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Upper Mississippian to lower Pennsylvanian biostratigraphic correlation of the Sahara Platform successions on the northern margin of Gondwana (Morocco, Algeria, Libya)

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ABSTRACT

Revision of several important Carboniferous stratigraphic successions in basins in the Saharan Platform allows us to propose distinct biostratigraphical boundaries for the upper Viséan, lower and upper Serpukhovian and lower Bashkirian, with the latter boundary separating upper Mississippian from lower Pennsylvanian strata. The boundaries are not only defined primarily by foraminifers but also incorporate ammonoid and conodont data. This study shows that the positioning of some boundaries differs significantly from previous studies in the region. For the studied interval, it can be recognized that two well-defined tectonic events were widespread in the entire Sahara Platform: a mostly late Viséan event and a latest Serpukhovian–early Bashkirian event. Both tectonic events show a marked tendency to become younger eastward, and they are compared to the intra-Viséan phase of the Variscan Orogeny and the main phase of this orogeny, respectively.

1. Introduction

The Sahara region of North Africa was part of the northern margin of Gondwana during the Mississippian, and a vast shallow siliciclastic/carbonate mixed platform developed on the continent margin over thousands of square kilometers in the region. This Sahara Platform comprises several basins and sub-basins that are currently separated by Pan-African and Variscan structures (Anti-Atlas, Ougarta, Reguibat Shield, Hoggar Massif, Sirt Arch), later rejuvenated during the Alpine Orogeny. The most important basins with Mississippian sediments in the Sahara are Tindouf, Taoudenni, Tafilalt, Béchar, Reggan, Ahnet, Mouydir, Illizi, Ghadames and Murzuq (Fig. 1). The geological database of these basins is unequal, which complicates correlation between them, as well as the recognition of the general factors that controlled the establishment and demise of the Sahara Platform. It is also noteworthy that a significant amount of the research in the area has been never published, because it was developed as part of exploration programs by oil companies (e.g., Boote et al., 1998; Echikh, 1998; Davidson et al., 2000; Hallett, 2002). Another important aspect of this research is the contribution of earlier studies from 1930s–1960s by pioneers in the exploration of North Africa and commonly associated with geological mapping projects. Since the 1970s and early 1980s, progress in this vast region been limited to a restricted number of publications. Most of the biostratigraphical data have been summarized in a multi-authored volume, edited by Wagner et al. (1985), that constitutes a comprehensive analysis of the Carboniferous rocks in North Africa. This work clearly demonstrates that the best-known basin is Béchar (NW Algeria; Fig. 2), resulting from a combination of earlier studies (e.g., Pareyn, 1961) through more recently published papers. Moreover, it represents stratigraphically, the basin with the longest marine Carboniferous succession in the area. In addition, Béchar Basin is significant because it exposes the Mississippian/Pennsylvanian boundary in the Tagnana Valley (Fig. 2). More recently, there have been publications in different sub-basins of Béchar, involving late Mississippian rocks (e.g., Mamet et al., 1994; Bourque et al., 1995; Sebbar, 1997, 2000; Malti et al., 2008). Other relatively well-known basins are Reggan and Ahnet–Mouydir (central Algeria), based mostly on the doctoral

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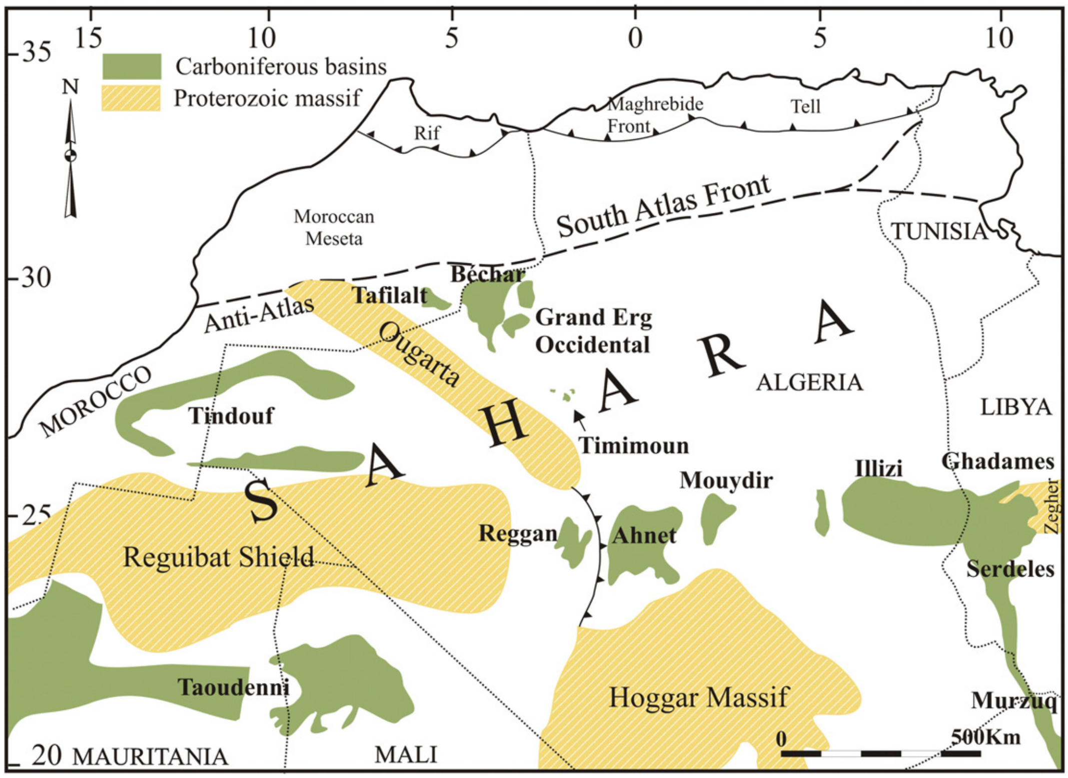

Fig. 1. Location of the Carboniferous basins and Proterozoic massifs in the Sahara, North Africa (subsurface outcrops and basins are not included). AA: Anti-Atlas.

dissertation of Conrad (1984) and subsequent publications by Sebbar et al. (2000b), Wendt et al. (2009) and Legrand-Blain et al. (2010). Knowledge on the Carboniferous of the Tafilalt Basin (eastern Morocco) was mostly based on the map by Destombes and Hollard (1986), until intensive research in the basin recommenced in the 1990s, which led to publications by Korn et al. (1999, 2007), Wendt et al. (2001) and Klug et al. (2006), and work in progress related to new geological maps (e.g., Aretz et al., 2013). Similarly, investigations in the Tindouf Basin (southern Morocco/western Algeria) are restricted to traditional studies and the recent revision of some sections on the southern (Sebbar et al., 2000a) and northern (e.g., Cózar et al., 2014a–c) flanks of the syncline.

Apart from these basins, biostratigraphic knowledge of the Taoudenni Basin (Mauritania/Mali) and the eastern and southern Ghadames Basin (western Libya) is mostly limited to studies in the 1960s and 1970s, and to unpublished reports, which prevents detailed comparison with the improved database in the rest of the Sahara Platform. Even within the better-known Béchar Basin, there are notable differences between the sub-basins. For example, knowledge of the Carboniferous successions in the Saoura-El Guelmouna-Tagnana valleys (Béchar s.s.; Fig. 2) and Grand Erg Occidental has progressed, whereas in Horreït, Abadla and Antar (Fig. 2), progress essentially ended with the work of Pareyn (1961) and Fabre (1976).

Nevertheless, correlation between these areas is, in some cases, based on limited biostratigraphical control and largely dependent on erroneous lithostratigraphical and tectonic interpretations, which have complicated the understanding of the Sahara Platform as a whole. In addition, the record of ammonoids and conodonts in this sector of Gondwana is scarce (Weyant, 1985). Thus, the timing of the initiation of different basins, the timing of the Serpukhovian/Bashkirian faunal crisis, the involvement of Variscan and Pan-African basement structures and tectonic pulses, and relationship of the basins to the overall tectonic regime involving the closure of the Rheic Ocean and the subsequent collision between Laurentia and Gondwana, require a better constrained lithostratigraphic framework for each time slice in the basins.

It is the objective of this paper to critically evaluate and synthesize the existing lithostratigraphic details of each basin, incorporating all the known biostratigraphic data, in an attempt to correlate all of the Saharan basins south of the South Atlas Front (Fig. 1). This will rely on a compilation of the existing biostratigraphic database for the region, utilizing previously published work and, where necessary, updating and revising key foraminiferal taxa based on the illustrated material. Emphasis will be placed on recognizing the important chronostratigraphic boundaries: base of the upper Viséan, base of the Serpukhovian, base of the late Serpukhovian and the Mississippian/Pennsylvanian boundary. The results obtained allow us to assess the relative impact of tectonics on basin stratigraphy, and correlate the observed events with the main tectonic phases of the Variscan Orogeny.

2. Geological setting

The Saharan Platform was situated on the northern border of Gondwana during the Carboniferous. It comprised several sedimentary basins and sub-basins, which mostly seem to be inherited from previous Pan-African and early Palaeozoic events, and their evolution is closely related to the West African Craton (Boote et al., 1998; Villeneuve, 2005; Dixon et al., 2010). The northern border of the Sahara Platform is considered to be the South Atlas Front (e.g., Bracène et al., 1998; Frizon de Lamotte et al., 2013), which was reactivated during the Mesozoic as a thrust. The Precambrian basement was part of Pangaea, but formed during the Pan-African Orogeny. Later rifting allowed the opening and expansion of the Rheic Ocean during the Caledonian Orogeny, and the closure of the Rheic Ocean in the Middle Devonian. This was followed by continental collision during the Variscan Orogeny. The structure of this northern margin of the Gondwana continent was mostly controlled by the evolution of the Rheic Ocean (Keppie et al., 2010; Murphy et al., 2010; Nance et al., 2010) and the subsequent Variscan Orogeny. This collision transformed the passive margin of Gondwana into an active margin, which reactivated some earlier Neoproterozoic Pan-African basement structures (Unrug, 1997; Bumby and Guiraud, 2005) that, in part, controlled the morphology of the different overlying Carboniferous sub-basins. However, the closure of the Rheic Ocean was