Tectonophysics 676 (2016) 250–260

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Crustal structure of Nigeria and Southern Ghana, West Africa from P-wave receiver functions

Ofonime Akpan [a,b,*], Andrew Nyblade [c,d], Chiedu Okereke [b], Michael Oden [b], Erica Emry [c], Jordi Julià [e]

[a] Centre for Geodesy and Geodynamics, Toro, Nigeria
[b] Department of Geology, University of Calabar, Calabar, Nigeria
[c] Department of Geosciences, Pennsylvania State University, University Park, PA 16802, USA
[d] School of Geosciences, The University of the Witwatersrand, Johannesburg, South Africa
[e] Departamento de Geofísica & Programa de Pós-Graduação em Geodinâmica e Geofísica, Universidade Federal do Rio Grando do Norte, Natal, Rio Grande do Norte, Brazil

ARTICLE INFO

Article history:
Received 20 November 2015
Received in revised form 1 February 2016
Accepted 2 February 2016
Available online 11 February 2016

Keywords:
Nigeria
Ghana
Neoproterozoic
Paleoproterozoic
Crustal structure
Suture zones

ABSTRACT

We report new estimates of crustal thickness (Moho depth), Poisson's ratio and shear-wave velocities for eleven broadband seismological stations in Nigeria and Ghana. Data used for this study came from teleseismic earthquakes recorded at epicentral distances between 30° and 95° and with moment magnitudes greater than or equal to 5.5. P-wave receiver functions were modeled using the Moho Ps arrival times, H–*k* stacking, and joint inversion of receiver functions and Rayleigh wave group velocities. The average crustal thickness of the stations in the Neoproterozoic basement complex of Nigeria is 36 km, and 23 km for the stations in the Cretaceous Benue Trough. The crustal structure of the Paleoproterozoic Birimian Terrain, and Neoproterozoic Dahomeyan Terrain and Togo Structural Unit in southern Ghana is similar, with an average Moho depth of 44 km. Poisson's ratios for all the stations range from 0.24 to 0.26, indicating a bulk felsic to intermediate crustal composition. The crustal structure of the basement complex in Nigeria is similar to the average crustal structure of Neoproterozoic terrains in other parts of Africa, but the two Neoproterozoic terrains in southern Ghana have a thicker crust with a thick mafic lower crust, ranging in thickness from 12 to 17 km. Both the thicker crust and thick mafic lower crustal section are consistent with many Precambrian suture zones, and thus we suggest that both features are relict from the collisional event during the formation of Gondwana.

1. Introduction

In this paper we report the first seismological estimates of crustal structure in Nigeria and Ghana using broadband data from the Nigeria and Ghana national seismic networks. In spite of the prominent role Nigeria and Ghana play in supplying the world with petroleum and other natural resources, very little is known about crustal structure within these countries as it relates to the geologic development of key tectonic features, such as the Cretaceous Benue Trough and the West African passive margin. The only published estimates of Moho depths in Nigeria come from regional gravity studies (e.g., Fairhead and Okereke, 1987, 1988; Okereke, 1988; Fairhead et al., 1991) or continental (Tugume et al., 2013) and global (Mooney et al., 1998; Bassin et al., 2000; Laske et al., 2013) models of crustal structure. Ghana has experienced historically large earthquakes, yet information on the crustal structure within the country is generally lacking. Previous information about the Moho depths in Ghana has come from regional gravity studies (Ako and Wellman, 1985), seismological studies (Bacon and Quaah, 1981), as well as continental and global models of crustal structure (Mooney et al., 1998; Tedla et al., 2011; Tugume et al., 2013; Laske et al., 2013).

Data from eleven broadband seismic stations have been used to obtain new point estimates of crustal thickness, V_p/V_s ratios, and crustal shear-wave velocities in two different tectonic regions of Nigeria, the Precambrian basement complex and the Cretaceous Benue Trough, and three different tectonic regions in Ghana, the Birimian and Dahomeyan terrains, and the Togo Structural Unit. The estimates come from Moho Ps arrival times in P-wave receiver functions (PRFs) (Zandt et al., 1995), applying the H–*k* stacking method of Zhu and Kanamori (2000) to PRFs, and a joint inversion of PRFs with Rayleigh wave group velocities (Julià et al., 2000, 2003). The new estimates are used to examine crustal structure in Nigeria and Ghana by comparing them with the structure of similar age crust in other parts of Africa, and with Moho depth estimates from previously published studies in Nigeria and Ghana.

2. Background

Nigeria consists of three major tectonic units, the Neoproterozoic basement complex, the Jurassic Younger Granites complex, and the

* Corresponding author at: Centre for Geodesy and Geodynamics, Toro, Nigeria. Tel.: +234 8036141300.
E-mail address: ofonua@yahoo.com (O. Akpan).

http://dx.doi.org/10.1016/j.tecto.2016.02.005
0040-1951/

Cretaceous to Recent sedimentary successions comprised of the Niger Delta, the Benue Trough, and the Borno, Dahomey, Bida and Sokoto basins (Obaje, 2009; Fig. 1). The seismological stations used in this study are located in the basement complex and Benue Trough.

The basement complex is a component of the West African Pan-African mobile belt (Black, 1980; Wright et al., 1985; Ajibade and Fitches, 1988; Ekwueme, 1990). In addition to the Pan-African tectonothermal event (Burke and Dewey, 1972; Ajibade and Fitches, 1988; Obaje, 2009), several older orogenies are recorded in the basement complex, including the Liberian (2700 ± 200 Ma), Eburnian (2200 ± 200 Ma) and Kibaran (1100 ± 100 Ma) orogenies (Ajibade and Fitches, 1988; Obaje, 2009; Ogezi, 1988; Rahaman, 1988; Ajibade et al., 1988; Dada, 1998). The basement complex, which was later intruded by the Younger Granites, is present throughout the country, underlying the sedimentary basins listed earlier (Avbovbo, 1980; Obaje, 2009). The rocks commonly found in the basement complex range in metamorphic grade and include migmatites, gneisses, schists, quartzites, granulites, amphibolites, phyllites, marbles, and igneous rocks such as calc-silicates, granites, syenites, granodiorites, adamellite, quartz monzonites and charnockites (Rahaman, 1988).

The Benue Trough is oriented in a NE–SW direction and is a component of the West and Central African Rift System with a length and width of about 800 km and 150 km, respectively (Benkhelil, 1989; Ofoegbu and Okereke, 1990; Obaje, 2009) (Fig. 1). It developed as a failed arm of the RRR Triple junction (aulacogen) following the separation of South America and Africa during the opening of the South Atlantic Ocean in the Early Cretaceous (Ofoegbu and Okereke, 1990; Binks and Fairhead, 1992; Guiraud and Maurin, 1992). After the Santonian tectonic and magmatic events, the major depositional axis in the Lower Benue Trough was shifted to the northwest, leading to the formation of the Anambra Basin (Wright et al., 1985). Therefore, the Anambra Basin is regarded as a part of the Lower Benue Trough containing post-deformational Campanian to Eocene deposits (Obaje, 2009). Several magmatic events affected the Benue Trough (Agagu and Adighije, 1983), most prominently the ones during the late Albian and Turonian (Offodile, 1976).

Moho depth estimates of 20 to 26 km beneath the Benue Trough and its adjoining rifts in Nigeria are reported in regional gravity studies (e.g. Fairhead and Okereke, 1987, 1988; Okereke, 1988; Fairhead et al., 1991). Within the rifted parts of the Benue Trough in Cameroon i.e. the Garoua rift, Moho depth estimates of 23 to 28 come from regional gravity studies (e.g. Poudjom Djomani et al., 1995; Nnange et al., 2000; Kamguia et al., 2005) and seismological studies (e.g. Stuart et al., 1985; Tokam et al., 2010). Continental and global models of crustal structure show Moho depths of 25 to 42 km on average beneath the Cretaceous Benue Trough and Precambrian basement complex, respectively (e.g. Mooney et al., 1998; Bassin et al., 2000; Tugume et al., 2013; Laske et al., 2013).

The geologic framework of Ghana consists of five major tectonic units, (1) the Paleoproterozoic Complex, including the Birimian and

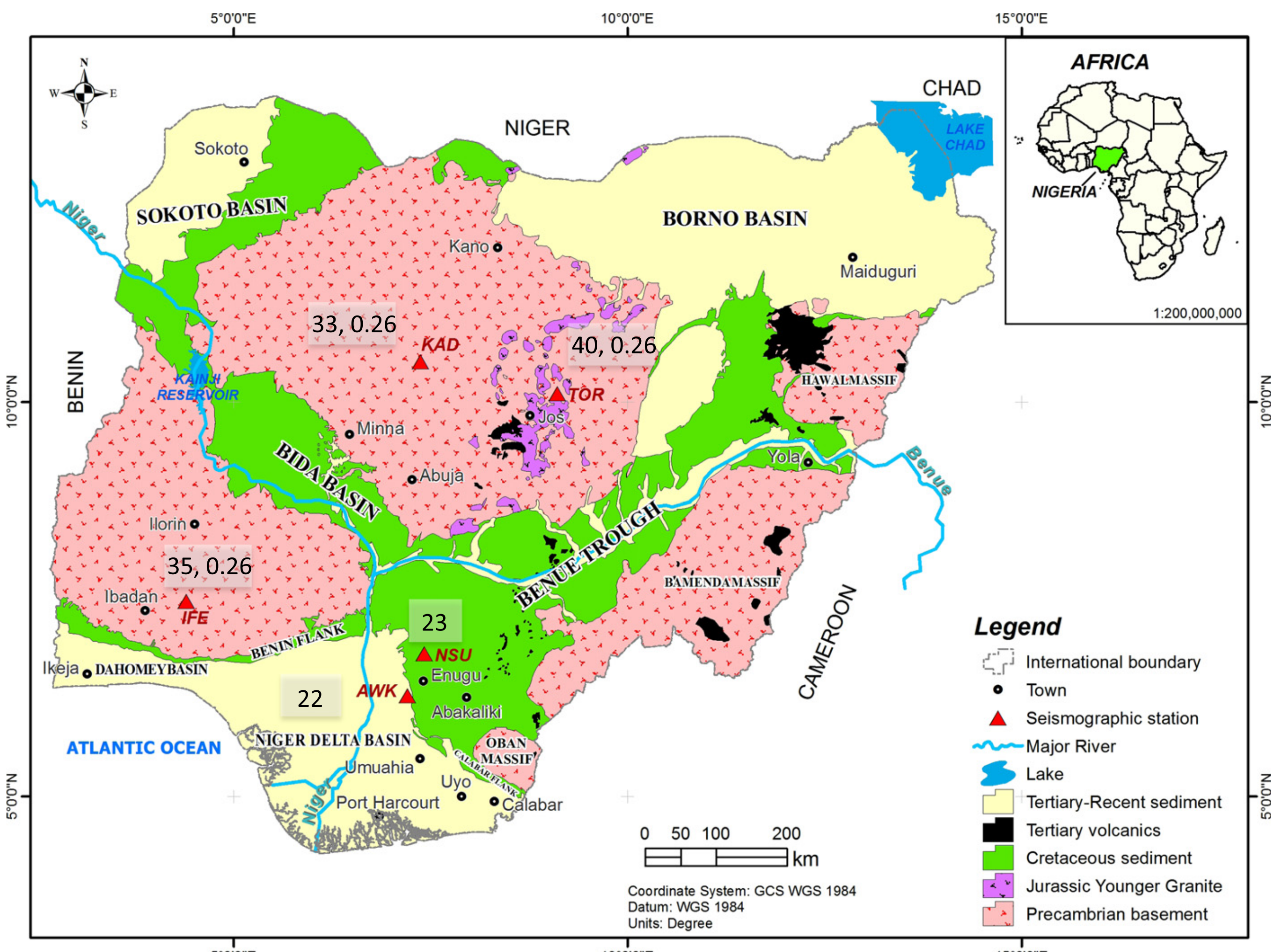

Fig. 1. Geological map of Nigeria showing the major tectonic features, seismological stations, Moho depths and Poisson's ratios (the first and second numbers close to each station).