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Research paper

Rare earth element geochemistry of petroleum source rocks from northwestern Niger Delta

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ABSTRACT

Geochemical investigation of forty two rock samples from three fields in the northwestern Niger Delta was carried out in order to determine their rare earth elements (REEs) content and their geochemical significances. The rare earth elements and trace elements in the rock samples were determined using inductively coupled plasma – mass spectrometry (ICP-MS) and instrumental neutron activation analysis (INAA). The results indicate that nickel is most abundant trace elements in ML field while cobalt is most abundant in MF and MJ fields. Vanadium had the least concentration in the three fields. Nickel had enhanced concentrations over vanadium in the three fields. The concentrations and ratios of the trace elements indicated that the source rocks in the three fields had strong terrestrial organic matter input and were deposited under oxic conditions. Gadolinium is the most abundant rare earth element in three fields. Neodymium had the least concentration in ML and MJ fields while praseodymium had the least concentration in MF field. The REE distribution patterns of source rocks from the three fields are similar, indicating similar genetic origin. Pearson correlation matrix revealed that europium, dysprosium, lanthanum and samarium are potential redox and source indicators.

1. Introduction

Source rocks are highly organic-rich type of sedimentary rock that are capable or may become capable or have been able to generate petroleum (Tissot and Welte, 1984). Source rock ultimately generates crude oil and contains measurable quantities of many trace metals and rare earth elements (REEs). Trace metals are incorporated into petroleum source rocks in the form of porphyrin complexes and may include direct incorporation from the biomass and formation during sedimentation. It may also involve diagenesis from organic molecules as well as metals derived from different biogenic and abiogenic sources (Barwise, 1990; Nwachukwu et al., 1995; Akinlua et al., 2007).

The type and the thermal maturity of organic matter and their depositional environment have significant effects on the concentration of trace elements in source rocks (Lewan, 1984). Metals of proven association with organic matter may be used as reliable correlation tools. Nickel, vanadium, and cobalt (usually referred to as biophile elements) are such examples (Barwise, 1990; Udo et al., 1992; Akinlua et al., 2007).

The geochemical characteristic and intrinsic distribution of rare earth elements in geological formation would make them useful geochemical tools to determine the origin, depositional environment, and thermal maturation of organic matter (Henderson, 1984; Takeda and Arikawa, 2005; Akinlua et al., 2008).

A wide range of metals have been determined in crude oils, bituminous substance and organic sedimentary rock all over the world (Ajayi et al., 2009; Akinlua et al., 2007; Barwise, 1990; Nwadinigwe and Nworgu, 1999; Shtangeeva, 2006; Udo et al., 1992). Trace-metal accumulation is known to be controlled by redox conditions in marine sediments (Algeo and Rowe, 2012). Some trace metals have proven to be good paleoenvironmental redox indicators (Lewan and Maynard, 1982; Mongenot et al., 1996; Alberdi-Genolet and Tocco, 1999; Tribovillard et al., 2006). Several studies have been carried out on trace metals in oils from the Niger Delta area (Nwachukwu et al., 1995; Ajayi et al., 2009; Akinlua and Torto, 2006; Akinlua et al., 2007) and a very few study on rare earth elements in oils from the Niger Delta (Akinlua et al., 2008).

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However, there is paucity of data on the determination and geochemical assessment of rare earth elements content of petroleum source rocks from Niger Delta Basin.

The present study is therefore an attempt to determine the rare earth elements content of source rock samples from Niger Delta in order to assess their suitability in the evaluation of origin and depositional environment of source rocks.

2. Geology of study area

The Niger Delta is one of the world's largest Tertiary deltaic systems and an extremely prolific hydrocarbon province. It is situated on the West African continental margin at the apex of the Gulf of Guinea (Doust, 1990). The area is located at the southern region (latitude 4° and 6°N and longitude 3° and 9°E) and occupies an area of about 75,000 km^2 with clastic sequence that reaches a maximum thickness of 9000–12,000 m of sediment and total sediment volume of 500,000 km^2 and makes up 7.5% of Nigeria landmass (Frank and Cordry, 1967).

The study area is bounded by older Cretaceous tectonic elements, such as the Abakaliki Anticlinorium and the Afikpo syncline (Ejedawe, 1981). The area is rich in oil and the host rocks are organic-rich sedimentary rocks. The Tertiary lithostratigraphic sequence of the Niger Delta consists of the Akata, Agbada, and Benin formations (Figs. 1 and 2) (Evamy et al., 1978). The lowest unit is the Akata formation with a uniform massive marine shale unit with age ranging from Paleocene to Recent. Akata Formation is overlain with Agbada Formation, which consists of intercalation of sandstone and shale with age ranging from Eocene to Recent (Short and Stauble, 1967). The Benin Formation that overlies the Agbada Formation consists of fluviatile sands and gravels with age ranging from Eocene to Recent (Avbovbo, 1978). The sandstones of the Agbada Formation are the reservoir rocks for liquid hydrocarbons that occur in this sedimentary basin (Evamy et al., 1978).

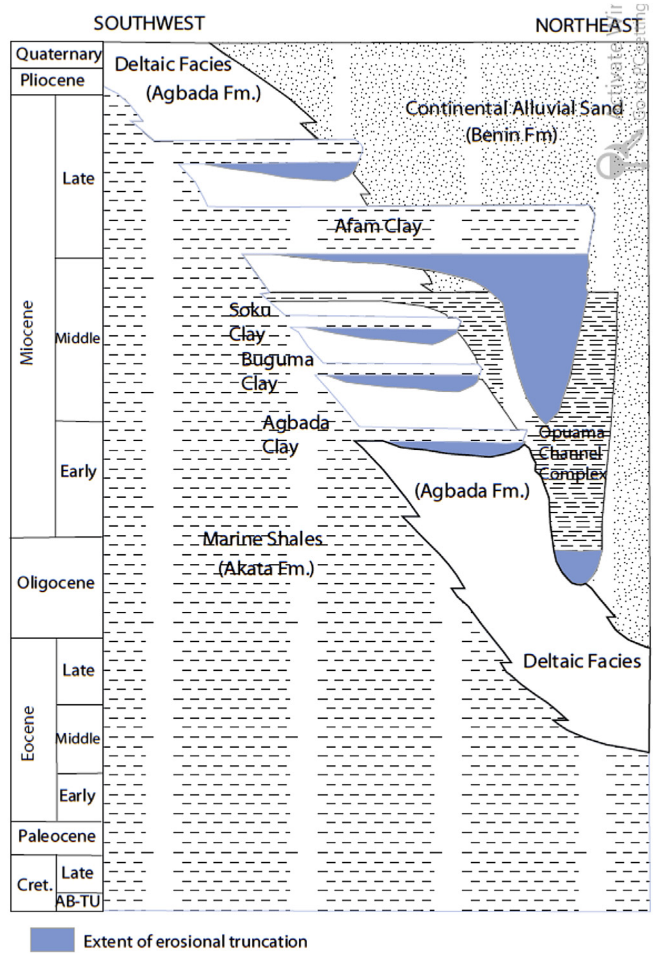

Fig. 2. Stratigraphic columns showing the three Formations of the Niger Delta (Doust and Omatsola, 1990).

3. Experimental

3.1. Sample collection

Source rock samples were collected at different depths, from three oil fields (ML, MF and MJ field) in the paralic sequence of Agbada Formation, northwestern Niger Delta (Fig. 3). Only rock samples with TOC above 0.5 wt% were selected for rare earth and trace elements analysis.

3.2. Sample preparation for ICP-OES

The source rock samples were prepared for inductively coupled plasma – optical emission spectrometric (ICP-OES) measurement by acid digestion into colourless aqueous solution. Dissolution of the source rock samples was achieved using microwave accelerated reaction system. 0.5 g of each sample was digested using 4 mL of

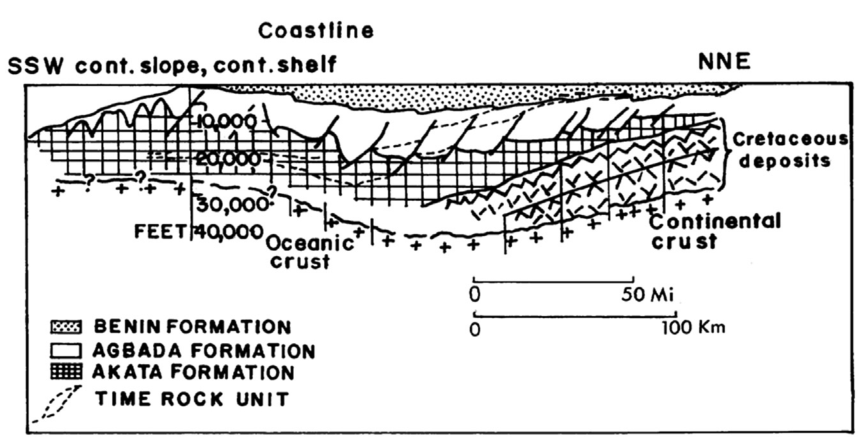

Fig. 1. Schematic cross section showing principal stratigraphic units of Tertiary Niger delta (Ekweozor and Okoye, 1980).