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ORIGINAL ARTICLE

Oxygen Isotopic Studies of a Species of *Pitar* (*Hyphantosoma*) from Quilon Formation, Kerala, Southwest India: Inferences on Seasonality during the Miocene (late Burdigalian)

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ABSTRACT

The carbonaceous shale of the Miocene (late Burdigalian) Quilon Formation (Kerala Basin, southwest India) were collected and processed to retrieve the microfaunal component. In the present study, the oxygen isotope analysis of the growth bands of the recovered bivalves *Pitar (Hyphantosoma) simonnei* and *Ostrea* sp. (both retrieved from the Quilon Formation) is emphasized to help reconstruct the palaeomonsoonal seasonality. The oxygen-isotope record for the specimens of *P. (Hyphantosoma) simonnei* and *Ostrea* sp. exhibits regular, high amplitude $\delta^{18}O$ cycles caused by the yearly seasonal temperature and monsoonal variations. Based on the number of $\delta^{18}O$ cycles, *P. (Hyphantosoma) simonnei* and *Ostrea* sp. have been considered to be approximately 2- and 4-year-old, respectively, at the time of deposition. The calculated palaeo-seawater $\delta^{18}O$ values between -0.6 to -1.1‰ [for *P.* (*Hyphantosoma*) *simonnei*] allow us to distinguish between the wet and dry seasons. In addition, the two-component mixing model is suggestive of seasonal freshwater discharge of ~70-80% during wet season and ~20-40% during the dry season into the depositional system. This reconstructed palaeo-seasonality clearly indicates presence of monsoon system in the south west of India during the Miocene (late Burdigalian).

INTRODUCTION

The monsoonal system is a complex interplay of both the seasonal changes in the wind direction dominant over the tropics and heating and cooling of the Tibetan plateau. Since the monsoon is a tropical phenomenon, it is likely that a monsoon system first appeared on the Indian plate when it entered the sub-tropical belt of the southern hemisphere (Saha 1993). The collision of the Indian plate and the Eurasia plate is generally considered to have taken place during the Paleogene (~56 to - 34 Ma interval) (Aitchison et al. 2007; Kapur 2020 and references therein), the real deformation, and Himalayan exhumation began only during the Neogene (most likely during Early Miocene: close to 23 Ma (Clift et al. 2008). The Intensification of the Indian Summer Monsoon (ISM) commenced about ~20 Ma ago because of uplift of the Tibetan plateau beyond a critical height (Prell and Kutzbach 1992; Harrison et al. 1993; Molnar et al. 1993; Retallack et al. 2018 and references therein). Although monsoon may appear to be regular in the sense that it occurs every year, its intensity, distribution and timings could vary considerably, often causing massive floods and droughts affecting half of the world's population (Webster et al. 1998; Cook et al. 2010; Mohan Kuppusamy and Ghosh, 2010). Since the Indian economy is heavily dependent on summer monsoon rains, understanding its past and present variability is of immense importance in making any attempt in predicting future monsoon variability in global warming scenarios (DelSole and Shukla 2002; Cook et al. 2010).

The timing of rainfall at the Kerala coast is known as "onset of Indian monsoon". The pre-monsoon months (March – May) account for the major thunderstorm activity in the state and the winter months (December – February) are characterized by minimum clouding and rainfall (Simon and Mohankumar 2004). It is widely also known as the "Gateway of summer monsoon" (Krishnakumar et al. 2009). Here, a Miocene (late Burdigalian) monsoonal seasonality from the carbonaceous shale of the Quilon Formation in Pozhikkara cliff section in southwest Kerala is presented. It corresponds to a global warming event at ~17–15 Ma (middle Miocene climate optimum, MMCO) (Reuter et al. 2013); this time also corresponds to when the global annual surface temperature was on average about ~3–4 °C higher than the present and equivalent to the warming predicted for the next century by the mid-range scenarios of the IPCC Fourth Assessment Report (You et al. 2009; You 2010).

The fossiliferous limestone rich in foraminifers, gastropods, bivalves, corals, echinoids, crabs, ostracods, bryozoans, serpulids and shark teeth is found in south west of Kerala, India (Jacob and Sastri 1952; Dey 1961; Verma 1977; Mehrotra 1982; Seralathan and Padmalal 1991; Harzhauser et al. 2009; Reuter et al. 2011). Previously, however, only a small outcrops at the base of sea cliffs or boreholes were studied (Dey 1961; Narayanan et al. 2007). Based on the previous studies, it is assumed that deposition took place on an open marine shelf with local coral reef occurrences in settings shallower than 20 m proximal to the coast (Raha et al. 1983; Narayanan et al. 2007).

GEOLOGICAL SETTINGS

Geologically, the major part of Kerala is occupied by Pre-Cambrian crystalline rocks. These crystalline rocks are fringed on the west by sedimentary formations belonging to the Tertiary and Quaternary periods. The Tertiary sedimentary rocks of Kerala state are distributed in the southern coastal region of peninsular India, and their exposures are identifiable in the central and northern coastal areas. The Tertiary sedimentary sequence belongs to the Warkalli Group which has been further divided into three litho-units i.e., the Amabalapuzha Formation, Quilon Formation, and Mayanad Formation, in descending stratigraphic order. The sedimentary unit belonging to the Quilon