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Geochemistry of Precambrian sedimentary rocks used to solve stratigraphical problems: An example from the Neoproterozoic Volta basin, Ghana

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ABSTRACT

The Neoproterozoic Volta basin of Ghana (~115,000 km^2; depth up to 5–7 km) consists of flat-lying sedimentary rocks, mainly sandstones that unconformably overlie the crystalline basement of the West-African craton. The stratigraphical column has been subdivided into three main units, in upward succession the Bombouaka, Oti and Obosum Groups, but poor exposure has resulted in major disagreements on stratigraphical correlations and on the areal extents of these units. Geochemical data (major and trace element concentrations as well as Rb–Sr, Pb and Sm–Nd isotope data) on siltstones and mudstones, intercalated with the sandstones from the different units, were used in an attempt to solve some of these problems. Siltstones and mudstones from the Bombouaka Group can be unequivocally distinguished from similar rocks from the Oti and Obosum Groups by higher K_2O and Rb, larger Eu anamalies, higher $^{87}Sr/^{86}Sr$, and more negative ε_{Nd} values. Geochemical distinction between samples from the Oti and Obosum Groups is ambiguous because published geological maps differ with respect to the relative extents of the Oti and Obosum Groups. Rb–Sr isotope data, combined with high degrees of correlation between the concentrations of K and Rb, and Ca and Sr, indicate that mobility of these elements did not significantly change their concentrations during surface weathering. The clear geochemical distinction between mudstones and siltstones from the Bombouaka Group and similar rocks from the Oti and Obosum Groups is used to solve one of the outstanding controversies regarding the stratigraphy of the Volta basin.

1. Introduction

Investigation of Precambrian sedimentary successions is often hampered by the lack of sufficient stratigraphic control. While granitoid rocks nowadays can be dated relatively easily, this is rarely the case for non-fossiliferous sedimentary rocks. Mapping of such rocks is therefore largely based on lithological characteristics which, especially in poorly exposed regions, may lead to equivocal results. The Neoproterozoic Volta basin in Ghana (Fig. 1) provides an interesting example of this problem—despite more than 60 years of study, major disagreements still exist on important aspects of its stratigraphy.

The Volta basin (e.g., Affaton, 1990; details below) consists of well preserved sedimentary rocks that unconformably overlie the crystalline basement of the West-African craton (Fig. 1). Although the basin occupies an area of ~115,000 km^2 (~40% of Ghana), interest in its geology has mainly been of academic nature until a few years ago. In recent years, however, new investigations have taken place under the EU-funded Mining Sector Support Programme (MSSP), in order to assess the mineral, hydrocarbon, and water potential of the basin. Under the MSSP most of the basin has been covered by air-borne radiometric, magnetic, electromagnetic and gravimetric surveys (Crowe and Jackson-Hicks, 2008). Simultaneously, a new geological map and lithostratigraphic model, based on remote sensing imagery and limited field work, was compiled by workers of the British Geological Survey (Jordan et al., 2006; Carney et al., 2008). At a workshop in Accra, March 10–17, 2008, most results of these new, and many older investigations were reported (see Kalsbeek, 2008; available on-line at http://www.geus.dk/program-areas/common/int_gh-uk.html). The various contributions of this workshop demonstrated that important aspects of basin stratigraphy as well as the extent of some stratigraphical units remain contentious. This has a major influence on the compilation of a geological map for the basin that all can agree upon (Fig. 1).

Numerous investigations have demonstrated that the chemical composition of sedimentary rocks is related to that of their source regions, although the relationships may be complicated (e.g., Fralick and Kronberg, 1997, and references therein). This tenet has been used, for example, to distinguish sedimentary rocks from

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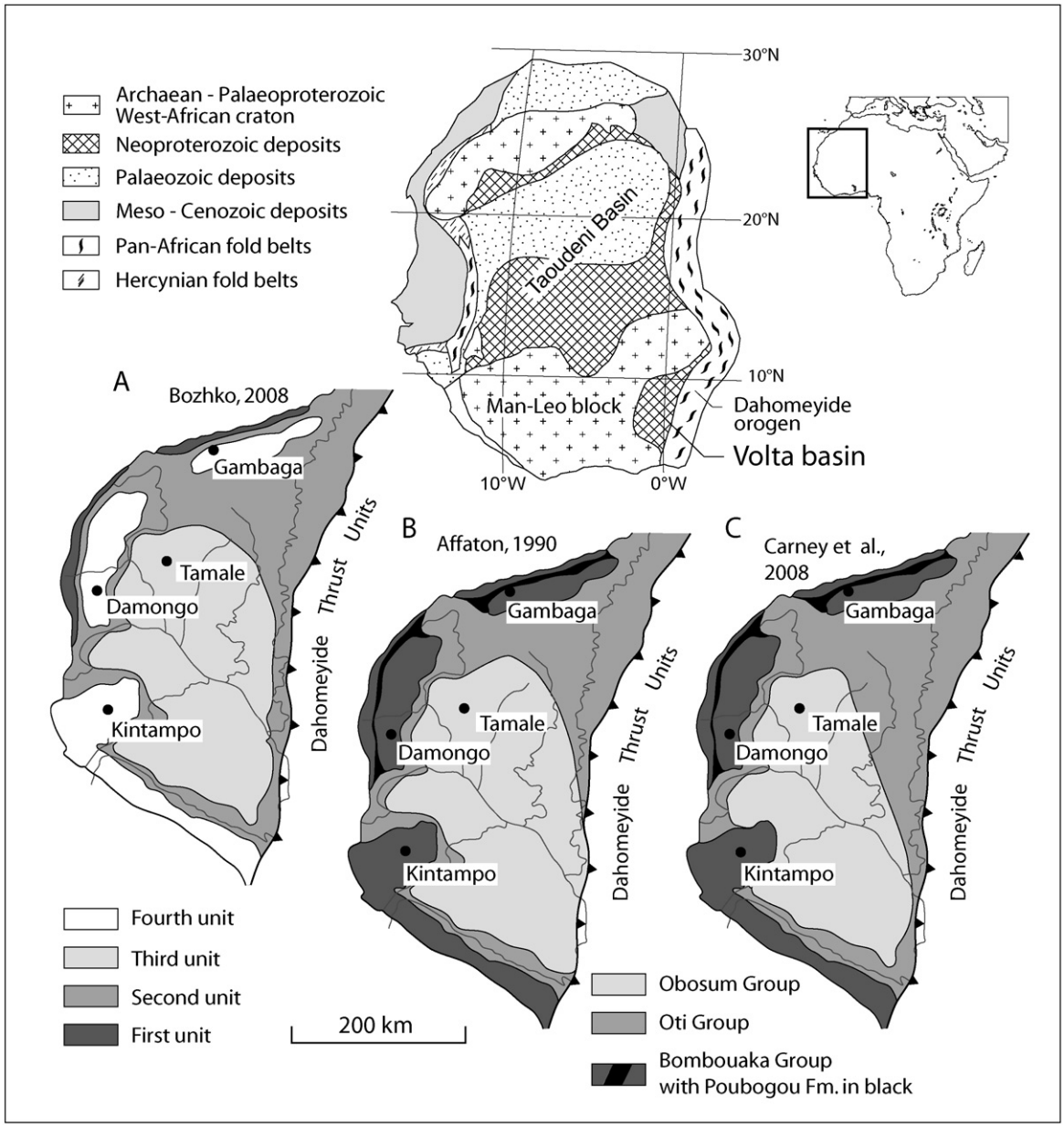

Fig. 1. Location map of the Volta basin in West Africa with sketches showing different interpretations of its stratigraphy and the distribution of its main stratigraphical units. (A) Stratigraphy after Bozhko (2008); (B and C) Stratigraphy after Affaton (1990) and Carney et al. (2008), but with differences in the areal distribution of the Oti and Obosum Groups.

different tectonic settings (Bathia, 1983; Bathia and Crook, 1986; Roser and Korsh, 1986), or to characterize the source rocks from which the investigated sedimentary strata were derived (Fralick et al., 2009). The study reported in this paper was carried out to test if geochemical data can be used to differentiate between different lithostratigraphic units in the Volta basin, and thereby solve some of the outstanding controversies regarding its stratigraphy and support the ongoing approaches to mapping the basin.

2. The Volta basin

2.1. Occurrence and previous investigations

The West-African craton (Fig. 1) consists of Archaean and Palaeoproterozoic crystalline rocks, stabilised ~2000 Ma ago during the Eburnean orogenic cycle. It is overlain by Neoproterozoic and younger sedimentary successions, and surrounded by Pan-African and Hercynian orogenic belts (Trompette, 1994). The largest occurrence of sedimentary rocks is the Taoudeni basin which covers most of the western Sahara and consists of Neoproterozoic and Palaeozoic to Quaternary formations.

The Volta basin (Junner and Hurst, 1946; Bozhko, 1967, 1969, 2008; Annan-Yorke, 1971; Affaton, 1975, 1990, 2008; Affaton et al., 1980; Porter et al., 2004; Carney et al., 2008; Fig. 2) is much smaller and consists of a 5–7 km thick succession of flat-lying Neoproterozoic to lower Palaeozoic (?) sandstones, siltstones and mudstones with subordinate proportions of limestone. Apart from the ~115,000 km^2 in Ghana, the basin occupies smaller areas in Togo, Burkina Faso, Benin and Niger (Fig. 2). Along its western margins Voltaian strata unconformably overlie the strongly deformed Palaeoproterozoic basement of the Man-Leo block (Fig. 1), here consisting of metabasaltic, metasedimentary and granitoid rocks of the Birimian complex and the slightly younger Tarkwaian sedimentary succession (Abouchami et al., 1990; Boher et al., 1992). Over