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The "eye of Africa" (Richat dome, Mauritania): An isolated Cretaceous alkaline–hydrothermal complex

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ABSTRACT

The Richat dome is a spectacular circular structure located in the Mauritanian part of the Sahara Desert. The current erosion level of this igneous complex presents a wide variety of contrasting extrusive and intrusive rocks from shallow to deep source regions providing insight into the magmatic process at the origin of the complex.

The Richat is the superposition of a bimodal tholeiitic suite crosscut by carbonatitic and kimberlitic magmatic rocks. The bimodal series is characterized by two concentric gabbroic ring dikes and two extrusive rhyolitic centers representing the remnant of two maar systems. Silica undersaturated magmas occur as carbonatite dikes, a kimberlite plug, and kimberlite sills extruded along the old regional anisotropies filling NNE–SSW dextral strike-slip faults and en-echelon tension gashes. An intense low-temperature hydrothermal event affected the Richat area. It is responsible, notably, for the karst-collapse central mega-breccia, the alteration of the rhyolites, the potassic alteration of the gabbros and the stable isotope enrichment in the carbonatites. A piston-like collapse is proposed to explain the contrast existing between the central and outer part of the Richat.

Structural inheritance played an important role in the history of the Richat complex. Pre-existing anisotropies acted as a pathway for the ascent of asthenospheric and sub-continental melts and allowed the coexistence of alkaline and tholeiitic magmas within the same igneous complex.

1. Introduction

Mauritania hosts the *Guelb er Richat*, a fascinating circular structure also called the "eye of Africa". The Richat complex appears as a large eroded dome, at least 40 km in diameter including rare exposures of volcanic and intrusive rocks from contrasting erosion levels. It consists of gabbroic ring dikes, kimberlitic intrusions, carbonatites dikes and felsic volcanic rocks and encloses a kilometer-scale siliceous breccia in its center crosscutting Proterozoic and Paleozoic plateform sediments.

This complex has been studied by several workers but its understanding remains very poor. Early workers cited the crater-like shape and the high-relief centre, with its kilometer-scale breccias, as evidence of a meteorite impact (e.g., Cailleux et al., 1964) or explained the structure as the result of basement adjustments and plutonic doming (Destombes and Plote, 1962; Dietz et al., 1969; Boussaroque, 1975). The debate has also focussed on the origin of the igneous rocks. "Analcimolite", a rock containing up to more than 75% analcime has been variously interpreted as an extrusive volcanic rock with primary analcime (Bardossy et al., 1963), a hot spring deposit (Fabre, 1999), a weathered sediment (Boussaroque, 1975) and a secondary deposit generated by the replacement of rhyolite, rhyolitic tuff, or sediment (Fudali, 1973). Gabbroic rocks were also poorly understood and thought to be associated to the Triassic/Jurassic extensive tholeiitic magmatism of West Africa (Trompette, 1973a; Netto et al., 1992) whereas the core megabreccia remained unexplained.

A first study on breccias was presented by Matton et al. (2005) and Matton (2008) and demonstrated their Cretaceous hydrothermal origin. The overall geodynamic context was presented in Matton and Jébrak (2009), showing the abundance of alkaline systems around 100 Ma and suggesting the role of reactivated pre-existing lithospheric structures during the opening of the Atlantic Ocean. Here, we present new petrological, structural, geophysical and geochemical data collected from three missions on the Richat structure. New features are documented, notably the felsic volcanic basins and associated maar systems, and the interpretation of the caldera in the centre of the dome. This paper proposes an overall understanding of the wide variety of rocks and their possible relations into a comprehensive model of the magmatic system. We demonstrate that the Richat magmatism

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involved a bimodal tholeiitic series crosscut by silica undersaturated carbonatitic and kimberlitic magmas. Our data show the importance of the regional structural system on the development of the caldera.

2. Geological and structural setting

The Taoudenni Basin, of Proterozoic to Carboniferous age, is one of the major structural units of the West African craton and covers about two million square kilometers (Bronner, 1992; Abdelsalam et al., 2011). The basin is bounded by the Reguibat and Man ridges of Archean age to the north and to the south respectively (Fig. 1A) and is bordered on its western side by the Pan-African Mauritanides orogen (Michard et al., 2010). Sedimentary units are composed of continental shelf marine sediments with terrestrial intercalations. The stratigraphy of the basin begins with a Late Proterozoic (∼1100–1000 Ma) sequence consisting of sandstone, mudstone, dolomite, and dolomitic limestone (Trompette, 1973b; Rooney et al., 2010). Overlying an angular unconformity, the Proterozoic (∼650 Ma) to Cambrian–Ordovician sequence is composed of alternating layers of limestone, dolomitic limestone, sandstone, chert, and mudstone. The summital units range in age from Late Ordovician to Carboniferous, and are mostly composed of sandstone with intercalations of mudstone and limestone.

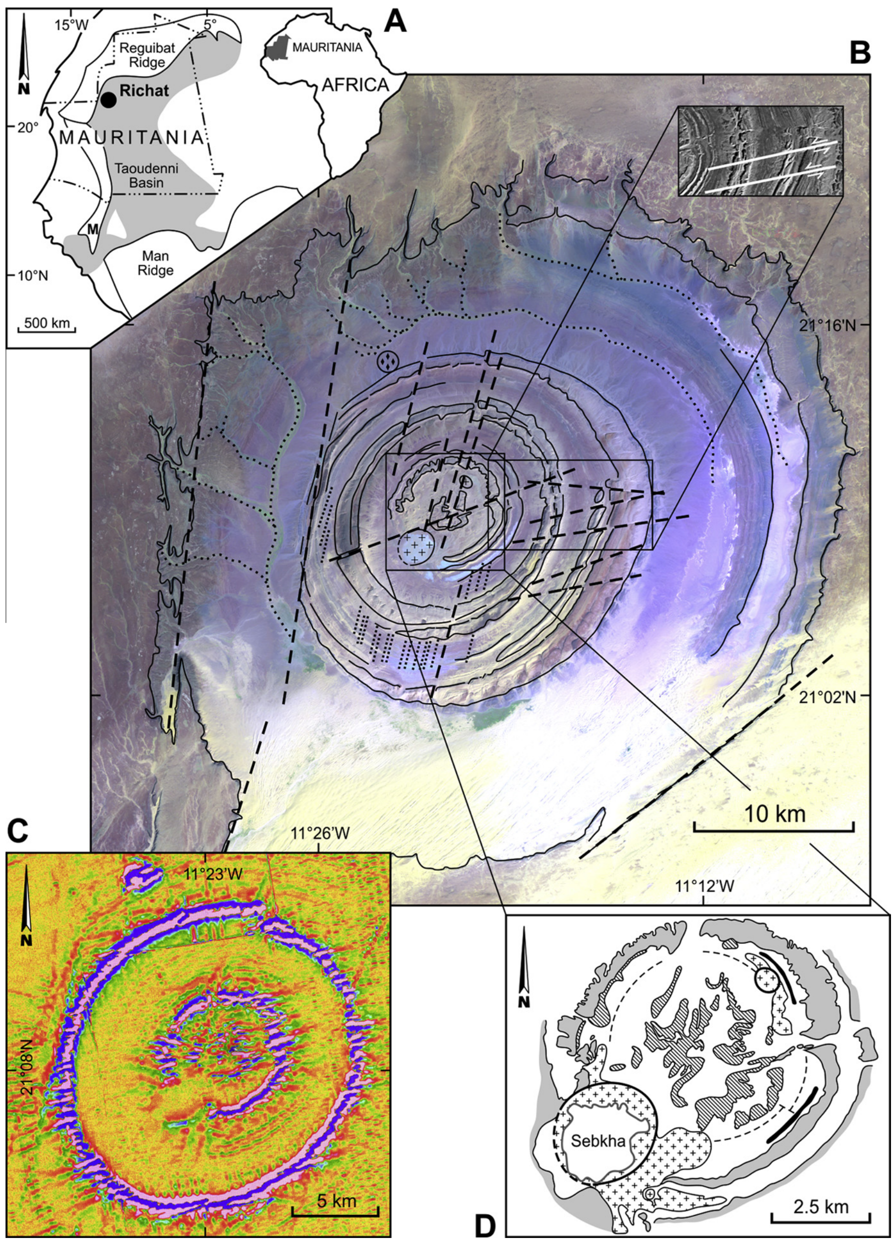

Fig. 1. (A) Location map for Richat dome. Taoudenni Basin is shaded; (M) Mauritanides. (B) Modified satellite image of Richat structure after NASA and U.S./Japan ASTER Science Team, 2000. ENE–WSW faults display sinistral movement as shown by offset of external ridge (white arrows). Dashed lines represent major faults and fractures; dot-stippled lines, endorheic fluvial streams. The irregular patch in the southwestern central area is the locus of a sebkha. Schematic map displaying distribution of magmatic phases: volcanic craters (crosses), high-K gabbro (star), kimberlitic plug and sills (diamond) and carbonatite dikes (dot-stippled lines). (C) Magnetic survey of the Richat structure showing the kimberlitic plug (northern part) and the gabbroic ring dykes. Note the gap in the southwestern part of the inner gabbroic dike due to the maar system and the displacement of the external gabbroic ring dike by the NNE–SSW fault system in the northeastern part of the map. Magnetic survey courtesy of Ashton Mining Inc. (D) Central part of Richat structure. Rhyolitic volcanic basins (crosses) and associated diatremes outcrop to SW and NE of breccia (triangles). Internal gabbroic ring dike (thick black lines) only outcrops in the eastern central part of the Richat. Circular faulting appears in dashed lines. Ring faults are inferred from stratigraphic considerations, repetitions of geological units, satellite imagery and from previous work (Monod and Pomerol, 1973; Boussaroque, 1975). The inner circular ridge is composed of sandstone and represented by a grey pattern.