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# INVERSION TECTONICS OF THE BENUE TROUGH

**L. I. MAMAH, C. O. OKOGBUE, and K. M. ONUOHA**

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ABSTRACT

The Benue Trough, an aulacogen at the re-entrant of the Gulf of Guinea in Nigeria, has been historically studied from the concepts of ortho-mio-eu – geosynclines at outcrops and in the subsurface. Its structural evolution reveals a tectonic scenario compatible with Plate tectonic evolution of the Atlantic Ocean. Spreading was, however, arrested by the rotation of the hot spot plumes onto the shoulders of the trough such as unto the Cameroon volcanic line by a sequence of events including crustal thinning and doming, rifting and faulting, grabens and horst formation, volcanism and subsidence, imbricate sedimentation and eustatic sea level changes, as shown by surface and sub surface studies.

**KEYWORDS:** ortho-geosyncline, mio-geosyncline, eu-geosyncline, aulacogen

## INTRODUCTION

### Early Basin formation hypothesis

Geosynclines are generally understood as thick accumulation of sediments prior to mountain building. This was the view of American and European geologists in the 19th century (1859 1900; Dott 1964). At the turn of the 19th century geosynclines (ortho- geosynclines) were thought to have been initiated on elongate linear basins by ophiolites sequences consisting of oceanic ultramafic and mafic igneous rocks succeeded by deep marine siliceous and argillaceous sediment fill (Dott 1964).

*Geosynclinal theory* gradually gave way to the *tectonic cycle* which supported that orogens ( belts of deformed rocks in many places accompanied by metamorphic and plutonic rocks as in Appalacian orogen ) developed in a similar manner and mostly at about the same time. According to Cady 1950 such a tectonic cycle would consist of:

(a) *Primary geosynclines* with actuate belts of mio-eugeosyncline couples and sub-marine volcanism, where *Miogeosynclines* are wedge accretion shelf sediments usually not associated with volcanism and *eugeosyncline* which is associated with volcanism and sedimentation. The volcanic part including ophiolites and plutons are usually in platform areas. Miogeosynclines lacked such rocks as carbonate rocks but are abundant in mature sandstones while greywacke and chert are more abundant in eugeosynclines.

(b) Primary mountain building cycle is said to succeed primary geosynclines. The primary *mountain building cycle* consists of nappes, syn-orogenic batholiths, and metamorphism which develop along geanticlines and secondary geosynclines.

(c) *A secondary mountain building cycle* would consist of folds and thrusts in secondary geosynclines with granitic plutons and alkalic intrusions and.

(d) A fourth cycle of *differential uplifts and subsidence* and block faulting such as the formation of grabens and plateau basalts.

Beloussov 1962 on the other hand recognized that such tectonic classification such as Cady's is associated with *subsidence stage* which is usually accompanied by marine transgressions and accumulation of sediments with minor folding and faulting, and a *basin inversion stage* representing a transition from subsidence to uplift and the general *mountain building stage* with faulting and igneous activity.

These cycles and stages in the Benue trough have been studied for many targets, such as lead –zinc mineralization or for coal deposits in the past (Mackay 1950, Simpson 1954); and more recently for petroleum deposits. The results of the various works show that a thick sedimentary cover starting with Asu River Group Formation of sandstones, limestones and shales were deposited during the Albian transgression. This formation and the subsequent ones of comparable age (Santonian) alternate in lithology typical of eustatic sea level changes resulting from basin inversion tectonics concomitant with folding (Nwachukwu 1972). The folding was predominantly compressional (Benkhelil 1988). The basin inversion created a sub basin with an axis off set by about 145km to form the Anambra and the Afikpo sub basins in the lower trough (Ofoegbu and Onuoha 1999). Popov 2004 however contends that such an axial shift was as a result of transpressional rotation about the Chain and Charcot transform faults with paleo signatures as the marginal fault bounding the trough and other complimentary faults. We are presenting new evidence in this paper to support the plate tectonic origin of the trough.

### Unifying Plate tectonic model

A unifying tectonic model was introduced by Dietz (1963) with the pioneering theory of *sea floor spreading* which established that continents were conceived as plates, undergoing tectonic cycles of *contraction and extension tectonics*. The plate tectonic model saw continents as plates with definite boundary characteristics such as with convergent or divergent properties. In this model Gondwanaland cratons were welded together during Neoproterozoic – pan African orogenies (1300 – 1000 ma) as a result of ocean closures, and continental collisions. The evidence of these orogens include imbrications, nappes and suture lines such as the pelusian mega suture with metamorphic isograde ranging from granulites to amphibolites ( Rahaman and Ocan 1978, Chukwuike 1981, Adekoya 1978,1993, Ekwueme et. al. 1988). The Ifewara fault system, for example, is 250 km in a NNE – SSW strike with nappes and imbrications coincident with the Schist belt whose western limit extends to Ghana, Togo, and Dahomey. Dates of the migmatites, quartzites and mica schists are probably 1100 – 2000 ma or pan African 550 my. (Ekwueme et. al.1988). The geodynamic setting of the belts is also controversial (Rahaman 2004).

**L. I. MAMAH, Department of Geology, University of Nigeria, Nsukka**
**C. O. OKOGBUE, Department of Geology, University of Nigeria, Nsukka**
**K. M. ONUOHA, Department of Geology, University of Nigeria, Nsukka**

Figure 1a:

Figure 1b:

***Extension tectonics***

The pelusian fracture zone has its structural axis in Nigeria today with a width of about 7 – 12 km and filled with thick sediments. The Benue trough is 170 km wide at the gulf of Guinea and is about 50 km wide at the continent in upper Benue trough (Hoque 1981). In accordance with the plate tectonic theory, *convection currents* initiated the mantle plume (such as shown in Fig 1a.), causing *crustal doming and subsidence, transgressions and regressions* as evident both on the surface outcrops Fig.2a. and in the subsurface Fig 2b; and at the equatorial bulge in a triple junction off the gulf of Guinea. The triple junction bulge created fractures that initiated the mio-geosyncline (gulf of Guinea) and consequently the *orthogeosyncline* that became the Atlantic Ocean; and then the transverse geosyncline (appropriately referred to here as the *miogeosyncline*, or *the eugeosyncline* or *the alacogen*) also known as the Benue trough which failed to develop into an ocean. Spreading was however known to have been recorded by late Jurassic Niecomian or Santonian as evidenced by alkali rhyolites at Burashika area and transitional alkalic basalts in Shani in the interval 146 ma ± 75 to 127 ma ± 6, in northern Benue Trough. The second magmatic period took place from Albian to Turonian in Nahantsi and Guburandi with emplacement of transitional alkali and tholeitic basalt respectively (Guirad 1989)

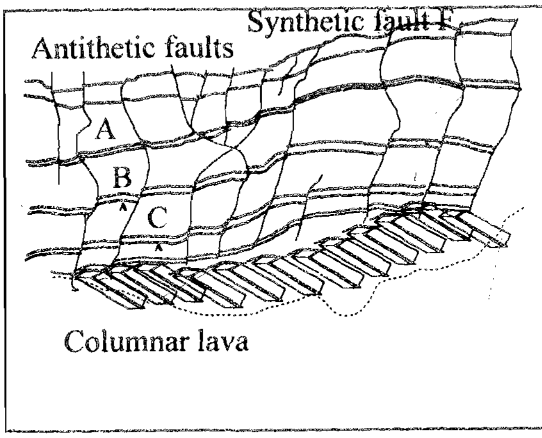
In the south Uzuakpunwa (1974) and Mamah (1975) had mapped Turonian explosive volcanism in the Ezeaku formation of the Abakaliki anticlinorium revealing pyroclastics and graded pisolitic carbonate granules.

Subsequent emplacement of magma may have occurred along shifted or rotated axis of the trough or on the shoulders of the trough as for examples the ring intrusions in the Jos area, and in the Biu basalts whose lava rest uncomformably on the Pan African basement or the recent volcanism along the Cameroon volcanic line. (Paschal 1999; Figs 1a, 1b.)

Conceptual magnetic profiles explaining the spreading scenario in Burashika horst is shown in Figs 3a and b. indicating respectively the paired synthetic magnetic anomaly across the northern Benue trough and the corresponding geologic model.

Correlation of surface tectonics and subsurface tectonics in the Benue aulacogen from Figs 2a and b show that:

a: There may be up to three distinct flooding surfaces



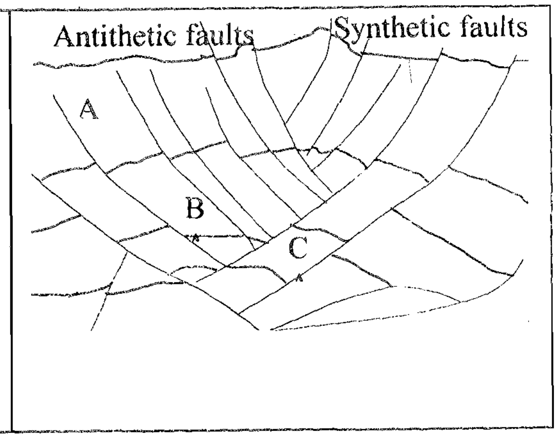
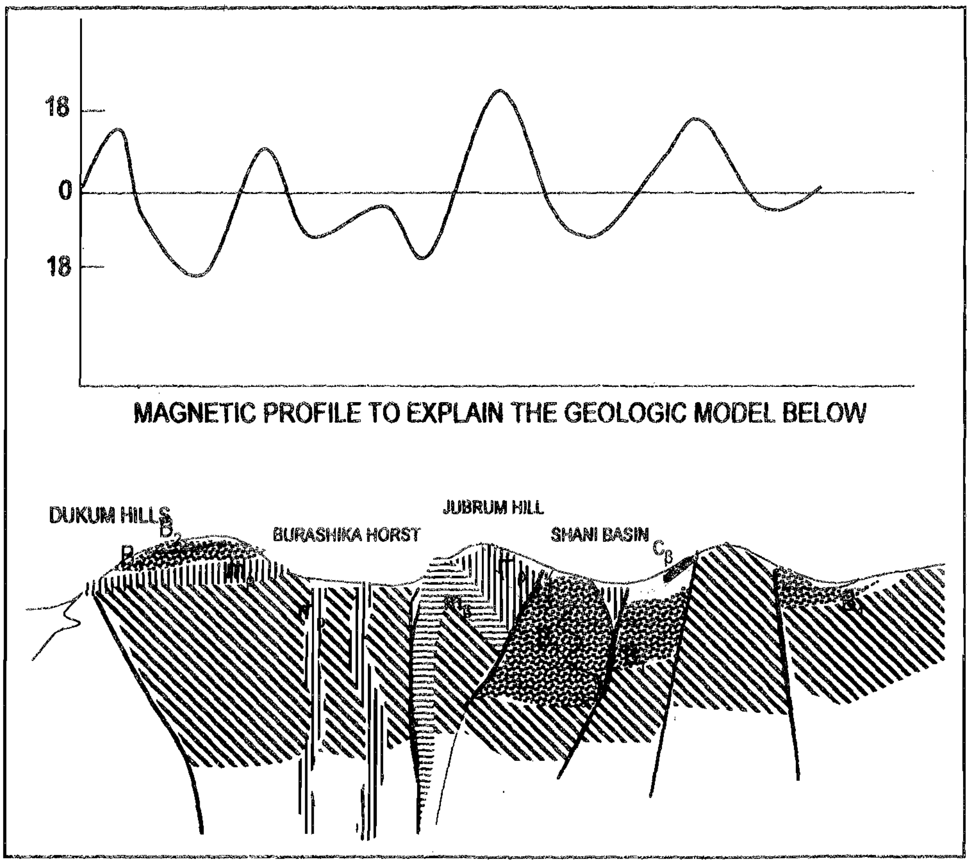




Fig 2a. Showing columnar structure of lava And cyclic sedimentation with regressive and transgressive phases at a surface outcrop (adapted from The Crust 1999 Cover picture)

Fig 2b. Subsurface correlation of the outcrop events from a seismic section from the Niger Delta. (adapted from Mamah 2000).




**Figs 3a and b. Show respectively the paired synthetic magnetic anomaly across the northern Benue trough and the corresponding geologic model. (Modified from Guirad 1989; Ofoegbu 1985)**

distinguished by the condensed sections (Fig 2a.) where major sequences are demarcated by thin faulted condensed sequences. The seismic section (Fig 2b) shows consolidated sequences with high amplitude contrast which may coincide with the condensed section.

b: Doming is associated with magma thrusts; fracturing, eustacy as indicated by up to five condensed sequences representing transgressions and regressions (Figs 2a. and 2b).

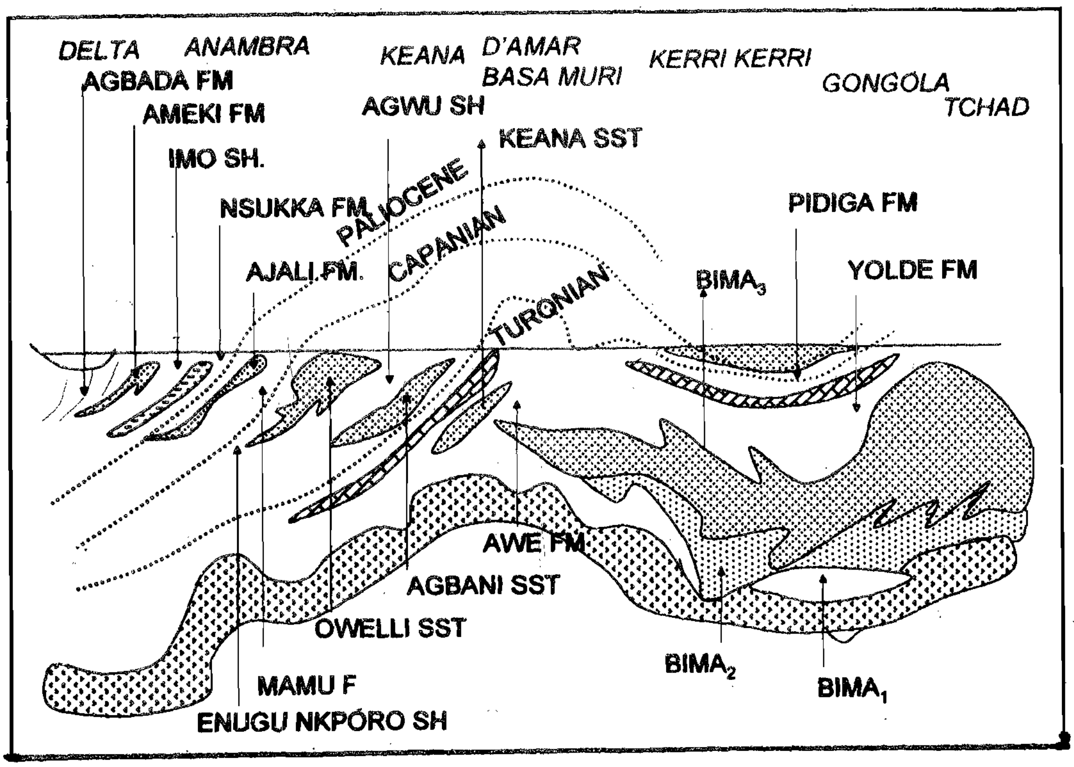



**Fig 4 Synthetic basin fill and the approximate time plane along the Benue trough (After Benkeli 1988)**

c: Types of fractures include synthetic and antithetic complementary types, and en echelon types

d: Fracturing may have been conduits for escape of gases and percolation of fluids, (Fig 2b) as insinuated from the distorted top horizons in black (Fig 2b).

e: Subsidence was the result of cooling of the magma (Fig2a).

f: Cooling is exhibited by columnar structures in basalt/rhyolites (Fig 2a).

g: Grabens and horst structures are exhibited as either exposed outcrop, (Fig 2a) or in the sub-surface (Fig 2b).

h: Unclear nature and depths and sizes of the imbricate units in the various sub basins of the trough as shown on (Fig 4).

## CONCLUSION

The geosynclinal theory in many respects explains the tectonic events of the Benue trough but lacks the global time uniqueness. The stages of the trough evolution within the plate tectonic model have been summed up by outcrop evidence and geophysical subsurface investigations and comprise the following: crustal thinning and doming; rifting and faulting; volcanism and subsidence; sedimentation and eustatic sea level changes. The northern and southern Benue trough examples investigated show that the cycle is repeatable. The most recent volcanism of April 2001 also lends credence to the cyclic episodes and rotation of hot spot plumes in the Benue trough as perhaps the motivating factor to the failed aulacogen. The extent and nature of deposited sediments remain to be properly understood especially in the subsurface.

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