Source Parameters of the Intraplate Event in Guinea, West Africa.

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ABSTRACT

This study reports the results of seismological studies conducted following the occurrence of the largest earthquake with associated ground breakage to affect Guinea, in West Africa in 100 years on December 22, 1983 (USGS location 11.93^{0}S and 13.60^{0}W) and was followed by about 1,000 aftershocks. The main shock of the intraplate earthquake was felt over an area of about 15 km and several lives and property were lost on that occasion. Earthquakes have been reported in Guinea during the century mainly in the area and to the north of Cape Verde Islands. Some source parameters of the December 22, 1983 Guinea have been calculated. Body wave magnitude m_b was calculated to be 6.3. Seismic moment, average fault dislocation, stress drop, seismic energy, and fault length were calculated to be 1.98 x 10^{20} N-m, 0.6m, 545 kpa, 1.3 x 10^{21} Joule, and 10 km, respectively. The significance of this study is its contribution to the observational data for such earthquakes in stable continental regions and for the seismicity of West Africa.

(Keywords: earthquake, West Africa, seismicity, seismic movement, average fault dislocation, stress drop, seismic energy, fault length)

INTRODUCTION

On December 22, 1983, a large earthquake, magnitude m_b = 6.3 occurred in Guinea, West Africa (Figure 1). It was followed by more than 1000 aftershocks in a region considered aseismic (USGS location, 11.95^{0}N and 13.60^{0}W). This earthquake is important because it is an example of an intraplate seismicity in a stable continental region. The main shock was felt over an area of about 15 km. The epicenter of the earthquake was located in a region bordering the West African craton at the southern end of the Mauritanides fold belt and at the edge of the Bowe Basin characterized by horizontal non-metamorphic sedimentary layers (Dorbarth, 1983). Earthquakes have been reported in Guinea during the century mainly in the area and to the north of Cape Verde Islands.

A wide range of geological features outcrops in the area; lower Proterozoic Metamorphic and granitic basement, upper Proterozoic to Devonian clayed sandstones and volcanics, large scale tectonics result from the superposition of the Pan-African orogeny (500-600 My), Hercynian folding and combined stretching and shearing induced by the opening of the Atlantic Ocean (Armijo, 1982).

No evident oceanic fractures seem to be related to the epicentral region, although the shelf extends abnormally off the Guinea coast. The topography of this area is also rather smooth, except a sandstone scarp about 30 meters high striking north-south. This region is at the foot of a large uplift, the Fouta-Djalon; its origin is not well studied, although it is generally considered as recent (Armiji, 1982).

The objective of this study is to obtain some basic source parameters of the earthquake that occurred on December 22, 1983 in Guinea, West Africa.

SEISMICITY OF WEST AFRICA

The seismicity of West Africa is low, hence the occurrence of an earthquake in Guinea was enigmatic. Notwithstanding, several large and damaging earthquakes have occurred in the region, such as in Accra, Ghana (Figure 1) and to the north of Cape Verde Islands, mainly in the coastal areas (maximum intensity 6 to 7). The existence of these large earthquakes as well as other damaging earthquakes pose a problem with respect to aseismic design of structures. The real problem is not the existence of these large earthquakes but rather the fact that the geological and tectonic correlation are in general lacking.

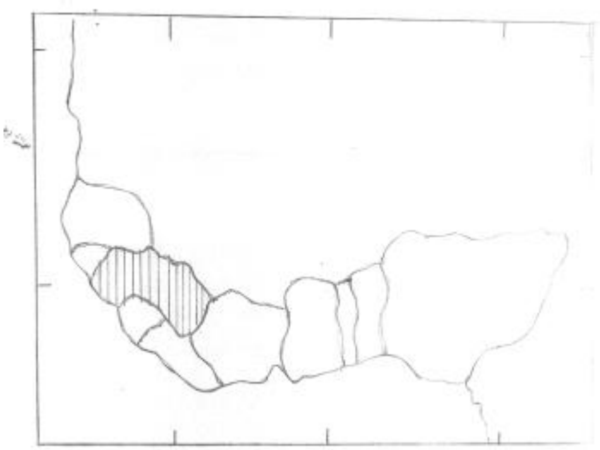

Figure 1: Map of West Africa showing Guinea, the Location of the Earthquake Studies.

This in turn hinders an understanding of the occurrence of these earthquakes. Thus the earthquake that occurred in Guinea on December 22, 1983 was significant because of its intraplate seismicity and plate driving mechanism.

A seismological station at Kedougou in Senegal, close to the Guinea border, recorded a foreshock to the December 22, 1983 event on the day before at 10.30 am with a local magnitude of 3.0 and more than 1,000 aftershocks were also recorded. Because of its significance for intraplate seismicity and plate driving mechanism, French and Moroccan seismologists conducted a seismological survey and mapped the surface breaks several days after the event.

MAIN SHOCK PARAMETERS

From an analysis of teleseismic signals, estimates of earthquake magnitude, seismic moment, and focal depth can be determined. Other parameters related to the source such as the strike of the fault and the fault area require additional geophysical data such as near field measurements (Knopoff and Mouton, 1975). A technique that is quite often used to determine the strike of the fault and the fault area of a large earthquake with aftershock activity is to measure the areal extent of the seismic activity immediately following the main shock. Later seismic activity is related to the readjustment caused by the main rupture and consequently extends over a broader region than that of the main rupture (Kanamori and Anderson, 1975).

FAULT LENGTH

In the present study, we have chosen the 24 hr seismic activity following the main shock to estimate the fault length of the latter. On this basis, we estimate a fault length of 5 to 15 km. However, when uncertainties in epicentral location of these events are taken into consideration, the above values tend to over-estimate the fault length. For this reason, the average fault length is taken to be 10 km with an uncertainty factor of +5 km.

MAGNITUDE

The magnitude of the earthquake in Guinea on December 22, 1983 was calculated on one scale. The body wave magnitude m_b was calculated using the expression (Bath and Duda, 1964):

$$m_b = 2.5 + 0.63 (\log a \; 3 \log \Delta - 2.92) \qquad \textbf{(1)}$$

where $a = 0.5$ μm, $\Delta = 10$ km

Our calculation shows that $m_b = 6.2$. This compares favorably with the result of Dorbarth et al., 1983, who obtained a magnitude of 6.3 in their analysis.

SEISMIC MOMENT

An average fault dislocation of 60 cm (Dorbarth et al., 1983) was used to calculate the seismic moment from the equation (Aki, 1968):

$$M_o = \mu AD \qquad \textbf{(2)}$$

where μ is the rigidity which was taken to be 3.3×10^{15} N/m^2 and A the fault area was taken to be 100 km^2. Thus the seismic moment M_o was found to be 1.98×10^{20} N-m.

STRESS DROP

A stress drop of approximately 545 kpa was computed from the relation (Kanamori and Anderson, 1975):

$$S = \frac{7 \pi \mu D}{16 r} \qquad \textbf{(3)}$$

where r is the radius of a circular fault which was taken to be 0.5 km. Dorbarth et al., 1983 obtained a higher value. This may be due to the fact that we used different fault models. The calculations of fault dislocations and stress drop are very dependent on the fault area. Some authors have found that intraplate earthquakes appear to have lesser stress drops than interplate earthquakes.

SEISMIC ENERGY

The seismic energy, E, was calculated from the Gutenbergy-Ritcher (1956) energy-magnitude formula:

$$\text{Log } E = 5.8 + 2.4 \times m_b \qquad \textbf{(4)}$$

where m_b. is the body wave magnitude. The seismic energy was calculated to be 1.3 x 10^{21} Joules.

CONCLUSION

This study of the source parameters of the rare occurrence of a large earthquake on December 22, 1983 in Guinea, West Africa, intraplate locale with a low level of historical seismicity has provided some information about the earthquake. The results indicate that seismic faulting occurred on a preexisting fault system. We cannot explain the reason for the unexpected occurrence of this intraplate earthquake. Thus, the significance of this study is its contribution to the observational data for such earthquakes and for the seismicity of West Africa.

Although this study has provided some estimates of the source parameters in the zone of seismicity in Guinea, West Africa, it remains for further study to determine the mid-crustal stress and structural characteristics of this zone that differ from those in adjacent area.

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