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 2.8 Ma.

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.
Paleomag shows plate twice at rest in past 200 Ma

$45^\circ$ Rotation intervened between 130 and 30 Ma

*Image courtesy of The Geological Society of South Africa.*
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.

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 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 Naval-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 emphasize 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.

Image courtesy of The Geological Society of South Africa.
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
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, 1955, his figure 703). Dashed lines = the extent of Lake Megaaba. French and German language writers had emphasized the location of the East African Rift on the crest of the East African swell and Krenkel in particular (1922, 1977) had emphasized 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”)

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

Bulge from A to B
a) ocean floor from 180 Ma
b) carbonate shelf 180-125 Ma
c) deltas 135-65 Ma

10 m dinosaur-catching crocodiles
Amazon until 125 Ma

Interior marine transgressions
a) I (lullemmeden Basin, Gao rift) five between 100 and 50 Ma
b) M (Benue and Maidugari Basins) five between 100 and 50 Ma
c) NEC (North East Congo) only late Cretaceous.

MM (Mahura Muthia) land plants in river gravels

erosion from rift shoulders
deltas

deltas in Benue rift before 85 Ma, onto ocean floor from 80 Ma

delta

140 to 30 Ma

Rift shoulders were eroded by ca.90 Ma.
Laterite formation and marine transgressions on the African surface between 100 Ma and 30 Ma (After Boucheresseq et al.)

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

Iullemaden basin is 1000 km inside the continent
Limited African plate igneous activity from ca.130-30 Ma

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

Image courtesy of The Geological Society of South Africa.
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 39: Isotope 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, Cameroonian 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 joint 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. 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.

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 km² outcrop, ca. 1 km thick (1 M km³)*

*Bulk erupted between 31 Ma 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 Yemen³ 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).

Image courtesy of The Geological Society of South Africa.
Volcanic Activity
In the Eastern Atlantic
Started Ca.30 Ma
(Soviet cruise Results)

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

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<th>Age</th>
<th>Millions of Years</th>
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<tr>
<td></td>
<td>222</td>
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<td></td>
<td>P_2 + P_1</td>
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<tr>
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<td>-----------------</td>
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Image courtesy of The Geological Society of South Africa.