# Importance of continental subductions for the growth of the Tibetan plateau

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cnrs advancing the frontiers

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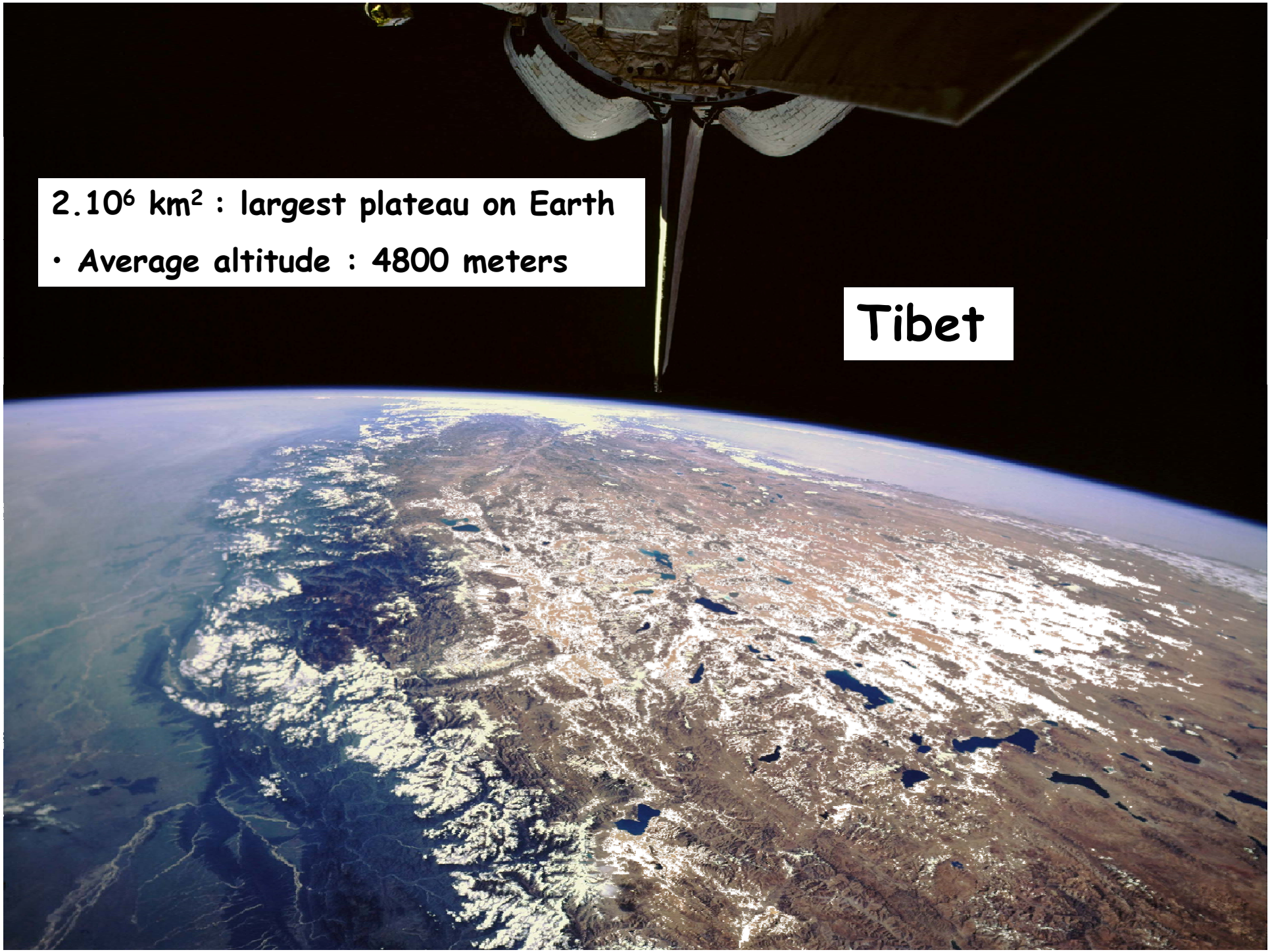
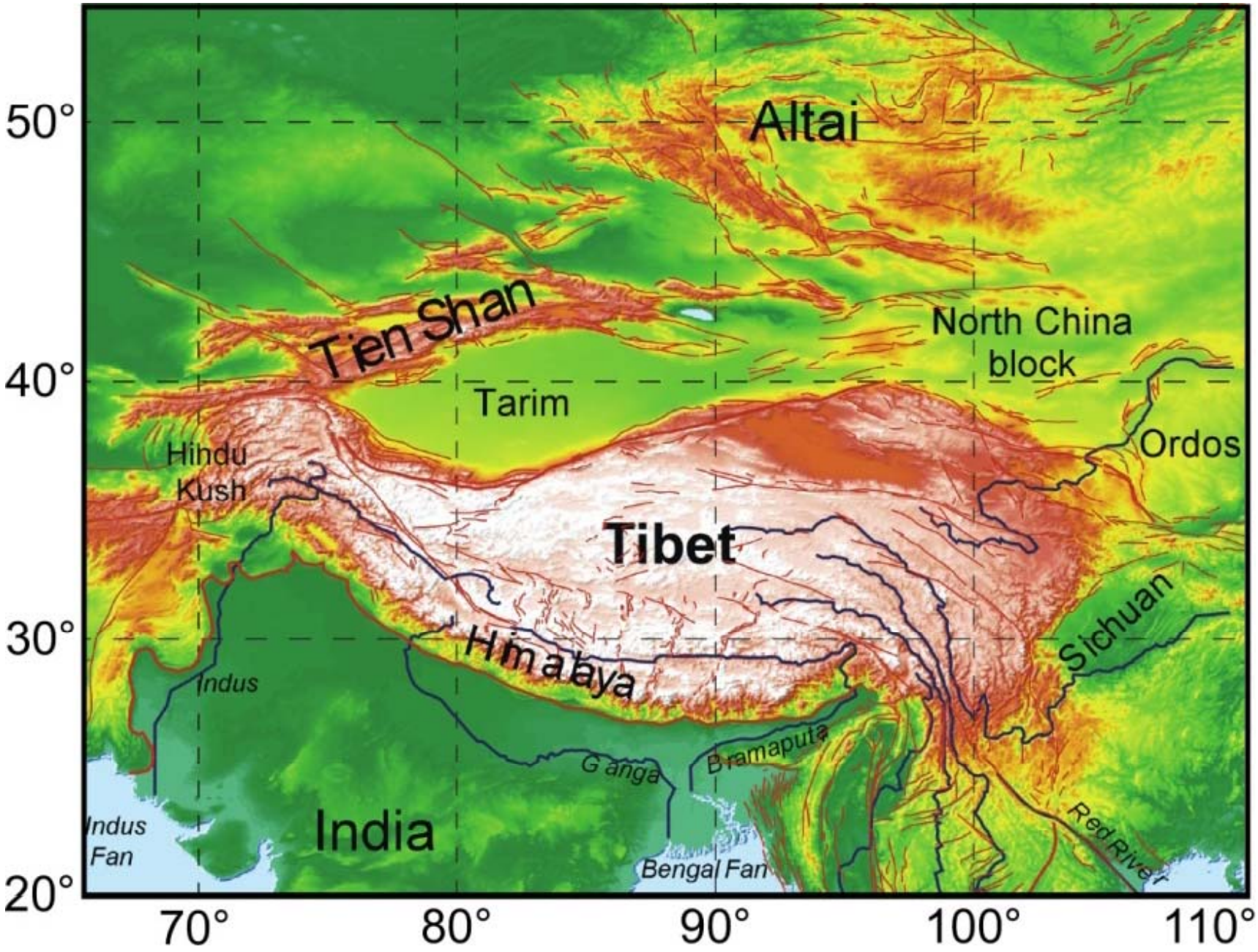
ISTerre Institut des Sciences de la Terre

OSUG Observatoire des Sciences de l'Univers de Grenoble


$2.10^6$ km$^2$ : largest plateau on Earth
• Average altitude : 4800 meters
Tibet



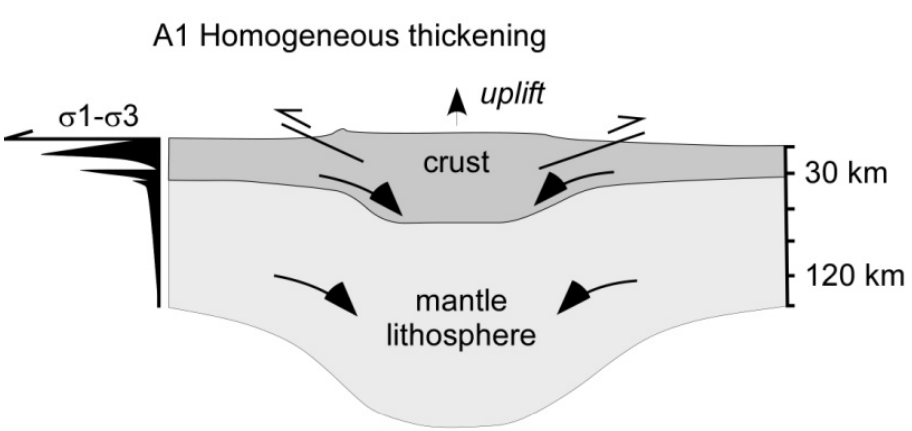

Guillot and Replumaz, 2013

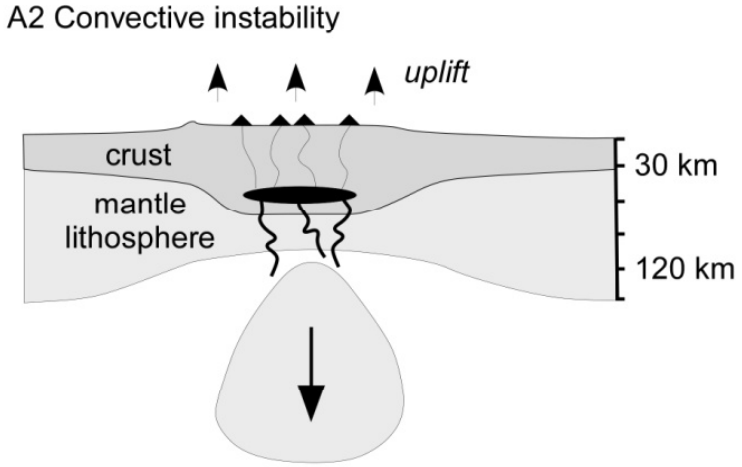
How the Plateau growth ?

When ?

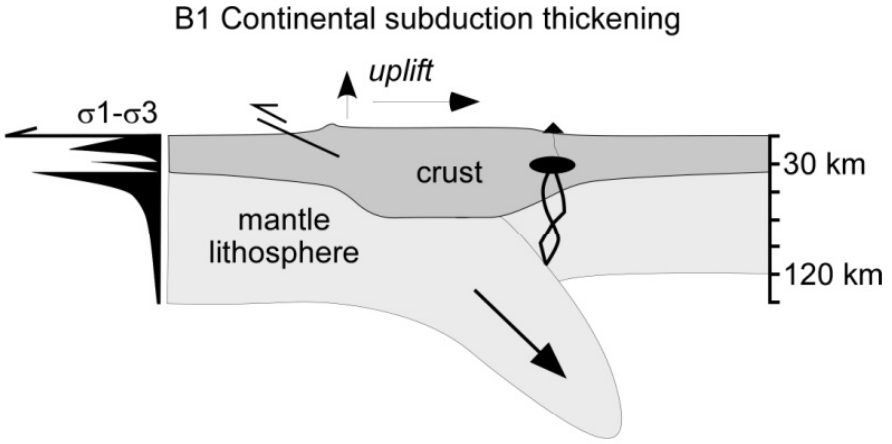
# Model of thickenning of the continental crust depends on the strenght of the lithosphere

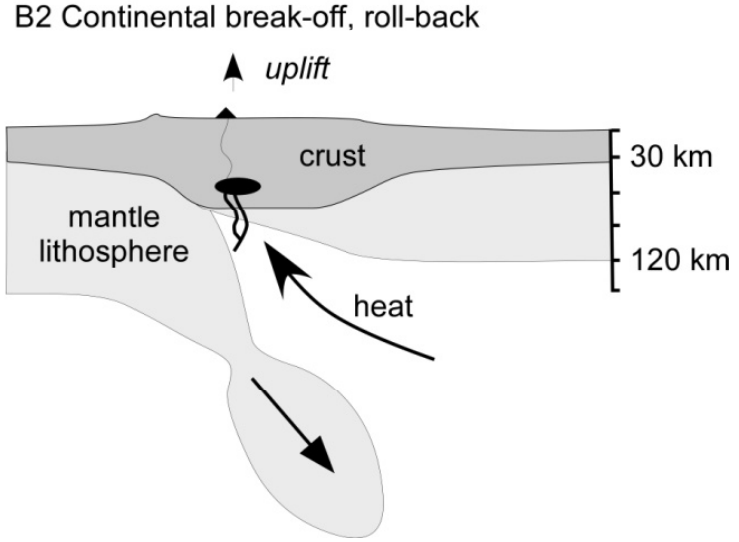
## Crème Brulé



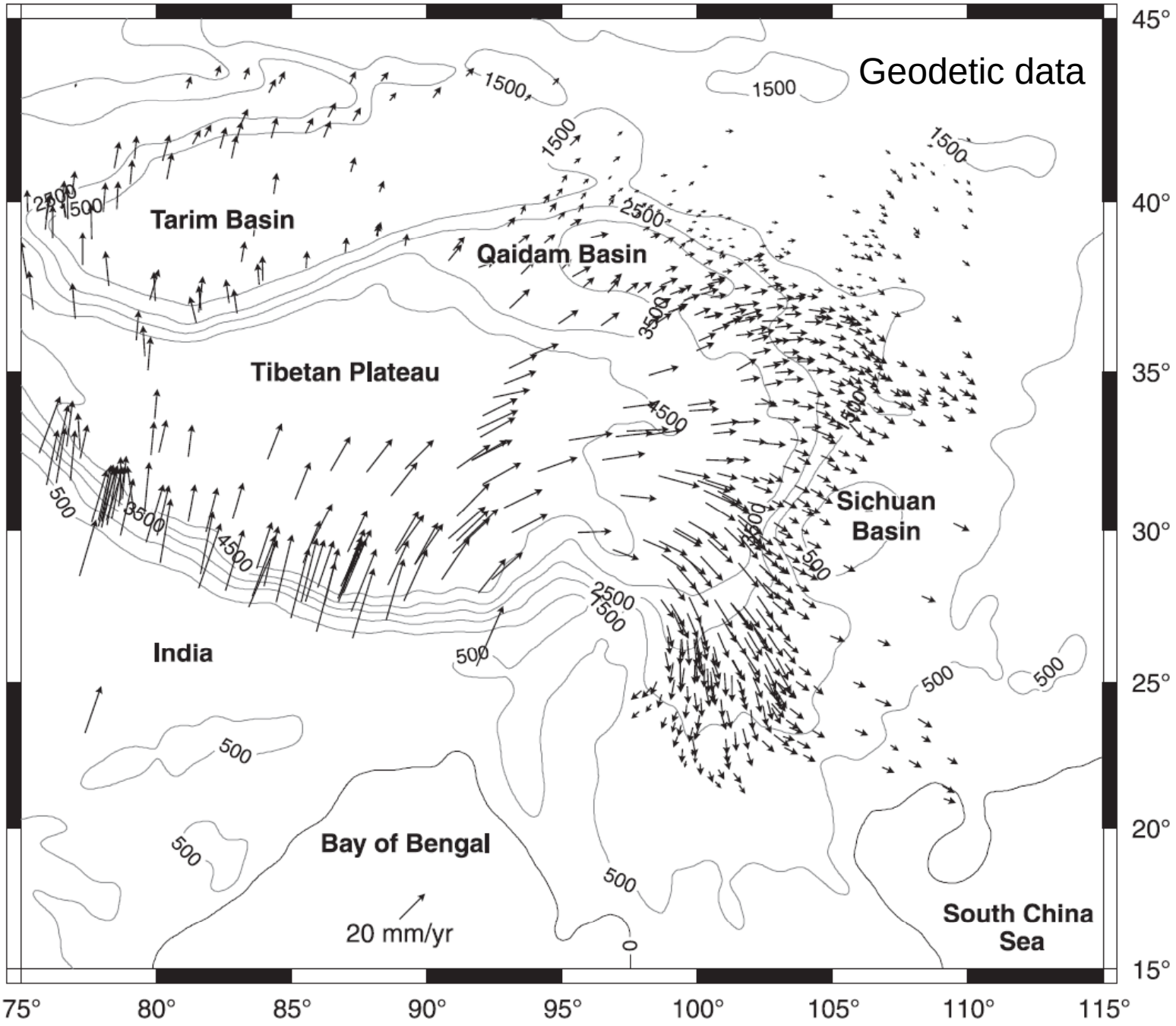




## Jelly Sandwich

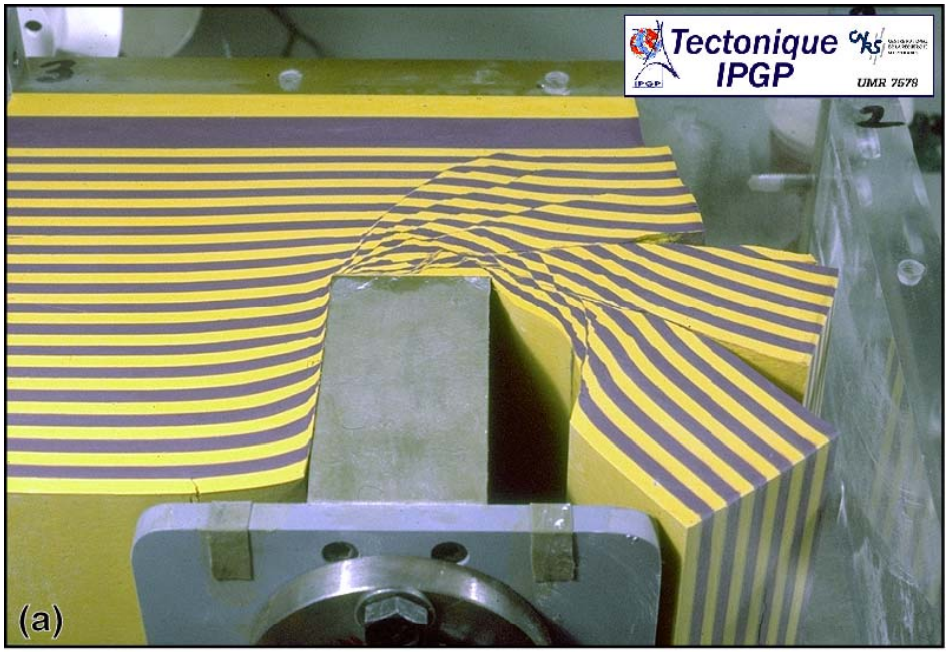



Guillot and Replumaz, 2013 (modified from Jackson, 2002)

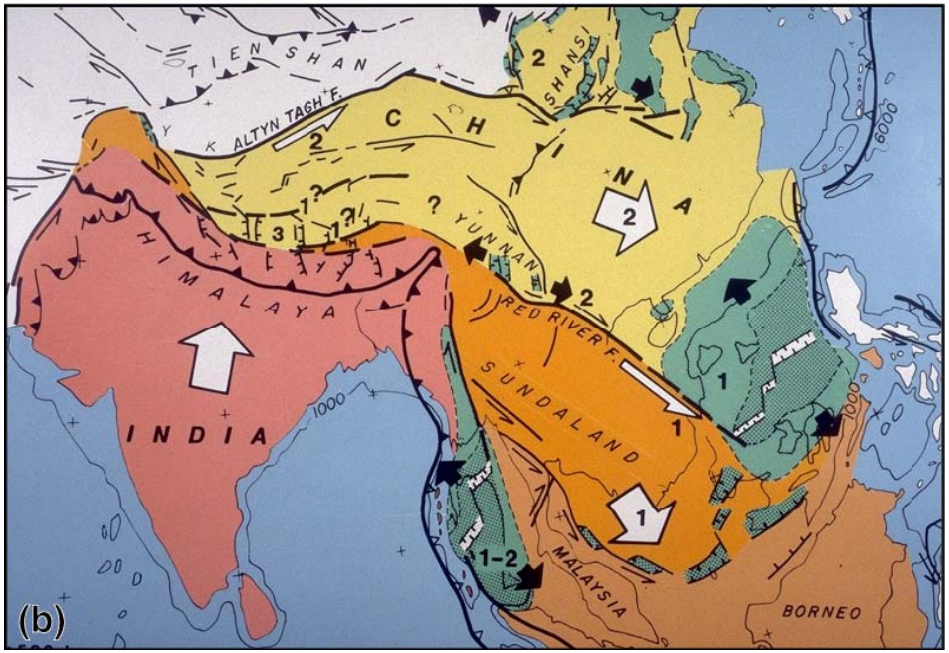



Gan et al. 2007

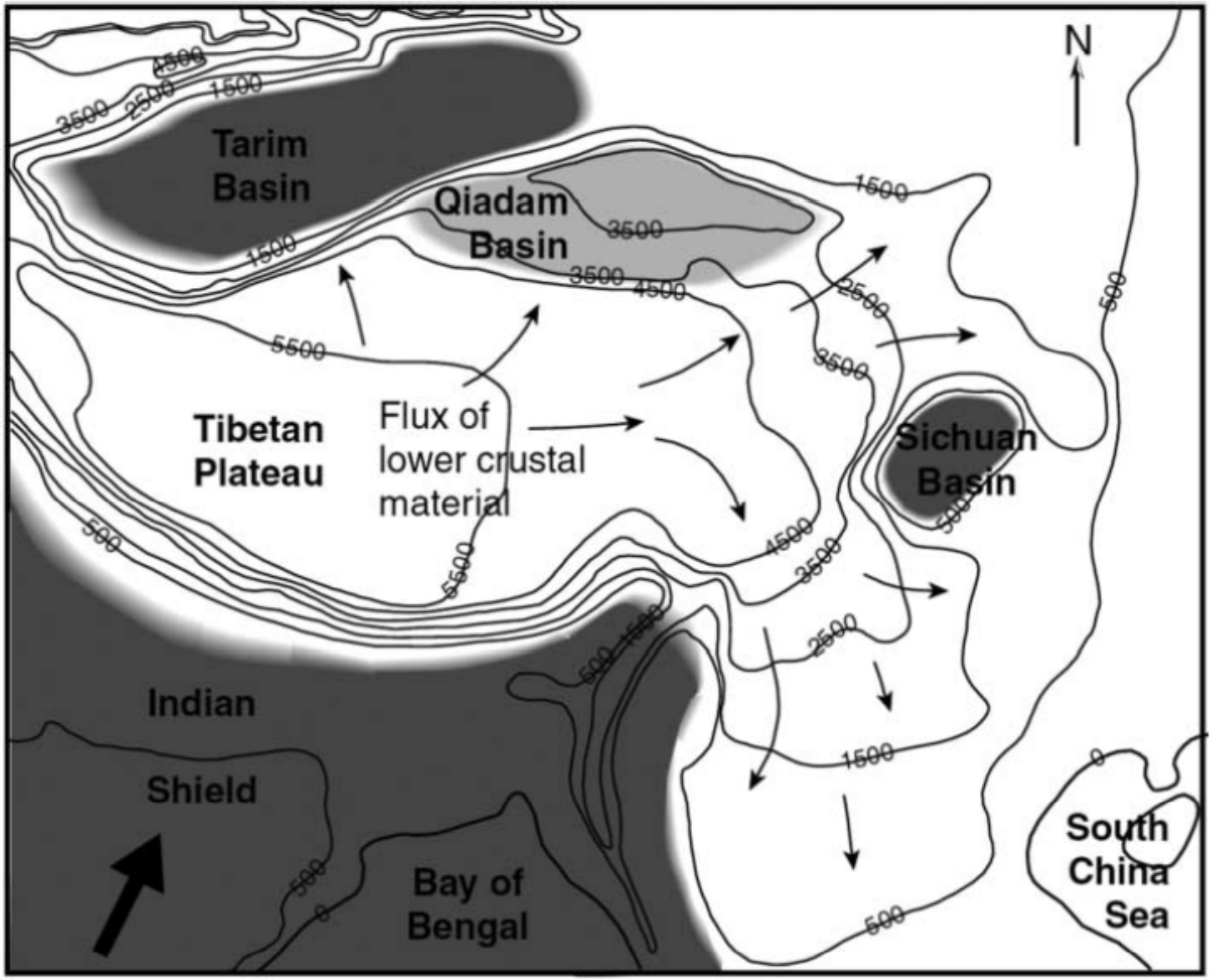



Strong Lithosphere

Localized deformation




Tapponnier et al., 1982



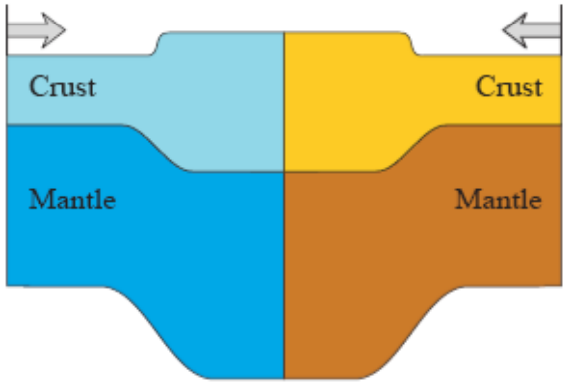

Soft Lithosphere

Distributed deformation

Clark and Royden, 2000

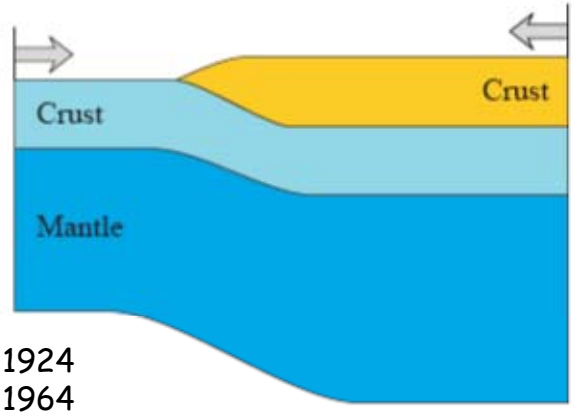
# Models of Tibetan plateau formation and Crustal Volume Balance (CVB)

## Homogeneous thickening CVB = 0



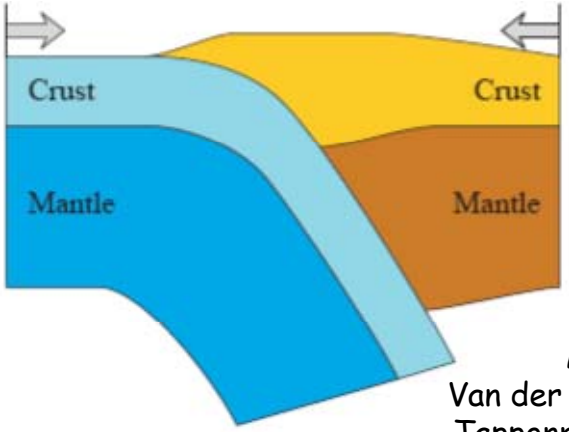

England & Houseman, 1986, 1989
Holt et al., 1995, 2000

## Indian Underthrusting CVB >0




Argand, 1924
Gansser, 1964
Powell & Conaghan, 1973

## Subduction CVB < 0

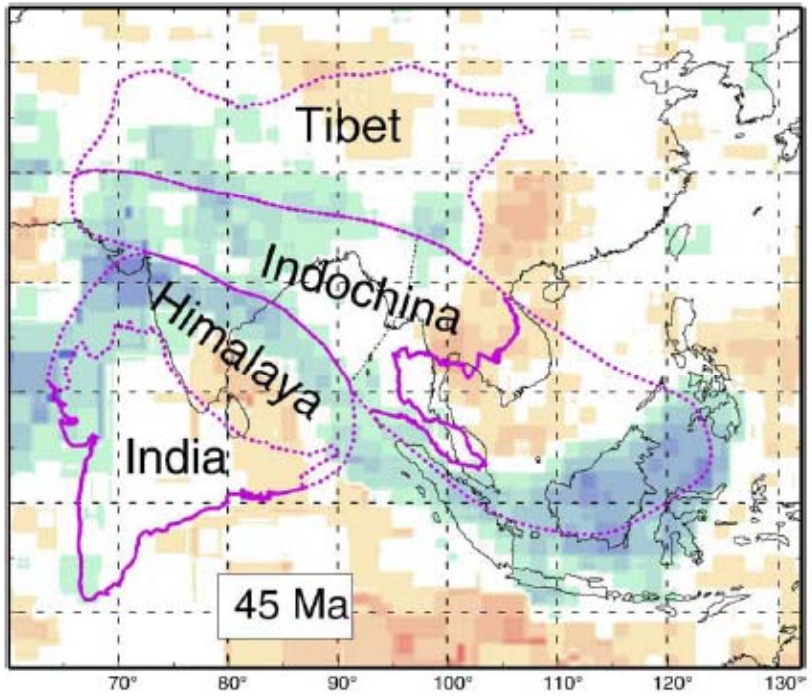



Miyashiro, 1982
Van der Voo et al., 1999
Tapponnier et al.,, 2001

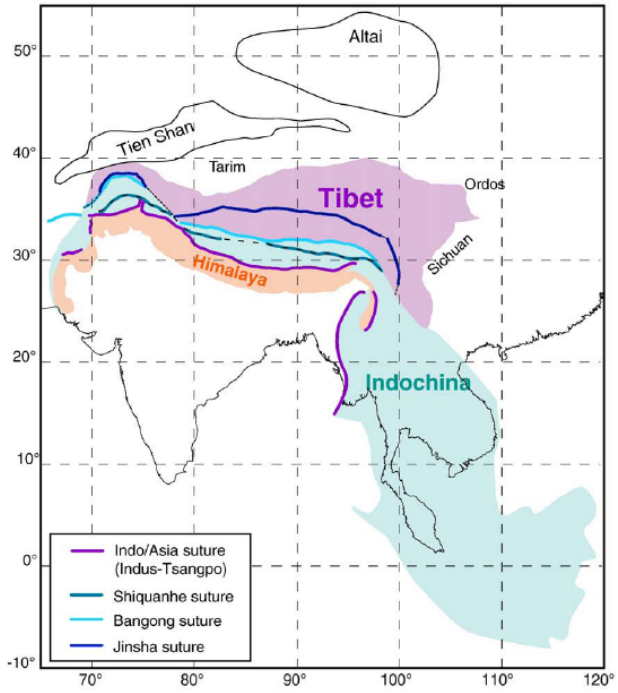
Estimation of Crustal Volume Balance between

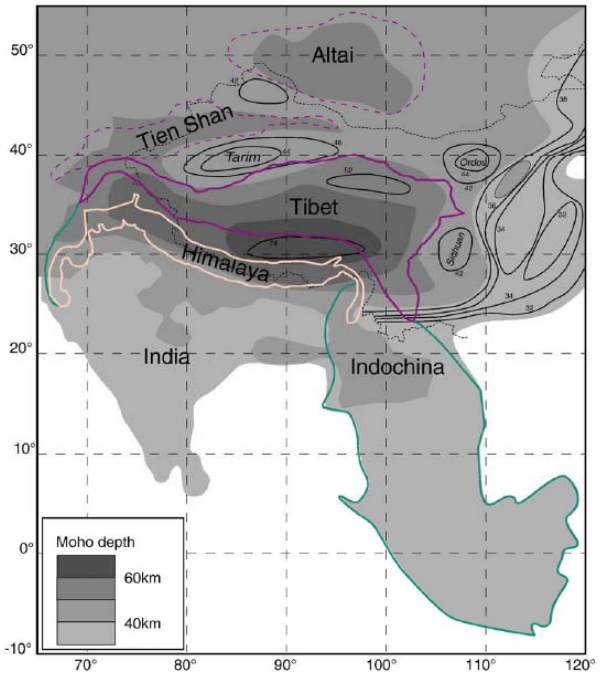
45 Ma and present-day

$(\text{Surface} * \text{thickness})_{0Ma} - (\text{Surface} * \text{thickness})_{45Ma}$

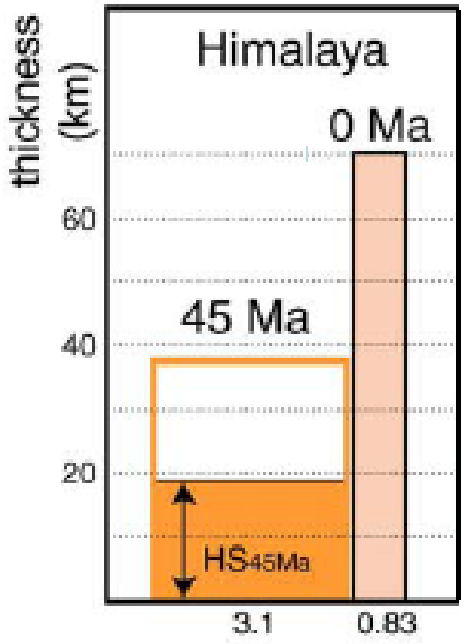



Initial thickness estimated in the surrounding undeformed area



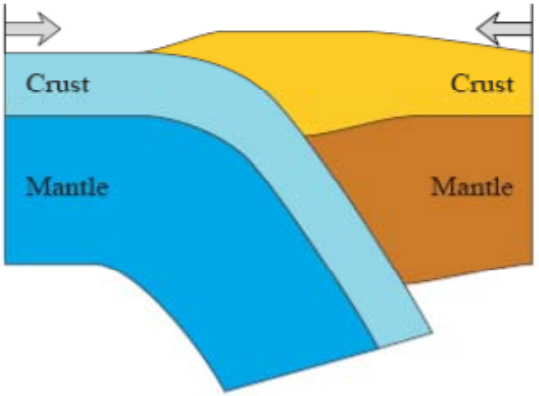

Replumaz et al., 2010

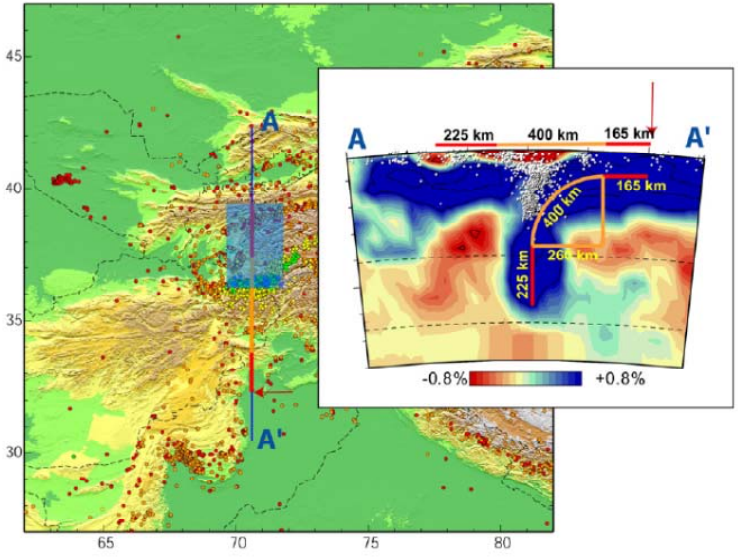


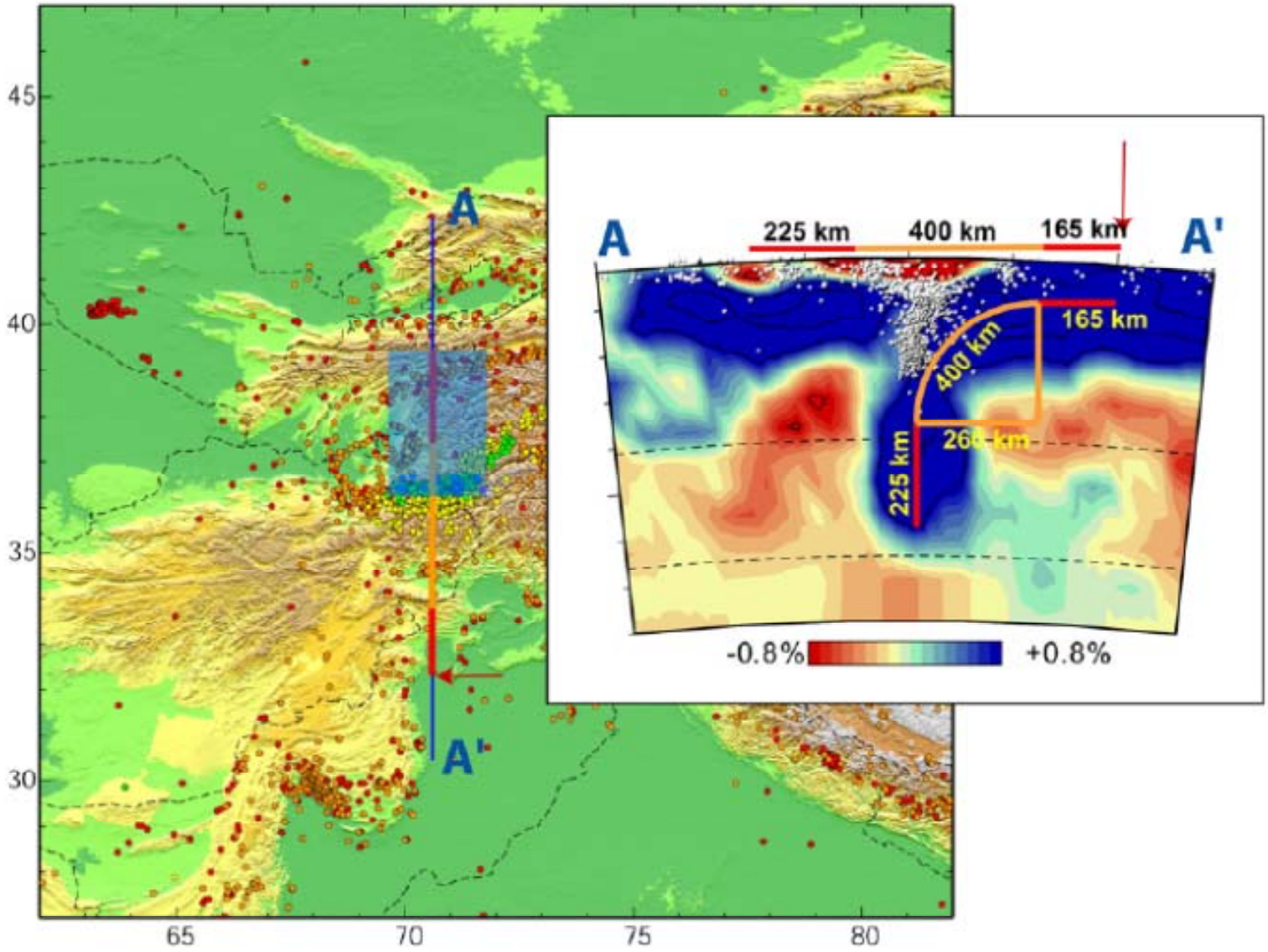

Replumaz et al., 2010

Himalaya : 40 to 50% of the crust was recycled in the mantle

## Continental Subduction

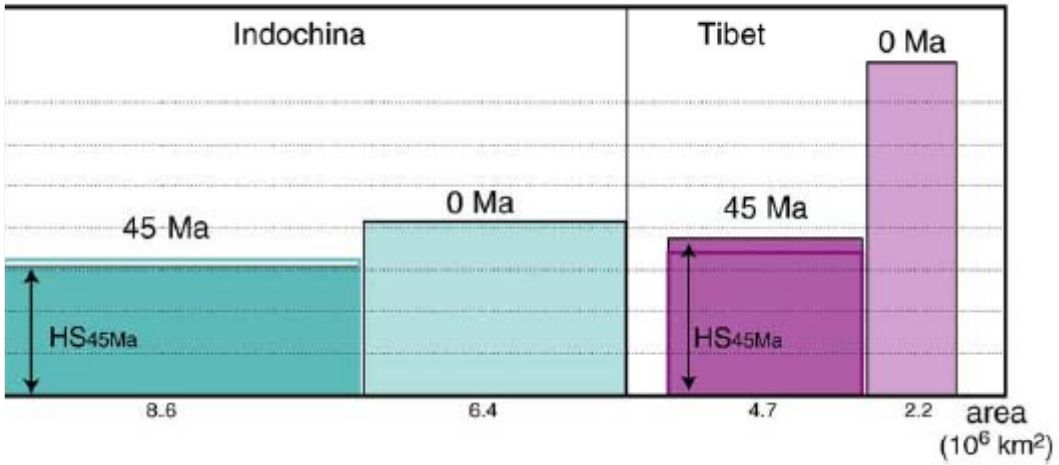




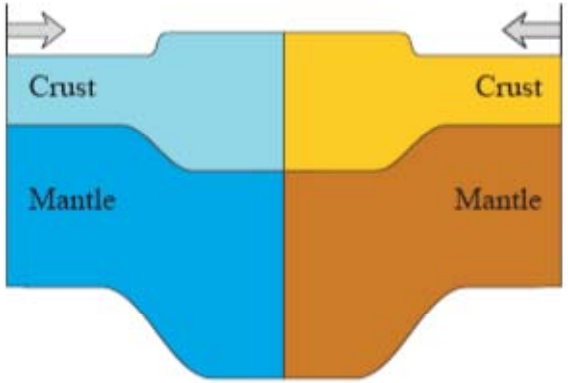

Negredo et al., 2006

Continental subduction of India beneath Pamir




Indochina + Tibet : only 3% of the crust was recycled in the mantle

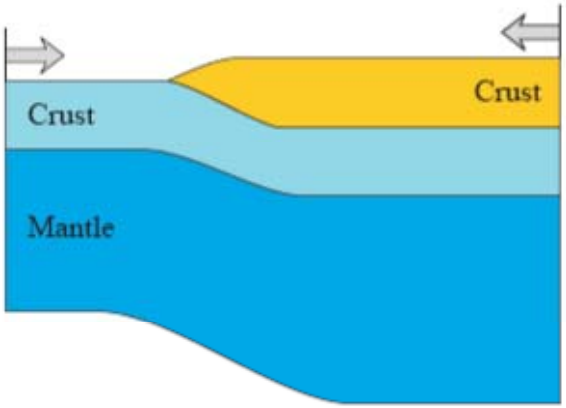
**Homogeneous thickening**




Replumaz et al., 2010

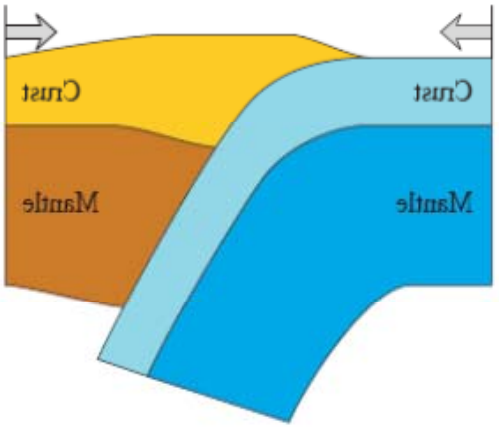
or

**Underthrusting**




+

**Continental Subduction**

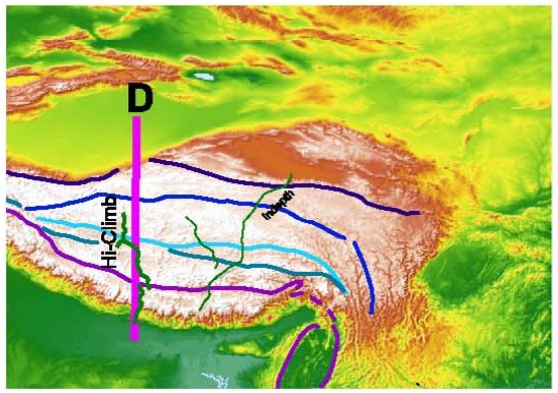


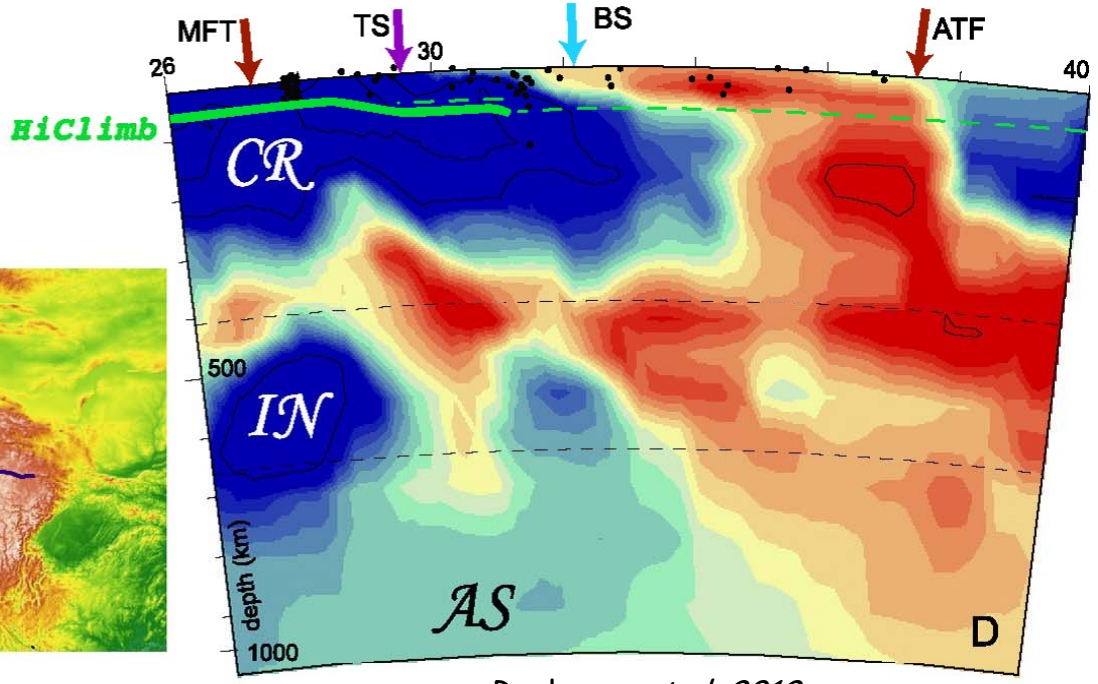

Indian side : add crust

Asian side : lost crust

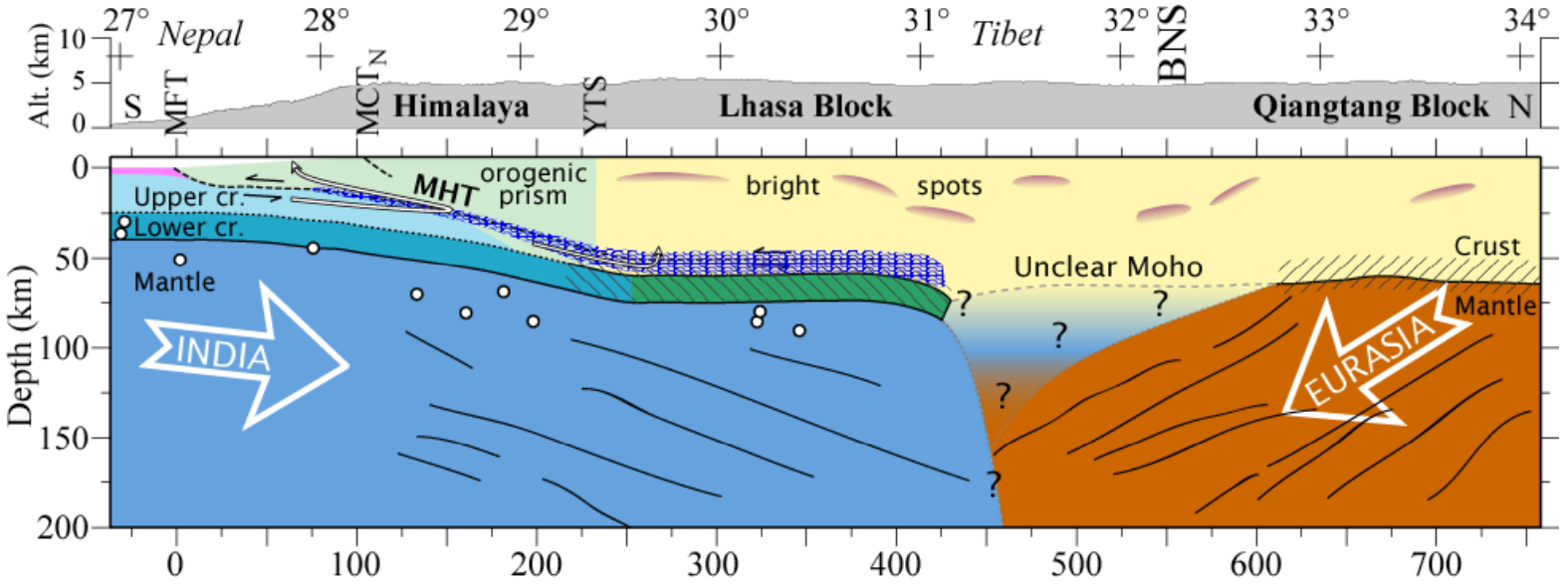
=> Crustal volume balance close to zero

# Underthrusting of Indian crust beneath S. Tibet



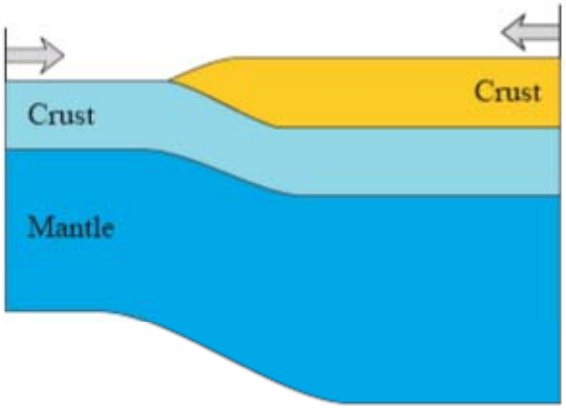




Replumaz *et al. 2012*



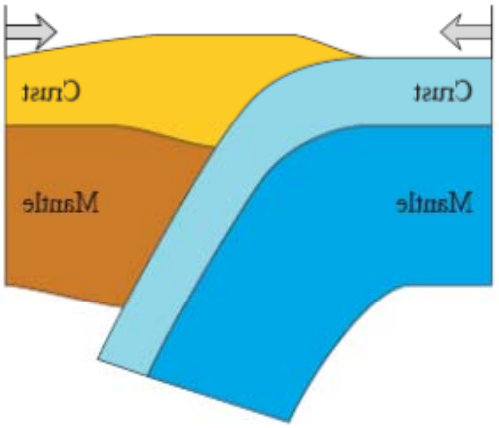

*Nabelek , Hetenyi et al., Science 2009*

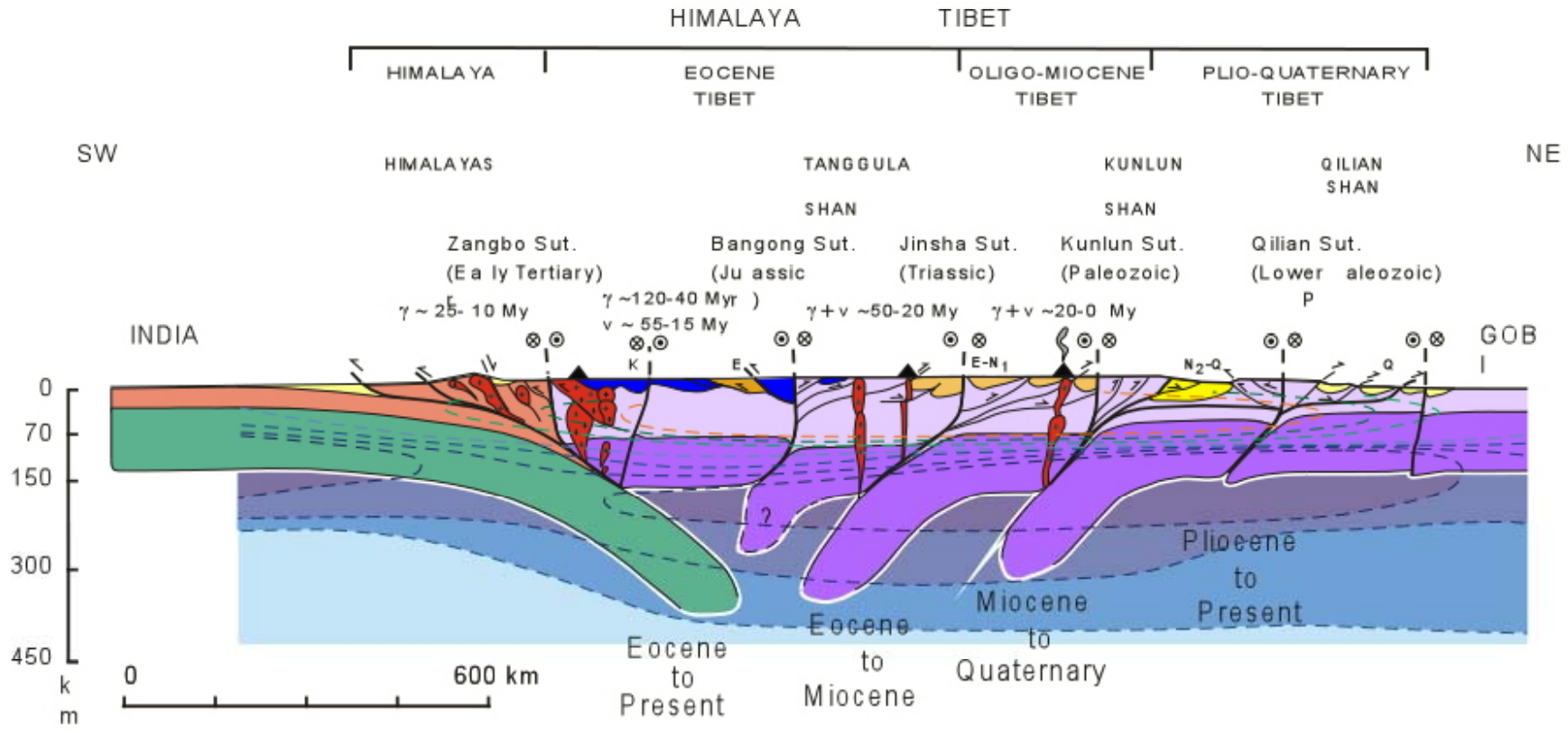
**Indian underthrusting: OK**




+

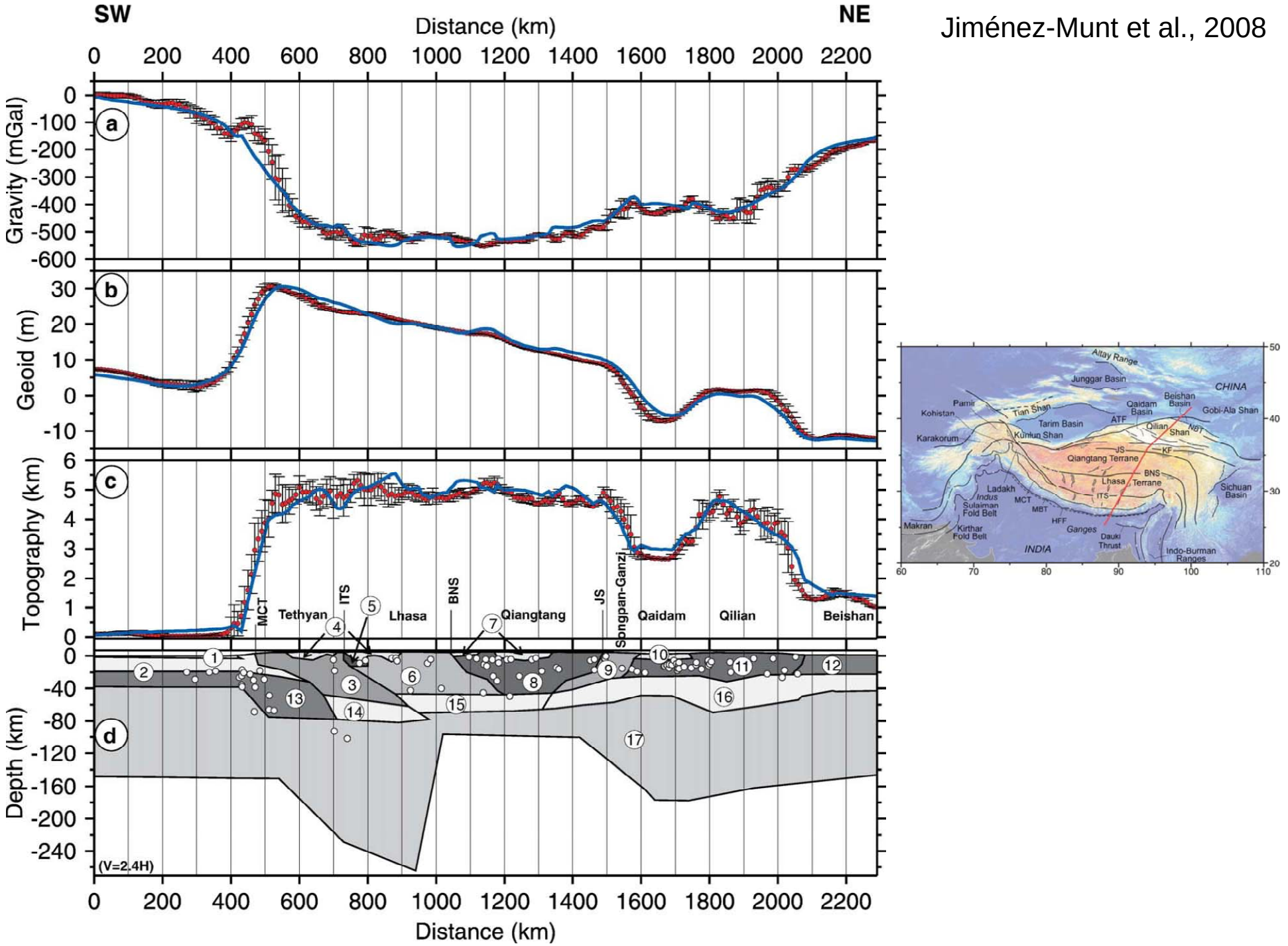
**Asia Continental Subduction ???**



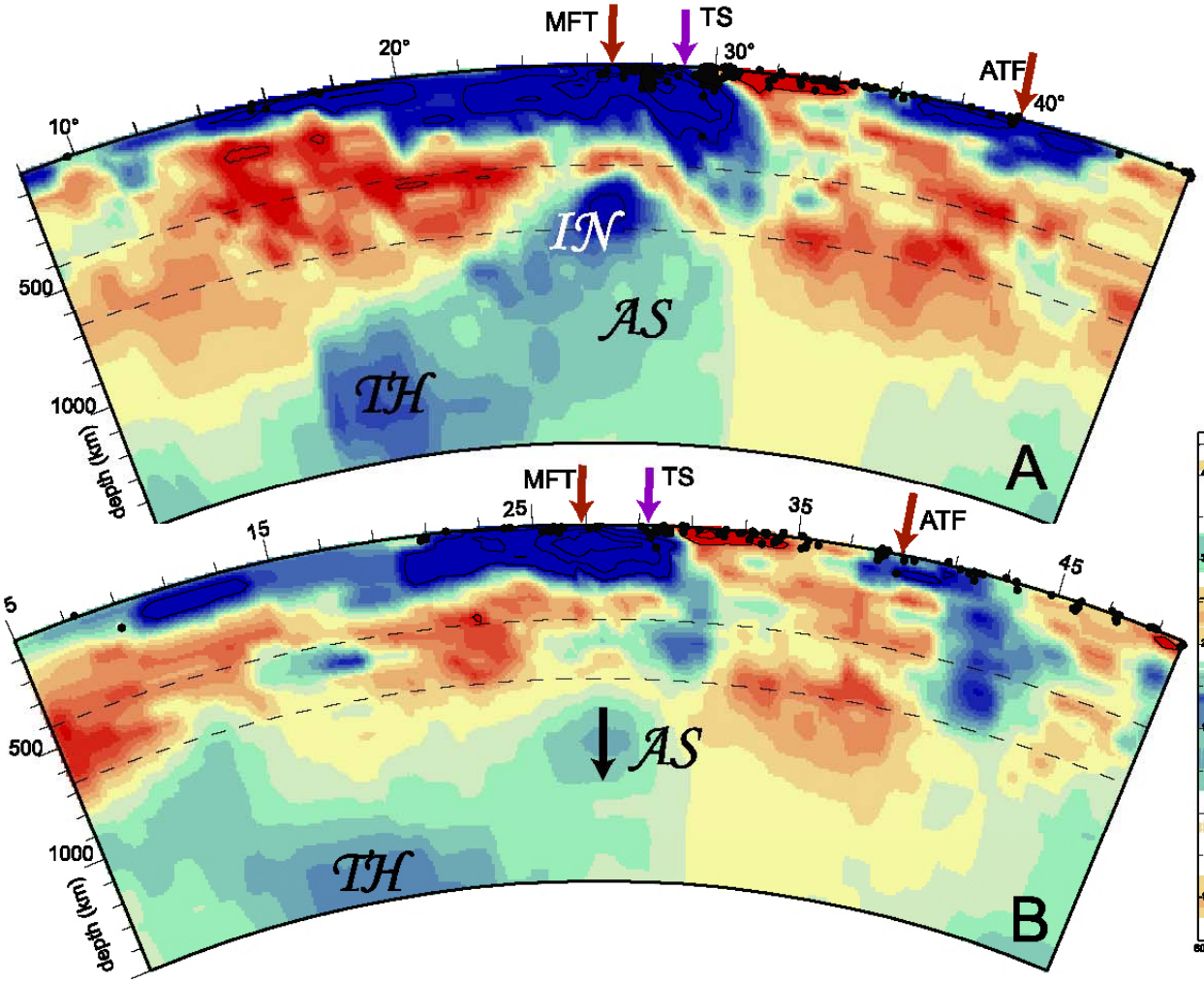


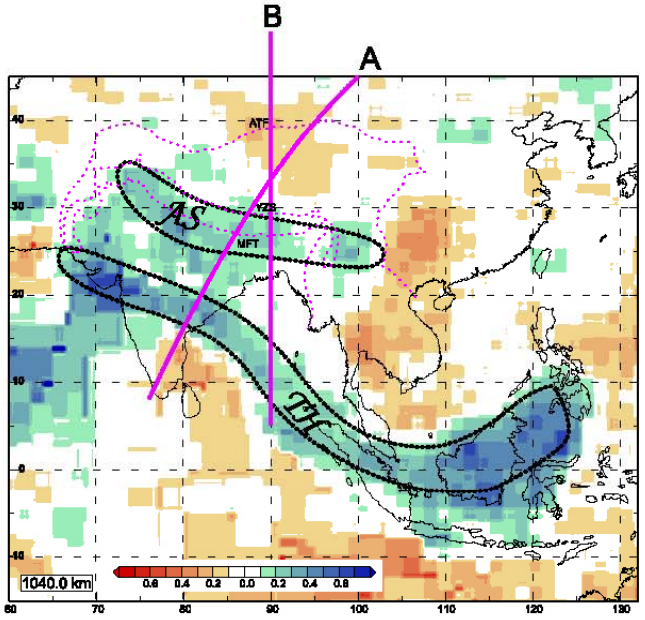

Tapponnier et al., 2001

Jiménez-Munt et al., 2008



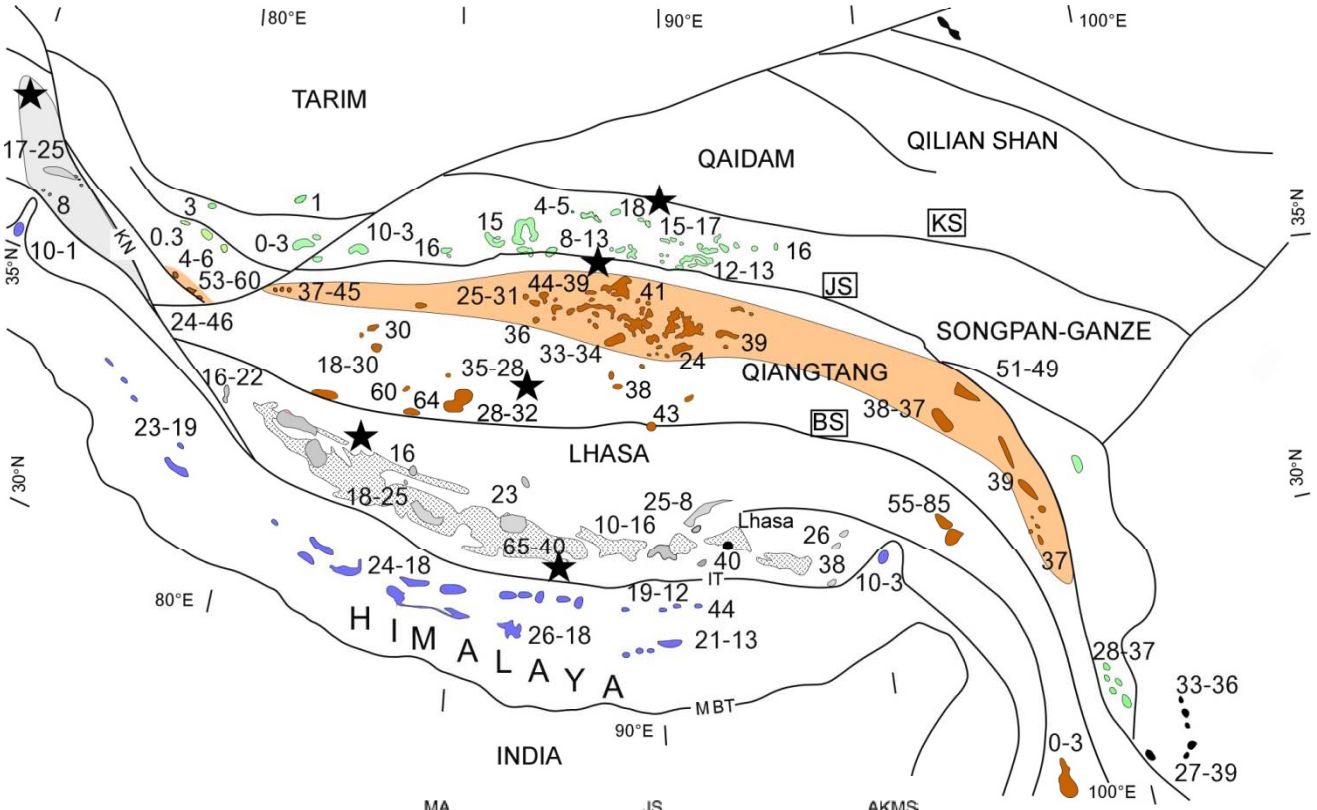
# Tomography evidences of Asian subduction

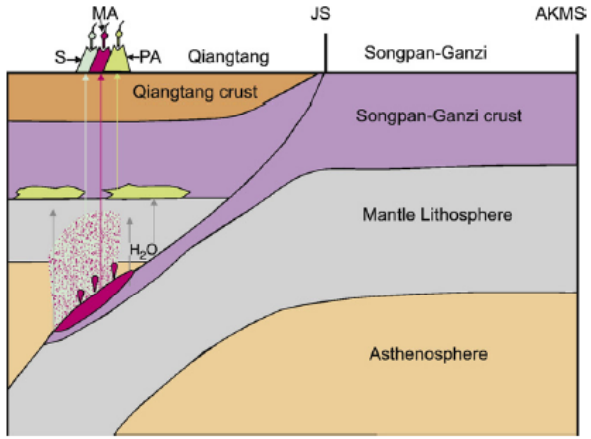



Replumaz et al., 2012

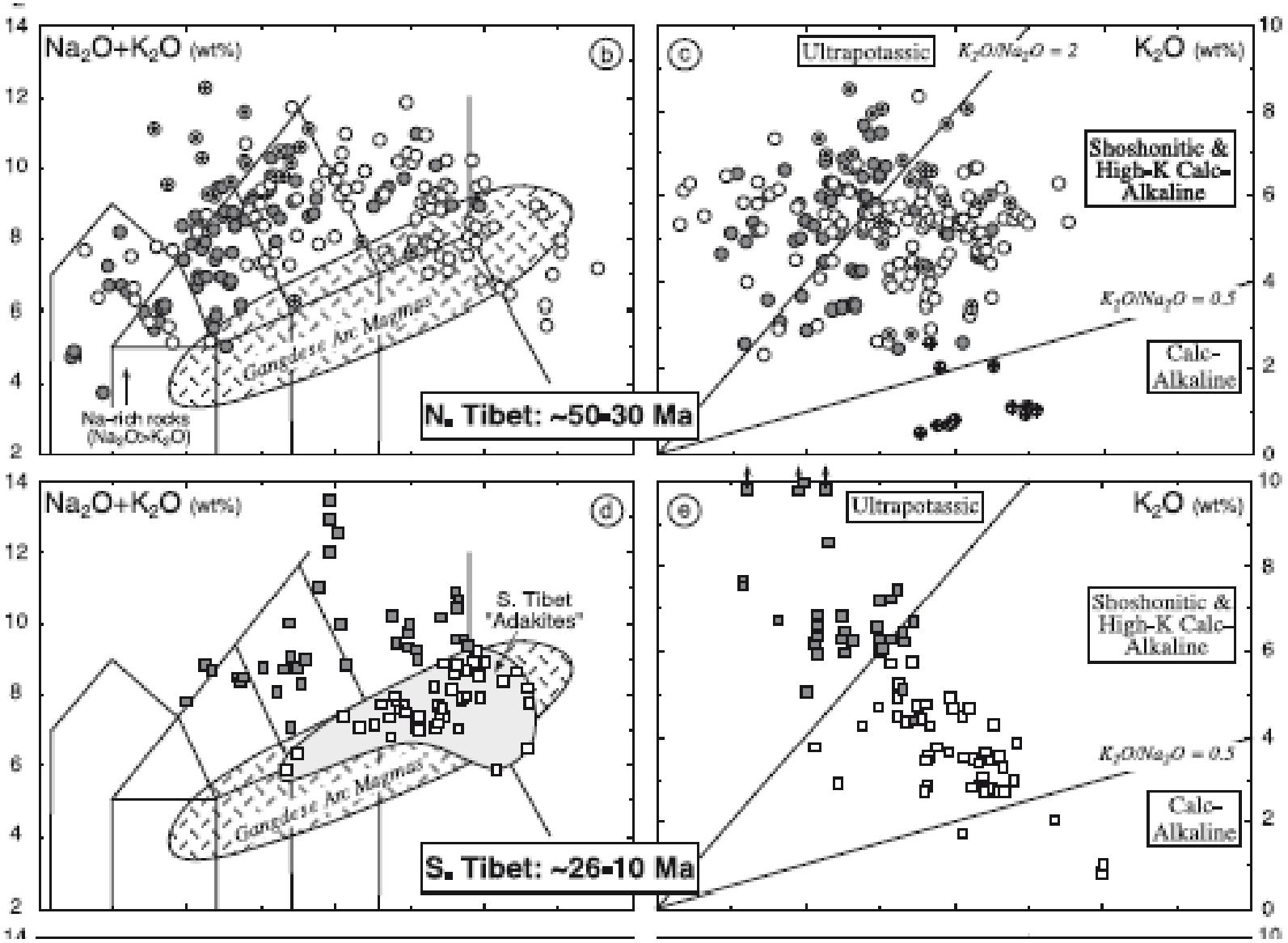
# Eocene volcanism : Songpan-Ganze Subduction (45-35 Ma)



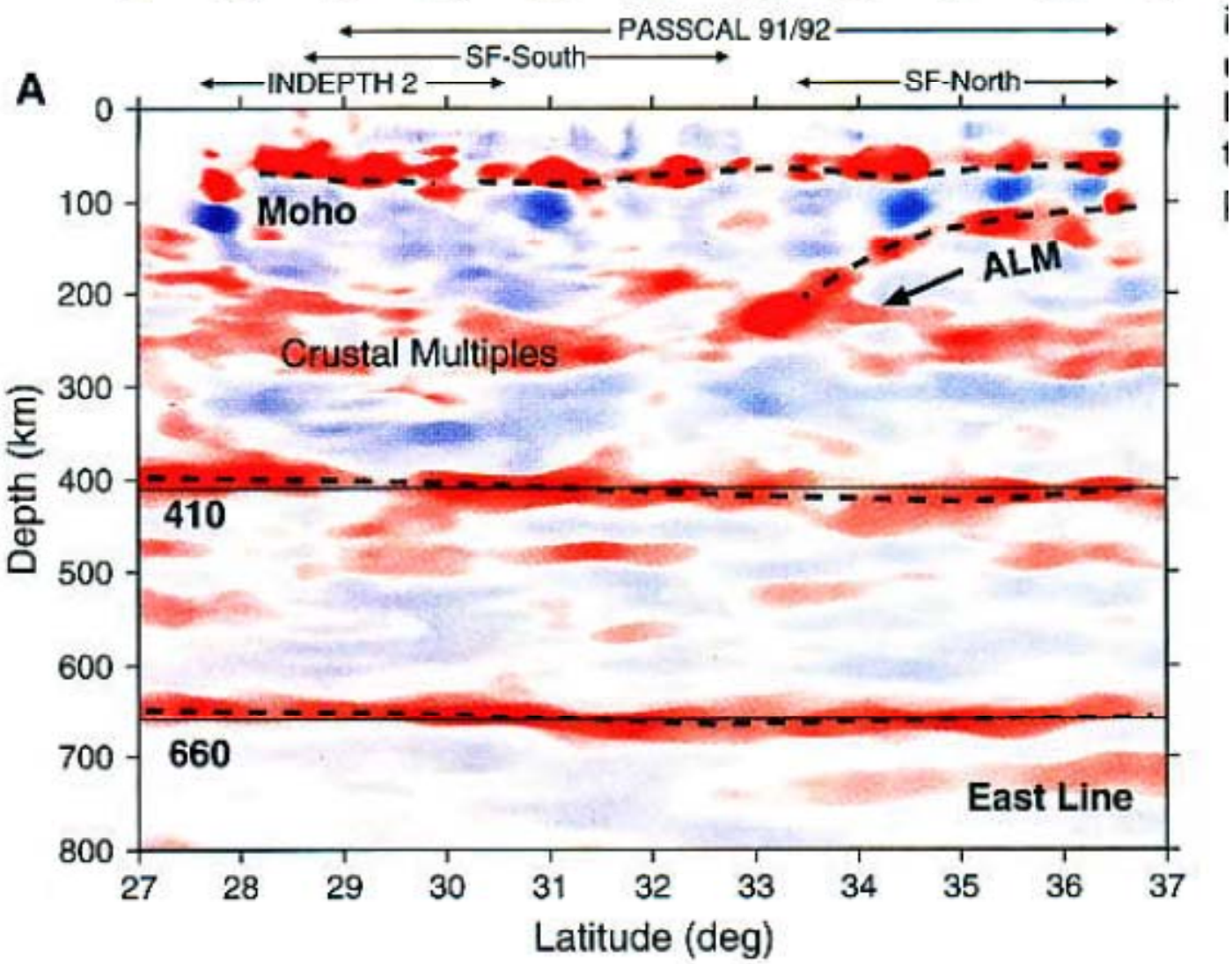




Guillot and Replumaz, 2013

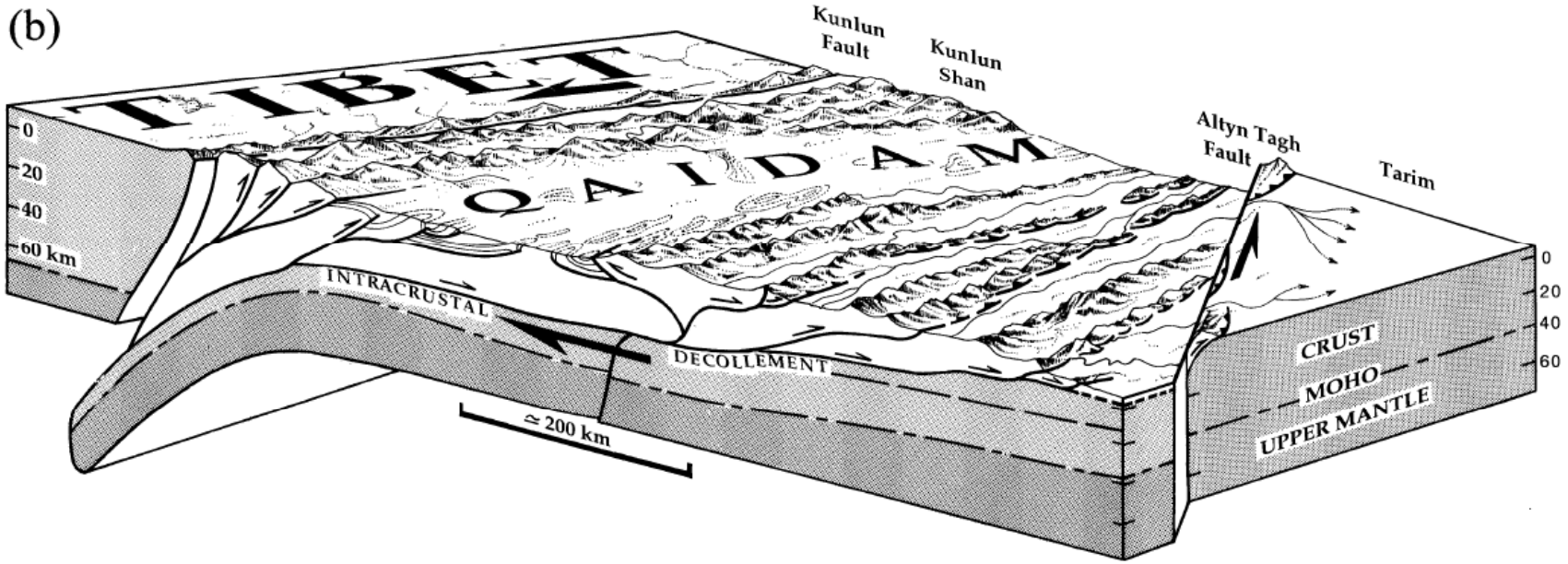
Wang et al. 2008



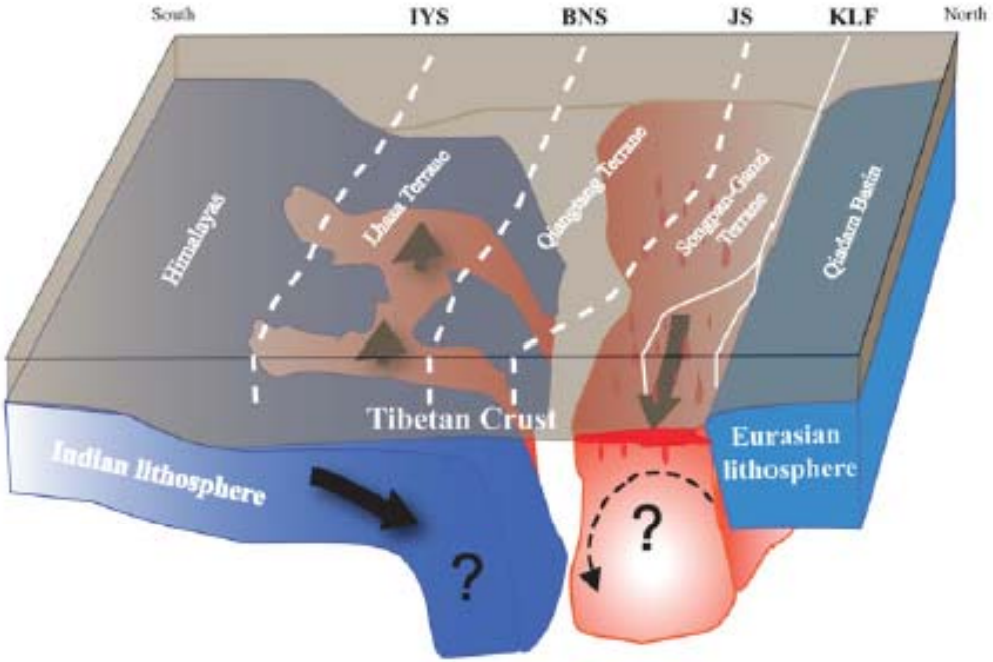

Chung et al., 2005




Kind et et al., 2010

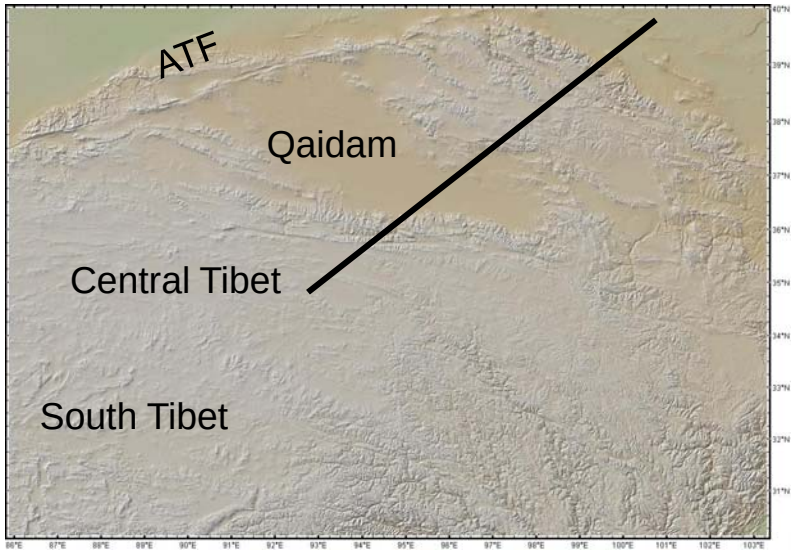


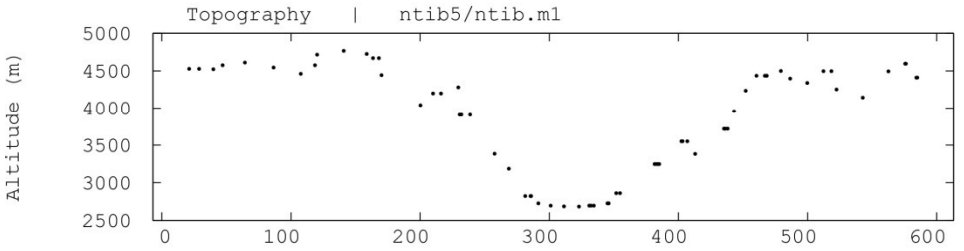

Meyer et al., 1998

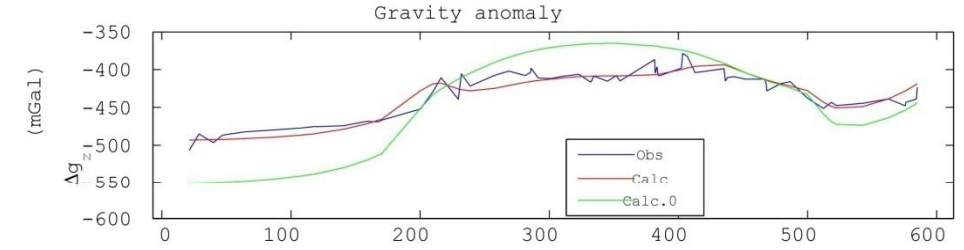


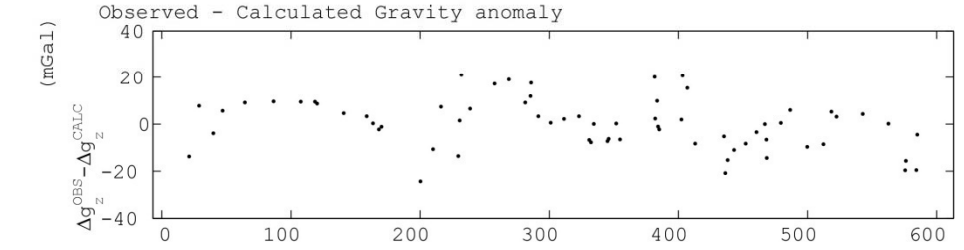

Liang et al., 2012

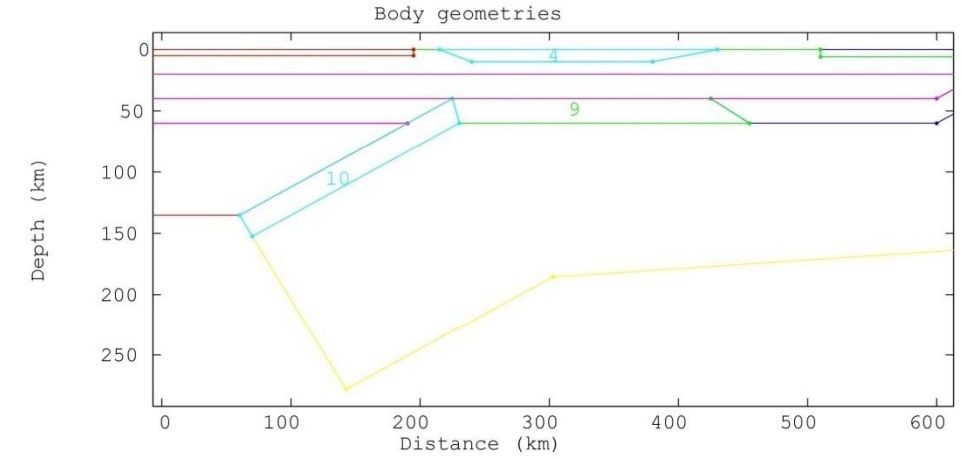
# Inversion of gravity anomaly



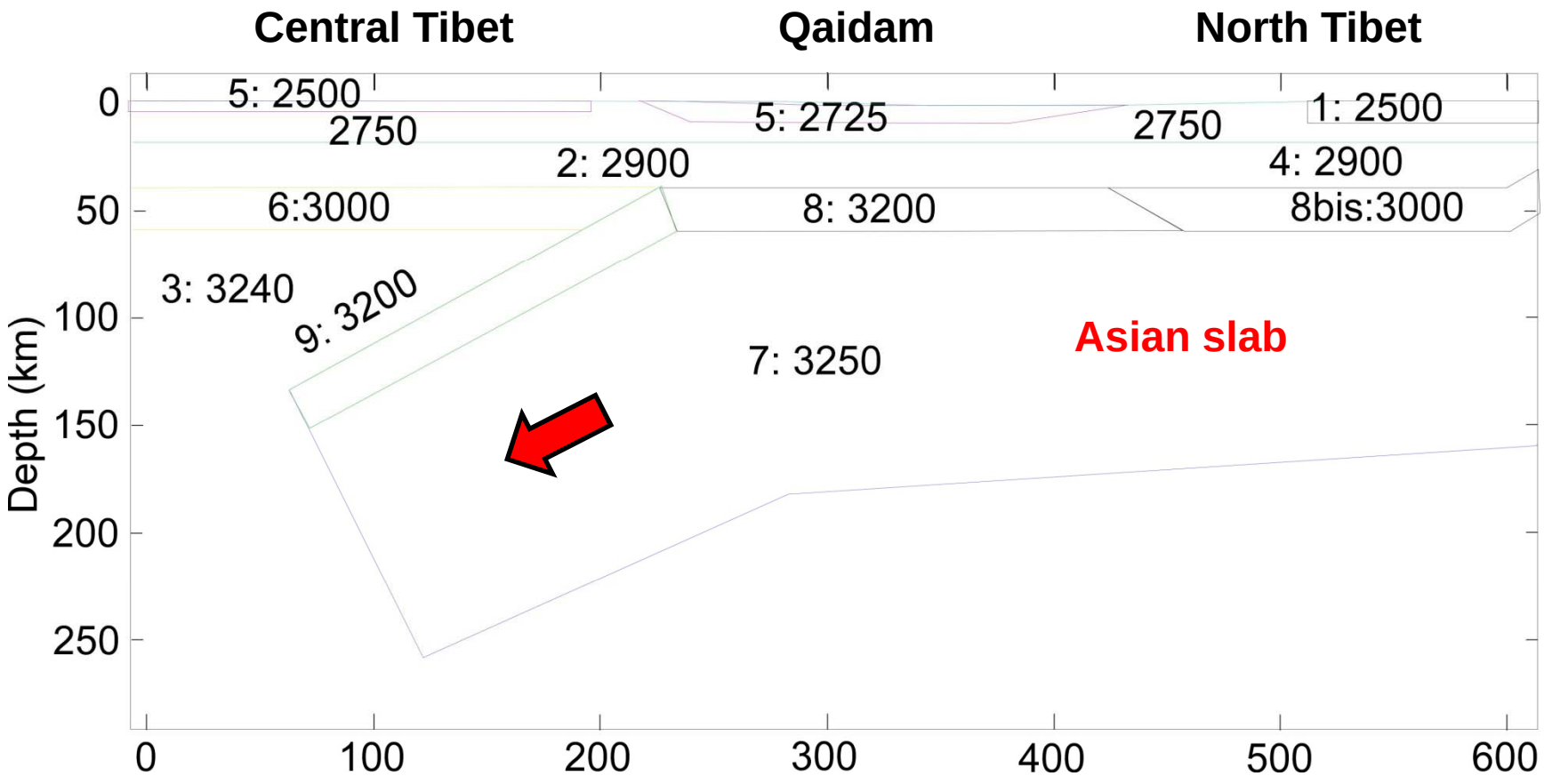




Guillot et al. in prep.

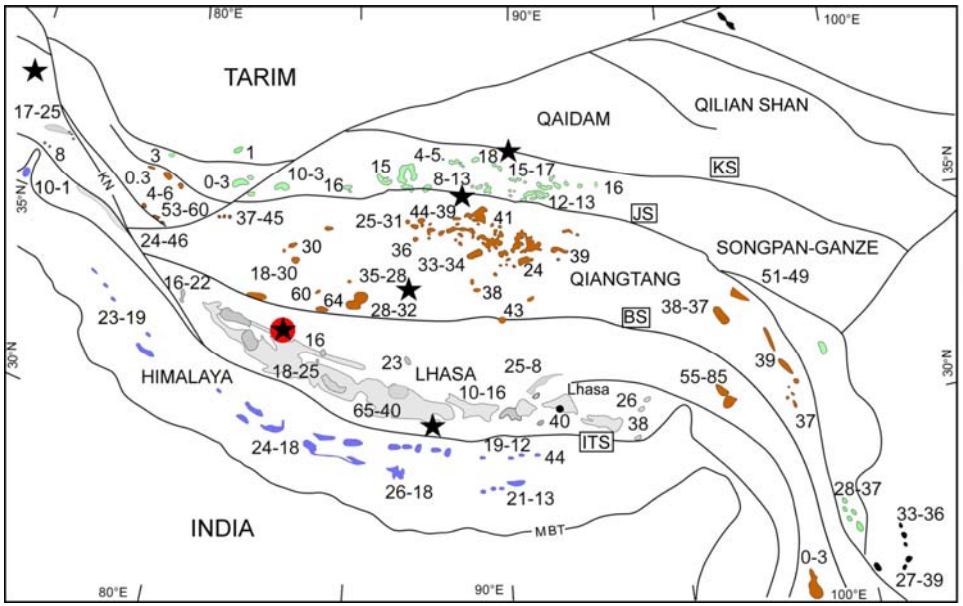
Density model for Asian Subduction

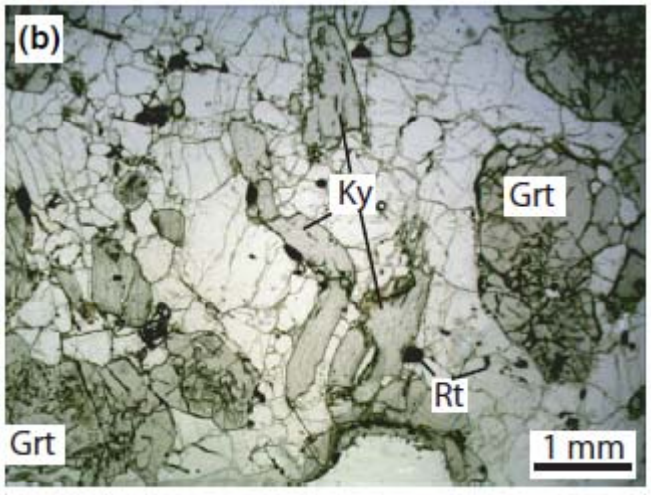
compatible with S receiver function data

*South* *North*

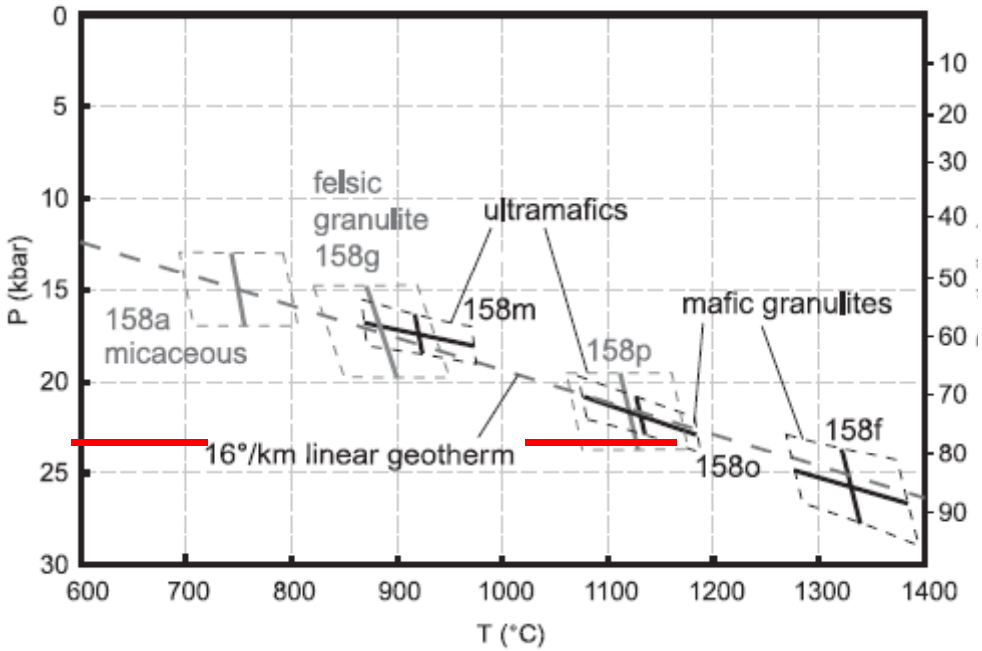



Guillot et al. in prep.



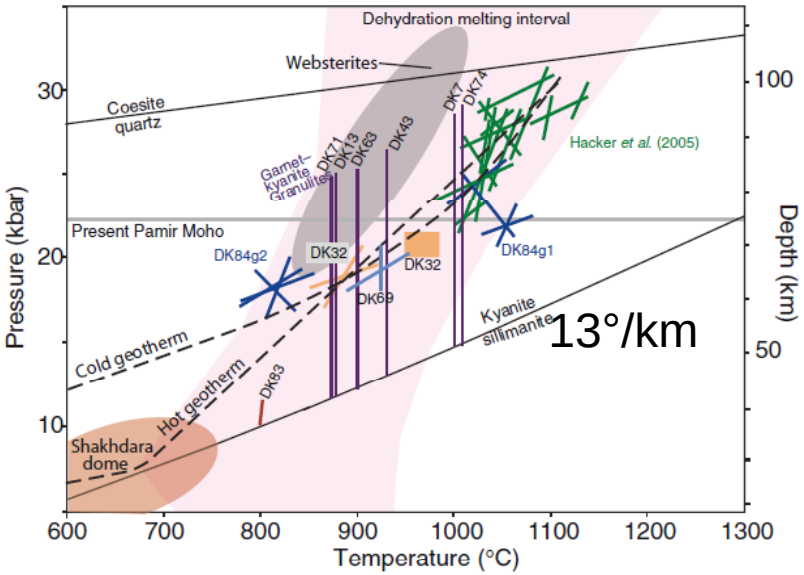




Xenolith thermobarometry



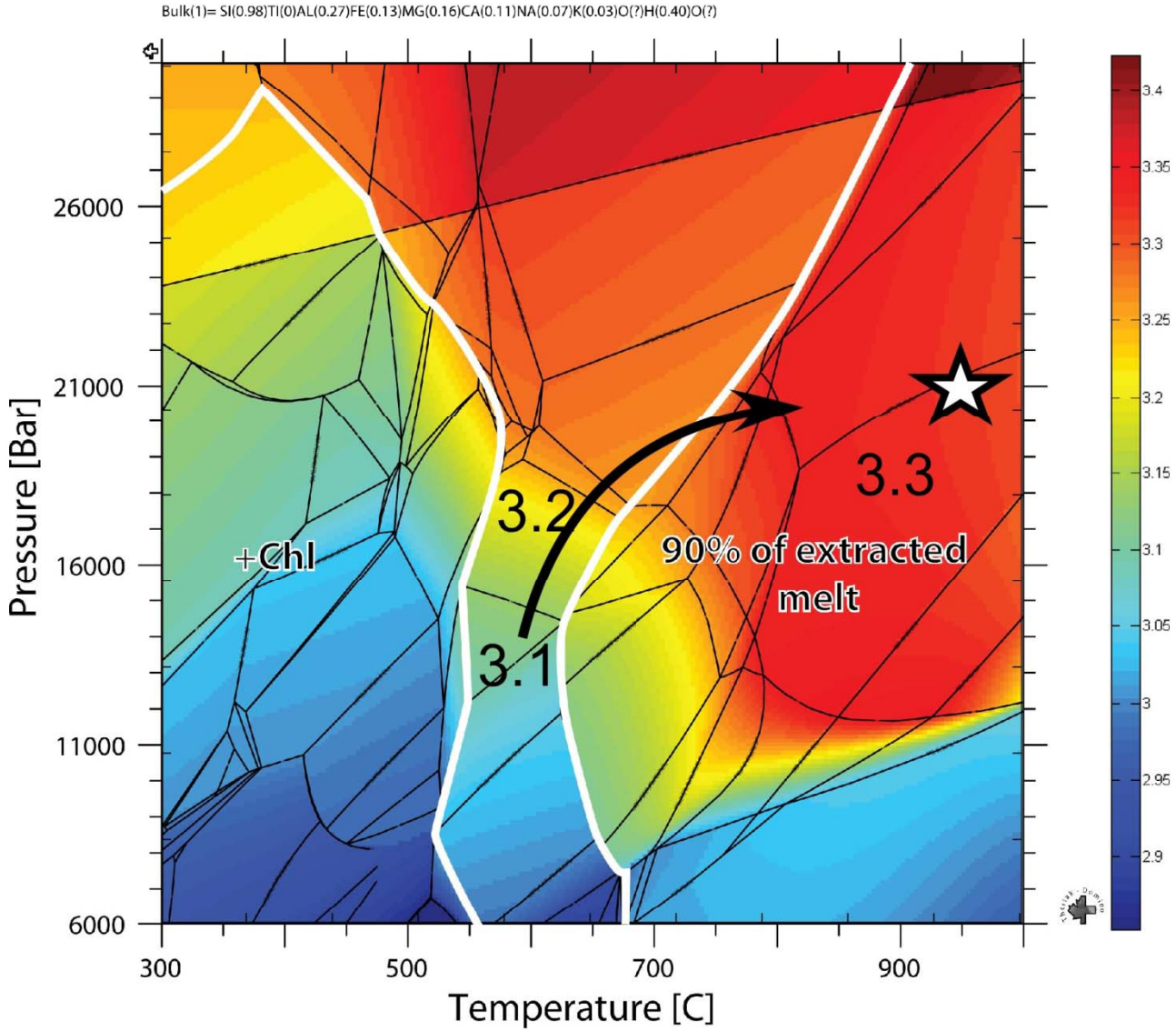

Southern Tibet xenoliths 14-17 Ma;

Chan et al., 2009



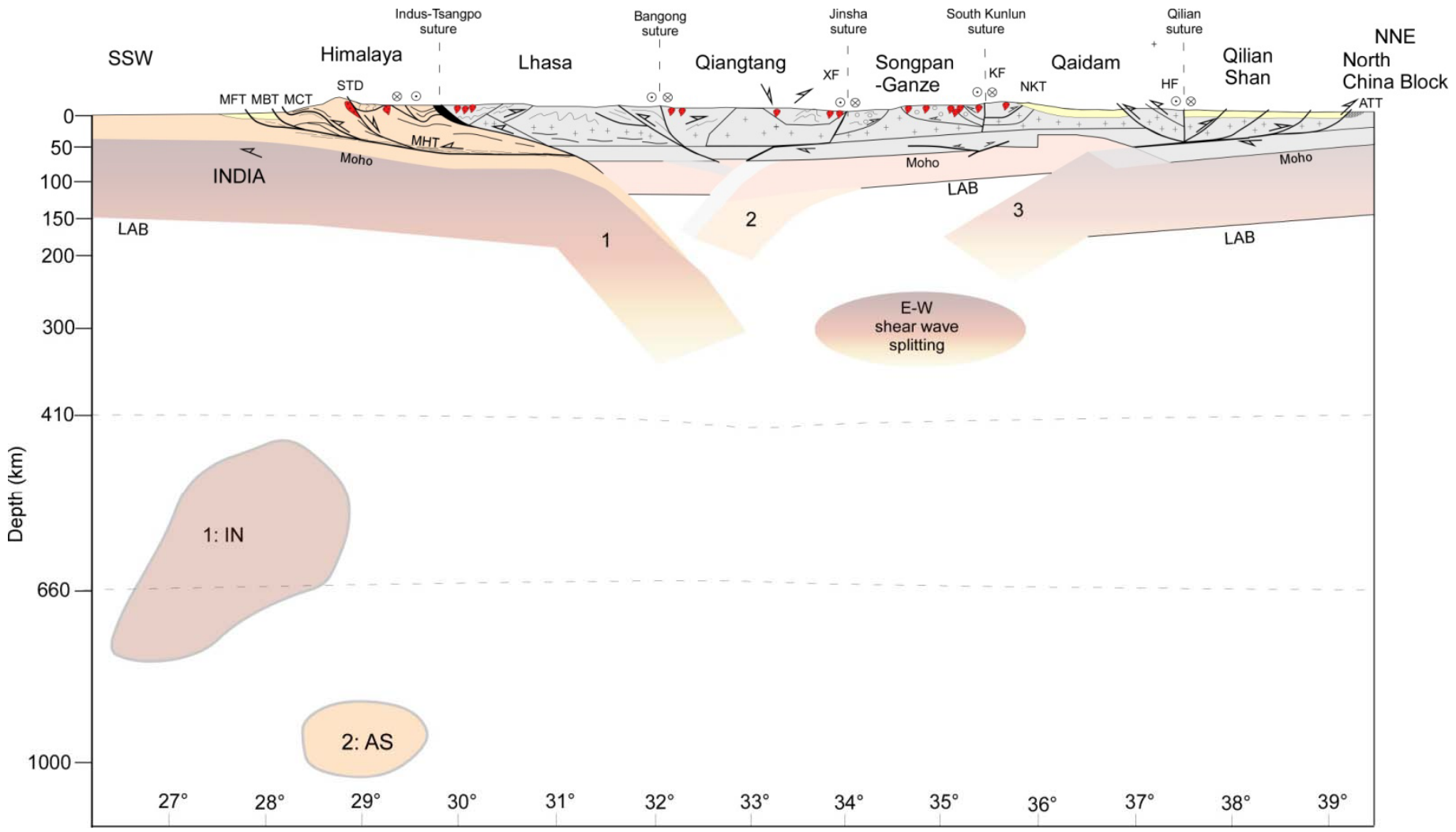

South Pamir, 11-12 Ma

Gordon et al., 2012




Initial composition
50% of metasédiments and 50% of metabasites
(total free water : 3%wt).

Guillot et al. in prep.




Guillot and Replumaz, 2013

# When the Plateau growth ?

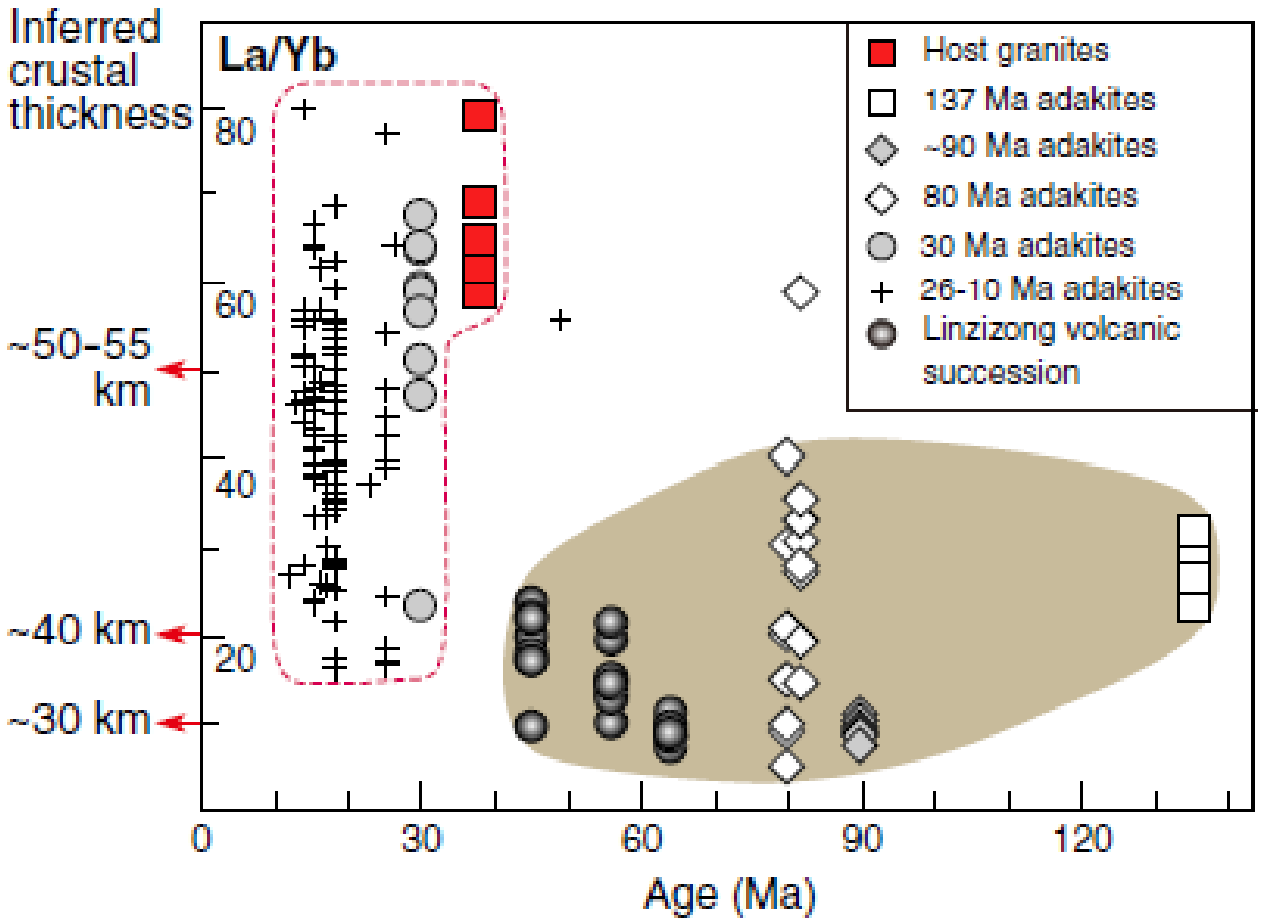
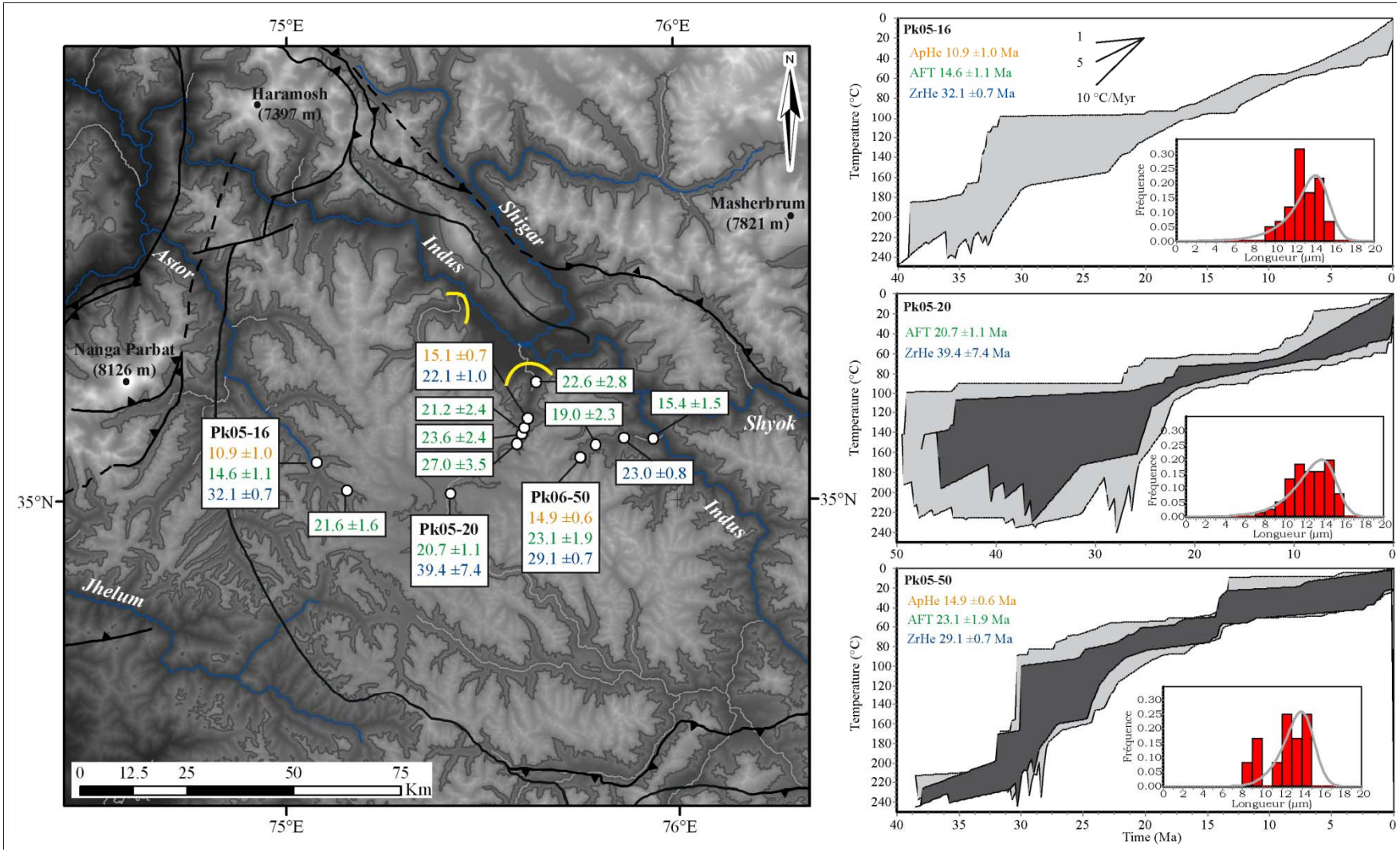



**Fig. 10.** Plot of La/Yb vs. U–Pb ages for the Cenozoic magmatic rocks in the Gangdese Batholith. Data sources are as in Fig. 4.

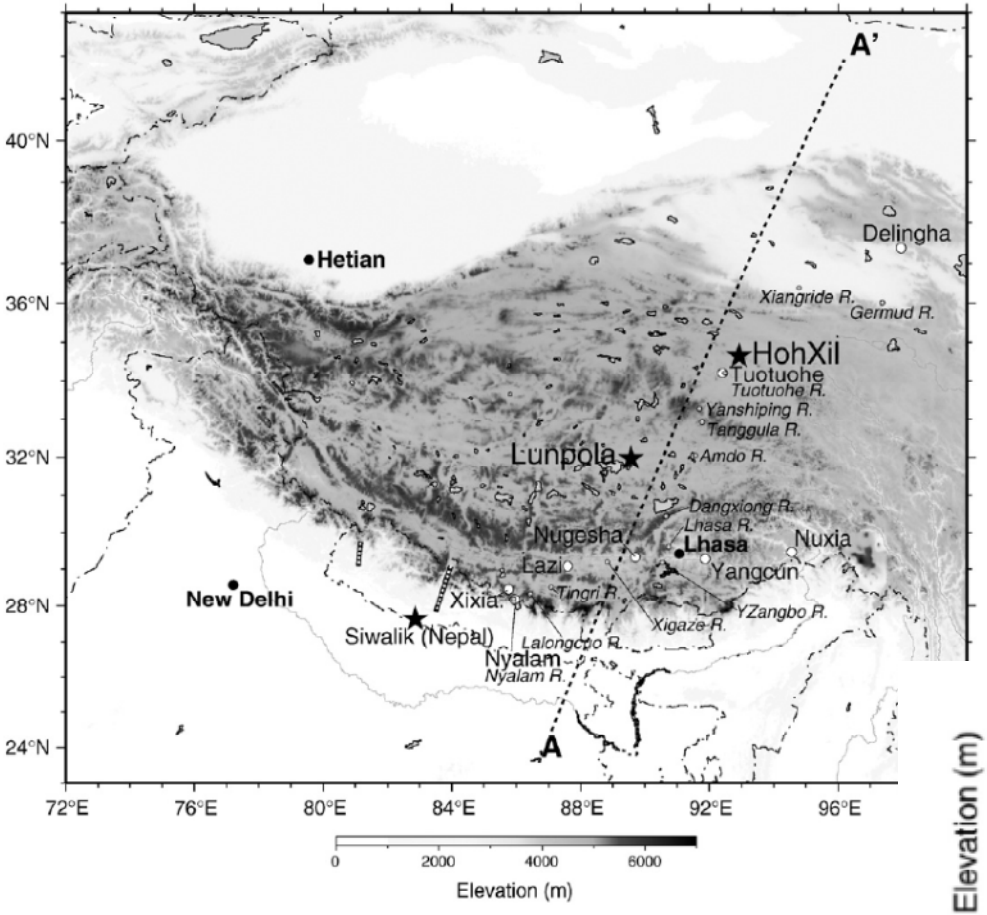
Guan et al., 2012

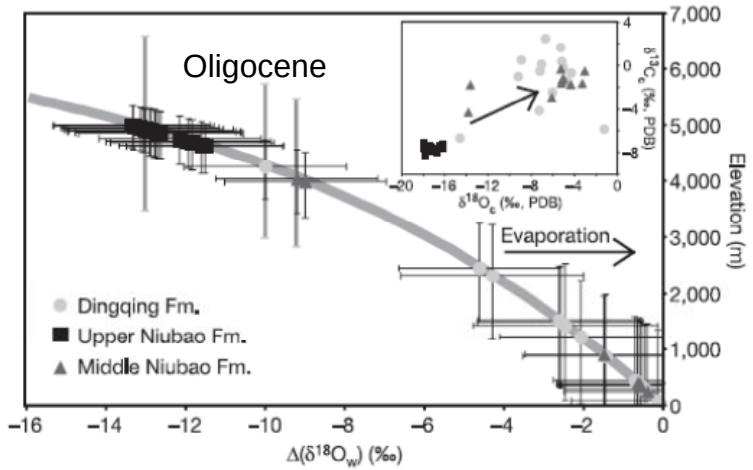
# Deosai Plateau – thermochronology data



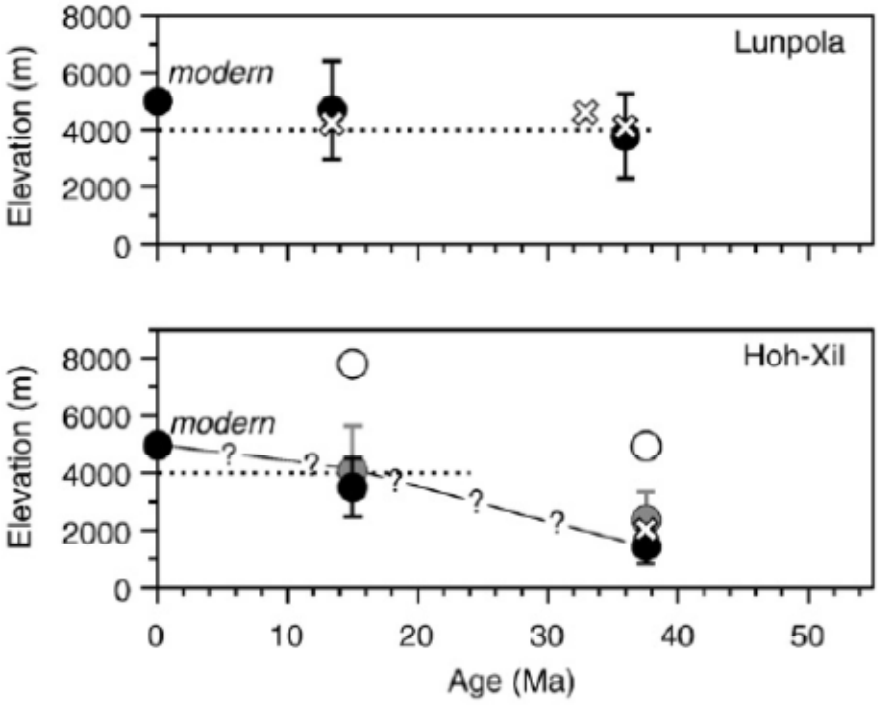

=> Vitesse de dénudation < 0.25 mm/an

van der Beek et al., *Nature Geosci.*, 2009




Rowley and Currie, 2006



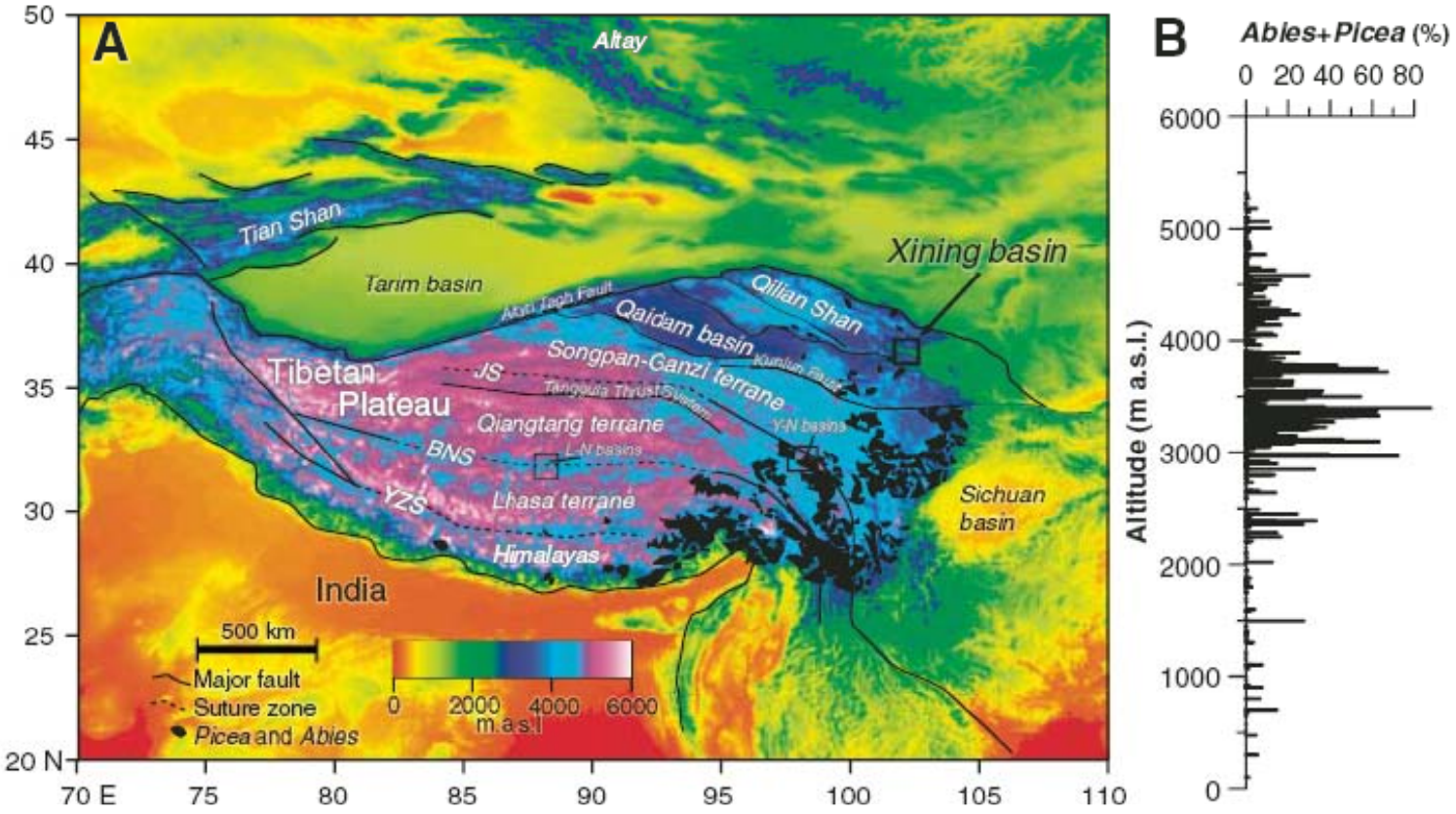

D/H restes de plantes

Polissar et al., EPSL, 2009

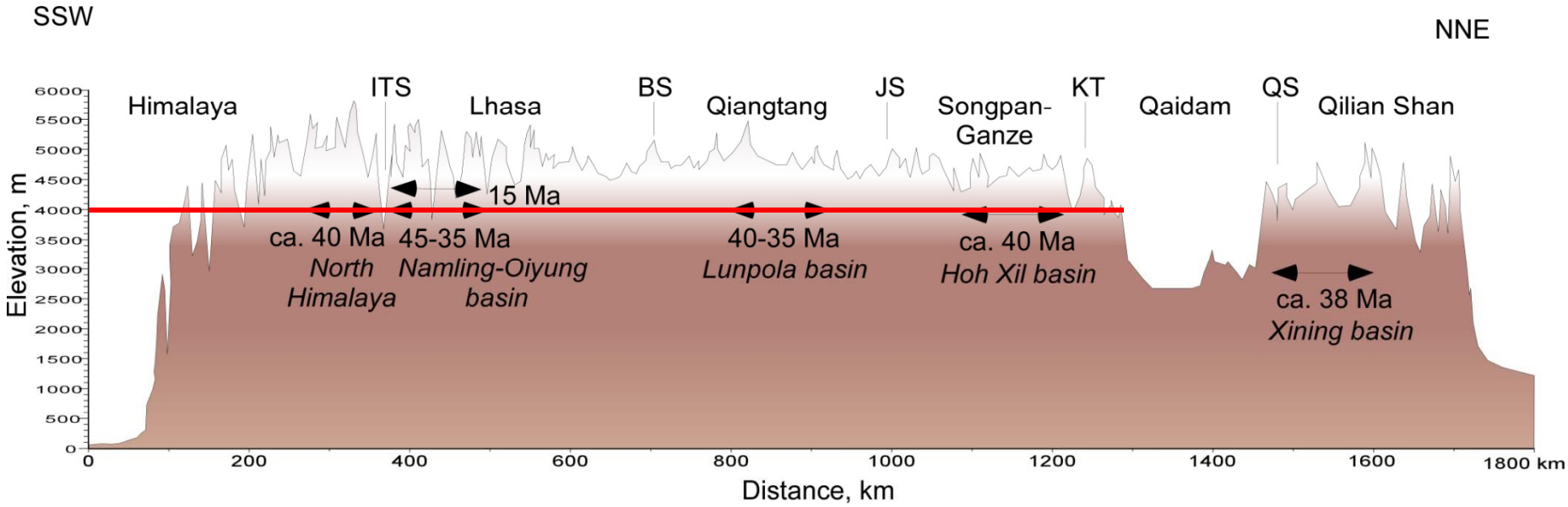
# Tibetan uplift prior to the Eocene-Oligocene climate transition: Evidence from pollen analysis of the Xining Basin

G. Dupont-Nivet[1]*, C. Hoorn[2], M. Konert[3]

Geology, 2008



40-35 Ma : South and Central Tibet at 4000 m.

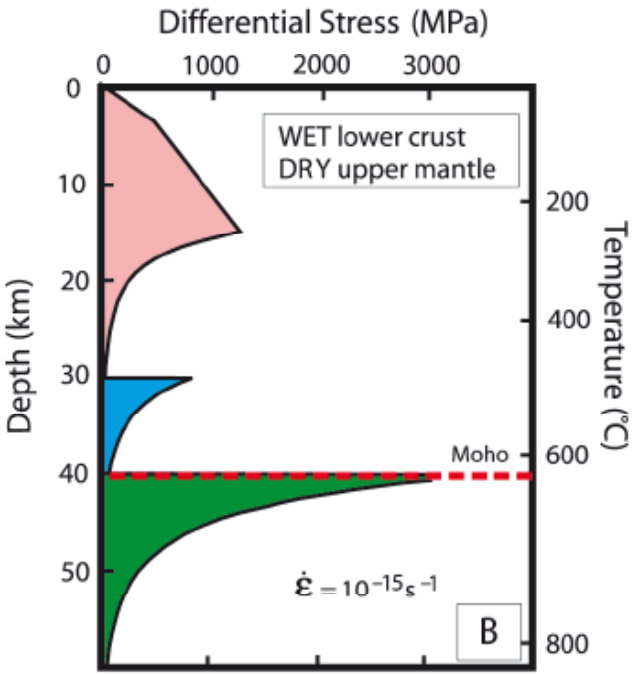



Guillot et Replumaz, 2013

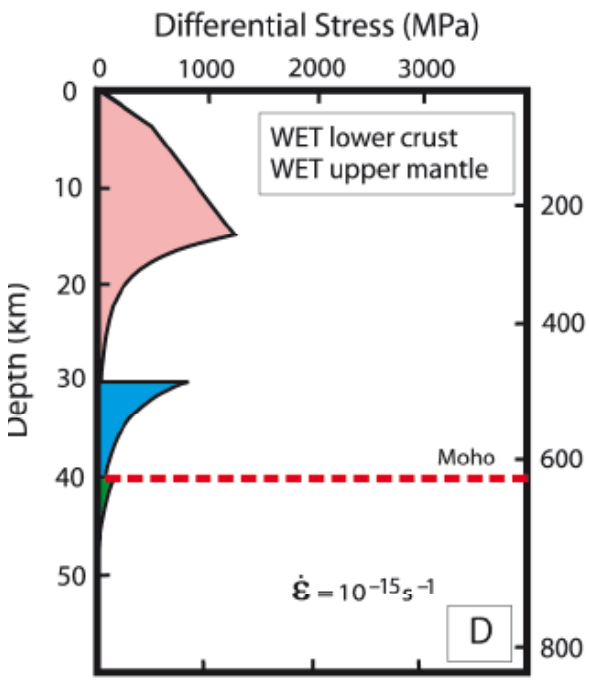
# Toward a model of

# Tibetan plateau growth

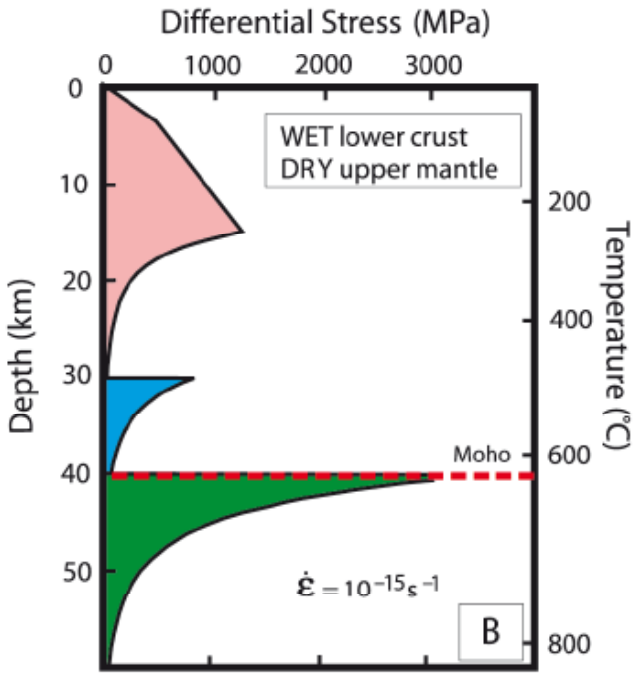
India

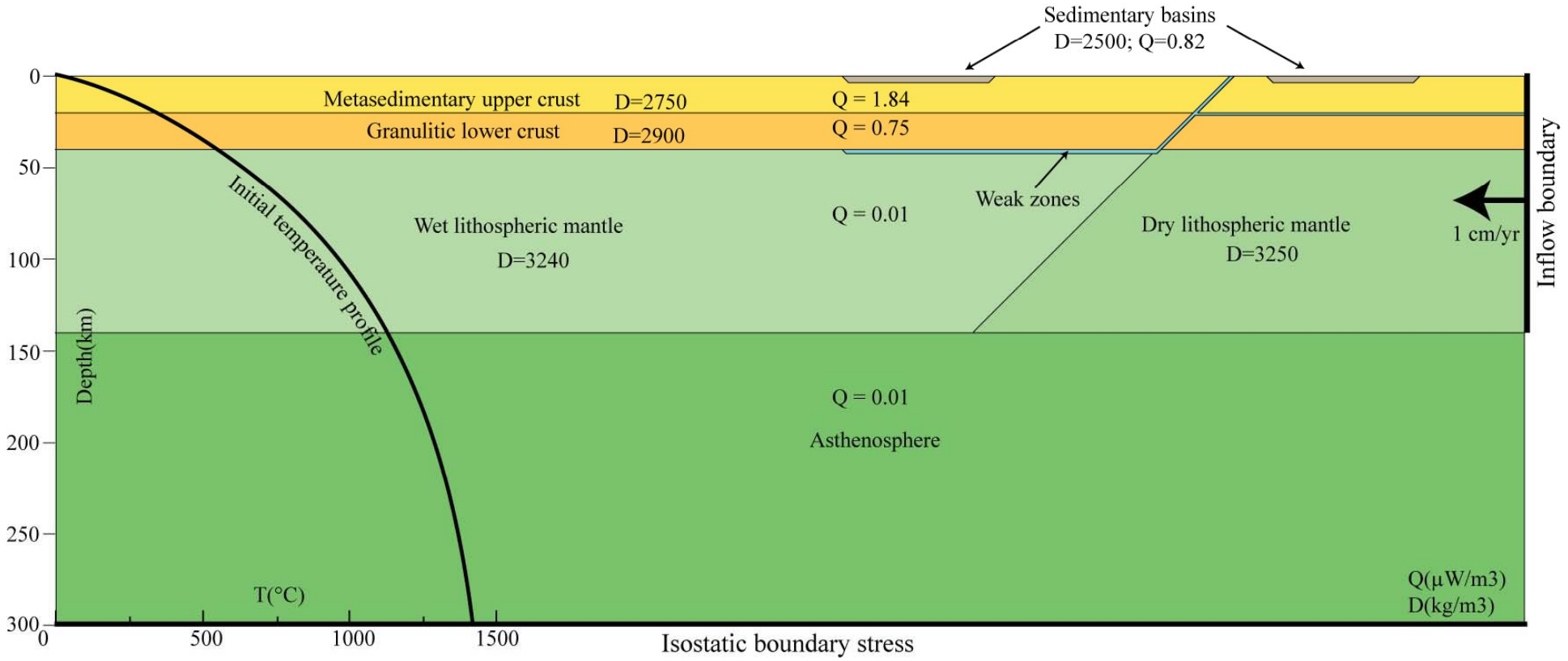



Tibet

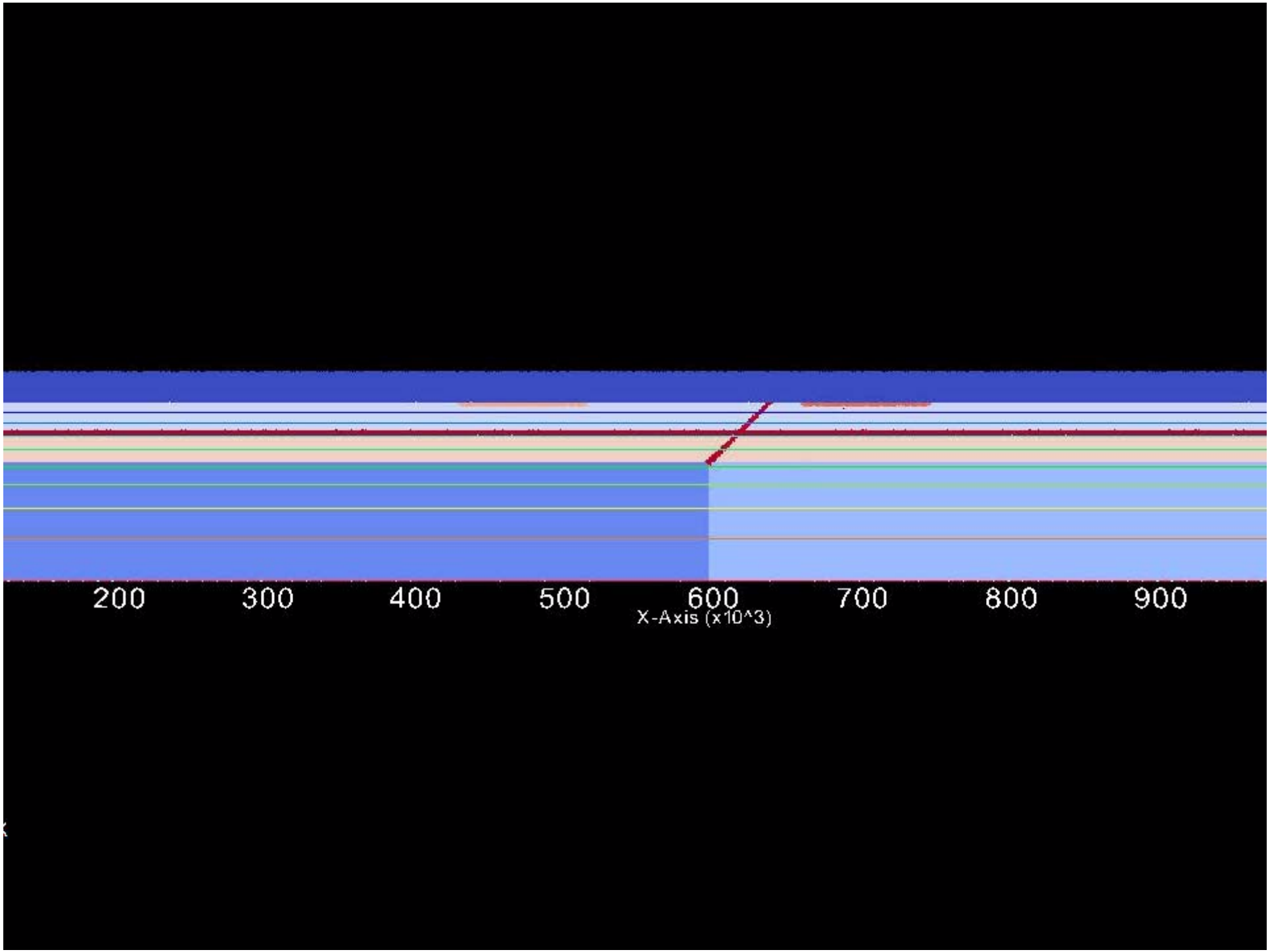


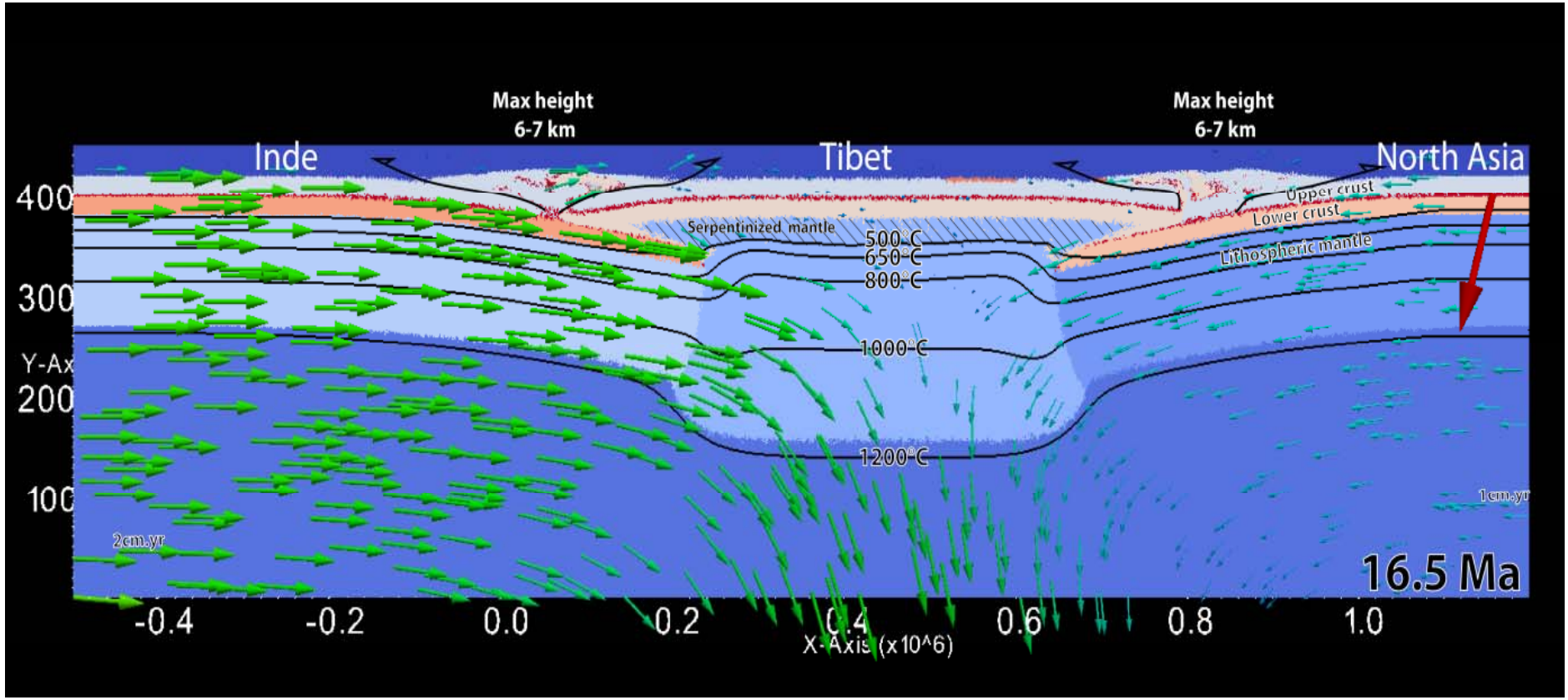

N. China

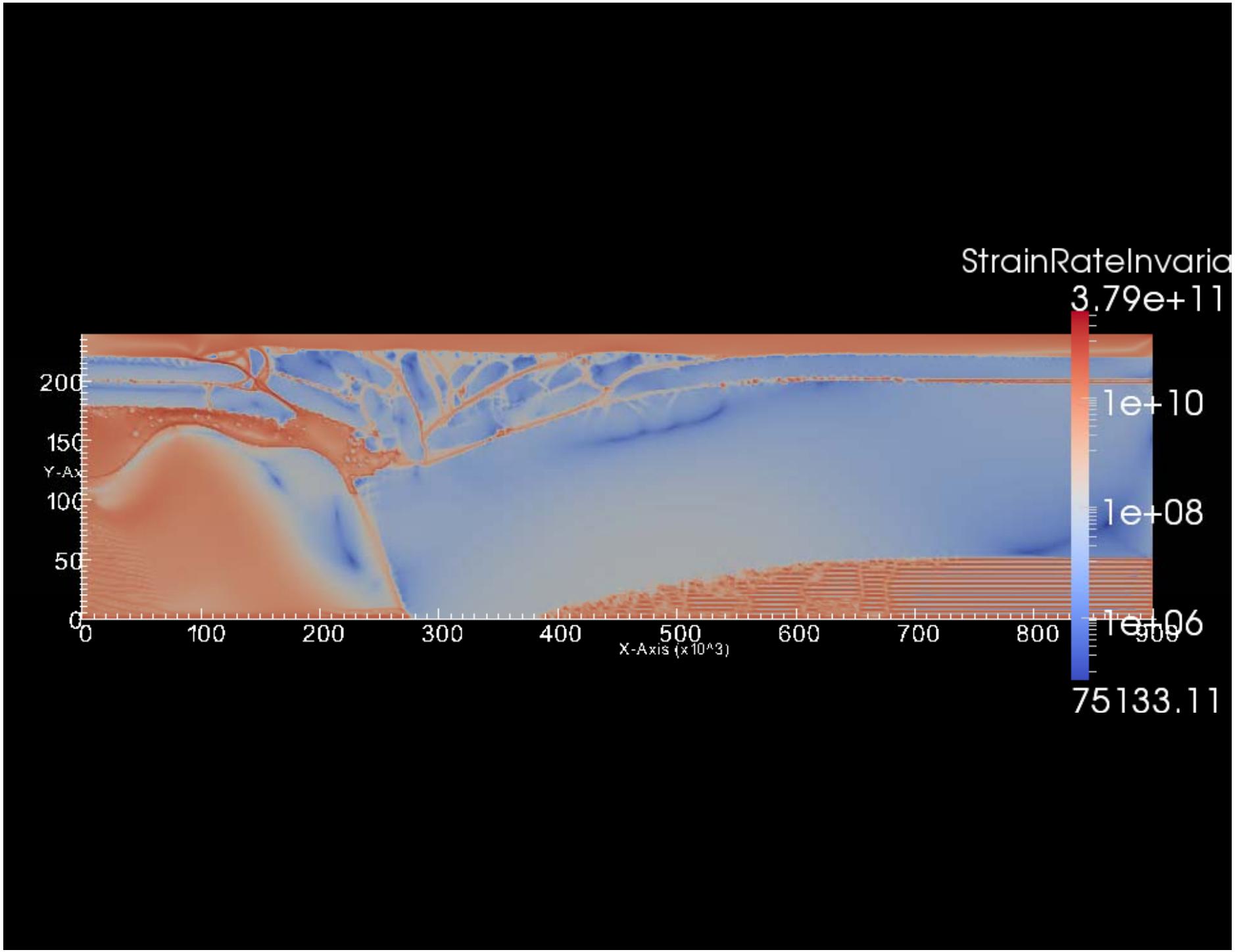


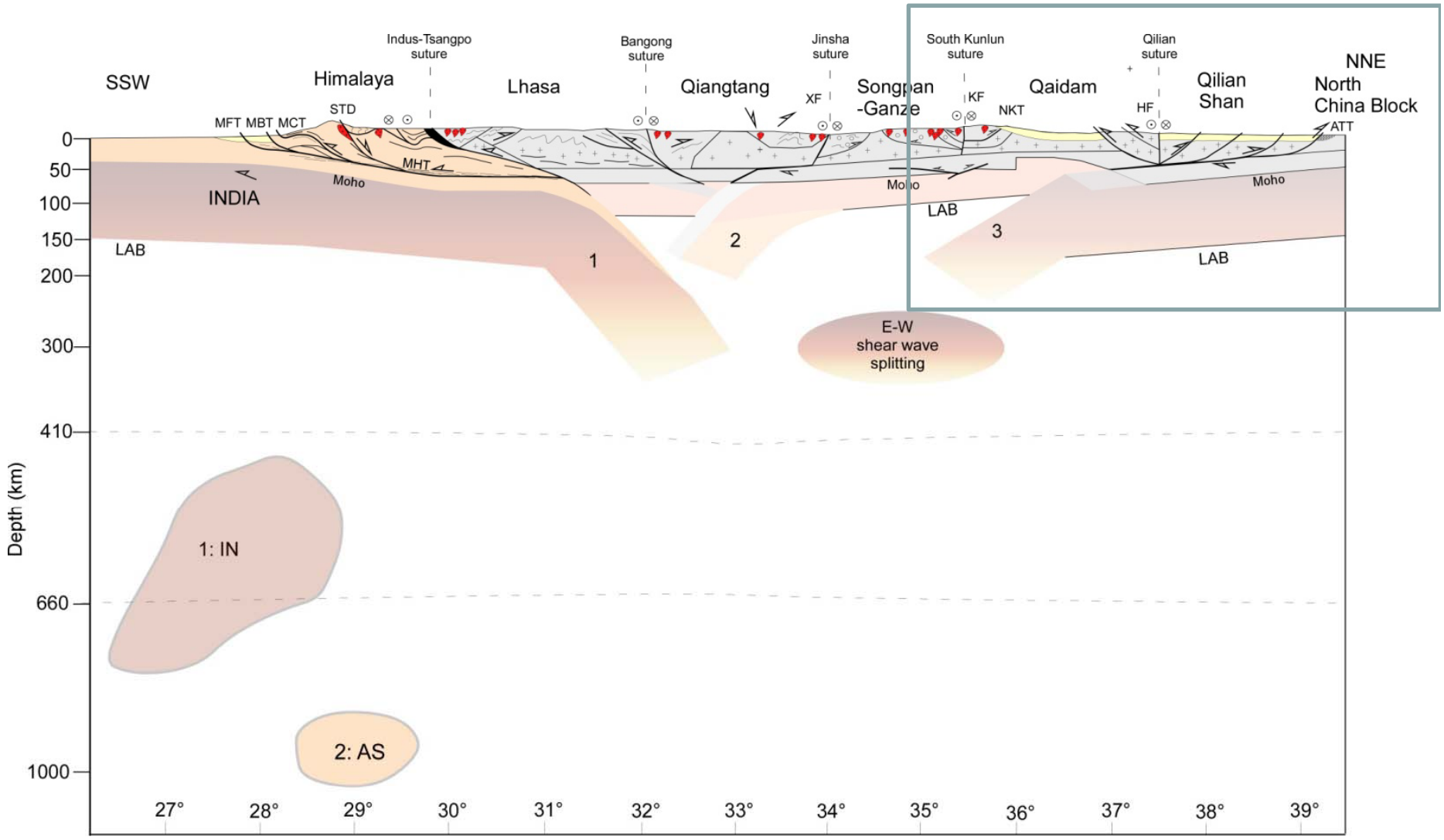



Guillot et al. in prep.

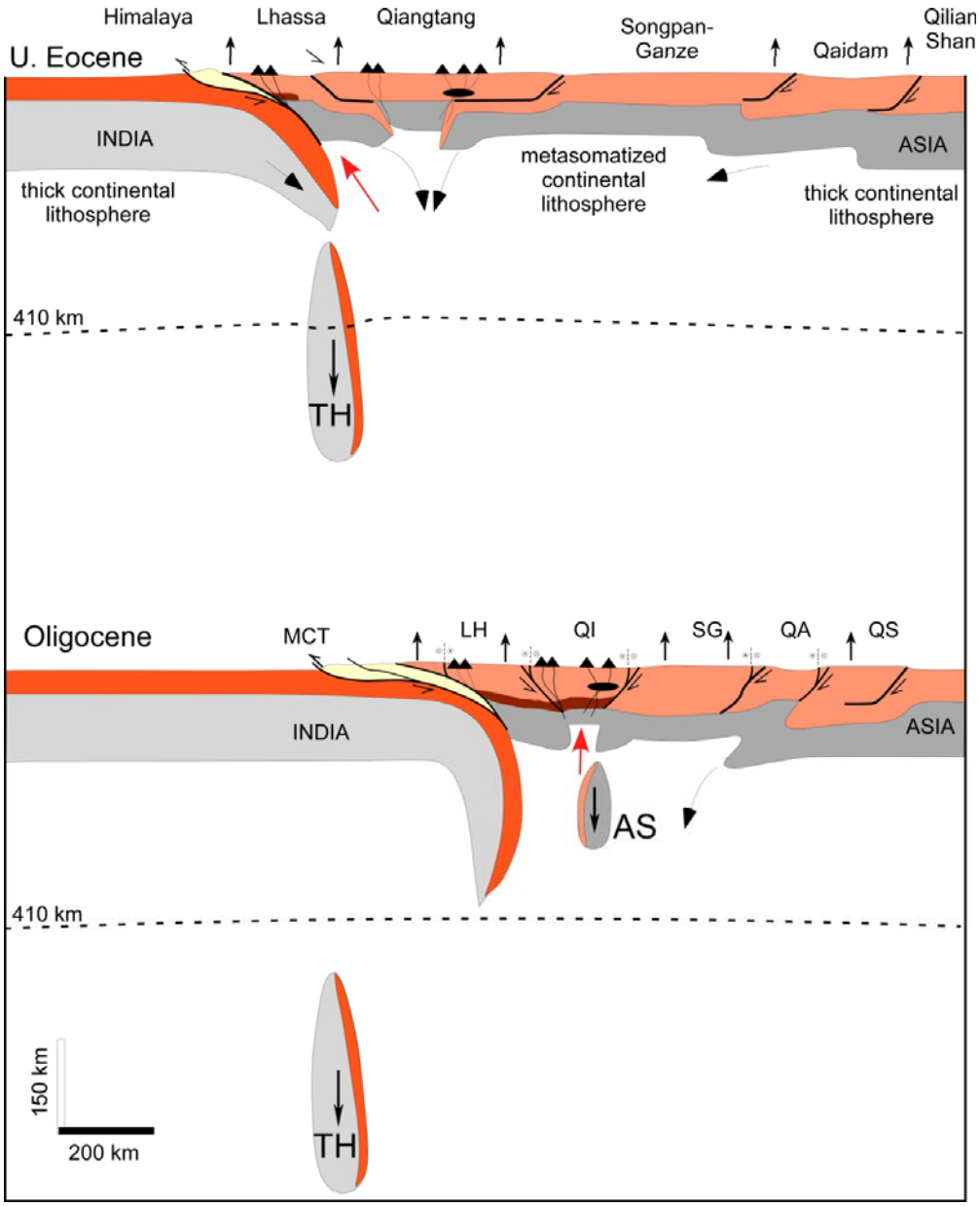

200
300
400
500
600
700
800
900
X-Axis (x10^3)


Max height
6-7 km
Max height
6-7 km
Inde
Tibet
North Asia
Upper crust
Lower crust
Lithospheric mantle
Serpentinized mantle
500°C
650°C
800°C
1000°C
1200°C
400
300
Y-Ax
200
100
2cm.yr
1cm.yr
16.5 Ma
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
X-Axis (x10^6)


StrainRateInvaria
3.79e+11
1e+10
1e+08
1e+06
75133.11
200
150
Y-Ax
100
50
0
0
100
200
300
400
500
600
700
800
900
X-Axis (x10^3)




Guillot and Replumaz, 2013



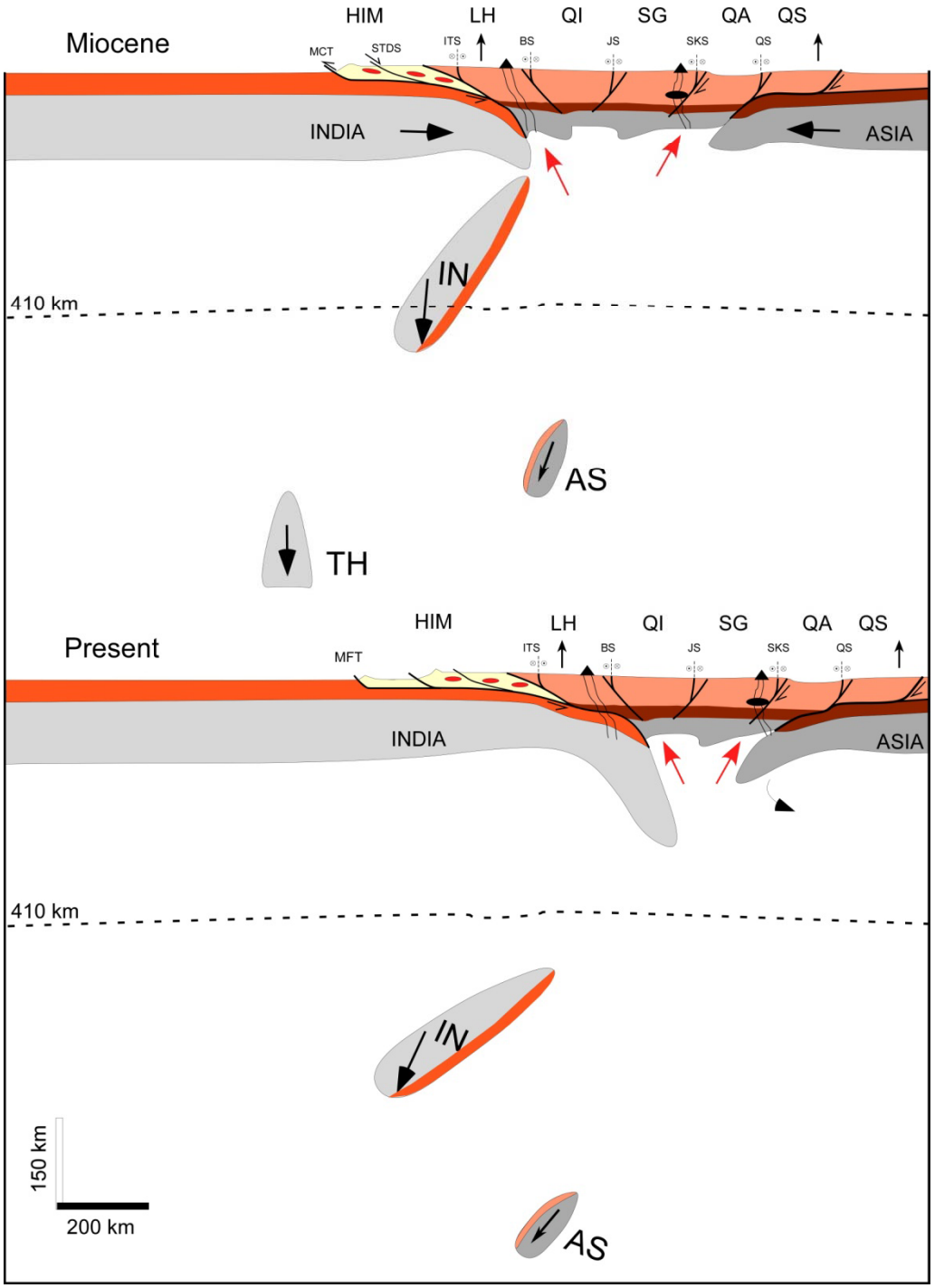

**Toward a model of Tibet evolution**

1- Indian underthrusting and
Asian subductions are dominant processes
for Tibetan growth

2 – The Tibetan crust was initially cold
enhancing upper crustal faulting

3 – The Tibetan lithosphere was initially weak
=> partly hydrated

Guillot and Replumaz, 2013




4 – heat advection from the asthenosphere
Is required to explain the magmatism &
a shallow LAB beneath Tibet

5 – slab breakoff and slab retreat triggered
asthenosphere upwelling

Guillot and Replumaz, 2013

# Conclusions

The Southern Plateau and Central Plateau are quite old (40 Ma)
formed by underthrusting
of the Indian and Asian  lower crust + rigid lithopheric mantle, respectively

But it is not enough !!

Upwelling of the hot asthenospheric mantle related to slab retreat and slab breakoff,
Without evidences of lithospheric delaminations

Understanding Tibetan growth : combining the 2 rheological  end-members
Creme brulée (CB) and Jelly Sandwich (JS)

Rigid lithosphere north and south of the Plateau (JD)
In between

Eevolution from a cold lithophere to an hydrous then a  hot lithosphere

Slow rheological contrast between the mantle and the lower granulitized crust

The resistance is at present in the upper crust (CB)