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Research paper

Nannoplankton calendar: Applications of nannoplankton biochronology in sequence stratigraphy and basin analysis in the subsurface offshore Nile Delta, Egypt

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A B S T R A C T

A comprehensive nannoplankton biozonation of the Pliocene-Pleistocene succession of off-shore Nile Delta has been recorded from two wells, namely Baltim-1 and NDOB-1, in the present contribution. The biozonation is relied the identification of 8 nannoplankton biozones and their associated bioevents. These biozones are *Pseudoemiliania lacunosa* Zone (NN19), *Discoaster brouweri* Zone (NN18), *Discoaster pentaradiatus* Zone (NN17), *Discoaster surculus Zone* (NN16), *Reticulofenestra pseudoumbilicus* Zone (NN15), *Discoaster asymmetricus* Zone (NN14), *Ceratolithus rugosus* Zone (NN13) and *Amaurolithus tricorniculatus* Zone (NN12) as arranged from top to base. The Pliocene-Pleistocene boundary is placed near to the top of *D. surculus Zone* (NN16). The lower boundary of the Pliocene is placed within the *A. tricorniculatus* (NN12). The recognized bioevents are used to calculate the sedimentation rates (SRs) and to delineate their relative variations versus the depth. The relative variations of the SR values were interpreted in accordance with the history of fluvial fresh water supply in the Delta region since the early Pliocene. The relationship between the values of the SR and the potential occurrences of hydrocarbon sources (organic matter oxic preservation) and reservoir (coarser clastics accumulation) rocks in the studied succession has been clarified. Likewise, the possible relationships of the SR values, history of fresh water input in the Nile Valley and the sapropel formation mechanism has been discussed. The relative variations of SRs versus the depth have been interpreted in a sequence stratigraphic framework, which led to identification of three correlatable genetic sequences in the studied succession. The nannoplankton bioevents are used instead of stage and epoch boundaries in plotting of the burial history models for the studied wells, which greatly improved the precision of the maturation onset and hydrocarbon generation. This collection of nannoplankton biochronology based applications is of large importance for the future petroleum exploration in the Nile Delta region.

1. Introduction

The biostratigraphic biozonation is an essential tool in gas exploration in Nile Delta region because of its rather complex subsurface geological setting. The exploration for petroleum in Nile Delta region is under continuous expansion in such promising territories with proven recoverable reserves of 225 billion m^3 of gas (Sestini, 1995). The biostratigraphic studies in Nile Delta region in the Pliocene – Pleistocene successions are relatively rare, sporadic and restricted to certain areas (El Deeb, 1993; Faris et al., 2007; Makled, 2011; Faris and Shabaan, 2013; Mandur and Makled, 2016). These studies depended on planktonic foraminifera, dinoflagellates and calcareous nannoplanktons and most of them have essential focus that is dedicated exclusively to biozonation. The biozonation schemes, especially these of nannoplanktons, from the Atlantic Ocean and Mediterranean Sea witness continuous improvements in terms of resolution (number of zones divided by geologic time) and biochronologic age dating (bioevents). These benefits can be used in other applications for basin analysis that are directly depending on the identifications of the bioevents. Accordingly, the present study aims to organize a comprehensive nannoplankton biozonation and its related bioevents in North Delta Basin and to extend the correlation with the standard biozonation schemes from other areas such as Martini (1971) and others. The

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identified bioevents are used to calculate the sedimentation rates in the studied rock successions, which are considered through the present contribution as the earliest records for Pliocene-Pleistocene age in the Nile Delta region. The successive changes in sedimentation rates are used to construct genetic stratigraphic sequences, which are stratigraphically important for basinal correlation. The bioevents are used to date and synchronize the environmental changes in the Nile Delta basin and Levant Basin such as sapropelic deposits. In addition, the bioevents are used to plot hypothetical burial history models of higher precession and better timing of maturation. These applications are of great value for the exploration for gas in the Nile Delta region.

2. Geological setting and lithostratigraphy

The Nile Delta basin occupies a large area in the northern part of Egypt. It extends from the south of Cairo and submerges forming an enormous submarine fan into the Levant Basin in the Mediterranean Sea (≈160 km, Fig. 1). It stretches as well to the east of the Qattara Depression and to the west at Port Said and North Sinai (≈240 km, Ross and Uchupi, 1979; Sestini, 1989). This area covers four structural-sedimentary realms, which are: a) the South Delta Block, b) the North Delta Basin, c) the Nile Cone at north east region, d) the Levant Platform at northwest region. The studied wells were chosen within the North Delta Basin (Figs. 1 and 2). The deposition in the Nile Delta Basin was accompanied by several tectonic deformation episodes, variable rates of clastic input by Nile River and changes of global and regional sea levels in Mediterranean Sea. Among the most significant tectonic deformations which had a direct influence on sedimentation in Nile Delta Basin are the deep E–W faults of the Tortonian chains and the shallower post-Messinian structural framework. The Pre-Tortonian fault chains are probably Eocene or Late Cretaceous. They border the Miocene subsidence and sedimentation belt in the North Delta Basin, while they induce an active Fault Flexure Zone of synsedimentary listric faults in the South Delta Block. This Fault Flexure Zone separates the South Delta Block from the North Basin and along it, faults down-throw to the north the Cretaceous- Middle Eocene carbonates of Northern Egypt. Consequently, the thickness of the Tertiary rock succession at the North Delta basin reaches 7 km, while in the South Delta Block reaches only one km (Salem, 1976; Korrat, 1977; Barber, 1981; Sestini, 1989, 1995, Figs. 1 and 2). The post-Messinian structural framework resulted from the sedimentary staking at the unstable delta margin and produce growth faulting, slumping and normal faults as well as diaprisim of uncompacted Pliocene clays and Messinian evaporites. Additionally, there are some structural highs that existed under Tertiary positive structures of carbonate top. These structures are oriented E–W to N–S and of uncertain pre-Tortonian age. These structures were recorded in the seismic sections in Nile Delta (Ross and Uchupi, 1979; Deibis, 1982; Sestini, 1989) and moreover by well drilling in some wells (e.g. Abuqir, Naf-1, Temsah, El Wakra, Abu Madi, Bilqas and in two of the studied wells in the present contribution NDOB-1 and Baltim-1 (Khairy, 1974; Ansary and Deibis, 1977; Deibis et al., 1986, Figs. 1 and 2). The deposition within the Nile Delta Basin is directly connected to the history of fresh water input of successive rivers in the Nile valley. The fresh water input undergo five fluvial intervals (Eo-, Paleo-, Proto-, Pre-, Neo-Nile) which differ notably in nature and amount of water input and quantities of sediment supply. They are separated by unconformities that mark periods of erosion coupled

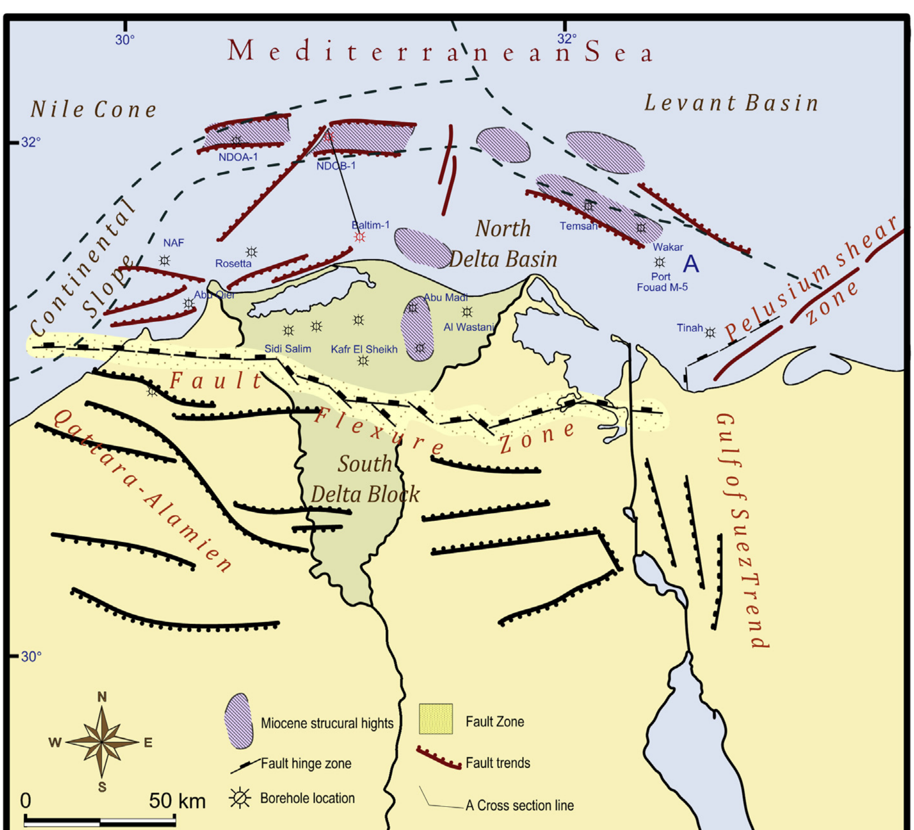

Fig. 1. Location map of studied wells and some related major structure elements. The map shows the four structural-sedimentary realms of the Nile Delta. It is modified after Barber (1981) and Sestini (1989).