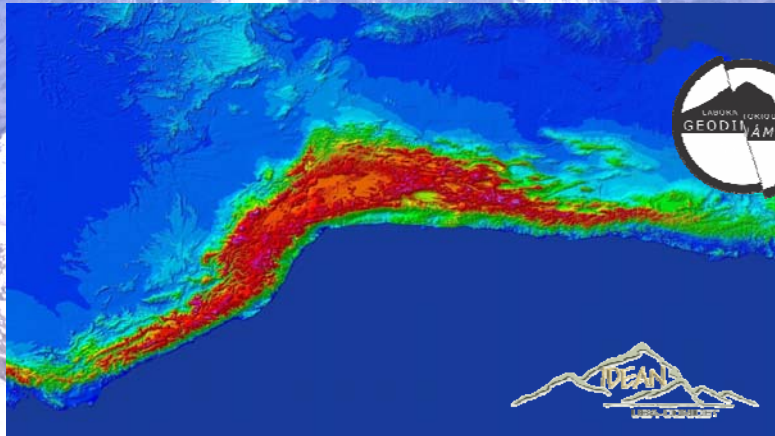


ENEGEOL 2017

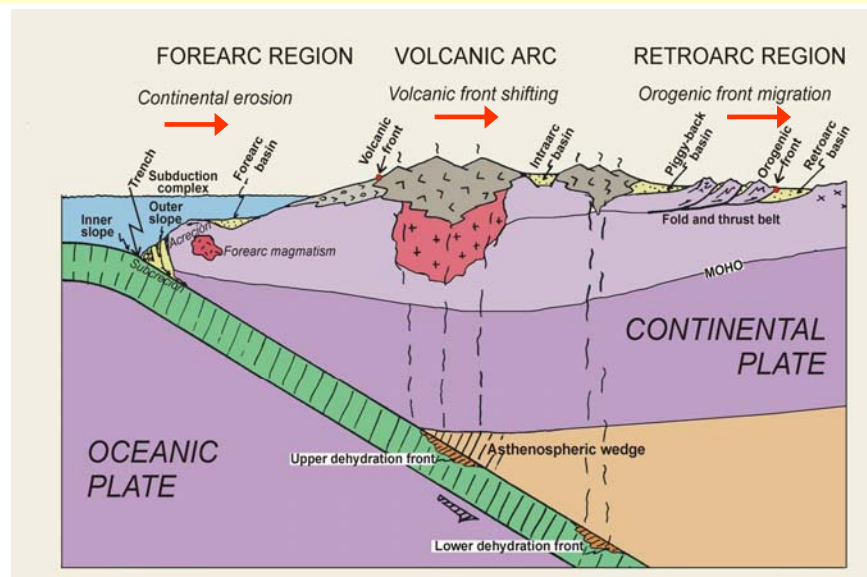
Encuentro Nacional de Estudiantes de Geología, Copiapó, Región de Atacama

Andrés Folguera



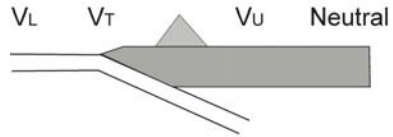
## Una introducción a los procesos formadores de montañas y a los Andes

### THE SUBDUCTION SYSTEM

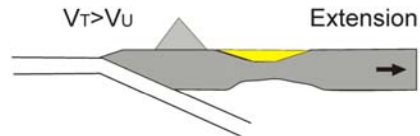


## VELOCIDAD DE RETROCESO (ROLL-BACK) DE LA TRINCHERA:

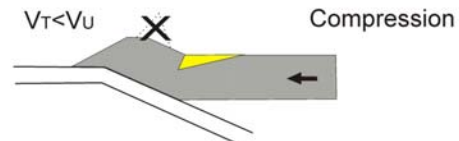
Sin cuenca de retroarco



Cuenca de retroarco extensional



Cuenca de antepaís de retroarco



**VELOCIDADES  
ABSOLUTAS ENTRE  
LAS DOS PLACAS**

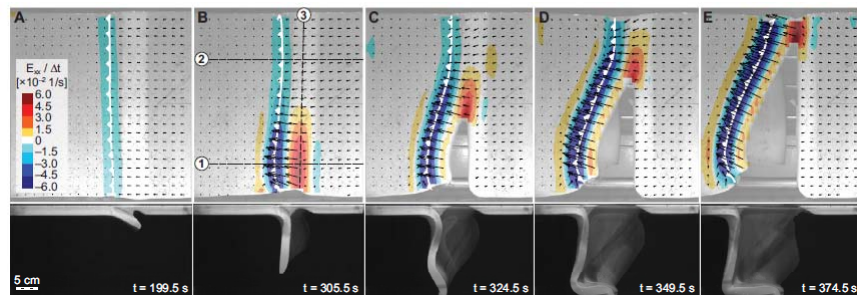
Relative velocities:

$V_T$  = Subduction hinge roll-back

$V_U$  = Overriding plate

$V_L$  = Lower plate

*Daly (1989)*

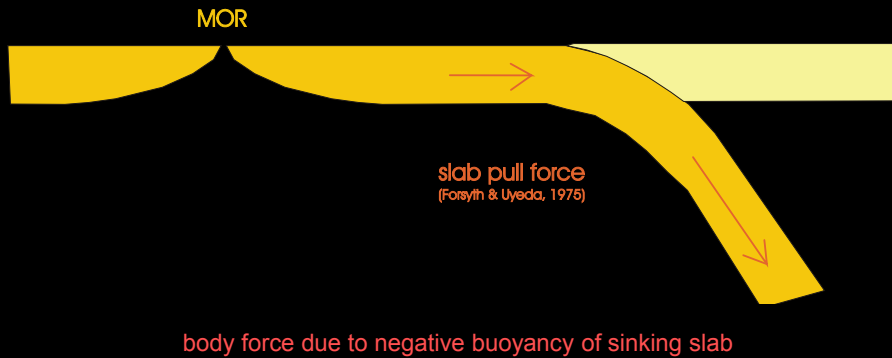


Boutelier y Cruden 2013

*foundational ideas and developments on plate tectonics*

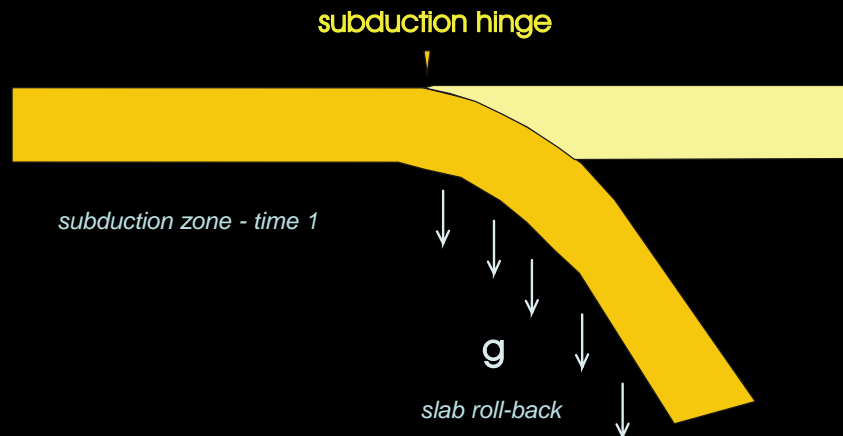
(Wegener, 1924; Elsasser, 1971; Forsyth & Uyeda, 1975; Chase, 1978; Dewey, 1980; Royden, 1993)

Animación: Rubén Somoza

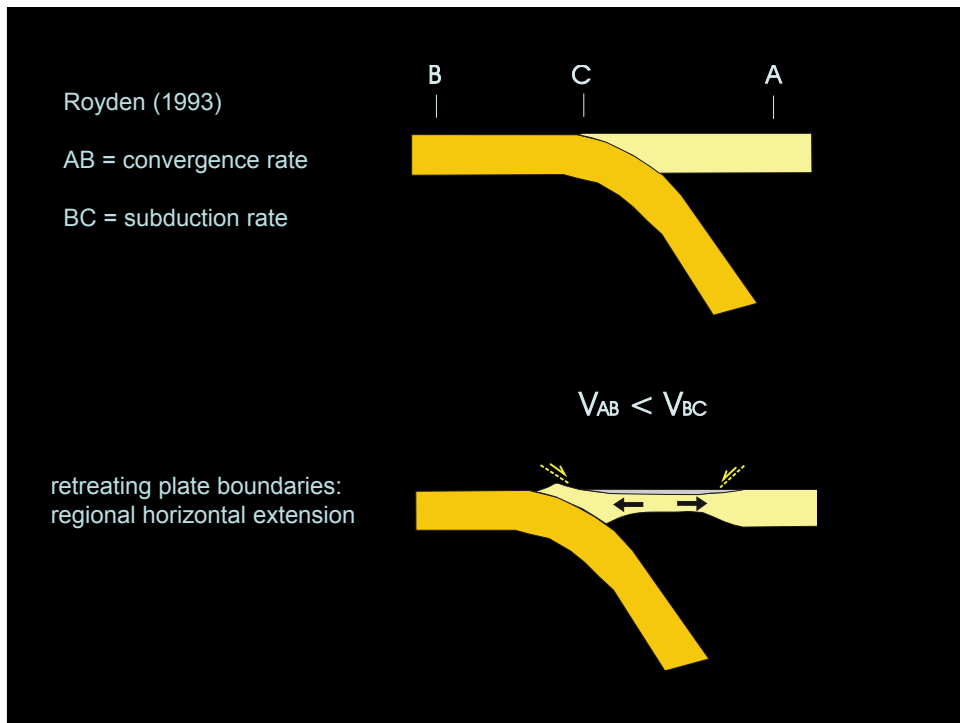
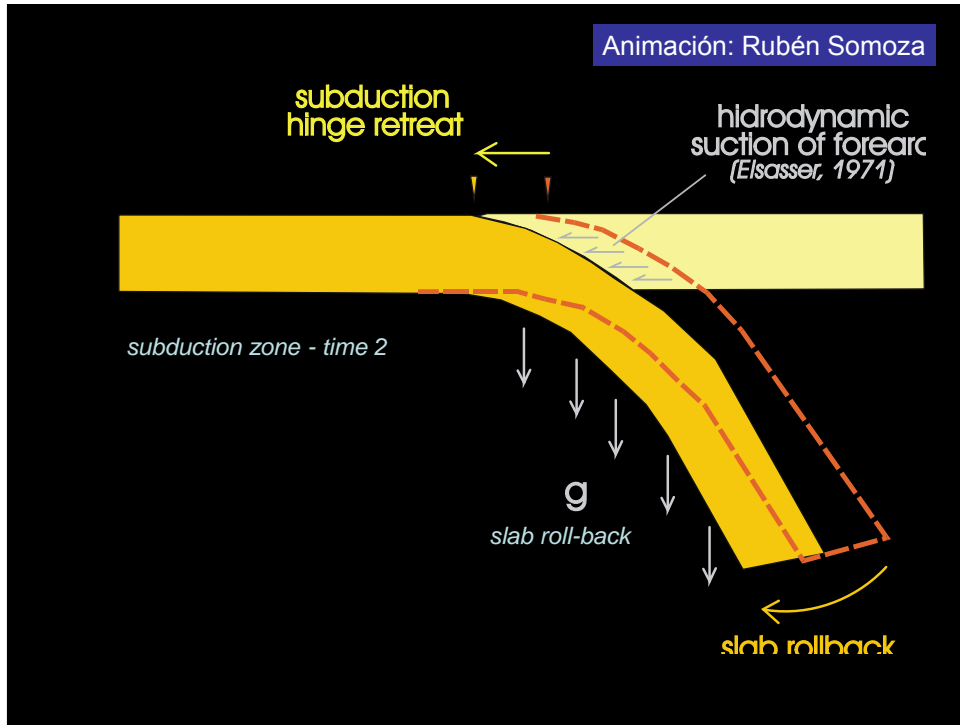


suction force

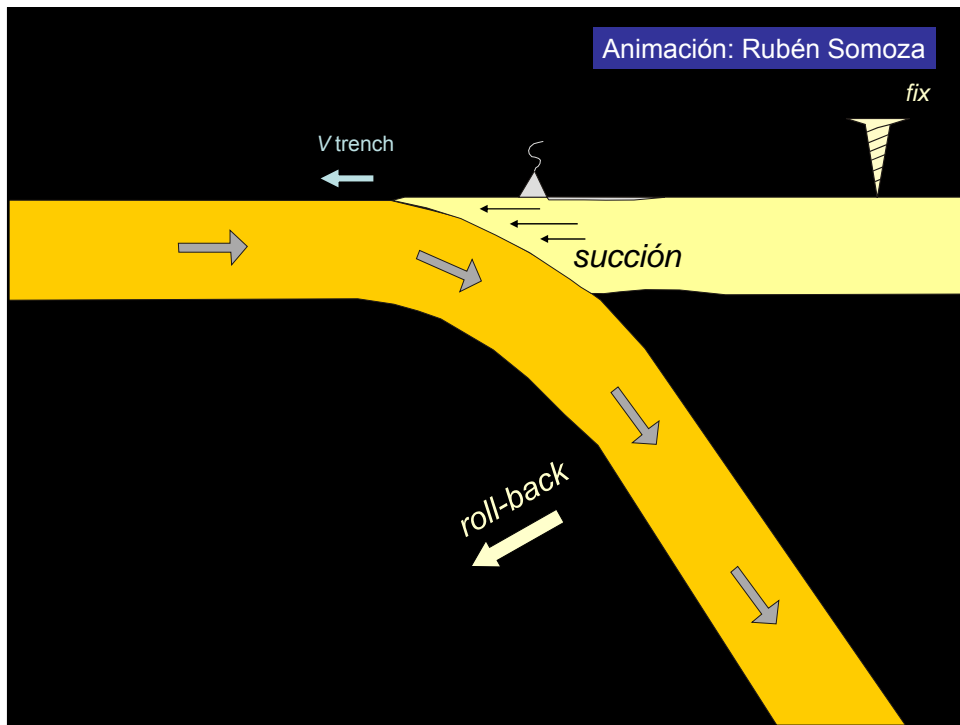
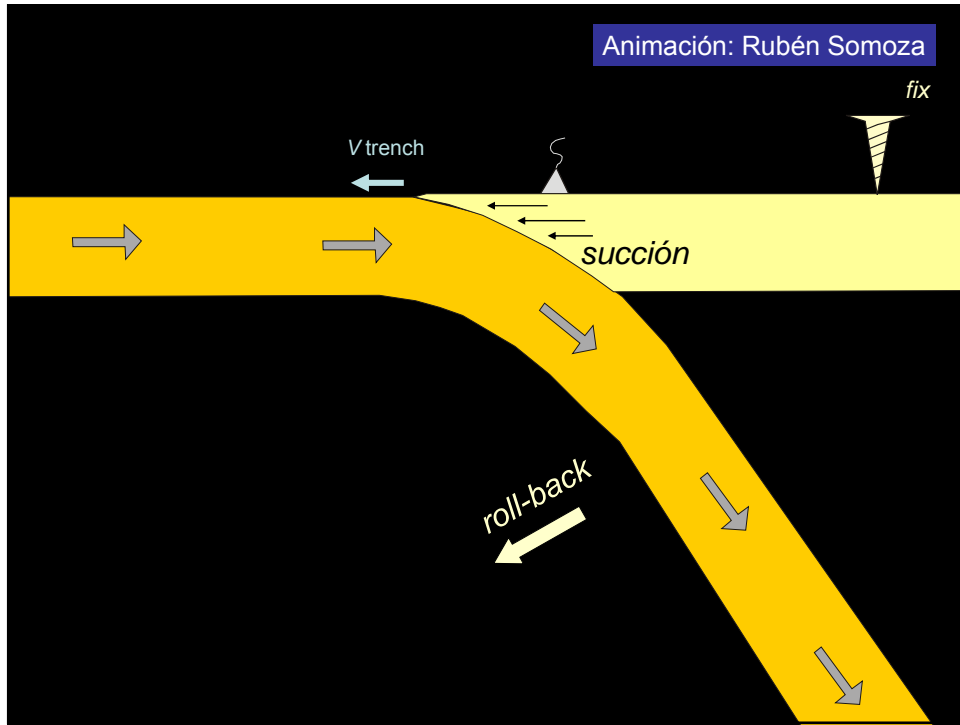
Animación: Rubén Somoza

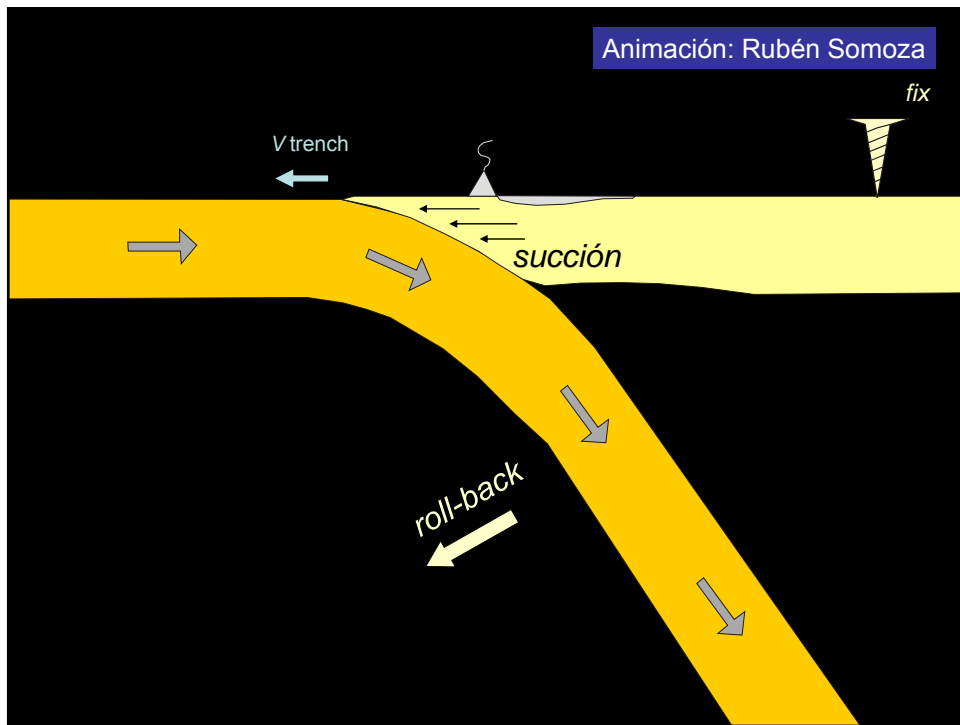
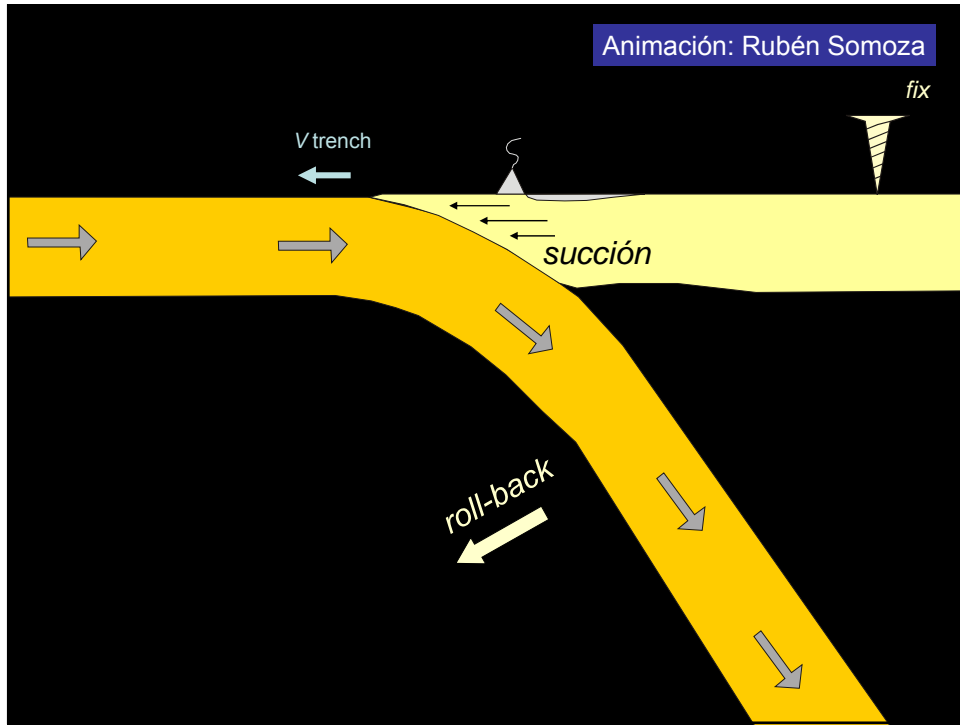


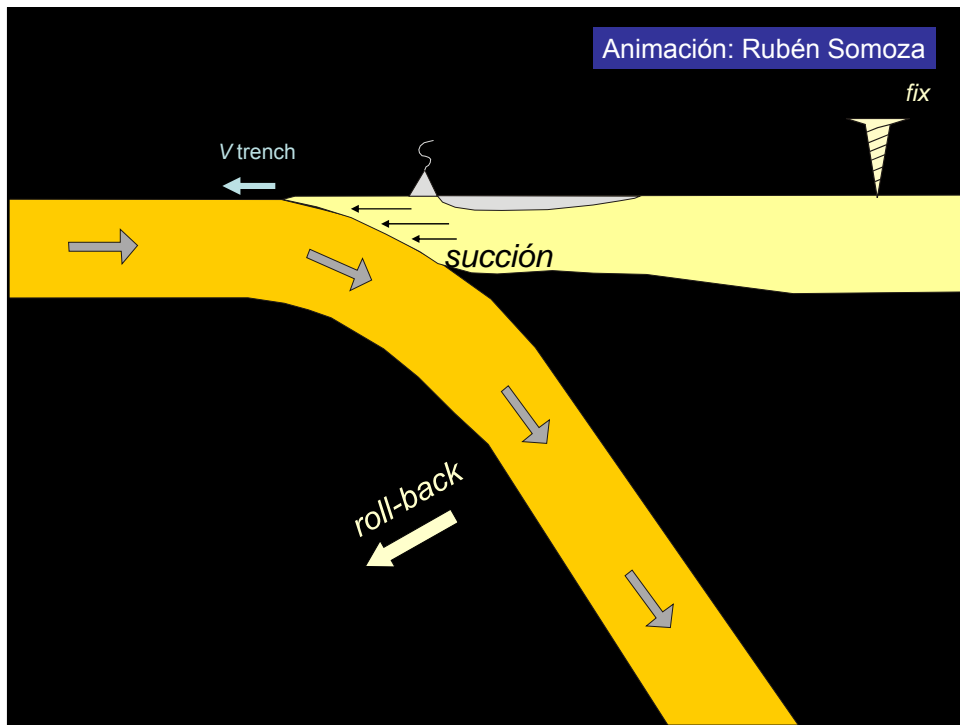
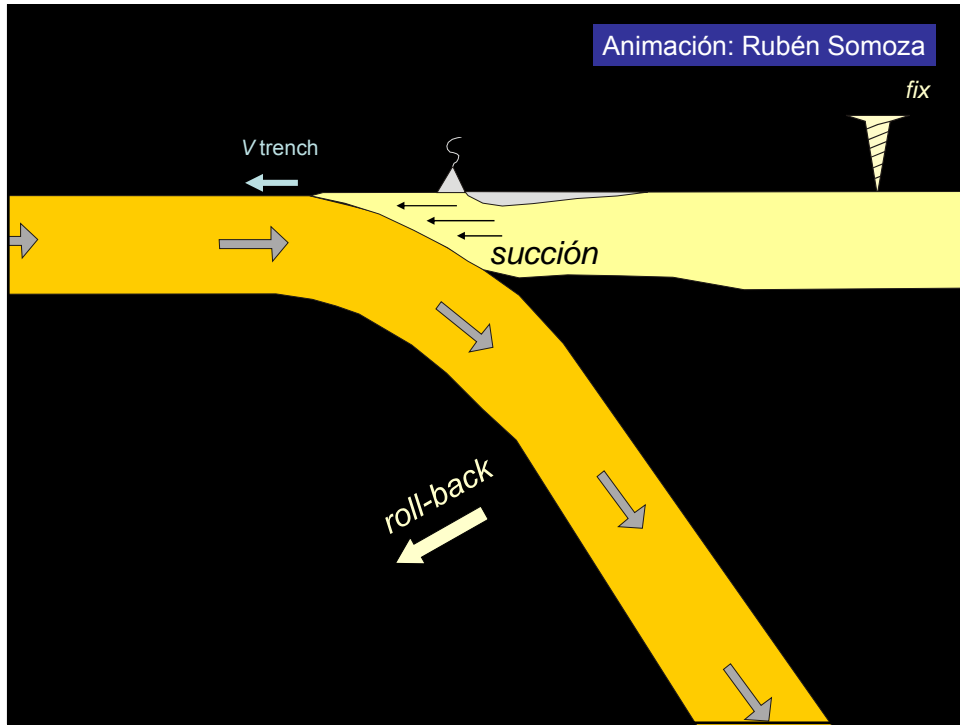
hydrodynamic suction of the leading edge of overriding plate due to continuous downwarping of the underlying plate at the trench

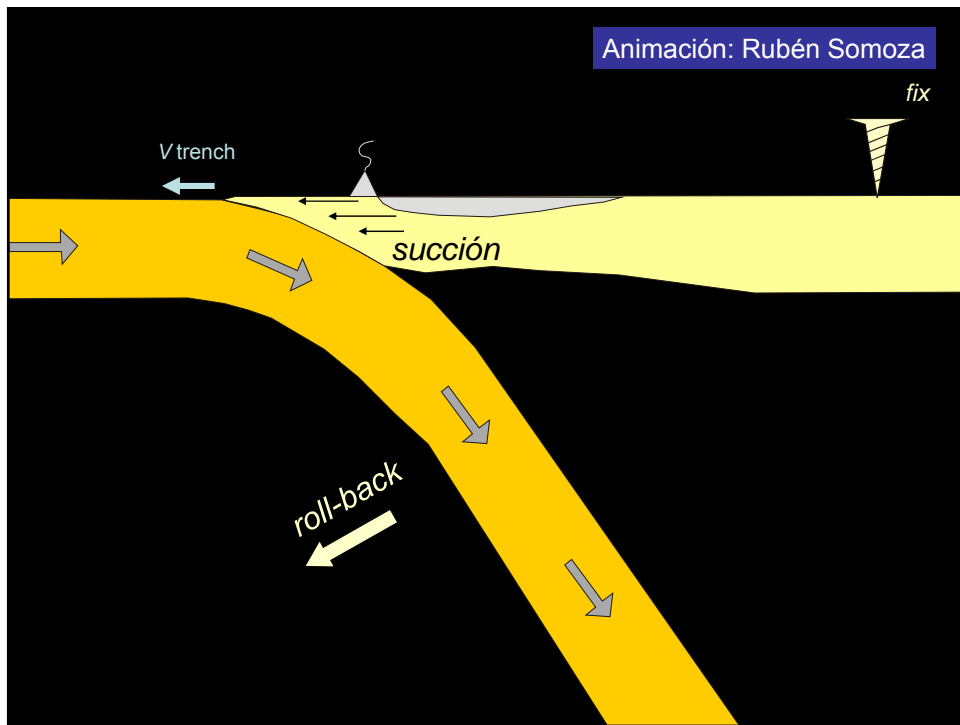
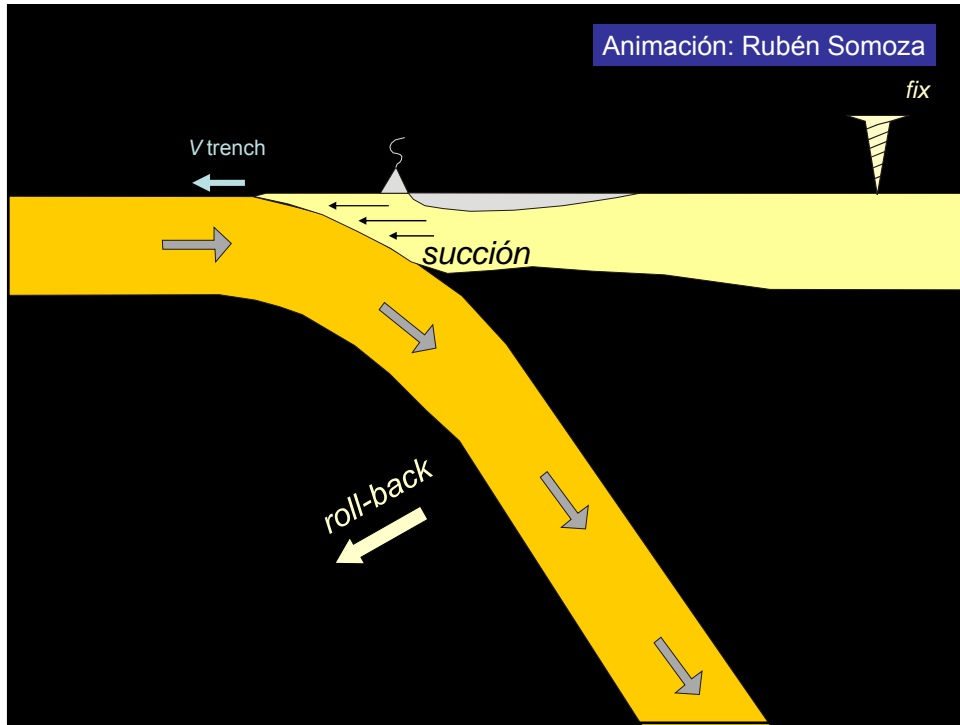














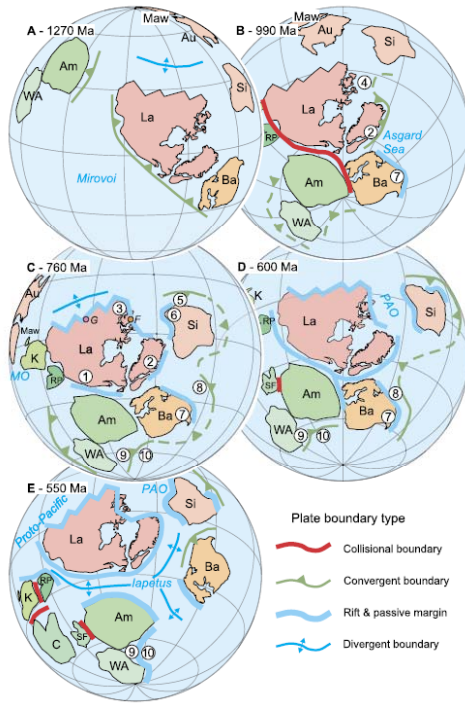


Cawood et al 2016

Actualmente se considera que roll back es un mecanismo poderoso para fragmentar supercontinentes

Tiempo de desarrollo de orógenos acrecionales periféricos a rodinia coinciden con tiempos de rifting

Se considera que retroceso de trincheras es el mecanismo que gatilla extensión supercontinental

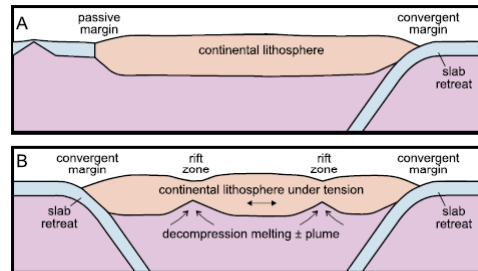


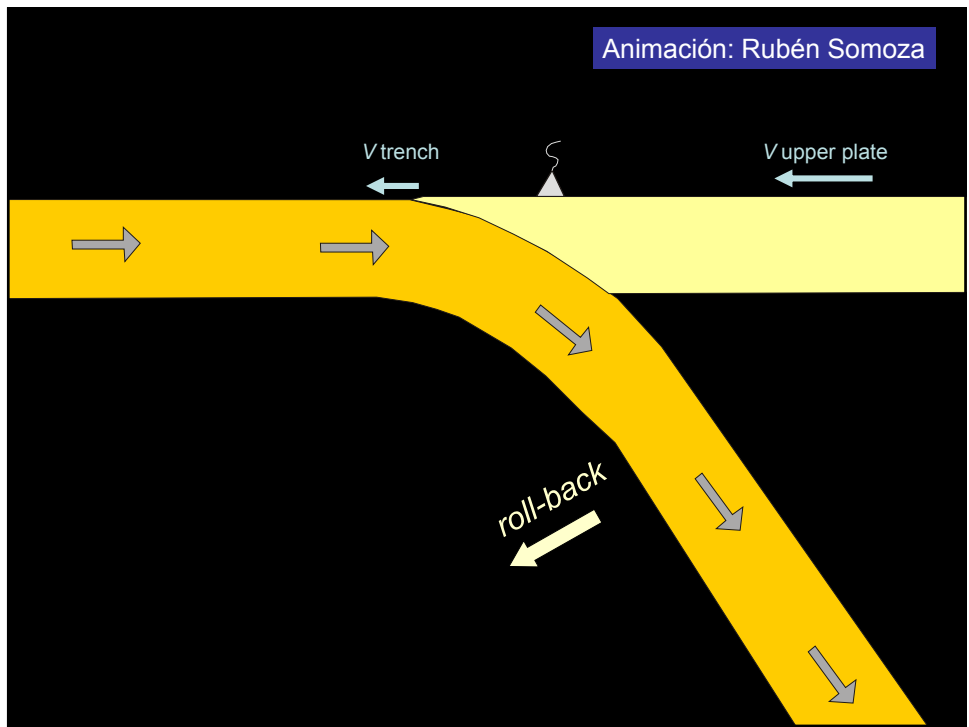
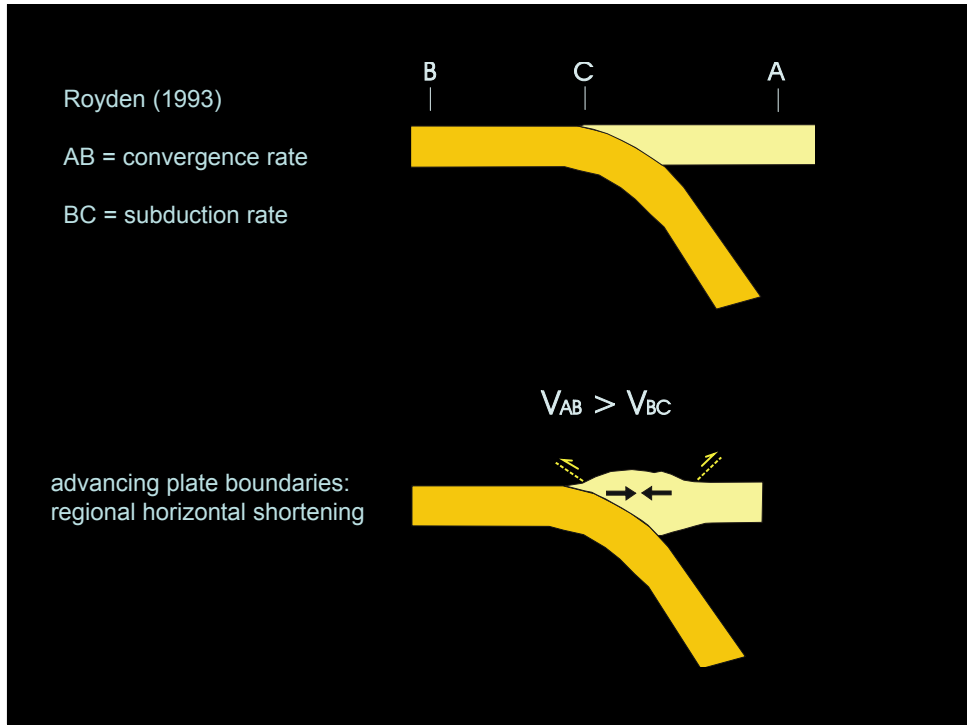
Cawood et al 2016

Actualmente se considera que roll back es un mecanismo poderoso para fragmentar supercontinentes

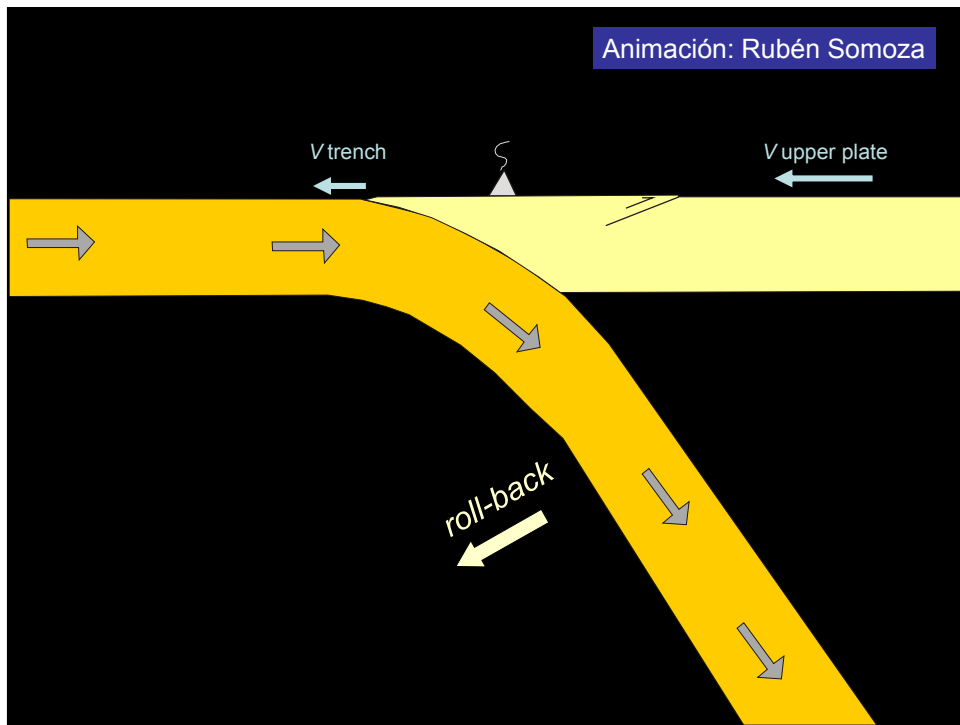
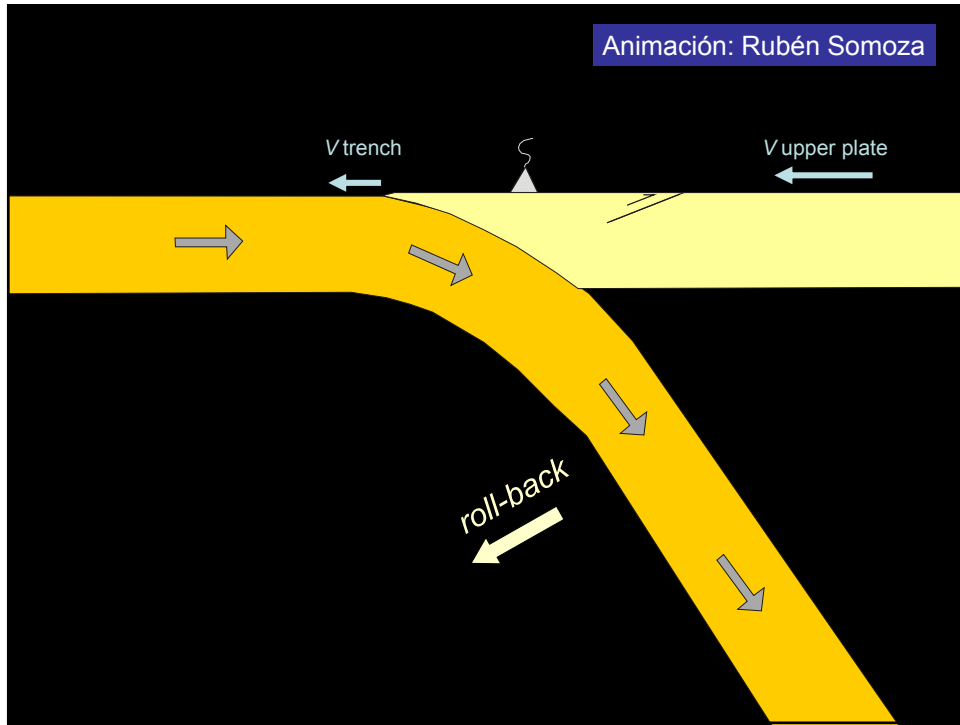
Tiempo de desarrollo de orógenos acrecionales periféricos a rodinia coinciden con tiempos de rifting

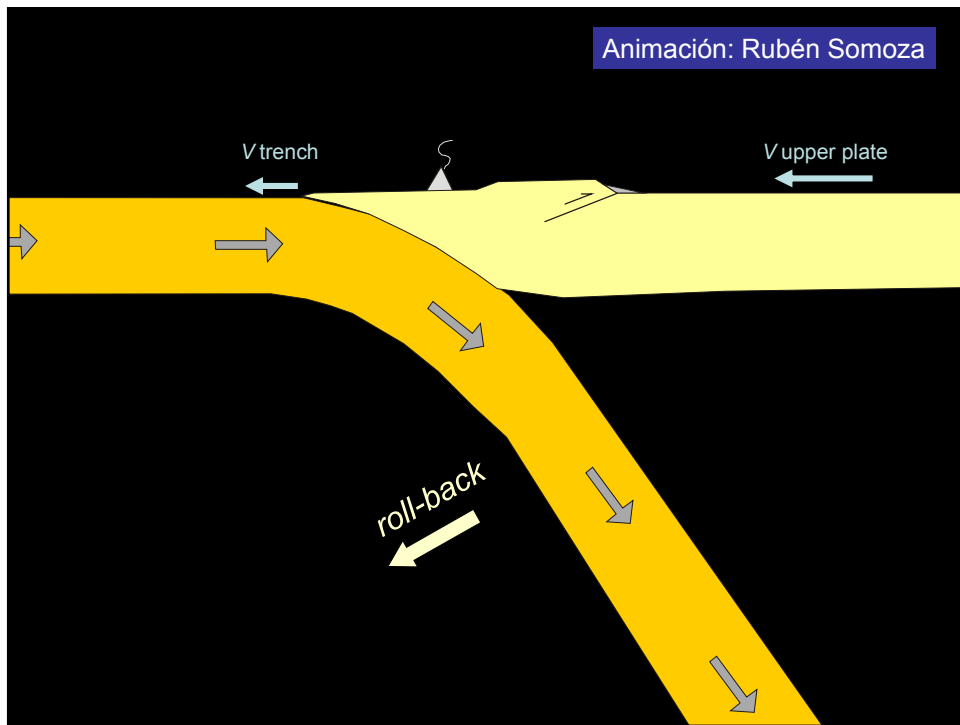
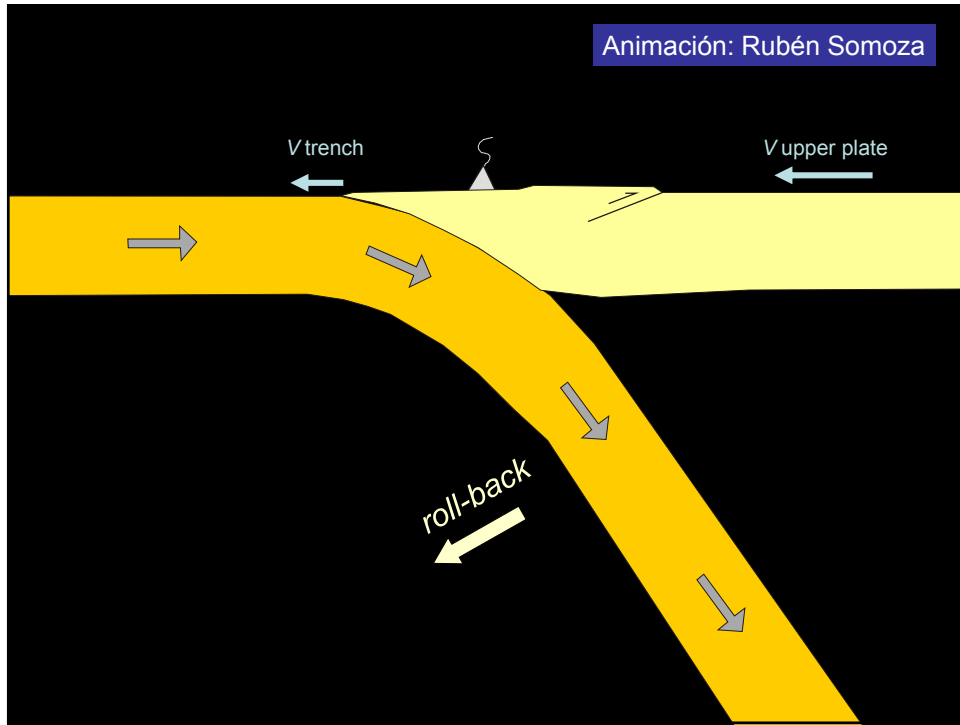
Se considera que retroceso de trincheras es el mecanismo que gatilla extensión supercontinental

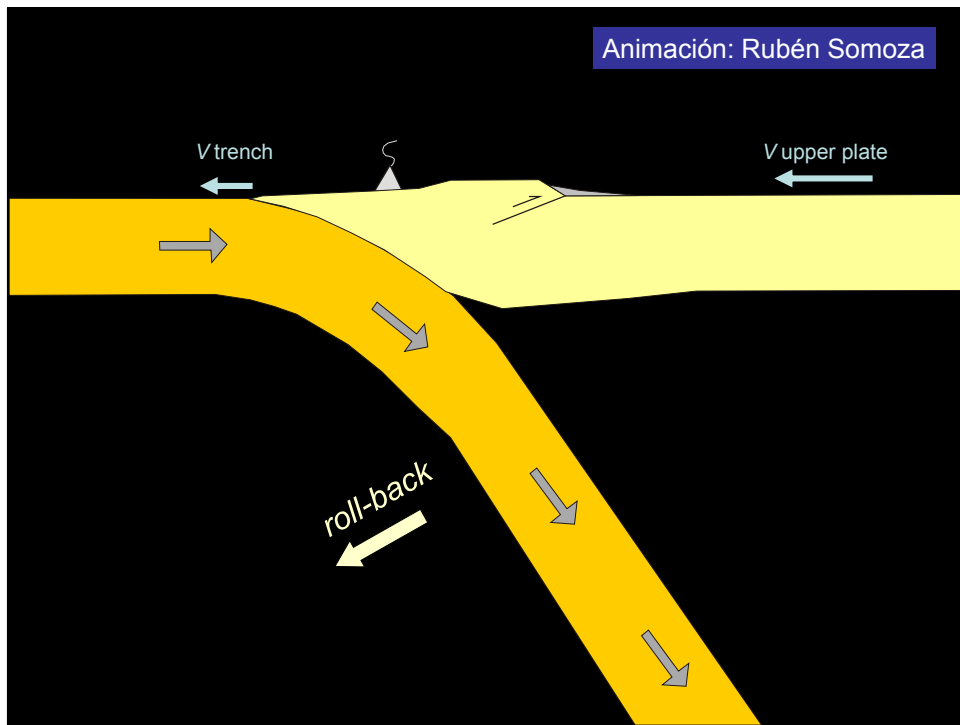
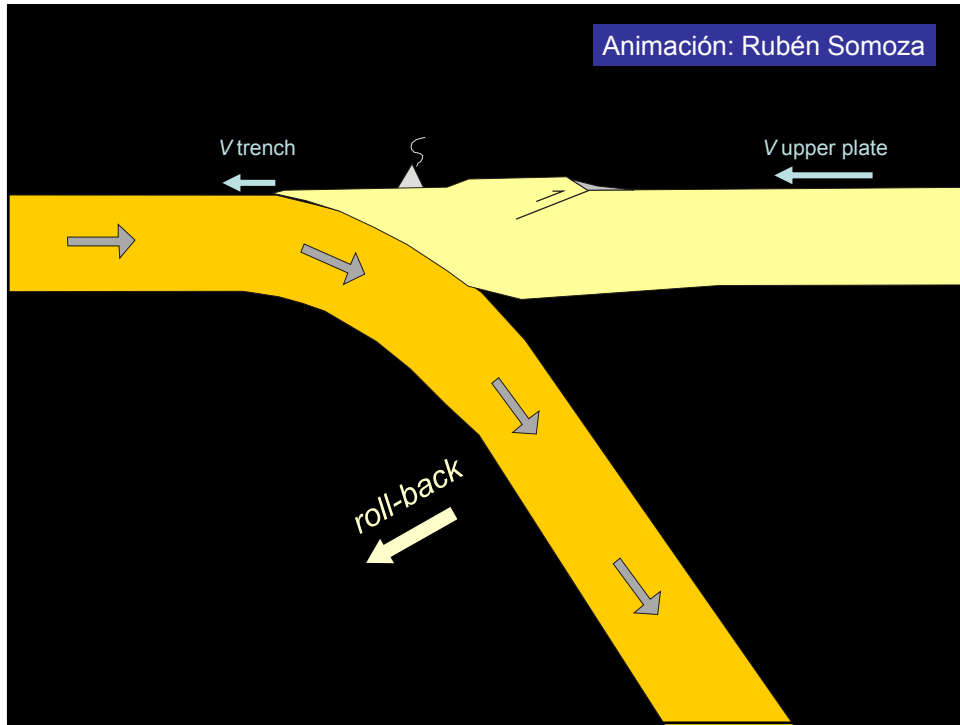


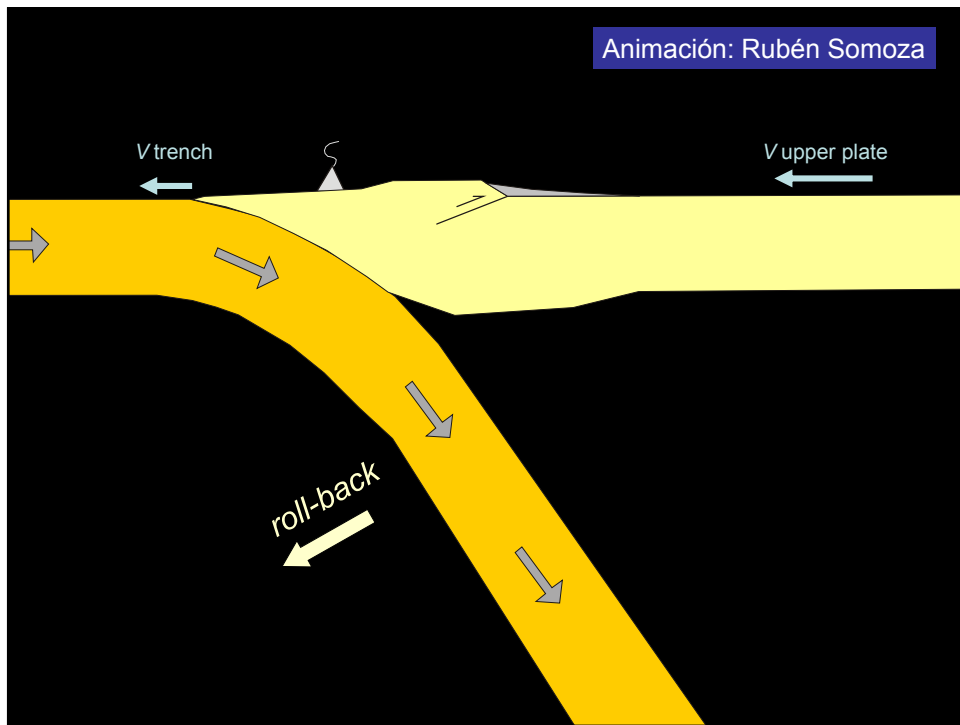
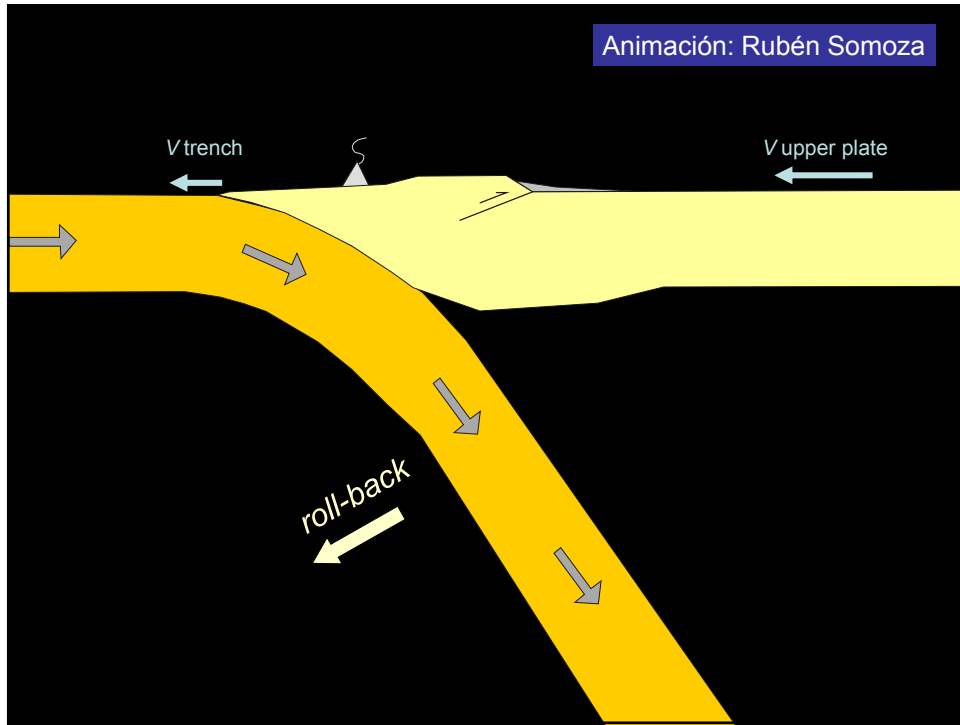


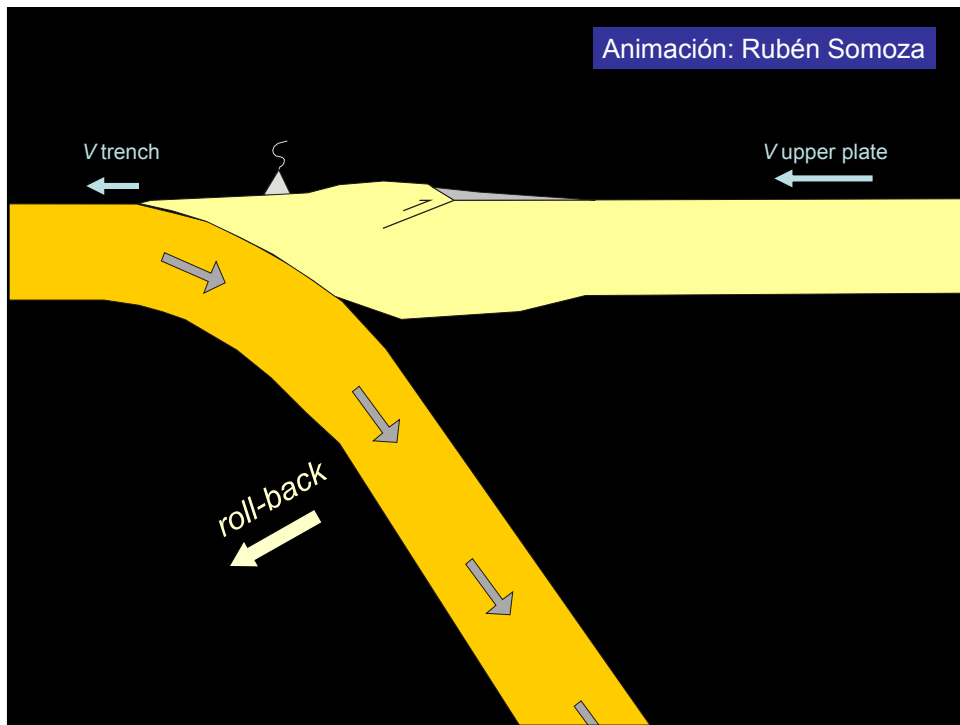
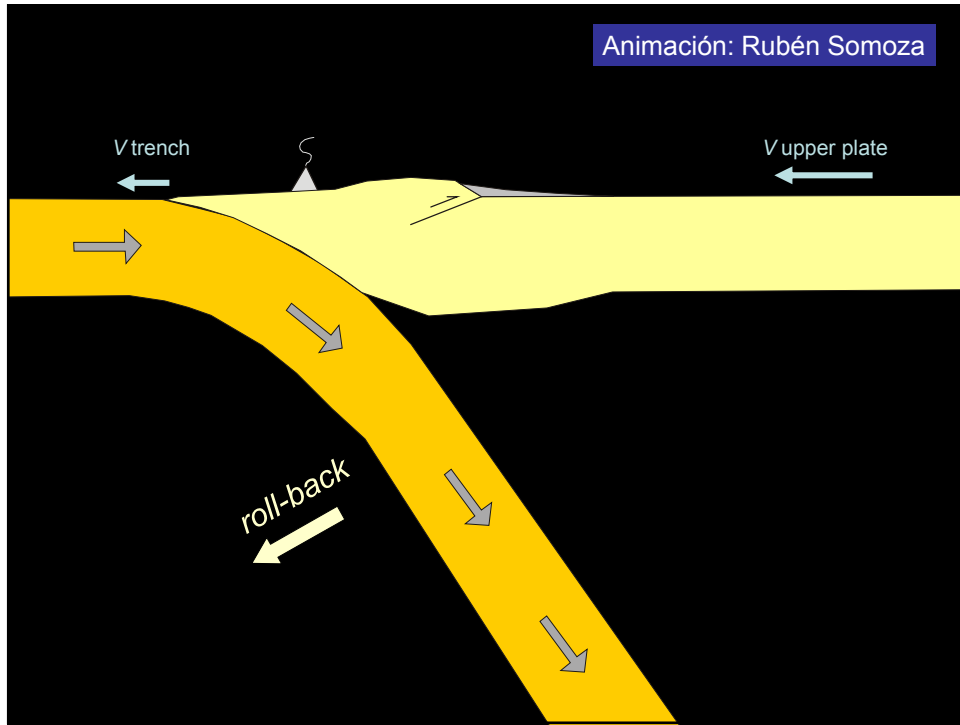


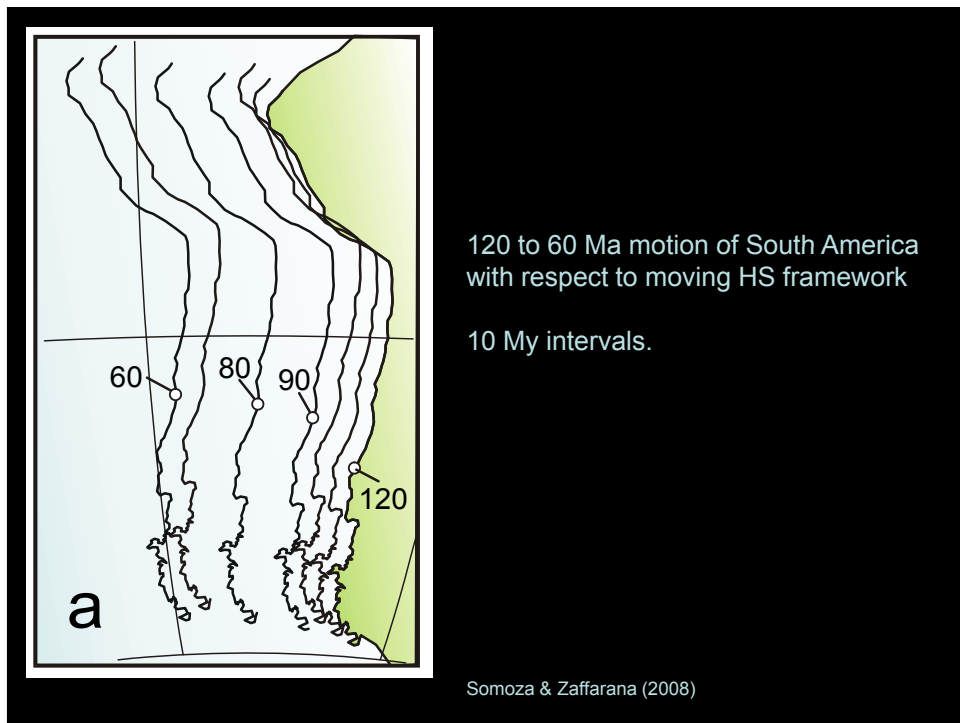
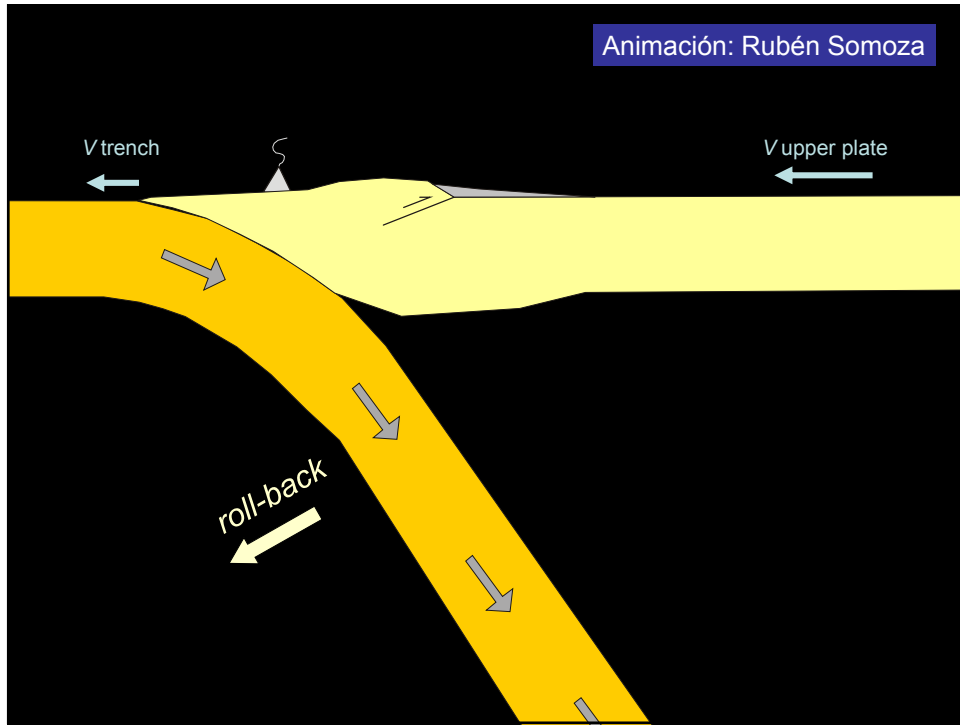


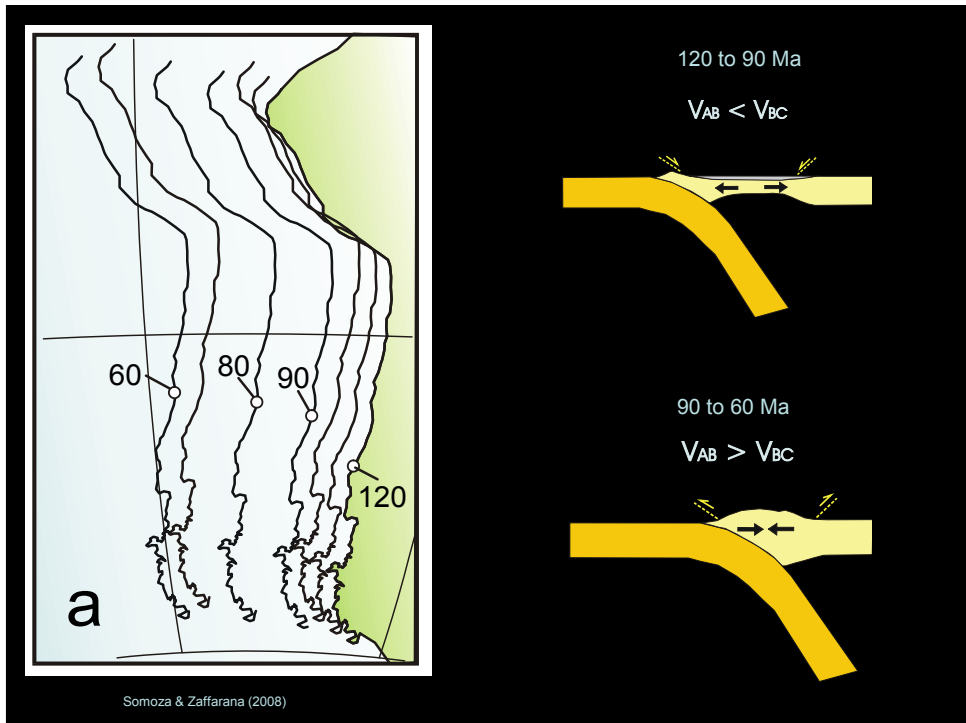
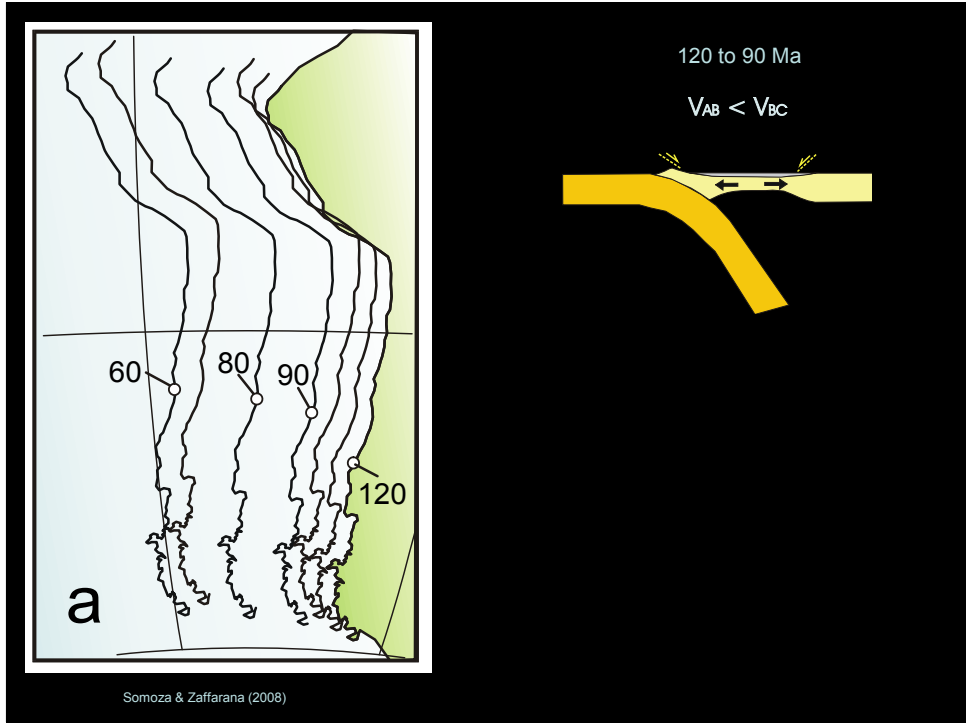






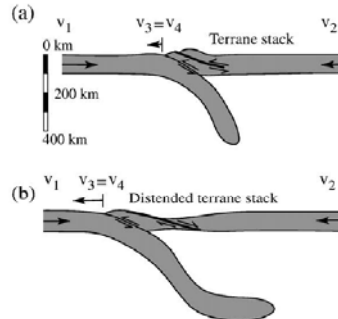






**Tectonic mode switches and the nature of orogenesis**  
 Gordon Lister □, Marnie Forster, 2009

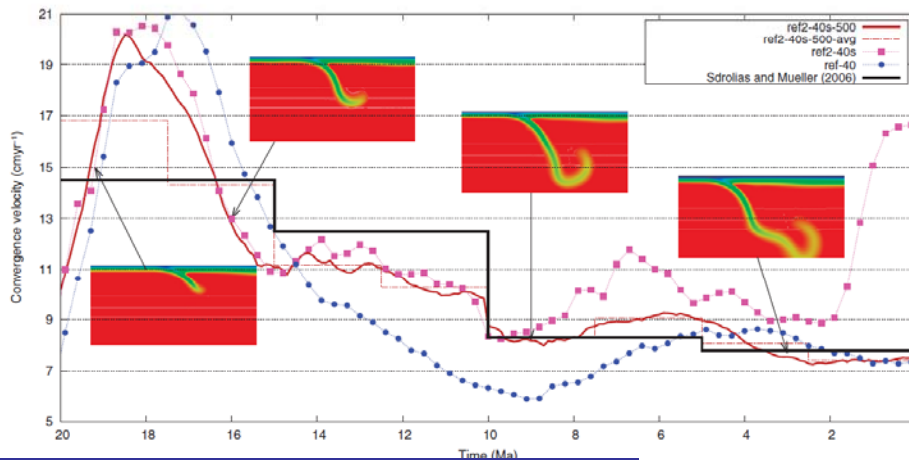
A slowing of roll-back (or of hinge retreat) means that the subduction flexure may subsequently begin to be “pushed back” or be “pushed over” by the advancing orogen. The consequence of such changes in relative motion is that orogenic belts are affected by abrupt tectonic mode switches. The change from “push” to “pull” leads to a sudden change from horizontal extension to horizontal shortening, potentially throughout the entire mass of the orogenic lithosphere that over-rides the subducting slab.



Cambio drástico entre orógeno arrastrado por un roll back hacia trinchera y una trinchera que drásticamente se frena en su retroceso promueve orogénesis

Quinteros et al., 2012

- 1) Aceleración de placa al aumentar longitud de segmento subducido
- 2) Máxima velocidad ante cambio mineralógico previo a 410 km
- 3) Desaceleración brusca en 660 km por flotabilidad de losa



Variaciones de velocidad en función de un ciclo subductivo

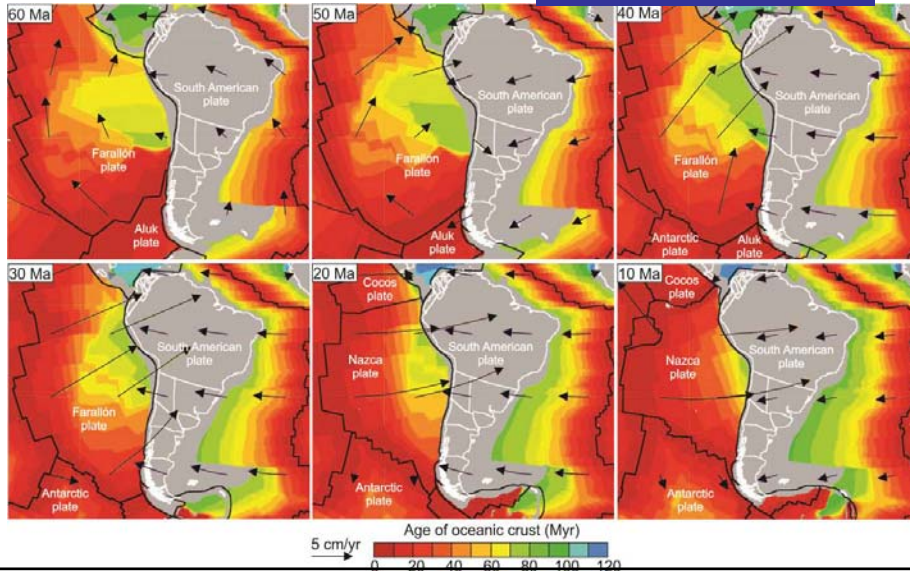


The role of the slab pull force in the late Oligocene to early Miocene extensional regime in the Central Andes (17°-46°S): insights from numerical modeling

Fennell et al 2017

Müller et al. (2016)

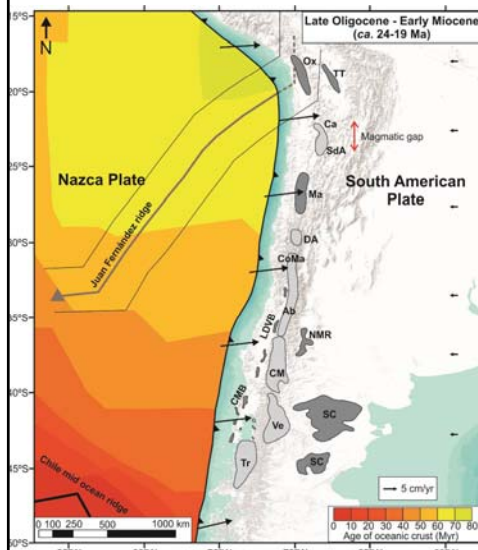
A partir de los 26 Ma comienza a introducirse el suelo oceánico en forma ortogonal en los Andes del sur



The role of the slab pull force in the late Oligocene to early Miocene extensional regime in the Central Andes (17°-46°S): insights from numerical modeling

Fennell et al 2017

A partir de los 26 Ma comienza a introducirse el suelo oceánico en forma ortogonal en los Andes del sur

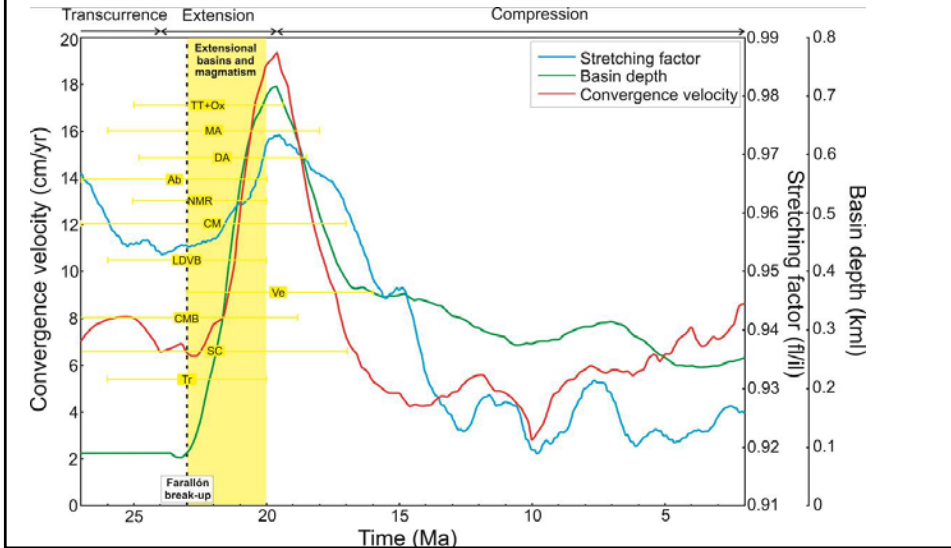


Cuencas extensionales oligocenas

The role of the slab pull force in the late Oligocene to early Miocene extensional regime in the Central Andes (17°-46°S): insights from numerical modeling

Fennell et al 2017

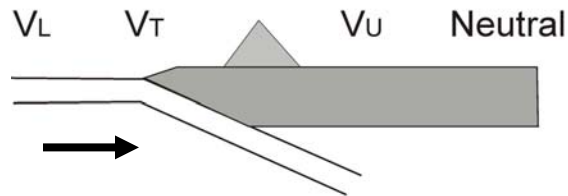
Evolution of the convergence velocity, stretching of the overriding plate and basin depth through time. Ages of extensional basins and magmatic events are plotted, overlapping between 23 and 20 Ma, which is in agreement with the duration of the extensional regime estimated through our model (references are the same than in Fig. 2). The age of the Farallón break-up (~23 Ma; Lonsdale, 2005) coincides with the increment of velocity and onset of extensional deformation, which suggests a link between the stress exerted by the slab pull force and the partitioning of this plate.



## SUBDUCCIÓN ANDINA:

### Régimen neutro: Tipo Oregon

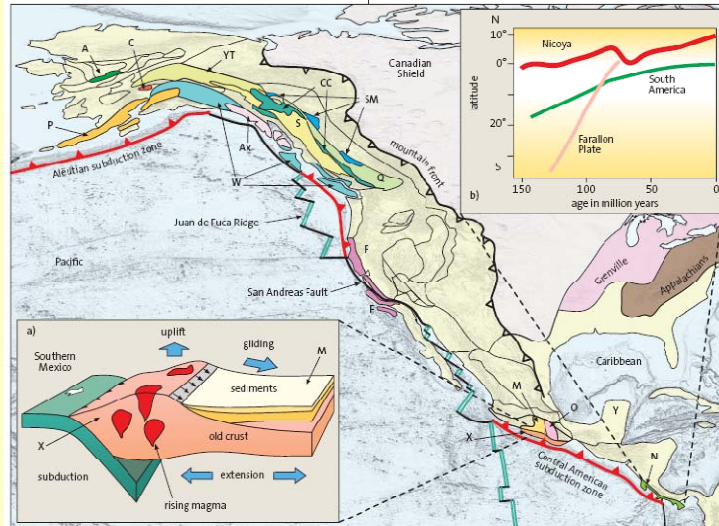
Sin cuenca de retroarco



- Con prisma de acreción compresivo
- Arco sin control estructural activo: ej.: Mt. Saint Helen
- Retroarco sin estructuras

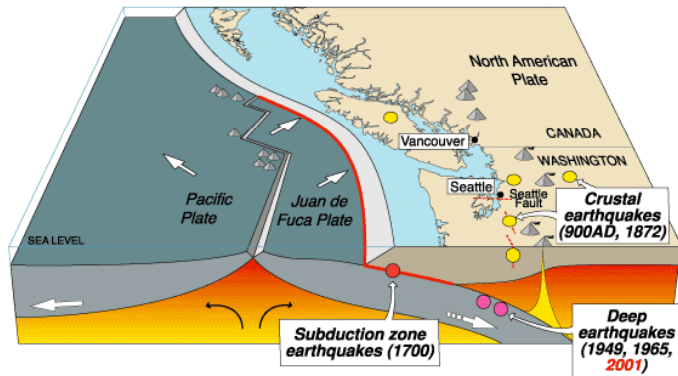
Dickinson y Selley (1979)

Tomado de Frisch et al., 2011

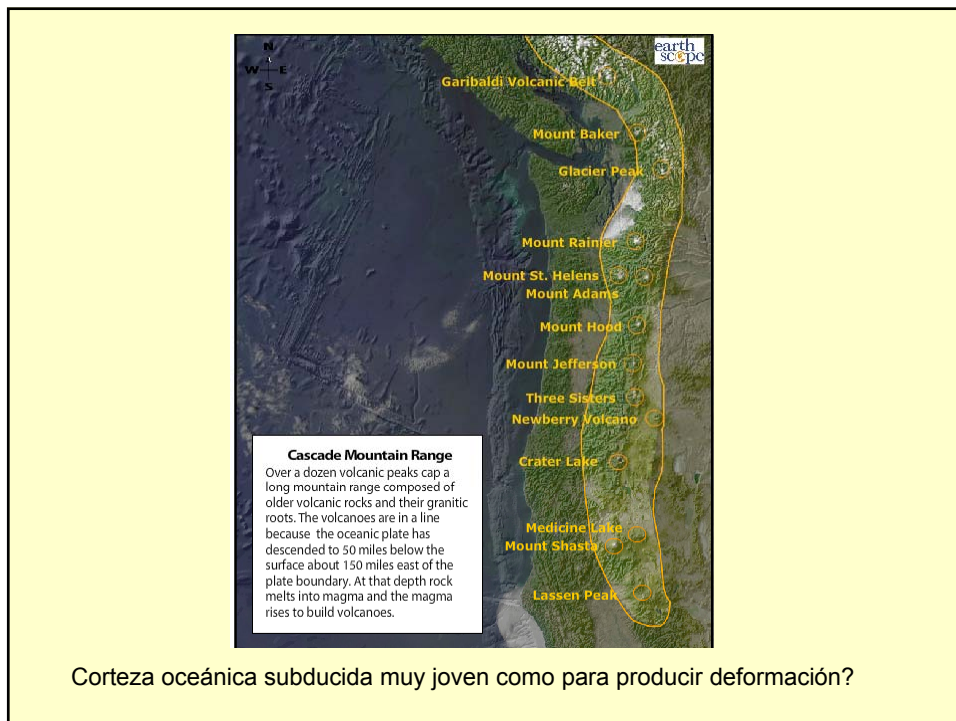
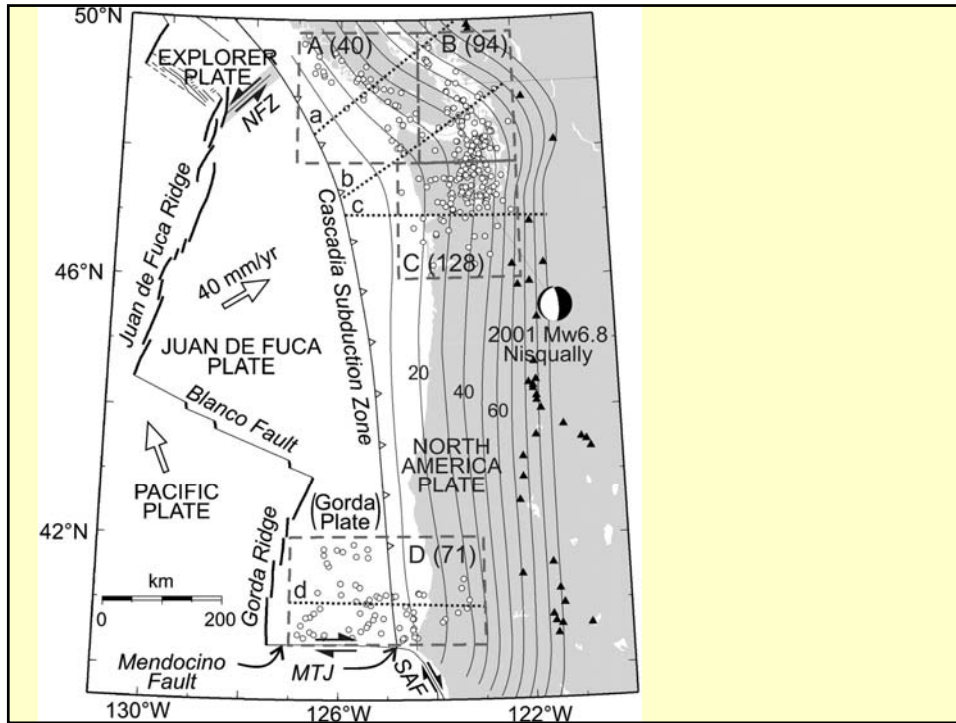


Corteza oceánica subducida muy joven como para producir deformación?

### Cascadia earthquake sources



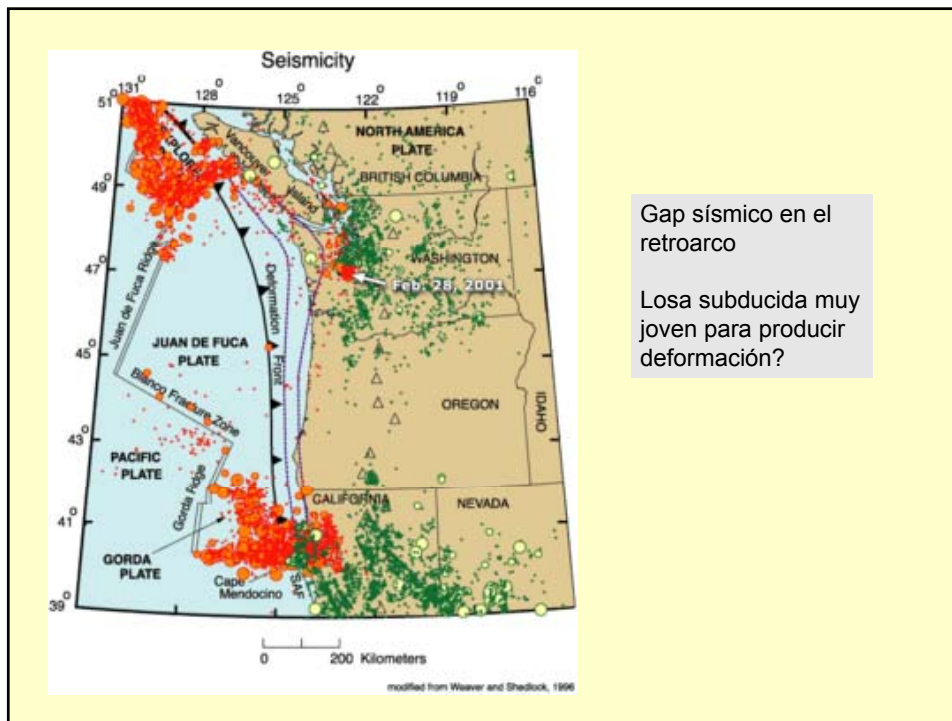
Source	Affected area	Max. Size	Recurrence
● Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
● Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
● Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?





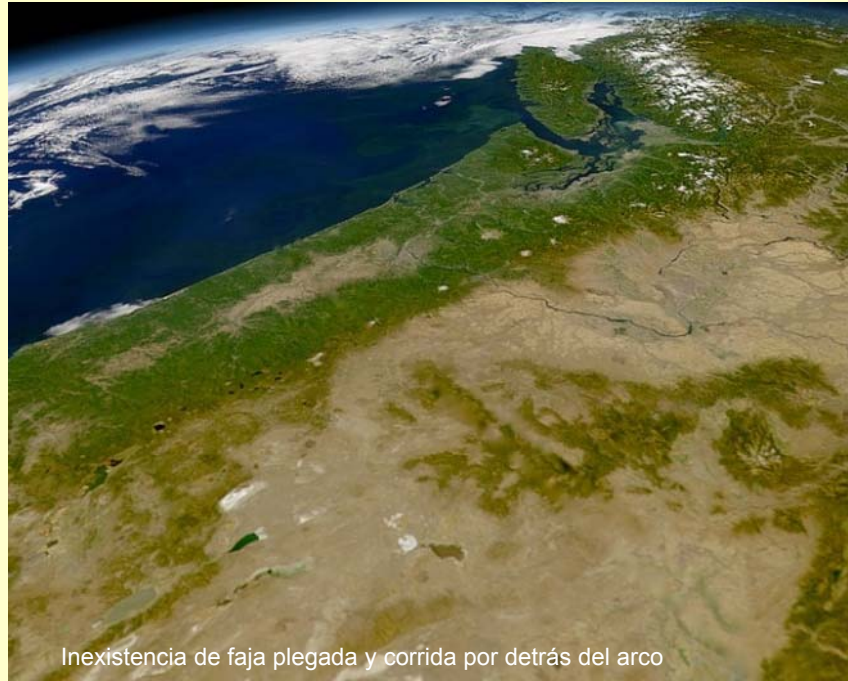
## CASCADIAN RANGES (Oregon y Washington)

- Corresponde a una cadena volcánica terciaria a cuaternaria con más de 50 volcanes activos.
- Monte *St. Helen* hasta *Crater Lake*, al sur del *Snake River plateau*.
- Arco volcánico desarrollado por subducción de la *Gorda Plate* y Norte América con velocidad de *roll-back* neutra.
- Nótese la falta de una faja plegada y corrida en la región de retroarco.



Gap sísmico en el retroarco

Losa subducida muy joven para producir deformación?



Inexistencia de faja plegada y corrida por detrás del arco

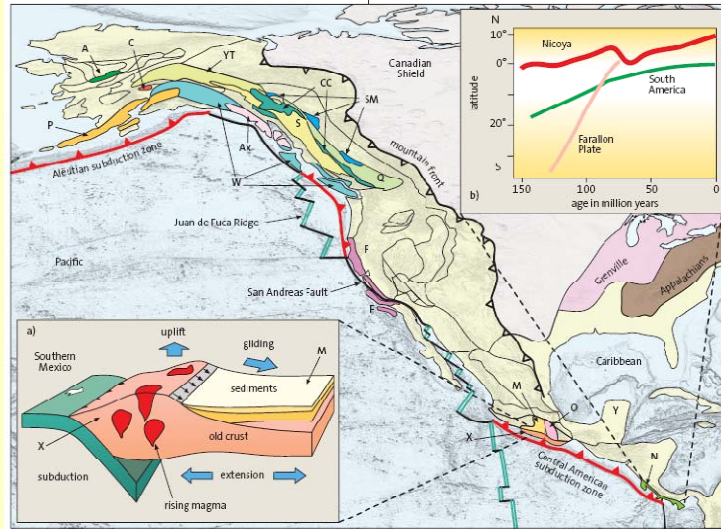
## CASCADIAN RANGES (Oregon y Washington)

- Retroarco de las *High Cascade Ranges* con aparatos volcánicos cenozoicos.
- No existe una faja plegada y corrida por detrás del arco.
- El retroarco está caracterizado por una planicie cubierta por material piroclástico y depósitos cuaternarios no deformados.
- En el centro norte de la imagen se observa el Walker Rim, un complejo anular de 30 km de diámetro.

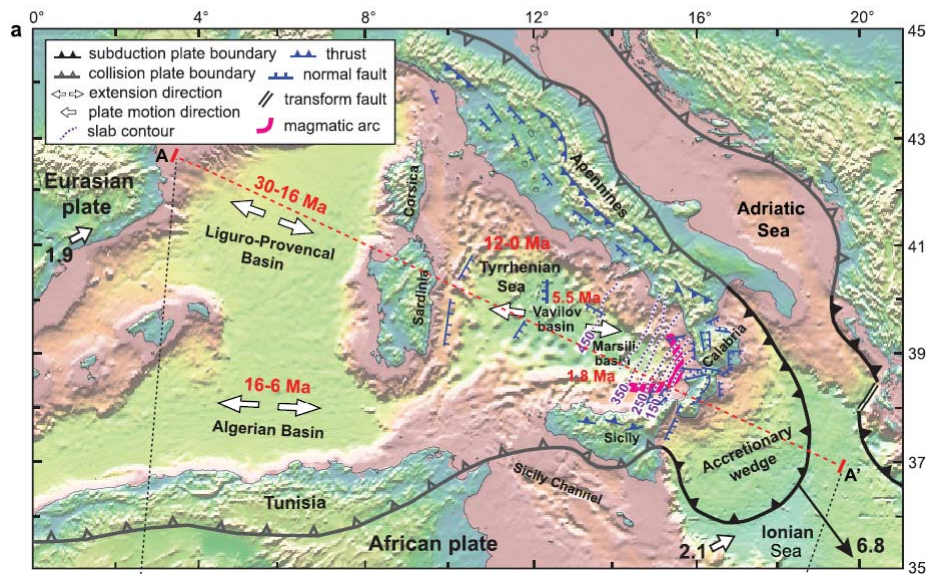




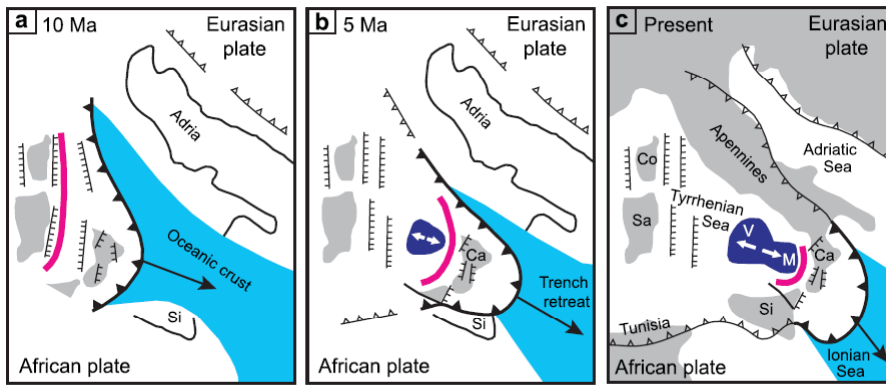
Tomado de Frisch et al., 2011



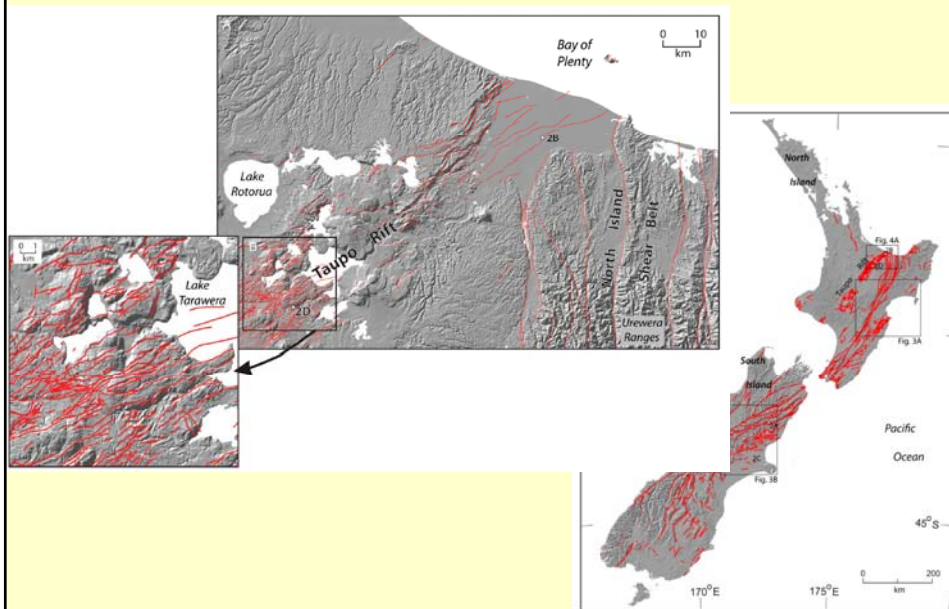
Chen et al 2015



Chen et al 2015



Landbridge et al 2016 the New Zealand Active Faults Database



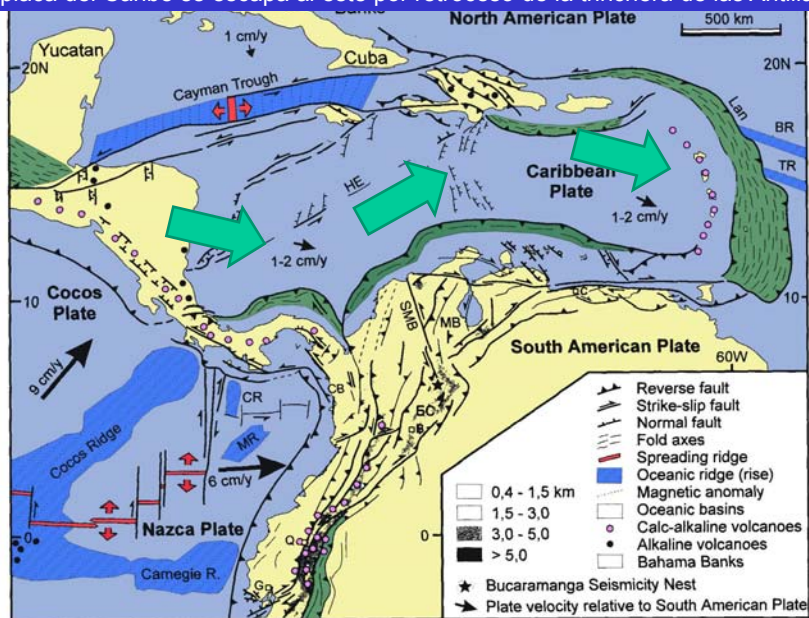


## SUBDUCCIÓN ANDINA:

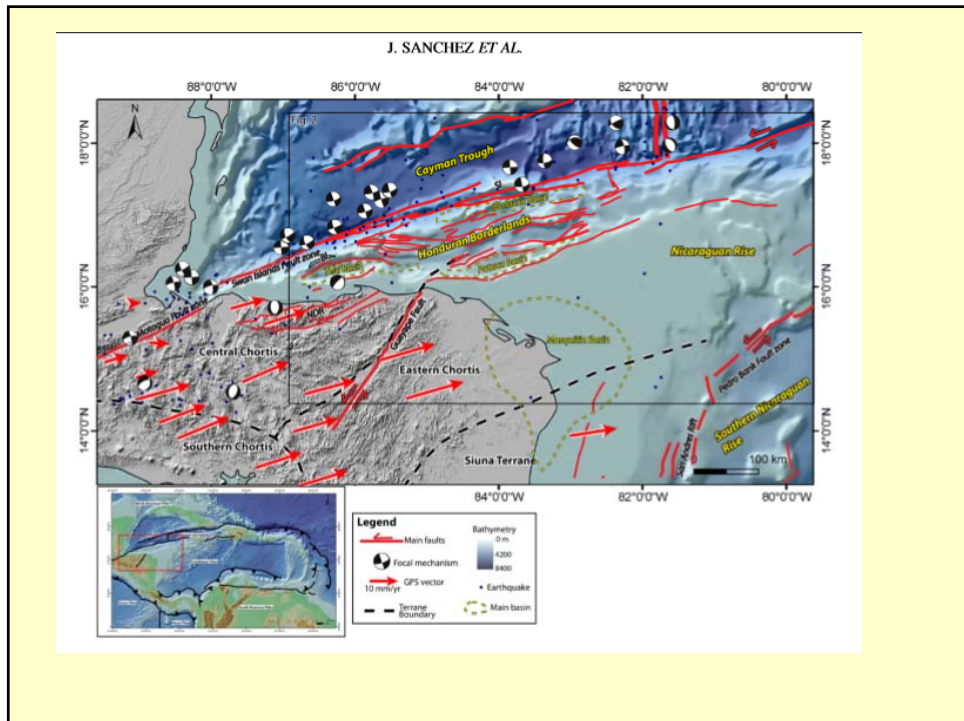
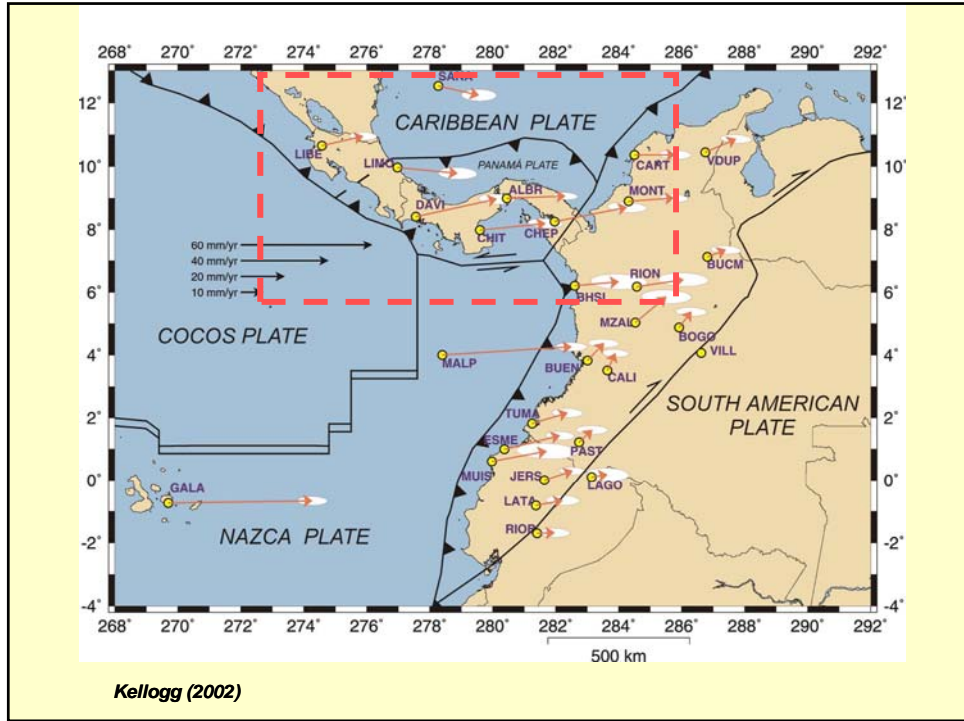
- Régimen extensional: tipo Guatemala



La placa del Caribe se escapa al este por retroceso de la trinchera de las Antillas

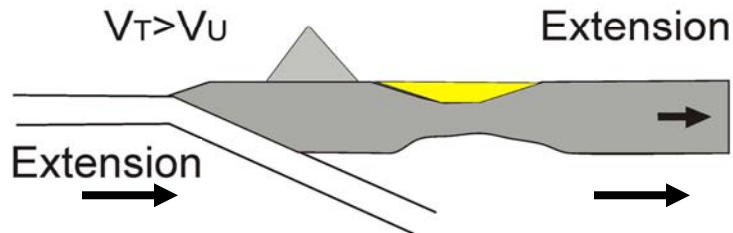


Taboada et al. (2000)



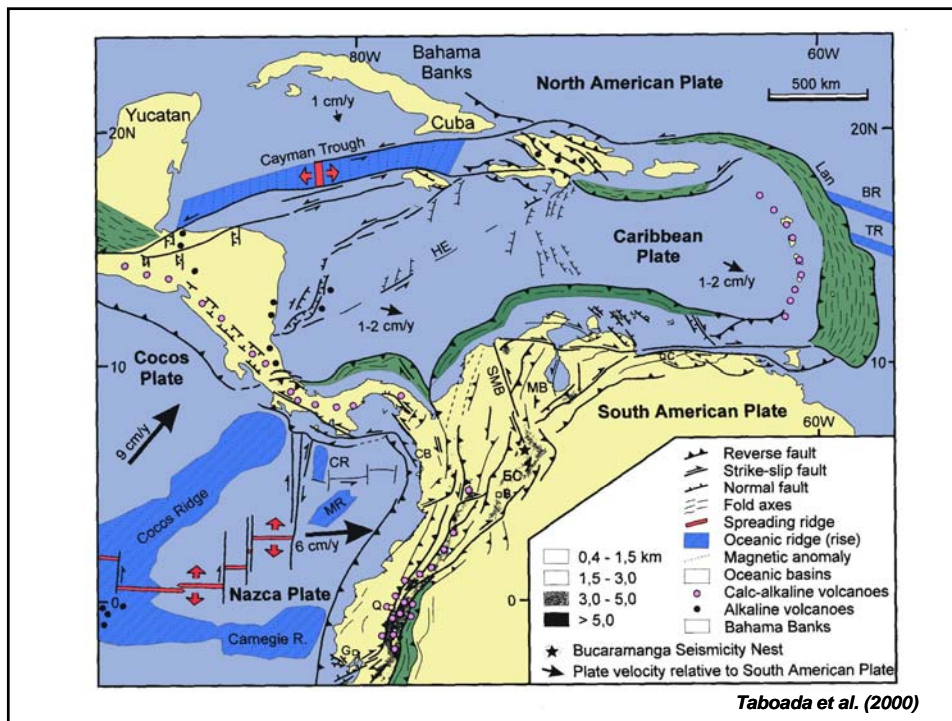
## SUBDUCCIÓN ANDINA:

- Régimen extensional: tipo Guatemala



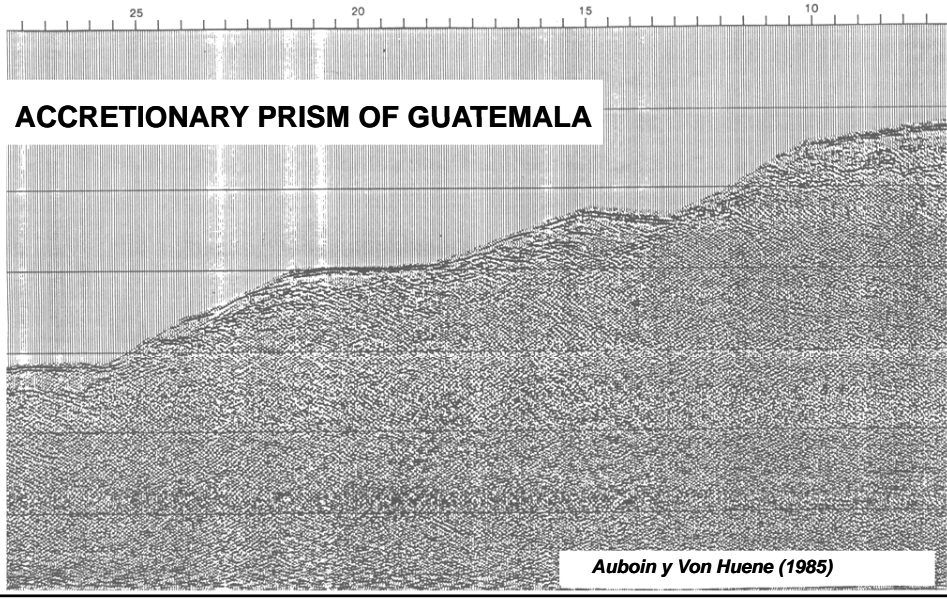
- Sin prisma de acreción compresivo
- Antearco y pendiente interna de la fosa con fallas normales.
- Arco controlado por sistema de rift
- Retroarco con sistemas de hemigrábenes

*Auboin (1984)*

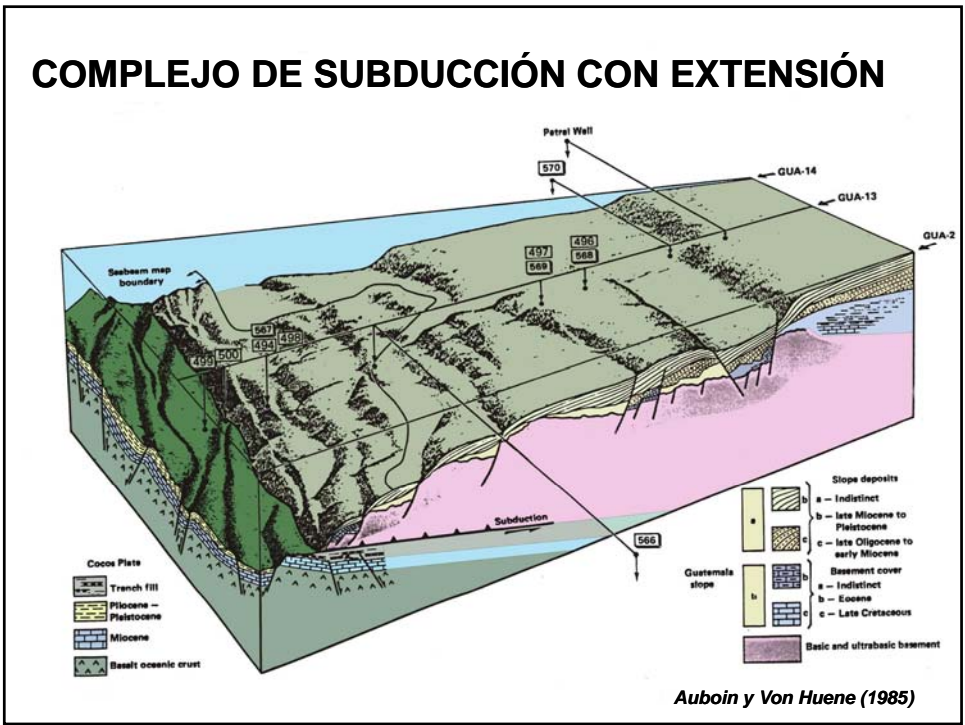


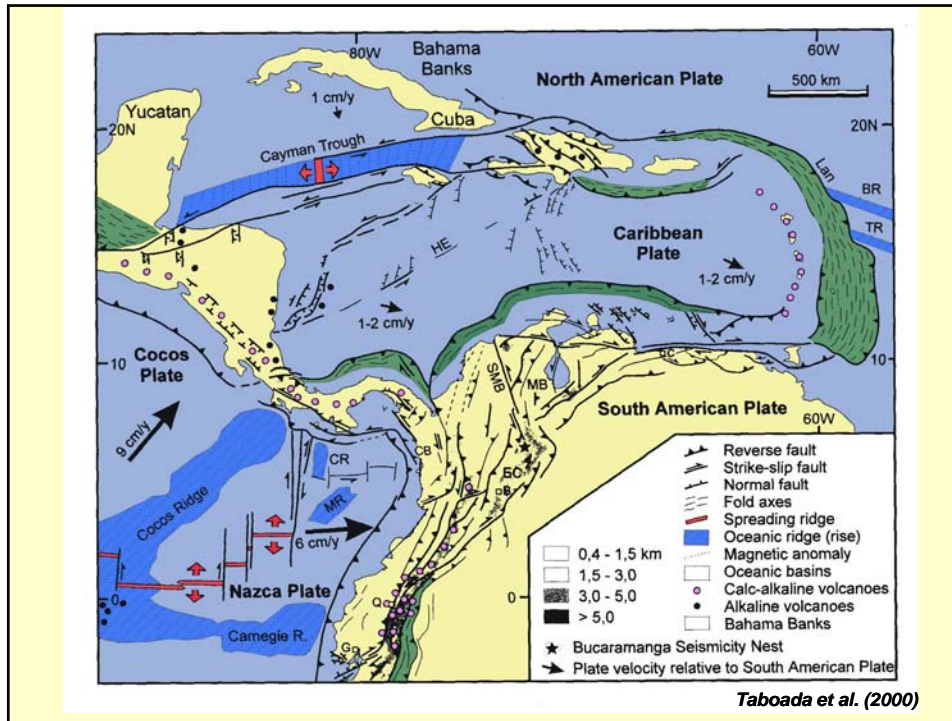


# COMPLEJO DE SUBDUCCIÓN CON EXTENSIÓN



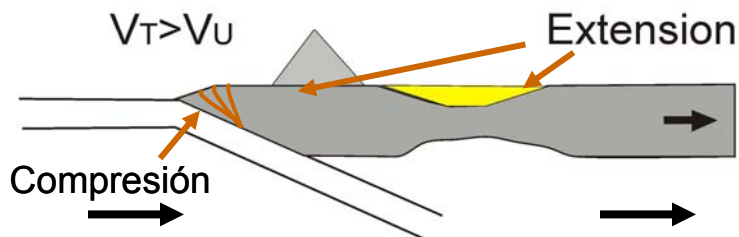
# COMPLEJO DE SUBDUCCIÓN CON EXTENSIÓN



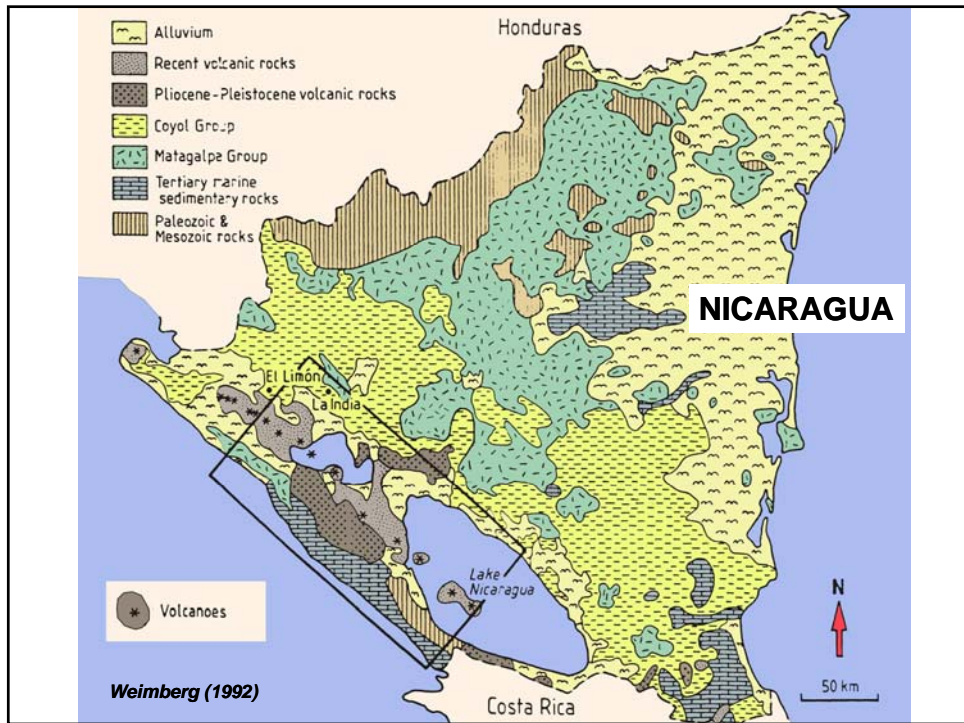
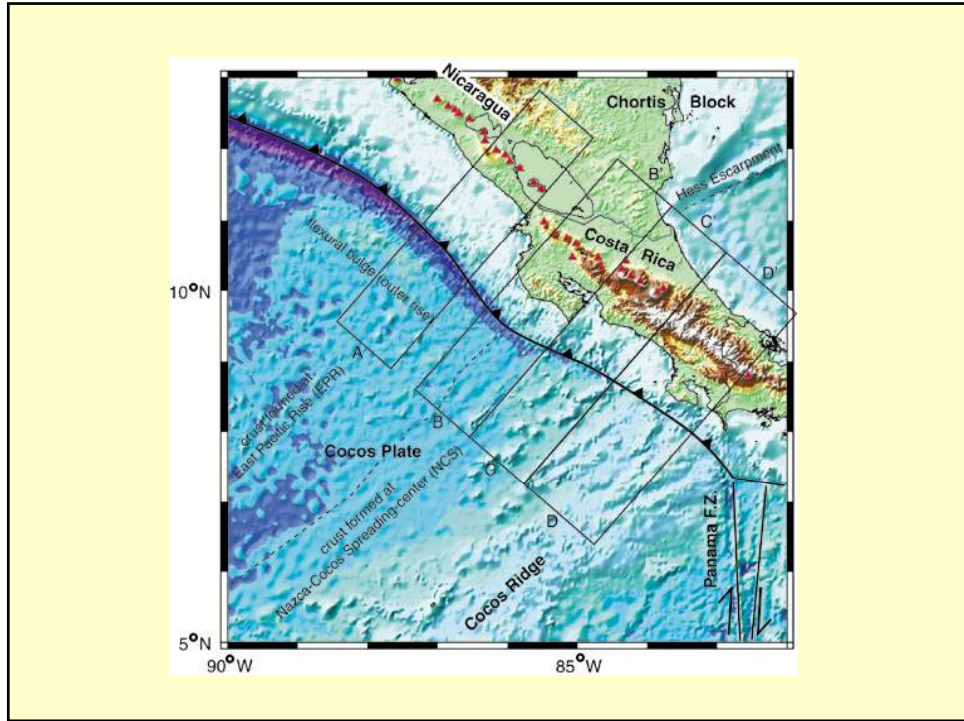


## SUBDUCCIÓN ANDINA:

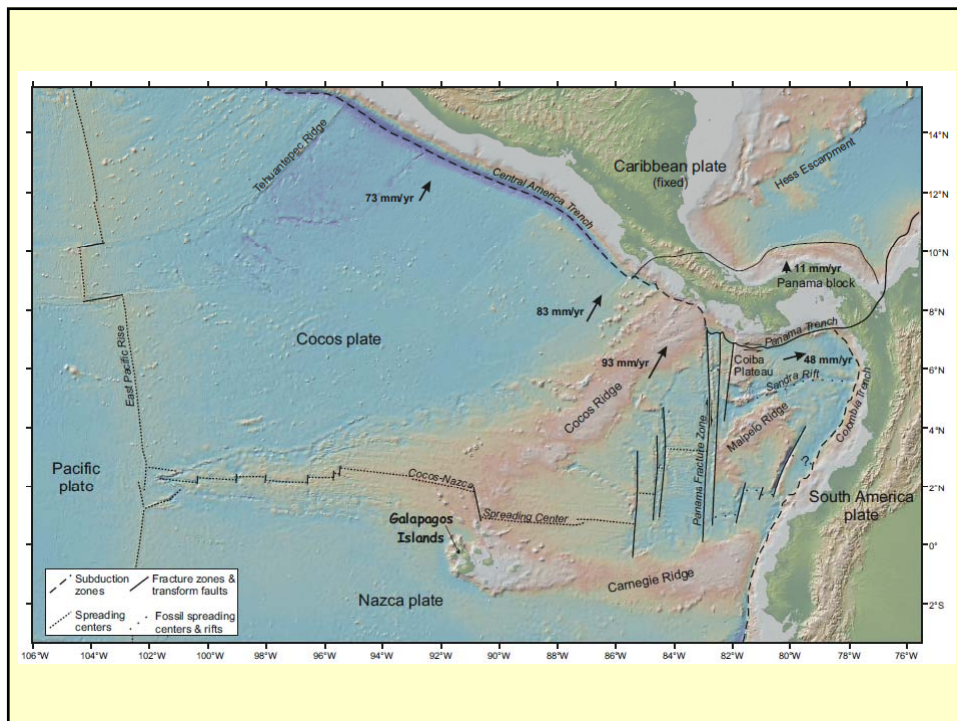
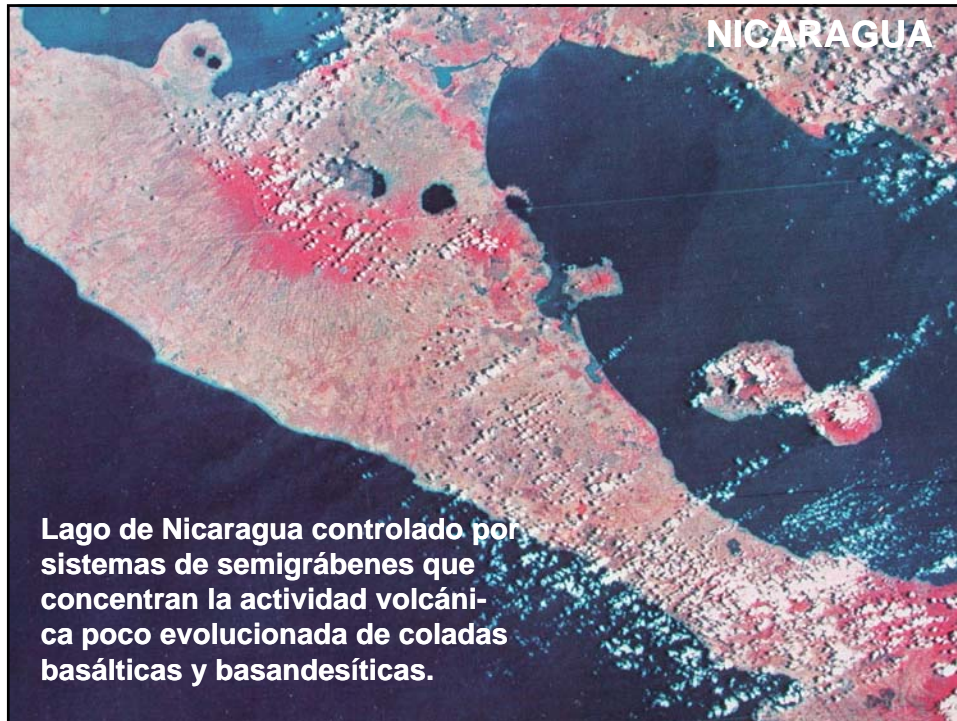
- Régimen extensional: tipo Nicaragua



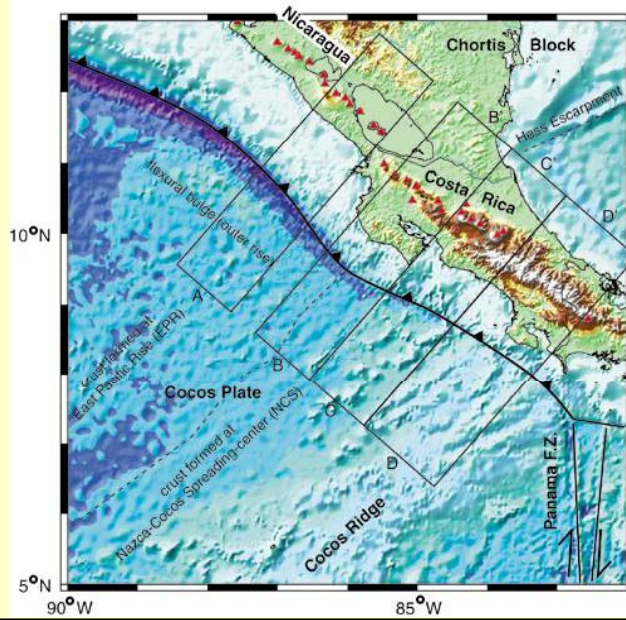
- Con prisma de acreción compresivo
- Antearco con deformación compresiva
- Arco controlado por sistema de rift
- Retroarco con sistemas de hemigrábenes



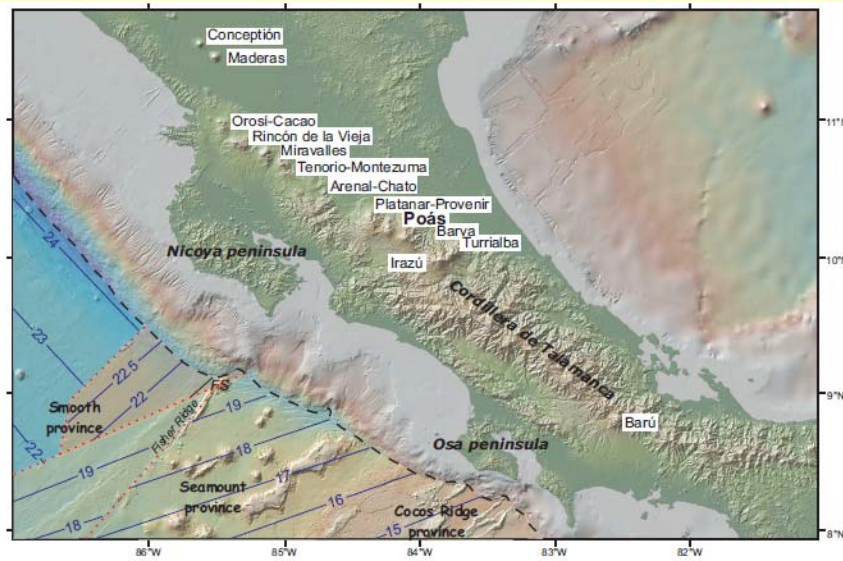




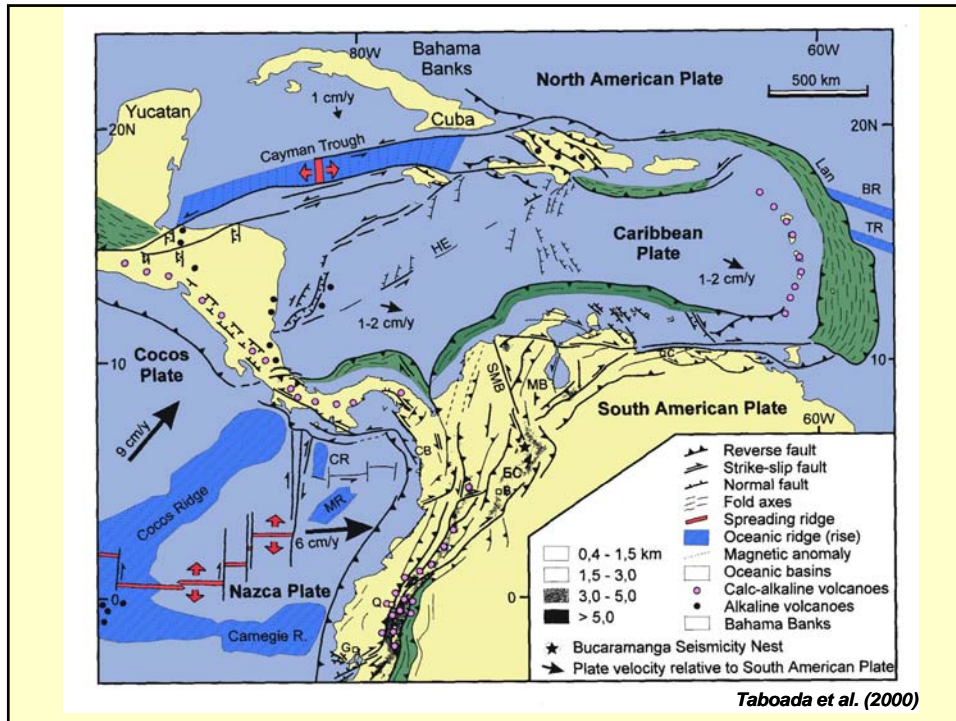
Gap volcánico en Costa Rica, pequeño flat slab y levantamiento de cordillera de Talamanca



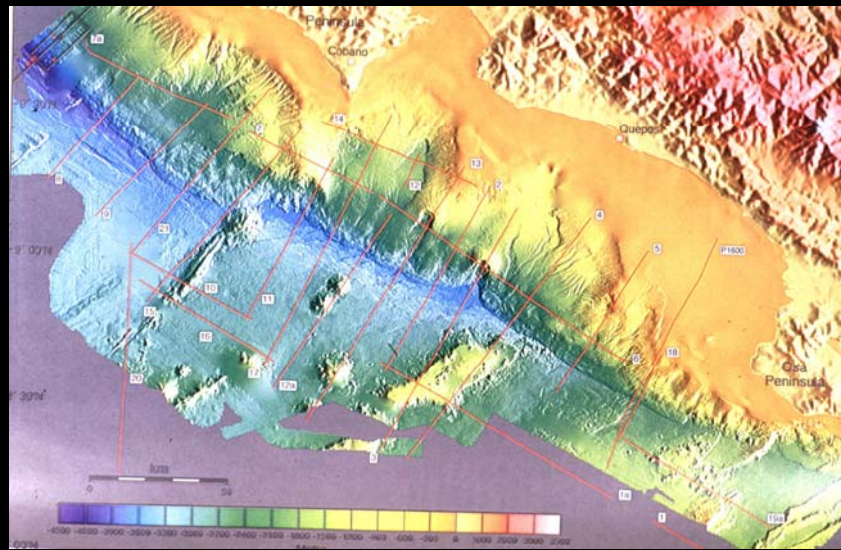
GAP EN LA ACTIVIDAD DEL ARCO POR COLISIÓN DE DORSAL DE COCOS



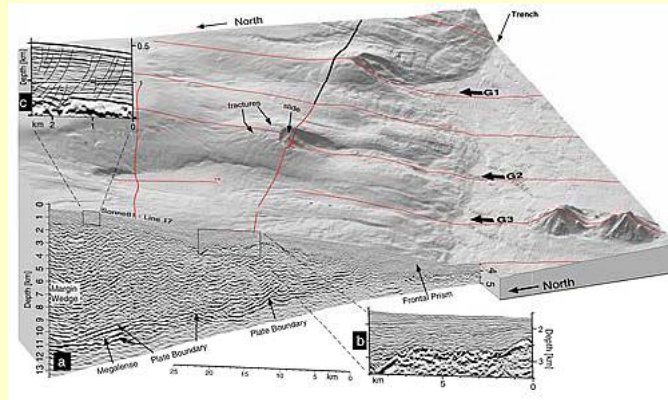




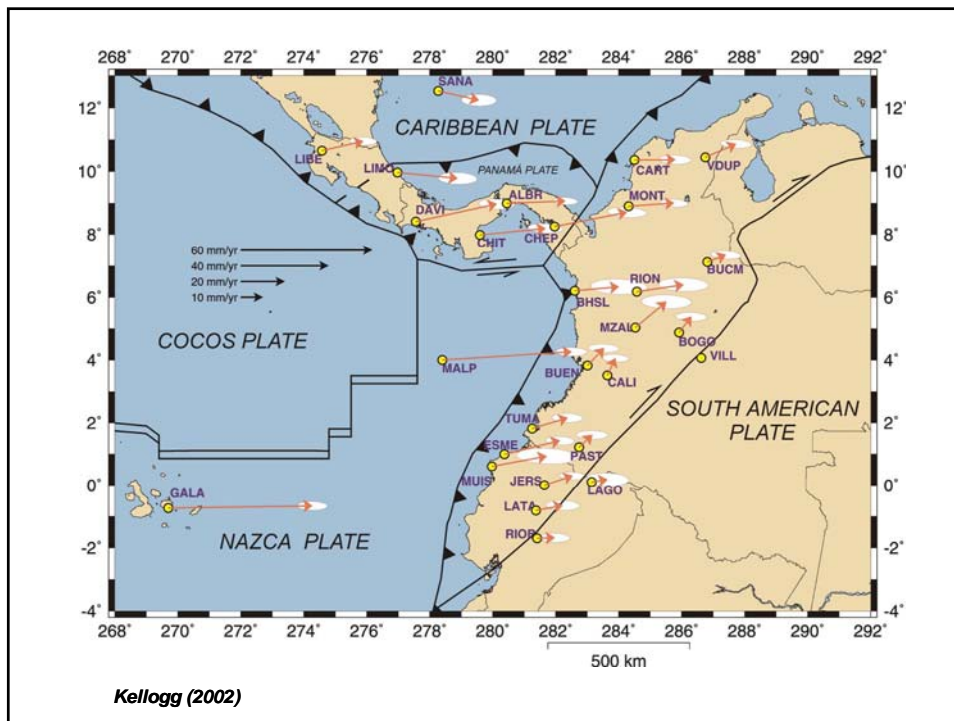
## COCOS RIDGE (COSTA RICA)

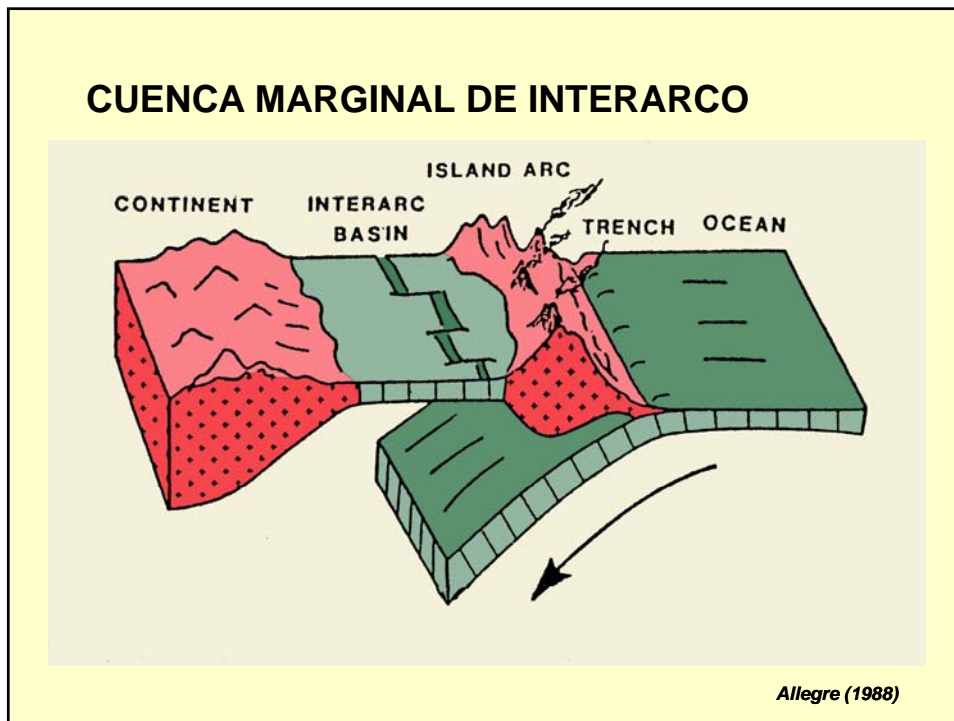
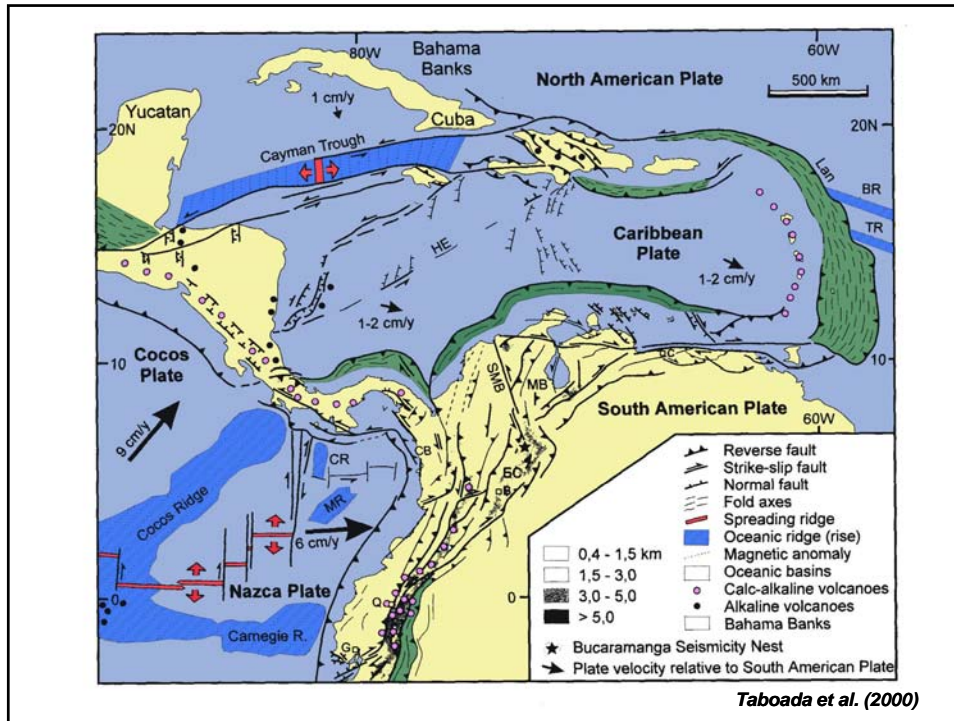


<http://www.geophysik.uni-kiel.de/~geo43/research/projects/sfb574.html>



Fuerte acoplamiento derivado de subducción de Cocos ridge

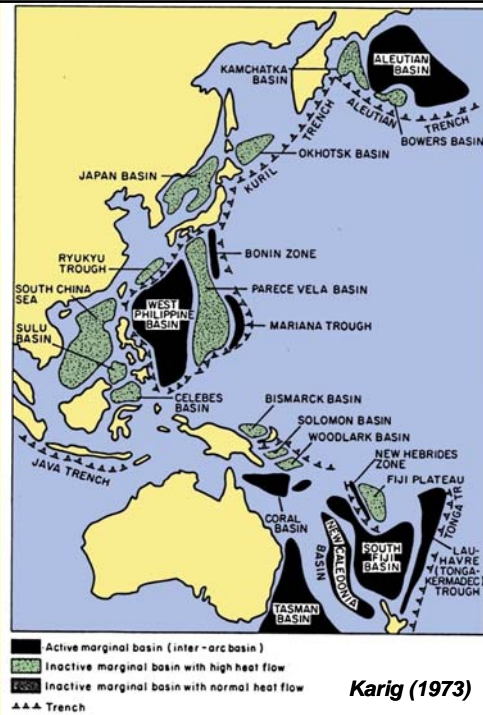




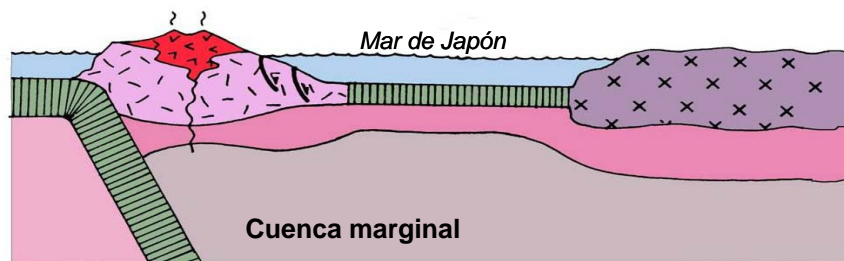
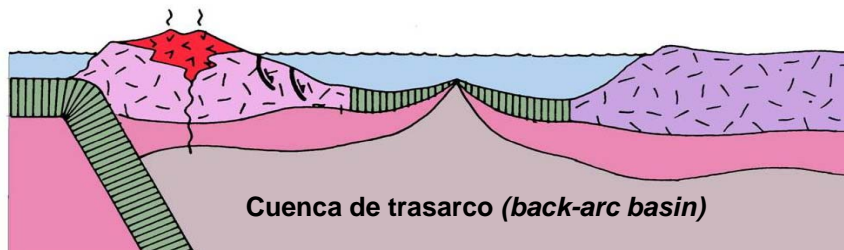


## CUENCAS MARGINALES

- En el Pacífico-sudoccidental hay una serie de arcos volcánicos que se desarrollan en los sectores marginales de los grandes bloques continentales, que en su sector trasero tienen corteza oceánica.
- Estas cuencas oceánicas las llamó Karig (1973) **cuencas marginales** que se caracterizan por tener corteza oceánica por detrás del arco.
- Estas cuencas se llamaron después **back-arc basins**, que se conocen como **cuencas de trasarco** en español.

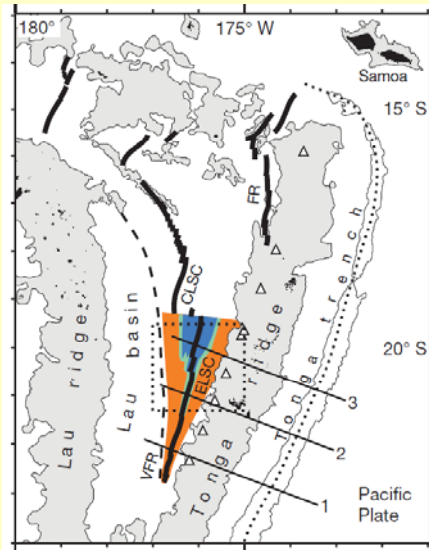


## CUENCAS MARGINALES



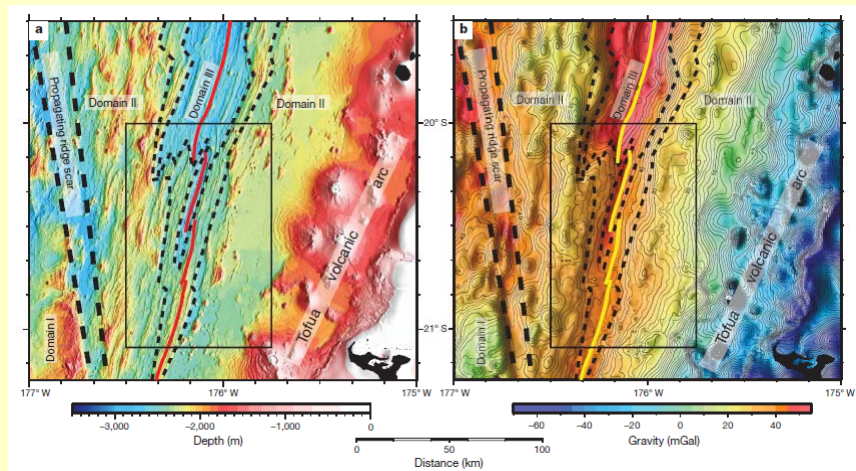
Dickinson (1976)

Dunn and Martínez, 2011  
 Nature; Contrasting crustal production and rapid mantle transitions beneath back arc ridges



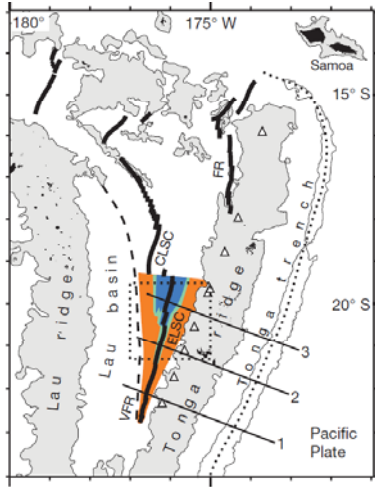
Evolución de una cuenca de back arc a medida que se expande

Dunn and Martínez, 2011  
 Nature; Contrasting crustal production and rapid mantle transitions beneath back arc ridges

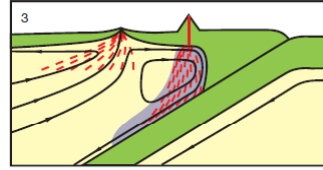


Evolución de una cuenca de back arc a medida que se expande

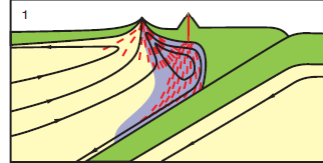
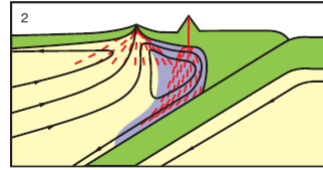
Dunn and Martínez, 2011  
 Nature; Contrasting crustal production and rapid mantle transitions beneath back arc ridges



Corteza más delgada, MORB, mineralogías anhidras

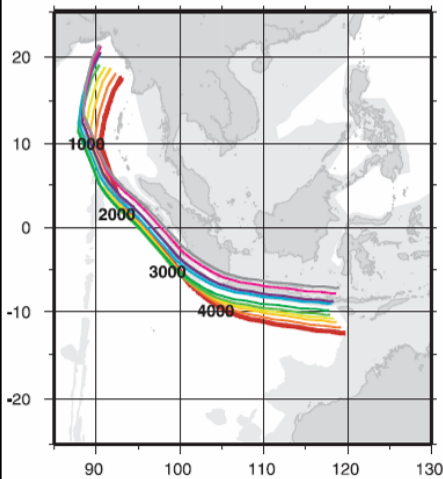


Producción de corteza oceánica gruesa Con química afín al arco (mineralogías hidratadas)

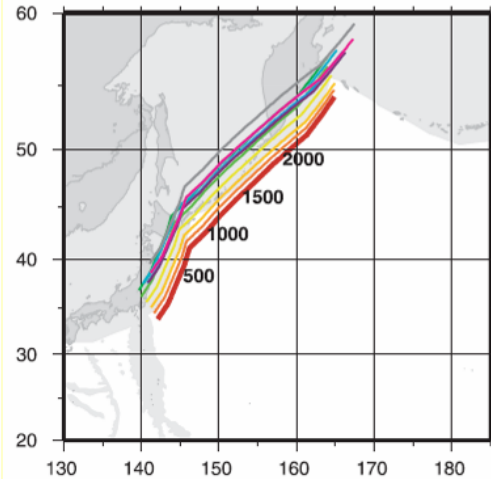


Evolución de una cuenca de back arc a medida que se expande

**SUMATRA SUBDUCTION**



**JAPAN KURILES SUBDUCTION**

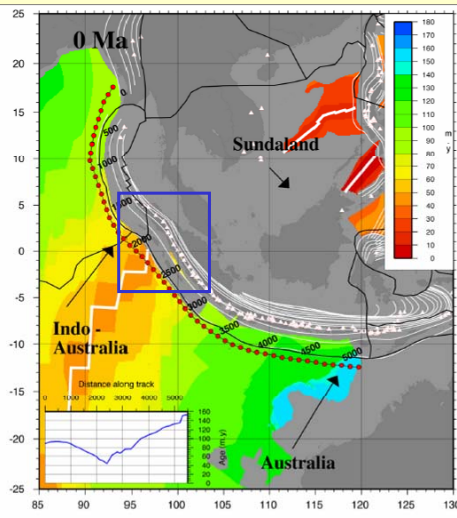


Trench retreat

Sdrolias y Müller (2006)

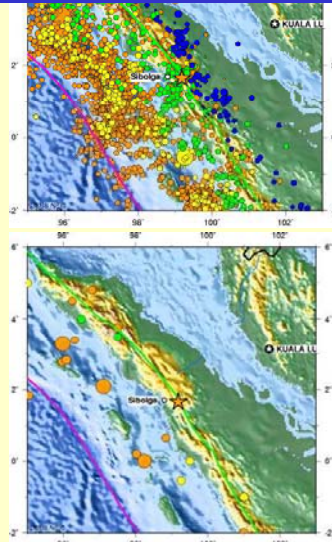


## SUMATRA SUBDUCTION



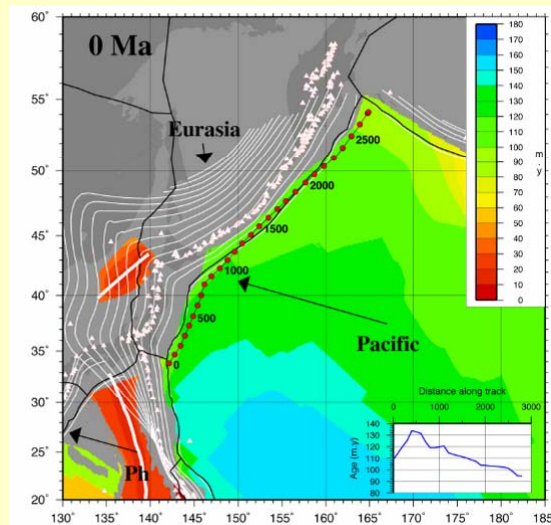
Edad de la corteza oceánica  
Velocidades absolutas

Cuencas marginales en sitios de rápido retroceso de la trinchera por lit'fera antigua y movimiento divergente de placa superior



Sdrolas y Müller (2006)

## JAPAN KURILES SUBDUCTION



Edad de la corteza oceánica  
Velocidades absolutas

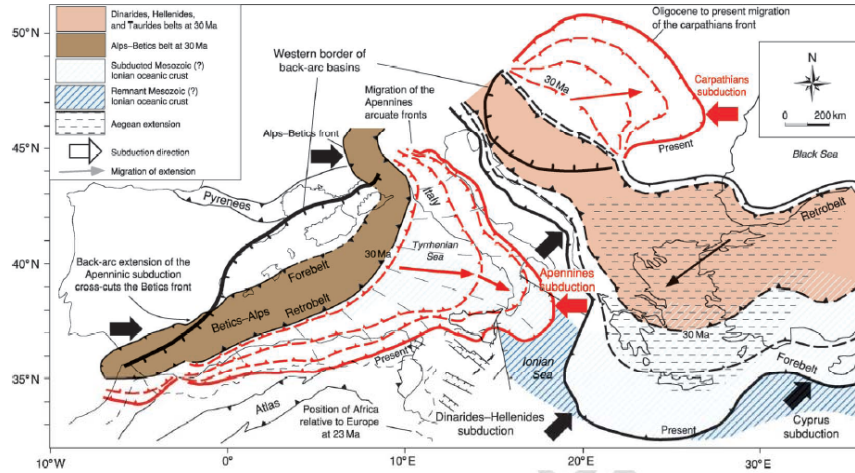
Desarrollo de cuencas marginales...

Cuencas marginales en sitios de rápido retroceso de la trinchera por lit'fera antigua y movimiento divergente de placa superior

PERO EN ALGUNOS CASOS  
LA PLACA SUPERIOR SE  
MUEVE HACIA TRINCHERA

PORQUÉ ENTONCES HAY UNA  
CUENCA MARGINAL??

Sdrolas y Müller (2006)



**Figure 6** Main tectonic features of the Mediterranean realm, which has been shaped during the last 45 Ma by a number of subduction zones and related belts: the double-vergent Alps-Betics; the single eastwards-vergent Apennines-Maghrebides and the related western Mediterranean back-arc basin; the double-vergent Dinarides-Hellenides-Taurides and related Aegean extension; the single eastwards-vergent Carpathians and the related Pannonian back-arc basin; and the double-vergent Pyrenees.

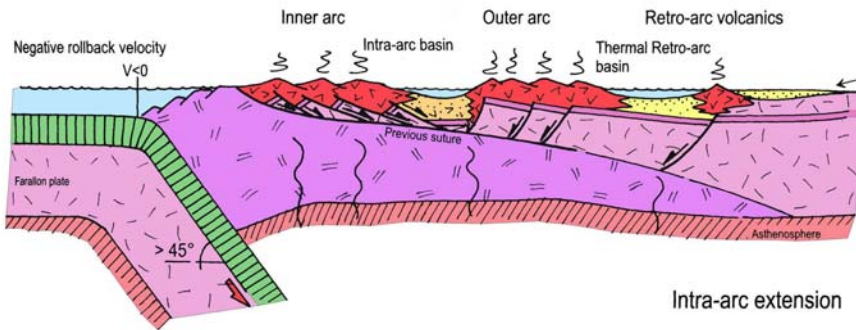
## CLASIFICACIÓN DE CUENCAS MARGINALES

- **Cuencas de trasarco (*back-arc basin*):** Cuenca de flujo térmico alto, ambiente restringido, escasa circulación, con desarrollo de una dorsal oceánica.
- **Cuencas de interarco (*interarc basin*):** Cuenca de flujo térmico alto, ambiente restringido, escasa circulación, con desarrollo de una dorsal oceánica, desarrollada sobre un arco remanente o fósil.
- **Océanos remanentes:** Cuenca de flujo térmico bajo, ambiente restringido, escasa circulación, sin desarrollo de una dorsal oceánica, asociada a un prisma de acreción.

## EVOLUCIÓN TECTÓNICA DE LA CORDILLERA PRINCIPAL (Sector central)

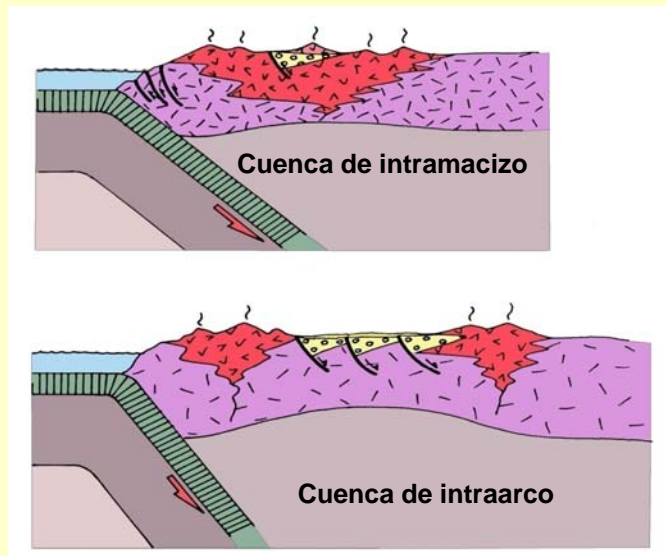
Jurassic-Early Cretaceous

150 - 115 Ma



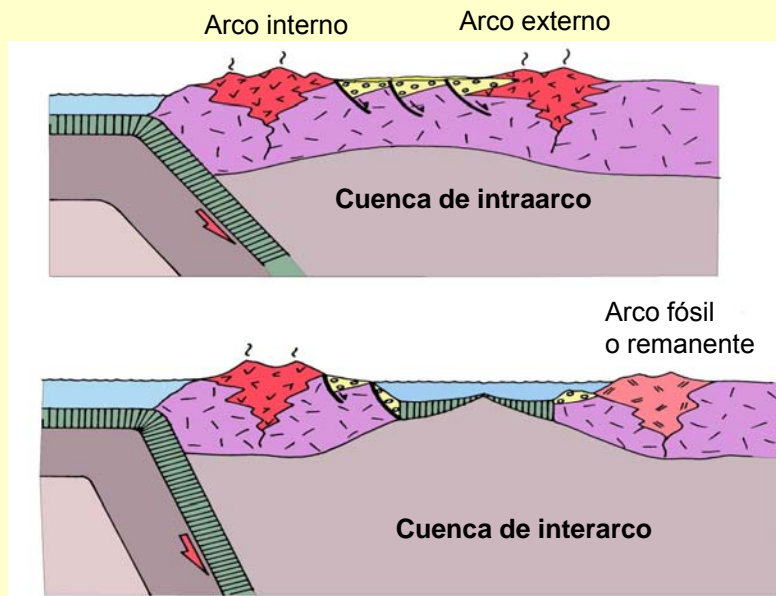
Ramos (2000)

## SISTEMAS EXTENSIONALES ASOCIADOS A SUBDUCCIÓN



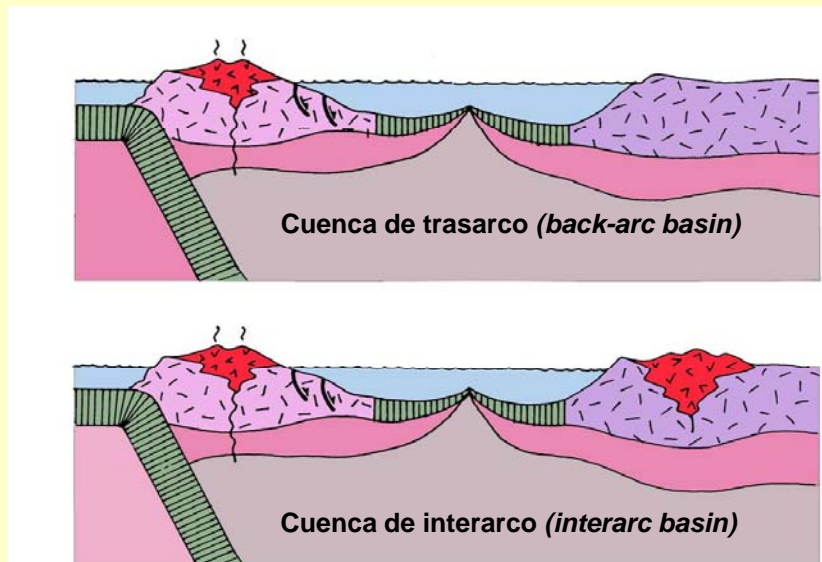
Dickinson (1976)

## SISTEMAS EXTENSIONALES ASOCIADOS A SUBDUCCIÓN



Dickinson (1976)

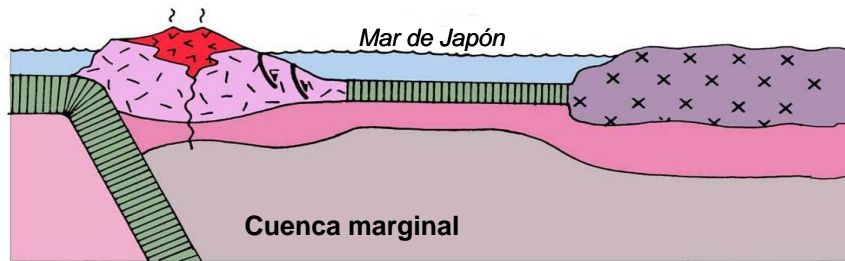
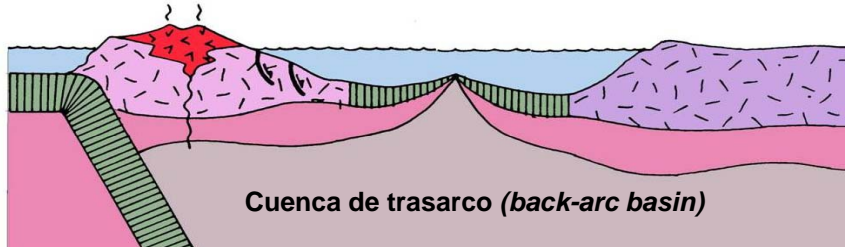
## CUENCAS MARGINALES



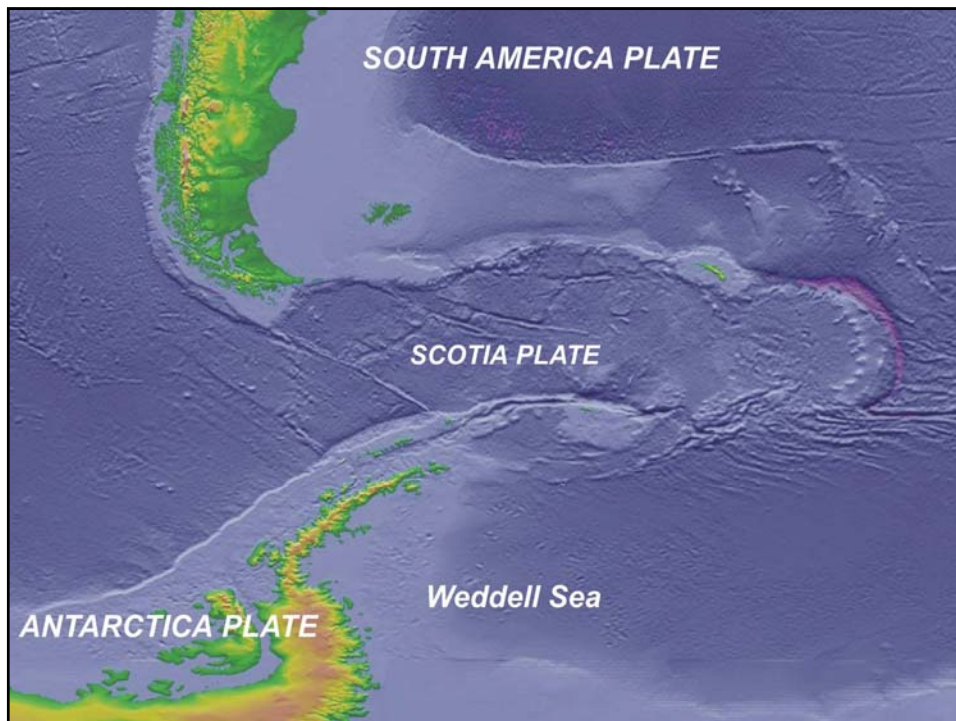
Dickinson (1976)



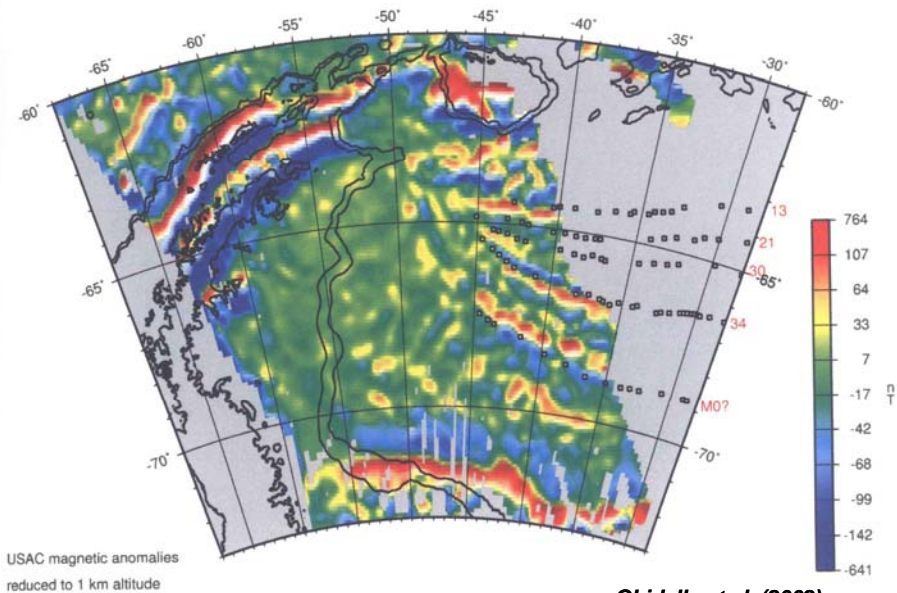
## CUENCAS MARGINALES



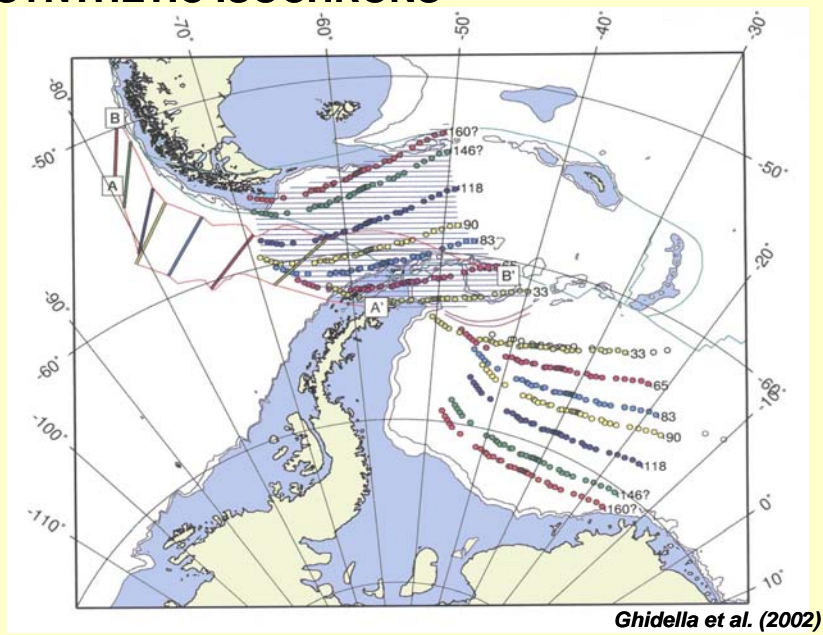
Dickinson (1976)



## MAGNETIC ANOMALIES OF WEDDELL SEA

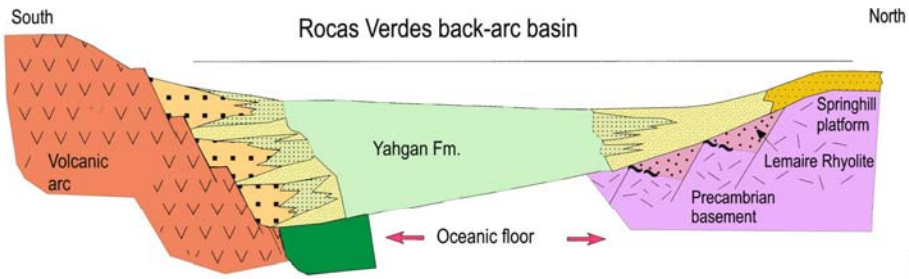


## SYNTHETIC ISOCHRONS





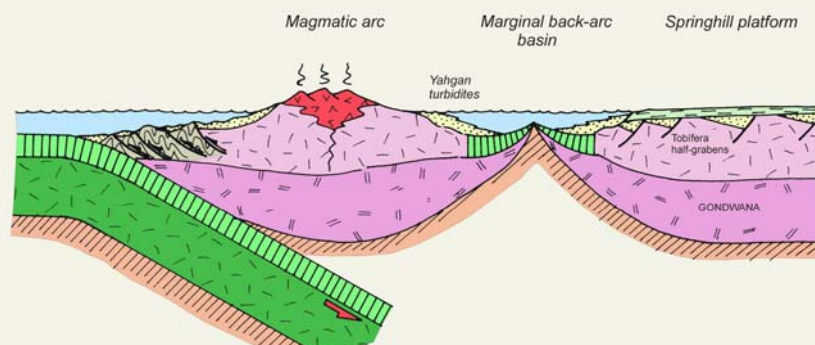
## CUENCA MARGINAL “ROCAS VERDES” (volcanismo extensional generalizado)



*Olivero et al. (2001)*

## CUENCA MARGINAL DE LA CORDILLERA FUEGUINA

(Early Cretaceous)

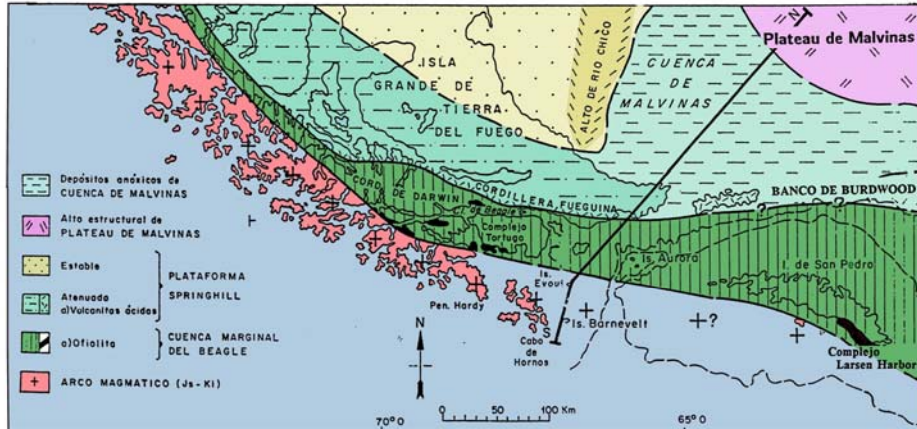


“ROCAS VERDES” MARGINAL BASIN

Dalziel et al. (1974)

# CUENCA MARGINAL DE “ROCAS VERDES”

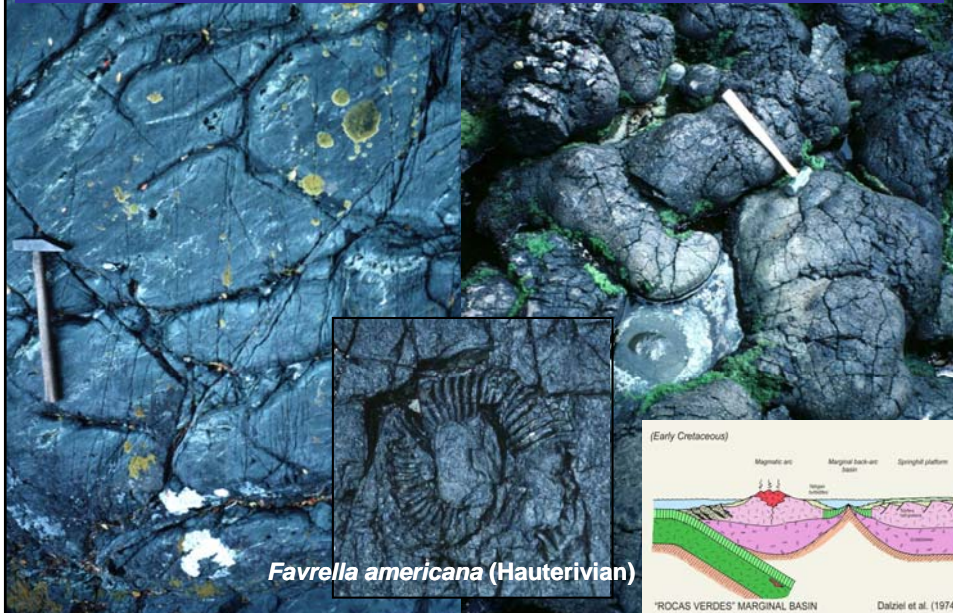
Jurásico superior a Cretácico inferior



Datzel et al. (1974)

## 1. Development of the Andean basement

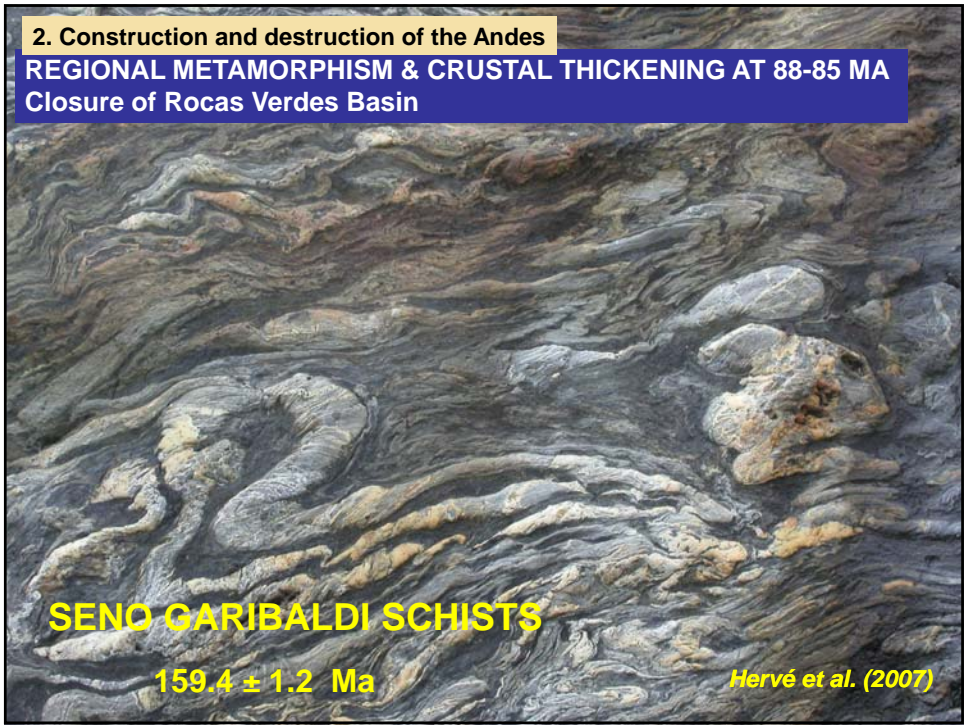
### “ROCAS VERDES” MARGINAL BASIN (Ocean floor basin development)



*Favrella americana* (Hauterivian)

**2. Construction and destruction of the Andes**

**REGIONAL METAMORPHISM & CRUSTAL THICKENING AT 88-85 MA  
Closure of Rocas Verdes Basin**



**SENO GARIBALDI SCHISTS**

**159.4 ± 1.2 Ma**

*Hervé et al. (2007)*



**ANDES ACRECIONALES vs.  
ANDES DE “TIPO ANDINO”**

Andes colisionales con obducción de corteza oceánica y metamorfismo de edad andina:

- Andes Septentrionales
- Andes Australes

Andes formados por subducción de corteza oceánica de tipo Andino (*sensu stricto*):

- Andes Centrales

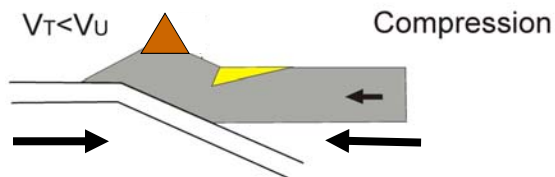
*Ramos (1999)*



## SUBDUCCIÓN ANDINA:

- Régimen compresivo: tipo chileno

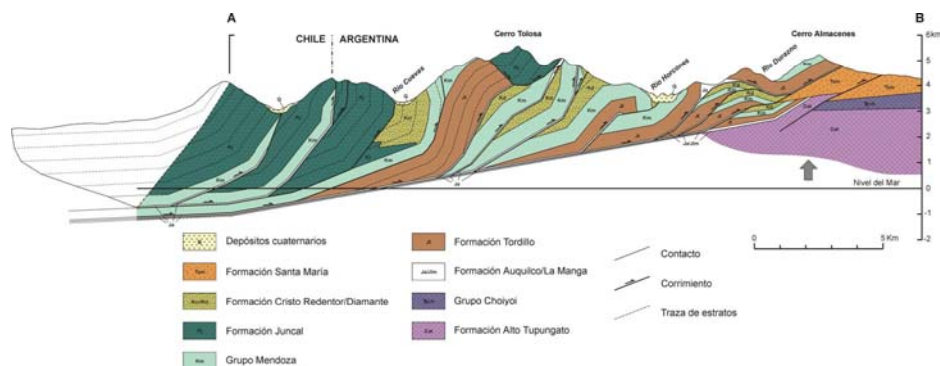
Cuenca de antepaís de retroarco



- Con prisma de acreción bajo erosión cortical.
- Antearco con deformación compresiva.
- Arco con magmatismo muy evolucionado
- Fajas plegadas y corridas de retroarco.

Uyeda (1982)

## FAJA PLEGADA Y CORRIDA DEL ACONCAGUA



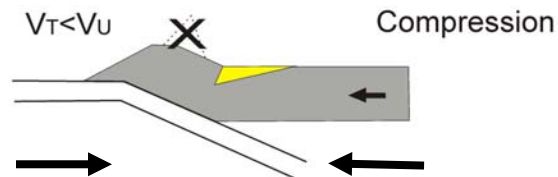
Cegarra (1994)





## SUBDUCCIÓN ANDINA:

- Régimen compressivo: tipo chileno con subducción horizontal (*flat-slab*)



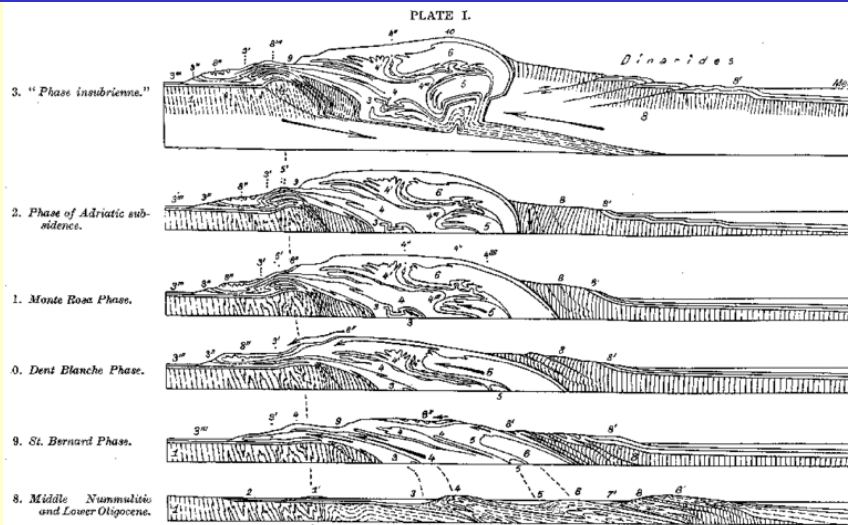
- Con prisma de acreción bajo erosión cortical.
- Antearco con deformación compresiva.
- Sin magmatismo de arco.
- Fajas plegadas y corridas de retroarco.
- Antepaís fragmentado (*broken foreland*)

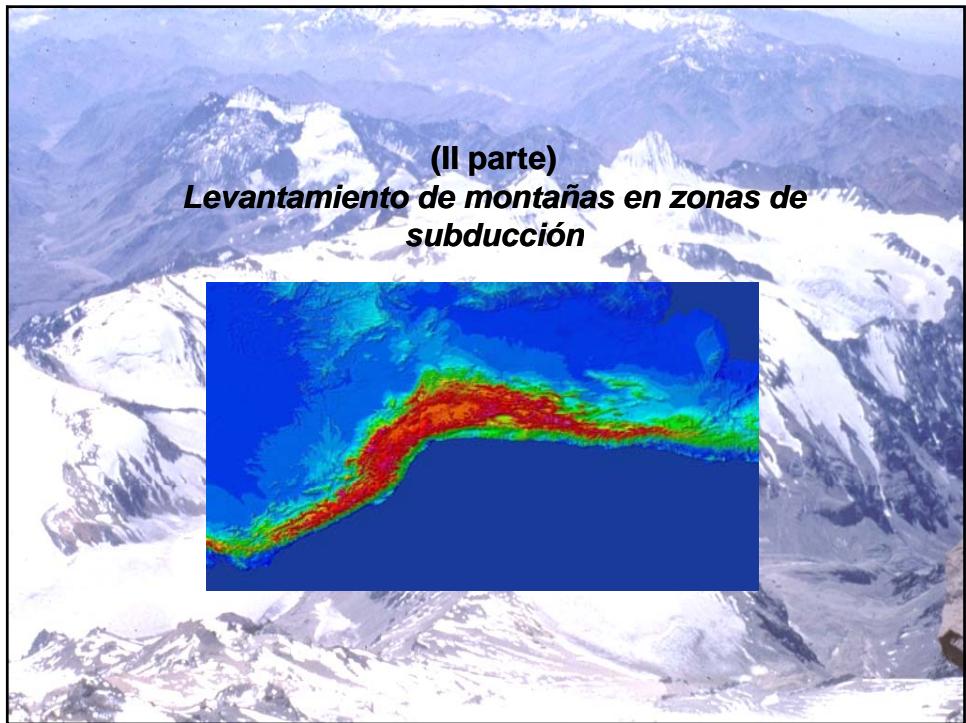
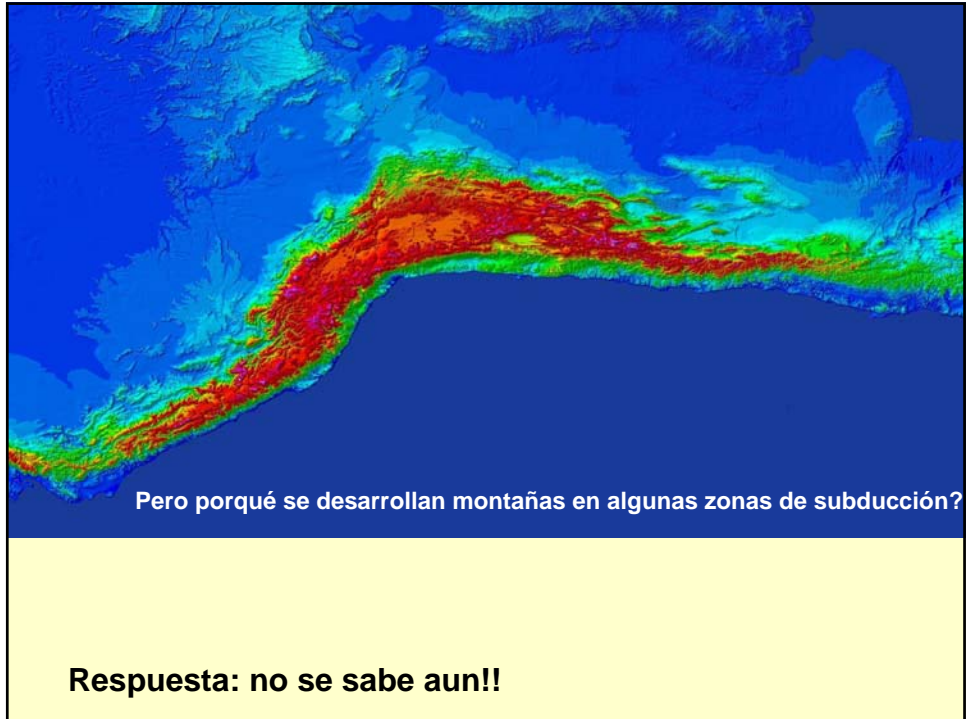
Barazangi y Isacks (1976)

## Evolución de los Alpes

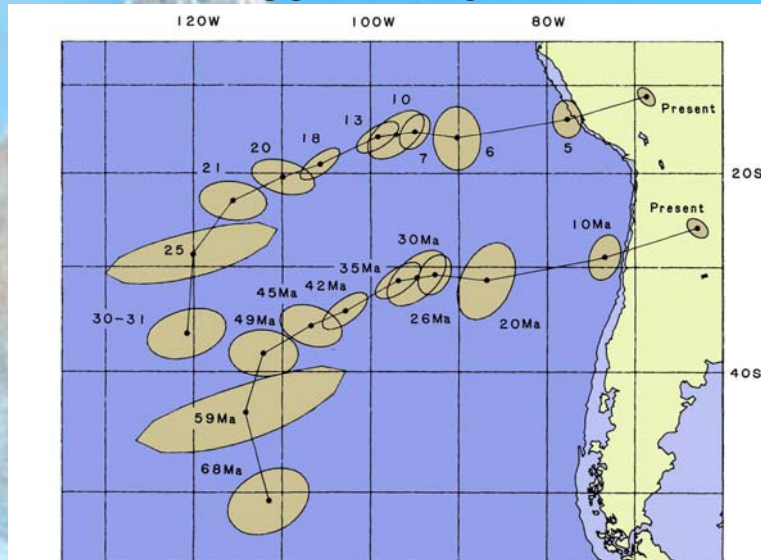
Argand (1916)

Históricamente se ha identificado a las zonas de colisión con la formación de montañas

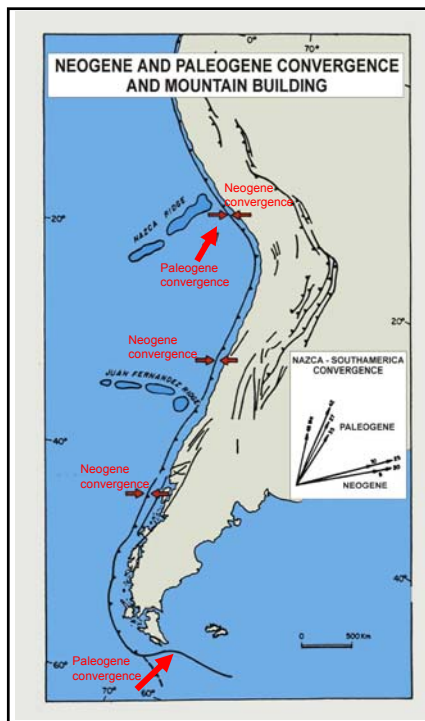




## POSICIONES DE NAZCA CON RESPECTO A SUDAMÉRICA



Pardo Casas y Molnar (1987)



## VECTOR DE CONVERGENCIA Y OROGENIAS CENOZOICAS

### Orogenia Incaica:

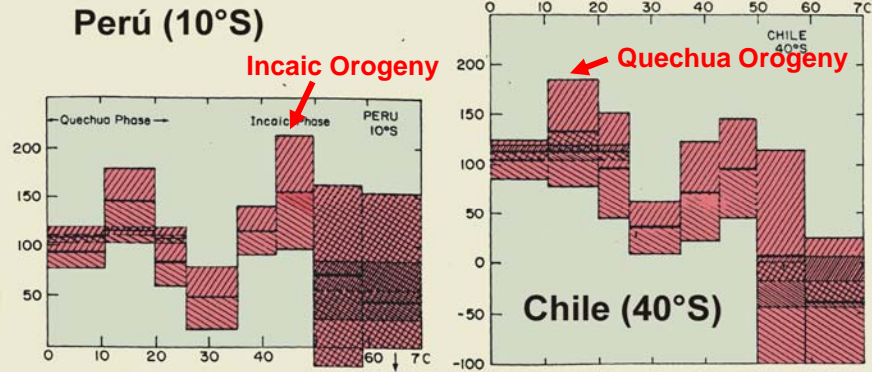
- Convergencia entre la placa de Farallón y Sudamérica hasta los 26 Ma.

### Orogenia Quechua:

- Ruptura de la placa de Farallón en las placas de Nazca y Cocos a los 27-26 Ma.
- Inicio de una fuerte convergencia ortogonal en los Andes Argentino Chilenos

## REGIMEN TECTÓNICO Y VELOCIDAD DE CONVERGENCIA

### CENOZOIC CONVERGENT RATES



PARDO CASAS & MOLNAR (1988)

## VECTOR DE CONVERGENCIA

- El régimen tectónico dependerá de la orientación del margen continental (trincher) con respecto al vector de convergencia.
- Debido a la gran variación de orientación del margen, en especial a ambos lados del oroclino boliviano, es imposible correlacionar fases de igual comportamiento en regiones diferentes.



# Topografía

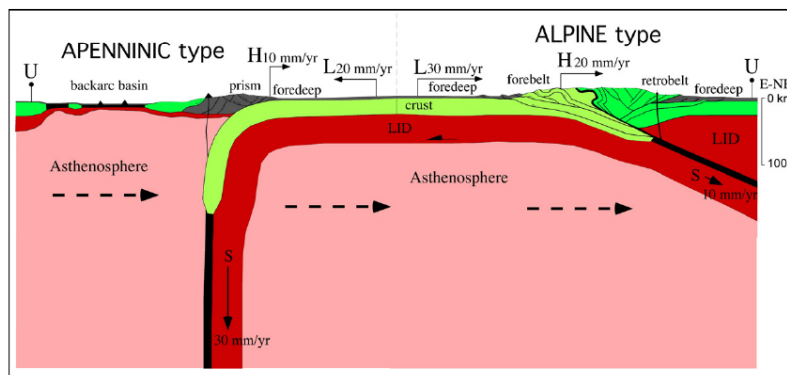


Fig. 31. Schematic sections showing how in an Alpine setting, the subduction rate is decreased by the migration of the hinge  $H$  toward the upper plate  $U$ , and the orogen in the final collisional stage is composed both by the upper and lower plate  $L$  rocks. In the opposed Apenninic setting, the subduction rate is rather increased by the migration of  $H$  away from  $U$ , and the accretionary prism is made of shallow rocks of the lower plate. Note also the shallower asthenosphere in the hangingwall, which is typical of W-directed subduction zones.

(Doglioni, 2007)

# Topografía

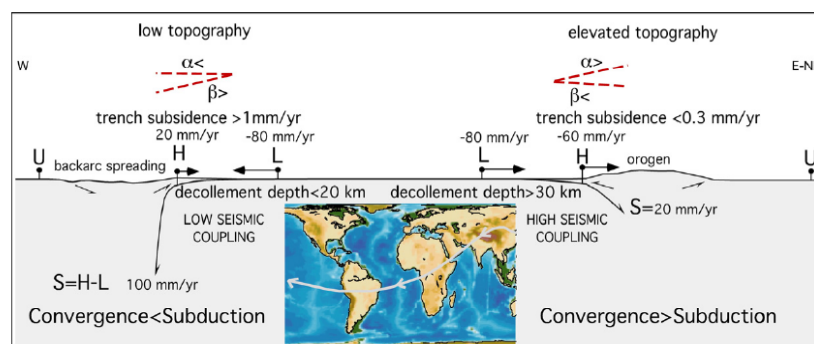


Fig. 32. Assuming fixed the upper plate  $U$ , along west-directed subduction zones the subduction hinge  $H$  frequently diverges relative to  $U$ , whereas it converges along the opposite subduction zones.  $L$ , lower plate. Note that the subduction  $S$  is larger than the convergence along W-directed slabs, whereas  $S$  is smaller in the opposite case. The two end-members of hinge behavior are respectively accompanied in average by low and high topography, steep and shallow foreland monocline, fast and slower subsidence rates in the trench or foreland basin, single vs. double verging orogens, etc., highlighting a worldwide subduction asymmetry along the flow lines of plate motions indicated in the insert (modified after Lencic and Doglioni, 2007).

(Doglioni, 2007)



Dorsales oceánicas podrían constituir barreras a los elementos incompatibles (fácilmente removilizables; K, U, Th, Nb, Ta, Rb, Ba) y así constituir una prueba de la existencia de un flujo global del manto

- “Generalmente presentan una batimetría 100-300 m mas somera, la cual puede ser explicada relacionándola con la topografía dinámica y el transito hacia el E de manto empobrecido luego de la fusión parcial en la dorsal” (Doglioni et al., 2003)

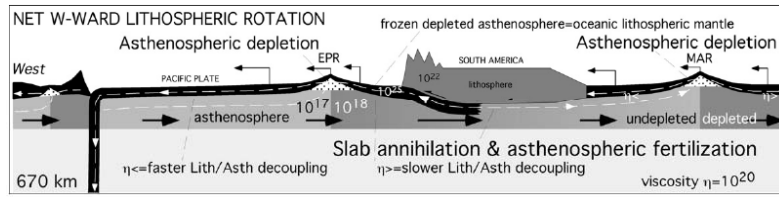
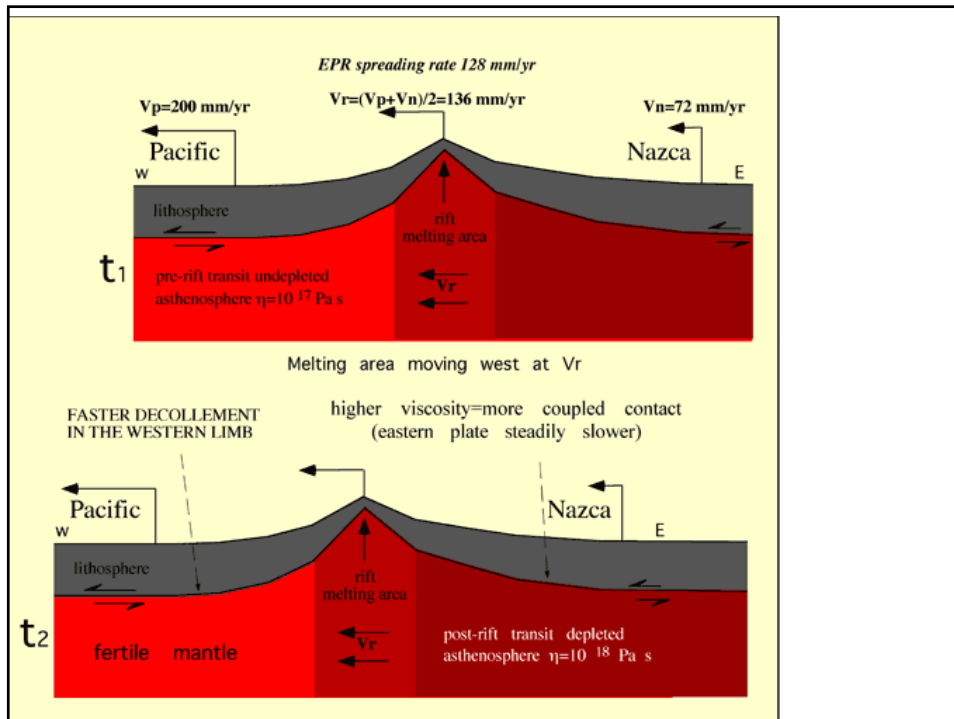


Fig. 29. Model for the upper mantle cycle. The lower the asthenospheric viscosity, the faster the W-ward displacement of the overlying plate. The asthenospheric depletion at oceanic ridges makes the layer more viscous and decreases the lithosphere/asthenospheric decoupling, and the plate to the east is then slower. The oceanic lithosphere subducting E-ward enters the asthenosphere where it is molten again to refertilize the asthenosphere. W-directed subductions provide deeper circulation. Note that the E-directed subduction (the Andes) tends to escape out of the mantle, but it is overridden by the upper plate (South America, after Doglioni et al., 2006a). (Doglioni, 2009)

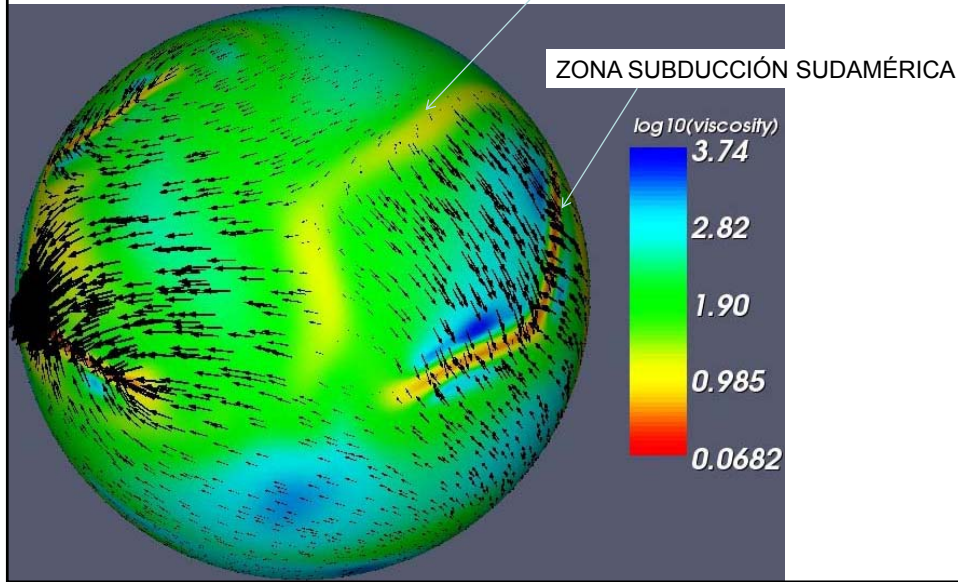


<https://speakingofgeoscience.org/2016/05/18/how-did-plate-tectonics-begin/>

BARRERAS NATURALES A LA VISCOSIDAD DEL MANTO

DORSAL PACÍFICA

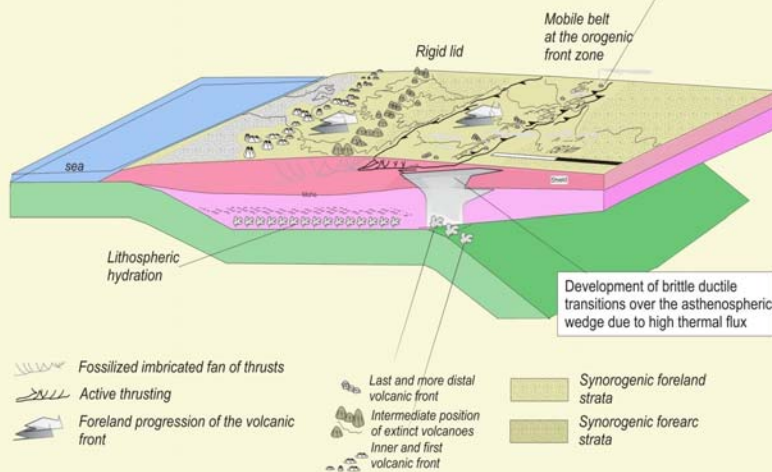
ZONA SUBDUCCIÓN SUDAMÉRICA



Zonas de subducción horizontal o somera

NORMAL-TO-FLAT SUBDUCTION AND MAGMATISM

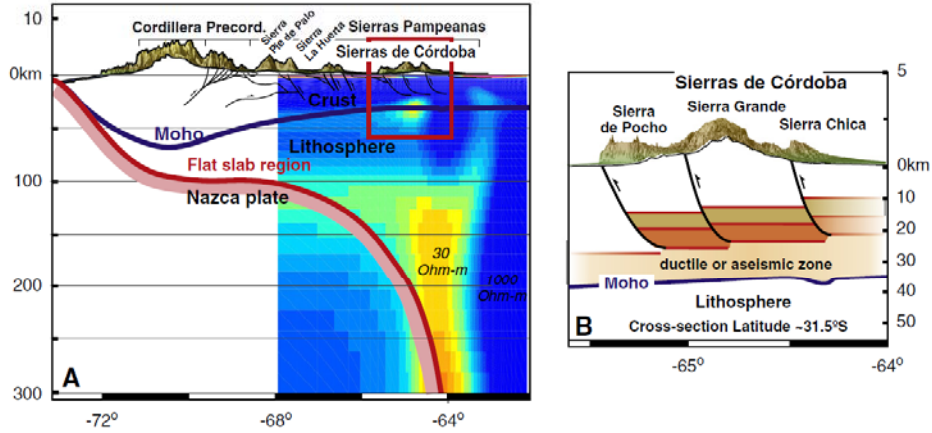
High-K low voluminous magmatic arc front



Flat slab provoca migración del arco y consigo cambia estructura térmica de la placa superior generando transiciones frágiles dúctiles que fragmentan el antepaís

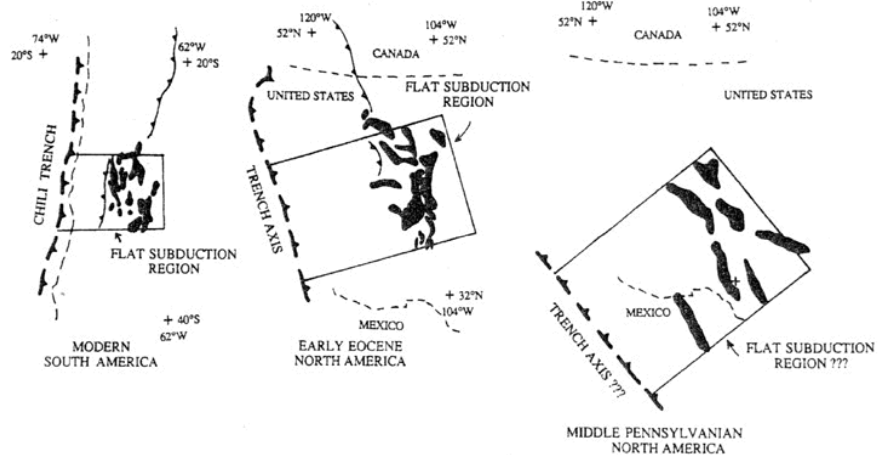
Perarnau et al 2012

Nivel de despegue de sierras Pampeanas cercano a Moho



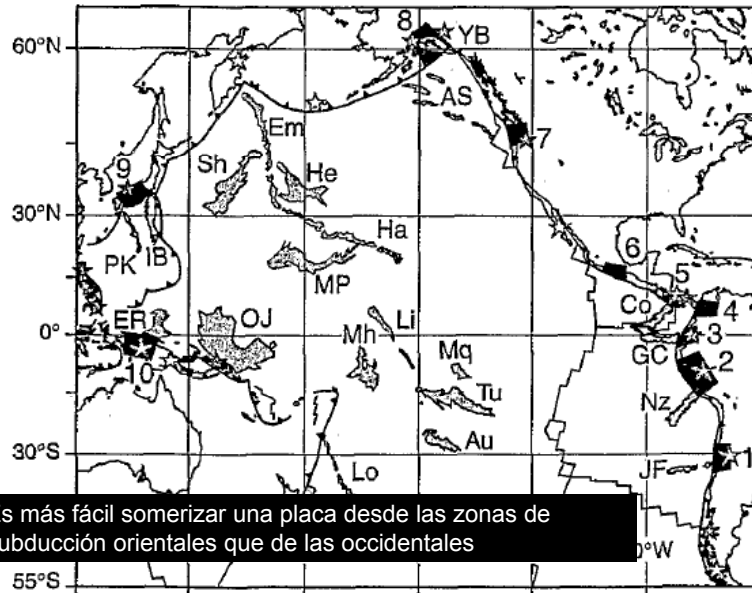
Ye et al 1996

Expansión del arco en zonas de subducción horizontal genera transiciones frágiles dúctiles sobre las cuales se expone el basamento en el antepaís

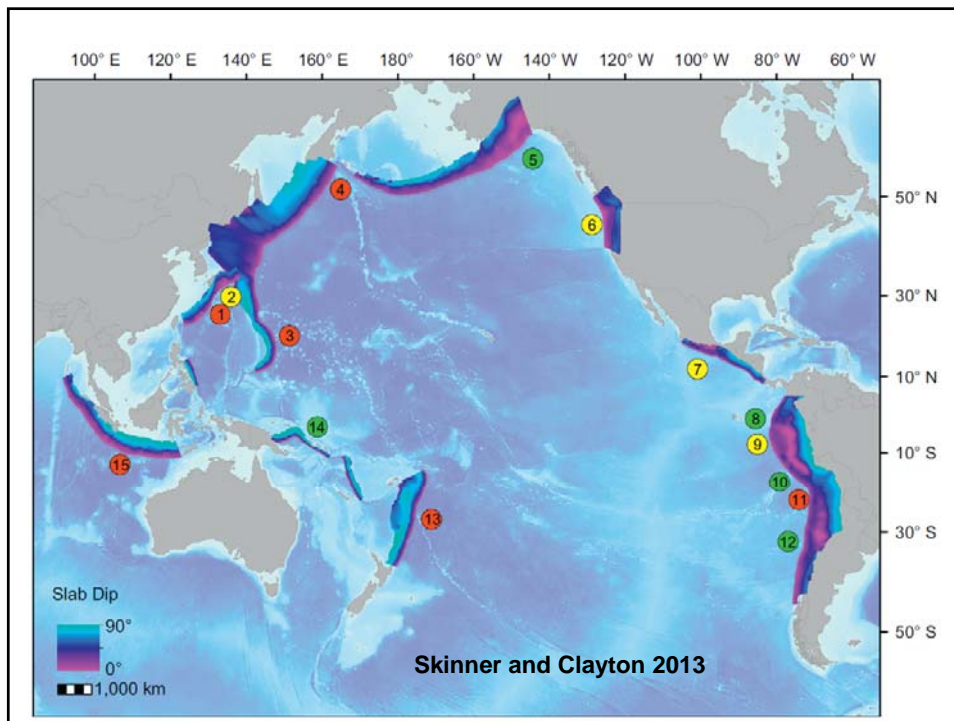


**Zonas de subducción horizontal actuales**

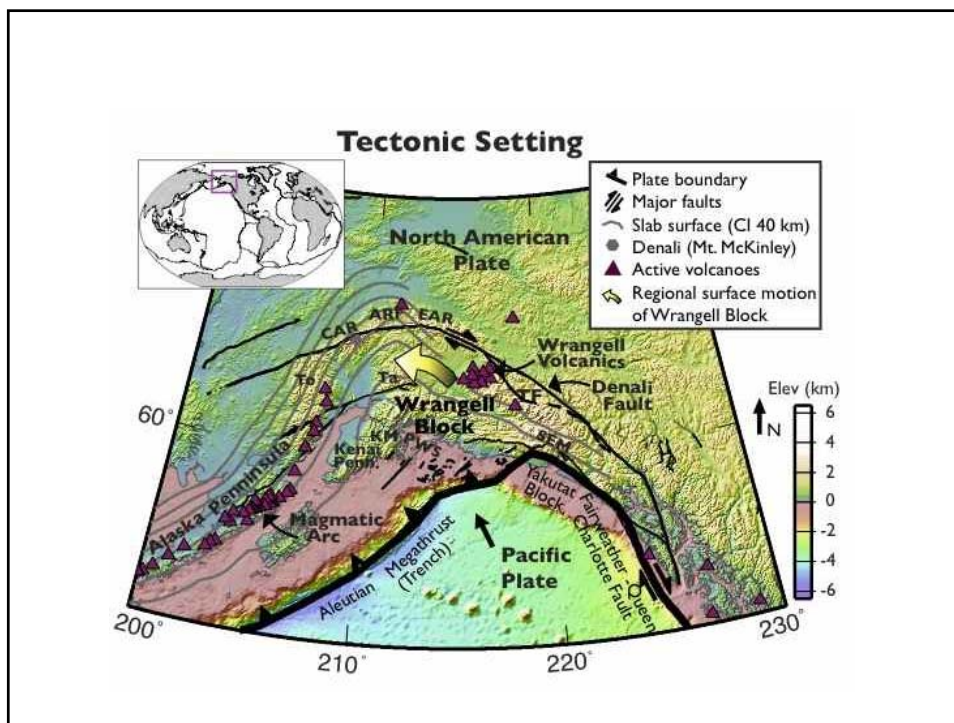
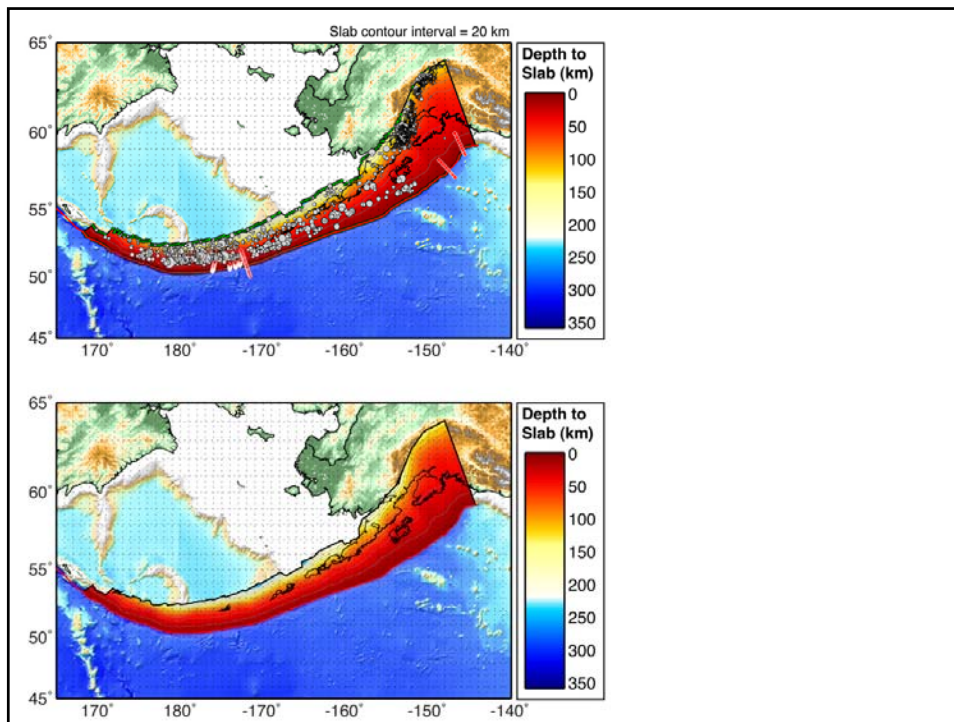
Gutscher et al., 2000



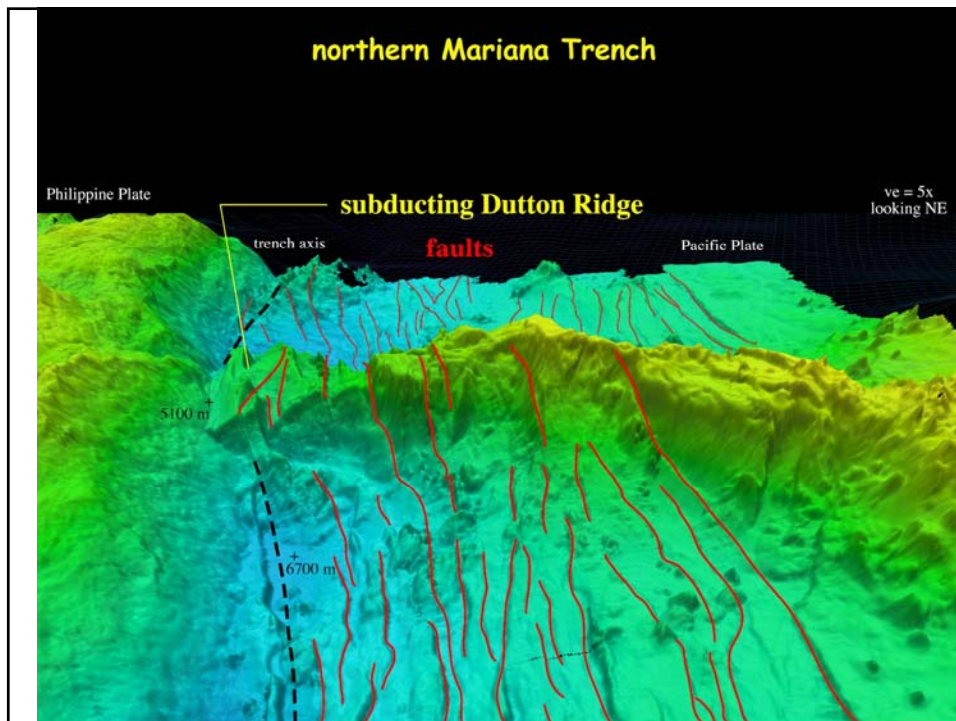
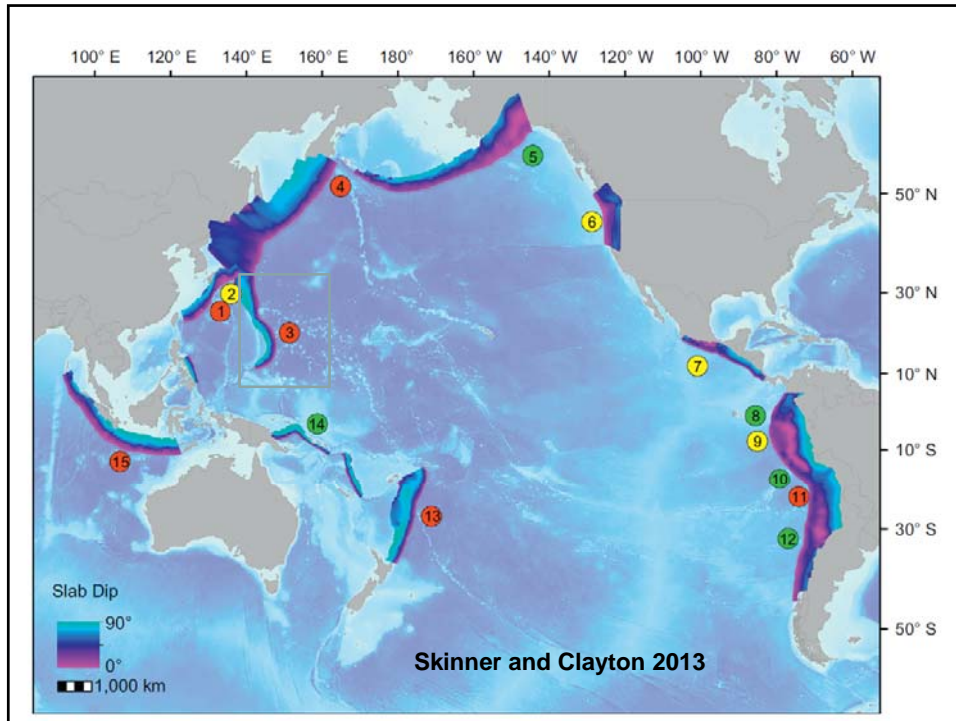
Es más fácil somerizar una placa desde las zonas de subducción orientales que de las occidentales

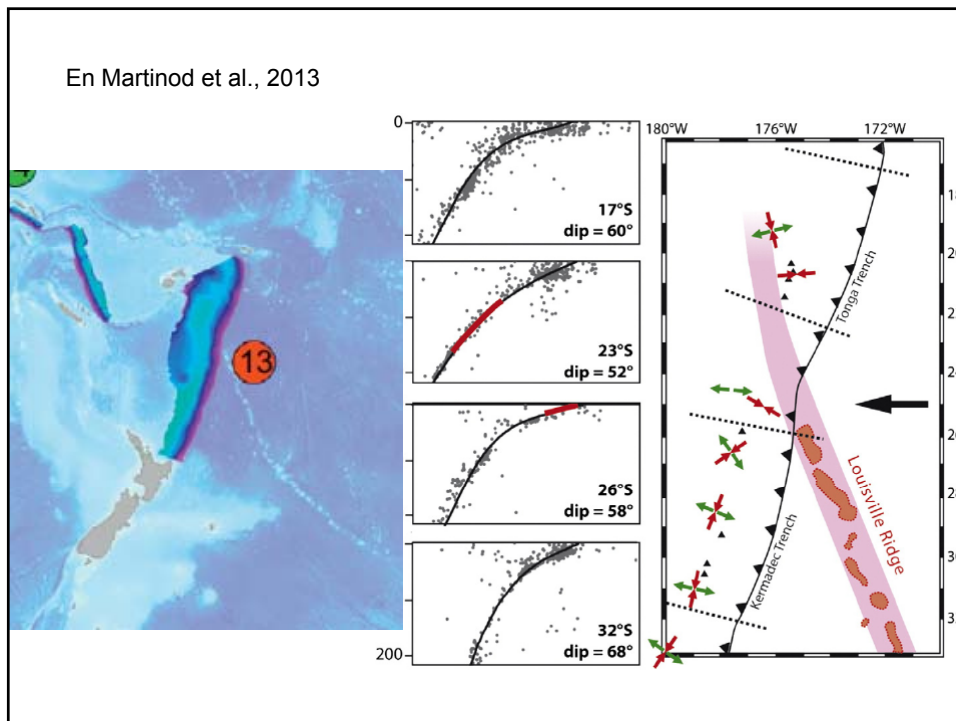
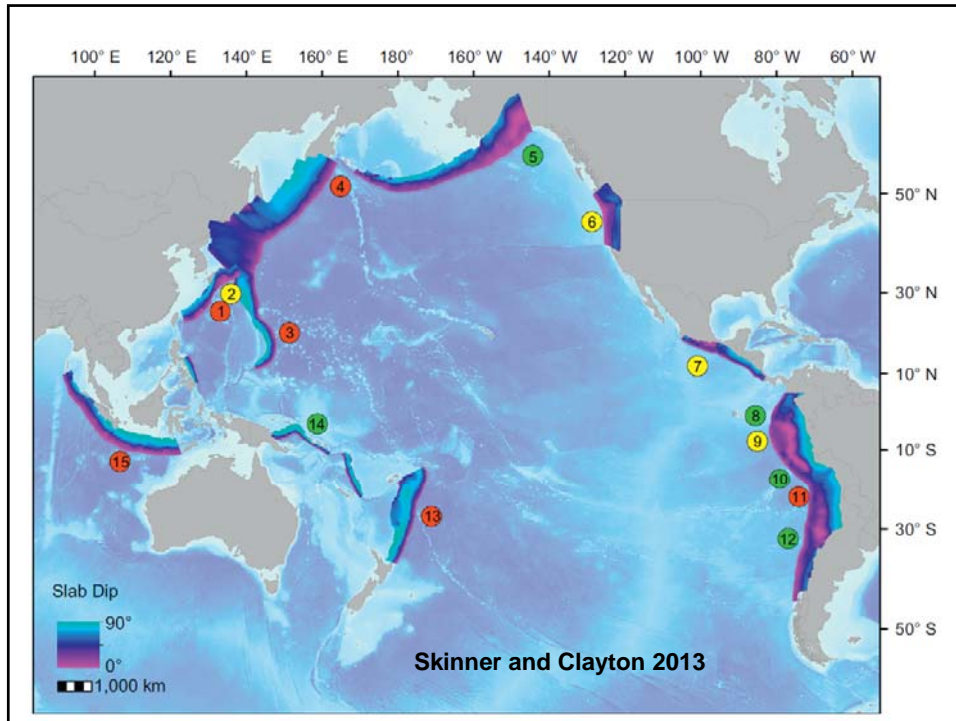






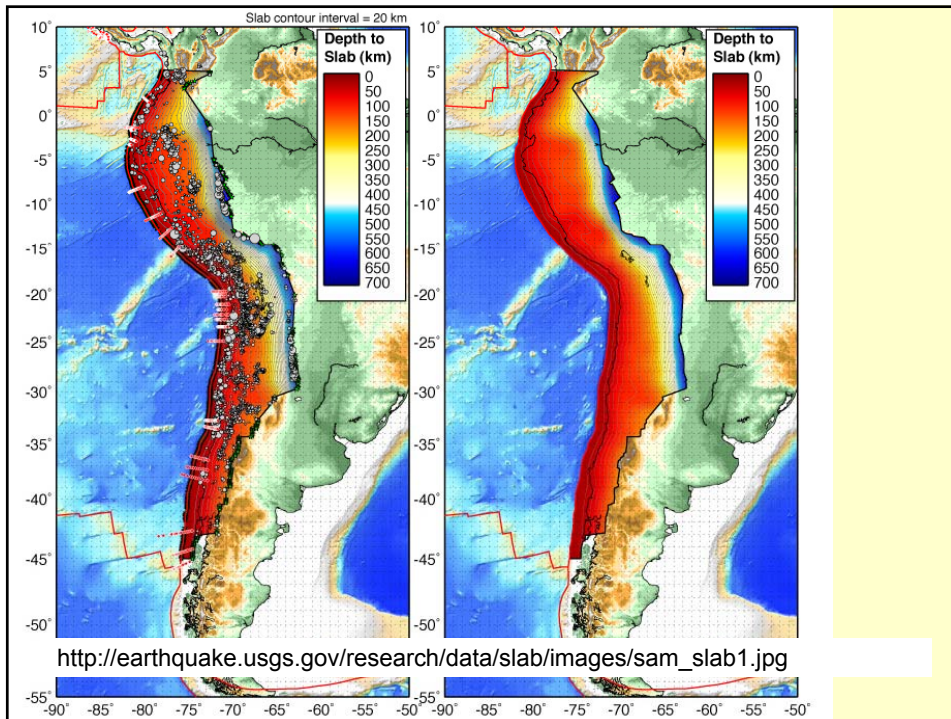


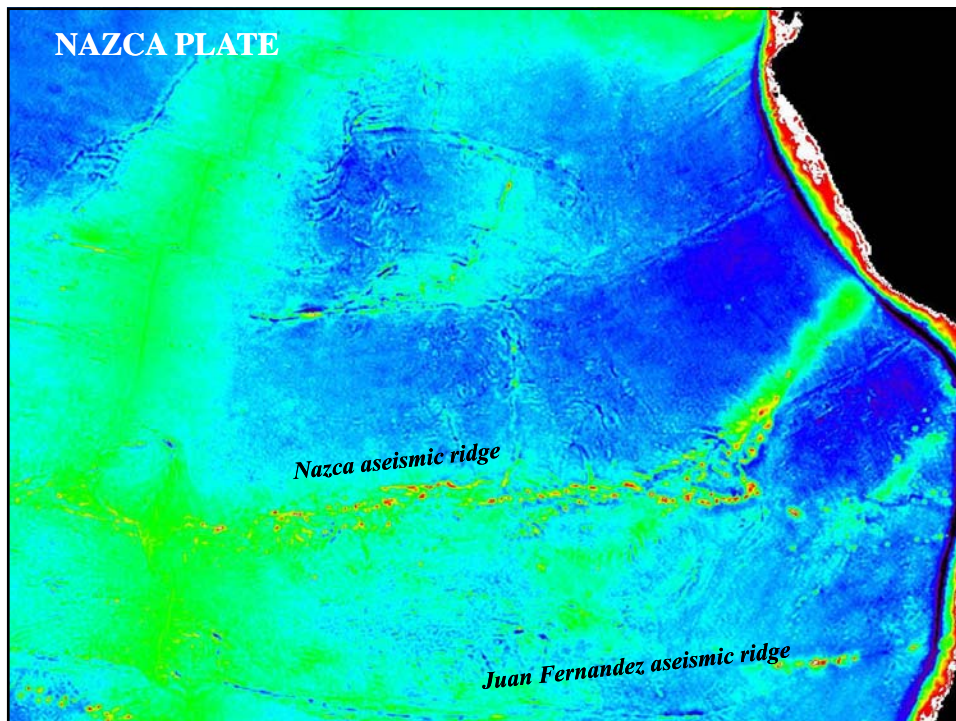


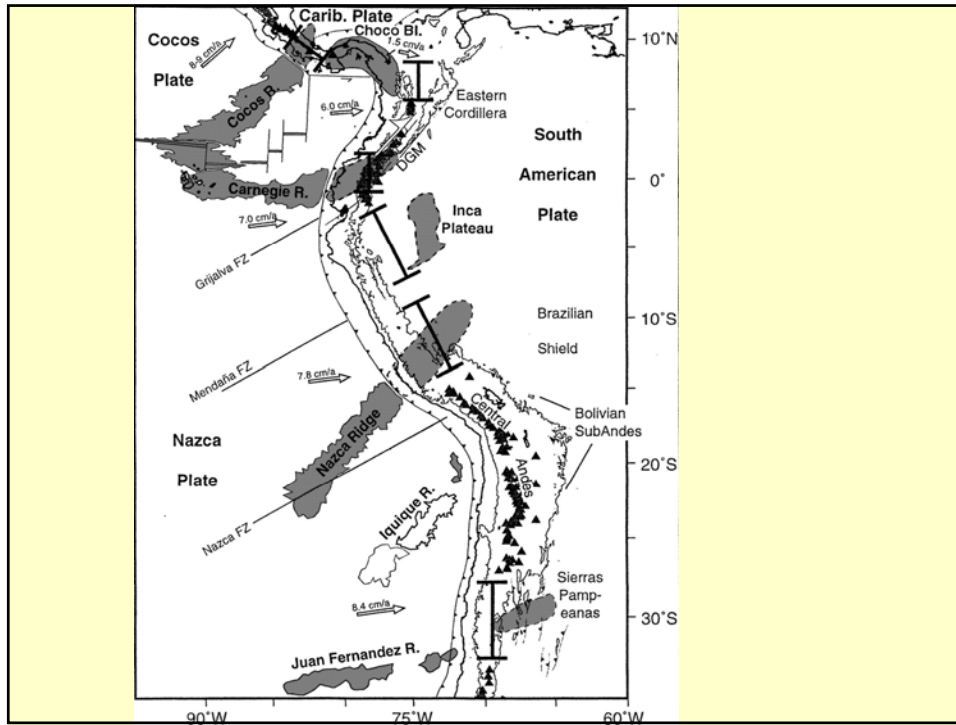




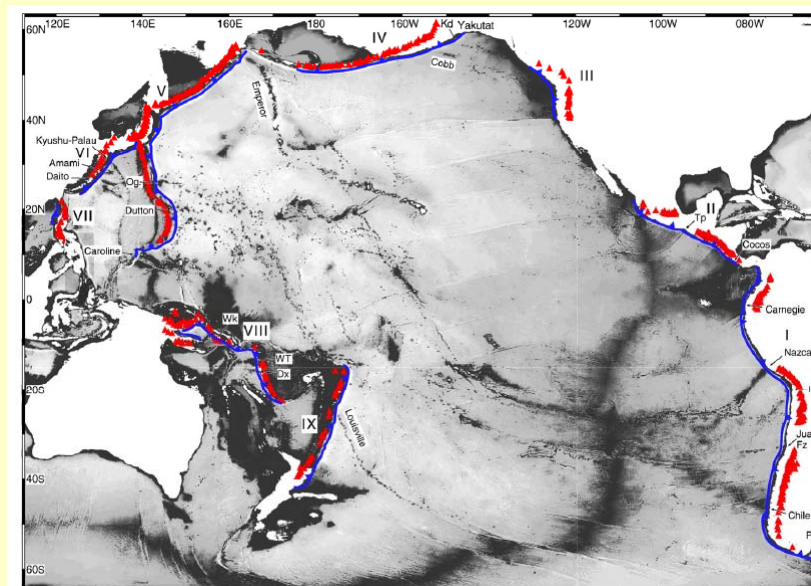
**Correlación actual entre zonas de colisión de dorsales asísmicas y flat slabs**







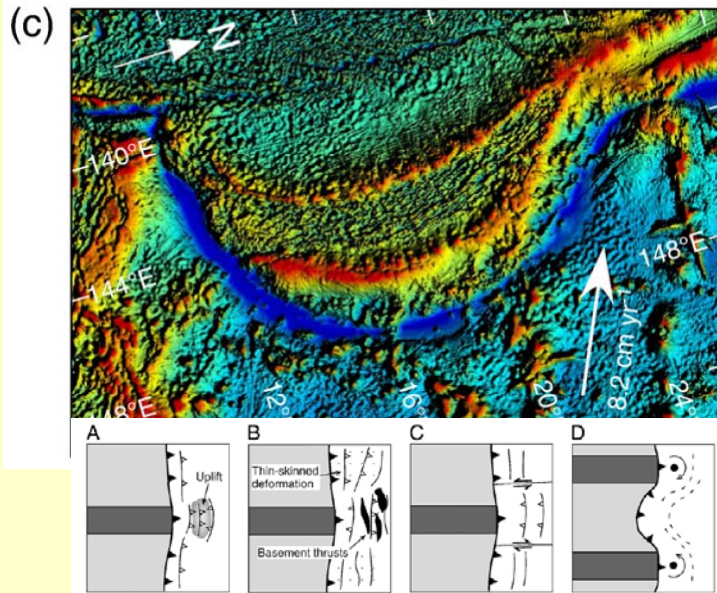
Las colisiones de dorsales asísmicas inhiben el retroceso de la trinchera en los puntos de colisión (velocidad de roll back) y determinan curvaturas en el margen



Rosenbaum y Mo, 2011



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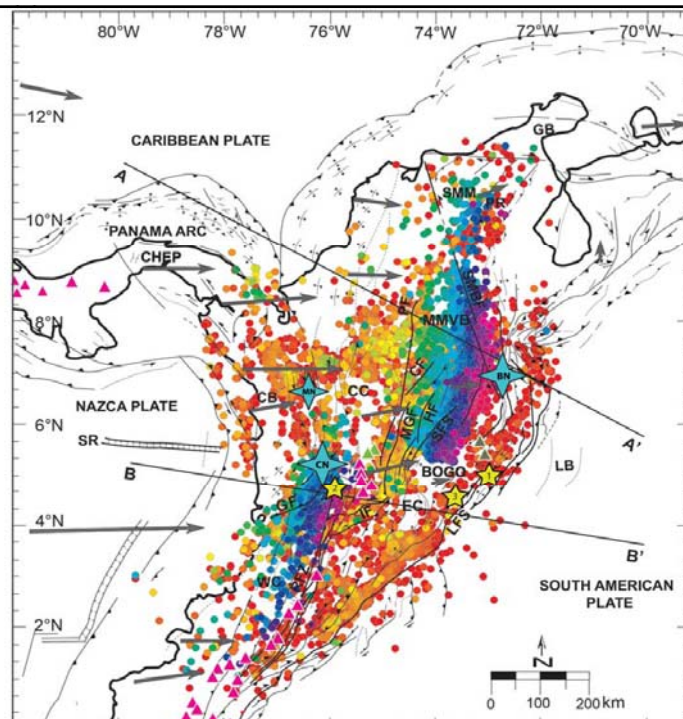


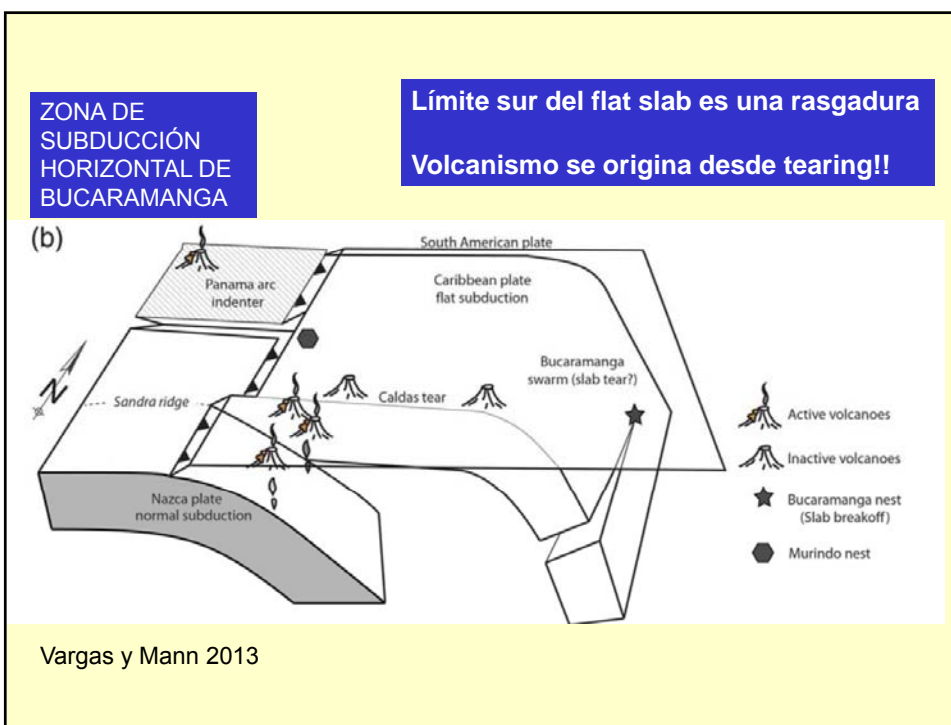
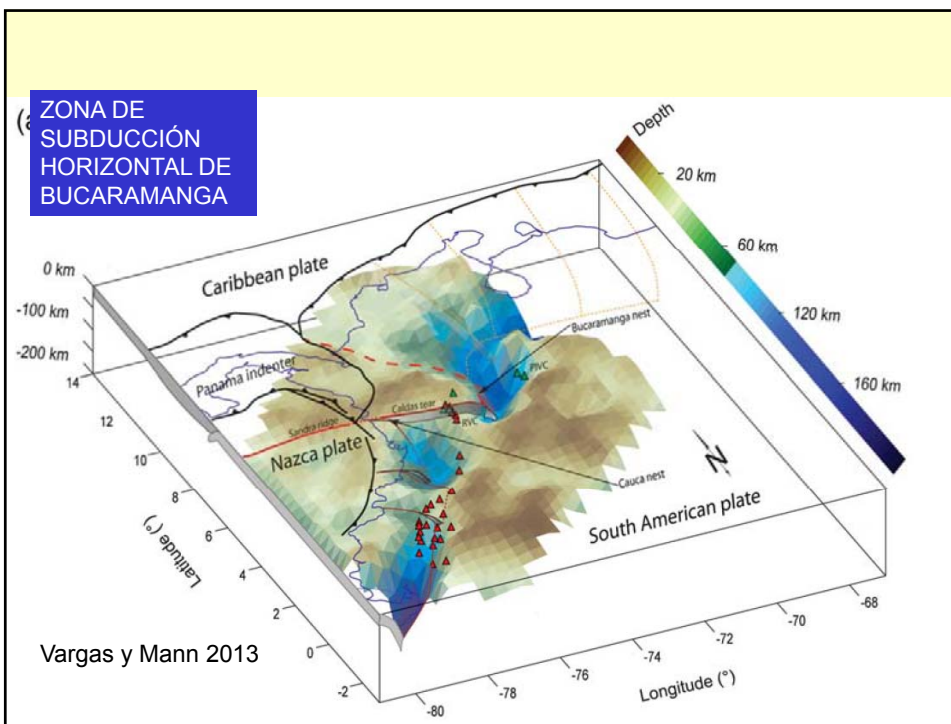
Rosenbaum y Mo, 2011

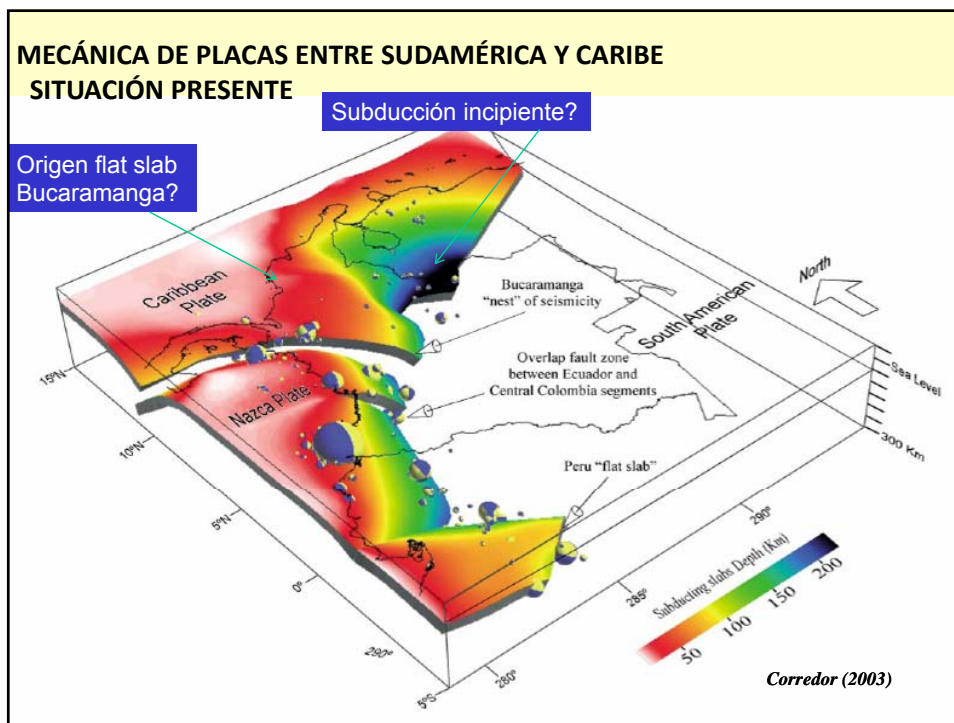
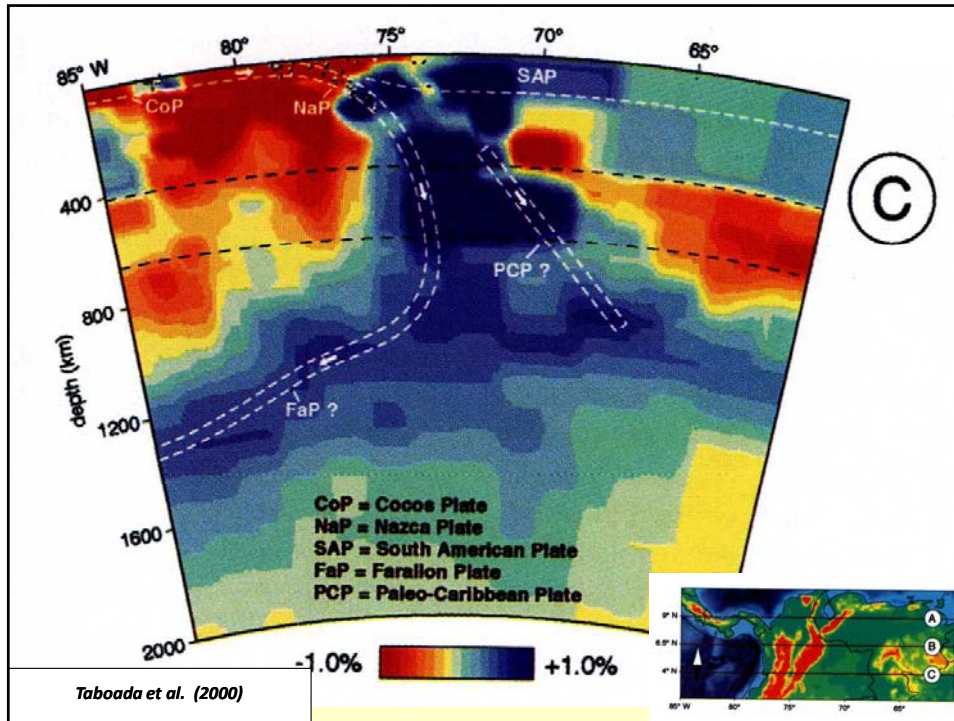
ZONA DE SUBDUCCIÓN HORIZONTAL DE BUCARAMANGA

Su origen?

Vargas y Mann 2013





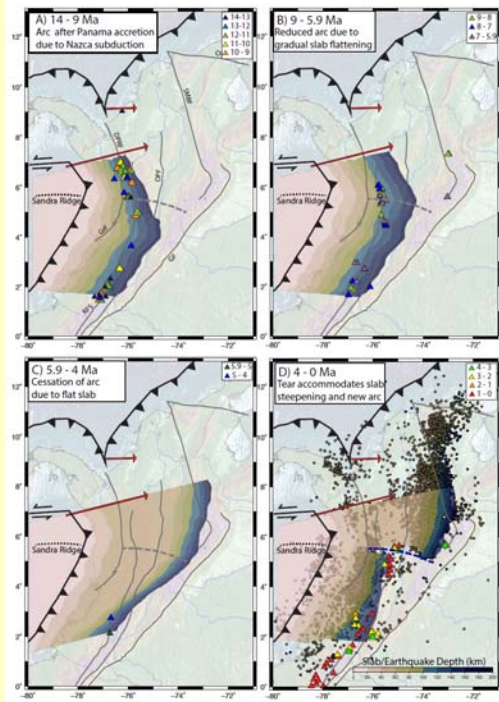








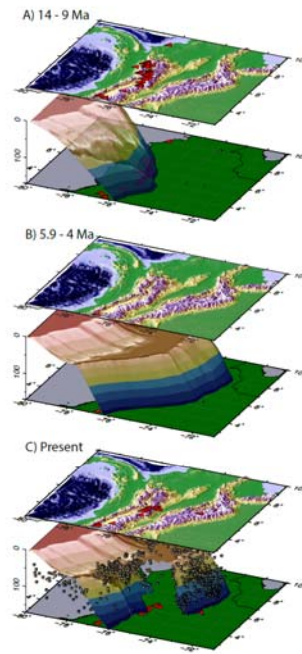
Wagner et al 2017



La otra posibilidad es q el tearing represente la verticalización de la parte sur de un gran flatslab

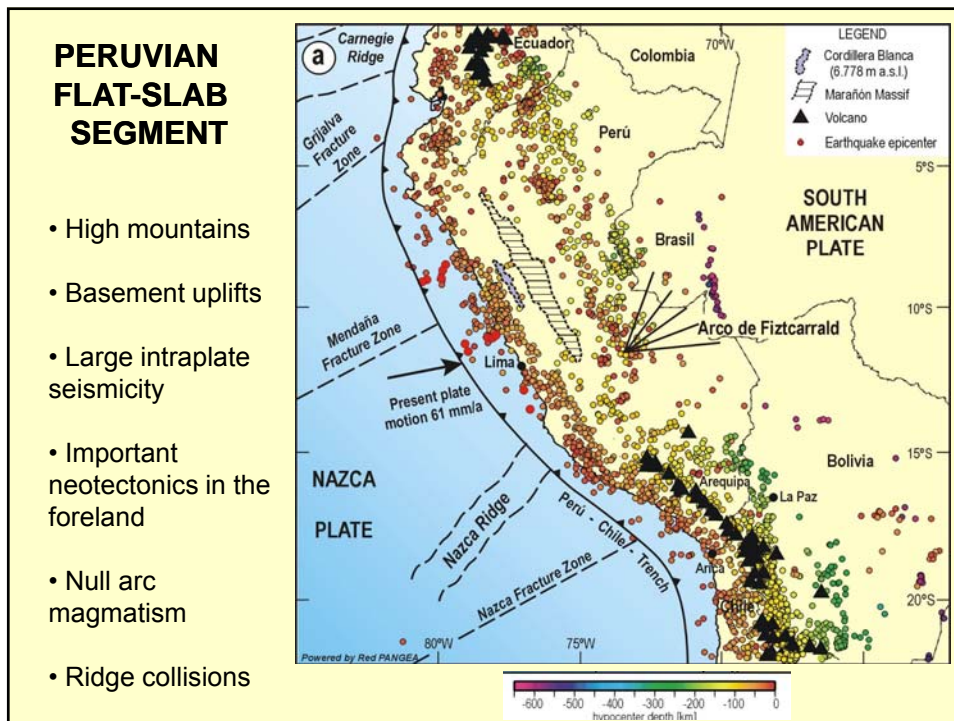
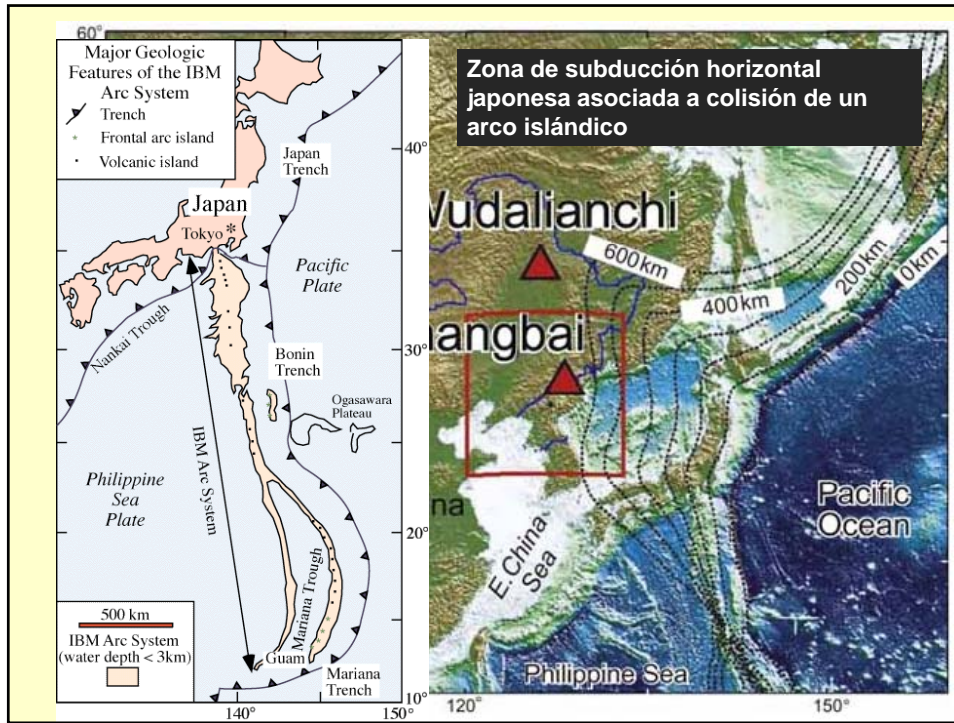
Ya que el arco magmático parece haber migrado en la parte sur también

Wagner et al 2017

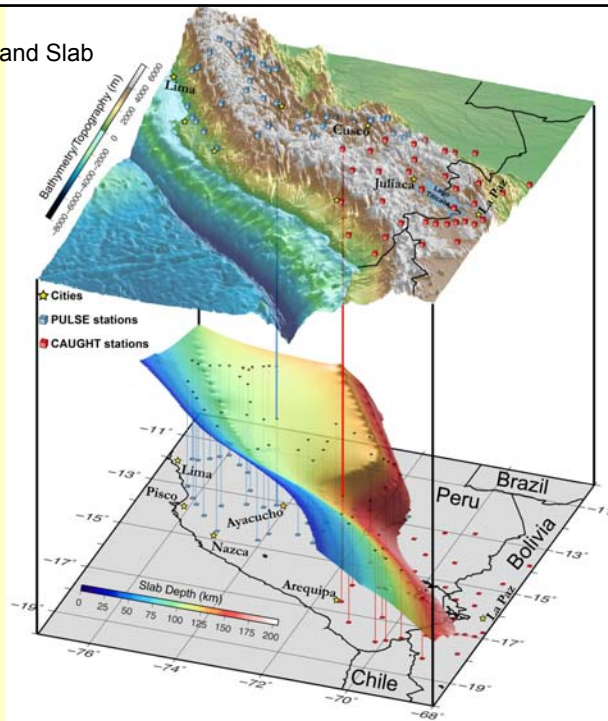


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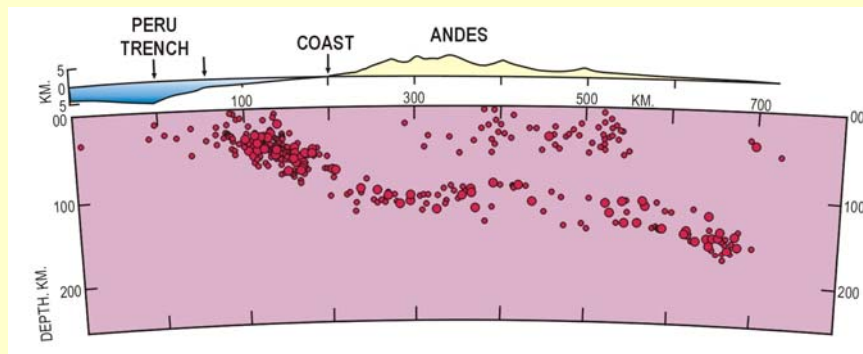


2012 IRIS Workshop  
 PULSE: The Peru Lithosphere and Slab  
 Experiment  
 L.S. [Wagner](#) et al 2012



## PERUVIAN FLAT SLAB SEGMENT

### Shallow intracrustal seismicity

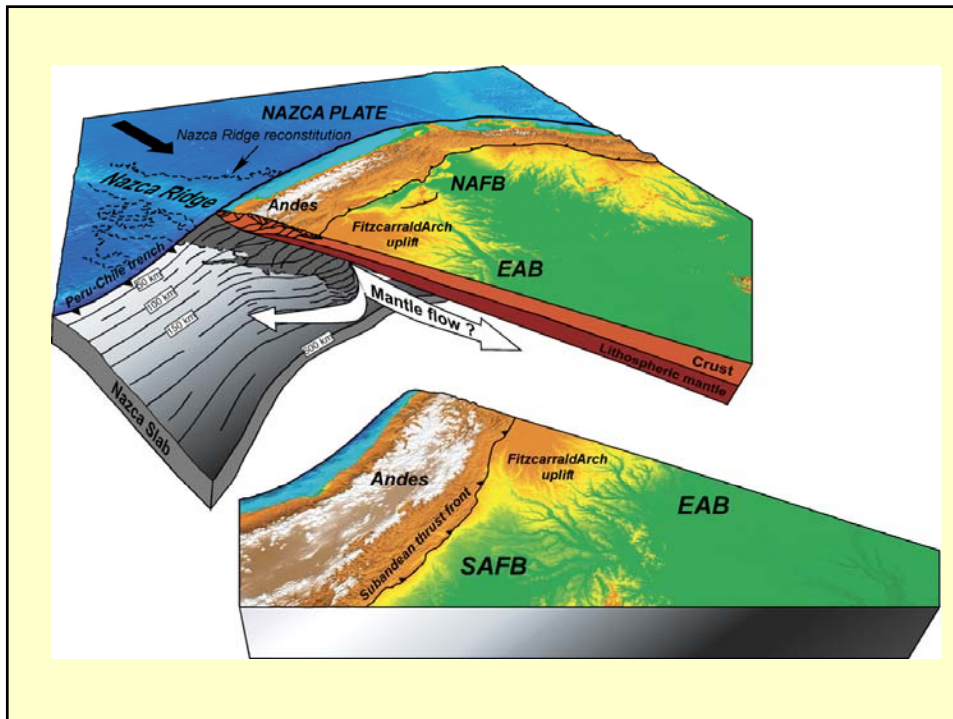
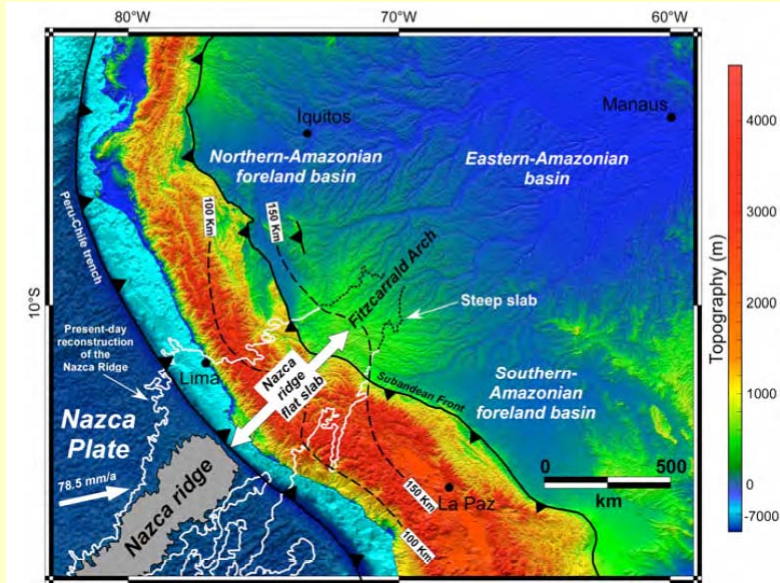


*Dorbath et al. (1991)*

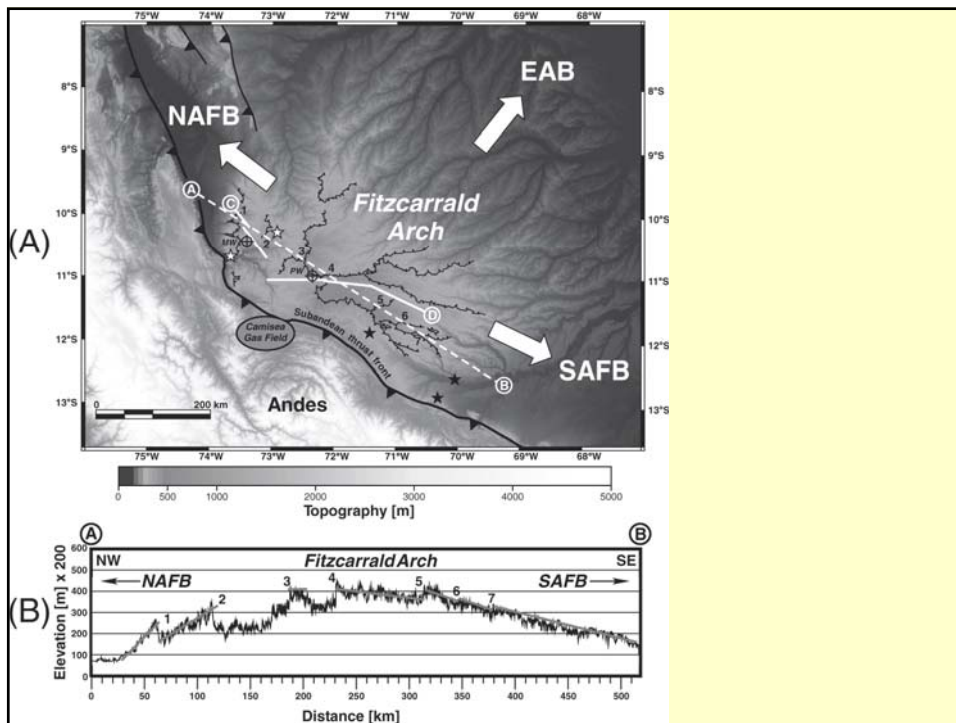
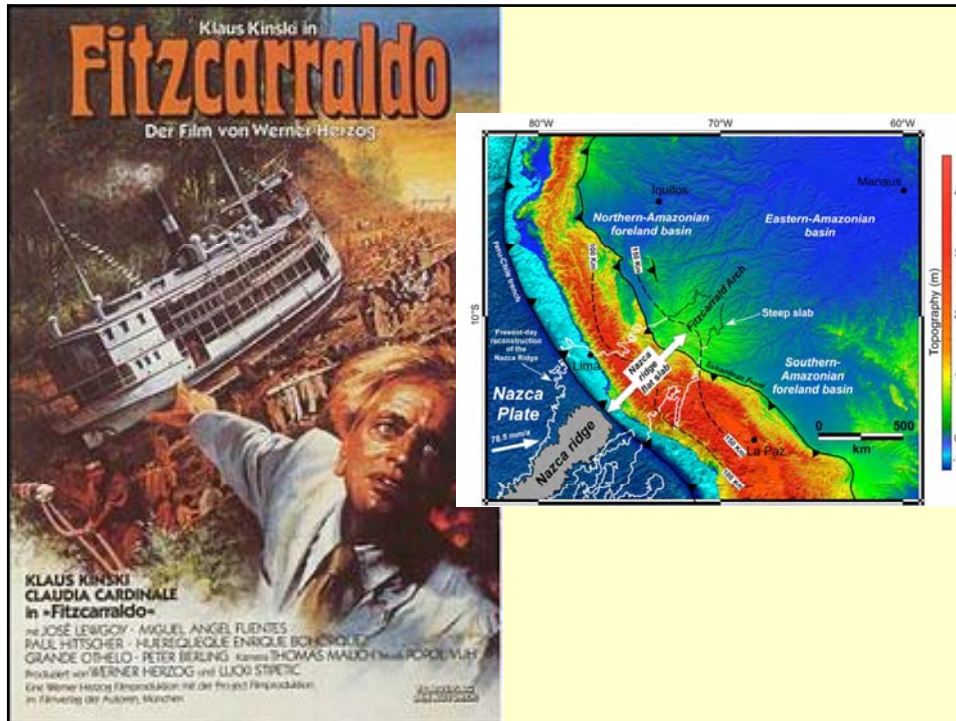


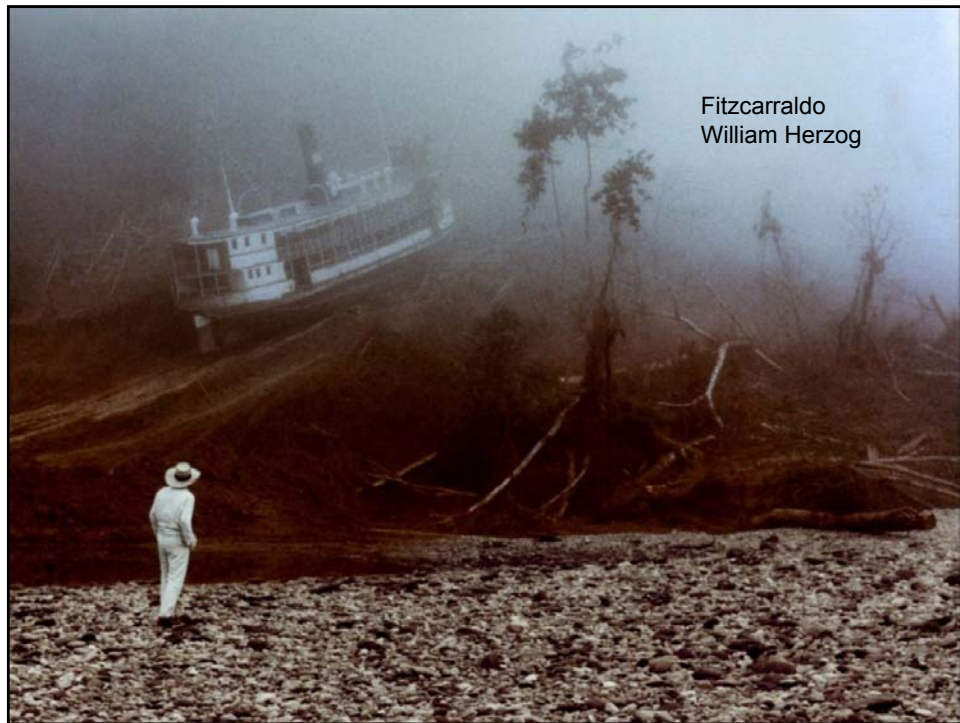
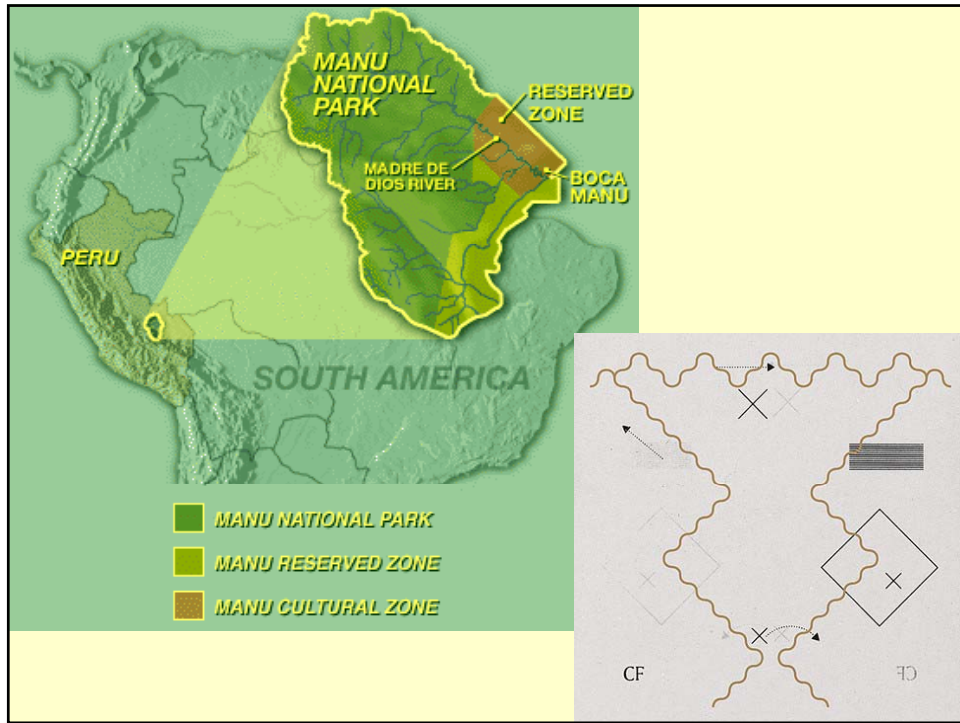
Arco de Fitzcarraldo en el Amazonas

Espurt et al., 2007  
 Martinod et al., 2008



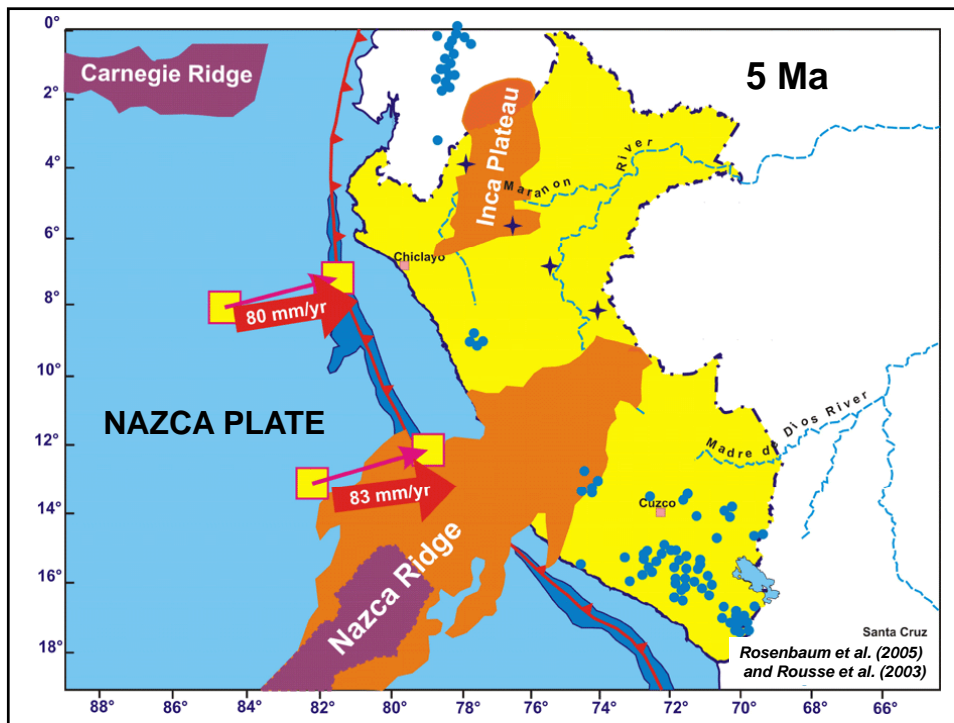
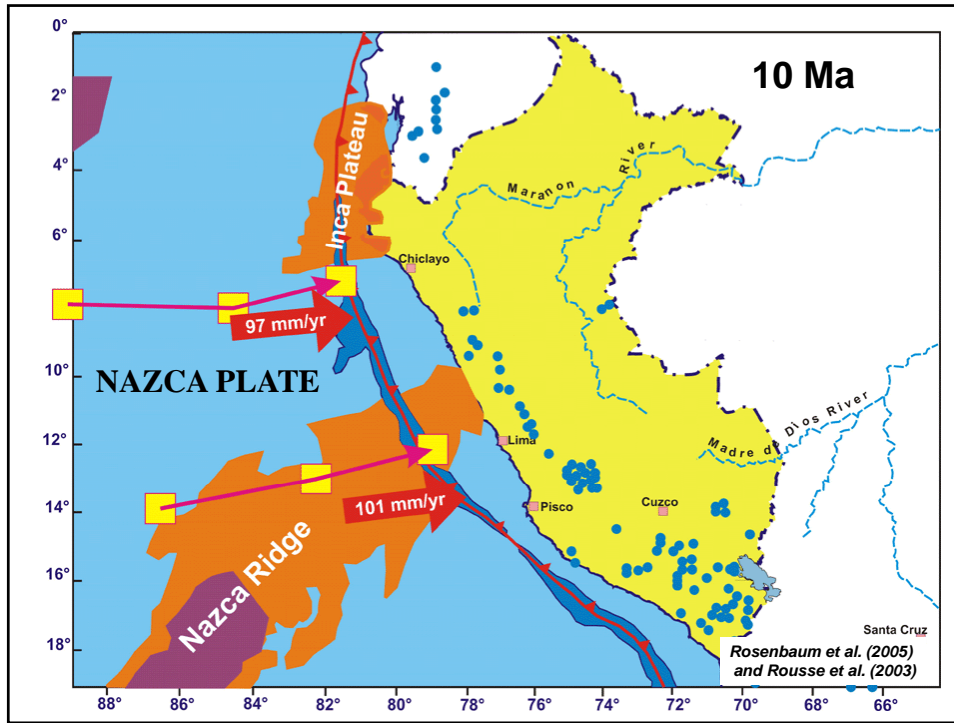




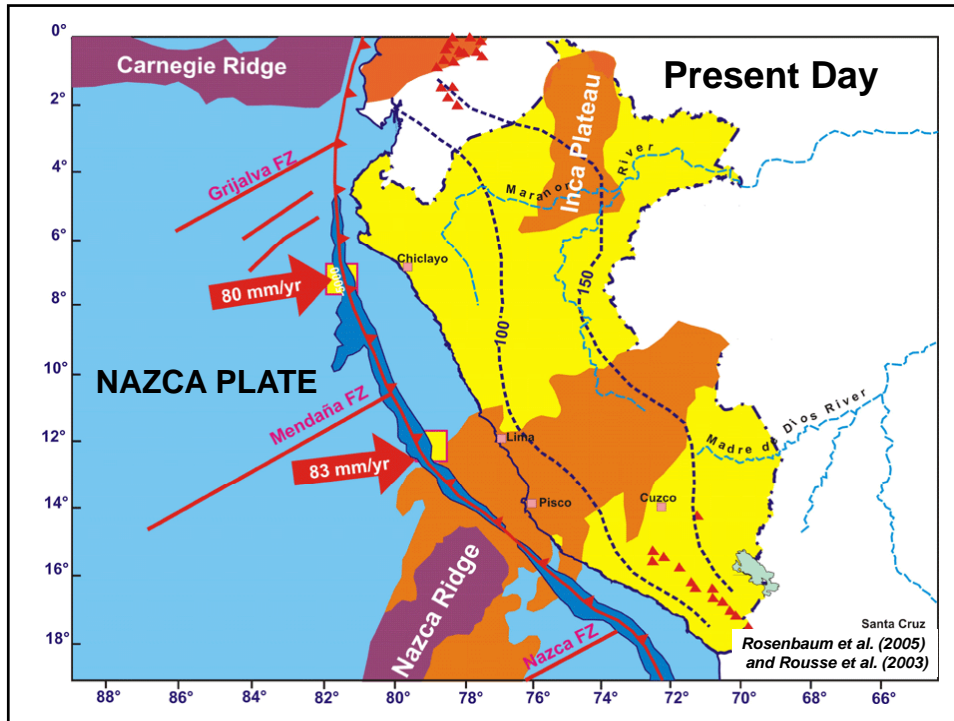




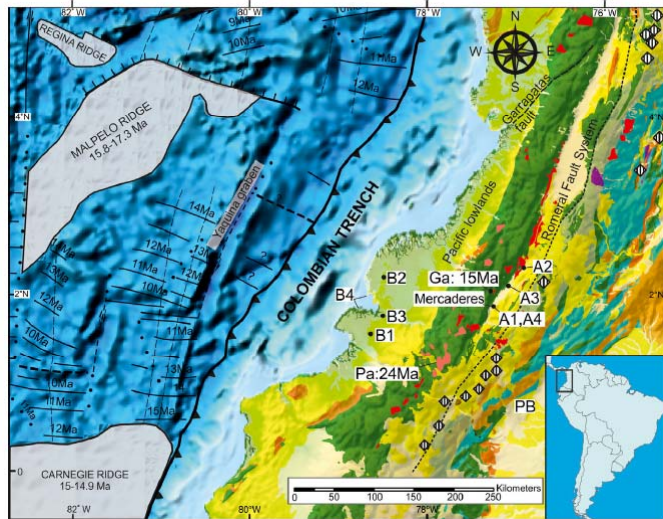








Probablemente subducción del inca plateau y quizás una extensión de carnegie gatillo en el sur de Colombia un episodio de somerización contemporáneo a flat slab peruano



Echeverri et al 2016

Probablemente subducción del inca plateau gatilló en el sur de colombia un episodio de somerización contemporáneo a flat slab peruano

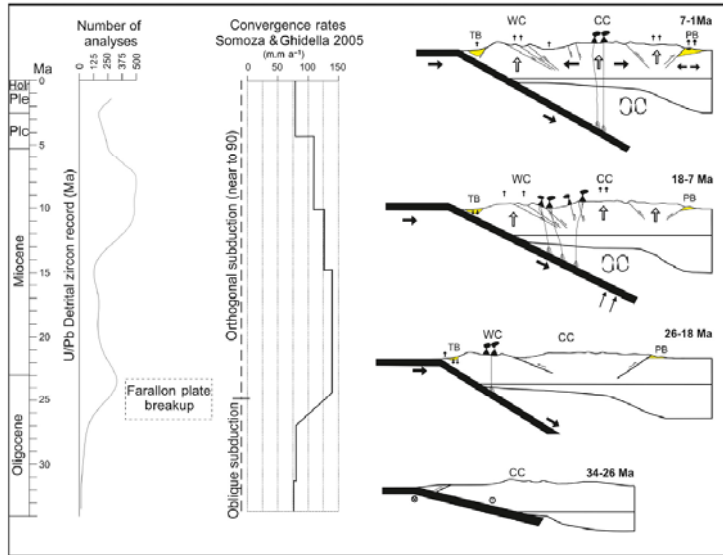
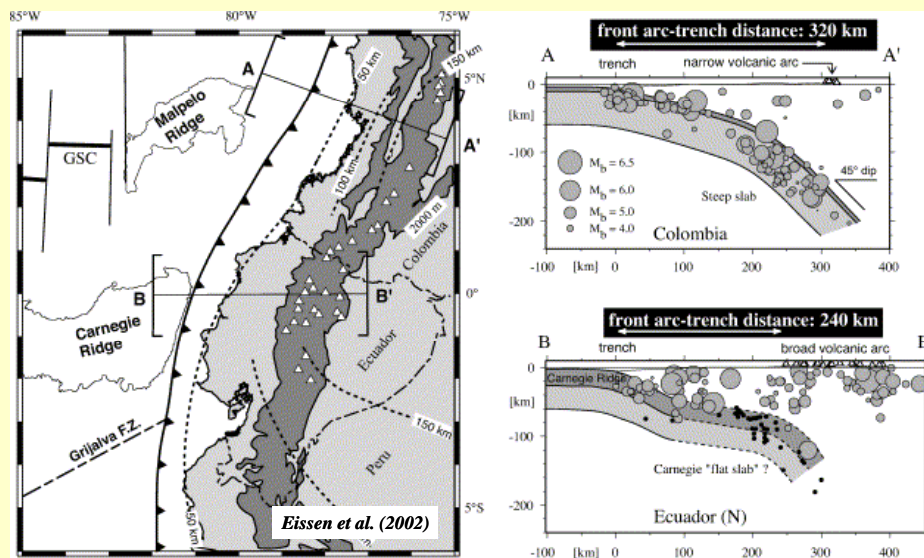
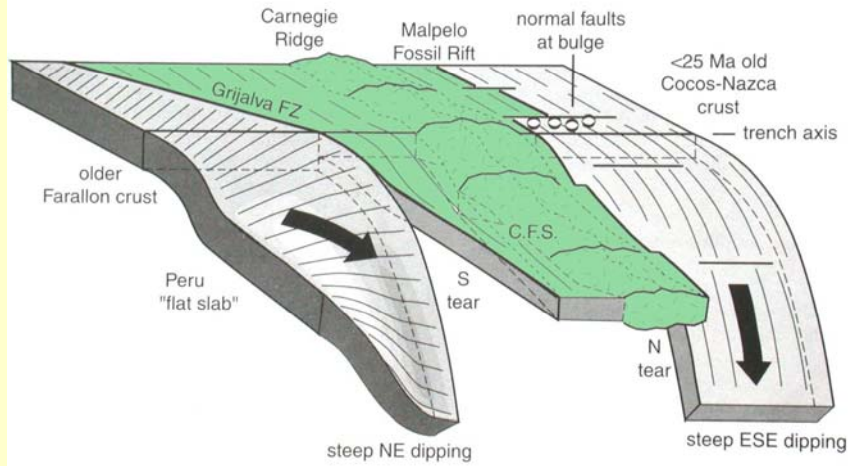


Fig. 3 Comparative chart showing the U/Pb detrital zircon ages, the tectonic variables in the Pacific margin of the northern Andes from the Oligocene to the present (after Meschede and Barchhausen, 2000) and the proposed tectonic model for the continental margin between 34 Ma and 1 Ma. CC, Central Cordillera; WC, Western Cordillera; TB, Tumaco Basin; PB, Putumayo Basin.

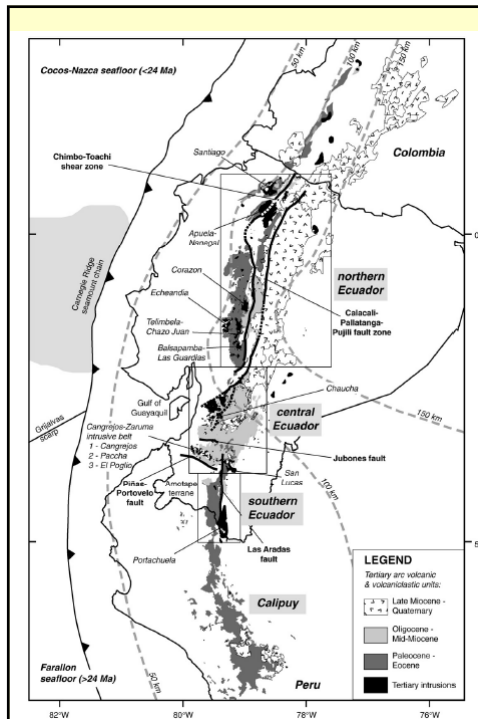
## CARNEGIE FLAT-SLAB (FLAT SLAB INCIPIENTE)



## COLISIÓN DE LA DORSAL ASÍSMICA DE CARNEGIE



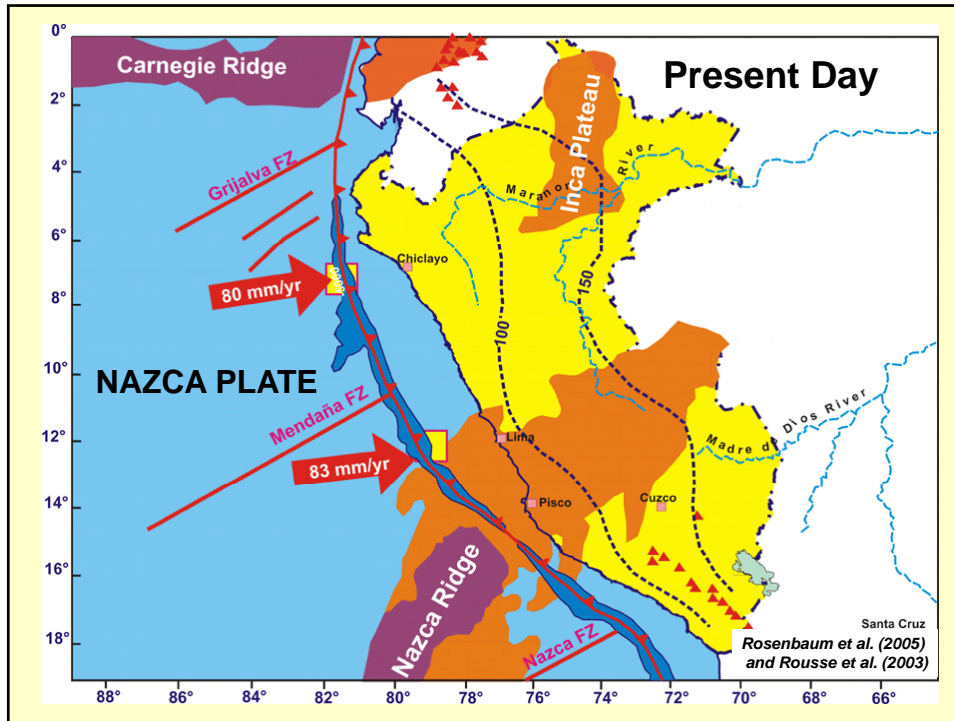
Gutscher et al. (2000)



UN ARCO EN PROCESO DE EXPANSIÓN POR COLISIÓN DE PLATEAU DEL INCA Y CARNEGIE

Scütte et al 2010

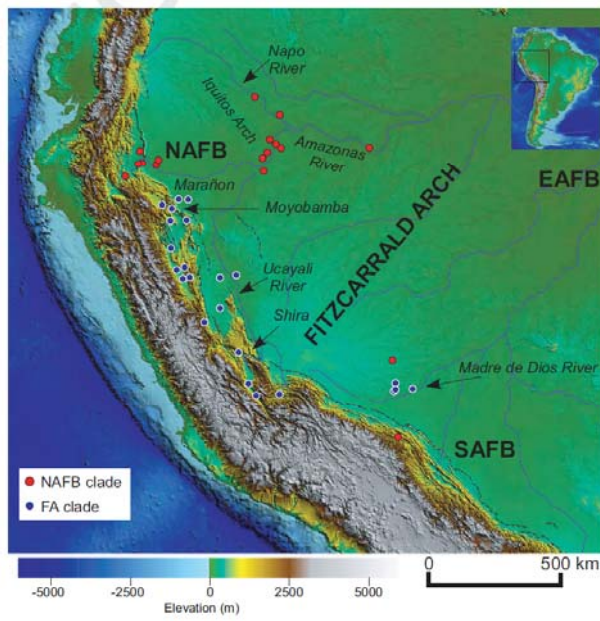
Somerización a partir del Mioceno medio a superior



LA DIVERSIDAD DE LAS PLAMERAS AMAZÓNICAS HA DEPENDIDO DE LA INCEPCIÓN DE LA DORSAL DE FTZCARRALDO?

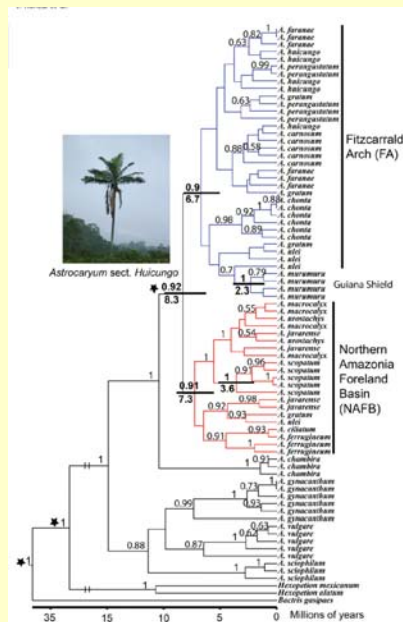


Cambios en la diversidad de palmeras regidos por inyección de dorsal de Fitzcarraldo

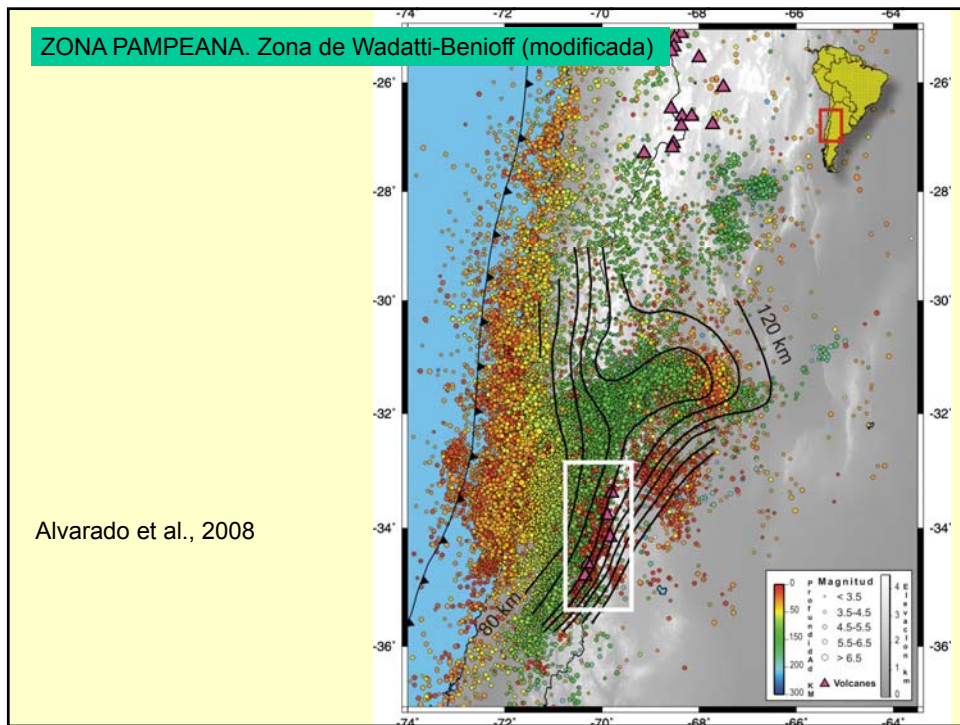
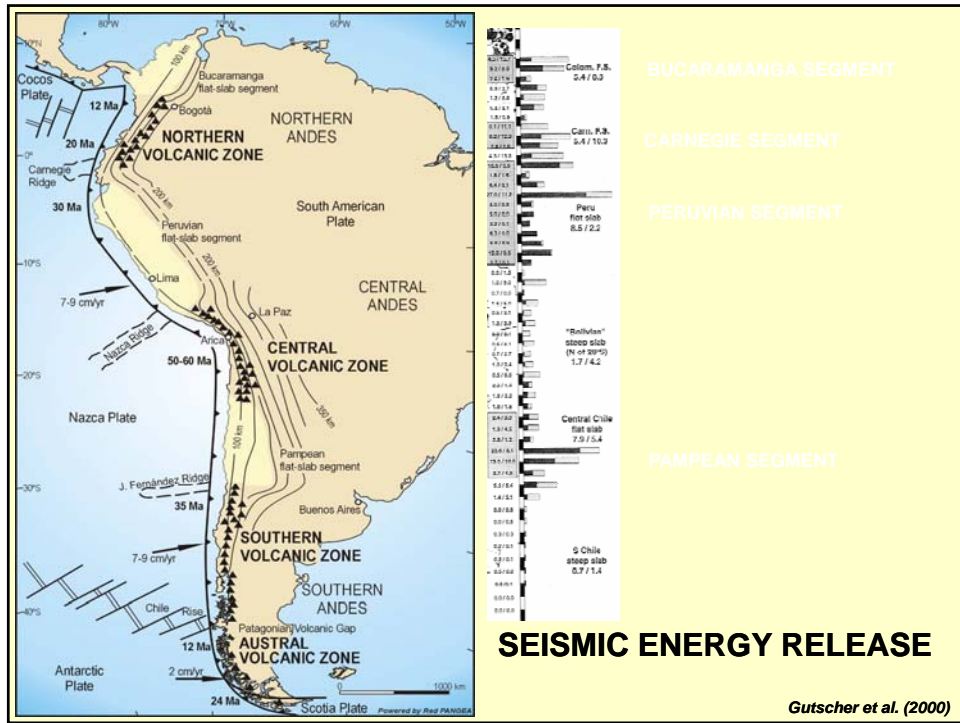


Roncal et al 2015

Cambios en la diversidad de palmeras regidos por inyección de dorsal de Fitzcarraldo

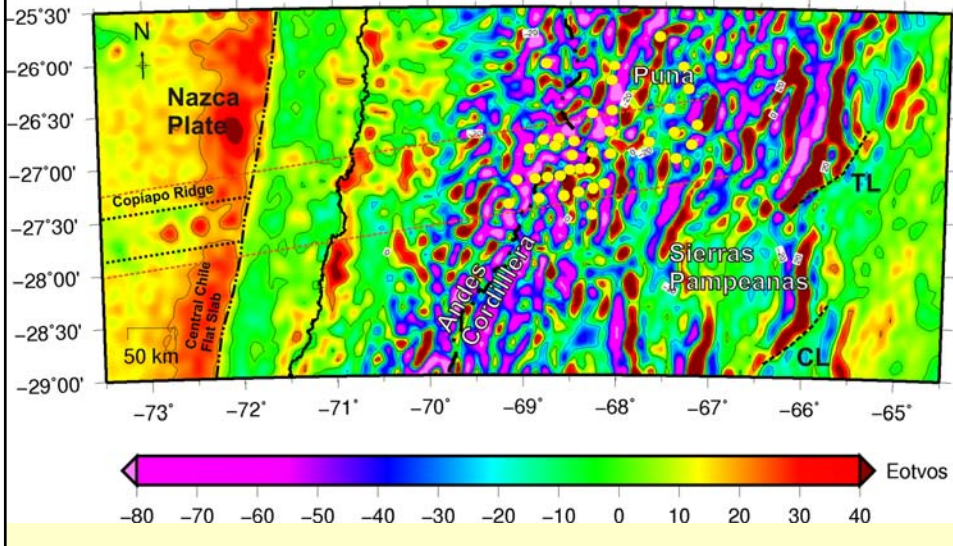


Roncal et al 2015



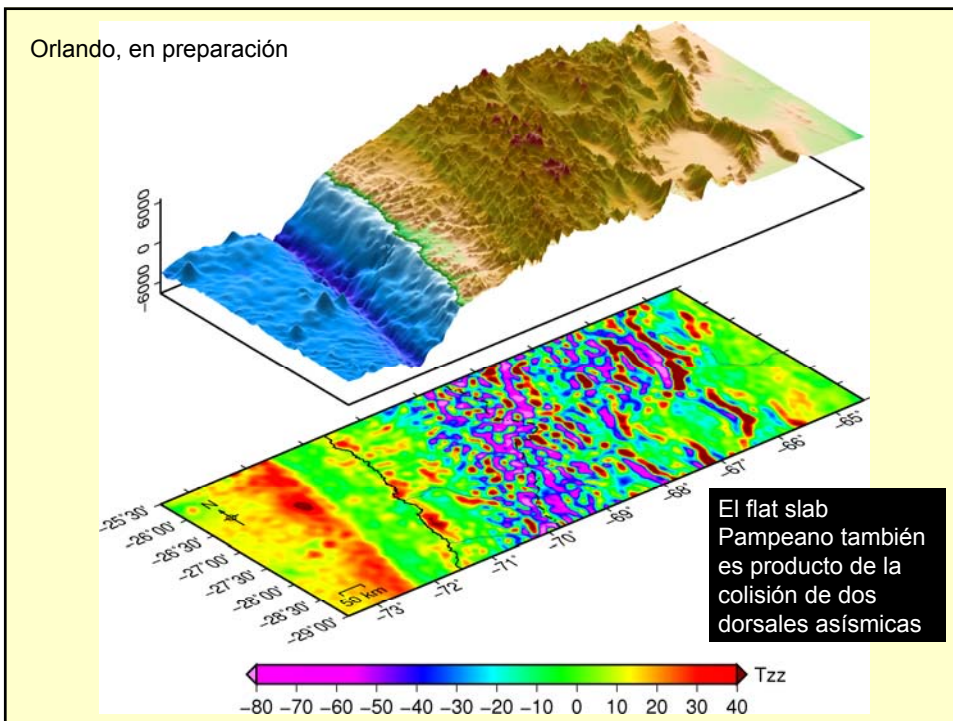
Orlando, en preparación

El flat slab Pampeano también es producto de la colisión de dos dorsales asísmicas

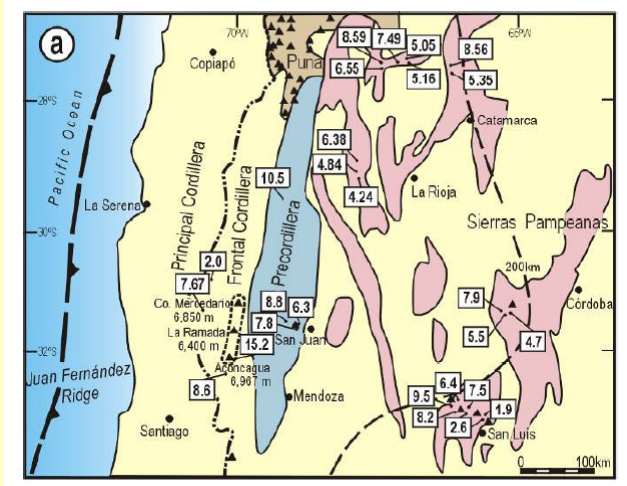


Orlando, en preparación

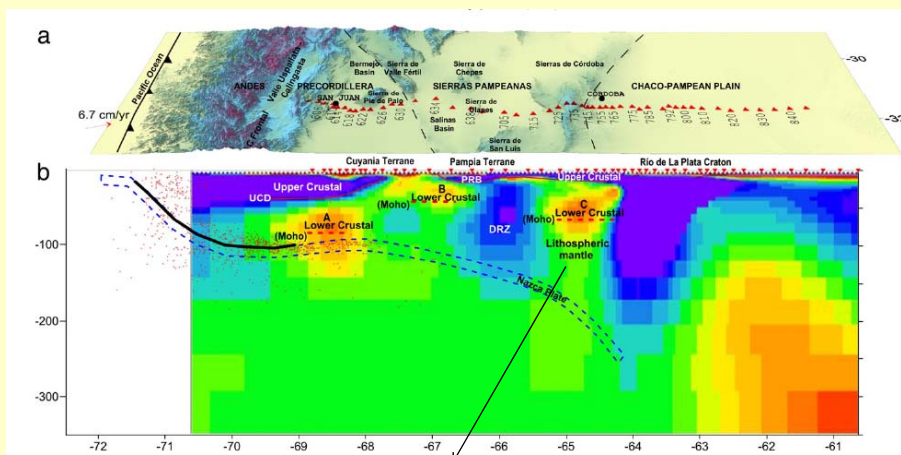
El flat slab Pampeano también es producto de la colisión de dos dorsales asísmicas



**ZONA PAMPEANA**  
Expansión del arco



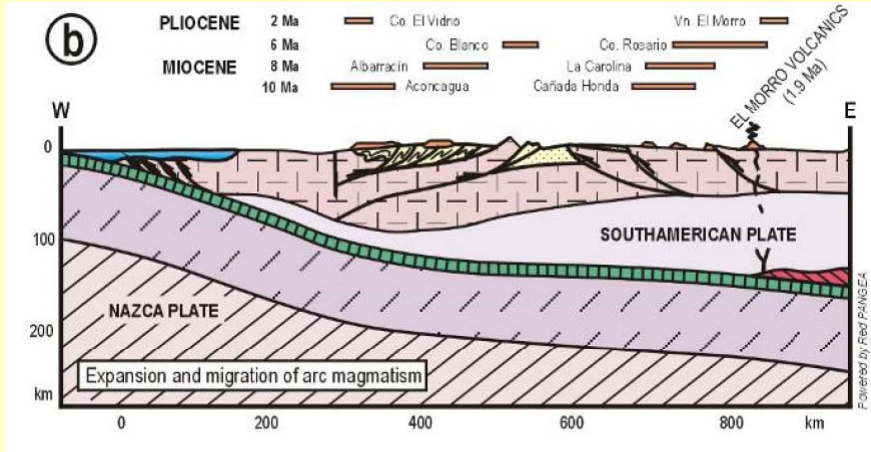
Orozco et al  
Sondeo magnetotelurico



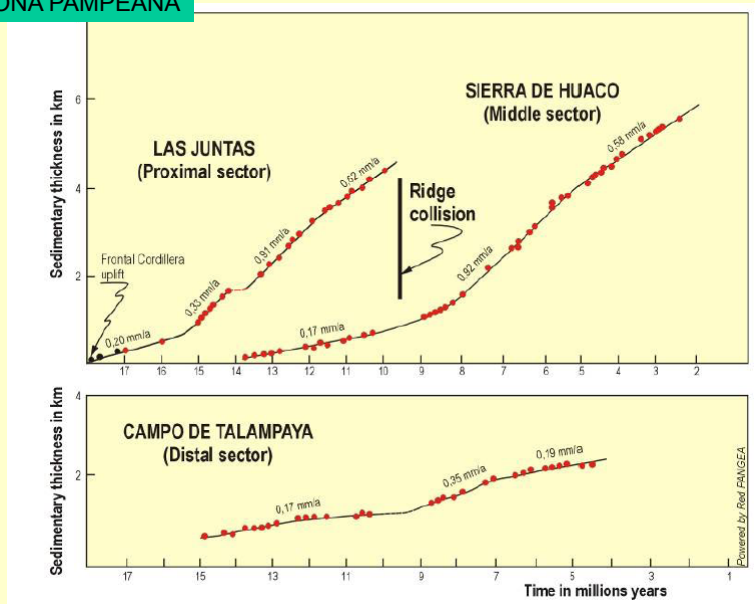
CUÑA ASTENOSFÉRICA  
PRODUCCIÓN DE MAGMAS

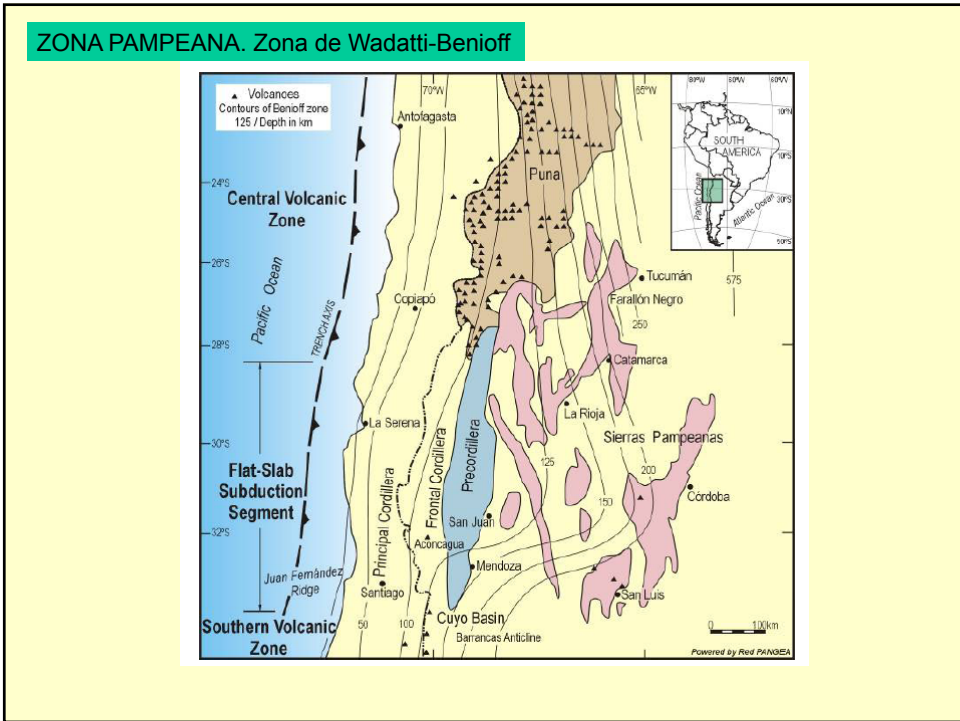
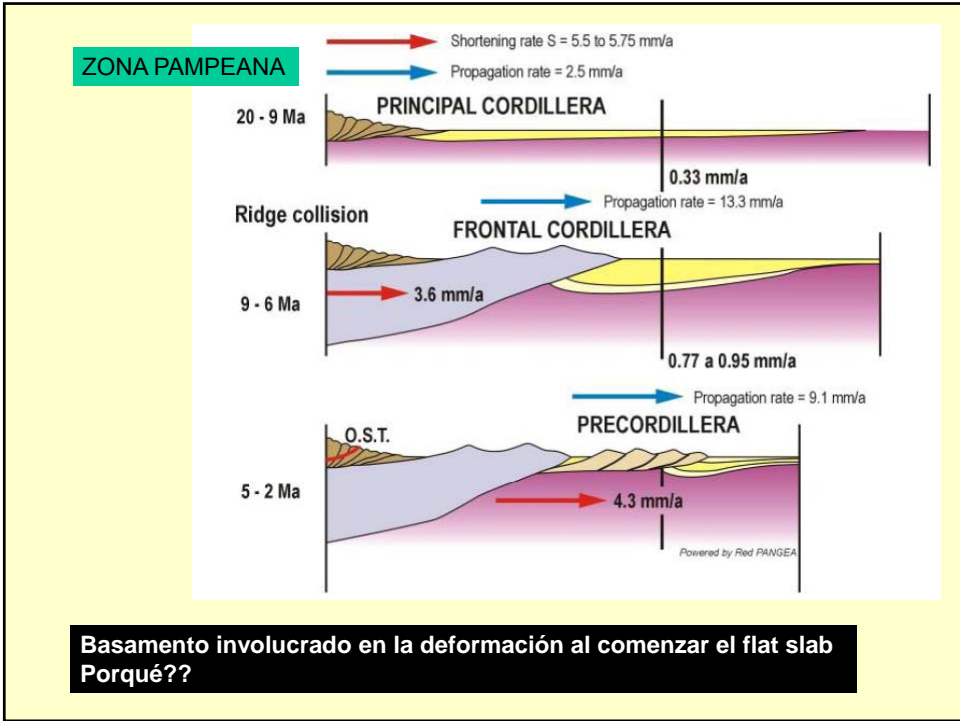


ZONA PAMPEANA

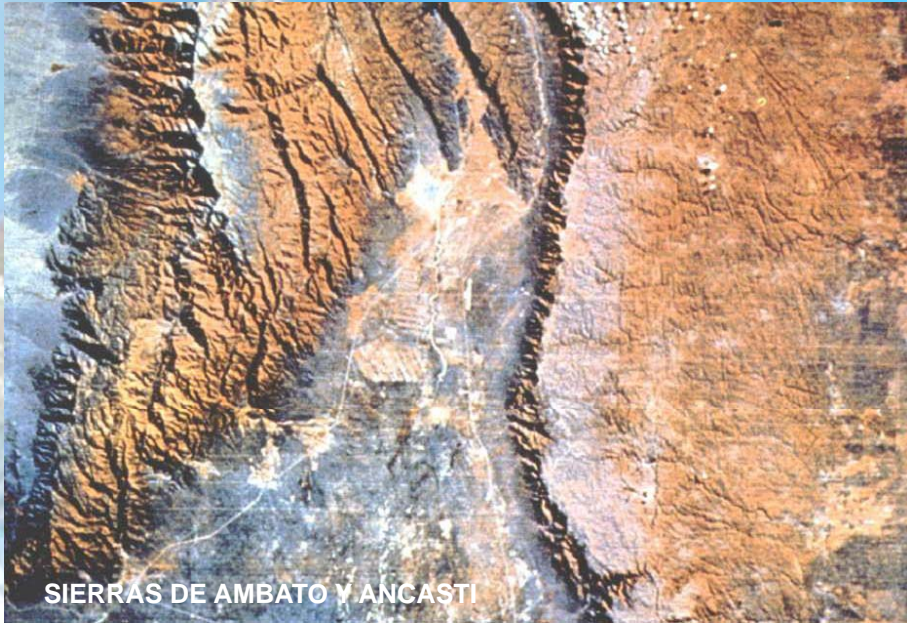


ZONA PAMPEANA





**BROKEN FORELAND**



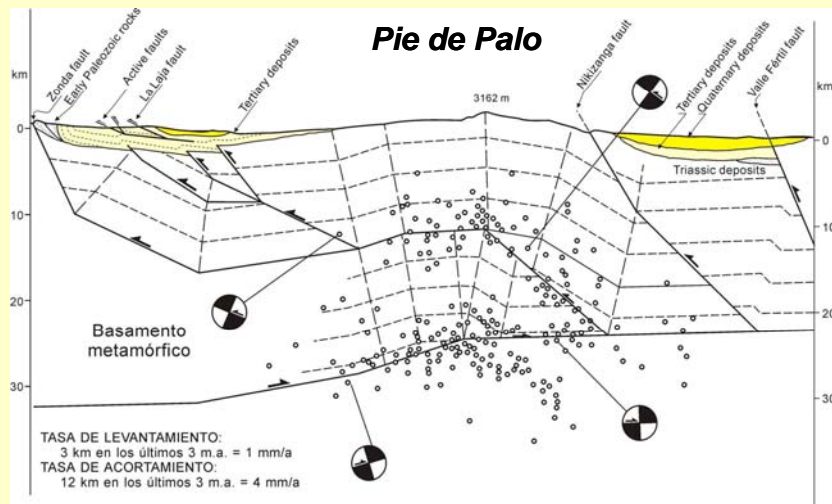
**SIERRAS DE AMBATO Y ANCASTI**



**SIERRA DE PIE DE PALO**



## SISMOS DE INTRAPLACA

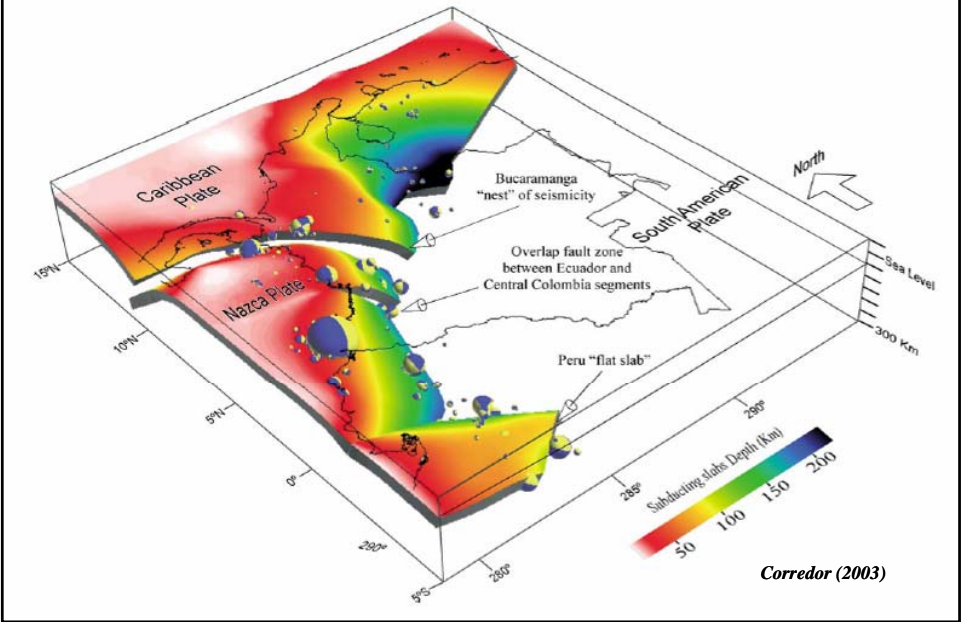


Ramos et al. (2002)

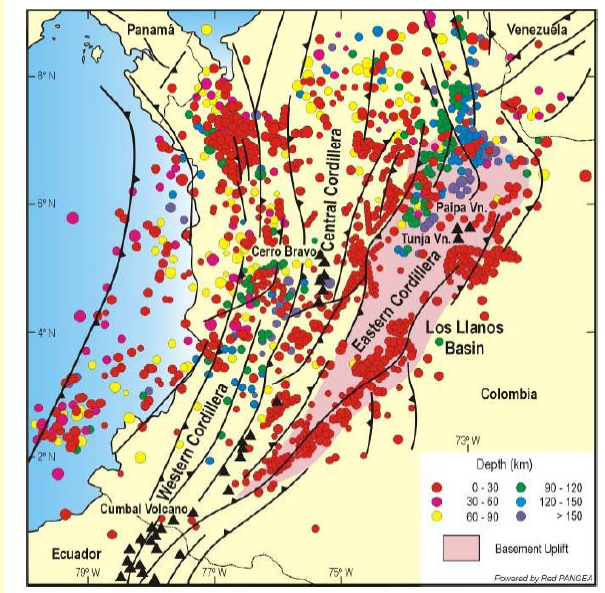




**MECÁNICA DE PLACAS ENTRE SUDAMÉRICA Y CARIBE  
SITUACIÓN PRESENTE**

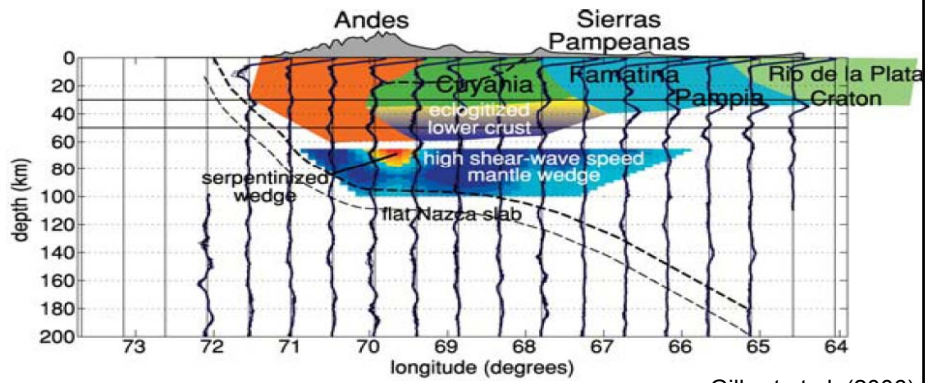


**ZONA DE BUCARAMANGA**



## Los flat slabs enfrían la litósfera

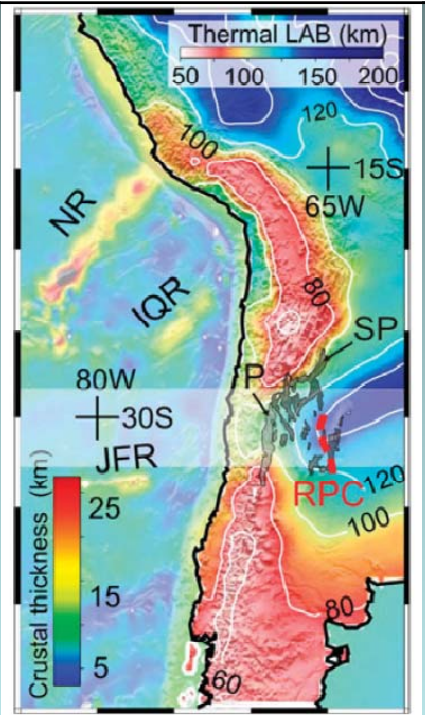
Tomografía sísmica flat slam pampeano



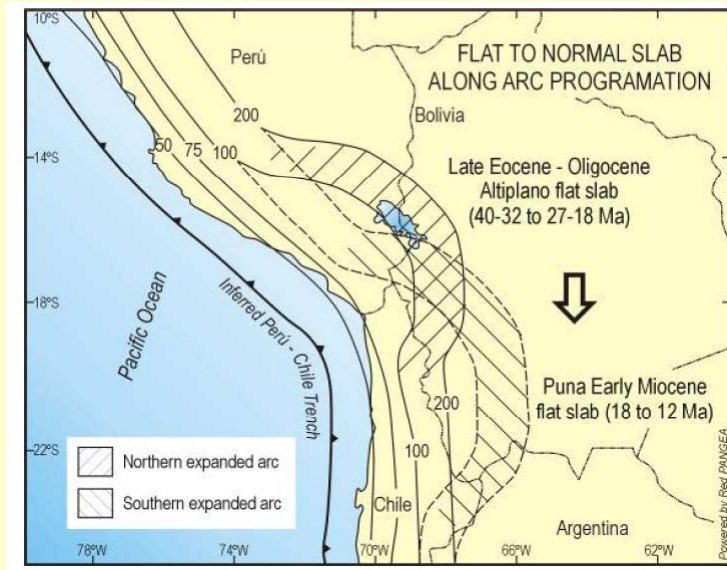
Gilbert et al. (2006)

Tassara et al., 2006

Límite inferior litósfera deprimido en flat slabs por bajo flujo térmico



James y Sacks, 1999



### ANDES ACRECIONALES vs. ANDES DE "TIPO ANDINO"

Andes colisionales con obducción de corteza oceánica y metamorfismo de edad andina:

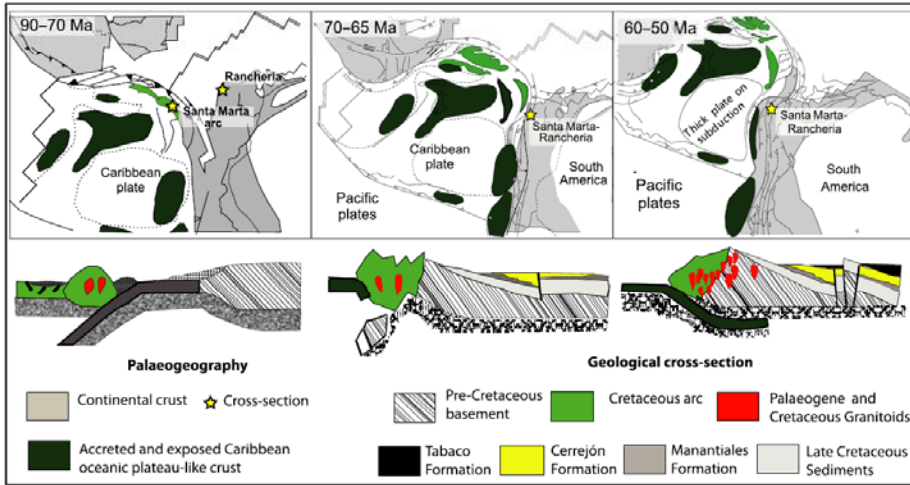
- Andes Septentrionales
- Andes Australes

Andes formados por subducción de corteza oceánica de tipo Andino (*sensu stricto*):

- Andes Centrales

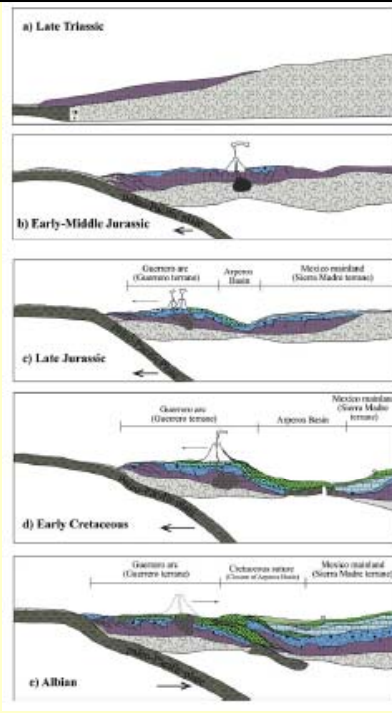
Ramos (1999)

Cardona et al 2016  
 Orógeno acrecional colombiano en el K/T evento de subducción somera por alta flotabilidad de material acretado



Un flat slab K en Mexico

Ortega Flores et al 2015





Los flat slabs K/Tc Colombianos y Mexicanos tienen que ver con colisión de un plateau oceánico

Hochmuth y Gohl 2017

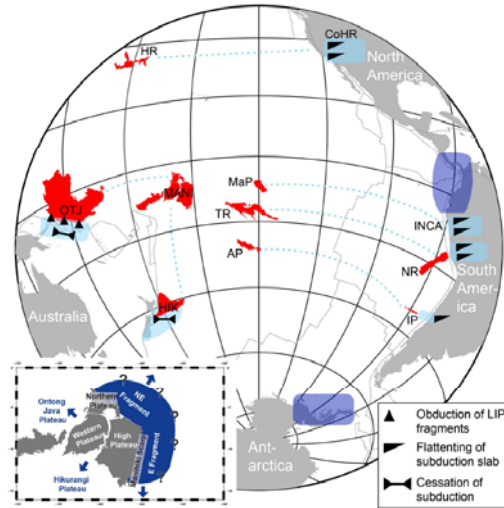
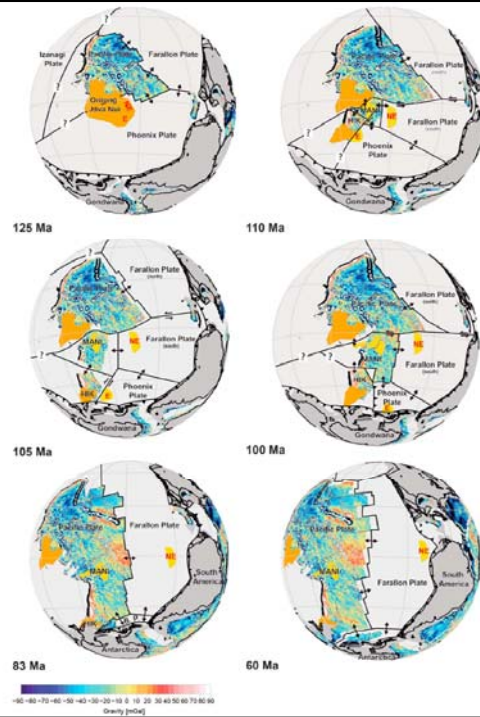
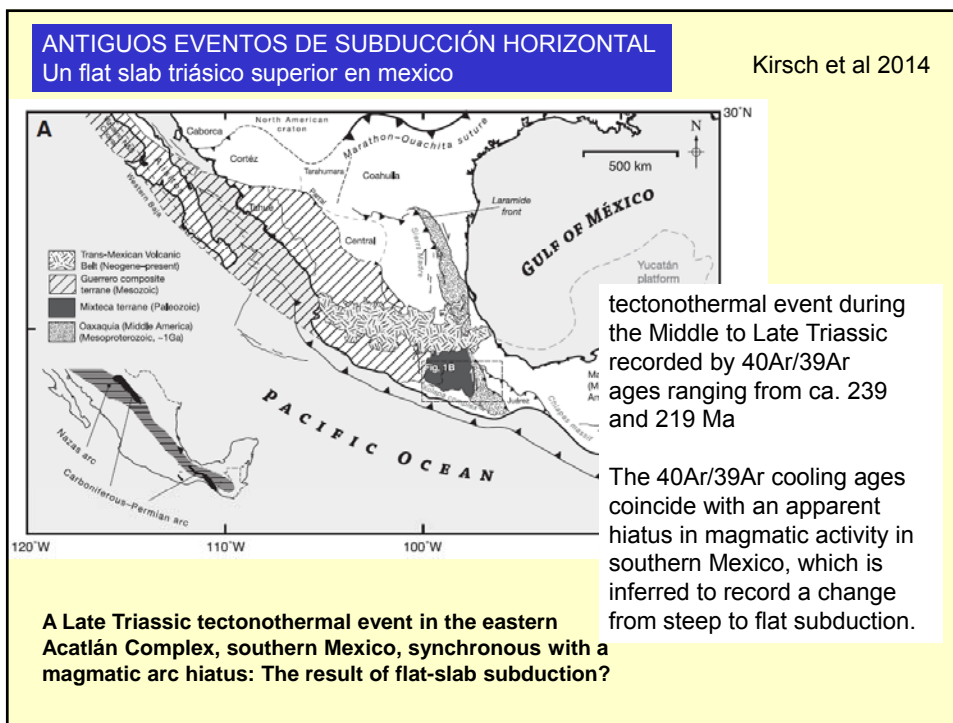
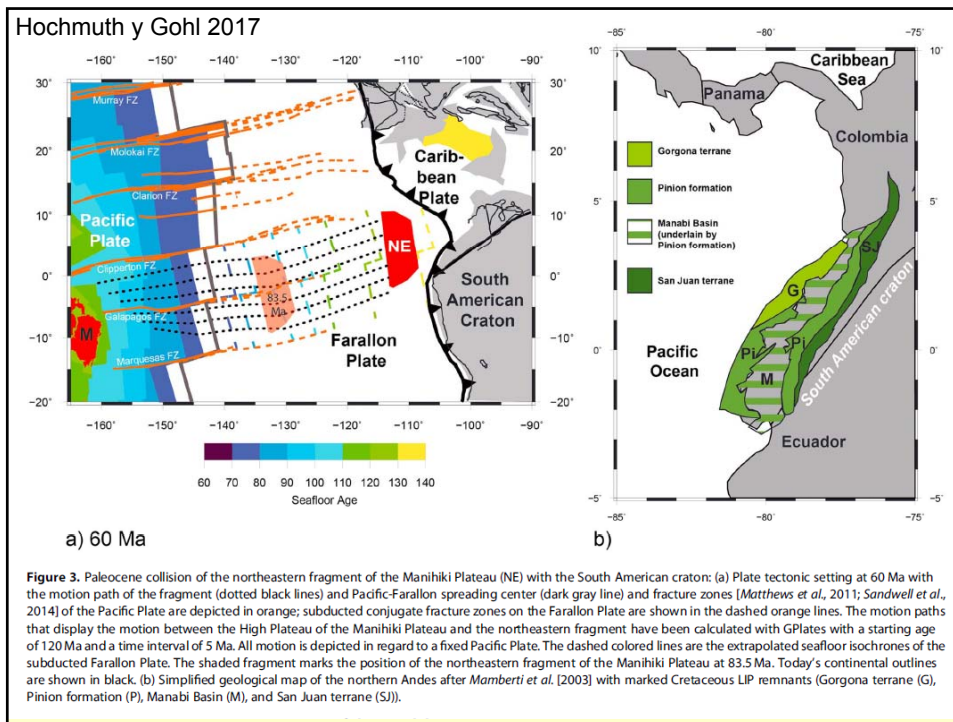


Figure 1. Overview of the some LIPs of the Pacific Ocean and their subducted remnants and accretion/subduction mode. Present LIPs—Hess Rise (HR), Ontong Java Plateau (OTJ), Manihiki Plateau (MANI), Marquessa Plateau (MaP), Tuamotu Ridge (TR), Austral Plateau (AP), Nazca Ridge (NR), Iquique Plateau (IP), and Hikurangi Plateau (HR)—are marked in red, areas of subduction are in light blue, which includes the conjugate of the Hess Rise (CoHR) and the Inca Plateau (INCA). The dark blue areas indicate the possible areas of subducted former northeastern (NE) and eastern (E) fragments of the Manihiki Plateau at the northwestern South America and West Antarctica margins. Previously identified joined employed LIPs are connected by dashed light blue lines. Present plate boundaries are marked in gray. The insert map shows the different subprovinces of the Manihiki Plateau and the position of the parts of Ontong Java Nui encircling the Manihiki Plateau.

Hochmuth y Gohl 2017





**ANTIGUOS EVENTOS DE SUBDUCCIÓN HORIZONTAL**  
Un flat slab triásico superior en mexico

Kirsch et al 2014

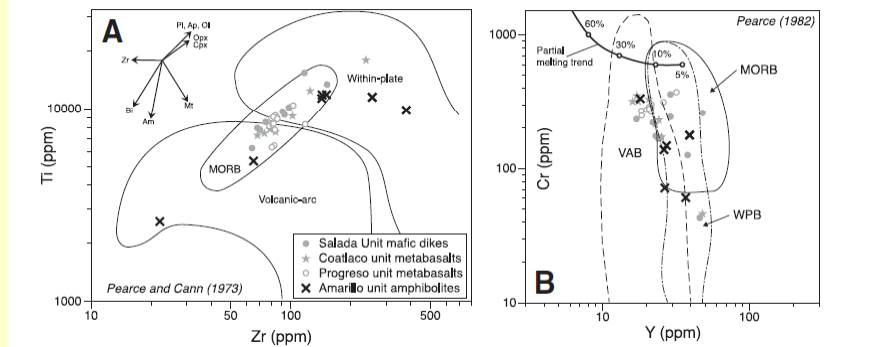


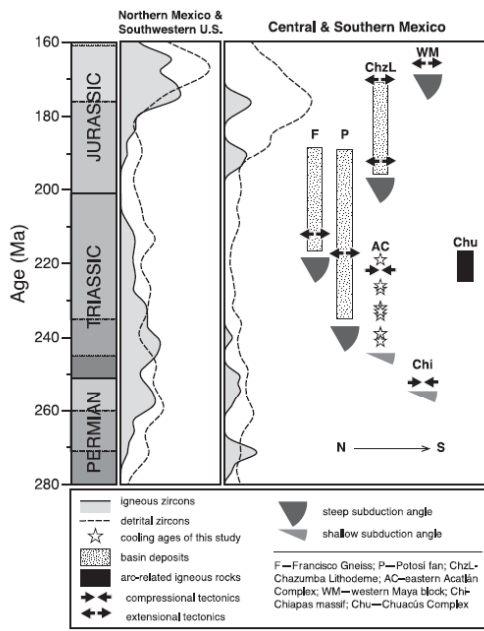
Figure 7. Tectonic discrimination diagrams for Amarillo unit amphibolites and comparative mafic igneous rocks. (A) Ti-Zr plot after Pearce and Cann (1973). Fractionation paths for olivine (Ol), orthopyroxene (Opx), clinopyroxene (Cpx), plagioclase (Pl), apatite (Ap), magnetite (Mt), amphibole (Am), zircon (Zr), and biotite (Bi) for  $F = 0.5$  are from Pearce (1982). (B) Log-log plot of Cr vs. Y after Pearce (1982). Compositional fields: VAB—volcanic arc basalt; MORB—mid-ocean-ridge basalt; WPB—within-plate basalt; OIB—oceanic-island basalt; BAB—backarc basalt; CFB—continental flood basalt; IAT— island-arc tholeiite.

**ANTIGUOS EVENTOS DE SUBDUCCIÓN HORIZONTAL**  
Un flat slab triásico superior en mexico

Kirsch et al 2014

Enfriamiento súbito  
Formación de cuencas en regímenes extensionales asociadas a material máfico de intraplaca

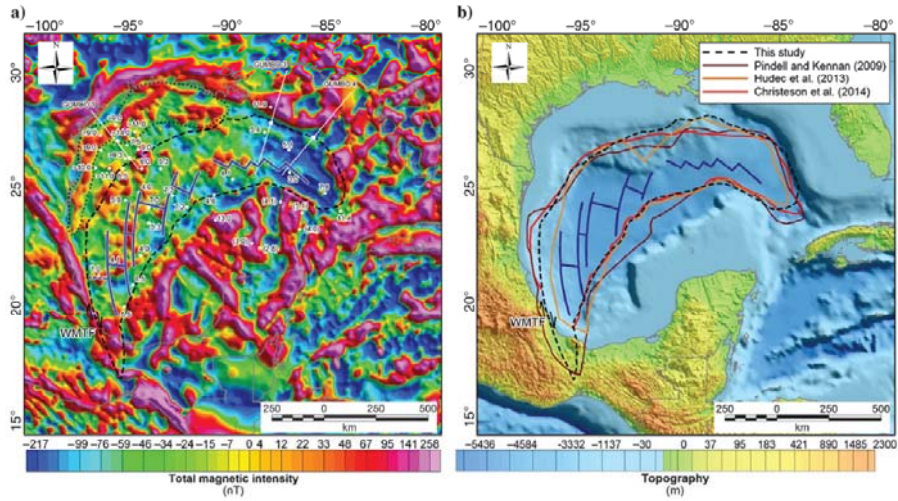
Flat slab



Cuenca del golfo es resultado de este empujamiento?

Gravity and magnetic constraints on the Jurassic opening of the oceanic

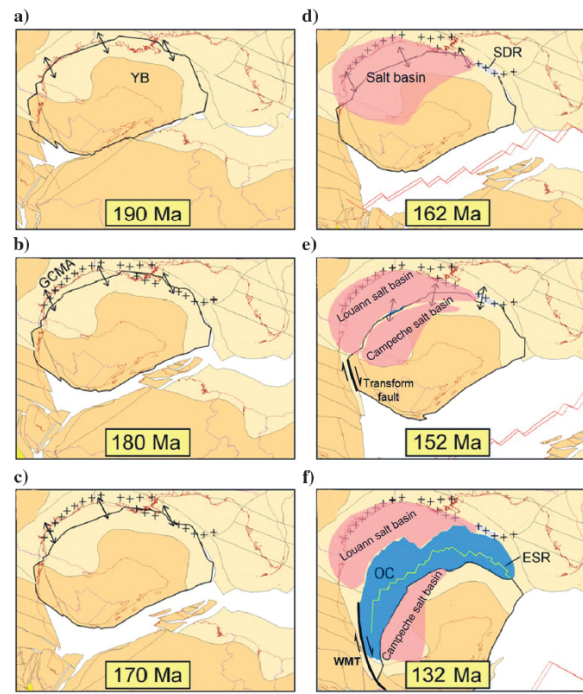
Luan C. Nguyen and Paul Mann



Cuenca del golfo es resultado de este empujamiento?

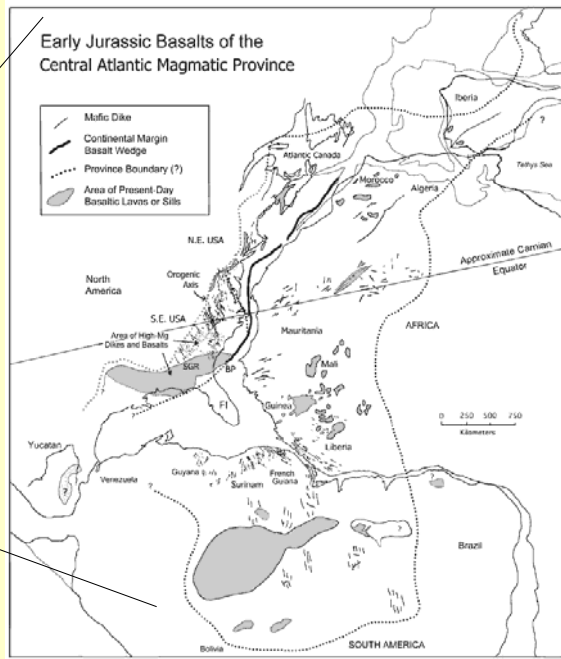
Gravity and magnetic constraints on the Jurassic opening of the oceanic

Luan C. Nguyen and Paul Mann

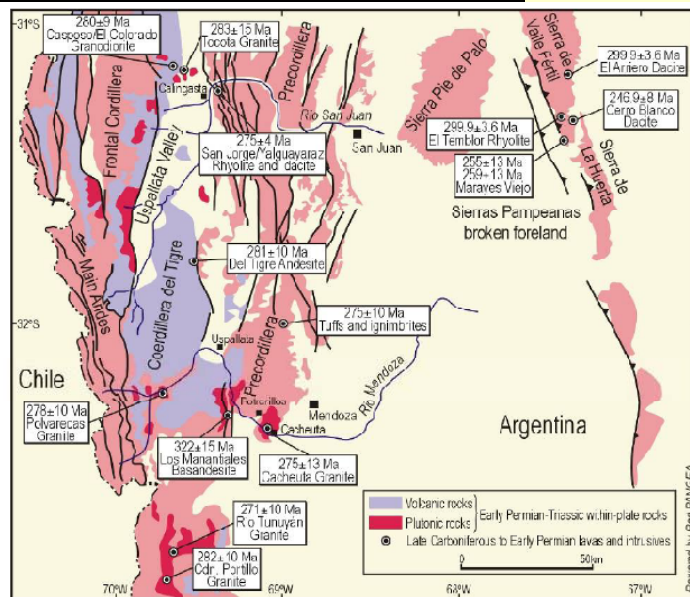




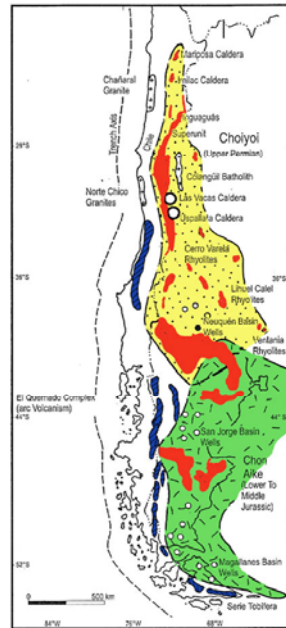
**Y quizás lo sea el CAMP y el océano atlántico norte??**



**Hipótesis del flat slab carbonífero superior-pérmico inferior (expansión de magmas calcoalcalinos)**



## Episodio del Choyoi



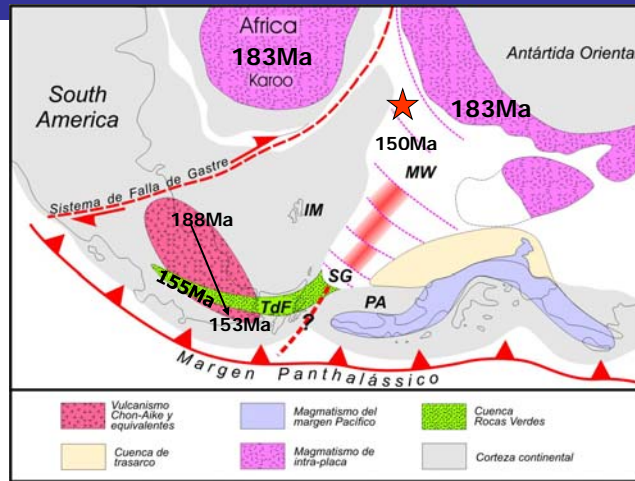
El choyoi es producto de verticalización de un flat slab pérmico??

## Episodio del Choyoi



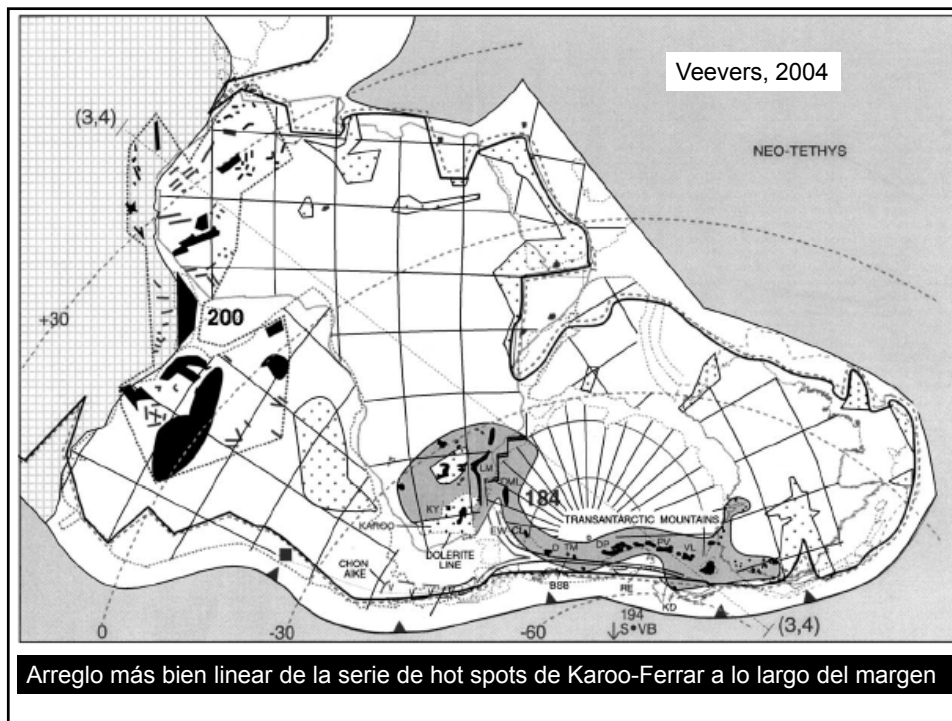
El choyoi podría ser un empinamiento de zona de subducción horizontal pérmica?

## Karoo-Ferrar-Chon Aike (183 Ma)



- La pluma de Karoo (actualmente Isla Bouvet) fue propuesta a partir de la presencia de diques radiales y su posición central respecto a los tres brazos del rift jurásico

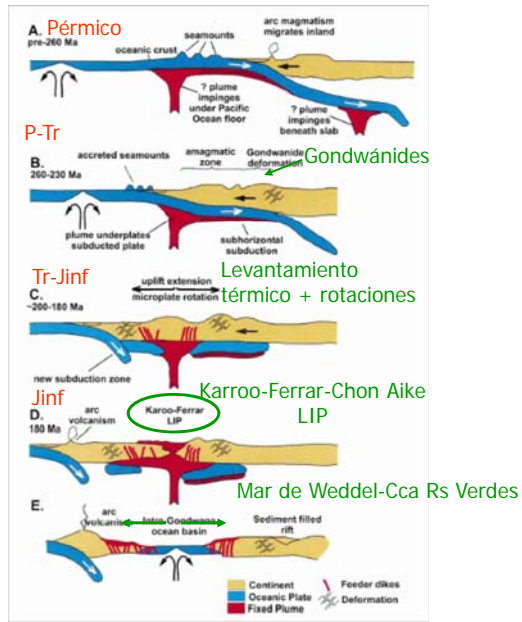
Storey et al., 1992



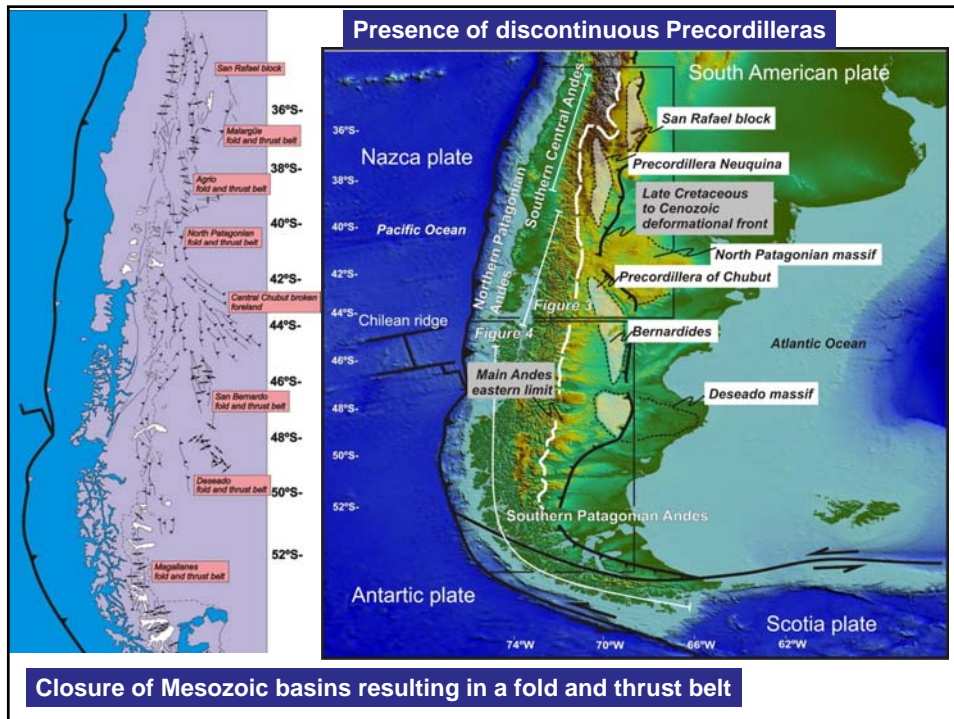
Arreglo más bien lineal de la serie de hot spots de Karoo-Ferrar a lo largo del margen



1. Pluma ubicada cerca o debajo de la zona de subducción.
2. Subducción subhorizontal debida a la mayor flotabilidad de la losa, causada por la inyección de material caliente del manto.
3. Ruptura térmica y mecánica de la losa subducida.
4. Ascenso térmico, previo a magmatismo, y extensión.
5. Efusión LIP Karoo-Ferrar.
6. Rifting e instauración de una zona divergente.



Dalziel et al. (2000)

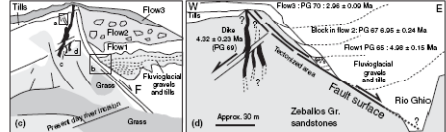
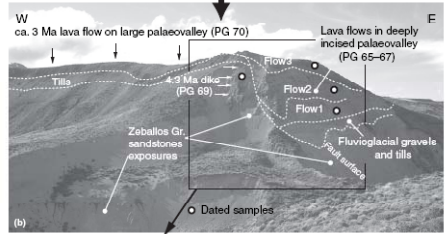
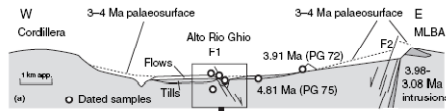
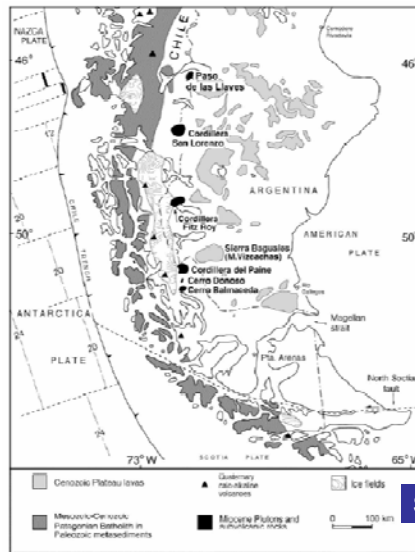






**Construction and destruction of the Andes**

**SANTA CRUZ shallow subduction zone; Late Miocene**



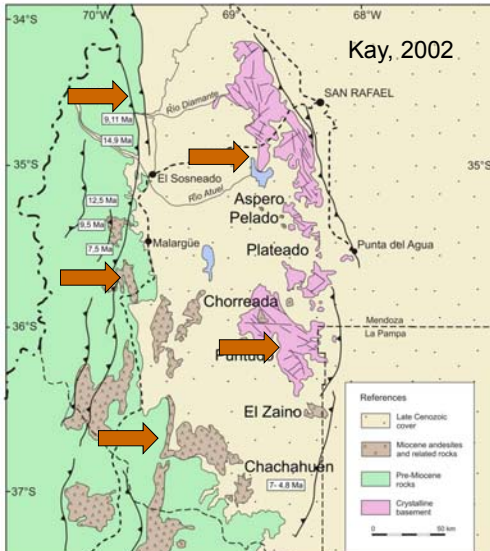
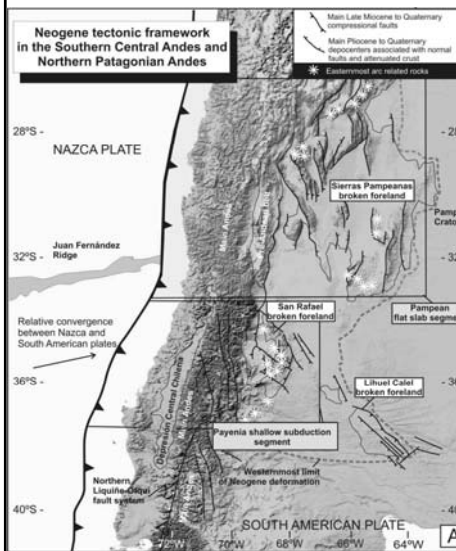
**SANTA CRUZ extensional relaxation; Pliocene**

Lagabrielle et al., 2007

Espinoza et al., 2007  
Sánchez et al., 2008

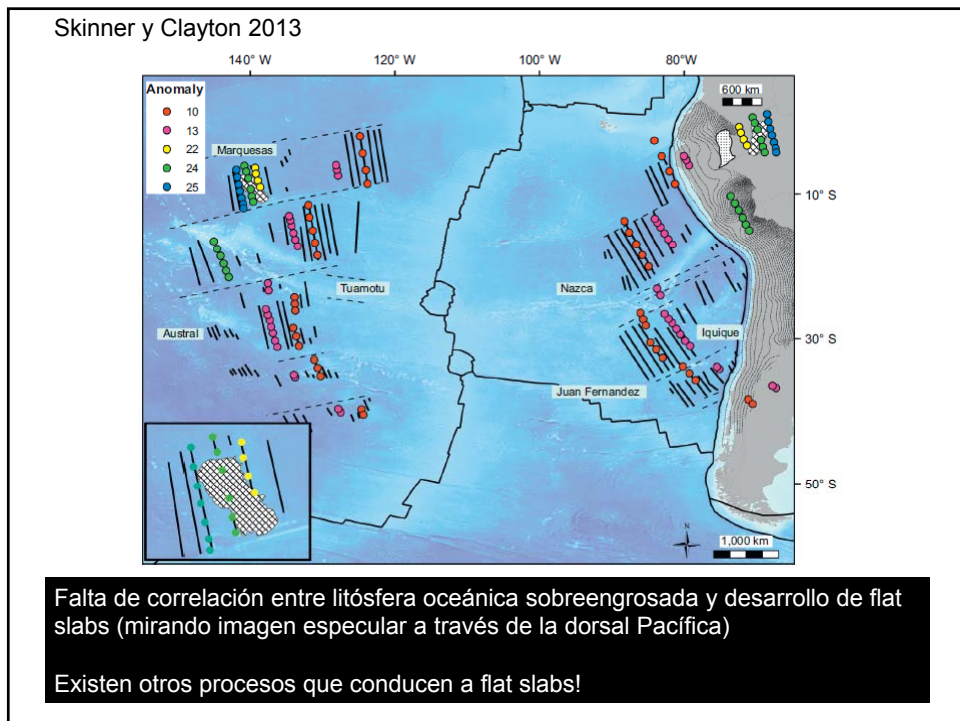
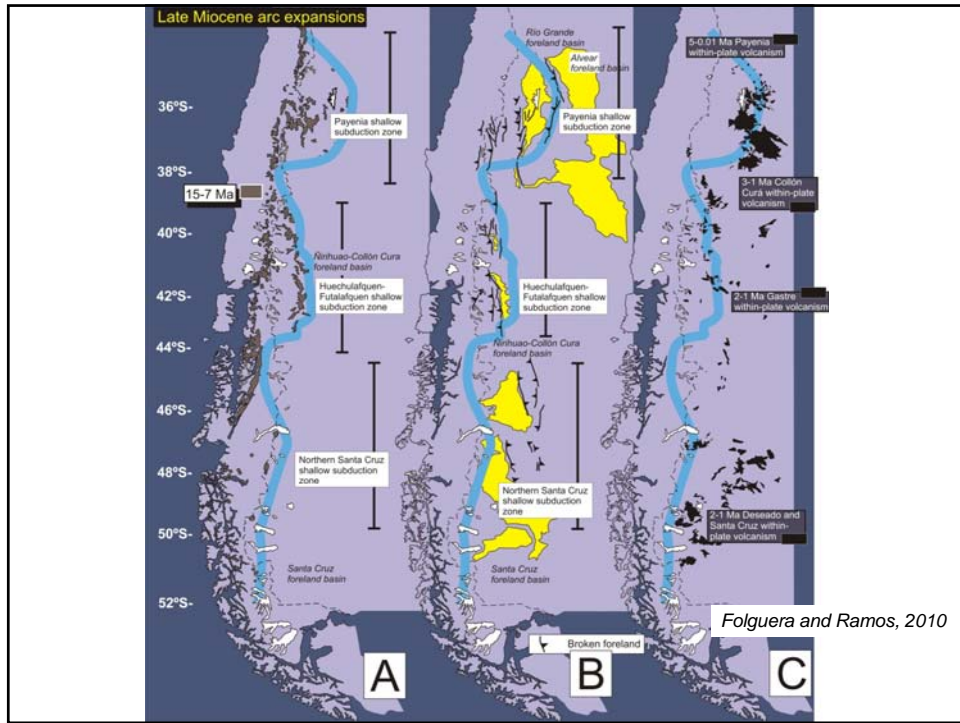
**Construction and destruction of the Andes**

**The Payenia shallow subduction zone in northern Patagonia**



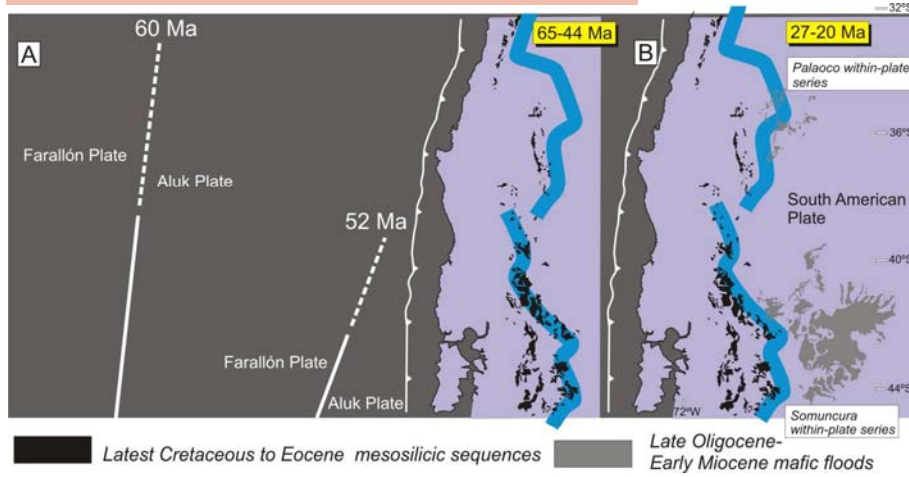
Late Miocene

The transient flat subduction extended from 13 to 4 Ma





**Discussion of orogenic and magmatic mechanisms**

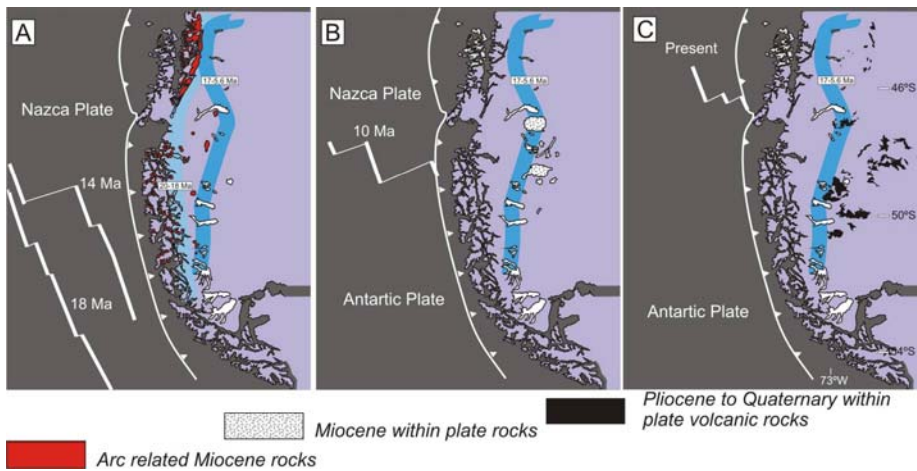


Does highly buoyant oceanic crust produce shallow subduction settings?

After Cande y Leslei (1986)

Folguera and Ramos (2010)

**Discussion of orogenic and magmatic mechanisms**

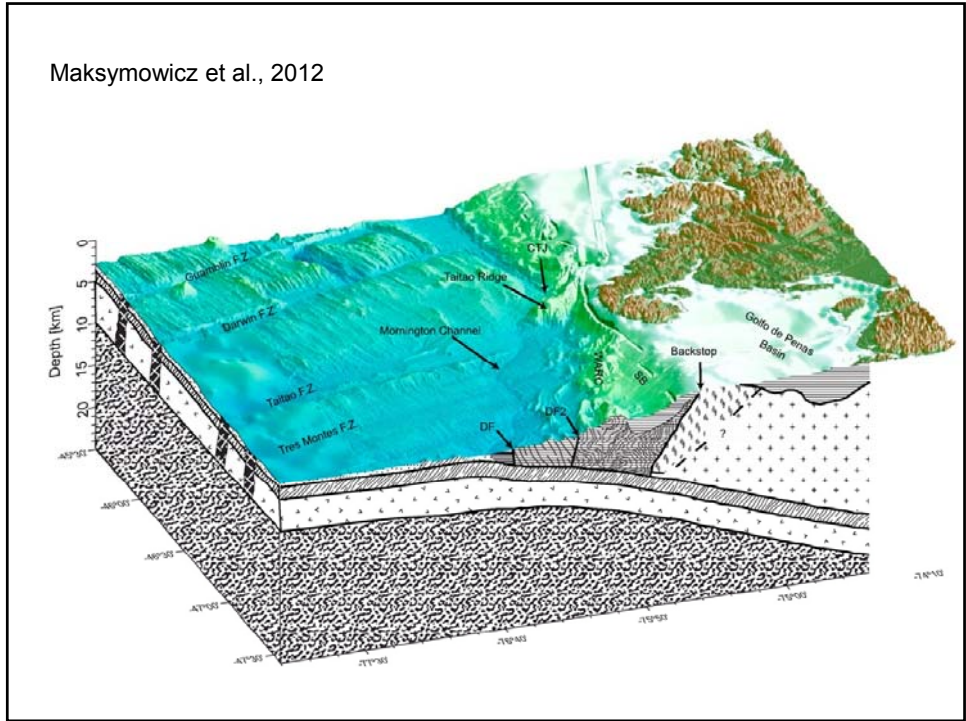


Does highly buoyant oceanic crust produce shallow subduction settings?

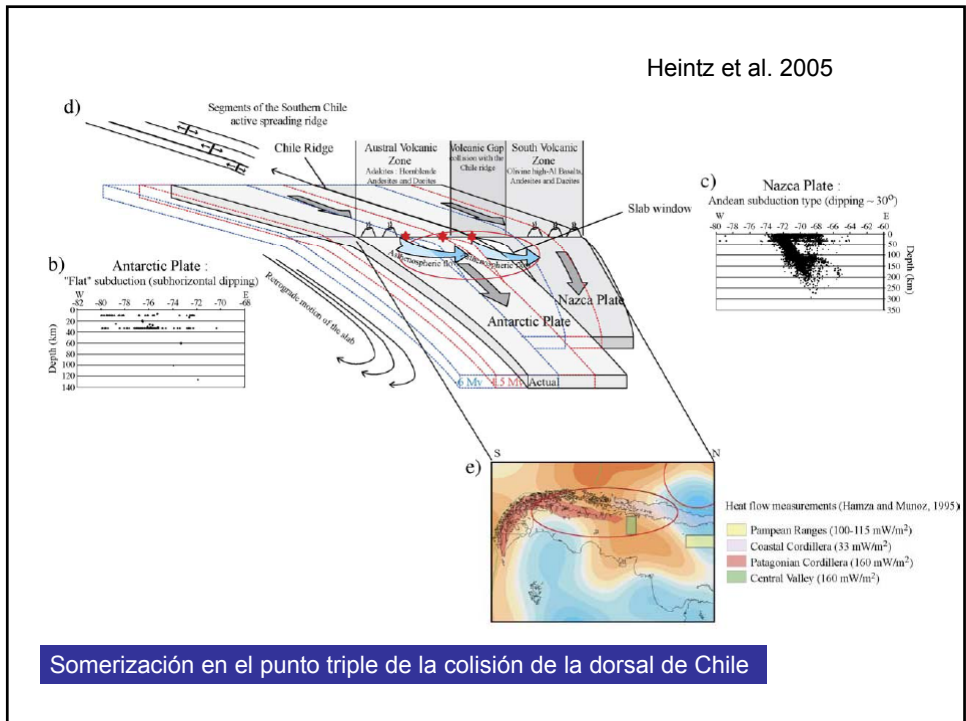
Folguera and Ramos (2010)  
after Espinoza et al. (2007) and Sánchez et al. (2008)



Maksymowicz et al., 2012



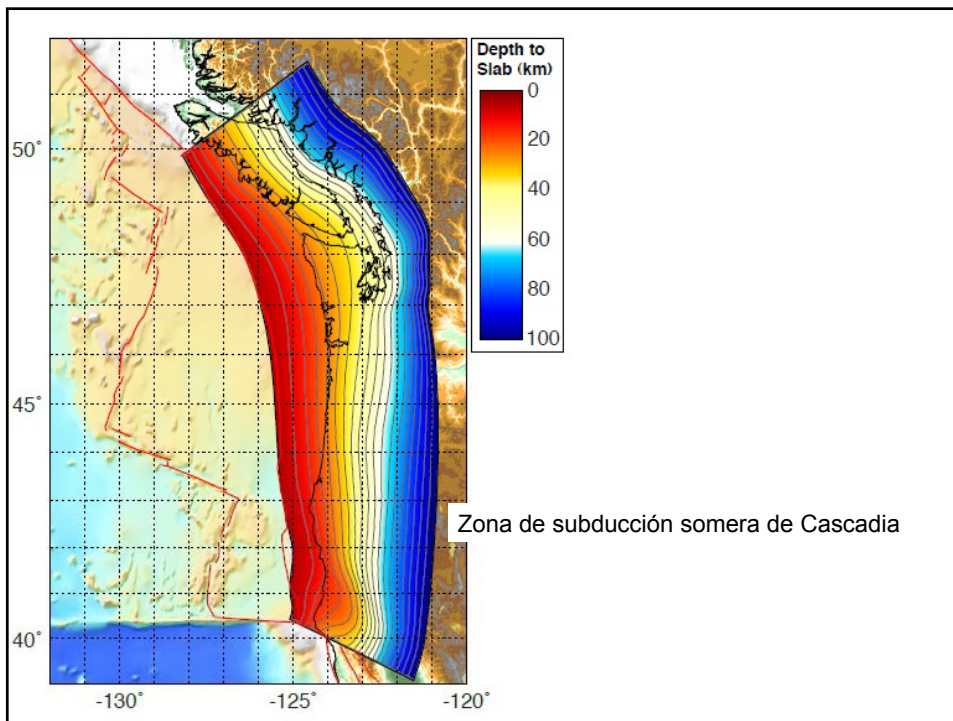
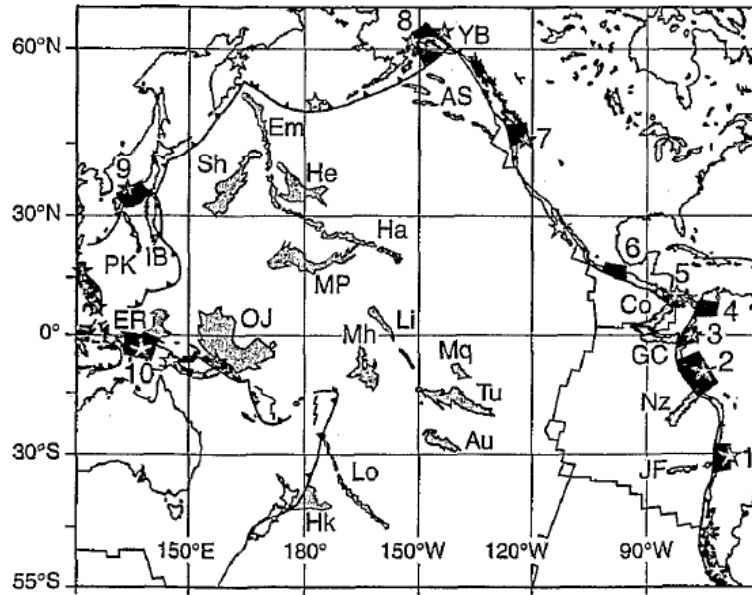
Heintz et al. 2005

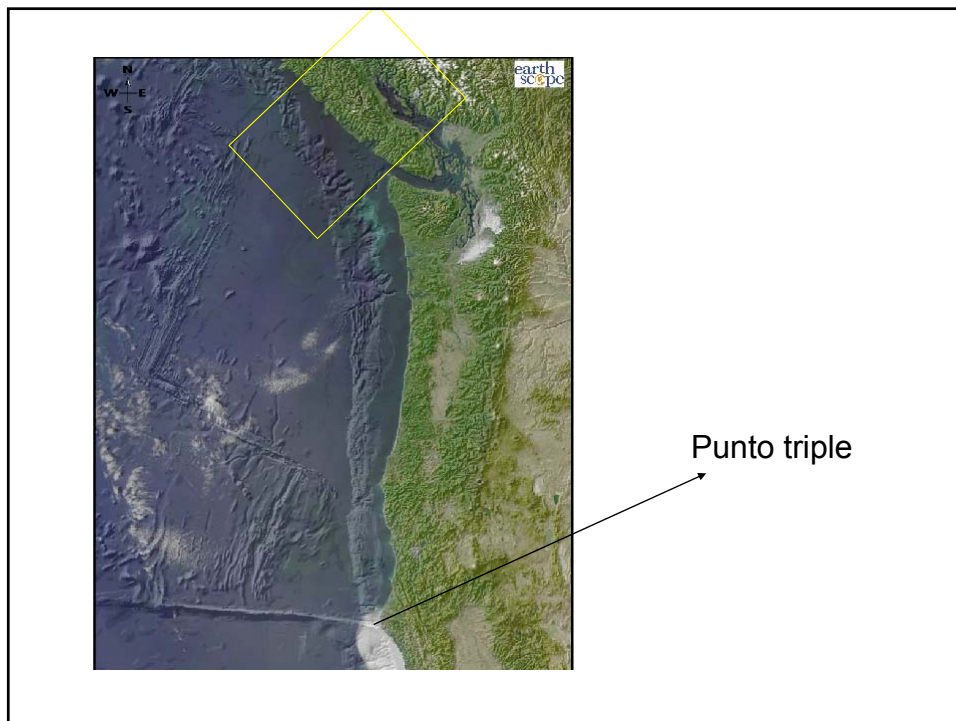
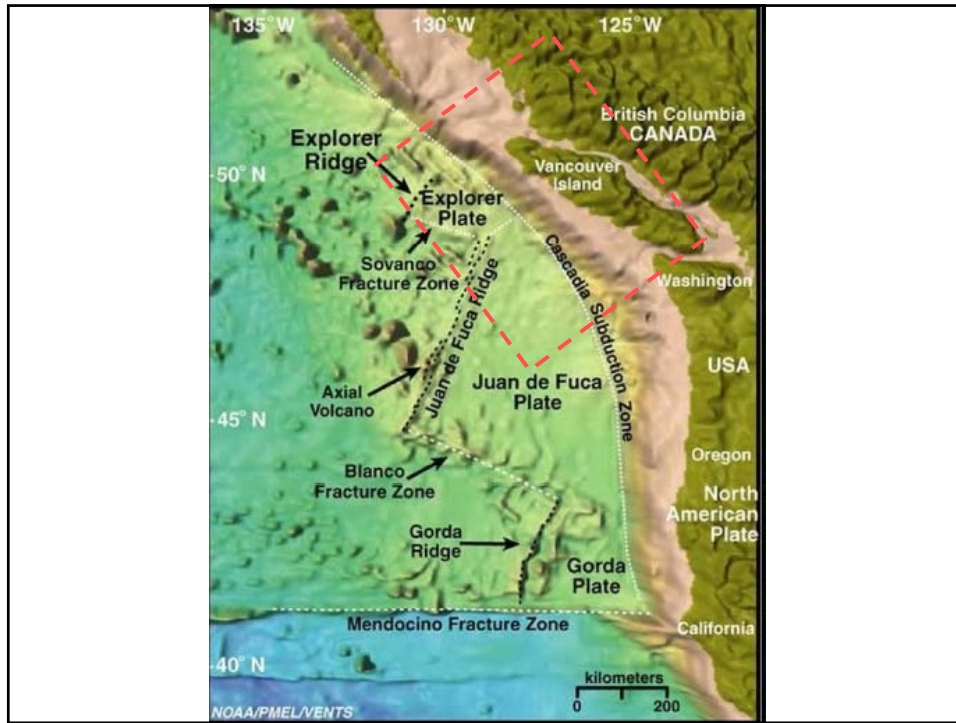


Somerización en el punto triple de la colisión de la dorsal de Chile

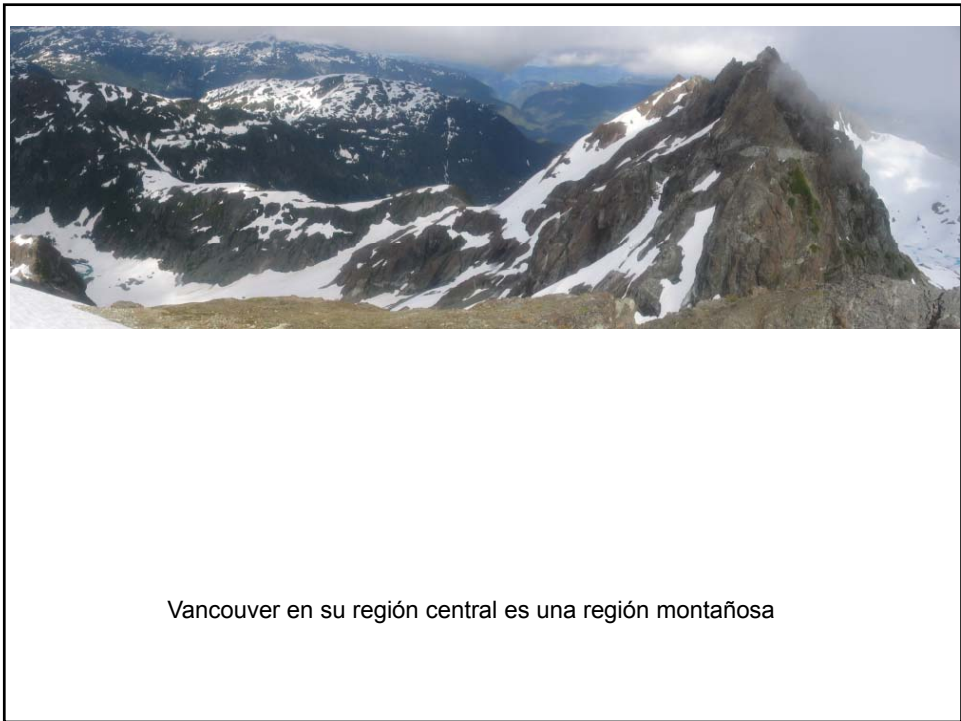
Zonas de subducción horizontal actuales

Gutscher et al., 2000



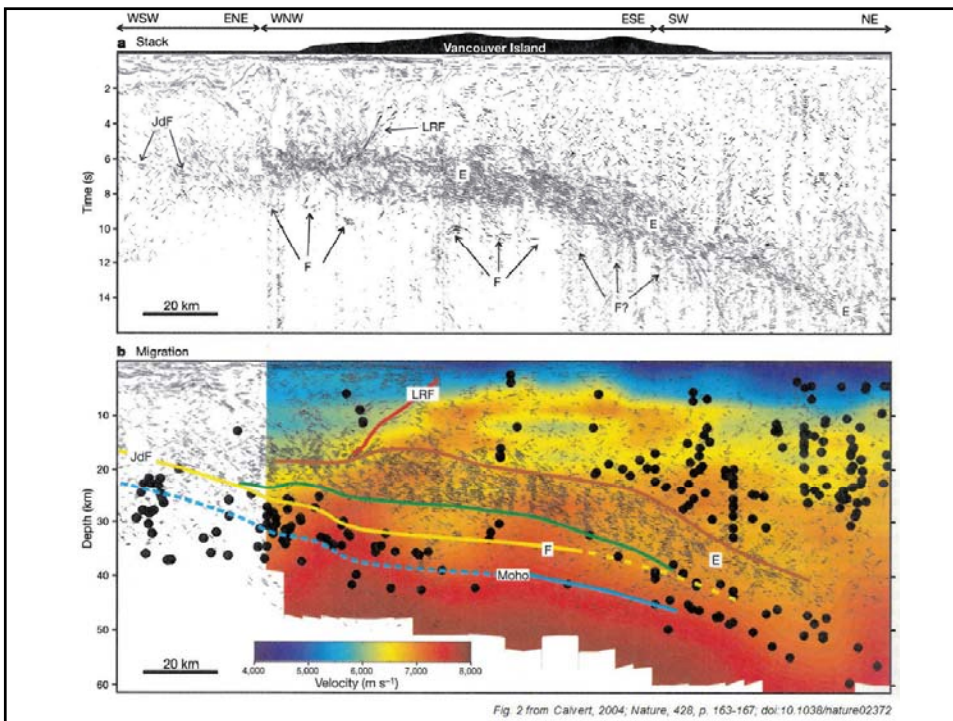
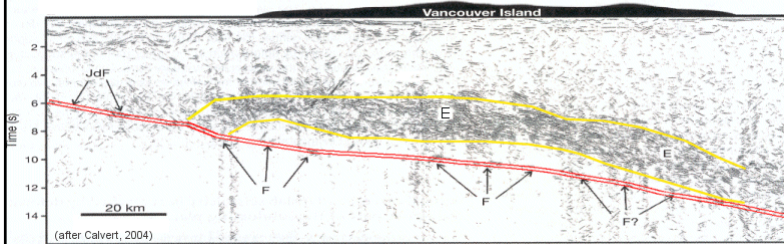
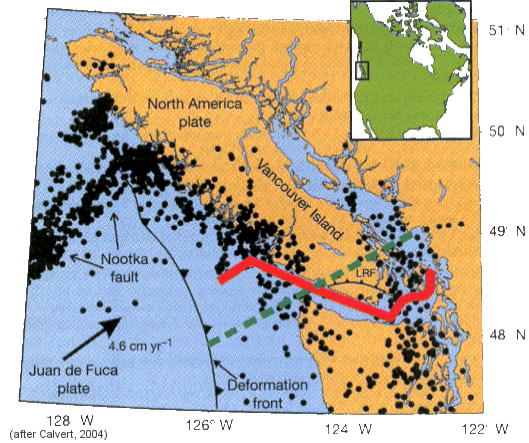


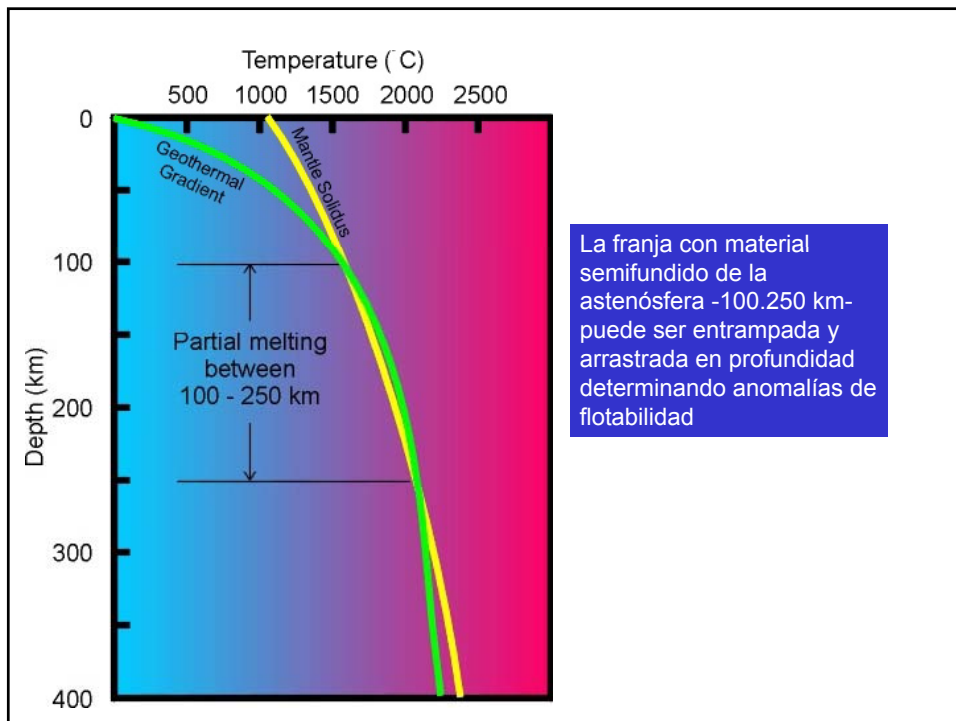
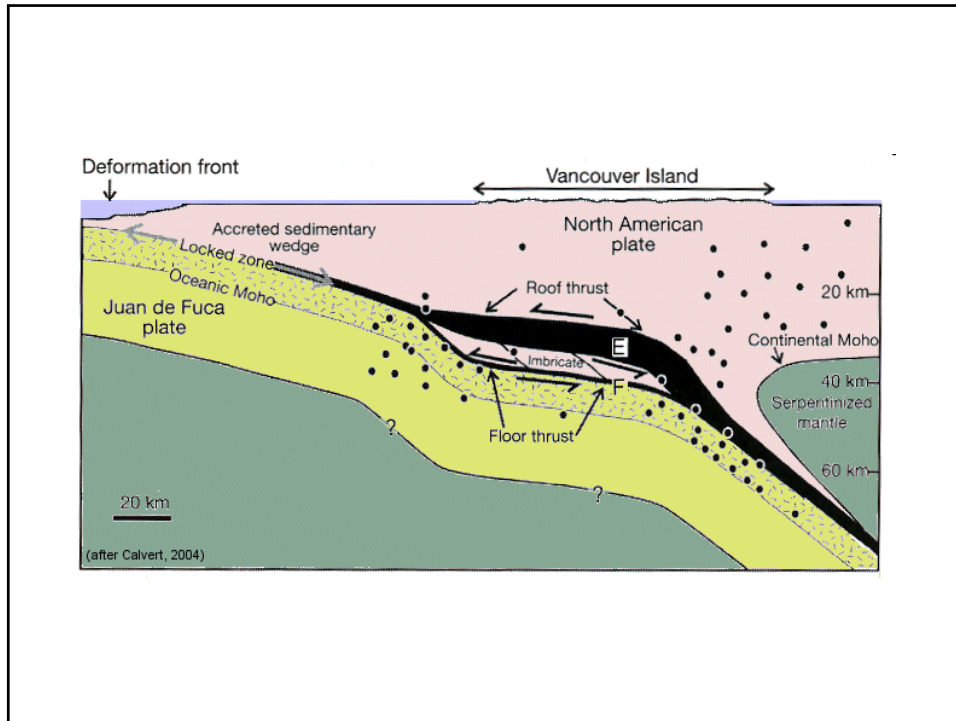






<http://records.viu.ca/~earles/split-subduction-mar04.htm>

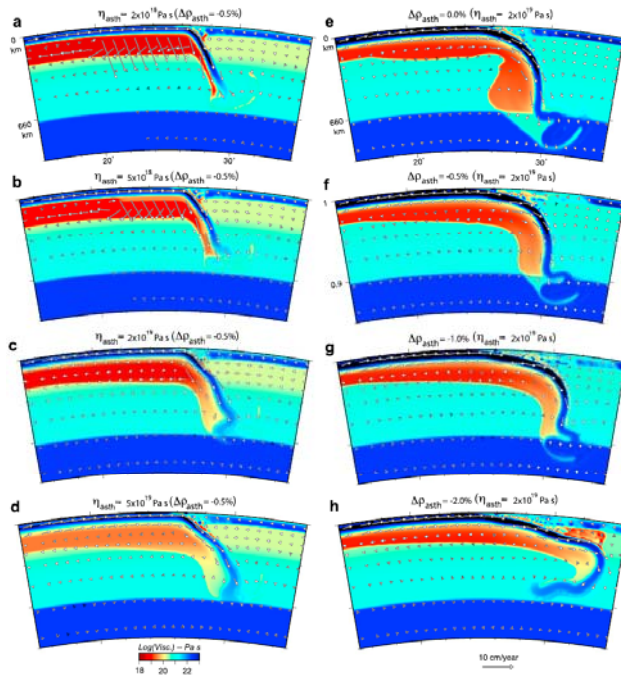




Deep recycling of oceanic asthenosphere material during subduction

Liu and Zhou 2015

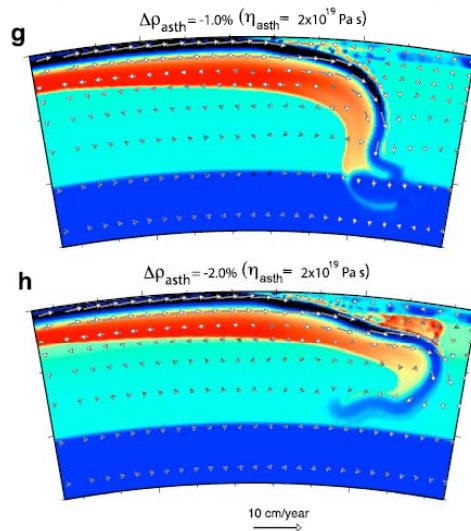
A más viscosidad de astenósfera o menos contraste de densidades entre corteza oceánica y astenósfera más espesor de astenósfera arrastrado por aumentar fricción



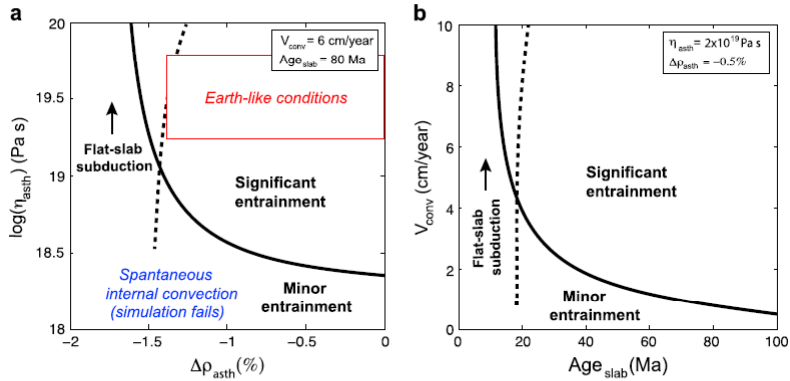
Deep recycling of oceanic asthenosphere material during subduction

Liu and Zhou 2015

A menos contraste de densidades entre corteza oceánica y astenósfera más espesor de astenósfera arrastrado por aumentar fricción

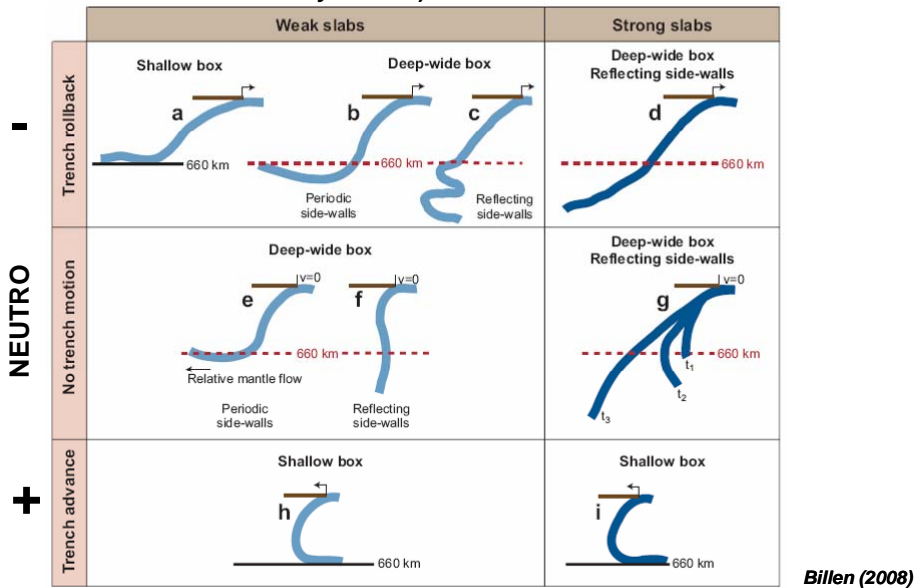


Litósfera oceánica joven tiene bajo contraste de densidades respecto de astenósfera e induce flat slabs



**Figure 3.** Scheme diagrams for asthenosphere entrainment. (a) Effects of asthenosphere viscosity and density anomalies on the amount of entrainment. Significant (minor) entrainment refers to a layer of at least (less than) 100 km thick of asthenosphere material translates down to more than 500 km depth, divided by the bold dark line. The thick dashed line separates flat slab versus nonflat slab scenarios. All calculations have a convergence rate of 6 cm/yr and a subducting slab age of 80 Ma. (b) Effects of convergence rates and slab age on the amount of asthenosphere entrainment. All calculations presented have the asthenosphere viscosity fixed as  $2 \times 10^{19}$  Pa s and its density anomaly at  $-0.5\%$ .

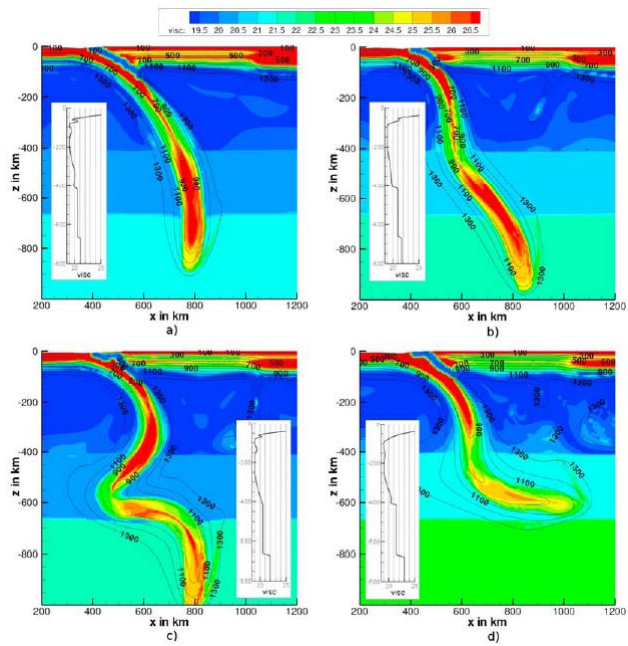
**SLAB SUBDUCTION OF WEAK AND STRONG CRUST AND ROLL-BACK (hipótesis de somerizaciones por interacción con discontinuidades de 410 y 660 km)**



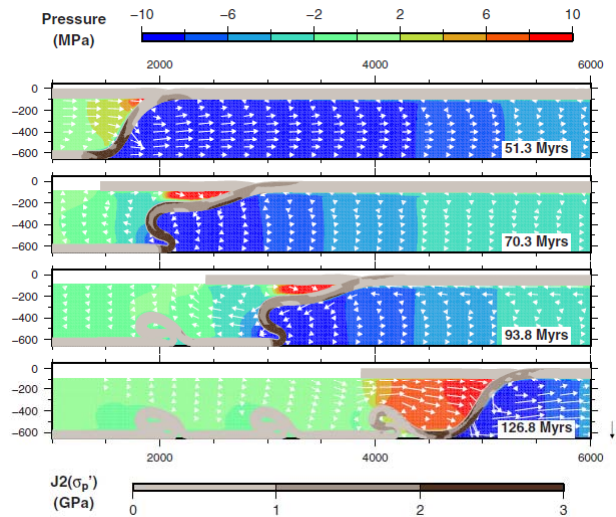


Quinteros et al., 2010

A más altos contrastes de viscosidad en manto entre transiciones de 410 y 660 km Losa oceánica experimenta flattenings y steepenings

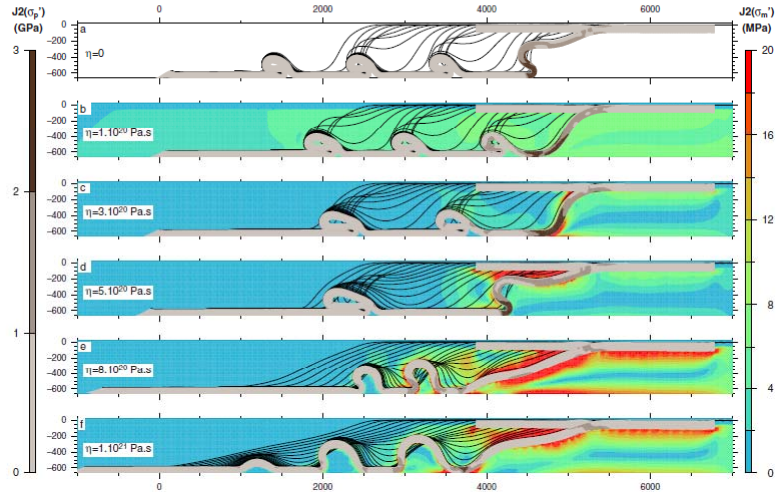


Cerpa et al 2014



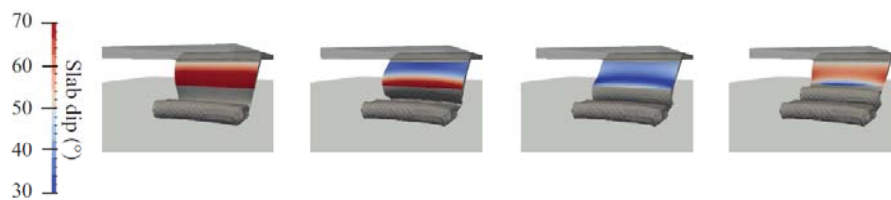
Periodicidad de arrugas de losa subducida sobre 660 km define movimiento oscilatorio de losa por debajo de litósfera continental

Cerpa et al 2014



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Cerpa et al 2015



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Cerpa et al 2014

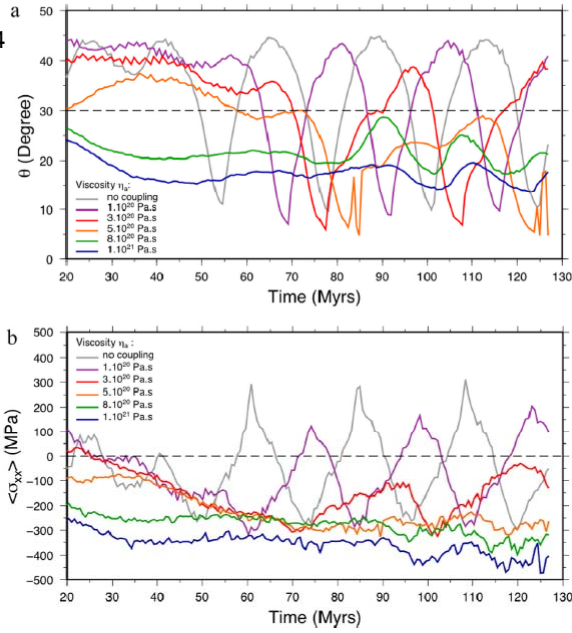


Figure 11. (a) Temporal evolution of the slab mean dip angle taken between 100 and 160 km of depth for different mantle viscosities. (b) Temporal evolution of the overriding plate state of horizontal stress, for different mantle viscosities.