Mesoproterozoic and Phanerozoic sedimentary basins in the northern Halls Creek Orogen: constraints on the timing of strike-slip movement on the Halls Creek Fault system

by A. M. Thorne and I. M. Tyler

Abstract

Fault patterns in the northeastern Halls Creek Orogen reflect large-scale (~90 km displacement) sinistral wrench faulting. Previous interpretations suggest much of this movement was coeval with deposition of the Mesoproterozoic Carr Boyd Group. This view is not supported by recent mapping, which shows that details of Carr Boyd Group sedimentation and stratigraphy are inconsistent with deposition in a strike-slip setting. Instead, most of the post-Palaeoproterozoic sinistral faulting occurred after deposition of the Carr Boyd Group, the principal movements having occurred in the post-Duerdin Group – pre-Antrim Plateau Volcanics interval, and also during the late Palaeozoic. The latter event has exerted a major influence on the development of upper Devonian (Frasnian) sedimentary basins in the northern Halls Creek Orogen.

KEYWORDS: Halls Creek Orogen, Carr Boyd Group, strike-slip faulting, Devonian sedimentary basins

Fault patterns in the northeastern Halls Creek Orogen (Fig. 1) are consistent with large-scale sinistral wrench faulting. The northeast-trending Dunham–Ivanhoe Fault system in the west and the Halls Creek Fault in the east are first-order faults linked by synthetic second-order structures, including the Carr Boyd, Glenhill, and Revolver Creek Faults. A complex network of smaller scale (third-order) faults, including synthetic and antithetic strike-slip shears, and both normal and reverse faults, occur between the main structures.

Attempts to determine the amount and timing of sinistral strike-slip movement along the Halls Creek Fault have been hampered by the paucity of suitable markers that can be matched on either side of this structure. Tyler et al. (1995) calculated a sinistral displacement of 90 km on the Halls Creek Fault, based on the offset of the Angelo and Osmond Faults. Support for this estimate comes from the recognition of similar magmatic-hydrothermal alteration associated with the McHale Granodiorite northwest of the Osmand Range and in the Angelo Granite south of Halls Creek (Witt and Sanders, 1996). Plumb et al. (1985) estimated the total accumulative left-lateral displacement of all faults in the Halls Creek System as approximately 200 km, although the details of how this value was obtained were not given.

Plumb et al. (1985) interpreted the Carr Boyd Group as having been deposited during a protracted period of strike-slip faulting in the Mesoproterozoic. This interpretation has been taken to represent a major constraint on the timing of tectonism in the Halls Creek Orogen (Tyler and Griffin, 1994). Here we discuss the timing of strike-slip faulting in the Halls Creek Orogen in the light of new information obtained during remapping of the LISSADELL* 1:250 000 map sheet.

Carr Boyd Group

The Mesoproterozoic Carr Boyd Group is exposed in the Carr Boyd and Pincombe Ranges in the northeastern part of the Halls Creek Orogen (Fig. 1)., and was first described by Dow et al. (1964), Dow and Gemuts (1969), Plumb (1968), Plumb and Veevers (1971), and Plumb and Gemuts (1976). The group unconformably overlies Palaeoproterozoic metasedimentary and igneous rocks of the Lamboo Complex and Kimberley Basin, and is in turn overlain unconformably by Neoproterozoic glacial deposits of the Duerdin Group. The Carr Boyd Group has been subject to very low-grade metamorphism.

No single complete section of the Carr Boyd Group is known because it has been disrupted extensively by faulting. However, six formations which together total ~4.4 km in thickness are recognized. These are (in ascending order): Hensman Sandstone, Golden Gate Siltstone, Lissadell Formation, Glenhill

* Capitalized names refer to standard map sheets.

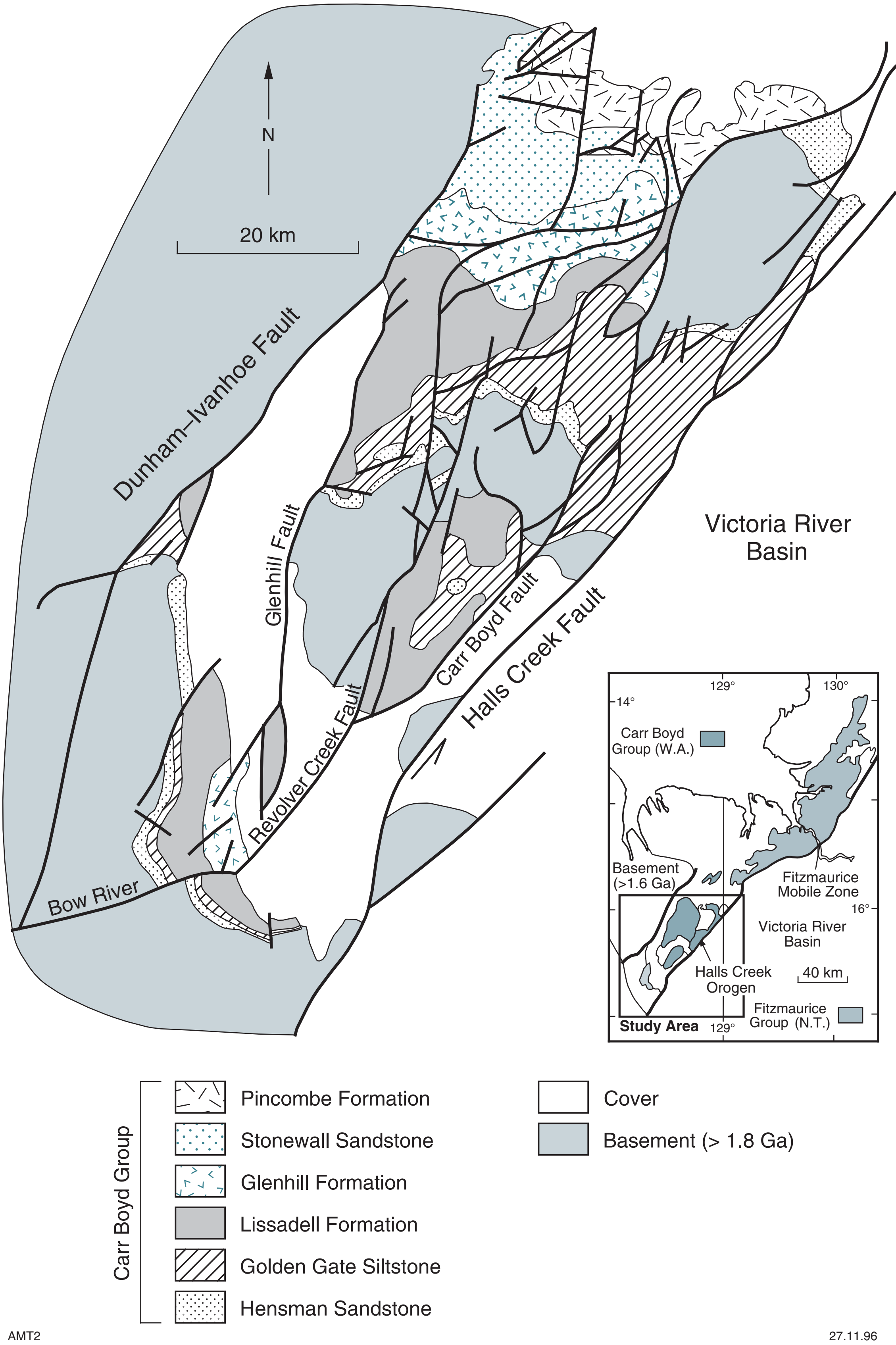


Figure 1. Carr Boyd Group outcrop and stratigraphy

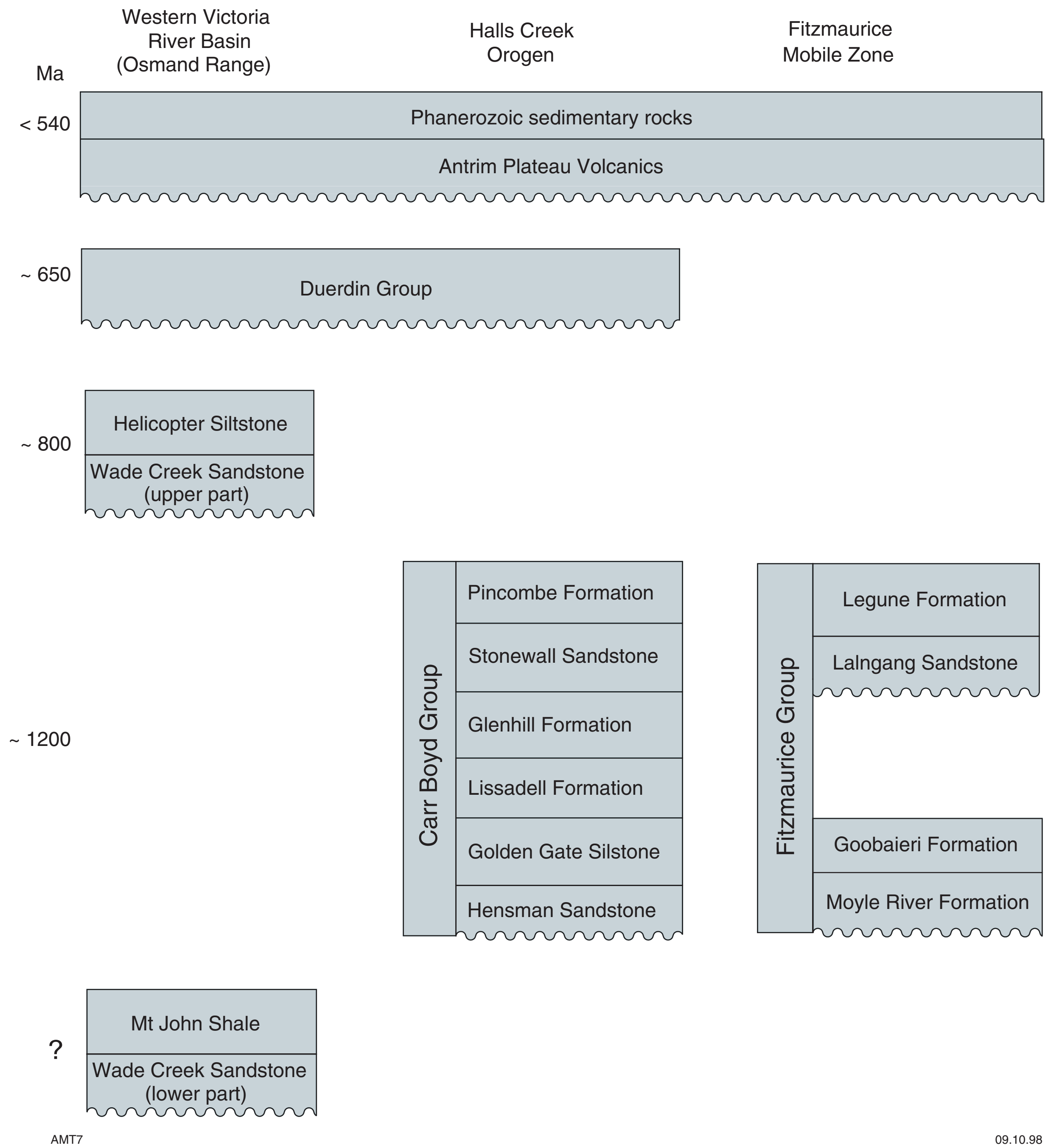


Figure 2. Regional correlation of the Carr Boyd Group

Formation, Stonewall Sandstone, and Pincombe Formation (Fig. 1). All formations are dominated by siliciclastic sedimentary rocks, comprising fine- to coarse-grained quartz sandstone, argillite, and minor lithic sandstone and conglomerate. These rocks have been interpreted as alluvial fan, fluvial, and shallow-marine shelf deposits that were laid down in an active strike-slip setting. (Plumb et al., 1985).

Previous workers recorded the presence of angular and erosional unconformities at the bases of the Lissadell and Glenhill Formations, and the Stonewall Sandstone (Dow et al., 1964; Dow and Gemuts, 1969; Plumb and Gemuts, 1976). Subsequent mapping (Thorne et al., in prep.) does not confirm the presence of these stratigraphic breaks and most discordant boundary relationships and anomalous thickness variations can be more readily attributed to post-Carr Boyd Group faulting.

Age of the Carr Boyd Group

The age of the Carr Boyd Group is loosely constrained by Rb–Sr whole rock dates of 1158 ± 123 Ma, 1057 ± 80 Ma, and 891 ± 149 Ma obtained from shales within the Golden Gate Siltstone, Glenhill Formation, and Pincombe Formation respectively (Bofinger, 1967, recalculated *by* Plumb et al., 1981). However, these ages are younger than the values of 1178 ± 47 Ma (Rb–Sr whole rock) or 1238 ± 12 Ma (K–Ar, phlogopite) reported from the Argyle lamproite diatreme (Pidgeon et al., 1989), which post-dates the Lissadell Formation (Boxer et al., 1989).

Regional correlation

The Fitzmaurice Mobile Zone forms the northeastern continuation of the Halls Creek Orogen into the Northern Territory. Here, the Lalngang Sandstone and Legune Formation in the upper part of the Fitzmaurice Group (Fig. 2) are correlated directly with the Stonewall Sandstone and Pincombe Formation respectively of the upper Carr Boyd Group (Sweet, 1977; Plumb and Gemuts, 1976). Older formations in the Carr Boyd and Fitzmaurice Groups cannot be correlated directly, although correlations (Fig. 2) have been made on the basis of inferred relations with the Angalarri Siltstone (Auvergne Group) in the Victoria River Basin (Sweet, 1977; Plumb and Gemuts, 1976; Plumb et al., 1985). However, a Rb–Sr whole-rock age of 838 ± 142 Ma from the Angalarri Siltstone (Webb and Page, 1977) and comparison with the Centralian Superbasin succession (Walter et al., 1995) suggests that the Auvergne Group and its Osmand Range equivalents (upper Wade Creek Sandstone and Helicopter Siltstone) are younger than the Carr Boyd Group.

Carr Boyd Group sedimentation

The Carr Boyd Group stratigraphy (Fig. 6) records the evolution of a sandy, braided delta complex and the adjacent siliciclastic marine shelf. Four broad facies associations are recognized and are interpreted to represent three major environments: wave-influenced shallow-marine shelf, delta front, and braided delta-plain.

Wave-influenced shallow marine shelf: mudstone–siltstone and siltstone–sandstone associations

Four major lithofacies make up these associations: laminated mudstone, graded siltstone–mudstone couplets, sandstone–siltstone, and cross-laminated siltstone and sandstone. The laminated mudstone facies is interpreted as the product of suspension fallout during periods of fair weather, whereas graded siltstone–mudstone couplets suggest an alternation of suspension fallout and weak gravity-flow depositional processes. Graded sandstone and siltstone layers represent deposition from stronger, storm-induced currents and gravity flows. Here, the presence of wave-ripple bedforms indicates that upper parts of the deposit were commonly modified by wave processes. Amalgamated units of cross-laminated siltstone and sandstone were laid down during relatively sustained periods of wave activity.

Delta front: complexly cross-stratified quartz sandstone association

This association is dominated by fine- to medium-grained quartz sandstone and comprises five lithofacies: parallel-planar stratified sandstone, low-angle planar stratified sandstone, undulatory cross-stratified sandstone, trough and planar tabular cross-stratified sandstone, ripple-laminated sandstone and siltstone. Palaeocurrent data from this facies are variable, the principal transport directions being toward the northwest, southeast and southwest (Fig. 3).

This association is dominated by moderate- to high-energy wave- and current-generated sedimentary structures that are typically found today on shoreface to foreshore environments (McCubbin, 1982; Harms et al., 1982; Elliott, 1986). Cosets of parallel planar cross-stratification are interpreted as swash stratification, formed in a foreshore setting. Trough and planar cross-stratification, parallel planar stratification and undulatory stratification record dune migration and storm deposition on the upper and lower shoreface. Thin interbeds of ripple-laminated sandstone and siltstone probably represent bar-top or bottomset deposits; thicker accumulations probably formed in a distal shoreface setting.

Braided delta-plain: medium and large-scale cross-stratified sandstone association

This association (Fig. 4) comprises thick, planar beds of medium-to coarse-grained or pebbly quartz sandstone. Internal structure consists of 0.5–1.0 m thick cosets of medium-scale trough cross-strata, and planar bounded sets of asymptotic trough cross-strata, 0.3–1.2 m thick. Fine-to medium-grained sandstone, which in places contains abundant argillite clasts, caps the tops of some beds. Upper bedding planes may preserve straight-crested symmetrical or asymmetrical ripples. Palaeocurrent data from the troughed portions are unimodal with low dispersion and indicate sediment transport was toward the northeast.

The dominance of large-scale trough cross-stratification, planar bedding, and unimodal palaeocurrent data suggest that this association represents the vertical infilling of broad, shallow channels by subaqueous dunes. The presence of wave ripples and mud flakes on upper bedding surfaces suggests periods of streamflow sedimentation. These were separated by intervals characterized by wave rippling and current reworking of channel sands and nearby slackwater deposits.

Depositional model and basin evolution

The proposed model for Carr Boyd Group deposition is shown in Figure 5. This reconstruction takes into account some 100 km of post-Carr Boyd Group sinistral strike-slip movement along the Halls Creek Fault system (*see* next section). The central feature of the model is a sandy braided-delta complex which progrades north and northeast-wards over a low-gradient, wave-influenced shallow-marine shelf. The fine grain size and compositional maturity of the sediment indicates the principal source area probably lay several hundred kilometres to the south and

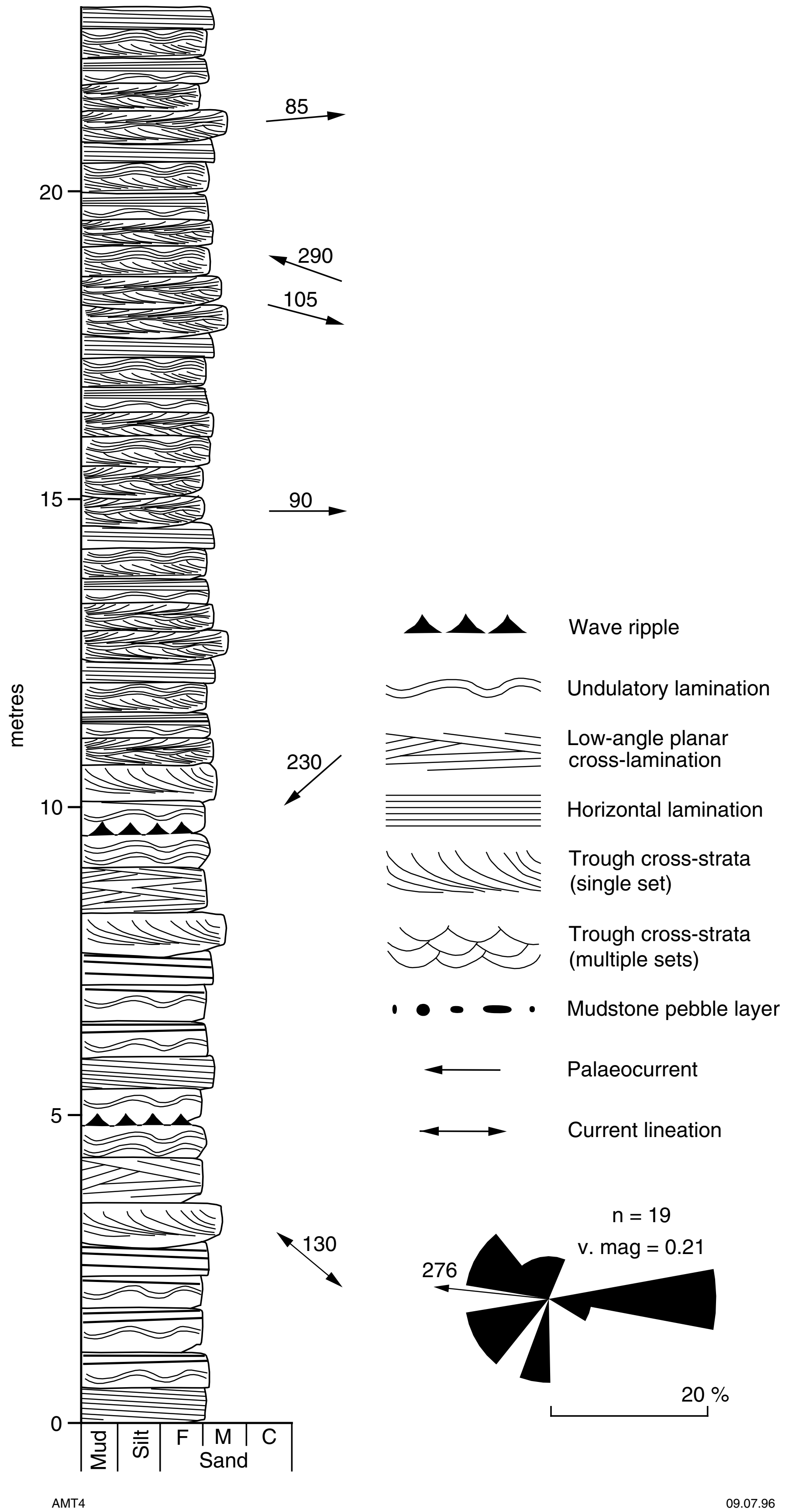


Figure 3. Vertical profile through the delta front facies association summarizing major rock types and internal structure

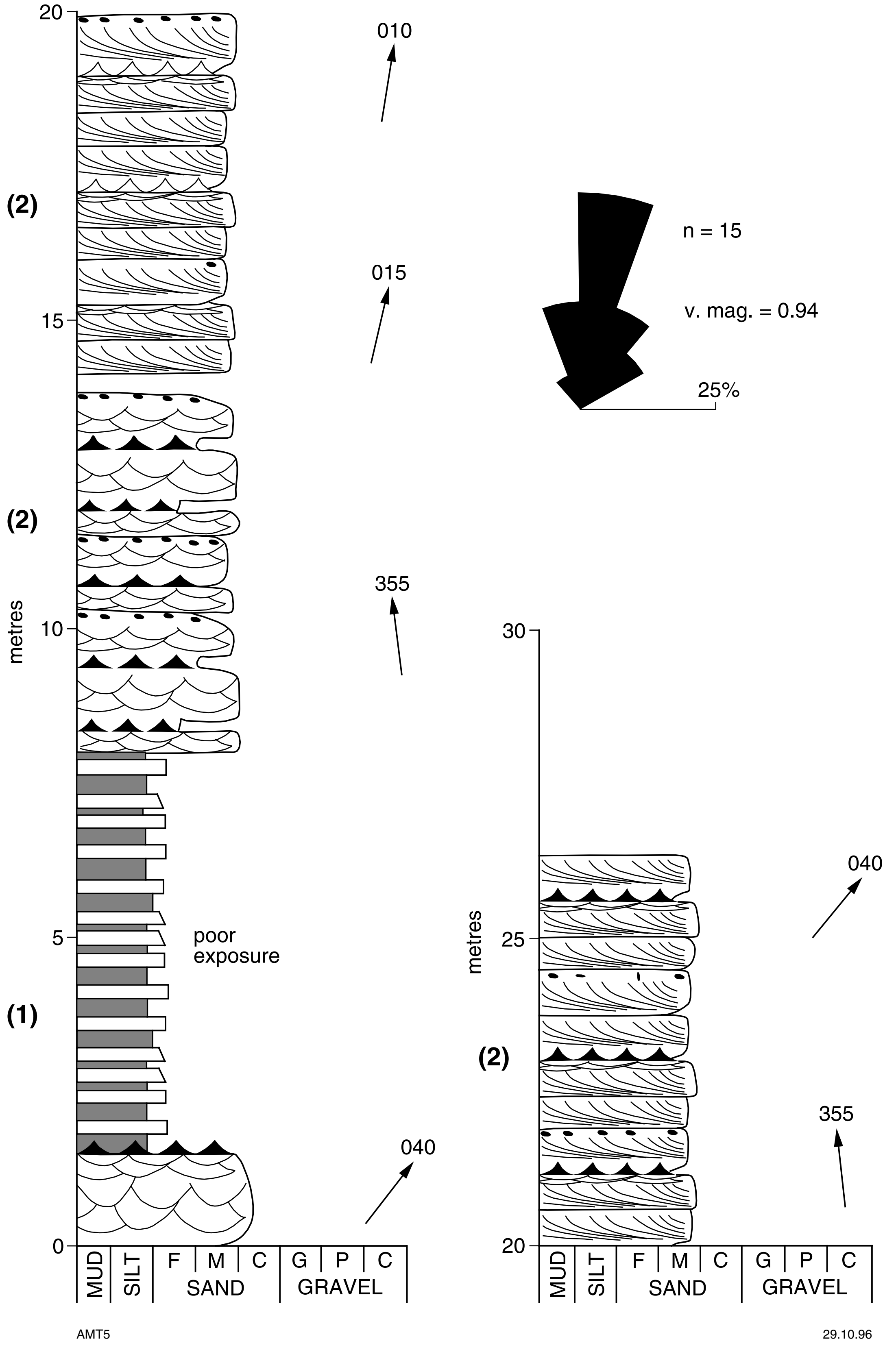


Figure 4. Vertical profile through the braided delta plain and delta front facies associations summarizing major rock types and internal structure. (1) delta front siltstone and sandstone, (2) delta plain sandstone. Symbols as for Figure 1

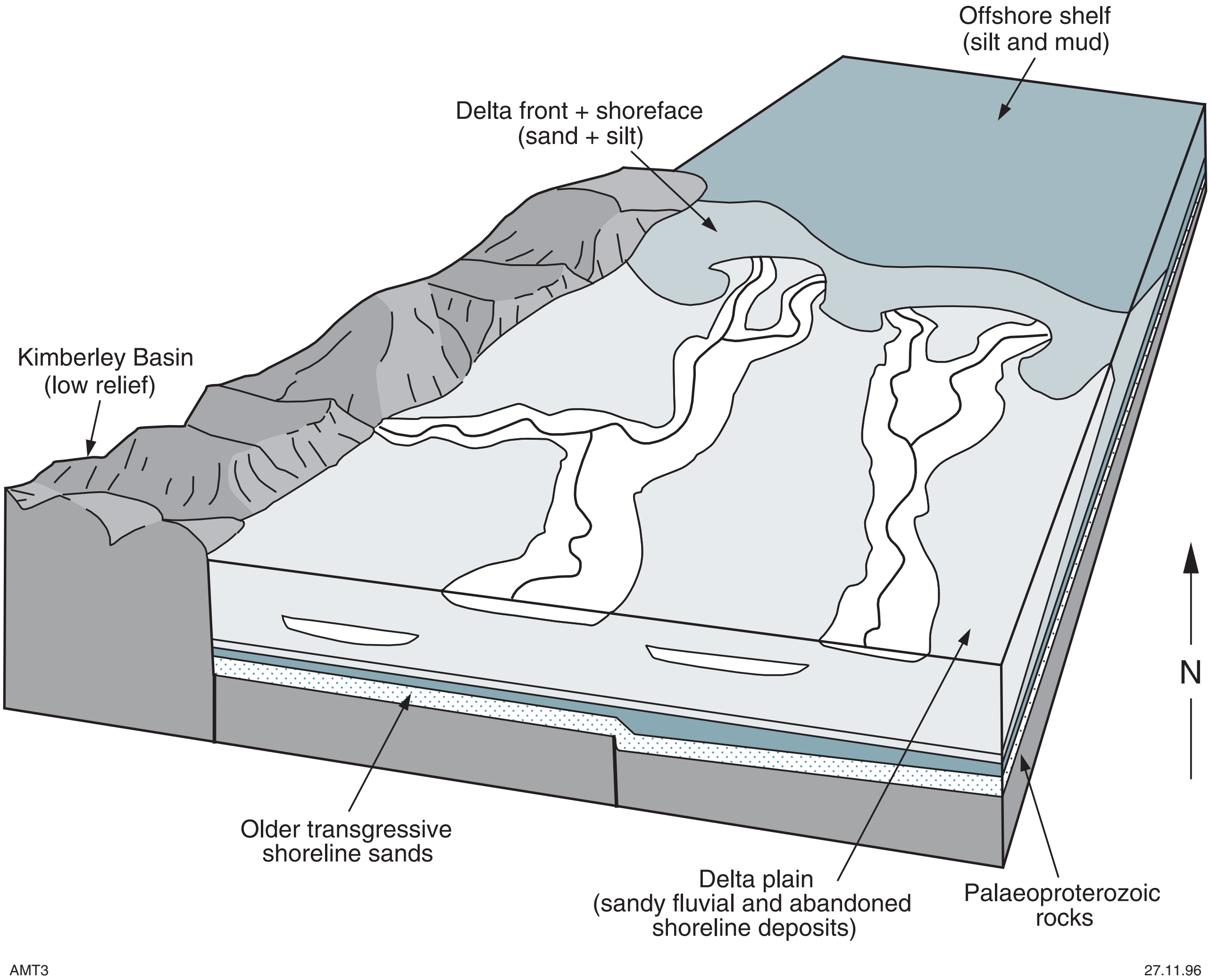


Figure 5. Depositional model for the Carr Boyd Group during delta progradation

southwest. Quartz sand was transported to the shelf by a system of shallow braided channels, and redistributed at the delta front by waves and longshore currents. Mud, silt, and sand were transported further offshore by storm-generated currents and weak sediment-gravity flows.

The Carr Boyd Group stratigraphy records an initial period of marine transgression during which shoreface sands (Hensman Sandstone) followed by finer grained offshore shelf deposits (lower Golden Gate Siltstone) were deposited over an eroded surface of Palaeoproterozoic rocks (Fig. 6). This initial flooding event was followed by four major cycles of braided-delta progradation and retreat (upper Golden Gate Siltstone to Pincombe Formation). The maintenance of deltaic and shallow-marine shelf (<100 m deep) sedimentation throughout this time implies that depositional rates generally kept pace with overall rates of basin subsidence.

Estimates of the former extent of the Carr Boyd depositional system depend upon the reliability of correlations with the Fitzmaurice Group and Victoria River Basin succession of the Northern Territory. Direct correlations between the Stonewall Sandstone and Pincombe Formation, and the Lalngang Sandstone and Legune Formation (Fitzmaurice Group) suggest the basin extended at least 200 km northeastwards into the Fitzmaurice Mobile Zone (Sweet, 1977; Plumb and Gemuts, 1976; Plumb et al., 1985). The southward extension of the basin is unknown because of the difficulty in correlating the Carr Boyd Group with the Victoria River Basin succession on the southeast side of the Halls Creek Fault.

Timing of strike-slip fault movement

Mesoproterozoic and Neoproterozoic

Plumb et al. (1985) considered that Carr Boyd Group deposition was strongly influenced by major strike-slip movements along the Halls Creek Fault system. However, much of the evidence that was used to support this concept, including the presence of synsedimentary faults and localized unconformities within

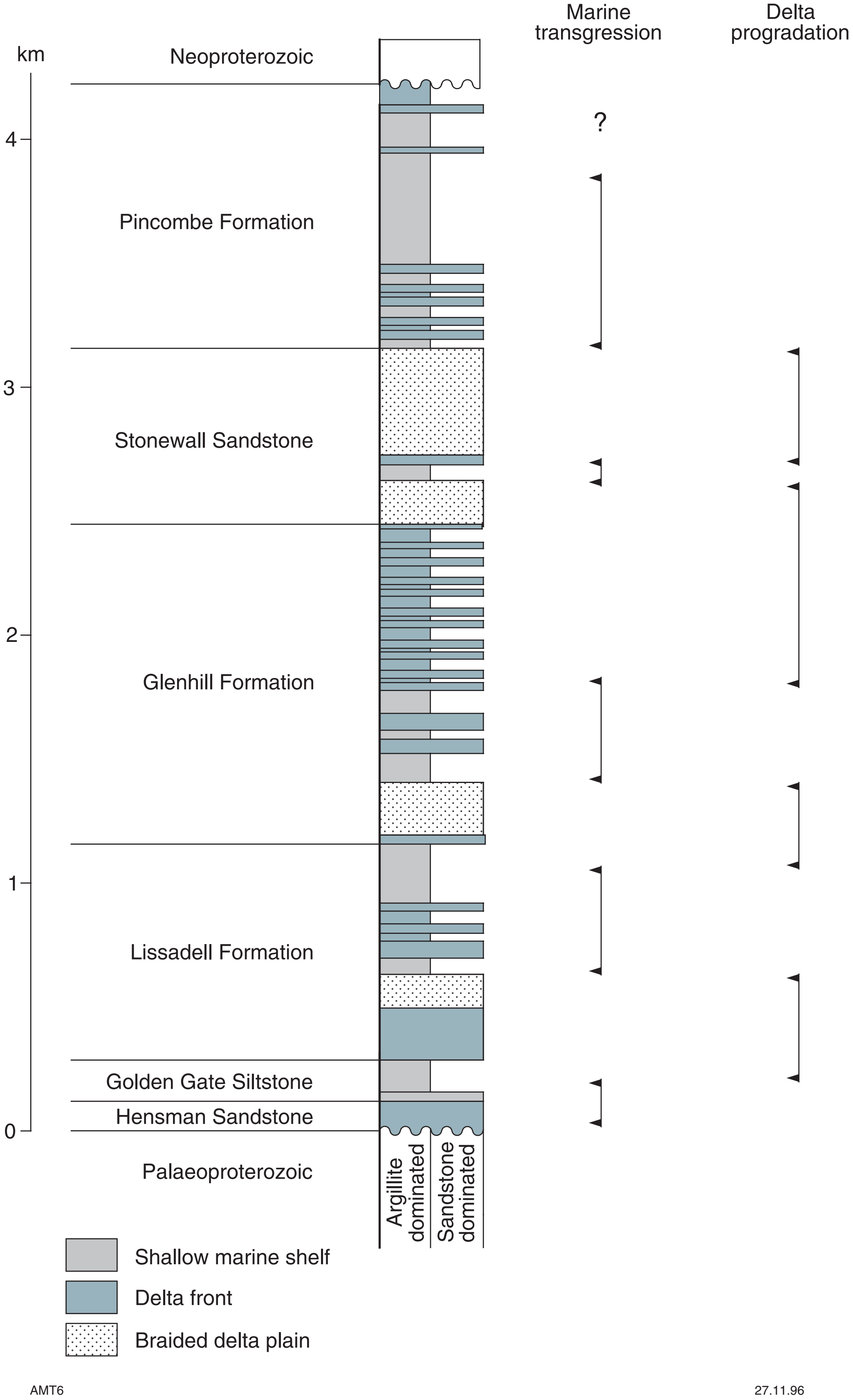


Figure 6. Depositional history of the Carr Boyd Group showing major episodes of delta progradation and marine transgression

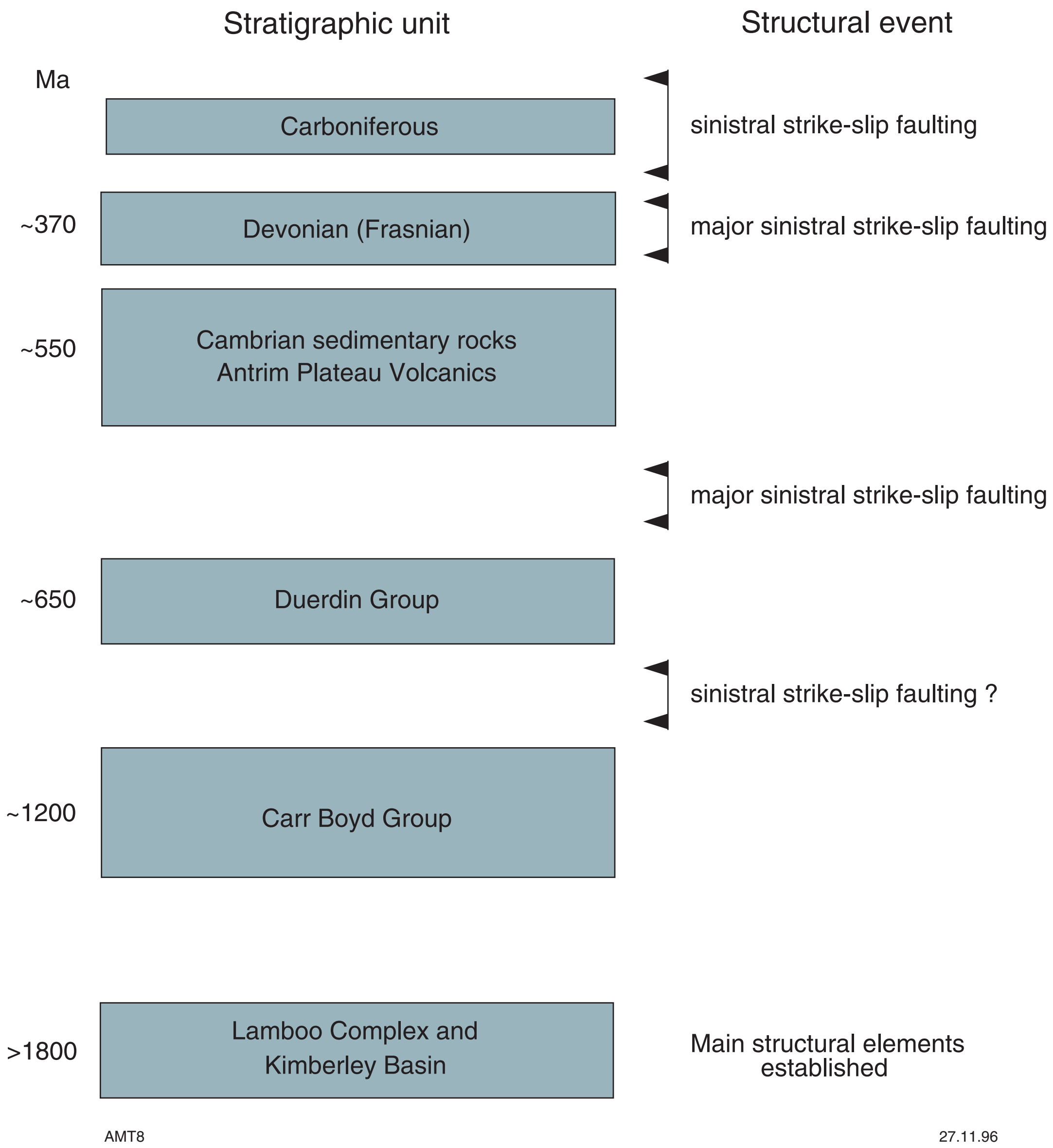


Figure 7. Timing of Mesoproterozoic to Phanerozoic fault movements in the northern Halls Creek Orogen

the Carr Boyd Group (Plumb, 1968; Plumb et al., 1985), has not been borne out by subsequent mapping (Thorne et al., in prep.). In addition, the Carr Boyd Group lacks most of the features normally associated with deposition in strike-slip settings (*see* Christie-Blick and Biddle, 1985; Nilsen and Sylvester, 1995). Specifically, the fine-grained (sand and argillite) character of the Carr Boyd Group, its uniform style of deposition (both spatially and temporally), and the lack of evidence for localized syndepositional uplift and adjacent rapid subsidence, are inconsistent with this interpretation. Instead, the overall character of the Carr Boyd Group suggests deposition probably took place within an intracratonic basin which formed following amalgamation of the North, West, and South Australian Cratons at about 1300 Ma (Myers, 1990; Myers et al., 1994).

Although there appears to be little evidence for major strike-slip movement having occurred along the Halls Creek Fault system during Carr Boyd Group deposition, the considerable thickness of the Carr Boyd Group, when compared with the total thickness of Mesoproterozoic sedimentary successions in the Victoria River Basin, suggests there may have been considerable (1–2 km) downward movement of the west block along this fault line during Carr Boyd Group deposition.

The high degree of brittle deformation that has affected both the Carr Boyd Group and the glacigene rocks of the Neoproterozoic Duerdin Group (Thorne et al., in press), combined with the problems experienced in correlating these units across the Halls Creek Fault, implies post-Carr Boyd Group faulting (Fig. 7) may account for much of the sinistral displacement in the Halls Creek Orogen. These movements took place through the reactivation of major basement structures that formed initially during the Palaeoproterozoic orogeny (Tyler et al., 1995).

Post-Duerdin Group – pre-Antrim Plateau Volcanics faulting and tilting indicates a major period of strike-slip movement took place during the Neoproterozoic, between about 650 and 550 Ma. This event may correlate with a phase of contractional tectonism in the King Leopold Orogen c. 560–530 Ma (Shaw et al., 1992a) and north– south compression in the Paterson and Petermann Orogens (Myers et al., 1994). In the east Kimberley, there is little evidence in the stratigraphic record for an earlier period of sinistral movement which would correlate with the c. 1000 Ma Yampi Orogeny in the King Leopold Orogen (Shaw et al., 1992a).

Palaeozoic

Upper Devonian (Frasnian) sedimentation in the northern Halls Creek Orogen (Mory and Beere, 1988) shows many of the features associated with active strike-slip sedimentation (Christie-Blick and Biddle, 1985; Nilsen and Sylvester, 1995).

- Sedimentation took place in isolated basins which are today bounded on one or more sides by strike-slip faults (Fig. 8)
- Basin margins were sites of conglomeratic alluvial-fan sedimentation; e.g. Ragged Range, Galloping Creek, and Cockatoo sub-basins
- Basin fill was derived from multiple basin-margin sources
- There is clear evidence of intraformational unconformities and syndepositional faulting within the basin fill (Mory and Beere, 1988)
- Basin fill is often very thick (up to 2.7 km, Mory and Beere, 1988) relative to basin size and it is characterized by abrupt facies changes
- They contain upward-coarsening sequences (Mory and Beere, 1988) that developed in response to tectonically induced basin deepening.

In addition, there is evidence of mismatched source areas north of Glenhill where alluvial-fan deposits on the western side of the Glenhill Fault show an easterly source and are juxtaposed against similar facies on the eastern side of the fault which show a westerly source (Mory and Beere, 1988, fig. 58). The most likely explanation for these relationships is that post-depositional sinistral strike-slip movement has displaced the basin on the western side of the Glenhill Fault a minimum distance of 10 km south relative to the basin on the eastern side of this fracture

Most of the Devonian sedimentary basins (here referred to as sub-basins) in the northern Halls Creek Orogen have the structural characteristics of either stepover or transpressional strike-slip basins (Nilsen and Sylvester, 1995). Examples of the former include the Optic Hill sub-basin, located in the extensional stepover zone between the Dillon Spring and Dunham Faults and the Halls Creek Fault, and the Burt Range sub-basin, which developed in an extensional setting between the Halls Creek Fault and a synthetic splay from the Ivanhoe Fault. Elongate transpressional basins such as the eastern Cockatoo sub-basin (Fig. 8) formed next to uplifted and overthrust fault blocks along the Cockatoo Fault. Here, subsidence has resulted from the flexural loading of Precambrian basement adjacent to the uplifted blocks.

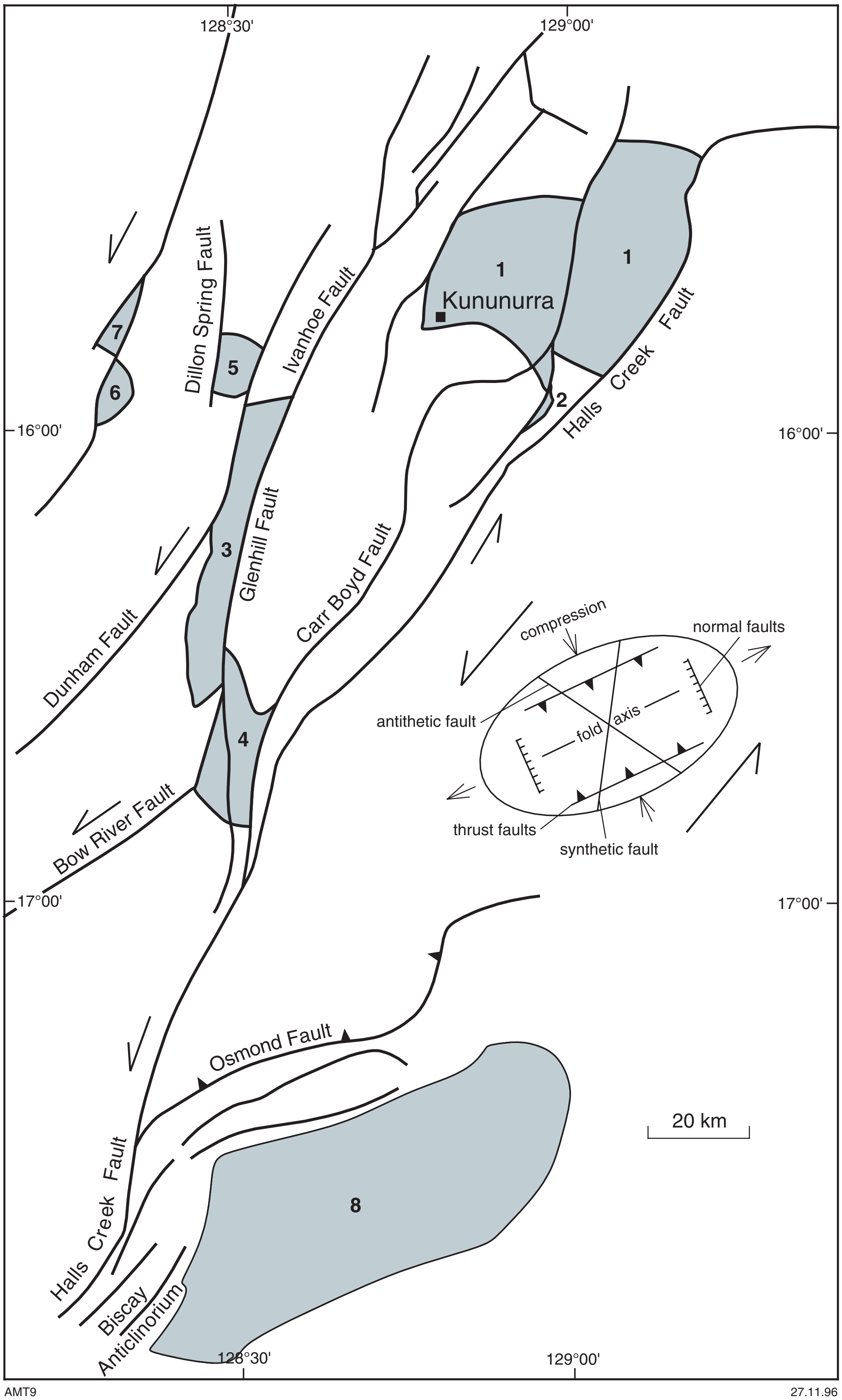
The Hardman sub-basin, 60 km southeast of Warmun, is another major Late Devonian depocentre which formed as a result of strike-slip deformation. Here, north-northwest – south-southeast compression, associated with Devonian sinistral movement on the Halls Creek Fault was responsible for thrust movement on the north-dipping Osmond Fault. The resultant folding and uplift in the Osmand Range was accompanied by flexural subsidence and the formation of the Hardman sub-basin in the area immediately to the south (Fig. 8). Subsidence along the western margin of this sub-basin was also enhanced by west-northwestward transpression against the Biscay Anticlinorium. Upward-coarsening fluvial to alluvial-fan deposits of the Frasnian Glass Hill Sandstone and Boll Conglomerate were deposited in the Hardman sub-basin, their presence reflecting sustained, coeval uplift in the Osmand Range to the north (Mory and Beere, 1988).

Sinistral strike-slip movement continued in the Halls Creek Orogen until the end of the Carboniferous and resulted in the reactivation of sub-basin boundary faults and associated splays, and development of large-scale open folds (e.g. Hardman Syncline). Post-Frasnian faults are associated locally with a steeply dipping Palaeozoic succession. On the western limb of the Hardman Syncline, the regional transpression has resulted in local overturning of the Cambrian Headleys Limestone. The sedimentary responses to post-Frasnian tectonism, though significant, were not as marked as during the Frasnian and resulted mainly in the development of local unconformities and syndepositional fault scarps within the Fammenian and Lower Carboniferous succession (Mory and Beere, 1988).

Large-scale Devonian to Carboniferous sinistral movement along the Halls Creek Fault coincides with a major period of north-northeasterly sinistral strike-slip faulting and transtension in the Pillara Range in the Canning Basin (Dorling et al., 1996). This deformation may reflect a widespread north–south compressive event that was felt throughout much of northern Australia during the 400–300 Ma Alice Springs Orogeny (Shaw and Black, 1991; Shaw et al., 1992b).

Conclusions

Details of Carr Boyd Group sedimentation and stratigraphy are inconsistent with deposition in an active strike-slip setting. Most of the post-Palaeoproterozoic sinistral faulting in the Halls Creek Orogen took place after deposition of the Carr Boyd Group. The principal fault movements occurred in the


128°30'
129°00'
16°00'
17°00'
Dillon Spring Fault
Ivanhoe Fault
Kununurra
Halls Creek Fault
Glenhill Fault
Carr Boyd Fault
Dunham Fault
Bow River Fault
compression
normal faults
antithetic fault
fold axis
thrust faults
synthetic fault
Osmond Fault
20 km
Halls Creek Fault
Biscay Anticlinorium
1
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post-Duerdin Group – pre-Antrim Plateau Volcanics interval and also during the late Palaeozoic. The latter event has exerted a major influence on the development of upper Devonian (Frasnian) sedimentary basins in the northern Halls Creek Orogen.

Figure 8. Structural setting of upper Devonian sedimentary basins in the northern Halls Creek Orogen:
1. Burt Range sub-basin,
2. east Cockatoo sub-basin,
3. Ragged Range sub-basin,
4. Galloping Creek sub-basin,
5. Optic Hill sub-basin,
6. Mount Rob sub-basin,
7. Gap Point sub-basin,
8. Hardman sub-basin

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