Foraminiferal assemblages in the Fossil Cliff Member of the Holmwood Shale, northern Perth Basin

by D. D. Ferdinando[1]

Abstract

Three parasequences are present within the type section of the Sakmarian (Early Permian) Fossil Cliff Member of the Holmwood Shale, with each parasequence consisting of a basal shale overlain by calcareous beds. Three distinct foraminiferal assemblages have been recorded from the member. The first is dominated by agglutinated foraminifera mainly from the genera *Hyperammina* and *Ammodiscus*. This assemblage remains consistent throughout each of the three parasequences. The second and third foraminiferal assemblages are characterized by calcareous hyaline and calcareous porcellaneous species respectively, with *Howchinella woodwardi*, *Lunucammina triangularis*, and *Protonodosaria irwinensis* dominating the calcareous hyaline assemblage, and *Hemigordius schlumbergeri*, *H. voltus*, *Calcitornella stephensi*, and *Trepeilopsis australiensis* characteristic of the calcareous porcellaneous assemblage. These calcareous foraminiferal assemblages are found in association with each other. The lowest parasequence is dominated by the calcareous hyaline assemblage, the middle parasequence is a mixture of the two assemblages, and the top parasequence is dominated by the calcareous porcellaneous assemblage. This variation is interpreted as an overall marine regression within the Fossil Cliff Member, in addition to minor eustatic sea-level variations and a change from a high terrigenous input to impoverished terrigenous input.

KEYWORDS: Permian, foraminifera, Fossil Cliff Member, eustacy, biostratigraphy.

Introduction

The type section of the Fossil Cliff Member of the Holmwood Shale lies on the northern branch of the Irwin River at latitude 28°55'S and longitude 115°33'E, 450 km north of Perth and 32 km northeast of Mingenew (Fig. 1). Exposed as a cliff face in the Irwin River valley, this section is approximately 17 m thick and comprises three parasequences, consisting of alternating beds of fossiliferous limestone, sandy siltstone, and shale, forming a progradational parasequence set. The maximum exposed thickness of the Fossil Cliff Member is at Beckett's Gully, 5 km to the southwest, where Playford et al. (1976) measured a 45 m-thick section. The Fossil Cliff Member lies at the top of the Holmwood Shale, and is conformably overlain by the High Cliff Sandstone (Playford et al., 1976), although at the type section the contact between the High Cliff Sandstone and the Fossil Cliff Member is not exposed.

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The upper part of the Holmwood Shale lies within the *P. confluens* palynomorph biozone (Backhouse 1998), and the Fossil Cliff Member falls within the *P. pseudoreticulata* palynomorph biozone (Foster et al., 1985), indicating a Sakmarian (Early Permian) age for the member. The presence of the goniatites *Juresanites jacksoni*, *Uraloceras irwinensis*, and *Metalegoceras kayi* lower in the formation provides further support for this age (Glenister and Furnish, 1961).

Stratigraphy of the Fossil Cliff Member

The Fossil Cliff Member consists of three parasequences forming a progradational parasequence set. Each parasequence consists of basal, black, finely laminated shale overlain by muddy calcarenite beds, the uppermost bedding surface of which marks the parasequence boundary (Fig. 2). Above the third parasequence is a bed of sandy siltstone to siltstone. The Fossil Cliff Member contains a diverse fossil assemblage, dominated by bryozoa and productid and spiriferid brachiopods, particularly in the second and third parasequences. The thickness of the shale beds at the base of each parasequence decreases up the parasequence set, and the exposed top-section of the third parasequence grades into a coarsening-upward sandstone bed. The coding scheme used for the facies outlined below follows that used by Le Blanc Smith and Mory (1995) and is summarized in Table 1.

Terrigenous facies

The shale lithofacies (*Al*) at the base of each parasequence consists of a

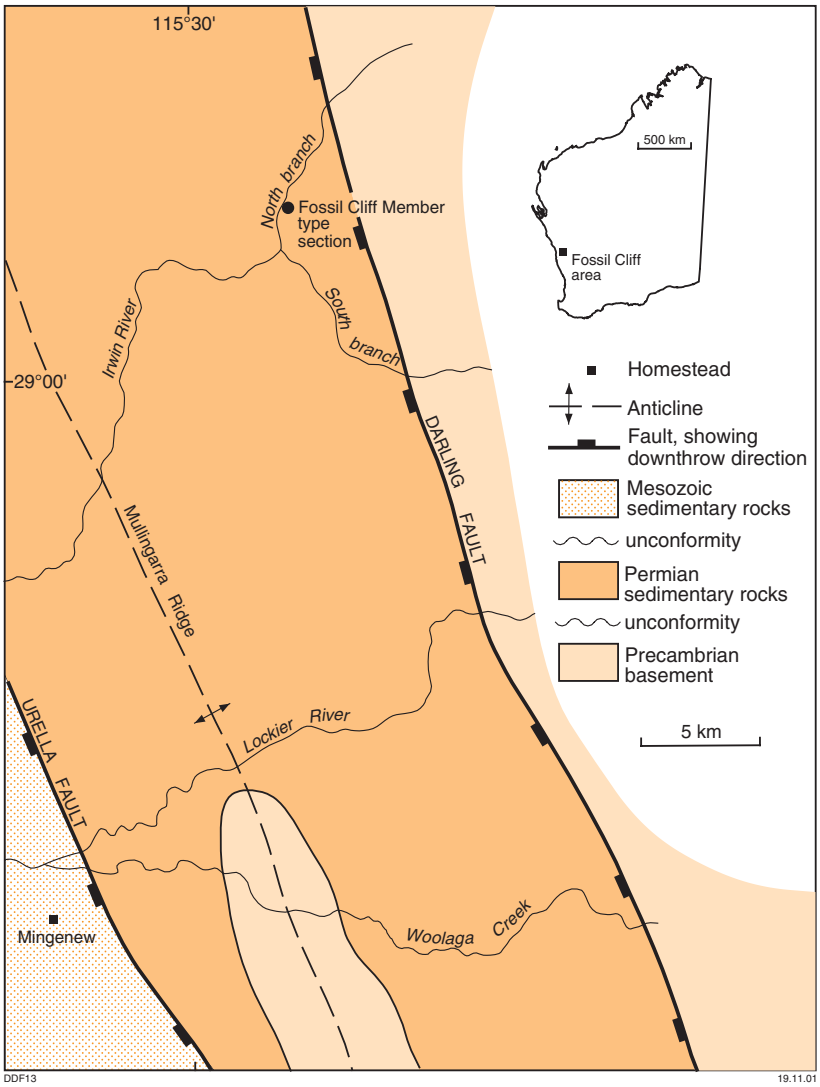

Figure 1. Locality diagram for the Fossil Cliff Member type section

very fine grained, dark-grey to black micaceous mud, which displays thin, planar laminae up to 5 cm apart, but generally about 3–5 mm apart, with bed thicknesses ranging from 20 cm to 4 m. Numerous veinlets of late diagenetic gypsum, subparallel to bedding planes, are present throughout the shale facies in addition to bands of jarosite formed from the alteration of pyrite during diagenesis.

Table 1. Facies coding scheme used in this paper

Terrigenous facies	
Al	Laminated shale and siltstone
(S/A)b	Bioturbated muddy fine-grained sandstone
Sm	Massive, coarse-grained sandstone
Calcareous facies	
(L/A)bs	Bioturbated, shelly, muddy calcarenite
Lbs	Bioturbated, shelly, indurated calcarenite to wackestone

The sandstone lithofacies (*Sm* and *(S/A)b*) above the third parasequence ranges in composition from quartzwacke to subarkose, and in part has an arenitic composition. This facies is only found overlying the third parasequence, and is presumably conformably overlain by the High Cliff Sandstone. The grainsize of the sandstones increases upward, from muddy fine-grained sandstone (*(S/A)b*) to well-sorted, coarse-grained quartz arenite (*Sm*) at the top of the exposure. Fossil assemblages from this lithofacies include a dwarfed fauna of fragmented bryozoa and agglutinated foraminifera.

The shale and sandstone lithofacies contains a sparse fossil assemblage consisting mainly of small crinoid ossicles, fenestrate bryozoan moulds, the thin-shelled chonetid brachiopod *Neochonetes (Sommeria) pratti*, and agglutinated foraminifera, dominated by *Ammodiscus* and *Hyperammina*. The delicate macrofossils are commonly preserved in the shale as external moulds along bedding planes. In the shaly facies the foraminiferal fauna is diverse, with more than 18 species recognized. They are predominantly agglutinated forms, although rare specimens of the nodosariid foraminifera *Protonodosaria irwinensis* and *Howchinella woodwardi* are also present.

Calcareous facies

Within the calcareous beds of the Fossil Cliff Member, three facies are evident. The first is a friable, buff, muddy calcarenite (*(L/A)bs*) containing an assortment of fragmented and intact bioclasts of varying sizes and shell strengths. The muddy calcarenite beds are generally 10–60 cm thick.

The second calcareous lithofacies is a brown, poorly sorted, friable packstone with 20–40% matrix (*(L/A)bs*). Bioclasts in this facies appear to have undergone very little transportation because fragile components such as bryozoa, crinoid stems, and thin-shelled brachiopods are generally intact. Beds of this facies are 10–30 cm thick and display planar bedding surfaces.

The third calcareous lithofacies is an indurated grey wackestone (*Lbs*) containing bioclasts similar in style and preservation to those of the second facies, with 40–65% matrix. The facies outcrops as distinctly lenticular beds, which extend laterally up to 20 m and are 20 to 50 cm thick.

In the calcareous beds of all parasequences, the fossil assemblage is extremely diverse, with more than

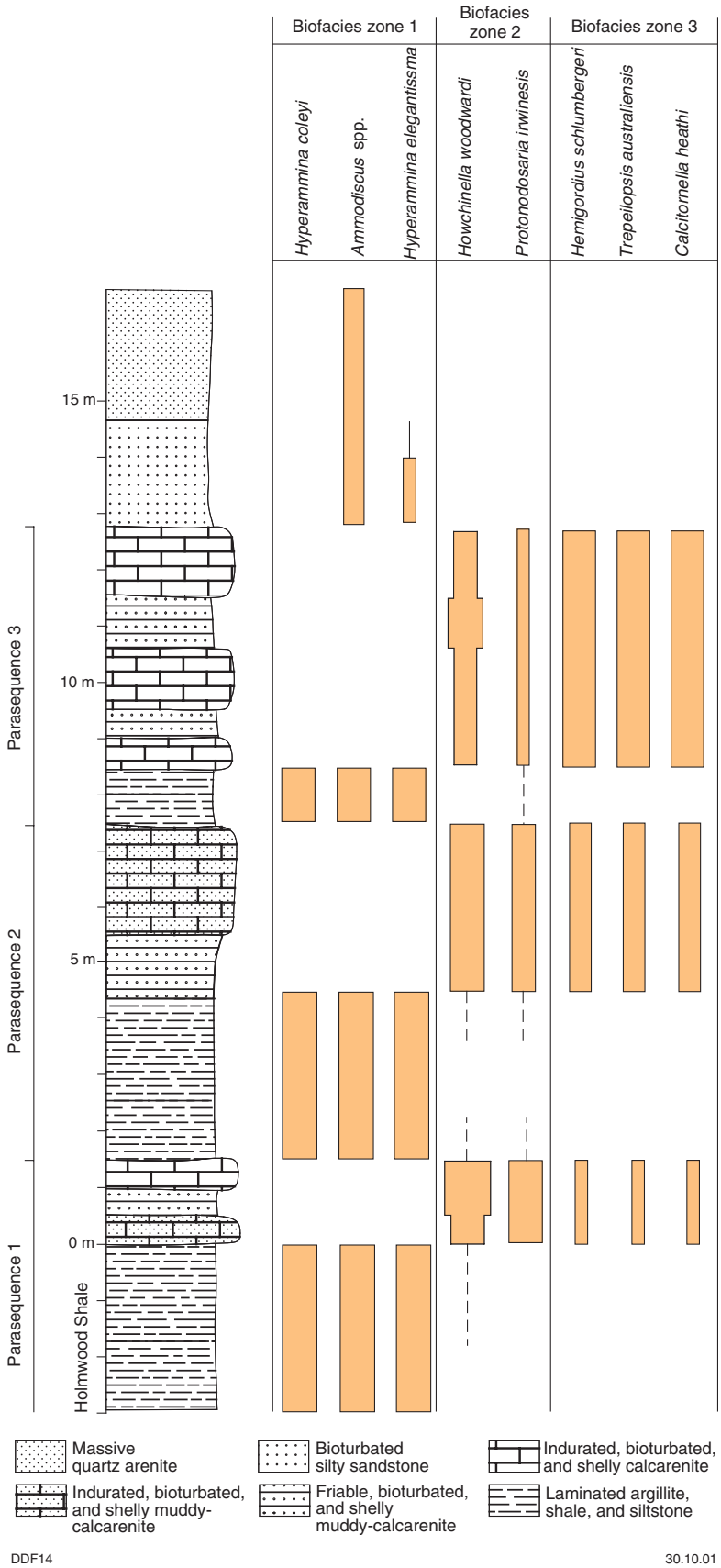

Figure 2. Stratigraphic section of the Fossil Cliff Member at its type locality showing relative abundances of selected species from the three biofacies zones identified

70 species present (Playford et al., 1976). The majority of identified fossils are brachiopods, notably productids and spiriferiids. Other groups present include solitary rugose corals, crinoids, blastoids, bryozoa, bivalves, gastropods, ammonoids, nautiloids, nodosariid and milioliid foraminifers, ostracodes, and rare trilobites. The abundance of the various species and groups in the carbonate beds differs between the parasequences. The significant variations are a decrease in abundance of spiriferiid brachiopods upwards through the member, coinciding with a decrease in the abundance of rugose corals, and an increase in the abundance of species of productid brachiopods upwards through the sequence.

Foraminiferal assemblages within the parasequences

Within the Fossil Cliff Member, the foraminiferal assemblages can be divided into two broad types. The first is an agglutinated foraminiferal assemblage (biofacies zone 1) within the facies *Al*, *Sm*, and *(S/A)b*, and the second is a calcareous assemblage, restricted to the calcareous facies *Lbs* and *(L/A)bs*. The calcareous assemblage can be further subdivided into a calcareous hyaline assemblage (biofacies zone 2) and a calcareous porcellaneous assemblage (biofacies zone 3). These three assemblages broadly correspond to the palaeoecological assemblages listed by Crespin (1958) for the Permian foraminifera of Australia, and their abundances within the member are illustrated in Figure 2. Transitions between the agglutinated and calcareous assemblages are sharp, and strongly controlled by palaeoenvironmental conditions.

Biofacies zone 1

Species within the agglutinated foraminiferal assemblage of biofacies zone 1 (Table 2) include *Ammodiscus nitidus*, *A. multicinctus*, *Hyperammina callytharraensis*, *H. coleyi*, *H. elegans*, *Trochammina subobtusa*, *Thuramminoides sphaeroidalis*, and *Glomospirella nyei*. There is little change in species diversity within the individual beds of lithofacies *Al*, although in lithofacies *(S/A)b* and *Sm* there is a marked decrease in the abundance of slender, tubular genera such as *Hyperammina*, with more robust forms such as *Trochammina subobtusa*, *Ammodiscus nitidus*, *A. multicinctus*, and *Thuramminoides sphaeroidalis* being dominant.

Biofacies zones 2 and 3

The calcareous lithofacies, *Lbs* and *(L/A)bs*, of the Fossil Cliff Member contains a varied fauna of calcareous foraminifera, which are divided into two main biofacies assemblages: the calcareous hyaline assemblage of biofacies zone 2 and the calcareous porcellaneous assemblage of biofacies zone 3 (Table 2). These two biofacies are intermixed, but biofacies zone 2 is the dominant element in the lowermost parasequence and, to a lesser degree, also in the middle parasequence, whereas biofacies zone 3 is dominant in the uppermost parasequence.

The characteristic species of biofacies zone 2 are *Howchinella woodwardi*, *Lunucammina triangularis*, and *Protonodosaria irwinensis*. Within biofacies zone 3 the characteristic species are *Hemigordius schlumbergeri*, *H. voltus*, *Calcitornella heathi*, *C. stephensi*, and *Trepeilopsis australiensis*. Transitions between these two biofacies are gradual, and there is a large degree of intermixing of assemblages within lithofacies *Lbs* and *(L/A)bs*.

Foraminiferal palaeoecology of the Fossil Cliff Member

Foraminifera of the Fossil Cliff Member display two main trends in their distribution. The first is a change based on palaeoenvironmental conditions, from biofacies zone 1 in lithofacies *Al* at the base of each parasequence, to the assemblages dominated by biofacies zone 2 and biofacies zone 3 in the carbonate-rich lithofacies *Lbs* and *(L/A)bs* at the top of each parasequence. The other palaeoecological trend is the dominance of biofacies zone 2 in carbonate beds of the lower parasequences, whereas biofacies zone 3 dominates the calcareous foraminiferal assemblages in the carbonate beds of the uppermost parasequence.

Table 2. Key foraminiferal species from each biofacies zone of the Fossil Cliff Member

Biofacies zone 1	
Hippocrepinella biaperta Crespin, 1958	*?Thuramminoides pusilla* (Parr), 1942
Thuramminoides sphaeroidalis Plummer, 1945	*Teichertina teicherti* (Parr), 1942
Sacammina arenosa (Crespin), 1958	*Hyperammina callytharraensis* Crespin, 1958
Hyperammina coleyi Parr, 1942	*Hyperammina elegans* (Cushman and Waters), 1928
Hyperammina elegantissima Plummer, 1945	*Kechenotiske hadzeli* (Crespin) 1942
Ammodiscus multicinctus Crespin and Parr, 1941	*Ammodiscus nitidus* Parr, 1942
Glomospirella nyei Crespin, 1958	*Ammobaculites woolnoughi* Crespin and Parr, 1941
Trochammina subobtusa Parr, 1942	*Tetrataxis conica* Ehrenberg, 1854
Biofacies zone 2	
Howchinella woodwardi (Howchin), 1895	*Lunucammina triangularis* (Chapman and Howchin), 1905
Protonodosaria irwinensis (Howchin), 1895	*Protonodosaria tereta* (Crespin), 1958
Vervilleina? grayi (Crespin), 1945	
Biofacies zone 3	
Calcitornella elongata Cushman and Waters, 1928	*Calcitornella heathi* Cushman and Waters, 1928
Calcitornella stephensi (Howchin), 1894	*Trepeilopsis australiensis* Crespin, 1958
Hemigordius schlumbergeri (Howchin), 1895	*Hemigordius voltus* Palmieri, 1985

Biofacies zone 1 consists of agglutinated foraminifera that require low amounts of dissolved carbonate in the seawater relative to the calcareous species, and are associated with bryozoa and brachiopod species that are sessile filter-feeders requiring low levels of dissolved oxygen (McKinney and Jackson, 1989). Oxygen levels during deposition of this shale facies were probably dysaerobic, and the substrate was in a reducing environment, with large amounts of terrigenous sediment washed into the area. The presence of intact, delicate fenestrate bryozoa in addition to the thin, delicate test walls of the agglutinated foraminifera, particularly those of the *Hyperammina*, suggests that the water energy was extremely low, with the substrate well below the storm wave base, probably in a protected embayment.

Biofacies zone 2 is found in conjunction with a rich and diverse macrofauna, containing sessile filter-feeding spiriferiid brachiopods and solitary rugose corals. The association of biofacies zone 2 with these faunal elements indicates that oxygen, nutrient, and dissolved carbonate levels in the water were high, the substrate was within the photic zone, and the water turbidity was low. The preservation of many intact specimens of delicate bryozoa, crinoids, and brachiopods suggests that water energy was also low, although there is some fragmentation of the fauna. This may indicate that water levels were generally below wave base, with fragmentation of the fauna on the substrate during infrequent storms.

Biofacies zone 3 dominates the upper parasequence. The species from this assemblage are generally robust and possess thick calcareous tests. They are associated with a rich and diverse macrofauna, which is generally fragmented in nature, lacks sessile filter-feeding groups such as rugose corals and spiriferiid brachiopods, and the brachiopod fauna is dominated by thick-shelled brachiopod species such as *Elivina hoskingae*. The palaeoenvironment of this biofacies is very similar to that of biofacies zone 2, with the exception that the water energy conditions were much higher. This biofacies was probably deposited in a near-shore environment, such as a carbonate shoal.

Conclusions

The two main facies within the Fossil Cliff Member, a faunally impoverished terrigenous-dominated facies and a faunally diverse and abundant calcareous-dominated facies, were deposited during eustatic marine regression. The foraminiferal assemblages within the member closely reflect varying palaeoenvironmental conditions, that is the gradual changes in water depth and energy due to the marine regression and the abrupt change from terrigenous- to calcareous-dominated deposition. The changes from relatively deep-water, dysaerobic deposition to carbonate beds in shallower aerobic conditions, which thicken upwards through the member, probably reflect amelioration of the climate during the Early Permian. This change is possibly associated with eustatic rebound as ice sheets retreated globally (e.g. Miller and Eriksson, 2000).

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