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ScienceDirect
Palaeogeography, Palaeoclimatology, Palaeoecology 251 (2007) 383–397
PALAEO
www.elsevier.com/locate/palaeo

Taphonomy and palaeoecology of a Late Ordovician caryocaridid from the Soom Shale Lagerstätte, South Africa

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Received 24 November 2006; received in revised form 11 April 2007; accepted 16 April 2007

Abstract

A new species of caryocaridid is reported from the Late Ordovician of South Africa. The fossils show a complex, multi-layered structure that may represent exceptional preservation of the original arthropod exo-, endo- and epicuticle. Alternatively, the layered structure may comprise the carapace, with a mineralized cast of the internal void and a layer of fibrous illite external to the carapace. The genesis of the fibrous illite is important as it demonstrates that not all fibrous textures associated with fossils in the Soom Shale, and perhaps other Lagerstätten, can be interpreted as mineralized muscle tissue.

Caryocaris cedarbergensis n.sp. extends the geographical, ecological and temporal range of the family and provides the first evidence of a zooplanktonic constituent to the Soom Shale biota. The genus most likely represents a cool-adapted mesopelagic group during the Early–Middle Ordovician, which inhabited an epipelagic cold-water shelf environment during the Late Ordovician.

Keywords: Caryocarididae; Soom Shale; Lagerstätte; Taphonomy; Palaeoecology; Ordovician

1. Introduction

The Soom Shale Konservat Lagerstätte (site of exceptional fossil preservation) contains several taxa displaying exceptional preservation of soft parts, most notably conodonts (Aldridge and Theron, 1993; Gabbott et al., 1995), eurypterids (Braddy et al., 1995, 1999) and enigmatic fossils. Compared with the Cambrian System, the Ordovician has few known Konservat Lagerstätten and of these the Soom Shale records the greatest number of taxa and the highest fidelity preservation of decay-prone tissues, principally as clay mineral replacements. Other occurrences of exceptional preservation in the Ordovician are the Late Ordovician Beecher's Trilobite Bed of New York State, USA, known for trilobites with appendages and other soft tissues preserved in pyrite (Briggs et al., 1991); the basal Caradoc mudstones of the Llanfawr Quarries, Llandrindod, Powys, Wales, which preserve an abundance of graptoloids, chitinozoans and sponges in pyrite (Botting, 2004); the Middle Ordovician Winneshiek Lagerstätte from the St. Peter Sandstone in Northeast Iowa which includes conodont apparatuses and a variety of other fossils (including caryocaridids) preserved with associated soft-tissue impressions (Liu et al., 2005, 2006); an arthropod described from the Tremadoc of England with preserved appendages (Siveter et al., 1995); and two Late Ordovician shoreline biotas from Manitoba, Canada, one of which, along with other taxa, has well preserved cnidarian medusae (jellyfish) (Young et al., 2006).

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0031-0182/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.palaeo.2007.04.006

The caryocaridids have been placed within the Class Malacostraca Latreille, 1806, and the Subclass Phyllocarida Packard, 1879; though there is currently no soft-tissue preservation of the head appendages to confirm their crustacean affinities. They were originally placed in the Family Ceratiocarididae Salter, 1860, by Salter (1863), but were established in their own family, the Caryocarididae by Racheboeuf et al. (2000). The caryocaridids attained their highest diversity and numerical abundance during the Arenig and Llanvirn (Early–Middle Ordovician) (Vannier et al., 2003). Previously, the family was known to range from the Tremadoc to the Early Caradoc (Braddy et al., 2004), when it was thought that they became extinct. They form a recurrent component of graptolite-bearing black, outer-shelf shales (Vannier et al., 2003; Braddy et al., 2004).

Here we report the occurrence of caryocaridids from the Soom Shale Lagerstätte; these specimens occur approximately 10 myr after the hitherto youngest caryocaridids from the early Caradoc of South America (Bulman, 1931; Vannier et al., 2003). The fossils are very rare, as only two specimens have been discovered in fifteen years of collecting. We also comment on the mode of preservation and palaeoecological significance of this new discovery.

1.1. Stratigraphy and sedimentology

The Cedarberg Formation, of which the Soom Shale is the lower member and the Disa Siltstone the upper member, constitutes the only significant fine-grained unit within the Lower Palaeozoic arenaceous Table Mountain Group (Rust, 1981), outcrops of which are found in the Western Cape, South Africa (Fig. 1). The Cedarberg Formation contains the only datable fossils within the entire sequence; these have indicated a late Ashgill (Rawtheyan or Hirnantian) age (Cocks et al., 1970; Cocks and Fortey, 1986; Theron et al., 1990). Sutcliffe et al. (2000) and Young et al. (2004) interpreted the Soom Shale as a postglacial transgressive deposit resulting from the demise of the Late Ordovician glaciers, as it directly overlies tillites of the glaciogenic Pakhuis Formation, thus representing an interval equivalent to the *persculptus* graptolite zone of the Hirnantian.

The Soom Shale comprises laminated mud and siltstone and is 10–15 m in thickness. Soom Shale siltstones and mudstones are black when fresh, for example at Sandfontein, but weather to a pale grey colour in surface exposures at Keurbos (Gabbott, 1998). The black colour of palynomorphs and chitinozoans indicates that the sediment has undergone burial anchimetamorphism to temperatures of at least 200 °C (Cramer et al., 1974; Gabbott et al., 2003). The laminae comprise alternations of silt and mud with darker layers, which may be degraded organic matter. The sediment is composed mostly of clay minerals, especially illites and mixed-layer clays, and detrital quartz. It also contains syngenetic/diagenetic pyrite and diagenetic chlorite and clay minerals (Gabbott, 1998).

1.2. Palaeogeography and palaeoenvironment

Previously, the basin in which Soom Shale was deposited was thought to be located at approximately 60° S (Gabbott et al., 1995; Gabbott, 1998; Aldridge et al., 2001); however, several continental reconstructions for the Late Ordovician have placed the tip of South Africa at between about 30° and 45° S (Fig. 2) (Beuf et al., 1971; Smith, 1997; Sutcliffe et al., 2000; Cocks and Torsvik, 2002; Fortey and Cocks, 2003; Young et al., 2004). The Soom Shale is a postglacial transgressive unit (Sutcliffe et al., 2000; Young et al., 2004), with dropstones recorded from the base of the member. This indicates a cold-water setting.

The depositional setting is thought to have been in a quiet water basin close to a retreating ice front (Theron and Thamm, 1990); water depth is unknown but was unlikely to have been great as the basin was in an intracratonic setting and the Soom Shale is bounded by subaerial tillites below and shallow marine siltstones above (Gabbott, 1999). On the basis of the lack of sedimentary structures, Gabbott (1999) suggested a water depth of at least 100 m, although she cautioned that it could be much shallower if microbial mats bound the sediment or if the sea surface was ice covered. This would represent an inner shelf setting. However, the water depth in the Soom Shale is imprecisely defined and not supported by a detailed sedimentological analysis. The laminated fine-grained nature of the Soom Shale might represent the outwashing of material during climatic amelioration and ice-sheet retreat (Theron and Thamm, 1990). Dominantly quiet water conditions in the Soom Shale lithology are indicated by a lack of flow-induced sedimentary structures and the taphonomy of the fossils. The Soom Shale sediment was largely anoxic; geochemical analyses indicate that euxinic bottom waters prevailed at times (Gabbott, 1998). In some areas metamorphism has transformed the shale and siltstone into a sheared slate, destroying primary internal features (Aldridge et al., 1994).

1.3. Palaeontology

To date, taxa found from the Soom Shale include conodonts (Theron et al., 1990; Aldridge and Theron, 1993; Gabbott et al., 1995), myodocopid ostracodes (Gabbott