Review of Palaeobotany and Palynology 197 (2013) 90–118

Contents lists available at ScienceDirect

Review of Palaeobotany and Palynology

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

Research paper

Latest Ordovician–earliest Silurian acritarchs and chitinozoans from subsurface samples in Jebel Asba, Kufra Basin, SE Libya

Bindra Thusu [a], Syed Rasul [a], Florentin Paris [b,f], Guido Meinhold [c,d,*], James P. Howard [c], Yousef Abutarruma [e], Andrew G. Whitham [c]

[a] Maghreb Petroleum Research Group, Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, United Kingdom
[b] Rue des Jonquilles, 35235 Thorigné-Fouillard, France
[c] CASP, University of Cambridge, West Building, 181A Huntingdon Road, Cambridge CB3 0DH, United Kingdom
[d] Geowissenschaftliches Zentrum der Universität Göttingen, Abteilung Sedimentologie/Umweltgeologie, Goldschmidtstraβe 3, 37077 Göttingen, Germany
[e] Mellitah Oil & Gas B.V., Dat Al Imad Complex Tower 5 Floor 13, P.O. Box 91651, Tripoli, Libya
[f] Géosciences Rennes, CNRS UMR 6118, Université de Rennes 1, Rennes cedex, France

ARTICLE INFO

Article history:
Received 5 July 2012
Received in revised form 17 April 2013
Accepted 9 May 2013
Available online 24 May 2013

Keywords:
biostratigraphy
acritarch
chitinozoan
Hirnantian
Silurian, Gondwana
Libya

ABSTRACT

Latest Ordovician–earliest Silurian Tanezzuft Formation shales recovered from core material of the shallow borehole JA-2 drilled in Jebel Asba at the eastern margin of the Kufra Basin, southeastern Libya, yielded well-diversified palynomorph assemblages with transparent and brownish to yellowish vesicles and organic matter (visual kerogen Types 1 and 2) from depth interval 46.20 to 67.82 m. In addition, miospores including cryptospores, and *Tasmanites* sp. ("*Tasmanites* with nodules"), scolecodonts, and a stratigraphically significant palaeo-marker, the enigmatic, tubular organic structure *Tortotubus protuberans*, were also recorded frequently in most samples. Kerogen colour based on miospores (TAI < 3) and chitinozoan reflectance indicate an immature facies for oil generation. The two uppermost samples (from 33.33 m and 46.20 m depths) and the lowermost ones (from 67.92 to 73.21 m depth) contain rare palynomorphs and other organic remains and have been partially affected by oxidation. Furthermore, palynological and palynofacies analyses were carried out on cuttings from an old well (UN-REMSA well), ca. 530 m towards the NNE from well JA-2. The composition of the organic residue is similar in both wells. However, the UN-REMSA well yields fairly numerous chitinozoans, scolecodonts and biofilms but lacks the "thread-like structures" and "*Tasmanites* with nodules" observed in well JA-2.
All the investigated samples in well JA-2 are dominated by a single chitinozoan species, *Euconochitina moussegoudaensis* Paris (in Le Hérissé et al., 2013). Based on correlation with chitinozoan-bearing strata around the Ordovician–Silurian boundary, the analysed samples from well JA-2 and from the UN-REMSA well are regarded as post-glacial, but still of either latest Hirnantian age, or at least no younger than earliest Rhuddanian. A well-diversified acritarch, miospore and cryptospore assemblage recorded in well JA-2 supports a marginal marine (nearshore) depositional environment. This assemblage is no older than earliest Rhuddanian yet the latest Hirnantian age of the assemblage cannot be completely ruled out as our current knowledge on the post-glacial, latest Hirnantian acritarch and miospore assemblages is poorly documented in North Africa.

1. Introduction

The precise location of the source rock horizons close to the Ordovician–Silurian boundary is an important question for hydrocarbon exploration in northern Gondwana regions. In areas of anoxic geological setting, typical "hot shale" horizons are easily identified by their peculiar lithology (e.g., black shales), a sharp positive excursion of the gamma-ray curve in the well logs and high total organic carbon (TOC) content (e.g., Lüning et al., 2000, 2005, 2006). These characteristics can also be determined by the visual nature and the abundance of the organic matter including palynomorphs, animal remains and associated amorphous organic matter (AOM).

The main goal of the present study is to record for the first time moderately rich to rich assemblages of acritarchs, chitinozoans, miospores and cryptospores recovered from well JA-2 in Jebel Asba, Kufra Basin, drilled by CASP (formerly known as Cambridge Arctic Shelf Programme) in April–May 2009 (Fig. 1).

2. Material and methods

2.1. Sampling

Core samples from well JA-2 (geographic coordinates: 22°35′49.31″N, 24°7′57.10″E) drilled in the Jebel Asba at the eastern margin

* Corresponding author at: Geowissenschaftliches Zentrum der Universität Göttingen, Abteilung Sedimentologie/Umweltgeologie, Goldschmidtstraβe 3, 37077 Göttingen, Germany. Tel.: +49 551 3933455; fax: +49 551 397996.
E-mail address: guido.meinhold@geo.uni-goettingen.de (G. Meinhold).

0034-6667/$ – see front matter
http://dx.doi.org/10.1016/j.revpalbo.2013.05.006

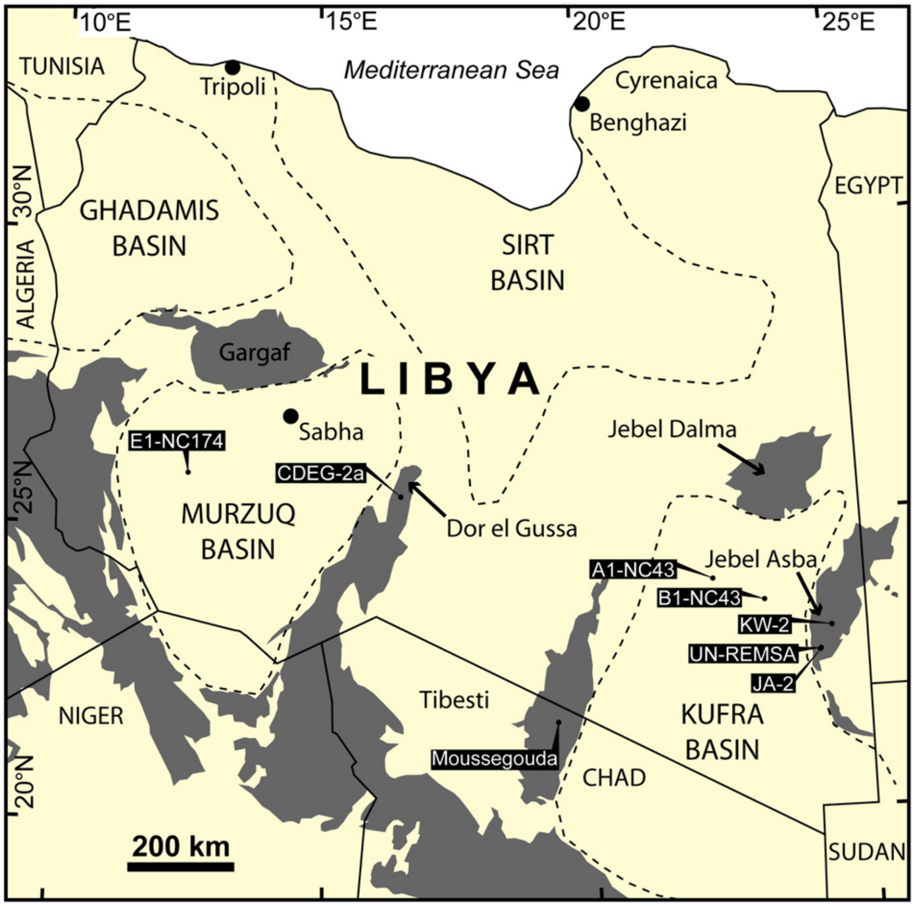

Fig. 1. Map of Libya showing surface outcrops with Paleozoic rocks (dark grey colour) and the location of Jebel Asba at the eastern margin of the Kufra Basin (after Paris et al., 2012). The drill site localities of well CDEG-2a in central Dor el Gussa (Paris et al., 2012) and wells JA-2 and UN-REMSA in southern Jebel Asba (this study) are indicated.

of the Kufra Basin (Figs. 1 and 2) and cuttings (single sample SJS0001) from a pile of drill cuttings surrounding the borehole collar of an abandoned well (geographic coordinates: 22°36′4.52″N, 24°8′4.67″E), apparently drilled by REMSA (Repsol Exploración Murzuq S.A.), some 530 m NNE of well JA-2 have been investigated for acritarchs and chitinozoans. However, we are not certain that the abandoned well was drilled by REMSA, and therefore we name it UN-REMSA well with UN standing for uncertain. Before starting the chemical processes, each core sample was observed under the binocular microscope in order to collect information on its grain size, petrology, and possible macrofossils. The degree of weathering of the rock sample was also evaluated as oxidation of the rock precludes the preservation of the organic matter (Table 1). This information is useful to interpret low chitinozoan abundances: low abundance in non-weathered and low-energy sediments is mainly caused by environmental conditions and the lack of palynomorphs in weathered or high-energy deposits, respectively, are due to oxidation of the organic matter, and to non-deposition of the lighter particles such as acritarchs or chitinozoans.

In well JA-2 (Fig. 2), the lowermost core sample at 73.21 m depth is grey shale. Samples from 67.97 to 69.12 m show evidence of weathering (e.g., oxidation of pyrite crystals; brownish micas) in very fine light coloured sandstone and in whitish (altered?) shale. The uppermost processed samples (33.33 m and 46.20 m) also display evidence of weathering (i.e. beige colour of the silty shale and oxidation of the organic matter). This alternation most likely corresponds to the deepest part of the sub-Recent weathering profile developed in many Saharan regions. In the interval 46.60–67.59 m, the lithology is fairly constant and ranges from grey and greenish shale to grey siltstone with micas. A lithological change is noticed between 67.59 and 67.82 m with the occurrence of very fine sandstone. However, for the microfossils, a major change occurs at 67.97 m with a dramatic drop in abundance of the chitinozoans, possibly related to either the oxidation, noticed in the core samples (Table 1), or to temporary emersion (e.g., during the latest Hirnantian–earliest Rhuddanian post-glacial rebound), which permitted the weathering of the older strata. Ground water circulation in a minor fault also might have caused oxidation of the rock and of its organic matter between 67.82 and 69.12 m. Because no biostratigraphical information is available on the underlying strata, it is not possible to favour one or the other of these hypotheses.

The cutting sample SJS0001 from the UN-REMSA well is susceptible to caving. However, because no strong lithological disparity was noticed in the cuttings collected and investigated, the drilled horizon represents likely dark grey silty shale, which is the most common component of the sample.

2.2. Sample preparation

The core material was split into equal parts and prepared separately for acritarch and chitinozoan analysis. For the acritarchs, the samples were treated according to standard palynological preparation methods. A zinc bromide solution (specific gravity 2 g cm^{-3}) was used for separation of organic matter, which was then screened using a 15 μm mesh for washing in order to separate the larger