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Rare earth element and stable sulphur (δ ^{34}S) isotope study of baryte–copper mineralization in Gulani area, Upper Benue Trough, NE Nigeria

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ABSTRACT

The geology of Gulani area comprises of inliers of diorite and granites of the Older Granite suite of the Pan-African (600 ± 150 Ma) age within Cretaceous sediments of the Bima, Yolde and Pindiga Formations and the Tertiary/Quaternary basalts of the Biu Plateau. Epigenetic baryte–copper mineralization occurs as baryte veins within the Bima and Yolde sandstones and fracture-filling malachite in Pan-African granites. Unaltered (distal), hydrothermally altered (proximal) granites and sandstones and vein materials (mineral separates of baryte and chalcopyrite/malachite mineralized rocks) were analysed for rare earth elements (REE) and stable sulphur isotopes. The REE patterns of the unaltered rocks (both granites and sandstones) indicate background values before mineralization, depicted by enriched LREE, depleted HREE and weak negative Eu anomalies typical of Pan-African (calc-alkaline) granites and sandstones derived from them. On the other hand, the hydrothermally altered and mineralized rocks and mineral separates show a distinct baryte and copper mineralization sub-systems characterized by similar high LREE and corresponding low HREE abundances. However, the negative Eu anomalies of the copper sub-system hosted by granites are typical of Pan-African (calc-alkaline) granites. The sandstone host rocks of the baryte sub-system are marked by positive Eu anomalies interpreted as reflecting the injection and subsequent deposition of the baryte-bearing hydrothermal solutions under oxidizing conditions. The baryte mineral separates show δ (^{34}S) isotope range of 12.3–13.1‰ (CDT) indicating sulphur from sedimentary formation sources. This ruled out magmatic source of the sulphur from the nearby Tertiary/Quaternary volcanic rocks of the Biu Plateau as well as ocean water. However, the stable sulphur isotopic determination of the sulphides (chalcopyrite/malachite mineral separates and mineralized rocks) did not yield peaks and therefore no inferences drawn in this regard.

1. Introduction

Epigenetic baryte–copper mineralization hosted by Cretaceous sediments (baryte) and Pan-African granites (copper) have been mapped in the Gulani area in Gongola Basin of the Upper Benue Trough, northeast Nigeria. This mineralization most likely forms the northern extension of the main mineralization system of Pb–Zn–Cu–F metallogenic belt of the Benue Trough (Farrington, 1952; Ford, 1989; Olade, 1976; Olade and Marton, 1980; Wright, 1989a). The belt which is about 80 km wide extends for about 600 km from Abakaliki in the southwest of the trough to Gombe in the northeast. Three mineralized zones have been located in this belt with Pb–Zn+Cu of Abakaliki district in the Lower Benue Trough; the Arufu–Akwana Pb–Zn–F+Ba district in the Middle Benue Trough and the Zurak–Gwana–Gombe Pb–Zn+Ag district in the Upper Benue Trough (Abba, 2009; Akande and Abimbola, 1987; Ford, 1989; Olade and Marton, 1980; RMR&DC, 2004). Several baryte occurrences some of which are of economic significance, are known in the Middle Benue Trough such as Aloshi, Keana, Azara, Akiri, Wuse, Chiata, Ibi, Gbande and Gboko areas (Adubok and Imoekparia, 2008; Ajayi, 1987; Akande and Abimbola, 1987; Chaanda et al., 2010; Tate, 1959). However, only few occurrences have been investigated. Therefore, this reports a new additional study of the Pb–Zn–Cu–Ba mineralization in the northern parts of the Benue Trough.

The Benue Trough is a fundamental tectono-sedimentological feature in the evolution of the Cretaceous and Tertiary geology of Nigeria. Its position in the evolution of Nigeria's geological features is such that most other sedimentary basins such as the Bida, Chad, Anambra, Dahomey and Niger Delta are genetically related to it (Benkhelil et al., 1989; Nwajide, 2013; Zaborski, 1998). The trough

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had been viewed simply as an elongate intracratonic structure over 1000 km long and up to 250 km at its widest parts, stretching in a SW–NE directions from the Niger Delta to the Chad Basin. It developed as a purely rift structure in the Pan-African mobile belt. Its orientation must have been predetermined by NE–SW trending shear zones of Pan-African age reactivated during the break-up of the Gondwana which lead to the opening of the South Atlantic during early Cretaceous times (Benkhelil, 1989; Nwajide, 2013; Olade, 1976). The mechanism of origin of the Benue Trough has been debated and remains quite controversial. The first interpretations on the origin of the Trough emerge when King (1950) and Farrington (1952) considered it as tensional in origin and therefore a rift-bounded basin. But since no bounding faults were directly in evidence at that time, the trough was considered as a flexure valley traceable to a deep-seated contraction of the basement complex. Carter et al. (1963) interpreted the trough as a Cretaceous rift-fault folded feature resulting from basement flexuring. Based on the first geophysical study, Cratchley and Jones (1965) proposed the same rift origin stressing that the main rift boundary faults were concealed by Cretaceous sediments. Olade (1975) and Wright (1989a) believed that the Benue Trough has been under a tensional stress regime from when it originated as the failed arm of a RRR triple junction throughout its history of sedimentation and deformation. The tensional regime was attributed to the continued but intermittent uplift of the Gulf of Guinea dome following the opening of the South Atlantic. They conceded that compressional uplift movements could have also caused the folding.

The rift origin was integrated in the "plate tectonics" concept leading to several models proposed to explain the origin of the Benue Trough in the 1970s. Burke et al. (1971) compared the trough to the Afar rift and suggested that there was a triple junction of the Ridge–Ridge–Ridge type with a new oceanic crust generated in the Abakaliki area. Burke (1976) related the continental rifting to mantle convection resulting in triple junctions developed at hot-spots with failed rifted arms leading into continents at major embayments. Major deltas commonly prograde down such failed arms into oceans, e.g. Mississipi, Rhine, St. Lawrence, Casmance, and Amazon deltas, and therefore also the Niger Delta (Nwajide, 2013). Earlier Grant (1971) attributed the origin of the Benue Trough feature to a spreading ridge related to an unstable RRF triple junction resulting in dilation and opening of the Gulf of Guinea. Burke and Dewey (1974) and Olade (1975) identified the trough as the third arm (Aulacogen) of three-armed rift system related to the development of hot spots. The rift origin of the Benue Trough became the basis for invoking a plate tectonic event in which the trough was seen as a direct consequence of the crack-up of the Gondwana supercontinent and the opening of the Atlantic Ocean (Nwajide, 2013).

Since 1980, the models proposed for the evolution of the Benue Trough were rather based on field geology and structural analysis then on Plate Tectonics consideration. Several workers such as Benkhelil (1982, 1989), Benkhelil and Robineau (1983), Guiraud (1990) and others have shown the structure of the Benue Trough to be a set of pull-apart sub-basins or grabens generated by sinistral displacements along a pre-existing zone of NE–SW trending transcurrent faults. Transcurrent movements were therefore the principal factor in the formation and subsequent evolution of the Trough.

Interpretation of aeromagnetic maps covering the onshore domain realized from 1974 to 1975 at 1: 100,000 scale for the then geological survey of Nigeria indicates four (4) trends of discontinuities approximately centred along N 25° E, N 55° E, N 90° E and N 145° E. The most important and dominant trend is the N 55° E which does not individually exceed 200 km in length is concentrated in two corridors about 50 km wide. On the onshore, these corridors are associated to the NW and SE flanks of the Benue Trough which respectively correspond the chain and charcot

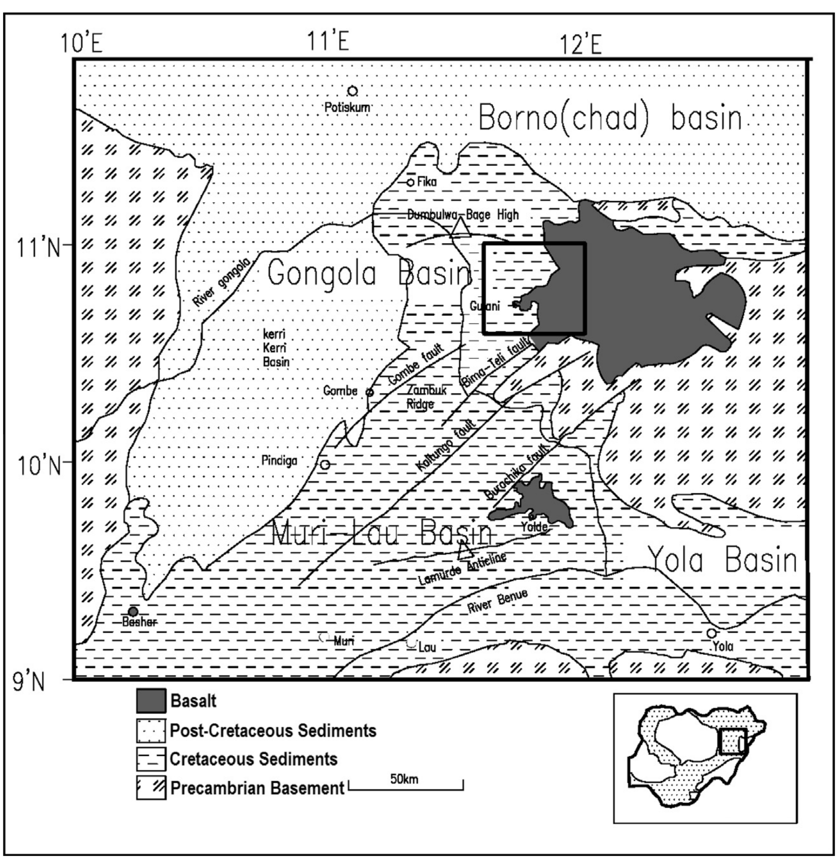

Fig. 1. Geological Map of the Upper Benue Trough showing the study area within the Gongola Basin (modified after Zaborski et al., 1997).