Fault-Plane Solutions of the 18 May 2001 earthquake in South Africa near Botswana border.

JG King[1], M Garegae[2], TH Ngwisanyi[3] and R Ranganai[1]

[1]*Physics Department, University of Botswana, Private Bag 0022, Gaborone, e-mail kingjg@mopipi.ub.bw.* [2]*Department of Earth Sciences, Leeds University, UK.* [3]*Geological Survey Department, Private Bag 14, Lobatse.*

Abstract
Fault-plane solutions of an earthquake can provide information about the type of fault. We report on the calculation of the fault-plane solutions of the earthquake that occurred on the morning of 18 May 2001 and was felt in the southern parts of Botswana and the North West Province of South Africa. The fact that there were few seismic stations in the vicinity of these areas meant that standard programs such as FOCMEC would produce a large number of possible fault-plane solutions. In this study a semi-manual method of determining fault-plane solution was utilized to obtain the most likely solution from a SEISAN program. The results obtained from these two methods shows that the focal mechanism for this earthquake was normal faulting. The two methods used compliment each other. Other information obtained includes epicenter at coordinates (longitude 26.0E, latitude 25.6S), magnitude of about 4.6 ML and origin time of 9:14.10.52 UTC.

Introduction
When an earth tremor occurs, it is of interest to know its origin place, origin time, magnitude and type of faulting. Information about all these parameters can be obtained from analyzing seismograms recorded by seismic stations. The main objective of this study is to determine the nature of faulting. Since there is comparatively lack of adequate seismic station density in southern Africa, the use of standard programs such as FOCMEC (Havskov and Ottemoller, 2000) results in many possible fault-plane solutions. It is not always possible to identify the most appropriate fault-plane solution. Ways of circumventing this obstacle has to be found. In this study a semi-manual method involving the use of the Stereonet program (Duyster, 2000) was utilized to determine the most likely solution from the SIESAN FOCMEC program fault-plane solutions.

Data Collection
Table 1 contains data for the stations used in this study. Apart from the Gaborone Seismic Station (GABZ) that belongs to the University of Botswana and the International Seismic Station near Lobatse (LBTB), the rest are for the Council for Geosciences of South Africa.

Station name	Area	Latitude	Longitude	P-S time (s)	Epicenter distance (km)
GABZ	Gaborone	-24.7376S	25.8873E	12.0	96
LBTB	Lobatse	-25.0145	25.5970	8.5	68
KSR	Koster	-25.8517	26.8972	13.0	104
BFT	Belfast	-25.6880	30.0448	52.4	419
BOSA	Boshof	-28.6137	25.2560	41.3	330
UPI	Upington	-28.3620	21.2527	68.3	546
SLR	Silverton	-25.7350	28.2817	30.3	242

***Table 1**.- Seismic station locations, P-S time and distance to epicentre*

Determination of routine earthquake parameters
After an apparent earth tremor was felt in Gaborone, we obtained seismograms from the GABZ seismic station and confirmed that indeed an earthquake had occurred (Figure 1).

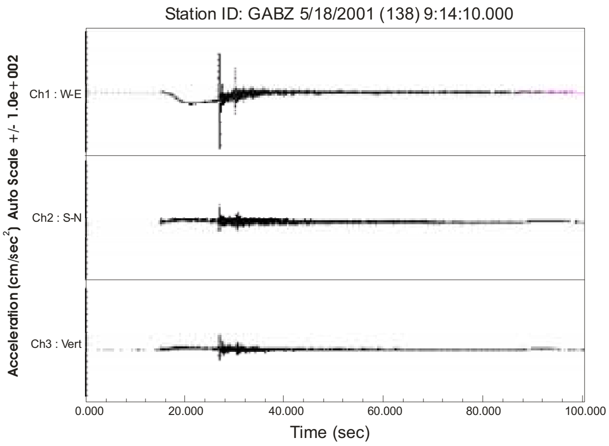
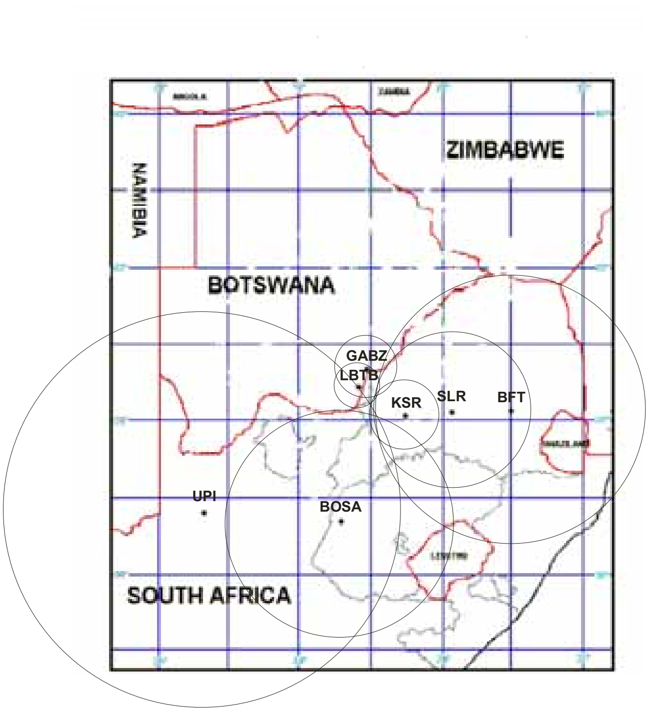


***Figure 1**.- Seismograms for the May 18th 2001 earthquake recorded at the Gaborone UB Seismic Station*

Seismograms of one station are often not adequate to use for the accurate determination of various earthquake parameters. It was necessary to get data from other stations in the region. Additional seismograms were obtained from the South African Council for Geosciences stations. To get the epicenter distance of this event for each seismic station, the time difference between P and S waves was determined and then multiplied by 8 according to Lay and Wallace (1995). Table 1 contains P-S time differences and epicenter distances obtained from the seismograms of the stations used. The method of triangulation (circles in Figure 2) was used to determine the epicenter position. The results of the triangulation method show that the most likely location of the epicenter is the region marked with a triangle in Figure 2 (latitude and longitude



coordinates of approximately longitude 26E latitude 25.6S.This is close to Ottoshoop in South Africa near the Ramatlabama border gate in Botswana. The origin time was determined through the so-called Wadati-Plot (Lowrie, 1997). This involves plotting the difference between S and P waves arrival times as a function of P-wave arrival times. The point where the plotted straight line crosses the P-wave arrival time axis is the origin time. The origin time for the plot shown in Figure 3 is 9:14.10.52 hrs UTC. This in local time is 11.14.10.52 hours. The magnitude was estimated to be 4.6 ML.

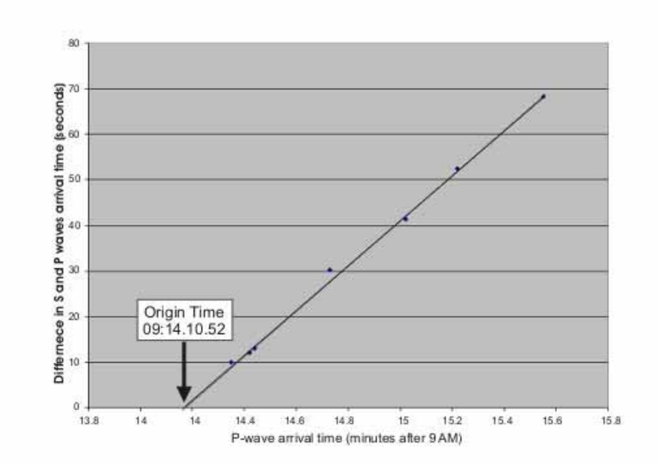


***Figure 3**.- Determination of the time of origin of the earthquake*

Focal-plane solutions using the semi-manual method

This method utilizes StereoNett software from the Ruhr-Universitat-Bochum developed (Duyster, 2000). The program can display data such as equal area projection or equal angle projection for either lower or upper hemisphere projection, density contours or Rose diagrams. The StereoNett program was used to plot the projections and then manually determine the nodal planes. This process may not be described entirely as manual as it involves the usage of a computer program, hence is referred to as the semi-manual method.

The program removes the tiresome and error prone process of plotting the first motions by hand. Figure 4 shows the lower hemisphere equal-area plot for compression (solid black dots) and rarefaction (open circles) for the 18th May earthquake that was plotted using the StereoNet program. On the same plot is the hand drawn manual plot of nodal planes. The fault-plane solution according to the plot is normal fault.

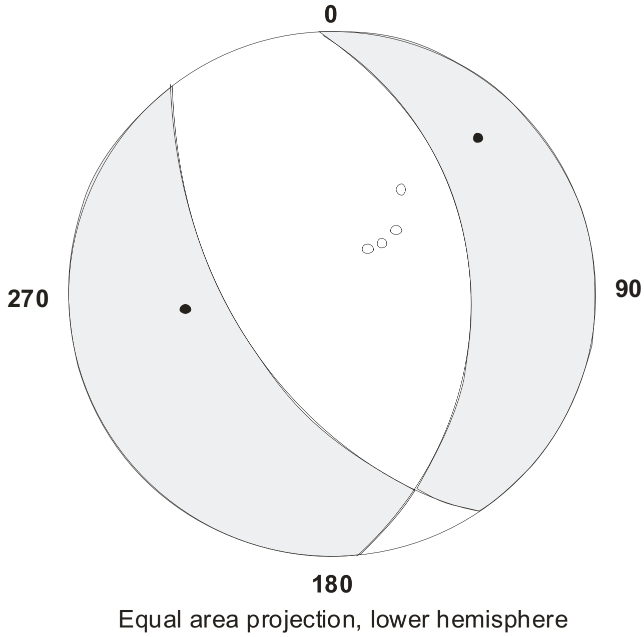


***Figure 4**.- Fault-plane solution for the May 18 earthquake as determined by the semi-manual method. Solid circles are for compression while open circles are for rarefaction*

Fault-plane solutions using SEISAN FOCMEC software

The Earthquake Analysis Software program SEISAN for windows version 7.1 was used in this study (Havskov and Ottemoller, 2000).

The SEISAN program produces many possible fault-plane solutions if a few seismic sections are used. The solution in the semi-manually program described in the above section was found to be very helpful in choosing the best possible solution from the many possible solutions from the SEISAN program. Figure 5 was found to be the best solution from the SEISAN program nearest to the fault-plane solution obtained using the semi-manual program (Figure 4) for this event. This solution from the SEISAN program is also a normal fault.

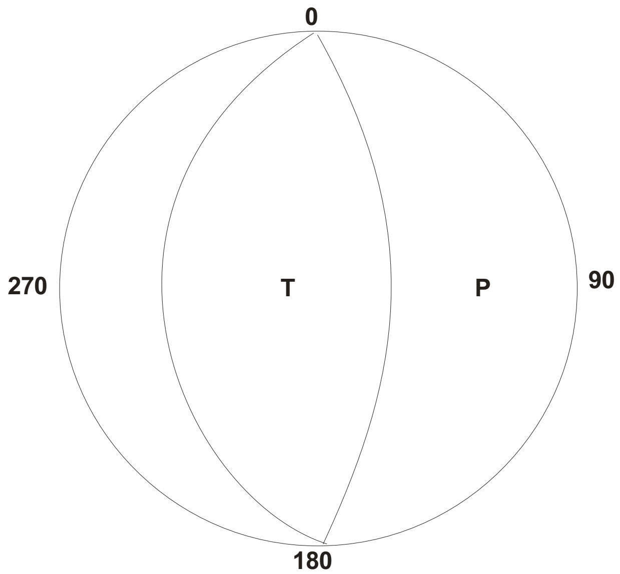


Figure 4.- *Fault-plane solution for the earthquake as determined from the SEISAN program. T is for rarefaction and P for compression*

Conclusions

The epicenter of this earthquake is at longitude 26.0E, latitude 25.6S. This is around the Ottoshoop area in the Republic of South Africa, which is near Ramatlabama border. The earthquake origin time is 9:14.10.52 UTC and its magnitude is 4.6 ML. The resulting fault-plane solutions (Figures 4 and 5) shows it to be a normal fault. The semi-manually method was found to be very helpful in the selection of the most likely type of fault-plane solution from the SEISAN program results; hence the two methods complement each other.

Acknowledgements

We thank Martin Brandt (Council of Geosciences, South Africa) for providing seismograms from the LBTB and all stations in South Africa used in this study. We thank the University of Botswana for providing sponsorship of this study.

References

Duyster, J., 2000: Stereonet Computer Program', http://www.Ruhr-Universitat-Rochum.de.

Havskov, J. and L. Ottemoller, 2000: SEISAN: The Earthquake Analysis Software, http://www.ifjf.uib.no/seismo/software/seisan.html.

Lay, T. and T.C. Wallace, 1995: Modern Global Seismology, Academic Press Inc.

Lowrie, W., 1977: Fundamentals of Geophysics, Cambridge University Press.

Manuscript submitted 280204
Accepted for publication 021205