Small volumes of volcanic rocks and evidence of basement uplift indicate that the source of the African plate < 30 Ma igneous rocks is not a very hot region (as the Ethiopian trap source must have been to make such a huge volume).

A shallow source is compatible with this consideration

The Dakar swell at the edge of the continent raises basement ca.2 km. Volcanism has been episodic on the swell over the past 24 My. Erosion has kept the surface close to sea-level. Sediment derived from that erosion has been deposited in deep water.

Elevation of swells relates to erosion (fn rainfall over 30 Ma).

Highest swells in (S & E Africa) are in driest regions

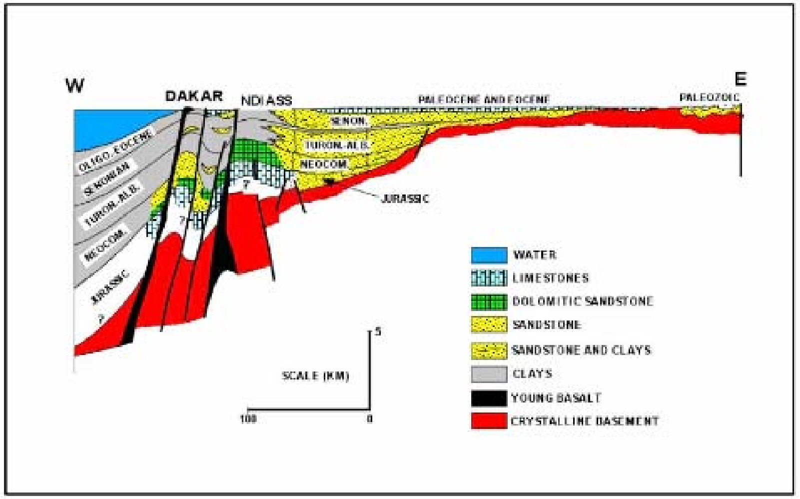

Figure 13 Cross-section through the Dakar hot spot at the westernmost point on the African continent showing that although the two volcanoes of Dakar (known as the *Mammelles*) have little topographic expression, they are associated with one or more kilometres of basement uplift. Redrawn from Spengler *et al.* (1966).

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Image courtesy of The Geological Society of South Africa.

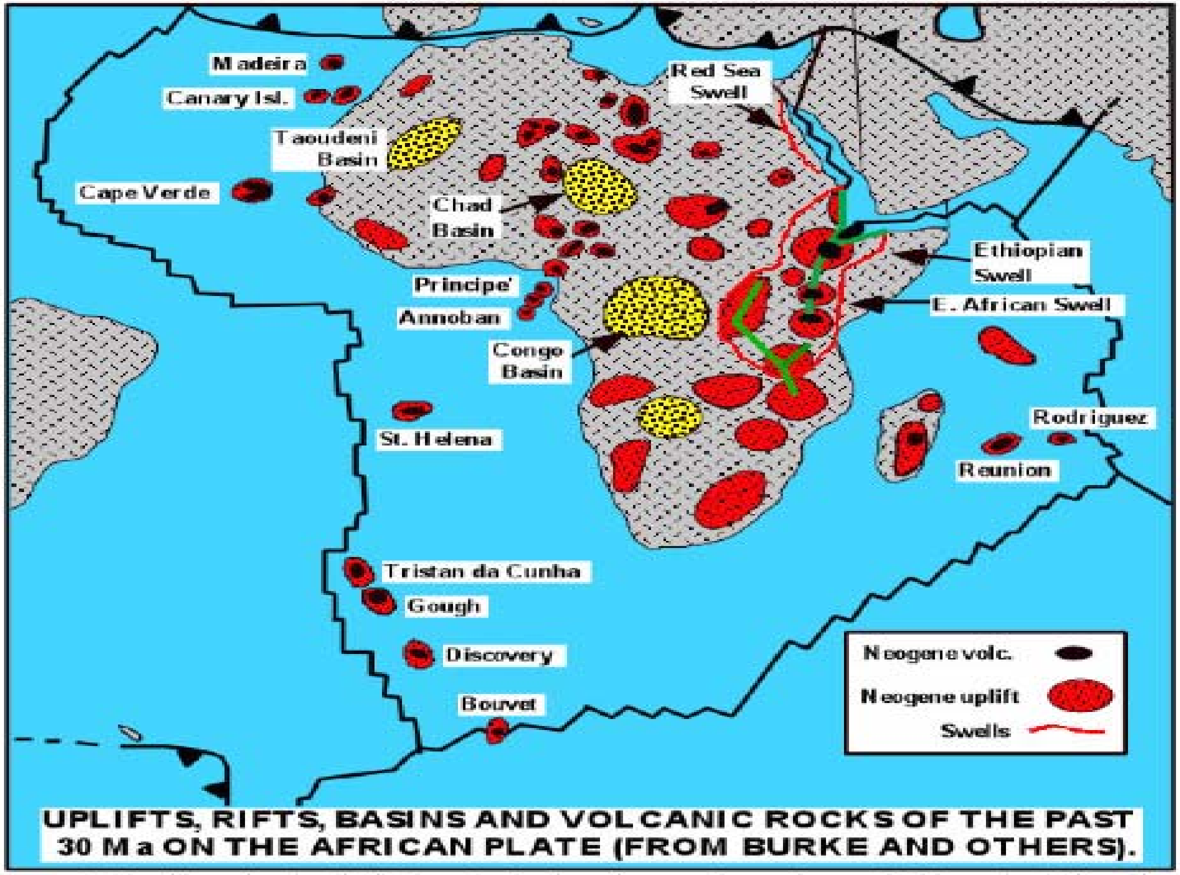

Figure 6 Map illustrating the distribution of volcanic rocks erupted over the past 30 Ma on the African Plate. Swells are enclosed by dashed lines. Note that much, but by no means all, of the volcanic activity occupies the crests of topographic or basement swells. The locations of four interior basins, bounded by swells, are indicated. From a figure drawn by Bill Kidd (figure 6.2.19) in *Basaltic Volcanism on the Terrestrial Planets* (1981).

Locations of Dakar, Ahaggar And Jos Swells.

Chad basin is surrounded by volcano crested swells.

The volcanoes describe an ellipse presumably indicating something about underlying convection

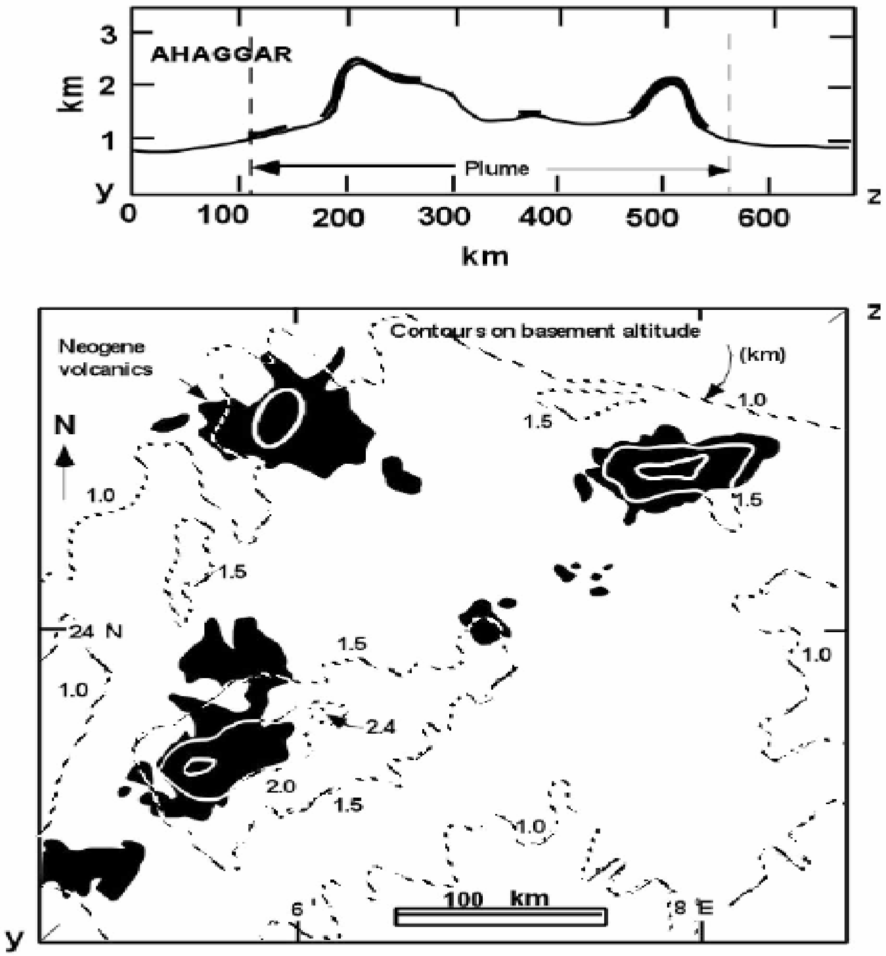

Figure 14 Map and cross-section through the Ahaggar massif in the central Sahara to show hot spot volcanism associated with an elliptical swell of about 300 km by 500 km. The three largest volcanic areas within the Ahaggar occupy separate smaller subswells roughly 100 km in longer axis. The cross-section indicates that the area may be underlain by a large plume with three smaller structures within it. Note that the hot spot volcanism consists of relatively thin outpourings of basalt on the top of the basement uplift. This is the rule among both oceanic and continental hot spots on the African Plate. The figure is redrawn from one in *Basaltic Volcanism on the Terrestrial Planets* (1981), which is itself based on one by Black & Girod (1970).

Image courtesy of The Geological Society of South Africa.

The Ahaggar (Hoggar) swell rises to almost 3 km asl but the volcanic rocks on the swell, (mainly basalts and trachytes), are thin. The plume sources of the shallow convection are too cool to generate much magma. Sub-swells trend NE as part of the circum-Chad ellipse

The small volcanoes of Jos lie on the crest of the topographic swell but the Bouguer gravity Anomaly and the relief are modified by low density (and hard to erode) Jurassic granites

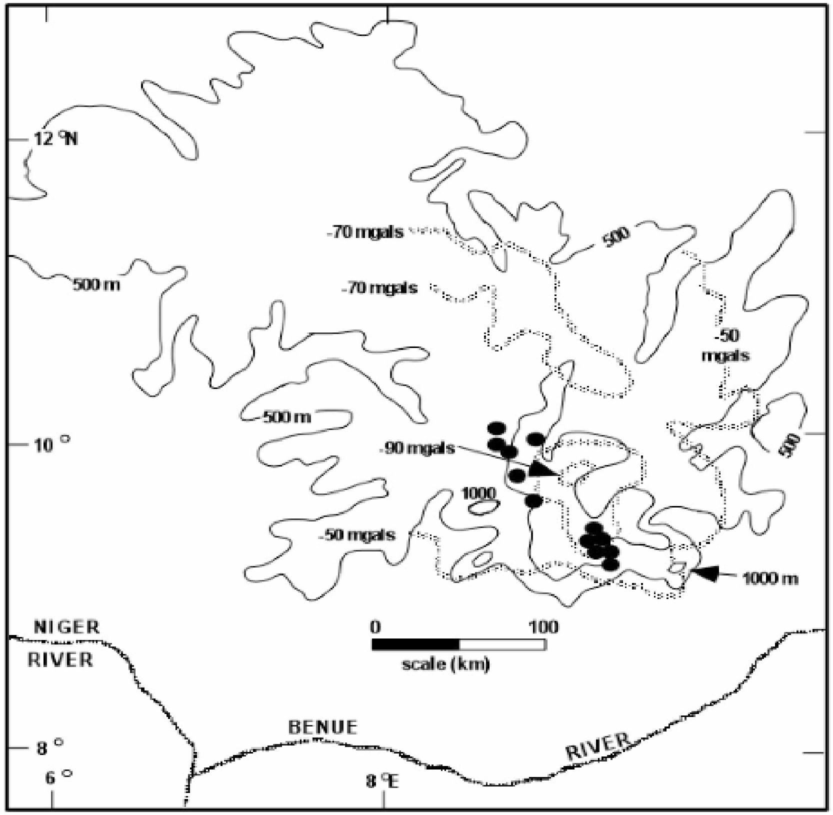

Figure 15 The Jos Plateau in northern Nigeria is one of the smaller swells of the African continent. The plateau consists of an elliptical area –400 km by 200 km. To indicate elevation, 1000 m and 500 m topographic contours have been drawn. Round dots show the sites of a line of twelve Quaternary cinder cones which parallels both the crest of topographic swell and the trend of the negative Bouguer anomaly (Ajakaiye & Burke, 1973).

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NW volcano trend as part of circum-Chad ellipse

*Abuja

Image courtesy of The Geological Society of South Africa.

On
Maio
In the
Cape
Verde
Islands
Jurassic
Ocean
floor
outcrops
In the
center
of a
Miocene
volcano

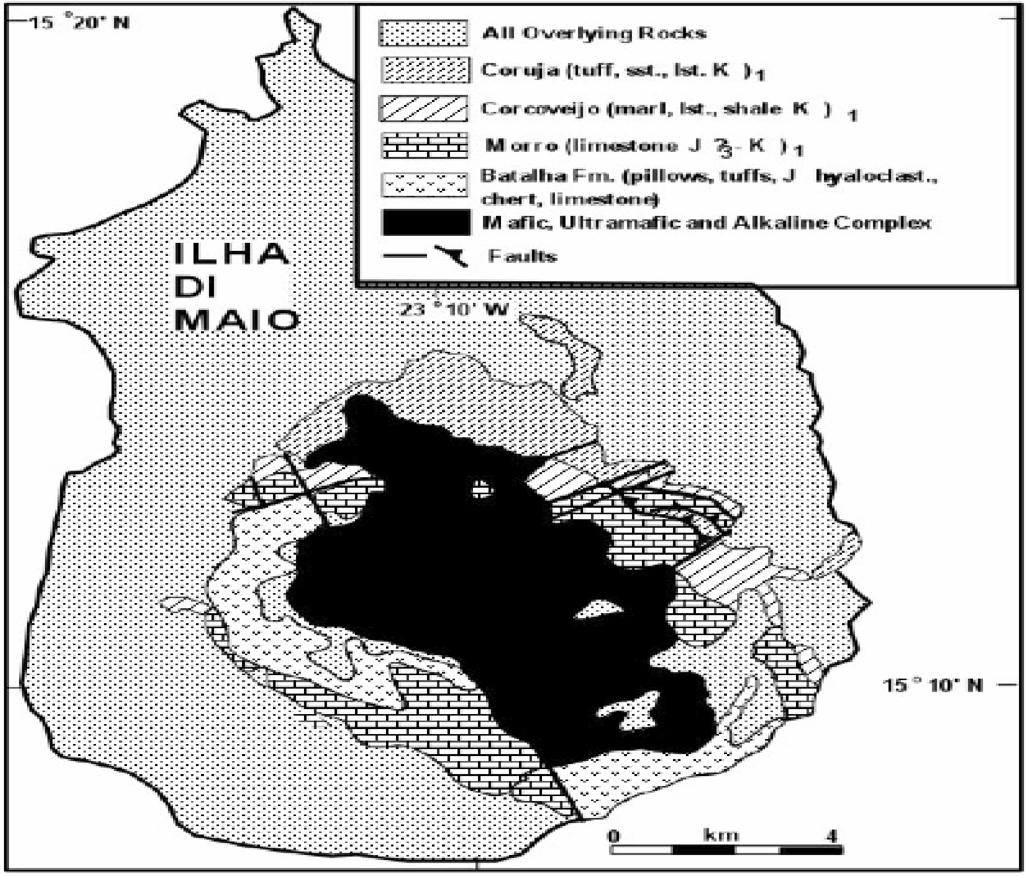

Figure 39 Sketch map simplified from Akhmet'yev *et al.* (1985) showing the uplifted Jurassic ocean floor and the overlying Jurassic and Cretaceous pelagic sediments which outcrop in the center of the island of Maio in the Cape Verde archipelago. The area occupied by the Miocene volcanic rocks erupted from the Cape Verde plume, which overlie the basement, is grey in this sketch. The outcrop pattern indicates the important role of basement uplift and small eruption volume in an African Plate oceanic hot spot. This relationship is familiar on the continent of Africa and may be common, but hard to discern on oceanic islands.

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The ocean
floor
basement
is elevated
by > 4km.
Only a
small
volume
of basalt has
been erupted
by the
volcano.

Image courtesy of The Geological Society of South Africa.

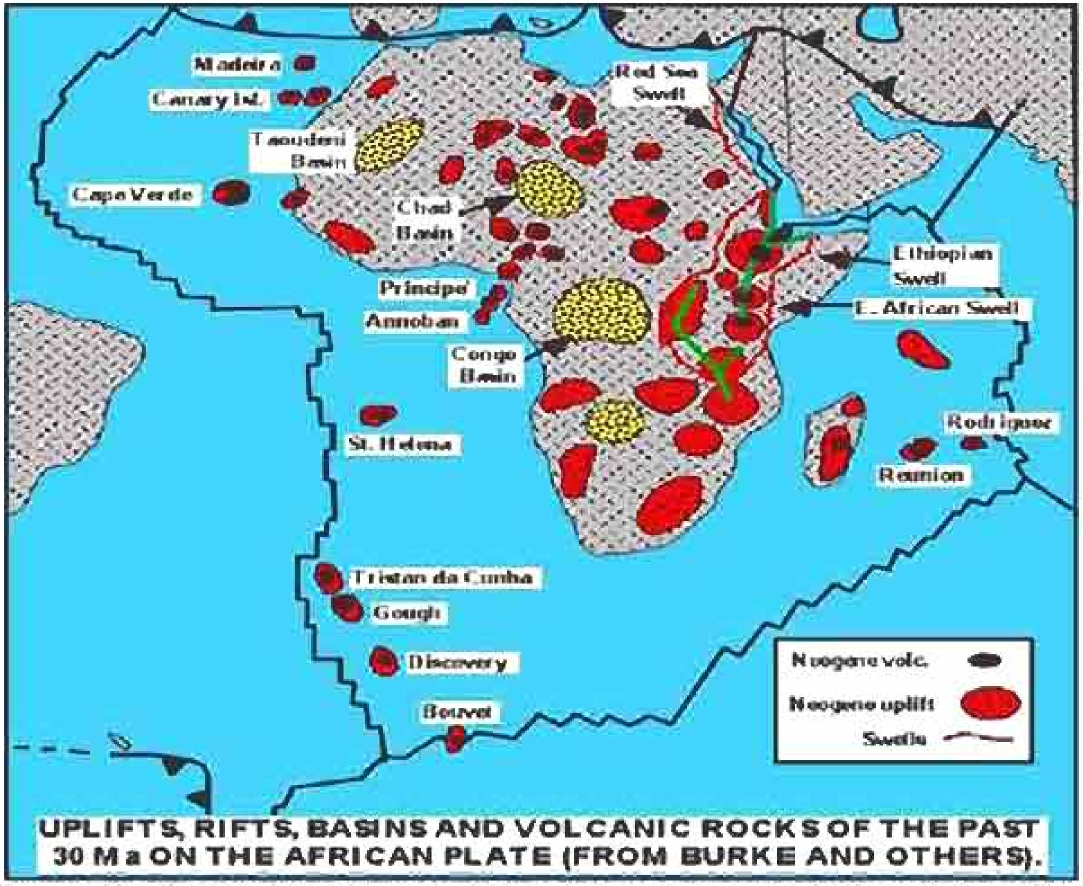

Figure 6. Map illustrating the distribution of volcanic rocks erupted over the past 30 Ma on the African Plate. Swells are enclosed by dashed lines. Note that much, but by no means all, of the volcanic activity occupies the crests of topographic or basement swells. The locations of four interior basins, bounded by swells, are indicated. From a figure drawn by Bill Kidd (figure 6.2.19) in *Basaltic Volcanism on the Terrestrial Planets* (1981).

Jurassic ocean Floor also outcrops in Lanzarote in the in shore Canary islands

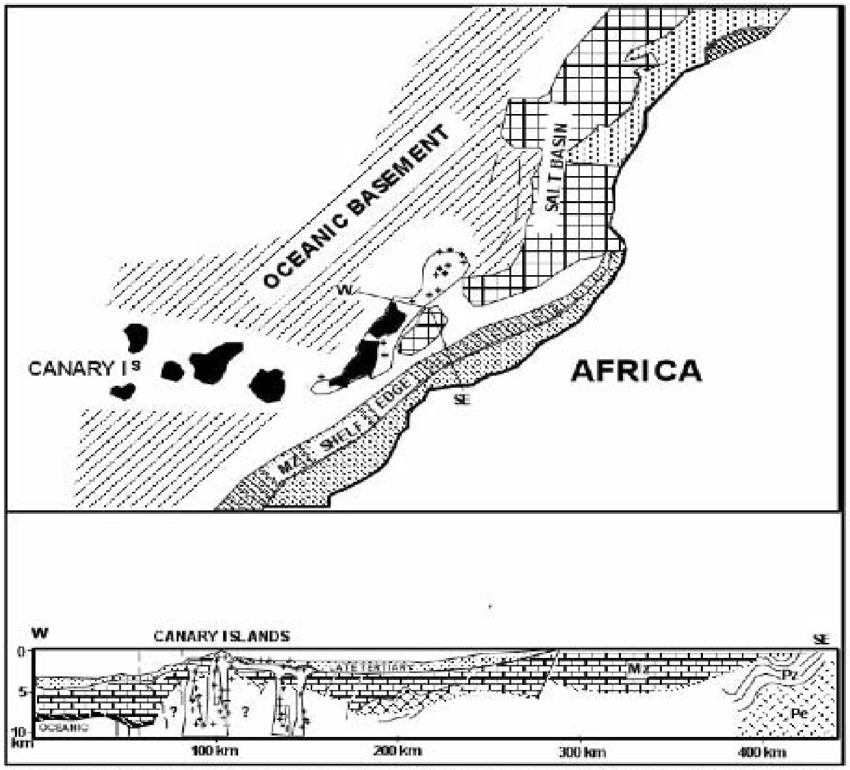

Figure 16 B Sketch of a regional seismic reflection profile across the innermost Canary islands of Fuenteventura and Lanzarote indicating basement uplift beneath the 30 Ma and younger hot-spot volcanic islands. This uplift accounts for the outcrop of Mesozoic ocean floor on the island of Lanzarote which is similar to that in Maio (see Figure 39). Redrawn from Lehner & De Ruiter (1977).

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Image courtesy of The Geological Society of South Africa.

The top of the

Ocean floor and

the seismic
MOHO

rise toward the

island of

Principe in the

Cameroons.

The island is on

a swell.

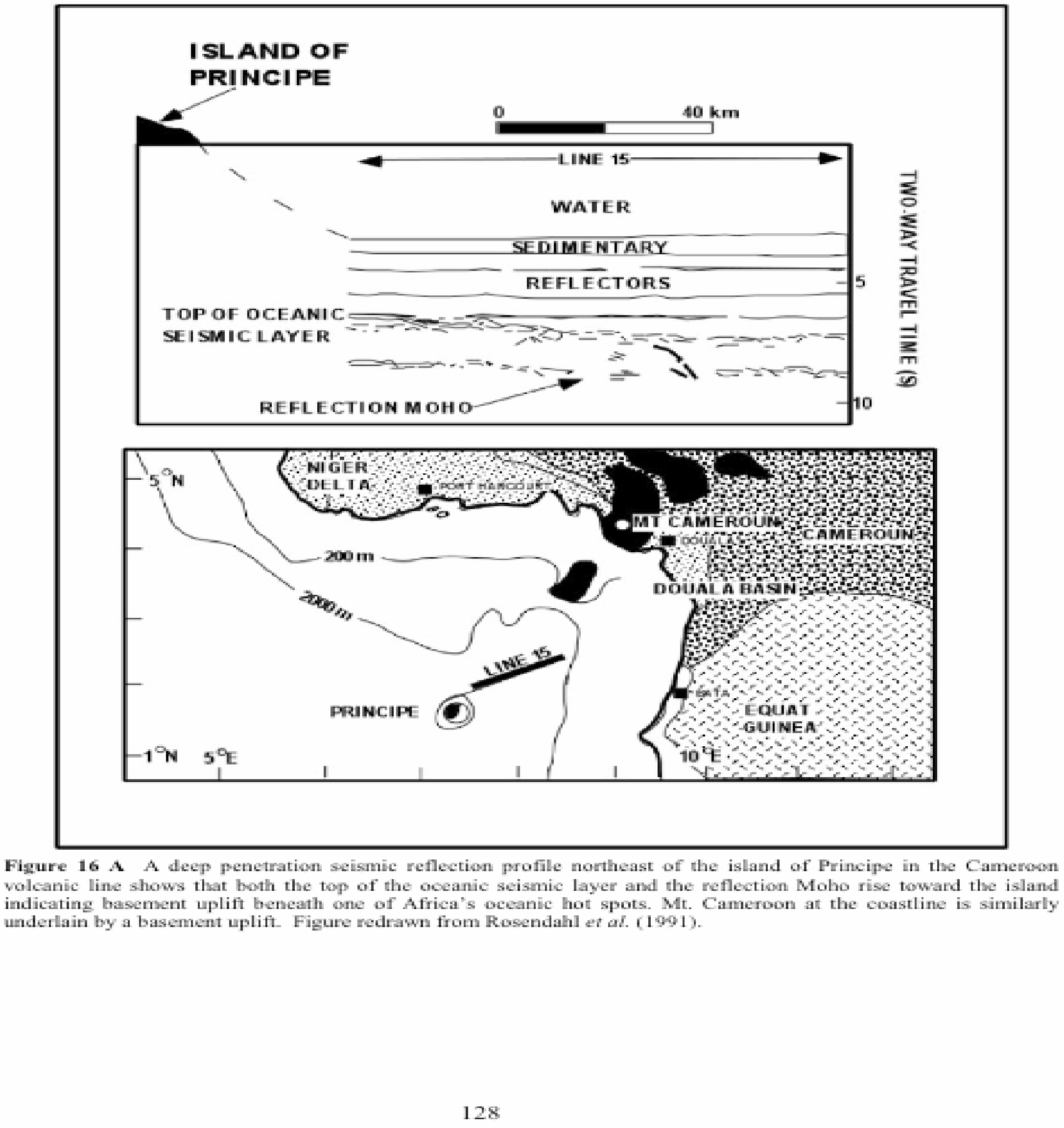

Figure 16 A A deep penetration seismic reflection profile northeast of the island of Principe in the Cameroon volcanic line shows that both the top of the oceanic seismic layer and the reflection Moho rise toward the island indicating basement uplift beneath one of Africa's oceanic hot spots. Mt. Cameroon at the coastline is similarly underlain by a basement uplift. Figure redrawn from Rosendahl *et al.* (1991).

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Image courtesy of The Geological Society of South Africa.

Doubt exists in the minds of some as to whether the volcanoes of the Oceanic part of the Plate are loads or basement is elevated.

A compromise is shown here!

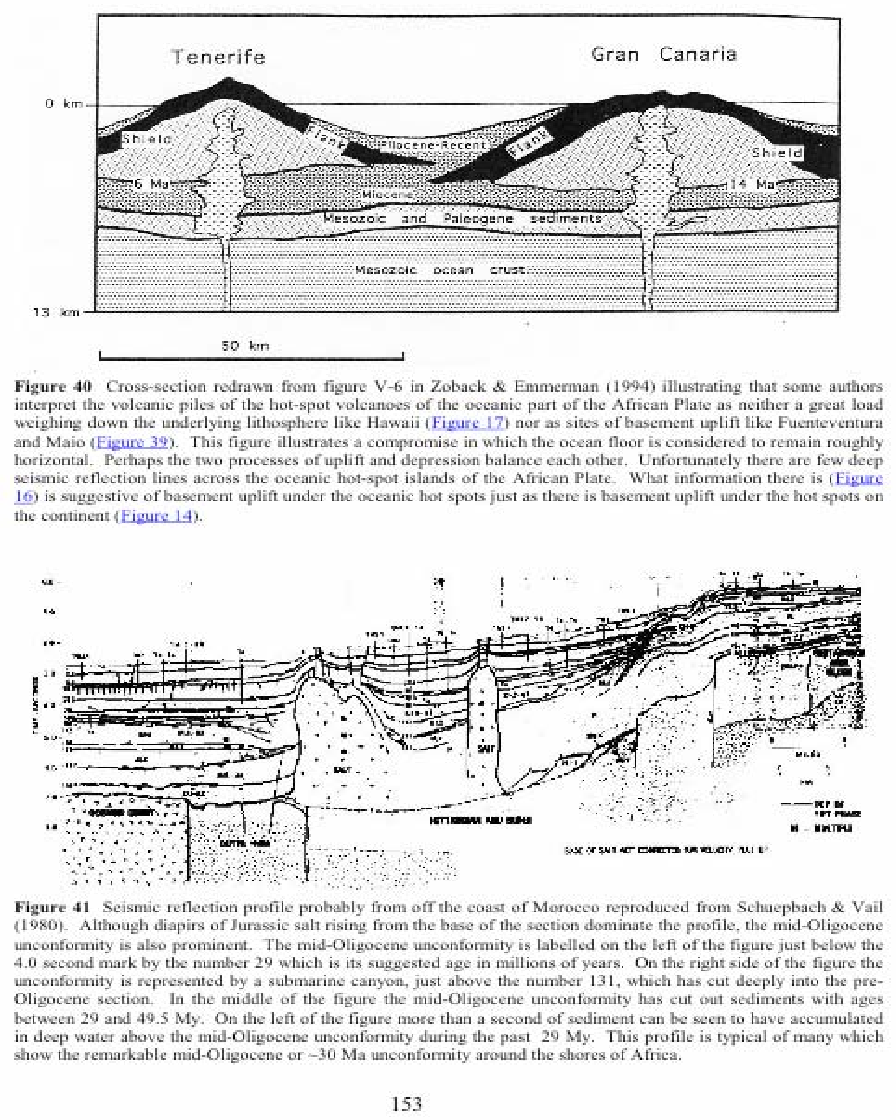

Figure 40 Cross-section redrawn from figure V-6 in Zoback & Emmerman (1994) illustrating that some authors interpret the volcanic piles of the hot-spot volcanoes of the oceanic part of the African Plate as neither a great load weighing down the underlying lithosphere like Hawaii (Figure 17) nor as sites of basement uplift like Fuenteventura and Maio (Figure 39). This figure illustrates a compromise in which the ocean floor is considered to remain roughly horizontal. Perhaps the two processes of uplift and depression balance each other. Unfortunately there are few deep seismic reflection lines across the oceanic hot-spot islands of the African Plate. What information there is (Figure 16) is suggestive of basement uplift under the oceanic hot spots just as there is basement uplift under the hot spots on the continent (Figure 14).

Figure 41 Seismic reflection profile probably from off the coast of Morocco reproduced from Schuepbach & Vail (1980). Although diapirs of Jurassic salt rising from the base of the section dominate the profile, the mid-Oligocene unconformity is also prominent. The mid-Oligocene unconformity is labelled on the left of the figure just below the 4.0 second mark by the number 29 which is its suggested age in millions of years. On the right side of the figure the unconformity is represented by a submarine canyon, just above the number 131, which has cut deeply into the pre-Oligocene section. In the middle of the figure the mid-Oligocene unconformity has cut out sediments with ages between 29 and 49.5 My. On the left of the figure more than a second of sediment can be seen to have accumulated in deep water above the mid-Oligocene unconformity during the past 29 My. This profile is typical of many which show the remarkable mid-Oligocene or ~30 Ma unconformity around the shores of Africa.

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Image courtesy of The Geological Society of South Africa.

What a contrast to Hawaii which depresses the lithosphere because It is a huge load

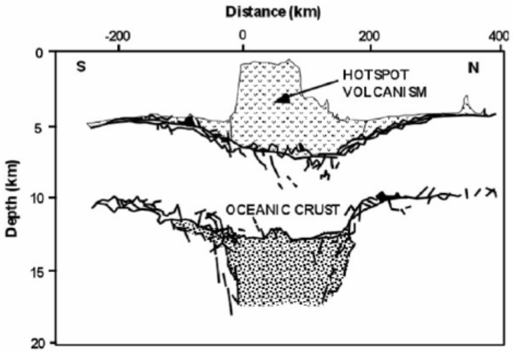

Figure 17 Section across the axis of the Hawaiian swell to illustrate a contrast with hot spots on the African Plate. The crustal thickness in this section reaches an average of ~18.5 km in the central region where a huge load of basalt bows down the lithosphere. African hot spots, both on the continent and on the ocean floor, are associated with basement uplifts and with the eruption of only small volumes of basalt. Some workers have interpreted the gravity field over hot-spot volcanoes on the African Plate in terms of a Hawaiian type structure but this seems inappropriate. Figure simplified from one in Morgan *et al.* (1995), which is itself based on the work of ten Brink & Brocher (1987) and Wessel (1993).

In summary: Igneous rocks of < 30 Ma on the African Plate are of small volume and concentrated on swells. They may reflect structure in a shallow underlying convection system. Distribution shows plate is at rest.

Image courtesy of The Geological Society of South Africa.

What can be learned about the
Basin& Swell structure from the
elevated areas themselves ?

As always in geomorphology the
Time over which processes have
Operated is very important.

The great changes of the past 30 My
Have sometimes been underemphasized

African and S. American hypsometry

Other continents have small areas of very high ground, as in the Andes and large areas close to sea level as in the Amazon basin.

Africa has a large area at intermediate elevation (ca 1.5km), no very high ground (> 6km) and only a very small area near sea level.

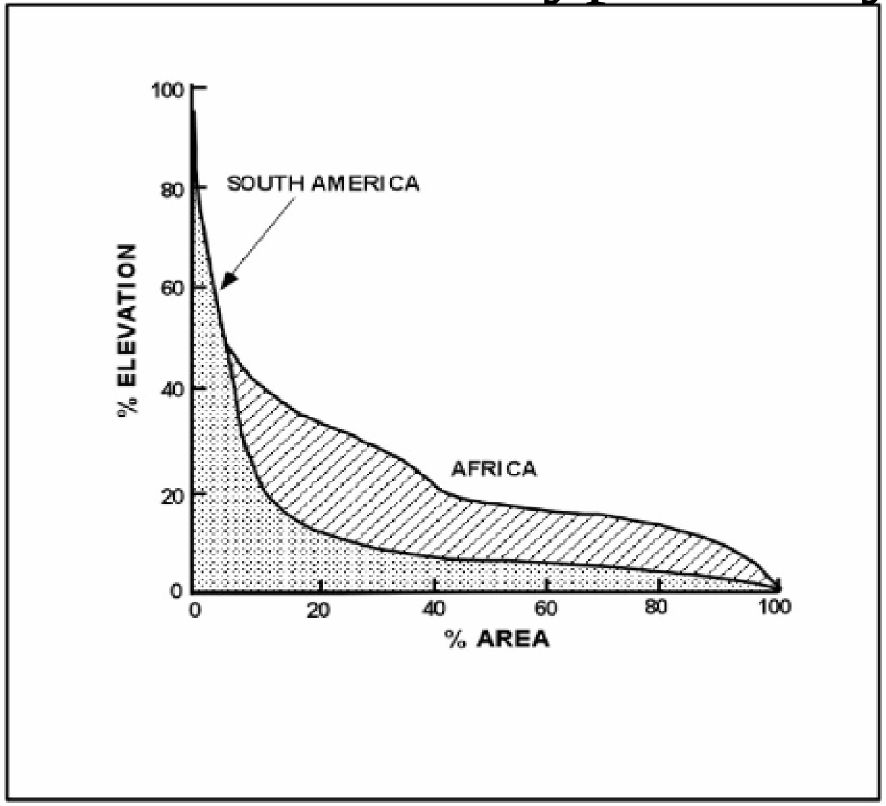

Figure 25 Comparison between hypsographic curves for Africa and South America serves to emphasise that although Africa has no mountain ranges as high as the Andes, an unusually large area of the continent is moderately elevated (figure redrafted from Cogley, 1987). The very small area of Africa close to sea level contrasts strongly with the extensive low-lying area of South America representing the Orinoco, Amazon and Plate Basins. The anomalous elevation of Africa is attributable to interaction between the stationary African Plate and underlying mantle plumes during the past 30 My.

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Elevation of a low-lying Africa in past 30 My can account for Africa's present unusual pattern of relief.

Image courtesy of The Geological Society of South Africa.

Southern Africa is a good place to start: much high ground in a few great swells, a peripheral "Great Escarpment" and a lot of information of diverse kinds.

Weaknesses include: No young igneous rocks (because cratonal) not much deep-water offshore seismic data.

One strength is the recent recognition of a shallow LVZ which is compatible with the idea of shallow mantle convection and , if it has developed in the past 30 My, accounts for Southern Africa's widespread elevation of ca.1km

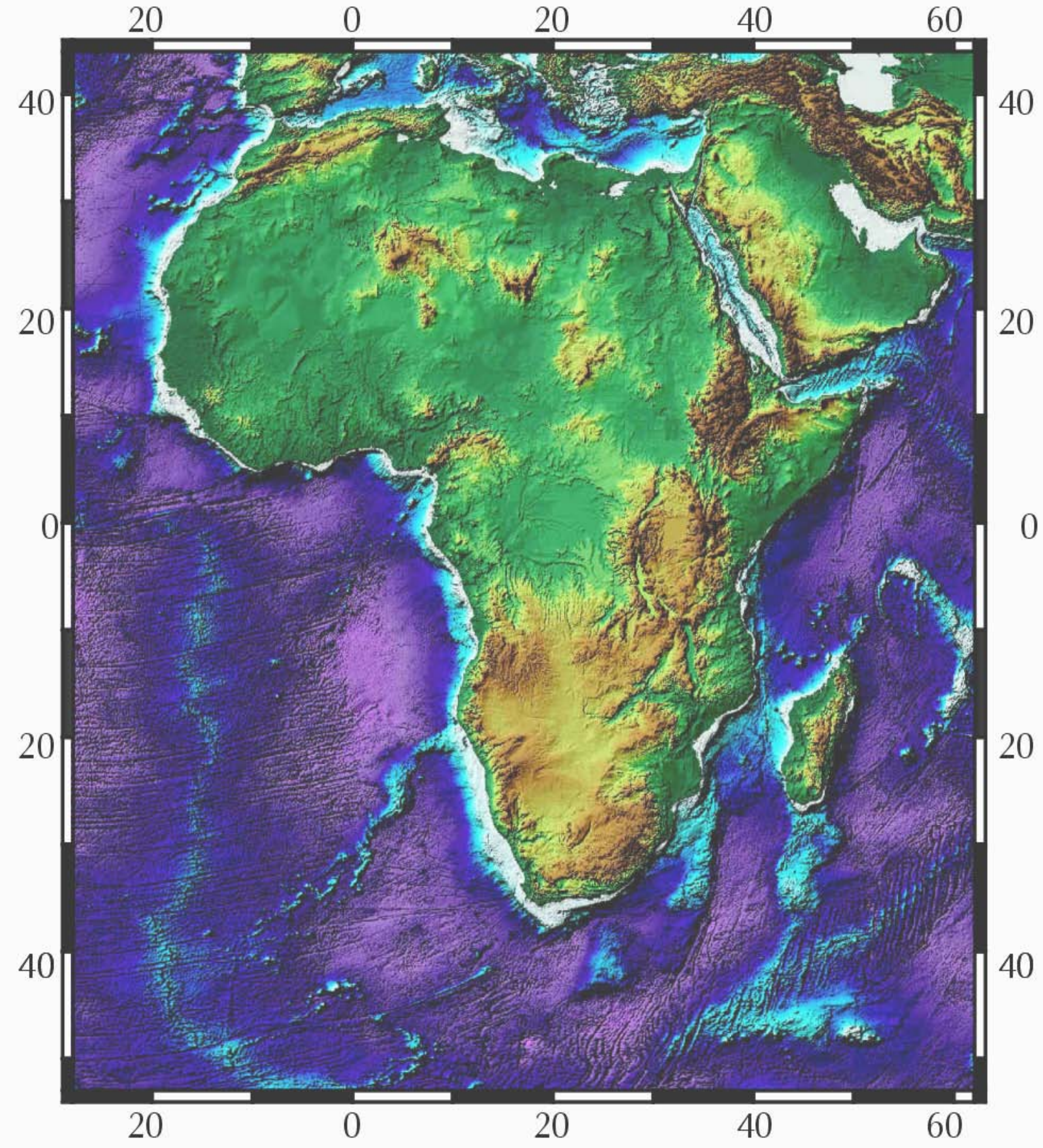


Image courtesy of NOAA and USGS.

AGE OF SOUTHERN AFRICA’S RELIEF

In Southern Africa there are two schools of thought:
One that stresses that the relief has developed since 30 Ma
(e.g.Burke 1996, Burke et al 2003)
and another that treats the relief, and particularly the
Great Escarpment, as having endured since the Cretaceous and
Perhaps since the continental margins formed at ca.125 Ma.

That “old relief” model is used for two main reasons:
(1) It is traditional (as for example in all but the last writings of the late L.C.King).
(2) It fits in with the popular idea of “Old escarpments at continental Margins”(e.g. Beaumont, also Matmon in Geology).
The main evidence cited by supporters of the “old relief” school is from the interpretation of apatite fission tracks (AFT) of the partially annealed zone (PAZ). See papers by Gleadow or R.Brown

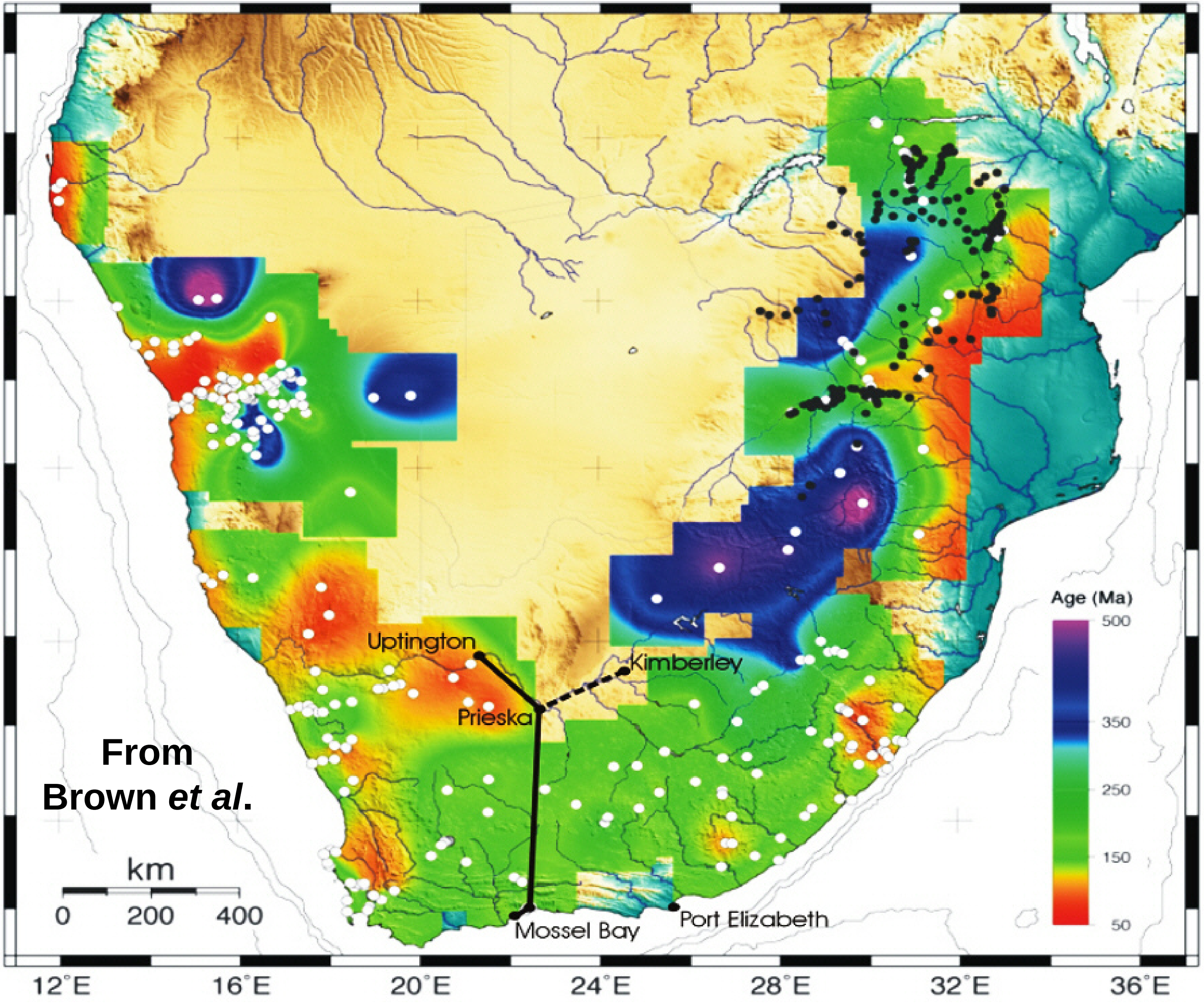
- The Great Escarpment (GE) runs parallel to the coast 100 to 200 km inland.
- Red and yellow AFT < ca.125 lie below the GE.
- Older AFT lie above the GE.

This can be interpreted as indicating no erosion of high ground which has been high since the margin rifted(125 Ma) .

Only areas below GE have been eroded and retreat has been slow.

It can also be interpreted on a "Two Event" model

Gallagher's figures show how:



From Brown *et al*.

YOUNG AFT AGES FORM A BELT CLOSE TO THE COAST

Courtesy of Annual Reviews Inc.
Used with permission.

Great Escarpment on west coast of S. Africa (and a small length in SE of image). Orange River traverses much of image.

Orange

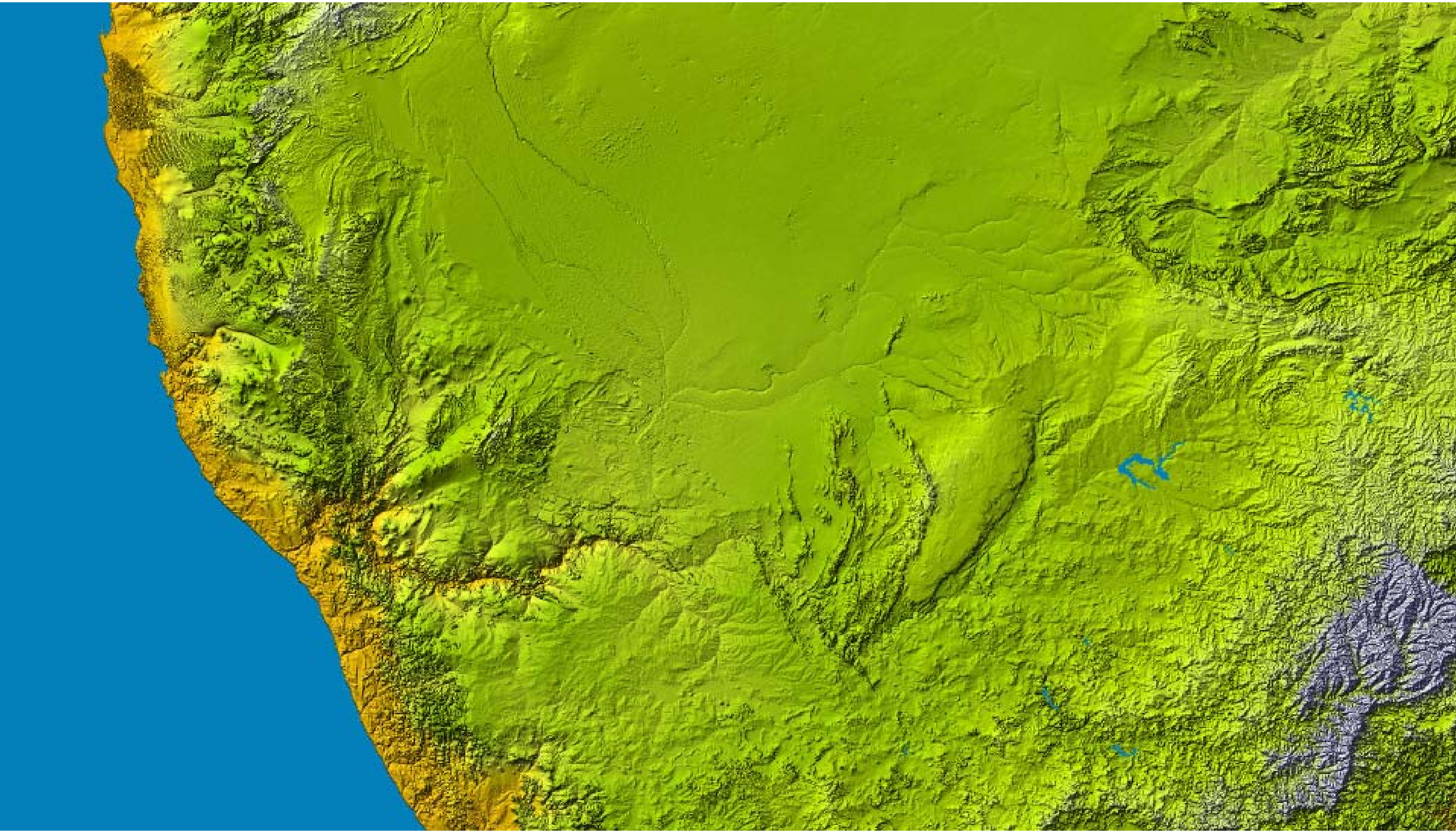
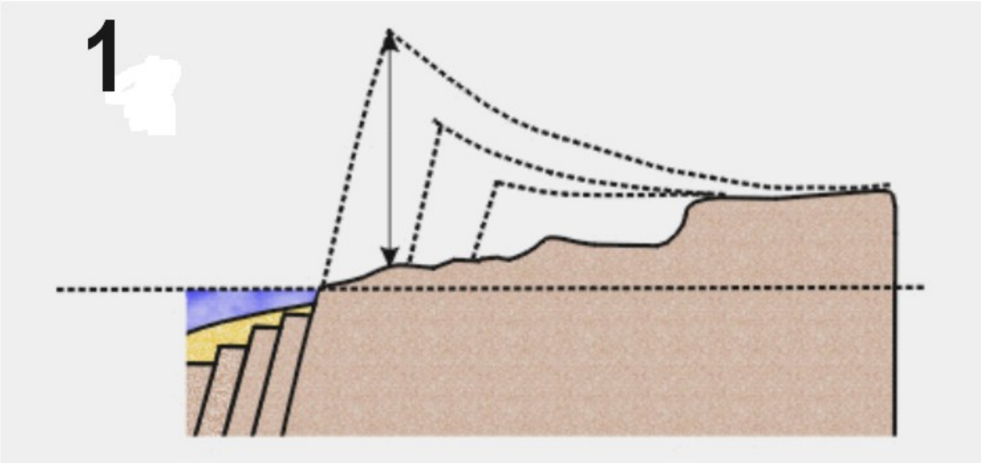


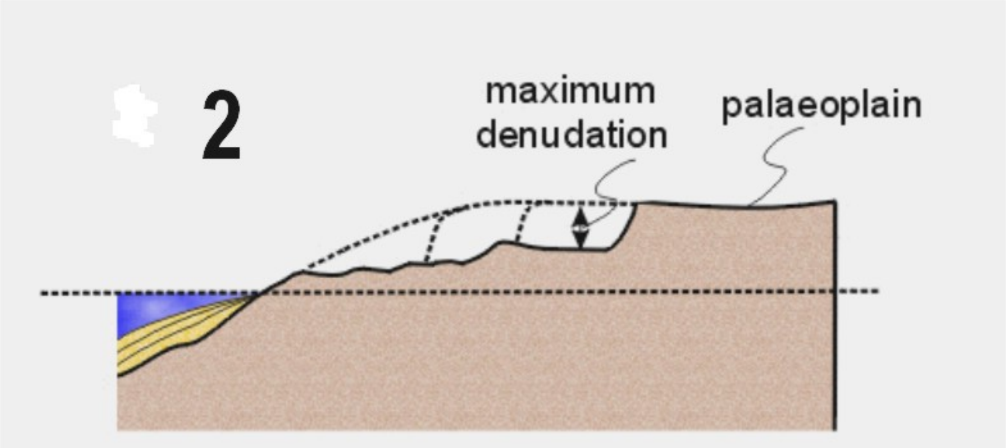
Image courtesy of NOAA and USGS.

History of continental margin escarpments

(Modified from Gallagher *et al*., 1998, AREPS)



scarp retreat model



downwarp model

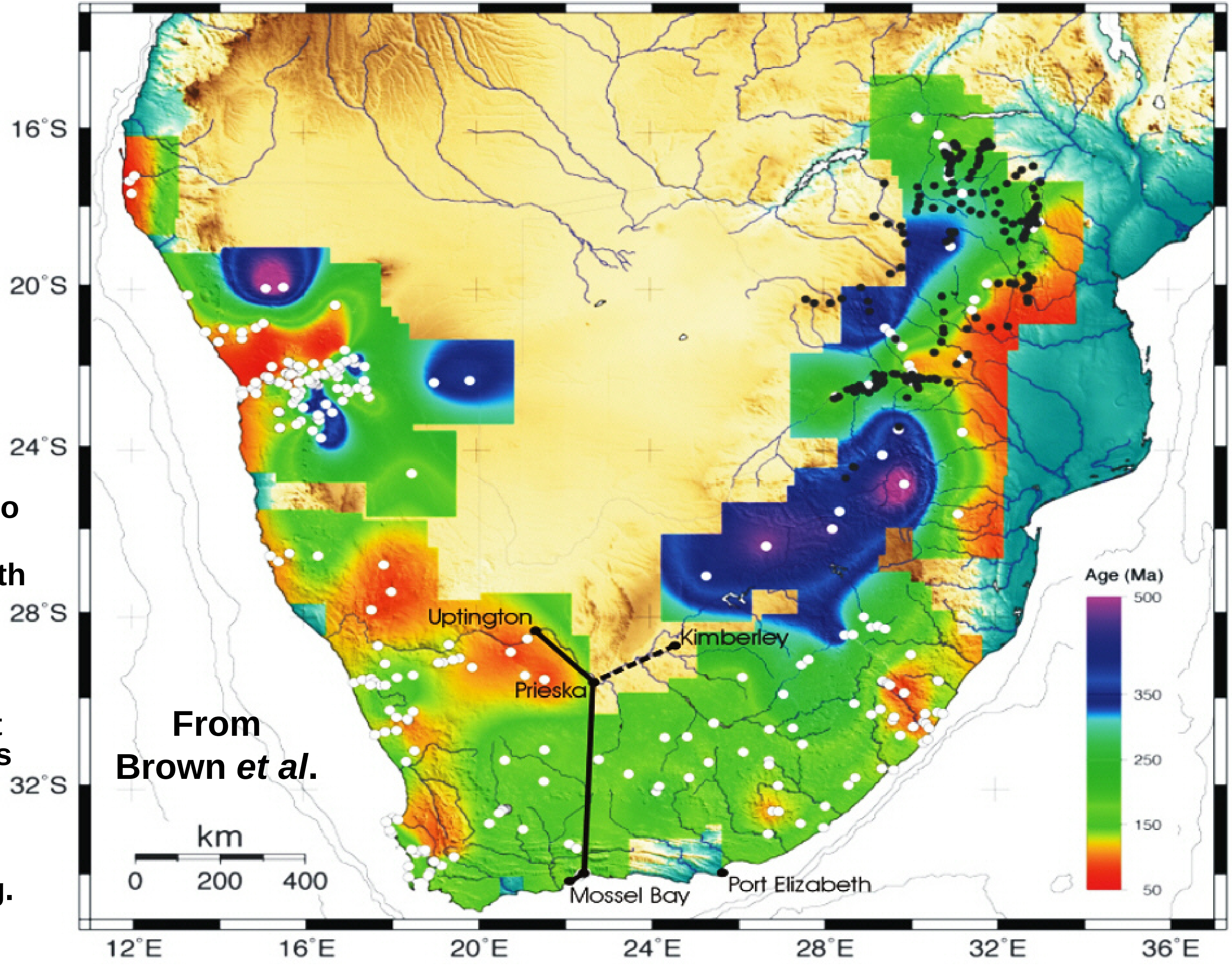
- AFT reset near coast when rift shoulders eroded (maybe 5 km) in tens of My.
- Too little erosion (<2km) in interior to reset AFT because AFT PAZ insensitive below 60º.(It is not clear that Gleadow accepts that)
- Africa low by 70 Ma is consistent with old AFT ages above scarp.
- A second event: Present Gt. Escarpment is new:Swells initiated at 30 Ma. Erosion is nearly all outboard of newly formed Great Escarpment.Too little erosion <2km to reset AFT since 30 Ma

- Up to 5 km were eroded from the rift shoulders when the ocean began to form because it was hot below. AFT were reset.

Inboard erosion took < 2 km by 70 Ma and AFT were not reset.

The flat continent was domed up in a swell to make the Great Anticline of South Africa beginning at 30 Ma.

The Great Escarpment that we see today was formed and began to Retreat after 30 Ma. Because margin was cold no AFT resetting. < 2km have been eroded.



From Brown *et al*.

HOW THE TWO STAGE MODEL ACCOMMODATES YOUNG AFT AGES IN A BELT CLOSE TO THE COAST

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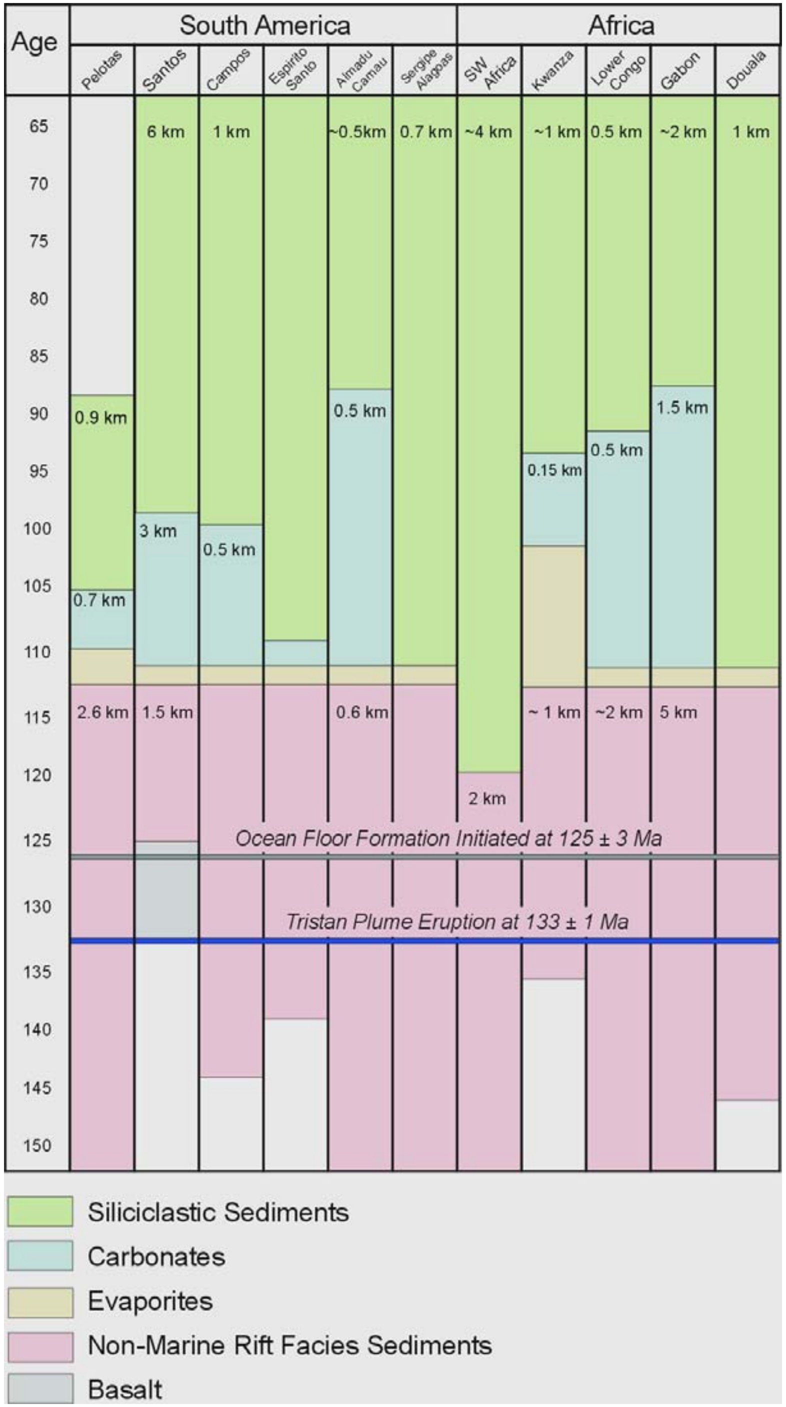
How long do escarpments at the continental margin last?



Coward *et al*. (1998) showed:

South Atlantic rifts formed 145 ± 5 Ma.

Rift deposition (pink) persisted in rifts and on ocean floor under air till sea water spilled in to form evaporites.

After evaporites were deposited, carbonate deposition (blue) followed ending at 20-35 M.y. after ocean floor began to form. “Rift shoulder time”.

Rift shoulders had been eroded by the time silici-clastic deposition (green) began at 105-90 Ma.

Long-lived escarpments did not persist

On the South Atlantic margins

Conclusion: Escarpments last a few tens of millions of years.