformity by Schultz Sandstone Member.
Burangoo Sandstone Member 35–150 m	Silicified to friable, fine to coarse, quartzic to sublithic sandstone with minor scattered granules and rare small quartz pebbles.	Shallow marine: upper shoreface to intertidal; may include braided fluvial.	Conformable between Pandanus and Wallis Siltstone members.
Pandanus Siltstone Member 20–50 m	Flaggy, micaceous, lithic fine sandstone; minor siltstone and shale.	Deeper marine: lower shoreface and storm-dominated shelf.	Conformable between Hedleys and Burangoo Sandstone members.
Hedleys Sandstone Member 10–15 m	Silicified to friable, thickly to very thickly bedded, fine to medium sublithic and quartzic sandstone, with mudclasts, and minor granules and small pebbles of quartz.	Shallow marine: upper shoreface to intertidal; may include braided fluvial.	Unconformable on Fickling Group in northeastern MOUNT DRUMMOND and on Caulfield beds in central part of mapsheet; overlain conformably by Pandanus Siltstone Member.
Mittiebah Sandstone 450–2200 m	Fine to coarse, quartzic to lithic sandstone; minor interbeds of pebble or cobble conglomerate and siltstone.	Alternating shallow storm-influenced marine and braided fluvial.	Conformable to disconformable on Crow Formation; top not exposed, but probably conformably overlain by Mullera Formation.
Wild Cow Subgroup			
Crow Formation up to 2500 m	Interbedded lithic micaceous siltstone and fine sandstone, shale, claystone, fine to medium quartzic to sublithic sandstone; minor, poorly sorted medium to very coarse sandstone, pebbly sandstone and matrix-supported conglomerate.	Shallow- to deep-marine shelf, with development of fan delta in northwest adjacent to tectonic uplift (localised interdigitated turbidite and debris-flow facies).	In NW: conformable on Bowgan Sandstone; locally unconformable on Benmara Group; conformably overlain by Tobacco Member or Mittiebah Sandstone. In S and E: conformable on Playford Sandstone; overlain disconformably or with angular unconformity by Constance Sandstone (or Mittiebah Sandstone in S).
Tobacco Member 300–600 m	Silicified, fine to very coarse ± pebbly, quartzic to lithic, often glauconitic sandstone and localised pebble–cobble conglomerate; minor, interbedded, shale and siltstone.	Shallow intertidal to storm-influenced marine shelf.	Conformable at top of Crow Formation in west; overlain disconformably or with angular unconformity by Mittiebah Sandstone.
Bowgan Sandstone up to 100 m	Variably ferruginous, lithic to sublithic, fine to coarse ± pebbly sandstone; possible rare chertified digitate stromatolites; local basal chert clast conglomerate or breccia	Braided fluvial to shallow marine intertidal	Probably unconformable on Murphy Metamorphics and Benmara Group; conformably overlain by Crow Formation; locally absent
Playford Sandstone composite 390–1400+ m; subdivided into three members			
No Mans Sandstone Member 130–200 m	Medium to coarse sandstone with granule to pebble lags; sublithic to quartz-rich; strongly trough cross-bedded	Fluvial or intertidal marine	Sharp, erosive, but conformable base on Top Lily Sandstone Member; conformably overlain by Crow Formation

Table 19.1. Stratigraphic succession of South Nicholson Group and Caulfield beds (after Rawlings *et al* 2008; **table continued on next page**).

Unit, thickness	Lithology	Depositional environment	Stratigraphic relationships
Top Lily Sandstone Member 140–1100 m	Thickly to very thickly bedded, very fine to fine, well-sorted lithic sandstone; minor, more thinly bedded, ferruginous very fine sandstone and siltstone, and haematitic siltstone to ironstone	Marine shelf to shoreline, and possibly tidal channel; minor supratidal, including aeolian	Conformable on Wangalinji Member; overlain conformably by No Mans Sandstone Member, or by Crow Formation
Wangalinji Member 115–750 m	Basal white, thick-bedded, medium- to coarse-grained silicified to friable, locally pebbly, sublithic to quartzic sandstone; overlain by laminated shale, thin-bedded siltstone, very fine-grained lithic sandstone, and interbeds of coarser white sandstone similar to basal beds	Basinal, through storm-dominated shelf, to shoreface or marginal marine environments	Overlies Widdallion Sandstone Member disconformably in most outcrops; angular unconformity SW of Mitchiebo Waterhole; overlain conformably by Top Lily Sandstone Member
UNASSIGNED TO GROUP			
Caulfield beds >600 m	Coarse-grained, poorly sorted lithic sandstone and matrix-supported conglomerate; minor intercalated carbonate, chert and siltstone	Debris flows and sandy turbidites in shallow to deep marine shelf setting (fan-delta); syntectonic deposition	Base not exposed; unconformably overlain by Constance Sandstone

Table 19.1. Stratigraphic succession of South Nicholson Group and Caulfield beds (after Rawlings *et al* 2008; **table continued from previous page**).

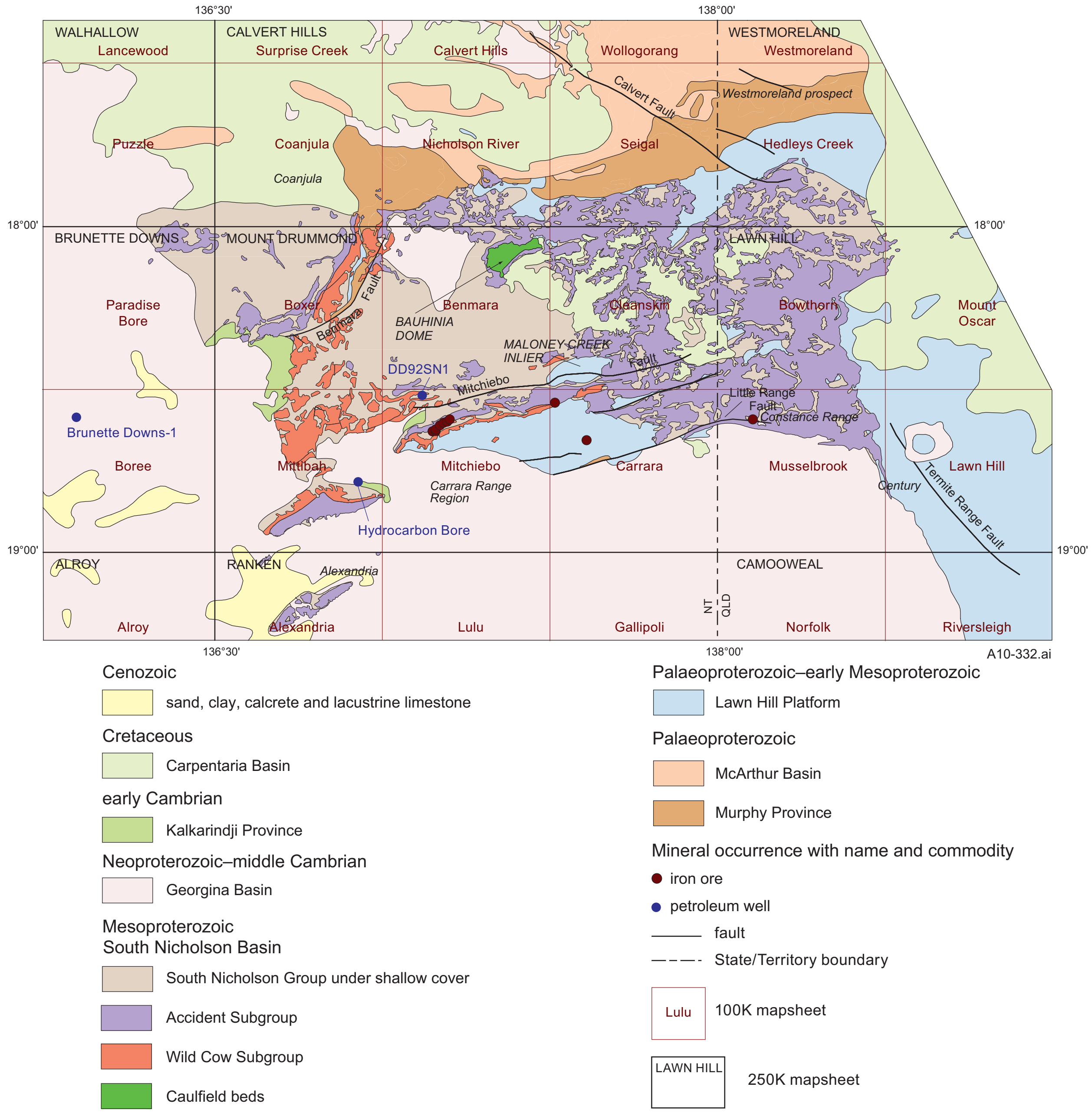

Figure 19.2. Simplified regional geology of the South Nicholson Basin, derived from GA 1:1M geology GIS dataset on base map modified from Rawlings *et al* (2008: figure 3).

(Murphy Province), and possibly the Westmoreland Conglomerate (basal McArthur Basin).

Rawlings *et al* (2008) interpreted the Caulfield beds as having been deposited at the same time as "foreland development and uplift" of the nearby Murphy Inlier to the north. Coarser intervals were interpreted as being rapidly deposited, subaqueous debris-flow deposits, coinciding with periods of tectonism. At other times, deposition of carbonate and finer-grained siliciclastic sediments occurred in a shallow-marine shelf environment in a probable fan-delta setting. Finer-grained and better-sorted sandstones and beds of dolostone, which resulted from traction current and chemical deposition, become more dominant up-section and indicate the waning and eventual cessation of tectonism towards the top of the unit.

The age of the Caulfield beds is difficult to constrain. The unit is older than the overlying Constance Sandstone and is presumably younger than the Nicholson Granite Complex and Cliffdale Volcanics of the Murphy Inlier, which were dated by Page *et al* (2000) at about 1850 Ma. Rawlings *et al* (2008) interpreted this unit to be a possible correlative of the Crow Formation of the South Nicholson Group, because it contains similar coarse-grained gravity-flow deposits, although it is also possible that it may correlate with parts of the older Fickling and McNamara groups of the Lawn Hill Platform.

MESOPROTEROZOIC

South Nicholson Group

The South Nicholson Group (**Figure 19.2**, **Table 19.1**) unconformably overlies the Palaeoproterozoic Murphy Metamorphics of the Murphy Province, and the Palaeoproterozoic McNamara and probably Benmara groups of the Lawn Hill Platform. It is unconformably overlain by the Neoproterozoic Bukalara Sandstone and middle Cambrian Wonarah Formation (Georgina Basin), the early Cambrian Helen Springs Volcanics (Kalkarindji Province), and by Cretaceous and Cenozoic rocks and sediments. There are no accurate geochronological constraints on the age of the group. A whole-rock (shale) Rb–Sr date of 1510 ± 120 Ma from the Mullera Formation is considered unreliable, as the possibility of the inclusion of detrital material, principally micas, cannot be discounted (Plumb and Derrick 1975). Furthermore, it is possible that the rocks dated were lower in the South Nicholson Group succession than previously thought (Rawlings *et al* 2008). Zircons from a basal feldspathic sandstone in the Constance Sandstone, 20 km south of the Century Deposit in Queensland, have yielded a maximum age of 1591 ± 10 Ma (Page *et al* 2000). Zircons from tuffaceous material from the Roper Group, which is correlated with the South Nicholson Group, have provided ages of 1492 ± 4 and 1493 ± 4 Ma (Jackson *et al* 1999). Based on this correlation, the age of the group is therefore interpreted to be in the range 1500–1400 Ma (Rawlings *et al* 2008).

Figure 19.3. Aerial view of strongly banded outcrop in Caulfield beds, eastern Bauhinia Dome. Banding results from alternating very thick beds of pebble conglomerate and pebbly sandstone, and poorly exposed finer siliciclastic rocks. BENMARA, 53K 751600mE 8001200mN, 37 km north-northwest of Wangalinji (after Rawlings *et al* 2008).

Wild Cow Subgroup

The Wild Cow Subgroup outcrops in the west and south of the South Nicholson Basin in the Northern Territory (**Figure 19.2**) and incorporates three formations, the laterally equivalent Bowgan and Playford sandstones and an overlying recessive siltstone- and sandstone-dominated unit, the Crow Formation. The subgroup unconformably overlies the Murphy Metamorphics and McNamara Group, and probably unconformably overlies the Benmara Group. It is overlain disconformably, and locally with an angular unconformity, by the Accident Subgroup. Rocks assigned to this subgroup by Rawlings *et al* (2008) were originally mapped by Smith and Roberts (1963) as younger units of the South Nicholson Group (now Accident Subgroup).

The *Playford Sandstone* forms the base of the South Nicholson Group in an area that extends from southeastern MOUNT DRUMMOND west to MITTIEBAH and north to BOXER. It comprises sublithic and quartzic sandstone, siltstone, granule sandstone and minor carbonate rocks, and outcrops as alternating strike ridges and narrow valleys that correspond to resistant sandstone and more recessive finer-grained rocks, respectively. The formation ranges from 390 m to at least 1400 m in thickness and has been divided into three conformable named members (Rawlings *et al* 2008): the basal *Wangalinji Member* consists of a basal, white, silicified to friable, thickly bedded, medium to coarse, locally pebbly, sublithic to quartzic sandstone overlain by laminated shale, thinly bedded siltstone, very fine lithic sandstone, and interbeds of coarser white sandstone similar to the basal beds; the medial *Top Lily Sandstone Member* comprises white, pink, and darker pink-red, fine-grained lithic sandstone (**Figure 19.4**) with minor siltstone, ironstone and stromatolitic carbonate rocks; and the upper *No Mans Sandstone Member* is a prominent, coarse-grained to granule-bearing cross-bedded sandstone (**Figure 19.5**). Rawlings *et al* (2008) interpreted the Playford Sandstone to have been deposited in a range of settings, ranging from relatively deep basinal, through storm-shelf facies, to shoreface or marginal marine sand environments (Wangalinji Member), to shallow-marine shelf and minor peritidal environments (Top Lily Sandstone Member); to fluvial or intertidal marine (No Mans Sandstone Member).

The *Bowgan Sandstone* is interpreted to be a lateral equivalent of the Playford Sandstone in the Benmara–Canyon Range area in the northwestern part of the basin. It probably unconformably overlies the Murphy Metamorphics and

Benmara Group and is conformably overlain by the Crow Formation, although contacts are generally poorly exposed. The unit is generally thin (<100 m, average ca 10 m) and is locally absent, particularly in the north. It comprises maroon, variably ferruginous, lithic to sublithic, fine- to coarse-grained sandstone with occasional laminae of quartz granules and small pebbles, and is medium- to thickly bedded with planar bedding, parting lineations, small-scale trough cross-beds and mudstone intraclasts. Rawlings *et al* (2008) interpreted the formation to have been deposited as a braided fluvial to shallow-marine intertidal deposit.

The largely recessive *Crow Formation* outcrops poorly throughout the western part of the South Nicholson Basin and was formerly mapped by Smith and Roberts (1963) as parts of the Mullera Formation, Mittiebah Sandstone and Benmara beds. It conformably overlies the Bowgan or Playford sandstones, or where the Bowgan Sandstone is absent, the Benmara Group and Murphy Metamorphics, and is conformably or disconformably overlain by the Mittiebah and Constance sandstones (**Figure 19.6**). The formation is up to 2500 m thick and is composed of interbedded lithic micaceous siltstone and fine-grained sandstone, red-brown to grey shale, chalky white claystone, fine- to medium-grained, quartzic to sublithic sandstone; and minor, local, red-brown, poorly sorted, feldspathic, micaceous, ferruginous and lithic, medium- to very coarse-grained sandstone, pebbly sandstone and matrix-supported conglomerate (**Figure 19.7**). The conformable top of the Crow Formation in the Canyon and Mittiebah ranges is assigned to the 300–600 m-thick *Tobacco Member*, which consists of white, silicified, fine- to very coarse-grained, quartzic to lithic, often glauconitic sandstone and localised pebble–cobble conglomerate, with minor, interbedded, white flaggy shale. Rawlings *et al* (2008) interpreted the Crow Formation to have had a close association with the nearby, tectonically active Murphy Inlier to the north. Coarse detritus was supplied rapidly from beach and fluvial settings at the margins of the inlier as interdigitated turbidites and debris flows, so as to form a fan or braid delta. More distal finer-grained deposits were deposited in an adjacent shallow-marine shelf environment that alternated in depth from below to above storm wave-base.

Figure 19.4. Very large-scale cross-beds in Top Lily Sandstone Member. Sandstone is mainly coarse-grained, with granule and pebble intervals. Regional bedding (dipping right at shallow angle) visible at top. MITCHIEBO, 53K 722000mE 7937000mN, 200 m south of Mitchiebo Waterhole (after Rawlings *et al* 2008).

Accident Subgroup

The Accident Subgroup (Rawlings *et al* 2008) overlies the Wild Cow Subgroup in the western and southwestern parts of the South Nicholson Basin, but comprises the

Figure 19.5. Sharp, erosive contact between pink-brown, fine-grained lithic sandstone of Top Lily Sandstone Member (below), and medium- to coarse-grained and pebbly cross-bedded sandstone of No Mans Sandstone Member (above). Type section for both members, MITCHIEBO, 53K 724230mE 7935820mN, 3 km east-southeast of Mitchiebo Waterhole (after Rawlings *et al* 2008).

Figure 19.6. Unconformity between Crow Formation (recessive unit in foreground) and Constance Sandstone (resistant ridge in background). Note truncation of shallowly west-dipping sandstone bed of Crow Formation at unconformity. MITCHIEBO, 53K 745000mE 7947000mN, No Mans Creek, looking south (after Rawlings *et al* 2008).

Figure 19.7. Massive to streakily planar-bedded granule to pebble conglomerate in Crow Formation. Clasts are mainly of K-feldspar and quartz. BOXER, 53K 703700mE 8008220mN, Canyon Range (after Rawlings *et al* 2008).

entirety of the South Nicholson Group in the central and eastern parts of the basin, including those parts in western Queensland (**Figure 19.2**). The contact between the two subgroups is conformable in the west, but disconformable and even an angular unconformity in the central parts of MOUNT DRUMMOND. In the east, where the Wild Cow Subgroup is absent, the Accident Subgroup disconformably or unconformably overlies the McNamara and Fickling groups of the Lawn Hill Platform, and in the Bauhinia Dome, it unconformably overlies the Caulfield beds. The subgroup is unconformably overlain by various late Neoproterozoic and Phanerozoic units, including the Georgina Basin succession. In southeastern MOUNT DRUMMOND, the Accident Subgroup has a minimum thickness of 400 m, but to the east, in the Constance Range region in LAWN HILL (northwestern Queensland), a thickness of up to 3350 m is attained (Rawlings *et al* 2008).

In the Northern Territory, the Accident Subgroup comprises three formations: the basal Constance and Mittiebah sandstones, and an overlying recessive shaly unit, the Mullera Formation. A fourth formation, the Tidna Sandstone, is present in adjoining Queensland (Carter and Zimmerman 1960). The various formations and members of the Accident Subgroup have been shown to interdigitate, or grade laterally and vertically into one another over tens of kilometres of strike in western Queensland (Dunster and McConachie 1990), thus complicating stratigraphic interpretations and nomenclature.

The basal *Constance Sandstone* is widespread throughout the South Nicholson Basin in both Queensland and the Northern Territory. It ranges from 100 to 1100 m in thickness in the Northern Territory and comprises medium- to coarse-grained, granule-rich and occasionally pebbly, quartz or sublithic sandstone, interbedded with very fine-grained sandstone and siltstone. Sandstone intervals are typically thickly bedded and cross-bedded; finer intervals contain coarser-grained sandstone interbeds. In the Northern Territory, the formation has been divided into three sandstone and two siltstone members (Rawlings *et al* 2008). These are, in ascending stratigraphic order, the Hedleys Sandstone, Pandanus Siltstone, Burangoo Sandstone, Wallis Siltstone and Schultz Sandstone members. The various sandstone members are recognisable only by virtue of the presence of the siltstone members between them. Since the siltstones are lenticular, or are truncated by overlying sandstone members, the Constance Sandstone has been mapped as a single unit where siltstones are absent.

The basal 10–15 m-thick *Hedleys Sandstone Member* is a white, thickly to very thickly bedded, fine- to medium-grained, sublithic and quartzic sandstone, which contains mudclasts and minor granules and small pebbles of quartz. Immediately above the basal unconformity, the sandstone is slightly coarser and contains siltstone pebbles. The 20–50 m-thick *Pandanus Siltstone Member* conformably overlies the basal sandstone and in CALVERT HILLS, was described by Roberts *et al* (1963) as being a micaceous siltstone with minor medium-grained quartz sandstone interbeds. In MOUNT DRUMMOND, it was described by Rawlings *et al* (2008) as consisting of flaggy, brown micaceous, fine-grained lithic sandstone and lesser siltstone and shale. The sandstone contains parting lineations, hummocky cross-stratification, small trough cross-beds, parallel laminations, slump structures and convolute bedding. Conformably overlying the Pandanus Siltstone Member is the 35–150 m-thick *Burangoo Sandstone Member*, which consists of white to pale yellow, fine- to coarse-grained quartzic to sublithic sandstone. This sandstone contains minor scattered quartz granules and pebbles, trough and planar cross-beds, scattered symmetric ripples and mudclasts, current lineations, symmetric ripples and synaeresis cracks. The conformably overlying *Wallis Siltstone Member* is up to 200 m thick and in CALVERT HILLS, was described by Roberts *et al* (1963) as being a micaceous and glauconitic siltstone with minor fine-grained quartz sandstone interbeds. Rawlings *et al* (2008) described the same unit in MOUNT DRUMMOND as consisting of green-brown-weathering, very fine- to fine-grained laminated sandstone with micaceous partings, and minor siltstone and shale. The member contains parallel and wavy laminations, cross-laminations, hummocky cross-stratification, synaeresis cracks, mudclasts, prominent (but not common) current lineations, low- to high-relief gutter casts, flute moulds and multidirectional drag and tool marks. The 120–600+ m-thick *Schultz Sandstone Member*, at the top of the Constance Sandstone, is a white to brown, friable, medium, coarse and very coarse to granule sandstone, containing a 220 m-thick interval of platy, thinly laminated very fine-grained sandstone. The base of the member is erosional on the Wallis Siltstone Member, and is expressed as a local disconformity or subtle angular unconformity. The upper contact with the Mullera Formation is apparently conformable. The Schultz Sandstone Member features planar and trough cross-beds at various scales, wave and interference ripple marks and mudstone intraclasts.

Rawlings *et al* (2008) interpreted the sandstone intervals of the Constance Sandstone as having been deposited in fluvial to shallow-marine, tide-dominated environments. The siltstone members were deposited in much lower-energy environments, most likely in marine shelf to lower shoreface settings. The stacking pattern is similar to the Roper Group, which has been interpreted as a series of third-order depositional sequences (Abbott and Sweet 2000).

The *Mittiebah Sandstone* ranges from 450 to at least 2200 m in thickness and outcrops towards the west of the South Nicholson Basin. It is conformable or disconformable on the Tobacco Member of the Crow Formation and in general, is unconformably overlain by Georgina Basin rocks or by Cenozoic sediments, so that its relationship with any overlying Mesoproterozoic rocks cannot be easily determined. Several informal sandstone members were recognised by Rawlings *et al* (2008). The formation is composed mostly of fine- to coarse-grained quartzic to lithic sandstone, with minor interbeds of pebble or cobble conglomerate and siltstone. Sedimentary structures include moderate- to high-angle planar and lesser trough cross-beds (**Figure 19.8**), small-scale trough cross-beds, granule laminae, mudclasts, symmetric ripples (sinuous and interference types), crude current lineations and parting lineations. Rawlings *et al* (2008) concluded that the depositional environment probably alternated between shallow storm-influenced marine and braided fluvial settings. The Mittiebah Sandstone is tentatively correlated with the Constance Sandstone. However, siltstone intervals are largely absent in the Mittiebah Sandstone.

The very recessive *Mullera Formation* is conformable on the Constance Sandstone, but as the unit does not outcrop in more westerly areas of the South Nicholson Basin, its relationship to the Mittiebah Sandstone is uncertain. In the Northern Territory, the formation is unconformably overlain by Georgina Basin rocks or by Cenozoic sediments. However, in Queensland, it is overlain conformably by the Tidna Sandstone, a unit at the top of the Accident Subgroup that is not recognised in the Northern Territory. The Mullera Formation is estimated to be >1100 m in the Northern Territory, but is up to 1800 m thick in Queensland (Carter and Zimmerman 1960). The principle rock types include green or red-brown to maroon, micaceous, locally ferruginous siltstone, shale and fine-grained lithic to quartzic sandstone, organic-rich shale and medium-grained quartzic sandstone (**Figure 19.9**). One sandstone unit, the medial *Middle Creek Sandstone Member* (**Figure 19.10**) has been mapped as a separate entity (Rawlings *et al* 2008). It consists of white silicified, fine to medium, sublithic glauconitic sandstone. The Mullera Formation is characteristically thinly bedded. It contains a variety of sedimentary structures including parallel, lenticular and wavy laminations, cross-laminations, small trough cross-beds, hummocky cross-stratification, symmetric ripples, gutter casts, synaeresis cracks, runzel marks, mudclasts and current lineations. As well as coarser beds that have been deposited under the influence of traction currents, there are also intervals that are composed only of red and green shale, with little sand or silt component and no evidence of traction current deposition. The Mullera Formation is therefore interpreted to have been deposited in a shallow-marine shelf environment, partly above wave base and partly below (Rawlings *et al* 2008). The lower Mullera Formation contains several ironstone intervals (**Figure 19.11**), which have been explored for iron in Queensland (Harms 1965). The main ferruginous beds there were grouped together as the *Train Range Ironstone Member* (Carter and Zimmerman 1960, Harms 1965, Slater and Mond 1980). Such ferruginous rocks appear to thin westward in the Northern Territory (see **Iron ore**), although locally, they are up to 10 m thick.

MINERAL RESOURCES

No significant mineralisation has been recorded from the Northern Territory portion of the South Nicholson Basin except minor iron ore concentrations in the Mullera and

Figure 19.8. Large-scale planar cross-bed in lower Mittiebah Sandstone. MITTIEBAH, 53K 699850mE 7915350mN, Mittiebah Range (after Rawlings *et al* 2008).

Figure 19.9. Grey shale of lower Mullera Formation, with lenticular interbeds of fine-grained lithic sandstone, some of which have gutter-casted bases. CLEANSKIN, 53K 798330mE 7974640mN, 2 km east of Big Bend Waterhole (after Rawlings *et al* 2008).

Figure 19.10. Fine-grained silicified quartzic sandstone of Middle Creek Sandstone Member of Mullera Formation, showing haematite-defined cross-bed laminations. CLEANSKIN, 53K 791800mE 7988550mN, No Return Creek (after Rawlings *et al* 2008).

Figure 19.11. Banded haematite/goethite in 'upper ironstone bed' of Mullera Formation. Banding appears to be of liesegang ring-like structures formed by mobility of iron oxides. 53K 712850mE 8007815mN, 7 km northwest of Connelly Waterhole (after Rawlings *et al* 2008).

Crow Formations. However, the basin is prospective for sandstone-type uranium, base metals and petroleum, as well as for iron ore.

Iron ore

In the Queensland portion of the South Nicholson Basin, fourteen separate iron ore deposits have been identified in the Train Range Ironstone Member in the Constance Range area (Carter and Zimmerman 1960, Harms 1965, **Figure 19.2**). Published reserves are 362 Mt averaging from 42 to 57% Fe.

In the Northern Territory, most iron occurrences occur within siltstone and claystone of the Mullera (**Figure 19.9**) and Crow Formations, but there are also occurrences within the Playford and Constance sandstones. Several 'Clinton-type' oolitic iron ore occurrences were documented by Rawlings *et al* (2008), who referred to them as 'Wabana (Newfoundland)-type' deposits. Oolitic ironstone occurs as massive stratiform bodies, 5–20 m thick and 100s to 1000s of metres long, which were deposited in a shallow-shelf to intertidal, clastic-dominated environment, in humid, periodically agitated conditions. Iron-rich sand grains were reworked with gentle wave/current activity and accumulated iron around a sand or pebble nucleus, so as to build up oolitic layers of iron. The mineralisation consists principally of oolitic haematite, siderite and chamosite. Haematite is typically fine grained, massive, and destructive to bedding. At least part of this mineralisation relates to primary depositional processes. However, local surficial supergene enrichment and fault-related fluid movement have also affected some of the ironstone bodies and led to higher iron concentrations.

Samples collected from a large prospective area of 1400 km^2 by Phosphate Australia Ltd have returned iron grades greater than 40%, up to a maximum of 63.7% Fe, with a relatively low P (phosphorus) content (Phosphate Australia Ltd ASX Announcement 10/08/2010).

Base metals

Rawlings *et al* (2008) concluded that there may be some potential for base metals in parts of the South Nicholson Basin. In particular, they noted that the Crow Formation and Caulfield beds, adjacent to the Murphy Inlier in the Canyon Range and Bauhinia Dome respectively, have recessive shaly intervals that may contain blind base metals deposits, possibly of SEDEX or MVT style.

Petroleum

There are mixed indications of the petroleum potential of the South Nicholson Basin. The first petroleum test of the basin in the Northern Territory was Brunette Downs-1, drilled in 1964 (Mines Administration Pty Ltd 1964). Although primarily targeted on the younger Cambrian section, the well intersected almost 200 m of the uppermost Mullera Formation. No hydrocarbons were detected and the best TOC reported from the formation was 0.14% (Lanigan 1993). Samples of the upper Mullera Formation in Queensland contain higher TOC contents of up to 3.0%, but are overmature for oil generation (Lanigan 1993).

Pacific Oil and Gas investigated the petroleum prospectivity of the South Nicholson Basin in the Northern Territory during the early to mid 1990s. Drillhole DD92SN1 was continuously cored from 54 m to 458.64 m (TD) and penetrated 430.7 m of what Pacific Oil and Gas regarded as dipping Mullera Formation and the upper 27.94 m of Constance Sandstone. Of twenty-four selected mudstone samples from the putative Mullera Formation, only five had greater than 1.0% TOC and the best was 1.5%. The generative potentials and levels of extractable hydrocarbons were all low and all samples were found to be beyond peak oil generation. There also appeared to be little reservoir potential due to primary clays and secondary cements. Pacific Oil and Gas's overall program was terminated prematurely, partly due to the poor results from DD92SN1 (Lanigan 1993), but following the remapping of MOUNT DRUMMOND, Rawlings *et al* (2008) suggested that the company had inadvertently drilled the Crow Formation, rather than the Mullera Formation, which remains untested in the Northern Territory.

Hydrocarbons and odours have been recorded from a shallow waterbore, known colloquially as 'Hydrocarbon Bore' or 'Blackfellow Bore', probably drilled in 2002 near Peaker Piker Creek on Mittiebah station. The approximate location of this bore was given by Rawlings *et al* (2008) as 53K 703000mE 7922000mN, but it may be more accurately located about 160 m south-southwest of this location at 53K 702951mE, 7921848mN (Bill Fraser, WJ Fraser and Associates Pty Ltd, pers comm 2010). Rawlings *et al* (2008) noted that organic-rich shale from about 120 m depth, near the bottom of Hydrocarbon Bore, had a TOC of 10.6%, was below the oil window, and was substantially less mature than rocks sampled in DD92SN1. Rawlings *et al* (2008) interpreted the intersected strata as possible Mullera Formation, but that unit does not outcrop in this westerly portion of the basin and the stratigraphic position is therefore uncertain.

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