Sedimentary Geology 214 (2009) 85–99

Contents lists available at ScienceDirect

Sedimentary Geology

journal homepage: www.elsevier.com/locate/sedgeo

Combined textural and stable isotopic data as proxies for the mid-Cretaceous paleoclimate: A case study of lacustrine stromatolites in the Gyeongsang Basin, SE Korea

O. Nehza [a], K.S. Woo [a,*], K.C. Lee [b]

[a] Department of Geology, Kangwon National University, Chuncheon, 200-701, South Korea
[b] Department of Mineral and Mining Engineering, Sangji University, 220-702, South Korea

ARTICLE INFO

Keywords:
Stromatolites
Cretaceous
Stable isotope
Paleoclimate
Gyeongsang Basin
Korea

ABSTRACT

Microbial interference of the prevailing sedimentary dynamics during stromatolite growth, records vital biogeochemical information, which reflects the prevailing paleoclimatic conditions. This study documents the simultaneous geochemical and textural changes in mid-Cretaceous lacustrine stromatolites (Gyeongsang Basin, SE Korea), deposited in a semi arid setting. Fibrous calcite/micrite couplets in the stromatolites occurring in the Sinyangdong, Hwasan and Banyawol formations constitute the basic growth cycles and can be divided into first-, second and third-order cycles. Second-order cycles show couplets with gradual textural changes from fibrous calcite to micrite laminae, and three different types of micrite are present. Sometimes, one type of micrite evolves into another, within the second-order cycle in the Sinyangdong stromatolites. Consistent enrichments in $\delta^{18}O$ and depletion in $\delta^{13}C$ towards micrites within the Sinyangdong and Hwasan stromatolite couplets and a concomitant depletion of both isotopes from fibrous calcite to micrite in the Banyawol sample can be observed. These shifts reflect paleohydrological changes in the lake water, related to paleoproductivity and paleosalinity fluctuations. Relatively higher paleosalinity values within the Sinyangdong lake water system is registered by higher $\delta^{18}O$ values of fibrous calcite and micrite in the SY-3, than in the SY-1 and SY-2 stromatolites. The consistent shifts in $\delta^{18}O$ and $\delta^{13}C$ isotopes in different textural growth fabrics indicate that paleohydrological factors could play a significant role in the formation of these primary lacustrine carbonates. Textural changes shown by the frequency of the growth cycles also corresponds with oxygen and carbon isotopic values. These results appear to have been influenced by climate-related paleohydrological changes.

1. Introduction

Stromatolites are the Earth's oldest fossils which span the geologic record as far back as 3.5 billion years ago (Awramik, 1992; Grotzinger and Knoll, 1999; Hofman et al., 1999; Schopf and Walter, 1983). They are commonly known as lithified and laminated sedimentary structures produced by trapping, binding, biomineralization and mineralization of benthic microbial mats (e.g. Awramik, 1984; Ginsburg, 1991; Riding, 1991). They are typically laminated as a result of microbial interactions (Gebelein, 1976), but Reid et al. (2000) and Visscher et al. (2000) indicate that lamination is due to cycling of microbial communities and microbial lithification as is the case in modern marine stromatolites from the Highborne Cay, Bahamas. Information on stromatolite studies can be applied to paleoenvironmental, paleohydrological, paleoclimatic, paleolimnological as well as paleoecological and paleostratigraphic studies (Casanova and Hillaire-Marcel, 1993; Krylov, 1976; Lezine et al., 1990; Talbot, 1990).

With respect to paleoclimatic studies, tree rings, deep sea cores, ice cores, speleothems and loess have been widely used to assess the mechanisms that governed past climate changes. Even stromatolites, contain an abundance of preserved geological record that can be used to better understand the dynamics of paleoclimate change.

A number of studies on lacustrine carbonate sedimentation and related paleoclimatic studies deal with sedimentological, paleontological and/or geochemical data such as stable isotopes which were used for paleohydrological interpretation of lacustrine carbonates and stromatolites (Talbot, 1990; Casanova and Hillaire-Marcel, 1993), while others concentrated on the sedimentary setting, growth pattern (Petrov and Semikhatov, 2001), seasonal differences in growth rate and climatic changes (Chafetz et al., 1991; Andrews and Brasier, 2005). Evidences of microbial influence in the preservation of carbon isotopic records in stromatolites and other carbonate rocks can be seen in recent studies. Andres et al. (2006) noted that more aragonite precipitates and heterotrophic isotopic signatures are recorded during respiratory processes of heterotrophic organisms. On the other hand, Sumner (2001) suggested that autotrophic isotopic signatures can be affected by continuous carbonate precipitation during intervals when respiration dominates or after cessation of active microbial growth. Also insights of microbial isotopic shifts and the preservation potential were noted by Andrews et al. (1993, 1997), Guo et al. (1996) and Sumner (2001).

* Corresponding author. Tel.: +82 33 250 8556; fax: +82 33 244 8556.
E-mail address: wooks@kangwon.ac.kr (K.S. Woo).

0037-0738/$ – see front matter
doi:10.1016/j.sedgeo.2008.03.012

In the central Paleo-Andean Basin in Bolivia, Camoin et al. (1997) elaborated on the stable isotopic analyses from different facies of a perennial and ephemeral carbonate lacustrine system. In a related study, Casanova and Hillaire-Marcel (1993) used the seasonal stable isotopic variations of the lake water and carbonates to infer hydrological changes in the paleolakes and used them as proxies of the composition of regional rainfall.

A good record of paleoclimatic information can be obtained from microbial carbonate deposits such as stromatolites, if they are well preserved and unaltered. In most previous studies that used stable isotopic data for this purpose, the interpretation was mostly based on geochemical imprints (e.g. Casanova and Hillaire-Marcel, 1993; Chafetz et al., 1991). In this study we present a record of texturally and isotopically analyzed paired microlaminae which represent separate growth cycles in the Cretaceous non-marine stromatolites of the Gyeongsang Basin SE Korea. These stromatolites with well preserved growth fabrics, textures and probably unaltered geochemical signatures, provide physico-chemical conditions of the lake water influenced by local paleoclimatic changes. Variations in the paleolake water chemistry are reflected in the continuous sections within stromatolites and this led to the interpretation and reconstruction of the local paleoclimate in Korea, during the growth of these Cretaceous stromatolites.

2. Study area and geological setting

The location of the study area in the SE Korean peninsula is shown in Fig. 1. The Gyeongsang Basin (127°–129°E, 36°–34°N) evolved in the southeastern part of the peninsula during the mid-Cretaceous when a warmer subtropical arid climate prevailed (Lee et al., 1987; Kim et al., 1993). This basin is the largest among the transtensional basins formed in South Korea during the Early Cretaceous (Lee, 1999a,b; Chough et al., 2000) and consists of a thick volcanic and sedimentary sequence, the Gyeongsang Supergroup (Chang, 1975) that is divided into the Sindong, Hayang and Yucheon Groups in ascending order (Chang, 1977, 1978, 1988).

In this study, the stromatolites were sampled from the Sinyangdong, Hwasan and Banyawol Formations of the Hayang Group. The presence of fossil charophytes, bird and dinosaur tracks in the Hayang Group suggest a shallow lacustrine depositional environment (Choi, 1987; Lockley et al., 1992). Desiccation cracks also indicate seasonal drying and wetting cycles (Paik and Lee, 1998). The occurrence of rhizoliths and ooids suggest that saline lakes were present under evaporitic and semi-arid to arid climatic conditions (Choi, 1985; Woo et al., 1991). Thus, it is likely that the lake basins were locally shallow and ephemeral reservoirs which were mainly characterized by seasonal drying and wetting. Paleontological data from spores and pollen (Choi, 1989), and charophytes (Seo, 1985; Choi, 1987) indicate for these deposits, an Albian age (Chang, 1988, Chough et al., 2000).

The Banyawol Formation (BY) consists of gray to black shales, siltstones, black mudstones, fine sandstone, and tan-colored lime mudstones (Fig. 2A). The sequence outcrops along a road-cut and consists of three stromatolite beds with thicknesses of 35 cm, 30 cm and 7 cm (Fig. 3A). The lowermost stromatolite bed is domal in shape, underlain by a calcareous mudstone horizon and overlain by a thick (~75 cm) black shale bed with rare concretions (Fig. 3C). The uppermost stromatolite occurs interlayered between fine sandstone beds composed of angular–subangular silt-sized quartz grains, pellets and some feldspar grains. The sandstones have low angle cross-laminations and ripple marks (Fig. 3D), and represent sand flats or shore deposits (Woo et al., 1992).

The facies sequence in the Hwasan Formation (HS) are composed mostly of finely laminated light gray to black shales which are frequently interlayered with calcareous mudstones and a limestone bed including stromatolites (Fig. 2B). Interbeds of thin sandstones and mudstones are also common. These deposits are inferred as shallow to marginal lake deposits, while the occasional intercalated silty layers are thought to have been deposited by periodic riverine inflow (Woo et al., 1991). The stromatolites which are 18–30 cm thick are generally

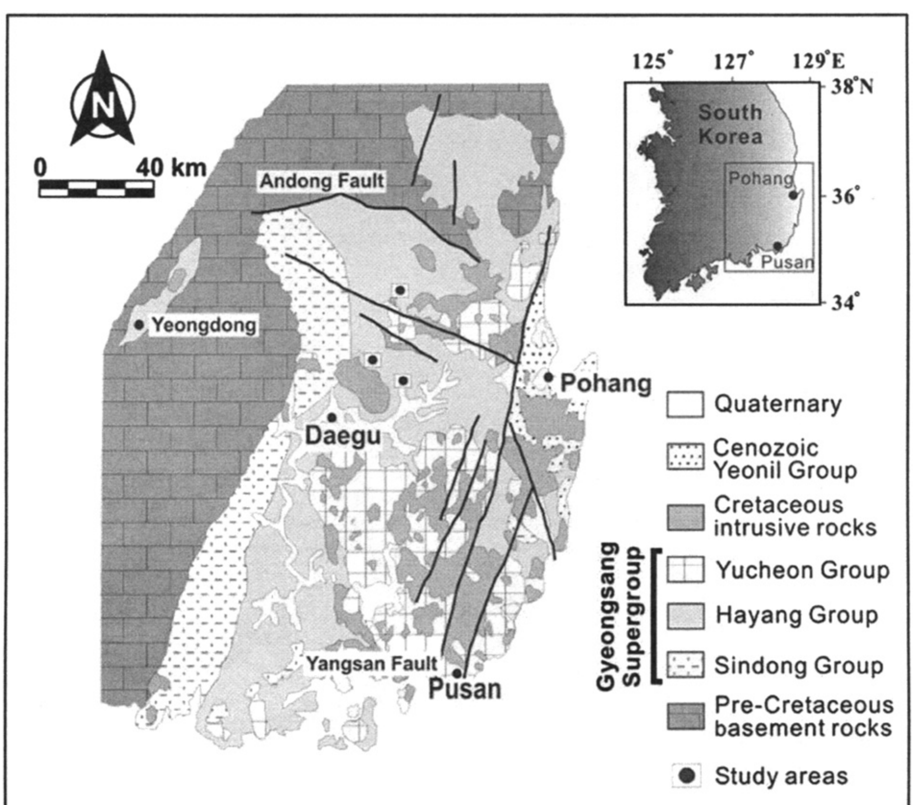

Fig. 1. Geological map of the Gyeongsang Supergroup and location of the study areas. S1 = Sinyangdong Formation, S2 = Hwasan Formation, S3 = Banyawol Formation.