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Carbon and oxygen isotope variations of the Middle–Late Triassic Al Aziziyah Formation, northwest Libya

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ABSTRACT

This study presents the $\delta^{13}C$ and $\delta^{18}O$ records from whole rock samples of the Middle-Late Triassic (Ladinian-Carnian) Al Aziziyah Formation that were deposited on a gently sloping carbonate ramp within the Jifarah Basin of Northwest Libya. The Al Aziziyah Formation consists of gray limestone, dolomite, and dolomitic limestone interbedded with shale. The Ghryan Dome and Kaf Bates sections were sampled and analyzed for carbon and oxygen isotope chemostratigraphy to integrate high-resolution carbon isotope data with an outcrop-based stratigraphy, to provide better age control of the Al Aziziyah Formation. This study also discusses the relation between the facies architecture of the Al Aziziyah Formation and the carbon isotope values. Seven stages of relative sea level rise and fall within the Ghryan Dome were identified based on facies stacking patterns, field observations and carbon stable isotopes. The Al Aziziyah Formation $\delta^{13}C$ chemostratigraphic curve can be partially correlated with the Triassic global $\delta^{13}C$ curve. This correlation indicates that the Al Aziziyah Formation was deposited during the Ladinian and early Carnian. No straight-forward relationship is seen between $\delta^{13}C$ and relative sea level probably because local influences complicated systematic environmental and diagenetic isotopic effects associated with sea level change.

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1. Introduction

Carbon and oxygen isotopic values of biotic and whole rock carbonates commonly are used to trace the chemical compositions of the oceans through geologic history (Veizer et al., 1999; Weissert et al., 1998; Grossman et al., 2008). The variation in $\delta^{18}O$ values can result from climate changes associated with glacial versus non-glacial periods, but can also reflect diagenetic fluids and temperatures (Emiliani, 1955; Shackleton and Opdyke, 1973; Marshall, 1992; Weissert et al., 1998; Grossman et al., 2008; Grossman, 2012a). In addition to revealing changes in seawater chemistry, the carbon isotope composition of carbonate rocks can be used for chemostratigraphy, providing a tool for stratigraphic correlation (Halverson et al., 2005; Weissert et al., 2008; Saltzman and Thomas, 2012).

Efforts to construct a global record of seawater $\delta^{13}C$ are hampered by the lack of pelagic sediments older than 200 Myr; thus, pre-Jurassic records must be based on macrofossils (e.g., brachiopods and belemnites) or whole sediments which often accumulated in restricted and semi-restricted environments such as epeiric seas, ramps and carbonate platforms (Vahrenkamp, 1996). While these histories may correlate with patterns in the oceanic $\delta^{13}C$ records (Vahrenkamp, 1996), skeletal and whole rock $\delta^{13}C$ records from such environments may be complicated by partial isolation from true open ocean conditions and susceptibility to exposure (e.g., Patterson and Walter, 1994; Immenhauser et al., 2003; Panchuk et al., 2006; Woodard et al., 2013). For example, shallow-water carbonate platforms exposed during sea level falls can show negative $\delta^{13}C$ shifts reflecting soil processes or cementation/recrystallization in the presence of meteoric water (Allan and Matthews, 1982; Immenhauser et al., 2003). In certain cases, carbon isotope data may serve as a proxy for sea level change, with positive $\delta^{13}C$ shifts associated with sea level rise and negative shifts associated with sea level fall, reflecting local changes in primary productivity, organic carbon burial, open ocean exchange, and/or freshwater input (Fanton and Holmden, 2007). Further complications of such carbon isotope records are the influences of vital effect (Woodruff et al., 1980; Wefer and Berger, 1991) and depositional mineralogy (aragonite versus calcite; Swart, 2008).

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The paucity of well-preserved fossils has hindered the development of a general stable isotope curve for Triassic seawater (Grossman, 2012b); however, Korte et al. (2005) have produced a composite, albeit fragmentary, record derived from brachiopod shells and whole rock carbonate. Other studies have relied exclusively on fine-grained or whole-rock carbonate, or bulk organic carbon to produce high-resolution $\delta^{13}C$ records of Triassic seawaters for select time intervals such as the Permian–Triassic boundary (e.g., Baud et al., 1989; Krull et al., 2000; Shen et al., 2011), the recovery period after the end-Permian extinction (e.g., Payne et al., 2004), and the Triassic-Jurassic boundary (Korte et al., 2009).

This study integrates high-resolution carbon isotope data with an outcrop-based stratigraphic framework in an attempt to improve isotopic correlation and age control of the Al Aziziyah Formation. This study also examines, within the framework of facies architecture, the influence of depositional environment on the isotopic values.

2. Geological setting

Northwestern Libya was at the edge of the Tethys during Mesozoic time (Cornell and Tekbali, 1993; Hallett, 2002). Post-Hercynian crustal adjustments resulted in a marginal trough extended westward into Tunisia and Algeria. During the Carnian circulation was restricted (Demaison, 1965; Cornell and Tekbali, 1993) in the western and central parts of the Jifarah Basin, maybe due to a major uplift alone the marginal trough (Demaison, 1965; Cornell and Tekbali, 1993). The Middle-Late Triassic (Ladinian-Carnian) Al Aziziyah Formation was deposited on a gently sloping carbonate ramp within the Jifarah Basin in northwest Libya (Fig. 1) and consists of gray limestone, dolostone and dolomitic limestone interbedded with shale to the north (Desio et al., 1963; Asserto and Benelli, 1971; Fatmi, 1977; Fatmi et al., 1980; Moustafa et al., 2012, 2014). The Jifarah Basin covers an area of 1500 km^2 in northwestern Libya (Fig. 3.1). This area is bounded by the Nafasah uplift to the south and by the offshore Sabrath Basin to the north (Hallett, 2002; Abohajar et al., 2009). Core data from wells in the Jifarah Basin indicate the deposition of Paleozoic to Jurassic sediments (Hallett, 2002). The Jifarah escarpment extends 400 km from southern Tunisia to southwest Libya and marks the southwest limit of outcrops in the Jifarah Basin (Fig. 1). The Jifarah Basin formed at the eastern end of the South Atlas lineament, which defines the southern margin of the Atlas fold belt that extends from Morocco to Tunisia (Dewey and Burke, 1973), where it branches to extend into northwest Libya as the Jifarah axis (Anketell and Ghellali, 1991).

The Jifarah Basin is situated at the junction of two major structures: the north-northwest trending Tripoli-Tibesti Arch, which formed in the Caledonian, and the east-west trending Jifarah Arch, which formed because of Hercynian deformation (Anketell and Ghellali, 1991; Abohajar et al., 2009; Swire and Gashgesh, 2000). The structural pattern of the Jifarah Basin was created by these Paleozoic structural trends (Anketell and Ghellali, 1991; Abohajar et al., 2009; Hallett, 2002). The subsidence of the Jifarah Basin continued into the Early and Late Triassic (Muttoni et al., 2001).

The Jifarah Basin is bounded to the south by the east-west oriented subsurface Al Aziziyah fault zone. Toward the east, the Al Aziziyah fault zone links the Wada Ghan fault zone (Arkell et al., 1957; Swire and Gashgesh, 2000; Raulin et al., 2011) and was active during the Triassic (Swire and Gashgesh, 2000; Raulin et al., 2011). The trend of these faults parallels Paleozoic structures.

The age of the Al Aziziyah Formation has been disputed (Fatmi, 1977; Asserto and Benelli, 1971; Magnier, 1963; Desio et al., 1960, 1963; Burollet, 1963; Muttoni et al., 2001). The Al Aziziyah Formation was deposited during the Carnian based on "Mojsisovicsites" ammonites in the upper part of the Ghryan Dome section (Fatmi, 1977). This ammonite genus ranges from Carnian to Anisian and occurs in the Alps, Spain, Sardina, Himalaya and in parts of the

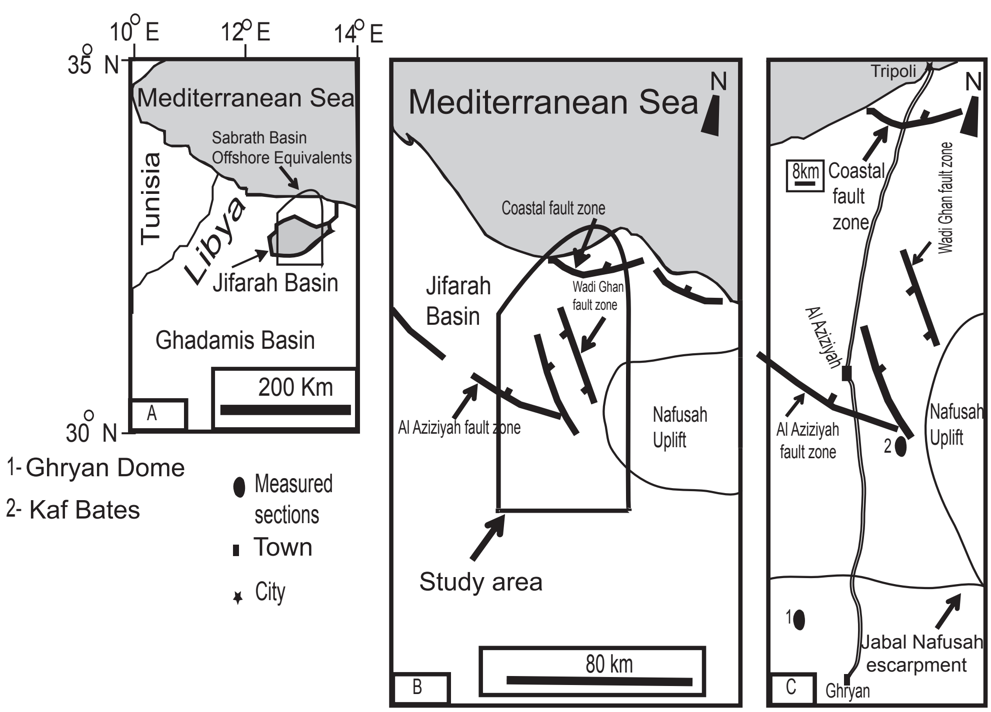

Fig. 1. A- Index map showing the location of the Jifarah Basin, Libya. B- Simplified structure map of the area. C- Location of measured sections. The distance between the two sections (Ghryan Dome and Kaf Bates) is approximately 80 km. The Ghryan Dome section (1) is located on the southern margin of the Jifarah Basin. The Kaf Bates section (2) is located north of the Ghryan Dome section, within the deep water facies.

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