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Seismicity of the East African Rift

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Seismicity of the East African Rift

A review

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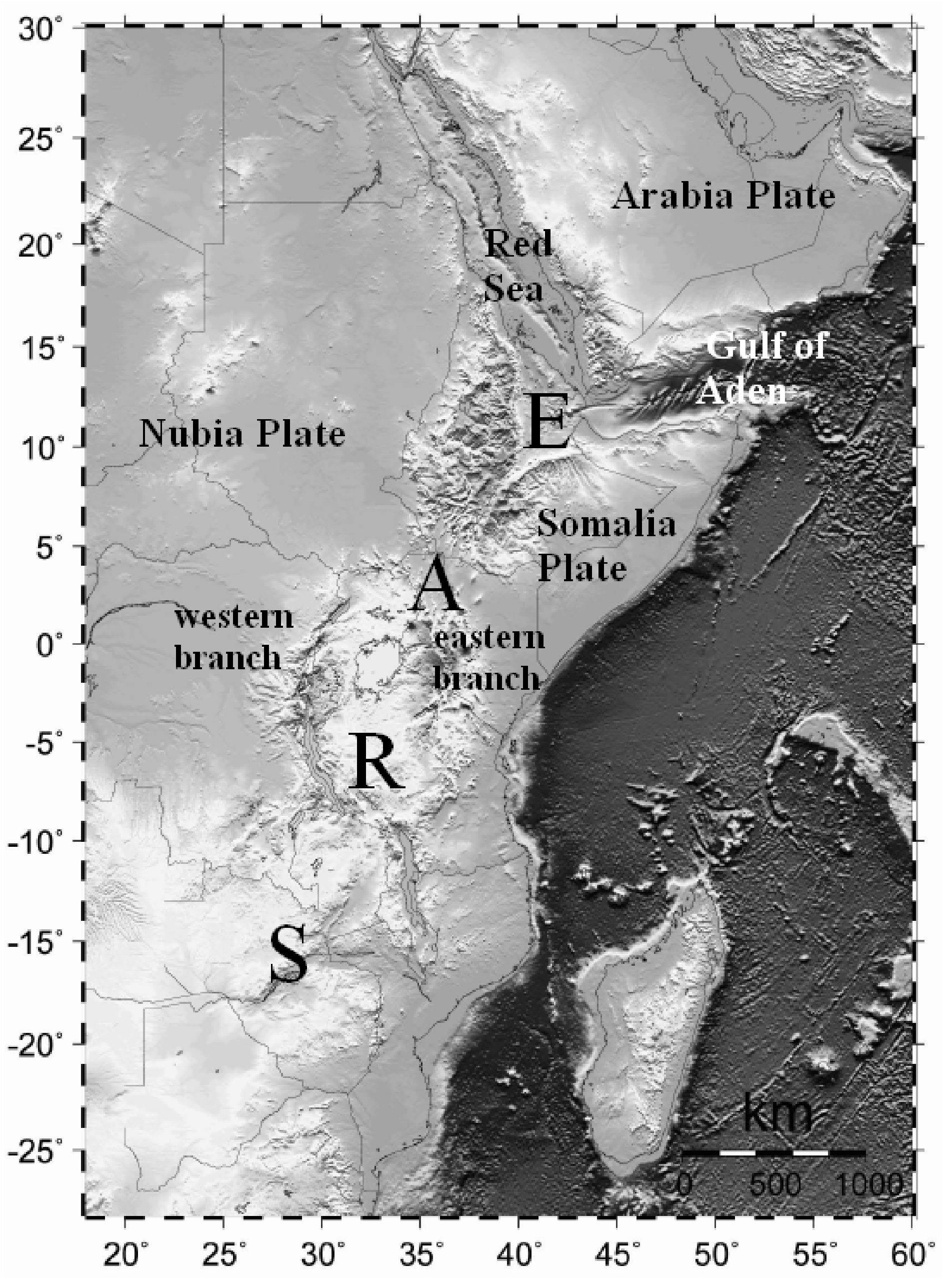
Content

- Introduction
- Non-instrumental seismicity
- Instrumental observation
- Few practical tips
- Conclusions and recommendations

Introduction



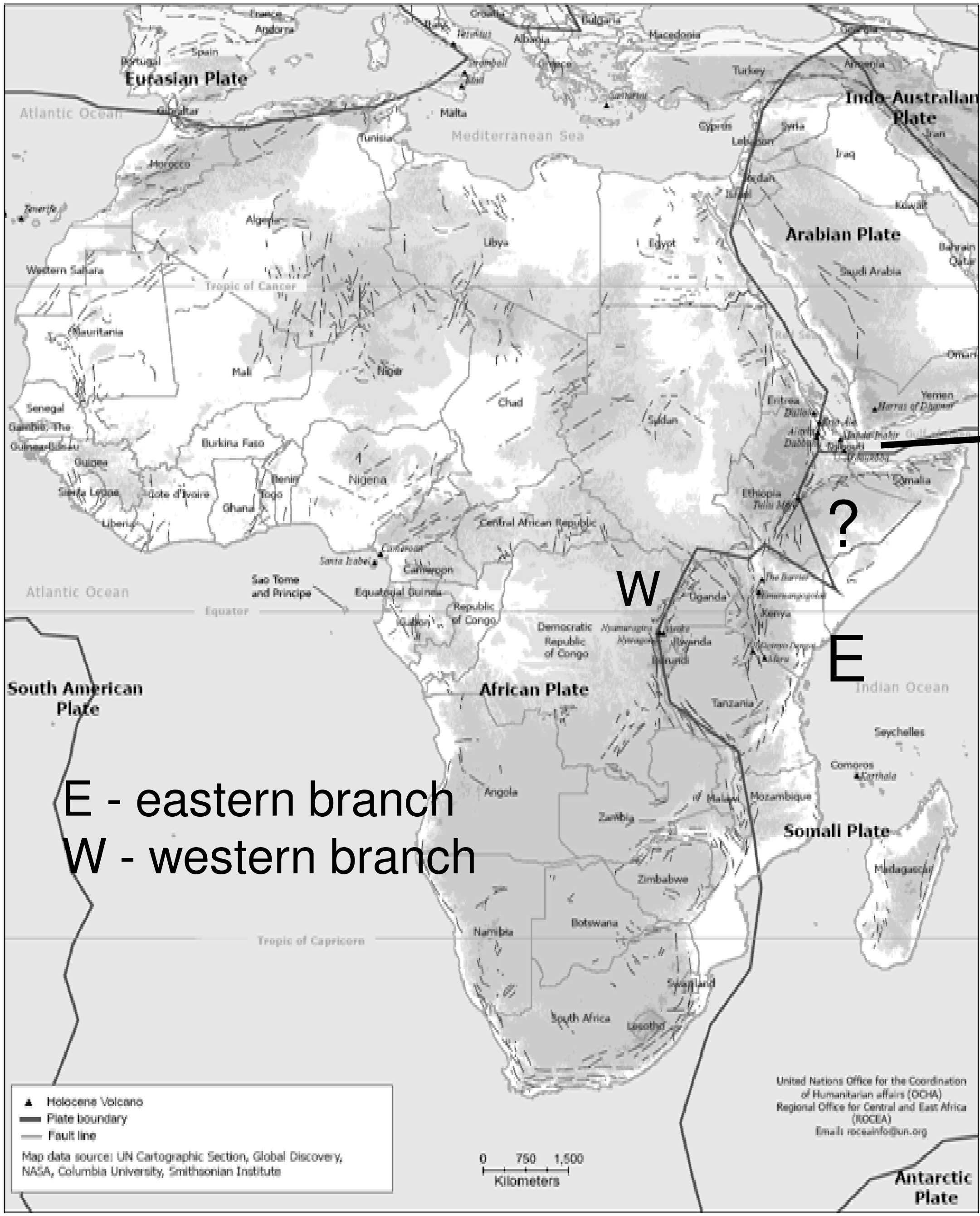
-The Gulf of Aden and the Red Sea oceanic rifts join the East Africa Rift System (EARS) in the Afar depression, forming a RRR triple junction

-In general EARS gets younger and younger from the Afar triple junction toward the Okavango delta

-EARS is one of the major late Cainozoic active continental rifts in the world (Rio Grande, Baikal, Rhinegraben) with the following characteristics

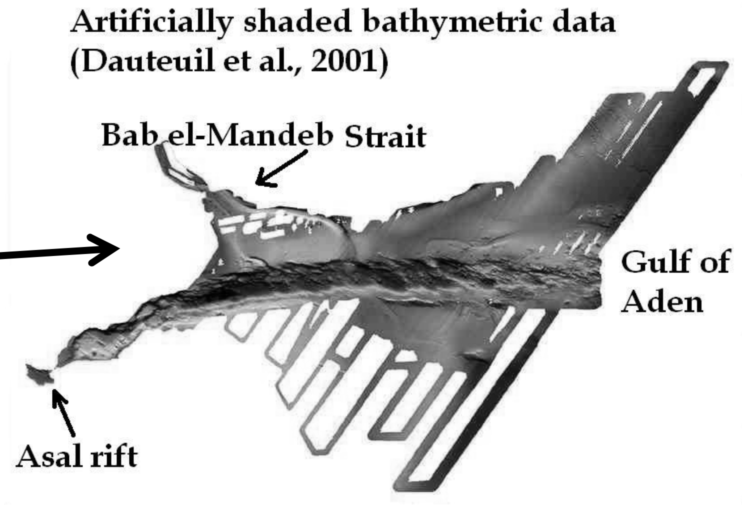
- high heat flow
- predominantly basaltic and associated silicic volcanism (bimodal volcanism)
- lithospheric attenuation in both the crust and mantle
- regional high elevation
- low seismic velocity and high electrical conductivity
- dominantly normal faulting in the crust with associated basin formation

Tectonic plates and faults in Africa, issued: December 2007



E - eastern branch
W - western branch

OCHA Regional office for Central and East Africa

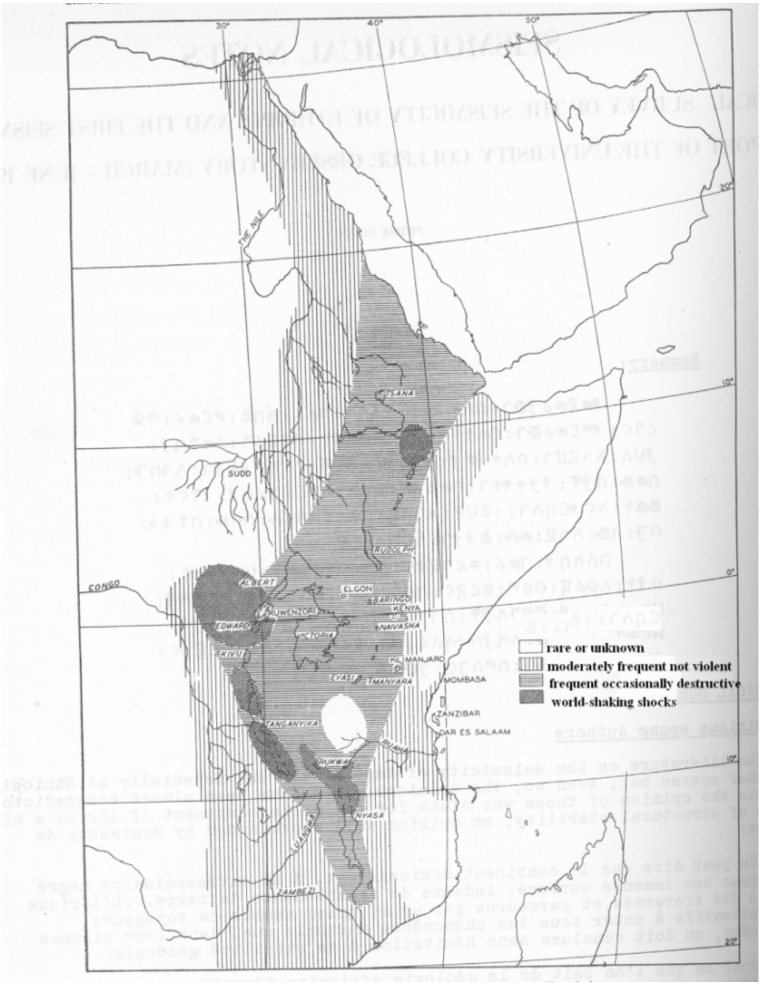


- the data for the inference of the EARS plate boundary is not clear

- is this plate boundary realistic or does it agree with data?

Non-instrumental seismicity

Sieberg's intensity map of Africa



rare or unknown

moderately frequent but not violent

frequent and occasionally destructive

world-shaking shocks (> 6.8)

Intensity map recorded by humans as "accelerometers" in the near field and probably the first "strong motion" map of Africa but teleseisms are undetectable!

Previous studies on seismicity in Africa

Gouin, 1979, Earthquake History of Ethiopia and the Horn of Africa

Shah, E., 1986, Seismicity of Kenya

Iranga D.m., 1991, Earthquake catalogue of Tanzania

Turyomurugyendo, G., 1996, Some aspects of seismic hazard …

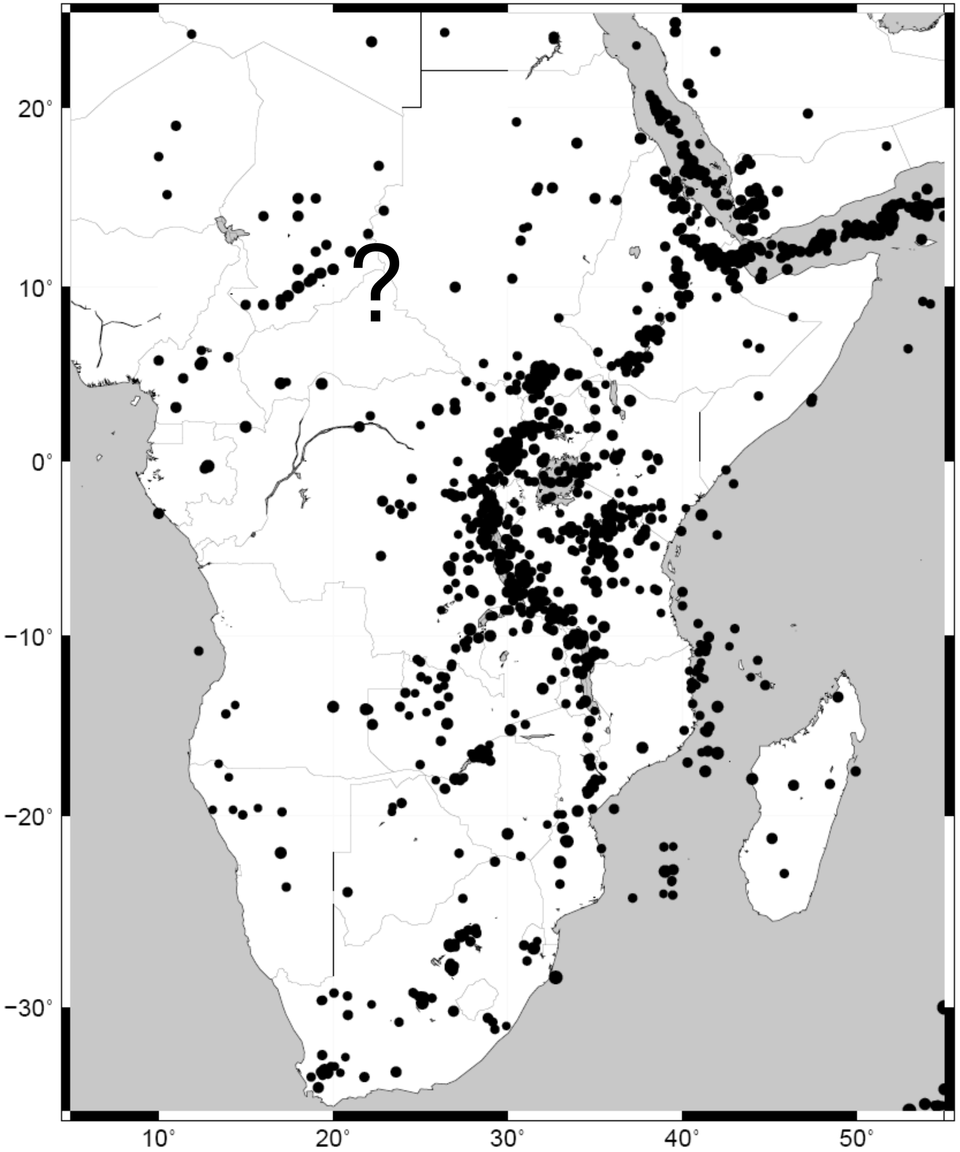
Jonathan, E., 1996., Some aspects of seismicity in Zimbabwe

Loupekine et al., 1966 UNESCO funded study on the Toro earthquake sequence of Uganda

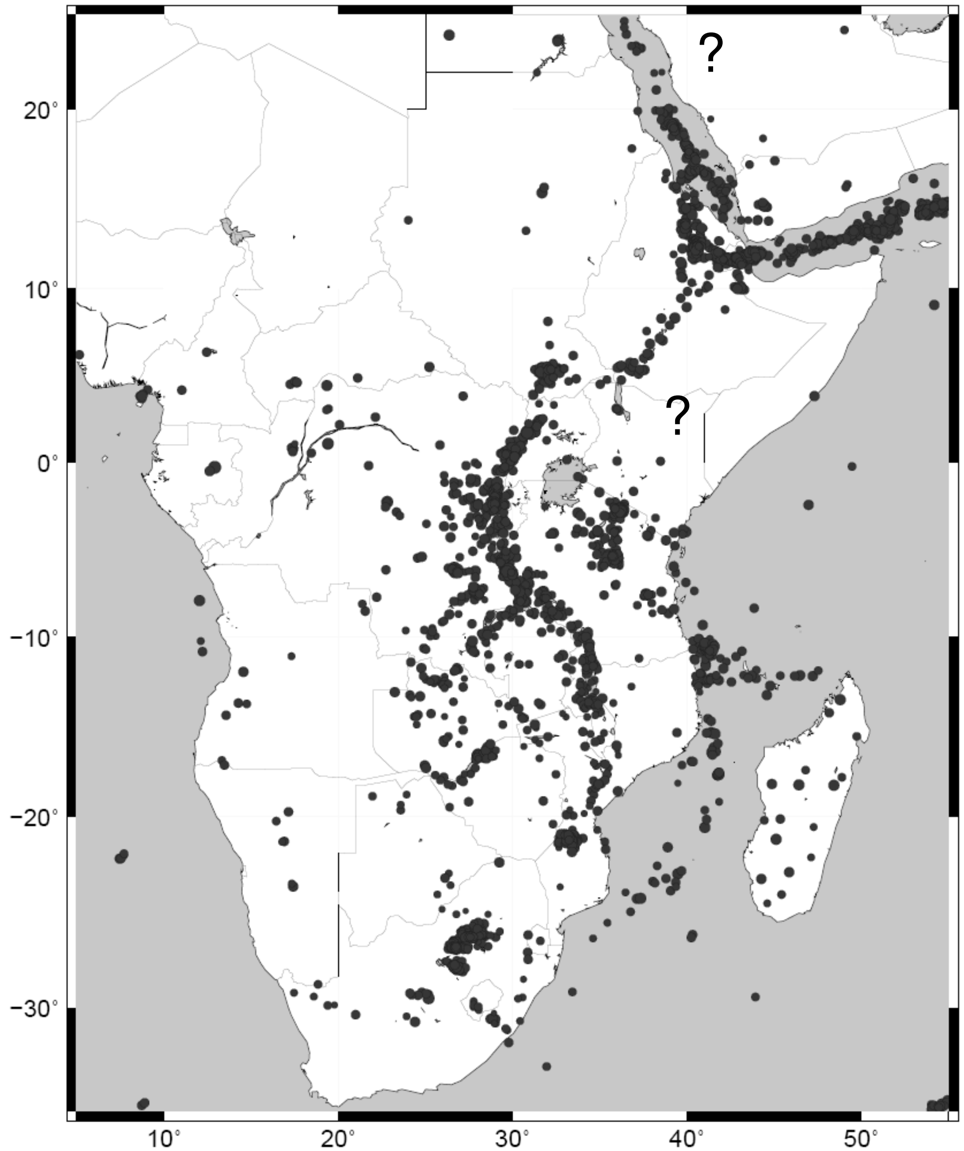
Gorshkov G.P., 1963 UNESCO funded study on seismicity of Africa

Turyomurugyendo's catalogue is the one used for the seismic hazard assessment of the region for the GSAP project in 1995

Seismicity and location uncertainties



Turyomurugyendo (1996) till 1994



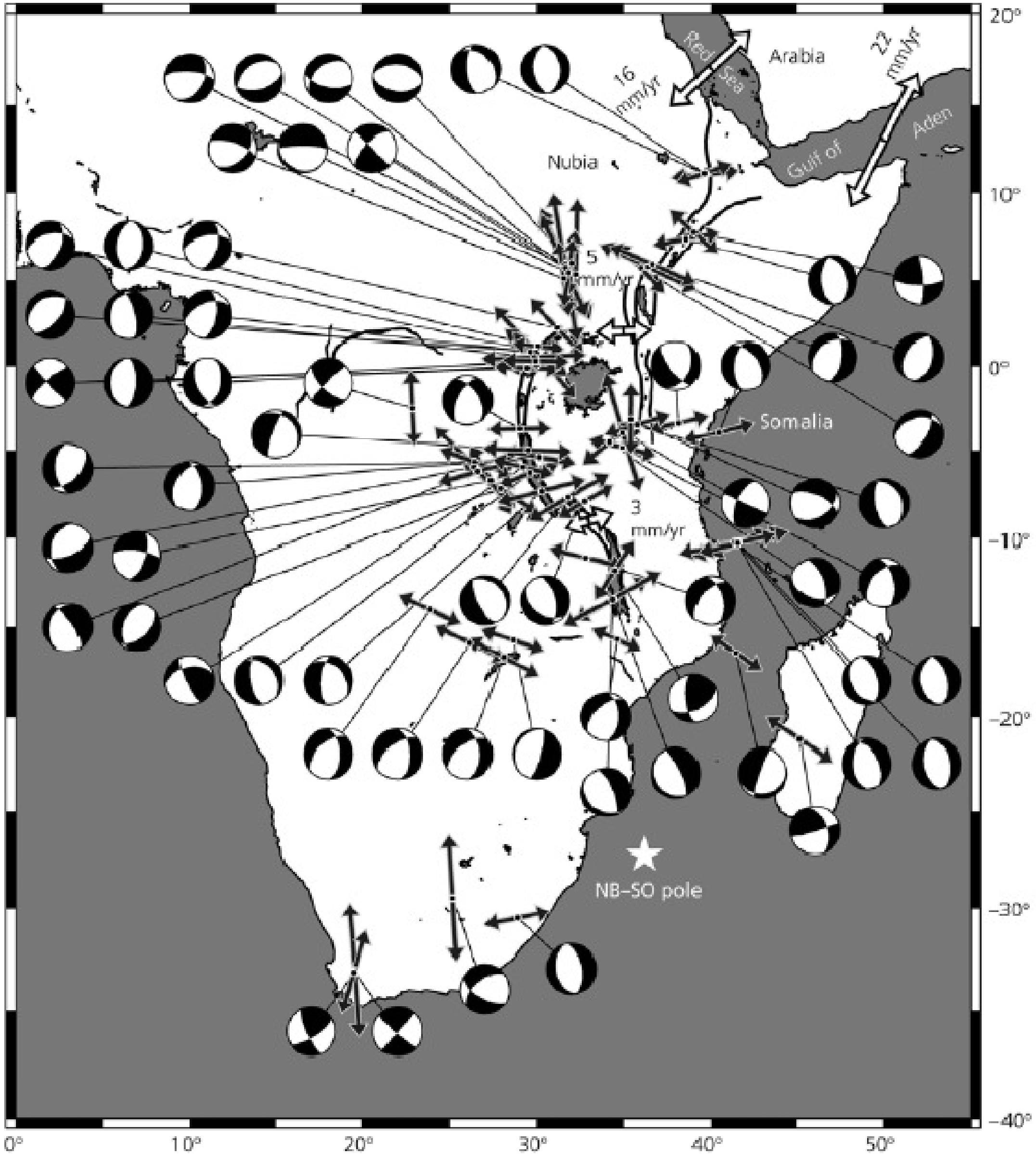
NEIC, 1973 to present

Some comments of interest

- Seismic catalogue of EARS needs revisiting
- Earthquake location from intensity maps can be biased by site effects due to sediments
- Continuity in seismicity is visible b/n the western branch and the Ethiopian part of EARS and
- Seismicity gap in central Red Sea north of Jiddha
- Earthquake damage is not correlated with even size

Some major earthquakes of interest in EARS

Major Earthquakes in EARS	Magnitude (Ms)	Damage (Deaths)
August 25, 1906 earthquake in MER, Ethiopia	6.8	None
The December 13, 1910 Rukwa earthquake in the then Tanganyika	7.4	None
The January 6, 1928 Subukia Valley earthquake (Kenya)	6.9	None
The Toro earthquake of March 20, 1966 (Uganda)	6.1	150
May 20 &24, 1990, Southern Sudan	7.1 & 7.2	20
February 23, 2006, Mozambique	7.0 (Mw)	4



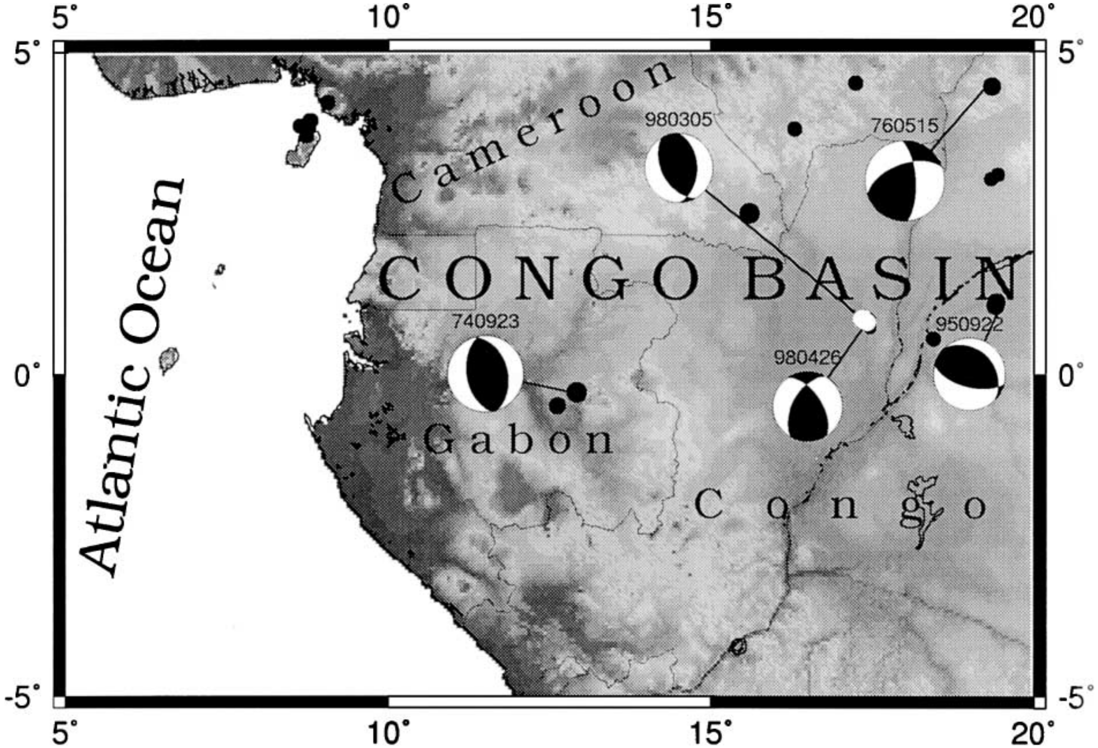
Earthquakes source parameters in EARS

- Magnitude 0-7.5

- depth 0-25 km

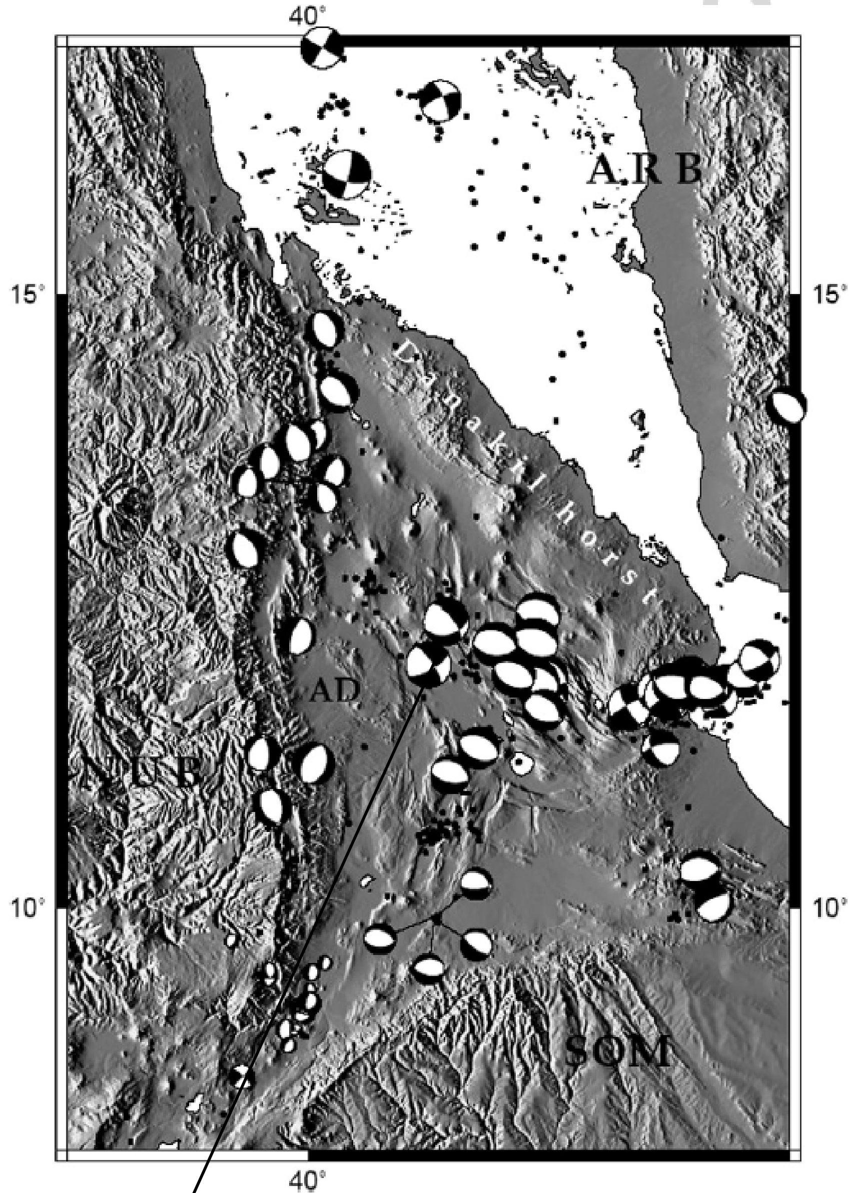
- mostly normal fault type but sometimes strike-slip events are possible with a rare occurrence of thrust faults

-Earthquakes can be tectonic or volcano-tectonic type



Ayele, 2000

- The causes for the thrust type deformation in the Congo basin is believed to be the two divergent plate boundaries



Ayele et al., 2007

Strike-slip or normal faults?

The 1966 Toro earthquake sequence in Uganda

	Date	Time(GMT)	Location			Depth	Magnitude
1.	Mar 20	01 42 49.9	0.58°N	30.16°E	(Uganda)	36km	6.1
2.	Mar 20	02 39 40.0	1.10°N	29.91°E	(Congo)	11km	5.5
3.	Mar 20	03 22 47.6	0.95°N	29.79°E	(Congo)	33km	5.1
4.	Mar 20	08 55 35.5	0.78°N	29.79°E	(Congo)	12km	5.3
5.	Mar 21	01 30 41.6	0.77°N	30.03°E	(Uganda)	33km	5.2
6.	Mar 22	09 23 53.2	0.77°N	30.01°E	(Uganda)	33km	4.8
7.	Mar 25	13 49 49.3	0.75°N	30.52°E	(Uganda)	33km	4.6
8.	Mar 25	21 57 37.7	0.79°N	30.46°E	(Uganda)	33km	n.d.
9.	Mar 29	17 24 12.6	0.76°N	30.41°E	(Uganda)	33km	n.d.
10.	Apr 1	07 59 37.0	1.06°N	30.01°E	(Uganda)	33km	4.4
11.	Apr 6	01 17 53.6	0.79°N	29.87°E	(Congo)	41km	4.4
12.	Apr 7	00 09 10.7	0.59°N	29.94°E	(Congo)	33km	5.2
13.	Apr 12	07 35 13.3	1.29°N	30.05°E	(Uganda)	24km	n.d.
14.	Apr 13	02 14 20.0	1.11°N	29.88°E	(Congo)	23km	n.d.
15.	Apr 13	09 43 05.4	1.12°N	30.21°E	(Uganda)	81km	4.0
16.	Apr 14	13 16 20.8	0.72°N	30.24°E	(Uganda)	21km	4.9
17.	Apr 15	03 08 16.3	0.85°N	29.93°E	(Congo)	33km	5.3
18.	Apr 16	14 43 20.5	0.84°N	29.90°E	(Congo)	33km	5.3
19.	Apr 30	20 38 47.0	0.67°N	29.77°E	(Congo)	33km	5.0
20.	May 16	05 44 19.6	0.58°N	30.22°E	(Uganda)	36km	n.d.
21.	May 17	07 03 29.4	0.74°N	30.11°E	(Uganda)	12km	6.3
22.	May 18	01 46 35	0.7°N	29.9°E	(Congo)	33km	n.d.

- underlined are events missed in Turyo. G (1996) catalogue
- This can be re-visited and alter the hazard map of the country

- how can we make the regional catalogue exhaustive and reasonably accurate?

- revisit historical bulletins and seismograms with contemporary techniques and algorithms

The Rukwa earthquake of December 13, 1910

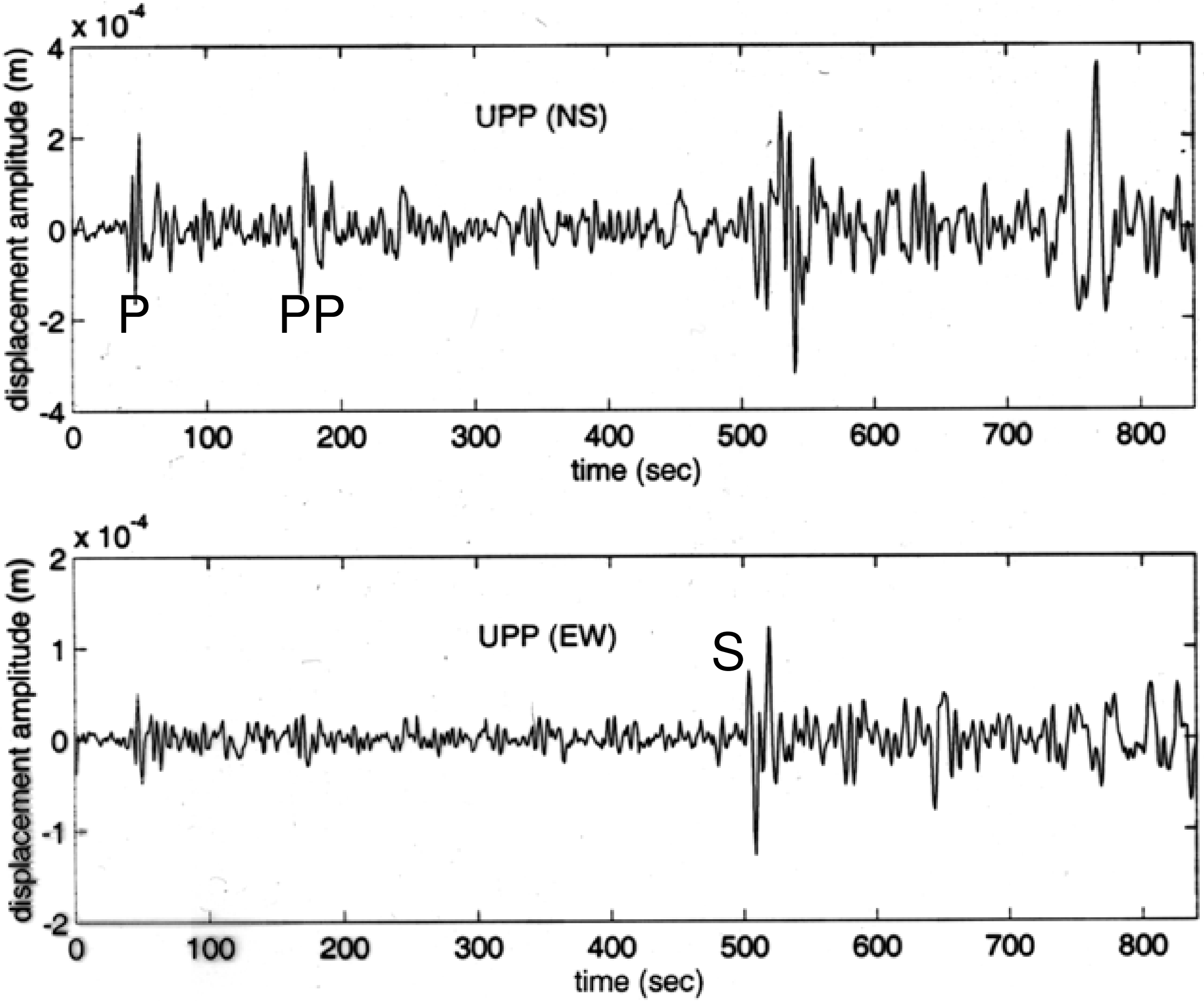
1910. Dezember. JENA

Dez.	Char.	Phasen	Zeiten	T E-W	T N-S	T Vert.	A_μ E-W	A_μ N-S	A_μ Vert.	Bemerkungen
		M_{2N}	$10^h\,46^m$		22			107,0		II
		M_{4V}	47^m			21			251,1	II
		M_{3E}	48^m	18			42,7			II
		M_{5V}	50^m	18	18	19	64,0	92,6	244,3	$= M_{4E} = M_{8N}$ II.
		C		15	15	13				II
		F	$12^h,7$							II
12.			$1^h,1-1^h,3$							Die Mi. B. scheint durch Beben gestört zu sein.
13.	IIu	i_1P_{NV}	$11^h\,47^m\,29^s$		7	5		2,6	4,5	Seebeben östlich von Zansibar (auch in Deutsch-Ostafrika gefühlt).
		eP_E	31^s							
		i_2	41^s	4	8	5	2,6	3,5	13,6	
		i_3	$48^m\,4^s$	7	7	6	4,8	6,5	28,2	
		i_1PR_{1V}	$49^m\,51^s$			5			8,2	
		i_1PR_{1E}	53^s	6			1,9			
		i_2PR_{1V}	$50^m\,8^s$			5			10,7	
		i_3PR_{1N}	28^s		9			2,2		
		i	$51^m\,17^s$		9			3,4		
		i	31^s	10			2,6			
		$i_2?PR_{2V}$	$52^m\,16^s$			5			8,9	
		eS_{EN}	$55^m\,39^s$	16	16		8,5	8,0		
		iS_V	54^s			20			125	
			$56^m,2$	16	16		13,6	19,8		
		SR_{1V}	$58^m\,9^s$			12			24	
		$SR_{2V}?$	$12^h\,0^m\,13^s$			11			20,9	
		eL_{1N}	0^m							
		eL_{1EV}	$2^m,4$							
		M_{1EN}	7^m	26	20		205,9	105,5		
		M_{2EN}	11^m	23	25		246,9	121,7		
		M_{1V}	12^m			21			311,6	
		M_{2V}	15^m			19			511,3	Auftreten regelmäßiger Schwebungen in V.
		M_3	18^m	13	15	13	107,8	171,3	204,2	
		C		12–15		12				
		eL_2	$4^h\,11^m$							Rückkehr des Bebens.
		M_{1NV}	17^m		20	19		5,6	28,2	
		M_{1E}	21^m	19			6,5			
		M_{2EV}	29^m	18		19	8,1		45,1	Auftreten regelmäßiger Schwebungen in V.
		C				12-15				
		eL_{3V}	$15^h\,9^m$							Zweite Rückkehr.
		F_V	$15^h,2$							$F_W = 15^h,2$.

- Bulletins of the JENA station in Germany recorded on Wiechert type seismographs

- These phase readings can be validated by digitizing historical seismograms which can help to relocate major earthquakes of hazard interest

The August 25, 1906 Mw 6.8 earthquake in the main Ethiopian rift

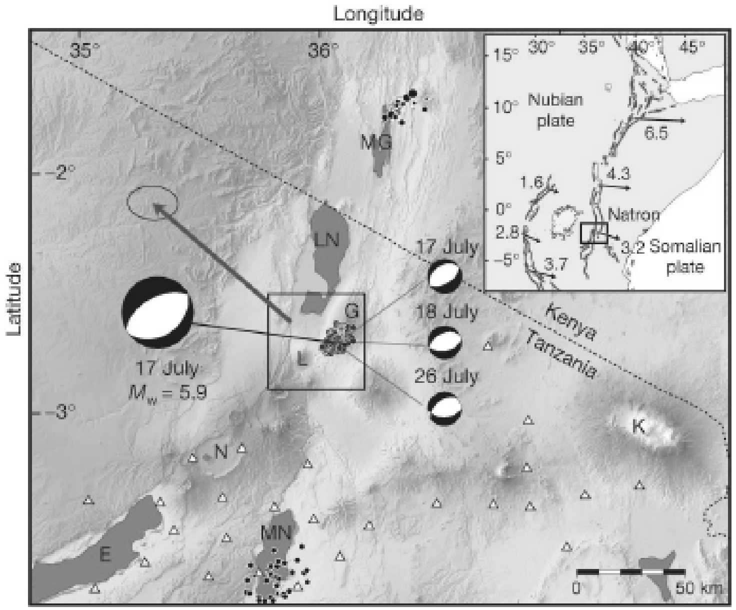


-Wiechert seismogram recorded in Uppsala

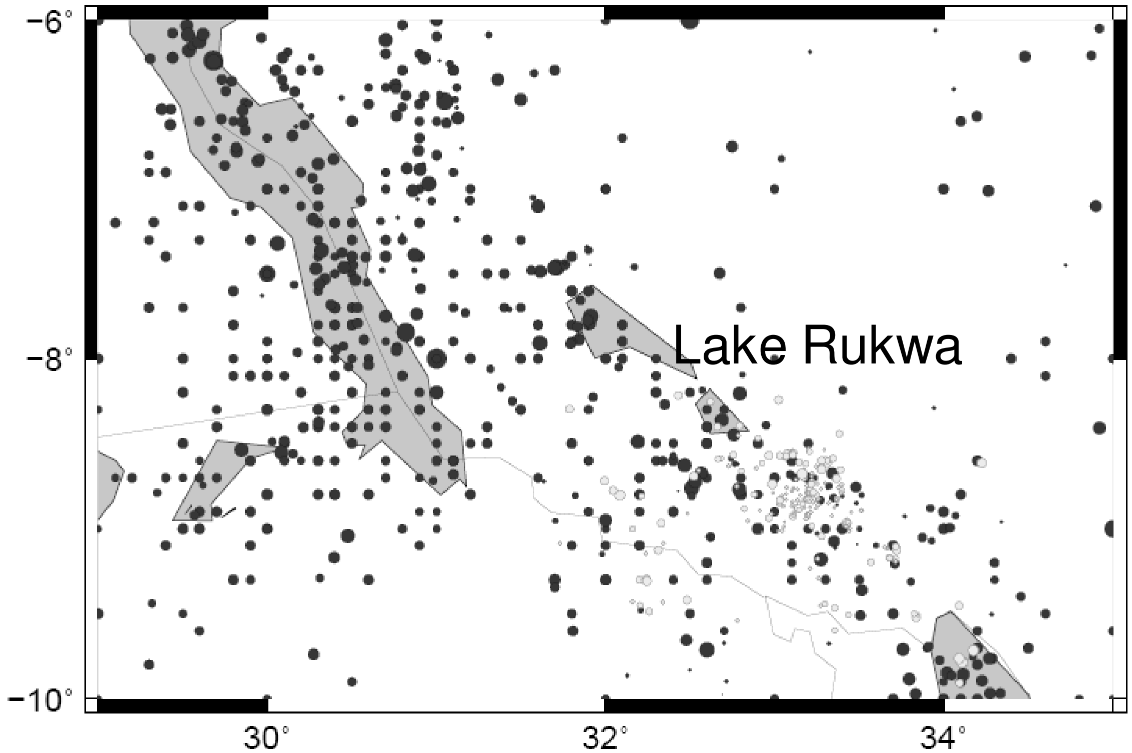
-The NS component mimics the radial component

- The teleseismic phases are distinct

Two hotspots of activity in Tanzania

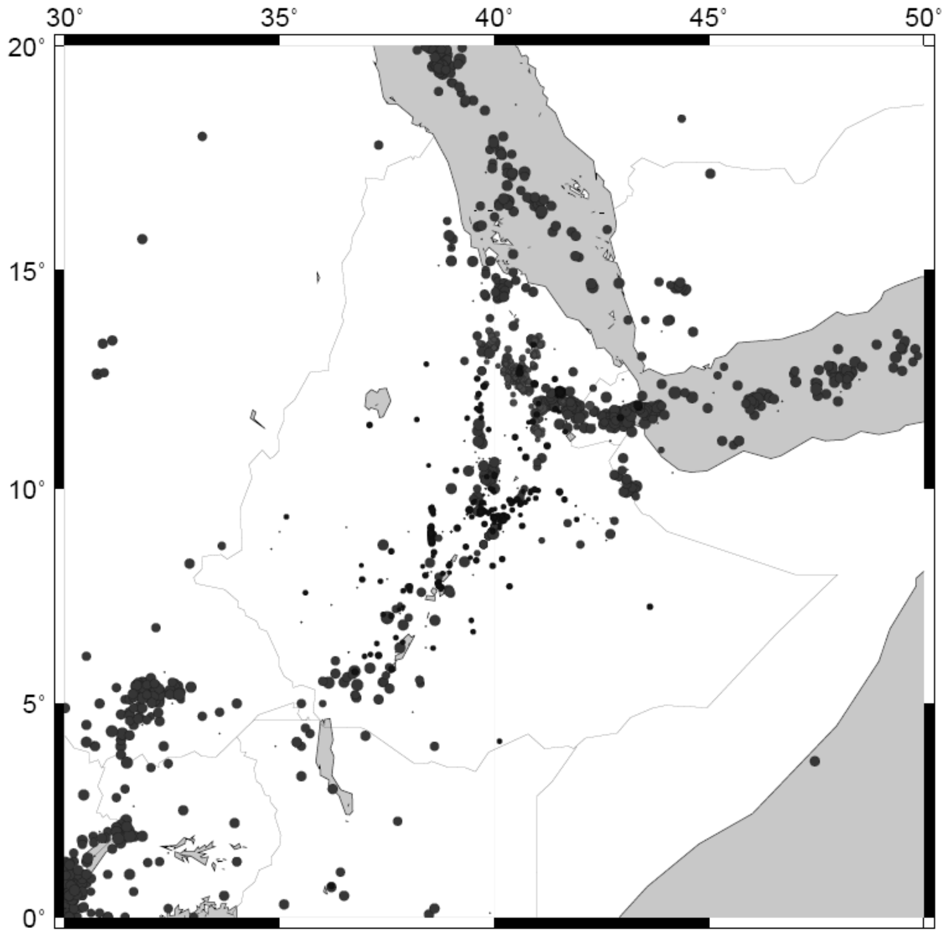


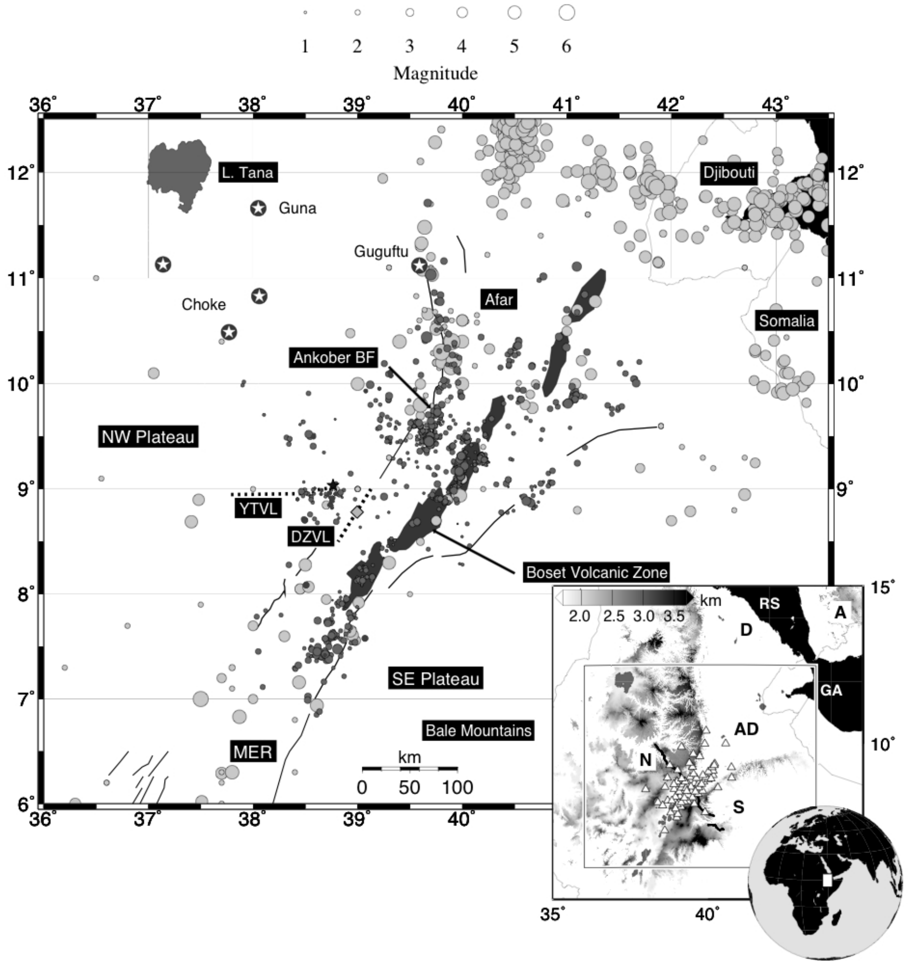
The Natron event
(Calais et al., 2008



Seismicity of the Rukwa area from
ISC and Mbeya network

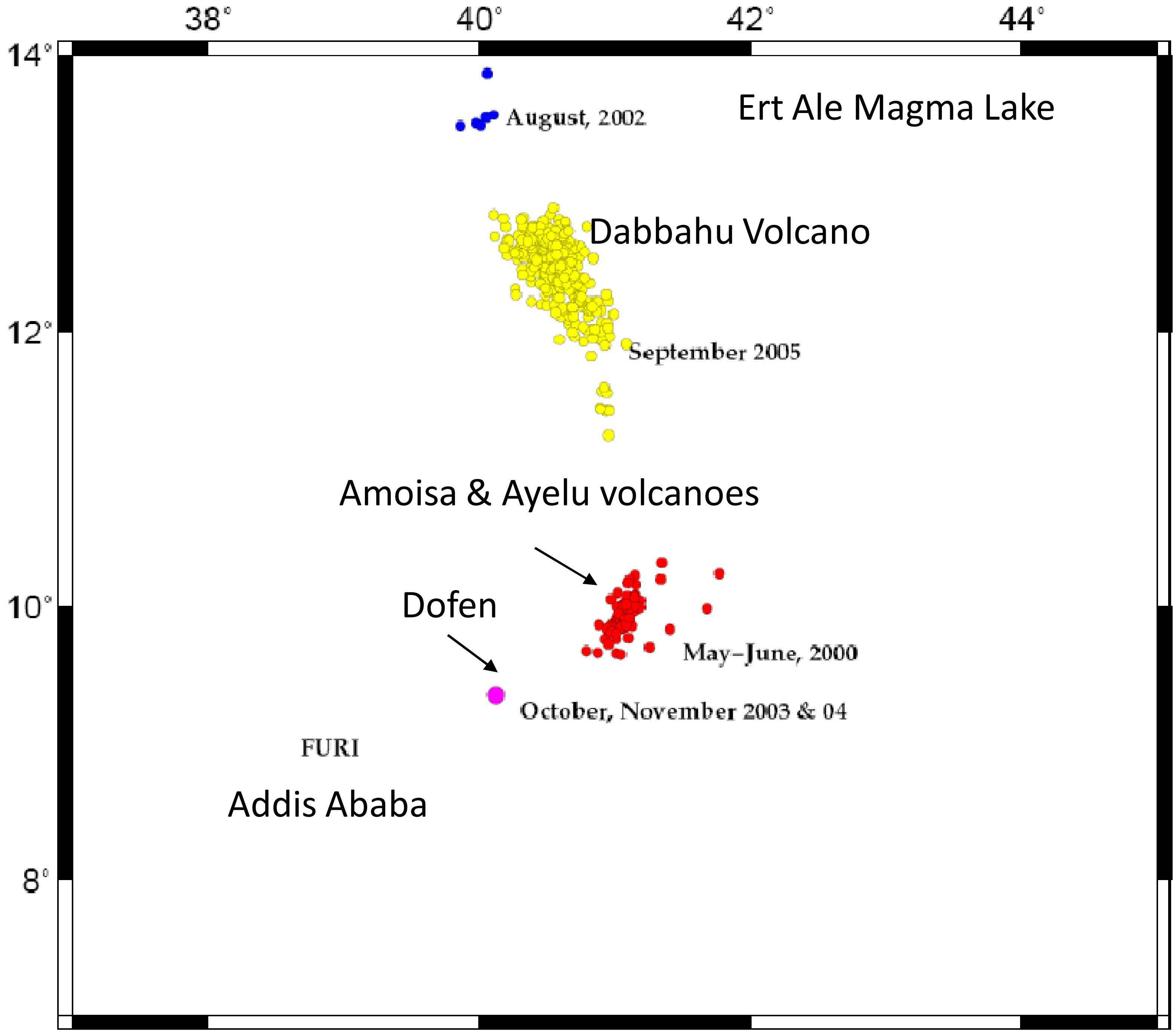
Seismicity of Afar and the Ethiopian rift





Keir et al., 2009

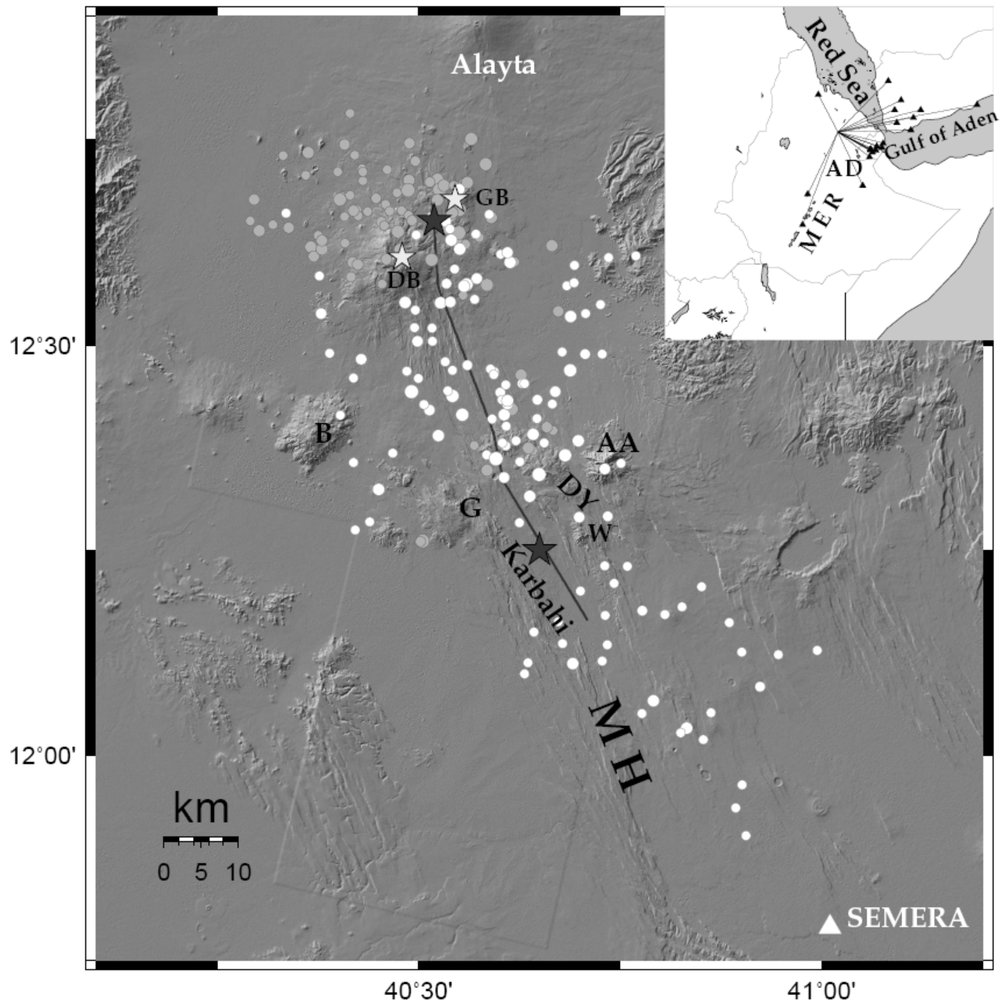
The Ankober area is the most seismically active part of the rift close to the capital Addis Ababa.

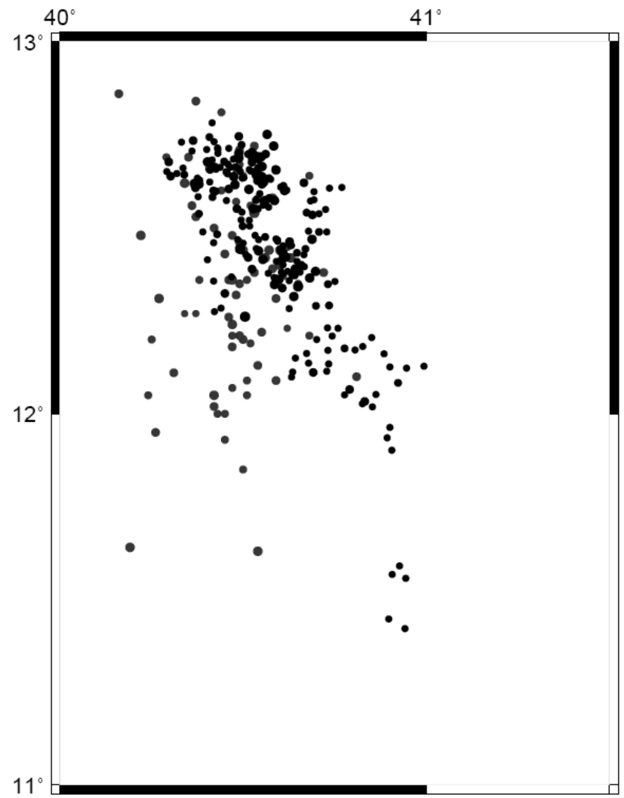


If major earthquake activity occurs in this part of the rift

- it is mostly related with some diking or volcanic activity

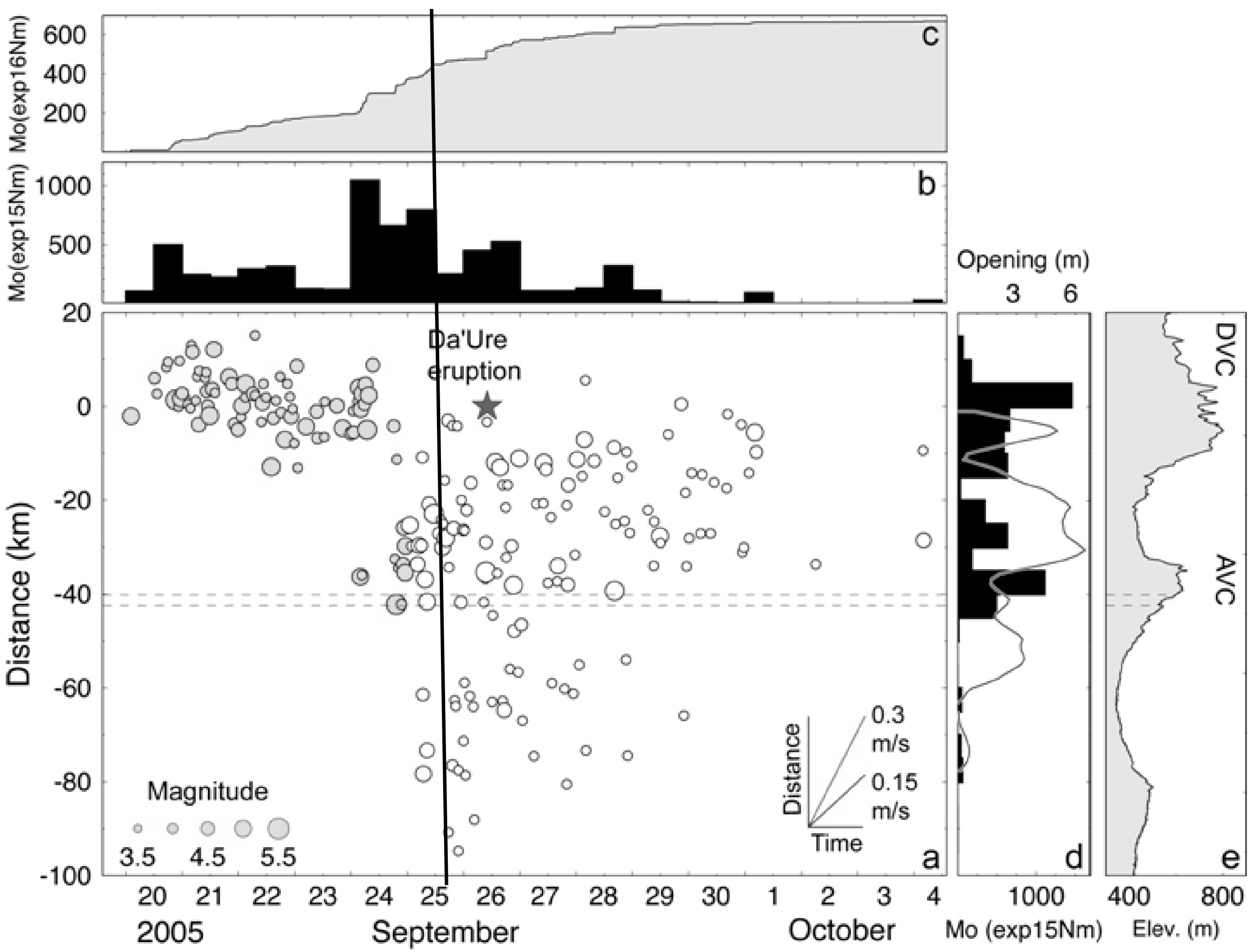
The September 2005 dike in Afar



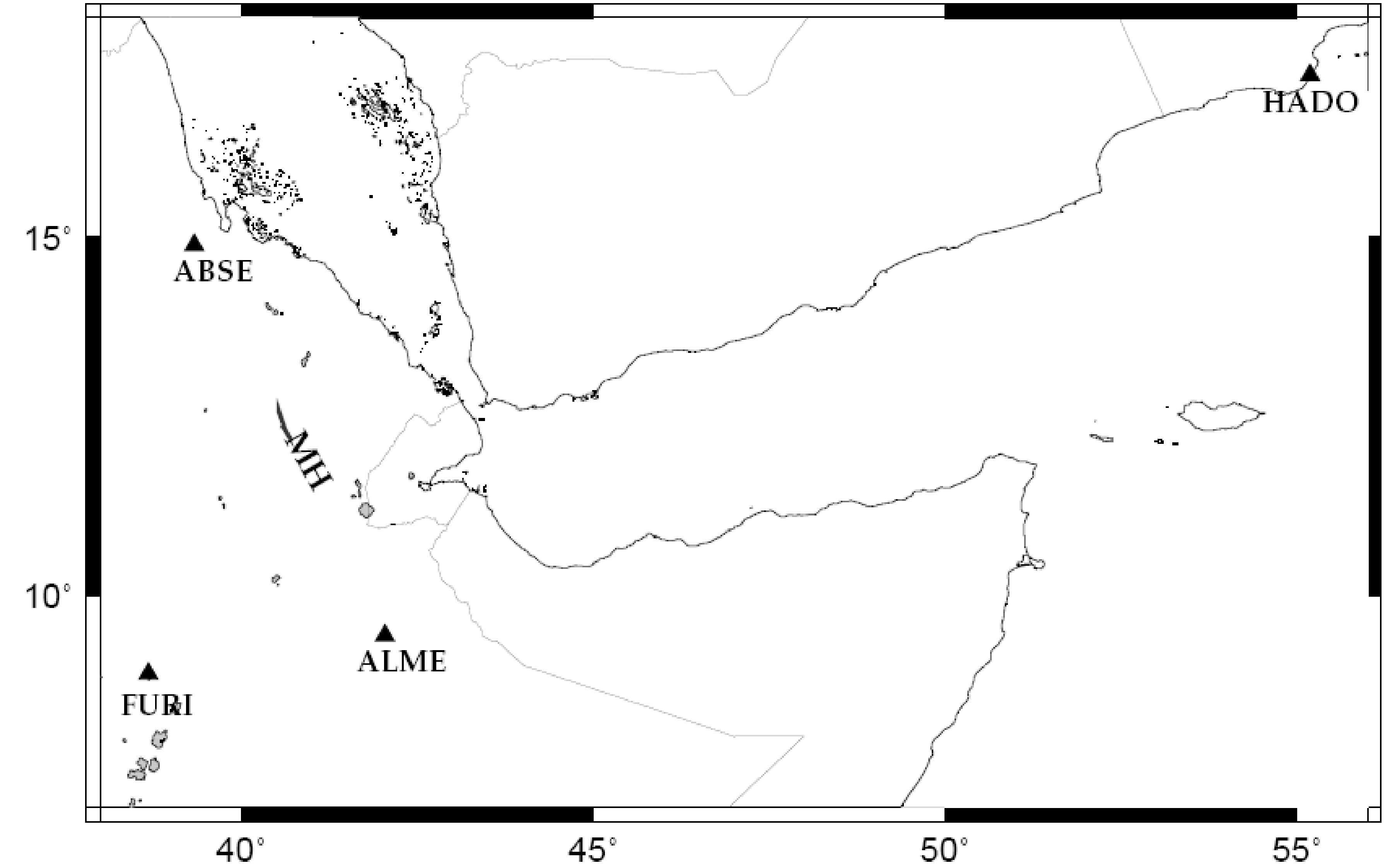


Red spots are NEIC locations and blacks are from Ayele et al., 2009(in press)

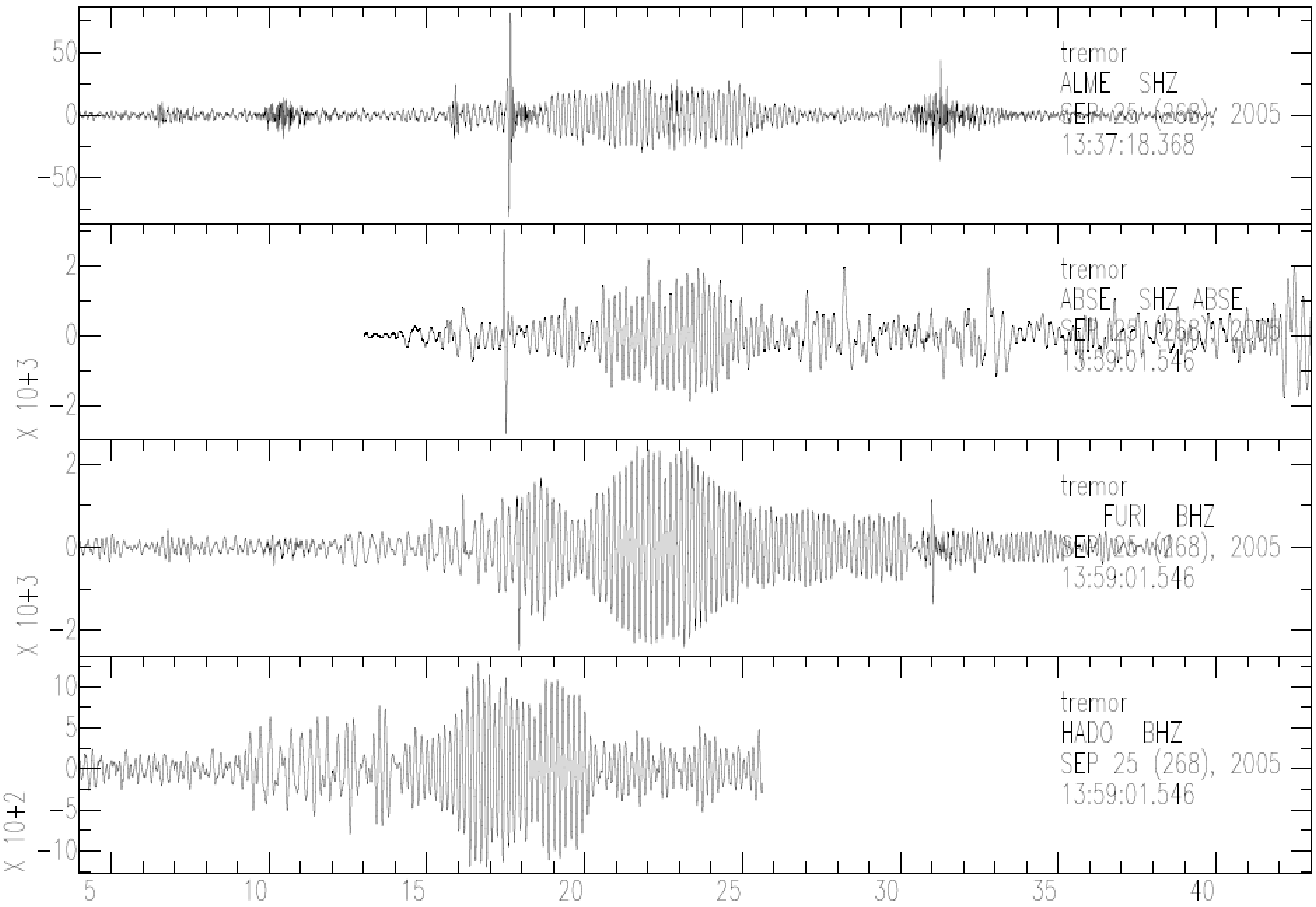
Time history of the 2005 dike



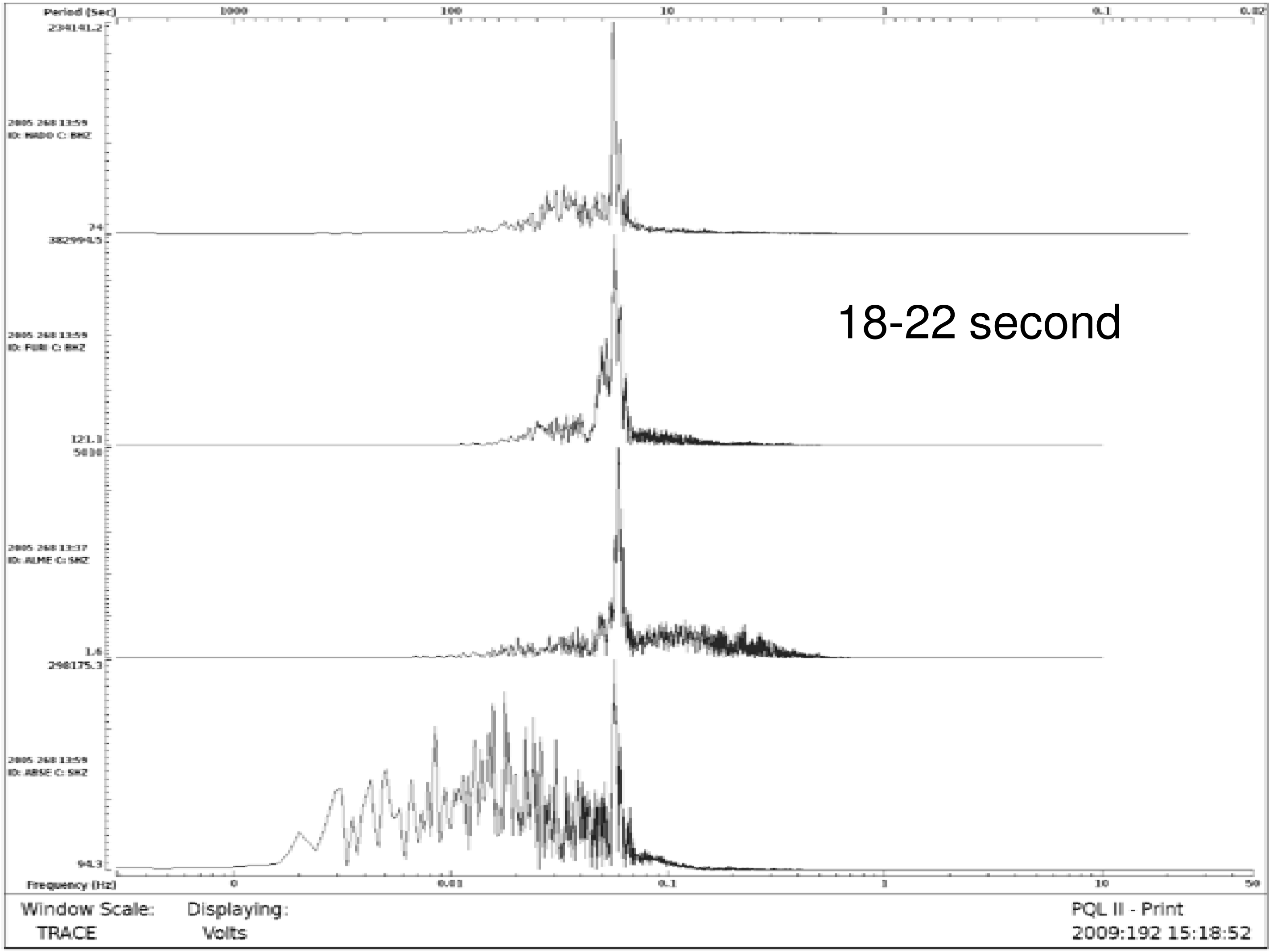
Stations that captured the September 25, 2005 tremor



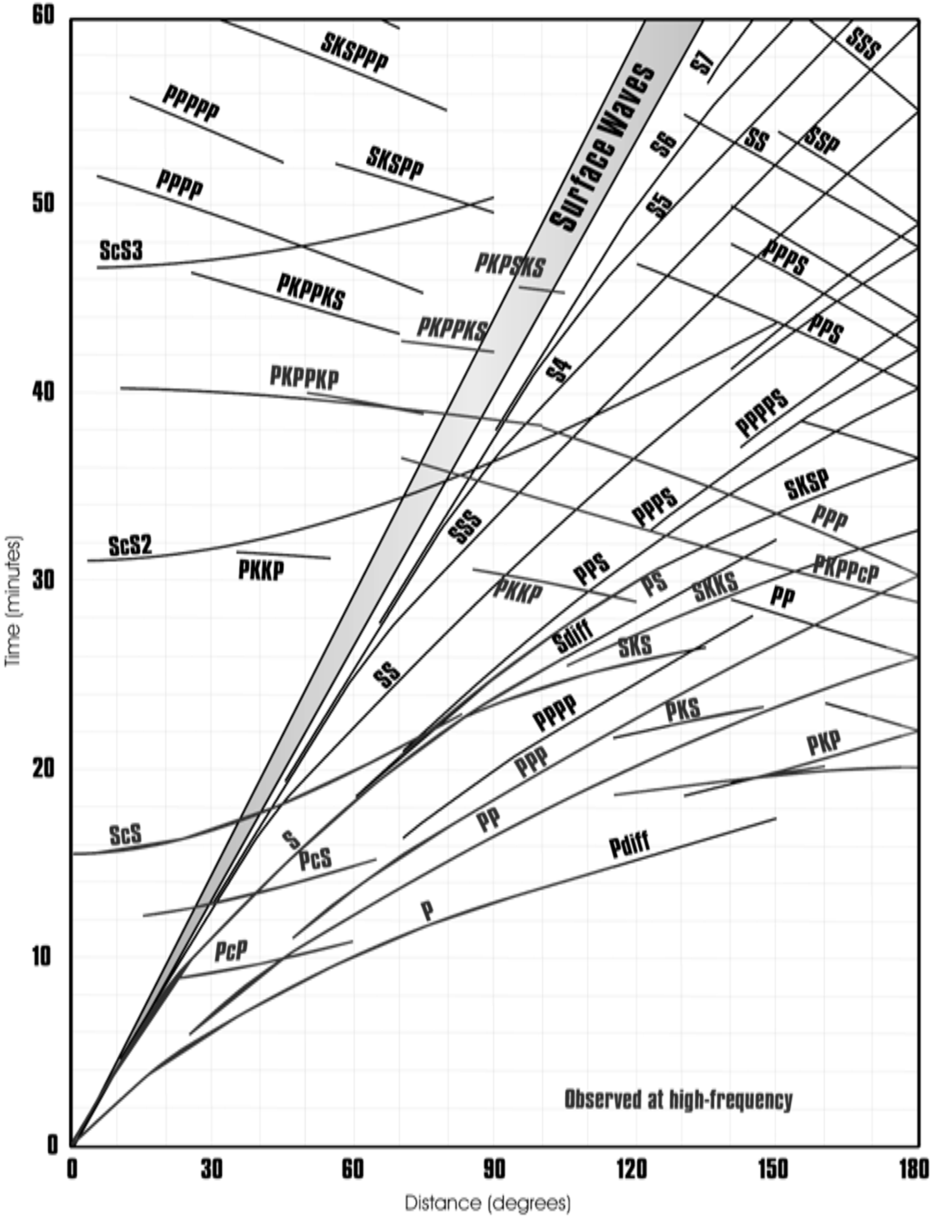
The tremors record on 4 stations

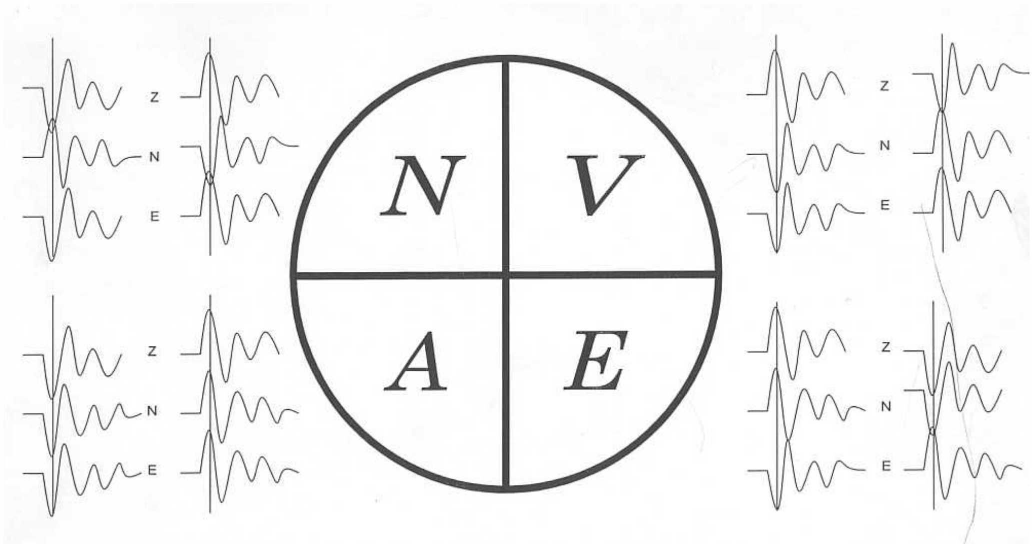


Spectra of the tremor



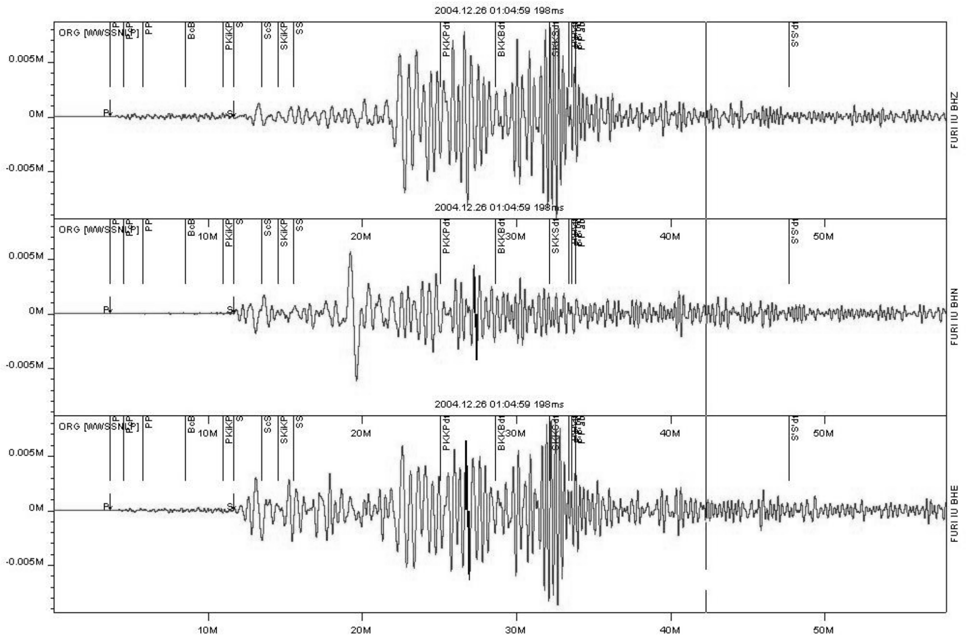
The classic single station earthquake location

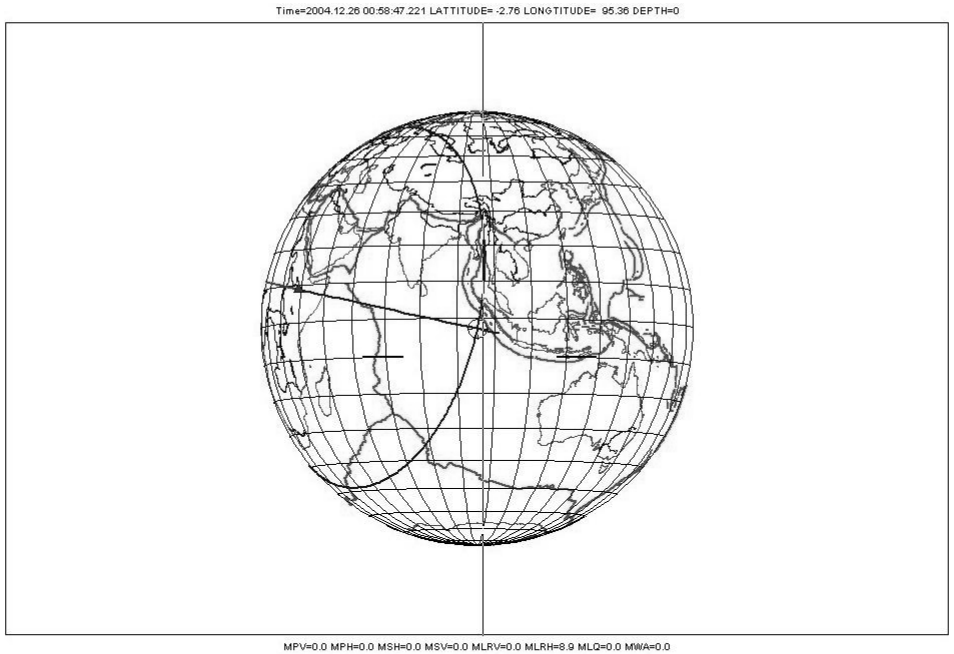




-This technique tells us which direction the earthquake comes from relative to the recording station but we still have to determine the azimuth for locating the event

The December 26, 2004 earthquake in Indonesia as recorded by FURI station





Our location:
Latitude -2.76N
Longitude 95.36 E

Actual location:
Latitude: 3.244N
Longitude: 95.825

-The single station location can give us the first hand information about seismic activity at any distance range
-Each African data centres should have one three component, broadband and digital station nearby to monitor at least what is going on in its environs

Conclusions and recommendations

- Two major aspects of my conclusions
  - Revisiting old database to improve earthquake catalogues in EARS
    - historical bulletins and seismograms
    - special studies and reports
  - To boost current monitoring and archiving capacity of national seismic networks in EARS
    - The fractal nature of the EARS seismicity is not properly captured
    - Build and maintain IT assisted capacity in EARS countries with the involvement of governments