MatNatSudanColl

Collaboration in Mathematics & Natural Sciences - Sudanese Universities and the University of Bergen

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Report from visit to Sudan, 7.12 – 18.12, 2006

Cooperation in Seismology

by

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Introduction

As part of the cooperation between the University of Bergen, Faculty of Natural Sciences and research institutions in Sudan, the University of Bergen has allocated funds to initiate the cooperation and several minor seed projects have been approved (see www.sudan.mnfa.uib.no). Cooperation in seismology started with a workshop in April 2006 at the Geological Research Authority of Sudan (GRAS) (http://sudan.mnfa.uib.no/docs/sudan_workshop_jh_2006_04.doc). During that visit, several minor activities were started up. The intention with this visit was to follow up on general activities in seismology and also to give a short course in seismic instrumentation. In addition, lectures were given at the University of Khartoum and Computer Man College and meetings were help with representatives in the MatNatSudanColl from University of Juba and Khartoum.

Content

Meetings

University of Juba, coordination committee

Participants: Ahmed K. Yagoub, College of Applied and Industrial Science (Chairman), Hamad El Neel, (Director of Scientific and International Cultural Relations), Tarig Osman Khidor (dean of College of Applied and Industrial Science), Salim Gibril Ahmed (dean of college of Natural Resources and Environmental Studies), Faiza Ahmed Ali (deputy dean of College of Applied and Industrial Science) and Samir Yanni Mishrigi (Chairperson, collaboration committee CNRES).
At the meeting, there was a general frustration caused by the lack of funds. However, there was understanding that with little funds, not much can be done. The main problem seems to be lack of communication from both sides with e-mail apparently not getting through. So few contacts have been made between the University of Juba and the University of Bergen. Considering the little funds available now (most have been assigned to current seed projects), it was agreed that future visits should be made on the principle that the travel is paid by the institution sending the person and living costs by the host institution.

University of Khartoum

Participants: Elbushra Elsheikh Elnur (dean of Faculy of Science) and Salah Abdalla (director of Geology). Unfortunately, due to lack of communication, the chairman of the Collaboration committee, Farouk Habani did not come. However, we later had a meeting at Acropole hotel. The current funding situation was discussed and there was in general a good understanding of the problems. The University of Khartoum is also willing to share the cost of future exchanges.

ComputerManCollege

Participants: Prof. Abed Emalik Elnaiem, the head of the ComputerManCollege, Dr. Abed Basit Mohmmed, (head of the planning centre), Dr. Ashraf Gasm Elseed (head of the satellite engineering and space technology centre) and a few others.
The discussion was centered around the possible cooperation between ComputerManCollege and GRAS in building and operating small array. A memorandum of understanding between GRAS and ComputerManCollege has been made and will probably shortly be signed. It was particularly discussed which advantages ComputerManCollege could have of making an array and several points were raised: Getting experience in signal processing, building data acquisition unit, advanced programming and seismological data. In addition, there are challenges in wireless data transmission.

GRAS

Participants: Dr. Abed Elrazig Obeid (Director of GRAS), Dr. El Sheikh M. Abed Elrahman (Director of Integrated Geological Survey), Mr. Fisal El Zebair (Head of the Geophysics department), Mr. Abrahim Saror (Head of the seismological department), Mr. El Hadi Ebrahim (Head of the instrument department)

The experience of the course was summed up and future developments discussed. There was a general understanding among the GRAS leadership that GRAS should:

- Start to exchange data with the international Seismological Center
- Record data continuously to avoid data loss
- Acquire new lightweight instrumentation making it easy to expand the network on a temporary or permanent basis
- Send seismological staff on training abroad, preferable short courses of 1-3 months duration

The course

The course had 15 participants from 4 institutions (see Appendix 1). The general course day consisted of a morning lecture followed by practical exercises with electronic components and seismological equipment. The majority of course participants had no prior knowledge of neither electronics nor seismological instruments. The course lasted for 5 days and covered the following topics:

General electronics
Signals
Analog to digital converter
Seismic sensors
Recording and triggering seismic signals

One day was used for a field trip to one of the stations of the seismic network. The station setup was demonstrated and seismic noise measurements were made with a portable seismograph.

Abd Alhadi Ibrahim Alhassan from GRAS was co-instructor in the course and has the intention of holding a similar course next year.

The SSN and data from the network

The Network in Sudan

The network has experienced large problems recently. Currently 2 stations are operating and recording continuously. Only one station (MRKH) has communication to the center. The third station has been down for 1 month due to a power problem. It seems that the problem with communication is deteriorating, either due to interference from radios using the same channel or due to new construction blocking the transmission. The result is that almost no data has been recorded the last months.

One station MRKH, has experienced a dramatic increase in the noise level above 1 Hz in the last months. Trigger parameters were also completely wrong. Since this is also the only station sending data to the center, no useful data have been received in the last months. The noise at the station has been measured both with an independent portable station and the data from the station itself, and both measurements coincide. This means that the noise is not caused by instrument failure but noise in the ground. The most likely explanation is some new industrial activity nearby. This can be investigated by measuring noise at several sites near the station.
On MRKH, the system was then set up to send all triggers and this was tested. Many detections were received every day, however due the above mentioned noise problem, all were noise burst. However this shows that the communication to MRKH is very good and that the system works as it should. With a high noise level and unpredictable noise bursts, it is hard to adjust the trigger parameters optimally and only using continuous data will assure that all possible events can be found in the data.

Data

Since April 2006, 2 local and 34 distant earthquakes have been recorded. Continuous data is available for part of the time. Considering that data has only been analyzed for 5 months, this corresponds to 7 events per month. This is an improvement compared to the previous 2.5 years where 4 events were detected per month.

The continuous data has not yet been processed and it has not been stored or handled in a systematic way, mainly due to problems of handling large amounts of data on the old Sun computer. Now the Lennartz processing system has been installed in a Linux PC (together with SEISAN) and faster and easier processing is possible. Processing the continuous data might increase the amount of data significantly.

The SSN data base was upgraded with data from other seismological catalogs and now contain 1023 events from the prime area around Sudan (Appendix 2). Of particular importance is the addition of fault plane solutions and preliminary analysis of this data (Appendix 3).
Tests were also made with noise data using the Nakamura method. It seems that the dominant frequency from most measurements are close to 1 Hz (Appendix 4).

On November 5, 2003, an earthquake was felt about 150 km east of Khartoum. Unfortunately, the digital data was lost. The Seismological Research Center made a report giving macroseismic area with a maximum intensity (V) and an estimate of the epicentre. The report also had hard copies of seismograms from 2 stations SLAT and MKHR. Using these seismograms, an estimate of location and magnitude was made. It seems that there were 2 events, not one as previously assumed. The events occurred within a few hours of each other separated at a distance of about 40 km. Both had magnitude around 4.0 based on coda duration. This preliminary analysis was made on the last day of the stay in Sudan and more work should be done on analyzing these earthquakes since they might have been the largest events to have occurred near Khartoum in the last 5 years.

Recommendations for network operation

Since the most important is to get data, it is recommended that:

- The MARS filed recorders are moved to the field stations and connected to the broad band sensors.
- The 1 HZ sensors are connected to the MARS88 recorders at stations with communication.
- Data is collected and analyzed every 2 weeks from all stations.

In this way no data will be missed and also a good record is obtained of the distant earthquakes which cannot be collected completely by the radio network.

Problem with the radio communication:

- There might not be an easy solution if new construction have blocked the way. One or two stations still seems to have good communication.
- Stations with good communication: For these stations it is recommend to collect all triggers on each station in order to not loose data if communication go down. In any case, the data should also be available from the continuous recording, however it is more work to extract it and the data arrives later.
- Stations(s) with no communication: Move the MARS88 to a site with communication (probably nearer Khartoum). This should be at a place with an existing building and electrical power so the solar power system can be left at the original station to be used with the broad band system.

Trigger problems:

- The staff processing the data should also adjust trigger parameters since they observe changes in noise level and also check all triggers.

Data completeness

- The continuous data must all be stored. This amounts to about 60 GB a year, so a new disk must be bought for the Linux system. Backup can be done on an additional disk or DVD.
- Regular backup on CD of event data.
- Regular running reports of
    - Number of events detected
    - Availability of continues data, if none available, reason for lack of data
    - Number of detected events (noise and earthquakes) per day from radio network, this will give a log of how the system is working and how the noise level is changing
    - Trigger parameters used

New equipment

Considering the radio transmission problems, the inability to transmit continuous data by radio, the availability of 2 spare systems and the possibility that ComputerManCollege might help with communication, there is no need to buy more radio based stations. It is recommended to buy small, inexpensive lightweight stations with low power consumption. The advantage is that they can be used for a variety of field operations like earthquake recording, refraction surveys as well as being used for permanent stations. They are easy to install and can be installed and operated by both technicians and seismologists. The instruments can be used with both inexpensive geophones (usually built in) or broad band seismometers (external). Since recording is flash memory, no special equipment or software is needed for collecting data.

New stations

- The fourth station: Before construction, do a careful measurement of radio communication with MARS88 equipment. If communication is unsatisfactory, consider another possible site, preferable to the west.
- Station near NAGA. The site is near a seismically active zone, has low noise level and provides security so some test recording should be done with portable equipment. If good results are obtained, a permanent station can be built.
- Portable stations: When available, take them to the filed when other field activities take place. Even one to two weeks of recording can provide valuable data giving new insight into local seismicity and potential new sites for stations. Ideally, portable stations should also be placed in other localities in the country like Port Sudan and Juba.

Training

- In Potsdam, Germany, comprehensive courses (6 weeks) in general aspects of seismology of offered free of charge (including travel costs) for participants from developing countries. Time of course is in September and October.
- The University of Bergen can offer participation in existing MSc courses or arrange a special training.

Participate in international data exchange

A large part of the data in the SSN data base come from the International Seismological Center (ISC). It is strongly recommended that SSN also sends seismological readings to ISC so that the Sudan observation of local end global earthquakes become available worldwide and integrated with data from other seismic stations. It is also recommended that SSN become member of ISC ($2000/year). This gives Sudan a place in the Governing Council of ISC and thereby influence on the ISC policy. SSN will also receive ISC bulletins and CD's with ISC data. However, there is no requirement to be an ISC member to participate in the data exchange.

Acknowledgements

GRAS provided very good support for the course, offered transport to the filed and help with temporary instrument import. Berit Storheim read and corrected this report. The University of Bergen provided support for the travel to Sudan.

Appendix 1 Course participants

	
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	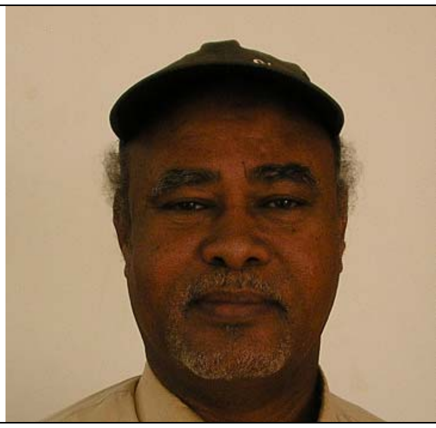
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Appendix 2

Technical report

Seismicity of Sudan Prime Area Until December 2006

by

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and
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Geological Research Authority of Sudan
(GRAS)

December 2006

1- Data Resources

The essential data reference is the Sudan catalog which has been prepared as a part of a report titled “The Seismic Catalog for Sudan”, presented during the workshop in seismology held at GRAS during the period from April, 24 2006 to May, 8 2006.
This catalog contains data which can be described as follows;

- All instrumental data for events recoded only by SSN during the period from Nov., 2003 to May, 2006.

- All instrumental and historical data available during the period from 1906 to 2006, using ISC and PDE as international standard resources.

2- Procedure

Data recoded by SSN only have been updated covering the period till December 2006.

Historical data for Sudan prime area have been introduced covering the period from Jan. 1850 to Nov. 1981, using (Ambraseys & Adams, 1986) as a reference. From Adams only events typed in that are not already in catalog.

Moreover, East African Seismological Catalog (EAF) has been considered as reference for Sudan prime area events during the period from 1993 to 2004. A total number of 14134 events were obtained. Among those 347 events are found to be new to our SSN data.

In addition to that, PDE solutions in the relative area have been checked and added when available.

3- Results

Upon the newly updated database, and following the above mentioned Procedure, a file has been constructed using SELECT program. The selection criterion was essentially considered for the latitude and longitude limits for Sudan prime area (taken as lat. 0 – 25 and long. 15 - 45). A total number of 1023 events have been revealed.

Then a seismicity map has been generated using EPIMAP program illustrating the seismicity of Sudan prime area, See Fig.1

Subsequently a file has been produced using SELECT program. In this case and in addition to the selection criterion for the latitude and longitude limits for Sudan prime area, the choice of Magnitude Agency has also been considered. This selection combination has been under gone twice both for ADA and EAF agencies.

For SSN agency, the same operation was followed, but in this case, and in addition to the selection criteria of the latitude and longitude limits for Sudan prime area and Magnitude Agency, a selection criterion of depth limits has also been taken into account. The range of the depth limits was taken as (0.1 – 99 Km). This option was taken in order to exclude the explosions out of the real events.

For SSN Agency the number of events was recorded to be 29, for ADA the number of events was found to be 36, and those of EAF Agency were obtained to be 347 events.

Then from the above constructed files 3 seismicity maps have been plotted using EPIMAP program, showing the seismicity of Sudan prime area using SSN, ADA and EAF Agencies one at each time. See Fig 2, 3 and 4 respectively.

4- Comments

The code ADA has been proposed to refer to the reference (Ambraseys & Adams, 1986) which has been considered as one of our references through the procedure of database updating.

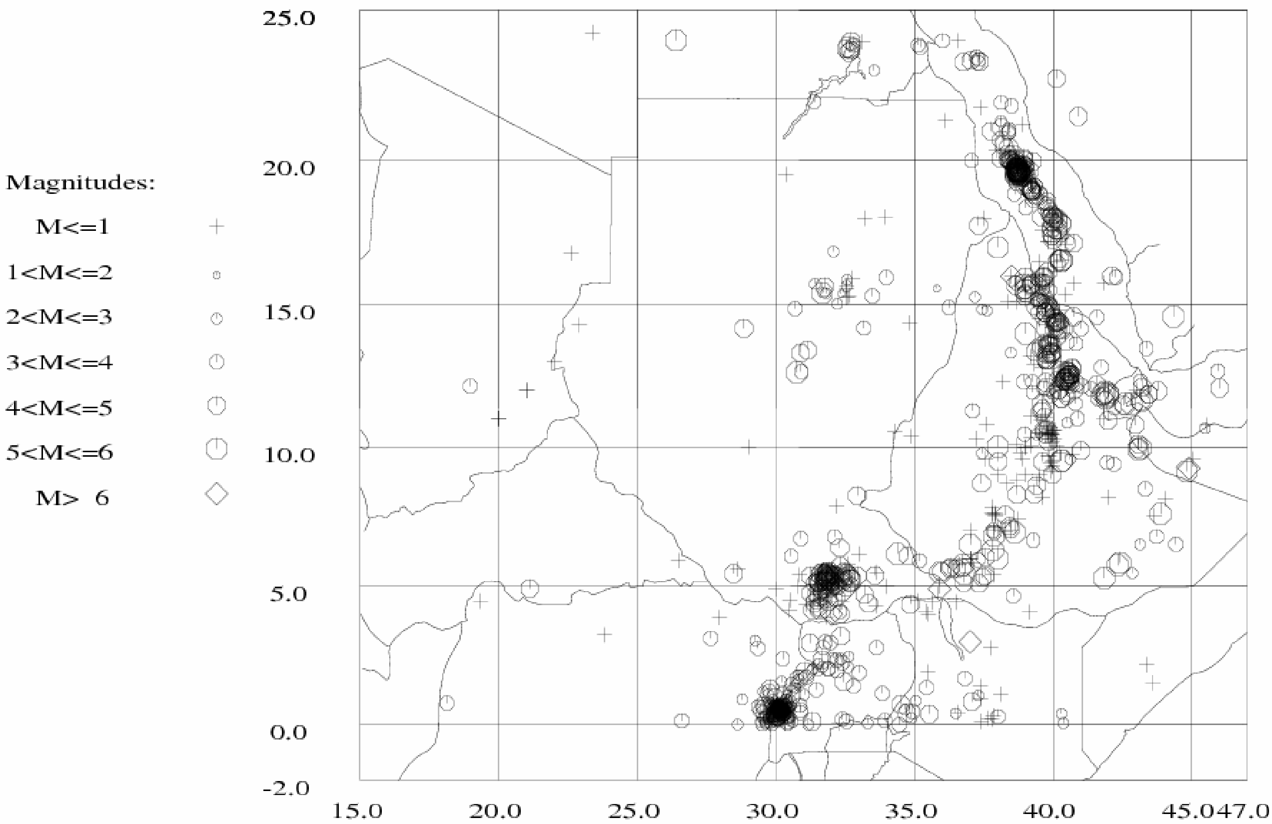

Fig. 1: Showing Total Number of Historical/instrumental Events Recorded By SSN, PDE, ADA, and EAF Agencies for Sudan Prime Area

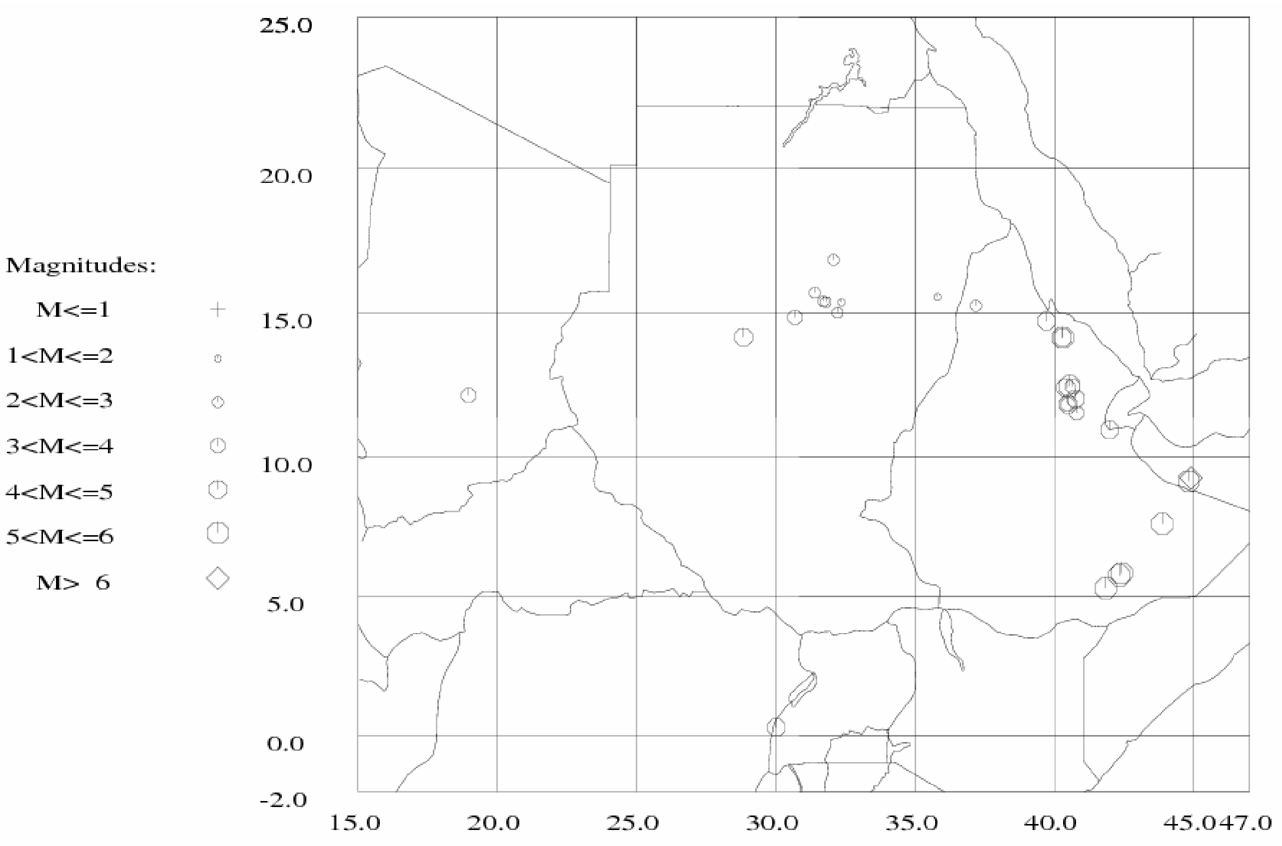

Fig.2: Showing Total Number of Events Recorded only by SSN for Sudan Prime Area

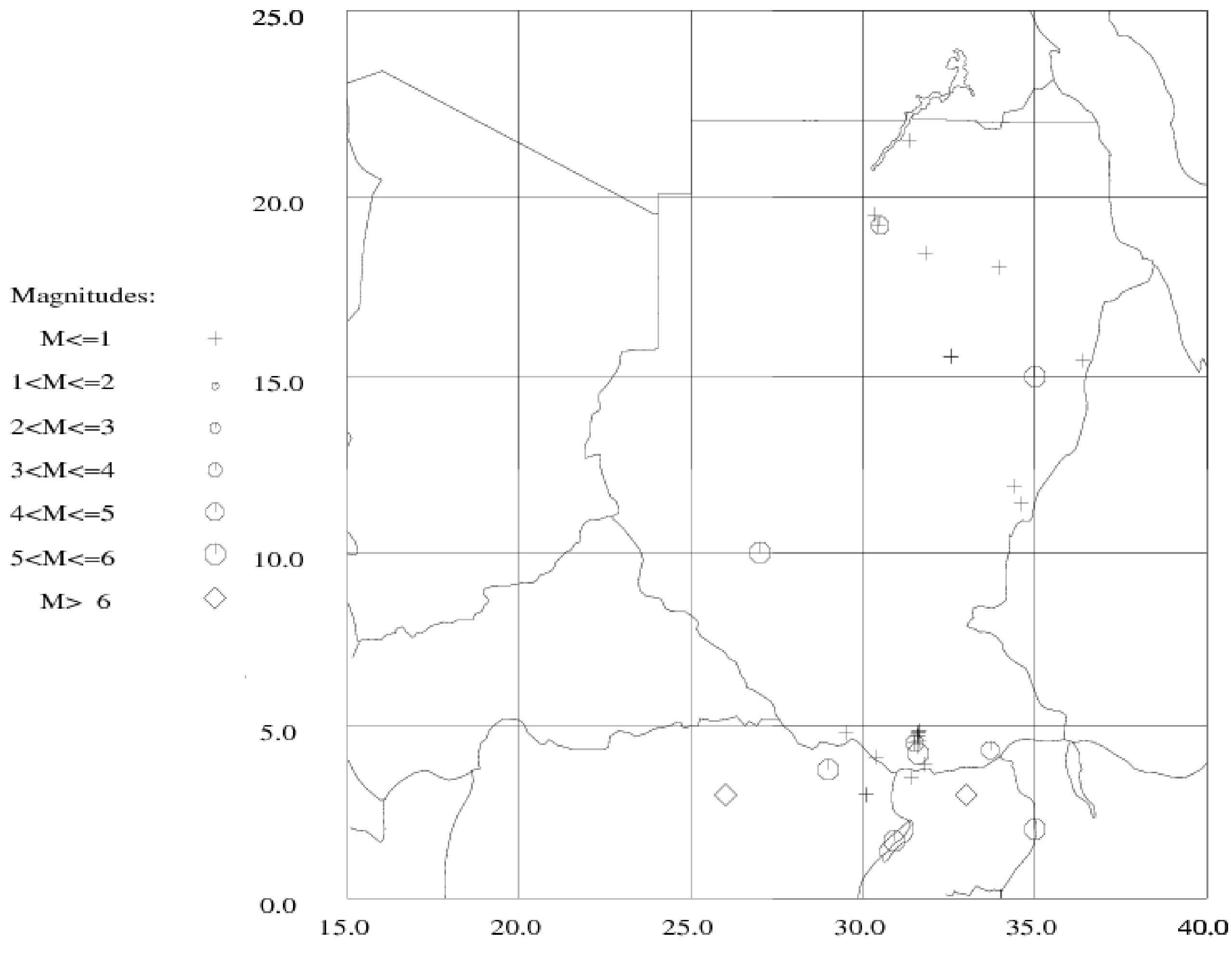

Fig. 3: Showing Total Number of Historical/instrumental Events Adopted After ADA for Sudan Prime Area

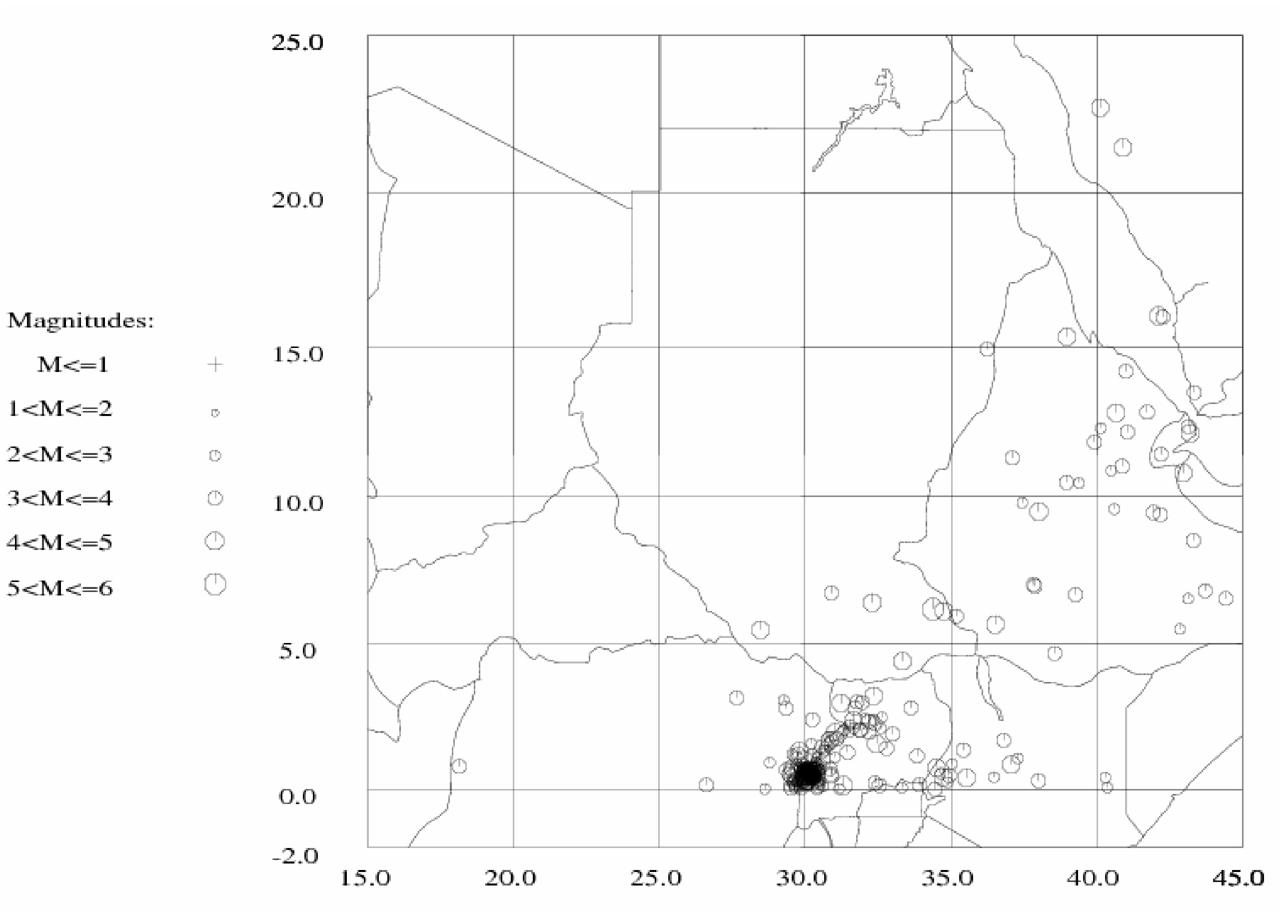

Fig. 4: Showing Total Number of Events Recorded EAF
For Sudan Prime Area

Local Seismicity of Sudan

1- Data Resources

Data used in this report were obtained form those mentioned and described on section1 in Seismicity of Sudan Prime Area report.

2- Procedure

See section 2 in Seismicity of Sudan Prime Area report.

3- Results

A file has been constructed using SELECT program. The selection criterion was basically chosen for the latitude and longitude limits for Sudan (taken as lat. 3 – 23 and long. 22- 38). A total number of 158 events were obtained.

Then a seismicity map has been drown using EPIMAP program, illustrating the local seismicity of Sudan, See Fig.1

Towards more detailed view of seismic activity in Sudan, a file has been constructed using SELECT program, taking into consideration that the selection criteria were both for the latitude and longitude limits for Sudan and Magnitude Agency. This selection combination has been operated twice both for ADA and EAF agencies.

For SSN agency, the same operation was followed, but in this case, and in addition to the selection criteria of the latitude and longitude limits for Sudan and Magnitude Agency, a selection criterion of depth limits has also been taken into account. The range of the depth limits was taken as (0.1 – 99 Km). This option was considered in order to exclude the explosions out of the real events.

A total number of 8 events were recorded for SSN as an agency, for ADA the number of events was found to be 29, and those of EAF were obtained to be 7 events

Then from the above described files, 3 seismicity maps have been generated using EPIMAP program. Those maps represent the Local seismicity of Sudan; taking SSN, ADA and EAF Agencies one at each time, see Fig 2, 3 and 4 respectively.

Reference

1- N. N. Ambraseys and R. D. Adams, Seismicity of the Sudan, a paper on Bulletin of the Seismological Society of America, Vol.76, NO. 2, pp. 483 – 493, April 1986.

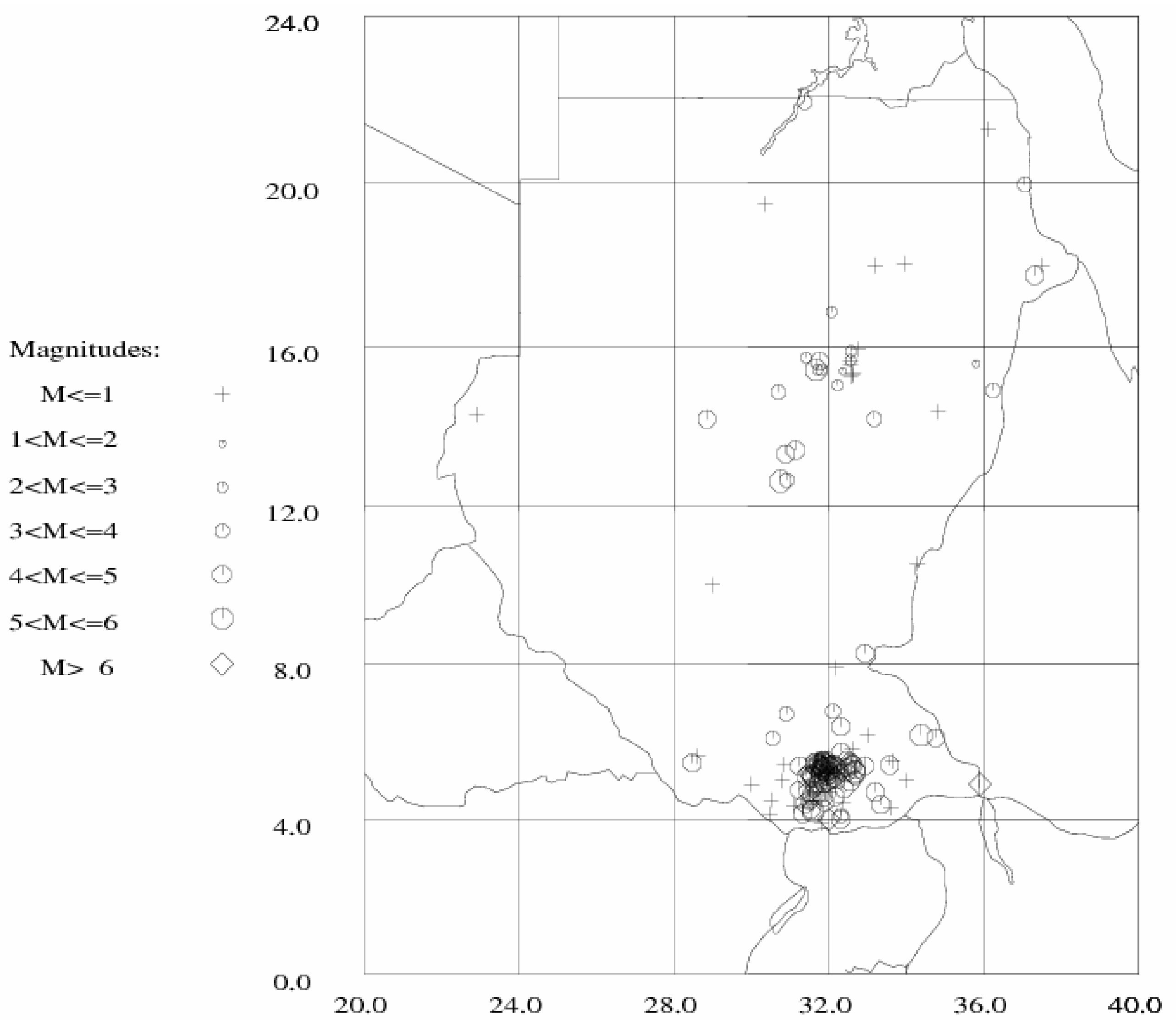

Fig. 1: Showing Total Number of Historical/instrumental Events Recorded By SSN, PDE, ADA, and EAF Agencies For Sudan

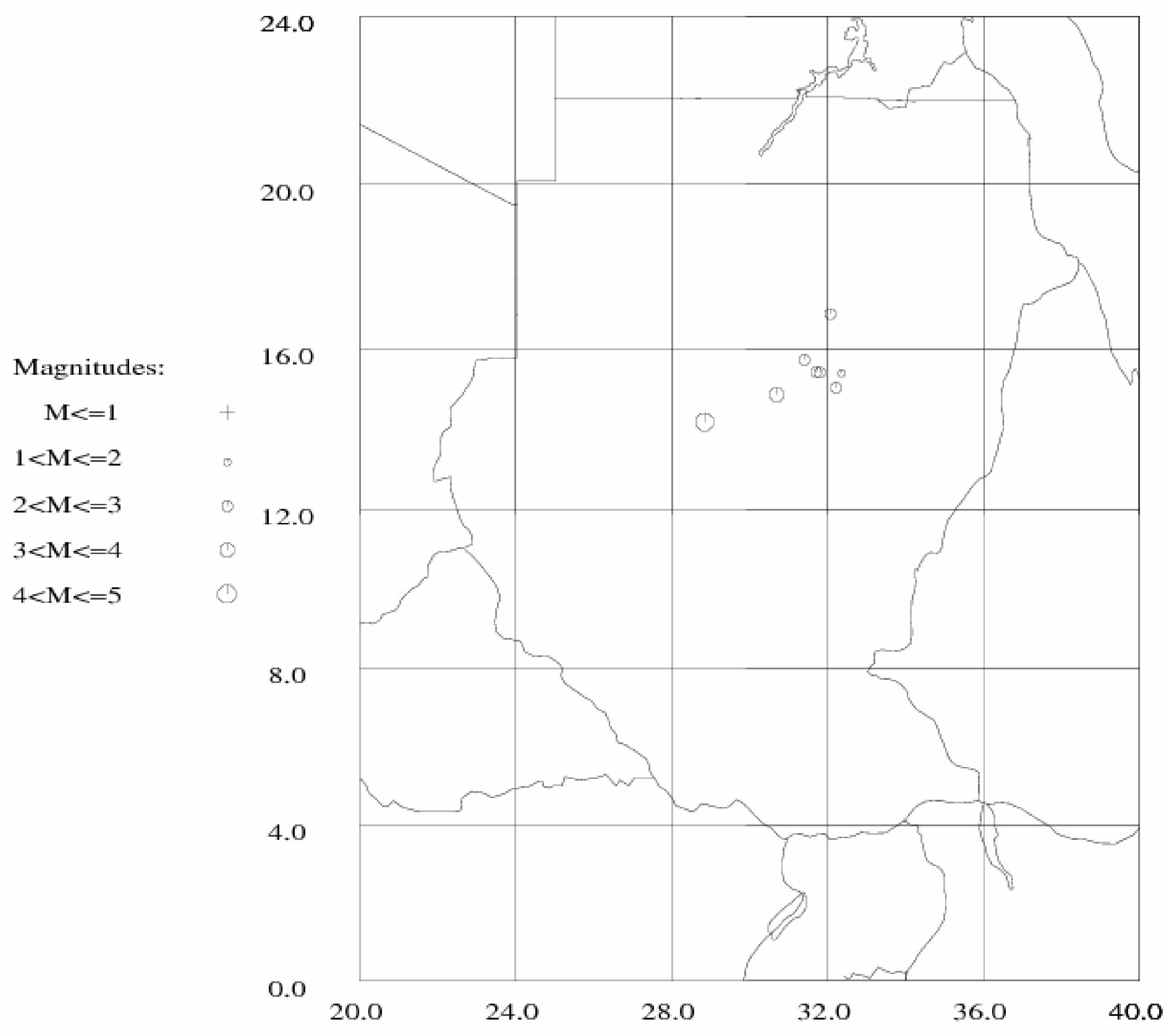

Fig. 2: Showing Total Number of Events Recorded only by SSN for Sudan

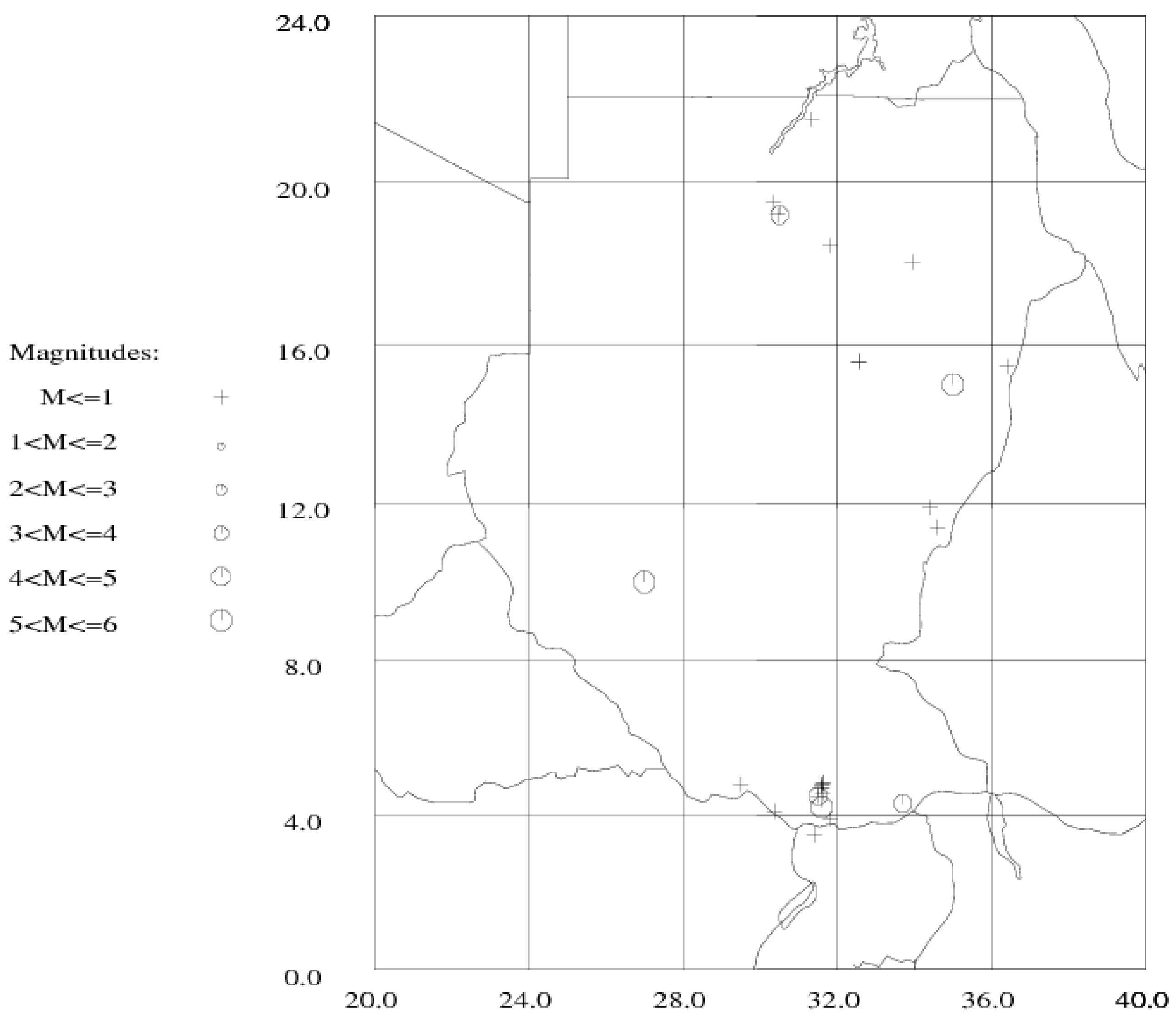

Fig. 3: Showing Total Number of Historical/instrumental Events Adopted After ADA for Sudan

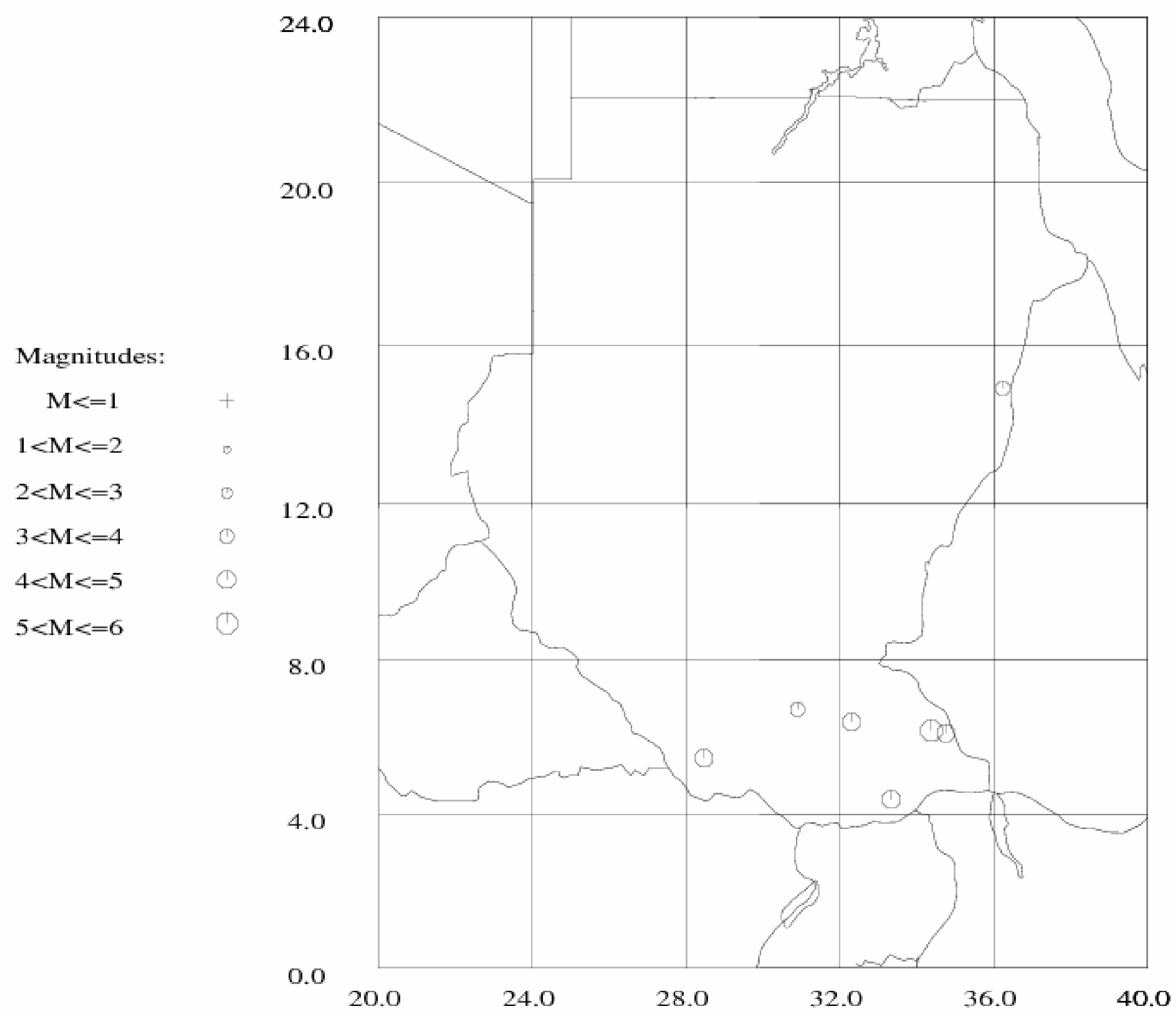

Fig. 4: Showing Total Number of Events Recorded EAF for Sudan

Appendix 3

Technical report

Seismotectonics of Sudan and the implication of the fault plane solutions on the stress of the area.

by

Nada Bushra

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(GRAS)

December 2006

Earthquakes constitute one of the most feared natural hazards. They normally occur without warning, often resulting in loss of life and great damage to property
Sudan is regarded as relatively stable seismically; however it has been struck by several devastating earthquakes resulting in severe damages the largest of these was probably the largest earthquake in Africa in the 20th century. It occurred on 20 May 1990 (Ms = 7.1 – 7.4,) [1, 2] near Juba in southern Sudan (Fig. 1). The main event was followed by several aftershocks, the largest of which had a magnitude of, Ms = 7.0. Other earthquakes whose effects caused major damage and even deaths, include the Suakin graben earthquake (Ms=5.8) of 12 May 1938, located on the western margin of the Red Sea, the Jebel Dumbier event located in Central Kordofan (Ms=5.6), which occurred on 9 October 1966 [3], and the Quz Abu Dulu event (Ms=5.5) of 1 August 1993 (Fig. 1.). The later earthquakes are of special interest, because they occurred away from the unstable belt of the East African Rift system and the sources are is not fully understood.

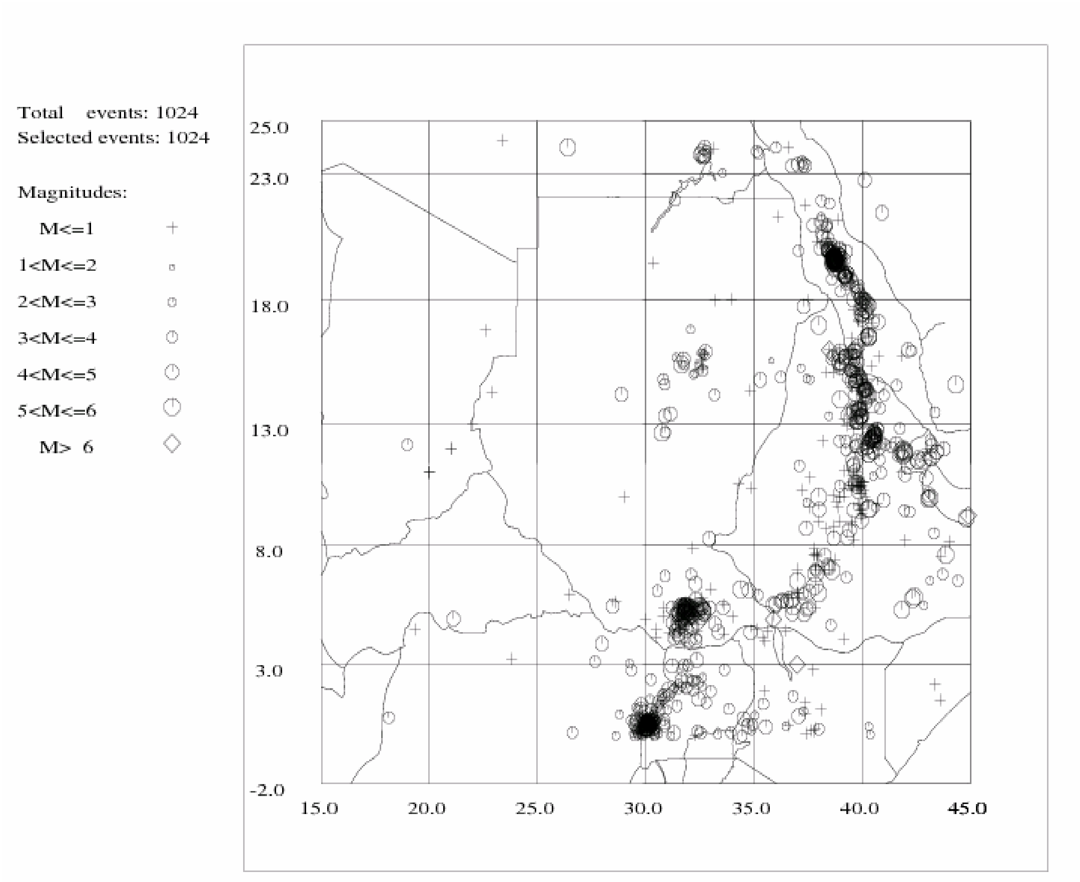

Figure 1. Seismicity for Sudan prime area for the time period 1906-2006.The data comes from ISC, PDE, EAF, ADA and SSN.A total of 1024 events are shown. Magnitude symbols are proportional to size.

Seismotectonics of Sudan

The seismotectonics of Sudan is characterised by large spreading of a complex rift system due to presence of the Central African System (CARS) and the East Africa Rift System (EARS), many of the epicentres found were associated with rift system in Sudan.

Central African Rift system in Sudan

The Central African Rift System (CARS), which is part of the Western African Rift System, extend for at least 2000 km a cross Africa.[4,5]. The CARS extend in a North-East to South-West direction in from gulf of Guinea in the Atlantic Ocean through Cameroon, Southern Chad, and the Central Africa Republic into Western Sudan. It passes North Nuba Mountains and North of Khartoum in to the Red Sea. Figure 2.

The boundaries of the CARS in Sudan north to include faults parallel to the River Nile North-West of Bayuda Desert and Wadi El Malik [6]. The faults parallel to the River Nile North-West of Bayuda Desert are believed to the cause of the August earthquake in Northern Sudan. There are many faults and shears zones are a part of the CARS. These faults and shears zones are potential location of earthquakes; the August 1, 1993 5.5 earthquake is attributed to the faulting system in this area.

Eastern African Rift System in Sudan

The East African Rift System (EARS) is apart of the afro –Arabian Rift System [7]. The Afro-Arabian Rift System (AARS) extends 6500 km from the Jordon-Dead Sea rift, north, through the Red Sea, the Gulf of Aden and the Eastern African Rift System. The East Africa system generally strikes in North-North-East to the border of Sudan. The East African Rift system defines a diffuse active place boundary within Africa, comprising two major branches. The first branch is eastern branch running from Afar (Ethiopia) north to northern Tanzania south, including the Gregory Rift in Kenya. The second extend branch from lake of Mobutu north to Mozambique coastal plain south [8]. The western branch of the east African rift system has some of the most seismically active faults in Africa. The Aswa Fault Zone (AFZ), which strikes in a North-West to South-East direction, passes through Numule in Southern Sudan [7].

The region around Aswa fault zone experienced several earthquakes of varying magnitude during the last 150 years. In May 20, 1990, southern Sudan experienced one of the largest earthquakes in this century in the whole of Africa. The main event is registered 7.4 in Richter at different stations. This earthquake has been followed by three after shocks comparable in magnitude to the main event and at epicenter and focal points in the vicinity of the main shock. These events occurred at the remote Aswa fault zone which passes near Numule and Juba in southern Sudan, which belong to the East Africa Rift System. The Aswa fault zone had been a site of several earthquakes beside the major event.

The Eastern branch of the EARS at its various faults is a source of major earthquakes in the eastern Sudan and the Red sea area. For example the May 12, 1938 magnitude 5.8 Sukin earthquake.

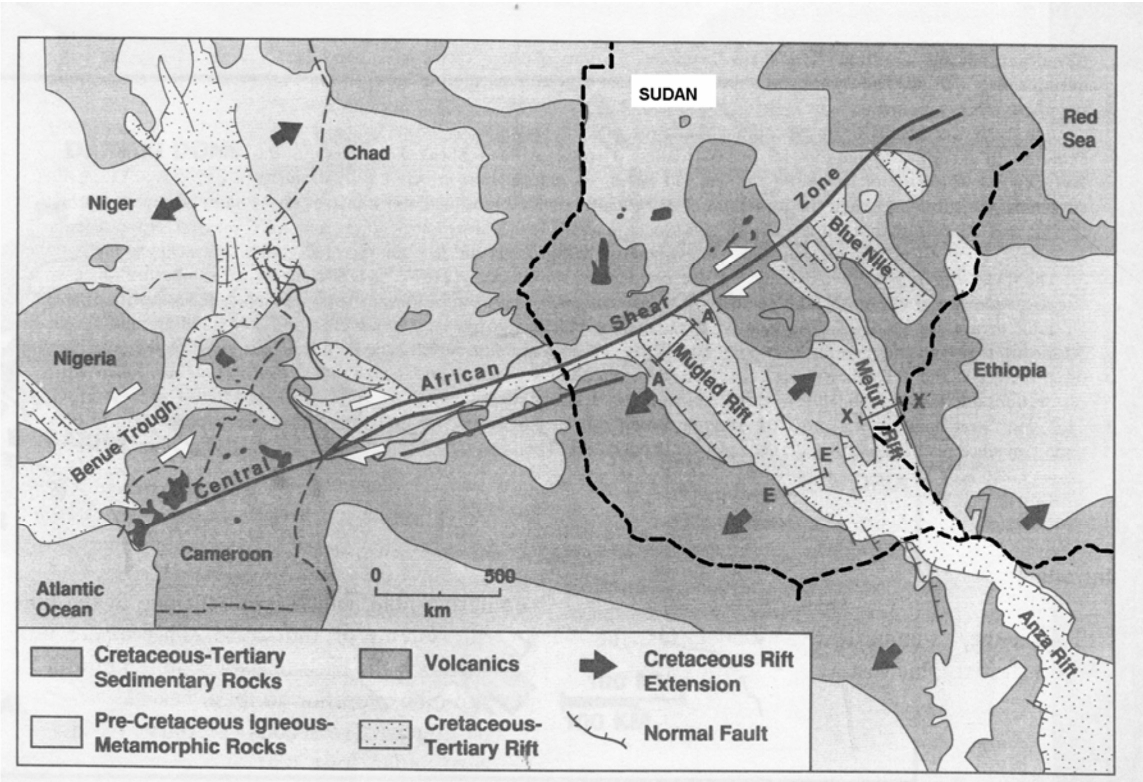

Figure 2. The main earthquake generating tectonic features in and around Sudan. Adopted from Fairhead [9].

Fault plane solution

A plot of events and their fault plane solutions from the period 1976-2004 adopted from Harward for our prime area lat. 0-25 and log. 15-25. Tow examples will discussed in terms of fault plane solution. Figure 3.

The Fault plane solution of the May 20, 1990 earthquake:

The Juba area in Southern Sudan was affected by a high-magnitude sequence of events in the period May-July 1990. Since no major seismicity has been reported by international catalogues for the Juba area. The large 1990 sequences provide the opportunity to understand the regional seismotectonic of the area. The focal mechanism, issued by Harvard, showed that a consistent component of strike-slip motion, vertical dip slip and also marked normal and thrust fault, fault Figure 4. .The dominant stress generated in this area is a compression in the North-East and East direction.

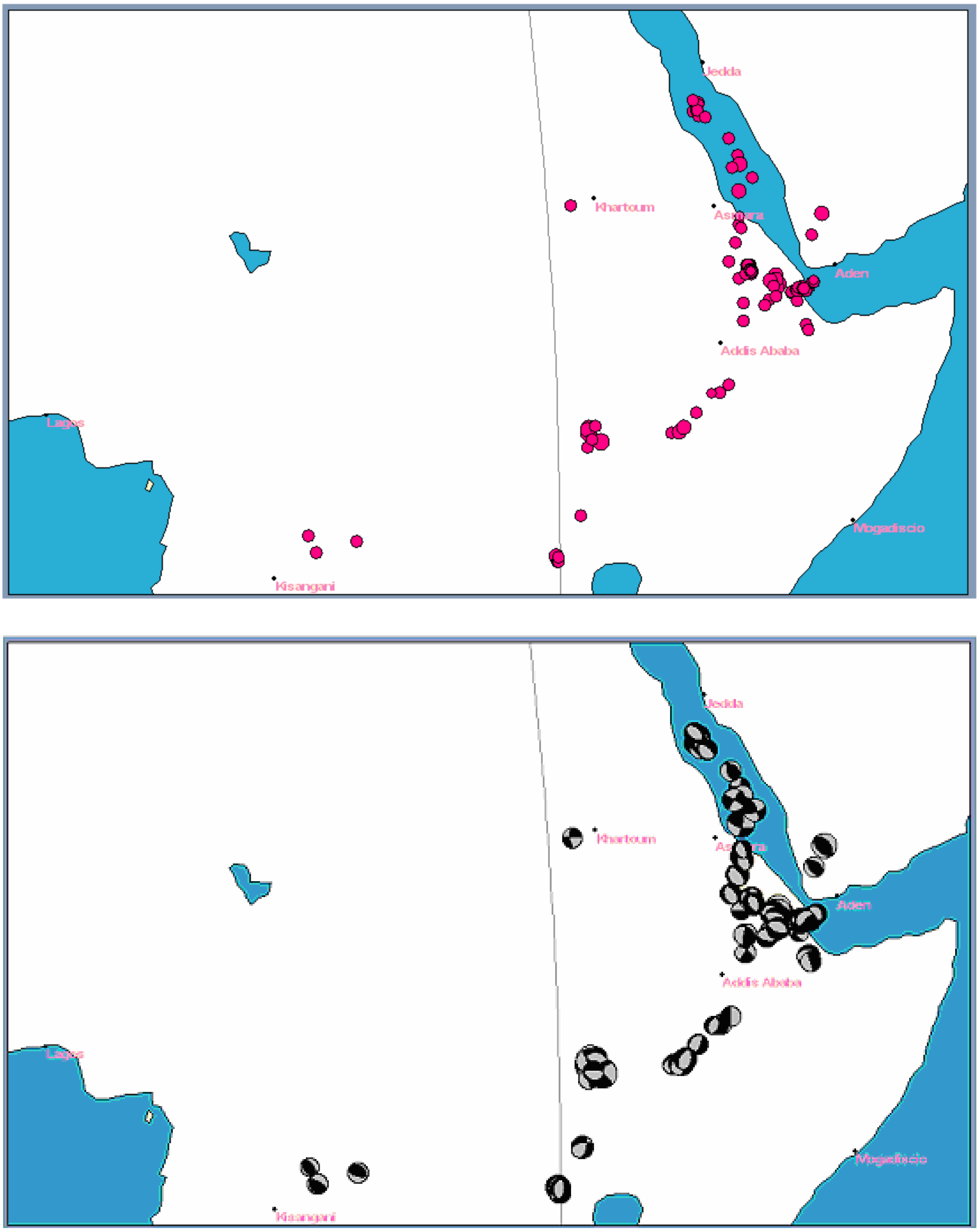

Figure 3. Plot of the epicentres and the fault plane solutions for the period 1976-2004 in our prime area.

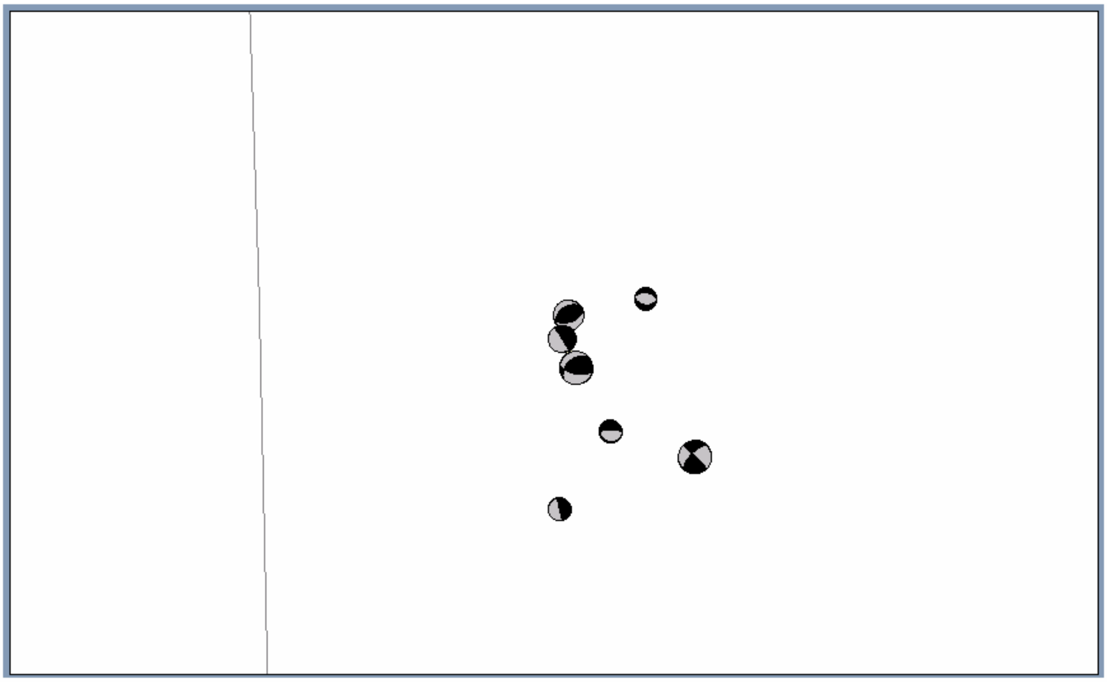

Figure 4. Plot of fault plane solutions for the period 1976-2004 for Juba area

The Fault plane solution of the August 1, 1993 earthquake

The epicentre of this earthquake lays in central part of Sudan, which is relatively quiet in terms of earthquake. However, recently study by [10] showed that a fracture zone trending NE–SW is believed to represent surface expression of movement related to the recent central Sudan earthquakes on Land sat imagery, the discovered zone west to Khartoum seems to be the epicenter of Khartoum 1993 earthquake. The focal mechanism for this event is also issued by Harvrad Figure 3. The plot indicates compression is in the NE and extension in the east

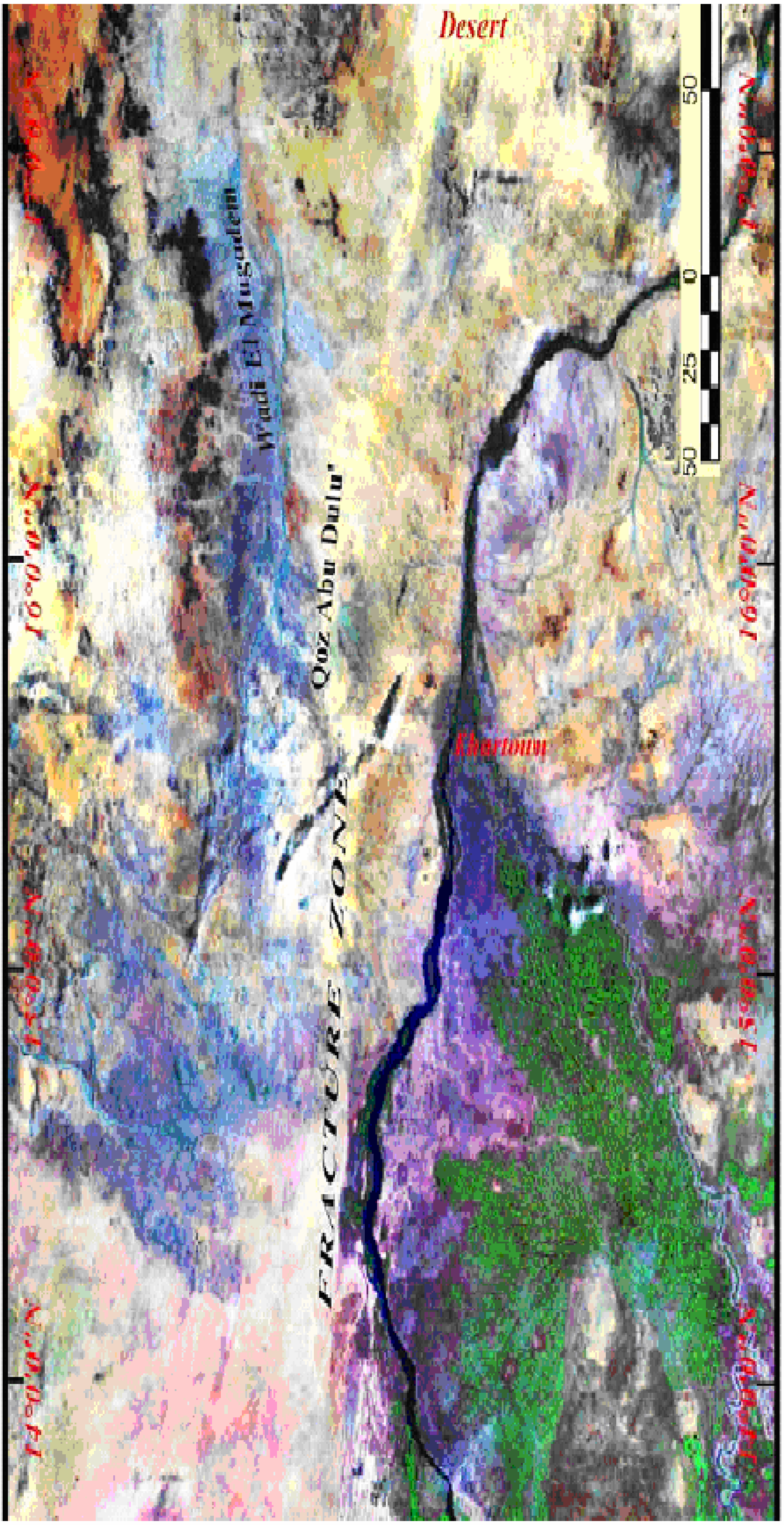

Figure 5. Mosaic of Land sat images, band 7, 4& Lin RGB, showing the regional and extension of the fracture zone.

The stress in our prime area

Geophysical studies of crustal and lithospheric structure of the West and Central African rifted basins indicate that these subsided in response to large amount of crustal extension. The rifted basins of Africa provided weak zones in an otherwise stable craton are extremely sensitive to change in the regional stress regime.

The focal mechanism for the red sea and Gulf of Aden is almost normal faults and is associated with extensional. That occurs in the Red Sea.

One can conclude that most part of Sudan subjected to compression stress results from the Red Sea extensional stress, and extensional stress resulted from the Central African shear zone ended in the river Nile and the stress activated from the Western part of the African Rift , this extension stress accommodated in the Aswa shear zone.

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Appendix 4

Technical report

Test of Site effect estimation using H/V Nakamura's Technique

by

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Introduction

Nakamura technique [1] is a method to estimate the dynamic characteristics of surface layers using microtromers on the ground surface. The method uses the ratio of spectral amplitude of horizontal component to the vertical one, and doesn’t require bedrock as reference. The noise data down to 0.3 Hz, be used for testing this method. The noise is generated through sediments and the soil transfer function can be estimated from the spectrum ratio of the horizontal and vertical components. Nakamura technique reveals the fundamental mode of vibration of the soil column and a rough estimation of the ground motion amplification.

Objectives

The main objective of this study is to test the estimulation the local site effect of different sites around Khartoum using the spectral ratio technique.

Data used in the study:

Noise data recording at GRAS using Sara seismograph and 2.0 Hz short period seismometer.
Noise data recording at different sites using Marslite seismograph and 1Hz short period seismometer.

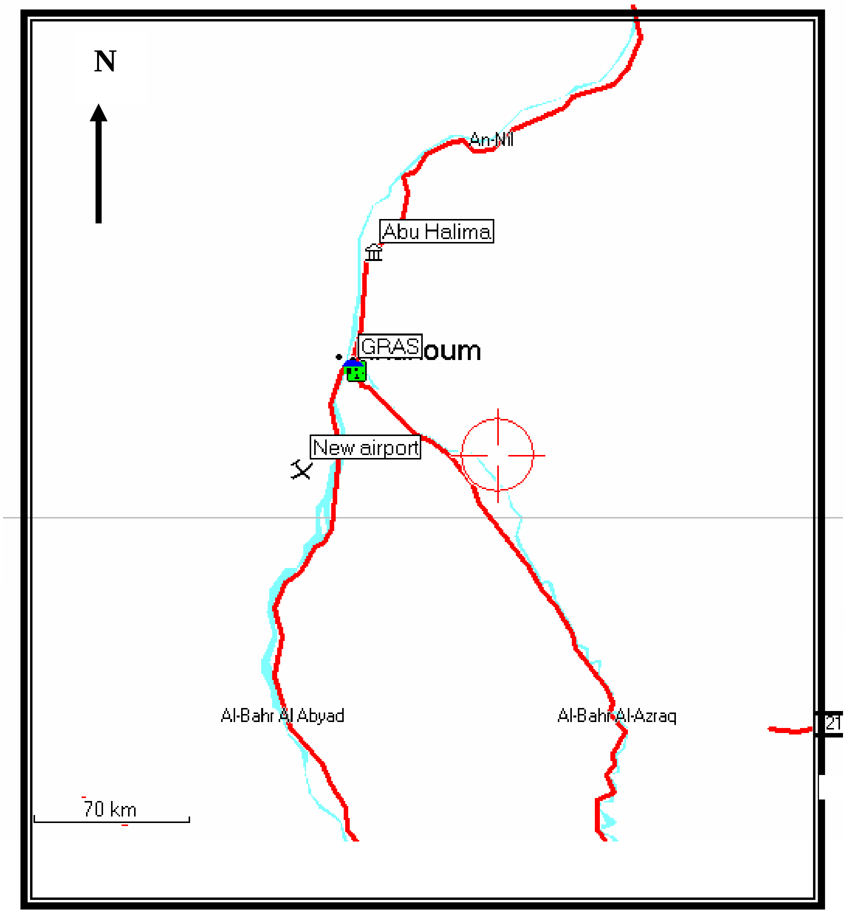

Figure (1) Location of Sites where the data were collected

Method

Using Nakamura techqunic for computing H/V spectral ratio and processed using sesame software [2].

Steps used in preparing the processing

- FFT
- Smoothing with several options. The Konno – ohmachi method is used.
- Merging two horizontal components with several options. Geometric method is used
- H/V Spectral ratio for each individual window
- Average of H/V ratios
- Merge spectral ratio for(v) NS and EW

Results:

The spectral ratio of the noise recorded windows were computed for the E-W and N-S components for three different sites in Khartoum (Gras), North of Khartoum (Abu Halima) and West of Omdurman city at (Elsalha). (New airport) see figure (1)

Table contains the Result of testing sites

Site	Resonance frequency	Amplification Resonance frequency
GRAS	1.3 Hz	4.4
West of Omdurman	1.2 Hz	1.6
Abu Halima	1.0 Hz	`6.6

At GRAS site, the geology of the area is Nubian sandstone the resonance frequency and amplification were found to be 1.3 Hz and 4.4 respectively.

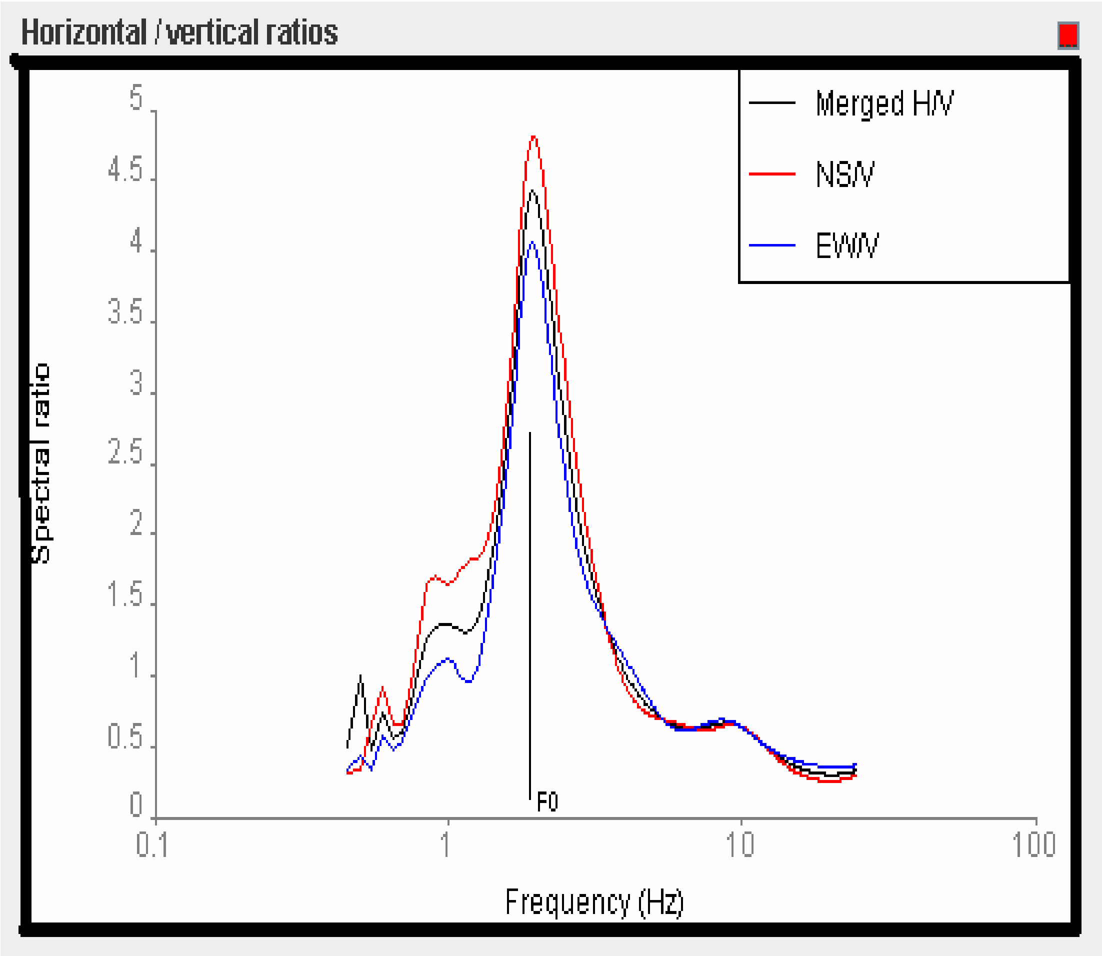

Figure (2) Site (1) GRAS Shows the spectral ratio of merged (H), NS and EW horizontal components and the spectra ratio of V, NS and EW for each individual window.

West of Omdurman city At (Elsalha) New airport site, the geology of the area is Nubian sandstone the resonance frequency and amplification were found to be 1.29 Hz and 1.6 respectively.

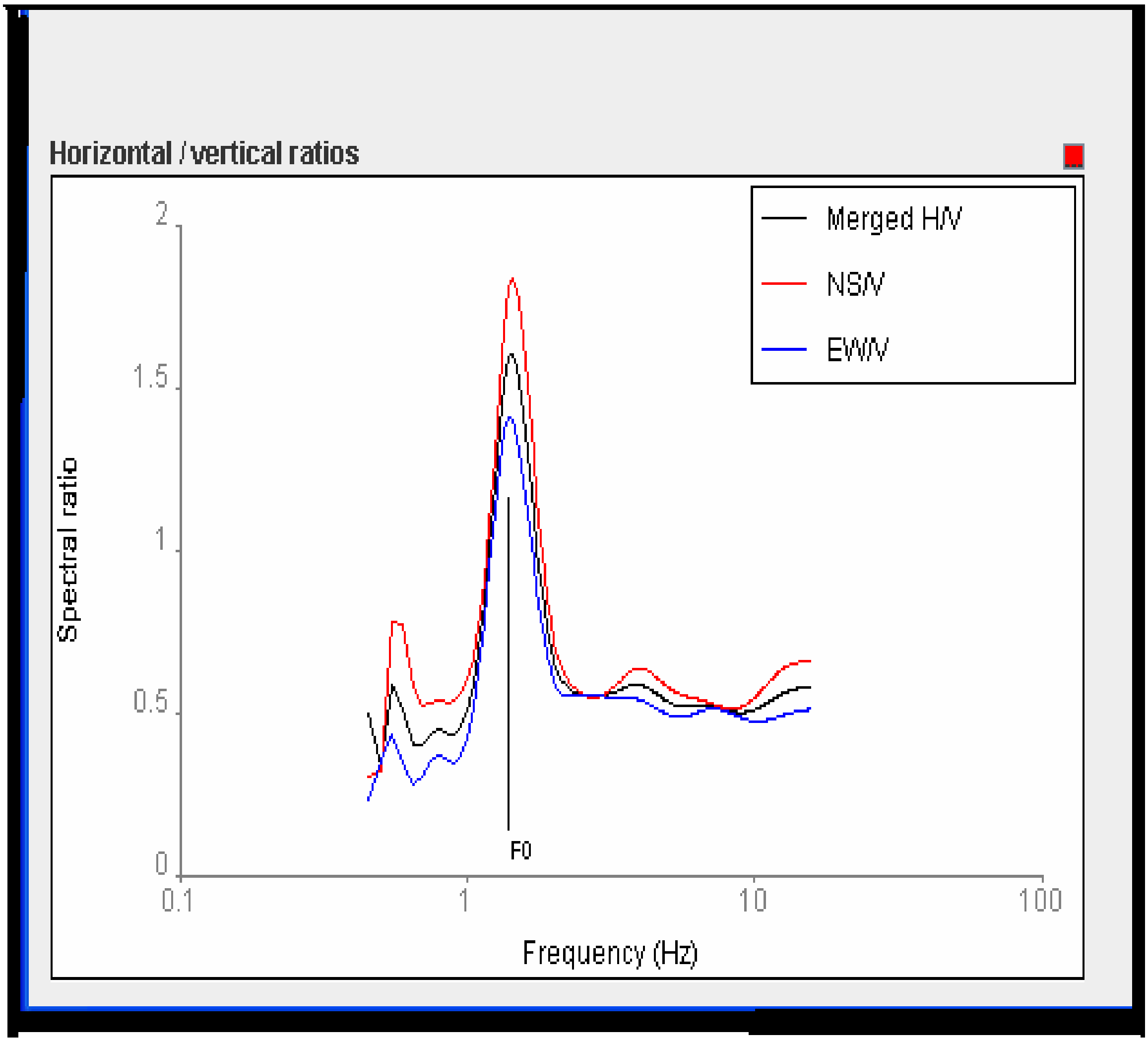

Figure (3) Site (2) New airport shows the spectral ratio of merged (H), NS and EW horizontal components And the spectra ratio of V, NS and EW for each individual windows.

North of Khartoum at Abu Halima site, the geology of the area is Nubian sandstone the resonance frequency and amplification were found to be 1 Hz and 6.6 respectively.

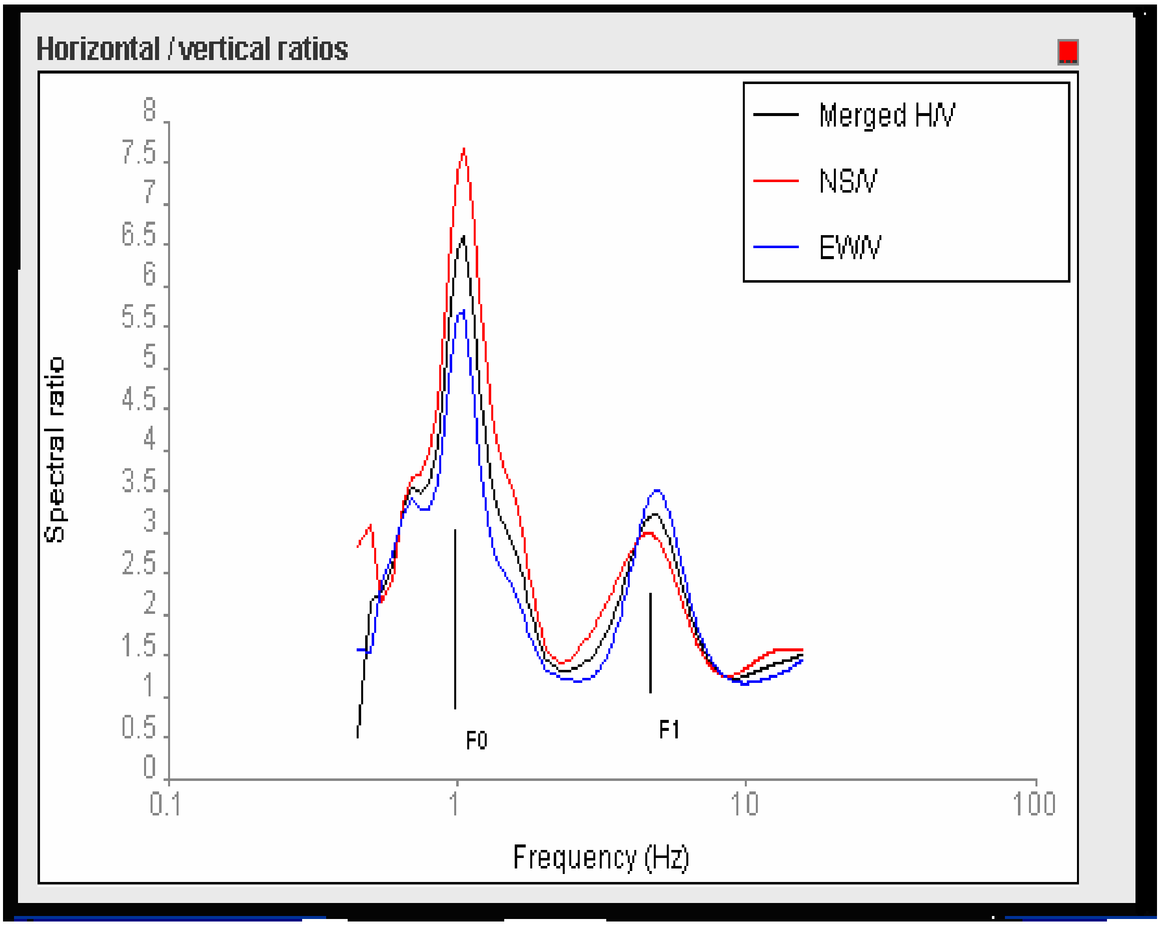

Figure (4) Site (3) Abu Halima Shows the spectral ratio of merged (H), NS and EW horizontal components And the spectra ratio of V, NS and EW for each individual windows.

Discussions and recommendation:

Comparing the results of the three sites, the best site(new airport) showed low amplification which is expected for this site near the bed rock, while the other two sites showed slightly or higher amplification due to both sites lay on the Khartoum basin. The same resonance frequency similar for all sites index
More investigation for geotechnical information will be needed to asses the site effecting for the area.

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