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Short communication

HISTORY AND OPERATIONAL CAPABILITY OF THE ETHIOPIAN SEISMIC STATION NETWORK (ESSN)

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ABSTRACT: Together with the three component short period WWSSN analog station operating at the Geophysical Observatory (AAE), five seismic stations are running in the country. FURI is one of the four three-component digital stations with a GURALP CMG 3T and STS1 broadband sensors. The other three seismic stations at Wendogenet, Dessie and Alemaya are equipped with Le-3d/5s seismometers with RefTek Data Acquisition Systems (DASs), which provide semi-broadband signals. Except AAE, all stations use GPS receivers for accurate timing and provide three-component digital record. Digital data facilitate quick interpretations of seismic signals using computers. The seismic stations are in a good position to date to monitor major seismic activities of the Ethiopian rift. The earthquake locations estimated using data from our own network are found to be reliable with reasonable accuracy. A total of 15 earthquakes are located in this pilot study of which only four are captured by the USGS (United States Geological Survey) bulletin and all lie along the rift in Afar and the main Ethiopian rift system.

Key words/phrases: Ethiopian rift, seismic station network, seismicity

INTRODUCTION

Earthquakes are one of the many natural hazards that have been causing deaths and can adversely affect the economic development of Ethiopia. As the seismically active East African Rift System passes through Ethiopia, recording earthquake activity and creating awareness in the society are scientifically important tasks in earthquake risk reduction in the country. The recent work by Keir *et al*. (2004) showed that the neighbourhood of Addis Ababa is seismically active and a damaging earthquake can occur any time.

Seismological observation in Ethiopia started in February, 1959 at the Geophysical Observatory of Addis Ababa University. Initially, Willmore seismometers were mainly used with photographic recording. The time marks were given by the observatory's master clock controlled by radio everyday, which is still in practice for station AAE. In the very early days of earthquake recording at the Geophysical Observatory, it was not possible to estimate epicentre locations mainly due to difficulty in determining the azimuth. However, magnitude and distance of earthquakes from the recording site used to be computed from t_s-t_p and amplitude readings.

The only major earthquake sequence ever to shake Addis Ababa in living memory occurred from June to September 1961 near Kara Kore with a main shock magnitude of m_b 6.4. Over 3,500 earthquakes of magnitude ML (AAE) ≥ 3.5 were recorded during the Kara Kore seismic crisis in 1961 (Gouin, 1979) with a relatively less equipped instrument facility. The village of Majete was completely destroyed but there were no casualties (Gouin, 1979). At the time the panic caused by the earthquake was moderated by the information that was being issued continually by the Observatory in Addis Ababa. As a result of the central role played by the Geophysical Observatory in the earthquake disaster of 1961, seismological observations have been given considerable importance in the country. The extent of damage caused by the earthquake sequence of 1961 was assessed during a field trip to the region and the macroseismic information that accumulated since then formed an important data base on which estimates of regional seismic attenuation relation was based. In June 1962, WWSSN station was installed at AAE and thereafter it was equipped with three-component (vertical, north-south, east-west) short period Bennioff and three-component long period Sprengnether seismometers. After AAE was upgraded to be a world-standard station, it was possible to estimate epicentre parameters of local, regional and teleseismic earthquakes using the single-station location method and macroseismic information mainly reported by regional authorities for local earthquakes in Ethiopia which helped a great deal to improve locations.

Routine interpretation of seismograms and determination of earthquake parameters for local and regional events led to the publication of several research papers. The book, 'Earthquake History of Ethiopia and the Horn of Africa', written by Gouin (1979) contains a substantial number of analyses of seismograms from station AAE and macroseismic information from field assessment of damages caused by earthquakes. The first seismic zoning map of Ethiopia was published in 1976 in relation to the national effort to draft a code for earthquake-resistant structures. Station AAE has contributed high quality data for the seismological community in the world and its name appeared on outstanding books and research papers.

Through SIDA/SAREC financial support for the Geophysical Observatory since September 1982, single-component S-13 sensors with portacorder seismographs (Teledyne Geotech) were installed at Alemaya (ALME), Asmera (ASME), Dessie (DESE) and Wendogenet (WNDE). Later on, the portacorders were replaced by Lennartz analog recorders with time marks made by internal clocks and synchronized daily to radio-broadcast time. Substantial amount of data were collected with the old station network and bulletins of the Geophysical Observatory are produced. However, independent event location using this seismic station network was not possible mainly due to bad timing of seismogram records from the remote stations.

Current Seismic Station Network of Ethiopia (SSNE)

With a generous financial support of SIDA/SAREC, which ended in 2000, three Le-3d/5s seismometers and RefTek Data Acquisition Systems (DASs) were obtained by the Geophysical Observatory. These three seismic stations are fully installed at Alemaya (ALME), Dessie (DESE) and Wendogenet (WNDE) in 2003 (Fig. 1). The delay of full installation was due to several over-sea seismic projects running in the country from May 1999 to February 2003, which enabled us to collect enormous amount of data for earthquakes in Afar and the Main Ethiopian Rift. Time drifts for the internal clocks of the RefTek DAS are corrected by GPS timing. Together with FURI, which is an IRIS/GSN seismic station that started operation in September 1997 and AAE (short-period with analog record); the Geophysical Observatory is currently running five seismic stations in the country. Under normal circumstances, this station configuration (Fig. 1, Table 1) can provide reliable earthquake data in Ethiopia. The three remote seismic stations provide semi-broadband three-component digital seismograms (Fig. 2). The instruments are well calibrated but the signal recorded by three Le-3d/5s sensors are band-limited and the total number of stations are only five which implies that ESSN is not good for fault plane solutions and other advanced seismological study at this stage except earthquake location and magnitude estimates. The station distribution is also sparse and this is not the best station configuration to monitor the seismicity of the main Ethiopian rift and Afar. All these demand several additional state-of-the-art broadband sensors with 24-bit digitizers for better performance of the network.

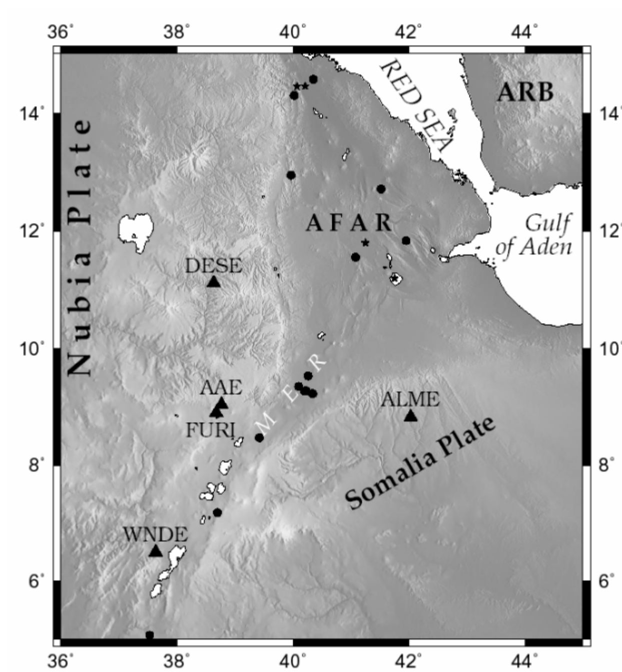

Fig. 1. Topography of the Horn of Africa and the Afar triple junction where the Red Sea, Gulf of Aden and main Ethiopian rift systems meet. A total of five seismic stations (black triangles) are displayed where four of them are three-component digital with gps timing while the other is analog short-period station with radio timing. The black circles are our locations for 15 earthquakes from some of the 2003 data recorded by the Ethiopian Seismic Station Network (eesn) and only four of them (black stars) are reported by the usgs pde bulletin. The acronyms are mer: main Ethiopian rift and arb is to mean Arabian Plate.

Table 1. Seismic station location: coordinates and elevations in meter a.s.l.

	Area	Station code	Lat. (°N)	Lon. (°E)	Elev. (m)	Sensor	Digitizer
1	Addis Ababa	AAE	09.035	38.766	2442	Benioff	analog
2	Alemaya	ALME	09.430	42.040	2027	Le-3d/5s	R. DAS
3	Dessie	DESE	11.120	38.640	2543	Le-3d/20s	R. DAS
4	Furi Mountain	FURI	08.895	38.680	2500	CMG-3T & STS1	Quantera
5	Wendogenet	WNDE	07.040	38.370	1844	Le-3d/5s	R. DAS

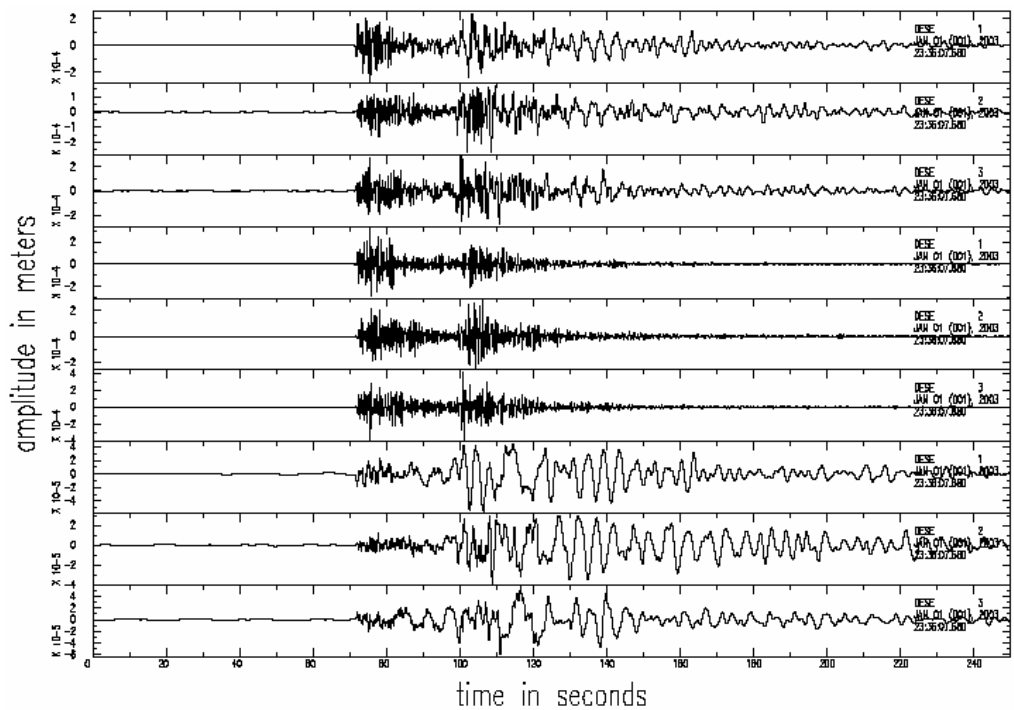

Fig. 2. Seismogram records of a magnitude 4.0 earthquake in Afar on January 1, 2003 as observed at DESE with the Le-3d/5s instrument before it was replaced by Le-3d/20s. The first three are raw data, the next three are WWSSN short period simulated and the last three are WWSN long-period simulated records after the Le-3d/5s instrument response is removed. This figure shows the Le-3d/5s is more than a short-period instrument.

Data and earthquake locations

Broadband digital seismic data are very convenient mainly to suppress noise and filter the frequency band of interest so as to facilitate phase picking. The three seismic stations at Dessie, Alemaya and Wondogenet are not broadband but are good for local earthquake recording (Fig. 2). The digital data can be optimized with different techniques so that seismic phases can be picked with reasonable accuracy, which will be used for locating earthquakes.

The software used in this study for locating earthquakes is Hypocenter (Lienert *et al.*, 1986). Plane parallel layers for crustal model are assumed for local and regional events (Atalay Ayele *et al.*, 2004). Coda magnitude, $\mathbf{m}_c$, is used to estimate earthquake sizes (Table 2). Fig. 1 and Table 2 show locations of earthquakes for the year 2003 for Afar and the main Ethiopian rift as recorded by our network and the distribution is in good agreement with the active rift trend and previous seismicity of the region (Gouin, 1979; Atalay Ayele, 1995). Only four of the fifteen earthquakes (Table 2) have been captured by the United States Geological Survey (USGS) Preliminary Determination of Epicenters (PDE) catalogue which shows that densifying seismic station distribution helps to monitor seismic activity of our region with better detail.

Table 2. List of the located events in 2003. The author managed to locate the following earthquakes using only our own network (ESSN). The USGS results are given in parentheses for comparison. m_b is body wave magnitude.

	Date	Origin time	Latitude (°N)	Longitude (°E)	Depth (km)	Magnitude, m_c
1	20030101	23 36 38.42	11.84 (*11.20*)	41.95 (*41.75*)	5 (*10*)	4.0 (*m_b 4.6*)
2	20030110	1213 56.04	08.47	39.42	2	3.0
3	20030125	18 27 00.70	05.06	37.53	3	3.5
4	20030519	23 18 22.80	12.95	39.97	6	3.7
5	20030528	08 48 13.04	07.18	38.70	13	3.0
6	20030610	07 10 41.00	14.30 (*14.45*)	40.02 (*40.07*)	2 (*10*)	5.0 (*m_b 4.6*)
7	20030610	18 23 19.24	14.57 (*14.46*)	40.35 (*40.21*)	5 (*10*)	3.6 (*m_b 4.3*)
8	20030807	12 05 52.00	12.72	41.52	5	3.7
9	20030818	20 07 56.48	11.56 (*11.80*)	41.08 (*41.25*)	10 (*10*)	3.7 (*m_b 4.0*)
10	20031019	23 20 52.83	09.27	40.20	6	3.6
11	20031020	07 14 09.14	09.27	40.22	5	4.0
12	20031022	14 14 55.71	09.28	40.22	5	3.0
13	20031024	06 19 09.25	09.35	40.10	5	4.0
14	20031031	06 31 31.98	09.53	40.26	5	3.7
15	20031102	23 34 04.24	09.23	40.34	5	4.0

CONCLUSIONS AND RECOMMENDATIONS

1. ESSN (Ethiopian Seismic Station Network) is capable of detecting earthquakes of magnitude about 3.0 and above in our area. If the seismic network can be operated with minimal failure rate, it will provide a precious data set for earthquakes of magnitude 3.0-4.5 where other data centres such as USGS (United States Geological Survey), ISC (International Seismological Centre) and IDC (International Data Centre) bulletin of CTBTO (Comprehensive Test Ban Treaty Organization) cannot.
2. Identifying earthquake prone areas in our region contributes significantly to the infrastructure development of the country through reduction of the effect of earthquakes. On the other hand, this will enhance understanding of the geo-dynamics of the East African rift. If the health status of the network is to be maintained in good condition for some time to come, there should be adequate funding for:
   a. the operation of the network of stations.
   b. upkeep of the Observatory's capability to process, disseminate and archive earthquake data.

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