New occurrences of 'strings of beads' in the Bangemall Supergroup: a potential biostratigraphic marker horizon

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Abstract

Enigmatic bedding-plane markings, commonly referred to as 'strings of beads', were initially described from three localities in the Mesoproterozoic Stag Arrow Formation of the Manganese Group, Bangemall Supergroup. They were compared to similar structures in the Belt Supergroup, Montana, USA, that were recently named *Horodyskia moniliformis*. The 'beads' have since been discovered at more localities in the upper Bangemall Supergroup (Collier and Manganese Groups). They are both abundant and geographically widespread and appear to be narrowly constrained stratigraphically. Despite uncertainties surrounding their biological affinities, they appear to be a significant biostratigraphic marker.

KEYWORDS: Bangemall Supergroup, Collier Group, Manganese Group, Stag Arrow Formation, Backdoor Formation, biostratigraphy, problematica, enigmatic fossils, 'strings of beads', Proterozoic

Introduction

The 'strings of beads' structures are enigmatic fossils first discovered in Western Australia by I. R. Williams in 1985 in the Mesoproterozoic Stag Arrow Formation of the Manganese Group (Bangemall Supergroup). Grey and Williams (1990) described the structures from three localities on the ROBERTSON[6] 1:250 000 sheet (Fig. 1; Table 1). They compared them to the 'strings of beads' earlier described from the Belt Supergroup, Montana, USA (Horodyski, 1982). In 1990, I. R. Williams and K. Grey discovered several new localities containing 'strings of beads' in the Backdoor Formation of the Collier Group, on the COLLIER, MOUNT EGERTON, and TUREE CREEK sheets (Fig. 1; Table 1).

In August 2000, further field studies were carried out by the authors (except K. Grey) at the known localities to try to establish the palaeobiological affinities of the beads and determine the extent of their similarity to *Horodyskia moniliformis* from the Belt Supergroup of Montana. Subsequent investigation by D. Martin has shown that the beads are abundant in the area around localities 7 and 8 (Fig. 1). The new localities show that the beads are present in a wider range of palaeoenvironments than previously recorded, and add considerably to interpretations of the morphology of the structures. The documented sites now extend over a distance of about 450 km, from southeast of Balfour Downs Homestead to west of Pingandy Creek Homestead, and confirm that the beads are abundant and appear to be restricted stratigraphically.

Geological setting and age

The stratigraphy of the Bangemall Supergroup, which consists of a number of groups, some of which may be coeval, is currently being reviewed. A revised subdivision into a basal Edmund Group and unconformably overlying Collier Group has been established on the EDMUND sheet (Martin et al., 1999). The 'strings of beads' structures are in the lower part of the Backdoor Formation of the basal Collier Group and in the Stag Arrow Formation towards the base of the Manganese Group. Lithostrati-graphic correlations between the Collier and Manganese Groups are

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6 Capitalized names refer to standard 1:250 000 map sheets.

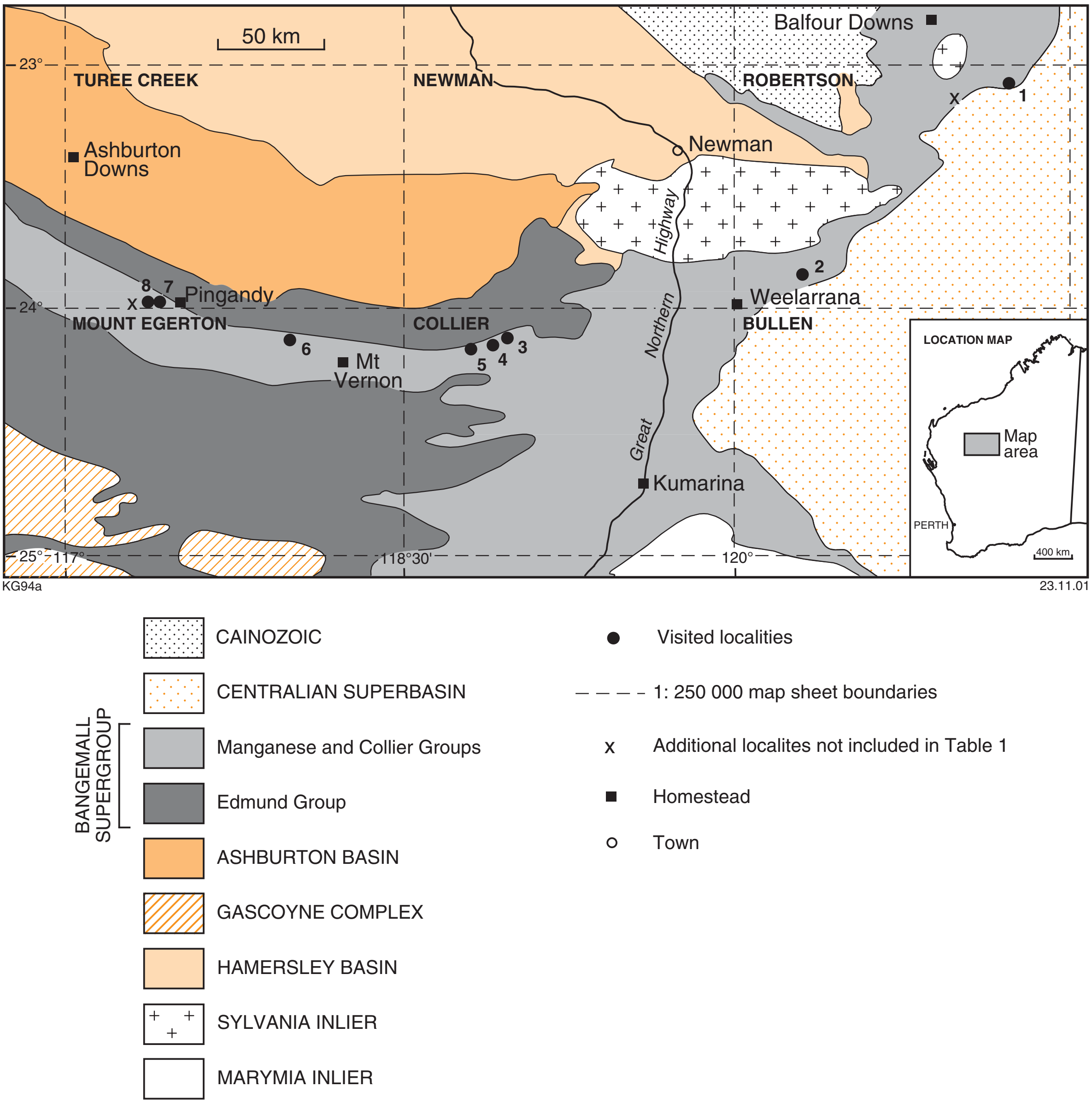

Figure 1. 'Strings of beads' localities in the Bangemall Supergroup, Western Australia (after Martin et al., 1999). Details are presented in Table 1

hampered by a lack of continuous outcrop, but partial stratigraphic equivalence between the Backdoor and Stag Arrow Formations has been suggested (Williams and Tyler, 1991). The presence and lateral continuity of 'strings of beads' in the Backdoor and Stag Arrow Formations suggests that this correlation warrants closer scrutiny, and that the 'bead' horizon may be an important biostratigraphic marker linking the two groups.

The 'bead' localities are all at about the same relative stratigraphic level with respect to the base of the Collier and Manganese Groups, and on COLLIER lie below and above a distinctive stromatolitic carbonate. The structures are in interbedded fine-grained sandstone and sandy siltstone with interbedded shales (Fig. 2a) that reflect energy regimes ranging from quiet water to high energy currents. Individual tabular sandstone beds are massive to normally graded with locally ripple-laminated tops. Rare tool marks (flute and groove casts) are associated with beads at some localities. Wrinkle marks are also common on the upper surface of many sandstone beds.

Constraints on the ages of the Collier and Manganese Groups are poor, but have been significantly improved by recent sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon and baddeleyite dating of the Collier Group, suggesting that the 'strings of beads' structures are between c. 1211 and 1070 m.y. old (Martin and Thorne, 2001). The Western Australian examples are therefore probably younger than those in the Belt Supergroup of Montana.

Table 1. Details of 'strings of beads' localities shown in Figure 1

Locality (Fig. 1)	*Map sheet 1:250 000*	*Position*	*Remarks*
1	ROBERTSON SF 51-13	Prolific 'strings of beads' are well exposed along a 3 km, southeasterly trending ridge, 8 km south-southwest of Millari Bore; particularly at 23°04'33"S, 121°11'34"E; 23°04'33"S, 121°11'48"E; and 23°05'08"S, 121°11'53"E	Assigned to the Stag Arrow Formation of the Manganese Group (Williams and Tyler, 1991), and described in Grey and Williams (1990); the 'strings of beads' are mainly on lower bedding-plane surfaces of thinly bedded, fine- to very fine grained, brown-weathering, grey sandstone interbedded with shale and siltstone; some thicker bedded (4–5 cm) ripple-marked sandstone also has beads preserved on the top surface both in the ripple troughs and oblique to the crests of the ripple marks; distribution of beads ranges from fairly linear and roughly parallel (current controlled) to random, arcuate and semi-circular forms (still-water conditions); possible branching forms identified; tool marks or current structures generally absent from the lower bedding-plane surfaces on which the 'strings of beads' are located
2	ROBERTSON SF 51-13	Sparsely scattered to locally abundant 'strings of beads' on a low rubble-strewn, flat-topped rise west and northwest of a claypan, 9.5 km bearing 139° from Mundiwindi; at 23°51'42"S, 120°18'09"E; and 23°51'30"S, 120°18'06"E	Assigned to the Stag Arrow Formation of the Manganese Group (Williams and Tyler, 1991), and described in Grey and Williams (1990); the 'strings of beads' are on weathered, flaggy, red-brown, fine-grained sandstone, commonly not in situ; linear, arcuate, and branching forms present; tool marks and current structures are common; some gutter casts have beads impressed on the base of the casts
3	COLLIER SG 50-4	Scattered and locally abundant 'strings of beads' on rubble- strewn flats and in situ on adjacent, benched northwest-facing, hillside 4.2 km bearing 212° from Boundary Bore; 24°08'28"S, 118°58'56"E; a small area of prolific beads is also located 1.3 km west of this locality at 24°08'31"S, 118°58'13"E	Assigned to the Backdoor Formation of the Collier Group (Martin et al., 1999); 'strings of beads' on lower bedding-plane surfaces of thin, fine-grained, green-grey sandstone and siltstone interbedded with greenish-grey shale; succession overlain by purple-grey stromatolitic dolomite; scattered beads are also in interbedded grey-green siltstone and calcareous shale overlying the stromatolitic dolomite unit; the small area to the west is notable for the prolific beads on the lower bedding-plane surfaces of very thin bedded, dark-grey-brown sandstone interbedded with shale; this horizon lies below the stromatolitic dolomite unit
4	COLLIER SG 50-4	Prolific 'strings of beads' are located in a 10 m cliff on the western side of a north-flowing sandy creek, 6.2 km bearing 230° from Boundary Bore at 24°08'30"S, 118°57'19"E; a second locality, lying 400 m and to the south also on the west bank, 24°07'46"S, 118°55'10"E, contains abundant beads	Assigned to the Backdoor Formation of the Collier Group (Martin et al., 1999); prolific 'strings of beads' are on the lower bedding-plane surfaces of thin, greyish-green fine-grained sandstone beds in laminated shale and siltstone. The irregular spaced sandstone beds are commonly wrinkle marked on the upper surface; beads are mainly large, linear and roughly parallel (current controlled); tool marks are sparse; this clastic succession is overlain by a stromatolitic dolomite unit. The abundant 'bead' locality, 400 m to the south, directly underlies the dolomite unit
5	COLLIER SG 50-4	Abundant 'strings of beads' on western side of an abrupt hill in gullies above a sandy creek, 16.6 km bearing 086° from Peterson Bore; on southern side of track at 24°09'16"S, 118°51'22"E	Assigned to the Backdoor Formation of the Collier Group (Martin et al., 1999); several horizons located with prolific to abundant beads in brown-weathering khaki greenish-grey sandstone interbedded with shale and siltstone; overlain by grey-violet stromatolitic dolomite; sparse beads in siliceous and calcareous shale and siltstone overlying the dolomite unit
6	MOUNT EGERTON SG 50-3	Sparse 'strings of beads' in flaggy rubble at base of low hill, 2.5 km bearing 350° from Mount Vernon and 1 km west of the Meekatharra – Ashburton Downs road at 24°06'09"S, 118°01'38"E	Assigned to the Backdoor Formation of the Collier Group (Martin et al., 1999); sparse beads on red-brown to grey-brown, flaggy, fine-grained sandstone; poor preservation, rubbly outcrop
7	TUREE CREEK SF 50-15	Sparse 'strings of beads' located in several areas north and south of the Mount Augustus – Pingandy road; around 11.2 km bearing 291° from Pingandy Homestead; 23°57'42"S, 117°24'51"E; and 23°57'29"S, 117°24'23"E	Assigned to the Backdoor Formation of the Collier Group (Martin et al., 1999); sparse beads are scattered over a wide area in rubbly, flaggy, dark red-brown weathered, fine-grained sandstone; some 'elephant-skin' texture (algal mat) on top of sandstone beds
8	TUREE CREEK SF 50-15	Prolific 'strings of beads' along a small gully 50 m north of the Mount Augustus – Pingandy road, 12 km bearing 290° from Pingandy Homestead; 23°57'29"S, 117°24'23"E	Assigned to the Backdoor Formation of the Collier Group (Martin et al., 1999); prolific beads on slabby and flaggy, dark grey-brown to red-brown, fine-grained sandstone, interbedded with siltstone and shale; some sandstone shows graded bedding; random arcuate distribution, branching forms; quiet water conditions; some tool marks

Description of the 'strings of beads' structures

The Bangemall Supergroup 'strings of beads' are commonly present as impressions on the undersurface of successive 2–6 cm-thick sandstone beds (Fig. 2b,c). They are commonly separated by a few millimetres of siltstone (now largely eroded). Preservation on the undersurface is common, but only rare impressions have been observed on the bedding plane itself. At one locality the structures are present in at least 30 m of section.

The 'strings of beads' consist of impressions of 3 to 30 beads, in strings from 1 to 7 cm long (Grey and Williams, 1990). Bead diameter ranges from 0.5 to 4 mm. Impressions are up to 1 mm deep and typically between 1 and 5 mm apart. Parameters are consistent on any one string. The strings vary from linear subparallel (Fig. 2b) to arcuate or semicircular (Fig. 2c) and their orientation appears dependent on current strength. Detailed discussions of morphological variation and statistical analyses were presented by Grey and Williams (1990). Beads from the new localities are similar to those already described, although size ranges are probably greater.

Discussion

The 'strings of beads' fossils are of considerable interest for evolutionary palaeobiology. Grey and Williams (1990) discussed the probable biological origin of the structures, and evaluated a range of possible origins. They suggested a likely metaphytic origin, possibly as megascopic algae with affinities to the Phaeophyceae (the brown algae or seaweeds), but did not formally name the structures.

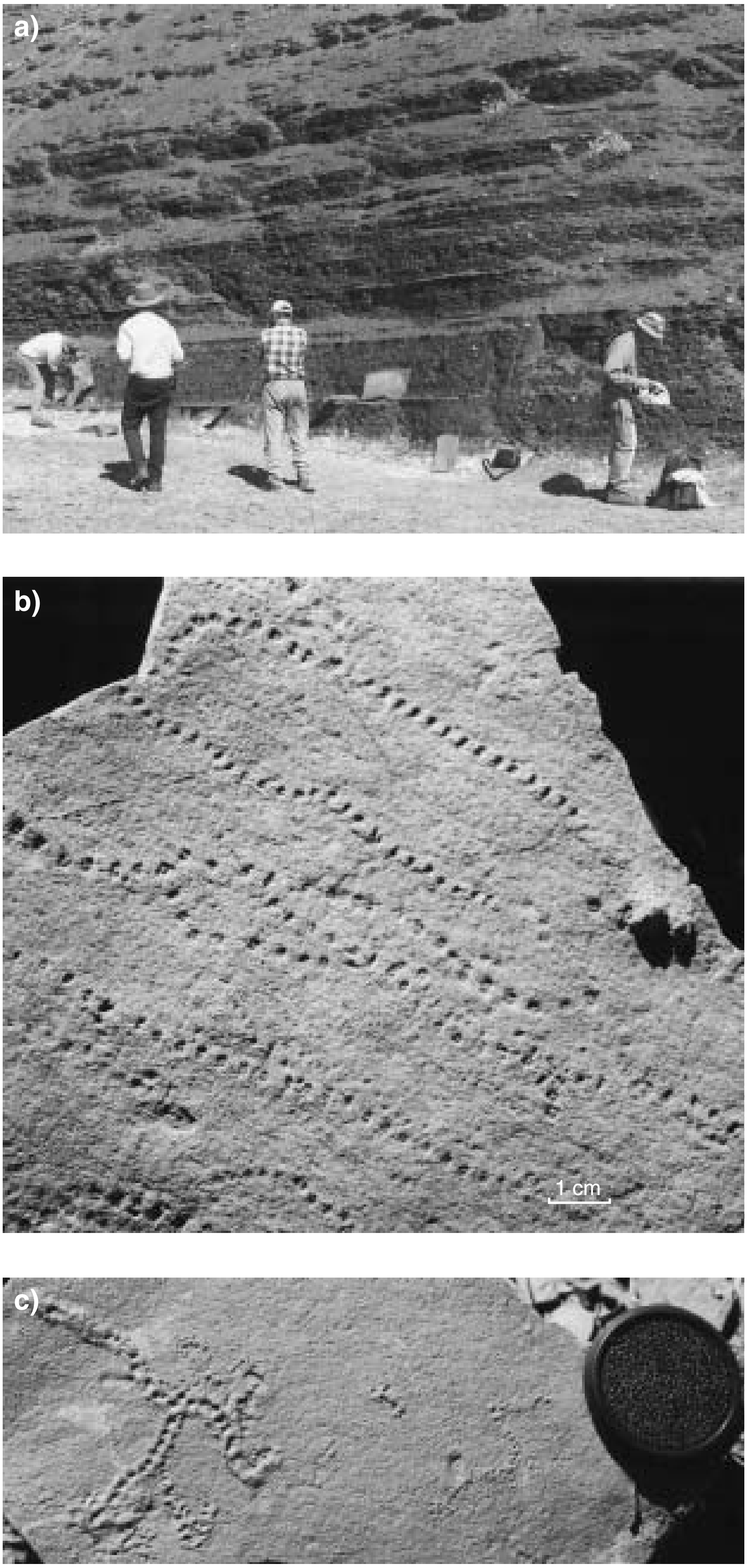

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Figure 2. Illustrations of 'strings of beads' fossils: a) examining the 'strings of beads' in thin interbedded sandstone and shales at locality 4; b) typical 'strings of beads' showing subparallel alignment on lower bedding plane surface at locality 1; c) 'strings of beads' showing random, sinuous orientation with beads impressed in soft sediment, locality 8

Horodyski (1982) was uncertain of the origin of the highly comparable Belt Supergroup structures. Other possible origins for the structures have been discussed. Fedonkin and Runnegar (1992) considered the Montana and Western Australian structures to be dubiofossils. Hofmann (1992) thought they were pseudofossils, comparing them to structures formed at the tips of evaporite veins in the McArthur Basin in Queensland, but there are no traces of evaporites in the Western Australian formations, and the beads have quite a different form from the structures referred to by Hofmann. Fedonkin et al. (1994) suggested that they were formed by a string of polyp-like creatures.

After studying the Montana 'strings of beads', Yochelson and Fedonkin (2000) concluded that they were fossils, and named them *Horodyskia moniliformis*. This species is present in the Appekunny Formation, which is older than 1443 ± 7 Ma based on SHRIMP U–Pb dating of zircons in the Purcell Lava (Evans et al., 2000).

K. Grey still favours an interpretation of the structures as metaphytes, possibly seaweed (Grey and Williams, 1990). M. Fedonkin and E. Yochelson favour an interpretation as metazoans, but other possibilities such as a microbial (prokaryotic) origin (B. Runnegar) require exploration. The size and complexity of these structures suggests that they were multicellular with well-developed tissue differentiation.

Conclusions

If an animal rather than plant origin can be demonstrated for the 'strings of beads', this would place animal evolution at least 700 m.y. earlier than current unequivocal traces (between about 550 and 600 Ma) and would overturn thinking about evolutionary pathways. A few recent models of molecular clocks predict a very early origin for the metazoans (Wray et al., 1996; Bromham et al., 1998), which is close to the age of the Bangemall fossils. The biostratigraphic potential of these structures also requires more detailed study. If, as it appears at present, the beads are extremely abundant but restricted in stratigraphic distribution, this makes them a valuable stratigraphic marker for rocks that are otherwise difficult to date and correlate. This is of particular significance for the revision of the Bangemall Supergroup currently being undertaken by the Geological Survey of Western Australia (Martin et al., 1999; Martin and Thorne, 2001).

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