Journal of African Earth Sciences 102 (2015) 86–101

Contents lists available at ScienceDirect

Journal of African Earth Sciences

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

A fish assemblage from an early Miocene horizon from Jabal Zaltan, Libya

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ARTICLE INFO

Article history:
Received 12 May 2014
Received in revised form 15 October 2014
Accepted 12 November 2014
Available online 27 November 2014

Keywords:
Africa
Neogene
Elasmobranch
Actinopterygian
Palaeoenvironments
Palaeobiogeography

ABSTRACT

Recent excavations and prospecting in the early to middle Miocene deposits of the Maradah Formation in Jabal Zaltan, Libya, yielded a diverse fish assemblage coming from an early Miocene locality. The material described here includes more than 18 marine and freshwater taxa most of which were previously unreported from the area. Jabal Zaltan is one of the very few early Miocene Afroarabian fossil sites that produced such a diverse fish sample. Therefore, the fossils described here provide a unique insight into the composition of the early Miocene fish faunas from the northern African coast; a critical time period for faunas of the continent, as contact with Eurasia ended 100 million years of African isolation. In addition, the Jabal Zaltan fossils help consolidate the validity of *Galeocerdo mayumbensis* and extend its geographic range to include the Tethys. The Maradah deposits also host the first occurrences of two genera (*Pteromylaeus*, *Distichodus*) in the fossil record. The fish finds support the presumed depositional environment that of tropical shallow estuarine to deltaic conditions, and the freshwater fishes document the presence of a modern-type Nilosudanian fauna containing elements with both African and Asian affinities. The Jabal Zaltan ichthyofauna, with its diversity of taxa, has the potential to become a key reference fauna for future studies of early Miocene African fishes.

1. Introduction

The Cenozoic fossil fish record of the Afroarabian continent has been the subject of numerous research papers over the years. A review of the relevant scientific literature indicates that most of the known Neogene, continental fish assemblages are of late Miocene or Pliocene age (see Stewart, 2001; Otero, 2010) while relatively little is known about the state of the Afroarabian ichthyofaunas during the late Oligocene and early Miocene. And yet, this time period is a critical one for our understanding of the fish faunas prior to Africa forming a connection with Eurasia and ending about 100 million years of African isolation. Of the very few early Miocene assemblages known to date, only those of the Arabian continent described by Otero and Gayet (2001) and the somewhat younger (late early to middle Miocene) eastern African sites discussed by Schwartz (1983) have been studied in detail. The scarcity of adequately studied and/or diverse early Neogene fish assemblages in Northern Africa has led to an apparent gap of knowledge concerning the post-Oligocene evolution of the regional ichthyofaunas and the timing of the emergence or migration of taxa that were common or even dominant during the late Neogene. Two key sites in Northern Africa, Jabal Zaltan (Libya) and Moghra (Egypt, see Priem, 1920; Cook et al., 2010) possibly hold the key for elucidating that virtual gap in the regional, early to middle Miocene fossil fish record. Here, benefited by new material from the 2009–2010 field missions of the East Libya Neogene Research Project (E.L.N.R.P.) to Jabal Zaltan, we provide new data about the composition of a rare early Miocene (Burdigalian) fossil fish assemblage from the region.

The early to middle Miocene fossiliferous deposits of the Maradah Formation in Jabal Zaltan (Gebel Zelten), Libya, were first

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http://dx.doi.org/10.1016/j.jafrearsci.2014.11.008
1464-343X/

discovered in the early 1930s by the Italian geologist Ardito Desio (Desio, 1935). However, it was not until the 1960s and the 1970s that the first extensive fossil collections were made (see Savage and Hamilton, 1973). Since then, several expeditions have uncovered a plethora of vertebrate fossils including fishes, turtles, crocodiles, birds and both marine and terrestrial mammals (e.g., Arambourg and Magnier, 1961; Savage and Hamilton, 1973; Gaziry, 1987; Wessels et al., 2003; Llinás Agrasar, 2004; Fejfar and Horáček, 2006; Pickford, 2006a,b; Wessels et al., 2008; Sanders, 2008; Domning and Sorbi, 2011).

Although fish fossils are present in many localities in Jabal Zaltan, few taxa have been reported previously and they have not been studied in detail. D'Erasmo (1934) was the first to work on the fish remains collected by Desio's expedition from various localities where rocks of the Maradah Formation are exposed, including Jabal Zaltan. He recognized the following taxa: *Carcharias cuspidata* (his *Odontaspis cuspidata*), *Carcharias* sp., Lamnidae indet., *Carcharocles* (his *Carcharodon*) *megalodon*, *Otodus* (his *Carcharodon*) *auriculatus,* putative *O. augustidens*, *Galeocerdo aduncus*, *Hemipristis serra*, *Myliobatis* sp., *Saurocephalus faiumensis, Pycnodus* sp., and *Diodon* sp. Arambourg and Magnier (1961) mentioned the presence of actinopterygian remains and attributed them to "silurids" and *Lates* sp. More information about the Jabal Zaltan elasmobranchs was provided by Savage and Hamilton (1973), who recognized five taxa: *Carcharias* (their *Odontaspis*) *acutissima*, *Carcharodon* (probably *Carcharocles* or *Otodus*) sp., *Hemipristis serra*, *Pristis* sp. and *Myliobatis* sp.

The present paper focuses on an early Miocene horizon containing numerous chondrichthyan and actinopterygian taxa, most of which were previously unreported or possibly misinterpreted from the site. This mixed assemblage offers a unique insight into the composition of the fish faunas and the aquatic paleoenvironments present at the gulf of Sirt, at the time. Furthermore, the new faunal list from the site is used as a reference for exploring the biogeographical context of the Afroarabian fishes during the early Miocene.

2. Geology

All fossils described here come from the Qarat Jahannam Member of the Maradah Formation and were found in the region of Jabal Zaltan. Jabal Zaltan is an elongate mesa that lies about 200 km from the coast of eastern-central Libya (Gulf of Sirt) and expands from west-northwest to southeast for more than 140 km (Fig. 1).

The Maradah Formation rests on Oligocene rocks of the Bu Hashish Formation (Selley, 1966; Savage and Hamilton, 1973; Mastera, 1985) and represents a single transgressive sequence that is occasionally interrupted by smaller scale regressive events (El-Hawat, 1980, 2008). It consists of six main depositional units of alternating carbonate and siliclastic-dominated beds that correspond to various palaeoenvironmental conditions, with facies ranging from open marine to estuarine and more terrigenous fluvial (El-Hawat, 1980, 2008). According to Mastera (1985) the Maradah Formation can be subdivided into two members, the lower siliclastic dominated Qarat Jahannam Member of Aquitanian–Burdigalian age, and the upper carbonate–siliciclastic dominated Ar Rahlah Member of Aquitanian–Serravallian age. Jabal Zaltan is situated near the palaeo-coastline dividing the northern, mostly marine, exposures from generally shallower marine and terrigenous exposures to the south. The deposits in the southern escarpments of Jabal Zaltan are mostly dominated by sands of fluvial, estuarine and lagoonal origins and are occasionally rich in more or less mixed vertebrate assemblages as well as fossil wood (Savage and Hamilton, 1973; El-Hawat, 1980, 2008).

Desio (1935) assigned a Burdigalian to "Helvetian" (i.e., mid-Miocene) age for the Maradah Formation, based on invertebrate fossils from the northern, mostly marine, exposures. Early studies of the mammalian assemblages from the southern escarpments of Jabal Zaltan indicated a possible early Burdigalian age for the corresponding fossiliferous horizons (Savage and Hamilton, 1973). A later biostratigraphic study on the macromammals resulted in a best fit age between 16 and 17 Ma for the Jabal Zaltan mammalian fauna (termed Langhian, Pickford, 1991), slightly younger than that of Moghra in Egypt (see discussion in Sanders, 2008 and references therein). Gammudi and Keen (1993) recognized four ostracod biozones present in the Maradah Formation with ages ranging from Aquitanian to Tortonian. More recent work on Jabal Zaltan micromammals revealed the presence of multiple faunas from different horizons with ages ranging from as young as 19 Ma to 14 Ma, i.e., middle early Miocene to early middle Miocene (Wessels et al. 2003, 2008; Fejfar and Horáček, 2006). A review of fossil proboscideans from the area supported origins of the fossils from multiple horizons and showed that the best fit age for most taxa is that of early middle Miocene (Sanders, 2008); however, in the same review a very primitive gomphotheriine was recognized, indicating the presence of earliest Miocene or even late Oligocene aged fossiliferous horizons. In an overall review of the Jabal Zaltan mammalian fauna, McCrossin (2008) concluded that a long time interval was represented by past faunal collections, ranging from the early Miocene (ca. 18–19 Ma) to middle Miocene (ca. 14–16 Ma).

The fossils described herein come from a calcareous sand horizon exposed near the base of a section, at locality Z100, the northernmost of the southern escarpments of Jabal Zaltan (see Fig. 1), and were found associated with other terrestrial and aquatic vertebrate fossils (e.g., land mammals, crocodiles, turtles) as well as shelled invertebrates. This horizon is situated low in the stratigraphic column (see Fig. 2) and correlates well (it is situated slightly lower in the stratigraphic column) with the horizon sampled in the nearby ATH5A locality that yielded micromammals of 19–18 Ma, i.e., middle early Miocene in age (Wessels et al., 2003, 2008; Wessels personal communication 2013). The fish fossils described by D'Erasmo (1934) were mostly found in the northern part of the Maradah Formation and correspond to more marine facies. Unfortunately, there is no clear evidence concerning the origin of the chondrichthyan taxa mentioned by Savage and Hamilton (1973).

3. Materials and methods

The material described in this study comes from surface collections made in 2009–2010 by the E.L.N.R.P. with the participation of four of us (TA, AhMM, PP and NTB). Several localities on the southern escarpments of Jabal Zaltan were sampled but locality Z100 (G.P.S. coordinates: 28°34′32.87″N, 019°53′48.35″E, see Fig. 1) was more prolific in fish fossils than others. In addition, along with the surface collections, at locality Z100 screening for smaller elements was also conducted. This is also the locality for which the best constrained age estimate is available. Each specimen was catalogued in the E.L.N.R.P. catalogues using a specimen number followed by the locality information. The material will be returned to the Museum of Palaeontology of the University of Benghazi where it will be permanently held.

The elasmobranch teeth and the more robust actinopterygian teeth were immersed in a buffered 10% acetic acid solution to remove remnants of sandstone matrix then washed with water to remove any acid residue. The figured material was either coated with ammonium chloride and photographed using a Nikon 1200C digital camera mounted on a Zeiss Discovery V8 stereo microscope, or was imaged with a Jeol Field Emission Scanning Electron Microscope (JSM-6301 FXV). Larger elements were photographed using a digital camera. Morphological terminology for elasmobranch teeth