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Physical volcanology, geochemistry and basin evolution of the Ediacaran volcano-sedimentary succession in the Bas Draâ inlier (Ouarzazate Supergroup, Western Anti-Atlas, Morocco)

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ABSTRACT

New geologic mapping, lithofacies and granulometric analysis, and geochemistry from the volcano-sedimentary successions of the central part of the Bas Draâ inlier, Western Anti-Atlas, constrain the Ediacaran Ouarzazate Supergroup evolution during the post-collisional stage of the Pan-African orogeny. Volcanosedimentary facies analysis is the key aspect of the present contribution. We distinguished sixteen terrestrial volcanosedimentary lithofacies in the Bas Draâ succession (BDS), which reaches a total thickness of 2000 m. BDS evolution can be grouped into four units (Aouinet Aït Oussa I to IV, AO I–AO IV). The earliest volcanic activity produced rhyolitic ignimbrite sheets (AO I), which had been considered as lava flows by previous workers, and which were presumably related to caldera system(s). During AO II, a complex of high-silica andesitic and rhyolitic lavas formed, punctuated by the explosive eruption of a high-temperature silica-rich magma leading to the formation of parataxitic ignimbrite. AO III consists of basalt and andesite lava fields and small explosive, in parts phreatomagmatic volcanic vents. It is dissected by fluvial systems depositing external non-volcanic and local volcanic debris. BDS evolution terminated with the formation of a large SiO_2-rich lava dome complex (AO IV), accompanied by small basalt effusive event. Volcanosedimentary facies analysis infers that the BDS evolved in a continental extensional setting developing in a low topography under humid paleoclimatic conditions. Alteration textures are dominated by a piemontite–calcite–albite–quartz (+ iron oxides) assemblage.

Chemical analysis of BDS volcanic and subvolcanic rocks belongs to high-k calc-alkaline and alkali-calcic to alkaline magmatic trend typical for a post-collision setting. Trace elements spidergrams show a pattern typical for subduction-related suites of orogenic belts. REE patterns show moderate enrichment in LREE relative to flat HREE, with strong negative Eu anomaly in rhyolitic rocks. Geotectonic diagrams suggest an affinity transitional between subduction- and within-plate settings. BDS magmatism can be explained by a magma source enriched in inherited components from Pan-African subduction. Volcanosedimentary facies, structural features, geochemical composition and radiometric data of BDS suggests correlation with the upper Ouarzazate Supergroup of the Anti-Atlas. Geodynamic evolution of the BDS was an expression of an extensional setting that operated in northern Gondwana margin precursory to the Cambrian anorogenic volcanic activity.

1. Introduction

The upper Neoproterozoic dynamic evolution in northwestern Africa is represented largely by thick volcano-sedimentary successions (Ouarzazate Supergroup) outcropping in inliers of the Anti-Atlas belt in Morocco. The Anti-Atlas Neoproterozoic successions evolved as the northern part of the circum-west African Craton (Doblas et al., 2002). It belongs to a network of Pan-African orogenic belts which extends from northwest Africa to northeast Africa (Arabian–Nubian shield), and southward to Brazil. There are extensions into North America and Europe (Nance et al., 1991; Kröner, 1993; Rogers et al., 1995; Trompette, 1997; Hefferan et al., 2000).

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Lithologic mapping, petrologic studies and radiogenic data in the Anti-Atlas inliers indicate that the volcano-sedimentary sequences formed during the Ediacaran and comprise basaltic, andesitic and rhyolitic lavas, rhyolitic ignimbrite and volcaniclastic rocks of variable thickness (Choubert, 1963; Hassenforder, 1987; Ouguir et al., 1996; Youbi, 1998; Fekkak et al., 2000, 2003; Bajja, 2001; Piqué, 2003; Thomas et al., 2002, 2004; Gasquet et al., 2005, 2008; Walsh et al., 2002, 2012). These successions formed during active tectonics, possibly related to a rifting episode or more probably to transtensional movements (Doblas et al., 2002; Thomas et al., 2004; Gasquet et al., 2005, 2008). Understanding of these magmatic rocks bears importance for the reconstruction of Ouarzazate Supergroup basin evolution.

The Bas Draâ inlier is the southwestern most outcrop area of the Ouarzazate Supergroup. Previous studies on the volcaniclastic sequences and associated intrusive rocks of the Bas Draâ inlier are mostly restricted to aerial photo-interpretation, geologic mapping (Choubert, 1956; Choubert and Faure Muret, 1969; Hawkins et al., 2001a,b), petrology and geochemistry (O'Connor, 2010), and radiometric dating (Aït Malek, 1997; Hawkins et al., 2001a,b; Maloof, 2004; Maloof et al., 2005; O'Connor, 2010). However, information is lacking concerning the physical geology and eruption style that lead to the formation of voluminous volcanic deposits, and of associated sediments.

We present here, for the first time, facies analysis of the Ouarzazate Supergroup successions in the Bas Draâ inlier, Western Anti-Atlas, Morocco, based on detailed lithostratigraphy fieldwork, physical volcanology and petrologic study in hand specimen and thin section. In addition, we used geochemical analysis to classify the volcanic products, and to constrain the geotectonic regime of the magmatism and type of metamorphic overprint. A regional correlation with other inliers along the Anti-Atlas aims at a better understanding of the Gondwana basin evolution during the Ediacaran time (upper Neoproterozoic) in northwestern Africa.

2. Geological framework and previous work

The Moroccan Anti-Atlas belt (AA) is one of the most important segments of the Proterozoic belt system in North Africa. It is considered as a key for understanding the late Proterozoic accretion and break-up events along the margin of the West African Craton (WAC; Hefferan et al., 2000; Ennih and Liégeois, 2001, 2003). The Precambrian basement is exposed in a series of ENE–WSW trending outcrops in several inliers (erosional "boutonnières") within late Ediacaran and younger units (Bas Draâ, Ifni, Kerdous, Tagragra of Akka, Tagragra of Tata, Igherm, Sirwa, Zenaga, Bou Azzer, Saghro and Ougnat, Fig. 1) distributed along two major fault zones (the South Atlas Fault, SAF and the Anti-Atlas Major Fault; AAMF, Fig. 1; Choubert, 1963; Thomas et al., 2004; Gasquet et al., 2005, 2008). The AA region was influenced by Hercynian and Alpine orogenies, which affected primarily the Meseta-Atlas domain north of the South Atlas Fault (SAF) and, to a lesser degree, the AA domain, located south of the SAF (Gasquet et al., 2005).

Two main periods of tectono-thermal magmatic activity, associated with crustal accretion, have been recognized during Precambrian time in the AA: (i) the Palaeoproterozoic Eburnean (Birimian) orogeny and (ii) the Neoproterozoic Pan-African orogeny (Thomas et al., 2004; Gasquet et al., 2005; Michard et al., 2008a). Eburnean basement rocks are found exclusively SW of the AAMF (Choubert, 1963, Fig. 1) but, they probably also constitute the basement of the Pan-African rocks to the NE (Ennih and Liégeois, 2001, 2003; Bouougri, 2003; Gasquet et al., 2005, 2008). The Palaeoproterozoic basement is composed of schists, paragneisses, and migmatites intruded by batholiths which yielded U–Pb ages on zircon ranging from 2200 Ma to 2030 Ma (Aït Malek et al., 1998; Walsh et al., 2002; Thomas et al., 2002; Gasquet et al., 2005, 2008; O'Connor, 2010). Dykes that intruded the Palaeoproterozoic basement yielded an age of 2040 ± 6 Ma (Benziane et al., 2002; Kouyaté et al., 2013; Walsh et al., 2002) and they were

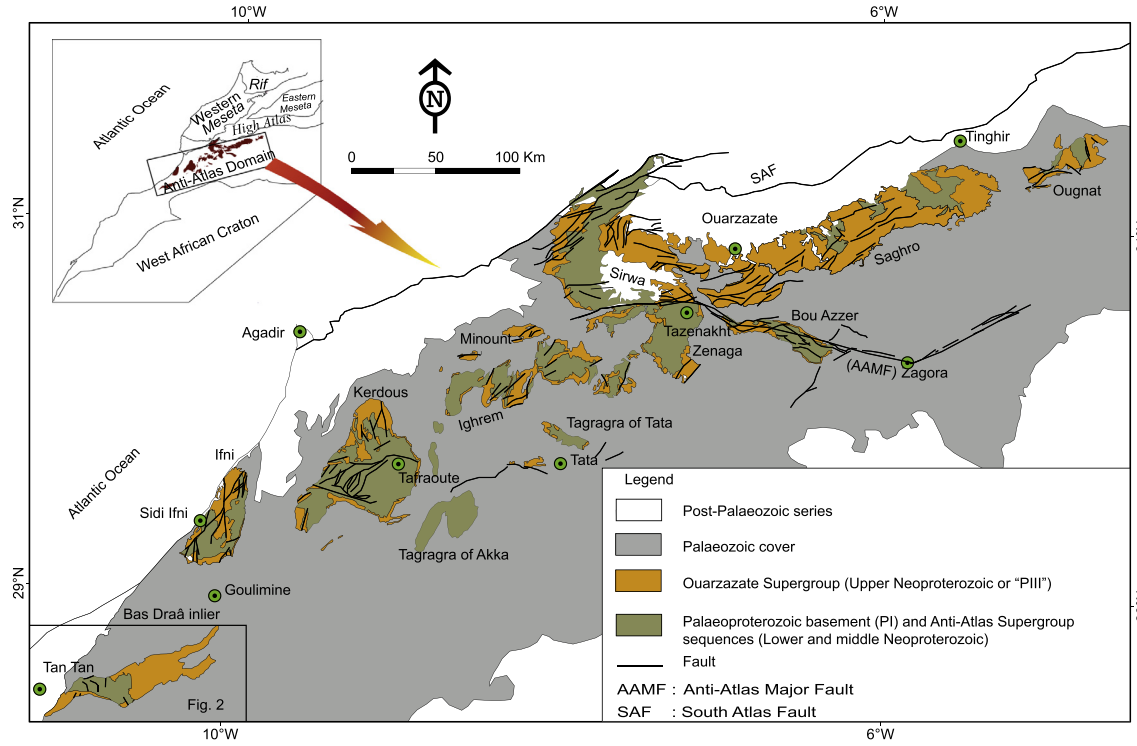

Fig. 1. Geological sketch-map of the Anti-Atlas showing the distribution of Proterozoic inliers, adapted from 1: 1,000,000-scale geological map of Morocco (Maroc Service Géologique, 1985).

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