



**The Abdus Salam  
International Centre for Theoretical Physics**



**2053-41**

**Advanced Workshop on Evaluating, Monitoring and Communicating  
Volcanic and Seismic Hazards in East Africa**

*17 - 28 August 2009*

**Monitoring Seismic and Volcanic activity in Cameroon**

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# Advanced Workshop on Evaluating, Monitoring and Communicating Volcanic and Seismic Hazards in East Africa

17-28 August 2009

ICTP, Trieste



# Monitoring Seismic and Volcanic Activity in Cameroon



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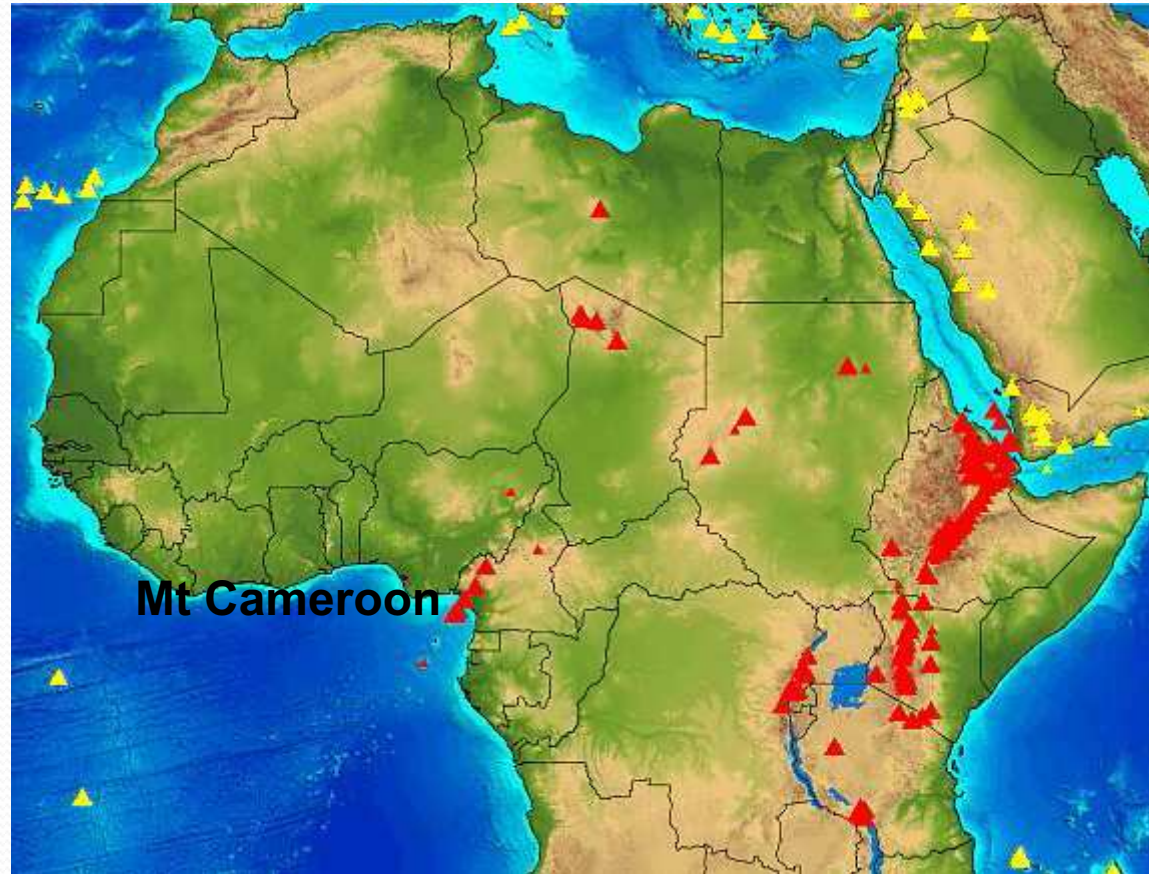
# Plan

- Part I: Seismological Activities
  - Main experiments carried out in Cameroon
  - Results
- Part II: Monitoring Volcanic activities
  - Mount Cameroon
  - Crater Lakes



# Part I

## Seismological Activities

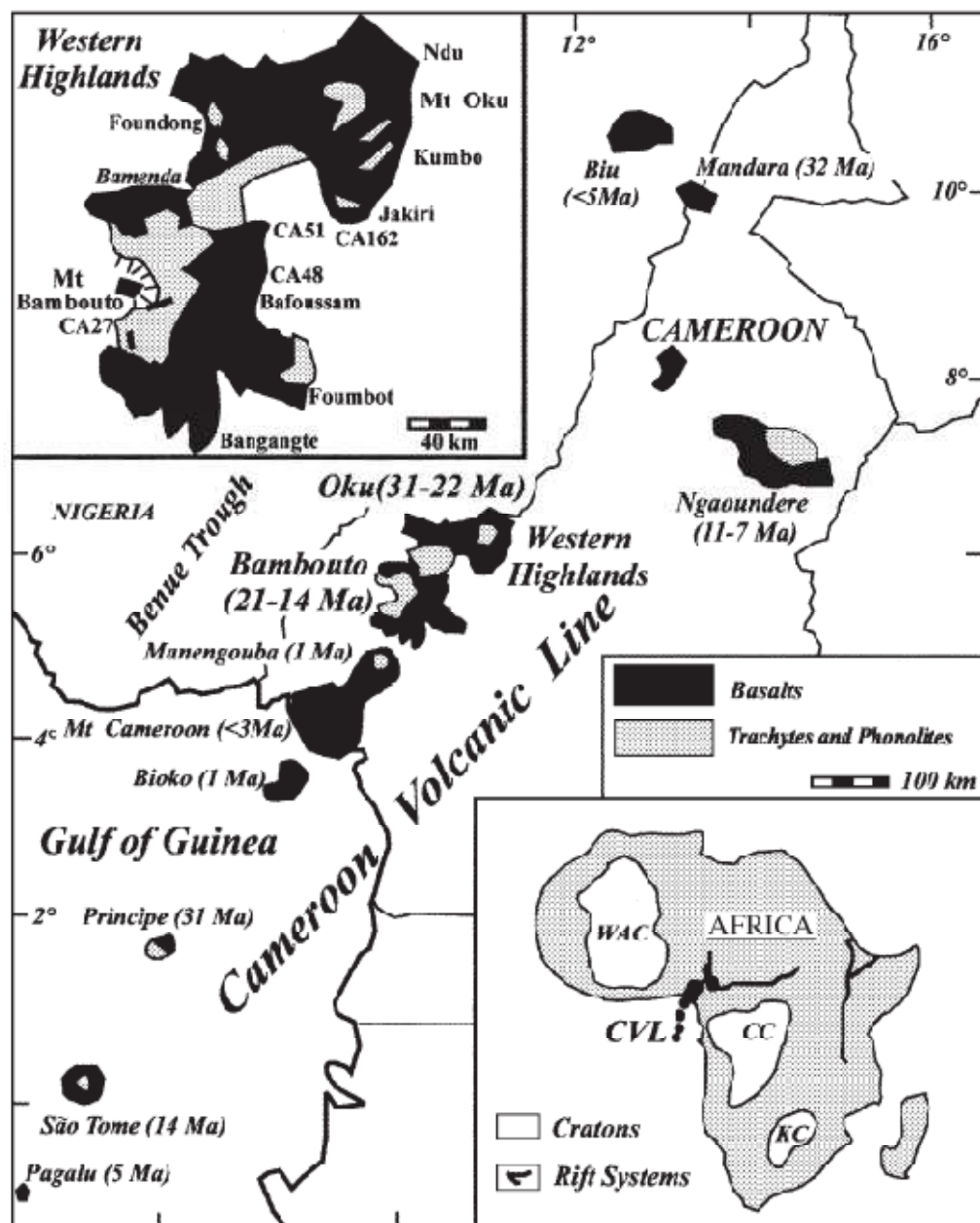


<http://www.volcano.si.edu/world/region.cfm?num=02>

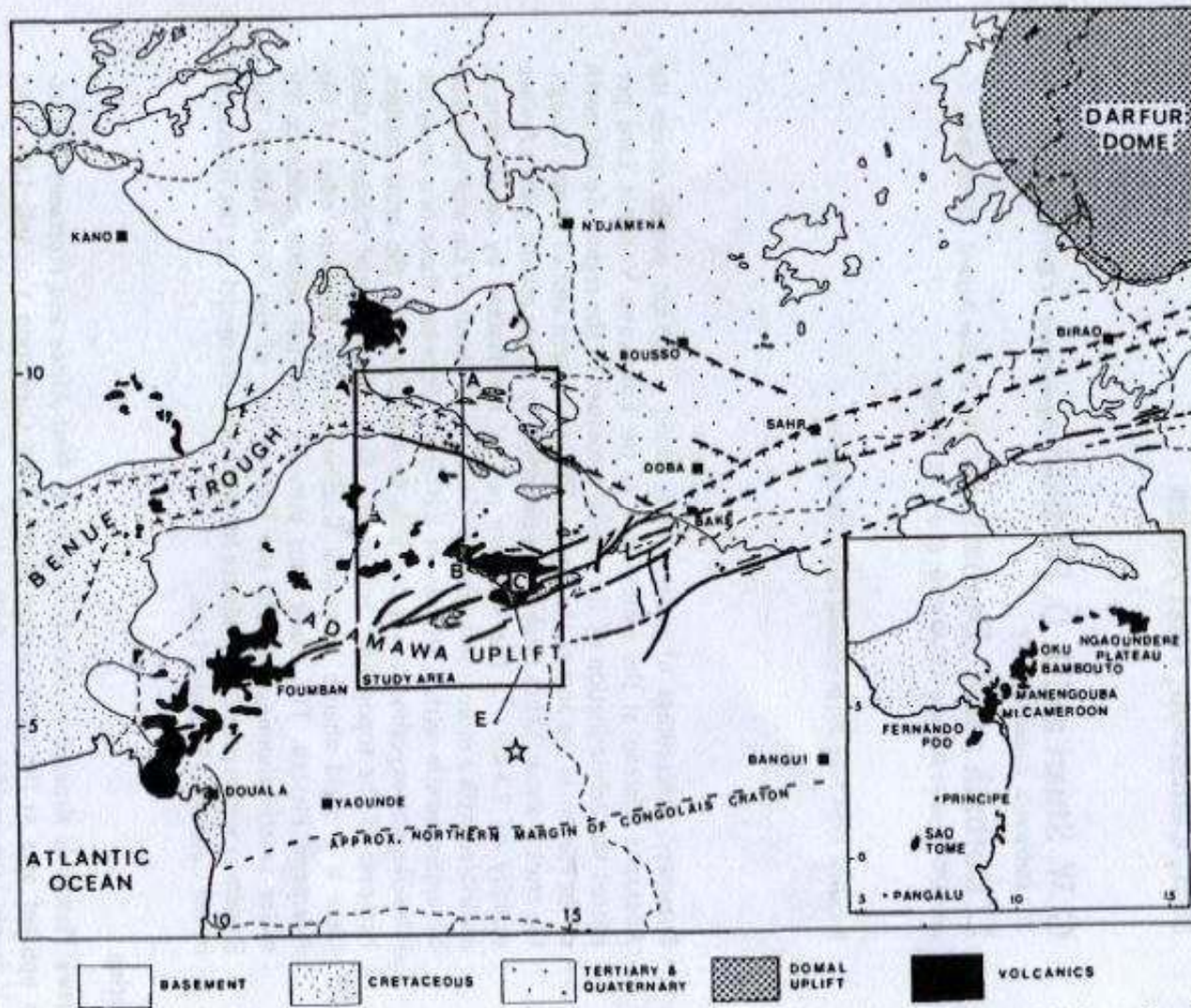


## Introduction

- The Cameroon Volcanic Line (CVL) is a chain of 12 volcanoes running for ~1600 km from the island of Pagalu in the Gulf of Guinea to the Biu plateau (N.E. Nigeria).
- It comprises 3 parts:
  - Oceanic
  - Continent/Ocean boundary, and
  - Continental sectors
- There is no defined pattern of the ages for these volcanoes.



Marzoli, A et al, 2000

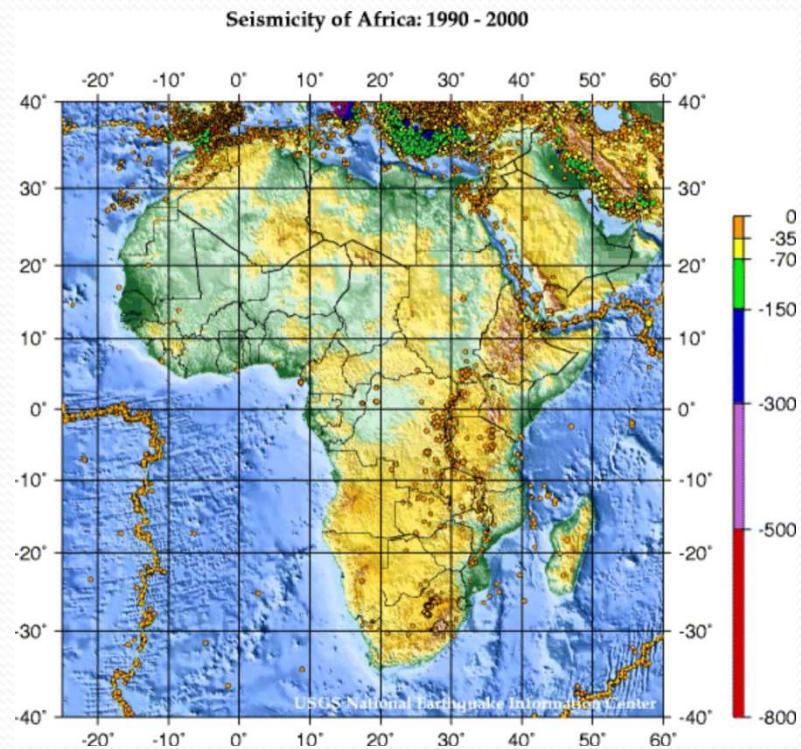


Stuart et al, 1985



# Introduction

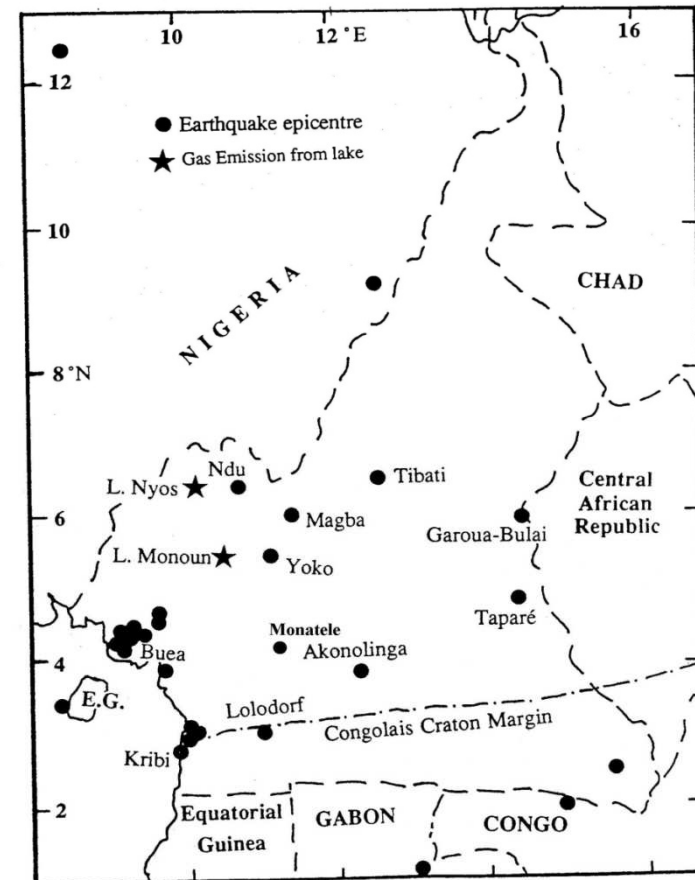
- By World standards Cameroon is not considered very seismically active
- Mount Cameroon is the highest peak (4095 m) and the most active volcano in West Africa.
- The last eruption occurred in the year 2000.



<http://earthquake.usgs.gov/regional/world/seismicity/africa.php>

# Seismic Activity

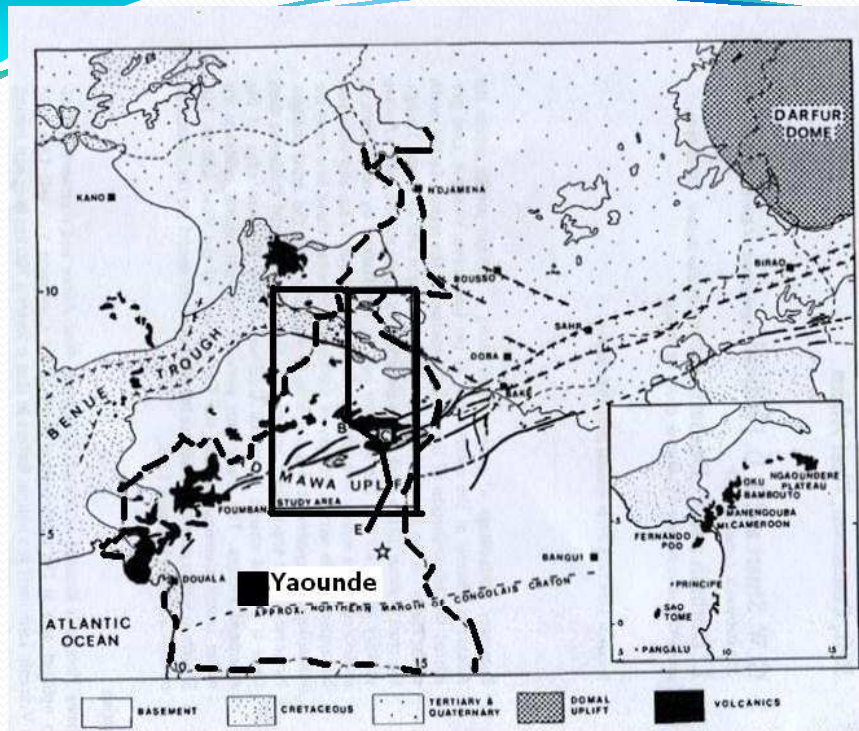
- However at a local scale, both felt and instrumentally recorded earthquakes have been recorded in Cameroon.
- The vast majority of these events have occurred along or close to the Cameroon Volcanic Line
- The overall seismic activity is concentrated in the Mount Cameroon region.



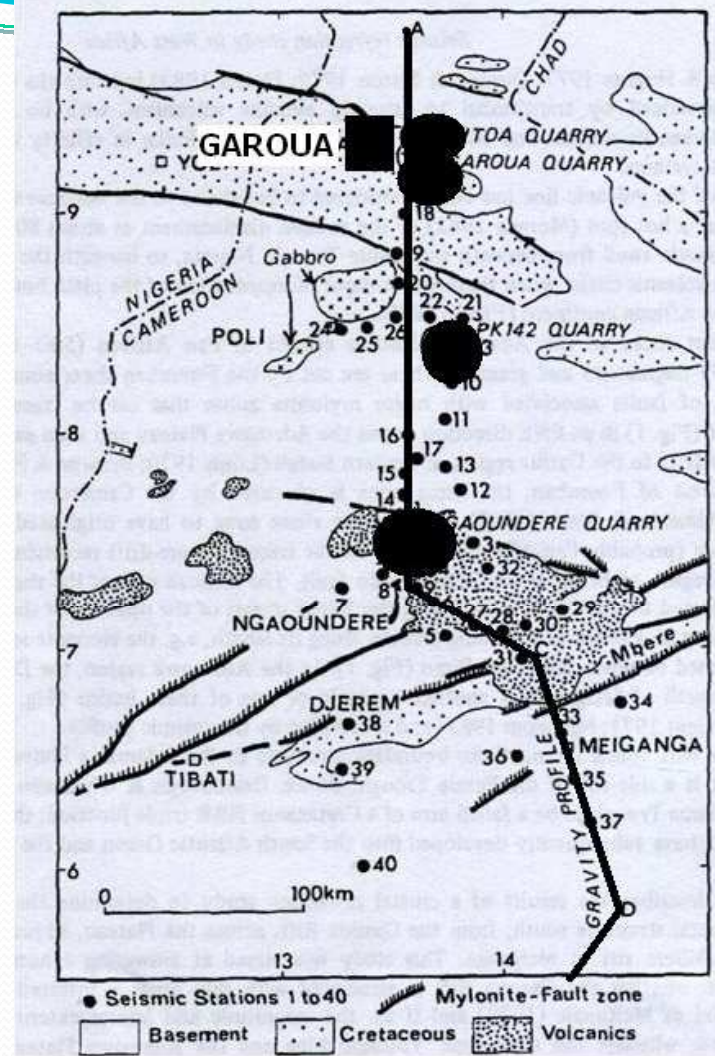
Felt earthquakes in and around Cameroon since 1852. The sites of lethal gas emissions from two lakes is also shown.

## Seismic Activity-Northern Cameroon

- The first seismographic station was installed in Yaounde in 1982
- In 1982, a seismic refraction experiment along a 300 km long profile was carried out in the north of Cameroon
- Total of up to 40 short period (1 Hz) seismic stations were installed along this profile
- Signals were recorded on tape recorders (Geostore) via radio links



Stuart et al, 1985;  
Dorbath et al, 1986



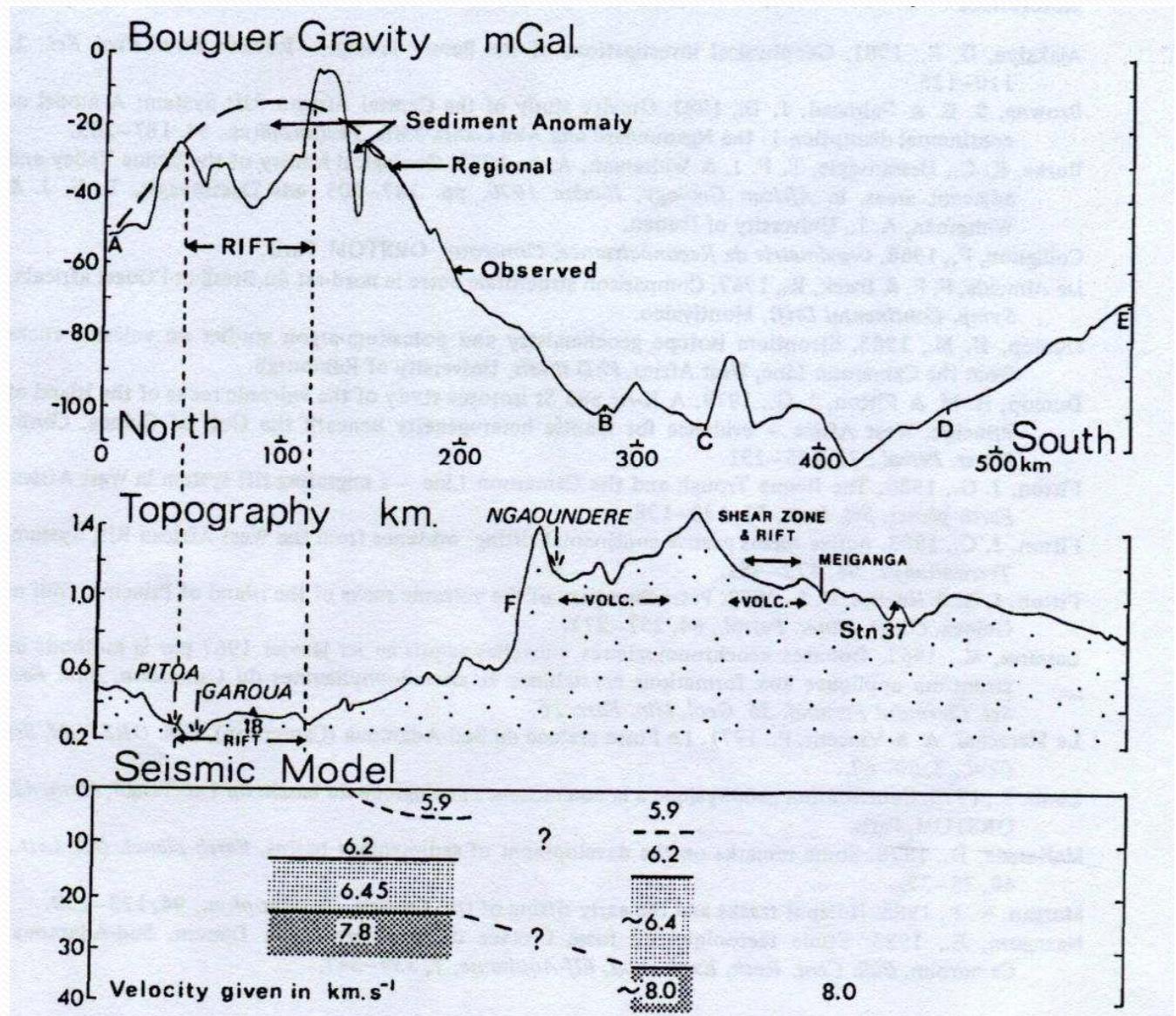
Location of seismic stations.  
*Quarries are shown as full circles.*

## Seismic Activity-Northern Cameroon

- The results show that:
  - The crust thins to about 23 km beneath Garoua rift
  - The crust has a normal thickness of ~33 km to the southern part of the Adamawa plateau
  - The Upper Mantle P-wave velocity is found to be about 7.8 km/s beneath the rift, and
    - About 8 km/s south of the Adamawa plateau
  - No local seismicity was recorded

# Seismic Crustal Model

Stuart et al, 1985



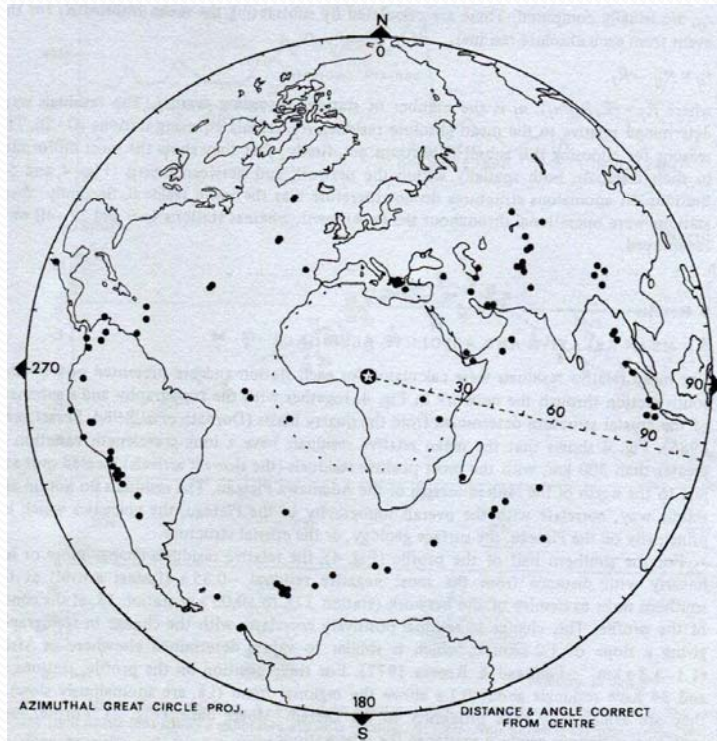


## Seismic Activity-Northern Cameroon

- The Adamawa plateau therefore seems quite unaffected by the presence of the Cameroon Volcanic Line
- The rise of magma in this region might have used the crustal flexure during the post cretaceous uplift of the Adamawa and the reactivation of the Fouban Shear Zone (FSZ)

# Seismic Activity-Northern Cameroon

- Besides recording quarry blasts, the seismic stations also recorded teleseismic events from around the world.
- Some of these were inverted for Upper Mantle structure



Earthquakes used  
in the telesismic study

Dorbath et al, 1986;  
Plomerova et al, 1993



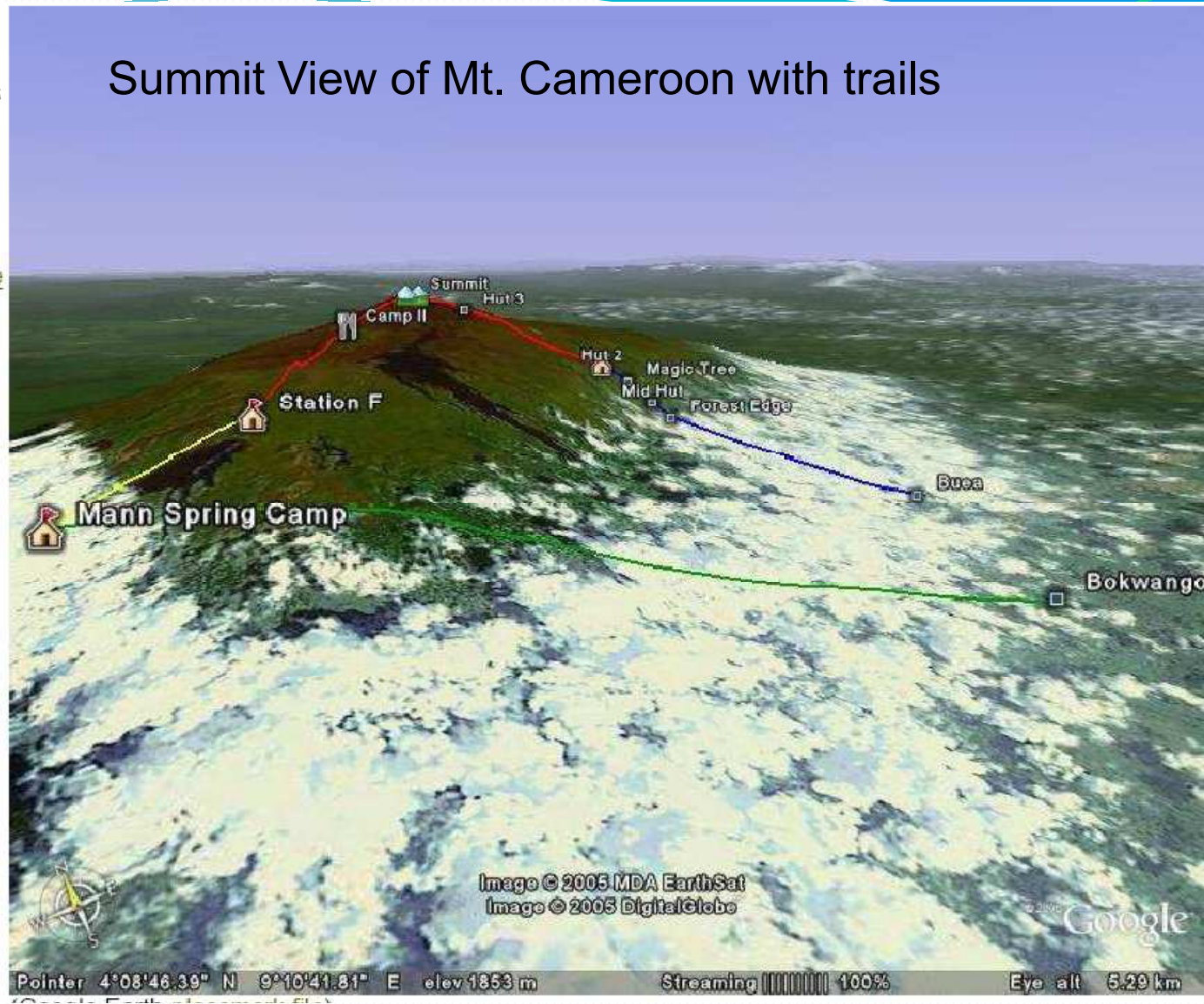
# Seismic Activity-Northern Cameroon

- The teleseismic study shows
  - That this part of the CVL is divided 3 ENE blocks
  - Velocity contrasts are low (<2.5%) down to about 190 km
  - The middle block is 2 % slower than the adjacent blocks and corresponds to the shear zone in central Cameroon
  - That the lithosphere thins beneath CASZ
  - The asthenosphere upwells from 190 to 120 km

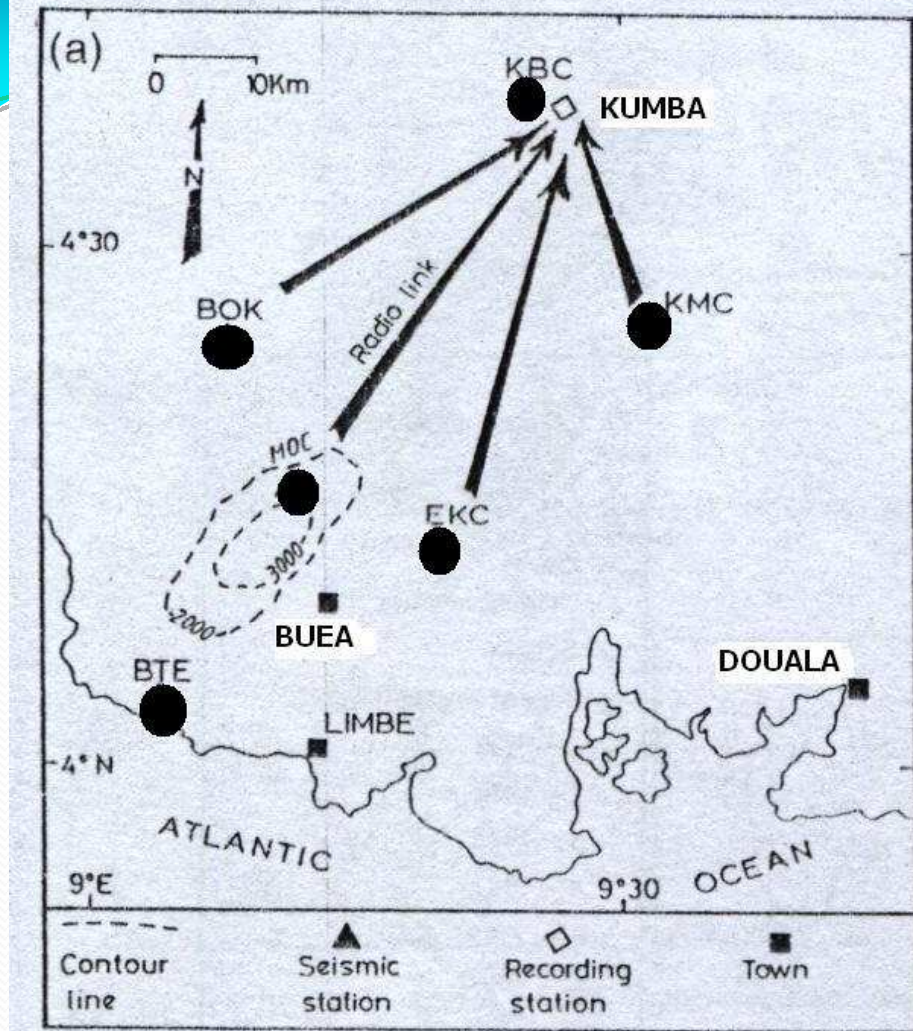
## Seismic Activity-Mt Cameroon/CVL

- In 1984 a permanent network of 6 stations was set up around Mt Cameroon
- Mainly Wilmore MK III short period seismometers
- In 1986 these stations were augmented by 8 *temporary* ones
- Recordings were by telemetry on drum/chart /magnetic tape recorders

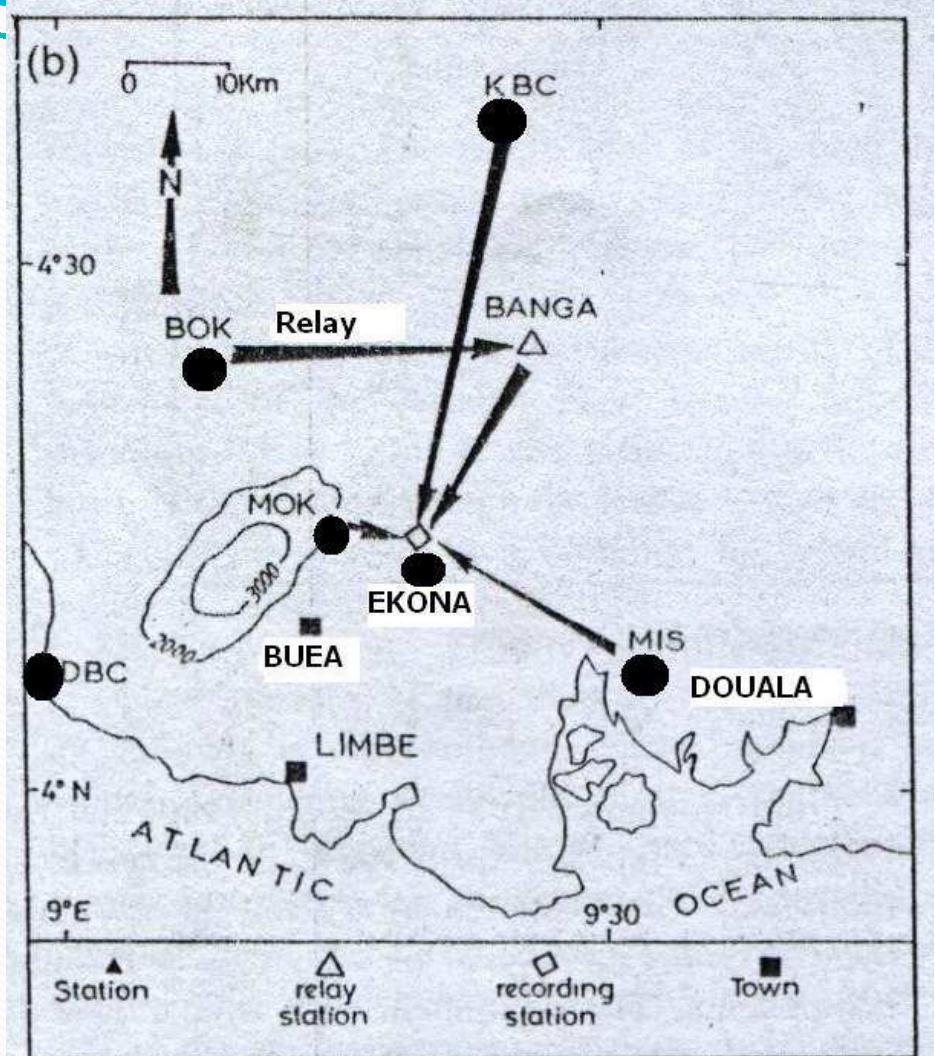
## Summit View of Mt. Cameroon with trails



<http://www.caboose.org.uk/journeys/CMintro.html>

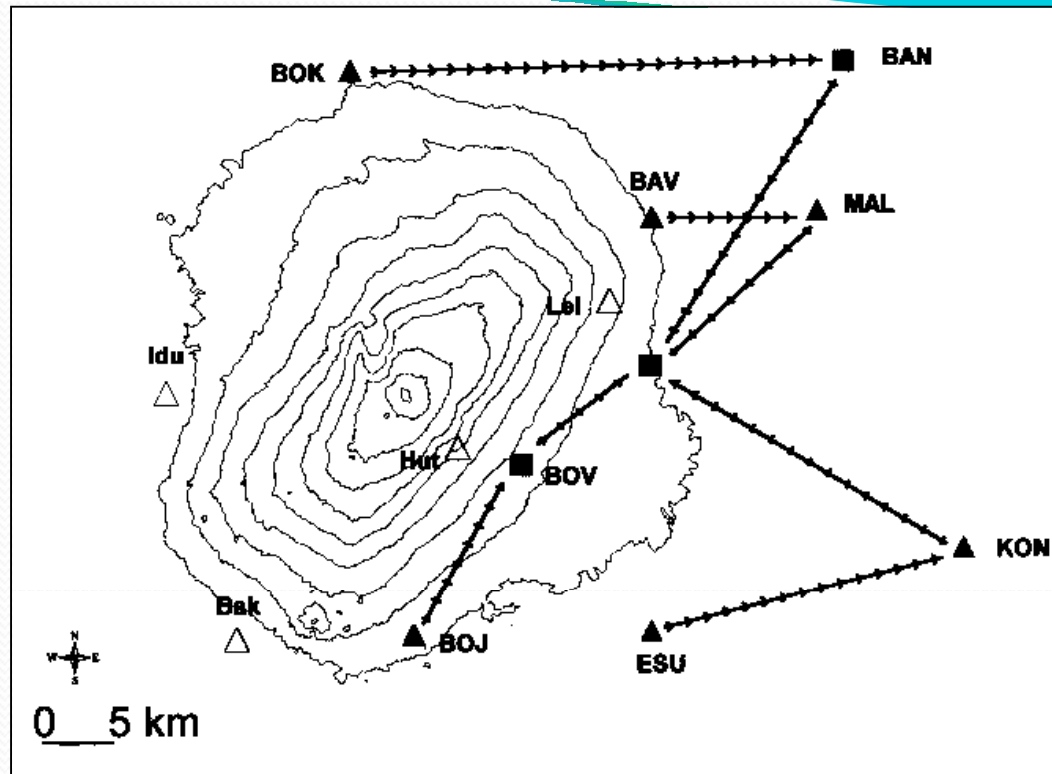


**1984 permanent stations (6)**



**1990 permanent stations (6)**

Ateba et al, 1997

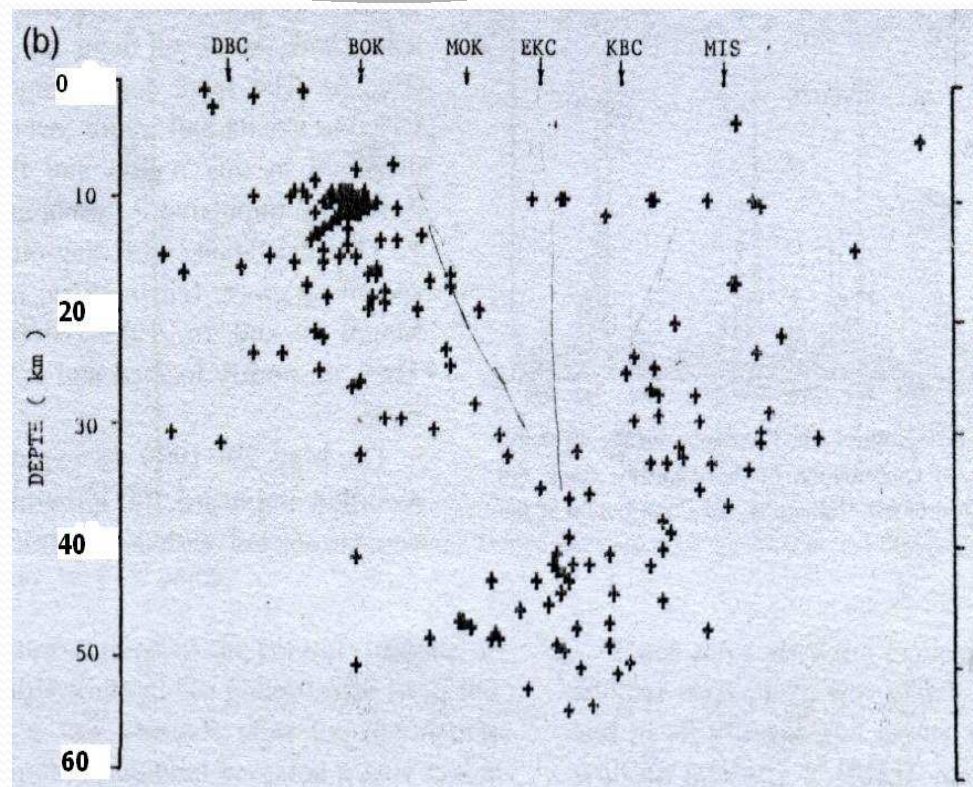
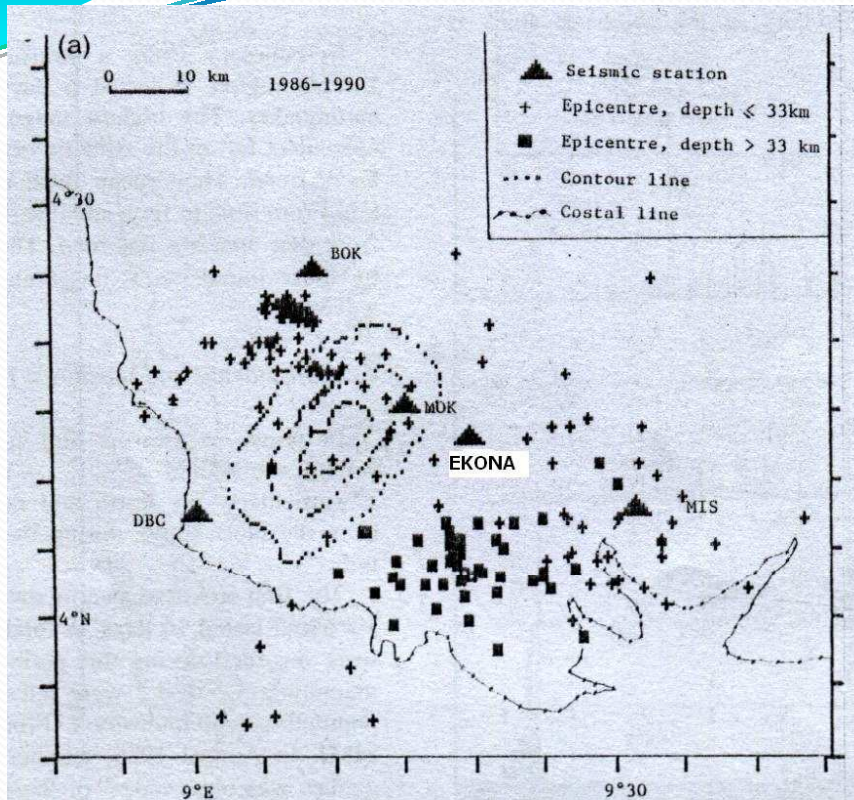


Mt Cameroon Digital Seismic Network since 2003.

▲ (1C Station), △(3C Mobile Station), ■(3C Station)

## Seismic Activity-Mt Cameroon/CVL

- The Mt Cameroon area is characterised by
  - swarm events lasting up to 14 months, and
  - regular deep seismicity (down to ~60 km)
- Subcrustal events occurring in the SE flank of the mountain and at a frequency of ~9-15 events per day
- Duration magnitudes are generally  $< 3$
- This activity may be attributed to the presence of a zone of weakness - a magma conduit



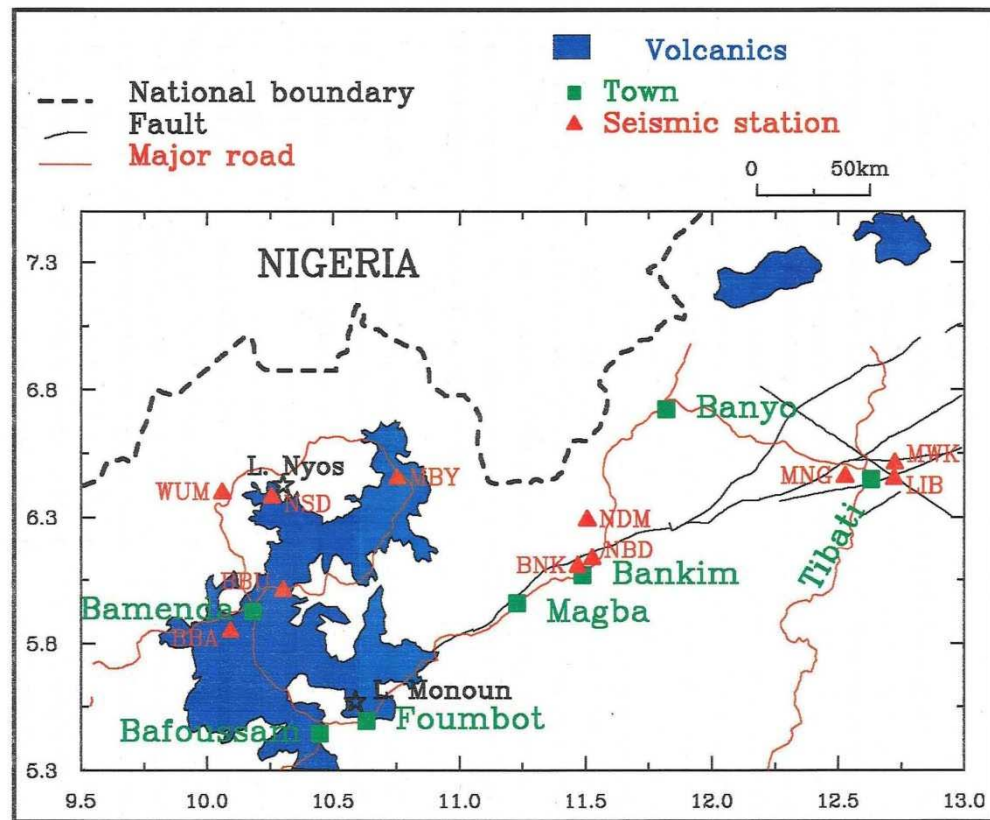
## Seismicity of Mt Cameroon

Ambah et al, 1989;  
Ateba et al, 1997

## Seismic Activity-Mt Cameroon/CVL

- In 1984 (Monoun) and 1986 (Nyos) two of Cameroon's crater lakes within the Cameroon Volcanic Line emitted toxic gases
- These killed 37 (Monoun) and 1700 (Nyos) people
- Seismic monitoring of Mt Cameroon was extended to include the regions of these lakes in 1987
- Temporary networks were set up for up to 4 months in 1988/1989





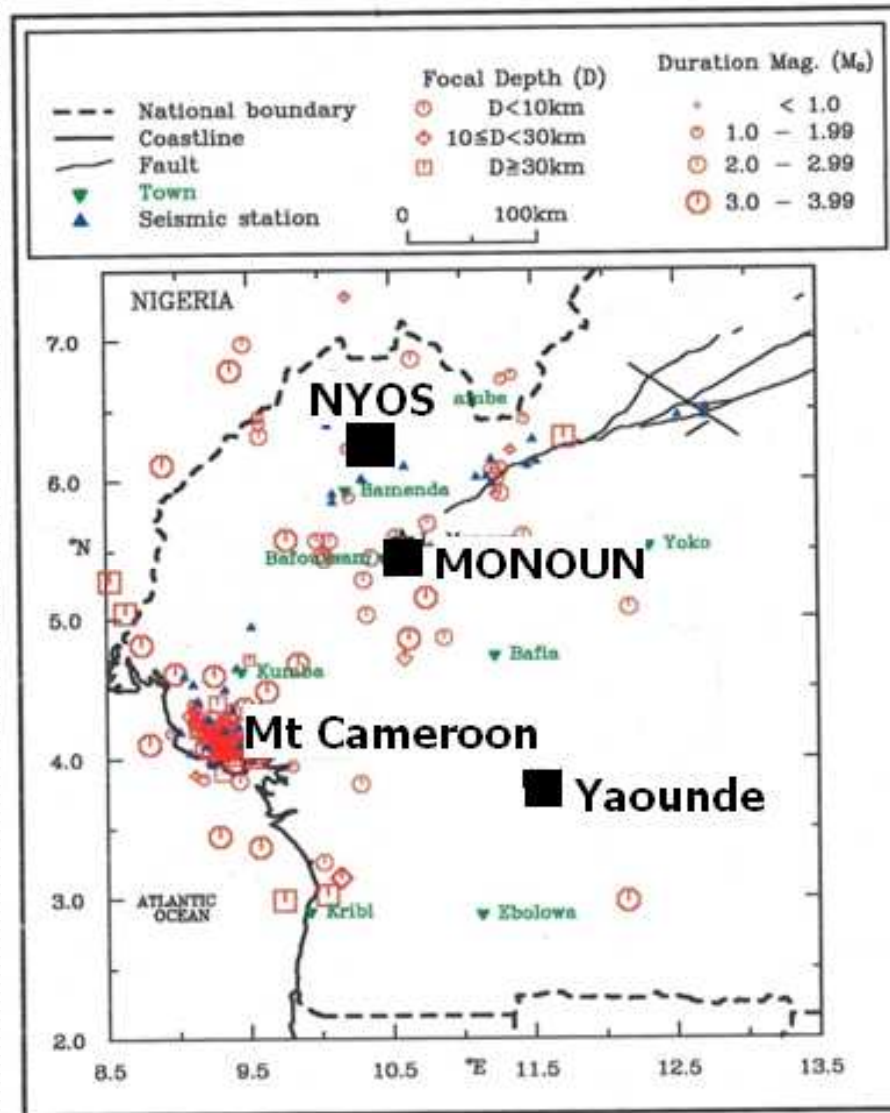
Seismic stations operated in the northern arrays the 1987/88 field season (Feb. '88 to April '88).

## Temporary Seismic Stations North of Mt. Cameroon

Tabod et al, 1992

# Seismic Activity-Mt Cameroon/CVL

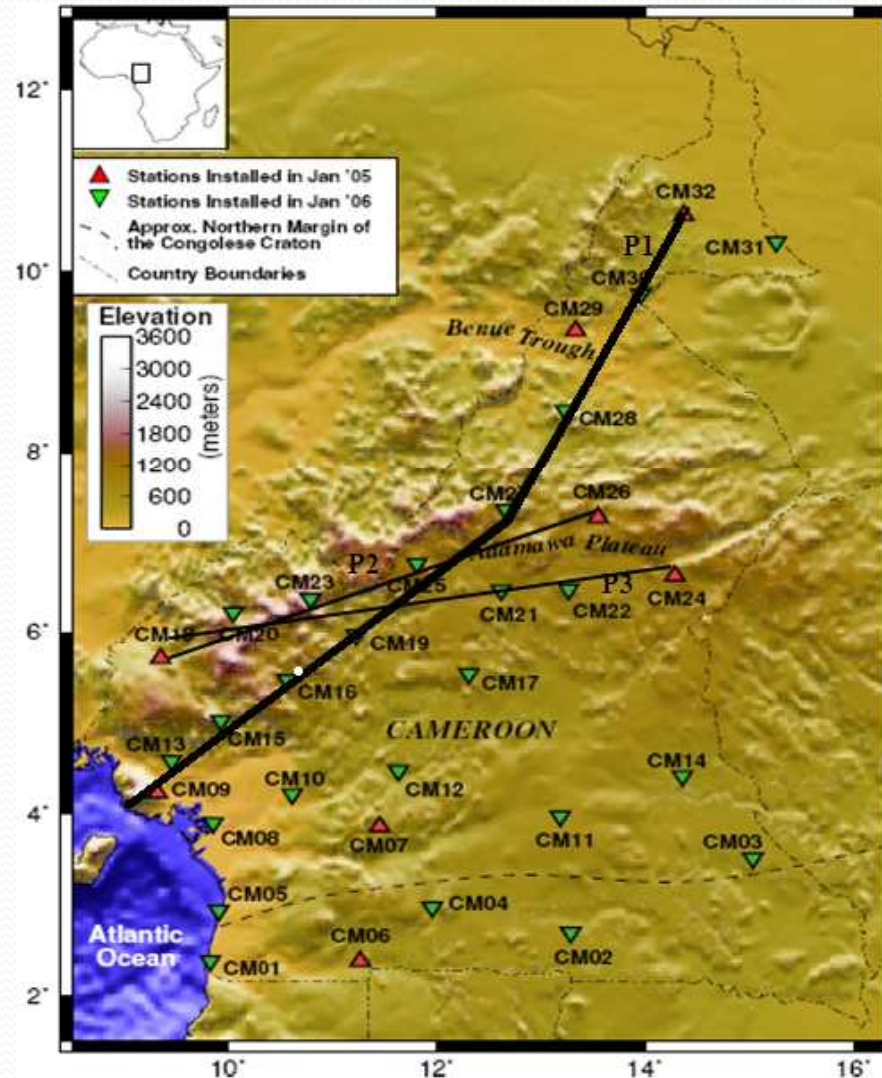
- Local seismicity in the region north of Mt. Cameroon is minimal
- Most seismicity recorded by temporary array originates from Mt Cameroon area
- A few felt earthquakes do occur in this region and are most like related to the tectonic activity along the Fouban Shear Zone



Tabod et, 1992

# Seismic Activity -Cameroon Seismic Project

- From 2005 to 2007 a network of 32 broad band stations was installed over the CVL and the Congo Craton to the south
- 8 stations were installed in 2005
- Stations upgraded to 32 in 2006
- Stations were dismantled in 2007 except 2 (AfricaArray):
  - EKONA (Mt Cameroon)
  - YAOUNDE



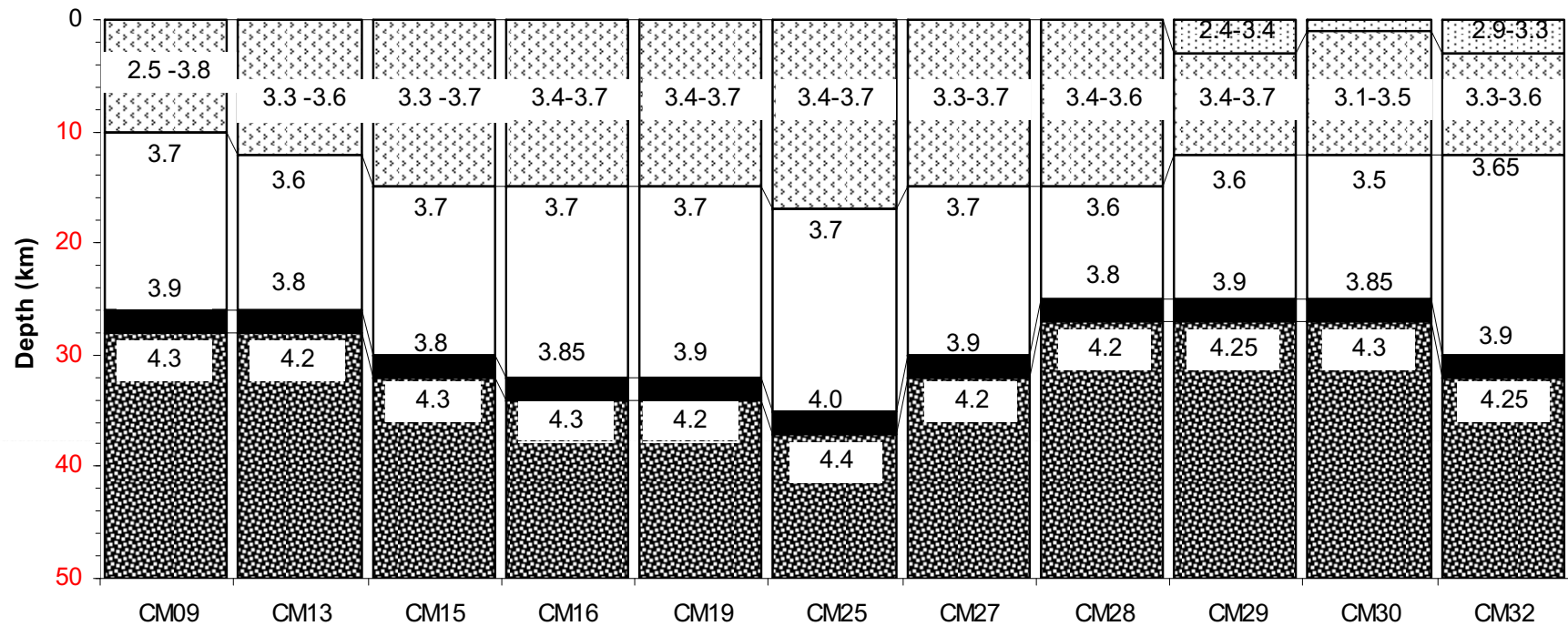
## Seismic Activity -Cameroon Seismic Project

- Surface wave phase velocity maps from this BB dataset imaged:
  - a low-velocity anomaly beneath the CVL as well as
  - high velocities associated with the lithosphere of the Congo Craton.
- P- and S-wave travel time tomography show a linear negative velocity anomaly directly beneath the CVL that
- This anomaly extends from shallow mantle depths to at least 400km.

## Seismic Activity -Cameroon Seismic Project

The joint inversion of Rayleigh wave Group velocities and Receiver has been carried out:

- A thin intrusion of  $< 5$  km thick is present in the upper crust with a high shear velocity contrast.
- Crust thins to  $\sim 25$  km under Garoua and Mt Cameroon
- Crust thickens to about 37km under the Adamawa plateau
- Shear velocity ranges between 3.8-4.0 km/s in the lower crust.
- In the uppermost mantle, shear wave velocity reach 4.2-4.4 km/s.



Crustal thickness along Profile 1 from South to North East



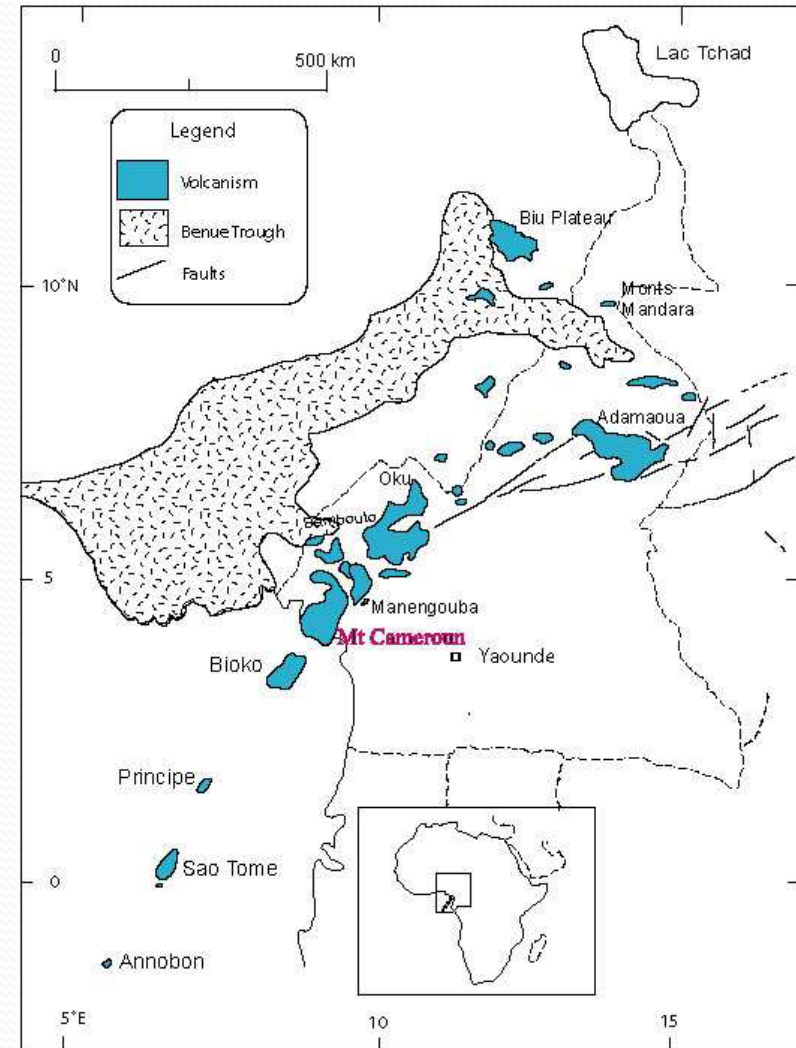
## Part II

# Monitoring Volcanic Activities

# Cameroon Volcanic Line (CVL)

The CVL an alignment of :

- Volcanic Islands from Atlantic Ocean
- Volcanic Centres
- Plutons Complexes
- Sedimentary basins



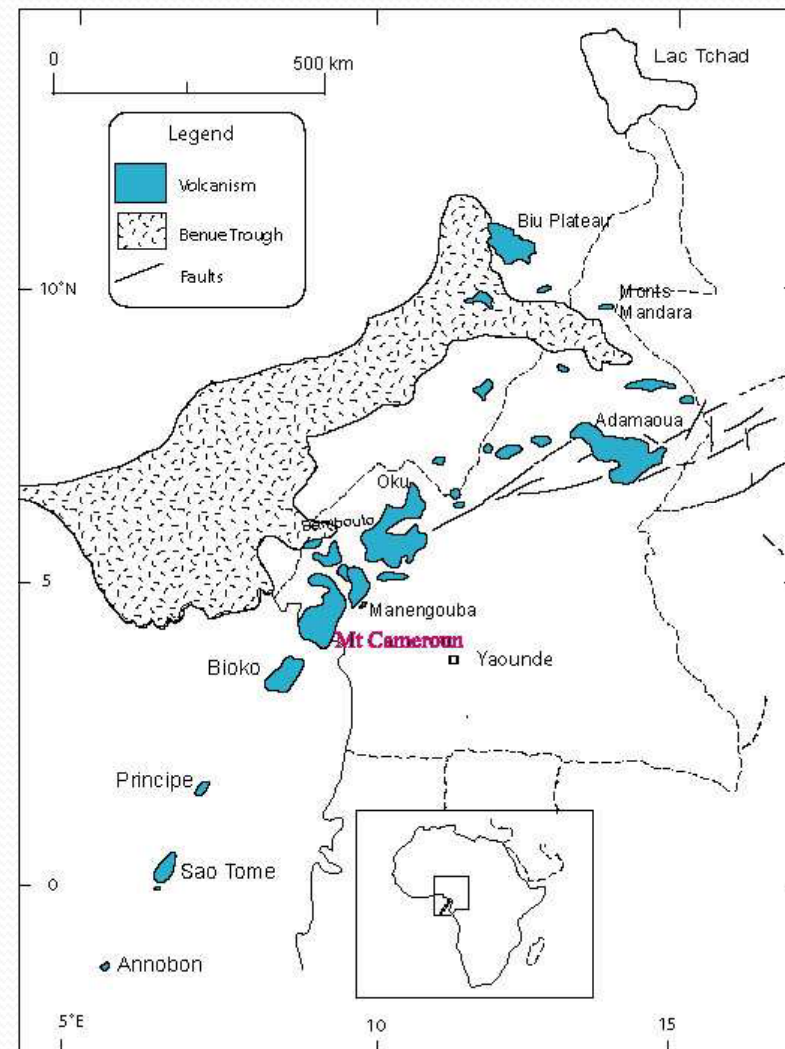
Fitton et al., (1980)



## Cameroon Volcanic Line (CVL)

The main natural hazards along the CVL are associated with :

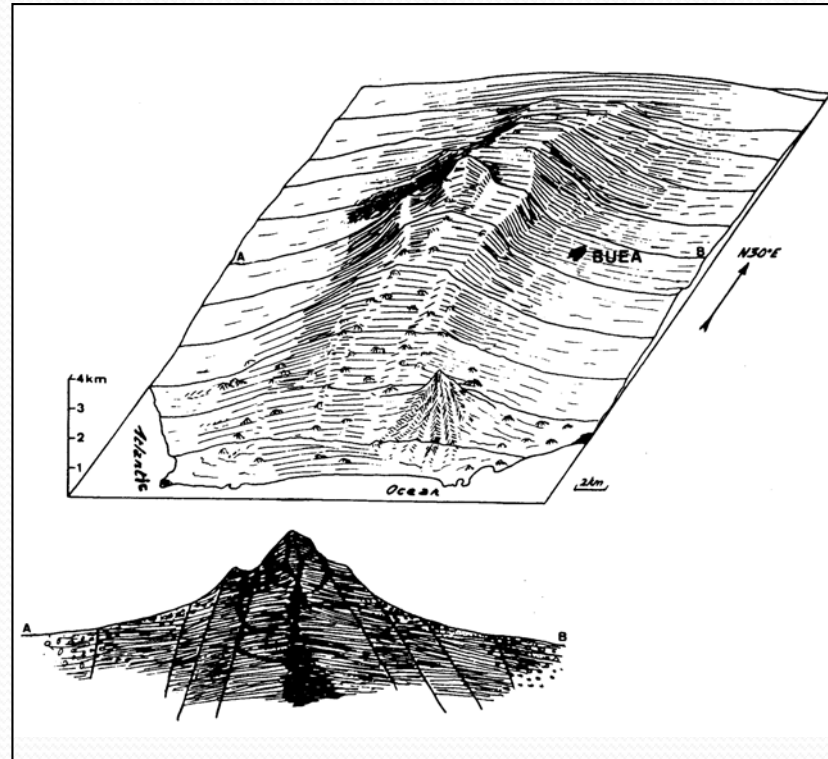
- Mount Cameroon, an active volcano and,
- The crater lakes (Nyos & Monoum).



Fitton et al., (1980)

# Mount Cameroon

- Dimensions  
50 x 35 km  
4 095 m
- Mt Etinde



Déruelle et al.,  
(1987)



## Mount Cameroon

- **Recent Mt Cameroon Eruptions**
  - 1909, NE flank
  - 1922, 2 eruptions : Summit & SW flank
  - 1954, Summit
  - 1959, East flank
  - 1982, SW flank
  - 1999, SW flank
  - 2000, Summit and SW flank.

# Monitoring Mt Cameroon Volcano

## Scientific approach Performed

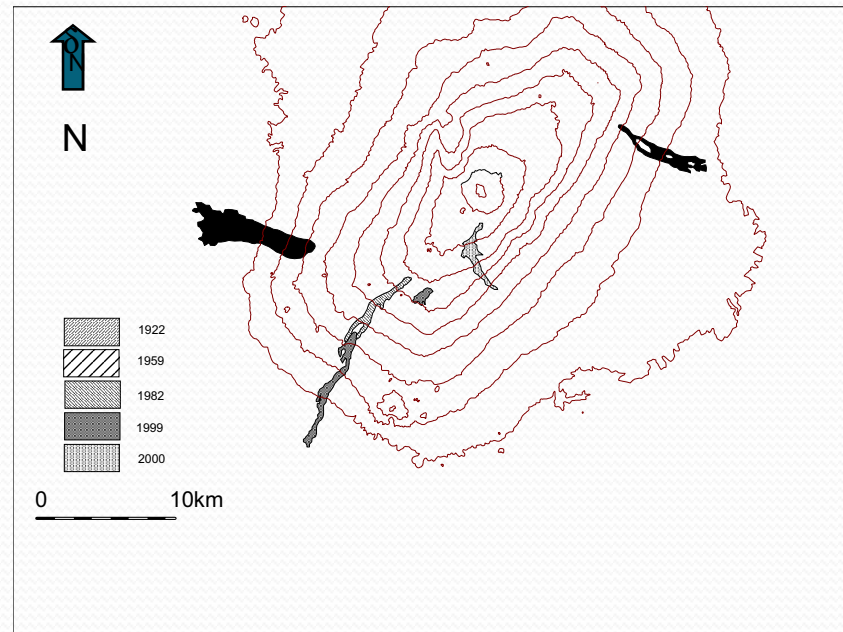
1. Ministry of Scientific Research  
(Research Institute)
2. Ministry of higher Education  
(Universities -Yaounde & Buea)
3. Ministry of Industries Mines and  
Technological Development  
(MINIMIDT)

# Monitoring Mt Cameroon Volcano

## Scientific studies

### 1. Volcanological studies

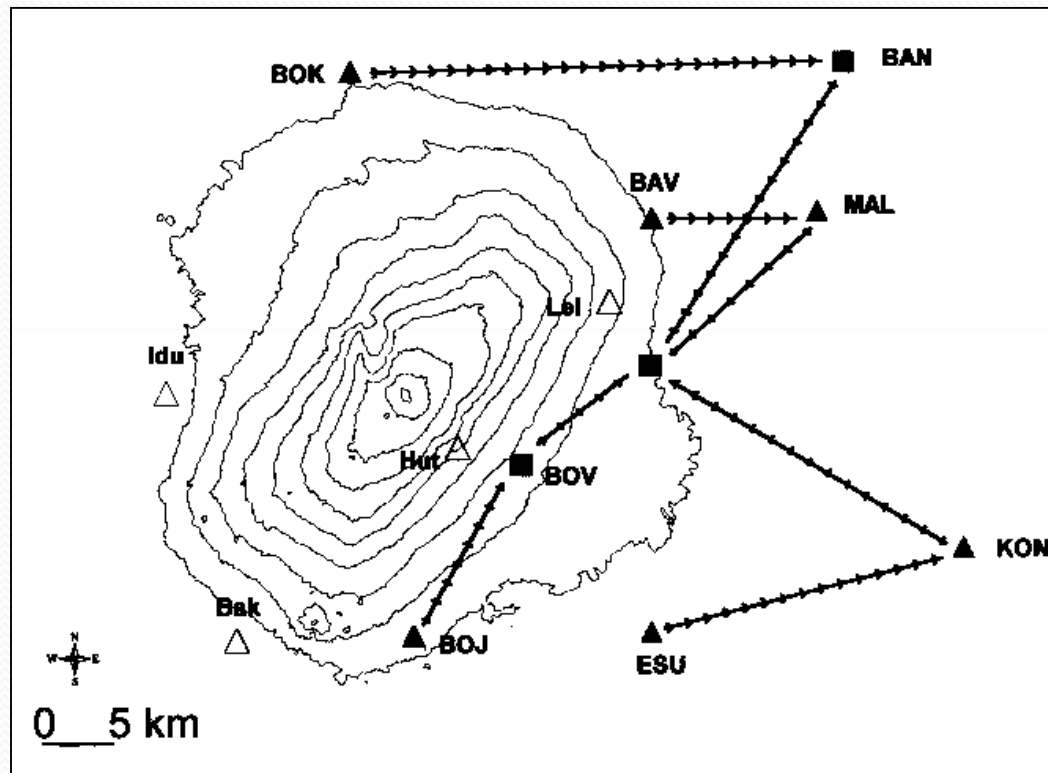
- Geological mapping
- Geochemistry (Pb and He isotopes)
- Natural Hazards



Recent lava flows on Mt Cameroon

# Monitoring Mt Cameroon Volcano

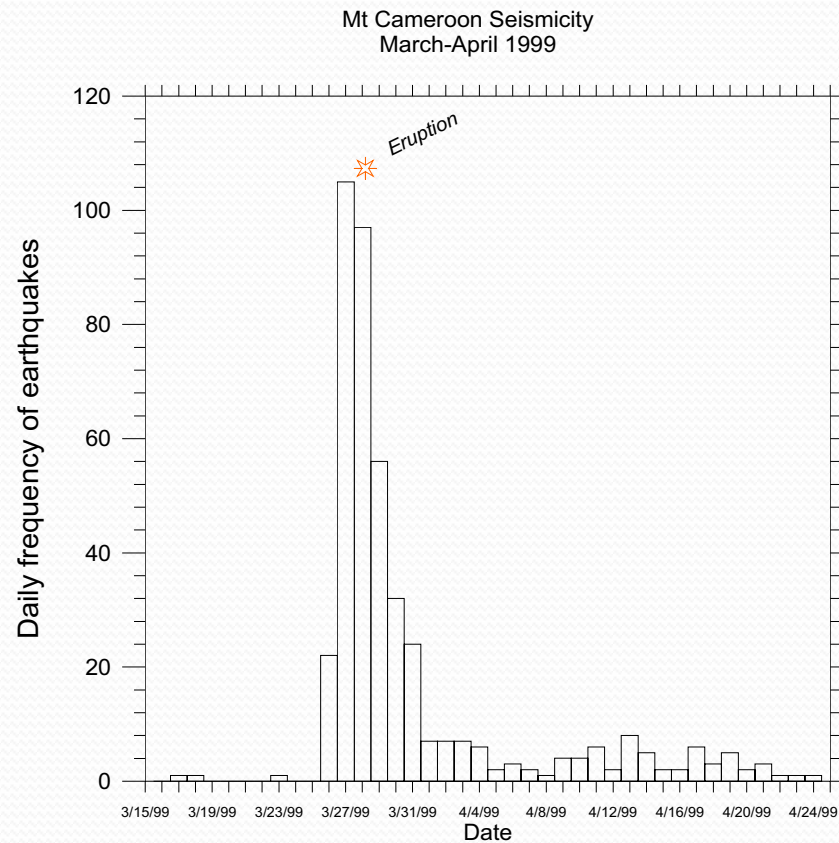
## 2. Seismological studies



Mt Cameroon Digital Seismic Network since 2003.

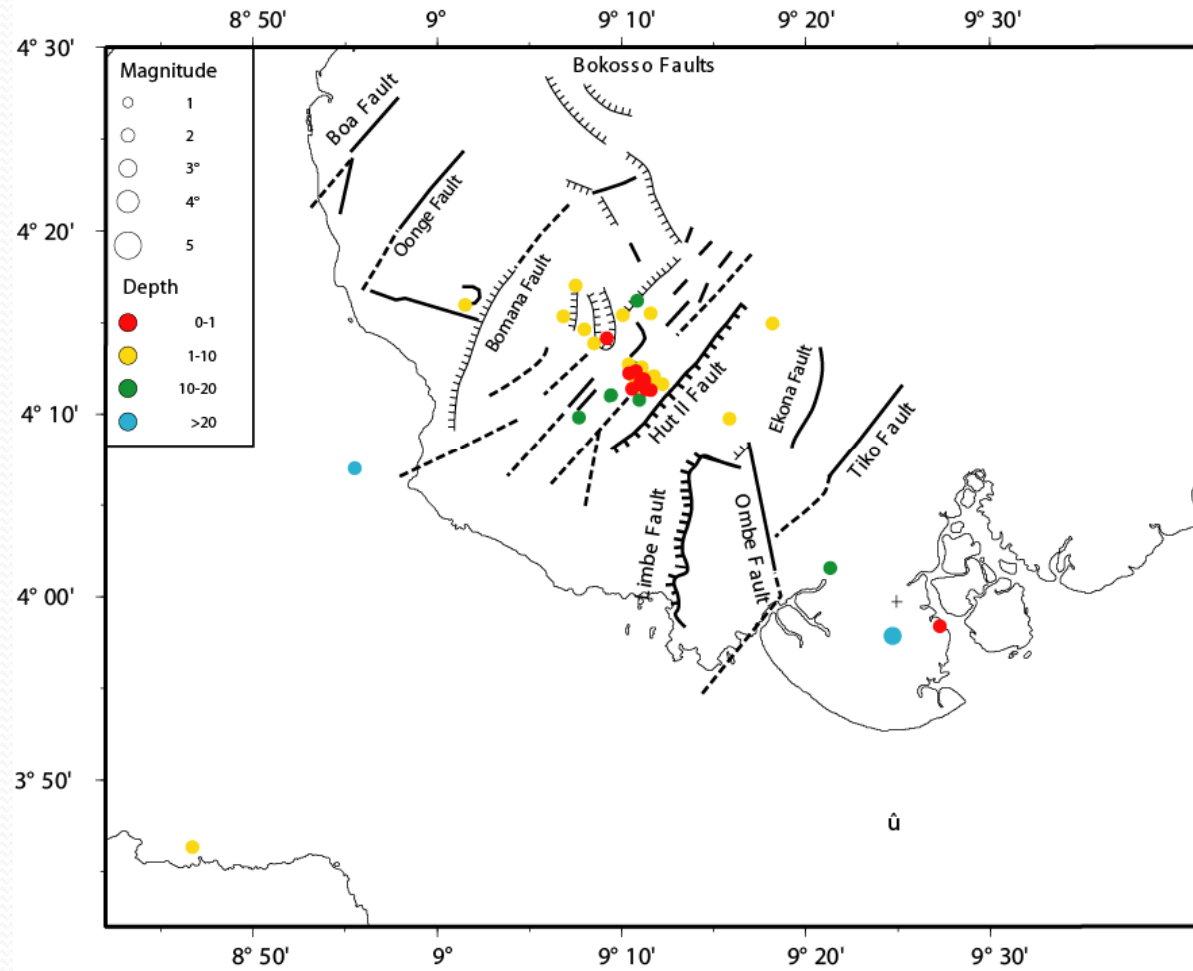
▲ (1C Station), △(3C Mobile Station), ■(3C Station)

# Monitoring Mt Cameroon Volcano



Histogram of 1999 Mt Cameroon Eruption

TECTONIQUE et SISMICITE DU MONT CAMEROUN  
juin à septembre 2000





# Monitoring Mt Cameroon Volcano

## Volcanic Hazards



Earthquakes



Lava flows



Ashes



Landslide

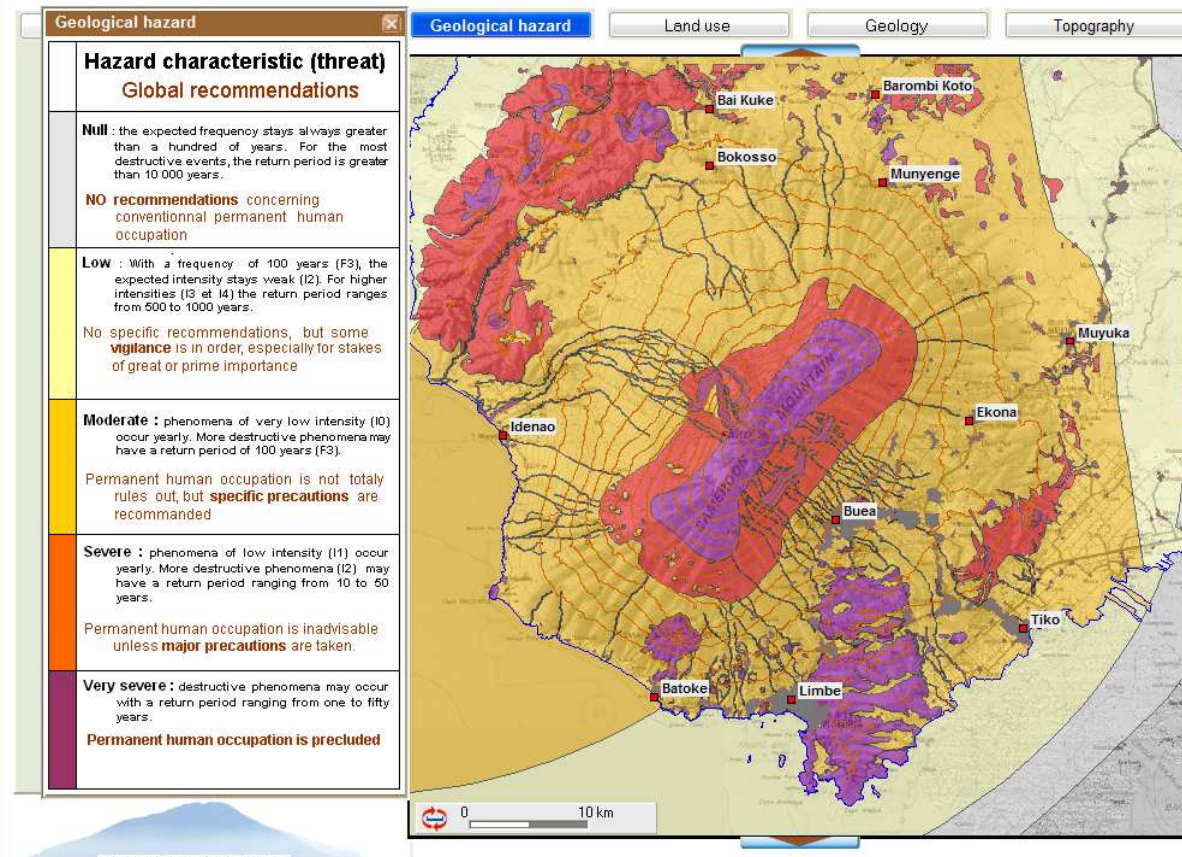
# Monitoring Mt Cameroon Volcano

## Volcanic Hazards

Results from a partnership between :

- BRGM (French Geological Survey) and
- MINMIDT (Cameroon).

## RISK ZONING ON MOUNT CAMEROON





## Monitoring Mt Cameroon Volcano

Traditional approach

Local inhabitants around the volcano think that the mountain is a half-god kingdom whose anger results in eruption.

Libations need to be made to calm down the anger.

Scientific equipment is also suspected to upset the spirits of the mountain

# Monitoring Mt Cameroon Volcano

## Crisis Management

Purpose: help local authorities to take appropriate decisions for civil protection.

### National level

Chairman: *Prime Ministre*

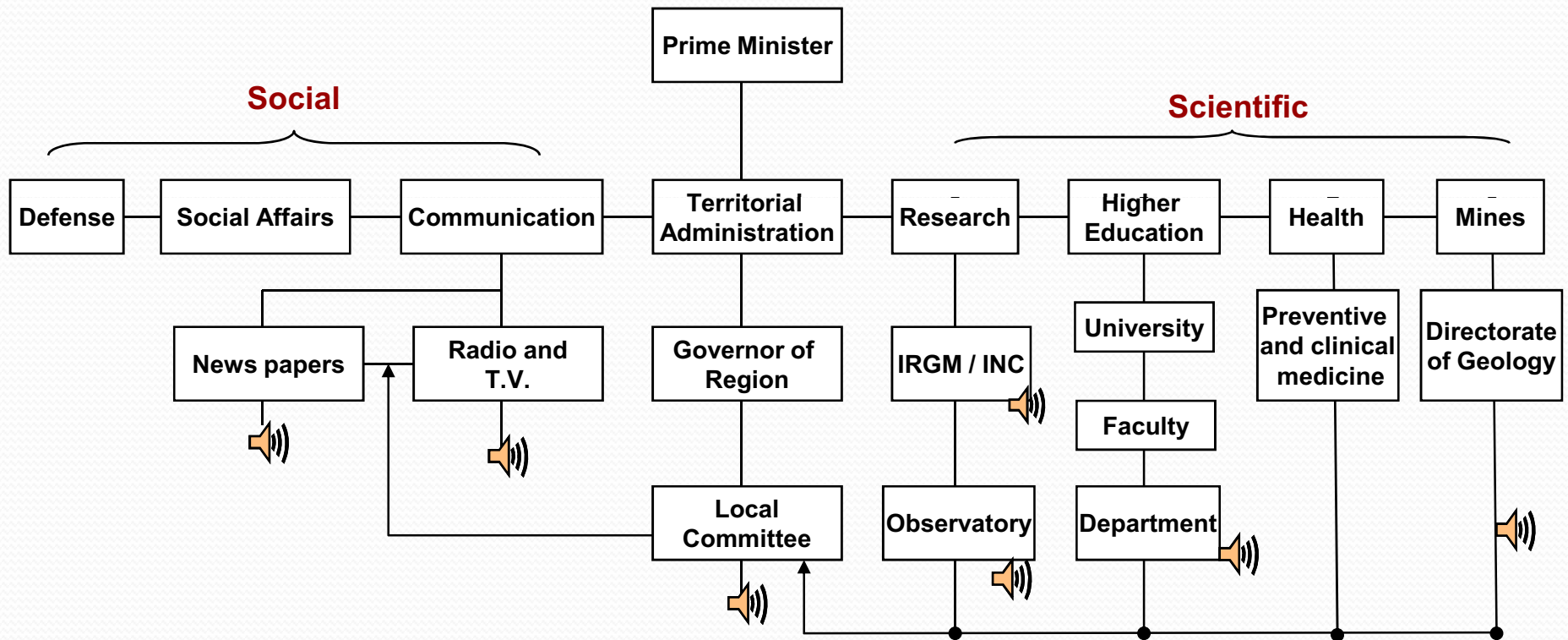
- Ministries: Territorial Administration, Higher Education, Scientific Research, Defense, Health, Social Affairs, Communication

### Local level

Chairperson : *Governor of the Region*

- Delegates of Ministries involved
- National Scientific Committee
- Traditional Rulers
- Non Governmental Organizations (NGOs)

# Monitoring Mt Cameroon Volcano



## Monitoring Mt Cameroon Volcano

### Communication

- ⇒ The local committee is split in different teams.
- ⇒ On a daily basis the governor calls for meetings during which each team gives a report of its activities in a hall.
- ⇒ Meetings are open. It is the best place to update the information to give to the public about the ongoing eruption. Then false rumors can be avoided.

# Monitoring Mt Cameroon Volcano

## Evaluation

Topic	Implementation	Institution
Seismicity	YES	- IRGM
Deformation	Testing	- University of Buea
Ground temperature	NO	- IRGM / Universities
Geomagnetic field	NO	- IRGM / Universities
Gravity	NO	- IRGM / Universities
Gaz content	NO	- IRGM / Universities

# Monitoring Volcanic Activity

## Crater lakes

- Monoun (1984 – 37 dead)
- Nyos (1984- 1700 dead)

Degassing Project going on





# Monitoring Mt Cameroon Volcano

## CONCLUSION

- Scientific Monitoring program is based on study of local seismicity and deformation.
- Eruptions are associated with earthquake swarms.
- Crisis Management Committee is set up when the eruption starts. It is in charge of Civil protection and collects informations to give to the public. A permanent structure is yet to be created.
- Traditional beleaves are an handicap for the monitoring program.
- Multi-disciplinary approach is still to be well implemented.
- Degasing project is going on the Crater lakes.

Thanks for your kind attention



Crater Lake Barombi Mbo



Field trip up Mt Cameroon