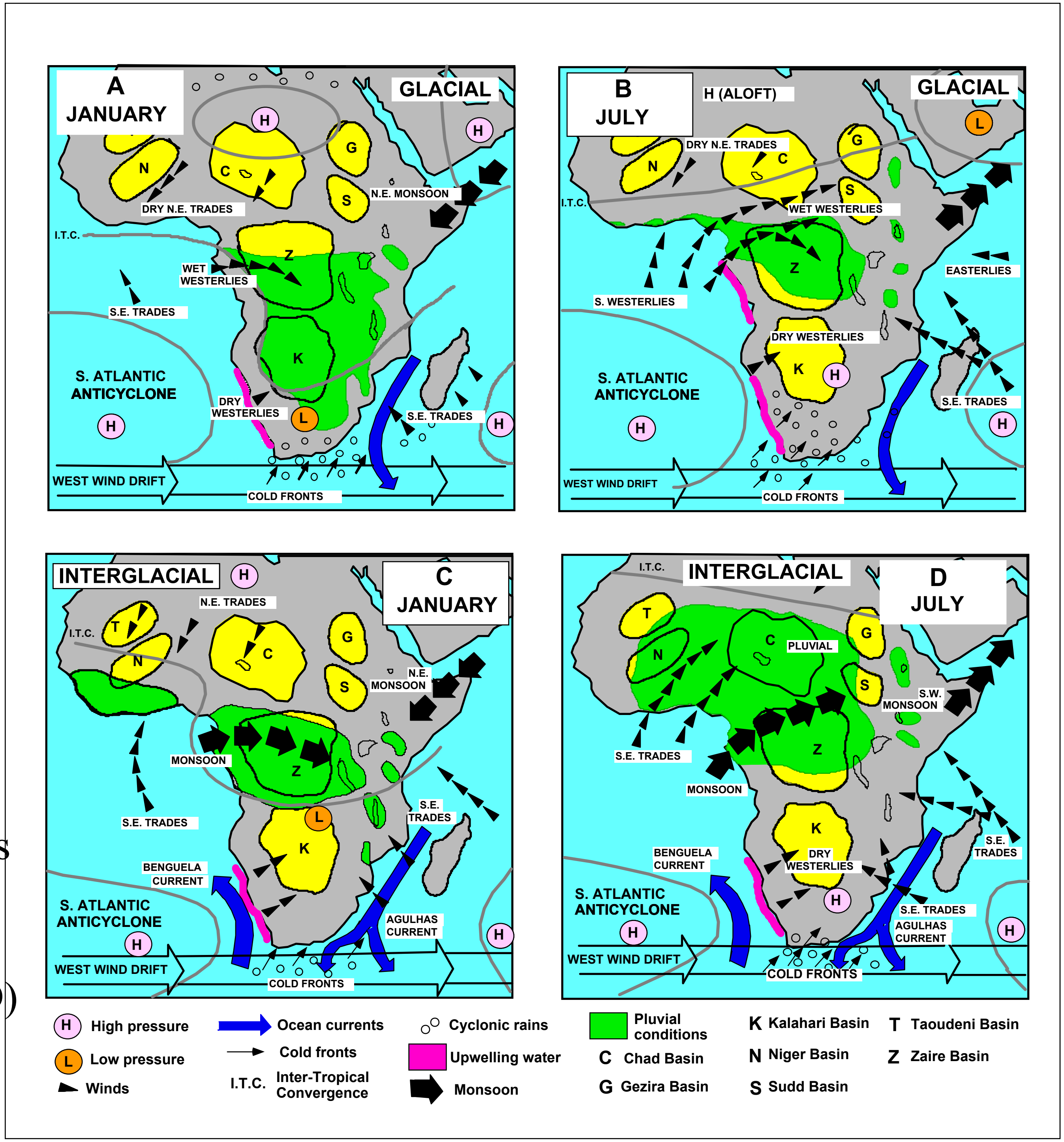
Africa's Past 30 Million Years

* Many phenomena of the past 30 Ma at and close to the surface of the African plate are responses to the eruption of the Afar plume.
* That plume formed at the CMB, rose to the surface and erupted at 31 Ma.

- No comparable direct association of an event at the CMB with a variety of surface phenomena is known on the Earth

Before Northern glaciations began (2.8 Ma) conditions from 34 Ma (when East Antarctic ice sheet formed) were similar to those of interglacials of the past 2.8 Ma (Figs.C &D)



Sahara first formed at 2.8 Ma.

Congo Basin (Z) is always wet.

July ITCZ reached far to the north before 2.8Ma

Namib has been a desert since 34 Ma because of Benguela current

AFRICAN PLATE PINNED

HOW ? As a result of Afar plume eruption.

WHEN ? 30 million years ago.

WHAT HAVE THE CONSEQUENCES BEEN ? Shallow mantle convection as a result of which:

(1) Basins, Swells and Rifts are forming.
(2)Intraplate volcanic activity on swells.
(3) Erosion of high ground.
(4) Deposition, mainly offshore.

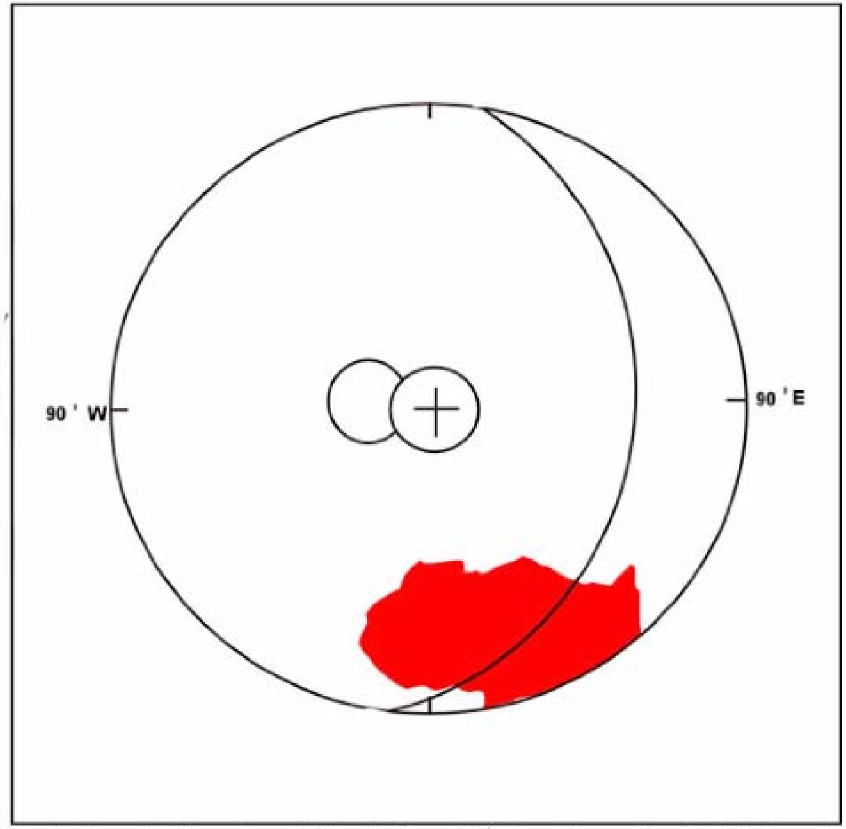


Figure 4 Lower hemisphere stereo projection showing small circles marking envelopes to the locations of paleomagnetic poles for volcanic rocks of Africa. Poles for rocks with ages between 200 Ma and 100 Ma lie within the open circle and poles for volcanic rocks with ages of < 30 Ma lie clustered about the present pole which is marked with crosslines. Between about 100 Ma and 30 Ma, the African Plate rotated a few degrees clockwise about a pole close to zero degrees of both latitude and longitude. Few igneous rocks were erupted on the plate during the 100 Ma to 30 Ma interval. Figure modified from Burke & Dewey (1974).

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Paleomag shows plate twice at rest in past 200 Ma

45^o Rotation intervened between 130 and 30 Ma

Intermittent igneous activity in small areas (~ 300 km diameter) shows that the African plate has not moved with respect to the underlying mantle convection pattern for ca.30 My. Four of many areas selected.

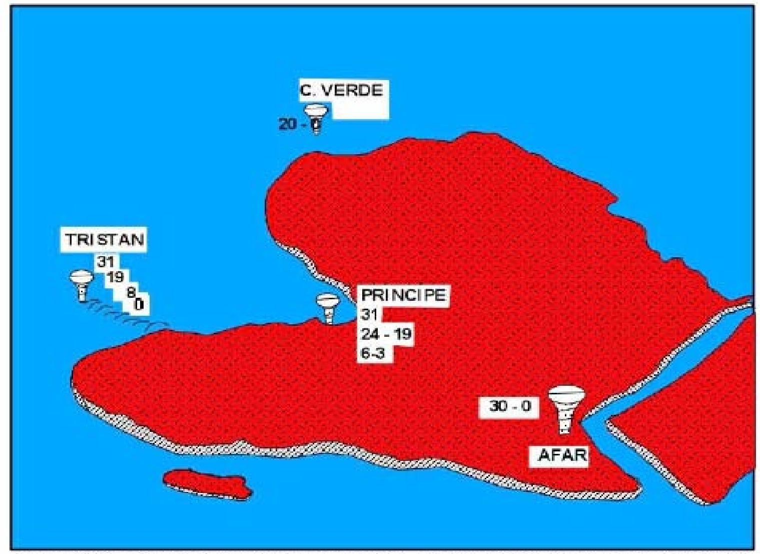

Figure 7 Oblique view of Africa showing it as screwed down. Episodic volcanic activity at the same place has been recorded for several areas on the African Plate through the past 20 to 30 My. This I interpret as showing: (1) that the African Plate has not moved with respect to underlying plumes which are the source of that volcanism, and (2) that those plumes have not moved with respect to each other over that interval.

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Image courtesy of The Geological Society of South Africa.

Alice Gripp and Richard Gordon found that Africa had moved little in the global hot-spot reference frame for the past 3.7 My. Their interest was in the Pacific. I cut their map in half, pasted and scanned it.

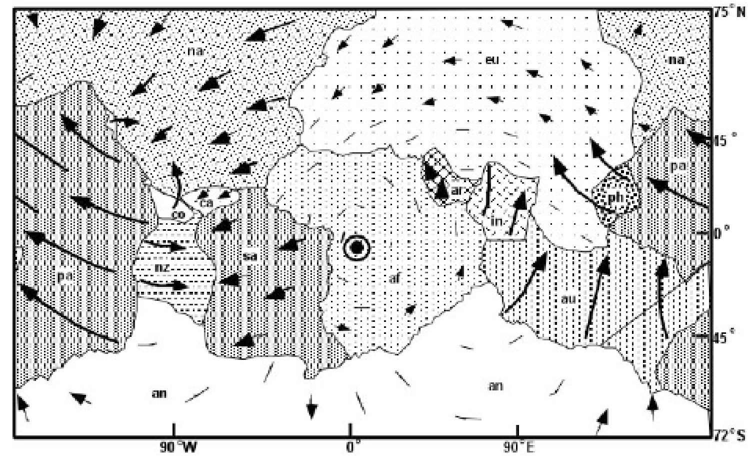


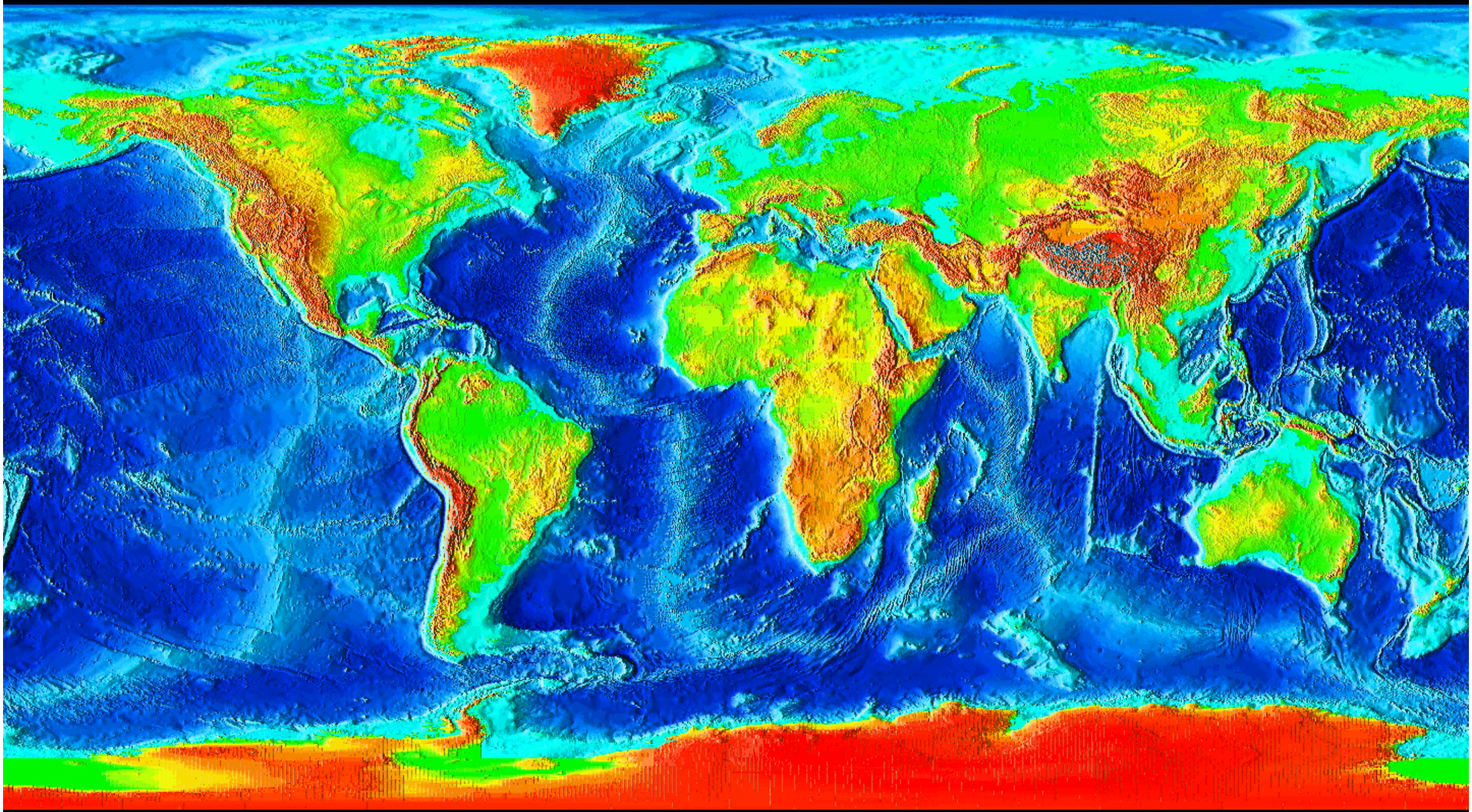
Figure 8 Sketch redrawn from Gripp & Gordon (1990) showing how far the individual plates that make up the earth's lithosphere would move with respect to a fixed hot-spot population over the next 45 My. It is assumed that the present motion of the plates derived from the Nuvel-1 study (DeMets *et al.*, 1990) and representing perhaps the past 3.7 My will persist. Note that the African Plate appears to be rotating very slowly about an internal pole at zero degrees latitude and longitude. It is important to emphasise that the directions of movement and the very slow velocities depicted by the short arrows shown on the African Plate are very poorly determined. Perhaps all that can be said is that the results of this study are not incompatible with those reported here which show that Africa has been at rest with respect to the underlying plumes for the past 30 My.

ACTIVE AFRICAN BASINS AND SWELLS ARE UNIQUE

THEY HAVE ALL FORMED IN THE PAST 30 My

IN ORIGIN THEY ARE UNLIKE FAMILIAR TYPES OF BASIN AND FAMILIAR TYPES OF MOUNTAIN BELT

World Map of Topography and bathymetry



Unique character of African Plate Basin & Swell structure

Image courtesy of NOAA and USGS.

Basin and swell structure of the African continent has long been recognized. This map is based on Holmes' 1944 map.
Krenkel (1923) spotted that volcanoes are on swell crests.
He suggested that mantle melting a process that he called "MAGMARSIS" made the swells.

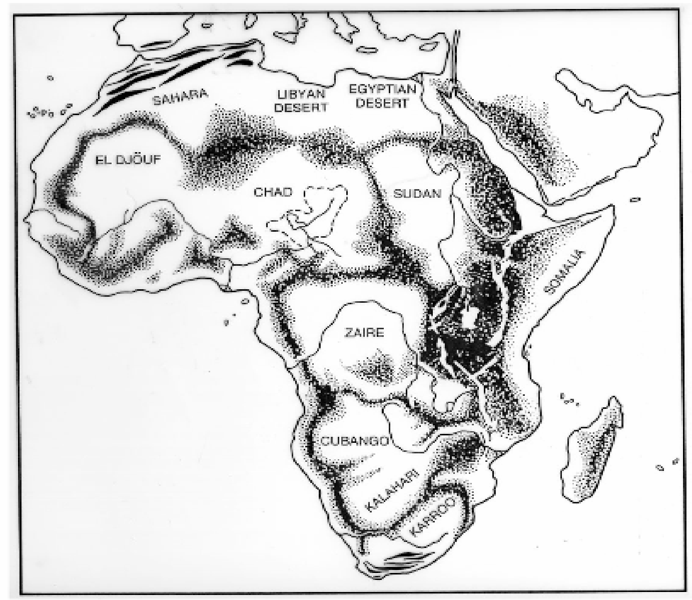


Figure 1 Basins and swells of Africa. Modified after Holmes (1944; 1965, his figure 763). Dashed lines = the extent of Lake Megachad. French and German language writers had emphasised the location of the East African Rift on the crest of the East African swell and Krenkel in particular (1922; 1957) had emphasised the Basin and Swell structure of the continent.

BASINS AND SWELLS

Image courtesy of The Geological Society of South Africa.

Argand attributed the basin and swell structure to long wavelength compressional folding. He called those folds “plis de fonds”(“basement folds”)

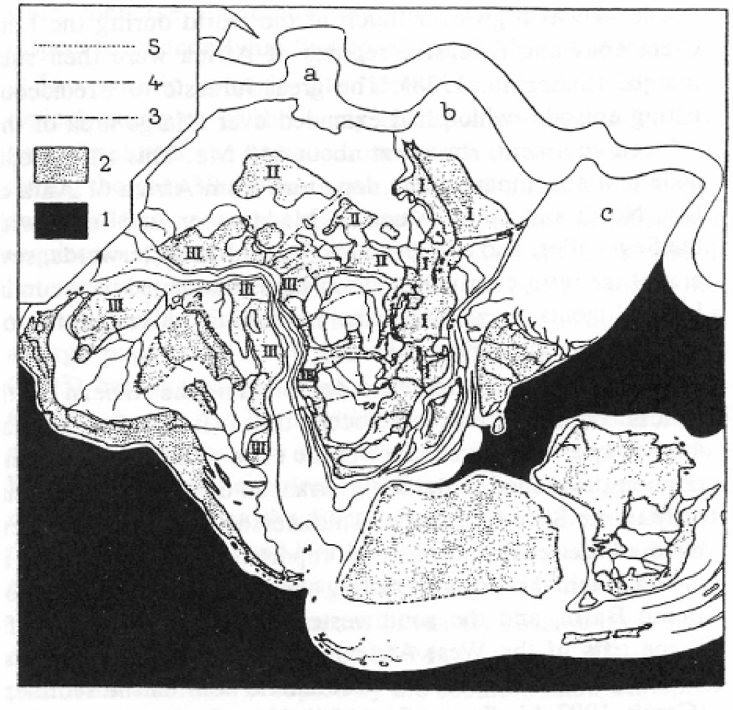


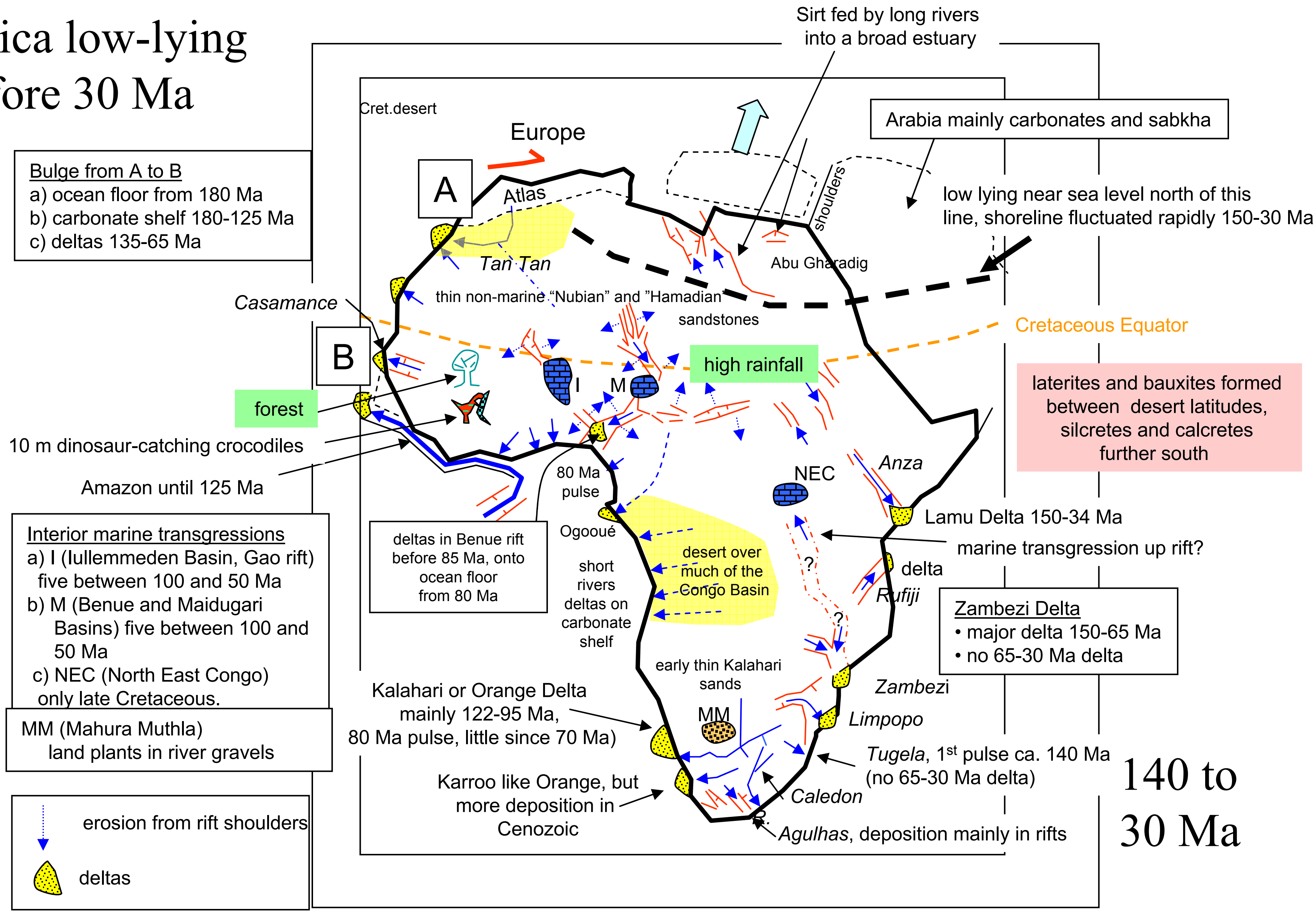
Figure 2 Argand (1924, his figure 6) had also recognised the basin and swell structure of Africa which he attributed to compressional folding. He applied the term *plis de fond* to these structures.

Image courtesy of The Geological Society of South Africa.

AFRICA WAS A RELATIVELY QUIET PLACE BETWEEN 130 Ma AND 30 Ma (That has to be demonstrated to show that something really did happen at 30 Ma)

The Afro-Arabian plate, surrounded by spreading centers, grew larger from 130-30 Ma.
The continent was low-lying with little igneous activity.
A few large rivers, many of which flowed in existing rifts drained the continent.
Relatively little siliciclastic deposition off-shore except in the deltas of major rivers.

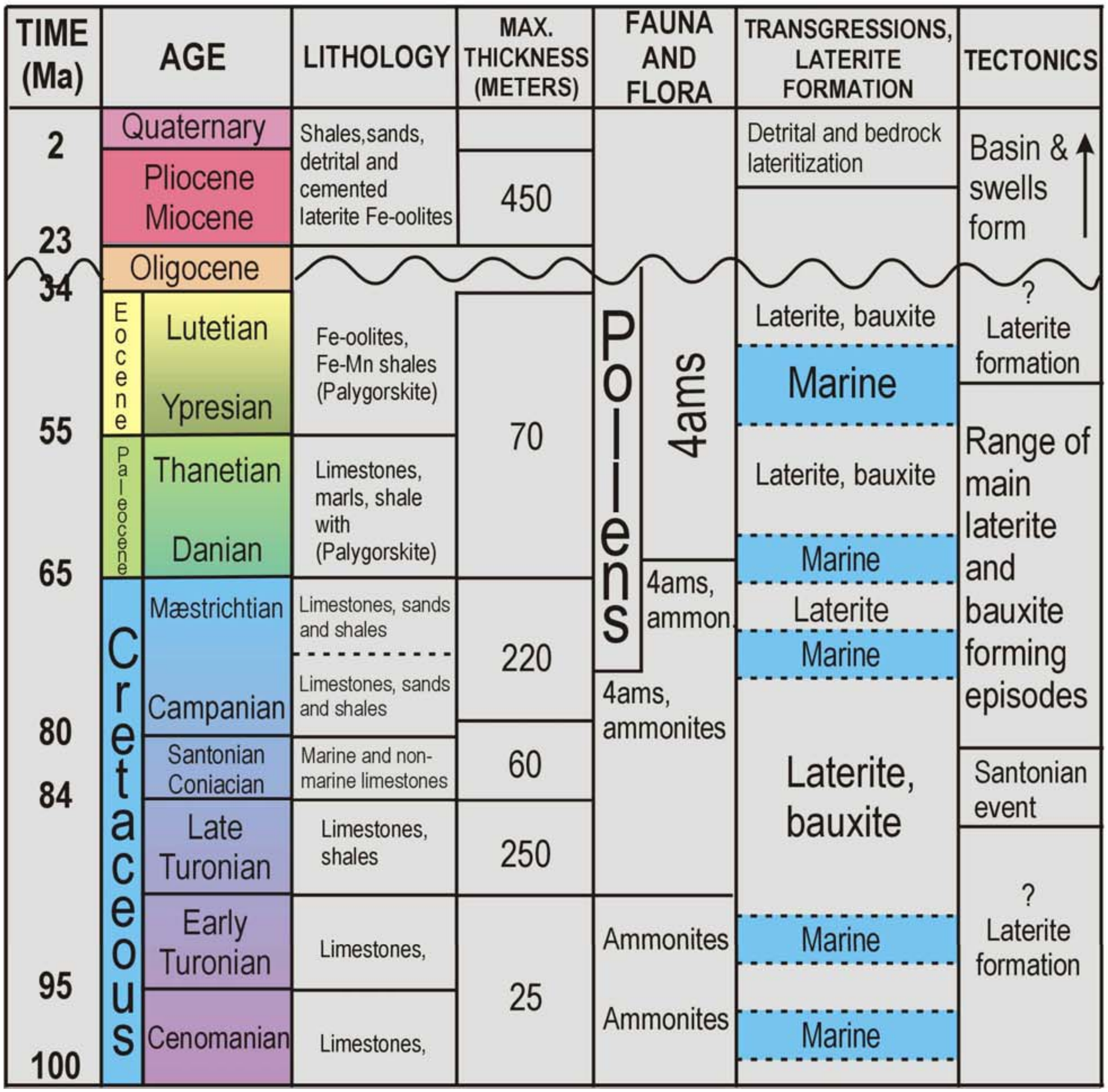
Africa low-lying Before 30 Ma



140 to 30 Ma

Rift shoulders were eroded by ca.90 Ma.

Iullemeden Basin



AFRICA A LOW-LYING CONTINENT FLAT AND SUBJECT TO MARINE INCURSIONS AT HIGH-STANDS

Laterite formation and marine transgressions on the African surface between 100 Ma and 30 Ma (After Bouderesseq *et al.*)

Time-scale simplified from Gradstein *et al.* (2004)

Iullemeden basin is 1000 km inside the continent

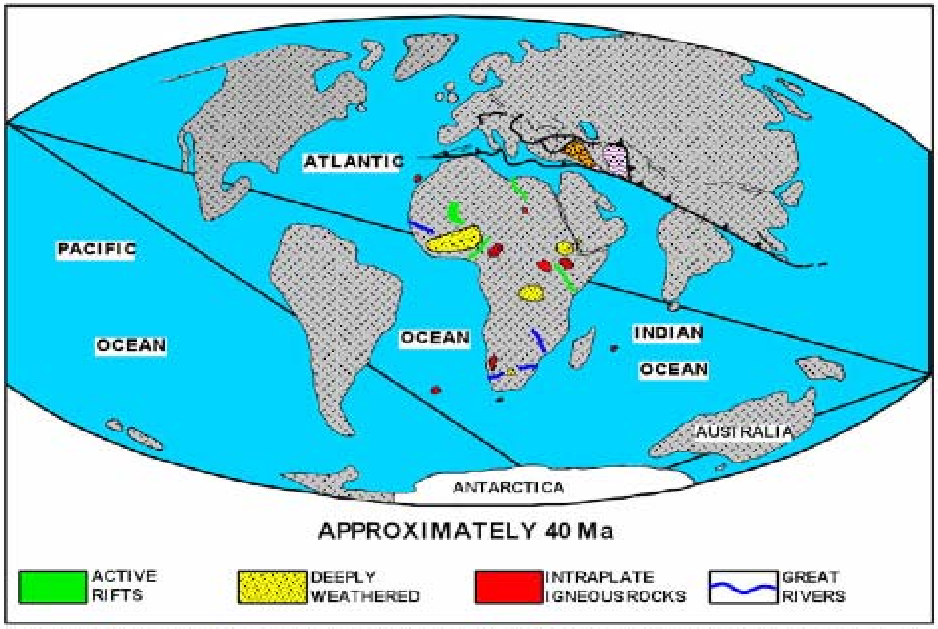


Figure 3 Africa about 40 Ma, before it collided with Eurasia, was a low-lying continent with widespread deep weathering. The Benue, Sirte and Anza Rifts which had formed near the beginning of the Cretaceous (~140 Ma) were continuing to receive sediment. Igneous activity on the African Plate was restricted to the Tristan and Deccan plume hot spots and to sporadic localities on the continent. Continental igneous activity between 65 and 45 Ma was short-lived everywhere except in northern Cameroon where there was continuous granitic activity. Figure modified from Sengör (1989).

Cameroon line granites 65-30 Ma, S.Ethiopian rift 45-35 Ma
Tristan plume active,Deccan plume active (dies at 31Ma)
Namaqualand 60-45 Ma (On a crack?) Agulhas 40 Ma
Canary Island and Jebel Uweinat now known < 30 Ma

Limited African plate igneous activity from ca.130-30 Ma

IGNEOUS ACTIVITY THAT STARTED AT ~30 Ma:

Small volumes, mostly on swells, onshore and offshore.
Afar plume products,which are of deep-seated origin, provide the exception

Decompression melting igneous activity
In the East African Rift system is distinct being part of the rift system evolution.

**CHARACTERISTIC FEATURES OF
VOLCANO-CAPPED SWELLS OF THE AFRICAN PLATE**

(1) Elliptical, longer axes 100-2000 km.
(2) On continent or ocean floor. Amplitudes low on ocean floor.
(3) Related to $<$ 30 Ma basement uplift.
(4) Basaltic rocks dominant.
(5) $^{3}He/^{4}He$ less than or similar to MORB. Afar, Reunion are exceptions.
(6) Volcanic rocks mainly derived from HIMU source. Afar and Tristan are exceptions. They show EM1 and EM 2.
(7) Volcanic volumes small compared to LIPS. Afar exception.
(8) Episodic eruption in same small areas (d<~ 300 km) back to as old as ~ 30 Ma in some cases.
(9) Volcanoes on swells show no consistent azimuthal age progression. There is progression on some swells but azimuths vary and tracks (for the past 30 My) < 300 km.

(From: Burke J.Geology 2001)

Isotope geochemistry in the Hart& Zindler Style. FOZO is between DMM and HIMU

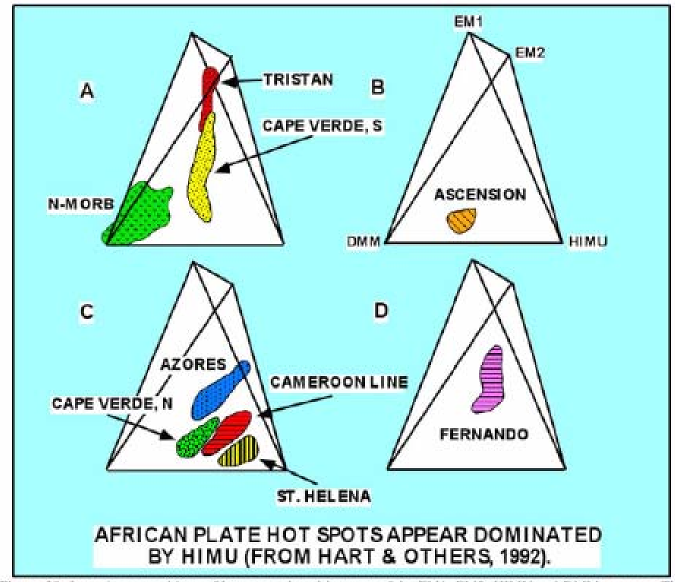


Figure 38 Isotopic compositions of hot spots plotted in terms of the EM1, EM2, HIMU and DMM sources. The figure is modified from Hart *et al.* (1992). Analyses of rocks from St. Helena, Cameroun line volcanoes and the northern Cape Verde islands plot close to the HIMU end member. Ascension, which is very near to the South Atlantic spreading center on ocean floor much less than 30 Ma, plots as a mixture between DMM (which is the MORB source) and HIMU. Tristan, which is not part of the young population of African hot spots, plots close to the join between EM1 and EM2. Only the southern Cape Verde islands among 30 Ma and younger African Plate hot spot volcanoes yield some analyses indicating involvement of EM1 and EM2 as well as the HIMU source. I interpret the results plotted in this figure as indicating that the HIMU source dominates in 30 Ma and younger African Plate hot-spot volcanic rocks.

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Image courtesy of The Geological Society of South Africa.

Basin & Swells

Offshore:

Limited erosion, thermal subsidence, deep-water deposits since 30 Ma

Elevations persist. Hard to date

Offshore swells. Amplitudes are mostly small

125 Ma submarine scarps. (Burke, 1969)

Onshore:

***Ethiopia*: At sea level before 34 Ma (Sengor 2001)**

Volcanism started: 31 Ma. It continues. Swells have been rising ever since.

No volcanoes on cratonic swells

***East Africa*: Anza river delta killed ca. 30 Ma.as E.A. swell began to rise.**

Turkana rifts fed from south from 30 Ma (Smith 1992).

***West Africa*: Dakar swell rise dated by**

volcanism since 24 Ma.

No present relief: erosion by Senegal river.

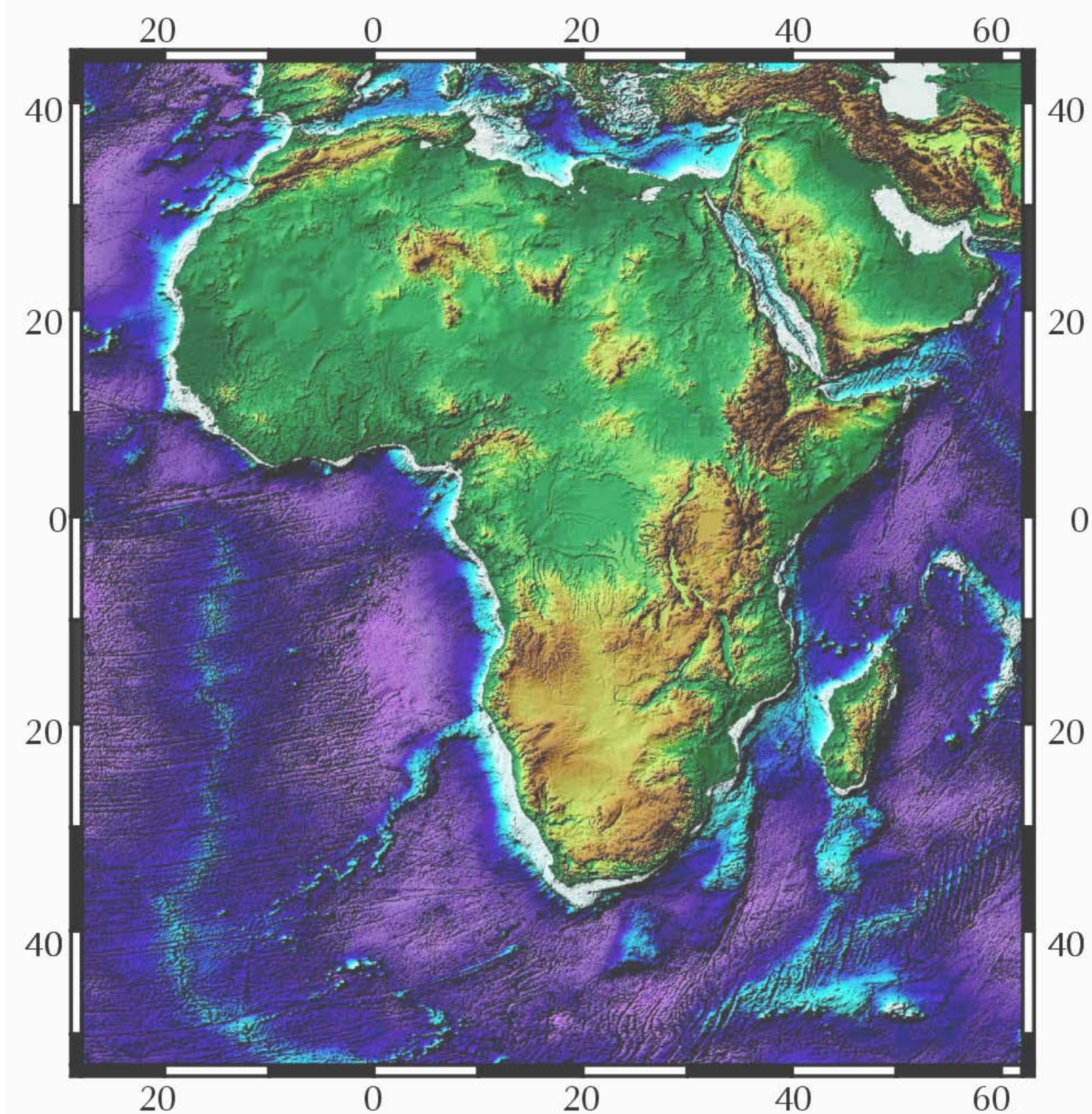

Image courtesy of NOAA and USGS.

The AFAR plume is distinctively different-----

So lets get it out of the way

It is different because it (or at least its energizing buoyant driving plume, if not its rock content), came from
The Core/ Mantle Boundary

AFAR PLUME LARGE IGNEOUS PROVINCE

*"Ethiopian Traps"ca. 1 M km^2 outcrop, ca. 1 km thick (1 M km^3)

*Bulk erupted between 31Ma and 28 Ma (Hofman et al.)
eruption persists from plume tail. Cited "increase" in past 5 My is partly because older rocks are buried and partly because sea floor spreading is beginning to penetrate the Afar.

*Eruption has been in the same place although area of eruption has shrunk since 28 Ma. Plume site is now linked to regions of decompression melting in Ethiopian rift, Red Sea and Gulf of Aden.
*Geochemistry: Schilling's review still helpful. Menzies for Yemen
^{3}He up to 20x R_A. EM1 & EM2 reflect lithospheric source. HIMU ?
*Time of formation of intra-continental rifts in Red Sea, Gulf of Aden and East African rift is, within resolution, the same as the time of Afar LIP eruption.

Isotopic ages(mainly K/Ar) of igneous
rocks of Africa (Burke 1976).
Gradual increase is probably unreal.
A step in abundance at ca.30 Ma seems more plausible.
Huge increase in < 5 My ages is relatable to hominid research.

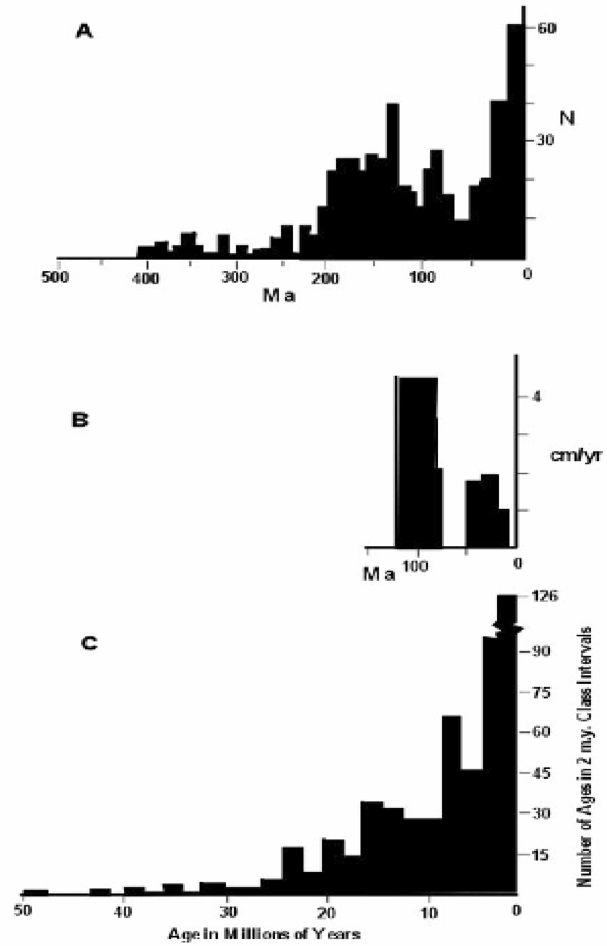

Figure 5 Histograms showing: (A) compilation of isotopic ages for African igneous rocks from Bailey (1993); (B) compilation, also from Bailey (1993), indicating how the velocity of Africa with respect to Eurasia fell during the 80 Ma to 50 Ma interval when few igneous rocks were erupted in Africa; (C) compilation illustrating how isotopic ages for igneous rocks of the African continent have become increasingly abundant over the past 30 Ma. From Burke (1976b).

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Image courtesy of The Geological Society of South Africa.

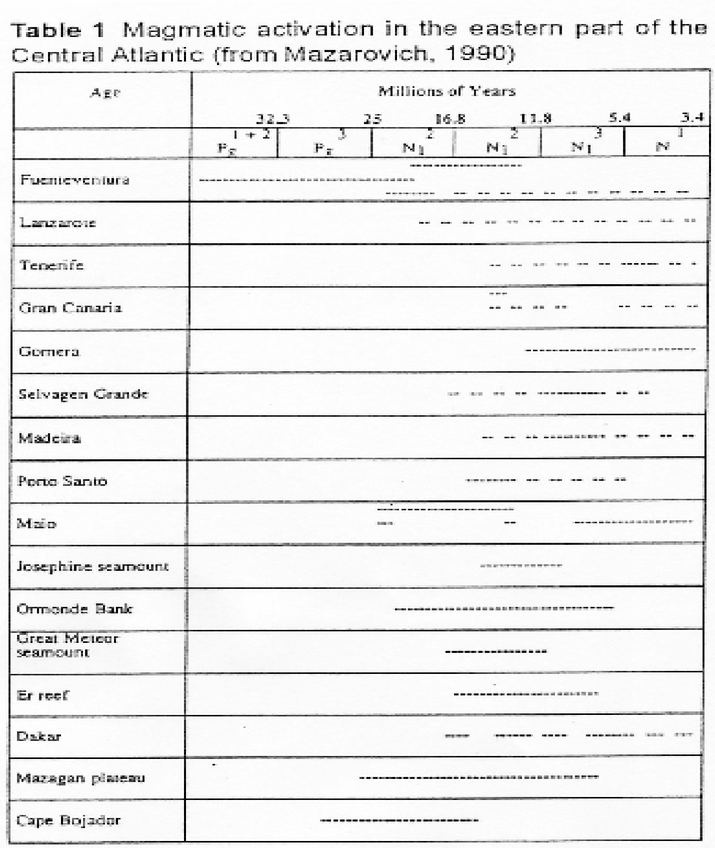

Table 1 Magmatic activation in the eastern part of the Central Atlantic (from Mazarovich, 1990)

Age	Millions of Years					
	32.3	25	16.8	11.8	5.4	3.4
	P_g^{1+2}	P_g^3	N_1^2	N_1^2	N_1^3	N^1
Fuerteventura	----	----	----	----	-- --	-- --
Lanzarote			--	-- --	-- --	-- --
Tenerife				-- --	-- ----	-- -
Gran Canaria				--- -- --	--	-- -- --
Gomera				----	----	----
Selvagen Grande			--	-- -- ----	----	-- --
Madeira				-- -- -- ----	-- --	-- --
Porto Santo				---- --	-- -- --	
Maio			--- ----	---- --	----	----
Josephine seamount				----	--	
Ormonde Bank			----	----	----	
Great Meteor seamount			--	----		
Er reef			-	----	----	
Dakar				---- ----	---- ----	---- --- ---
Mazagan plateau		----	----	----	----	
Cape Bojador		----	----	--		

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Volcanic Activity In the Eastern Atlantic Started Ca.30 Ma (Soviet cruise Results)

Image courtesy of The Geological Society of South Africa.