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Satellite imagery and airborne geophysics for geologic mapping of the Edembo area, Eastern Hoggar (Algerian Sahara)

Takfarinas Lamri [a, *], Safouane Djemaï [b], Mohamed Hamoudi [a], Basem Zoheir [c], Abderrahmane Bendaoud [b], Khadidja Ouzegane [b], Massinissa Amara [a]

[a] Department of Geophysics, Faculty of Earth Sciences, Geographical and Country Planning, Houari Boumediene University of Sciences and Technology (U.S.T.H.B), BP 32, El Alia, Bab Ezzouar, 16111, Algiers, Algeria
[b] Department of Geology, U.S.T.H.B, BP 32, El Alia, Bab Ezzouar, 16111, Algiers, Algeria
[c] Department of Geology, Faculty of Science, Benha University, 13518, Benha, Egypt

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A B S T R A C T

Satellite imagery combined with airborne geophysical data and field observations were employed for new geologic mapping of the Edembo area in the Eastern Hoggar (Tuareg Shield, Sahara). Multi-spectral band fusion, filtering, and transformation techniques, i.e., band combination, band-rationing and principal component analysis of ETM+ and ASTER data are used for better spectral discrimination of the different rocks units. A thematic map assessed by field data and available geologic information is compiled by supervised classification of satellite data with high overall accuracy (>90%). The automated extraction technique efficiently aided the detection of the structural lineaments, i.e., faults, shear zones, and joints. Airborne magnetic and Gamma-ray spectrometry data showed the pervasiveness of the large structures beneath the Paleozoic sedimentary cover and aeolian sands. The aeroradiometric K-range is used for discrimination of the high-K granitoids of Djanet from the peralumineous granites of Edembo, and to verify the Silurian sediments with their high K-bearing minerals. The new geological map is considered to be a high resolution improvement on all pre-existing maps of this hardly accessible area in the Tuareg Shield. Integration of the airborne geophysical and space-borne imagery data can hence provide a rapid means of geologically mapping areas hitherto poorly known or difficult to access.

1. Introduction

The Tuareg shield (5.5 × 105 km^2), between the West African craton and the Saharan Metacraton in West Africa, forms an orogenic collage of thrust and megashear zones-decorated crustal terranes of Precambrian basement that are unconformably overlain by subhorizontal Palaeozoic, mostly arenaceous sediments (e.g., Black et al., 1994; Liégeois et al., 1994; Liégeois et al., 2003; Abdelsalam et al., 2002). The shield includes cratonic fragments of microcontinents and remobilized Paleoproterozoic crustal blocks as well as Neoproterozoic island arcs. According to Black et al. (1994), amalgamation of these differing terranes (blocks) to form the Tuareg shield occurred through a two-phase Pan-African orogeny. The early phase was collision with the East Saharan craton (*ca.* 700 Ma), likely related to continental delamination (Liégeois et al., 1994). The late phase was collision with the West African craton (*ca.* 600 Ma), and was mainly related to major movements along north-south megashear zones.

The Eastern Hoggar is the most inaccessible, least studied part of the Tuareg shield. It is made up of the Aouzegueur, Edembo and Djanet terranes (Black et al., 1994). The Edembo terrane has a particularly interesting position in the shield, between the eastern margin of the Hoggar swell and the western fringe of the Murzuk craton (Fig. 1a: Bertrand and Caby, 1978; Black et al., 1994; Fezaa et al., 2010; Liégeois et al., 2013). This terrane is underlain by variable crystalline basement and sedimentary rocks, and preserves major discontinuities and megashears. Reconnaissance geological mapping of Edembo quadrangle (1:200 000) was carried out by the Bureau de la Recherche Minière Algérien (BRMA) 50 years ago (Guerange, 1961).

In the present study, remote sensing and airborne imagery data are used to meet the need for up-to-date information and detailed geological maps of the hardly accessible Eastern Hoggar. ASTER and ETM + data, integrated with airborne aeromagnetic and gamma-

* Corresponding author.
E-mail address: tlamri@usthb.dz (T. Lamri).

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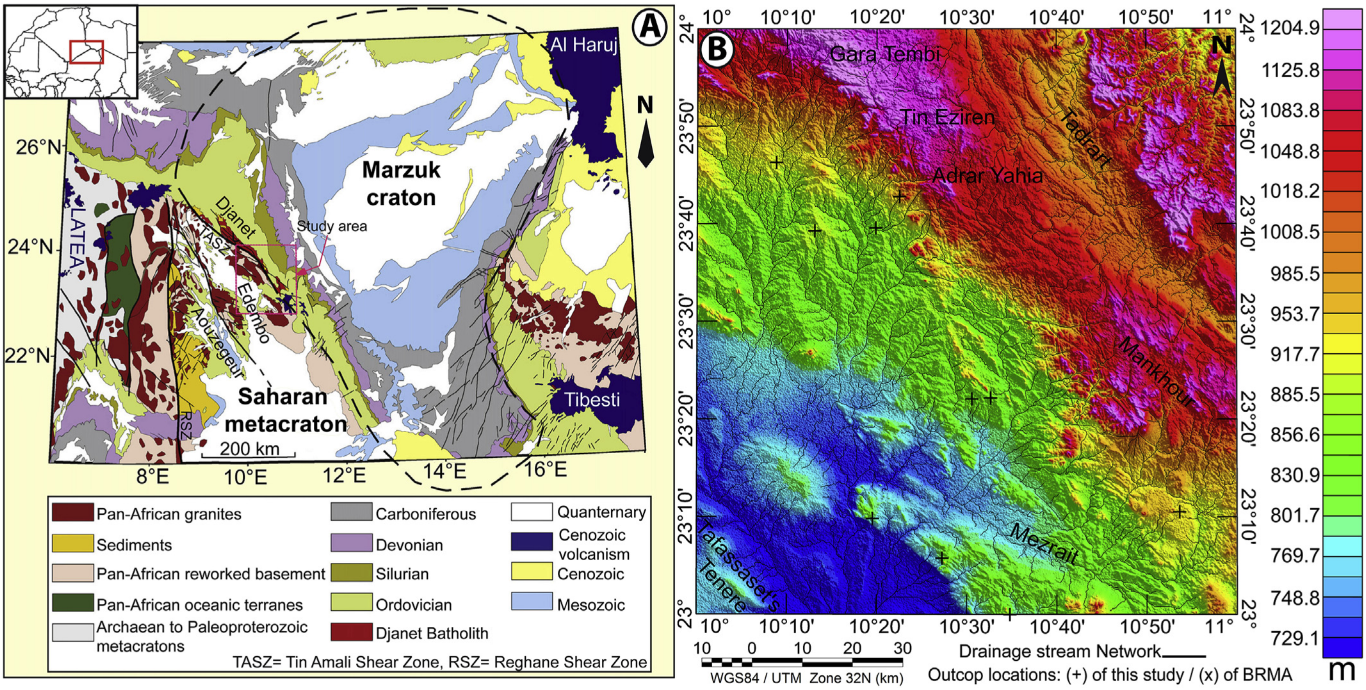

Fig. 1. (A) Geological map showing a part of the Tuareg Shield (Eastern Hoggar), including the Edembo and Djanet Terranes, a part of the Tibesti shield and the Marzouk craton, Lelubre (1952), Bertrand and Caby (1977), Black et al. (1994) and Le Caignec et al. (1957), modified from Fezaa et al. (2010); (B). Drainage Network derived from SRTM-Aster data draped on the Digital Elevation Model (DEM) of Edembo area.

ray spectrometry data, along with fieldwork are used to determinate the geological features and understand the litho-structural relationships of the Edembo terrane. Correlation between the results of supervised classification of satellite images and the gamma-ray spectrometry serves as a new contribution to the current understanding of the evolution of the Eastern Hoggar. The new map adds important details on the major structures.

2. Geological setting

The Tuareg shield comprises the Hoggar massif in southern Algeria, the Adrar of Iforas in northern Mali and Aïr in northern Niger. This shield is interpreted to have been developed during the Neoproterozoic convergence of several old Archean-Paleoproterozoic continents and intervening oceanic basins (23 displaced terranes have been identified) during oblique convergence between the West African craton and the Saharan metacraton. The Pan-African intercontinental collision (630–580 Ma) between the West African craton and the Saharan metacraton generated a general northern tectonic escape of the Tuareg terranes (Black et al., 1994; Abdallah et al., 2007; Liégeois et al., 2013). Emplacement of high-K calc-alkaline batholiths marked the final convergence (620–580 Ma), and continued until ~520 Ma with the emplacement of calc-alkaline and alkaline intrusive complexes along reactivated megashear zones (e.g., Azzouni-Sekkal et al., 2003; Acef et al., 2003; Liégeois et al., 2003).

The Eastern Hoggar is bounded to the west by the Raghane megashear zone (Liégeois et al., 1994), which represents the western boundary of the Saharan metacraton (Abdelsalam et al., 2002: Fig. 1a). U–Pb data on zircons reveal that the Eastern Hoggar has experienced a late Ediacaran potassic magmatism (568 ± 4 Ma: Fezaa et al., 2010).

The Edembo terrane is separated from the adjacent Djanet terrane by the Tin Amali Shear Zone (TASZ; Fig. 1a), and both terranes are unconformably overlain by Palaeozoic sedimentary rocks. The Edembo terrane is composed of abundant migmatites (Fig. 2a) intruded by various Pan-African granitoids. Migmatites are characterized by strong ductile deformation, evolving towards pockets of two-mica, magnetite-rich granite. The study area (Fig. 1b) is characterized by alternated, NW-elongate lithological units (Fig. 1), including migmatitic gneisses, granites, and rhyolite (Figs. 1a and 2b). The area includes large exposures of granitic rocks include porphyritic migmatitic granite, generally rich in biotite and poor in K-feldspars (Guerange, 1961). Edembo granite or granodiorite is characterized by coarse- or fine-grained, equal-granular or porphyritic textures. Sheared parts of the Djanet batholith (Djanet terrane; Fezaa et al., 2010; Liégeois et al., 2013) are reported in the northeastern side of TASZ. The Djanet Group comprises greenschist-facies metasedimentary rocks (Fig. 2f), i.e., slate, quartzite, and metaconglomerate. These rocks are cut by the Tin-Amali felsic dyke swarms (Fig. 2c). The Edembo terrane is cut by micro-granite dykes mostly oriented NW–SE (Fig. 2e).

The sedimentary rocks including late Cambrian conglomerate, early Ordovician Tassili's sandstone (Fig. 2f), and Silurian intercalated sandstone, claystone and less common siltstone beds. The Ordovician–Silurian boundary is marked by a low relief erosional unconformity (Zazoun and Mahdjoub, 2011). The Lower Devonian rocks are coarse-grained sandstones interleaved by siltstone and clay beds. Late lava flows covering large area (350 km^2) in the southwestern part of the study area are thought to be manifestations of recent volcanic edifices (2.86 ± 0.07 Ma, Yahiaoui et al., 2014).

3. Data and processing techniques

This work is based on satellite imagery, i.e., ETM+ and ASTER, along with airborne gamma-ray spectrometry and aeromagnetic data. Unpublished geological maps (scale 1:200 000) by BRMA