Palaeogeography, Palaeoclimatology, Palaeoecology 297 (2010) 138–143

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Trace fossils on a Late Ordovician glacially striated pavement in Algeria

Daniel Paul Le Heron

Department of Earth Sciences, Queen's Building, Royal Holloway University of London, Egham, Surrey, TW200BY, UK

ARTICLE INFO

Article history:
Received 8 September 2009
Received in revised form 5 July 2010
Accepted 23 July 2010
Available online 30 July 2010

Keywords:
Striated pavements
Ordovician
North Africa
Glaciation
Trace fossils

ABSTRACT

An exceptional exposure of Late Ordovician glaciogenic sediments crops out in Dider, SE Algeria, within the Tassili N'Ajjer region. The sediments consist of sandstones and diamictites sandwiched between a Mid Ordovician fluvial and tidal sandstone (In Tahouite Formation) below and Early Silurian shale (Oued Imirhou Formation) above. Stratigraphic discontinuities within the Late Ordovician glaciogene succession include palaeovalley incisions and glacially striated pavements. Striation and fluting of a soft-bedded sediment beneath an ancient ice sheet is supported by abundant dewatering structures and soft-sediment gouges interpreted to have been produced by the action of stone ploughing. In Dider, two types of previously undescribed circular structures sit in negative relief on this glacial pavement, namely 1) paired thumb-shaped impressions 2 cm in diameter and 3 mm in depth, and 2) a 5 cm wide impression with 3 segmented nested cycles. A framboid or aggregate origin may be appropriate for the smaller of the features but the larger impression is interpreted as biogenic: internal complexity is characteristic, discounting concretion moulds and water escape structures. A biogenic origin as a coelenterate resting trace is proposed with speculation on conditions of exceptional preservation in an ancient periglacial environment.

1. Introduction

Upper Ordovician glacially related sediments of the Tamadjert Formation crop out over a wide region of Algeria and are particularly well exposed in the Tassili N'Ajjer National Park (Fig. 1). There, this formation comprises a succession of clastic sedimentary rocks (sandstones, mudrocks, diamictites) in a succession that is punctuated by discontinuities and angular unconformities, and which was deposited by a ~443 Myr old Saharan ice sheet that advanced northward (e.g. Le Heron and Craig, 2008). In common with correlative sections in Libya and Morocco, many of the discontinuities bear soft-sediment striae formed by the action of Late Ordovician ice sheets shearing an unconsolidated, sandy substrate (e.g. Le Heron et al., 2005, 2006, 2007). A considerable amount of research has been conducted into the origin of these glacially striated surfaces across North Africa, which, drawing attention to the prevalence of dewatering structures and small lobate folds of sandstones that drape such surfaces, concludes that they formed in unconsolidated sediment (Deynoux and Ghienne, 2004; Le Heron et al., 2005). Closer to the ice centre, in Niger, striated pavements are beautifully exposed and have been subject to analysis in great detail by Denis et al. (2009).

Body fossils are very rare within Late Ordovician glaciogenic sandstones of the central Sahara, although exquisite examples of the *Hirnantia* brachiopod fauna have been described from the Gargaf Arch in neighbouring Libya (Sutcliffe et al., 2001). Furthermore, Late Ordovician glaciogenic deposits are notoriously difficult to correlate over large distances, with many studies relying on microfossils such as chitinozoa (Bourahrouh et al., 2004), which are only preserved in hyper-arid conditions in deep oil boreholes. As such, at outcrop, any structure of potential biogenic origin is worthy of consideration as a potential biostratigraphic tool. The present paper, therefore, provides a description and interpretation of enigmatic pitted circular structures, peculiarly preserved on a glacially-striated pavement, of probable biogenic origin.

2. Geological setting

The study area (Fig. 1) forms part of an extensive outcrop belt of Cambrian through Silurian clastic sedimentary strata (Eschard et al., 2005) that define the southern flank of the Illizi Basin. This outcrop belt forms the southern flank of the Illizi Basin and exposes a generally monotonous layer cake stratigraphy (Beuf et al., 1971). This stratigraphy, which contains sedimentary rocks bearing fluvial, shallow marine and rare glacial facies in the Late Ordovician (Beuf et al., 1971), is characterised by a diagenetic overprint that includes ferruginous nodules. The distribution of these ferruginous nodules is considered to relate to deep-seated basement faults that traverse the Hoggar Massif and extend northward into the Tassili N'Ajjer (Guerrak, 1991). In the Tassili N'Ajjer, in common with other outcrops at the flanks of North Saharan basins, a wide range of concretions and nodules can be recognised in the desert sandstones (Seilacher, 2001).

E-mail address: d.leheron@es.rhul.ac.uk.

0031-0182/$ – see front matter
doi:10.1016/j.palaeo.2010.07.023

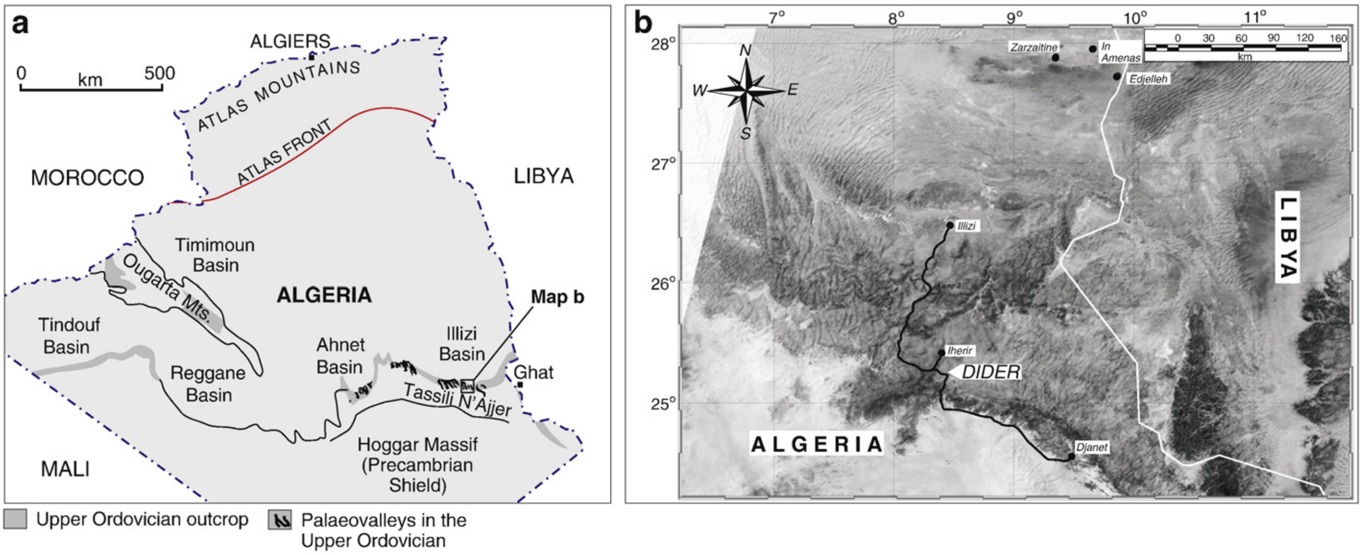

Fig. 1. a. Location of the Tassili N'Ajjer in southern Algeria. The map shows both the extent of Upper Ordovician outcrop across Algeria and the distribution of glacial palaeovalleys as mapped by Beuf et al. (1971). b: Map of the Tassili N'Ajjer National Park, SE Algeria, showing the location of the study section at Dider, located on the main road (shown in black) between Djanet and Illizi.

In the Tassili N'Ajjer national park, the Ordovician through Silurian succession comprises the In Tahouite Formation at the base, the Tamadjert Formation in between, and the Oued Imirhou Formation above (Eschard et al., 2005) (Fig. 2). The Tamadjert Formation (Late Ordovician) is famous for its glacial features, including palaeovalleys cut by meltwater (Fig. 4), push moraines, diamictites, and striated glacial pavements (Beuf et al., 1971; Hirst et al., 2002). This formation is summarised below to place the striated pavement at Dider into stratigraphic context.

3. Stratigraphic context of enigmatica

At Dider, the Tamadjert Formation rests in disconformity upon the In Tahouite Formation (Figs. 2 and 3). The contact between these two formations can be described as one of several palaeovalley incisions originally identified in the Tassili N'Ajjer by Beuf et al. (1971) (Fig. 3). The palaeovalleys in the Tassili N'Ajjer were cut beneath Late Ordovician ice sheets as "tunnel valleys" (Hirst et al., 2002). The base of the palaeovalley at Dider consists of a striated pavement which is overlain by green, clast-poor silty diamictites and massive sandstones (Fig. 3). At Jbel Hamsailikht in Morocco, a similar striated pavement in the Upper Ordovician is partially concealed by a stratified, boulder-bearing diamictite: that deposit was interpreted to record deposition from ice-rafting processes in a glaciomarine environment (Le Heron, 2007). A similar interpretation has been proposed for the Tassili N'Ajjer outcrops (Hirst et al., 2002), hence forming a mechanism to preserve the delicate structures on striated pavements.

This striated pavement at Dider, in common with those studied by the author in both north and south Morocco and in east and west Libya (Le Heron et al., 2005, 2007), is underlain by a network of vertical dewatering structures (Figs. 4 and 5 a). The association of soft-sediment deformation and glacial features (Figs. 4 and 5 b, c) in Upper Ordovician glacial sediments suggests that ice sheets advanced over an unconsolidated substrate (Le Heron et al., 2005).

Unlike many Upper Ordovician soft-sediment striated pavements in North Africa, the Dider example can be regarded as "stratigraphically isolated" in the sense that additional striated pavements are not found immediately above or below. This is contrast to the more widely known stacked striated surfaces that occur at repeated stratigraphic intervals over a few metres. These are interpreted to result from intraformational shear within a pile of unconsolidated sand (Deynoux and Ghienne, 2004; Le Heron et al., 2005; Denis et al., 2009). Stratigraphically isolated, fluted surfaces were interpreted by Le Heron et al. (2005) to have formed at the ice-sediment interface, rather than within the sediment column. Therefore, decay of ice sheets that produce such stratigraphically isolated surfaces is expected to expose the sediment surface to the air (if terminating on land) or to the water column (if tidewater).

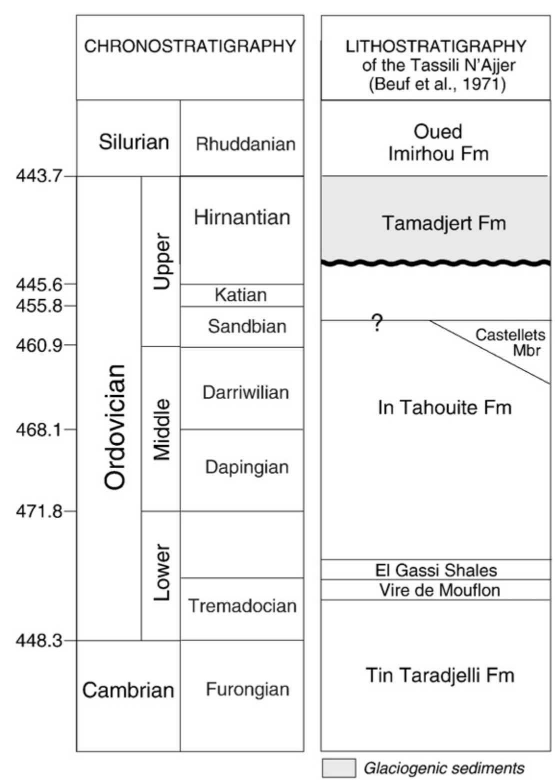

Fig. 2. Stratigraphy of the Lower Palaeozoic succession in Dider, from Beuf et al. (1971).