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Paleomagnetic dating of continental geological formations: Strong diachronism evidenced in the Saharan platform and geodynamical implications

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ABSTRACT

The paleomagnetism is a powerful tool to date formations that have age not constrained by paleontological, stratigraphical or radiochronological data. It was applied, on the western border of the Murzuq basin in Algeria (Saharan platform), to the Zarzaïtine formation, attributed to a Middle–Upper Triassic–Lower Jurassic age. Comparison of the obtained paleomagnetic pole with previous poles from the same geological formation outcropping in another basin and from other Carboniferous to Lower Mesozoic African formations yielded a clearly older age (Late Permian) than expected. That evidences a strong diachronism (at least 40 My) of the deposition of this formation on the Saharan platform. The post-Hercynian structural evolution was therefore different according to the parts of this platform, with significant differential vertical tectonic movements. The latter were at the origin of erosion, hiatus or sediments deposition according to areas.

1. Introduction

The paleomagnetic tool is mainly used to determine movements of the main tectonic plates and paleocontinental reconstruction (e.g. Van der Voo, 1988, 1990; Torsvick et al., 2012), or to determine more or less local tectonic rotations (e.g. in the Western Alps – Westphal, 1973; Henry, 1992; Thomas et al., 1999; Maffione et al., 2008). It is also applied for relative or absolute dating in sedimentary or volcanic sequences with the magnetostratigraphic approach that is mainly based on the polarity of the paleomagnetic direction (e.g. Zhu et al., 2003; Hüsing et al., 2011). However, by comparison of this direction with a previously established reference curve (variation of the direction, measured in well-dated "objects", as a function of time), it could be as strong tool for dating. Presently, such application is widely used for dating within a recent period for archeological structures (Thellier, 1938; Le Goff et al., 2002) or lava flows (Tanguy et al., 2007). For that, a reference curve, based on declination and inclination of the measured direction on dated recent "objects" was determined and is still improved in different countries (e.g., Thellier, 1981; Bucur, 1994; Gallet et al., 2002). This separation by areas is made in order to have very precise curve independent of regional anomalies of the Earth magnetic field, which does significantly change in such short period.

2. Paleomagnetic dating

Reference curves for paleomagnetic data are built with another approach (Creer et al., 1954), to be independent of the location of the studied object in very large zones. It is based on paleomagnetic data from well-dated geological formations. An Apparent Polar Wander Path (APWP) is a plot of the sequential positions of paleomagnetic poles from a particular area (tectonic plate, continent, etc.), usually shown on the present geographic grid (see Butler, 1992). The constraining factor to determine such areas is the lack of local rotations within them. It is however sometimes possible to correct such rotations, like for Lachland belt in Australia (McElhinny et al., 2003), or even to use paleocontinental reconstruction to have reference curve for very large areas (Besse and Courtillot, 2002; Torsvick et al., 2012).

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For geological "objects", paleomagnetic dating was mostly employed to determine the age of a geological event that yielded remagnetization of the studied rocks (e.g. Rouvier et al., 2001; Ricordel-Prognon et al., 2010; Lamali et al., 2013). Dating using primary magnetization has been rarely used for geological formations (e.g. Censier et al., 1995), except for ore deposits (e.g. Leach and Sangster, 1993; Symons and Sangster, 1994).

Among geological formations, continental deposits are often those with the poorest dating criteria, and they can represent very large window of time, particularly in cratonic areas. The Permian period in the Saharan platform is a typical example of such "geological gap". The last marine well-dated Paleozoic levels are of Upper Carboniferous (Moscovian) age. The age of the overlying continental levels is very imprecisely defined. These levels are in part of the platform of Stephano-Autunian age, and are themselves covered by continental deposits, called "Zarzaïtine" formations, locally dated of the Middle–Upper Triassic–Lower Jurassic times. In other areas, these last deposits are directly in contact with the marine Moscovian formation. To better understand this "geological gap" in the Saharan platform, we therefore applied a paleomagnetic dating to compare the age of the "Zarzaïtine" formation in different areas (Fig. 1).

The interest of such a dating was not some local precision in stratigraphy, but concerns the effects of post-Hercynian structural evolution in these areas very far from the continental collision suture between Gondwana and Laurasia in Western Africa. Post-Hercynian tectonic events have been already pointed out on basins of northwestern border of the Hoggar (Smith et al., 2006; Derder et al., 2009). They represent key information for petroleum research. In Niger, in "Monts Doumergue" area about 60 km south of the Algerian boundary, a cartographic discordance shows Zarzaïtine series directly overlying the Lower Carboniferous formations and even Cretaceous levels overlying these formations (Fig. 1d). Unfortunately, this area, very isolated in the northern Niger, is presently not accessible for safety reasons and we tried to obtain new data on the Zarzaïtine formation, to compare them with previous results obtained in the Illizi basin (Kies et al., 1995). To this aim, the Anaï area in Algeria was selected. No significant post-Hercynian local rotations affected this part of the Saharan platform. The new studied sites correspond to the western border of the Murzuq basin.

3. The Zarzaïtine series

The Zarzaïtine formation represents continental deposits largely developed in South Algeria, Libya and Niger. The underlying «Tiguentourine» continental formation is considered as missing in a large part of these countries, being for example restricted in Libya to some deep basins (Hallett, 2002). Due to bad outcrop conditions, it is sometimes not possible to determine what formation, Tiguentourine or Zarzaïtine, overlays the last marine Carboniferous well-dated levels. In areas without paleontological arguments the actual age of the Zarzaïtine deposits is in practice unknown. This is

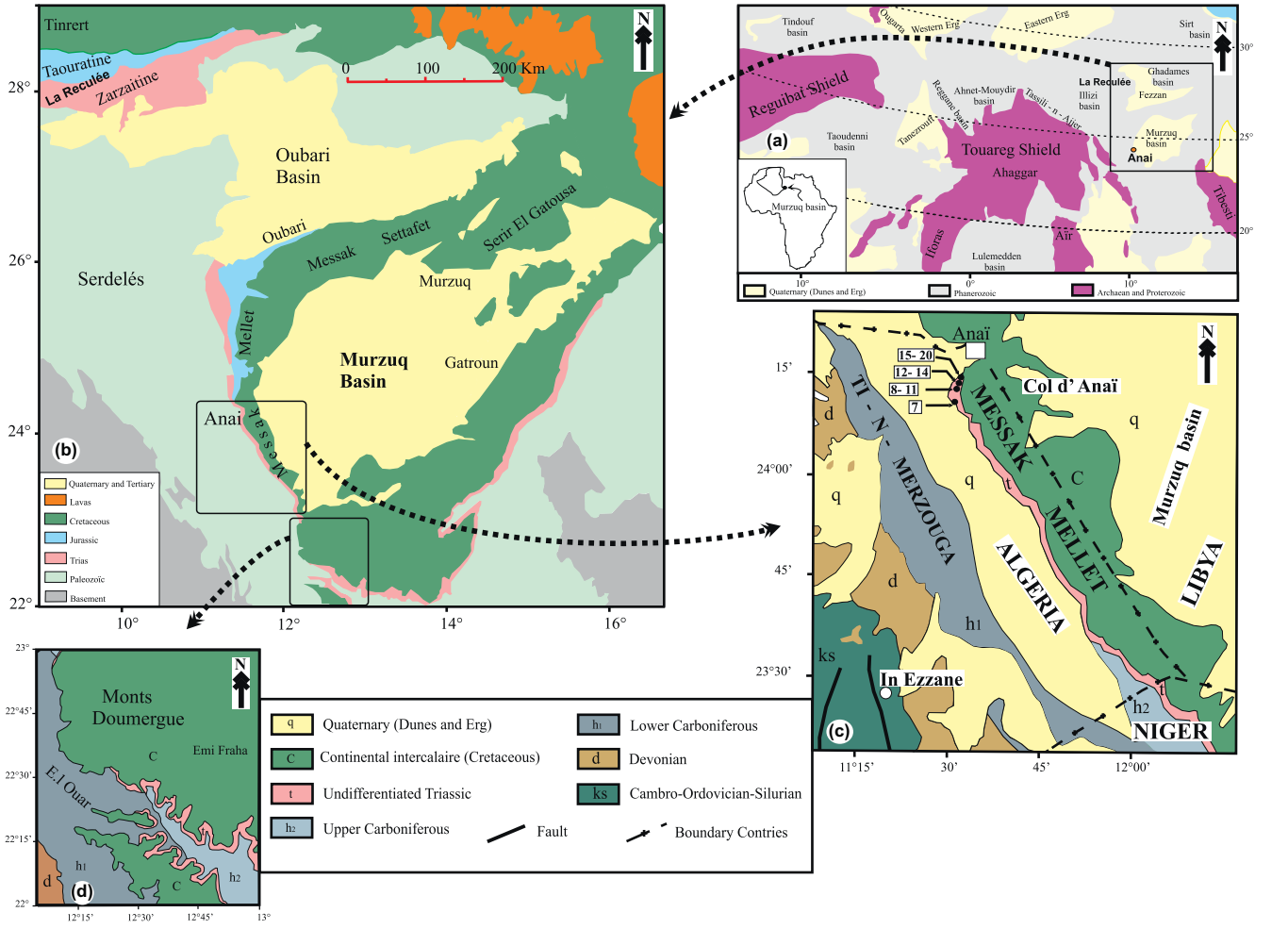

Fig. 1. Map of the studied area (after the "Carte Géologique du Nord-Ouest de l'Afrique – Sahara Central", 1962). Location of the sampling sites on figure c.

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