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Research paper

Climate-controlled palynofacies and miospore stratigraphy of the Jauf Formation, Lower Devonian, northern Saudi Arabia

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ABSTRACT

The Jauf Formation miospore succession is synthesized in terms of palaeoenvironments and sequence stratigraphy. The data set for this study is obtained from four overlapping, continuously cored, and extensively sampled, boreholes that form a 940 ft (287 m) composite section. The Jauf Formation ranges in age from late Pragian to latest Emsian. The palynological assemblages, recognized herein, provide the basis for recognizing depositional environments present in the Lower Devonian of northern Saudi Arabia. Transgressive–regressive cycles are indicated not only by lithology, but also by marked changes in the marine to terrestrially dominated palynological assemblages, which are described in detail. Flooding events are recognized by the replacement of spore-dominated assemblages by organic-walled microphytoplankton and could be climate-controlled. The maximum flooding interval for the Jauf Formation is reinterpreted based on a correlative event consisting of diverse acritarchs and abundant chitinozoans. The sequence of palynological assemblages corresponds to fourth order cycles in the Hammamiyat Member. The new northern Gondwanan biozonation developed by Breuer and Steemans (2013) and used here allows a high-resolution regional biozonation for the Arabian Plate and larger-scale correlation of the Jauf Formation with other Gondwanan and Euramerican localities. One new spore genus (*Zonohilates*) and four new spore species (*Insculptospora maxima*, *Camarozonotriletes alruwailii*, *Devonomonoletes crassus* and *Zonohilates vulneratus*) are proposed.

1. Introduction

Dispersed plant spores are the primary tool used for biostratigraphic age determination and correlation of the Devonian deposits of Saudi Arabia supplementing marine faunas that are confined to Jauf Formation outcrops (e.g. Boucot et al., 1989; Forey et al., 1992). More than a decade ago, Saudi Aramco drilled a number of shallow core holes in northern Saudi Arabia with the intention of studying the Devonian deposits of this area and correlating them to the nearby outcrops. Leszczyński et al. (2010) described the sedimentology of two pairs of core holes located ca. 350 km apart (Fig. 1), and documented the bioturbation and sedimentological structures present in the Jauf Formation (Figs. 2 and 3). The JNDL-3 and JNDL-4 core holes are located in the vicinity of Domat Al-Jandal while BAQA-1 and BAQA-2 are near the town of Baq'a. The Jauf Formation in northern Saudi Arabia is divided into five members based on lithofacies. The lower part of formation occurs in the BAQA core holes whereas its upper part occurs in JNDL-3 and JNDL-4. Stratigraphic overlap of the cores gives a complete composite Jauf Formation succession (942 ft/287 m thick) and includes all members (Fig. 4).

These core holes were studied palynologically to establish a detailed Devonian biostratigraphy and correlate with subsurface sections from eastern Saudi Arabia (Breuer et al., 2005, 2007; Breuer and Steemans, 2013). Palynological slides from previous studies were re-examined and complemented by newly processed samples and observations. This paper represents the synthesis for the spore-based stratigraphy of the Jauf Formation in northern Saudi Arabia. Although the majority of spore species from the studied assemblages were described by Breuer et al. (2007) and Breuer and Steemans (2013), some are new and described below in the Systematic Palaeontology. Finally the results of the quantitative study carried out on palynological assemblages are presented herein and palaeoenvironments are discussed regarding the detailed sedimentological study of the sections by Leszczyński et al. (2010).

2. Jauf Formation

The Jauf Formation is exposed in northern Saudi Arabia (Powers, 1968). The formation is described in the explanatory notes of several geological quadrangle maps where it is present (Vaslet et al., 1987;

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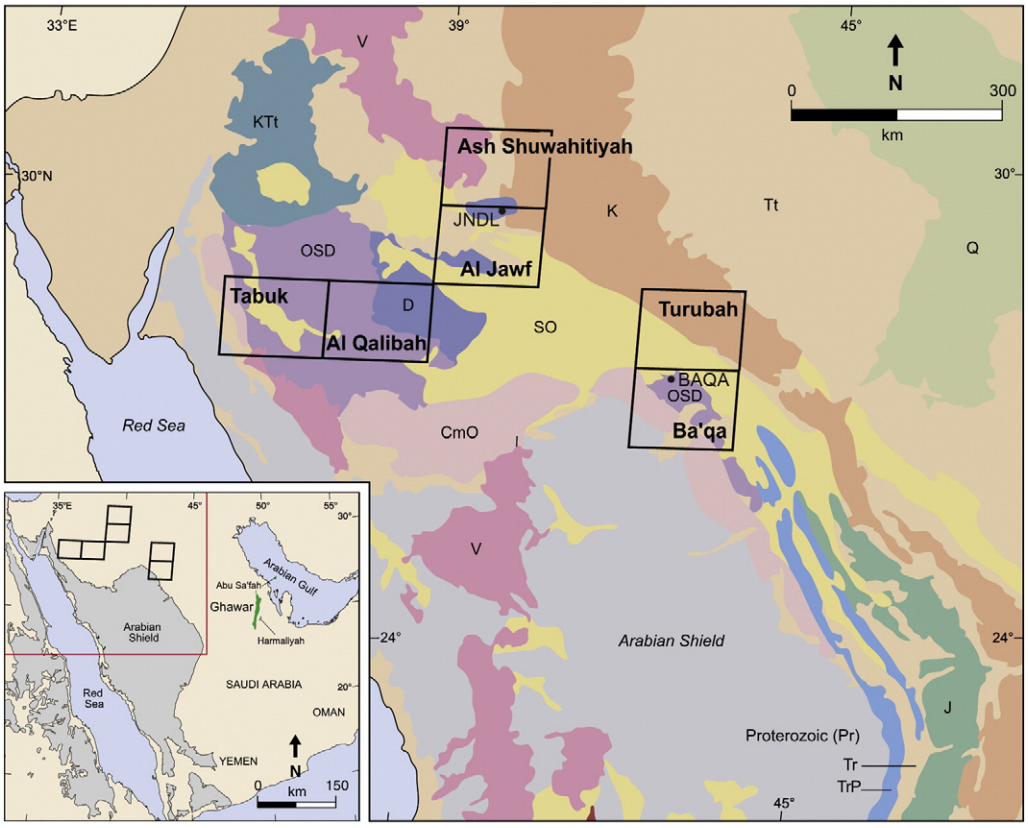

Fig. 1. Location of core holes discussed in this study. The Jauf Formation exposed in northwestern Saudi Arabia was described from indicated geological quadrangles (Devonian indicated by the letter D; undifferentiated Ordovician–Silurian–Devonian indicated as OSD).

Wallace et al., 1996, 1997; Janjou et al., 1997a,b; Lebret et al., 1999). The Jauf Formation in outcrop was also studied by Helal (1965), Bahafzallah et al. (1981), Al-Laboun (1982, 1986) and Al-Husseini and Matthews (2006). Macrofauna from the Jauf Formation were investigated for brachiopods (Boucot et al., 1989) and fish (Forey et al., 1992). Spore assemblages were only recorded from the subsurface (see below). Over many Arabian Plate tectonic structures and palaeohighlands the Jauf formation is absent because of Late Palaeozoic uplift and subsequent erosion (Wender et al., 1998; Konert et al., 2001). In eastern Saudi Arabia, the Jauf Formation is only present in the subsurface (e.g. Wender et al., 1998; Al-Hajri et al., 1999).

In northwestern Saudi Arabia, the Jauf Formation varies in measured thickness between 886 ft (270 m) and 1083 ft (330 m) (Helal, 1965; Powers, 1968; Boucot et al., 1989; Wallace et al., 1997). It overlies disconformably or unconformably the continental to shallow-marine Tawil Formation, and is unconformably overlain by the continental Jubah Formation. Although the shift from continental (Tawil) to marine (Jauf) sedimentation would presumably involve a hiatus, some authors interpret the Jauf/Tawil Formation contact to be conformable (e.g., Powers, 1968; Vaslet et al., 1987; Al-Hajri et al., 1999). Others declare that the Jauf Formation overlies the Tawil Formation in disconformity (Janjou et al., 1997a; Wallace et al., 1997) or unconformity (Wallace et al., 1996). Although the contact between the Jauf and Jubah Formations appears to be conformable (Al-Hajri et al., 1999), the upper part of the Jauf Formation (Murayr Member) is unconformably overlain by Jubah sandstone beds (Wallace et al., 1996, 1997; Janjou et al., 1997a). This major erosional boundary between the Murayr tidal sandstone and the Jubah fluvial sandstone reflects an abrupt change in the sedimentary environment and is a sequence boundary.

2.1. Lithostratigraphy

The alternating siliciclastics and carbonates of the Jauf Formation in northwestern Saudi Arabia are used to subdivide it into five members: the Sha'iba, Qasr, Subbat, Hammamiyat and Murayr members (in ascending order). The five members constitute a conformable succession according to Wallace et al. (1996, 1997). Although the lithological characters of the Jauf Formation change little throughout northwestern Saudi Arabia, the different members are described according to the region where the studied core holes cut through them (Figs. 2 and 3).

2.1.1. Sha'iba Member

This unit is only drilled by BAQA-2 core hole (Fig. 2). In the Baq'a Quadrangle (Vaslet et al., 1987), the Sha'iba Member in outcrop is composed in the lower part of beige fine-grained sandstone sometimes with cross-bedding and reworked clay galls and plant remains. This sandstone interval is capped by a ferruginous surface. The interval above comprises green to red, micaceous silty claystone including rare pinkish, laminated, silty dolomite at the base. The 6.5 uppermost feet (2 m) are composed of yellow to pinkish, lenticular dolomite intercalated with ochre, laminated, fine-grained sandstone and green, micaceous, silty claystone. Estimate of the thickness inside the Baq'a Quadrangle in the Al Muyyah section is 85 ft (26 m) (Vaslet et al., 1987) whereas the Sha'iba Member is about 121 ft (37 m) thick in BAQA-2 (Fig. 2). In the Baq'a Quadrangle, the contact between the Jauf and the underlying Tawil Formations is sharp and characterized by a reworking of the palaeosol capping the Tawil sandstone and is conformable according to Vaslet et al. (1987). This boundary is distinctively marked by plant root structures in BAQA-2 (Fig. 2).