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Microfacies and biofabric of nummulite accumulations (Bank) from the Eocene deposits of Western Alborz (NW Iran)

Mehdi Hadi [a], Hossein Mosaddegh [b,*], Nasrollah Abbassi [c]

[a] Department of Geology, Faculty of Science, Ferdowsi University of Mashhad, Mashhad, Iran
[b] Department of Geology, Faculty of Earth Sciences, Kharazmi University, Tehran, Iran
[c] Department of Geology, Faculty of Science, University of Zanjan, Zanjan, Iran

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A B S T R A C T

The nummulite bank from the Eocene Ziarat Formation is described for the first time from Alborz, Iran, enhancing the record of these nummulite-rich accumulations in the Eocene of the circum-Tethyan carbonate platform. Five microfacies types have been defined within the shallow-water carbonate deposits of the Ziarat formation located in the western Alborz zone. Microfacies type 1 contains the most diverse *Alveolina* species associated with predominance of *Nummulites* A-forms. Microfacies type 2 is characterized by the presence of bivalve (oysters) fragments. Microfacies type 3 is supported by the high abundance of nummulitids. Microfacies type 4 is dominated by the occurrence of encrusting foraminifera-algal with flat growth forms that are mainly formed within the acervulinids assemblage. Finally, there is the presence of orthophragminids and nummuitids represented by microfacies type 5. Microfacies data obtained from the investigation area show that nummulite banks were formed within the back, core and fore-bank palaeoenvironments. The classification method of this paper is based on use biometric, biofabric, taphonomic and palaeoecological characteristics of larger benthic foraminifera. In addition, the calculated intraskeletal porosity by the use of numerous sections and FE-SEM images of *Nummulites* tests were displacement of tests in order to achieve a better understanding of paleoconditions that occurred during sedimentation. We conclude that differences among bank frameworks suggest that small biconvex A-forms of *Nummulites* tests along with alveolinids were living in shallow, euphotic waters, whereas robust and ovate nummulitid tests thrived and concentrated in the intermediate (40–80 m) water with biofabrics in the min-scales, which indicates the influence of waves and currents in combination with wave-winnowing processes. More distal accumulations, the fore-bank were characterized by orthophragminid and nummulitid tests in the deeper part of the photic zone.

The larger benthic foraminifera, as confirmed by *Discocyclina javana* (VERBEEK), *D.* cf. *dispansa* (SOWERBY), *Assilina* ex. gr. *exponens* (SOWERBY), *Nummulites* ex. gr. *globulus*)SCHAUB(, *Alveolina ellipsoidalis* (SCHWAGER), *A. subpyrenaica* (LEYMERIE), *A. pisiformis* (HOTTINGER), *A. tumida* (HOTTINGER), *A. cemali* (SIREL et ACAR), *A. laxa* (HOTTINGER), *A.* ex. gr. *cremae*)CHECCHIA-RISPOLI(, suggest the early Ilerdian-Middle Eocene age of these sediments.

1. Introduction

nummulite accumulations (or nummulite banks) known from the Eocene carbonate deposits are widespread along the Tethyan margins (Fig. 1). Different hypothesis have been attempted to explain their origin. The biological (mainly involving reproduction strategies of larger foraminifers) and physical (principally winnowing) processes are thought to be responsible for the formation and fabric of nummulite bank (i.e. Aigner, 1982; Racey et al., 2001; Beavington-Penney et al., 2005, 2006; Jorry et al., 2006). Arni (1965) described "*Nummulites* banks" as barriers separating "fore-bank" from more restricted "back-bank" environments. Different works have used Arni (1965) model e.g. Eocene sedimentary accumulations from the Tatra Mt., Poland (Kulka, 1985), Jdeir Formation in offshore Libya (Anketell and Mriheel, 2000), Tremp Basin in Spain, Kesra Plateau, Djebel Ousselat and Kef El Garia at onshore

* Corresponding author.
E-mail addresses: mehdi_hadi_s@yahoo.com (M. Hadi), mosaddegh@khu.ac.ir (H. Mosaddegh), abbasi@znu.ac.ir (N. Abbassi).

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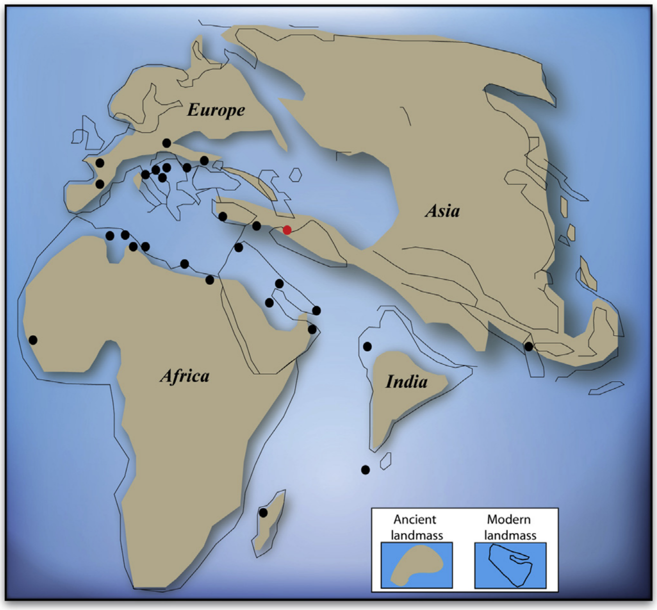

Fig. 1. Palaeogeographic map and geographic distribution of the nummulite accumulations deposits of the Eocene (modified after Scotese, 2001; Racey, 2001; Jorry et al., 2006). Studied area is marked by red dot while black dots depict the position of these facies around the margins of Tethys. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Tunisia, and also outcrops from NE Cyrenaica and C137 license in NW offshore zones operated by Total from Libya (Jorry et al., 2006). On the other hand, Aigner (1982) model regards such accumulations as a result of reworking in high energy environments, in which foraminiferal tests were transported by wave actions (induced by tidal currents or storms) (i.e. Loucks et al., 1998; Racey, 2001; Hasler, 2004). Aigner (1982) suggested that some of these accumulations are the result of repeated winnowing, according to Mateu-Vinces et al. (2012) they are the products of internal waves. In this paper we describe deposits of nummulite accumulations (banks), of Western Alborz zone (NW Iran) based on morphological, biofabric and paleoecological characteristics from Ziarat Formation in western Alborz zone (NW Iran). This paper develops a practical morphological, biofabric/based approach for the use of nummulite accumulations in paleoecological analysis of shallow marine systems. The main objectives of this study are (1) to describe the Eocene microfacies types and to separate different parts of nummulite accumulations based on different microbiofacies, (2) to interpret the hydrodynamic energy in which the accumulations formed, (3) to estimate the intraskeletal porosity and its role in transportation of *Nummulites* tests and to discuss their significance in interpreting the origin of deposits and paleoenvironments of Ziarat Formation. It is considered that the trends in morphological and biofabric characteristics determined from this case-study could be used as a basis for interpretation of shallow marine systems in subsurface studies and provides a framework that can be used to compare with other nummulite accumulations occur in the Eocene successions.

2. Geological setting and stratigraphy

The Alborz range in northern Iran (approximately 600 km long and 100 km wide) is part of the largest mountain belt of the Alpine-Himalayan Belt and is situated between the Caspian Sea to the north and the Iranian Plateau to the south (Fig. 2). It extends westward into the Pontides Arc (Turkey) and the Lesser Caucasus (Armenia) (Asiabanha and Foden, 2012). Stöcklin and Nabavi (1973) have divided extensive W-E range of Alborz in to three main zones) 1(Western Alborz zone and Azarbayjan; (2) Central Alborz zone including south-central, north-central and anti-Alborz; (3), Kopet-Dagh zone. So that study areas (Gheynarjeh 1, 2 sections and Ghaziabad section) are located in the Western Alborz zone and Azarbayjan. A generalized stratigraphic of setting for the southern flank of western Alborz (Soltanieh mountains) comprises three formations: (1) Fajan Formation (Paleocene- Early Eocene) characterized by conglomerates and red sandstones; (2): Ziarat Formation (Early and partly Middle Eocene) composed of foraminiferal limestones with abundant larger benthic foraminifera; (3): Karaj Formation (Middle Eocene) marked by the deposition of more than 3000 m thick successions, dominated by sandy limestone turbidities and tuff (Figs. 3 and 6a). Fajan is closely associated and in some places overlapped with nummulite-bearing reef-type limestones of the Paleocene-Eocene Ziarat Formation. The Ziarat Formation further contains tuffs, conglomerates, gypsum and marls (Dellenbach, 1964). According to Stöcklin and Eftekhar-Nezhad (1969) wherever the Fajan and Ziarat formations are absent, Eocene volcano-sedimentary rocks of the Karaj Formation uncomfortably overlie the older strata. Lateral interfingering of the Ziarat and the Karaj formations has been observed in western Alborz zone (Dellenbach, 1964).

3. Material and method

This work is based on the study of three sedimentary successions from Gheynarjeh and Ghaziabad locations (Fig. 4). Gheynarjeh 1, 2 are located at 19 km southeast of the city of Zanjan (close to Gheynarjeh Village) with thickness of 52 m and 33 m respectively. The Ghaziabad section is 25-m thick and located near the Ghaziabad Village (about 25 km south of the city of Zanjan) and about 5 km southwest of the Gheynarjeh 2 section (Fig. 4). Due to the lack of diagnostic sedimentary structures, the palaeoenvironmental interpretation is mainly based on and described with respect to the textures and biotic components, with special emphasis on the nummulite accumulations (nummulite banks). Textural and compositional characteristics were interpreted on the basis of 110 thin sections studied under transmitted-light microscope (Olympus BX51). The thin sections have dimensions of 7.5 cm $\times$ 2.5 cm and were cut vertical to the bedding plane. Within these thin sections oriented larger benthic foraminifera were identified (about 20 thin sections were prepared from limestone samples). The textural descriptions and microfacies follow Dunham (1962) and Flügel (2004). We have used relative difference in D/T measurement of *Nummulites* and the ratio of megalospheric (A-form) to microspheric (B-form) for paleoenvironmental interpretation. Also, biofabric types of *Nummulites* tests were determinate on thin sections, based on the published works on the shell fabric of nummulite accumulations (e.g. Aigner, 1985; Racey, 2001; Beavington-Penney et al., 2005). "Depositional model" interpretation is based on the model of nummulite accumulations includes five microfacies types with a little modification from Arni (1965). In addition, the micro-pores of the *Nummulites* tests were studied on two preserved specimen of A-forms under field emission scanning electron microscope (FE-SEM) (S-4160 Hitachi) at the Electronic Thin Film Laboratory, Department of Electrical and Computer engineering, University of Tehran (Iran), which resulted in porosity as determined by image analysis. Chamber lumen area visible was estimated on photographs taken of the axial sections by image analysis and point counting, which point counting calculations was used by JmicroVision v1.2.7-win32 software (www.jmicrovision.com). The present study was accomplished by the use of one of the most popular applications, JmicroVision software, which