Journal of Geology and Mining Research Vol. 4(7) pp. 168-173, December 2012
Available online at http://www.academicjournals.org/JGMR
DOI: 10.5897/JGMR12.008
ISSN 2006-9766 ©2012 Academic Journals

Full Length Research Paper

Geology and tectono-sedimentary disposition of the Bima sandstone of the Upper Benue Trough (Nigeria): Implications for sandstone-hosted Uranium deposits

I. V. Haruna[1]*, H. A. Ahmed[1] and A. S. Ahmed[2]

[1]Geology Department, Modibbo Adama University of Technology, Yola, Adamawa State, Nigeria.
[2]Nestle Group, Port Harcourt, Rivers State, Nigeria.

Accepted 10 December, 2012

The Bima sandstone is the oldest, thickest, and most extensive formation in the Upper Benue Trough, located in north-eastern Nigeria, and it is included in a region known for its Uranium mineralisation. The sandstone has been subdivided into three siliciclastic members: B1, B2, and B3. Sedimentological and structural factors necessary for uranium precipitation are recognised within the members. B1 consists of basement-derived conglomerates supported in a gravelly or sandy matrix. B2 is coarse- to medium- and fine grained sandstone with good lateral continuity. B3 consists of well-sorted, uniformly fine grained ferruginised sandstone interbedded with more clayey to shaly carbonaceous beds. The Benue Trough represents a rift-related basin formed in horst and graben structures, and is characterised by numerous post-depositional structures such as fracture/fault zones. The sedimentological and structural factors may reduce permeability of sediments and prolong regional scale fluids circulation. We anticipate that, Uranium that is leached from sub adjacent basement granites and disseminated in the sandstone may be concentrated in the fracture/fault zones within B3 and B2/B3 transitional sequences that form sandstone-hosted Uranium deposits.

Key words: Geology, Bima sandstone, Uranium, Upper Benue Trough.

INTRODUCTION

The Benue Trough is a 1,000 km long, 50 to 150 km wide intracontinental NE – SW trending rift depression in Nigeria. The basin (Benue Trough) is filled with continental and marine sediments (about 6,500 m). Different models have been proposed for the evolution of this megastructure. However, all the models imply an intraplate rifting for the genesis of Benue Trough. Based on a three arm rift model, Grant (1971) presented the structure as a basin which had experienced deformation (aulacogen). Benkhelil and Robineau (1983), Benkhelil (1986) and Maurin et al. (1985) interpreted the Benue Trough as a set of juxtaposed pull apart basins initiated in the Early Cretaceous, and formed by sinistral movement along a NE - SW transcurrent fault inherited from the Atlantic oceanic crest. Popoff (1990) and Fairhead and Binks (1991) suggested that the Benue Trough is genetically related to the opening of the equatorial domain of the South Atlantic.

The Benue Trough is divided into three segments: the lower, middle and upper Benue regions. The Upper Benue Trough (Figure 1) is a Y-shaped basin bounded to the Northeast by the basement rocks of the Hawal Massif, to the South by the Adamawa Massif, and to the west by the sandstone of the Keri Keri Formation. The Upper Benue Trough is subdivided into three sub basins: the Southern Muri-Lamurde branch trending Northeast, the E – W trending Yola Arm to the east and the N – S Gongola Arm to the North (Figure 1). Here, we analyse the stratigraphy and tectonic framework of the Bima

*Corresponding author. E-mail: Vela_hi@yahoo.co.uk. Tel: +2348030963828.

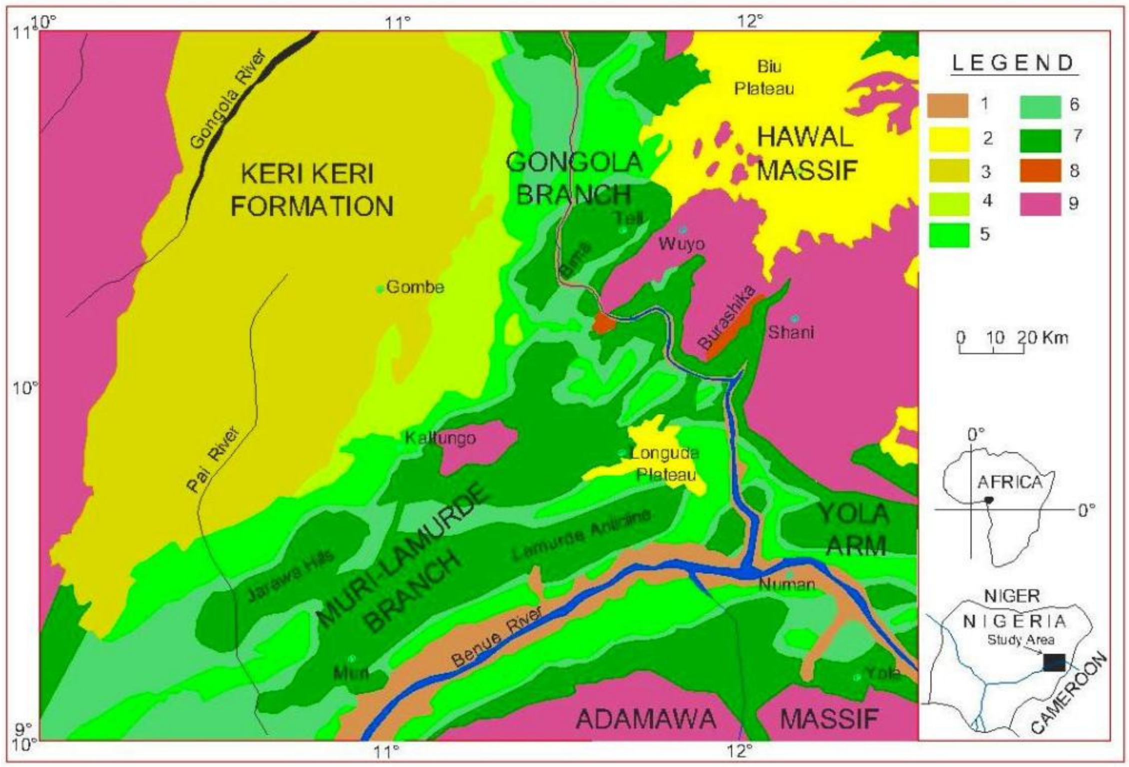

Figure 1. Geological map of the Upper Benue Trough. 1, quaternary alluvium: 2, tertiary to recent volcanism: 3, kerri kerri formation: 4, Gombe sandstone: 5, pindiga formation: 6, yolde formation: 7, Bima sandstone: 8, burashika group (Mesozoic volcanism): 9, granitoids precambrian (modified after Maurin et al., 1985).

sandstone of the Upper Benue Trough, to assess whether it has the necessary characteristics for sandstone hosted Uranium deposit.

GEOLOGICAL SETTINGS

In the Upper Benue Trough, the Precambrian basement is unconformably overlain by the Aptian-Albian Bima sandstone (Figure 2) which is the oldest, thickest, and most extensively outcropping formation in the trough (Carter et al., 1963; Guiraud, 1990; Abubakar, 2006; Mamman et al., 2010). Sedimentological studies (Guiraud, 1990) showed that the Bima sandstone can be divided into three silicaclastic members namely the Lower, Middle and Upper Bima Members, respectively designated as B1, B2, and B3. B1 is rich in basaltic and rhyolitic clasts and in rhyolitic to basaltic volcanic lenses, indicating contemporaneous volcanic activity (Guiraud, 1990; Guiraud and Maurin, 1992).

The Bima sandstone is overlain by transitional interbeds of shale, siltstone and calcareous mudstone of the Yolde Formation (Cenomanian-Turonian), grading into massive of beds of limestone and thick shale of the Gongila Formation, in the Gongola sub-basin and its lateral equivalents: the Dukul formation (mainly of gray shales and thin silty beds), and the Jessu and Numanha Formations in the Yola Sub-basin. These sequences are poorly overlain to moderately sorted sandstone of the Gombe Formation (Campanian-Maastrichtian) in the Gongola sub-basin and Lamja sandstone in the Yola Arm. The succession is capped by sandstone of the Keri keri Formation (West of Gombe town) in the Gongola Arm.

The Upper Benue Trough is structurally marked by numerous NE – SW trending mylonitic shear zones generated during the late Pan-African phase, and reactivated as sinistral strike-slip faults during the Cretaceous (Benkhelil and Robineau, 1983; Benkhelil, 1986; Maurin et al., 1985). Generally, three major fracture zones trending northeast have been recognised: the Gombe fault, the Kwol-Kaltungo lineament which extends for about 150 km, and the Burashika fault. These major fractures, cross-cut the Cretaceous deposits and affects the basement. The tectonic deformation along these major fractures is represented by cataclastic and brecciated bands that are about 300 m to 1 km wide in the basement, and by 100 m wide crushed zones in the sedimentary cover. This deformation superimposes the Pan-African mylonitic shear zones, and provides post depositional fracture/fault zones which are favourable sites for Uranium concentration in the sedimentary units.

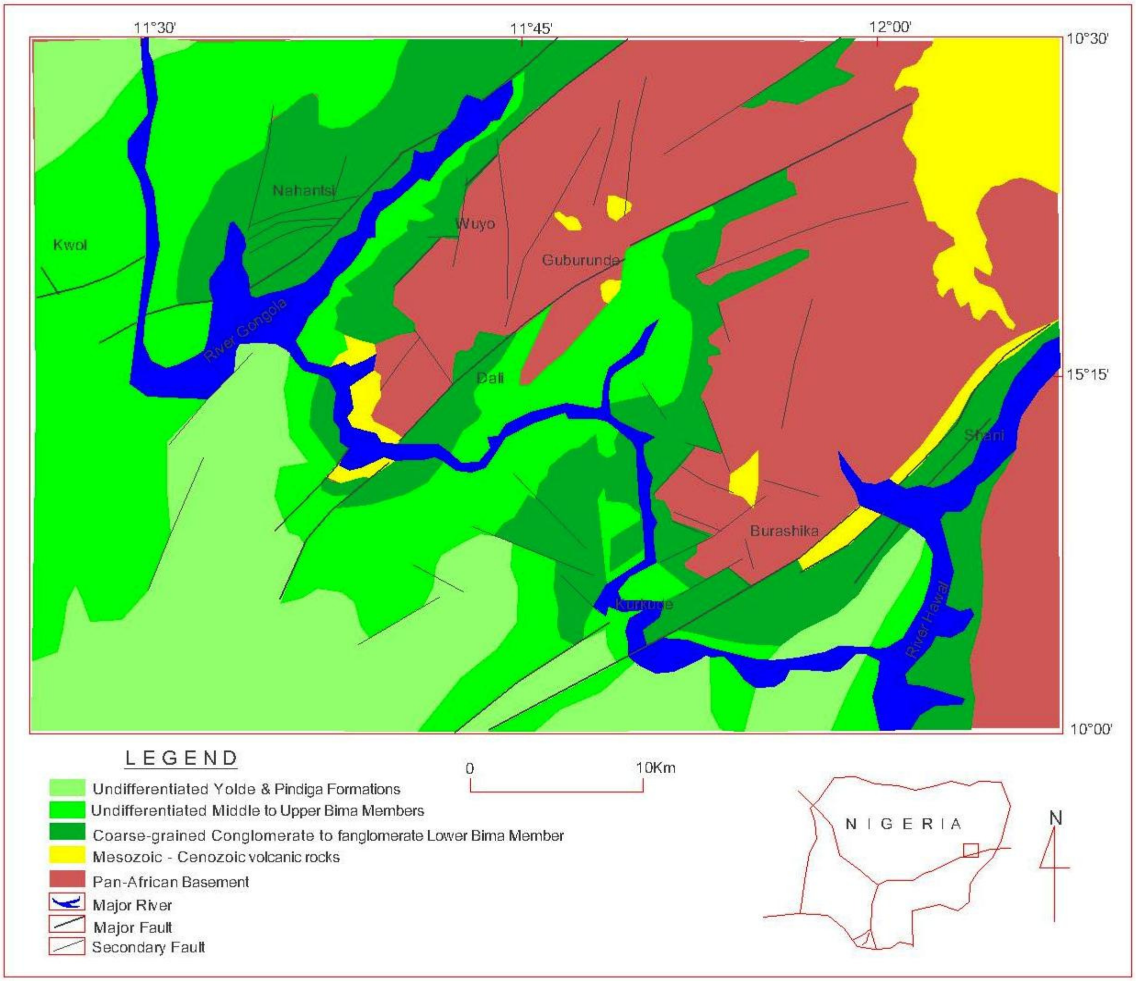

Figure 2. Geological map of part of Upper Benue Trough (modified after Guiraud, 1990).

The border of the Upper Benue Trough in the area between the N – E trending southern domain (Muri-Lamurde branch) and Yola arm consists of three northeast trending fault-bounded Early Cretaceous sub basins: the Nahantsi, Kurkude, and Shani sub-basins (Figure 2). Bordering these sub basins are two NE – SW trending uplifted basement blocks: the Wuyo-Guburunde Horst and the Burashika Horst. Large scale NE – SW trending Lamurde anticline and Dadiya syncline in the Upper Benue Trough were generated by a general N – E compression which affected the Northern part of the Benue Trough at the end of the Cretaceous period (Benkhelil, 1982, 1986).

TECTONO-SEDIMENTARY SETTING

The Geological aspects and structural sedimentary relationships in the Upper Benue Trough have been examined in details by Guiraud (1990). Figure 3 showed the various relationships between the lower, middle, and upper members of the Bima Formation in the Upper Benue Trough. The formation of the principal Early Cretaceous tectonic structures was contemporaneous with the deposition of the lower Bima Member. The Middle Bima sediments overlie the lower Bima Member (preserved in half grabens) in areas like Nahantsi and Shani, but directly rest on the basement in areas such as Kwol, Dali, and Kurkude where the lower Bima Member may be absent (Figure 4). The simultaneous faulting and sedimentation of the lower Bima in the Upper Benue Trough during the Early Cretaceous created areas was with high relief. These high relief areas were subjected to erosion, and were progressively destroyed before the deposition of the middle Bima sediments. Throughout the Upper Benue basins, the gravels and coarse-grained sandstones of the middle Bima Member fills the syn-depositional faults present within the lower Bima Member. The highly matured sediments of the upper Bima Member indicate a widespread system of very shallow braided rivers. Thus, sedimentation was contemporaneous with the final stages of erosion.

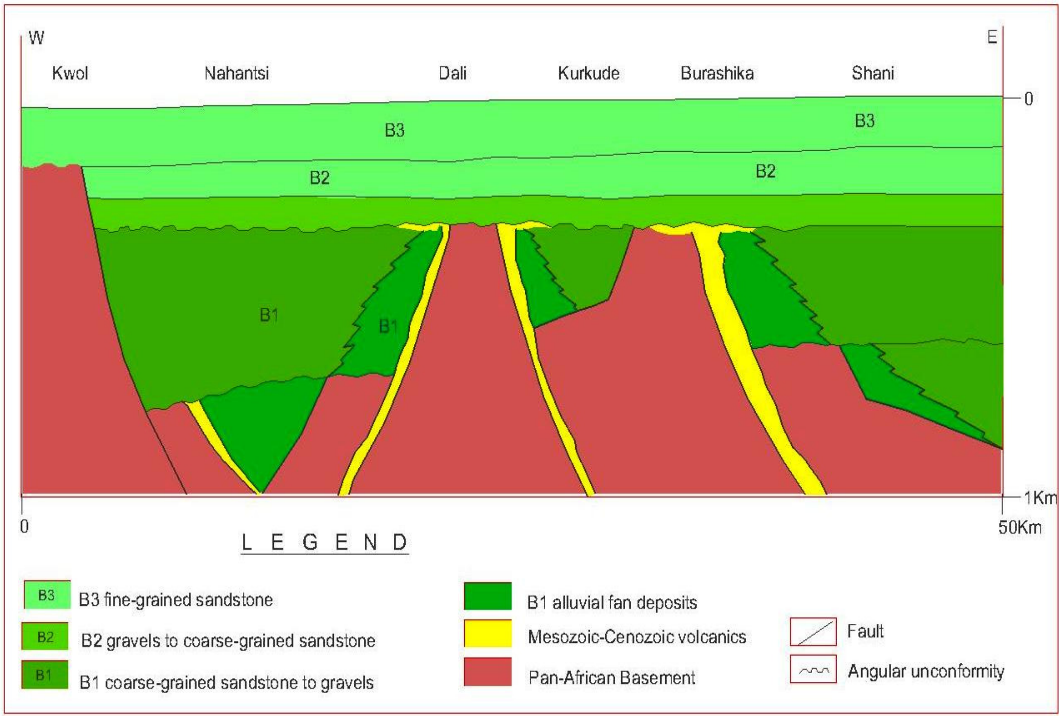

Figure 3. Spatial relationships between B1, B2, and B3 members of Bima sandstone.

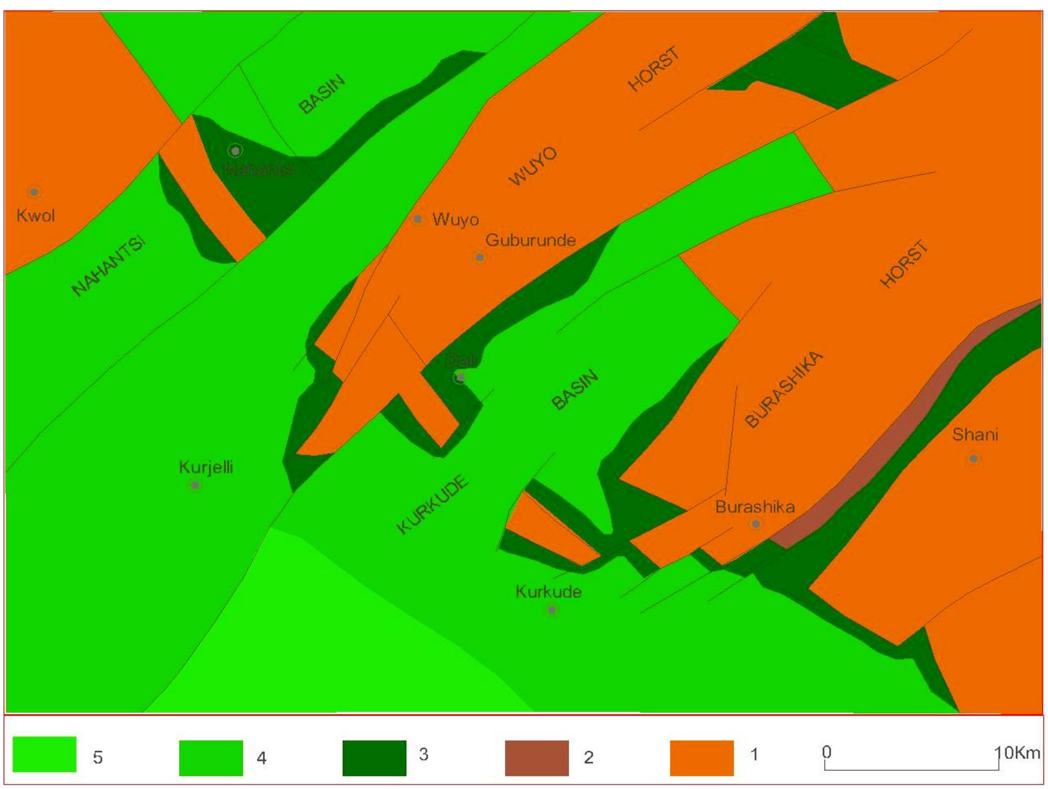

Figure 4. Environment of the study area during deposition of the Lower Bima Member. 1, ganitoids (Pan-African): 2, early cretaceous magmatism: 3, lower Bima alluvial fan deposits: 4, coarse sandstone to gravels of the lower Bima member: 5, lower Bima lacustrine siltstones and shales (modified after Guiraud, 1990).

LITHOSTRATIGRAPHIC UNITS OF THE BIMA FORMATION

The sandstone of the Bima formation is the oldest sedimentary unit in the Upper Benue Trough. This Early Cretaceous Bima sandstone rests unconformably on the Pan African basement and forms the basal part of the sedimentary succession. The sandstone is poorly stratified, and comprises of rare sedimentary structures. It has internal scouring surfaces filled with finer materials. The sandstone beds have poorly defined contacts and lack good lateral continuity. Upwards coarsening sequences are common; upwards fining sequences are subordinate. Steel and Thompson (1983) postulated that, basins forming tectonism that increases in intensity can cause upwards coarsening trends in sedimentary sections, whilst more stable tectonic conditions account for upwards fining trends. This interpretation adequately explains the sequence in the lower Bima sandstone as upwards maturity reflects a period of intense tectonic activity, followed by more stable conditions. The sedimentary features described for B1 as ealier suggest that, the sediments of B1 mostly represents medial fan detritus dominated by stream channel deposits (Steel and Thompson, 1983; Steel, 1988). Paleocurrent direction is from East – Southeast to West – Northwest.

The middle Bima Member (B2) overlies B1 by an angular unconformity. The contact contains ferruginous crusts and paleosols. The middle Bima Member is 50 to 200 m thick and consists of gravels to coarse grained sandstone dominated by large scale trough cross bedding. Sedimentary structures such as simple cross laminations are common. Beds have good lateral continuity and contain reddish silty beds and claystone lenses. The sequences in B2 are poorly developed and generally fining upward, with sandstone beds getting silty towards the top. The paleocurrent direction is similar to that of B1. All these features suggest that the middle Bima sediments represent fluvial deposits; at deposition, the alternating coarse and fine layers represent strong variations of energy at deposition. The presence of coarse grained facies and poorly-developed, generally fining upward sequences in B2 are probably the result of deposition in channels with low sinuosity. The silty and clayey lenses reflect proximal lacustrine or small fluvial overbank deposits in the environments.

The 600 m thick sandstones of B3 overlie B2 sediments. The Member consists of a succession of oblique, planar cross-bedded deposits with only rare cross stratifications. The sandstone is well-sorted, fine grained and contains well rounded fragments. It is interbedded with a ferruginous reddish brown to yellowish arkosic sandstone alternating with more clayey, light grey, carbonaceous, and pyritic beds. The sandstone of B3 grades into siltstone both laterally and vertically. Small scale trough cross laminations are occasionally present and fining upwards trends occur towards the top. Lower parts have small scale upwards coarsening patterns.

Collinson (1986) postulated that, fine member deposits with features, such as those of B3 sediments are typical of inter channel areas are built up during floods. The sedimentation environment of B3 may be flood plains, perennial swamps or shallow lakes. The small scale upwards coarsening units probably represent the filling of small deltas in shallow lakes during flood events (Flores, 1981; Gersib and McCabe, 1981).

DISCUSSION AND CONCLUSION

Reduced claystones in lacustrine and deltaic environments often show a high background radiometric value in sandstone hosted Uranium deposits. For instance, Le Roux (1991) has demonstrated that most of the Uranium bearing sandstones of the Karoo Basin were deposited by distal braided rivers with significant inputs from lacustrine delta deposits. This conclusion is in agreement with the observations of Suh et al. (2000) on the Zona Uranium occurrence in the Upper Benue Trough. Suh et al. (2000) observed that, background radiometric readings for the various facies of B1, B2, and B3 vary on the average between 90 and 150 cps above the background counts of 50 cps. This variation is not unrelated to the varying sedimentological features of the different Bima members. The background values are generally higher in the muddy materials. Le Roux (1993) further reasons that the permeability of such deposits must not be too important, because a too high permeability will leave little time for Uranium to precipitate from ore bearing fluids. In contrast, relatively low permeable fine- to very fine-grained sandstones are good host rocks, they provide sufficient time for the precipitation of Uranium. Following the model of Le Roux (1991), B3 offers the best sedimentological features for Uranium precipitation in sandstone, with alternating sandstone and claystones in reduced and oxidised facies, organic matter, and moderate permeability. The fine sediments of B3 are likely to create permeability barriers necessary for Uranium precipitation. B2 sediments offer moderate ore deposit potentials. B1 is certainly not a good host rock for Uranium precipitation in the Upper Benue Trough, because of its high permeability and absence of fine sediments.

The structural and sedimentary disposition of the Upper Benue Trough is similar to the rift-related Pasha Ladoga basin (Russia) described by Molchanov et al. (2001) and Kuptsova et al. (2011). The Pasha Ladoga basin is a rift-related basin, characterised by small sediment thickness, and formed by horst and graben structures, similar to those of the Upper Benue Trough, with abrupt facies transition and presence of regional aquitards such as basalt flows. According to these authors, all these factors may reduce the permeability of sediments, and prevent prolonged regional scale fluid circulation which is critical for the formation of sandstone hosted Uranium deposits. Uranium deposits of rift-related basins are low grade, and show results of multiple tectonic reactivation and reprecipitation of ore.

The two factors such as sedimentological and structural are necessary for Uranium precipitations that are present in the Upper Benue Trough. We follow the model of Le Roux (1991) that the concentration of Uranium derived (or epigenetically remobilised) from suitable sediments is not only controlled by sedimentological features but also by syn- and post-deposition deformation structures such as fractures/fault zones within the sandstone sequences.

REFERENCES

Abubakar MB (2006). Biostratigraphy, paleoenvironment and organic geochemistry of the Cretaceous sequences of the Gongola Basin, Upper Benue Trough, Nigeria. Unpublished PhD Thesis. Abubakar Tafawa Balewa University, Bauchi. Nigeria. P. 289.

Benkhelil J (1982). Benue Trough and Benue Chain. Geol. Mag. 119:115-168.

Benkhelil J, Robineau B (1983). Le fosse de la Benoue est-il un rift? Bull. Centres Recherches Expl. Prod. Elf-Aquitaine 7:315-321.

Benkhelil J (1986). Structure et évolution geodynamique du basin intercontinental de la Bénoué (Nigeria). Thése de Doctorat d'Etat, Université de Nice. P. 226.

Carter JD, Barbar W, Tait EA (1963). Geology of parts of Adamawa, Bauchi and Borno Provinces in the Northeastern Nigeria. Geol. Surv. Nig. Bull. 30:108.

Collinson JD (1986). Alluvial sediments. In: Reading, H.G. (Ed.), Sedimentary Environments and Facies. Blackwell Sci. Pub. Oxford pp. 20-62.

Fairhead JD, Binks RM (1991). Equatorial opening of the Central and South Atlantic Oceans and the opening of the West African rift system. Tectonophysics 187:191-203.

Flores RM (1981). Coal deposition in fluvial paleo-environments of the Pleocene Tongue River Member of the Fort Union Formation, Powder River area, Powder River Basin, Wyoming and Montana. In: Ethridge, F.G., Flores, R. M. (Eds.), Recent and Ancient Non-marine Depositional Environments: Models for Exploration. Soc. Econ. Paleont. Min. Spec. Pub. pp. 169-190.

Gersib GA, McCabe PJ (1981). Continental coal-bearing sediments of the Port Hood Formation (Carboniferous), Cape Linzee, Nova Scotia, Canada. In: Ethridge, F.G., Flores, R. M. (Eds.), Recent and Ancient Non-marine Depositional Environments: Models for Exploration. Soc. Econ. Paleont. Min. Spec. Pub. pp. 95-108.

Grant NK (1971). The South Atlantic Benue Trough and Gulf of Guinea Cretaceous triple junction. Geol. Soc. Am. Bull. 82:2295-2298.

Guiraud (1990). Tectono-sedimentary framework of the early Cretaceous continental Bima Formation (Upper Benue Trough, Northeastern Nigeria). J. Afr. Earth Sci. 10:341-353.

Guiraud M, Maurin JC (1992). Early Cretaceous rifts of Western and Central Africa: an overview. Tectono-phys. 213:153-168.

Kuptsova AV, Khudoley AK, Davis W, Rainbird RH, Kovach VP, Zagornaya NY (2011). Age and provenance of sandstones from the Riphean Priozers and Salmi formations in the eastern Pasha-Ladoga Basin (Southern Margin of the Baltic Shield). Strat. Geol. Corr. 19:3-19.

Le Roux JP (1991). Flume experiments on permeability and organic matter as related to the genesis of uranium deposits in the Beaufort Group. S. Afr. J. Geol. 94:212-219.

Le Roux JP (1993). Genesis of stratiform U-Mo deposits in the Karoo Basin of South Africa. Ore Geol. Rev. 7:485-509.

Mamman YD, Dike EFC, Haruna IV, Haruna AI (2010). Clay mineralogy and paleodepositional environments of Late Cenomanian-Turonian sediments in the Yola Arm, Upper Benue Trough, Northeastern Nigeria. J. Min. Geol. 46(1):1-11.

Maurin JC, Benkhelil J, Robineau B (1985). Fault rocks of the Kaltungo Lineament (Northeastern Nigeria) and their relationship with the Benue Trough. J. Geol. Soc. London 143:587-599.

Molchanov AV, Terentiev VM, Efimov SA (2001). Uranium potentials of the Anabar Shield (in Russian). D. Geol. Uran. REE. 143:62-68.

Popoff M (1990). Déformation intercontinental gwondwanienne. Rifting Mesozoïque en Afrique (Evolution Meso-cénozoïque du fossé de la Bénoué, Nigéria). Relation avec Pouverture de l'Océan Atlantique Sud. Thése d'Etat, Université Aix-Marseille III. P. 425.

Steel RJ, Thompson DB (1983). Structures and textures in the Triassic braided stream conglomerates ('Bunter' Pebble Beds) in the Sherwood Sandstone Group, North Staffordshire, England. Sedimentology 30:341-367.

Steel RJ (1988). Coarsening-upward and Skewed fan bodies: symptoms of strike-slip and transfer fault movement in sedimentary basins. In: Nemec, W., Steel, R.J. (Eds), Fan Deltas: Sedimentology and Tectonic Settings. Blackie and Son. pp. 75-83.

Suh CE, Dada SS, Matheis G (2000). Host rock geology and geochemistry of the Zona uranium occurrence, Pete Gulf Syncline (Upper Benue Trough), Northeastern Nigeria. J. Afr. Earth Sci. 31:619-632.