Kenya Rift Valley: Tectonics, Natural Resources, Hazards and Hazard Mitigation

By E.W. Dindi, Ph.D

Senior Lecturer, Department of Geology, University of Nairobi.

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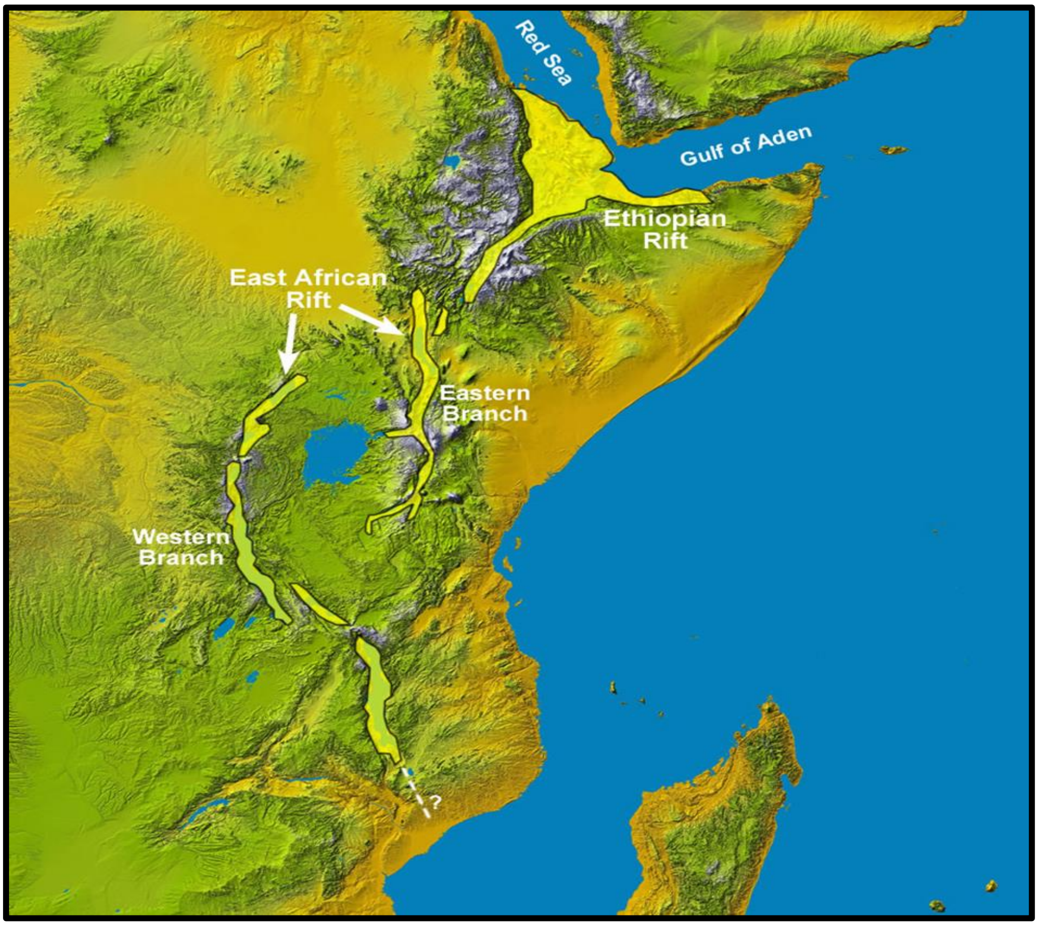
Introduction

"The African Rift Valleys do not constitute one long continuous trough with a curving branch to the west. Some of the individual faults can be traced for long distances, but others are shorter and commonly arranged en echelon. But looking at the rift faults as a whole it is impossible not to recognize that they are all closely related parts of a single system of tectonic features which extends from the Zambezi to the Red Sea." (Arthur Holmes, 1965.)

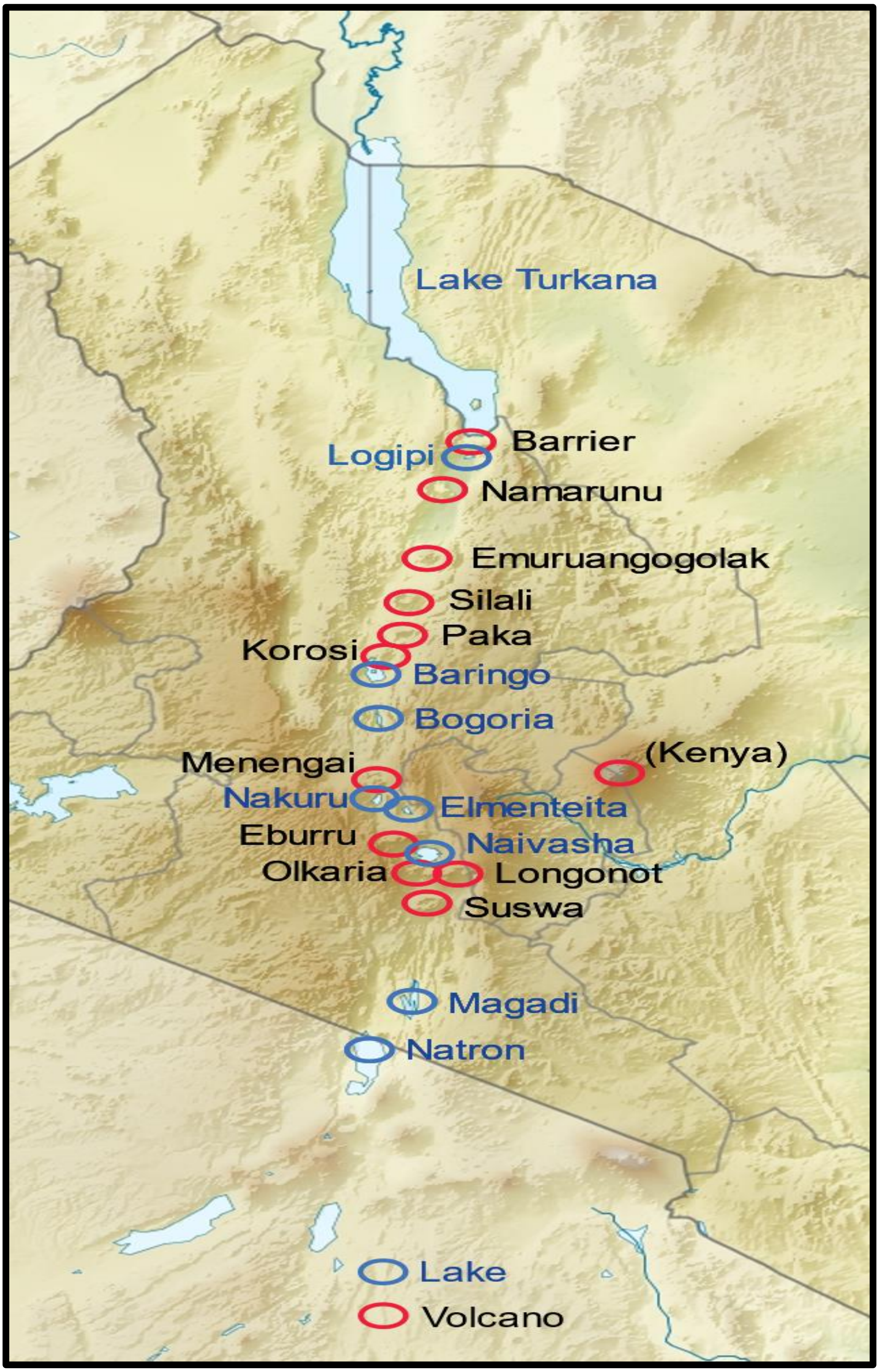
A view of the Kenya Rift from the eastern shoulder showing step faulting and the rift floor in the background (Courtesy: m.youtube.com)

Observable features of the Kenya Rift Valley:

- It is about 50-60 km wide.
- Boundary faults have large throws of up to 2000m (est. 3000-4000m).
- Shoulders are marked by escarpments which bound the rift floor (e.g Nguruman Esc., Mau Esc., Laikipia Esc. and Elgeyo Esc.).
- The rift floor is highly faulted and traversed by grid faults trending approximately north-south.
- The rift floor is comprised volcanic rocks and ash and lake sediments.
- The Kenya Rift is a zone of internal drainage.
- Lakes are dominant along its axes (widely distributed lake beds bear witness that large lakes existed in the past on the floor of the Rift Valley.
- Geothermal manifestations: hot springs, fumaroles, geysers occur and the rift zone is characterized by high heat flow typical of active rifts.



Main Features of the East African Rift System. (*Courtesy: blogspot.com*)



Distribution of volcanoes and soda lakes in the Kenya Rift Valley
(Courtesy: boundifulsafaris.com)

A: TECTONICS

Origin of the Kenya Rift: *Attributed to a series of events that include doming, tensional stresses, collapse of the central part followed by alternating episodes of faulting volcanicity and sedimentation with zone of activity moving towards the axial zone.*

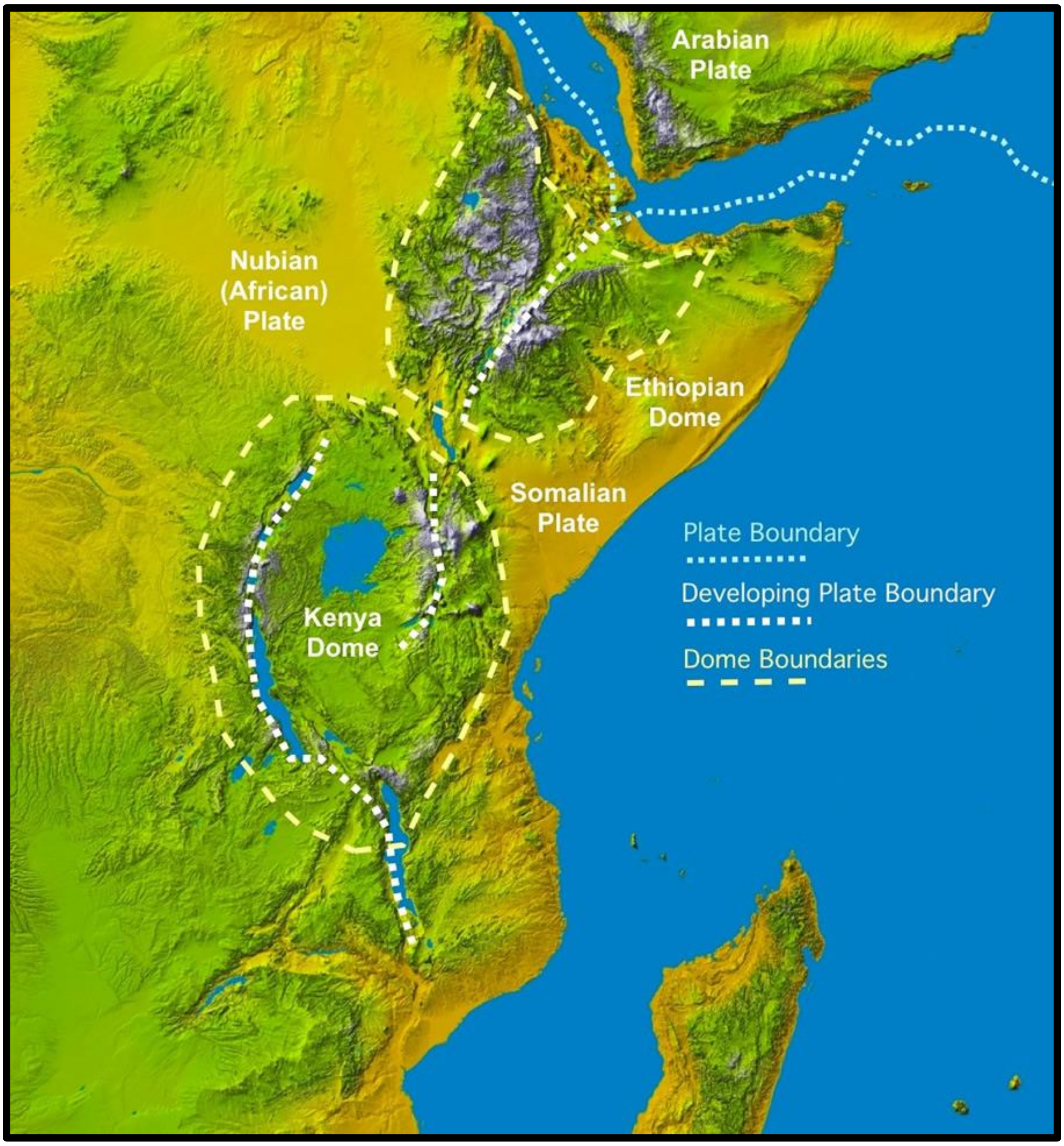
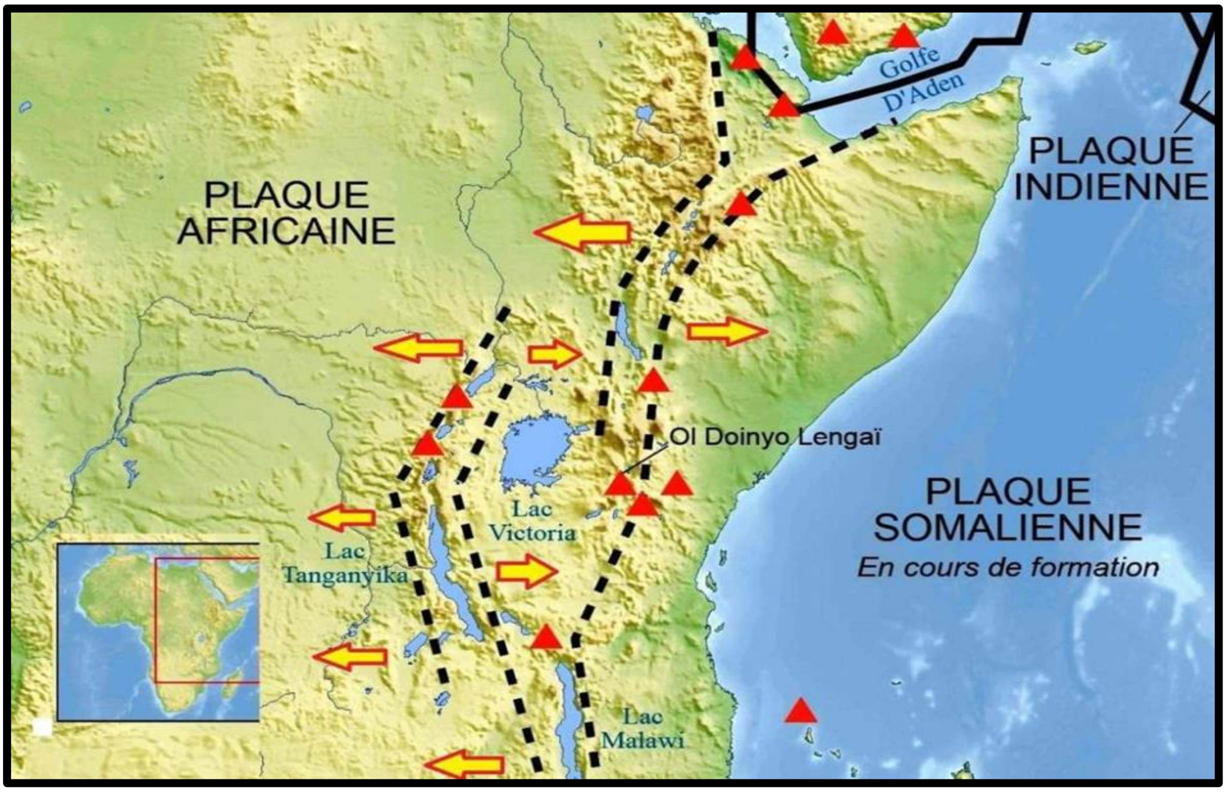


Illustration of the doming to form the Kenya Dome and the Ethiopian Dome. (Courtesy: *geology.com)*



The current stress field associated with the East Africa Rift System. (Courtesy: geologyin.com)

A simplified illustration of the stress field affecting the Nubian and Somali plates. Courtesy: allmapslibrary.blogspot.com)

Crustal Studies

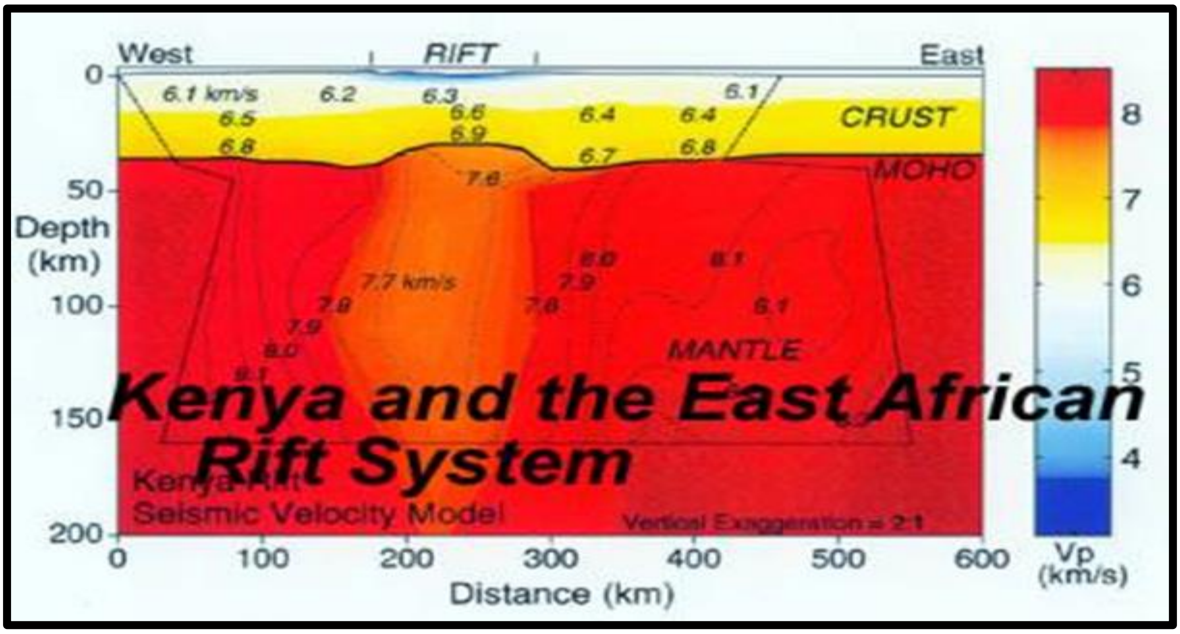
Past crustal research had the objectives of determining the crustal structure and composition along and across the Kenya Rift Valley.

Most comprehensive such research was under the auspices of the Kenya Rift Valley Seismic Project (KRISP)

These involved integrated investigations involving use geological and geophysical methods (seismic reflection and refraction, gravity, magnetics and seismology)

Findings:

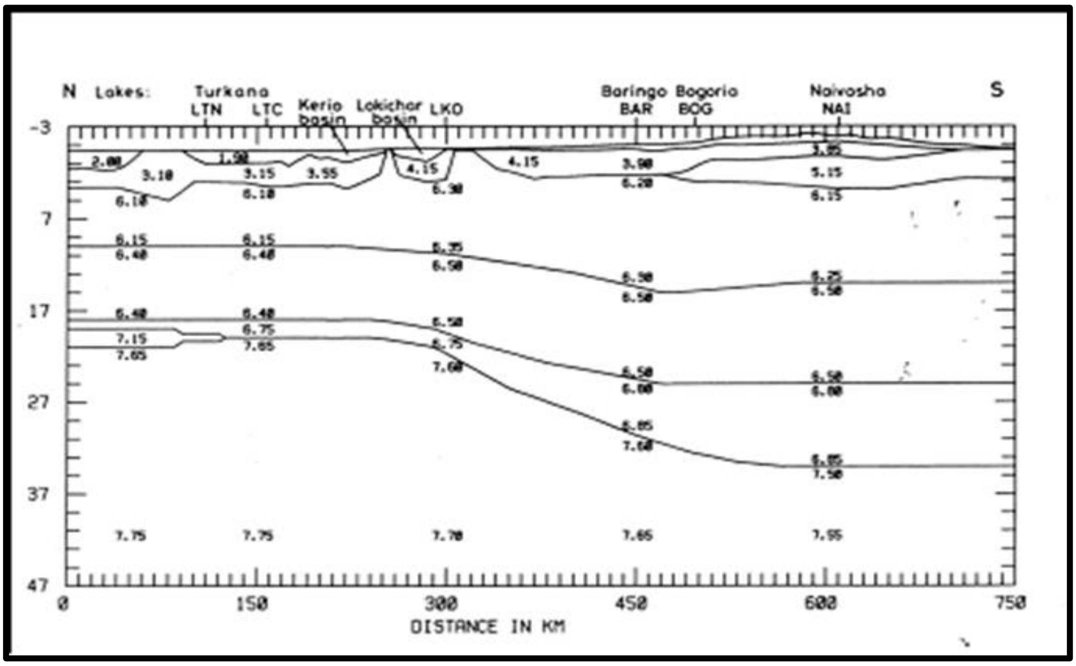
- The rift show variation in structure and composition along and across its axes.
- Crustal thinning occurs along the axis of the Kenya Rift from a Moho depth of 35km in the south beneath the Kenya Dome in the vicinity of Lake Naivasha to only 20km in the north beneath Lake Turkana.
- Low Pn velocities (7.5km/s – 7.7 km/s) are found beneath the whole of the axial line.
- The mantle underneath the rift is abnormal compared with that beneath the shoulders (low velocity and more fluid). – partial melt.
- The abnormal mantle is also characterized by a broad negative Bouguer anomaly over the rift zone.
- The axial part of the rift is characterized by a positive gravity anomaly implying presence of a dyke like injection into within 5km of the surface.
- The dyke like injection is considered to be closely linked to geothermal system within the rift
- Along the axial line the rift infill consists of volcanic rocks and minor sediments up to 6km beneath L. Turkana and L. Naivasha.



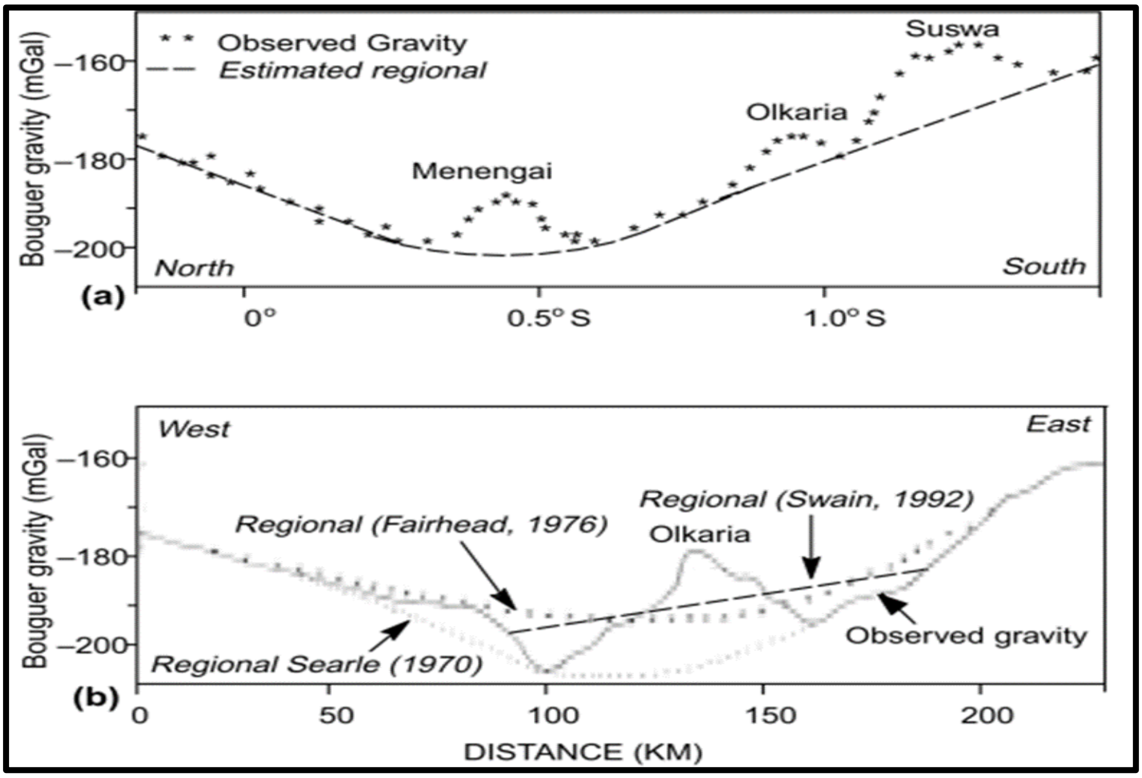
The crustal structure across the Kenya Rift Valley according to KRISP90 with abnormal mantle under the rift zone.

More recent research, using GPS systems confirm that the Kenya rift is characterized by tensional movements.

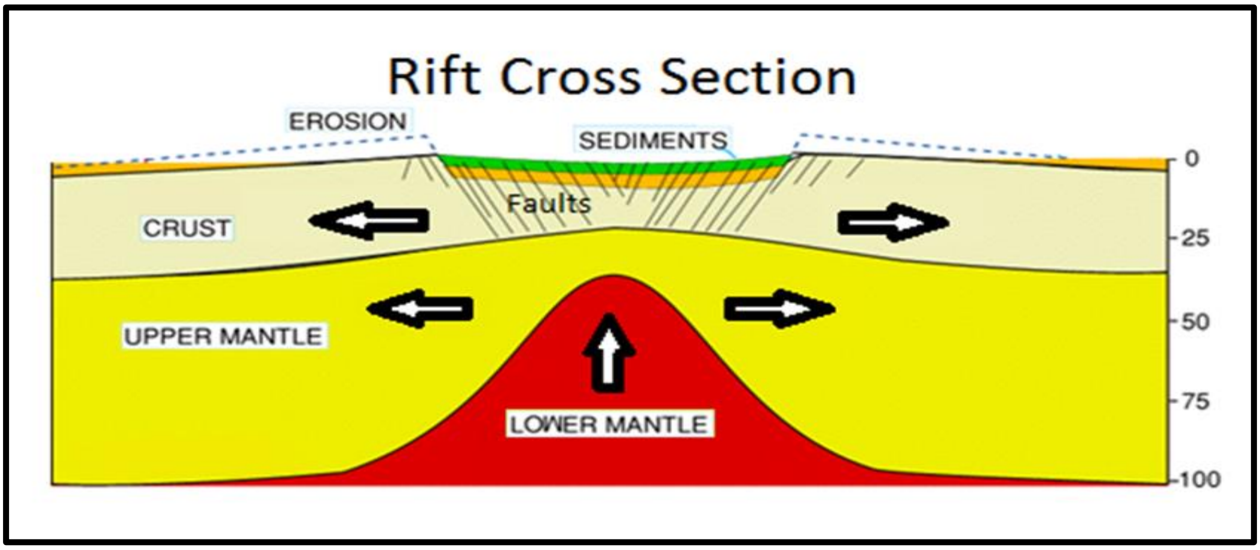
Results of all past studies point at the Kenya Rift being a spreading center in other words, a divergent plate boundary.



An illustration of the crustal structure in the north-south direction along the axial plane of the Kenya Rift Valley (KRISP90).



Observed gravity profiles and interpreted regional anomaly profiles (a) axial (N-S) gravity profile along the Kenya Rift Valley through Menengai, Olkaria and Suswa volcanoes (b) E-W gravity profiles crossing the rift valley and passing through Olkaria (Simiyu, 1990)



A plate tectonic model of an active rift in initial stages of separation.

(Courtesy: Wikimedia)

The Kenya Rift is therefore unique in that although its evolution trajectory is similar to the of the Mid-Oceanic ridges, we are able to see it while the two sides are still intact.

This explains why the international community is injecting so much money in the work on the Kenya rift. A major project GEOPRISMS that seeks to study *origin and evolution of continental margins and their dynamics* has been going on for some time now. Another major project seeking to investigate *how climate change and tectonics in the rift influenced life and evolution* has just been approved for funding by the NSF.

B: NATURAL RESOURCES

The consequences of rifting were that:

- Drainage pattern in eastern Africa was changed resulting in the rift becoming a closed zone – zone of internal drainage giving rise to lakes.
- Intense volcanism and faulting resulted in large volumes of lavas, ash and lake beds being deposited on the rift floor
- Interaction of rain water with hot rocks by percolation through faults was facilitated.
- Basin structures that facilitate trapping of hydrocarbons were put in place.

Based on the above, natural resources associated with the rifting include:

- Energy resources – steam for electricity generation and other uses, and hydrocarbon accumulations
- Building materials – aggregate, dimension stones(tuff) and sands.

Flamingoes at one of the soda lakes. (Courtesy: boundfulsafaris.com)

- Industrial minerals – Magadi soda, diatomite, clays
- Spa sites with soapy waters for treatment of skin ailments
- Touristic, pre-historic and geoparks sites – (e.g Hells Gate)
- Varied ecosystems and their fauna and flora (wild life etc)
- Weathering of volcanic rocks giving rise to fertile volcanic soils
- Microalgae found in the alkaline lakes are a potential source of energy and high-quality compounds.

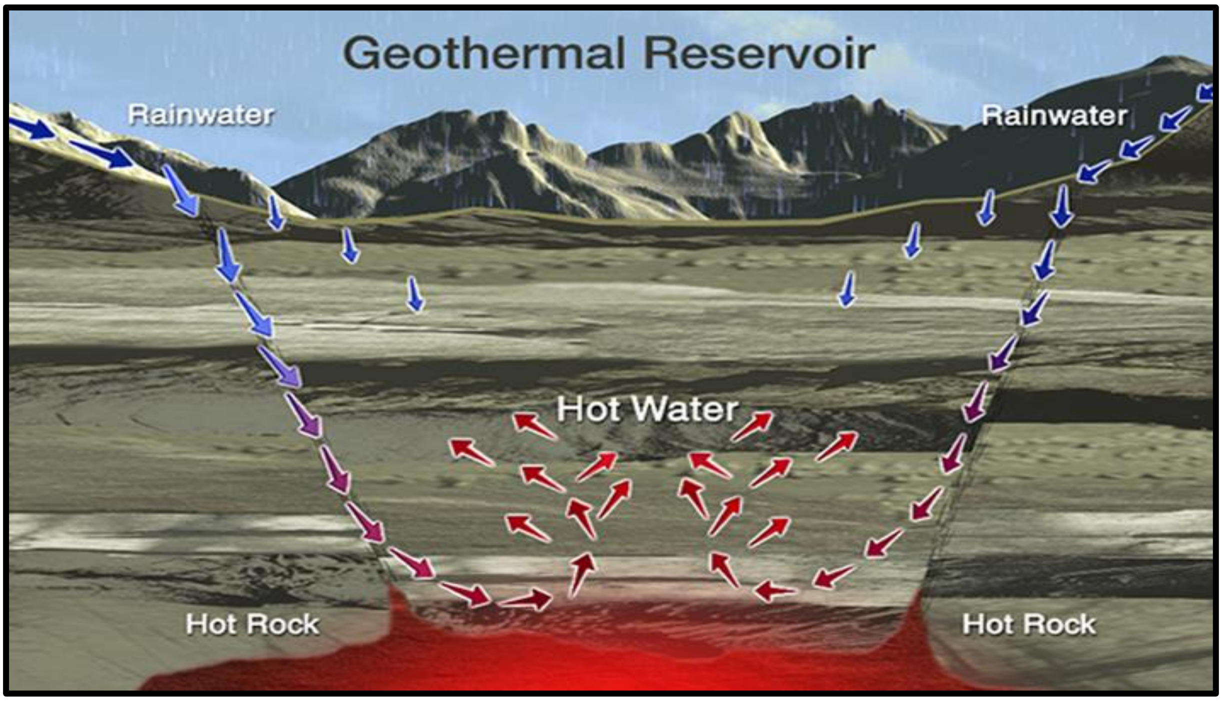
Geothermal Energy resource

Global utilization of Geothermal energy which is grouped among renewals is very low. This partly because only very few countries are endowed with the resource and partly because most these are far from realizing full potential.

Only a few (about 24) countries are endowed with Geothermal energy. These include Kenya, Ethiopia, New Zealand, Iceland and USA.

Some countries like Germany had tried drilling experiments to reach the hot rocks (Dry Hot Rock Project) but have not been successful so far.

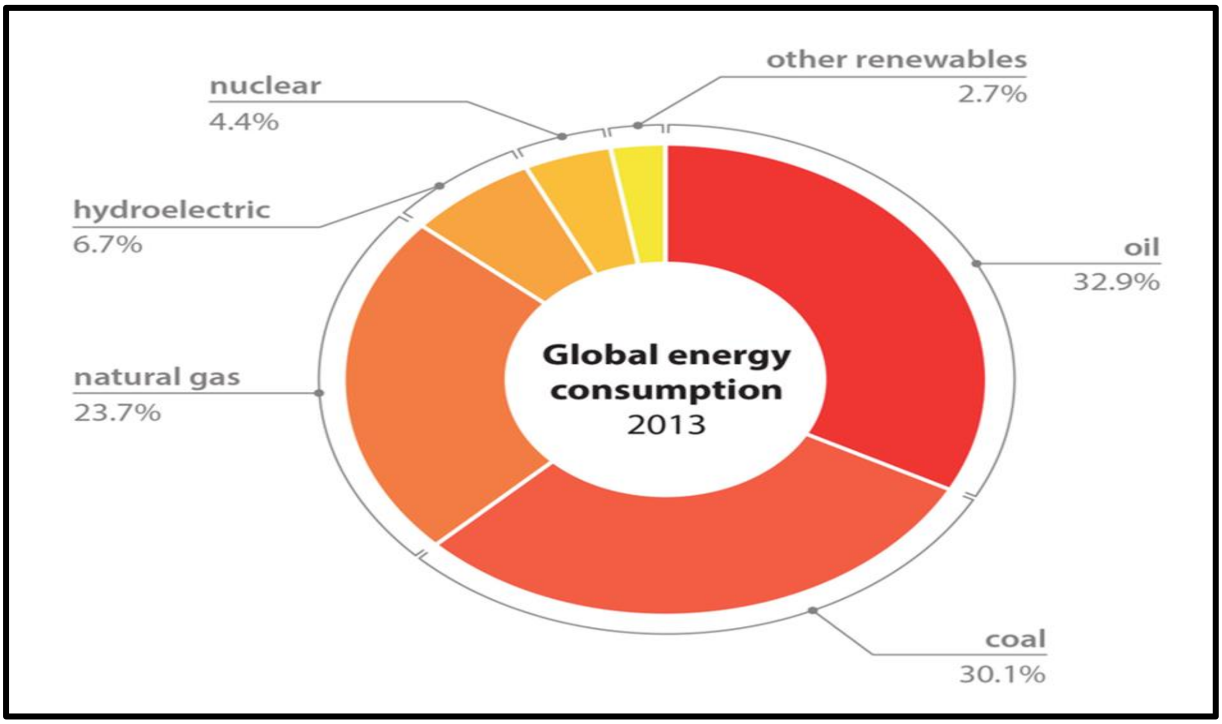
Global utilization of renewables which include geothermal is at only 2.7%



An illustration of the interaction of surface waters with hot rocks through faults. (Courtesy: kengen)

Steam extraction equipment at Menengai III power generation station.
(*Courtesy: constructionreviewonline.com*)

Proportion of renewable energy exploitation in the world relative to other energy types.



Level of energy consumption by energy type in 2013

1.	Hydro	820.7MW	35.12%
2.	Geothermal	627.0MW	26.84%
3.	Biomass	28MW	1.12%
4.	Wind	25.2MW	1.09%
5.	Thermal (Fossil)fuel	816.2MW	34.93%
6.	Off-grid	19MW	0.08%
	Total	2,336.4MW	100%

Comparison of energy type usage in Kenya (from MOEP website)

Country	Installed capacity (2018)	Estimated potential
USA	3639MW	Potential
Indonesia	1948MW	28,994MW
Philippines	1868MW	?
Turkey	1347MW	?
New Zealand	1005MW	?
Mexico	944MW	?
Iceland	755MW	?
Kenya	627MW(?)	Rift Valley > 2000MW; National geothermal potential between 7000 and 10000MW

Installed capacities of some of the Geothermal energy countries in 2018

Global geothermal power generation potential is about 70-80GW. However, just 15% of known geothermal reserves around the world are exploited for electricity production generating 13 GW (World Bank)

An underexplored Resource for Biotechnology

Algal cultivation has received substantial attention in recent decades. Microalgae have come to the fore as a potential source of **energy and high- quality compounds.**

Algae are sources of **natural dyes, polysaccharides and vitamins** along with other substances of pharmaceutical interest.

For commercial purposes, microalgae have to be cultivated in either in open pond systems or closed photobioreactors. Mass cultivation in open pond systems is usually restricted to extremophiles which minimize contamination by other organisms.

Open ponds are less expensive and easier to maintain. They are the most economic algae mass cultivation.
Open ponds are highly depended on local climate and are therefore not suitable for continuous operation in temperate regions but ideally placed in the tropics.

The Kenya Rift Valley environment thus offer ideal environment for algae biotechnology taking into account (i) **high incoming irradiance (ii) none arable land over large areas (iii) saline-alkaline lakes occupied by extremophiles.**

Besides synthesis of high-quality compounds, extremophiles are of interest for use in biorefineries, because they contain extremozymes. Alkaline-saline environments are rich sources of such organisms.

Possible applications are in laundry detergents, detoxicants and decontaminants.

C: NATURAL HAZARDS AND HAZARD MITIGATION

Natural hazards are extreme events that can cause loss of life, extreme damage to property and disruption of human activities.
The Kenya Rift Valley with its endowment has its share of natural hazards; these include:

- Earthquakes and Volcanoes
- Flooding related to lake water level rises
- Exposure to hydrogen sulphide gases
- Land subsidence
- Landslides and rock falls

The Kenya rift is characterized by low magnitude earthquake but occasionally earthquakes of large magnitude can occur. A good example was the Subukia earthquake that occurred on 6 January, 1928 which was associated with a 38km surface break that showed normal faulting with maximum throw of 240cm and had magnitude 6.9.

Mitigation measures for **earthquakes and volcanic eruptions** require continuous monitoring of the seismicity in and around the rift. Large volumes of such data can help estimate return period of large earthquake and hence enhance preparedness.

The CTBTO has one seismic and one infrasound stations in Kenya that operate continuously. Complemented with other seismic stations in the country, analyses and interpretation of such data on a continuous basis can greatly contribute to prepared for earthquakes and volcanic eruptions. These a potential area of future research where the challenge continues to be allocation of dedicated staff as the data processing has to run 24/7.

Flooding

As the rift is an area of internal drainage, floods waters can drain into the ocean as is the case with none rifted areas. The water levels can only drop through evaporation or percolation into the ground. Thus, extended precipitation can easily result in waters accumulating at a faster rate than the combined rate of percolation and evaporation.

This phenomenon has also been reported for the mountain lakes of the Alps where a rise of lake level by 2m has flooding the near shore areas has been reported. Mitigation entails monitoring the lake level and evacuation where necessary. Land use planning to avoid encroachment of the areas of high-water level can be a long-term mitigation measure.

Flooding due to level rise of Lake Baringo. (Courtesy:facebook.com)

Land subsidence

Land subsidence across the Mai Mahiu – Narok road in 2018. (Courtesy:face2faceafrica.com)

Land subsidence in Mt. Suswa area of the Kenya rift valley in 2012(Courtesy: nationalgeographic.org)

Cracking and land subsidence have been reported with the Kenya Rift on several occasions. Some of the widely reported cases were in Nakuru in 1985, and more recently in Mai Mahiu in 2012 and 2019. In all these cases flow of traffic was disrupted caused of large linear cracks having developed across the roads. Research carried out during the Nakuru Case in 1985 showed that the cracking was not associated with any earthquake but that it is always associated with periods of above average rainfall. The phenomena appear to be triggered by accelerated subterranean erosion along existing faults. The erosion of materials through the fault leaves part of the unconsolidated overburden unsupported and hence the collapse.

As the depth of the affected faults is not known, the only mitigation measure is to map all faults accurately and monitor them especially during the rainy season.

Landslides and rock falls

Landslides are common in the northern part of the Kenya rift especially the Elgeyo Marakwet areas. These are triggered by saturation of steep slopes that have been created by rifting. Rock falls can also occur during the rain season or other times. Mitigation measures include proper land-use planning to avoid use of the vulnerable areas.

Rockfalls could also be a danger to road users especially in the hills the cases where the road was cut through agglomerates.

Exposure to hydrogen sulphide gases

Risk is low mainly because areas where it is released near fumaroles and geysers is far from settled areas. Exposure risk exist for staff working on the steam pipelines during connection of steam pipelines with the geothermal power plants.

Potential future research topics

1. Detailed gravity mapping and modelling with the help of satellite gravity data.
2. Analysis of earthquake data from the current seismic network stations
3. Integrated investigations to identify new geothermal fields
4. Assessment of the size of Kenya geothermal potential through integrated investigations in potential areas.
5. Detailed review of data from geothermal drilling and generation monitoring to take advantage of lessons learnt.
6. Detailed mapping of faults that are prone to subterranean erosion.
7. Interactions between fresh and saline groundwater.
8. Biotechnology research on the alkaline saline lakes.

Despite its hazards, the Kenya Rift Valley is an asset of immense magnitude from the clean energy perspective.

Statement by Germany Ambassador to Kenyans by Ms. Annett Guenther on Germany's Independence Day included the following words.

"Germans look with envy at Kenya's share of over 85% renewables in electricity generation and we are willing to support Kenya in expanding these capabilities" (The Standard, 3 October, 2020)

Summary

(a) Kenya rift is a unique and spectacular feature that over years continue to attract earth scientists, life scientists, researchers and tourists.

(b) It is unique that it the ideal rift for studies on how mid oceanic ridges form.

(c) The natural processes associated with the rift have endowed region many natural resources making it one of the riches regions of Kenya.

(d) While plate separation is not expected in another 50 Million years, the process has already started and its physical effects of separation process will continue to be felt.

(e) Monitoring as part of mitigation measures should be undertaken to minimized hazards known to be associated with this natural earth process.

(f) There is still a lot that is not known about the Kenya Rift Valley and therefore more research on several fronts is required to better understand the extend of the natural resources both on and beneath it.

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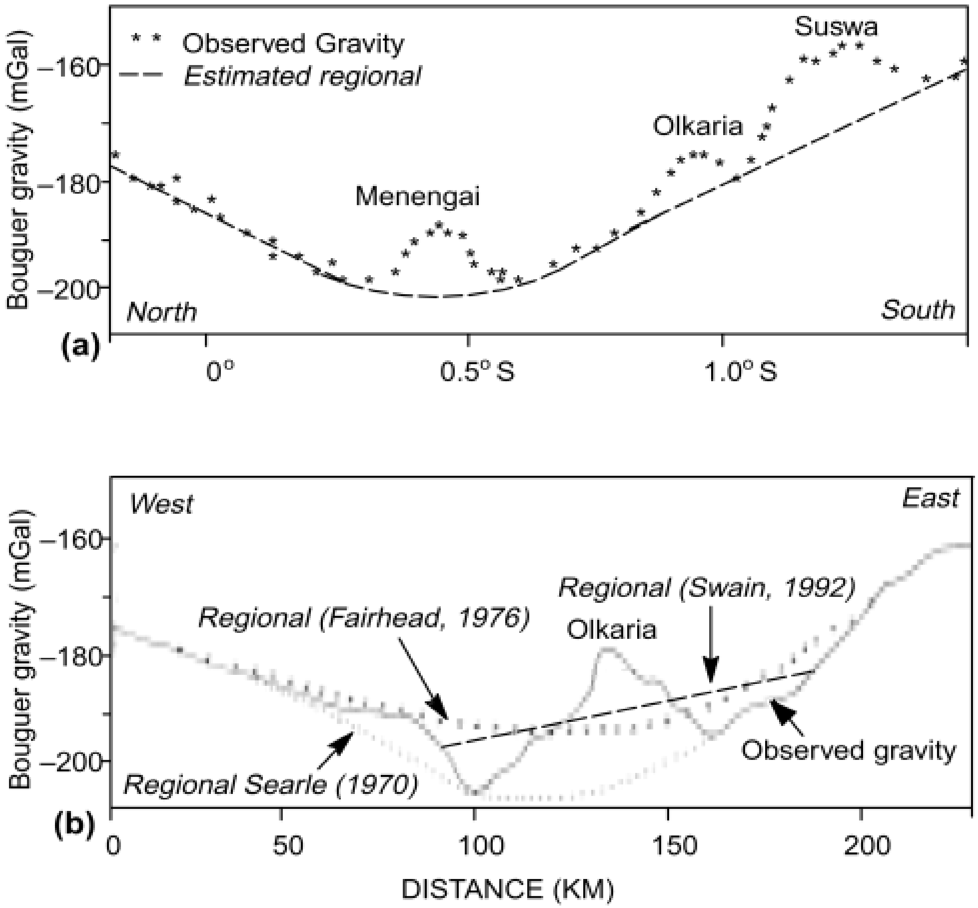
Below are extra diagrams for discussions if there will be need.


Observed Gravity
Estimated regional
Suswa
Olkaria
Menengai
Bouguer gravity (mGal)
−160
−180
−200
North
South
(a)
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0.5° S
1.0° S
West
East
Regional (Swain, 1992)
Regional (Fairhead, 1976)
Olkaria
Observed gravity
Regional Searle (1970)
(b)
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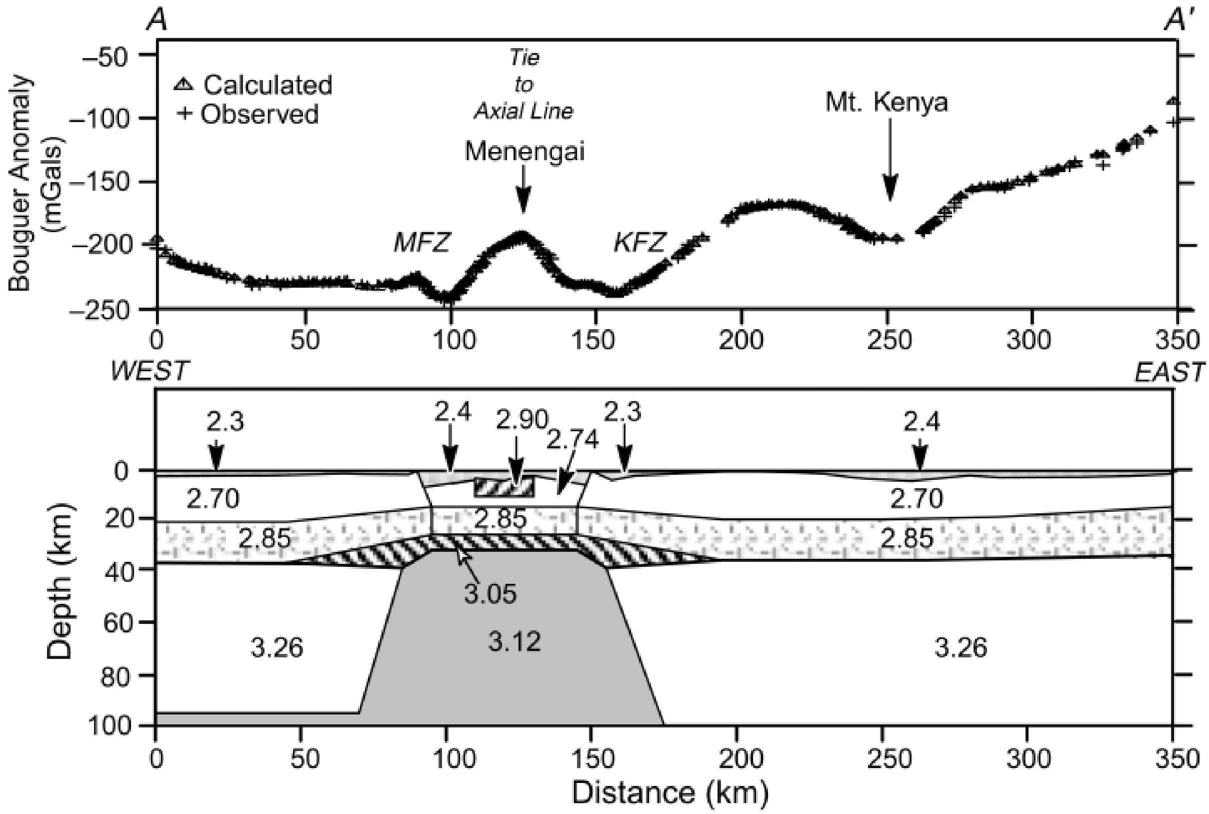
DISTANCE (KM)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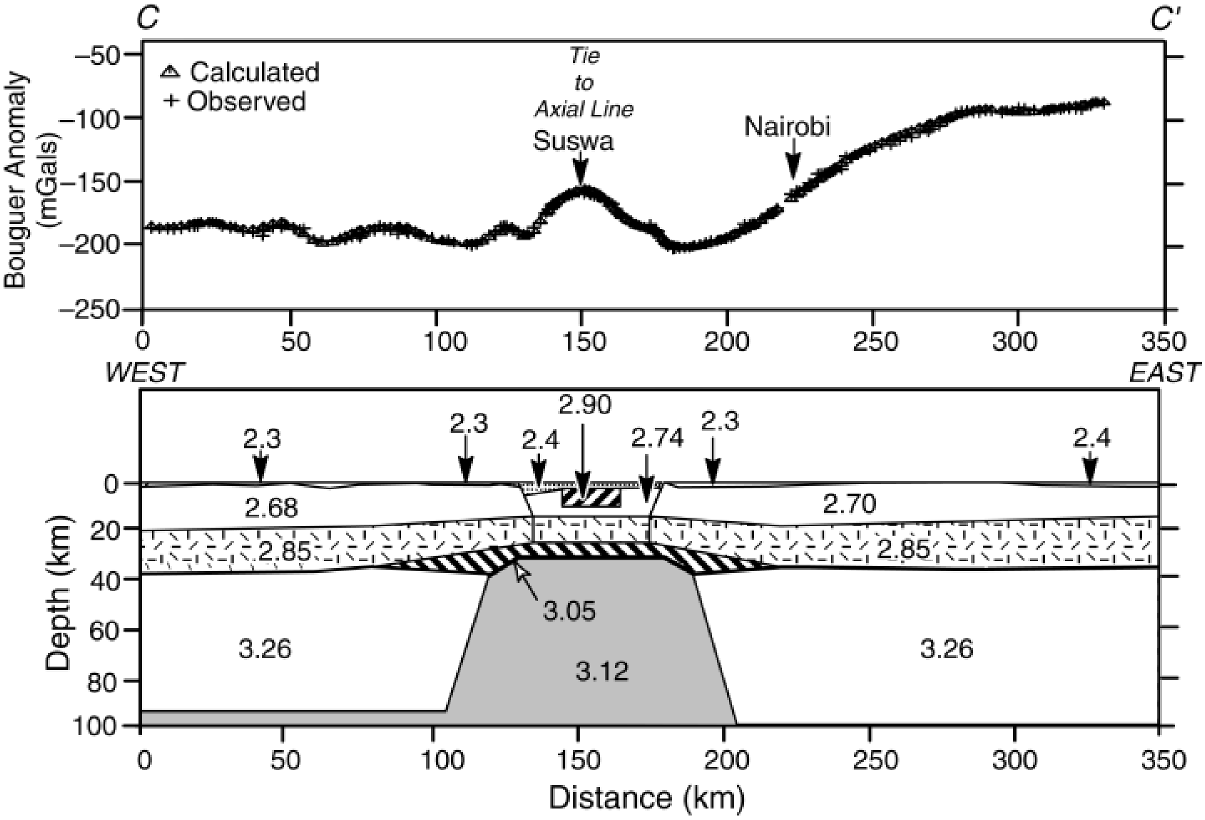
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