Review of Palaeobotany and Palynology 212 (2015) 60–84

Contents lists available at ScienceDirect

Review of Palaeobotany and Palynology

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

# Late Ordovician–earliest Silurian chitinozoans from the Qusaiba-1 core hole (North Central Saudi Arabia) and their relation to the Hirnantian glaciation

Florentin Paris [a,b,*], Jacques Verniers [c], Merrell A. Miller [d], Sa'id Al-Hajri [e], John Melvin [f], Charles H. Wellman [g]

[a] Rue des Jonquilles, 35235 Thorigné-Fouillard, France
[b] Géosciences-Rennes, CNRS UMR 6118, Université de Rennes 1, 35042 Rennes, France
[c] Research Unit of Paleontology, Department of Geology and Soil Sciences, Ghent University, Krijglsaan 281/S8, 9000 Ghent, Belgium
[d] IRF Group, Inc., 2357 East 23rd street, Tulsa, OK 74114, USA
[e] Saudi Aramco, Exploration Technical Services Department, 31311 Dhahran, Saudi Arabia
[f] Saudi Aramco, Gas Fields Characterization Division, 31311 Dhahran, Saudi Arabia
[g] Department of Animal and Plant Sciences, University of Sheffield, Alfred Denny Building, Western Bank, Sheffield S10 2TN, UK

ARTICLE INFO

*Article history:*
Received 10 April 2014
Received in revised form 16 October 2014
Accepted 16 October 2014
Available online 5 November 2014

*Keywords:*
Chitinozoan
Biostratigraphy
Carbon isotope
Late Ordovician
Hirnantian glaciation
Saudi Arabia

ABSTRACT

The continuously cored Qusaiba-1 drilled in North Central Saudi Arabia penetrated successively the Qalibah, Sarah and Qasim formations. Silurian graptolites and chitinozoans from the Qusaiba Member of the Qalibah Formation were previously investigated. The present study focuses on the Upper Ordovician and lowermost Silurian parts of the core hole. Part of the sample set yielded abundant and well-preserved specimens associated with eurypterid remains, scolecodonts, acritarchs and cryptospores. Other samples from glacially derived shaly sediments contain only a few fragmented chitinozoan vesicles of Middle and Late Ordovician species indicating reworking through glacial processes. Four different chitinozoan assemblages are identified. The first recorded chitinozoan assemblage is restricted to the deepest processed sample (core 56). It contains *Belonechitina* cf. *robusta*, *Hercochitina* sp. A, and *Spinachitina* cf. *kourneidaensis*, and taxa also represented in the second assemblage, e.g., *Fungochitina spinifera* and *Euconochitina* species. This first assemblage, however, lacks some of the diagnostic species of the second one (e.g., *Acanthochitina barbata*, *Tanuchitina* cf. *elongata*) and suggests a slightly older late Katian age. The second recovered chitinozoan assemblage is documented in the upper part of the Qasim Formation (cores 49–56) and in the deeper core samples referred to the lower part of the Sarah Formation (cores 45–47 from the disrupted facies of the Sarah Sandstone Member). It contains abundant and well-preserved *Armoricochitina nigerica* and *Ancyrochitina merga* associated with e.g., *Euconochitina lepta*, *Calpichitina lenticularis*, *A. barbata* and *Desmochitina typica*. In addition to these classical components, new species have been observed. This assemblage occurring in pre-glacial as well as in glacially related strata is assigned to the late Katian–earliest Hirnantian (Ashgill). The overlying productive interval, corresponding to the Baq'a Shale Member, is less productive and sometimes virtually barren of chitinozoans. This interval yields a third assemblage mainly composed of broken specimens of *Angochitina* cf. *curvata*, *C. lenticularis*, *Cyathochitina* sp., *D. typica*, *F. spinifera*, *Tanuchitina fistulosa*, *Euconochitina* gr. *lepta*, and even *Siphonochitina formosa*. Most of these forms are interpreted as glacially reworked. The youngest assemblage is restricted to three samples (core 27), which are located very close to a Silurian gamma ray peak and above the highest evidence of glacial sediments represented by the Sarah Formation. This forth assemblage contains extremely abundant chitinozoans coexisting with a few graptolite remains and inarticulate brachiopods. This chitinozoan assemblage is dominated by *Cyathochitina caputoi*, which is associated with *Belonechitina pseudarabiensis* and subordinate numbers of *Ancyrochitina* and *Euconochitina* species. The classical Late Ordovician chitinozoan taxa are no longer present and an earliest Rhuddanian age is proposed.
Carbon stable isotope ($\delta^{13}C_{chit.}$) values have been measured on picked chitinozoan vesicles from the upper part of the Quwarah Member (upper Qasim Formation) and from the basal part of the Qusaiba Member (Qalibah Formation) where they register a shift towards more negative values close to the Gamma ray peak. The timing of the Late Ordovician glaciation and correlation with Hirnantian glacial events recorded in Northern Gondwana regions are briefly discussed based on the recovered chitinozoans.

* Corresponding author at: Rue des Jonquilles, 35235 Thorigné-Fouillard, France.
*E-mail address:* florentin.paris@orange.fr (F. Paris).

http://dx.doi.org/10.1016/j.revpalbo.2014.10.005

Four new species, i.e., *Conochitina rotundata* sp. nov., *Belonechitina tenuicomata* sp. nov., *Hercochitina multiansata* sp. nov., and *Calpichitina bernardae* sp. nov. are described, discussed and illustrated. Biometric data are provided for *Acanthochitina barbata* and for *Armoricochitina nigerica*.



## 1. Introduction

Chitinozoans and graptolites are among the most useful fossil groups for accurately dating Lower Palaeozoic clastic sediments. In Saudi Arabia, graptolites (Zalasiewicz et al., 2007, and references therein) and chitinozoans (Paris et al., 1995a, 2008a) are found to be abundant in lower Silurian shales, which therefore benefit from precise age assignment in terms of standard Llandovery stages and graptolite biozones (see Paris et al., 2014). In Upper Ordovician strata, however, graptolites are virtually absent and the age assignments, especially for subsurface strata, depend principally on chitinozoan data (see Al-Hajri, 1995; Paris et al., 2000b, and references therein).

In Saudi Arabia, as well as in the Sahara, samples from outcrops are usually deeply weathered. Such meteoric oxidation generally precludes the preservation of the organic-walled microfossils, including chitinozoans. The present study was initiated to provide accurate correlations between the Ordovician and Silurian formations exposed in the Palaeozoic outcrop belt adjacent to the Arabian Precambrian Shield (Fig. 1a) and the subsurface strata in the eastern part of Saudi Arabia (Al-Hajri and Owens, 2000). To overcome the weathering problems, during 2002, Saudi Aramco drilled a series of shallow cores in the northwestern part of Central Saudi Arabia, in the type areas of the Saudi Arabian Ordovician and Silurian formations and members. One of these, the Qusaiba-1 core hole, penetrated Upper Ordovician strata (Paris et al., 2008b) beneath Aeronian graptolite bearing shale of the Qusaiba Member (Zalasiewicz et al., 2007; Paris et al., 2014). The Upper Ordovician and basal Silurian parts of this shallow core are investigated in detail here for a better understanding, through their chitinozoan content, of the timing of the Late Ordovician glaciation. Correlation with the major Hirnantian glacial events documented in Northern Gondwana regions (Mauritania, Morocco, Algeria, Turkey) are discussed based on the chitinozoan data.

The current lithostratigraphy of the Late Ordovician and early Silurian of Saudi Arabia was progressively formalized during a surface geological mapping programme (Manivit et al., 1986; Williams et al., 1986; Vaslet et al., 1987; Janjou et al., 1996). The resulting detailed lithostratigraphical nomenclature (Fig. 2) was widely used with some minor adjustments (see Vaslet, 1990; Mahmoud et al., 1992; Stump et al., 1995; Senalp et al., 2002: Miller and Al-Ruwaili, 2007). These formal lithostratigraphic names replaced older terms used for instance by McClure (1988) who illustrated Ordovician and Silurian chitinozoans from the Tabuk and Qasim areas. Melvin (2014) has adopted this terminology to describe and interpret the sedimentology of the Late Ordovician lithostratigraphic units, namely the Quwarah Member of the Qasim Formation and of the overlying Sarah Sandstone, Baq'a Shale and Baq'a Sandstone members of the Sarah Formation (Fig. 2). Concerning more specifically the Sarah Formation in the Qusaiba-1 core hole, Melvin (2014) has distinguished a "basal disrupted facies" corresponding to the lower part of the Sarah Sandstone Member in the Qusaiba-1 core hole.

## 2. Materials and methods

### 2.1. Samples

The Qusaiba-1 core hole was drilled in the type area of the Qusaiba Member of the Qalibah Formation, close to the Qusaiba depression, at c. 15 km north of the Quwarah village, (Fig. 1b). This shallow core hole (total depth: 551.0 ft) penetrated 257 ft (c. 78 m) of the Qusaiba Member of the Qalibah Formation and 294 ft (c. 90 m) of the underlying Ordovician section. The local Upper Ordovician succession includes the

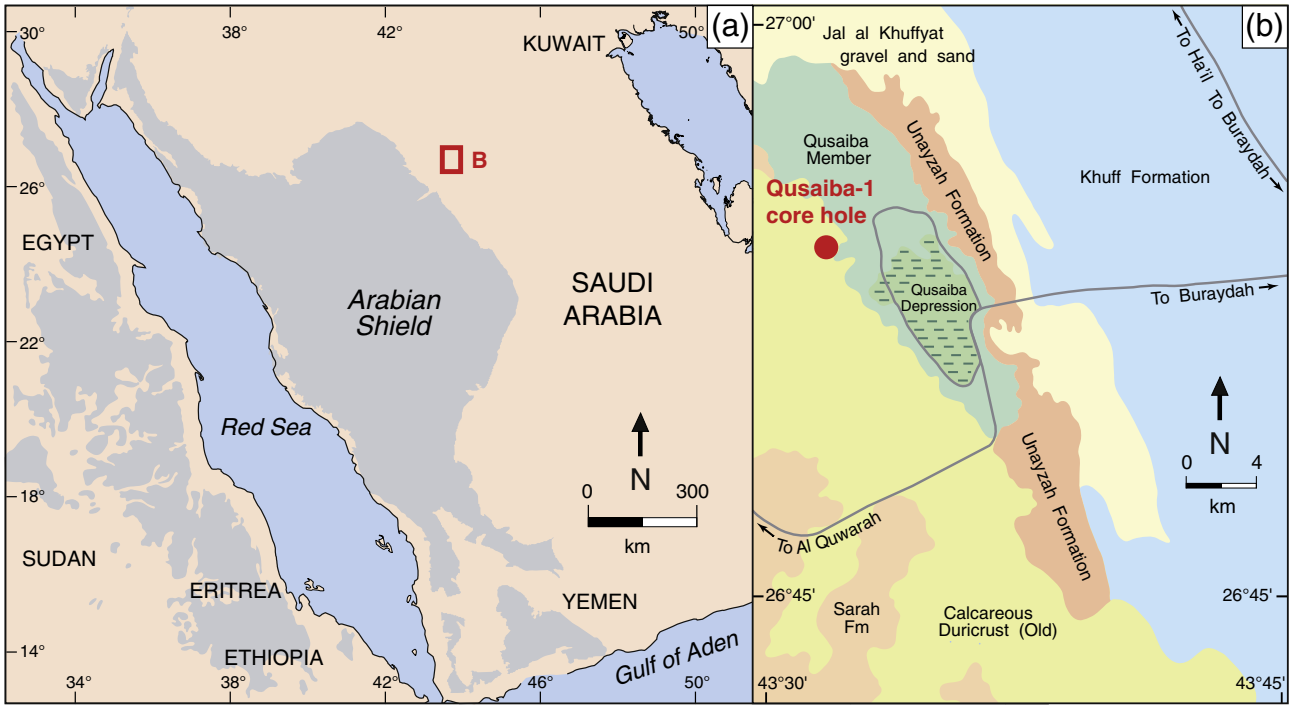


**Fig. 1.** Location map showing the study area in Saudi Arabia (1a), and the position of the Qusaiba-1 core hole (1b). Adapted from Zalasiewicz et al. (2007).