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*THE REAL SCIENCE

TECTONIC EROSION AT PACIFIC-TYPE CONVERGENT MAGRINS: definition and new evidence from Central Asia

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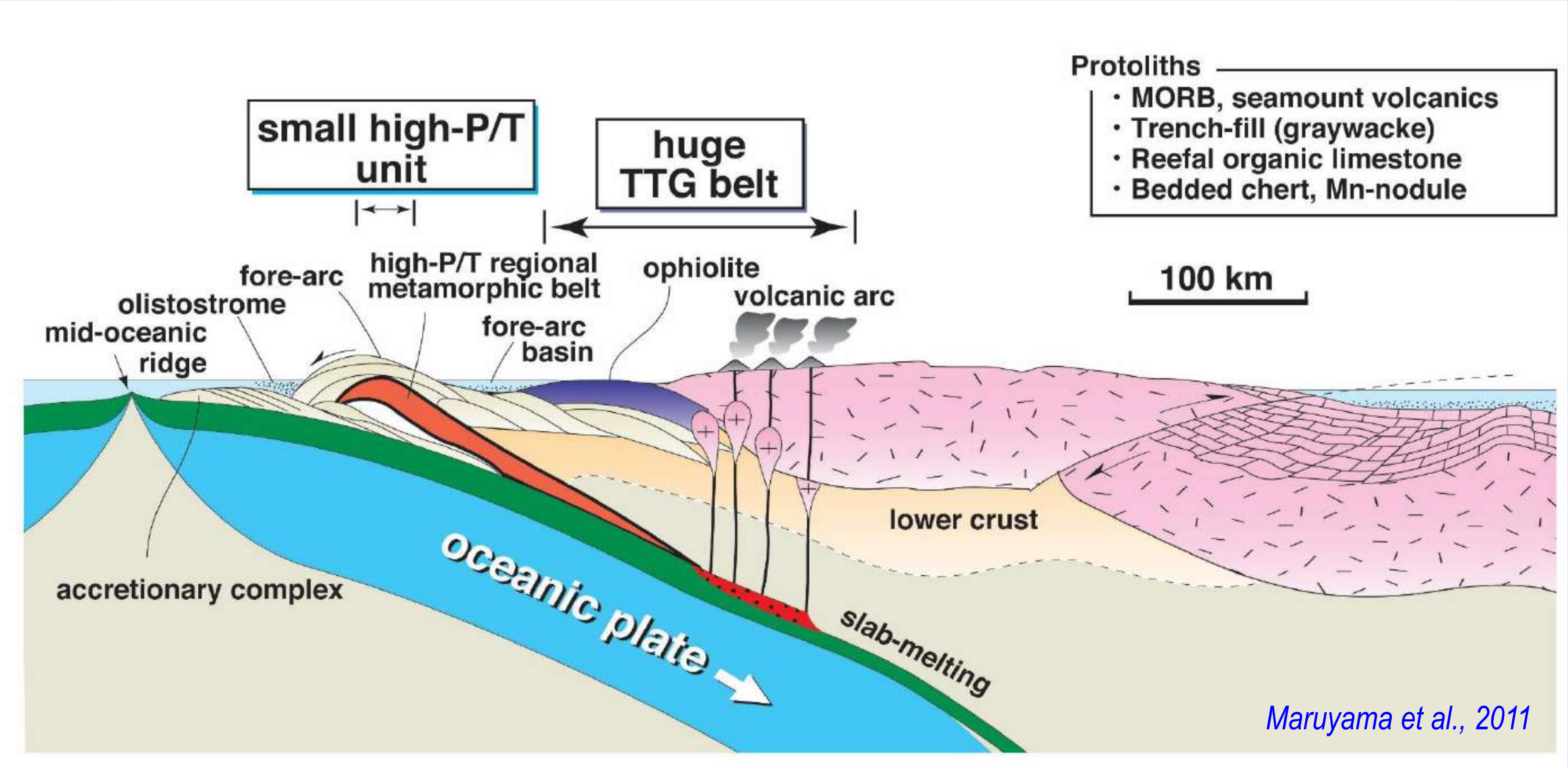
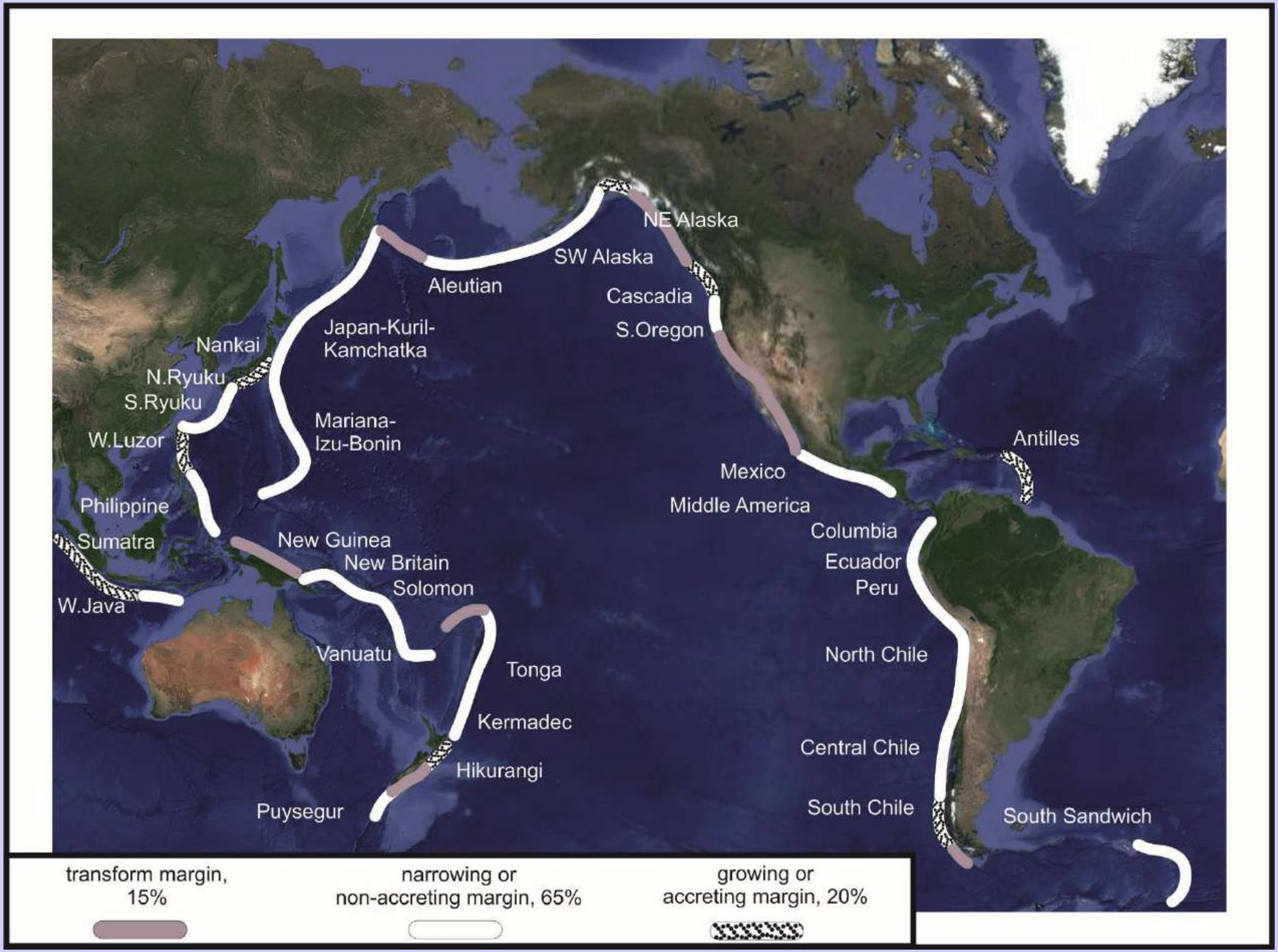
Pacific-type (P-type) convergent margin



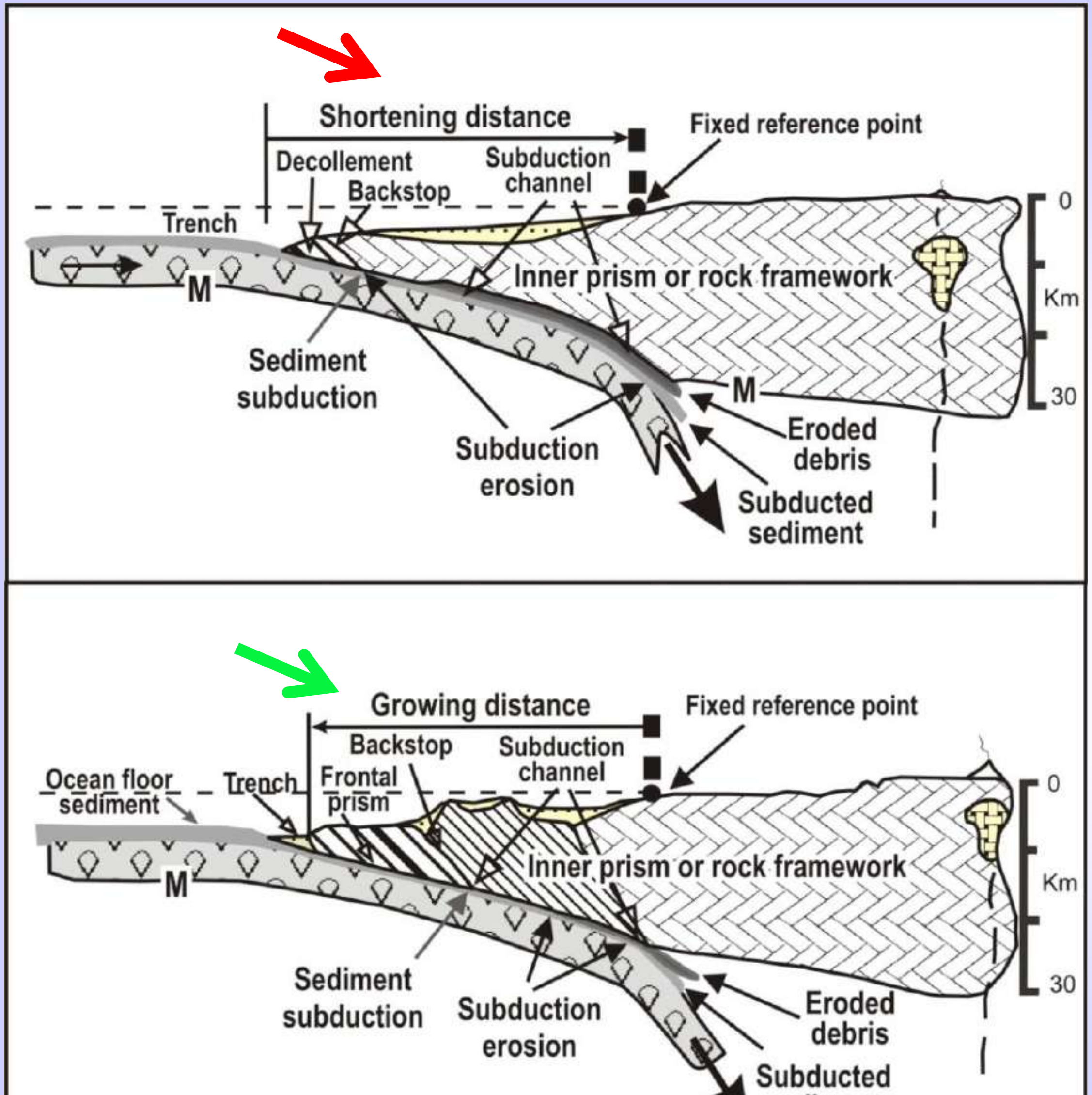
Maruyama et al., 2011

Documenting the mass flux through convergent plate margins is important to the understanding of petrogenesis in arc settings and to the origin of the continental crust, since subduction zones are **the only major routes** by which material extracted from the mantle can be returned to great depths within the Earth. Despite their significance, there has been a tendency to view subduction zones as areas of **net crustal growth only**. However, they are also places of strong plate interactions and **crust destruction through tectonic erosion**.

Accreting vs. eroding convergent margins of the Circum-Pacific



Eroding and accreting P-type convergent margins

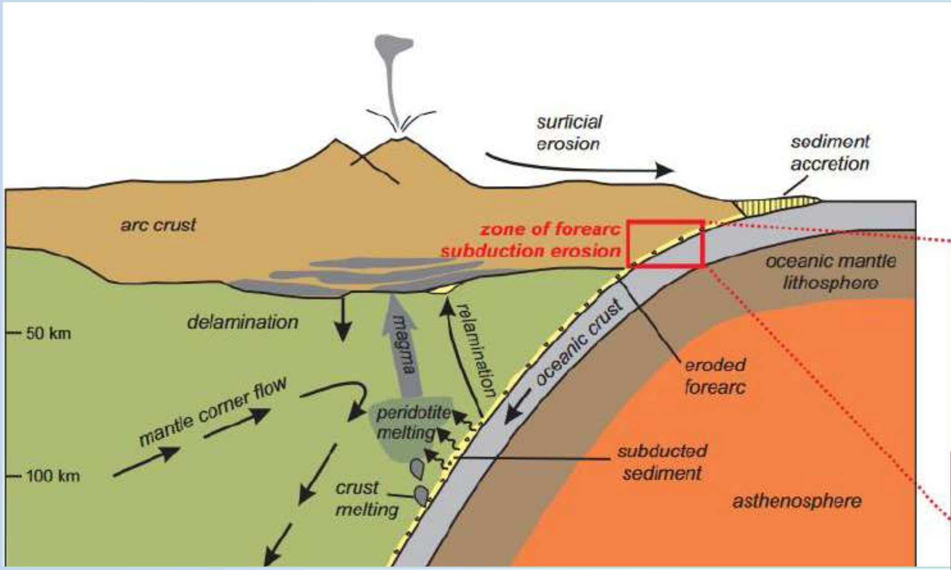


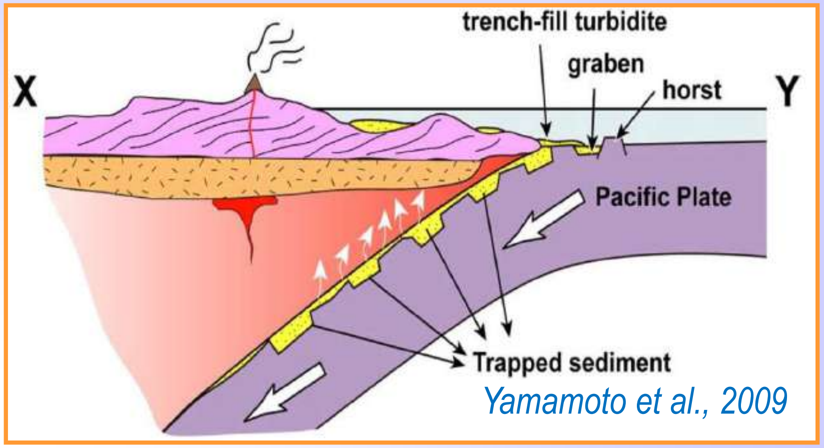
from Scholl and von Huene, 2007

Eroding or non-accreting margins are characterized by the close approach of the margin's rock framework to the trench and small or lacking older prisms of accreted lower plate sediment. With time, eroding margins narrow with respect to a reference point on the margin; i.e., the trench advances landward.

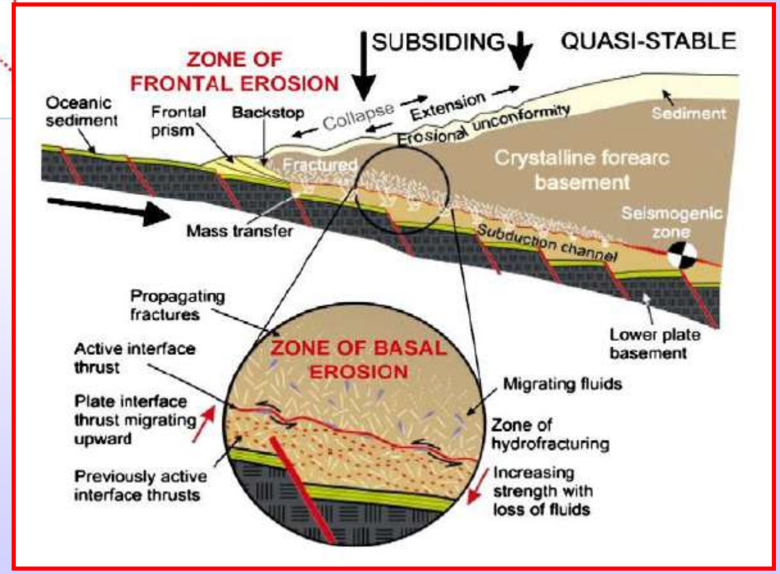
Accreting or growing margins are characterized by rocks deeply buried under thick older accreted units and frontal prism of actively deforming sediment scraped off the subducting plate. With time, accreting margins widen, i.e., the trench retreats seaward.

Tectonic erosion is **destruction** of oceanic slab, island arcs, accretionary prism and fore-arc by thrusting, oceanic floor relief (horst/graben), (hydro)fracturing





Yamamoto et al., 2009



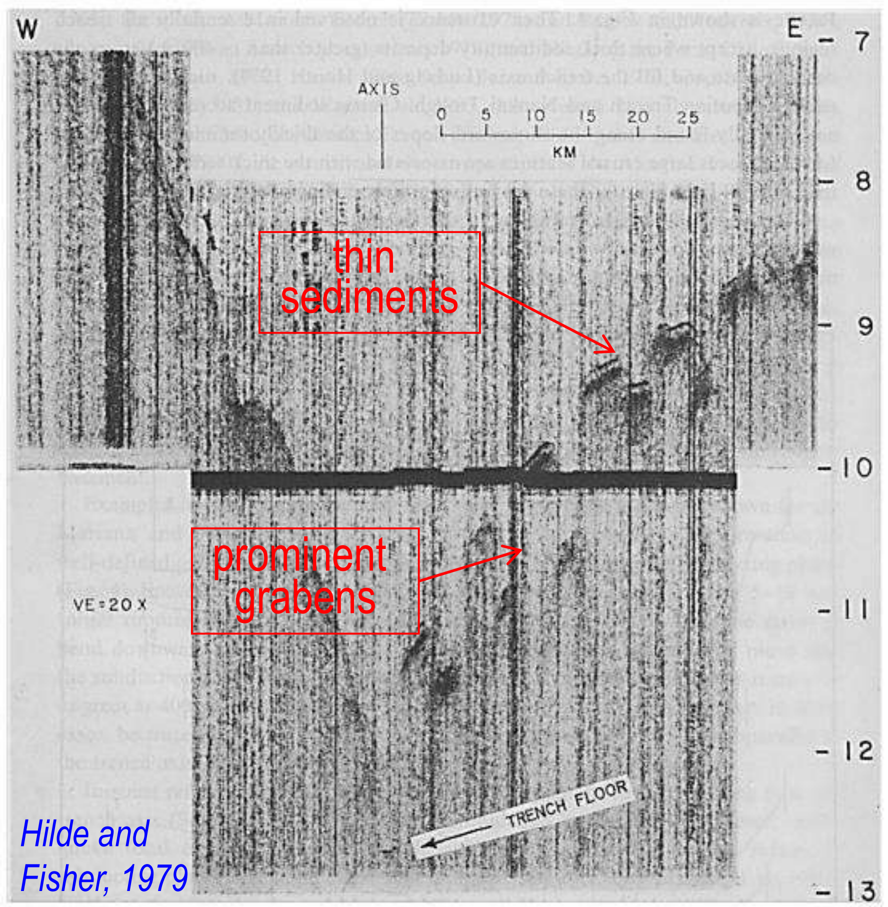
Von Huene et al., 2004

Tectonic erosion is favored in regions where convergence rates **exceed 6 ± 0.1 cm/yr** and where the sedimentary cover is <1 km. **Accretion** preferentially occurs in regions of **slow convergence (<7 cm/yr)** and/or trench sediment thicknesses >1 km (*Clift, Vannucchi, 2004*).

Tectonic erosion

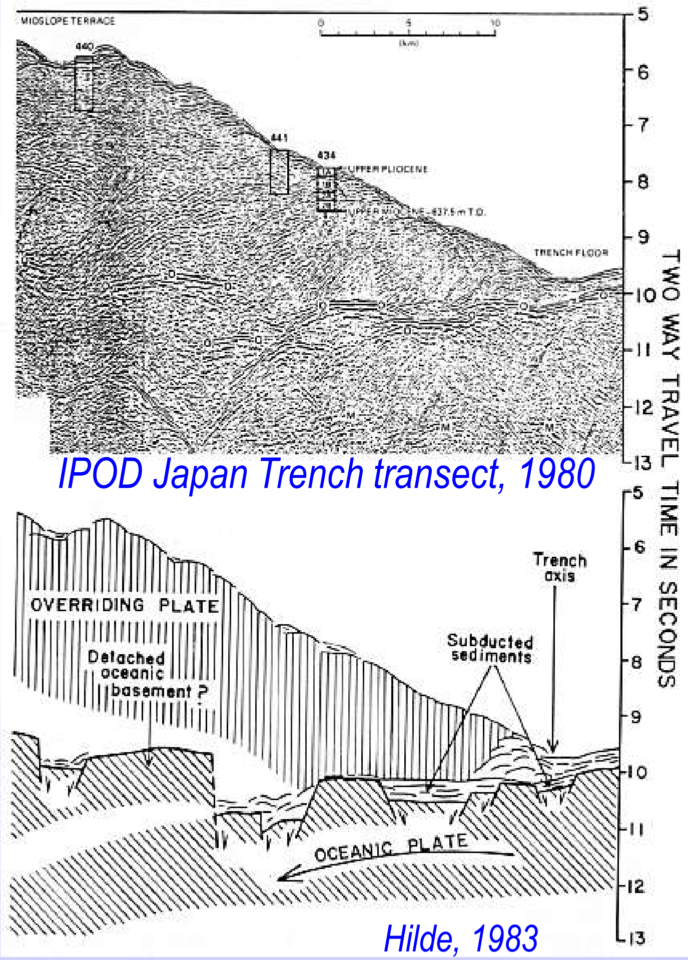
first evidence for tectonic erosion

Tonga trench



Hilde and Fisher, 1979

Japan trench

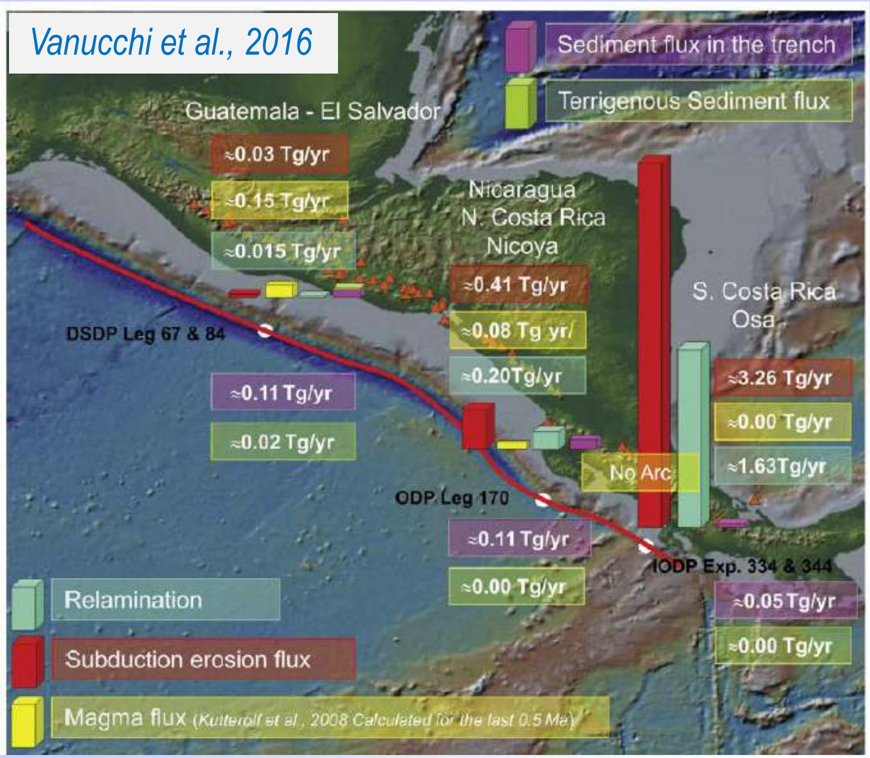


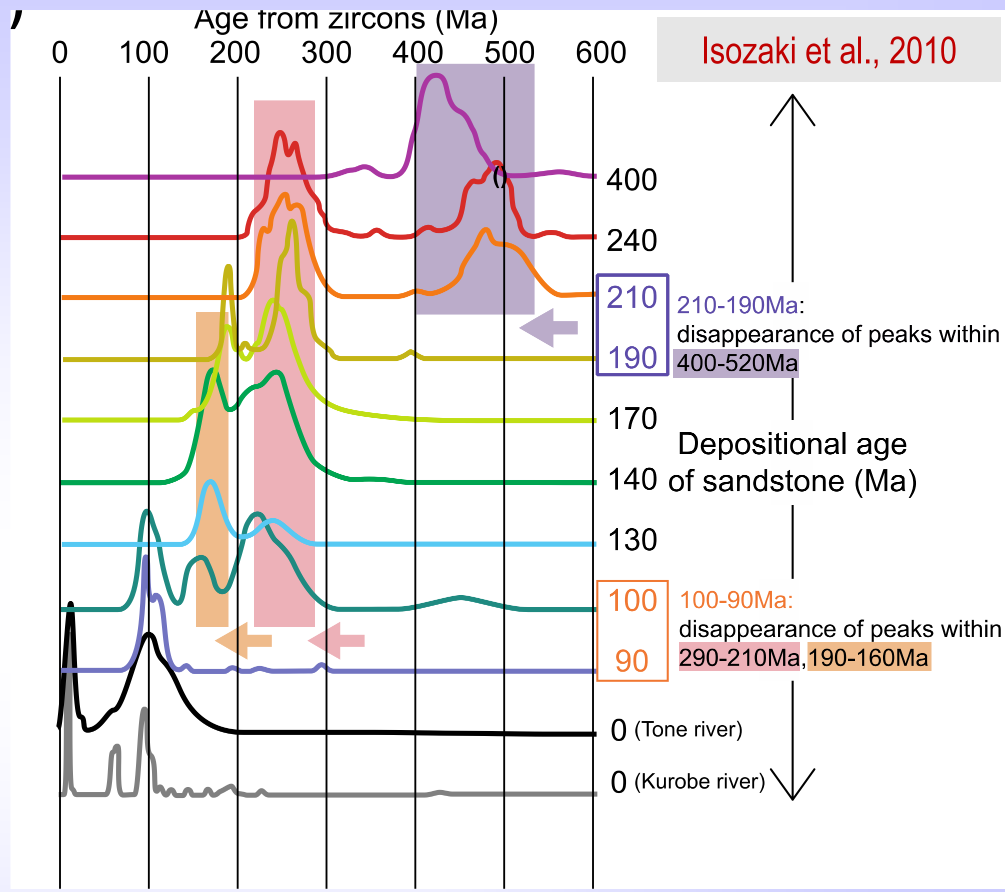
IPOD Japan Trench transect, 1980

Hilde, 1983

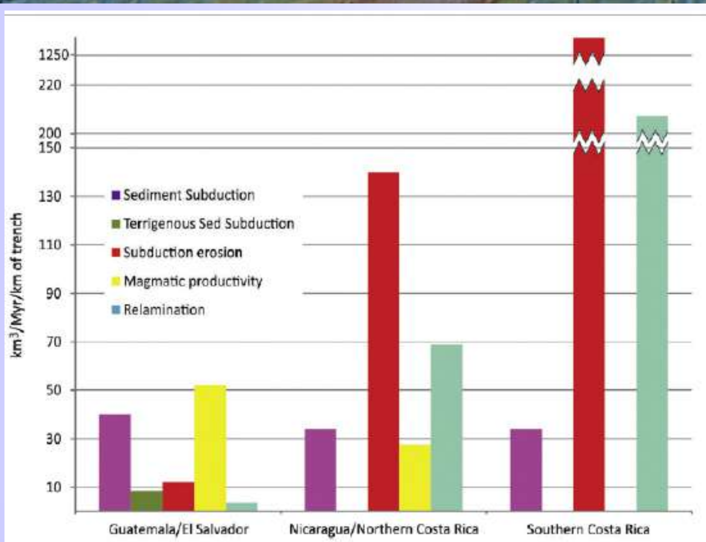
Seismic reflection profiles

Many proved cases of tectonic erosion



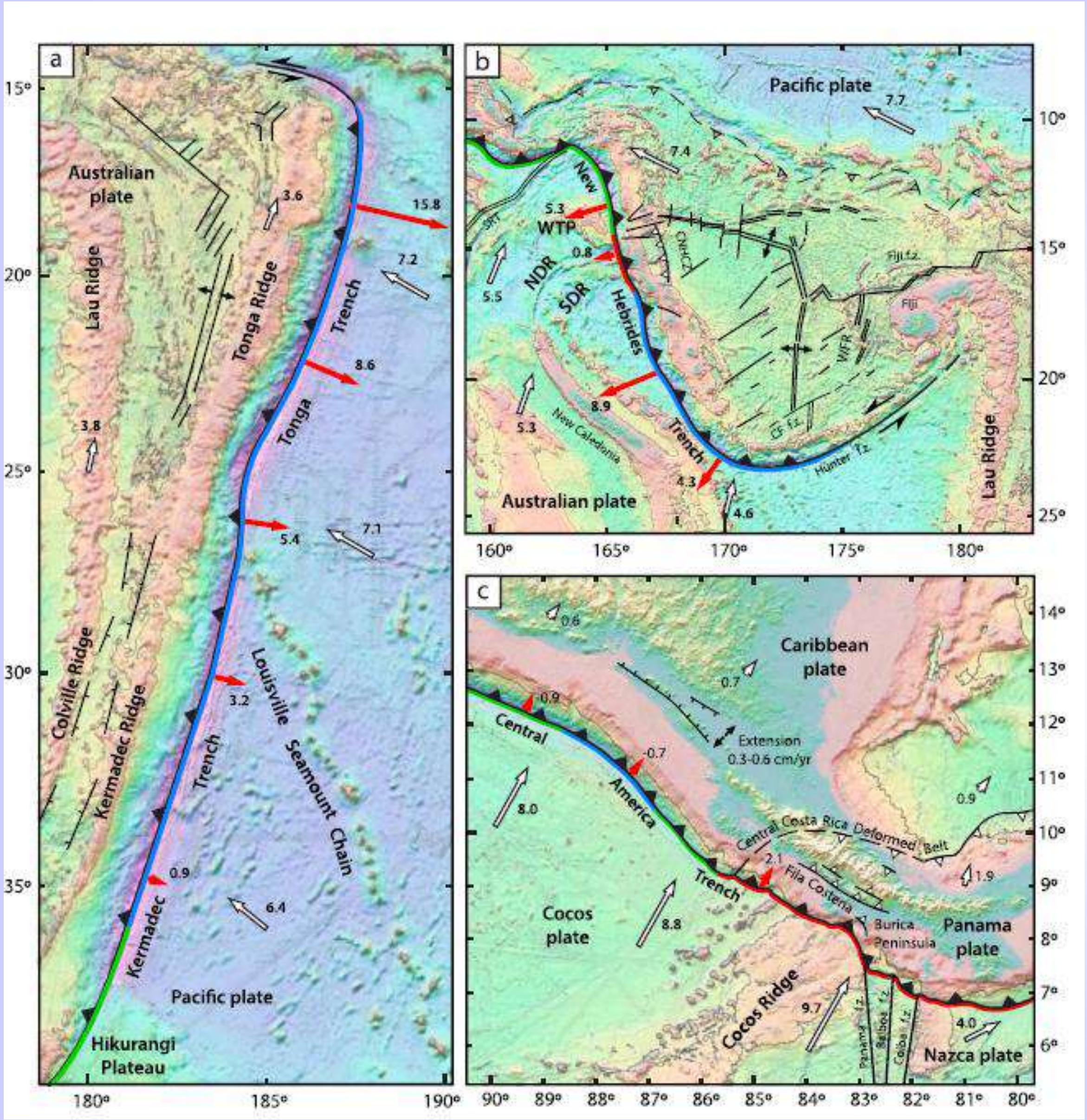


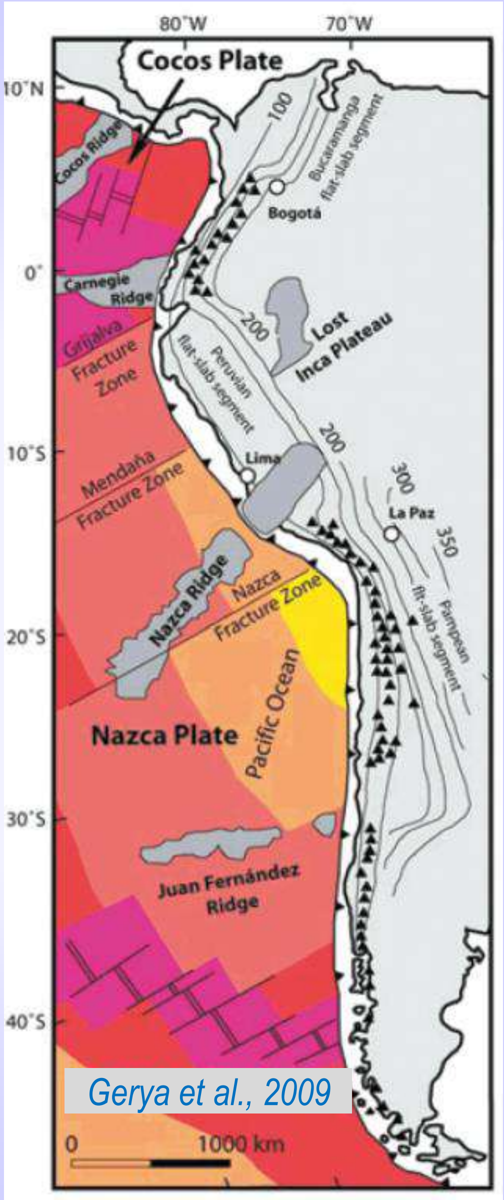
Vanished arcs according to U-Pb zircon age patterns for sandstones of Honsu Is., Japan



Tectonic erosion estimates made at the Guatemala-Costa-Rica shoreline

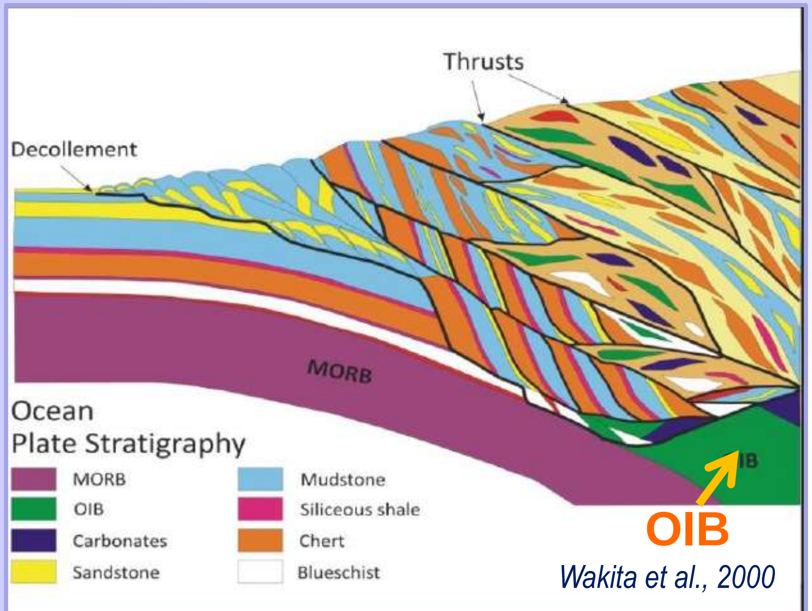
Tectonic erosion trigger #1: aseismic ridge subduction

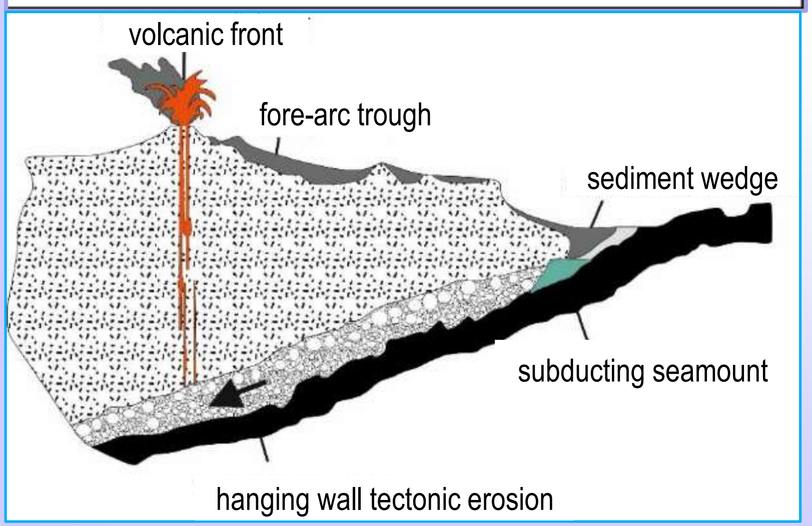


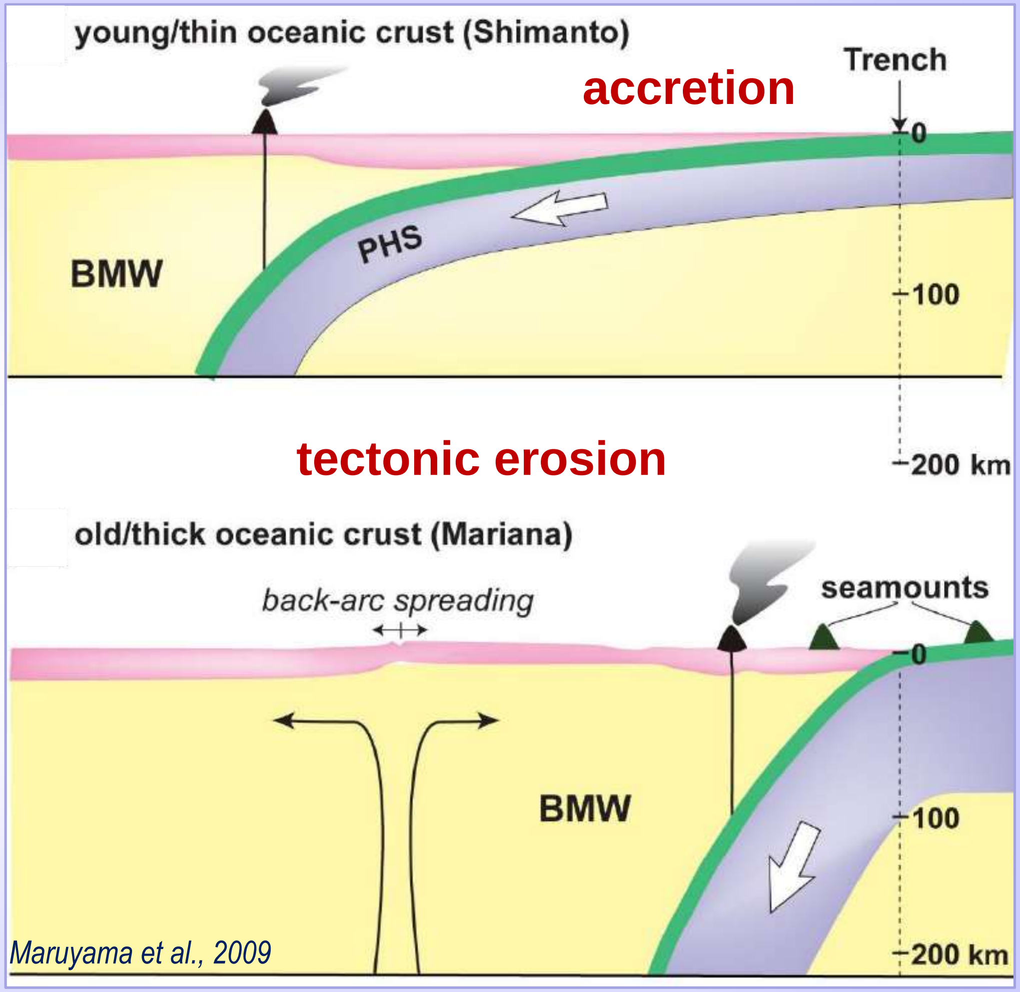


Impacts: topography uplift, **enhancement of tectonic erosion**, displacement of trench axis landward

Tectonic erosion trigger #2:
convergent margin and seamount interaction

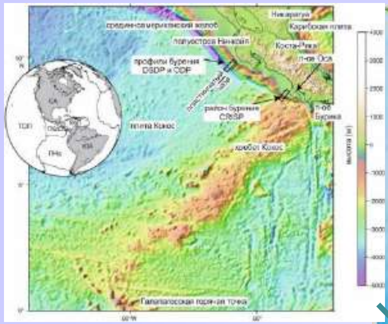


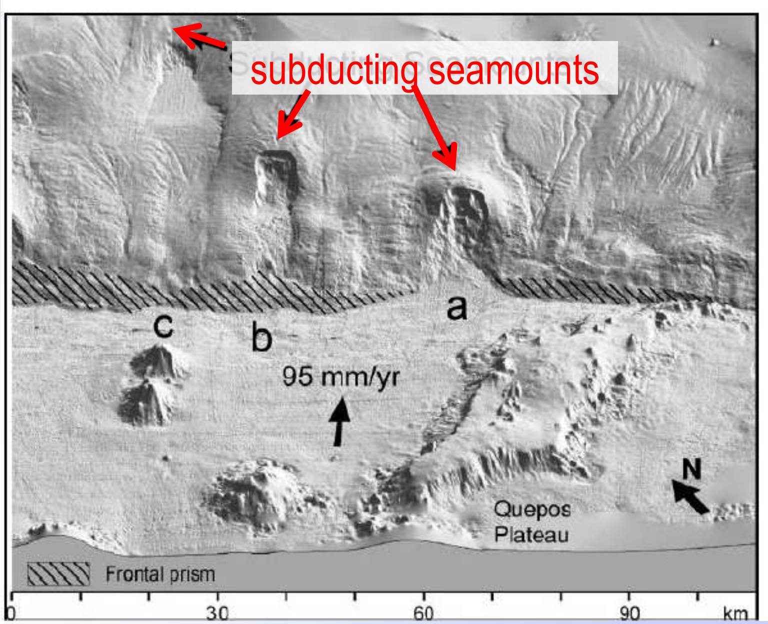




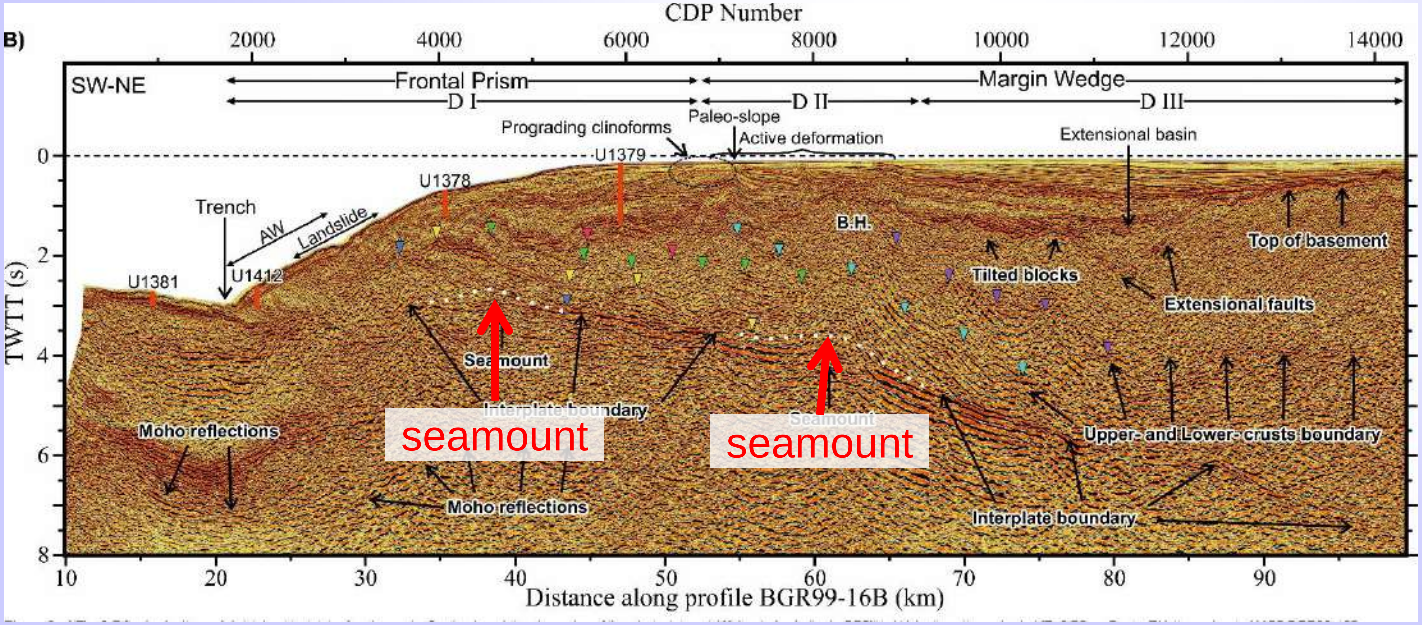
Enhancement of tectonic erosion is more typical of thicker oceanic crust

Interaction of seamounts with the Costa-Rica convergent margin





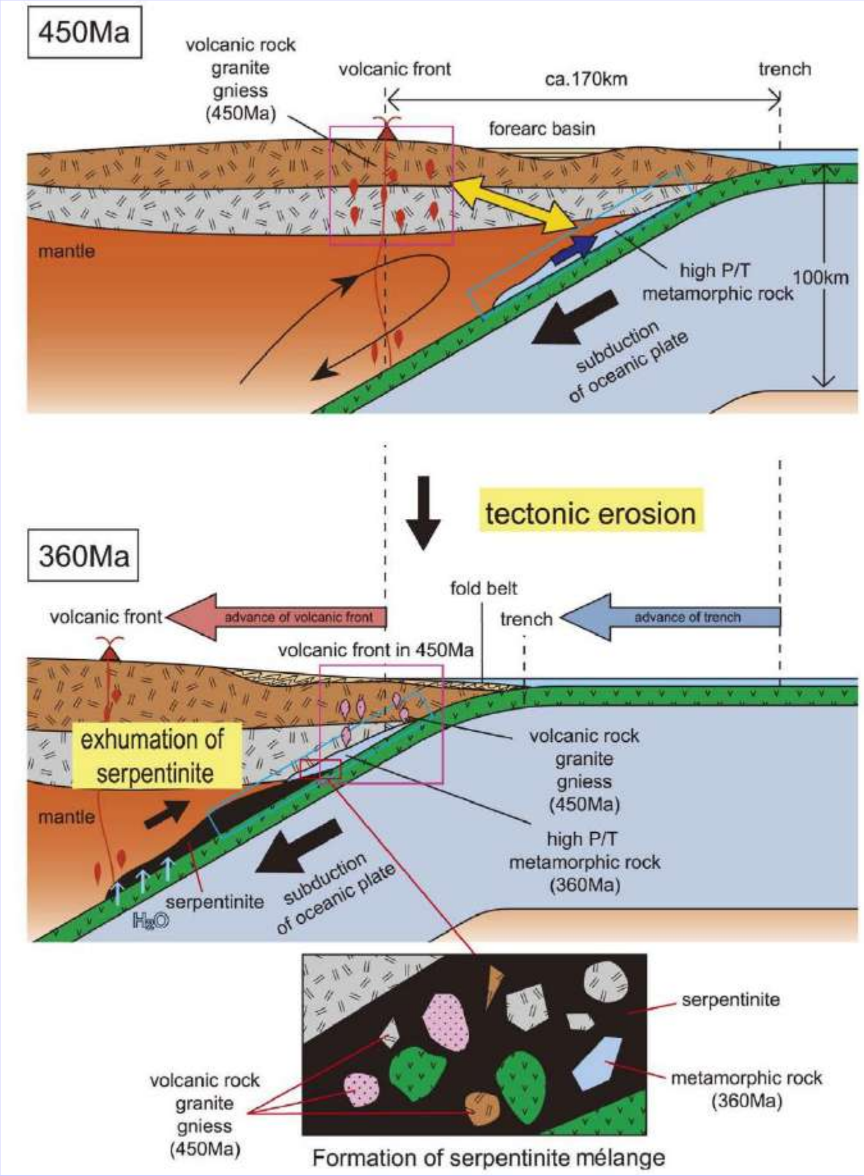
von Huene et al., 2000

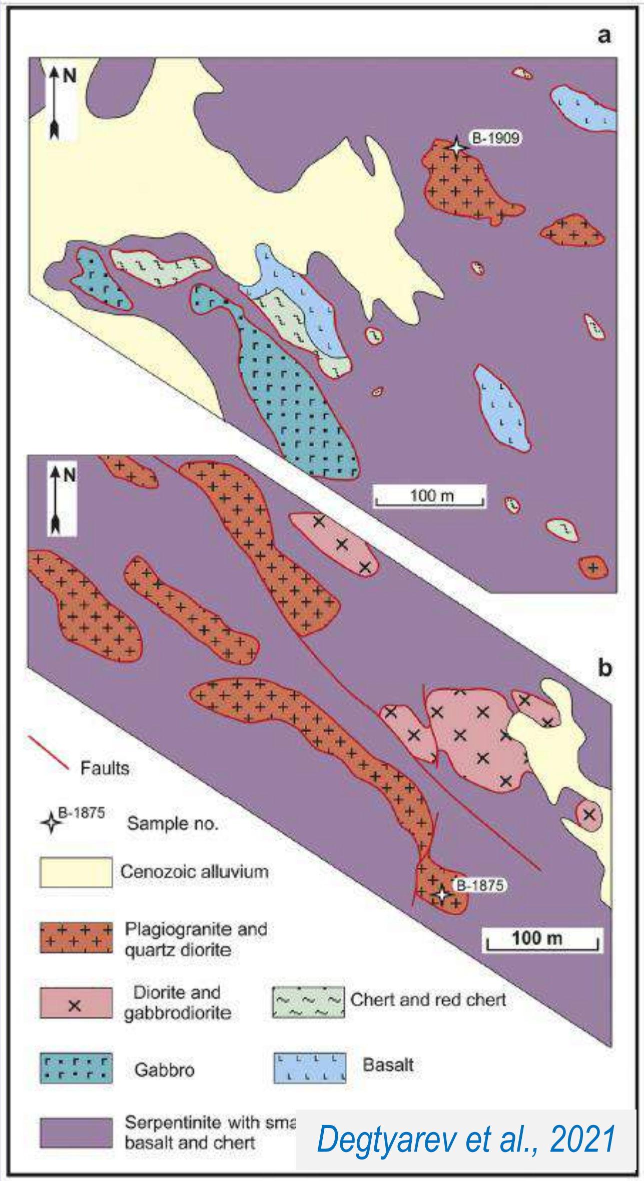


Martínez-Loriente et al., 2019

Reconstructing episodes of tectonic erosion

Fragments of arc-derived igneous rocks hosted by serpentinite mélange



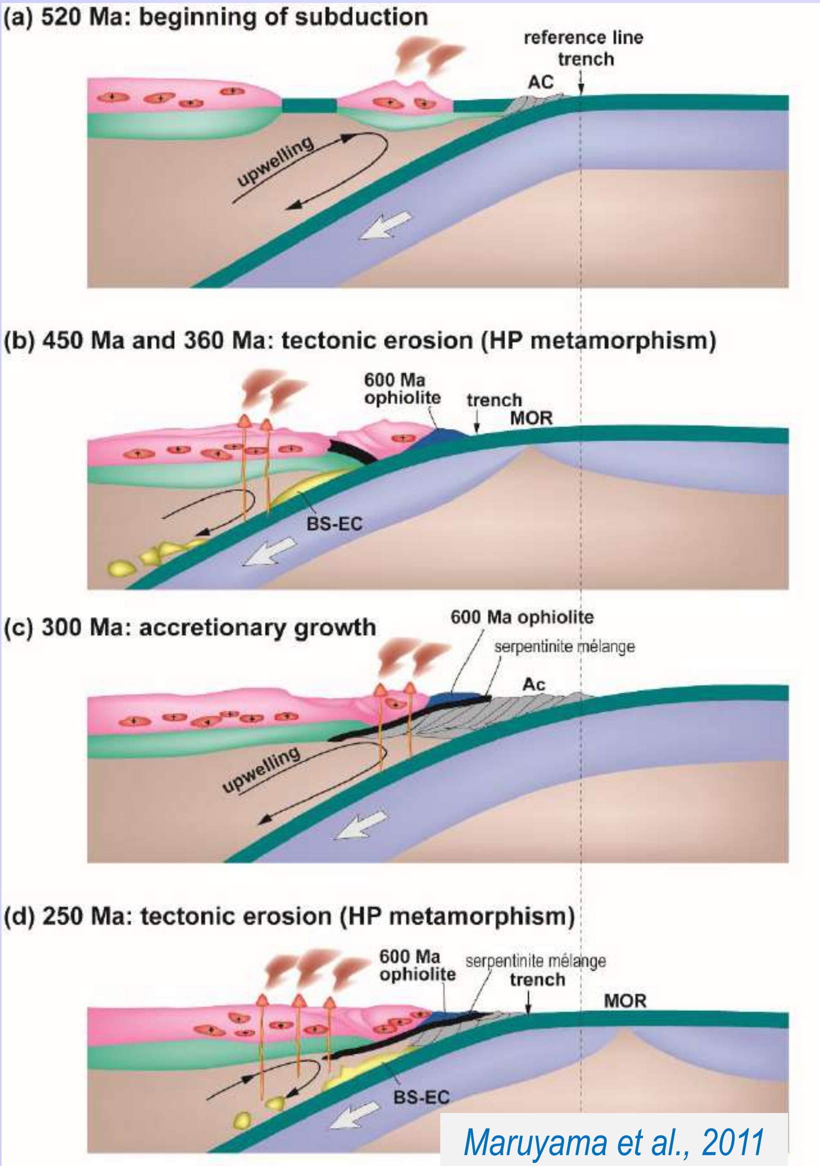


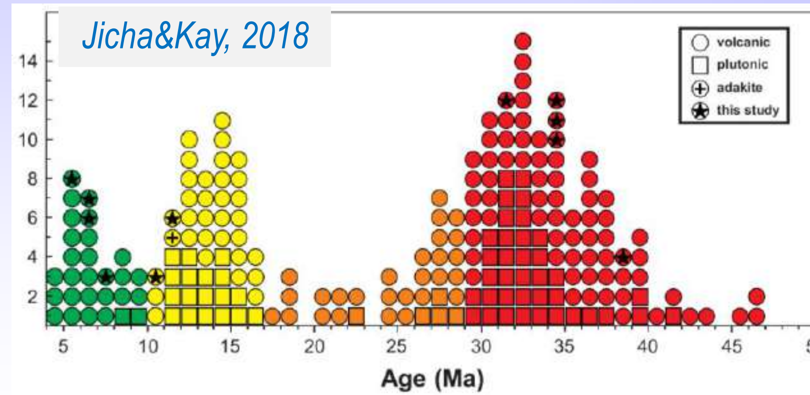
Degtyarev et al., 2021

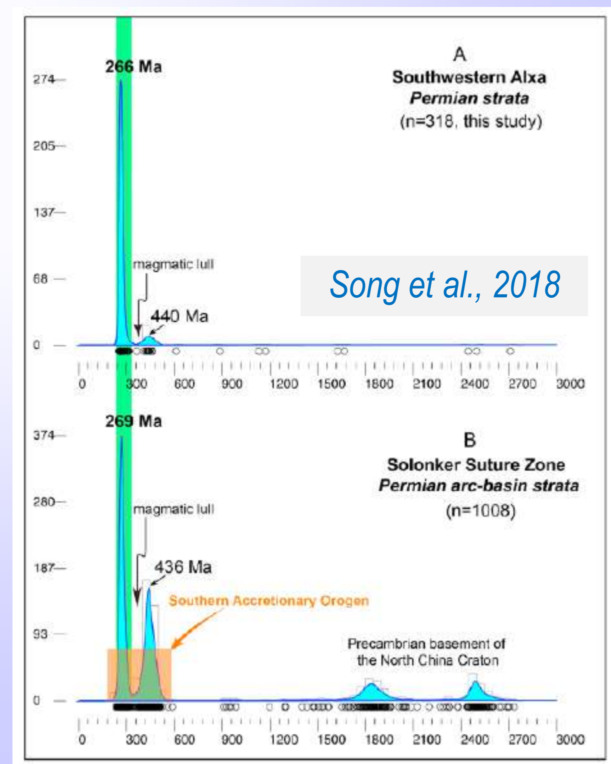
Suzuki et al., 2010

Reconstructing episodes of tectonic erosion

Arc vanished: magmatism stopped due to sunk active margin and trench displaced landward

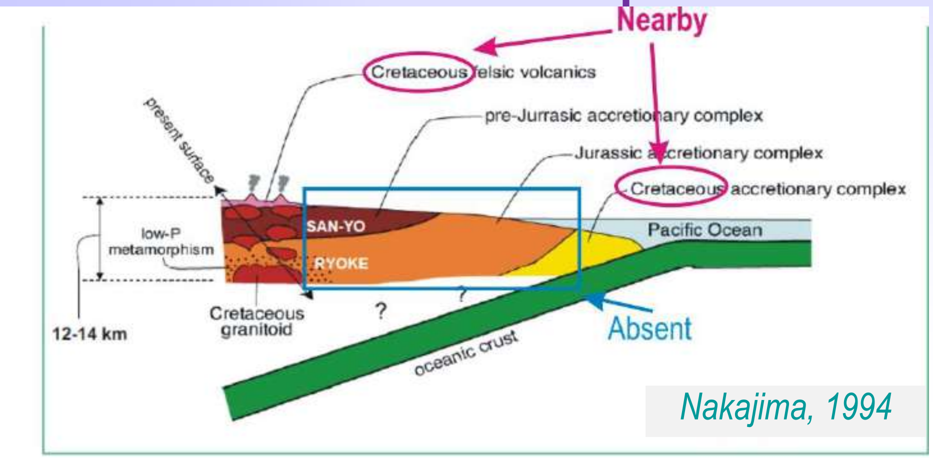






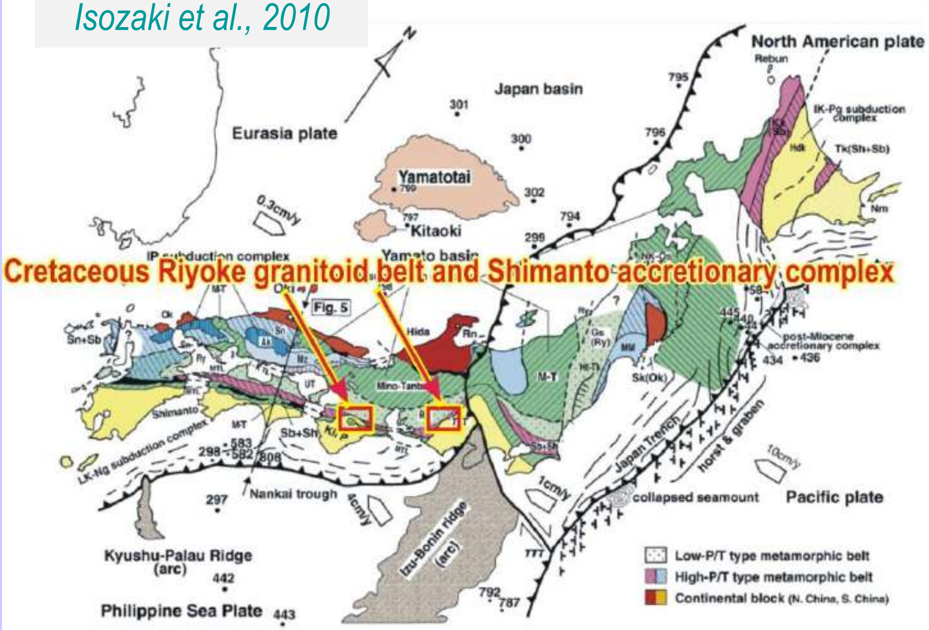
Reconstructing episodes of tectonic erosion

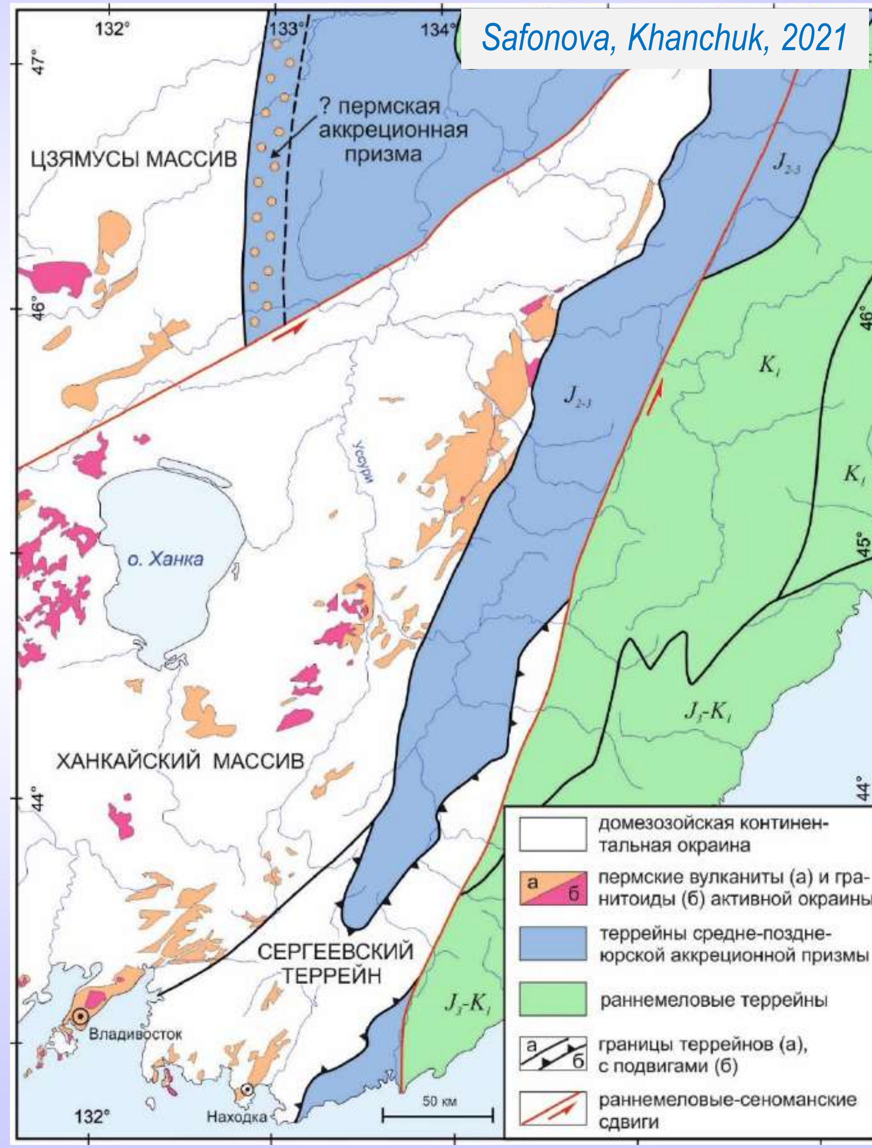
Arc preserved by older accreted units vanished: shortened distance between **coeval arc and trench deposits**



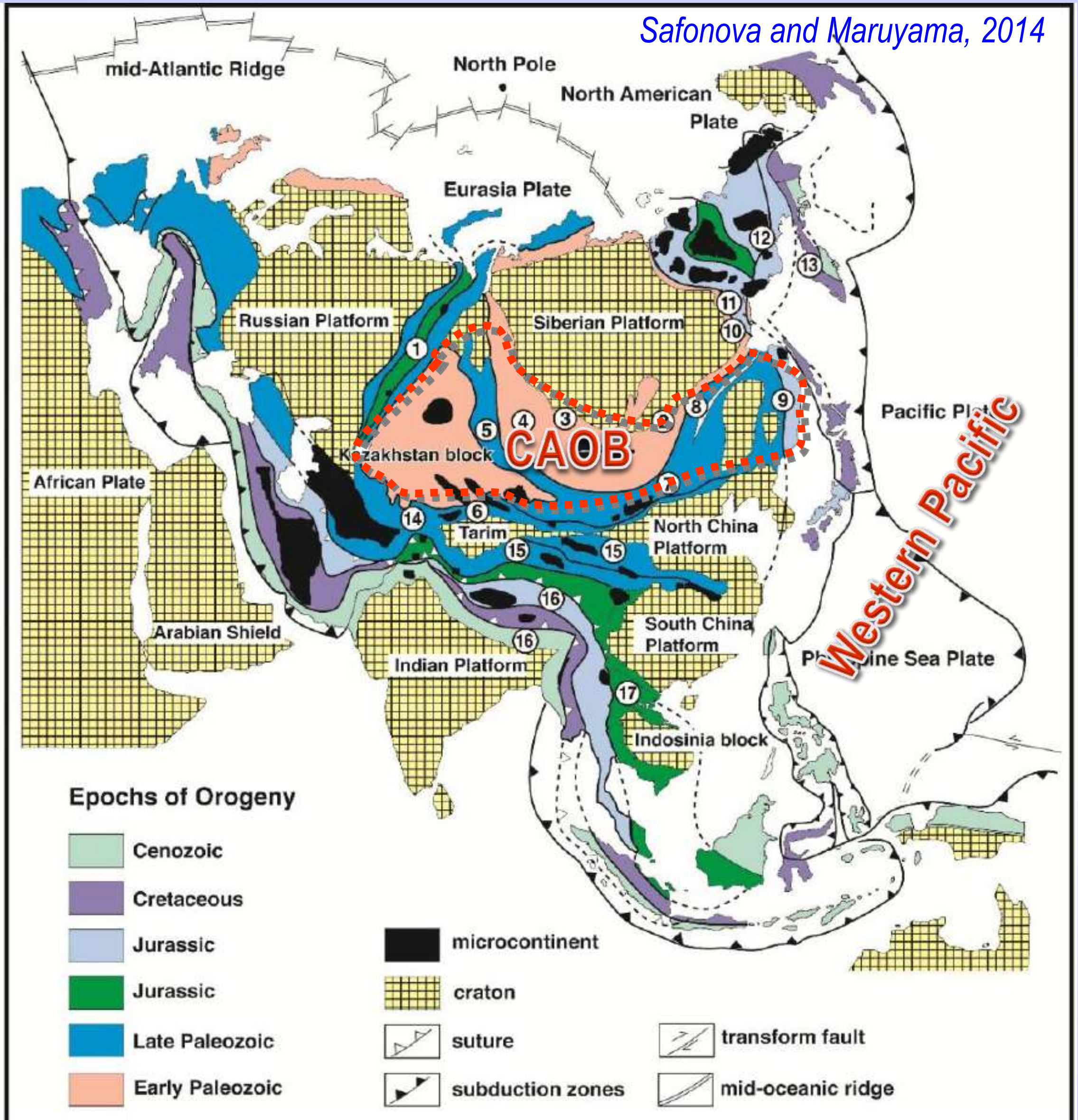
Nakajima, 1994

Isozaki et al., 2010





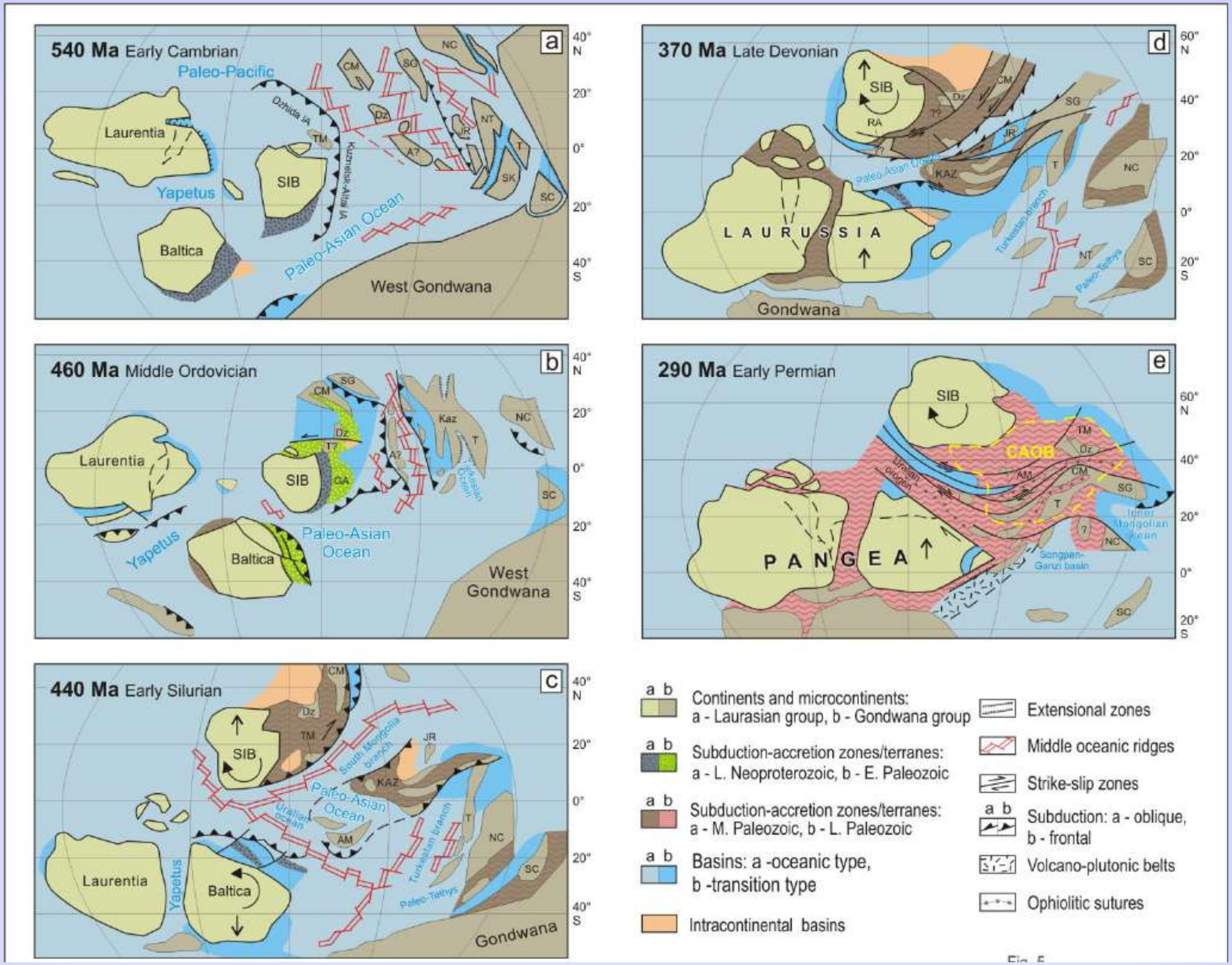
Major tectonic units of Asia



The world youngest and largest continent EurAsia includes many P-type orogenic belts because it was formed by multiple oceanic subductions and continental collisions and it is still overgrown by the modern western Pacific accretionary orogeny. Eurasia includes six major cratonic blocks and numerous microcontinents, including those derived from Gondwana, and their separating orogenic belts.

Eurasia hosts the world largest FOSSIL Pacific-type belt – Central Asian Orogenic Belt

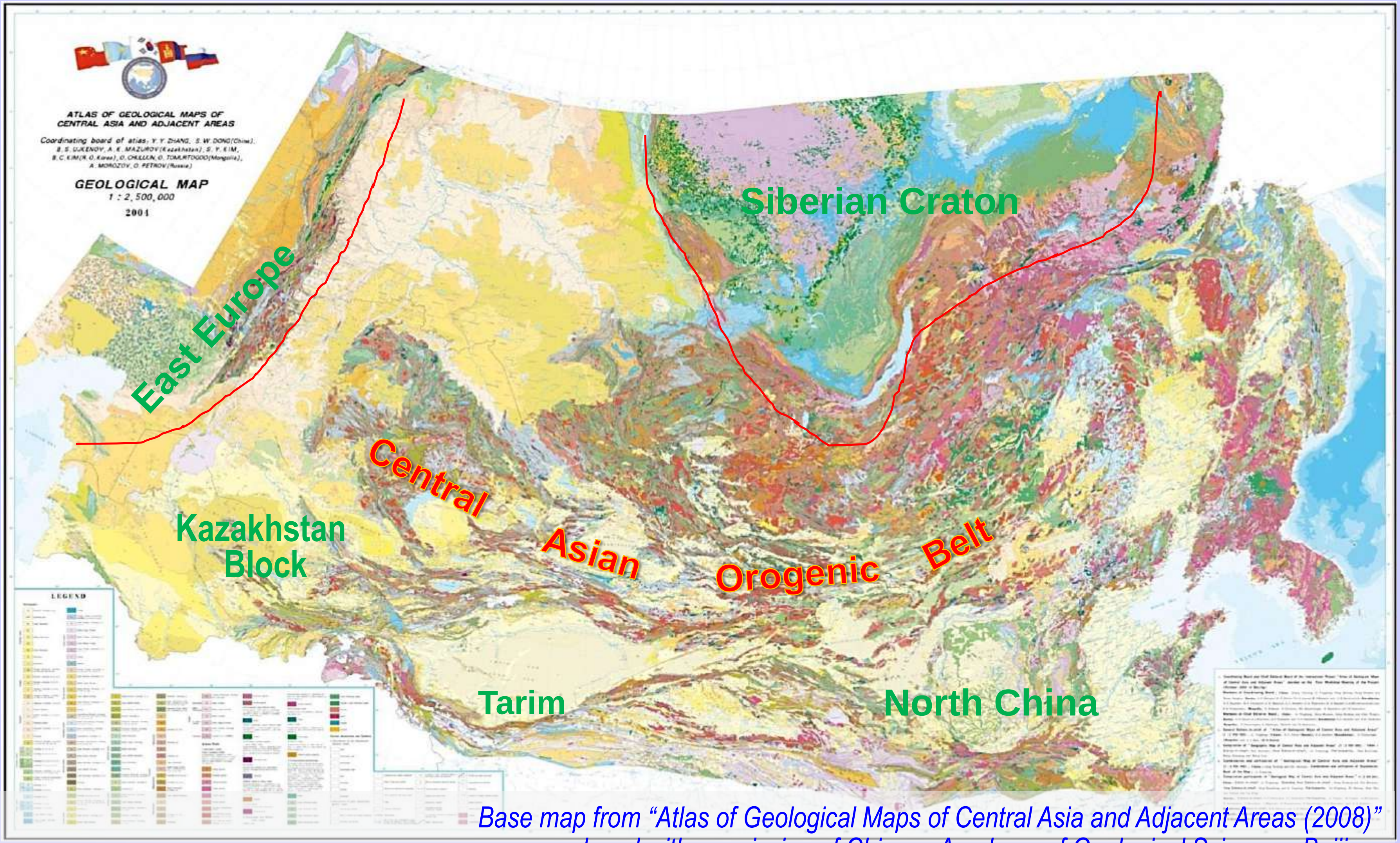
Paleo-Asian Ocean and formation of the CAOB



The **CAOB** formed by the Neoproterozoic-Paleozoic subduction of the Paleo-Asian Ocean and multi-stage collisions of the Siberian, Kazakhstan, Tarim, and North China blocks.

Zonenshain et al. 1990 ; Didenko et al., 1994; Buslov et al. 2001, 2004; Filippova et al. 2001; Kurenkov et al., 2002; Khain et al. 2003; Kheraskova et al. 2003; Torsvik&Cocks, 2017

The Central Asian Orogenic Belt
– the world largest fossil Pacific-type orogen

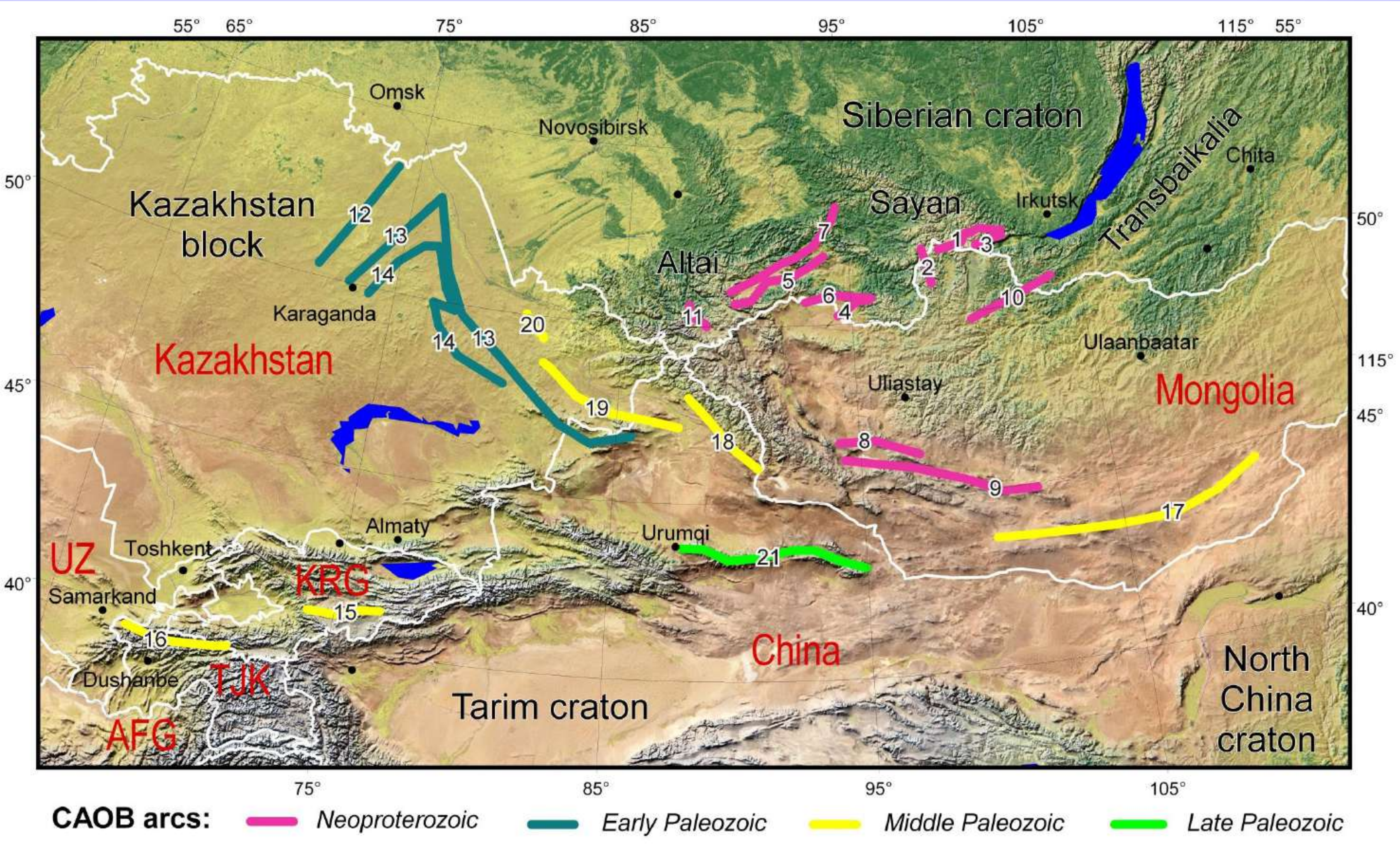


Base map from "Atlas of Geological Maps of Central Asia and Adjacent Areas (2008)" reproduced with permission of Chinese Academy of Geological Sciences, Beijing.

The major site of juvenile continental grown on the Earth

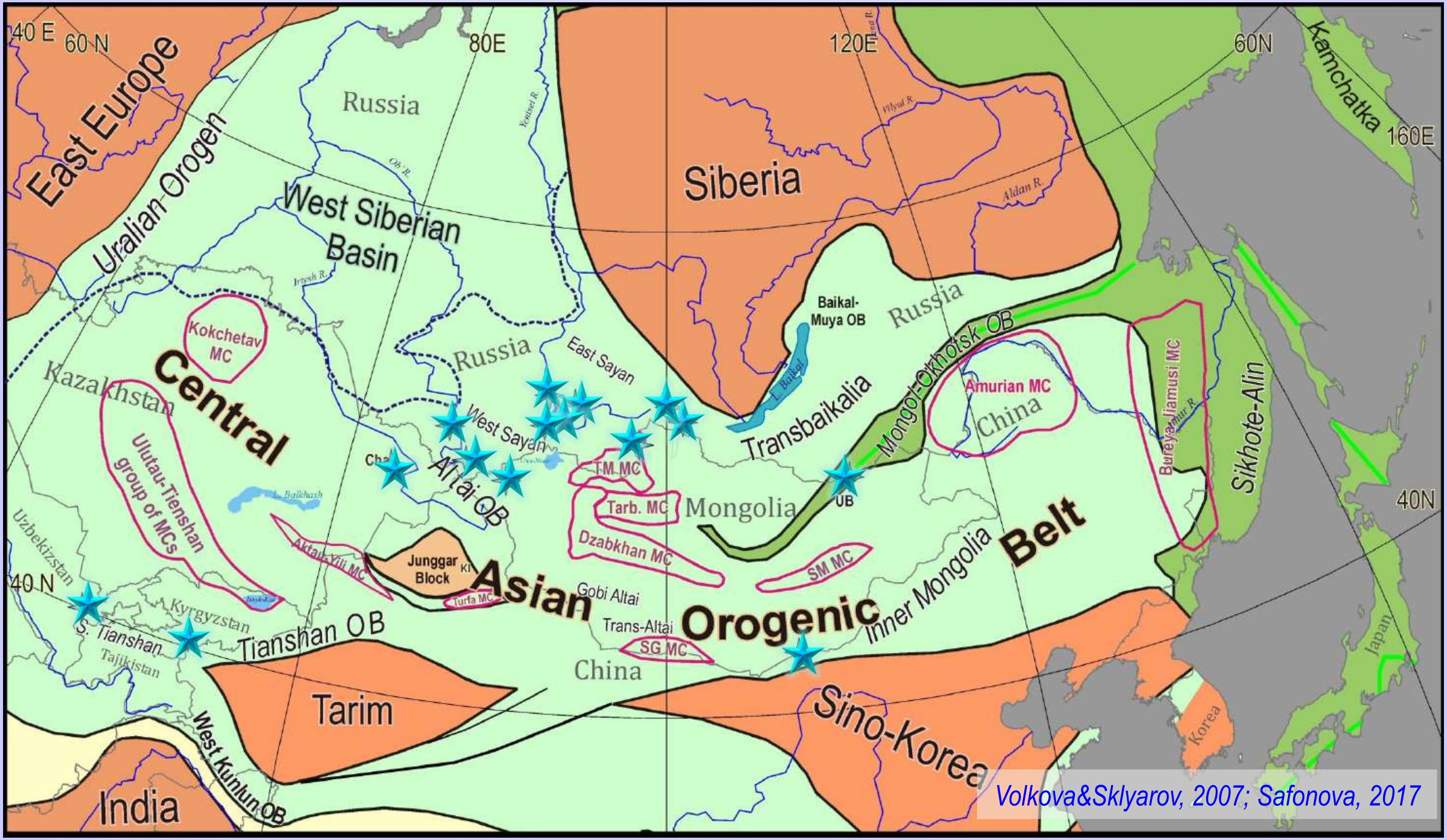
Geologically CAOB is a typical PACIFIC-TYPE OROGENIC BELT

Evidence #1 for the P-type nature of the CAOB:
wide occurrence of intra-oceanic arcs

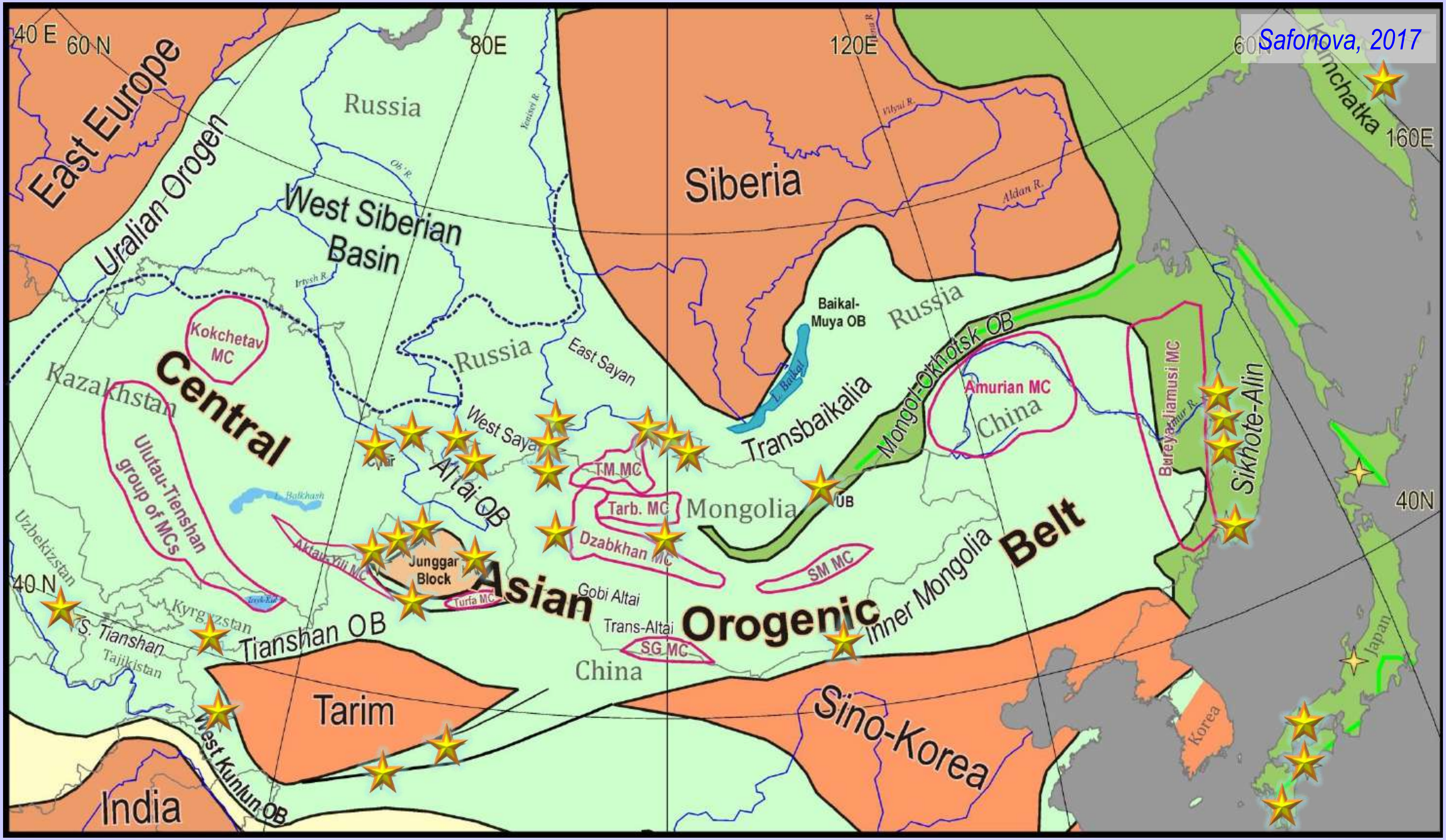


Safonova et al., 2017

Evidence #2 for dominating P-type orogens in the CAOB:
wide occurrence of blueschists formed after MORB, OIB and OPB

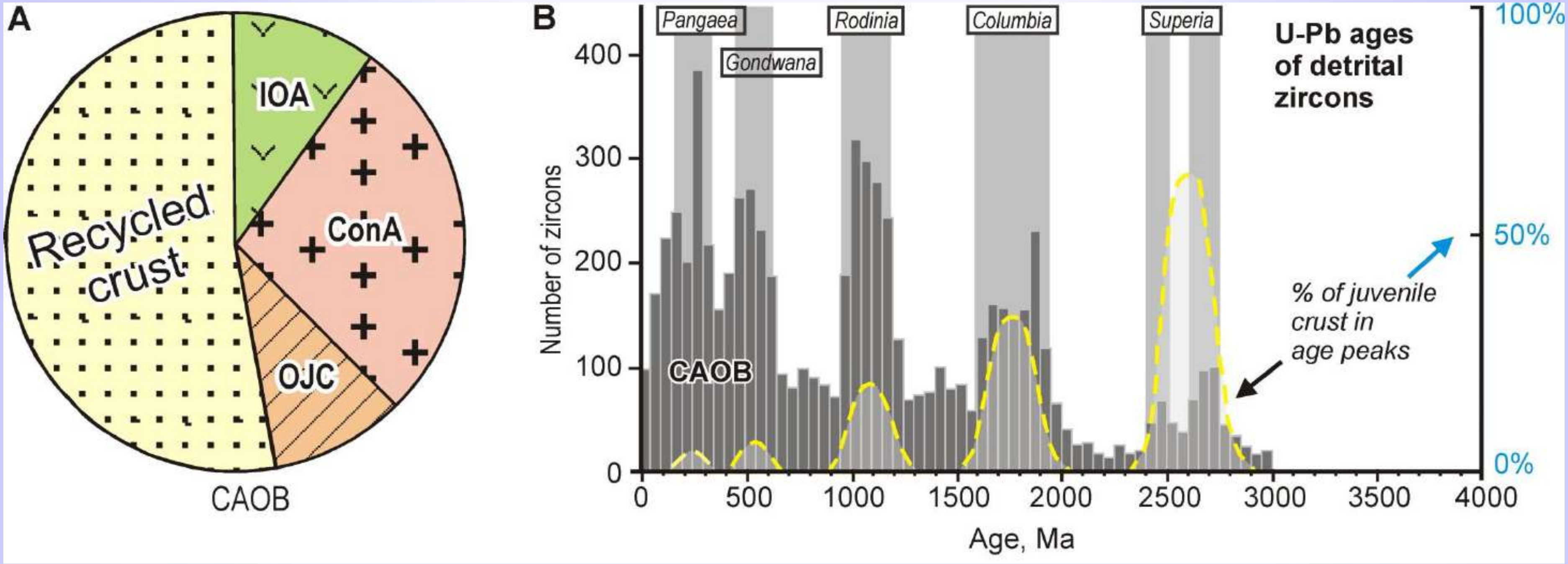


Evidence #3 for dominating P-type orogens in the CAOB:
wide occurrence of accreted OPS



The stars show location of accretionary complexes with Late Neoproterozoic to Late Mesozoic OIB and OPB

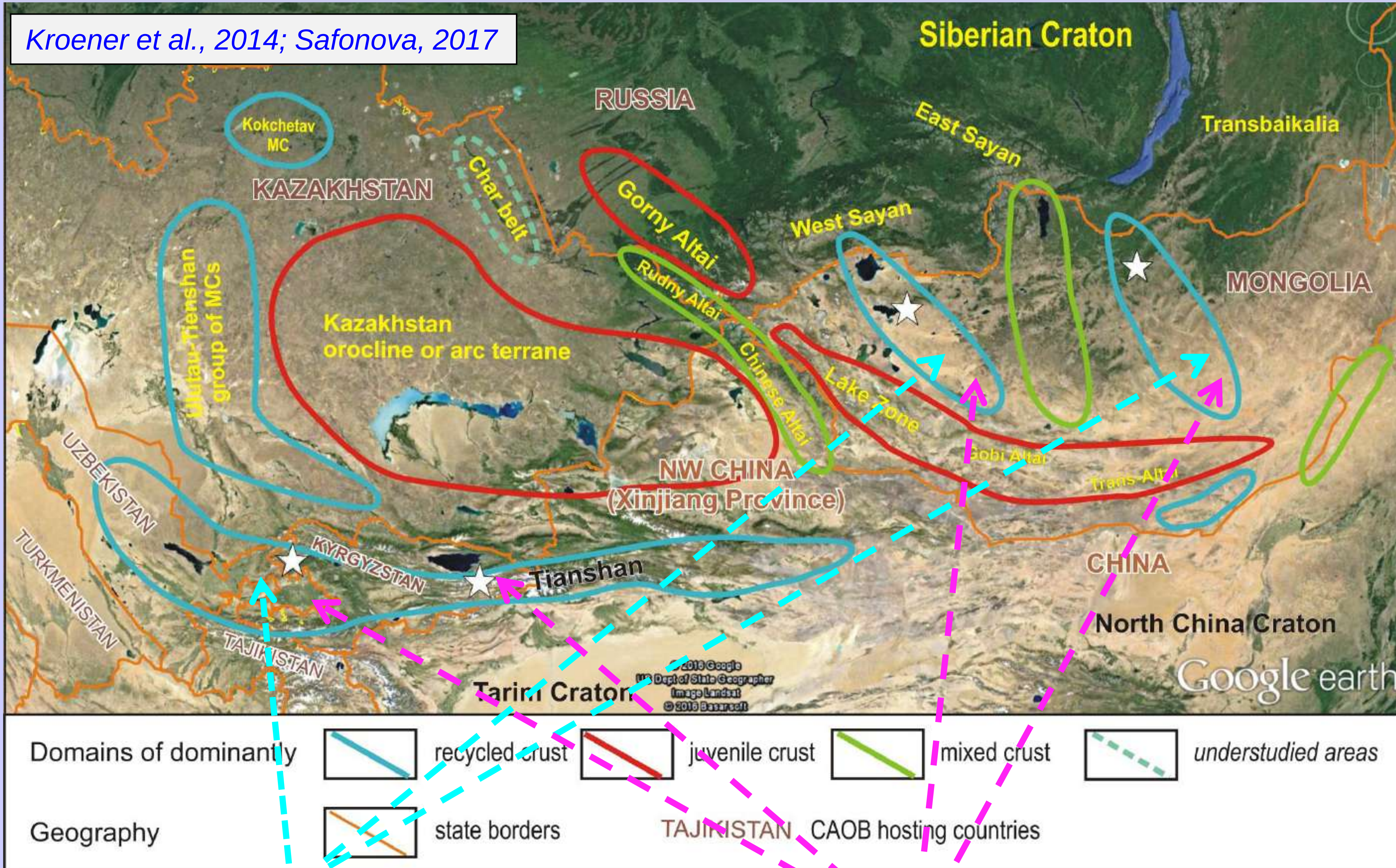
HOWEVER recent Hf-in-zircon isotope studies show a big portion of recycled crust in the CAOB



Condie&Kroener, 2013

Hawksworth et al., 2010

Disagreement between geology and isotopes
areas of recycled and juvenile crust in the CAOB



Isotope-implied recycled crust

Accretionary complexes with OPS-hosted OIBs and BS

A time vs. geography chart of OPS from accretionary complexes of Central and East Asia

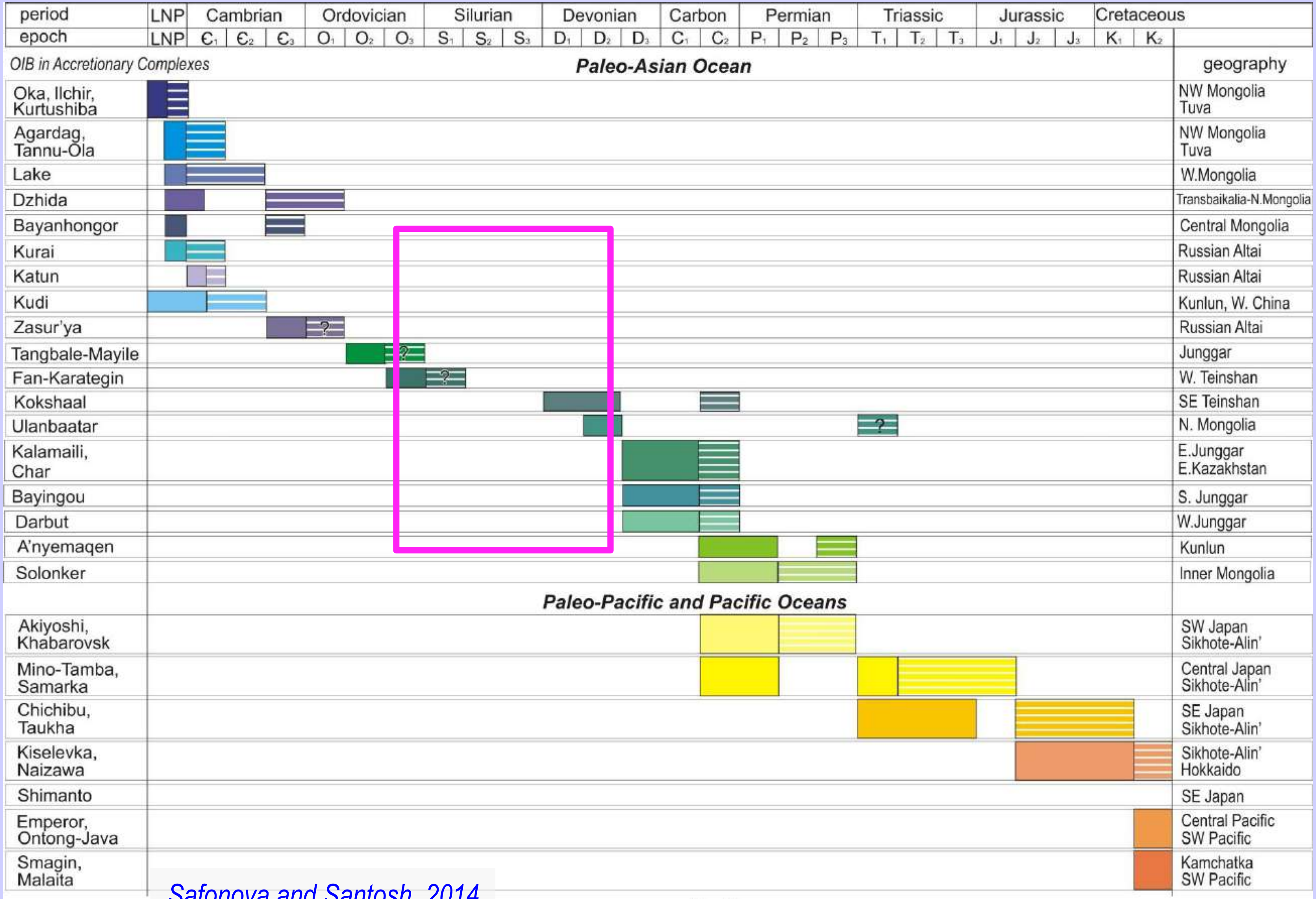
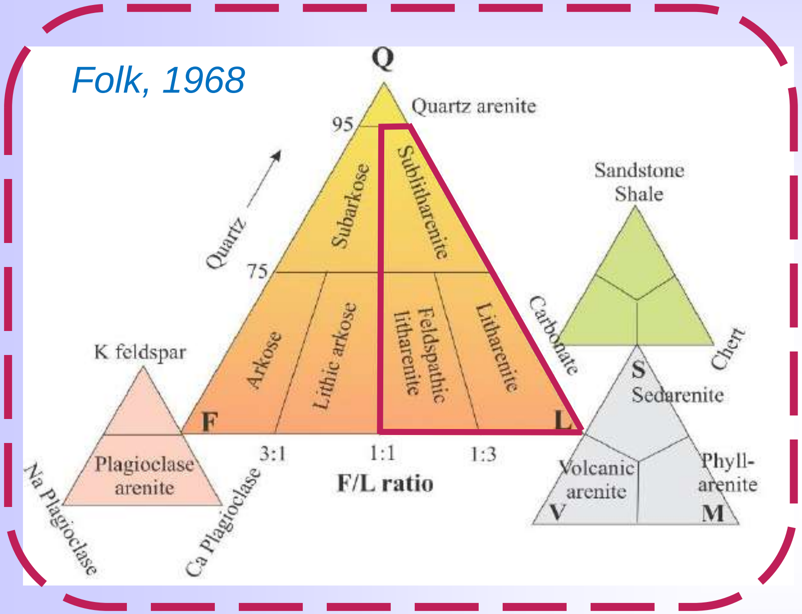
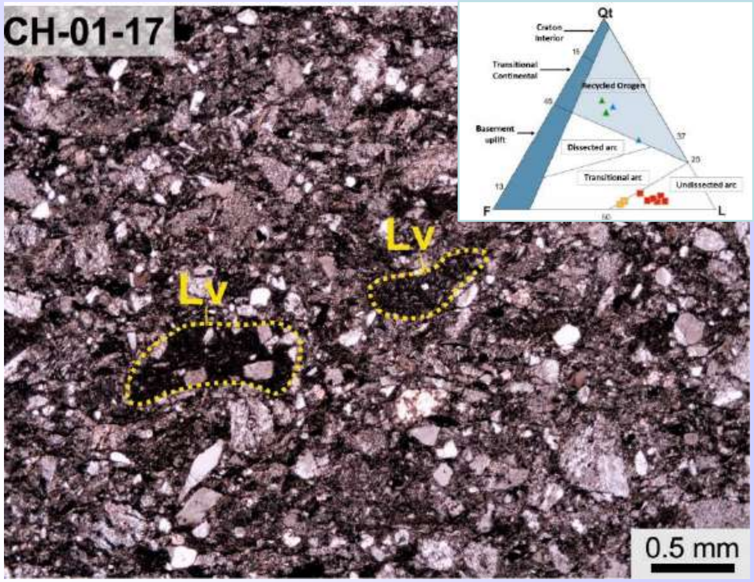


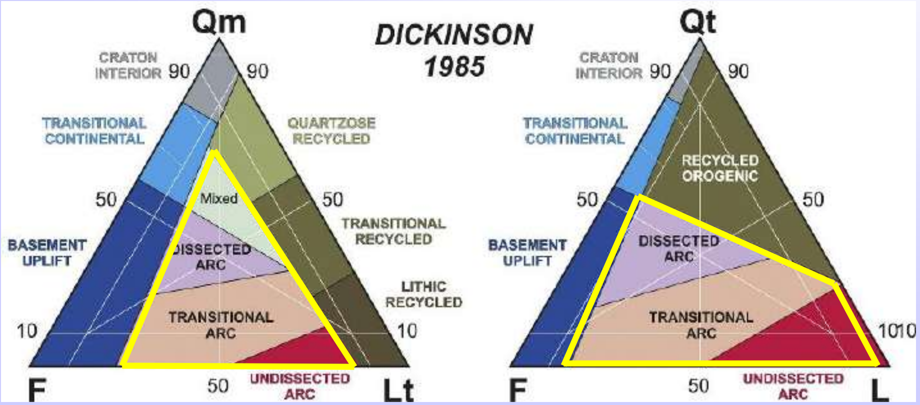
Fig. 19

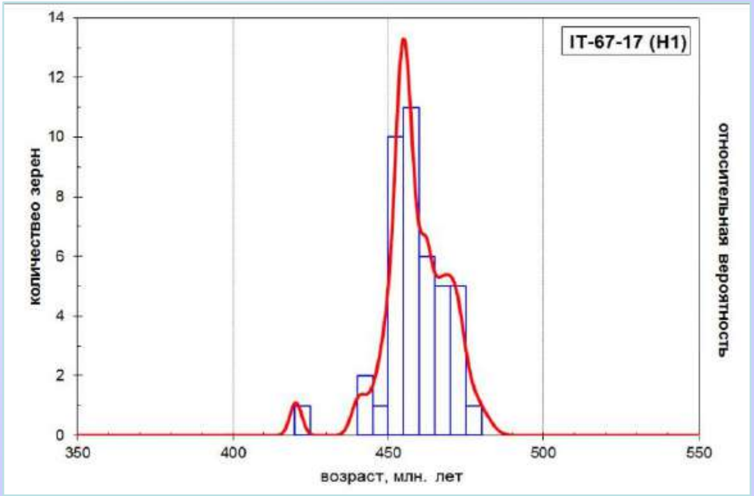
Reconstructing fossil events of tectocni erosion

Eroded arc: few to nil igneous formations. We study **greywacke sandstones** hosted by accretionary and/or supra-subduction complexes

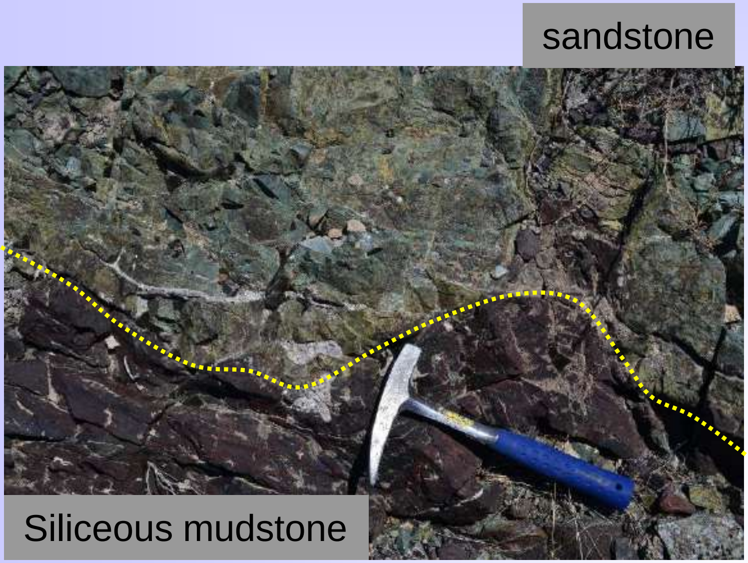


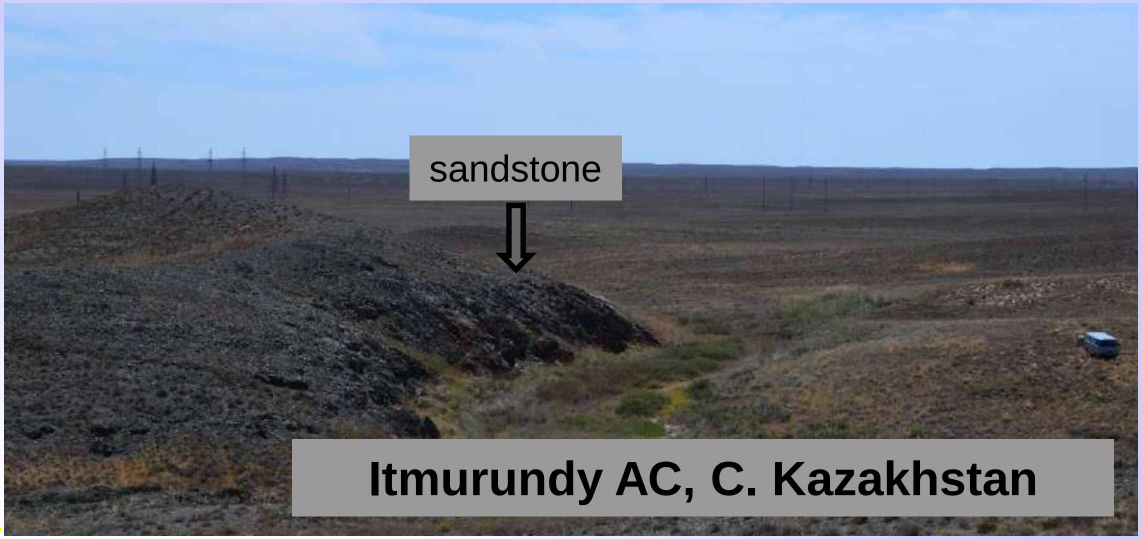




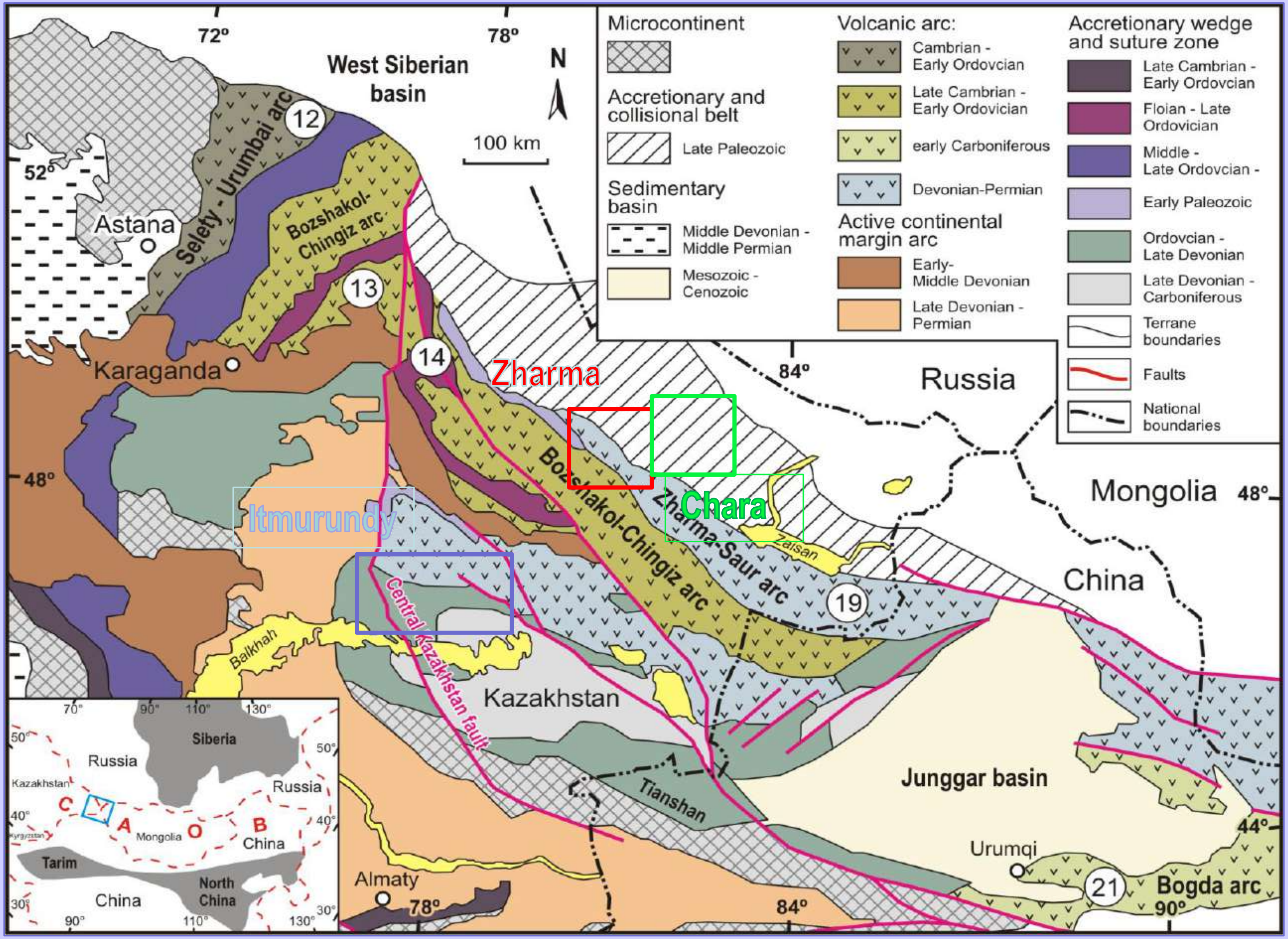


Greywacke sandstones





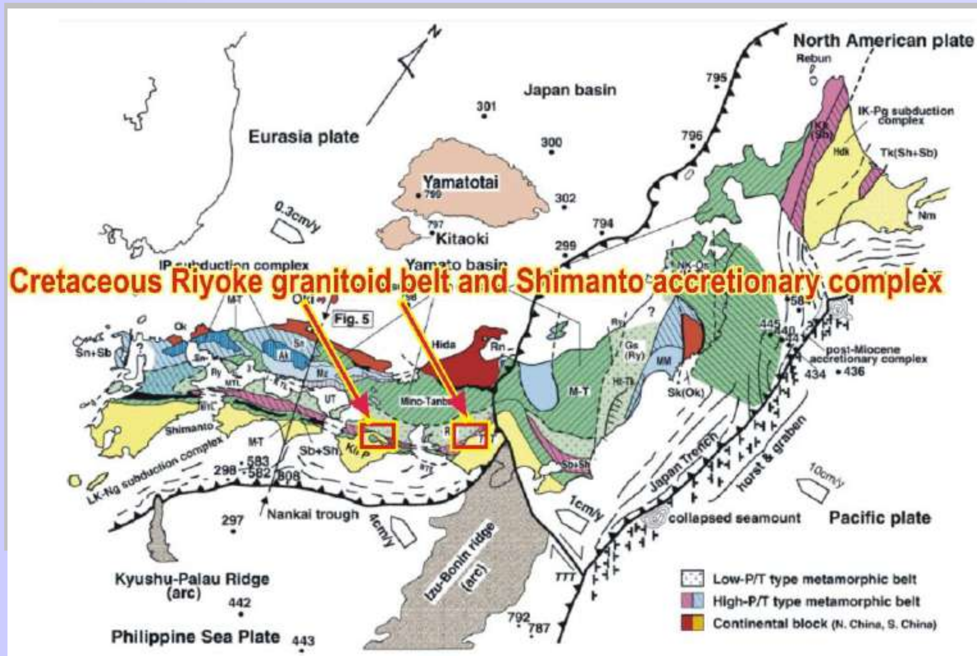
The tectonic map of the western CAOB

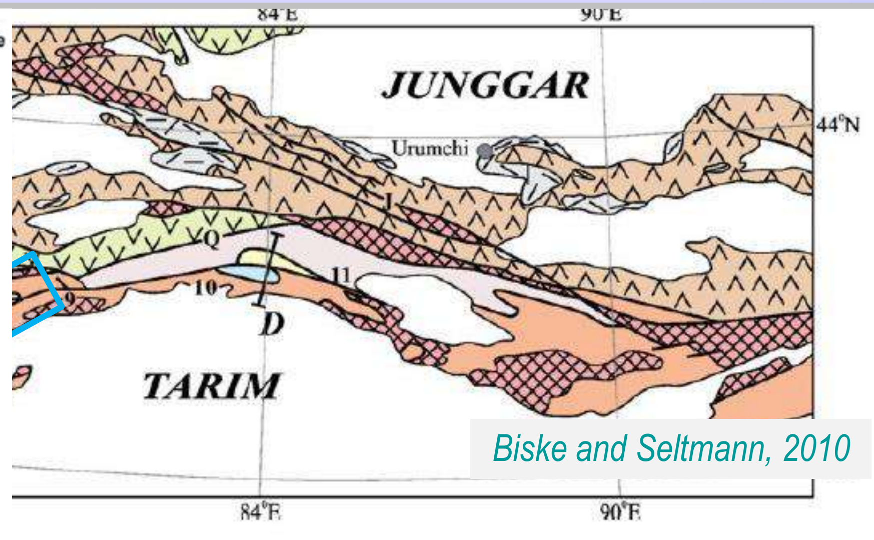


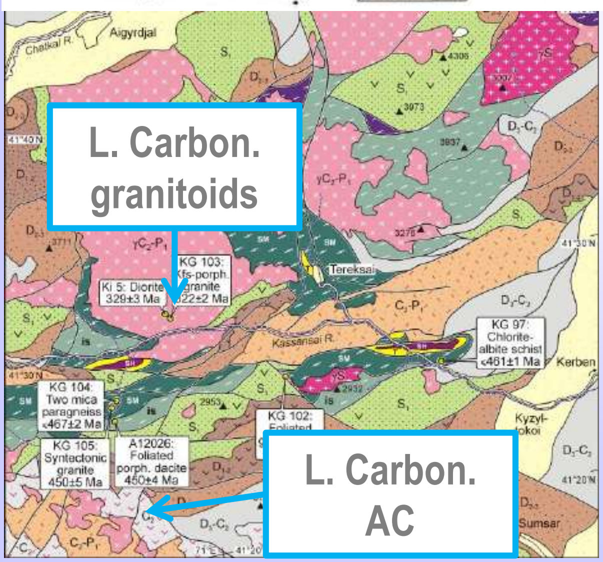
modified from Windley et al., 2007; Degtyarev, 2012

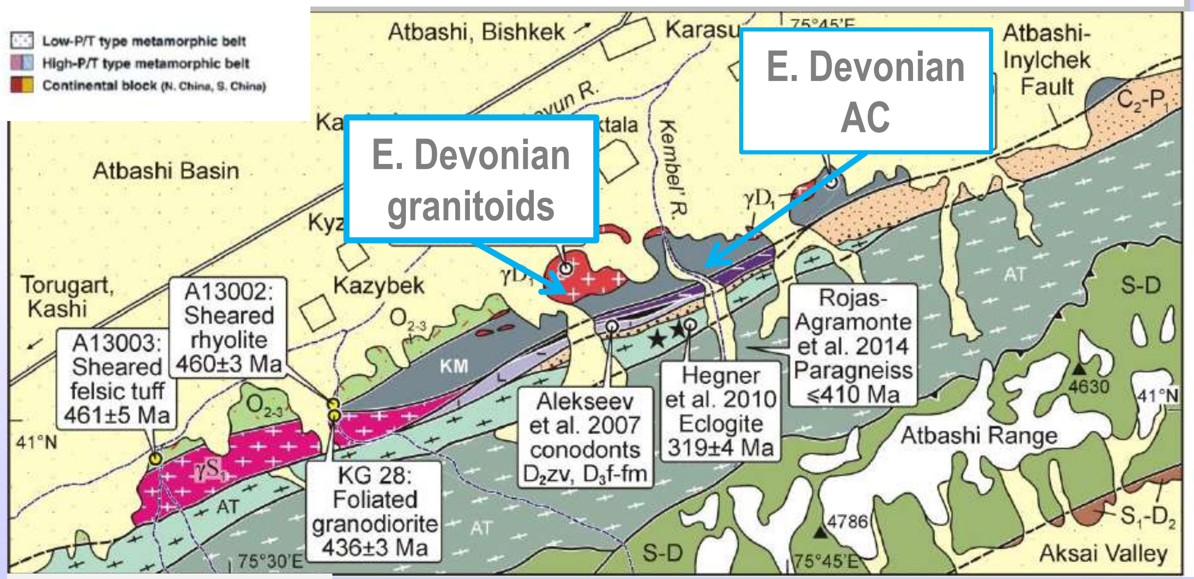
Probable cases of tectonic erosion in the CAOB

Chatkal-Kurama arc, southern Tienshan





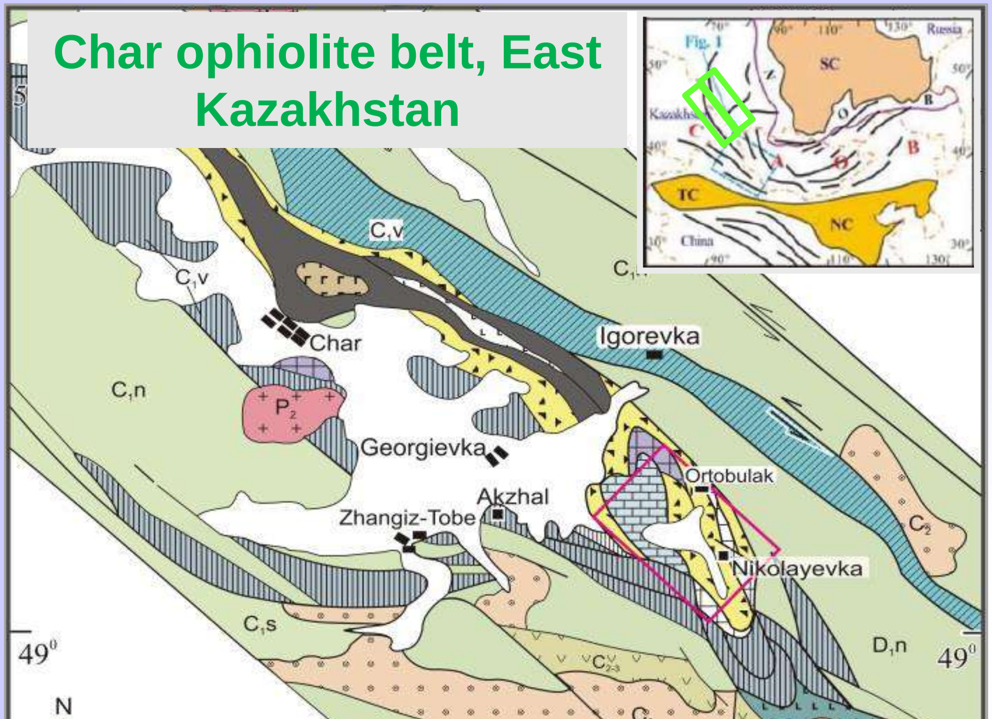


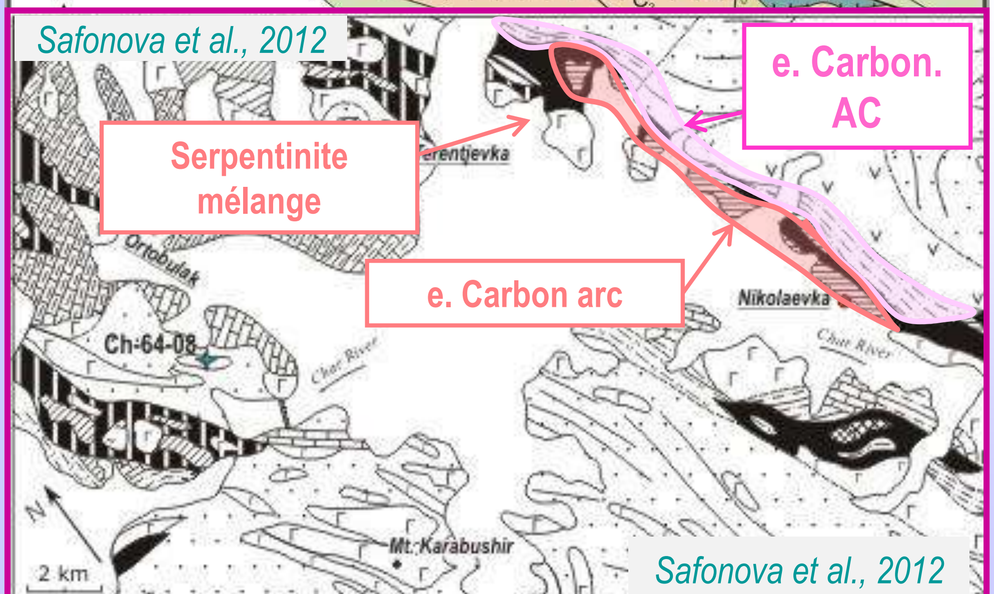


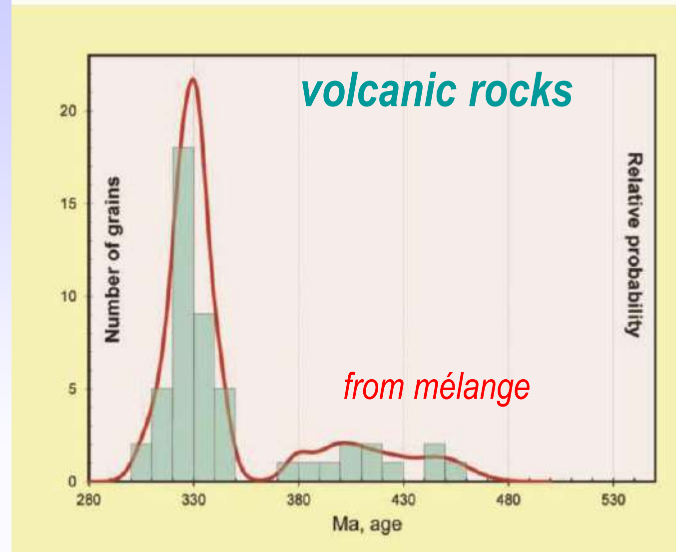
Alexeiev et al., 2016

Probable cases of tectonic erosion in the CAOB

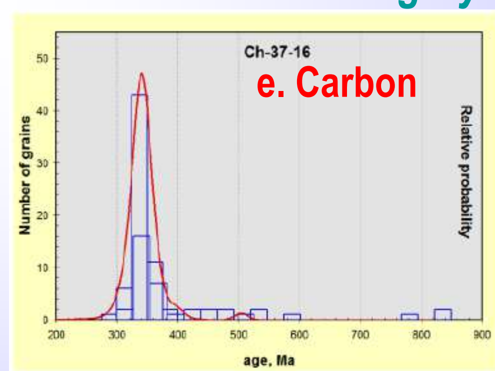
Char ophiolite belt, East Kazakhstan



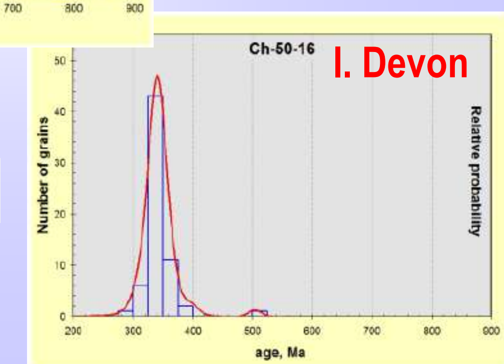




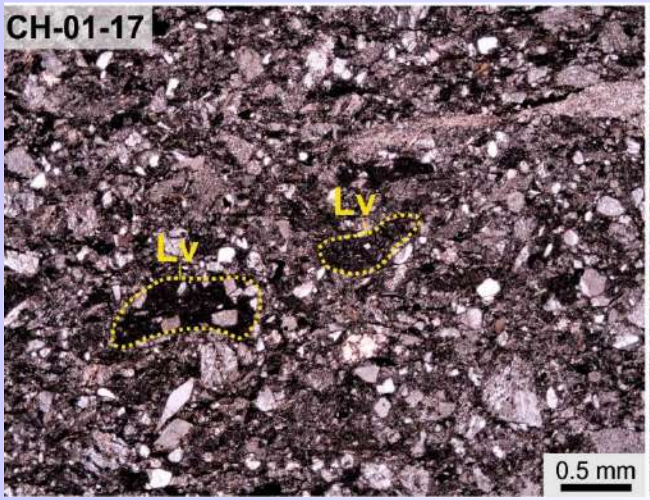
greywacke sandstones

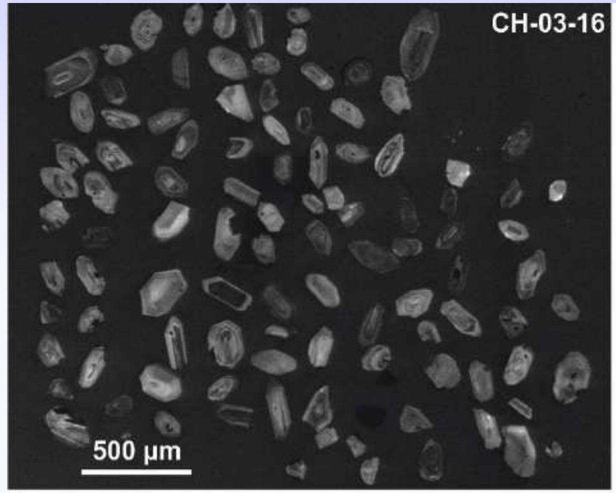


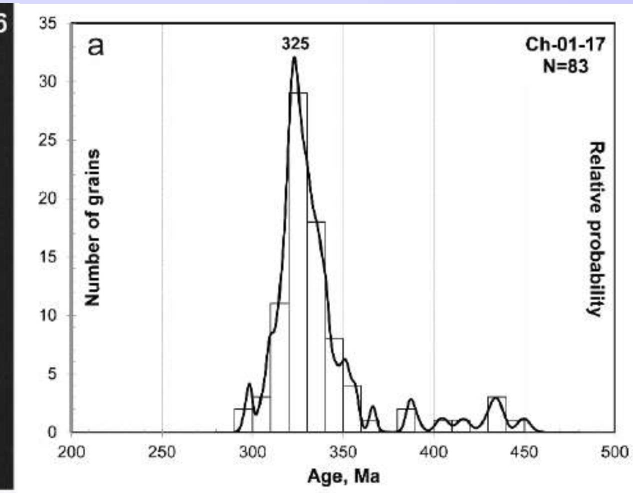
Safonova et al., 2018

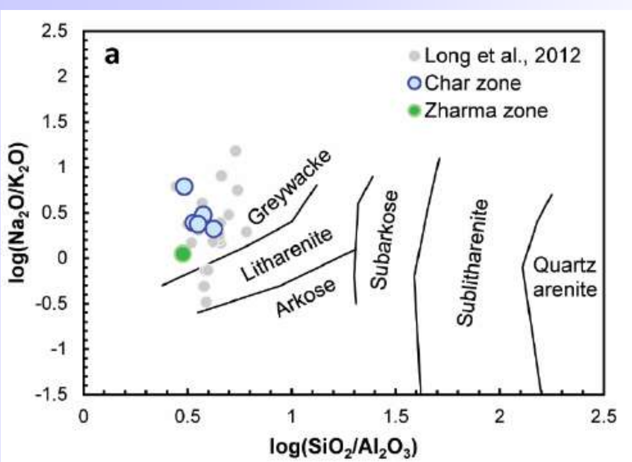


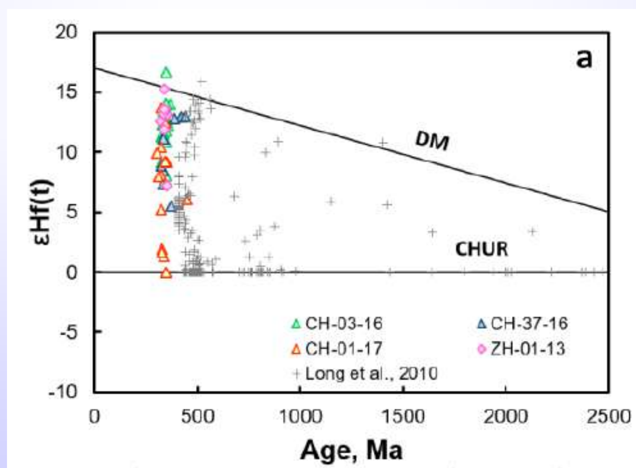
Char belt greywacke sandstone, E. Kazakhstan

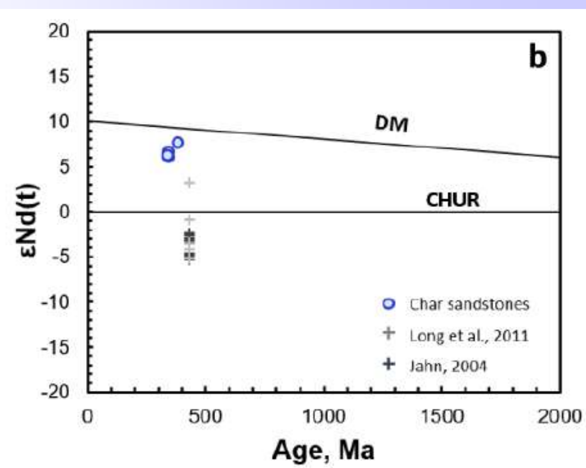








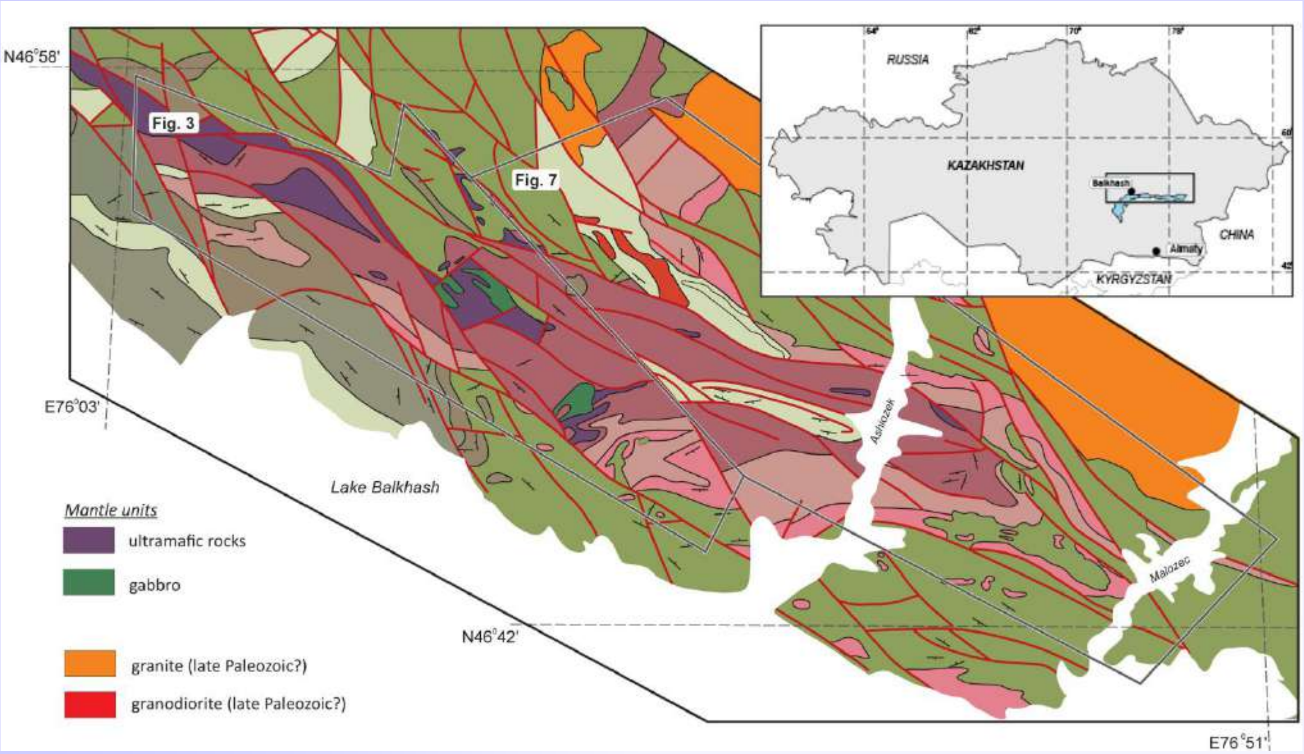




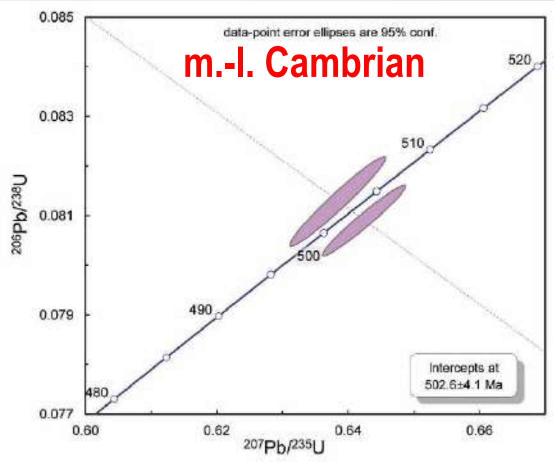
Safonova et al., 2021

Probable cases of tectonic erosion in the CAOB

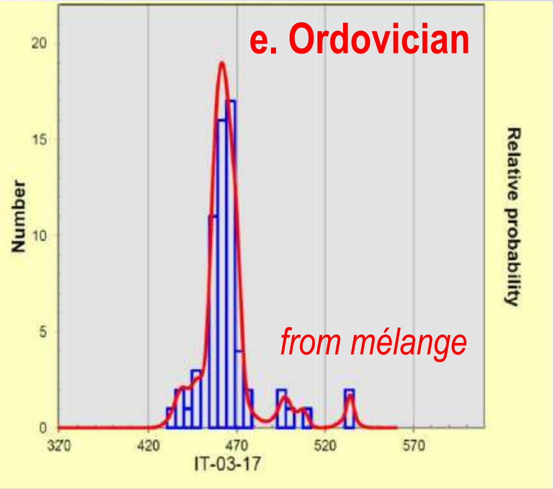
Itmurundy AC, C. Kazakhstan, Ordovician

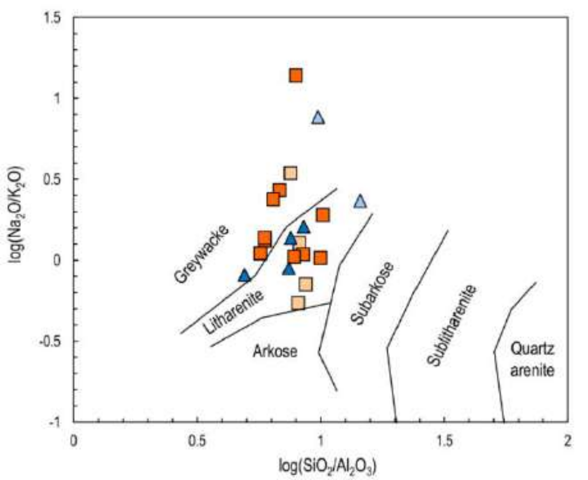


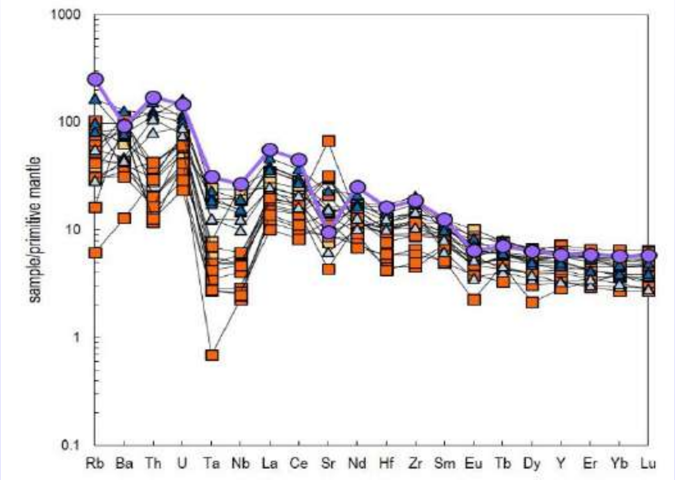
Igneous rocks



Greywacke sandstones







Probable cases of tectonic erosion in the CAOB

Adatsag AC, N. Mongolia

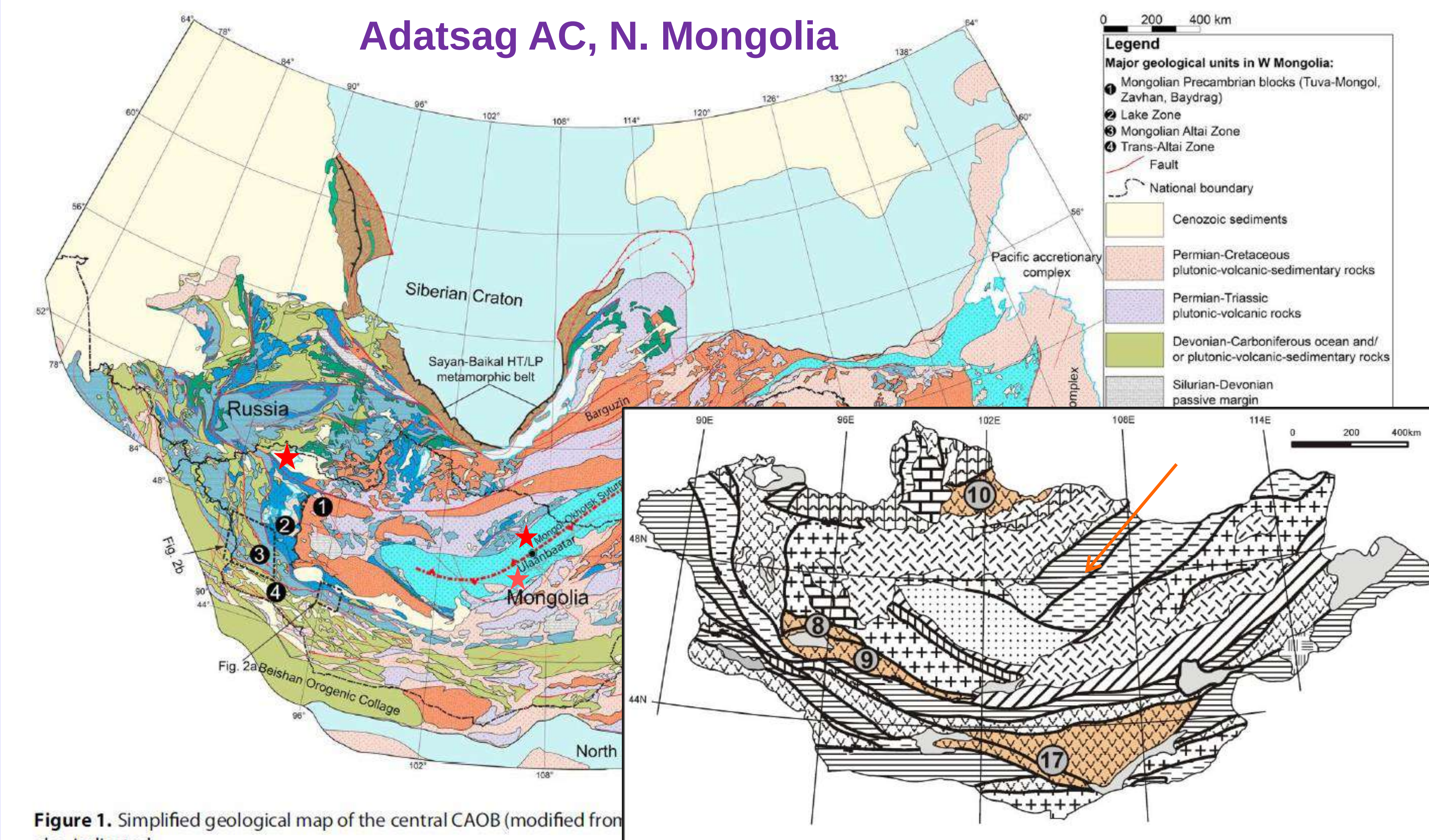
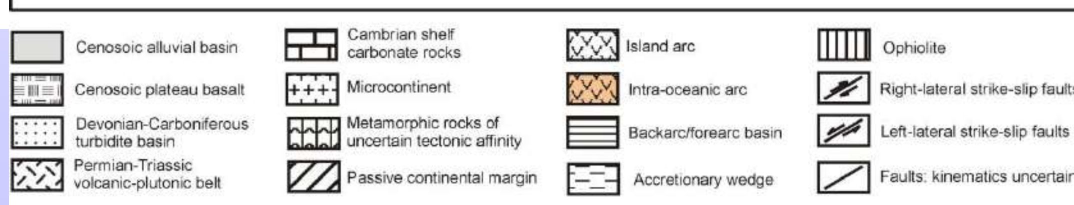
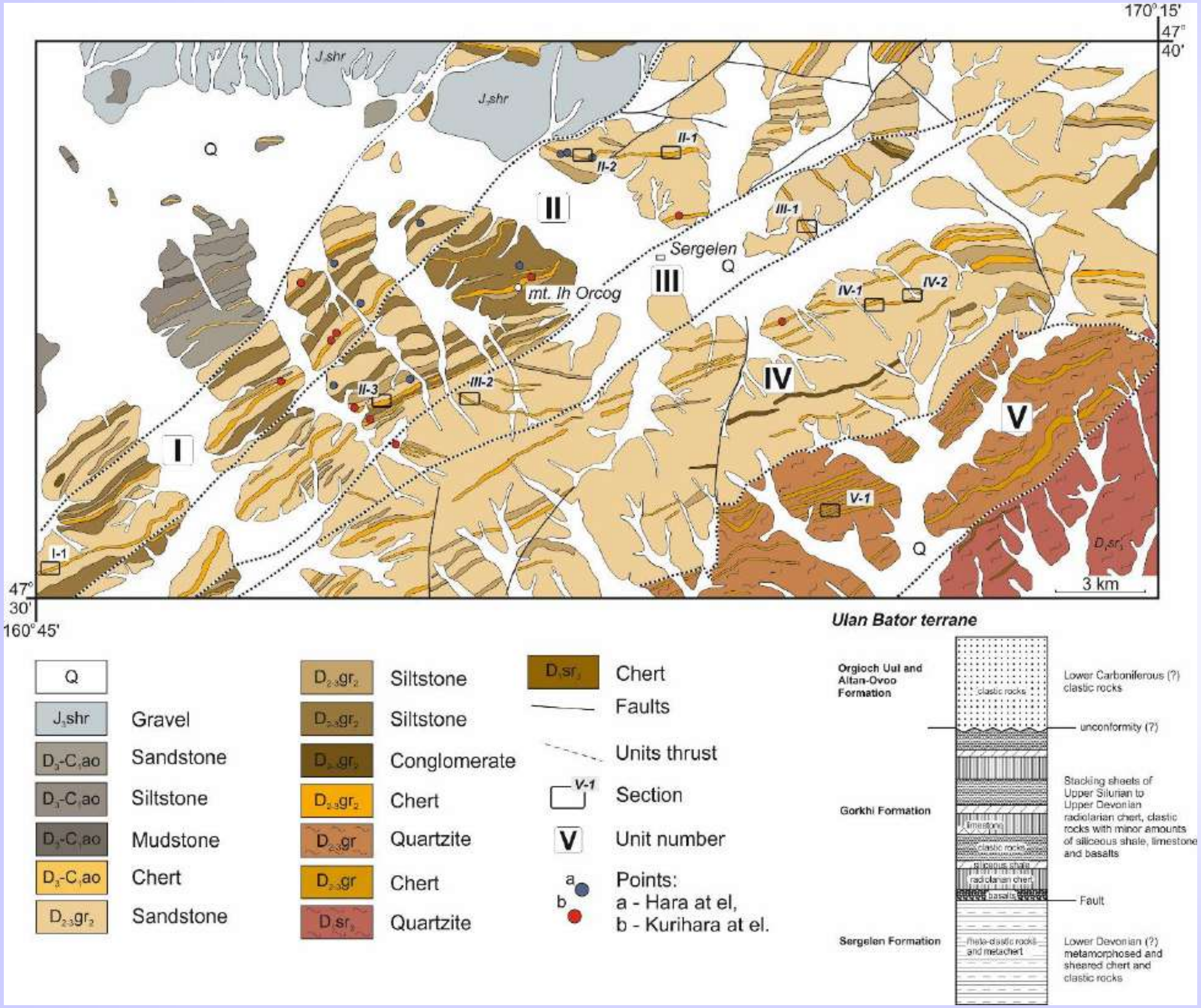


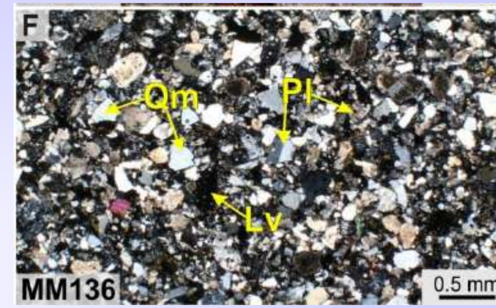
Figure 1. Simplified geological map of the central CAOB (modified fron also indicated.

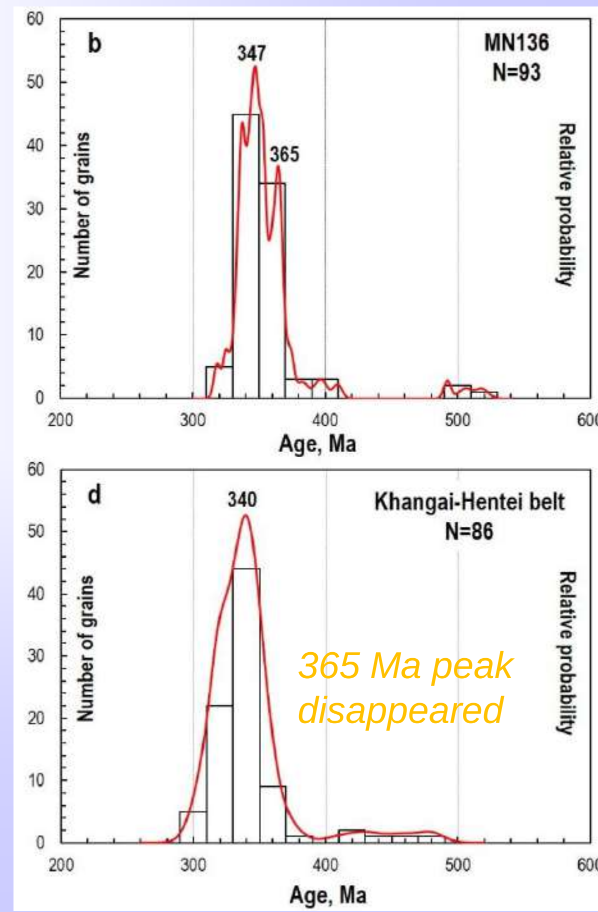


Probable cases of tectonic erosion in the CAOB

A Carboniferous arc? – no volcanic rocks, but greywackes only

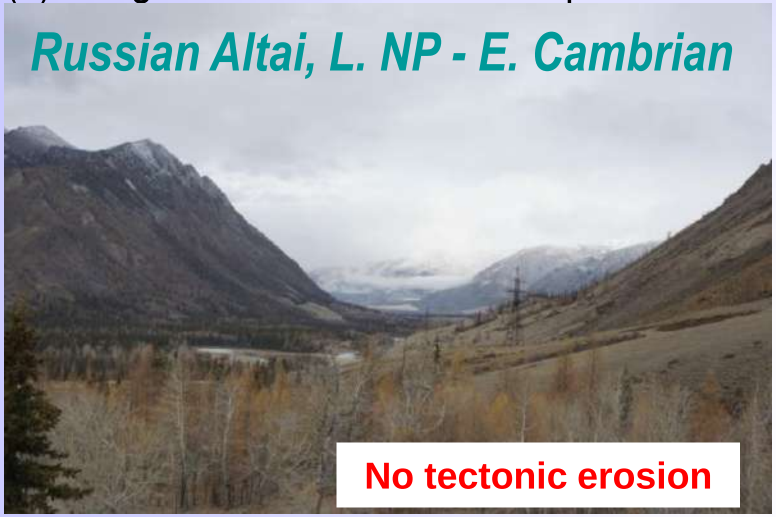


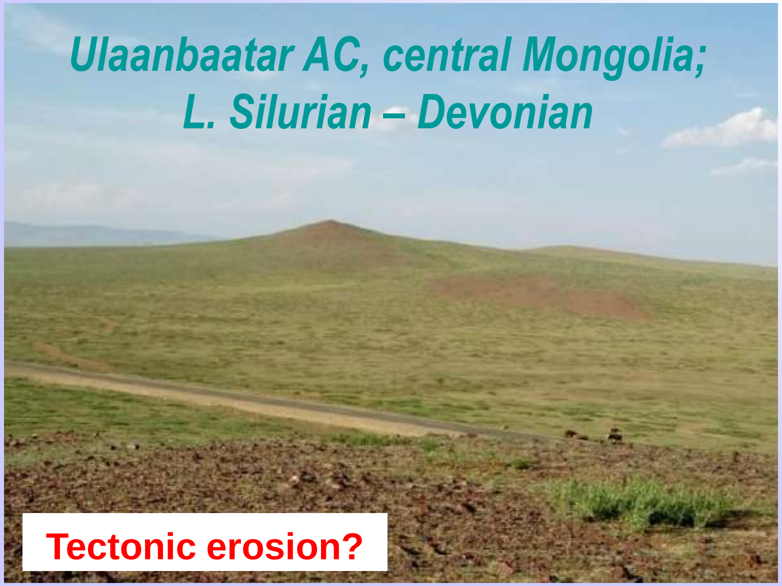




A summary for evidence for tectonic erosion in ancient orogens:

(1) Small sizes of magmatic bodies possessing supra-subduction features;
(2) Short to nil distance between trench and magmatic arc;
(3) Serpentinite mélange hosting fragments of supra-subduction magmatic rcks;
(4) Magmatic lull and trench displacement landward





Evidence for tectonic erosion in ancient orogens:

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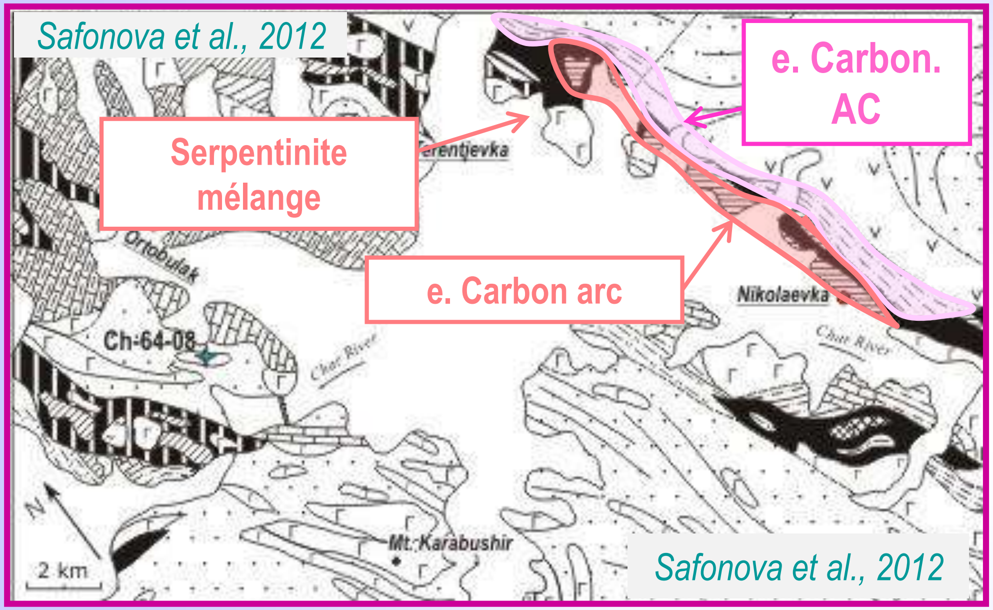

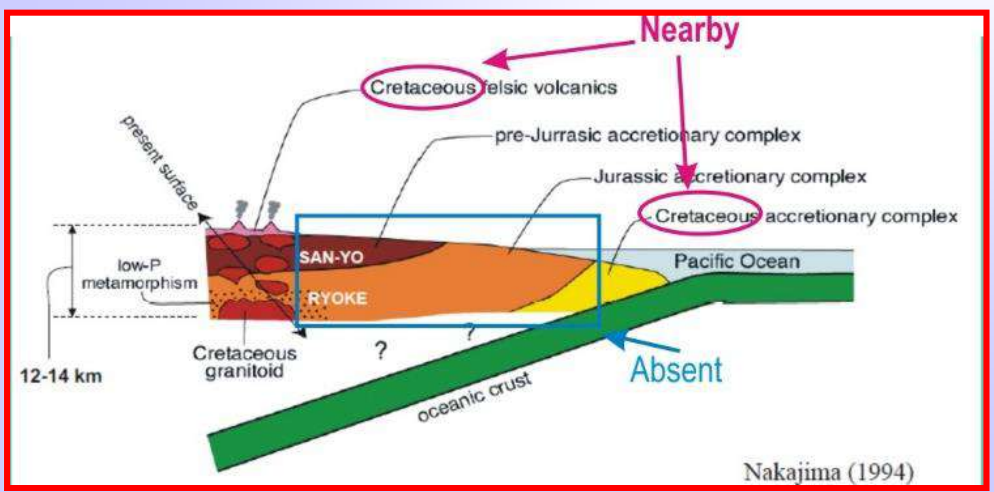

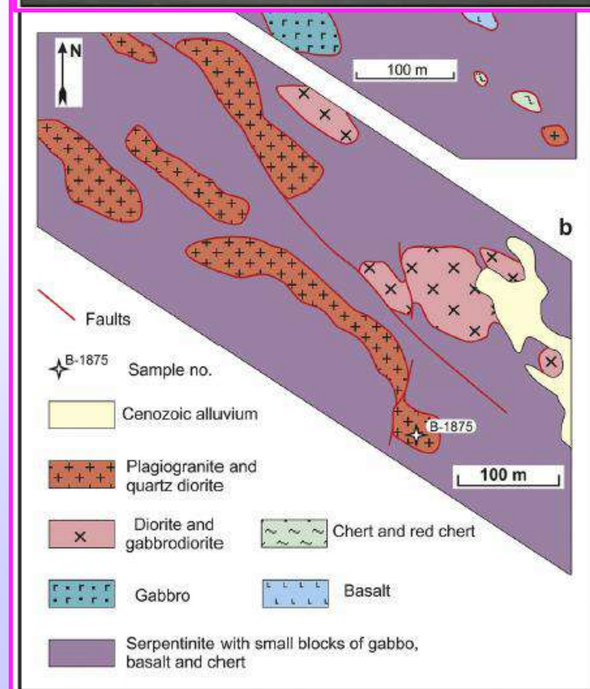

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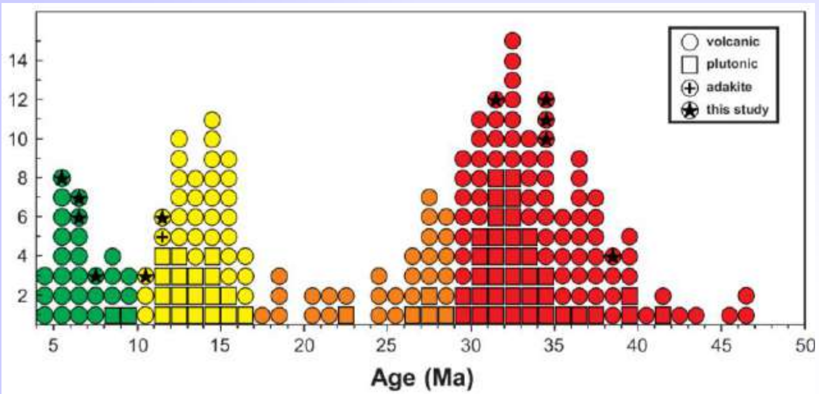
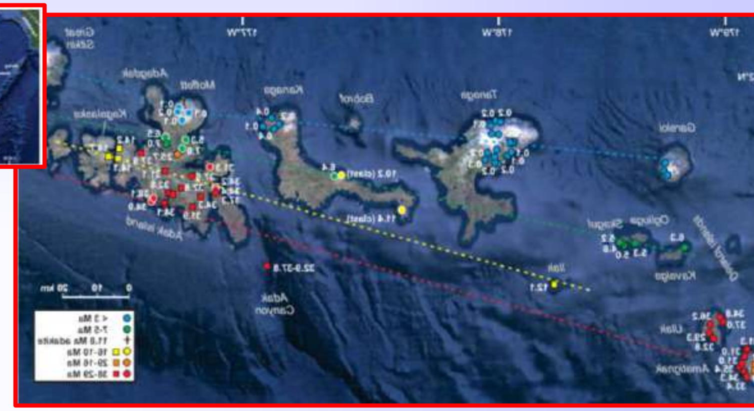
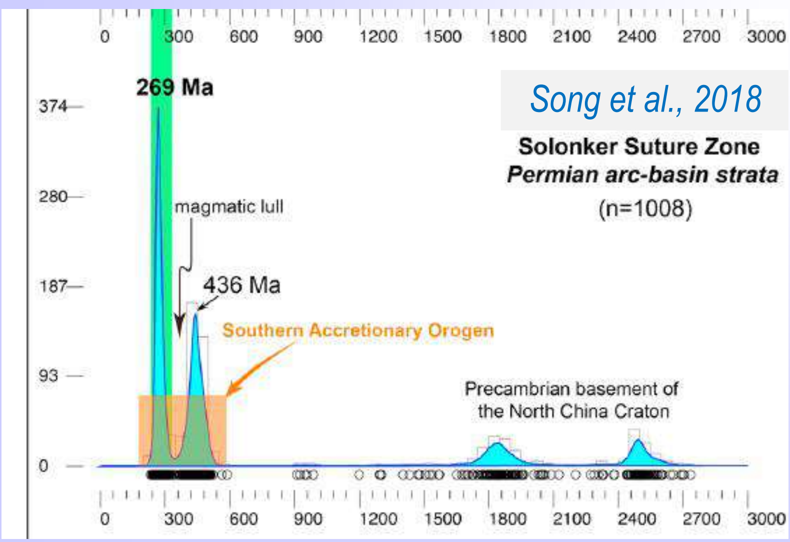
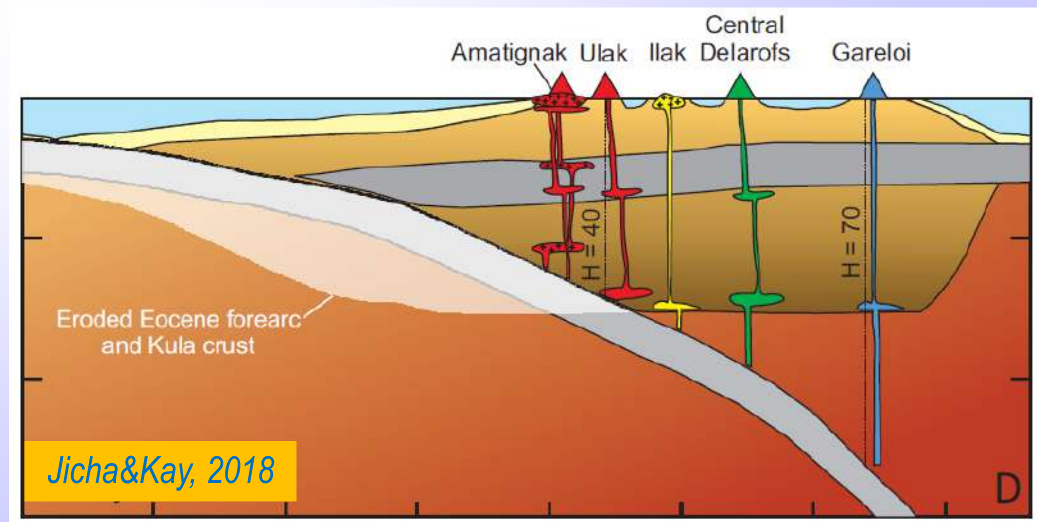




Aleutian arc

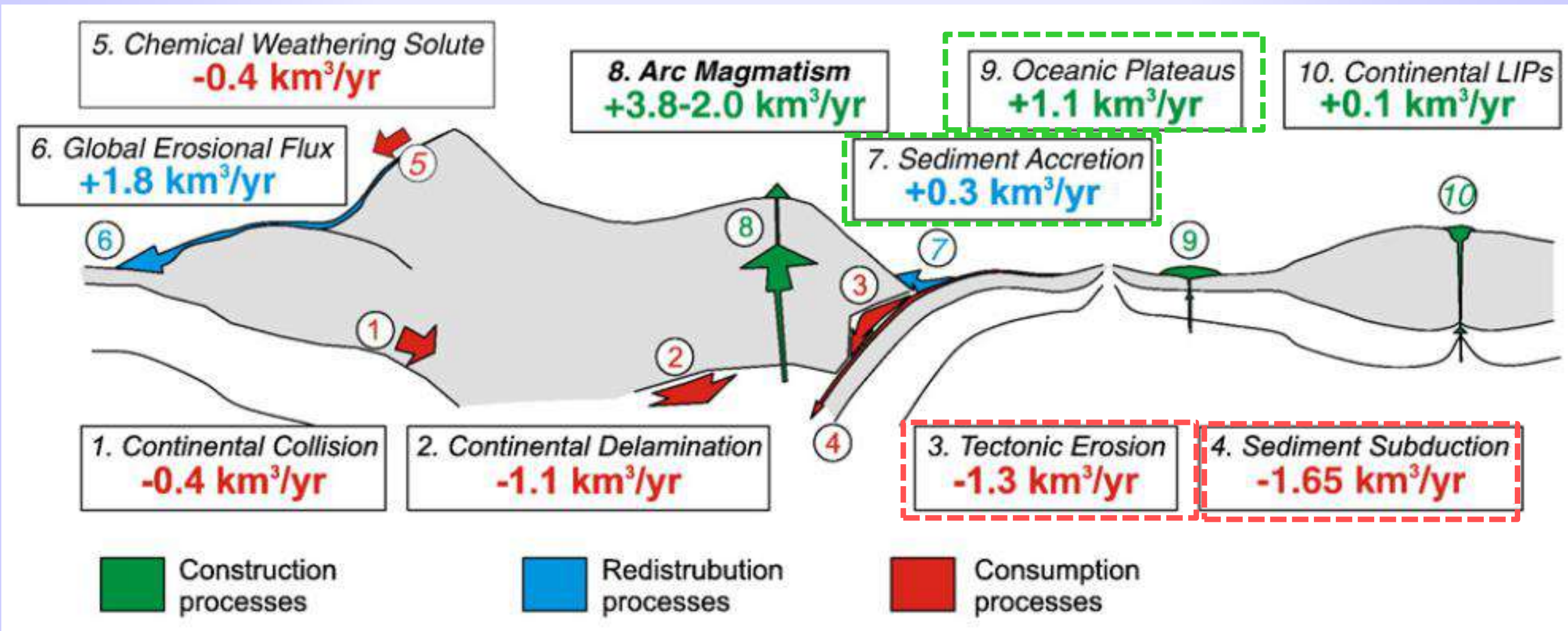
Jicha&Kay, 2018





Direct consequences of tectonic erosion: crust destruction

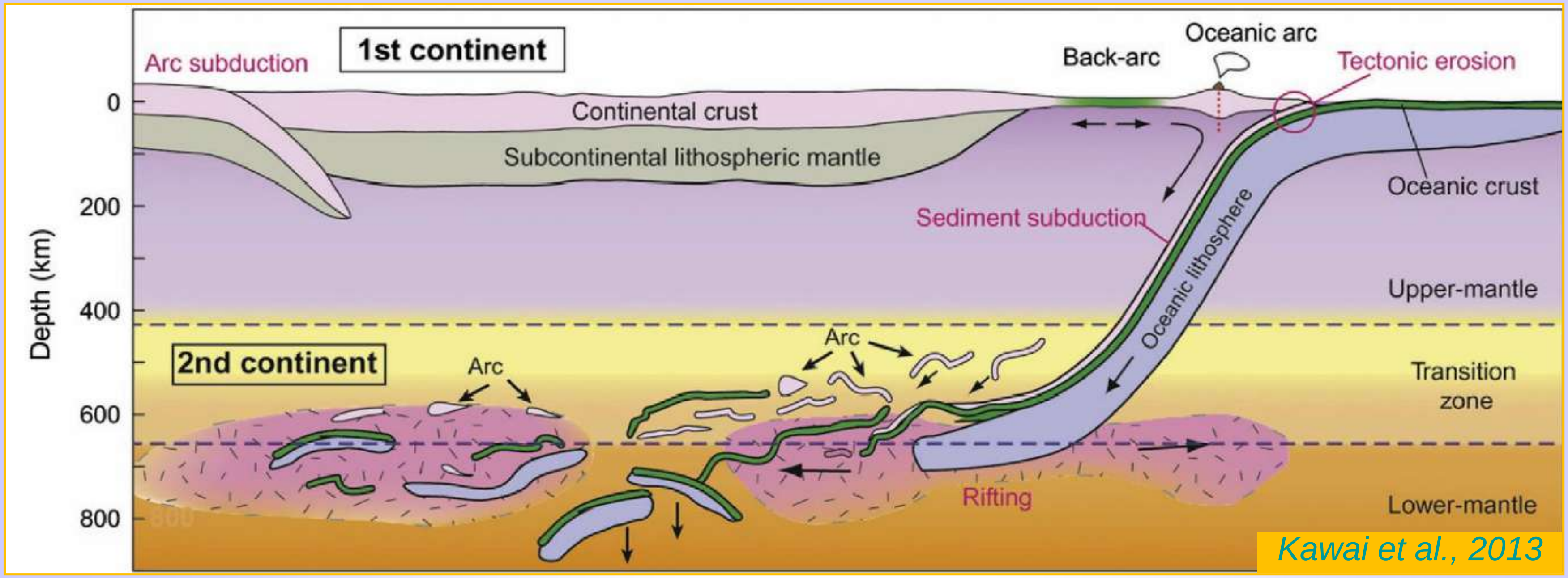
Global long-term estimates for crust formation and destruction



Clift et al., 2009

Crust volume balance: **- 0.55 km^3/year**

Indirect consequences of tectonic erosion:
various materials can be tectonically eroded at PCMs



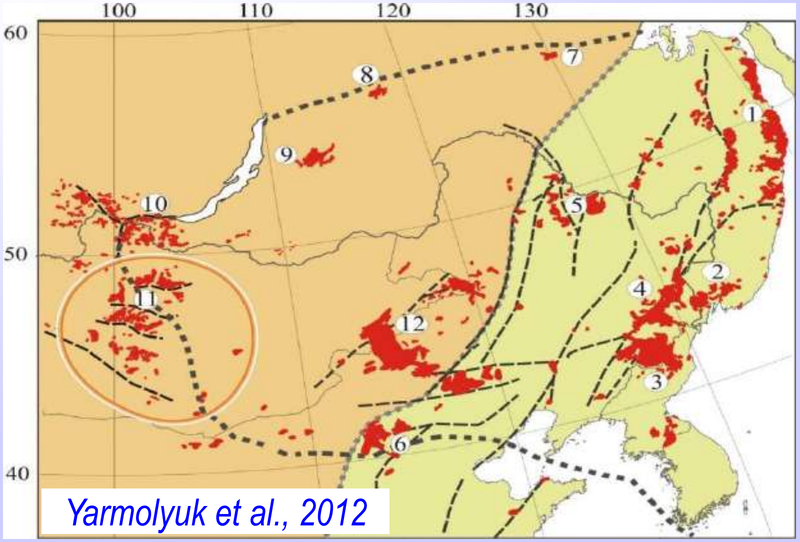
Kawai et al., 2013

Materials subducting to the deep mantle:

(i)   **hydrated and carbonated material of oceanic crust/OPS**: source of **water and CO_2**;

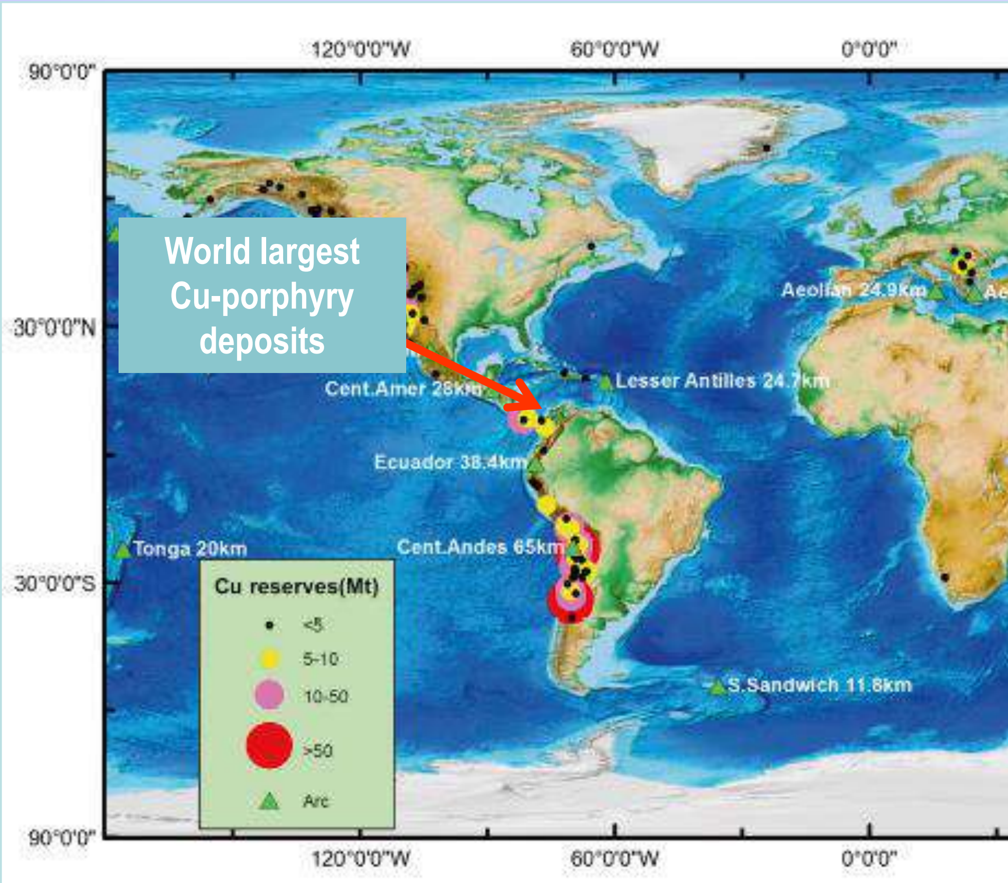
(ii) **continental crust material**: source of **U,Th, K**;

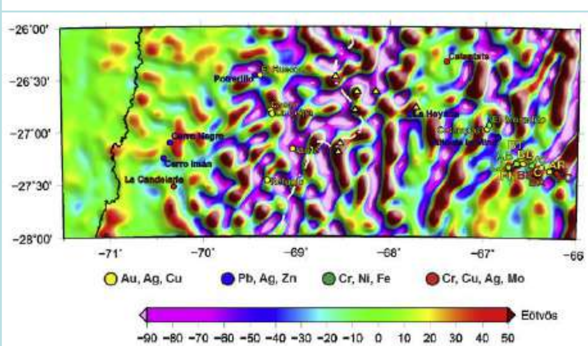
(iii) dehydrated **MORB**: source of **Ti, Nb** (?)

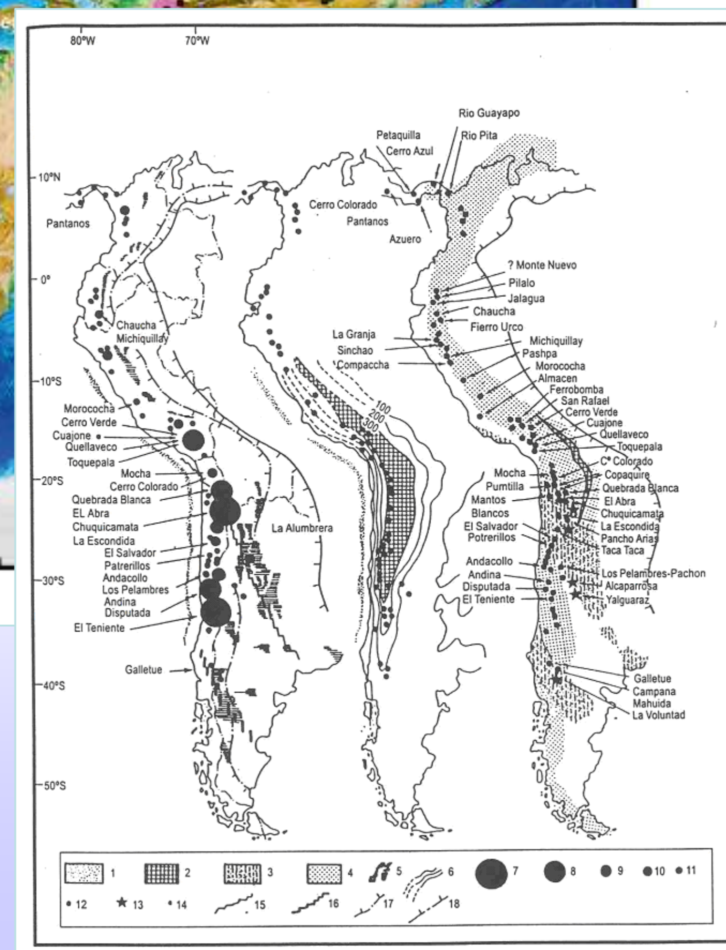


Yarmolyuk et al., 2012

Indirect consequences of tectonic erosion: enhancement of ore mineralization



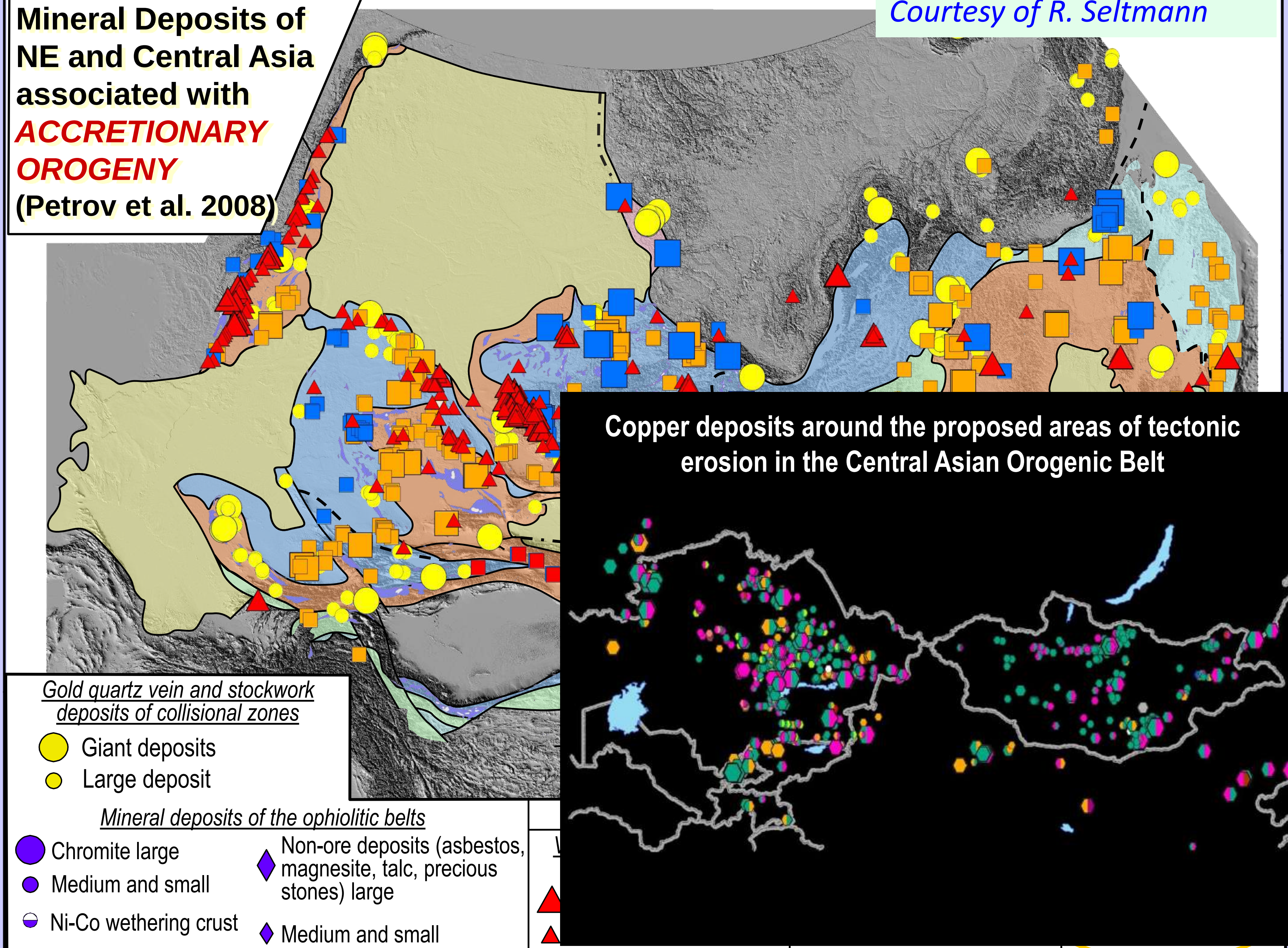




Gimenez et al., 2019

Mineral Deposits of NE and Central Asia associated with *ACCRETIONARY OROGENY*
(Petrov et al. 2008)

Courtesy of R. Seltmann



Conclusions

1. Tectonic erosion is a **typical phenomenon at modern convergent margins** of the Circum-Pacific.

2. The **data and methodology** from South America and Japan can be applied in fossil P-type orogenic belts, like the **CAOB**

3. The most promising areas of tectonic erosion in the CAOB are eastern and central **Kazakhstan, Tienshan** and **Transbaikalia-northern Mongolia**

4. A huge volume of juvenile continental crust was tectonically eroded and **disappeared from the surface**.

5. **Tectonic erosion** may change mantle composition and conditions, trigger mantle plumes and related **intra-plate magmatism** and contribute to the formation of mineral deposits.

Kazakhstan-2016