Trace Fossil Protovirgularia McCoy, 1850 from the Nonmarine Cretaceous Jinju Formation of the Sacheon area, Korea

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경상남도 사천 지역의 백악기 진주층에서 산출된 비해성

Protovirgularia McCoy, 1850

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요 약: 경상남도 사천 지역에 분포한 백악기 진주층의 비해성(非海成) 퇴적층에서 생화화석 Protovirgularia McCoy, 1850을 보고한다. 이 지역의 진주층은 주로 호수 환경에서 퇴적된 희석의 이암과 세일 및 세립질 사암으로 구성되어 있다. 이러한 Protovirgularia의 산출은 비해성 퇴적 환경에서 희유으로 보고되는 것이다.

주요어: 생화화석, Protovirgularia, 비해성, 백악기, 진주층

Abstract: The ichnogenus Protovirgularia McCoy, 1850 is reported from nonmarine strata of the Cretaceous Jinju Formation of the Sacheon area, Korea. There, the Jinju Formation is composed mainly of fine-grained sandstone, grey to brownish grey mudstone, and shale which were deposited in a freshwater lacustrine environment. This occurrence represents the first formal recording of the ichnotaxon from Korea and the first, on a global basis, from a nonmarine depositional environment.

Key words: trace fossil, Protovirgularia, nonmarine, Cretaceous, Jinju Formation, Korea

INTRODUCTION

The ichnogenus Protovirgularia McCoy, 1850 is characterized by a small keel-like trail which is composed of an elevated median line and lateral wedge-shaped appendages alternating on both sides (Häntzschel, 1975). Protovirgularia, an enigmatic ichnotaxon, has been recorded and discussed by many authors for well over a century and has previously been interpreted as an octocoral (McCoy, 1850), a graptolite (Richter, 1853), and a structure produced by crabs (Gümbel, 1879), arthropods (Richter, 1941; Volk, 1961) and annelids (Richter, 1941; Claus, 1965). It was not until 1958 that Häntzschel (1958) convincingly established it as a trace fossil. More recently Seilacher and Seilacher (1994) further demonstrated that Protovirgularia was most likely produced by burrowing bivalves in, or crawling on, soft substrates.

Han and Pickerill (1994), based on a literature review, considered the nomenclatural history of the ichnotaxon and provided a detailed taxonomic evaluation of Protovirgularia. They recommended that three ichnospecies of Protovirgularia, namely, P
harknessi Lapworth, 1870, P. nereitarum (Richter, 1871), and P. mongraensis Chiplonkar and Badve, 1970, should be considered as junior synonyms of the type, P. dichotoma McCoy, 1850. In the same year, however, Seilacher and Seilacher (1994) also revised the taxonomy of Protovirgularia and proposed five ichnospecies, namely, P. dichotoma, P. triangularis (Macanoy, 1967), P. tuberculata (Williamson, 1887), P. rugosa (Miller and Dyer, 1878), and P. longespicata (Stefani, 1885). Subsequently, Uchman (1998) described seven ichnospecies of Protovirgularia from flysch deposits of the Polish Carpathians; i.e., P. dichotoma, P. pennatus (Eichwald, 1860), P. rugosa, P. obliterata (Książkiewicz, 1977), P. vagans (Książkiewicz, 1977), P. ?longespicata, and P. dzulynskii (Książkiewicz, 1977).

Irrespective of these various ichnotaxonomic considerations, the ichnogenus Protovirgularia has previously been reported from several Paleozoic deep and, less commonly, Devonian to Carboniferous and Mesozoic shallow marine environments (Han and Pickerill, 1994). To our knowledge, there is no unequivocal formally reported nonmarine occurrences of Protovirgularia. Indeed the only possible previous recording is that by Buatois et al. (1996) from Jurassic turbidites of central China but as Tuberculichnus vagans Książkiewicz, 1977, which Uchman (1998) reservedly included within P. vagans. The unique and exceptional recording herein is therefore undoubtedly significant with respect to paleoenvironmental changes of ichnotaxa throughout geologic time. The purpose of this paper is, therefore, to document the ichnogenus from an unequivocal nonmarine sequence. This recording also represents the first for the ichnotaxon from strata in Korea.

GEOLGICAL SETTING AND FOSSIL LOCALITY

The Cretaceous sedimentary strata in the southeastern part of Korea are referred to the Kyongsang Supergroup (Chang, 1975). This is composed exclusively of nonmarine epiclastic and volcaniclastic sediments which were deposited in various environments including alluvial fan, alluvial plain, fluvial, and lacustrine systems. The Kyongsang Supergroup has been divided, in ascending order, into the Sindong, Hayang, and Yucheon groups (Chang, 1975). A nonmarine origin of the sediments of the Kyongsang Supergroup has long been recognized from the occurrence of fossil plants (Yabe, 1905; Tateiwa, 1929), freshwater molluscs (Yang, 1975, 1978, 1979a, 1979b), dinosaur footprints (Yang, 1982, 1986; Lim et al., 1989; Lim, 1990; Lockley et al., 1992), pollen and spores (Choi, 1985), charophyta (Seo, 1985; Choi, 1987), and an absence of marine fossils. These fossils also indicate that the geologic age of the Sindong, Hayang, and Yucheon groups are Berriasian to Barremian, Aptian to Albian, and Cenomanian respectively (Chang, 1982).

The Sindong Group consists mainly of alluvial fan, floodplain, and lacustrine deposits. The Hayang Group comprises floodplain and lacustrine sediments intercalated with minor volcaniclastic sediments (Um et al., 1983) and the overlying Yucheon Group of volcanic rocks.

The Sindong Group has been subdivided, primarily on the basis of variation in rock color, into, the Nakdong, Hasandong, and Jinju formations, in ascending order. The Hasandong Formation is a red bed sequence underlain by the non-red colored Nakdong Formation and overlain by the non-red colored Jinju Formation.

The Jinju Formation is widely and well-exposed in the study area, Gurangri, Jahaeri, and Gupyungri of Seopomyeon, Sacheon City, Kyongsangnamdo, southern coast of Korea (Fig. 1). The lower part of the Jinju Formation, well-exposed along the coast, is about 150 m thick and generally dips 10°SE. The formation is composed mainly of grey mudstones and shales interpreted as having been deposited in a marginal lacustrine environment, and intercalated sandstones