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Review

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Review of the geology of mamfe sedimentary basin, SW Cameroon, Central Africa

Edwin Ayuk Ndip,[1,2,3,4] Agyingyi CM,[3,4] Nton ME,[2] Oladunjoye MA[2]

[1]Institue for Life and Earth Sciences, University of Pan African, Nigeria

[2]Department of Geology, University of Ibadan, Nigeria

[3]Petroleum Geosciences Research Group, University of Buea, Cameroon

[4]Department of Geology, University of Buea, Cameroon

Correspondence: Edwin Ayuk Ndip, Institue for life and Earth Sciences (including Health and Agriculture), Pan African University, Ibadan, Nigeria, Email ndipedwin70@gmail.com

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Abstract

This paper presents a review of the tectonic evolution, stratigraphy, paleontology, hydrogeological aspects and economic geology of the Mamfe basin. The main structures are basement –involved and detached fault and simple symmetrical fold with NE-SW trend. The basin measures 130 km in length and the widest part is about 60 km and a maximum area of 3200 km^2. The maximum sediment thickness is estimated at 4–7 km and the sedimentary infill includes a lower alluvial fans to fluvial basal conglomerate and conglomeratic sandstone, a middle alternating (cyclic) aqueous to anoxic deep lake bottom black shale and limestone unit and an upper fluvial to transitional deltaic nearshore conglomeratic sandstone unit. The Ostracod fauna from the shale are very similar to the coeval fauna from adjacent Benue trough. The reported fauna have no biostratigraphic significance because of their uncertain age, low diversity, and cosmopolitan distribution during the early Cretaceous. Over 30 salt springs exist across the Mamfe basin with the most concentrated yielding 79 g/L of high quality halite. Several mineral indices (including diamond) have been identify and the geological condition favour the occurrences of hydrocarbon.

Keywords: stratigraphy, paleontology, hydrogeological aspect, economic geology, mamfe basin

Introduction

The Mamfe Sedimentary Basin in the SW region of Cameroon is also known Mamfe embayment, Ikom-Mamfe embayment, Mamfe Gulf, or Mamfe Rift.[1-13] It is a small intra-continental basin that forms an arm of the Benue Trough of Nigeria (Figure 1) extending into Cameroon.[14] The basin is part of the West and Central African Rift System (WCARS) that is intimately associated with the opening of the South Atlantic Ocean and the formation of the Gulf of Guinea.[15-17] Several research projects have been on going in the Mamfe basin regarding geology and lithostratigraphy. With the current need of the government of Cameroon to avoid entering the state of an emergent nation in 2035, there is every need for the geology of this hinterland basins to be reviewed in order to highlight its economic potential. Therefore, the aim of this study is to present a review of the tectonic evolution, stratigraphy, hydrogeological aspects, paleontology and economic geology of the Mamfe basin. The data base for this contribution comes from previous research on the Mamfe basin. This is significant because it will awaken exploration and exploitation activities in the Mamfe sedimentary basin and further call for the government of Cameroon to fund research in the basin

Geographical setting

The Mamfe Sedimentary Basin located between 5°30' to 6°00'N and 8°15' to 9°45' E underlies a coastal plain in Cameroon with low to slightly high relief whose heights range from 30 to 300m.[4,18] It is locally bordered by high igneous terrains (Mount Nda Ali: 1200 m, Mount Mbinda: 1000 m, Nkogho hills: up to 600 m). The basin is regionally bordered by upland areas (Figure 2) (Mount Rumpi, Bambouto, Bamenda, Manengouba and Koupe), which are part of the Cameroon Volcanic Line.[19,20] The Mamfe Basin is administratively situated in the Manyu Division made up of four sub-divisions (Mamfe Center, Eyumojock, Upper Bayang, and Akwaya) and occupied by three main ethnic groups: the Kenyangs, Akwayas, and Ejagham.[18] It measures 130 km in length and the widest part is about 60 km and a maximum area of 3200 km^2.[21] The maximum sediment thickness is estimated at 4–7 km.[22,23] The climate in this division is hot and humid and consists of a rainy and a dry season modified by the deviation of the monsoon and the relief of Mount Cameroon.[24] The vegetation is dominantly that of the equatorial rain forest,[18] and the drainage system is principally that of the Cross River (Figure 3) whose main source is found in Mount Bambouto.[25] The sources of its main tributaries the Munaya and Badi Rivers are at Mount Rumpi and Nda Ali respectively. [18]

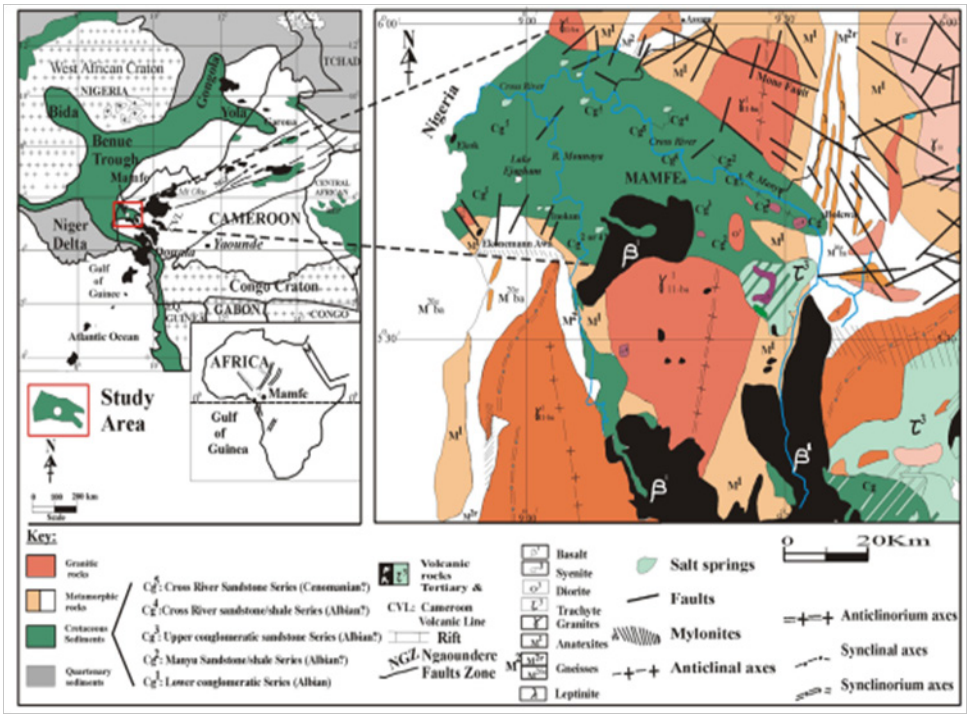

Figure 1 Location of the Mamfe Basin in relation to the Benue Trough into the south-western part of Cameroon Volcanic Line (CVL) and the West and Central African Rift System (WCARS) (adapted from Benkelil, 1989 and the geologic map of Cameroon, 1979 edition).

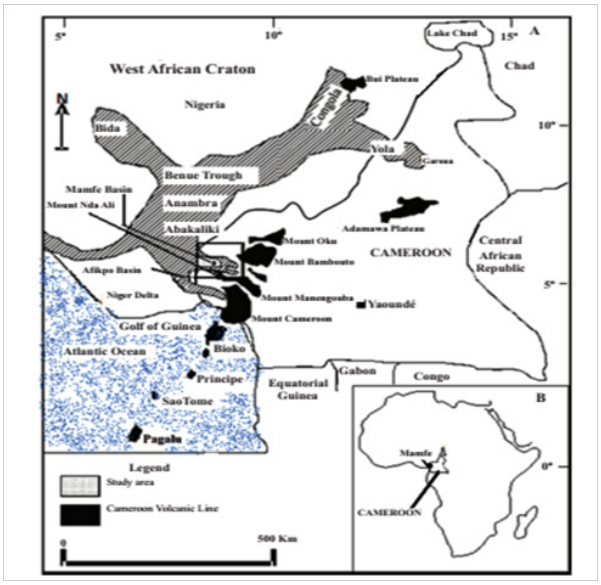

Figure 2 Location of the Mamfe sedimentary basin in the regional context (Benkhell, 1989 and Maluski H et al. 1995).

Tectonic evolution

The Mamfe Basin is an appendix of the Benue Trough located at the South East border. The Benue Trough and associated basins (Figure 4) including the Gongola Trough (extending N-S mostly in Nigeria), Bornu (extending W-E and reaching Cameroon eastwards) and Yola basins are located in the convergence of the West African Rift System (WARS) and Central African Rift System (CARS) in the junction between the Northwest, Northeast and Southern African plates.[9] The Benue Trough represents the abandoned arm of a ridge-ridge-fault triple junction at the origin of the opening of the South Atlantic Basin and extension in the WARS and CARS.[9,26-30] The trough represents a major direction of NE-SW filled with continental and marine sediments. Subsidence in the Benue Trough begins during the Late Jurassic - Barremian interval;[9,30,31] the oldest sediments, Barremian in age[30] are conglomerates, covered with lacustrine deposits. In north-eastern Nigeria, marine conditions partly occurred during the latest Cenomanian latest "Senonian" (Campanian Maastrichtian?) interval.

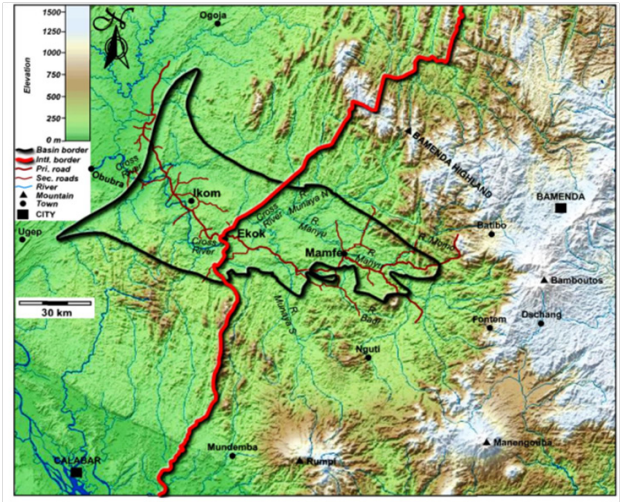

Figure 3 Map of SE Nigeria and SW Cameroon showing drainage and road network within Mamfe basin (Modified from Google Terrain Map).

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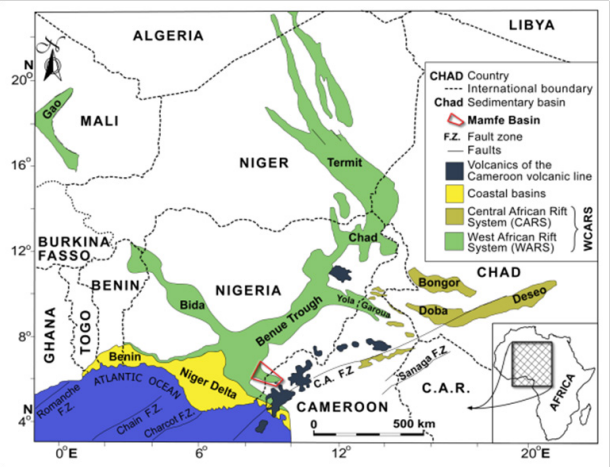

Figure 4 Map of the Benue trough, the West and Central African rift systems (WCARS) in western Central Africa (After Genik, 1993).

The Mamfe basin is laterally correlated to the Asu River Formation in Nigeria.[9] It is an important tectono-sedimentary and intra-continental geological structure.[14] The Mamfe sedimentary basin is a rift basin that was initiated by the response of the Precambrian basement of this region to the break-up of Gondwana and subsequent separation of South American from the African continental plate.[2,5,9,11,12] Like other rift basins of this sub-region, the Mamfe Basin is part of the West Central African Rift System (WCARS) that is intimately associated with the opening of the South Atlantic Ocean and the formation of the Gulf of Guinea.[17,32] During its formation, this basin appeared as a bifurcation or an eastern tectonic arm that extended eastward from the south-eastern portion of the Benue Trough into the south-western part of Cameroon. It should be noted that, like the Mamfe Basin in the south-east, a second arm also extended eastward into Cameroon, but from the north-western portion of the Benue Trough, known as the Garoua Basin.

Abolo[33] outlined a five phased tectono-stratigraphic evolution of the Mamfe Basin slightly modified here as follows:

- Eo-rift phase that was characterized by the initial rifting and possible deposition of the first alluvial fan conglomerates during the Barriasian-Pre Barremian.
- Syn-rift and subsidence phase (Barremian-Early Albian and Late Albian-Cenomanian) during which rifting and alluvial fan conglomerates deposition continued together with fluvial sandstones and lacustrine shales.
- Post-rift phase-1 characterized by folding, faulting and erosion which occurred during the Santonian-Early Campanian in response to the Abakaliki tectonic event in Nigeria.
- Post-rift phase-2 which include all other events that occurred during the latest Cretaceous and beyond; continued erosion, magmatization and possibly uplift.

Table 1 Various Stratigraphic frame works of the Mamfe Basin in use as proposed by some authors. Note the disparities in the subdivisions and nomenclature of the various units

Stratigraphy of Mamfe Basin		Le Fur (1964)	Dumort, (1968)	Eseme, (2006)	Abolo, (2008)	Bassey *et al.*, (2013)	Eyong *et al.*, (2013)	
Age	**Formation**		**Series**	Series	**Members**		**Formation**	**Members**
Tertiary			Volcanics	Igneous rocks				volcanics
Cenomanian		Cg5	Cross River sandstone series	Arkosic and conglomeratic sandstones	Manyu	Kesham	Cross River	Esagem /Munaya
Albian	Mamfe Formation	Cg4	Clayey sandstone series	Shales (oolitic, bituminous)		Manyu	Baso	Bagba
		Cg3	Upper conglomeratic series	Sandstones and conglomerates	Nfaitok		Nfaitok	Okoyong
		Cg2	Manyu clayey sandstone series	Shales intercalated with sandstones; evaporites?				Mamfe
		Cg1	Lower sandy conglomerate series	Conglomeratic sandstones with basement fragments	Etoko/ Okoyong			Manyu
							Ngeme	Basai/Inokun
Pre-Cambrian	Basement	Granito-gneissic	Granito-gneissic	Granito-gneissic	Granito-gneissic	Basement	Granito-gneissic	Granito-gneissic

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Stratigraphy

The stratigraphic framework of the Mamfe Basin was initiated by the early authors; Wilson[1], Le Fur[34], Dumort[4]. The sedimentary infill of the Mamfe Basin is collectively and formally referred to as the Mamfe Formation. The type locality of this formation is at the banks of River Manyu in Mamfe.[1,3,35] Further and most recent publications are marked by gross inconsistencies in the manner in which each author sub-divides and present the framework of the sedimentary deposits of this basin. Le Fur [34] had earlier recognized and sub-divided these rocks into five units (Series) which were identified as C1 to C5 respectively from base to top. IRGM/DYU1 (2000) recognized only three units (unspecified) that were later on supported by Abolo[33] who packaged the entire 4000 m thick sedimentary infill of the Mamfe Basin into a single formation made up of three members. Eyong et al.[17], on the other hand, sub-divided these same rocks into five formations some which were further sub-divided into several members. Bassey et al.[36] further compounded the controversies by recognizing only two members from a lone Mamfe Formation. However, preliminary outcomes of current research aimed at appropriately correcting the stratigraphic framework of the Mamfe Basin are pointing to three fundamental stratigraphic units (Formations) for this basin.

Paleontology

Fossils that have thus far been identified in sediments of the Mamfe Basin include impressions of Lower Cretaceous ichthyodectiform fish *Proportheus kameruni jaekel*,[1] Otracods ichnofossils, conchostracan of the genus *Estheriina*,[17] and abundant microflora.[37,38] The reported fauna have no biostratigraphic significance because of their uncertain age, low diversity, and cosmopolitan distribution during the early Cretaceous.[39-41] Also, recent dinosaur trackways have been reported in the Cretaceous strata at Nfaitok Bridge by JE Martin 2017.

Hydrogeology

The Mamfe Formation constitutes the main source of groundwater supply in the basin. In area of shallow depth the basement complex can supply groundwater. Since ground water is confined to the zones of weathered rock, joints and fractures in the basin. Mamfe basin is characterized by evaporate deposits that constitute the sediments of the basin high mineralized Soduim Chloride composition and Total dissolved solute higher than sea water range from 13000 to 36000 mg/L. Meanwhile, the large part of the water of the basin is in good quality and content (Ca, Na) - HCO_3).[42-44]

Economic geology

Important mineral indices have so far been identified in the basin. Lead, Zinc, Rutile and Sapphire have been identified by Lapplaine and Soba,[45] Du Mort,[4] Ndougsa-Mbarga et al.[11] Kanouo,[18] Kanouo et al.[46] Nguimbous-Kouoh, Takougam, Nouayou, Tabod and Manguelle-Dicoum.[12] Carbonate, sulphide and evaporite minerals have widely been reported in Cretaceous sedimentary facies of the Mamfe Basin in Cameroon.[1,4,34] In addition, over 30 salt springs exist across the Mamfe basin[47] with the most concentrated yielding 79 g/L of high quality halite.[53] Gem corundum and coarse zircon have been reported in detrital sediments (in Nsanaragati) at about 10 km east of the nearest basaltic flow in Ekok.[18,46] Although not yet confirmed, the presence of diamond indices within sedimentary clasts in the western part of Mamfe Basin is mentioned in Laplaine and Soba.[45] The aspect of the depositional environments and petroleum geology of the Mamfe Basin has been reported by Wright et al.[48] Ajonina;[14] Ajonina et al.[49-51] Bassey and Ajonina;[52] Eyong,[41] Eseme et al.[53] Abolo;[33] Bassey et al.[36] Eyong et al.[41] Njoh and Njie.[54] Geological condition that favour the discovery of hydrocarbon occurrence in the Mamfe basin. SNH [55] proposed the hydrocarbons generation and migration as followed:

- Occurred during Santonian and Early Tertiary.
- Source rocks are located at the center of the basin. Shallow reservoirs appear at the east due to uplifting and erosion, suggesting hydrocarbon migration to the surface and hydrocarbon destruction by meteoric waters. Deep reservoirs are elsewhere across the basin.
- Geological models suggest that hydrocarbons can still be trapped within deep structures.

Discussions and conclusion

The geology of the Mamfe sedimentary basin is characterized with four stage tectono-stratigraphic evolution that is the Eo-rift phase, Syn-rift and subsidence phase, Post-rift phase-1, and Post-rift phase-2 in which the following type of rock have being deposited: alluvial fan conglomerates, fluvial sandstones and lacustrine shales, fault-bounded granitogneissic rocks of the Pan-African Mobile Belt (550±100 Ma) and Tertiary anorogenic and effusive basic intermediate rocks such as syenites, diorites, trachytes and basalts that belong to the CVL. The stratigraphy succession of the Mamfe basin is highly controversial as there is no accepted lithostratigraphy framework for the basin. However current research is pointing to three fundamental stratigraphic member for this basin. Until these findings are published, it is generally agreed by many that the rocks of this basin can best be sub-divided into three members: a lower alluvial fan conglomerate to a fluvial channel cross bedded conglomeratic sandstone, a middle predominantly repeated sequences of alternating black shales, limestones, sandstone and evaporates (lacustrine), and another fluvial sandstone unit at the top of the basin. In term of its economics potential the basin is endowed with several mineral indices (including diamond) and the geological condition favour the occurrences of hydrocarbon.

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