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ScienceDirect

Precambrian Research 153 (2007) 236–261

Precambrian Research

www.elsevier.com/locate/precamres

The Ediacaran sedimentary architecture and carbonate productivity in the Atar cliffs, Adrar, Mauritania: Palaeoenvironments, chemostratigraphy and diagenesis

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Received 3 July 2006; received in revised form 16 November 2006; accepted 22 November 2006

Abstract

The Neoproterozoic strata of the Taoudeni Basin (West African Craton) display a single glaciogenic deposit, late Cryogenian in age, and included within a stratigraphic-marker 'Triad' of tillite, carbonate, and bedded chert. This work is focused on the analysis of the sedimentary architecture and episodic carbonate productivity related to its transgressive deglaciation recorded in the Atar cliffs of Adrar, Mauritania. It offers a joint chemo-, event-, and sequence-stratigraphic analysis that allows us to control problems of stratigraphic completeness and time resolution, necessary for regional and worldwide stratigraphic correlation.

In the Atar cliffs, the 'cap carbonate sequence' is underlain by a composite unconformity that comprises the Pan-African-I discordance and an inherited palaeorelief associated with the glaciation. The transgressive sequence began with accumulation of a sheet-like apron onlapped by a toe-of-slope to basin transition with (cap) carbonates, bedded cherts and distal turbidites (Tichilît-el-Beïda shales).

The carbonate strata of the Atar 'cap carbonate sequence' have recorded both dolomitization and dedolomitization processes destroying the original cement textures. Carbon isotope values from the sheet-like apron range from 0 to −0.6‰, were directly controlled by the reworking of the underlying Atar strata, and do not reflect primary variations in seawater composition. The general pattern of $\delta^{13}C$ fluctuations within the overlying incomplete 'cap carbonate sequence' is consistent with other post-late Cryogenian strata, except in the initial shift from slightly to moderately negative values recognized elsewhere that is not preserved in the study area. Carbon isotope values in the preserved upper part of the cap carbonate record a pronounced rise in $\delta^{13}C$ from −6.2‰ to highly enriched values (+3.7‰), followed by the final demise of carbonate productivity. The 'cap carbonate sequence' is topped by an erosive unconformity succeeded by the recovery of carbonate accumulation represented by an onlapping dolostone deposited in coastal to foreshore environments. There, the carbon isotope values reflect the return to moderately negative values ranging from −0.9 to −2.0‰.

The palaeogeographic development of a palaeorelief associated with the end of glacial conditions and deposition of the onlapping Atar cap carbonate is related to the presence of interbedded felsic bentonites and phenocrysts, and reflects the intermittent influence of a neighbouring explosive volcanism.

Keywords: Cap carbonate; Carbonate productivity; Chemostratigraphy; Neoproterozoic; Mauritania

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0301-9268/$ – see front matter
doi:10.1016/j.precamres.2006.11.010

1. Introduction

The Neoproterozoic Era was punctuated by climatic fluctuations, including unusually severe glaciations. Palaeomagnetic data (Sohl et al., 1999; Trinidade et al., 2003; Macouin et al., 2004; Kilner et al., 2005; among others) ascertain that during at least one of these glaciations, the late Cryogenian glaciation (ca. 635 Ma), large ice sheets spread over equatorial and subtropical areas and uphold, thereby, the concept of episodes of frozen Earth (Harland, 1964; Kirschvink, 1992) during the Ediacaran (635–542 Ma; Knoll et al., 2004), sometimes referred to as 'snowball Earth' (Hoffman and Schrag, 2002). Geological evidence comprises glacial deposits but also ubiquitous post-glacial carbonate strata named 'cap carbonates'. These are regionally persistent, thin intervals (commonly < 5 m) of carbonate strata associated with a −5‰ negative carbon isotopic excursion (Halverson et al., 2005). Cap carbonates have been ascribed to a variety of environments, such as lacustrine (Walter and Bauld, 1983; Von der Borch et al., 1989), supratidal (Hegenberger, 1993), peritidal (Nédelec et al., in press), subtidal storm-emplaced (Tucker, 1986; Fairchild et al., 1989), below storm-wave base (Kennedy, 1996), and slope-related (Kennedy et al., 1998; Myrow and Kaufman, 1999). They have also received several interpretations referred to both inorganic (Grotzinger and Knoll, 1995; Hoffman et al., 1998; Kennedy et al., 2001) and biogenic (Shields, 2005) processes. In addition, stratigraphic completeness is a major constraint when correlating cap carbonates from different parts of the world. Incompleteness in some of these terrestrial and marine nearshore environments can arise from erosion or non-deposition, two processes difficult to recognize in some outcrops. In fact, the contact of the cap carbonates with the underlying glacial unit ranges from gradational (Kennedy, 1996) to erosive (Von der Borch et al., 1989), and the time span involved in some cap-related stratigraphic gaps is unknown.

Numerous workers have been compiling successive composite $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ records for the Neoproterozoic glaciation intervals, yielding a useful tool for worldwide correlation. However, some of these compilations have no high-resolution stratigraphic controls including event- and sequence-stratigraphic frameworks. These allow the recognition of erosive discontinuities and related gaps that punctuate some of the apparently continuous chemostratigraphic profiles. As a result, a joint chemo-, event-, and sequence-stratigraphic analysis can solve problems of stratigraphic completeness and time resolution, two key factors for palaeogeographic reconstruction and chemostratigraphic correlation. Neoproterozoic glacial deposits on the West African Craton are particularly difficult to correlate with better-constrained strata elsewhere because they are poorly studied in terms of their isotopic and event-stratigraphic record. This work is focused on the analysis of carbonate productivity, post-dating a late Cryogenian glaciation, recorded in the Atar cliffs of Adrar, Mauritania (Fig. 1A). Well-exposed and easily accessible outcrops in this part of the northern Taoudeni Basin, situated to the SW of the Jbéliat region (the standard area where numerous lithostratigraphic units are defined in Mauritania; Trompette, 1973; Deynoux, 1980; Fig. 1B), allow reconstruction of the sedimentary architecture displayed by the stratigraphic units that succeeded the late Cryogenian glaciation. High-resolution stratigraphy in these unconformity-bearing incomplete mixed (carbonate-siliciclastic) strata recording the transition from Neoproterozoic periglacial to post-glacial conditions can provide both a method of evaluating stratigraphic completeness and useful tools for regional and worldwide stratigraphic correlation.

2. Geological setting and stratigraphy

The West African Craton is surrounded by several Upper Proterozoic-to-Palaeozoic fold belts. The Archean (ca. 2500 Ma) and Birrimian (2000–1700 Ma) basement of the craton is mainly exposed along the Reguibat and Leo Shields, although smaller inliers occur scattered along the Bassaride and Mauritanide belts, as well as at the core of the Anti-Atlas belt (Fig. 1A).

The cratonic sedimentary cover is well exposed in the Taoudeni Basin. The infill of the basin ranges from Proterozoic (ca. 1000 Ma) to Late Carboniferous, reaches 2000–3000 m in average thickness, and is overlain in the centre of the basin by a thin Mesozoic–Cenozoic cover. Three main tectonic events were involved in the structuration of the Taoudeni basin: (i) the Pan-African-I or Bassaride orogen (ca. 665–655 Ma; Villeneuve and Dallmeyer, 1987; Villeneuve, 1988; Villeneuve et al., 1991; Blanc et al., 1992); (ii) the Pan-African-II or Rokelide orogen (550–500 Ma; Culver et al., 1991; Villeneuve and Cornée, 1994); and (iii) the Hercynian orogen responsible for the emplacement of internal nappes in the Mauritanide fold belt (320–270 Ma; Sougy, 1962). The Taoudeni Basin has been divided into eight different sub-basins (Fig. 1A), three of which contain thick Palaeozoic strata: the Adrar, Hohd and Hank sub-basins (Villeneuve, 2005).

The Adrar sub-basin, on which this paper is focused, shows a monocline structure gently dipping towards the South. The lithostratigraphic nomenclature of