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STUDY OF RELATIVE TRAVEL TIME RESIDUALS OF P-WAVE AT TELESEISMIC DISTANCES AT THE AHMADU BELLO UNIVERSITY ZARIA SEISMIC STATION

A. S. ONIKU, O. S. BAKARE and O. I. BABATUNDE

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ABSTRACT

Relative travel time residuals at the Ahmadu Bello University Zaria seismic station have been studied. About thirty events which were recorded by all the stations in the stable West Afican craton, Congo craton and the seimically active East African rift valley were considered. These events were randomly distributed in five different regions. It was found that the trend of the relative travel time residuals is an indication of lateral in homogeneity of the crust and upper mantle between the various stations and Zaria station. Also the study reveals that the relative residuals are highly dependent on the direction of approach of P- waves.

KEYWORDS: Relative, teleseismic, Events, P-wave, Residuals

INTRODUCTION

Teleseismic P-wave travel time residuals find useful applications in the study of crustal and upper mantle structure especially with regards to the geodynamic processes taking place in these regions. The basic assumption of the method is that seismic wave velocities vary not only as a function of the dilatant behavior within the stressed medium, but also with changes in the state of the material caused by external processes such as heat, pressure and other similar factors. It is, therefore, of interest and practical importance to monitor tectonic regions for velocity changes. A distinct velocity difference is expected, for example, between stable shield regions and regions of recent tectonic activity. These variations manifest themselves in many ways, including:

1. regional deviations from standard velocity-depth functions.
2. lateral variation of crustal structure
3. lateral variation of the upper mantle low velocity layer
4. lateral inhomogeneities in the lower mantle.

One approach to the study of this effect is to use the large number of recorded teleseismic earthquakes as signal sources to monitor P-wave travel-time residuals in order to isolate velocity changes occurring in the vicinity of the receiver. This approach is useful, for example, in regions without local networks and of low seismicity, such as in Nigeria where velocity data on a local scale is not available.

However, travel-time residuals suffer a major difficulty in isolating that part of it associated with changes in crustal velocity near the receiver from travel-time variations produced by earth structure near earthquake source and along paths within the lower mantle (Engdahl et al;1977, Dziewonski and Anderson, 1984). For this reason, the station residuals may be isolated by independent studies of the station region (e.g. seismic refraction studies) or through the relative residuals. Relative travel-time residual are computed relative to a reference station in a group, and ensures that the residuals are not limited by the uncertainty of the absolute value of the travel-time but by that of the slope of the travel-time standard (Agarwal *et al.*; 1976).

The aim of this study is, therefore to establish the relative travel time residuals between Zaria station and some near by stations in West Africa, Central Africa, and East Africa (Fig. 1) by considering some events recorded by all the stations so that the effect due to travel time variations produced by the earth structure could be reduced to that of the earth structure along the propagation path.

METHODOLOGY

A travel-time residual is defined as the difference between the observed travel-time of the seismic wave and the theoretical as obtained from the J-B tables. In the computation of travel times, the following conditions must be satisfied:

1) Focal parameters of an earthquake, i.e. geographical coordinates, focal depth, and the origin time t_o, must be accurately known.

2. Accurate measurement of the arrival time, t_a, of the seismic phase of interest at the observing station must be made.

3. Geographical coordinates of the station must also be known in order to determine the epicentral distance of the earthquake from the station.

4. There must be the existence of a standard travel time table which describes the travel time, T, as a function of epicentral distance, A and focal depth, h. This gives the theoretical travel time $T_c = T(A, h)$ for a standard earth model. The observed travel time is given as

$$T_o = t_a - t_o \quad (1)$$

while the absolute travel time residual is defined as

$$R = T_o - T_c \quad (2)$$

For this study, the focal parameters were obtained from the monthly listings of the Preliminary Determination of Epicentres (PDE) published by the United States Geological Survey (USGS) National Earthquake Information Centre. The seismic phase used was P-phase and the Jeffreys-Bullen (J-B) travel time tables (Jeffreys and Bullen, 1970) were used to obtain the theoretical travel times. Usually, travel time residuals are made up of contributions from the source region, propagation path and the station region. Therefore, a common problem in the analysis of travel times is how to distinguish between these components and also errors in the standard travel time table. This problem is greatest at small epicentral distance where the angle of incidence is large, and travel paths in the source and station regions are insignificant (Ojo, 1994). Therefore, to correct for this, this study employs relative travel time residuals

A. S. Oniku, Department of Physics, Federal University of Technology, Yola, Nigeria
O. S. Bakare, Department of Physic; Ahmadu Bello University, Zaria, Nigeria
O. I. Babatunde, Department of Physic, Ahmadu Bello University, Zaria, Nigeria

which are computed relative to a reference station in a group. The expression is given by the equation below

$$T_{ij} = r_i - r_j \qquad (3)$$

where r_j is the reference station residual, and r_i is the residual reported from other stations. Equation (3) ensures that the residuals are not limited by the uncertainty of the absolute value of the travel time but only by that of the slope of the travel-time standard (Agarwal *et al.*; 1976). Source residuals may be indicated by comparison of the source area with its surroundings (Gregersen, 1977).

DATA AQUISITION

The Ahmadu Bello University Seismic Station Zaria provided the data base used for this study. The arrival times of seismic events were picked off from seismograms recorded on daily basis since 1984 when the instrument was installed. However, because of the non-stability of the station in the first year of operation (Ojo, 1994), the data for 1984 were not considered reliable and only events from 1985 to 1992 were considered in this study. Out of a total of two hundred and thirty (230) events recorded at the station only 30 events were recorded by all the stations in Fig 1. Therefore only these thirty events were used for the computation of relative travel time residuals.

The absolute travel time residuals of these events for stations in Senegal, Cote D'Ivoire, Ghana, Central African Republic, Cameroon, Zaire and Kenya (Fig.1) were obtained from the International Seismological Centre (ISC) Bulletins. About thirty (30) events which were recorded by almost all the stations were considered for this study. The events have their sources azimuthally distributed randomly in five different regions, viz; Mediterranian, Kazakhstan, Burma/India/China, North Ascension and South and Central America.

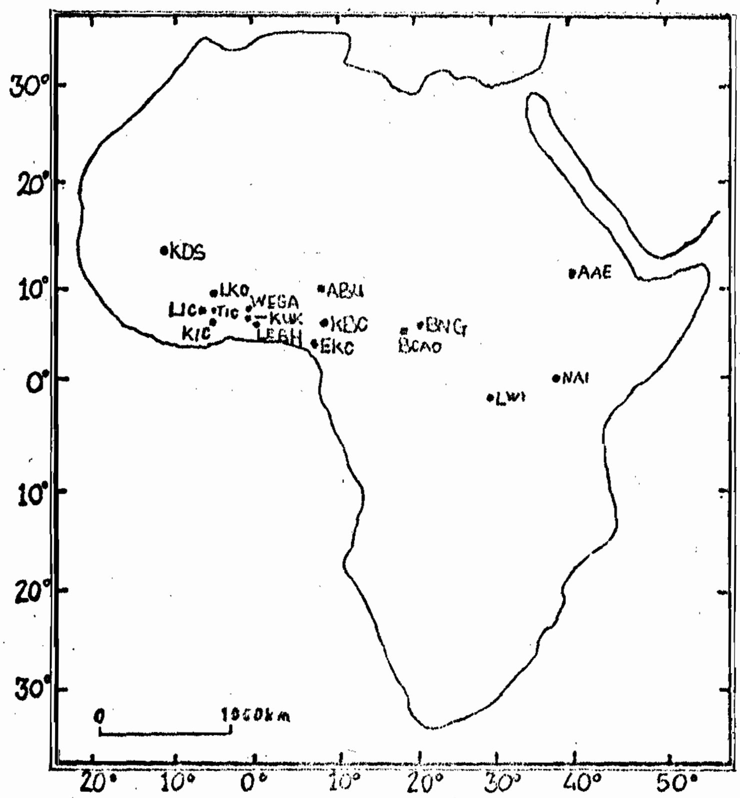

FIG. 1: Relative position of some selected seismic stations in West, Central and East Africa

DISCUSSION OF RESULTS

The absolute travel time residuals are made up of contributions from the source region, propagation path and station region, except at large epicentral distances when the source and station effects become small compared to the propagation path effect. Azimuthal contributions to the absolute travel time residuals were examined (Adetola, 1999), this reveals that there is a large scatter in the values of the absolute travel time residuals due to changes in the propagation paths. Consequently, in order to minimize the observed scatter in the absolute residuals, it is therefore imperative that the contributions be reduced to that of the station region only. To achieve this, relative residuals of some events listed in table 1 are computed relative to a reference station (Zaria) for a group of stations in Senegal, Cote D'Ivoire, Ghana, Cameroon, Central African Republic, Zaire and Kenya. The choice of Zaria as reference station is due to its central location in the group. Therefore, the contribution to the residual is reduced to the contribution due to lateral variation in the crust or upper mantle structure in the station region only.

Table 1 summarizes the absolute and relative travel time residuals for the stations and events selected for the study. The events are located in five different regions; North Ascension, Burma/India/China, East Kazakhstan, South and Central America and the Mediterranian regions (Greece, Eagean sea, coast of Libya, Ionian Sea and East Mediterranian).

A closer look at the table reveals that events from Mediterranian region have early arrivals in most of the stations except for stations in Cameroon and Kenya. The mean relative residual for this region is -1.76 ± 0.91 s. Events from South and Central America also show a negative relative residual with a mean of -1.93 ± 0.79 s for all the stations in West and Central Africa, but have a positive residual for the station in Kenya. Also, events from North Ascension indicate negative relative residuals at all stations in West and Central Africa, with a mean residual of -2.9 ± 3.5 s. The large mean relative residual and large standard deviation of events for this region is due to the high values of the absolute residuals reported by the reporting station to ISC. Events from East Kazakhstan have positive relative residuals with a mean of 0.55 ± 0.41 s, while events from India/Burma/China give negative relative residuals for all stations in West and Central Africa with a mean of -1.804 ± 0.76 s.

The trend of the relative residuals indicate lateral inhomogeneity of the crust and the upper mantle between the various stations and Zaria station; in which case the relative travel time residuals are highly dependent on the direction of approach of the P- waves (Bolt and Nuttli, 1976).

TABLE I: List of events used in computing relative residuals.

Date	Event Region	Dist (deg)	Station code & country	Absolute Station Residual, R_A	Zaria Station Residual R_s	Relative Residual $R_R = R_A - R_s$
270285	North Ascension	25.33	KIC Cote D'Ivoire	-5.1	+.5	-5.6
			KDS Senegal	-4.7		-5.2
			KBC Cameroon	+0.6		+0.1
			BNG C. Africa Republic	-1.0		-1.5
			LWI Zaire	-0.5		+1.0
			NAI Kenya	+1.7		+1.2
061288	North Ascension	25.99	LIC Cote D'Ivoire	-7.3	+0.7	-8.0
			TIC	-6.3		-7.0
			KIC	-7.1		-7.8
			LEGH Ghana	-4.2		-4.9
			KUK	-4.4		-5.1
			KOGH	-3.8		-4.5
			SHGH	-3.2		-3.9
			BNG Cen. Africa Rep.	-2.4		-3.1
			LWI Zaire	-0.9		-1.6
040289	North Ascension	26.54	LIC Cote D'Ivoire	-5.1	+0.2	-5.3
			TIC	-5.1		-5.3
			KIC	-4.7		-4.9
			LEGH Ghana	-3.4		-3.6
			KUK	-1.9		-2.1
			KOGH	-2.4		-2.6
			SHGH	-1.6		-1.8
			BCAO Central Africa Rep.	-0.2		-0.4
			BNG	+0.5		+0.3
			LWI Zaire	+0.7		+0.5
090789	North Ascension	26.31	LIC Cote D'Ivoire	-5.0	-0.6	-4.4
			TIC	-5.3		-4.7
			BNG Central Africa Rep	+0.6		+1.2
			LWI Zaire	+0.5		+1.1
140790	North Ascension	27.23	LIC Cote D'Ivoire	-3.9	-1.4	-2.5
			TIC	-4.4		-3.0
			KIC	-4.1		-2.7
			BCAO Central Africa Rep.	+1.3		+2.7
050890	North Ascension	24.62	LIC Cote D'Ivoire	-6.6	+0.3	-6.9
			NAI Kenya	+2.4		+2.1
300485	Greece	31.08	KBC Cameroon	+2.1	+1.5	+0.6
			EKC "	+1.6		+0.1
			KIC Cote D'Ivoire	-0.8		-2.3
			NAI Kenya	+1.5		0.0
280687	Coast of Libya	26.48	TIC Cote D'Ivoire	-1.5	-2.0	-3.5
			KIC "	-1.6		-3.6
			LIC "	-1.5		-3.5
			KDS Senegal	[illegible]		-3.1
			BNG Central Africa Rep	-2.0		-4.0
			BCAO "	-2.4		-4.4
			LWI Zaire	-1.2		-3.2
			NAI Kenya	+2.6		+0.6

161088	Ionian Sea	29.21	TIC Cote D'Ivoire KIC " LIC " KUK Ghana SHGH " LEGH " LWI Zaire NAI Kenya	-0.9 -0.8 -0.7 -1.6 +1.1 -0.3 -0.2 +1.9	+2.6	-3.5 -3.4 -3.3 -4.2 -1.5 -2.9 -2.8 -0.7
201188	East Meditteranian	30.69	TIC Cote D'Ivoire KIC " LIC " KUK Ghana SHGH " LEGH " BNG Central Africa Rep. LWI Zaire	-0.1 0.0 0.0 +0.1 +0.5 +0.6 +1.1 +2.4	+1.0	-1.1 -1.0 -1.0 -0.9 -0.5 -0.4 +0.1 +1.4
130986	Southern Greece	28.89	TIC Cote D'Ivoire KIC " LIC " BNG Central Africa Rep BCAO " LWI Zaire NAI Kenya	-0.8 -1.0 -3.0 -1.5 -0.8 +0.5 +3.4	0.0	-0.8 -1.0 -3.0 -1.5 -0.8 +0.5 +3.4
260185	Argentina	84.64	LIC Cote D'Ivoire TIC " KIC " BCAO Centr. Afric. Rep. BNG " NAI Kenya	-2.7 -2.5 -2.6 -0.8 -1.7 +6.2	+1.1	-3.8 -3.6 -3.7 -1.9 -2.8 +5.1
090388	Off Coast of Peru	66.92	LIC Cote D'Ivoire TIC " KIC " LEGH Ghana KUK " SHGH " BNG Central Africa Rep	-1.2 -0.8 -1.1 -0.7 +0.1 -0.2 +0.7	+1.6	-2.8 -2.4 -2.7 -2.3 -1.5 -1.8 -0.9
140888	Coast of Central Chile	85.24	LIC Cote D'Ivoire KIC " LEGH Ghana KUK " BNG Central Africa Rep. LWI Zaire	-0.8 -0.5 -0.6 -0.4 +0.1 +6.6	+0.5	-1.3 -1.0 -1.1 -0.9 -0.4 -6.1
050489	Northern Chile	81.75	LIC Cote D'Ivoire KUK Ghana BCAO Centr. Afric. Rep. BNG "	-3.9 -3.3 -2.3 -2.4	+0.6	-4.5 -3.9 -2.9 -3.0
050589	Western Brazil	80.95	LIC Cote D'Ivoire TIC " KIC " LEGH Ghana KUK "	-0.2 -0.2 0.0 -1.0 +1.2	+1.5	-1.7 -1.7 -1.5 -1.6 -0.3

			SHGH "	+0.2		-1.3
			BNG Central Africa Rep	-0.1		-1.6
			BCAO "	-0.1		-1.6
			LWI Zaire	+0.1		-1.4
291189	South of Peru	84.41	LIC Cote D'Ivoire	-1.6	+0.3	-1.9
			TIC "	-1.4		-1.7
			KIC "	-1.4		-1.7
			KUK Ghana	-0.6		-0.9
			SHGH "	-0.9		-1.2
			LEGH "	-1.7		-2.0
			BCAO Centr. Afric. Rep.	-0.4		-0.7
030487	East Kazakhstan	69.43	TIC Cote D'Ivoire	-0.1	-0.4	+0.3
			KIC "	0.0		+0.4
			LIC "	-0.1		+0.3
			BNG Central Afr. Rep.	-1.3		-0.9
			BCAO "	-1.2		-0.8
			NAI Kenya	+1.1		+1.5
040588	East Kazakhstan	69.40	TIC Cote D'Ivoire	-0.2	-1.2	+1.0
			KIC "	-0.1		+1.1
			LIC "	-0.1		+1.1
			SHGH Ghana	-0.2		+1.0
			LEGH "	+0.1		+1.3
			LWI Zaire	-0.6		+0.6
200687	East Kazakhstan	69.37	TIC Cote D'Ivoire	0.0	-0.4	+0.4
			KIC "	+0.1		+0.5
			LIC "	0.0		+0.4
			BNG Central Afr. Rep.	-1.1		-0.7
			LWI Zaire	-0.5		-0.1
			NAI Kenya	-0.6		-0.2
220189	East Kazakhstan	69.44	TIC Cote D'Ivoire	0.0	-1.1	+1.1
			KIC "	+0.1		+1.2
			LIC "	0.0		+1.1
			KUK Ghana	-0.4		+0.7
			SHGH "	-0.4		+0.7
			LEGH "	0.0		+1.0
			BNG Central Afr. Rep.	-1.0		+0.1
			LWI Zaire	-0.9		+0.2
290386	Eagean Sea	31.31	KIC Cote D'Ivoire	-1.0	+0.4	-1.4
			BNG Central Afr. Rep.	-1.4		-1.8
			LWI Zaire	-4.9		-5.3
			NAI Kenya	+4.8		+4.4
060888	Burma/India Boarder	83.08	KIC Cote D'Ivoire	+0.3	+2.6	-2.3
			TIC "	+0.1		-2.5
			LIC "	-0.1		-2.7
			KUK Ghana	-0.1		-2.7
			KOGH "	+0.2		-2.4
			LEGH "	+0.1		-2.5
			LWI Zaire	+0.3		-2.3
180587	Burma/India Boarder	82.24	KIC Cote D'Ivoire	+0.1	-0.4	+0.5
			LIC "	0.0		+0.4
			TIC "	0.0		+0.4
			BNG Central Afr. Rep.	-1.1		-0.7
			LWI Zaire	-0.5		-0.1
			NAI Kenya	-0.6		-0.2
250489	Sichuan	86.01	TIC Cote D'Ivoire	+0.1	+2.8	-2.7

	Province China		LIC Cote D'Ivoire	+0.1		-2.7
			KUK Ghana	+1.5		-1.3
			KOGH "	-0.2		-3.0
			BNG Central Afr. Rep	-0.7		-3.5
			BCAO "	-0.6		-3.4
			LWI Zaire	-0.4		-3.2
030589	Sichuan Province China	86.05	KIC Cote D'Ivoire	0.0	+0.3	-0.3
			TIC "	-0.1		-0.4
			LIC "	-0.2		-0.5
			KUK Ghana	+3.2		+2.9
			KOGH "	+5.5		+5.2
			LEGH "	+4.7		+4.4
			BNG Central Afr. Rep	-1.1		-1.4
			BCAO "	-1.0		-1.3
			LWI Zaire	+0.6		+0.3
220989	Sichuan Province China	88.26	BNG Central Afr. Rep	-0.3	+1.1	-1.4
			BCAO "	-1.1		-2.2
120488	Near Coast of Peru	83.85	TIC Cote D'Ivoire	-1.3	+2.0	-3.3
			KIC "	-1.3		-3.3
			LIC "	-1.4		-3.4
			LEGH Ghana	-3.1		-5.1
			KUK "	-0.9		-2.9
090989	South of Panama	87.00	LIC Cote D'Ivoire	-0.8	+0.7	-1.5
			TIC "	-1.0		-1.7
			KIC	-0.9		-1.6
			BNG Central Afr. Rep	-0.8		-1.5

CONCLUSION

In conclusion, this study has shown that patterns of travel time residual are a good indicator of the upper mantle structure underneath a station. The relative residuals suggests that the temperature regime of the upper mantle in the Zaria region is hotter than for other regions in the stable West African Craton and Congo Craton (Vitorello and Pollack, 1987). The tectonic process taking place in the region involves the partial melting of the emplaced granitic magma, the so called older granite which forms the basement rock.

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