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Sedimentary petrology and provenance interpretation of the sandstone lithofacies of the Paleogene strata, south-eastern Nigeria

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ABSTRACT

The Paleogene strata in the south-eastern Nigeria include the Imo Formation, the Ameki Group and the Ogwashi Formation. Petrographic studies suggest quartz arenite to arkosic arenite and sub-arkose for sandstones of the Imo Formation. Sandstones of the tide-dominated estuarine system of Ameki Group are classified as quartz arenites, sub-arkoses, sub-litharenites and litharenites. Sandstones of the Ogwashi Formation are classified as quartz arenites and sub-litharenites. These Paleogene sandstones are derived from mixed provenances based on the petrographic interpretation. The provenances include cratonic interiors, transitional continental blocks as well as recycled orogenic and transitional continental, transitional recycled and quartzose recycled. Paleoclimatic condition for the Paleogene region is semi-humid to humid climate. The sandstone composition suggests detritus from igneous rocks, metamorphic rocks and recycled sedimentary rocks. Heavy mineral analysis confirms the possibility of mixed provenance for the Paleogene sediments. The source areas include the Oban Massif, the West African Massif and the recycled sedimentary rocks of the older sedimentary rocks of probably the Anambra Basin and Afikpo Syncline.

1. Introduction

Provenance studies on clastic sedimentary rocks have been carried out using a number of analytical techniques such as petrographic modal analysis of arenites (Dickinson, 1970; Dickinson and Suczek, 1979; Ingersoll and Suczek, 1979; Zuffa, 1985, 1987; Johnsson, 1993). The composition of arenites is mainly controlled by source lithology, tectonics, climate, topography, weathering, transport and depositional environment, thus, the provenance is not easily interpreted from petrographic analysis alone (Johnsson, 1993; Critelli et al., 2007). A more integrated approach that includes heavy mineral analysis is used to provide detailed paleogeographic reconstruction of source or basin systems. According to Pettijohn et al. (1987), the aim of provenance studies is to deduce the characteristics of the source areas from the compositional and textural properties of sedimentary rocks, supplemented by information from other lines of evidence. Heavy mineral analysis is an effective tool for reconstruction of sediment provenance (Mange and Otvos, 2005). Petrology and heavy mineral analysis of sediments in the southern Nigeria sedimentary basins have been previously limited to the Benue – Abakaliki Trough and the Anambra Basin (Hoque, 1977; Hoque and Ezepue, 1977; Odigi, 1986; Amajor, 1987; Tijani et al., 2010). Heavy mineral assemblages in the Albian–Turonian sediments show major contributions from plutonic and metamorphic rocks of the Oban and Adamawa Massifs (Fig. 1) (Odigi, 1986), collectively called the Cameroon basement (Hoque, 1977). Amajor (1987) suggested a major sedimentary source and a minor contribution from the crystalline basement of Oban Massif for the Maastrichtian Ajali Sandstone of the Anambra Basin. This was recently supported by Tijani et al. (2010); they integrated X-ray fluorescence (XRF) with grain-size analysis and petrography. Hoque (1977) considered the sandstones of the Abakaliki Basin to be first sedimentary cycle deposits (from the Cameroon basement) based on the dominance of feldspathic sandstone. Sediments of the Anambra Basin are considered to be a product of a second sedimentary cycle with contributions from both the Abakaliki folded terrain (as a sedimentary source) and the granitic

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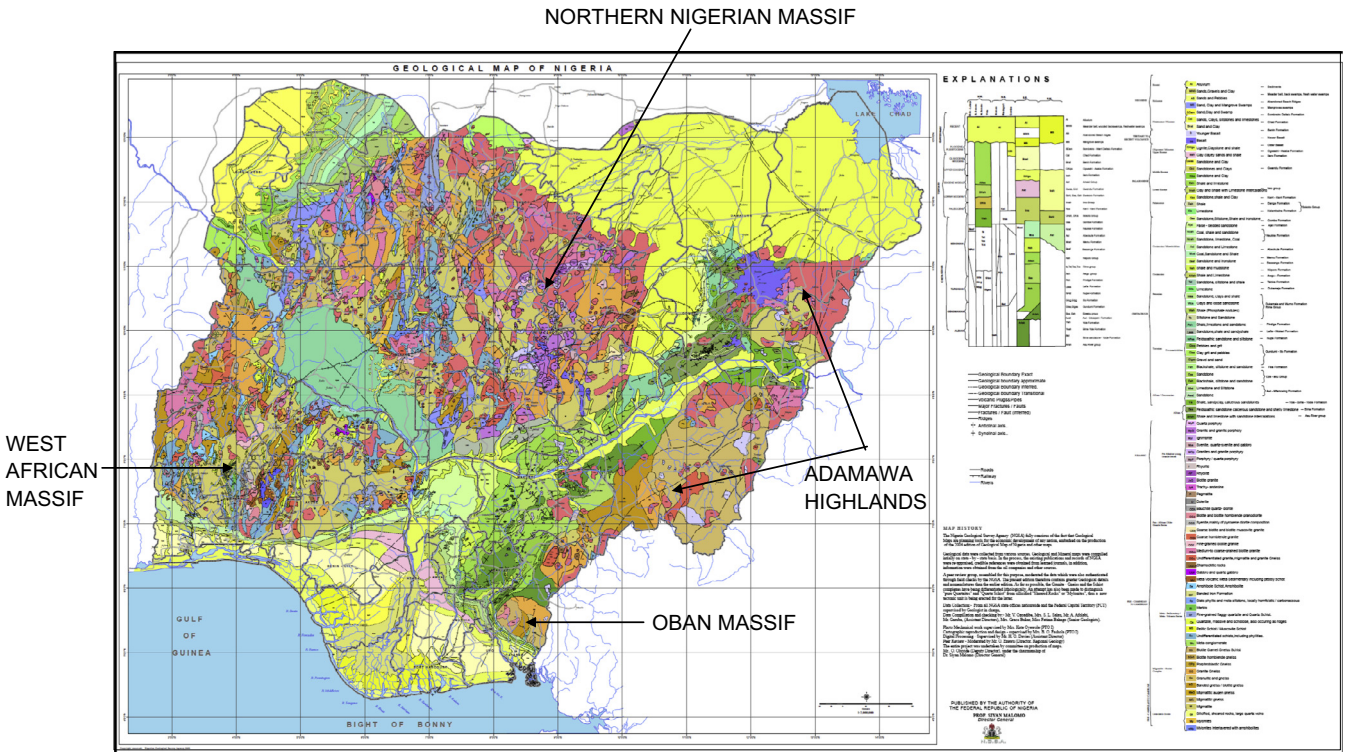

Fig. 1. An overview of the detailed (a) and simplified (b) geologic map of Nigeria showing the basement complex (after Nigerian Geological Survey Agency, 2004; redrawn and modified after Okezie, 1974).

complex of Cameroon basement. Fig. 1 is an overview of the geological map of Nigeria showing the basement complex.

Published petrographic and heavy mineral studies of the Paleogene strata of the outcropping Niger Delta are limited to the Nanka Formation (Hoque, 1977; Nwajide, 1980). Nwajide (1980) noted the high proportion of ultrastable minerals, zircon, tourmaline and rutile and also the presence of kyanite, staurolite and sillimanite which suggest a medium to high grade metamorphic provenance.

This study aims to use petrography and heavy mineral analysis to provide a framework for reconstructing sediment provenance of the outcropping Niger Delta, to ascertain the tectonic setting and interpret the paleoclimatic condition during the Paleogene. This study also acts as research tool for further research work.

2. Geological setting

The geology of the sedimentary basins of southern Nigeria has received considerable attention since the discovery of oil in the Niger Delta Basin, Nigeria. The origin of these sedimentary basins is traced to the inception of and subsequent evolution of the Benue Trough. The Benue Trough evolved from the separation of the Afro-Brazilian plate during the Early Cretaceous (Reyment, 1965; Murat, 1972; Nwachukwu, 1972; Olade, 1975; Petters, 1978; Wright, 1981; Benkhelil, 1982, 1989; Hoque and Nwajide, 1984). The paleogeography and stratigraphy of the Abakaliki Basin, the Anambra Basin and the Niger Delta are well documented in the works of Short and Stäuble (1967), Nwachukwu (1972), Murat (1972), Oboh-Ikuenobe et al. (2005), Nwajide (2013) and Ekwenye et al. (2014). The stratigraphy of the southern sedimentary basins were discussed in three depositional phases – the Aptian–Santonian, the Campanian–Early Eocene and the Late Eocene–Pliocene depositional phases. The Aptian–Santonian phase led to the deposition of the sedimentary rocks of the Asu-River Group from the Aptian to the Albian times.

Initial assumption that the Cenomanian heralded a tectonic event (Murat, 1972; Nwachukwu, 1972) in the Abakaliki Basin that resulted to the restriction of the Cenomanian Odukpani Formation (now called Mfamosing Formation) to the Calabar Flank and the occurrence of lead–zinc mineralization in the Albian strata was disapproved by the presence of Cenomanian sediments in the Eze-Aku River section at Aka-Eze; Amaseri Sandstone, Umukwueke; Ibir and Ekukunella; Ezillo and Agala Formations and other areas in the Central and Northern Benue Trough (Benkhelil, 1986; Ojoh, 1992; Umeji, 2007). The strata of the Eze-Aku Group were deposited during the transgressive Turonian and the sediments of the Awgu Formation were laid during the Coniacian. The Coniacian regression culminated with the deposition of the Agbani Sandstone Member in the Abakaliki Basin. Sedimentation in the Abakaliki Basin was halted due to the Santonian thermo-tectonism (Fig. 2).

The Santonian compressional phase resulted in the folding, faulting and uplifting of the Abakaliki Basin to form an anticlinorium; displacing depo-centers westward and eastward to form the Anambra and Afikpo basins respectively. Sedimentary units of the Anambra Basin consist of the Nkporo Group and the Coal Measures, with the Nsukka Formation, as the uppermost in the succession, terminating the Cretaceous sedimentation in the Anambra Basin (Nwajide, 2006). The Anambra Basin sedimentation was terminated by an extensive Paleocene transgression