Earthquakes in Ngamiland

by C.V. Reeves*

Data concerning the occurrence of earthquakes are generally available from two sources:

(1) seismograph records.

(2) Personal reports.

Even today, no permanent seismograph station operates in Botswana, so one must refer to data collected by authorities operating seismographs in surrounding territories. Within Botswana the population is so thinly distributed that even large earthquakes could go undetected, and it is very unlikely that enough personal reports could ever be obtained to pinpoint an epicentre accurately by this means.

It is unfortunate that the continent of Africa as a whole was not endowed with seismograph stations at an early stage. Until as late as 1950, little reliable information was being recorded of earthquakes occurring even in the southern part of the African continent. A single reference has been found to personal evidence of pre-1950 earthquake activity in Botswana, namely that of Wayland (1944). In discussing widespread horizontal fractures in stalagtite columns in Drodsky's Caves, Western Ngamiland, he mentions: "We are told that at the beginning of this century a severe earthquake shook Ngamiland; could this have caused the columns to break?" The source of this information remains unknown to the present writer.

Between 1949 and 1951 the first seismograph network that can justifiably be called "modern" was set up in South Africa. Four Benioff short-period vertical seismographs were installed at Pretoria, Grahamstown, Pietermaritzburg and Kimberley respectively. Gane and Oliver (1953) describe in detail the installation and operation of these instruments. It was during this period that seismic activity in Bechuanaland was first recognised scientifically and no less than 30 events were recorded there, mostly exceeding magnitude 5 on the Richter scale and clustering in the region of the Okavango Delta, Ngamiland. Four events were observed during 1951 and a major series followed in the second half of 1952, continuing into 1953. The series culminated in a Richter magnitude 6.7 event on October 11th, 1952. This event, and an earlier one of magnitude 6.1 on September 11th, 1952, were felt at Maun, the larger event causing the collapse of the bulging stoep walls of the Assistant District Commissioner's house and other minor damage (Bent, 1952). Thirty-five seismograph stations recorded this event, mainly in Europe and California. The epicentre calculated by the *Bureau Central International de Seismologie* is at 19½°S, 23°E (some 80 kilometres north-west of Maun in the heart of the Okavango Delta), which is ½° south of the epicentre calculated in southern Africa, all of which may therefore require displacement by that amount (Gane and Oliver, 1953).

Events of about magnitude 5 on September 12th and 13th 1952 were not noticed at Maun, but mild tremors were experienced by Messrs Brind and Moiraith working near the confluence of the Gomoti and Thamelakane, some 40 kilometres to the north-east (Bent, 1952) suggesting a closer proximity to the epicentre. The existing seismograph network was incapable of locating an event in northern Bechuanaland with an accuracy better than about $\pm$ 50 kilometres.

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During the thirteen months May 1952 to May 1953 inclusive, a total of no less than thirty-three events were observed, two of them in excess of magnitude 6.0, twenty-one of magnitude 5, and ten of magnitude 4. Events of smaller magnitude were almost certainly undetectable at the range of the South African seismographs. Two magnitude 5 events were noted during 1954-5, but despite the introduction of an additional station at Windhoek in March 1958, giving improved coverage for northern Botswana, only three other minor events were noted during the following ten years, until August 1965.

A new station at Bulawayo came into operation in April 1959, and preceded the introduction of the full network of the Rhodesia Meteorological Services which became operational from the point of view of events in Botswana from the middle of 1965. Prior to that date the network was very thin and attention focussed on seismic events triggered by the flooding of the Kariba Lake. The network consisted at first of three stations at Bulawayo, Broken Hill (Zambia) and Chileka (Malawi) respectively. Two more stations in Rhodesia were added in 1968, and a fourth in 1971.

The monthly bulletins of results from this network for the six-year period September 1965 to August 1971 have been thoroughly scanned, and fifty seismic events within or very near Botswana have been reported. The magnitudes of these events are distributed as follows:

Magnitude 5 and greater	– One event
Magnitude 4	– Four events
Magnitude 3	– Twenty-seven events
Magnitude 2	– Sixteen events

Well over half of these events occurred within or near the Okavango Delta. C.B. Archer of the Goetz Observatory, Bulawayo (personal communication), claims that the Rhodesia Meteorological Service Bulletins for the period September 1965 to August 1971 are complete for Botswana earthquakes of magnitude 3 or more, within and to the east of the Okavango Swamps, and are therefore easily the most reliable source of epicentral data for Botswana.

The Worldwide Standard Seismograph Network (WWSSN) came into operation in 1963, largely as 'spin-off' from the quest to detect nuclear test explosions. The first full results of this network, operated by the US Coast and Geodetic Survey, were published by Barazangi and Dorman (1969). A limiting magnitude of 4.5 to qualify for inclusion in their map of global seismicity precludes events in Botswana during this period. Fairhead and Girdler (1969) at the University of Newcastle-upon-Tyne have, however, recalculated some WWSSN data for southern Africa using, for higher accuracy, their method of joint epicentral determination (JED). Accuracy of $\pm$ 10 kilometres is claimed in latitude and longitude. The June 1st, 1959 event near Matsitamma predates the Rhodesian Network, but was recorded by the South African Network. The other two JED events are confirmed by the Rhodesian data, and agreement with locally calculated epicentres is better than 30 kilometres in all three cases.

The Distribution of Epicentres

The main area of seismicity in Botswana undoubtedly lies in the Okavango Delta (Reeves 1972). Considering the limits of reliability in the epicentres, their distribution in the Okavango appears to be a random one about a single point. The mean place of the distribution is at 19°.22 S, 23°.31 E, and all but six of the epicentres (i.e. 75%) lie within one degree of this point, suggesting that a single tectonic cause could be responsible for all these events. The mean place of the twenty-four epicentres bears interesting comparison with the supposedly most accurate single epicentre available, namely the JED value for the August 22nd, 1967 event: 19°.58 S, 23°.64 E.

The points given by both these values lie amongst the more important channels of the Delta at the present day, which one might expect to be the case if seismicity reflects regional subsidence.

Recent geophysical work and drilling nearby suggests that a very considerable thickness of sediment has accumulated in this region since the Karroo. Over 150 metres of sediment has been proved by drilling, and gravimetric interpretation suggests that perhaps several hundred metres of Cainozoic sediments may prevail in this area. Seismic activity is probably not confined to the Okavango Delta, however. The northernmost epicentres are probably due to events in the Chobe Swamps where, as in the Okavango, major linear features and large gravity gradients are known to occur.

Fifteen of the sixteen remaining epicentres fall in a broad belt trending roughly north-east to south-west across the central Kalahari. The uncertainty in epicentral positions permits that all these events could be attributed to a single broad linear feature. Seismicity in the Central Kalahari has not been recognised before, and the present writer feels this new-found axis of seismicity bears an important relationship to the geological structure of Botswana, particularly the central unexposed areas. The axis is strikingly parallel to the Palaeozoic fold axes exhibited in the Ghanzi Ridge to the west of the Central Kalahari, suggesting north-east to south-west structural control over a very long period of time. It may have been the principal force controlling the deposition of the Karroo within the Kalahari Basin, the total thickness of which is unknown. At present, there is insufficient geological evidence in central Botswana to support or refute this.

An interesting relation is evident between the seismic axis and post-Karroo features.

(a) Lake Dow, the lowest point of the Okavango-Boteti drainage, lies on the axis, as would be expected if it were an axis of continuing subsidence.

(b) The whole area of the Makgadigadi salt pans lies astride the axis, representing the lowest lying area in Botswana (marginally below 900 metres), now deprived of significant water supply by i) climatic changes, (ii) probable recent faulting in the Okavango changing drainage patterns there.

(c) The "fossil" drainages of the Central Kalahari drain towards the seismic axis, then follow it north-eastwards towards Lake Dow, again suggesting that the axis is one of subsidence continuing into the geologically recent past.

(d) The kimberlite pipes in the area of Orapa fall very near the seismic axis providing direct geological evidence of post-Karroo activity from a source at depth. The Kalahari axis also parallels two major lines of late-Karroo kimberlite intrusions and mineralisations in Angola and South West Africa (Haughton, 1963) suggesting that other parts of the Kalahari axis might prove worthy of economic investigation.

(e) Poorly exposed fault features in the Makgadigadi region and south of Ghanzi are broadly sub-parallel to the seismic axis.

The writer feels that the Kalahari Axis is part of a larger seismically active belt trending north-east to south-west across central southern Africa from the East African Lakes to the mouth of the Orange River.

Plate Tectonics

The corner-stone of the theory of plate tectonics, which has become generally accepted during the course of the last two or three years as the controlling force of geological events at least since the Mesozoic (Vine, 1970), is the distribution of earthquakes on a global scale. With very few exceptions, earthquakes are found to be confined to plate margins, i.e. mid-ocean ridges where ocean-floor spreading and volcanic intrusion produces plate accretion, and island arcs and Tertiary fold belts where colliding plate margins either buckle or are largely re-consumed into the Mantle.

–The global distribution of earthquakes supports this conception whole-heartedly and, within oceans earthquakes are confined to very narrow lines corresponding to mid-ocean ridges and island arcs. Over continental areas, the distribution is more random (Barazangi and Dorman, 1969) and Africa displays a particularly widespread pattern of epicentres, which remains something of an enigma for the plate tectonic theory (Fairhead and Girdler, 1971).

The main African seismic source, namely the East African Rift System, is assumed broadly to be a mid-ocean ridge type structure. Accretion has not been very active, however, as the origin of the Rift would appear to predate the opening of the South Atlantic Ocean, and during the time the mid-Atlantic ridge has accreted several thousand kilometres of new crust, the East African crust has expanded no more than 60 kilometres (Girdler *et al.*, 1969). If one is prepared to define rift systems by lines of seismic activity, the Luangwa Valley – Kalahari Axis must be a part of the East African feature, but it is certainly not a major one. Within Botswana there is no geological evidence of rift faulting and no present day volcanic activity.

The isolated seismicity of the Okavango remains a mystery, in so far as it is offset some 250 kilometres from the Kalahari Axis. There is no denying that, in recent years at least, it is seismically far more active than the Kalahari Axis, and even with the scant geological information currently to hand, greater thicknesses of post-Karroo formations have been proved in the Okavango than are known anywhere in the Central Kalahari. Since the topography of the ground surface is unlikely to have changed very radically from its present extremely featureless aspect since Karroo times, subsidence must have been proceeding faster in the Okavango than in the Kalahari over this period. A geomagnetic deep-sounding array study in Ngamiland, run by the CSIR Geophysics Unit in Pretoria in cooperation with the Botswana Geological Survey and Mines Department in the early part of 1972, was designed to investigate the possibility that an active "hot-spot" in the earth's Mantle may lie hidden several hundred kilometres below the Okavango Delta. Such an anomaly could account for the seismicity of the area. The results of the study are currently undergoing computer evaluation in Canada.

The Human Aspect

In a flat, largely unpopulated area such as Ngamiland, there is unlikely to be much danger to life and limb from the continued earthquake activity. Landslides, the bursting of dams, collapse of tall buildings, fires resulting from fracture of gas mains and collapse of electricity lines may bring a toll of death in the wake of an earthquake in mountainous and populated countries but present no real threat to the inhabitants of Ngamiland.

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Technical Note: The Richter Scale of Earthquake Magnitudes

An earthquake magnitude on the Richter Scale is an estimate of the total energy released by the fracturing of rock at the source of the disturbance. The scale is a logarithmic one. Each increase of one in the Richter magnitude represents a 250-fold increase in energy release and, on a global scale, a 10-fold decrease in the frequency of such an event. Earthquakes of magnitude 9 or greater are virtually unknown. Approximately one event of magnitude 8 occurs each year, ten of magnitude 7, one hundred of magnitude 6 and so on. A Richter magnitude of 5 approximates the energy released by the underground explosion of a one megatom bomb.

The Richter scale should not be confused with the Mercalli scale which, like the Beaufort wind scale, assessed earthquake severity in terms of actual damage on the ground at any given point.