

Tectonic Denudation of the Cordillera Central Linked to the Eastern Venezuela Thrust Belt Emplacement (Revised Version)*

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Abstract

Numerous tectonic models have been proposed for the Northern Venezuela plate margin. These proposals are commonly associated with palinspastic reconstructions, some of which invoke right-lateral displacements of the order of 400 km of the Araya Peninsula. However, many problems have remained unsolved.

A recent palinspastic reconstruction of the Eastern Venezuelan Fold Belt has shed new lights on the mechanics and dynamics of the area. In order to be as objective as possible, only one map has been used in the reconstruction exercise. The idea presented here came from a quick look at a regional map (Mascle, Letouzet, et al., 1990) and preparing two examples of match between deep-seated structural features from the Cordillera Central and shallow structural features of the Eastern Venezuela Thrust Belt after reconstruction.

The proposed model invokes, in association with the right-lateral displacement, a mega-detachment of the whole cover of the Cordillera Central; i.e., all of the nappes belonging to the prolific oil-bearing Eastern Venezuela Thrust Belt (essentially Norte Monagas) and its foreland up to, and including, Trinidad. The gliding and transport of these nappes resulted from a combination of subduction of the Caribbean Plate, extension in Eastern Venezuela, and activity of the Venezuelan Andes (Bocono Fault), which allowed the separation of the nappes from the rest of the cordillera.

After reconstruction, most of the major transverse features from Eastern Venezuela match the existing major transverse features of the Cordillera Central. Moreover, paleontological, sedimentological, and petrological anomalies can now be explained (e.g., of tens of thousands of feet of erosion, including a large volume of carbonates, with no evidence of deposition in Venezuela). Age dating of rare facies associations in a group of stratigraphic units (from two outcrops reunited after reconstruction) allow one to narrow the age range of the “gravity”-driven tectonic event between the late Pliocene and Pleistocene.

Brief Review of Problems of Existing Models

Various geological anomalies are hard to fully comprehend in the light of the existing geological models dealing with the northern margin of Venezuela. From these, one can cite the following problems:

1. The fit of Trinidad in the tectonic and sedimentary history of eastern Venezuela (Babb and Mann, 1999; Pindell and Kennan, 2000).
2. The generation of the Gulf of Paria (Pindell et al., 1998, Flinch et al., 1999).
3. South of the Deformation Front in eastern Venezuela, the listric faults are younger towards the West (Di Croce et al. 1999); could they be slump head tensional listric faults?
4. The existence of the very deep depression of the Barlovento region filled with more than 10,000 feet of very young sediments.
5. The existence and preservation of the two islands of the “Farallon Centinella” and more particularly their location, alignment, and three-dimensional geometry.
6. The occurrence of Pliocene to Pleistocene extensional tectonics in the Cordillera Central (F.A. Audemard; Audemard et al., 2006).
7. The generation of the Gulf of Cariaco.
8. The late East-West extensional phase seen in the Furrial Trend (Chatellier et al., 2002).
9. The similarity of young sedimentary series between the Western part of the Araya Peninsula and the Southeastern part of Falcon (Padrón et al., 1998, 2000a, 2000b; Estévez et al., 2001).
10. The speed of the denudation of the Cordillera Central based on petrology of key minerals, possibly linked to a subduction associated with an orogen-parallel extension (Smith et al., 1999).
11. The recent strike-slip activity of the Bocono Fault (Audemard et al., 1999; Beck et al, 2002) in line with a long history of activity (see Complejo de la Iglesias in Figure 4).
12. Various sedimentological studies have outlined the problem of a mismatch between the sandstone composition of the sediments found in the giant fields of Norte Monagas (Furrial, Carito, and Santa Barbara) and the craton where the sediments are supposed to have been derived.
13. Other problematic observations to be kept in mind are the general orientation of the various environments during the Oligocene and the associated transport direction (towards the ENE).

The Reconstruction

The focus of this reconstruction has been restricted to outcrop observations and interpretations from the northeastern part of Venezuela. All of the nappes corresponding to the Serrania del Interior and of the deeply buried “Norte de Monagas” have been displaced to the East, together with the Araya Peninsula. However, strike slip along the Pilar Fault Zone has moved the Araya Peninsula a bit farther to the east (tens of kms).

Gravity gliding would have been responsible for the tectonic denudation of the Cordillera Central and for the present position of the Eastern Venezuelan Thrust Belt. The exact level of decollement is still to be determined; that could be linked to the Colon and Querecual series. The

Lara Nappes and the Eastern Venezuela Nappes would then have belonged to the same thrust system until their recent separation. The entire Orinoco Delta could well be part of the mega-detachment.

It is expected that the present hypothesis will be the source of debate among geologists and geophysicists who have access to more geological and seismic data; it is also hoped that analogues will be found in other places where there is a combination of subduction, strike slip, and passive margin (e.g., Morocco).

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Tectonic Denudation of the Cordillera Central Linked to the Eastern Venezuela Thrust Belt Emplacement

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Originally presented as a poster at the 2003 AAPG Convention

Talk outline

- How this research started
- Geological setting of Venezuelan example
 - Problems unresolved from previous interpretations
- The pieces of the puzzle
- The reconstruction
- Implications
 - for Venezuela and Trinidad
 - For other thrust belts

Why this study

A major catastrophe led to
the death of some 30,000 people
essentially in the area around Vargas

and

the flooding of a large area
in the Barlovento Depression

That was December 16th 1999

The Barlovento Depression

A large part of the Barlovento Area was flooded

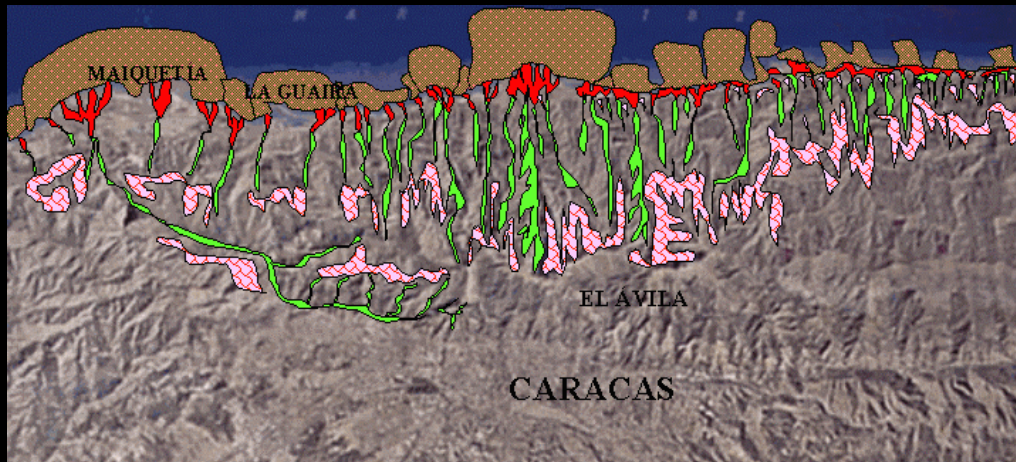
A well known geophysicist told me, that in the Barlovento Depression, the sedimentary sequence was made of at least 10,000 feet of Quaternary “mud”

How could that be with
so much basement rocks around?

In memory of the Vargas Mud Slides

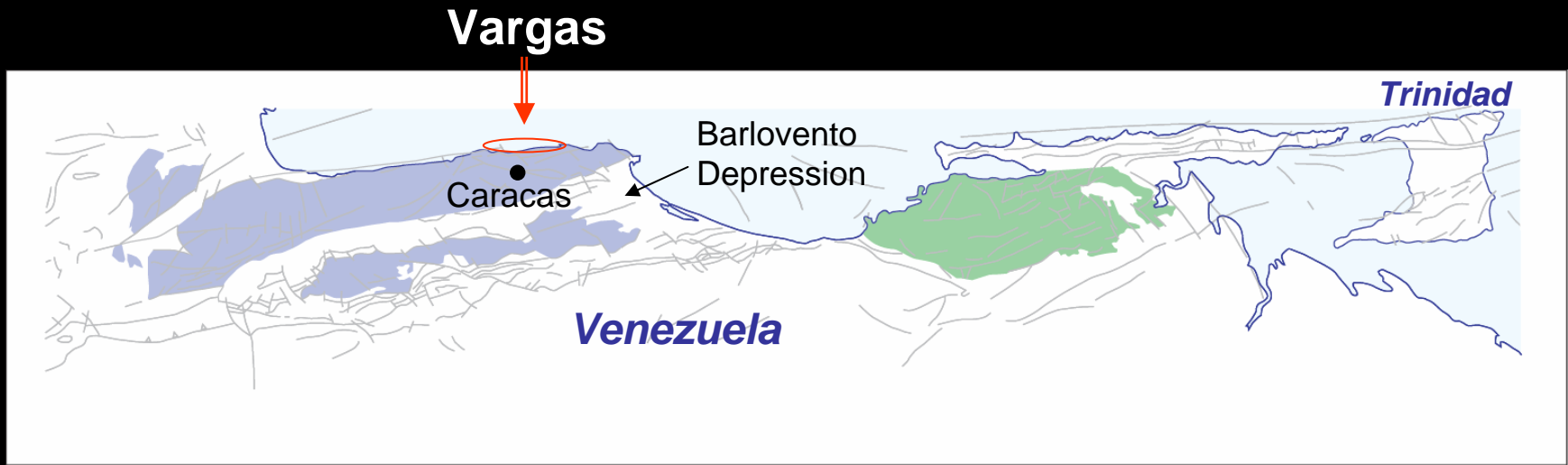
December 16th 1999

Aerial map of main disaster area



The Vargas Mud Slides

December 16th 1999

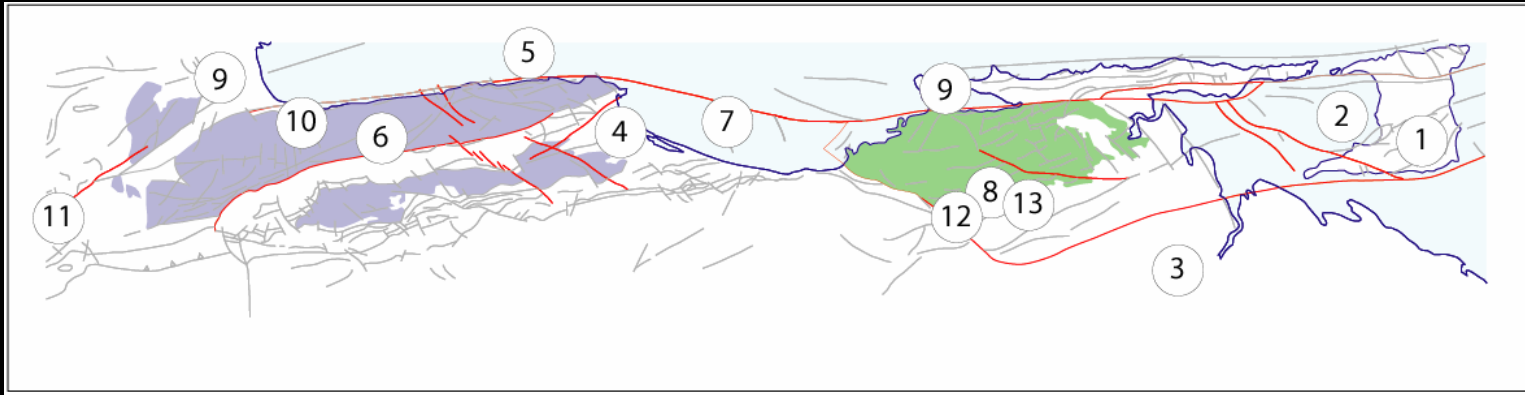


30,000 people died in Vargas

Barlovento to the east was under water

Geological setting

and some unresolved problems



- 1 - The fit of Trinidad in the tectonic and sedimentary history of eastern Venezuela (Babb and Mann, 1999; Pindel and Kennan, 2000).
- 2 - The generation of the Gulf of Paria (Pindell et al., 1998, Flinch et al., 1999).
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- 9 - The similarity of young sedimentary series between the Western part of the Araya Peninsula and the Southeastern part of Falcon (Padrón et al. 1998, 2000a, 2000b; Estévez et al., 2001).
- 10 - The speed of the denudation of the Cordillera Central based on petrology of key minerals, possibly linked to a subduction associated with an orogen-parallel extension (Smith et al., 1999).
- 11 - The recent strike-slip activity of the Bocono Fault (Audemard et al., 1999; Beck et al, 2002) in line with a long history of activity.
- 12 - Various sedimentological studies have outlined the problem of a mismatch between the sandstone composition of the sediments found in the giant fields of Norte Monagas (Furrial, Carito, and Santa Barbara) and the craton where the sediments are supposed to have been derived.
- 13 - Other problematic observations to be kept in mind are the general orientation of the various environments during the Oligocene and the associated transport direction (towards the ENE).

Method / approach

One Single Map to be used

(authored by one consortium led by BRGM & Ifremer)

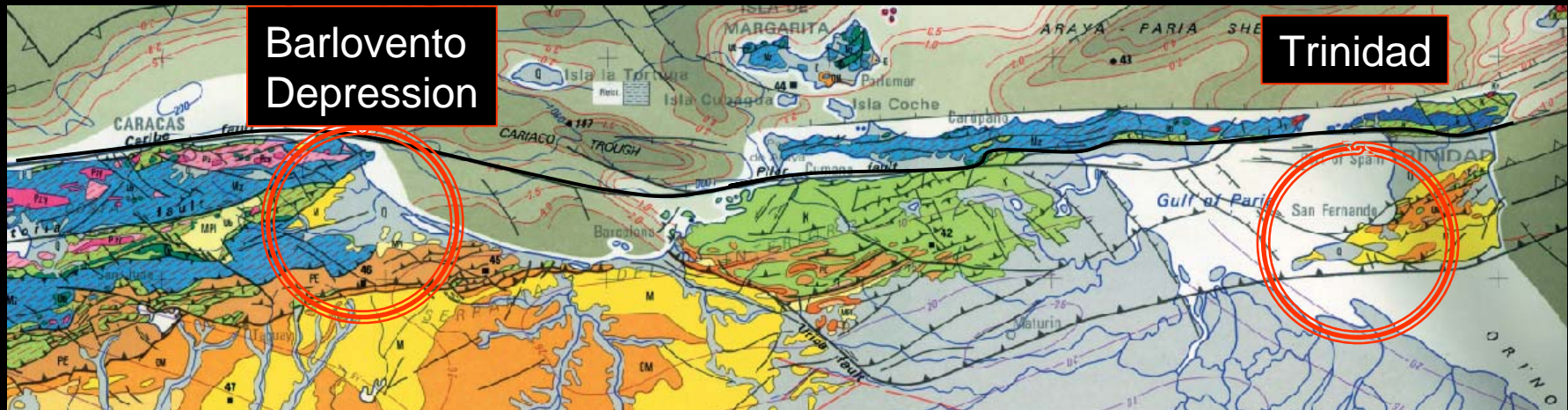
Mascle, A., Letouzet, P., et al., 1990

to remain as objective as possible

No alteration whatsoever of the map

The main piece of the puzzle

The shape and geology of the Barlovento Depression and surroundings are strikingly similar to the shape and geology of the Southwestern edge of Trinidad

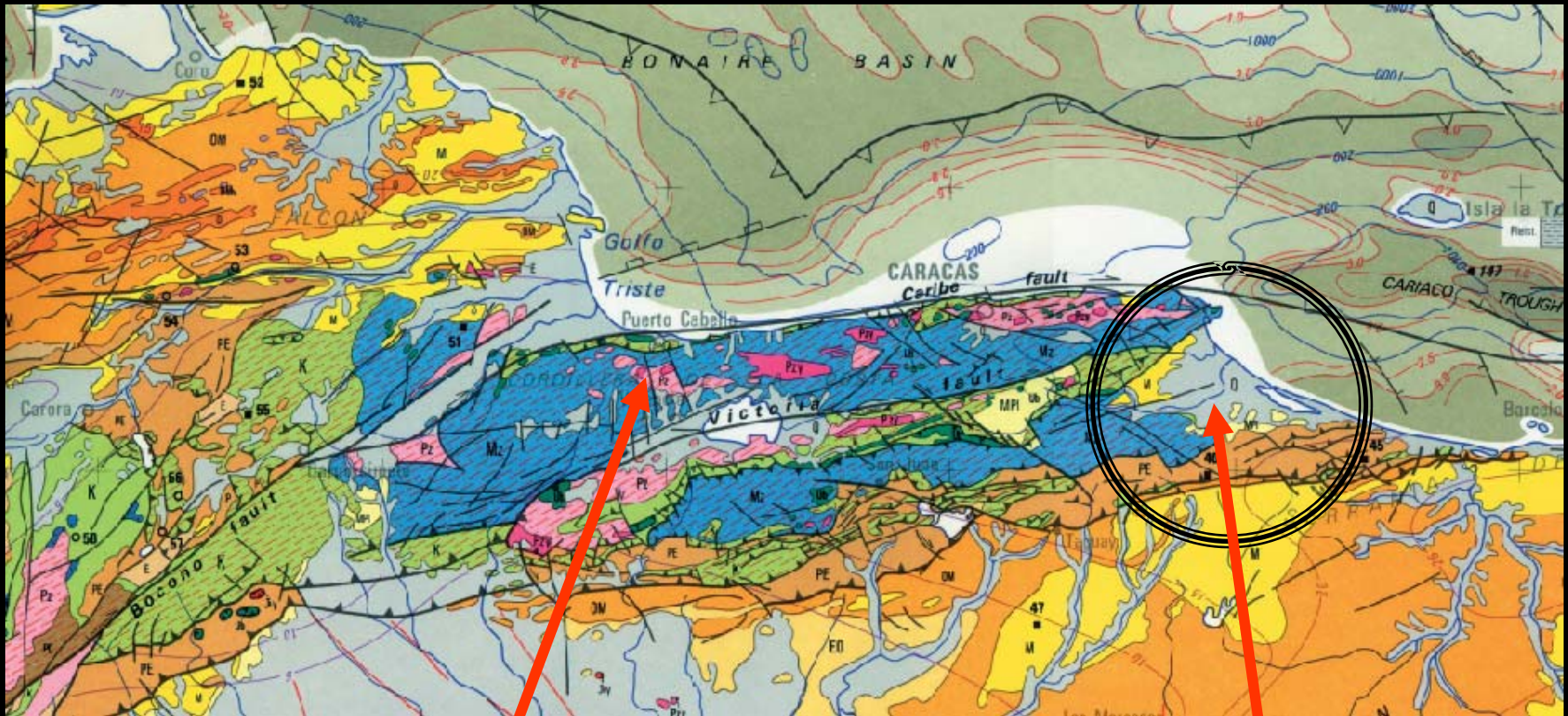


Mascle, A., Letouzet, P., et al., 1990

The eye-catching match

Barlovento Depression and Cordillera Central

Main problems

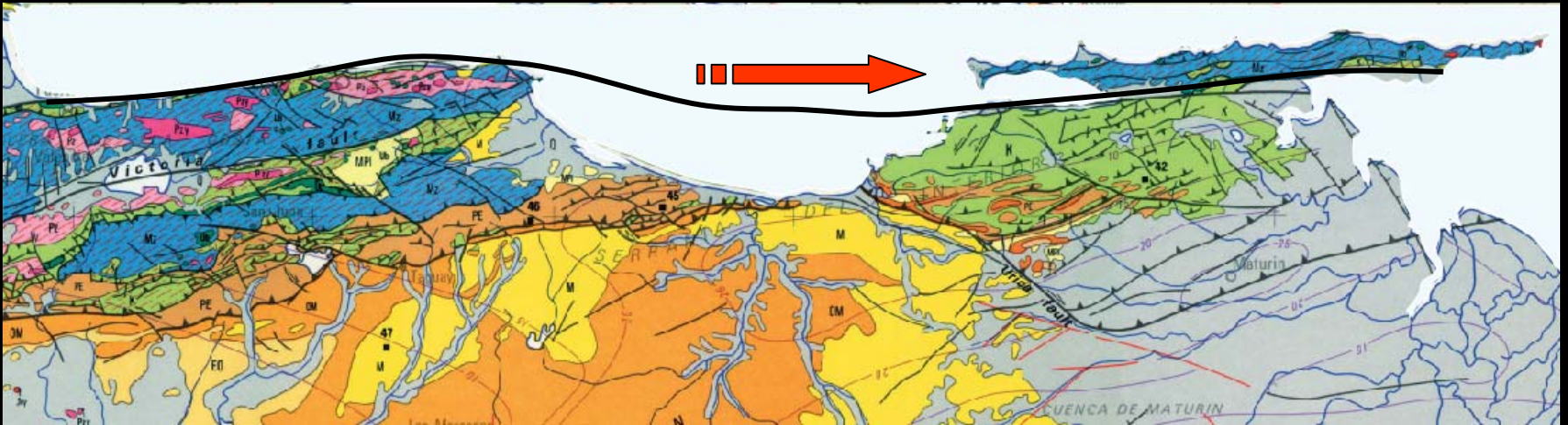


10-30 km erosion !!!!

10 km clay and silt !!!!

The strike-slip based model

← About 425 km of hypothetical strikeslip →



Seems obvious

Proposed by many scientists

Accepted by most

Using the strike-slip model

with 425 km displacement

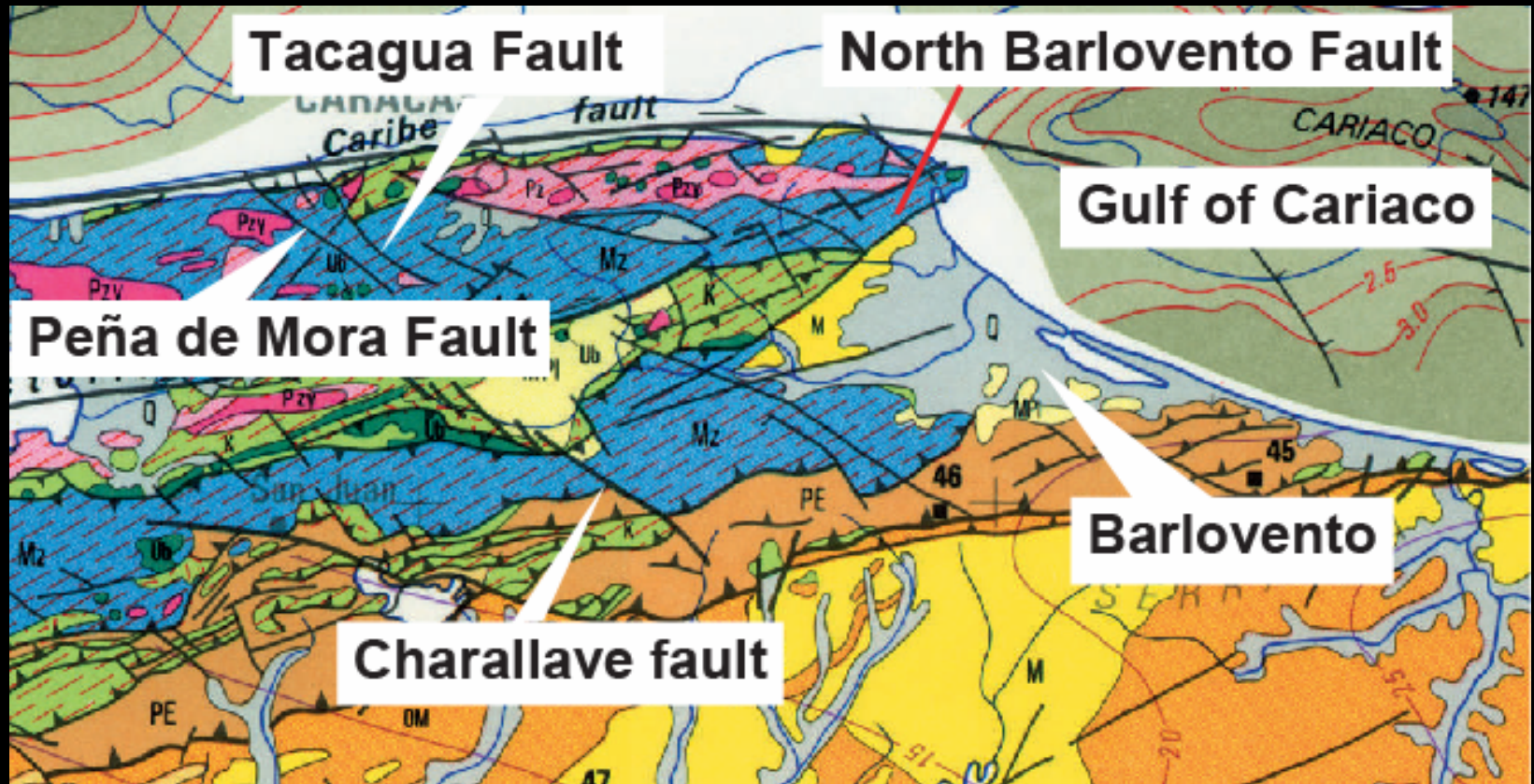
Southwestern Trinidad is a perfect match

for the missing block of the

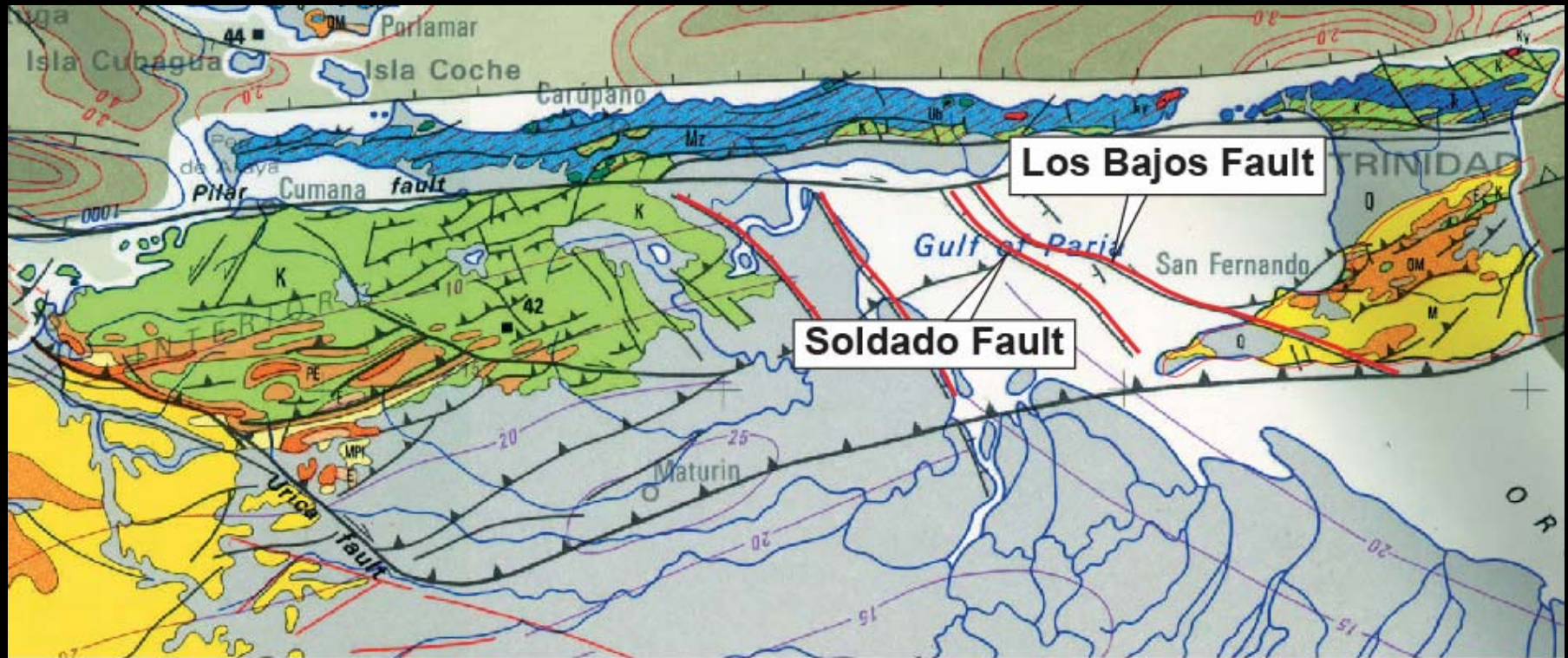
Barlovento Depression

However, there is a major problem: the whole of Trinidad needs to stay undeformed and that cannot be achieved by just strike slip

Structural elements of interest in the restoration Western part

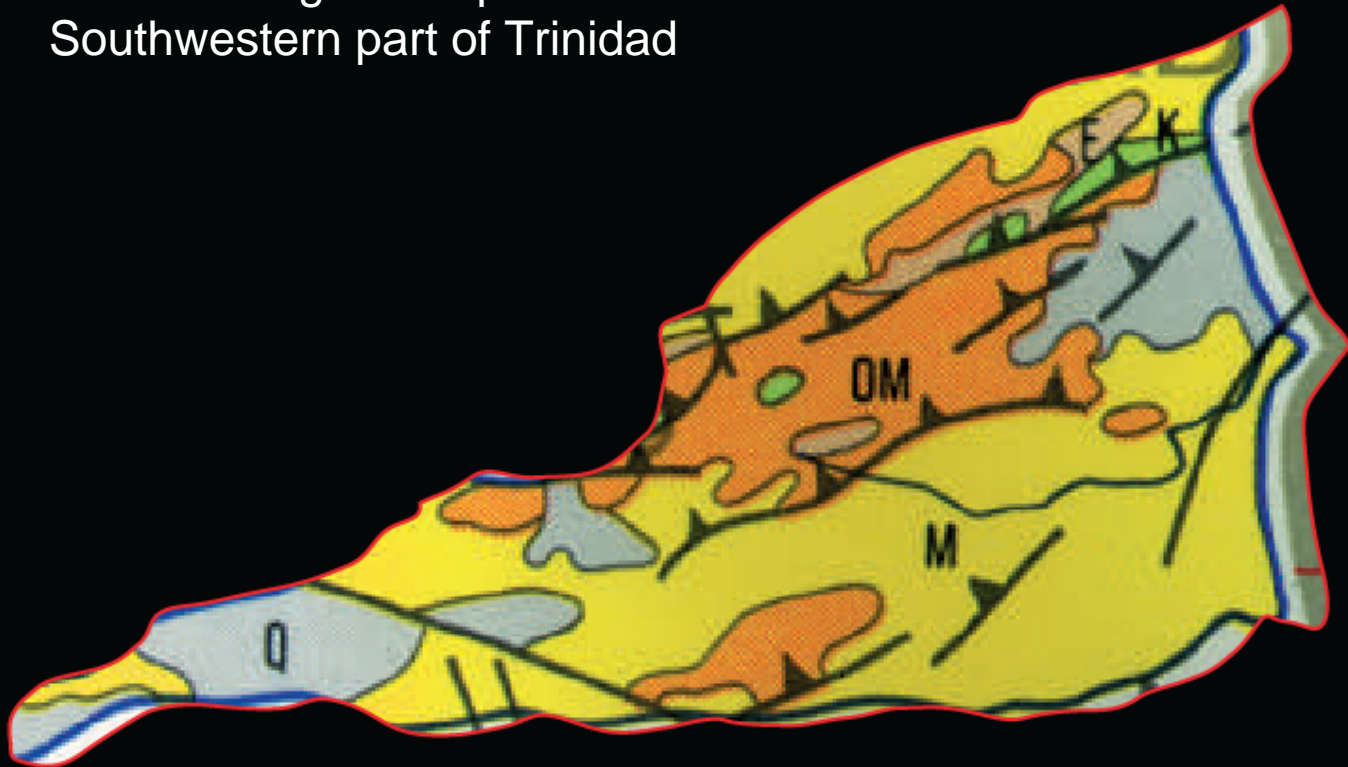


Structural elements of interest in the restoration Eastern part

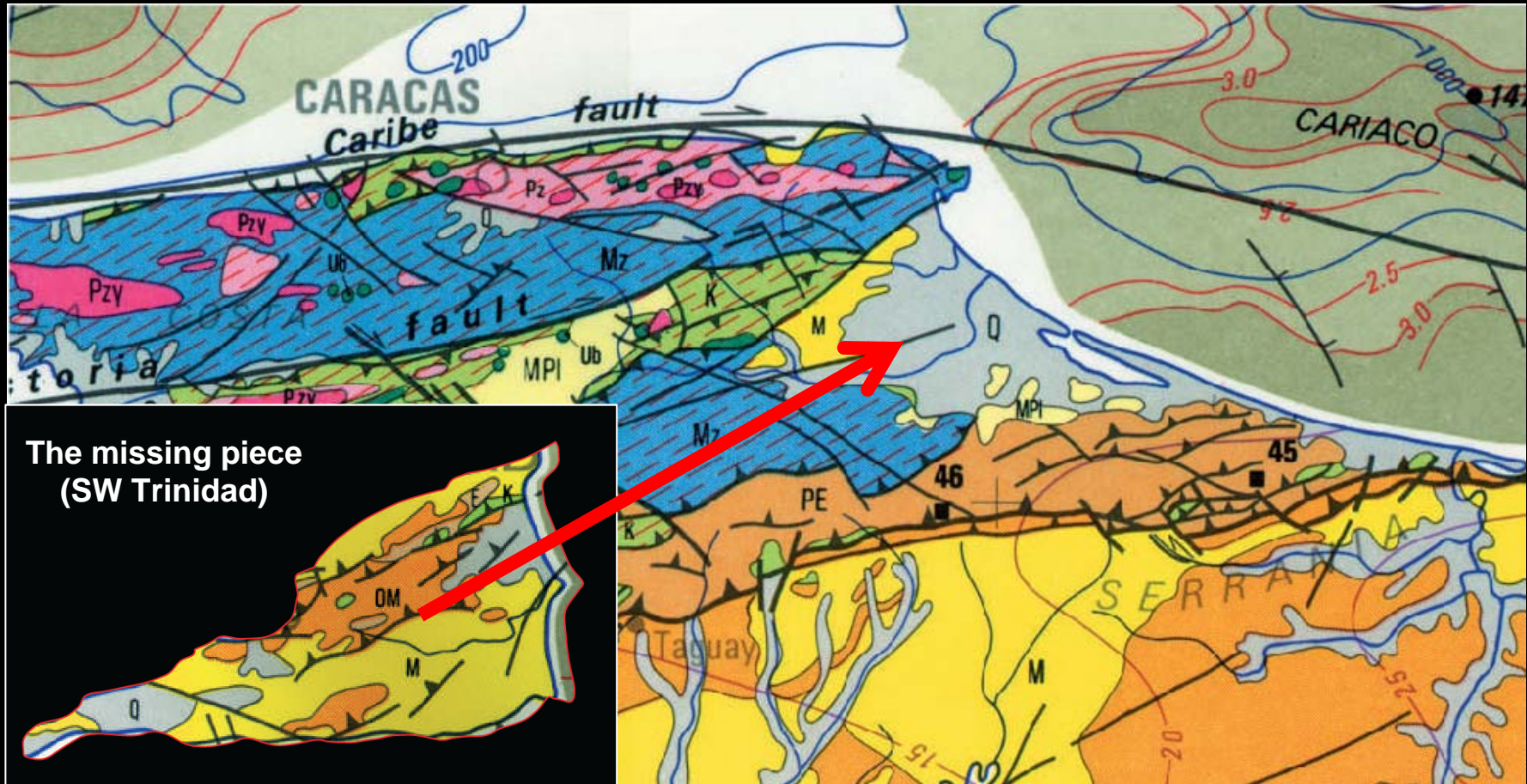


Zoomed view of what is missing in Barlovento

Geological map of
Southwestern part of Trinidad

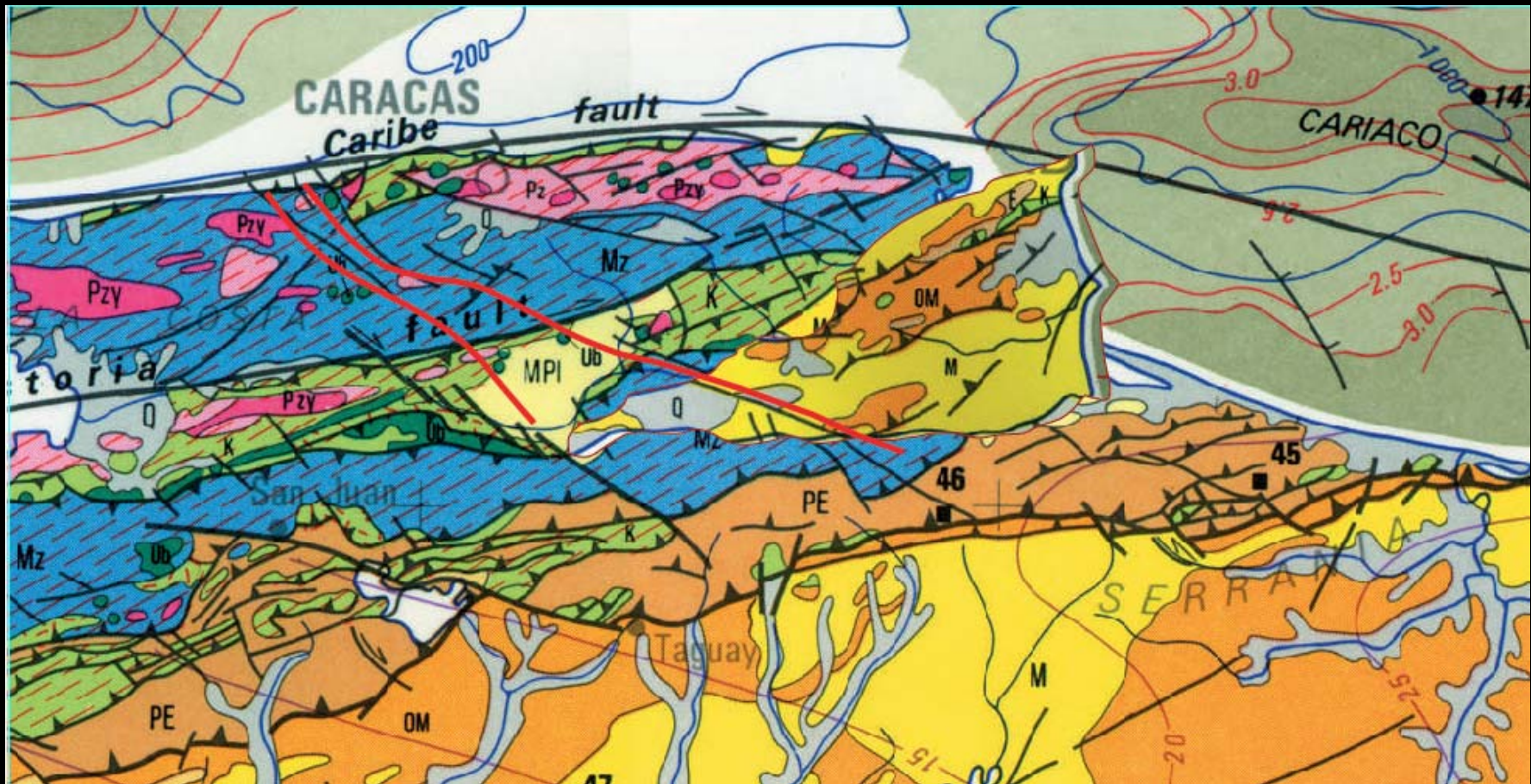


The Barlovento missing piece



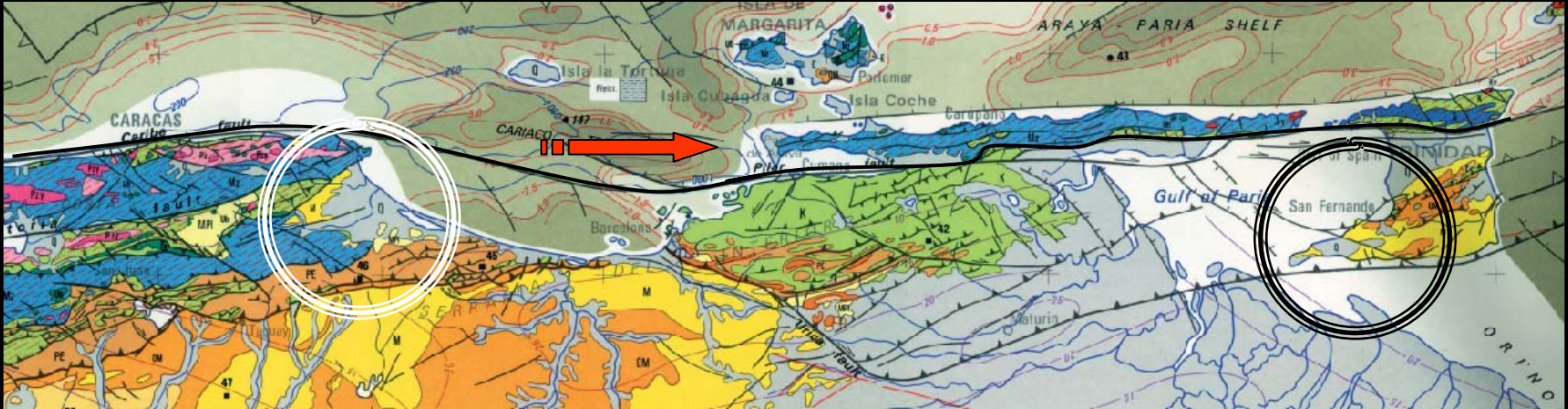
The fit is incredible: the Western part of Trinidad is the piece that is missing in the Barlovento Region

Fitting Trinidad in Barlovento



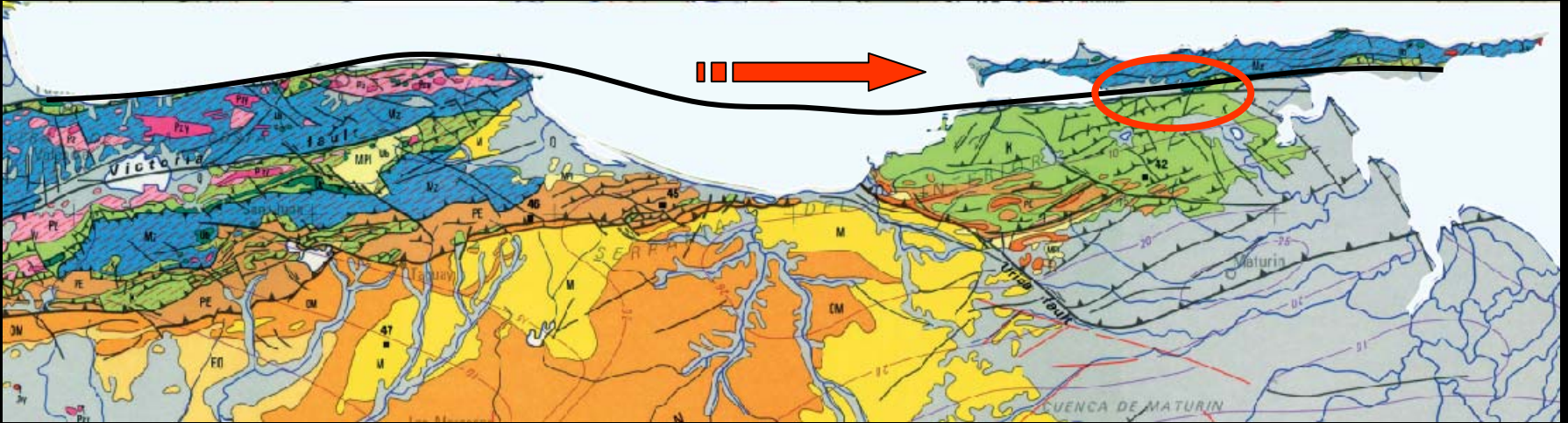
The fit is incredible: the Western part of Trinidad is the piece that is missing in the Barlovento Region

Strike slip gives a perfect match



The missing triangular block from Barlovento
is
the southwestern part of Trinidad

1st Problem with the strike-slip model



All neotectonic work shows that:

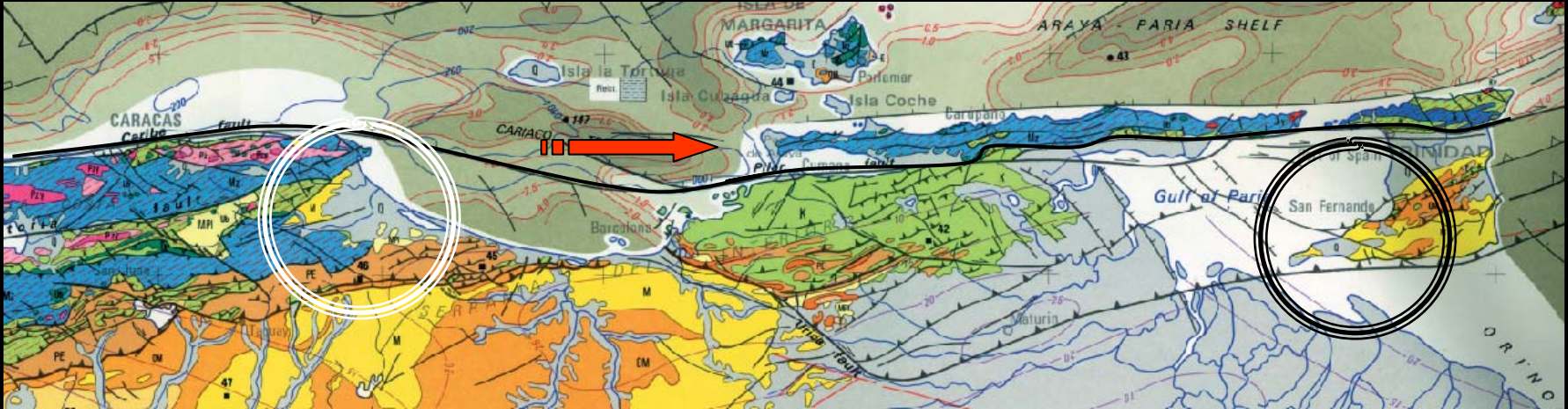
Maximum strike slip is of the order of **40 km**

Complete certainty with well defined markers

(Dr Frank Audemard & Funvisis Foundation)

Personal communication 2000

Strike slip alone is not a solution



The southwestern part of Trinidad
is a **perfect** match for
the missing triangular block from Barlovento

STRIKE SLIP does not make sense

Gravity Gliding is the only solution

I am very fond of strike slip

Gravity gliding had never been in my mind before

Two years to accept that it was the only solution

Gravity Gliding

The various lines of evidence

- Cross-sections

- Deep-seated faults in basement and cover

- Problematic recent grabens

- Eclogite and rate of exhumation

- Problematic geometries and age of extension

- Ichnofabric and possible age of event

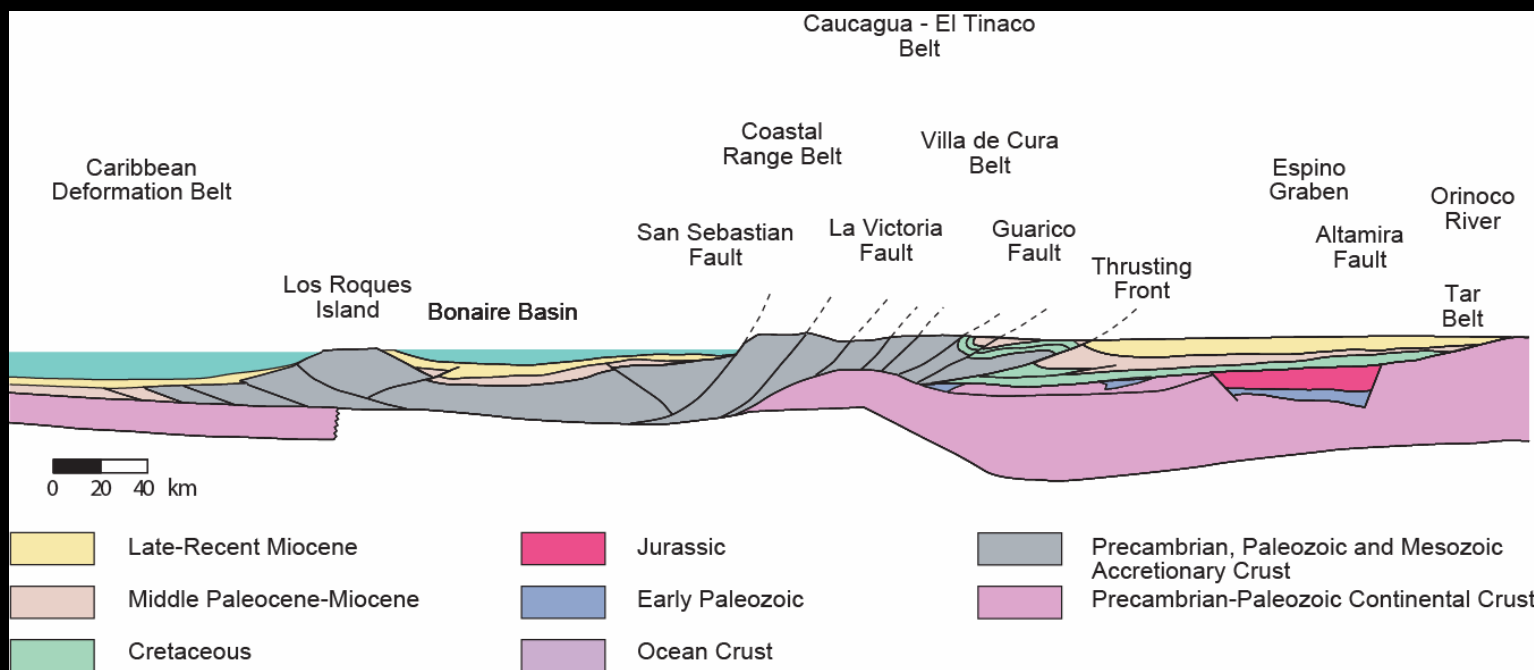
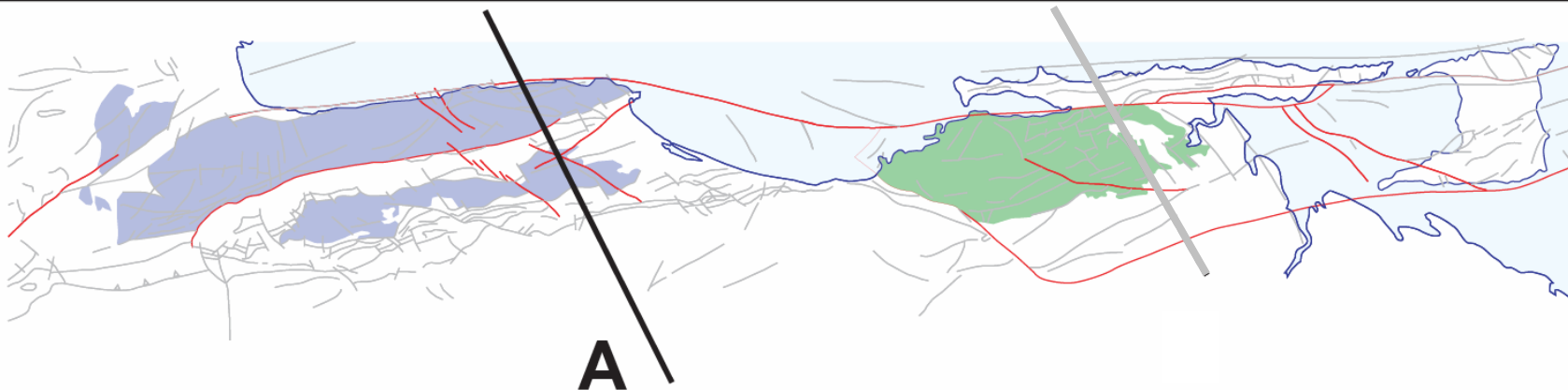
Cross-sections from one Single author

Professor Frankin Yoris,

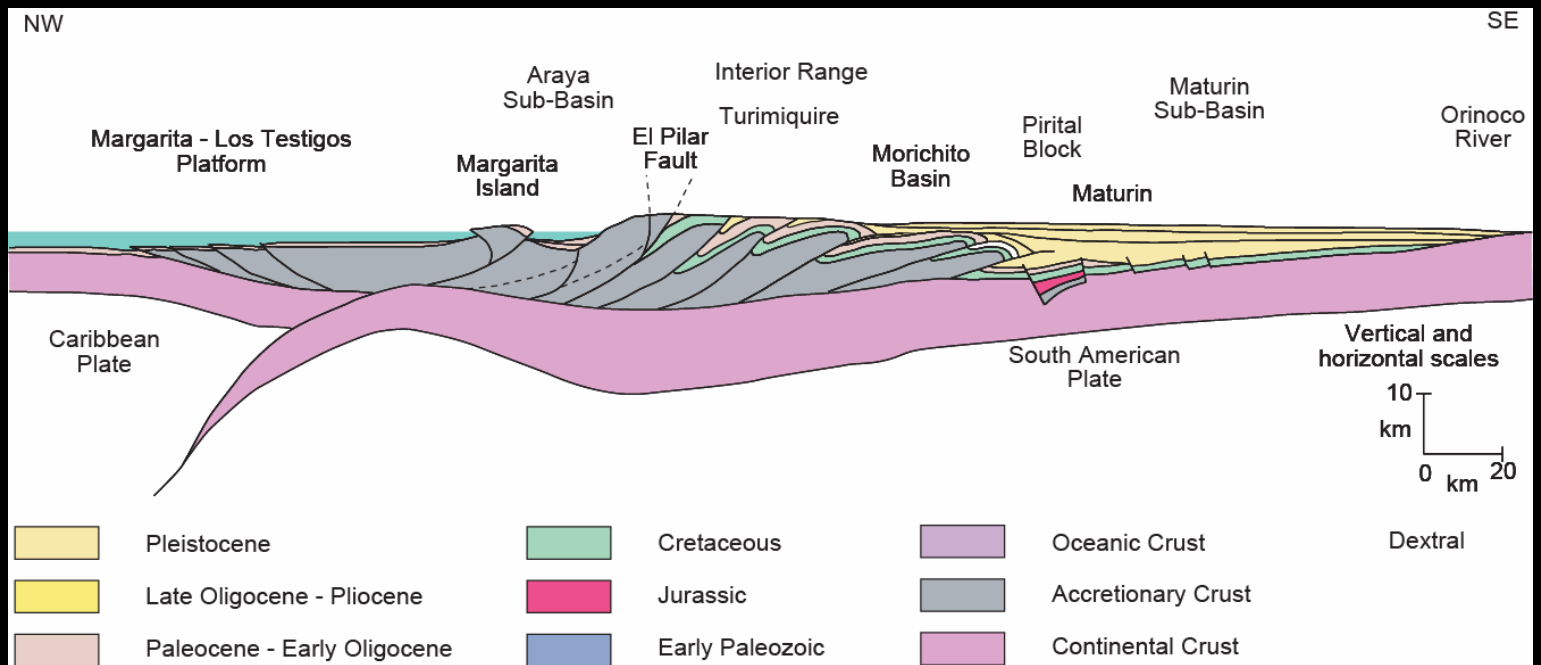
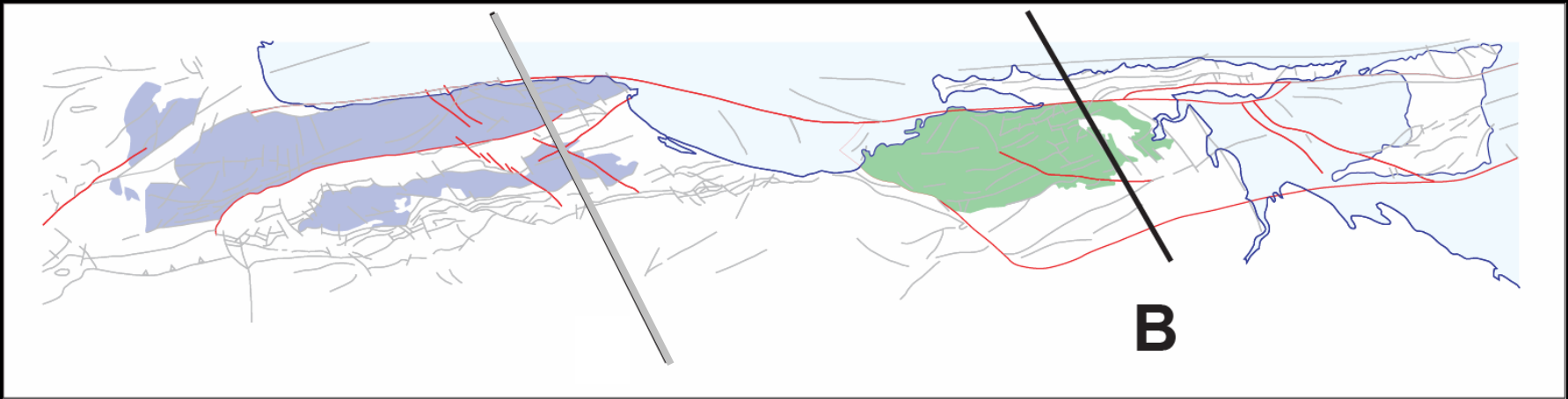
Universidad Central De Venezuela

to remain as objective as possible

No alteration whatsoever of cross-sections

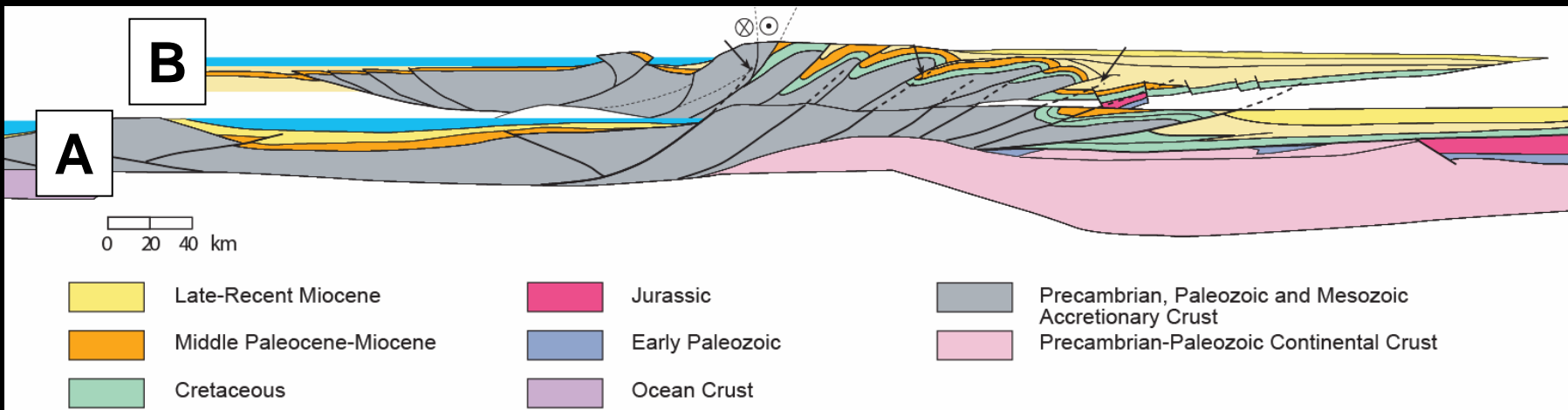
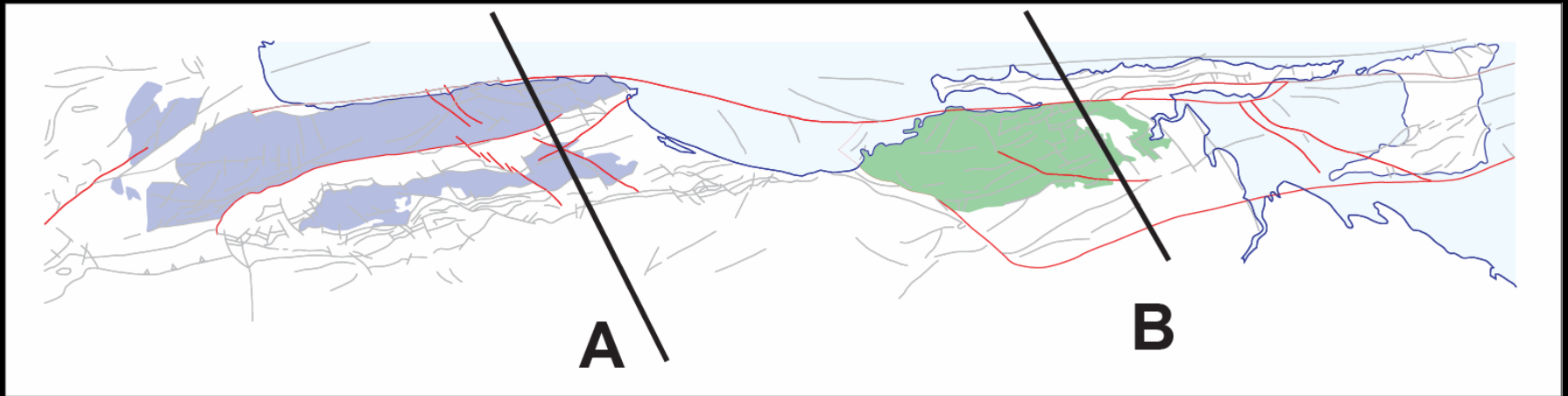


Cross-section from F. Yoris, 1997 (WEC Venezuela)



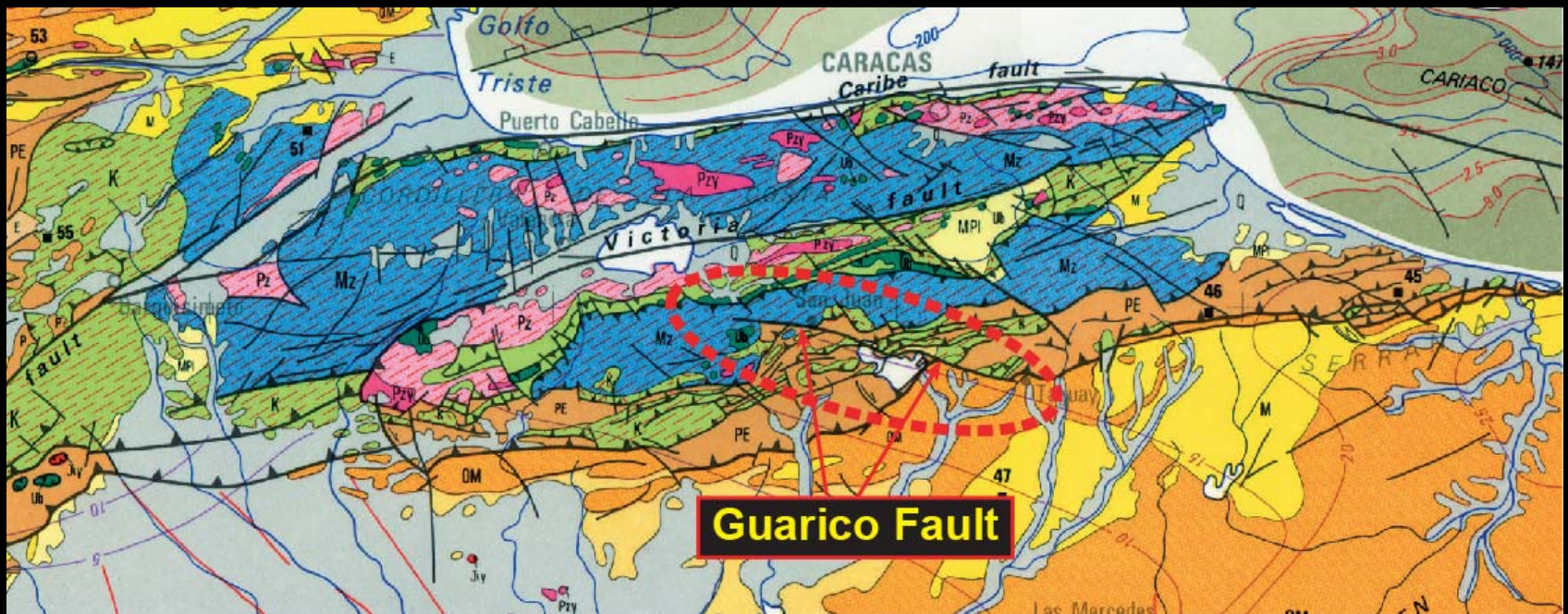
Cross-section from F. Yoris, 1997 (WEC Venezuela)

Palinspastic Reconstruction



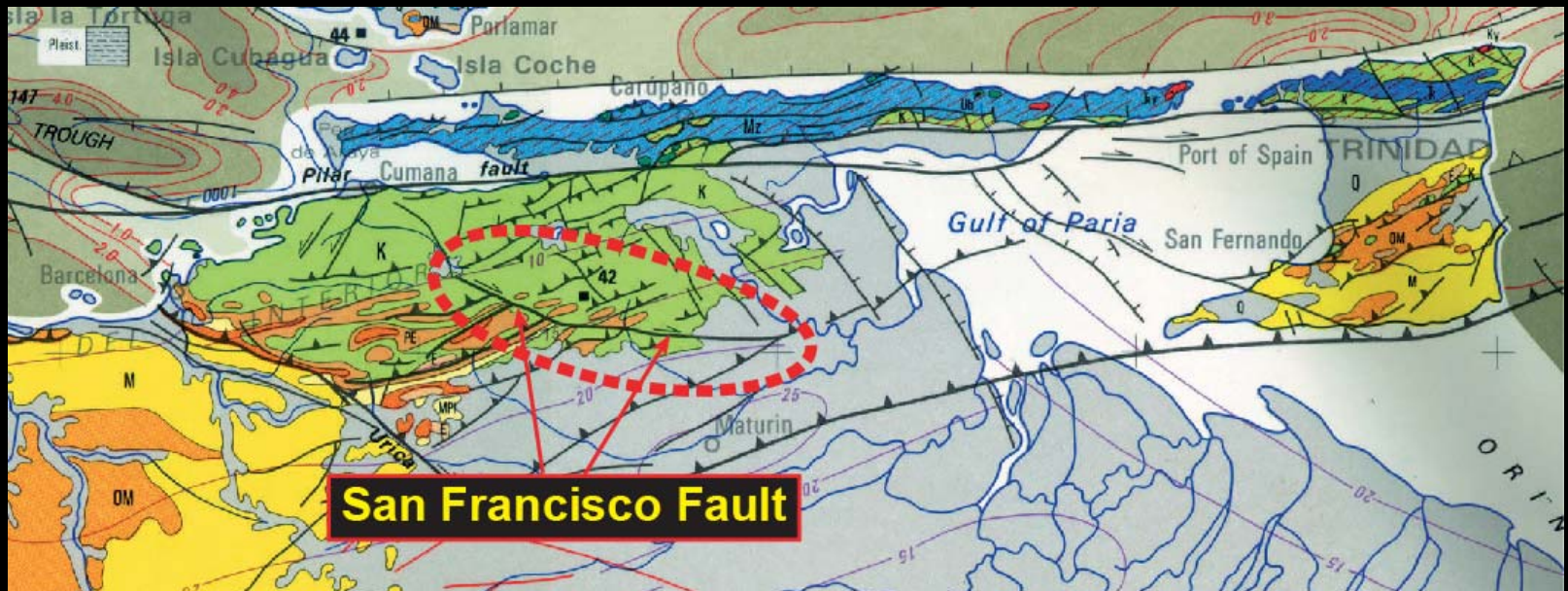
A composite based on 2 cross-sections from F. Yoris, 1997 (WEC Venezuela)

Cordillera Central Structural Elements

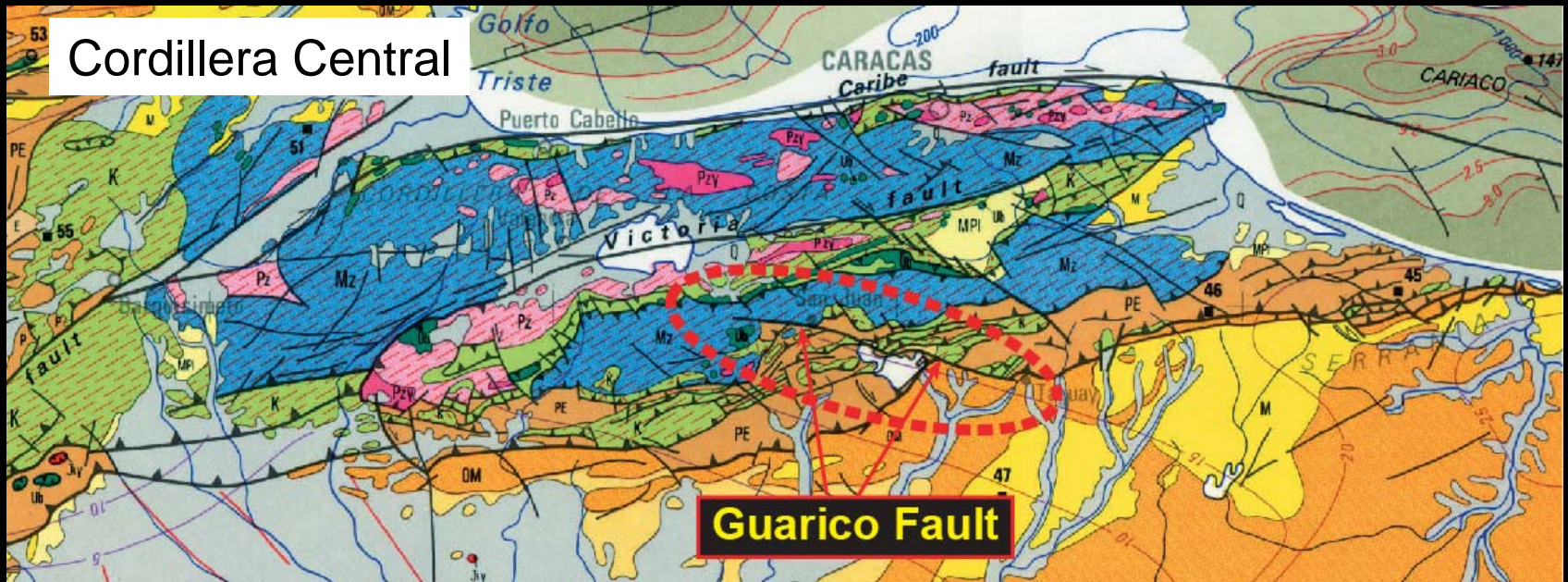


E.V.T.B. Structural Elements

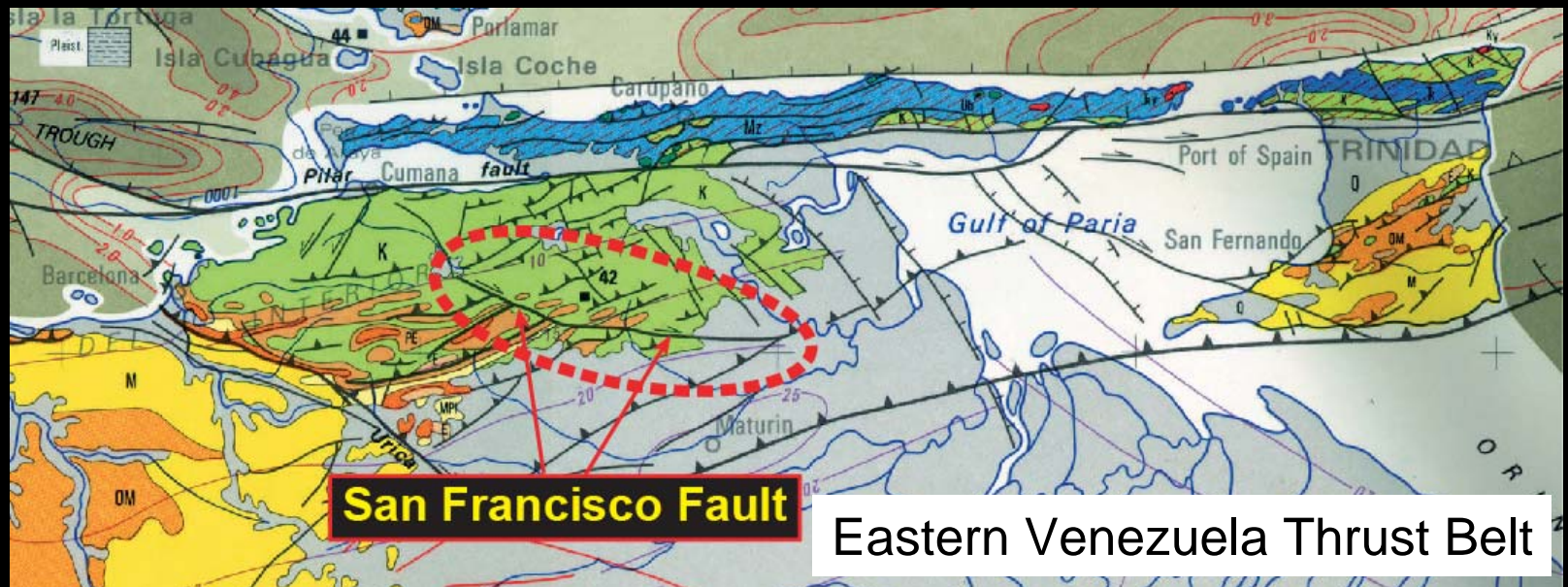
(Eastern Venezuela Thrust Belt)



Cordillera Central



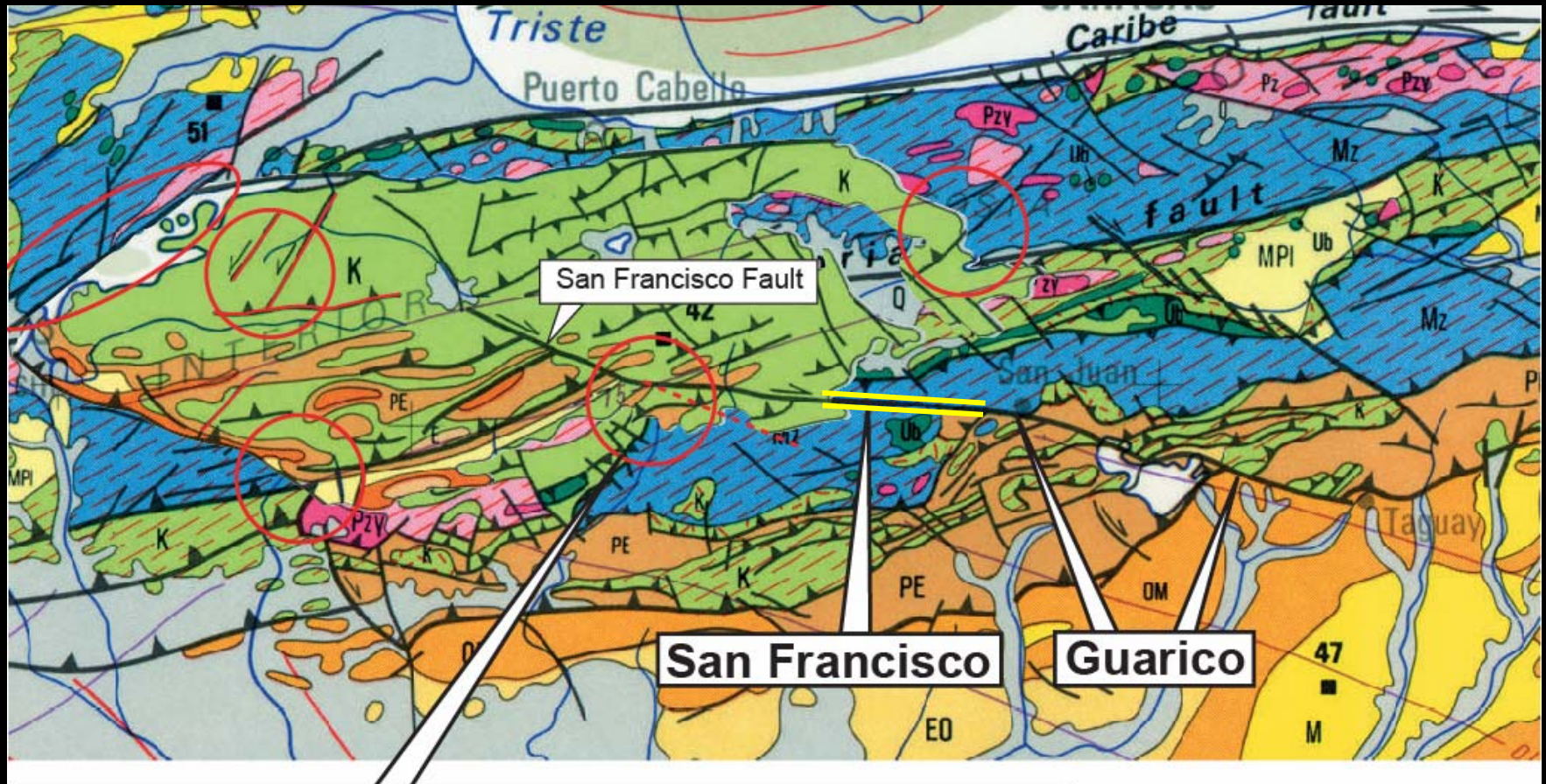
Guárico Fault



San Francisco Fault

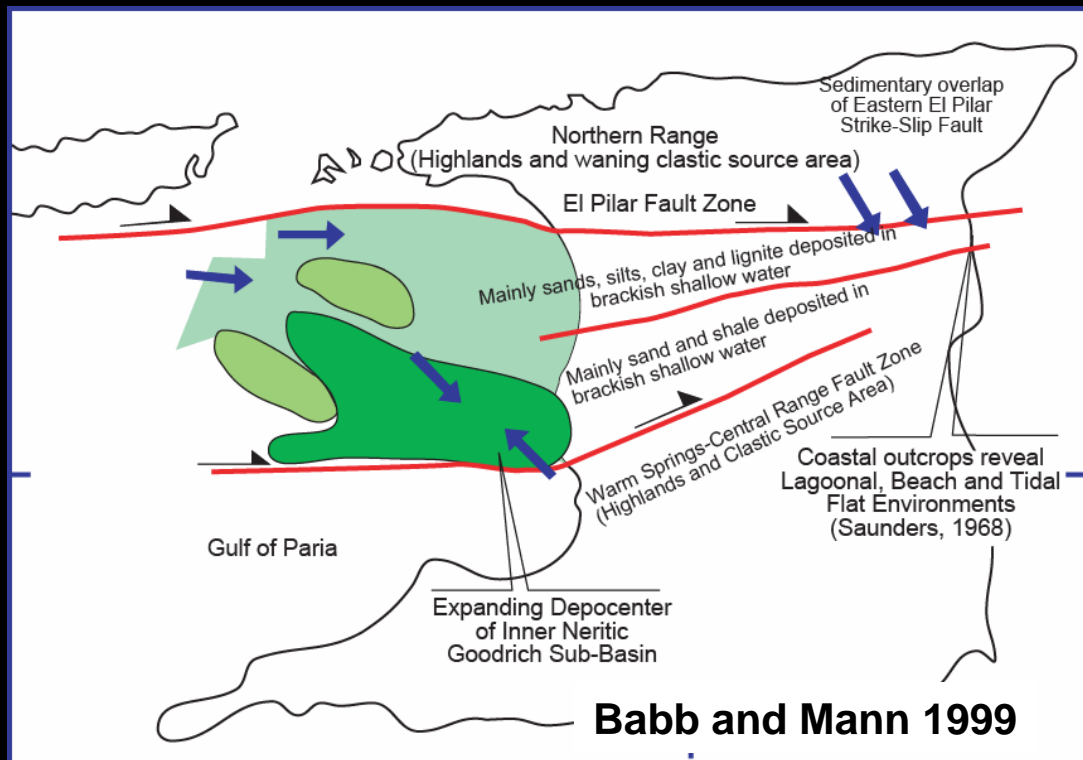
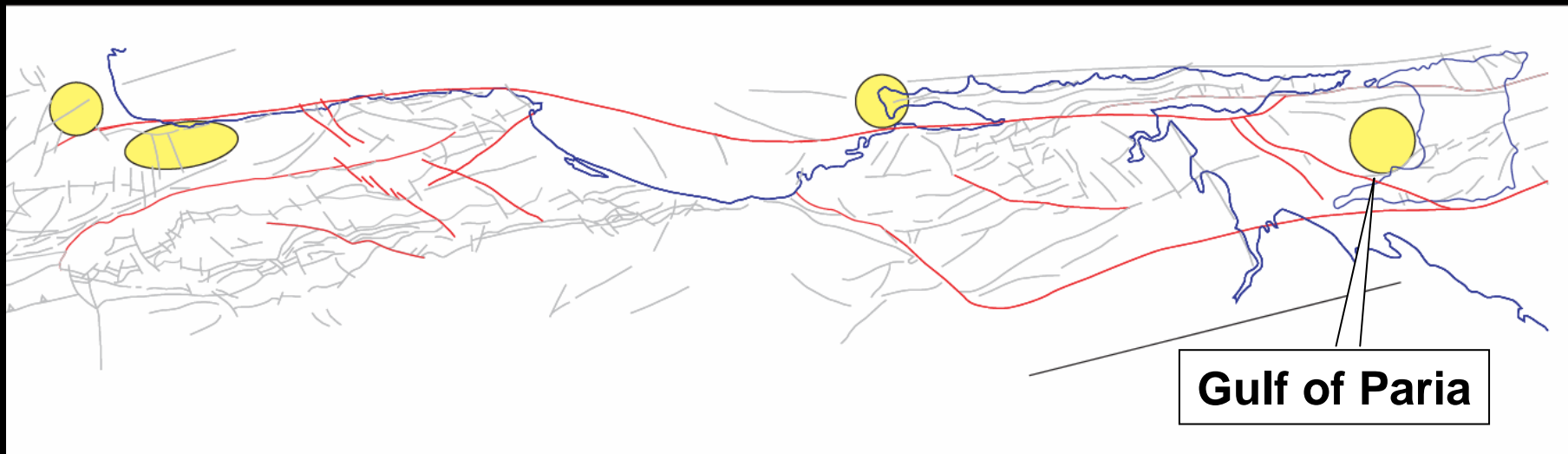
Eastern Venezuela Thrust Belt

After reconstruction



Aligned directional change in faults from both the restored cover (San Francisco Fault) and from the Cordillera Central (Thrust)

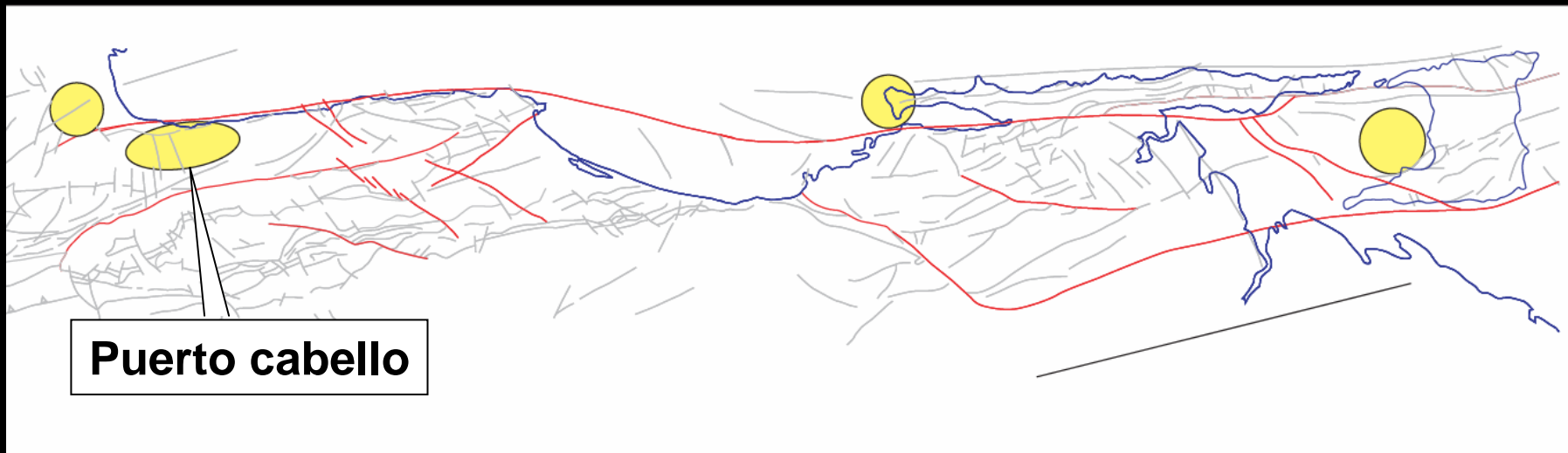
 Match after reconstruction



Gulf of Paria

problem to explain

Plio-Pleistocene
Depocenter

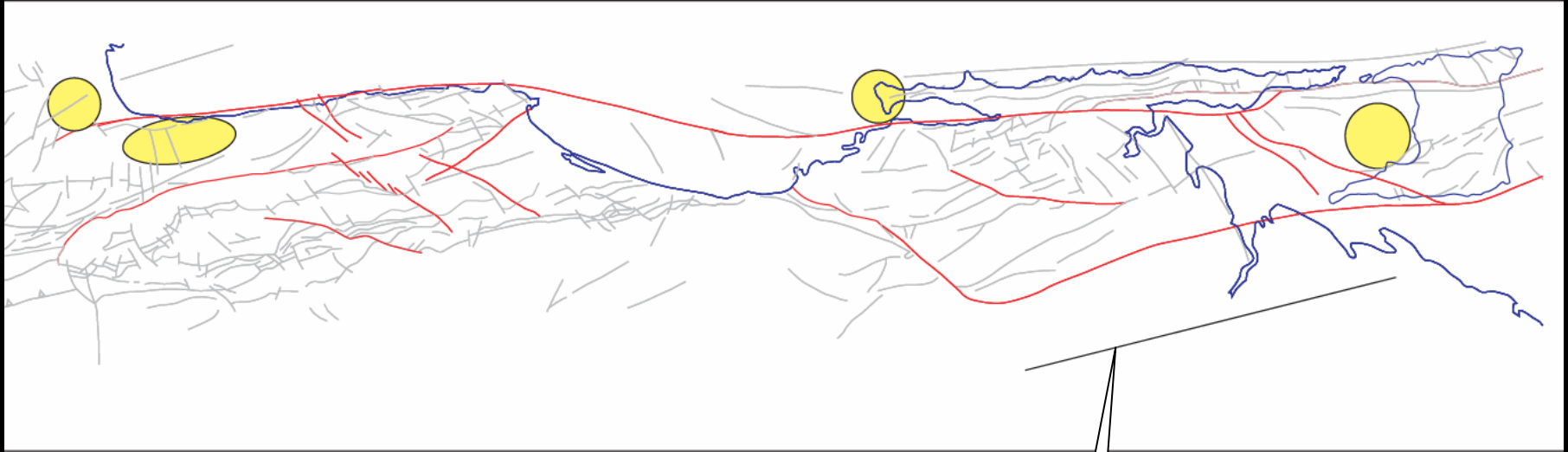


Eclogites

Garnet – Epidote

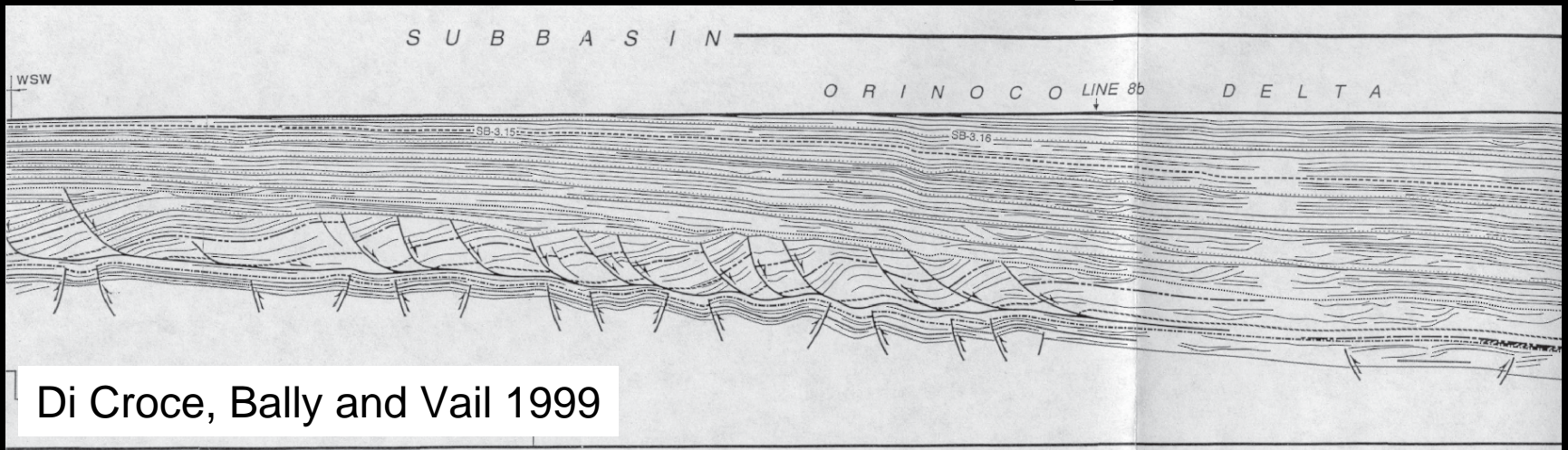
extremely rapid
exhumation



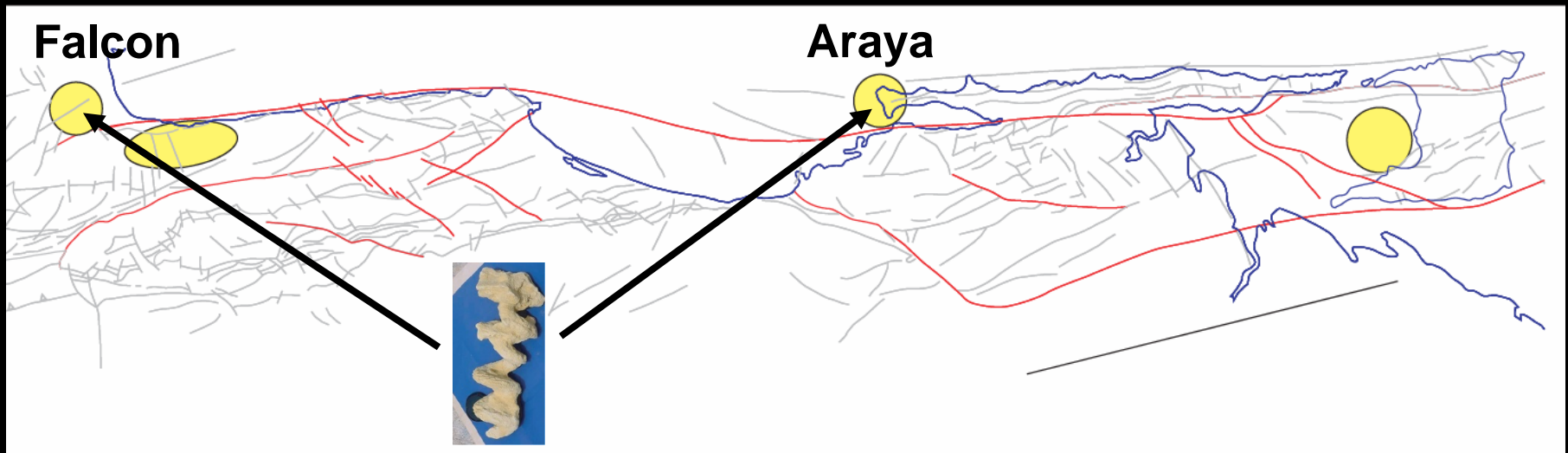


Problem of younger listric faults
towards the West

Solution:
Slump head



Di Croce, Bally and Vail 1999



Gyrolithes

and other ichnofacies

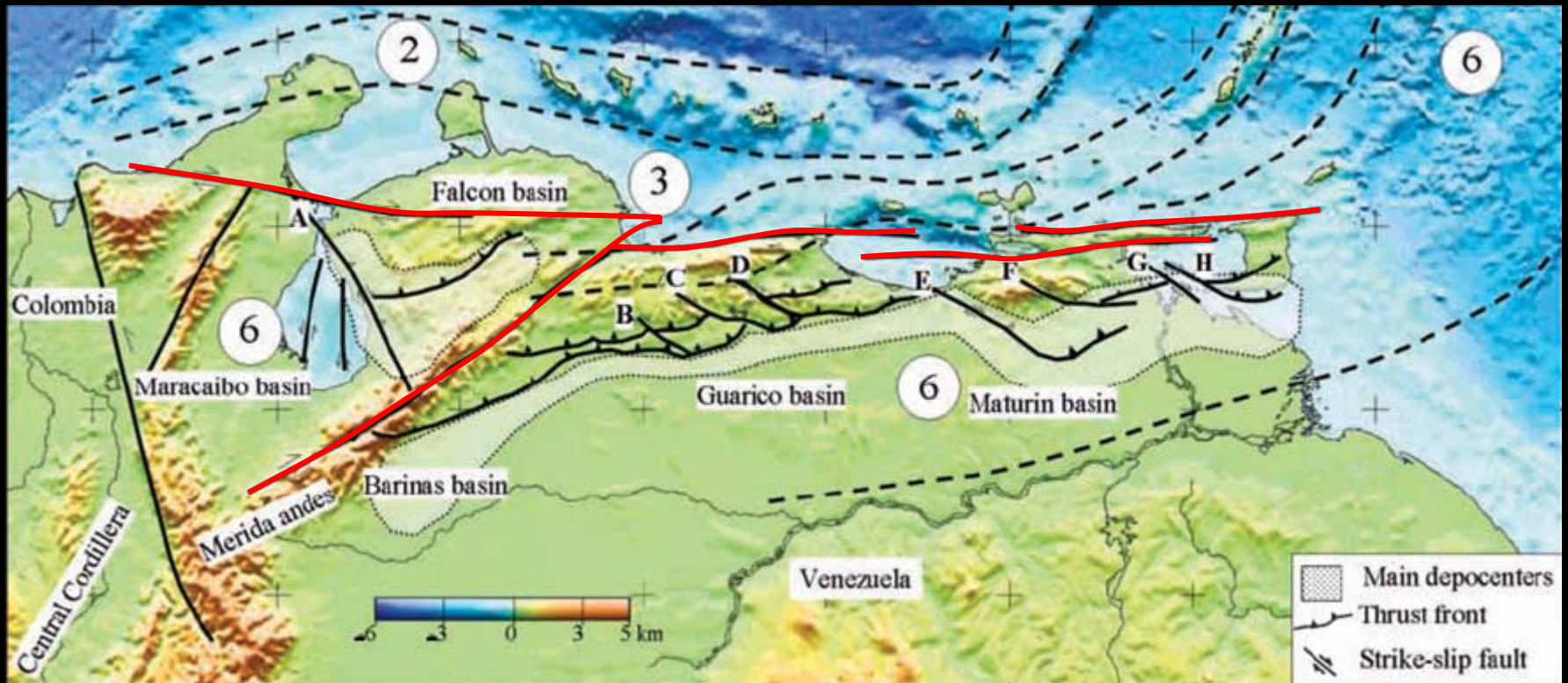
Rare and identical
successions
of ichnofabric
associations
in two places

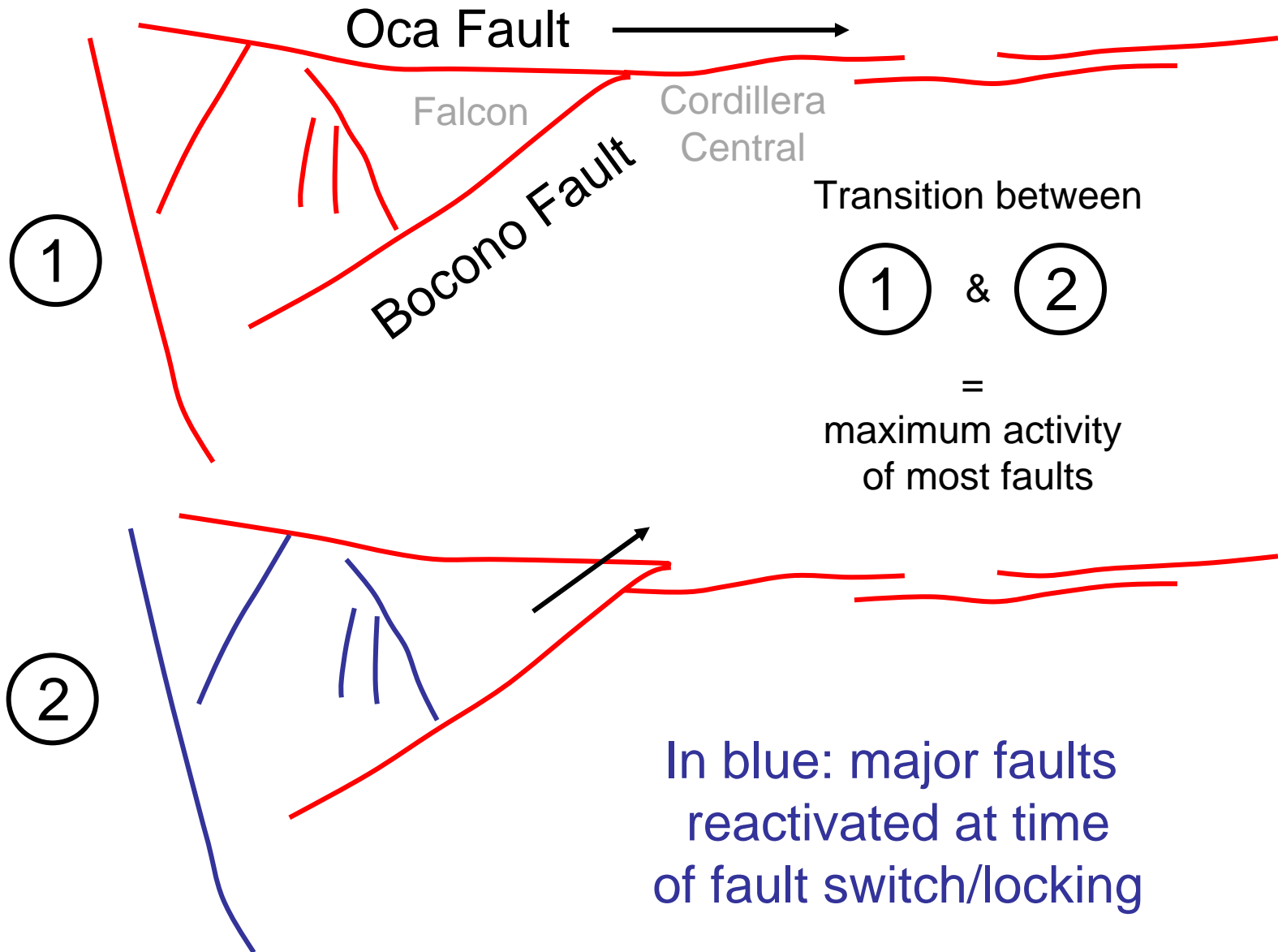


Gravity Gliding

A simple mechanism

Important faults involved in the gravity gliding hypothesis

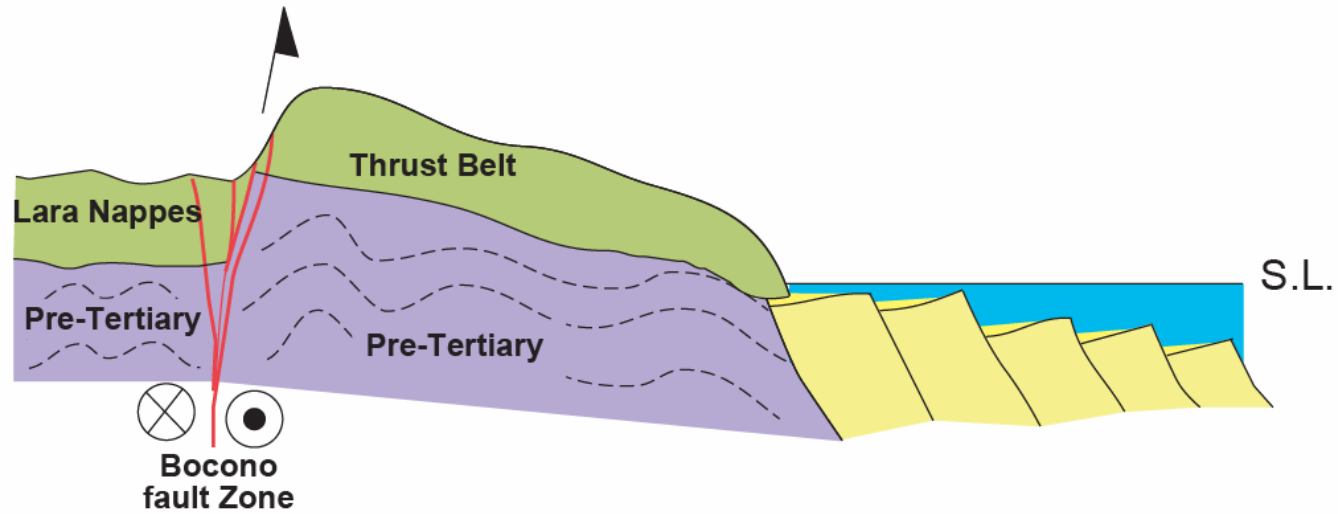




W

Falcon

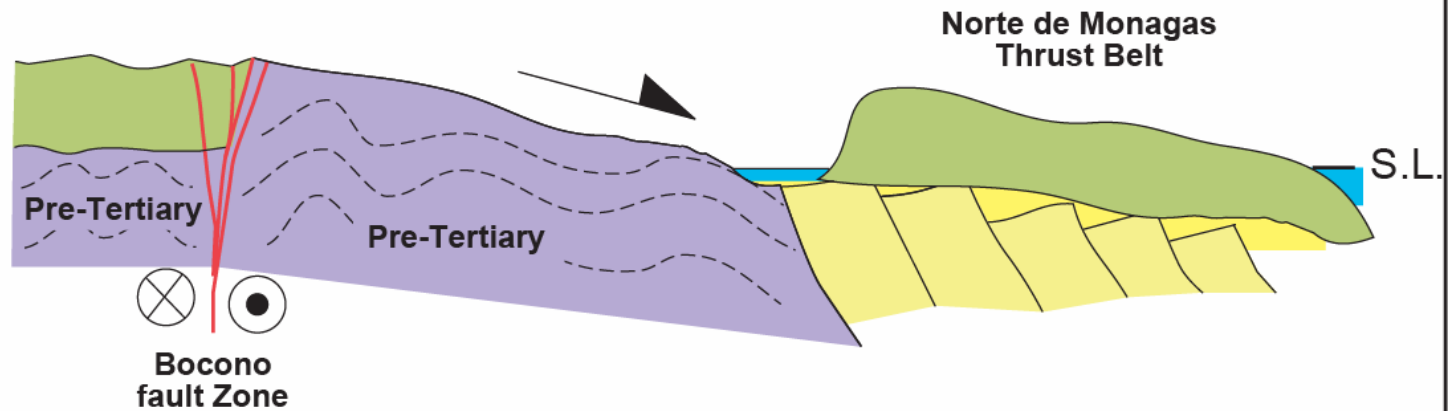
Cordillera Central

Eastern Venezuela
(Anzoategui & Sucre)**E****W**

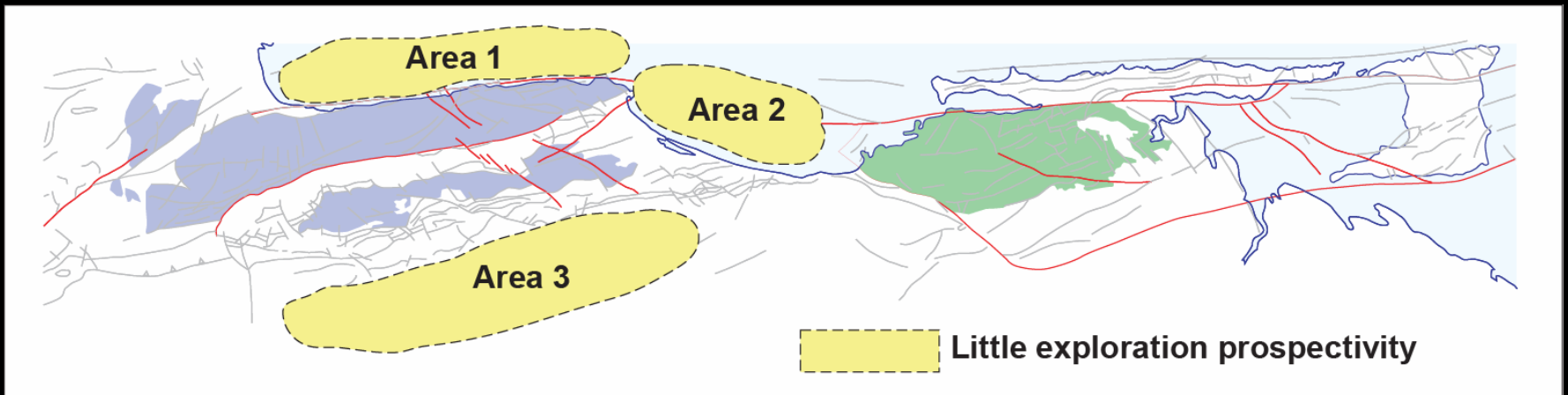
Falcon

Cordillera Central

Eastern Venezuela

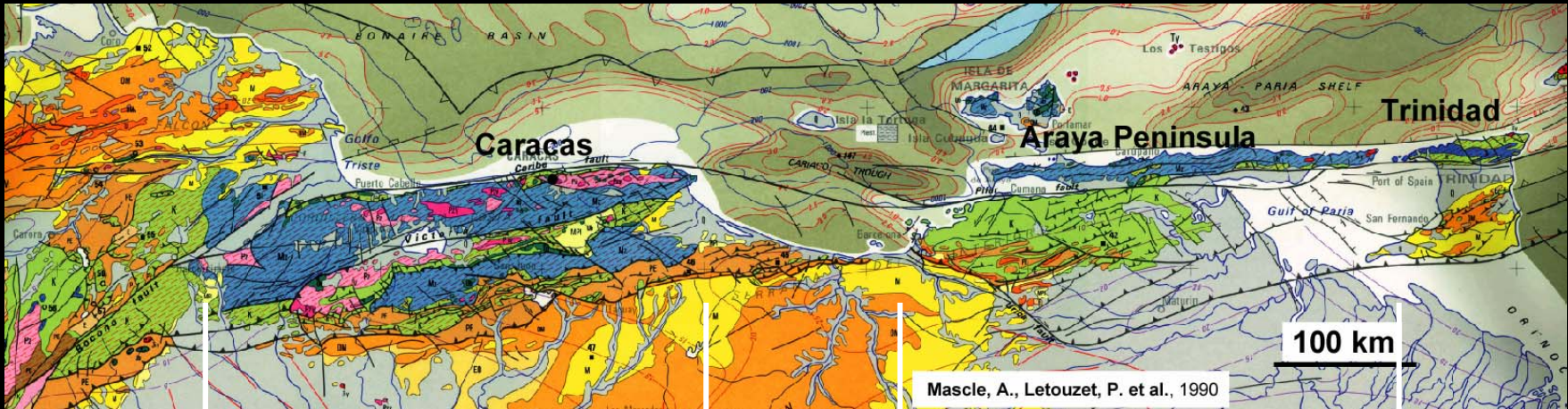
E

Understanding gravity gliding can save you big dollars



No sediments were found in any of the surrounding areas

A simple large-scale gravity glide



Missing
Cover

Cover
Found

Conclusions

- A huge vacuum below Barlovento was formed when Trinidad and the Eastern Venezuela Thrust belt glided away from the Merida Andes
- Gravity gliding is proposed as it does not deform many structural features that were matched between Area 1 and Area 2
- A major strike slip activity is responsible for giving freedom to the mega-block (to glide)
- The Atlantic passive margin to the east and the oblique subduction to the north (along Oca-Pilar fault system) are the two main dragging/driving mechanisms for the gravity gliding

For exploration

- Many dry wells could have been avoided and huge amount of money saved
- The giant fields in Eastern Venezuela could have been found 30 years earlier if people had understood the gravity gliding mechanism
- Other areas in the world are replicas of the example shown, some closer to us than you may think

This is promising for the future

References about existing geological interpretation problems in Venezuela

- Audemard, F et al., 1999, Trench investigation along the Merida section of the Bocono fault (eastern Venezuelan Andes), Venezuela, Tectonophysics vol., 308 p-1-21
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