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Guelb el Ahmar (Bathonian, Anoual Syncline, eastern Morocco): First continental flora and fauna including mammals from the Middle Jurassic of Africa

Hamid Haddoumi [a], Ronan Allain [b], Said Meslouh [c], Grégoire Metais [b], Michel Monbaron [d], Denise Pons [b], Jean-Claude Rage [b], Romain Vullo [e], Samir Zouhri [f], Emmanuel Gheerbrant [b,*]

[a] Département de Géologie, Faculté des Sciences, Université Mohammed 1er, BP. 524, 60 000 Oujda, Morocco
[b] CR2P — Centre de Recherches sur la Paléobiodiversité et les Paléoenvironnements, UMR 7207, Muséum National d'Histoire Naturelle, CNRS, UPMC, Sorbonne Universités, MNHN, CP38, 8 rue Buffon, 75005 Paris, France
[c] Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement, Rabat, Morocco
[d] Département de Géosciences, Université de Fribourg, Switzerland
[e] UMR-CNRS 6118, Géosciences Rennes, Université de Rennes 1, Campus de Beaulieu, 263 avenue du Général Leclerc, 35042 Rennes, France
[f] Laboratoire de Géosciences, Faculté des Sciences Aïn Chock, Université Hassan II de Casablanca, Km 8, route de l'Université, 20100 Casablanca, Morocco

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ABSTRACT

We report the discovery in Mesozoic continental "red beds" of Anoual Syncline, Morocco, of the new Guelb el Ahmar (GEA) fossiliferous sites in the Bathonian Anoual Formation. They produced one of the richest continental biotic assemblages from the Jurassic of Gondwana, including plants, invertebrates and vertebrates. Both the sedimentological facies and the biotic assemblage indicate a lacustrine depositional environment. The flora is represented by tree trunks (three families), pollen (13 species, five major clades) and charophytes. It suggests local forests and humid (non-arid) conditions. The vertebrate fauna is dominated by microvertebrates recovered by screening–washing. It is rich and diverse, with at least 29 species of all major groups (osteichthyans, lissamphibians, chelonians, diapsids, mammals), except chondrichthyans. It includes the first mammals discovered in the Middle Jurassic of Arabo-Africa. The GEA sites yielded some of the earliest known representatives of osteoglossiform fishes, albanerpetontid and caudate amphibians, squamates (scincomorphans, anguimorphan), cladotherian mammals, and likely choristoderes. The choristoderes, if confirmed, are the first found in Gondwana, the albanerpetontid and caudatan amphibians are among the very few known in Gondwana, and the anguimorph lizard is the first known from the Mesozoic of Gondwana. Mammals (Amphitheriida, cf. Dryolestida) remain poorly known, but are the earliest cladotherians known in Gondwana. The GEA biotic assemblage is characterized by the presence of Pangean and Laurasian (especially European) taxa, and quasi absence of Gondwanan taxa. The paleobiogeographical analysis suggests either a major fossil bias in Gondwana during the Middle Jurassic, and an overall vicariant Pangean context for the GEA assemblage, or alternatively, noticeable Laurasian (European) affinities and North-South dispersals. The close resemblance between the Bathonian faunas of GEA and Britain is remarkable, even in a Pangean context. The similarity between the local Anoual Syncline Guelb el Ahmar and Ksar Metlili faunas raises questions on the ?Berriasian age of the latter.

1. Introduction

On the main part of the Moroccan Atlasic domain, continental red beds were deposited since the Middle Jurassic to the Upper Cretaceous (du Dresnay, 1956; Choubert and Faure-Muret, 1960–1962; Jenny et al., 1981; Michard et al., 2008). Their age has been highly debated because of the lack of undisputable chronostratigraphic markers. The historical controversy is synthesized in Monbaron (1988). Since the 1980s, new paleontological discoveries with significant stratigraphical implications were made, especially for vertebrates (Monbaron and Taquet, 1981; Sigogneau-Russell et al., 1988, 1990; Monbaron et al., 1999; Allain et al., 2004; Haddoumi et al., 2008, 2010) and microfossils (Charrière, 1992; Charrière et al., 1994, 2005). Together with sedimentology study, they also provide new paleoenvironmental and paleogeographical data.

During the geological study of the Anoual Area, eastern part of High Atlas Mountains, Morocco, Haddoumi (1998) and Haddoumi et al. (2008) reported in the Guelb el Ahmar site the discovery of fossil remains of the semionotid fish *Lepidotes* from a lacustrine limestone bed of the Jurassic Anoual Formation. The fossiliferous bed is located stratigraphically

* Corresponding author. Tel.: +33 1 40 79 30 20; fax: +33 1 40 79 30 80.
E-mail addresses: haddoumihamid@yahoo.fr (H. Haddoumi), rallain@mnhn.fr (R. Allain), meslouh.said@gmail.com (S. Meslouh), metais@mnhn.fr (G. Metais), michel.monbaron@unifr.ch (M. Monbaron), denise.pons@snv.jussieu.fr (D. Pons), jcrage@mnhn.fr (J.-C. Rage), romain.vullo@univ-rennes1.fr (R. Vullo), s.zouhri@fsac.ac.ma (S. Zouhri), gheerbra@mnhn.fr (E. Gheerbrant).

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high in the Anoual Formation, about 100 m below the contact with the Ksar Metlili Formation (Discordance D1 in Haddoumi et al., 2008).

In 2010 we developed new prospects and field researches for vertebrates in the Jurassic and Cretaceous of the Anoual area (Anoual and Qsar Jilali synclines), with the sponsorship of the *National Geographic Society*. This resulted in the discovery and study of the new Guelb el Ahmar microvertebrate fauna (acronym GEA) from the Anoual Formation that includes in particular the first known Middle Jurassic mammals from Arabo-Africa.

2. Material and methods

Most of the recovered fossils are microremains of vertebrates that were collected by water screening–washing (diameter of mesh = 0.8 mm), except for larger fossils found by surface collecting. The fossil specimens that were found are deposited in the collections of the University Hassan II — Casablanca.

SEM images were made at the UMR 7207 and at the MNHN "Plateforme de microscopie électronique". Two specimens (GEA 2-1, GEA 2-20) were studied by computed scanning microtomography. CT scanning was conducted at the X-ray Tomography Imagery Platform AST-RX of the MNHN, using a GE Sensing and Inspection Technologies phoenix|x-ray v|tome|x L240-180 CT scanner with the nanofocus RX source (180 kV/15 W). The GEA 2-1 scan was made with an isotropic voxel size of 1.35987 µm under a voltage of 55 kV and a current of 260 µA. The GEA 2-2 scan was made with an isotropic voxel size of 2.24292 µm under a voltage of 90 kV and a current of 170 µA. Data were reconstructed using phoenix datos|x 2.0 reconstruction. 3D processing and modeling of the CT scans were made with the help of the program Materialise Mimics Innovation Suite 16 at the 3D imaging platform of the UMR 7207 (CR2P).

Paleobotanic studies

Palynological samples were processed using the standard treatment used in palynology (Erdtman, 1943; Batten, 1999). The slides were analyzed under a Nikon Eclipse 80i light microscope using a differential interference contrast objective (after Nomarski) and equipped with a Nikon D 300 digital camera. Several separate optical section pictures were taken for each sample and photographic depth of field was reconstructed using the program Helicon Focus.

Abbreviations

GEA: Guelb El Ahmar locality (3 loci, GEA I, 2, 3; Anoual Syncline), belonging to the Anoual Formation, Bathonian.

KM: Ksar Metlili locality (Anoual Syncline), belonging to the Ksar Metlili Formation, ?Berriasian.

3. Location and geological context

3.1. Geological and stratigraphical context

The Guelb el Ahmar sites (acronym GEA) yielding vertebrate remains are located on the northern rim of the eastern High Atlas Mountains, about 7 km NNE of Anoual city (Fig. 1). The mostly continental Jurassic red beds ["couches rouges" also termed *Continental Intercalaire* by pioneering French geologists (e.g., Kilian, 1931)] are widely distributed in the Middle and High Atlas Mountains (Allain and Aquesbi, 2008). Their age has been highly debated because of the lack of undisputable chronostratigraphic markers (du Dresnay, 1969; Monbaron, 1988). In the Atlasic domain, this clastic sequence of red beds corresponds to the filling of Middle Jurassic basins, and it precedes the Aptian or the Cenomanian marine transgression (Choubert and Faure-Muret, 1960–1962; du Dresnay, 1979; Charrière, 1992, 1996). In the Anoual area, this sequence of red beds is stratigraphically sandwiched between the marine upper Bajocian-?lower Bathonian marly calcareous unit (*Pholadomya* marls and limestones Formation) and the marine Cenomanian-Turonian limestone bank (Fig. 2).

In the Anoual area, these red beds are moderately affected by tectonics and are about 500 m thick (Haddoumi et al., 2008, Fig. 1). They are usually divided in two or three lithological units separated by disputed unconformities. The considerable time interval of deposition (from the Middle

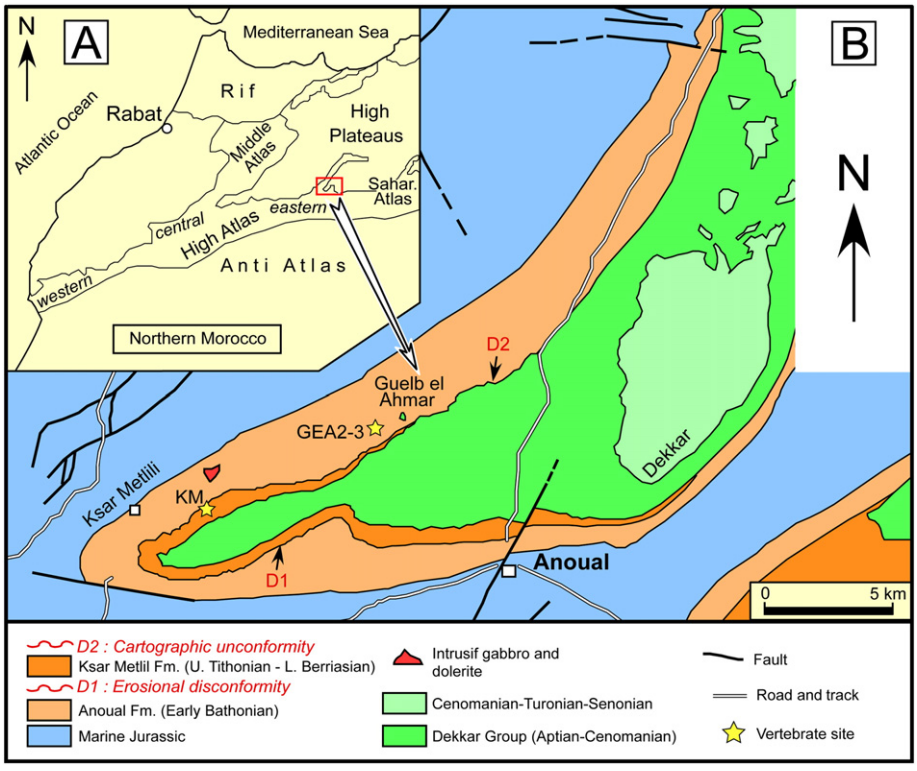

Fig. 1. Geographic and geological settings of the investigated outcrop areas. A: location of the study area in Eastern High Atlas. B: simplified geological map of the Anoual Syncline (from du Dresnay, 1976; Caïa, 1972; Haddoumi et al., 2008) showing the vertebrate localities of Guelb el Ahmar (GEA, Anoual Fm, Bathonian) and Ksar Metlili (KM, Ksar Metlili Fm, ?Berriasian).