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*THE REAL SCIENCE

Tectonic erosion at Pacific-type convergent margins: evidence from the western Central Asian Orogenic Belt

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Makuhari Messe
Chiba, Japan

Novosibirsk Scientific Center

Novosibirsk

Novosibirsk State University

Novosibirsk – Japan cooperation

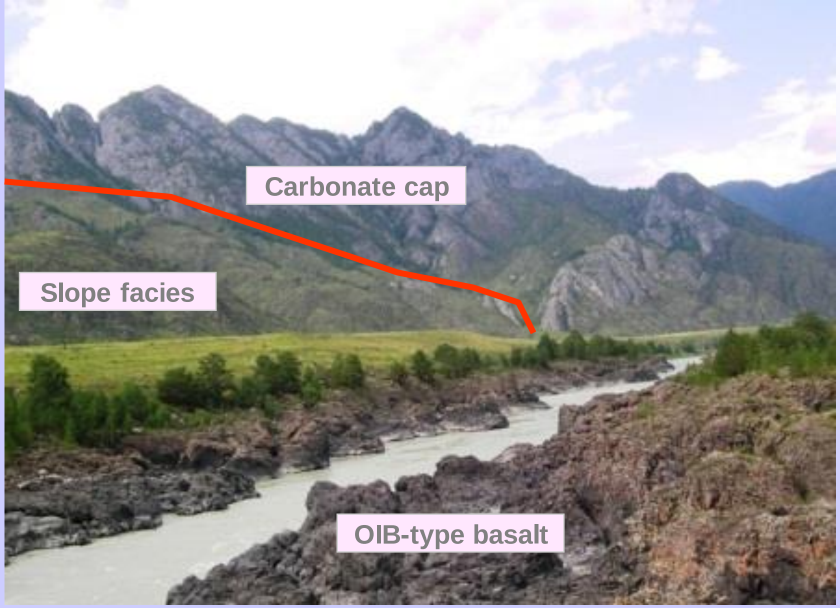
Hokkaido University
1992-2002
T. Watanabe
Altai-Japan correlations

Tokyo Institute of Technology
1995 - present
S. Maruyama
OPS, accretionary orogeny, mantle plumes

Tohoku University
1999 (?) - present
E. Ohtani
Deep mantle and core structure

Tokyo University
2010 - present
T. Komiya
Pacific-type orogeny worldwide

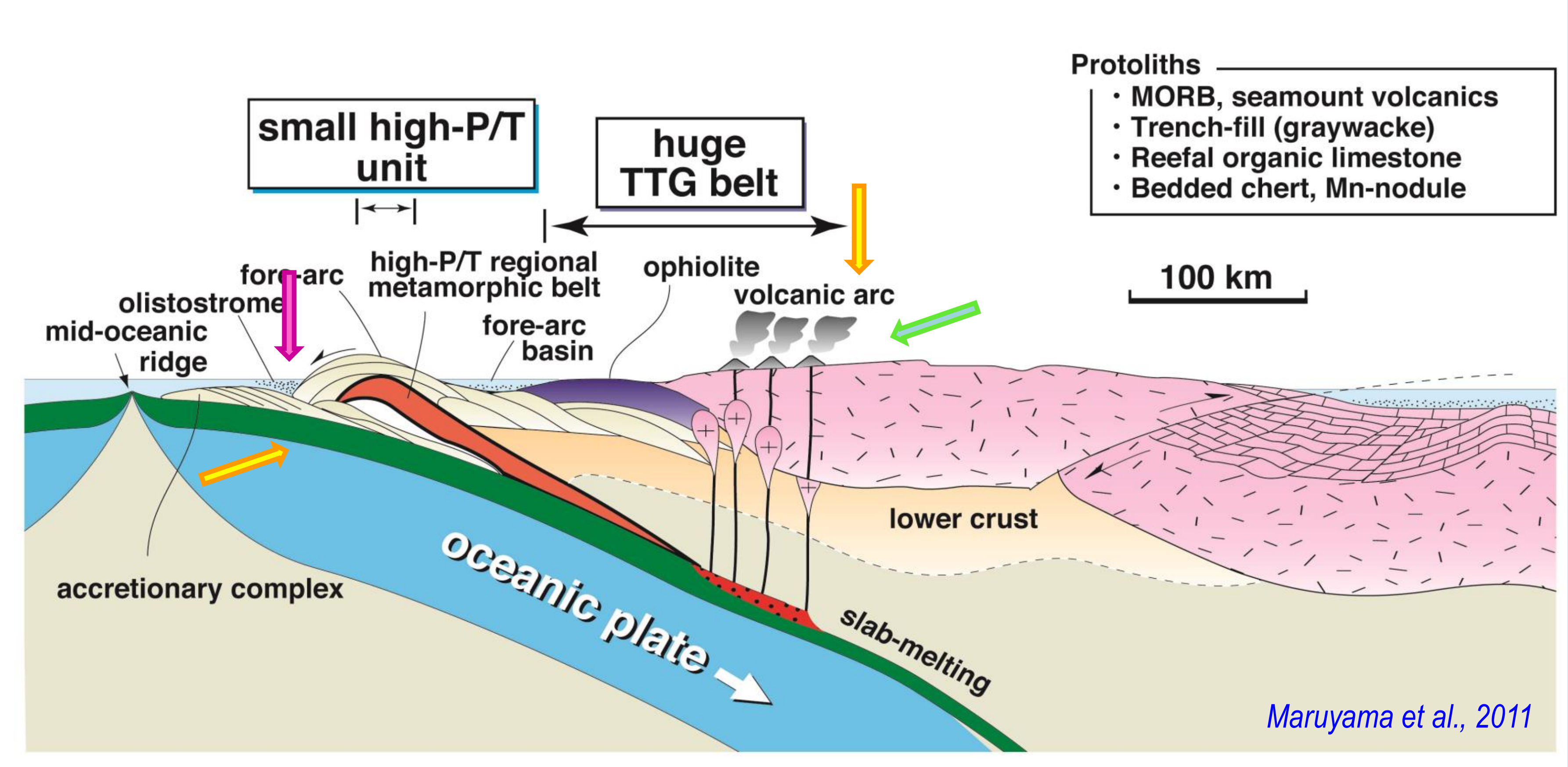
Russian Altai, 2008 and 2010:
Japanese-Russian field mission and conference trip



Laboratory of Evolution of Paleo-Oceans and Mantle Magmatism
*LEPO**M**;* [*http://lepom.nsu.ru/*](http://lepom.nsu.ru/)

A multidisciplinary study of Pacific-type orogenic belts and development of a holistic model linking evolution of oceans, their active margins and mantle magmatism

Pacific-type (P-type) convergent margin

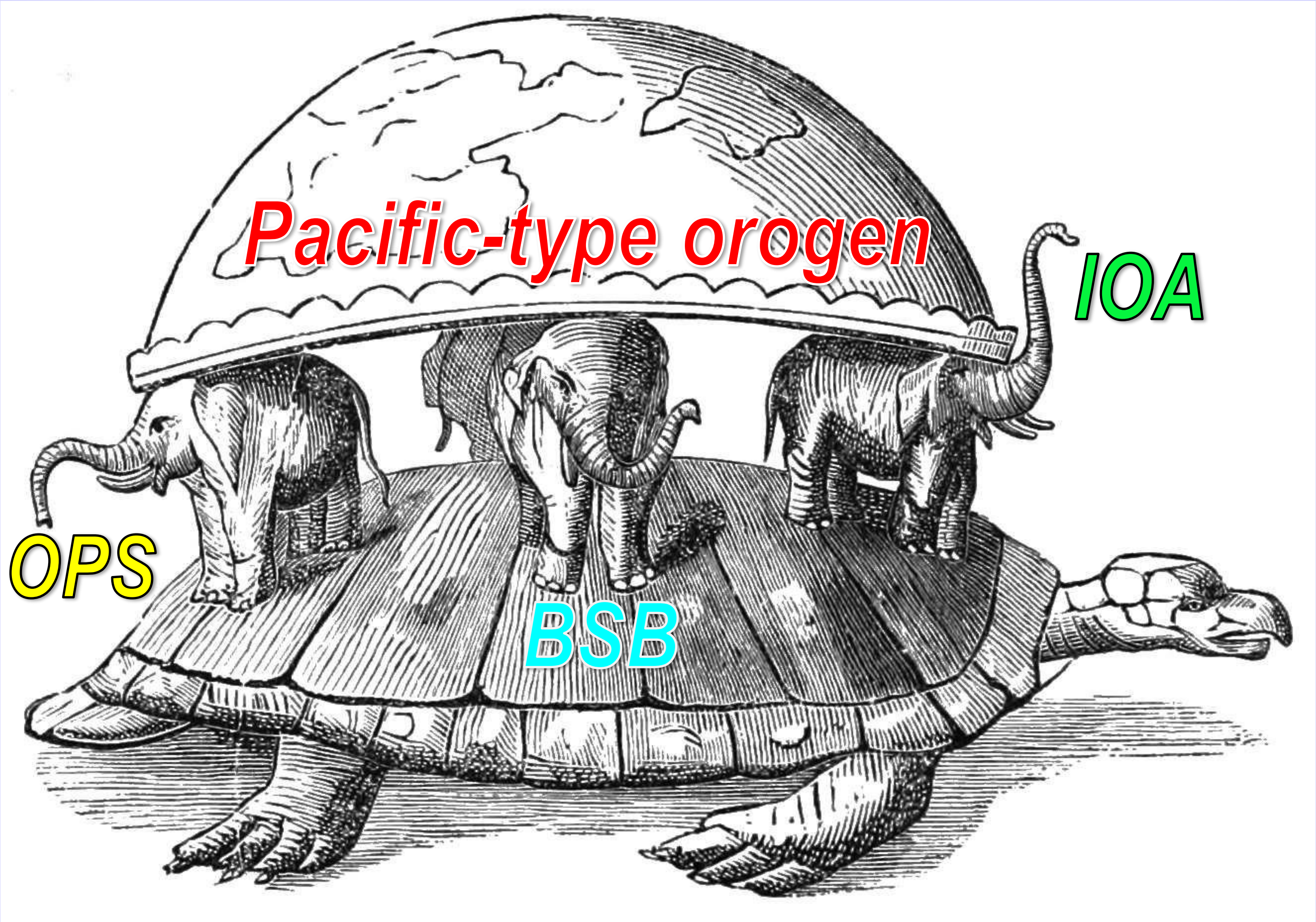


P-type margins exist over subduction zones, where oceanic lithosphere is submerged under intra-oceanic arcs or active continental margins. P-type margins provide **major continental growth** through **juvenile magmatism** and **accretion**.

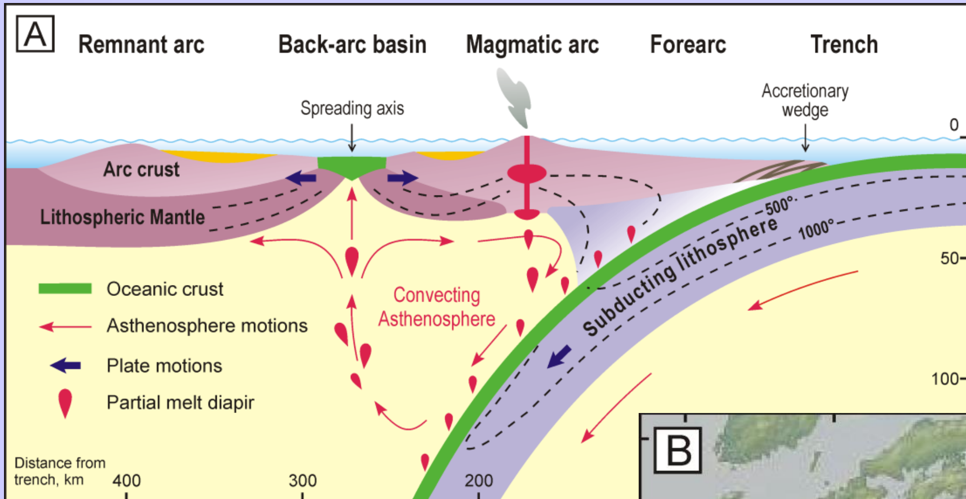
P-type margins are also places of strong plate interactions and **crust destruction**.

P-type margins are **the only place on Earth** where surface materials can be subducted to **the deep mantle**

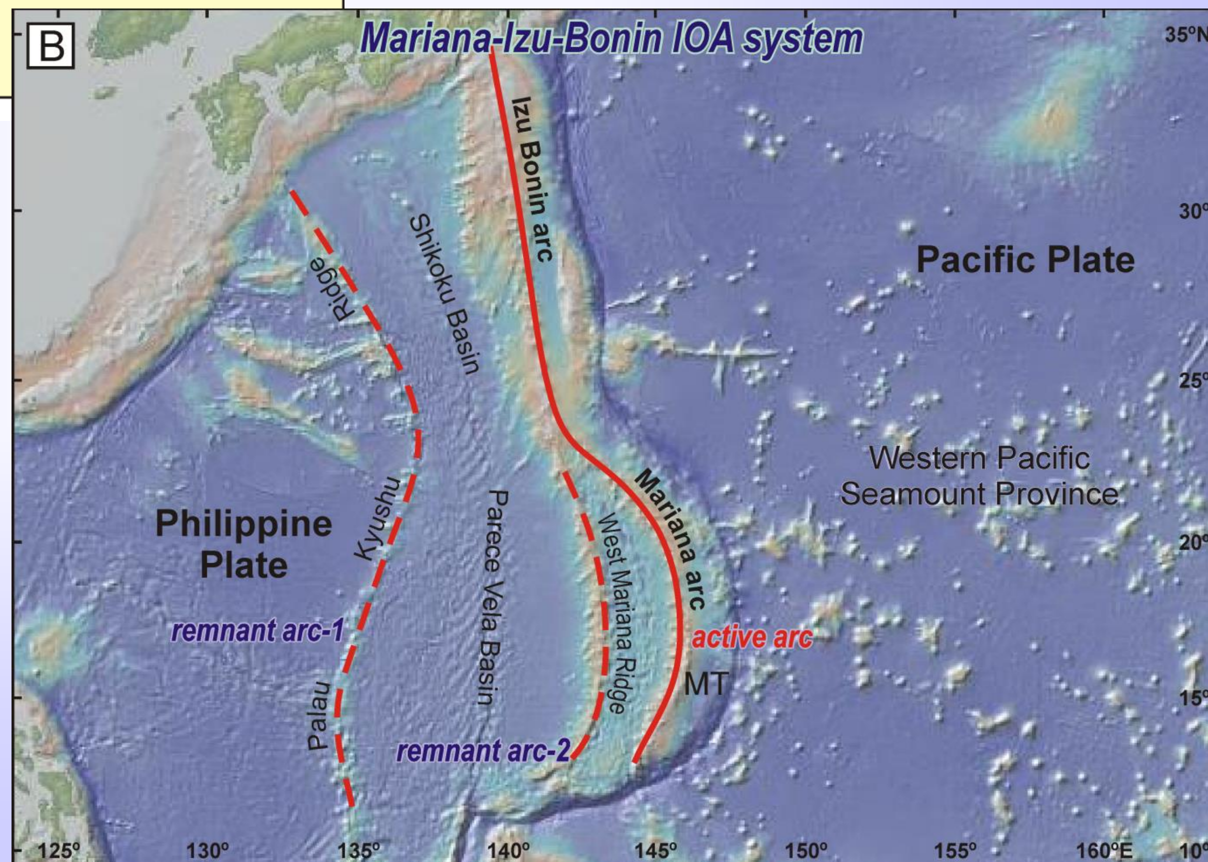
Major diagnostic elements of P-type orogenic belts



Element 1: Intra-Oceanic Arcs



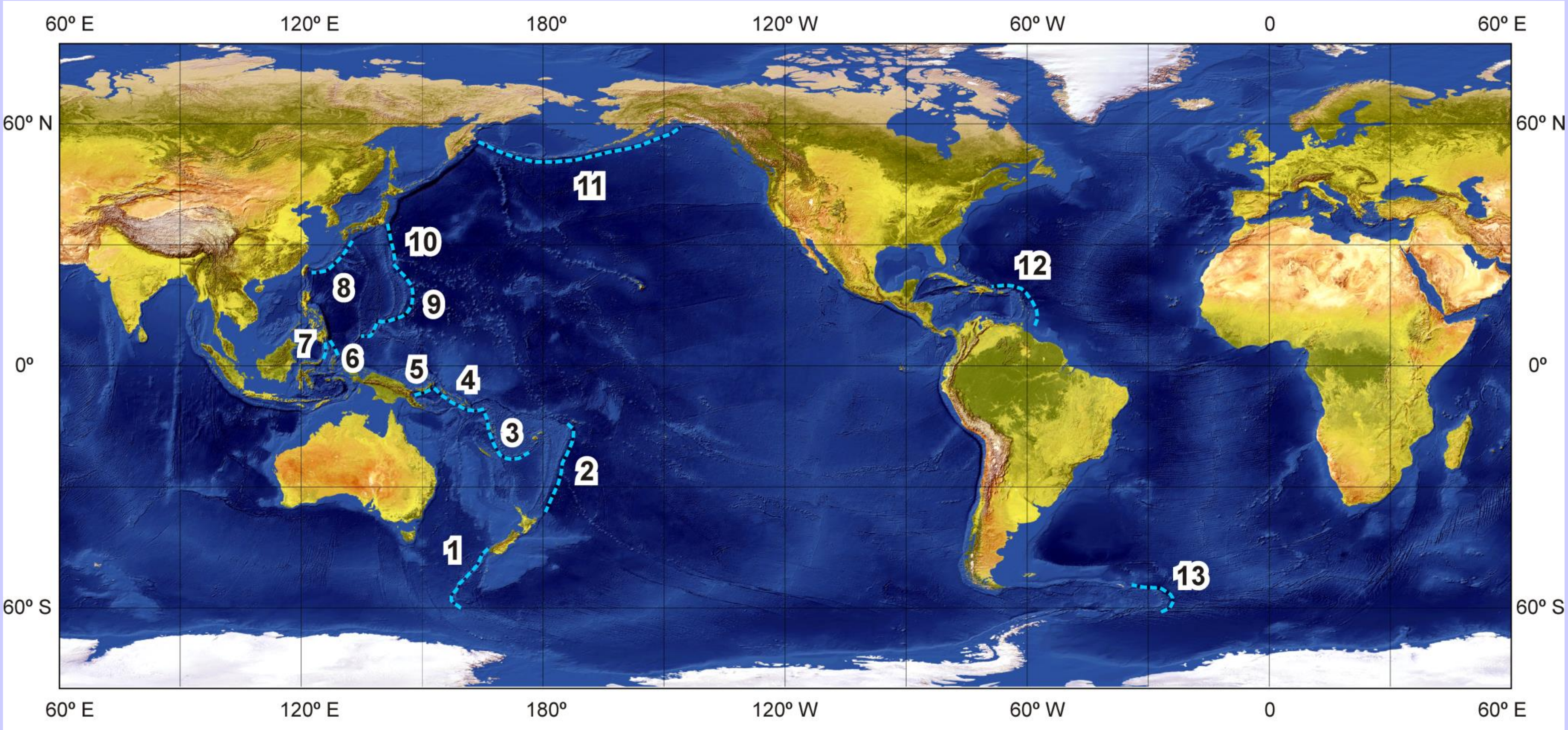
A schematic model of intra-oceanic arc system including a back-arc basin (modified from Stern, 2010)



Major topographical and tectonic features of the Izu-Bonin and Mariana arc systems (modified from Straub et al., 2015).

Modern intra-oceanic arc systems of the world

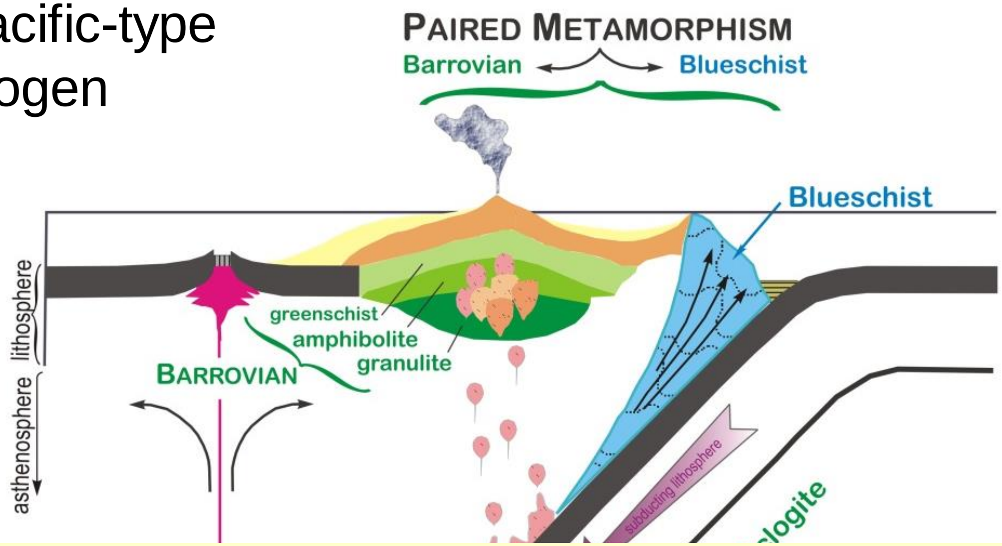
(Leat and Larter, 2003)



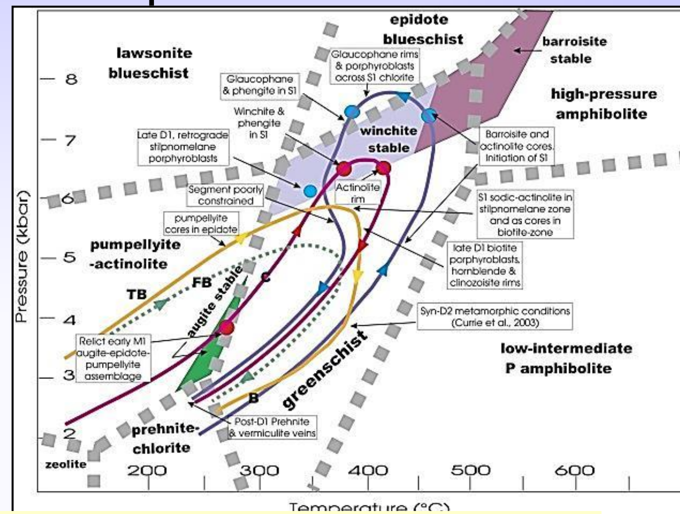
1 – MacQuarie; 2 – Tonga-Kermadec; 3 – Vanuatu; 4 – Solomon; 5 – New Britain; 6 – Halmahara; 7 – Sangihe; 8 – Ryuku; 9 – Mariana; 10 – Izu-Bonin; 11 – Aleutian; 12 – Lesser Antilles; 13 – South Sandwich.

Element 2: Blueschist Belts

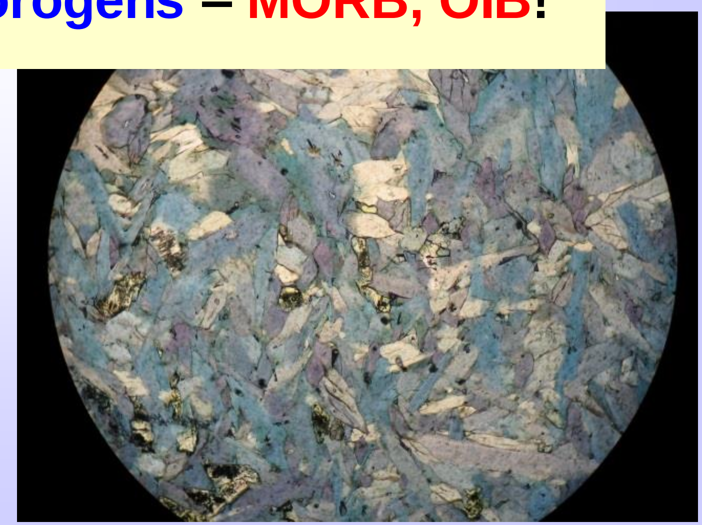
Pacific-type orogen



P–T path of HP/LT rocks



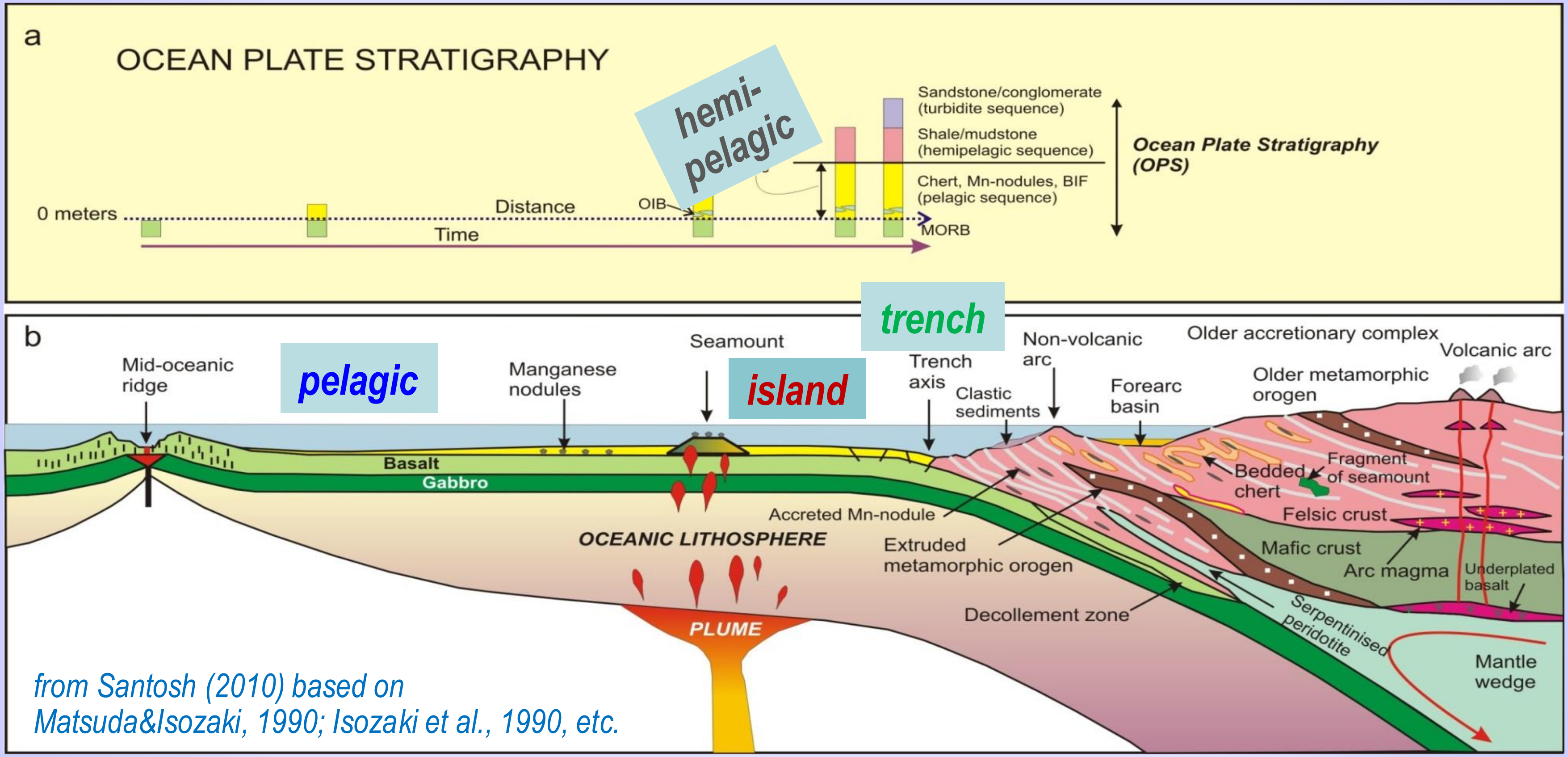
Protolith of blueschists in Pacific-type orogens – MORB, OIB!



Typical outcrops of blueschists

Element 3: Ocean Plate Stratigraphy

Ocean Plate Stratigraphy (OPS) implies a regular succession of igneous and sedimentary rocks of the oceanic lithosphere, which were, respectively, erupted and deposited on the sea floor as the underlying oceanic basement traveled from mid-oceanic ridge to subduction zone.

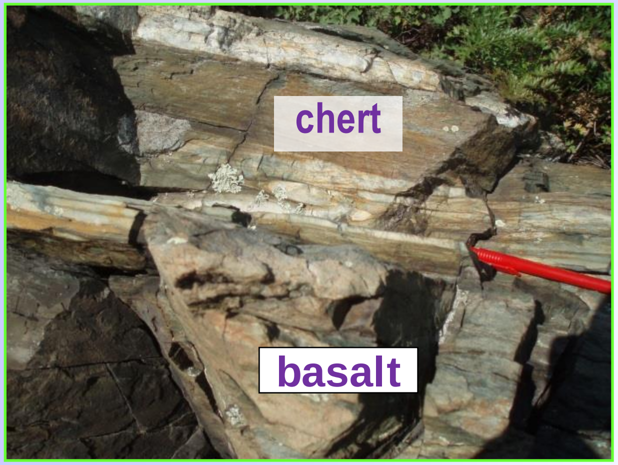


from Santosh (2010) based on Matsuda&Isozaki, 1990; Isozaki et al., 1990, etc.

1. **Pelagic** sediments and MORB, sheeted-dike complex, gabbro, and ultramafics: oceanic floor.
2. **Hemipelagic** siliceous shale and mudstone: close to trench
3. **Trench** turbidite, greywacke and conglomerate: trench axis
4. **Oceanic island/seamount/plateau:** OIB-type basalt capped by carbonates and slopes facies

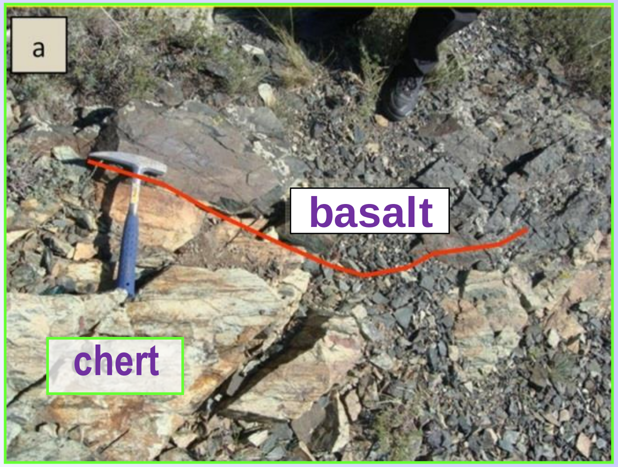
OPS pelagic formations

Zasur'ya AC, L. Camb., Russian Altai

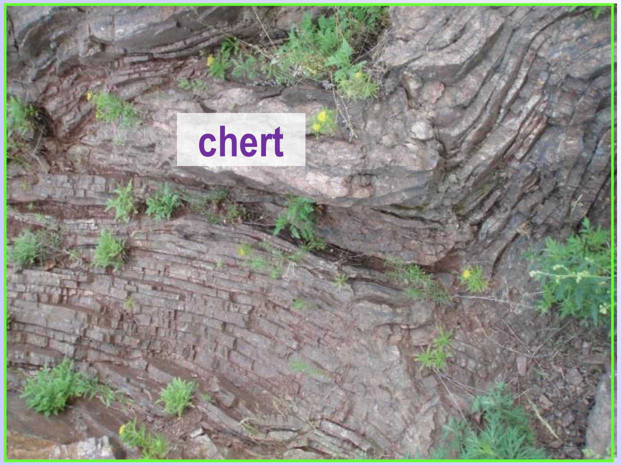


Adaastag AC, L. Silurian, Mongolia

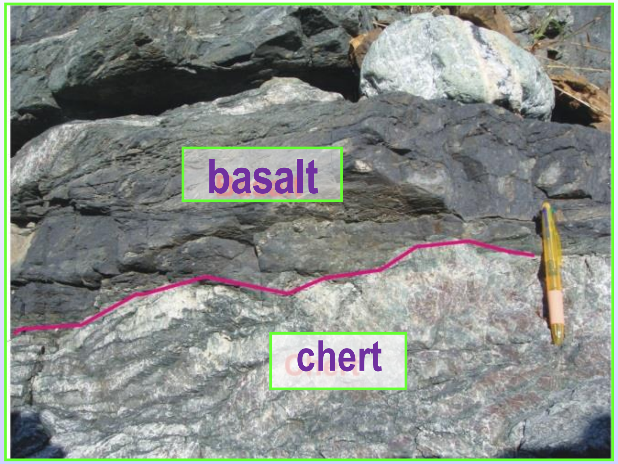
Char AC, L. Devon., E. Kazakhstan



Khabarovsk AC, Triassic, E. Russia



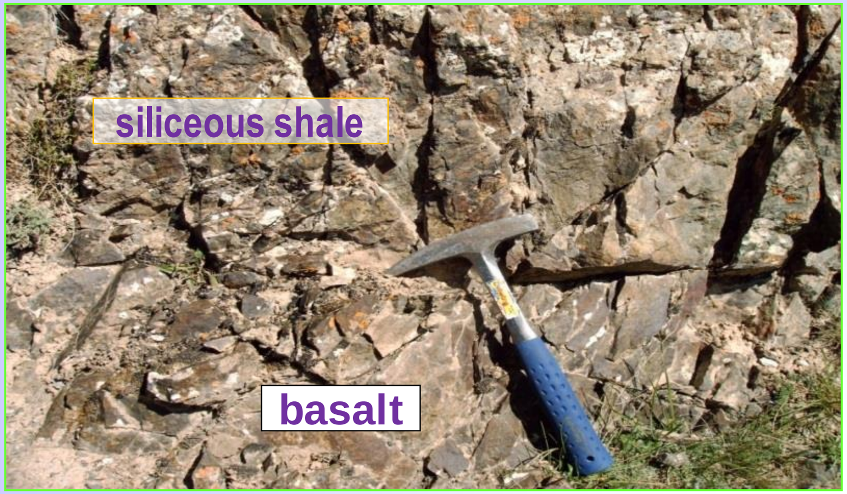
Chichibu AC, Jurassic, SE Japan



Shimanto AC, Cretaceous, SE Japan

OPS: hemipelagic formations

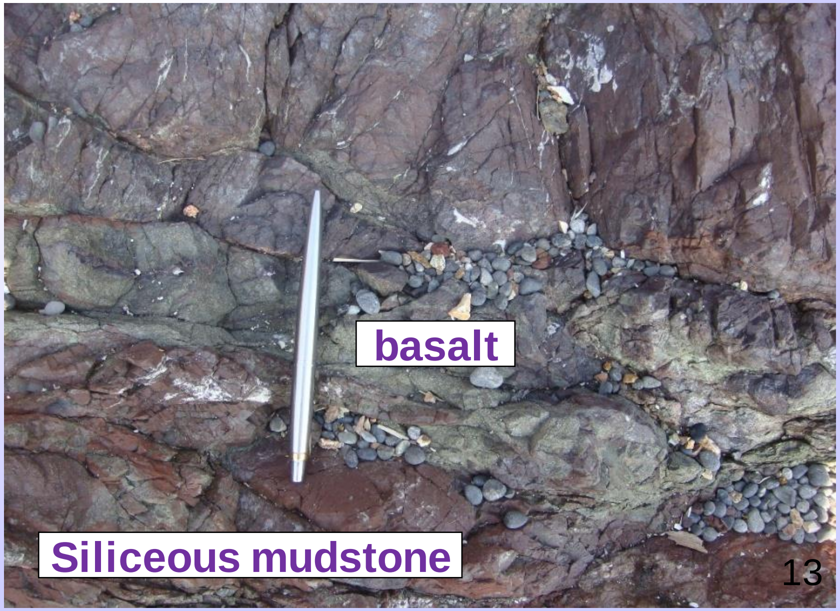
Kokshaal AC, M. Devonian, Kyrgyz Tienshan



Khabarovsk AC, L. Carboniferous; E. Russia

Mino-Tamba AC, Triassic, central Japan

Shimanto AC, Cretaceous, SE Japan



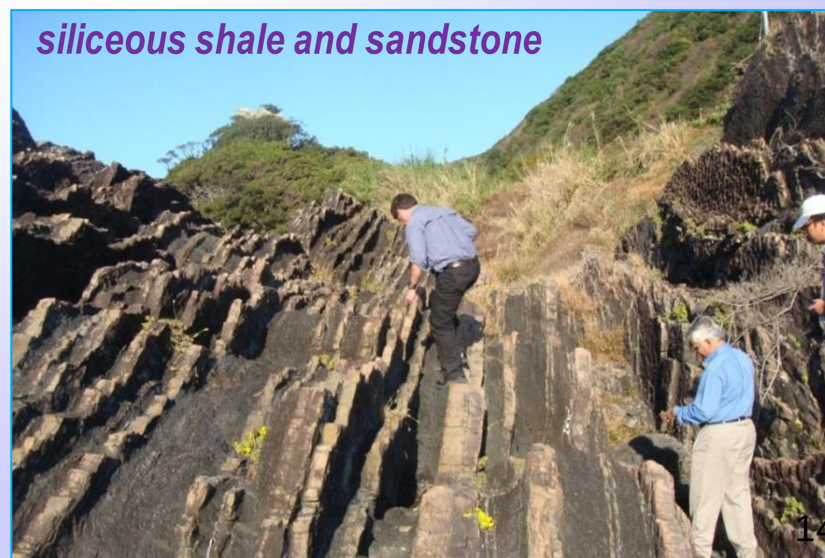
OPS: trench formations

Kurai AC, L. Neoproterozoic, Russian Altai

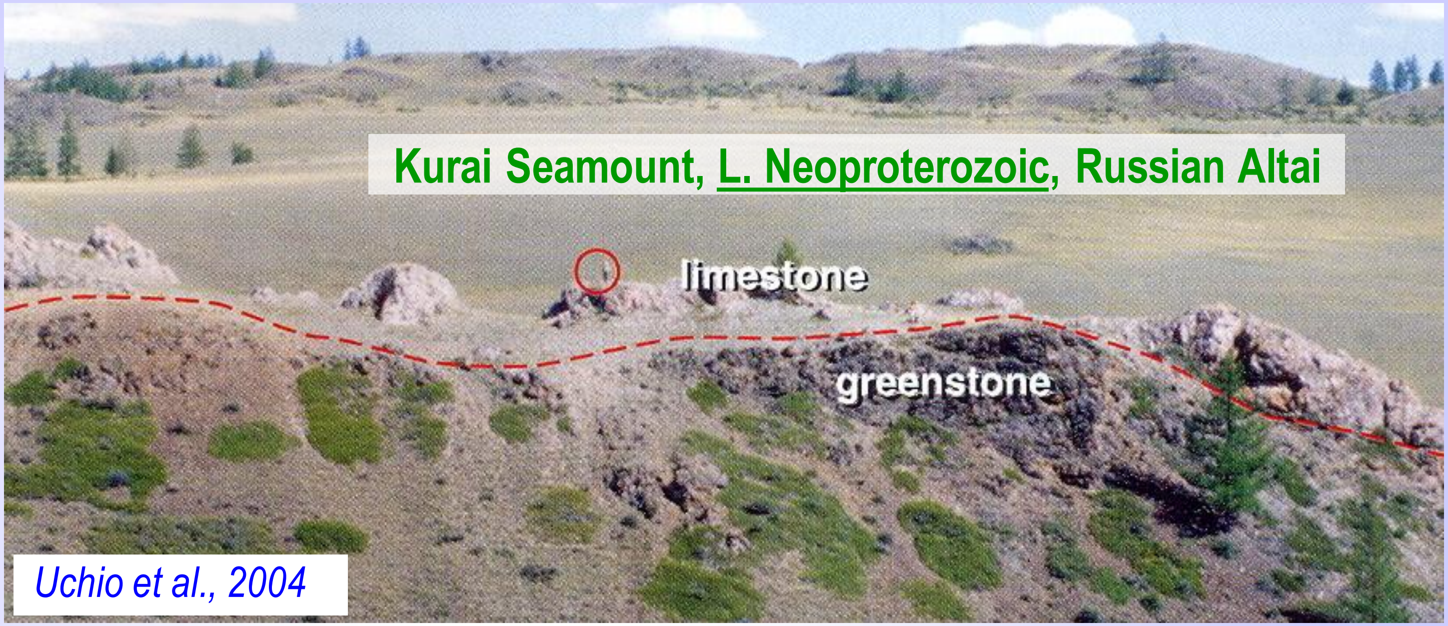
Katun AC, E. Cambrian, Russian Altai

Mino-Tamba AC, Triassic, SE Japan

Shimanto AC, Cretaceous, SE Japan



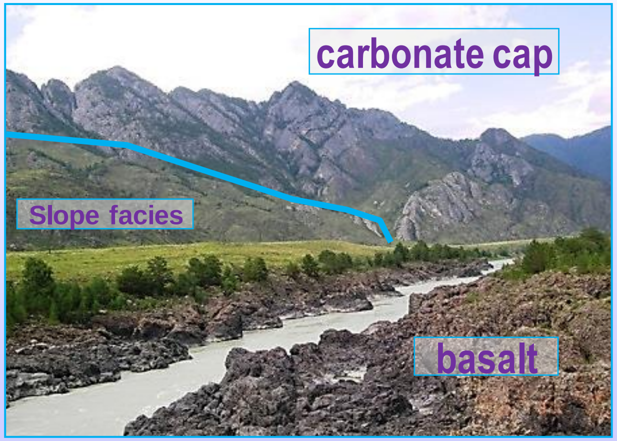
Accreted Oceanic islands



Kurai AC, L. Neoproterosoic OPS, Russian Altai

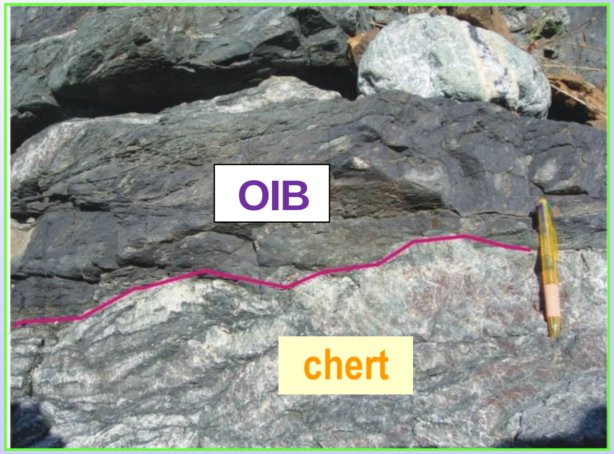
Buslov et al., 2002

Katun AC, E. Cambrian OPS, Russian Altai



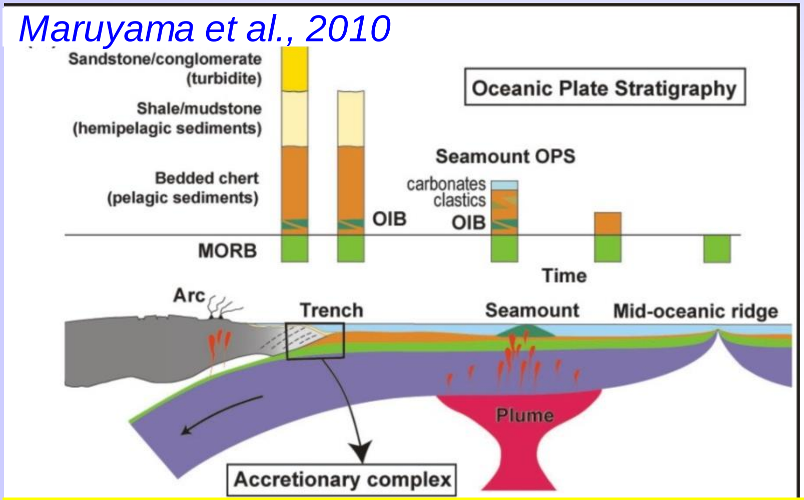
Safonova et al., 2011

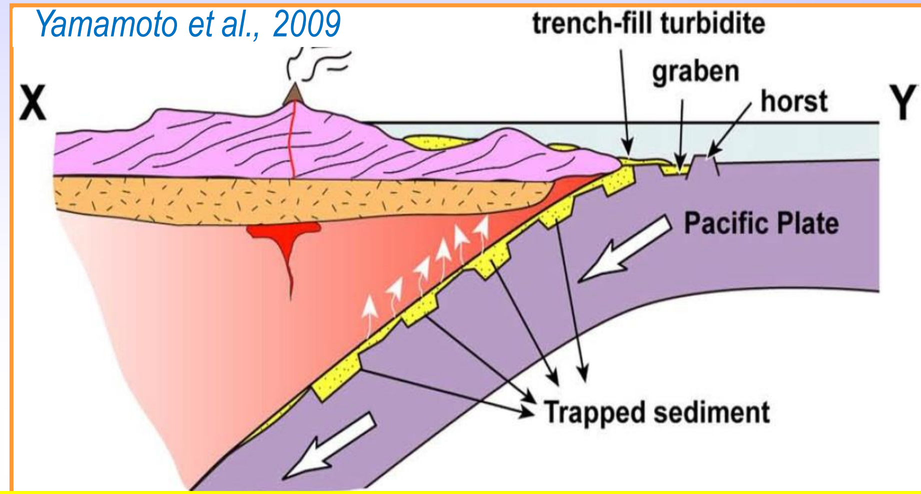
Khabarovsk AC, Triassic OPS, Russian Far East



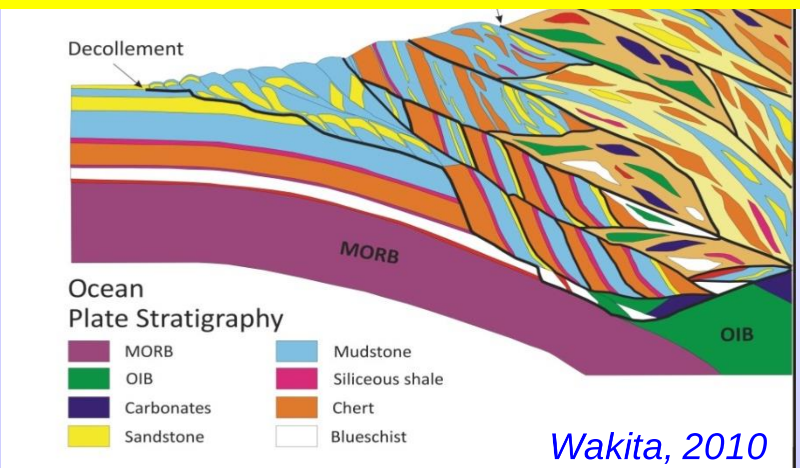
Safonova et al., 2015

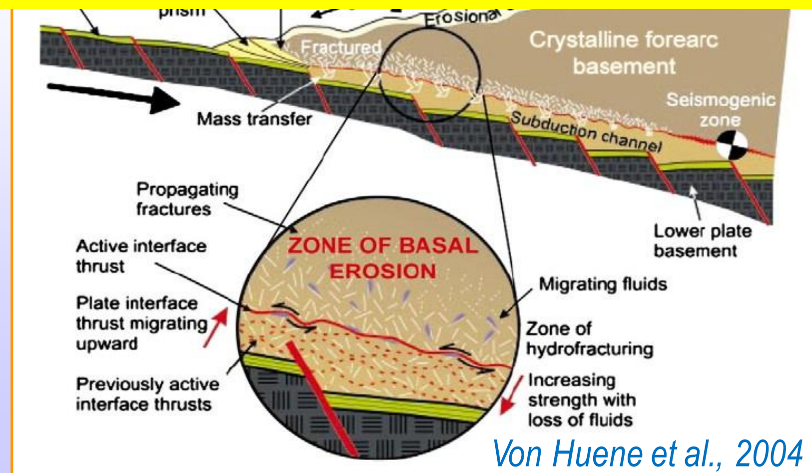
Observation #1: at P-type convergent margins subducting oceanic crust can be accreted or subducted and arc materials can be tectonically eroded and also subducted



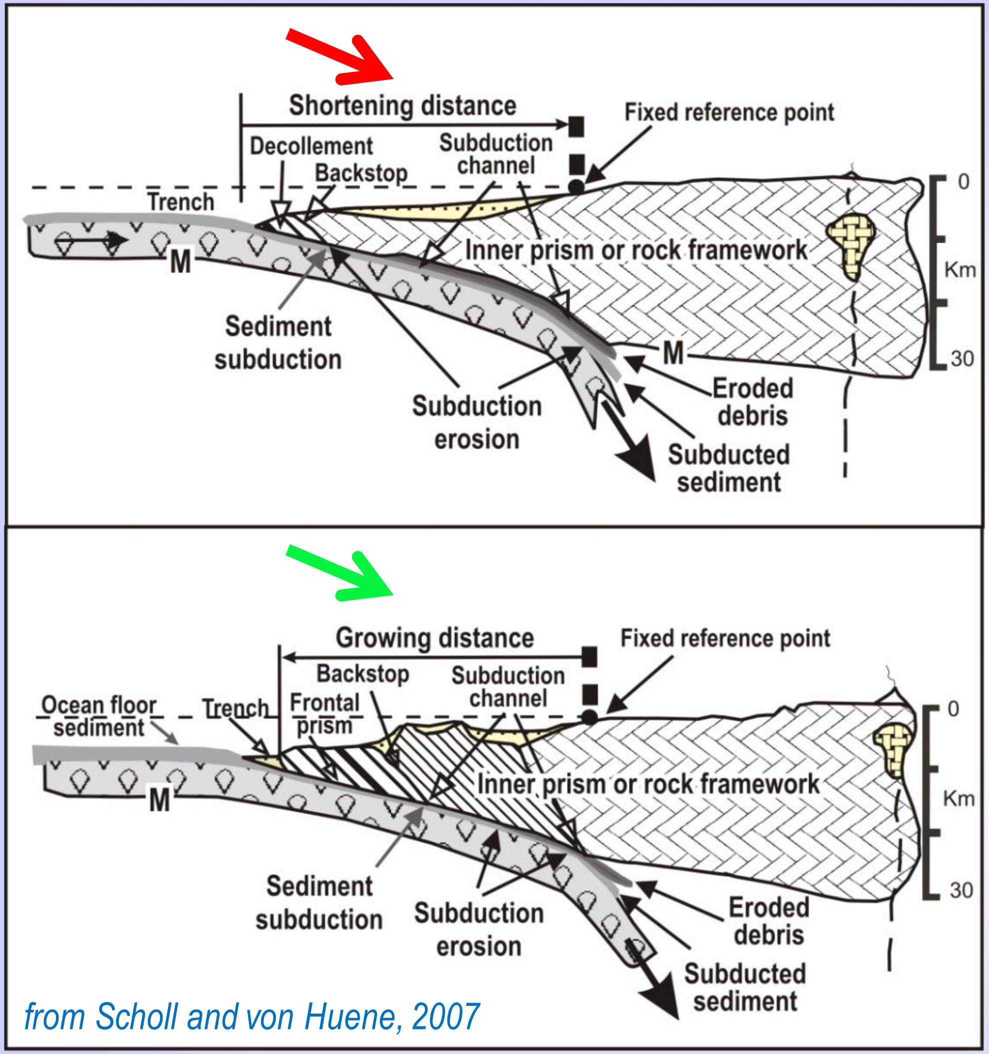


Tectonic erosion is **destruction** of oceanic slab, island arcs, accretionary prism and fore-arc by thrusting, oceanic floor relief (horst/graben), (hydro)fracturing





Eroding and accreting P-type convergent margins

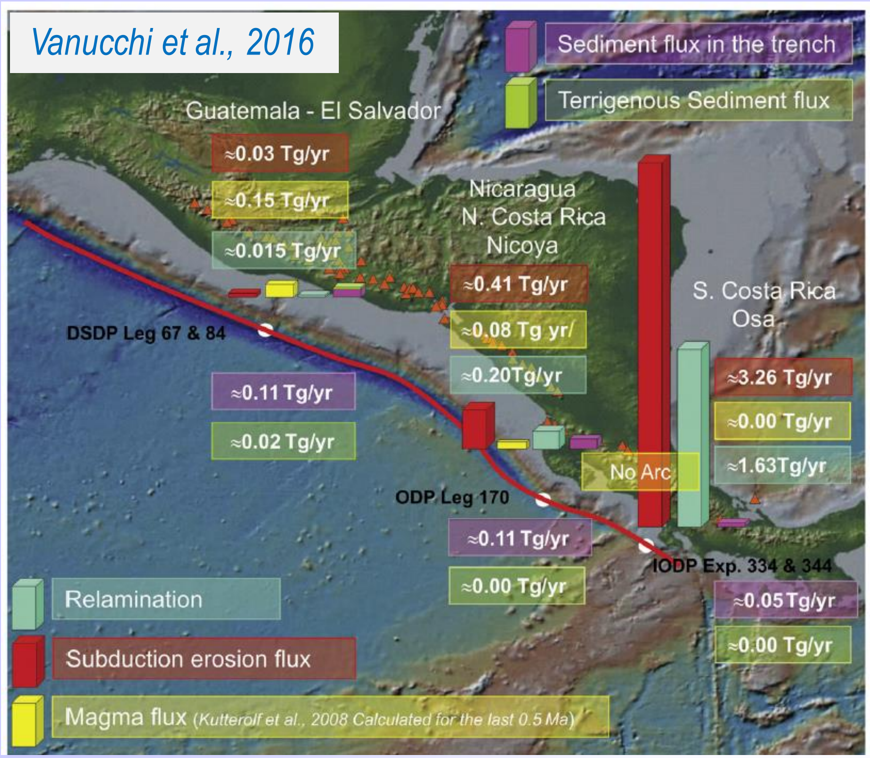


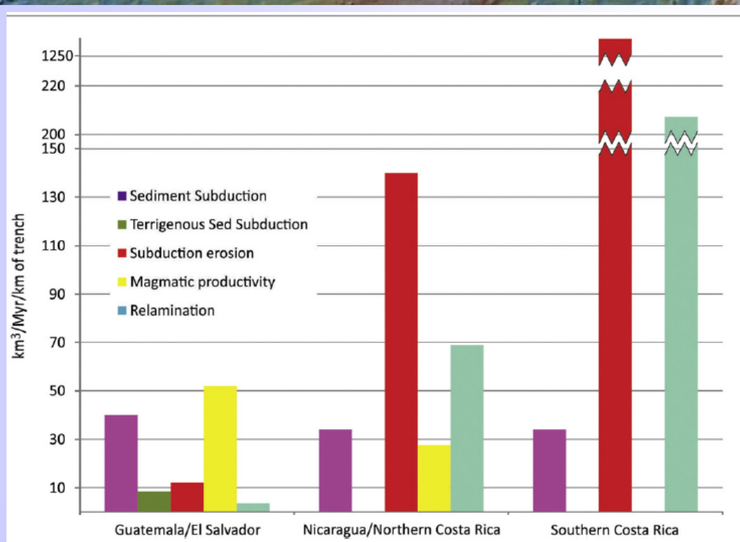
Eroding or non-accreting margins are characterized by the close approach of the margin's rock framework to the trench and small or lacking older prisms of accreted lower plate sediment. With time, eroding margins narrow with respect to a reference point on the margin; i.e., the trench advances landward.

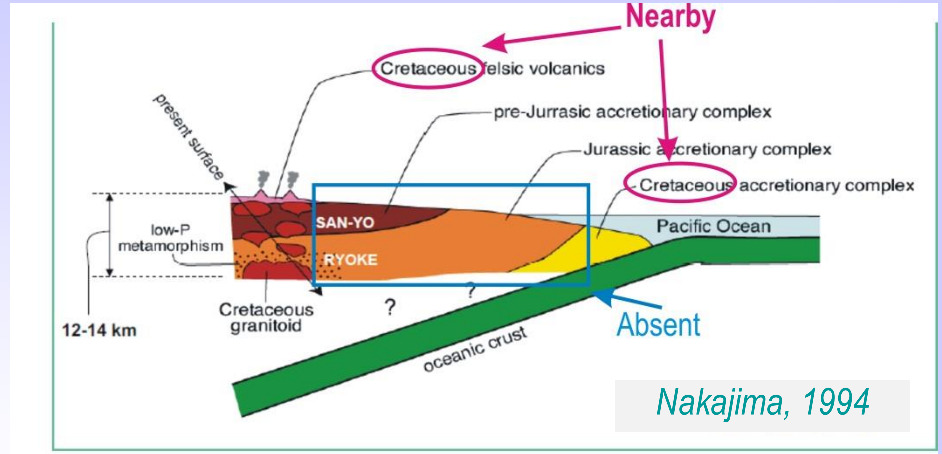
Accreting or growing margins are characterized by rocks deeply buried under thick older accreted units and frontal prism of actively deforming sediment scraped off the subducting plate. With time, accreting margins widen, i.e., the trench retreats seaward.

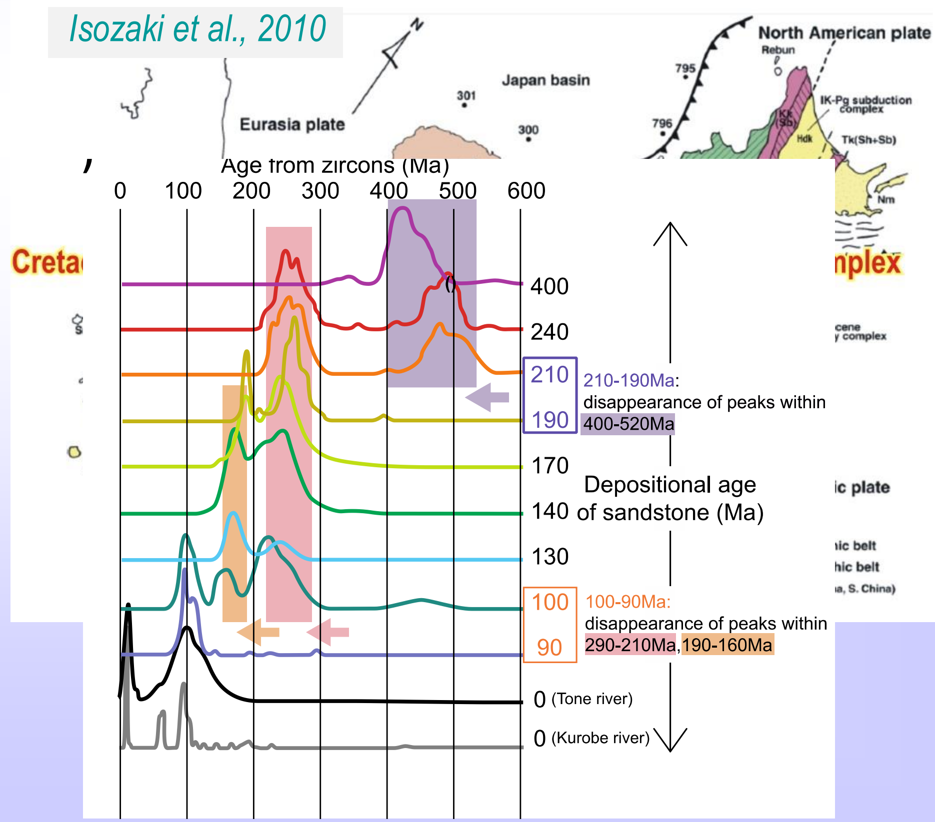
The longer are the periods of tectonic erosion and subduction, the larger will be the volume of the material arriving to the mantle. Therefore, it is very important to highlight the periods of tectonic erosion in fossil P-type belts to evaluate the amount of the surface material eroded in the past.

Many proved cases of tectonic erosion

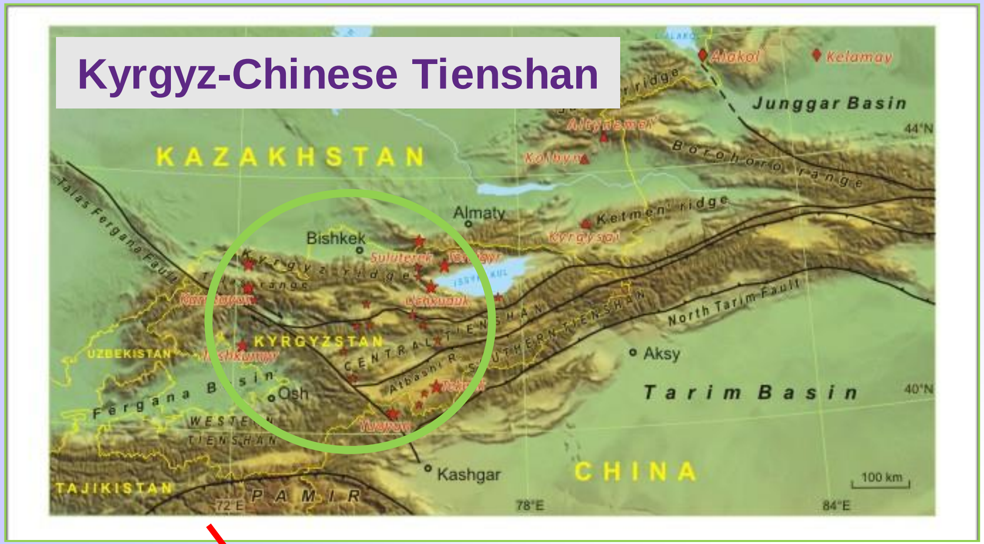


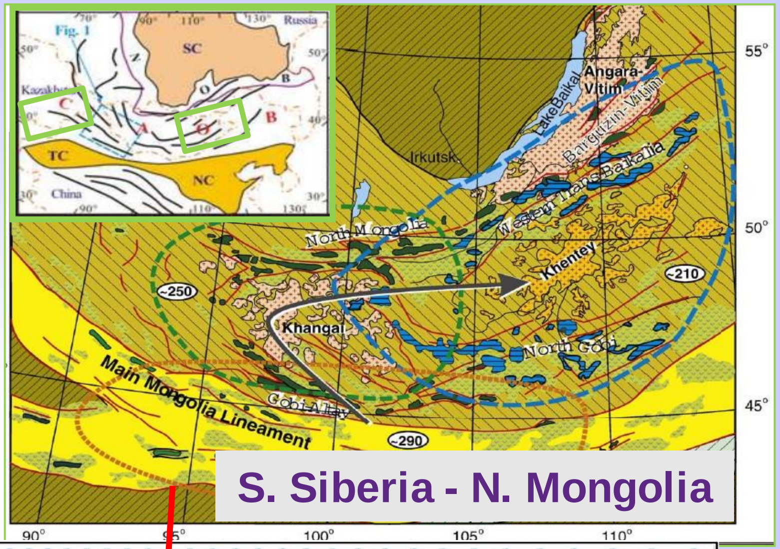


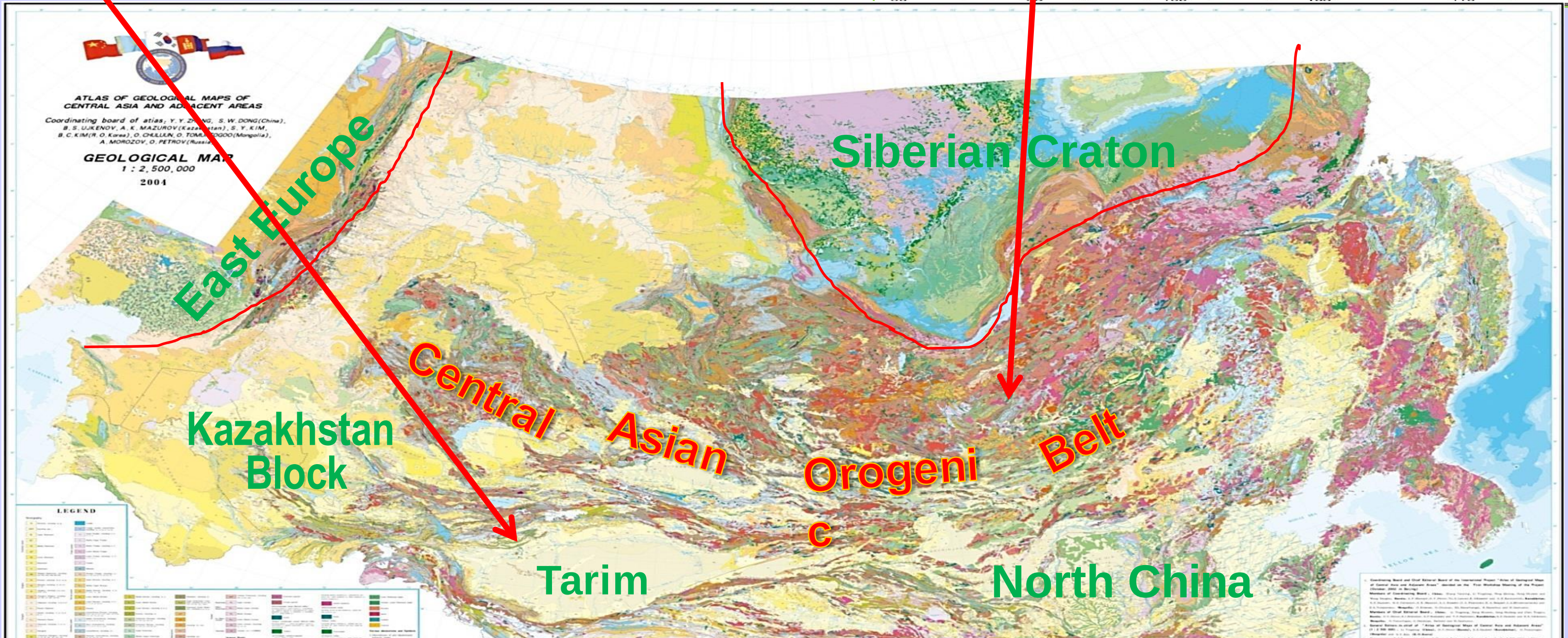




Mesozoic-Cenozoic mantle volcanism of Central Asia: also linked to oceanic subduction?



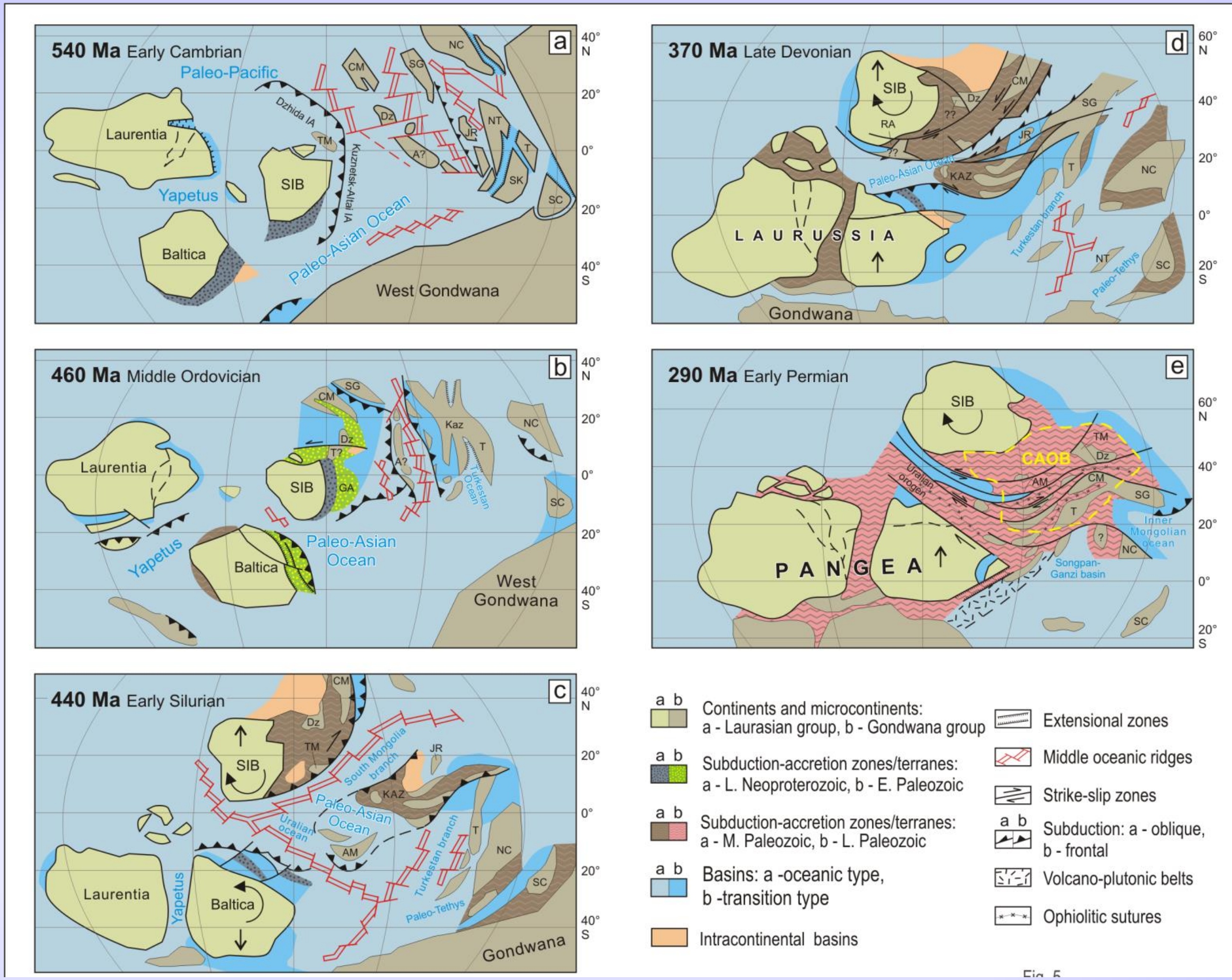




Base map from "Atlas of Geological Maps of Central Asia and Adjacent Areas (2008)" reproduced with permission of Chinese Academy of Geological Sciences, Beijing.

Paleo-Asian Ocean and formation of the CAOB

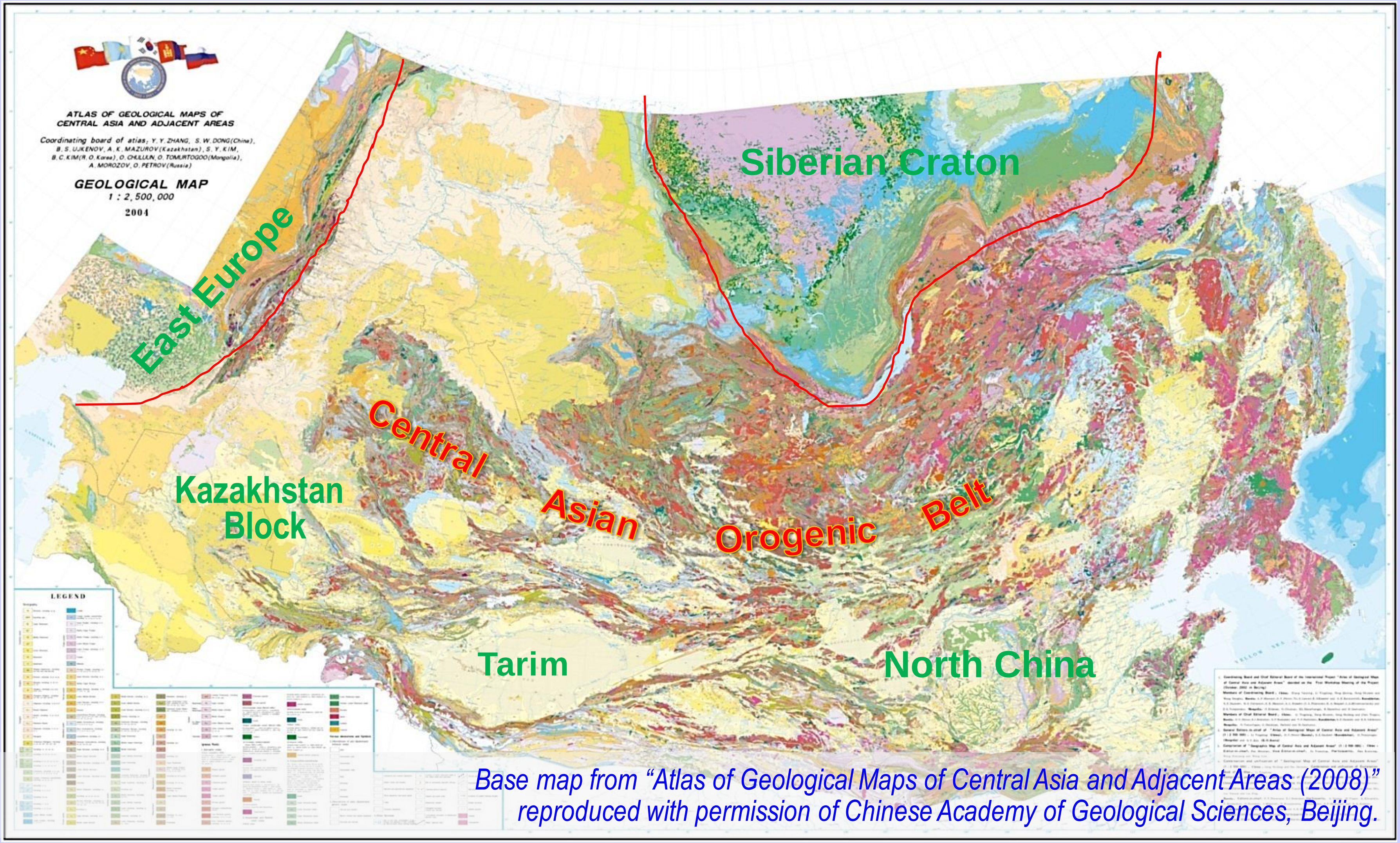
Safonova et al., 2017



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.

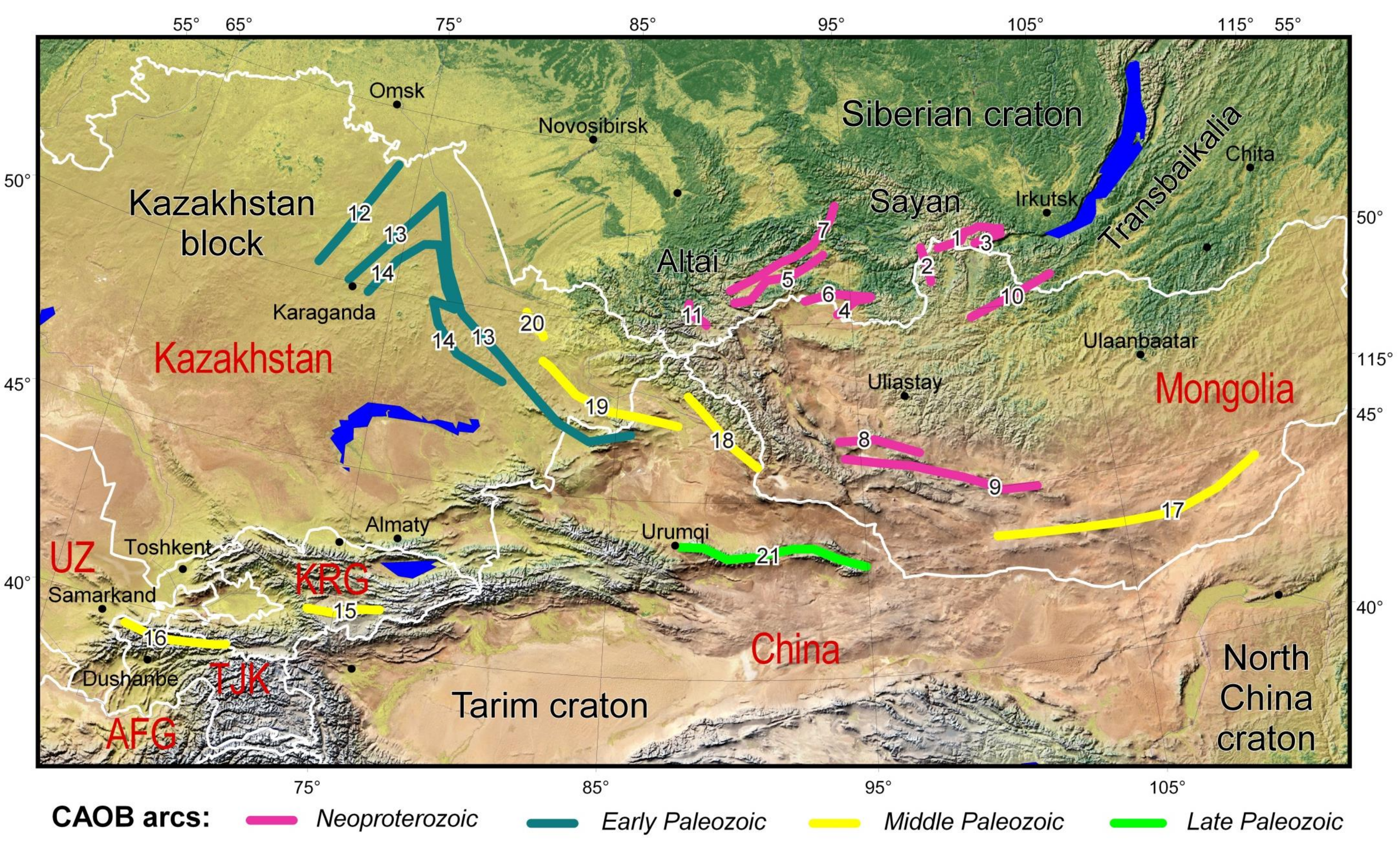
Zonenshain et al. 1990 ; Didenko et al., 1994; Buslov et al. 2001, 2004; Filippova et al. 2001; Kurenkov et al., 2002; Khain et al. 2003; Kheraskova et al. 2003; Torsvik&Cocks, 2017

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



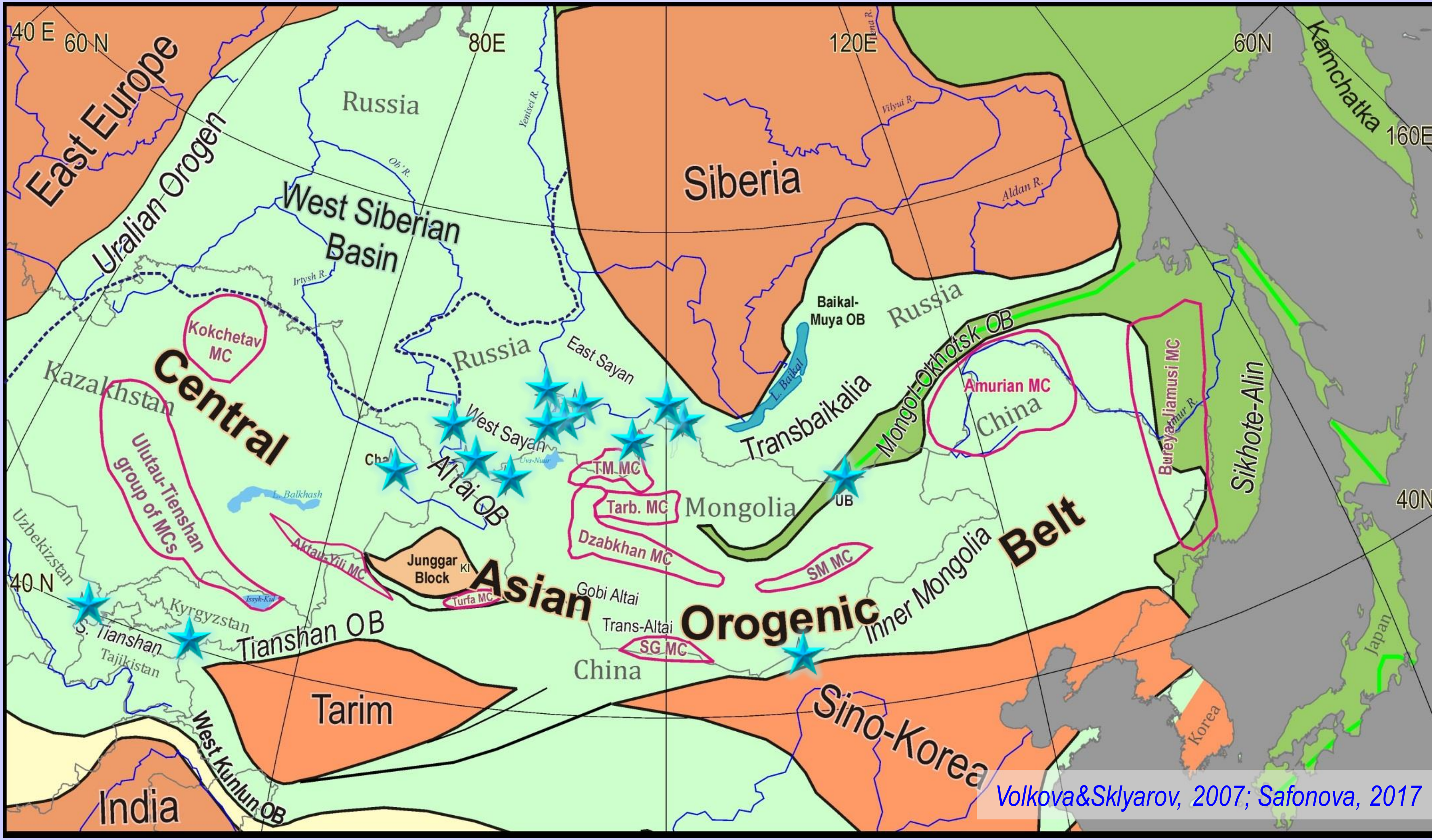
Base map from "Atlas of Geological Maps of Central Asia and Adjacent Areas (2008)" reproduced with permission of Chinese Academy of Geological Sciences, Beijing.

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



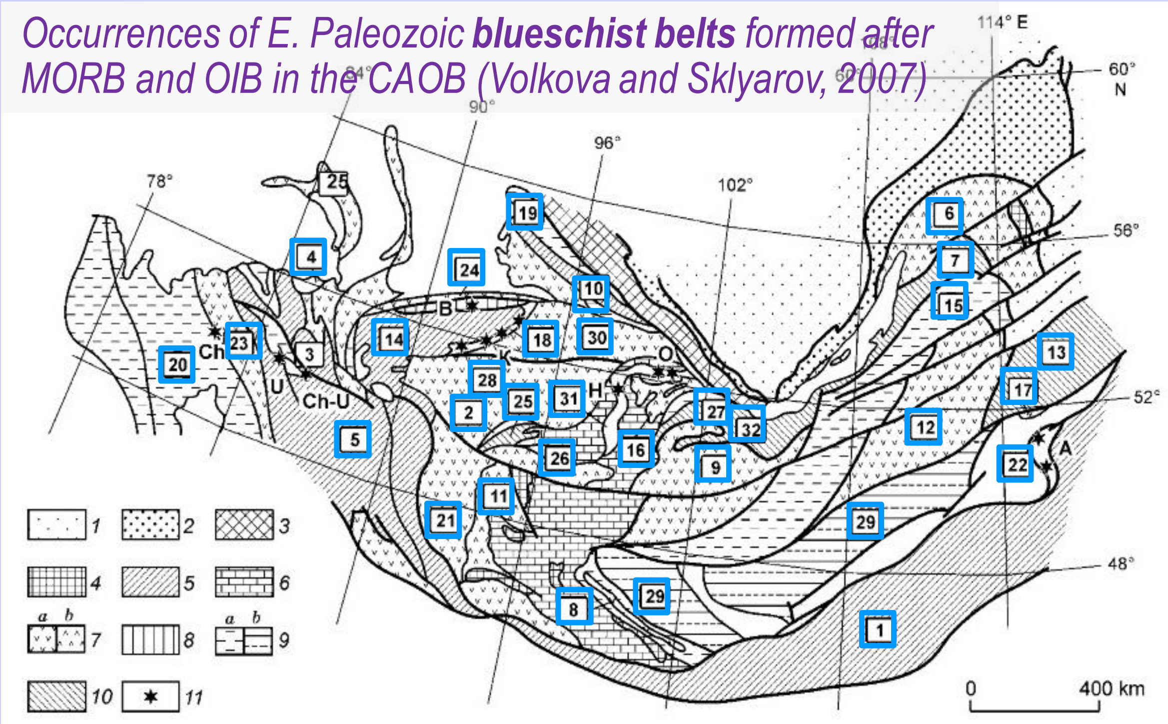
Safonova et al., 2017

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

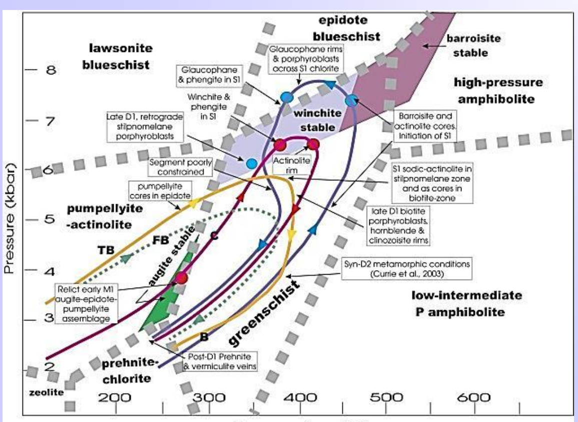


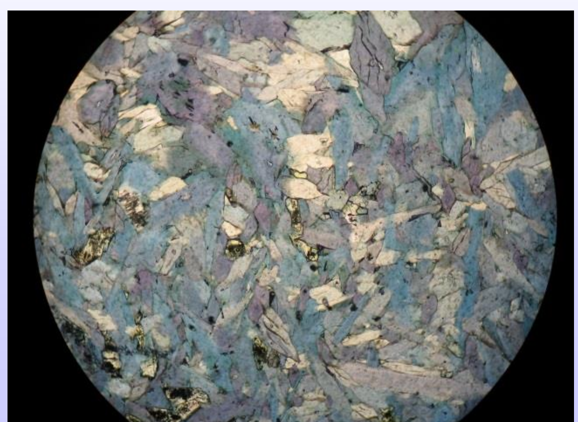
Volkova&Sklyarov, 2007; Safonova, 2017

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

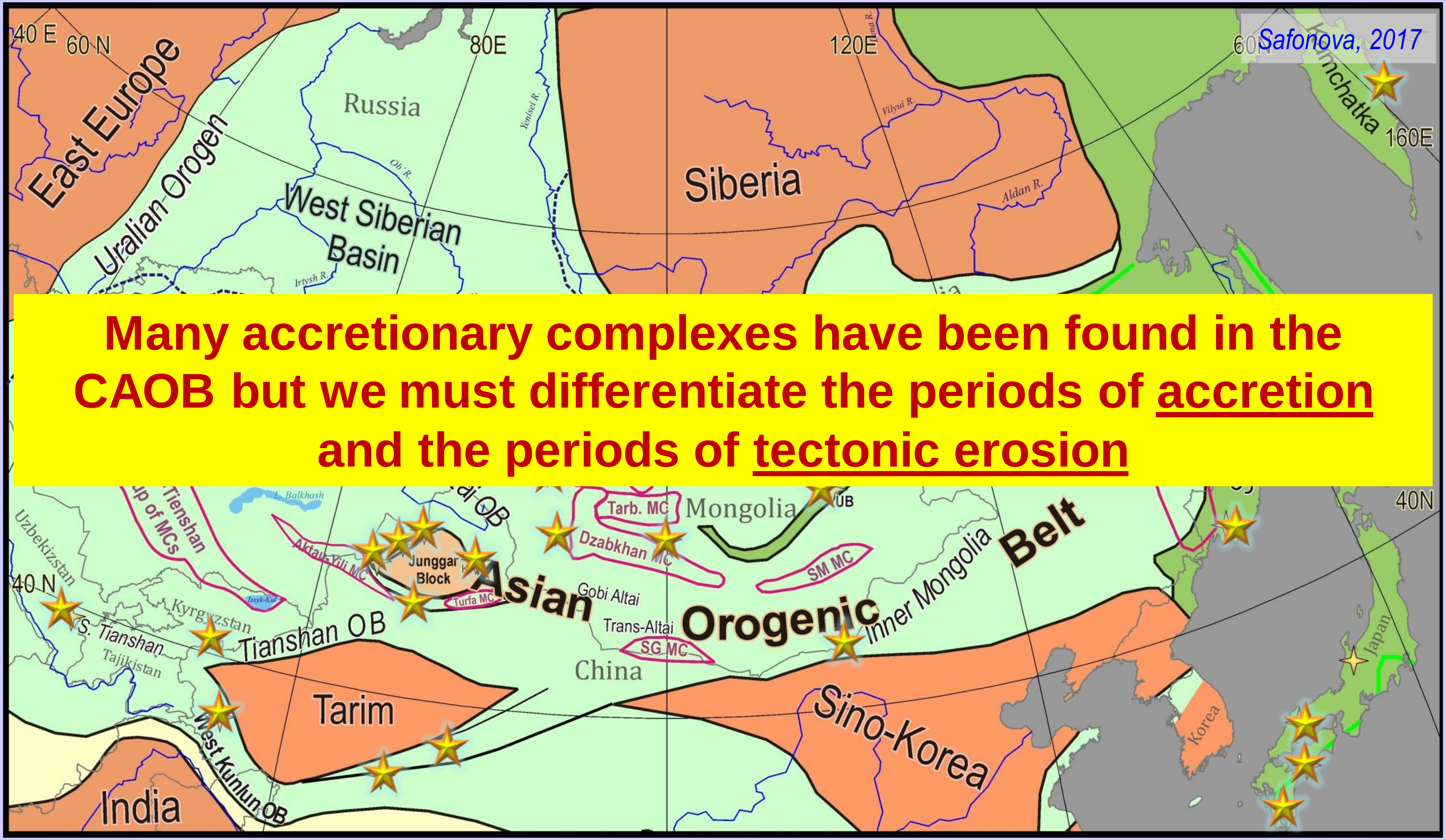


*Occurrences of E. Paleozoic **blueschist belts** formed after MORB and OIB in the CAOB (Volkova and Sklyarov, 2007)*





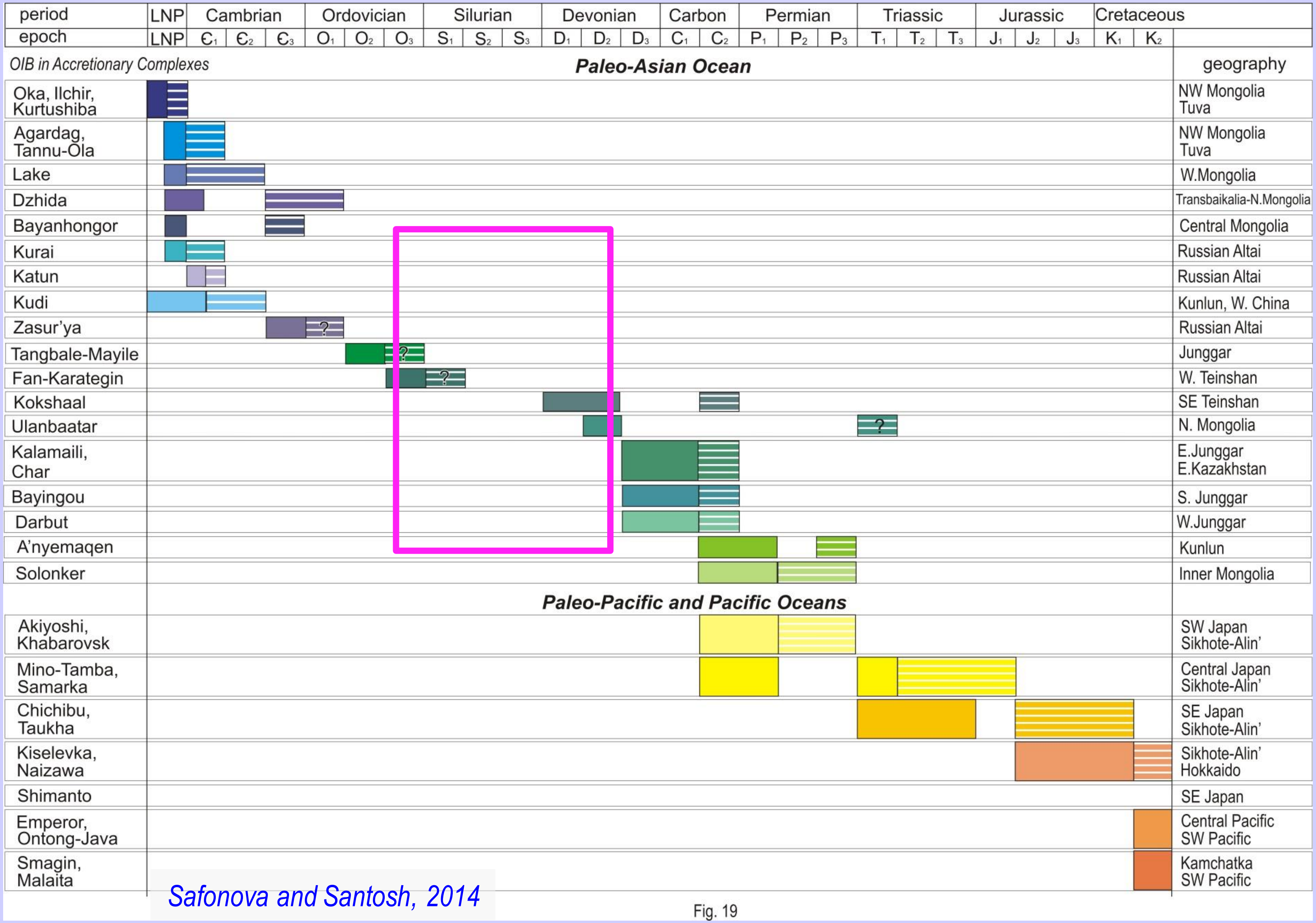
Evidence #3 for dominating P-type orogens in the CAOB:
wide occurrence of accreted OPS



Many accretionary complexes have been found in the CAOB but we must differentiate the periods of <u>accretion</u> and the periods of <u>tectonic erosion</u>

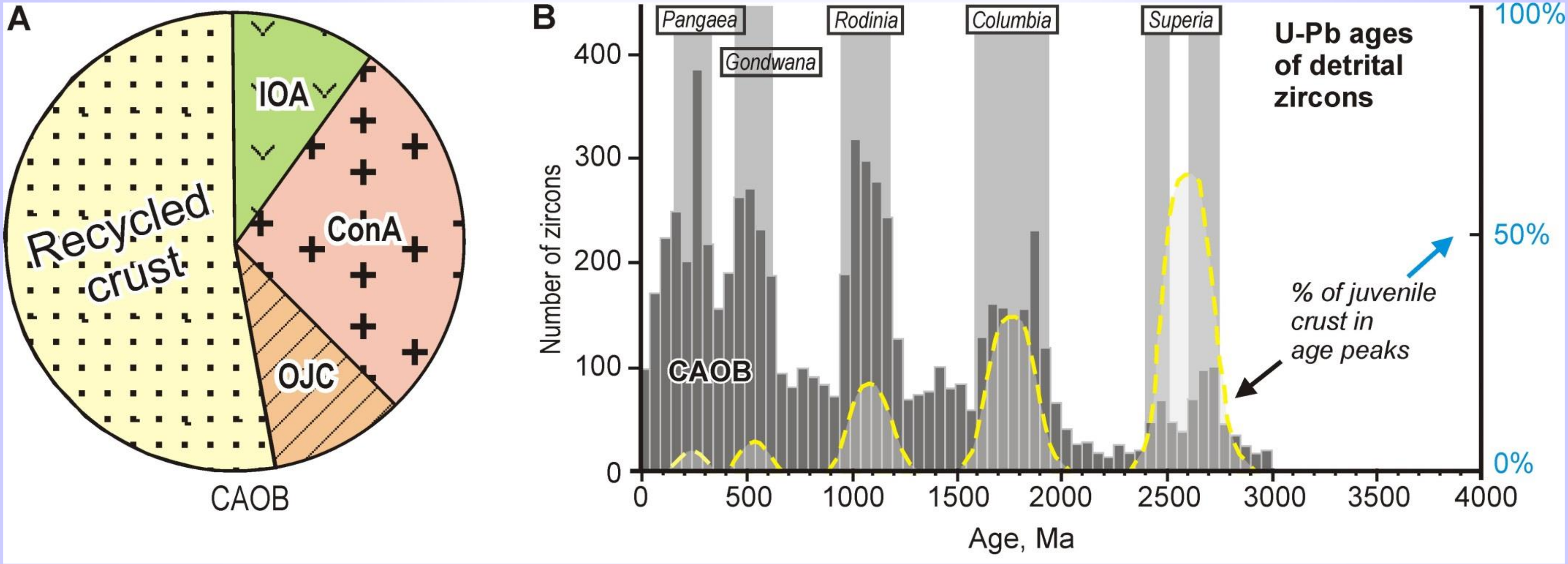
The stars show location of accretionary complexes with Late Neoproterozoic to Late Mesozoic OIB and OPB

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



Geologically CAOB is a typical PACIFIC-TYPE OROGENIC BELT

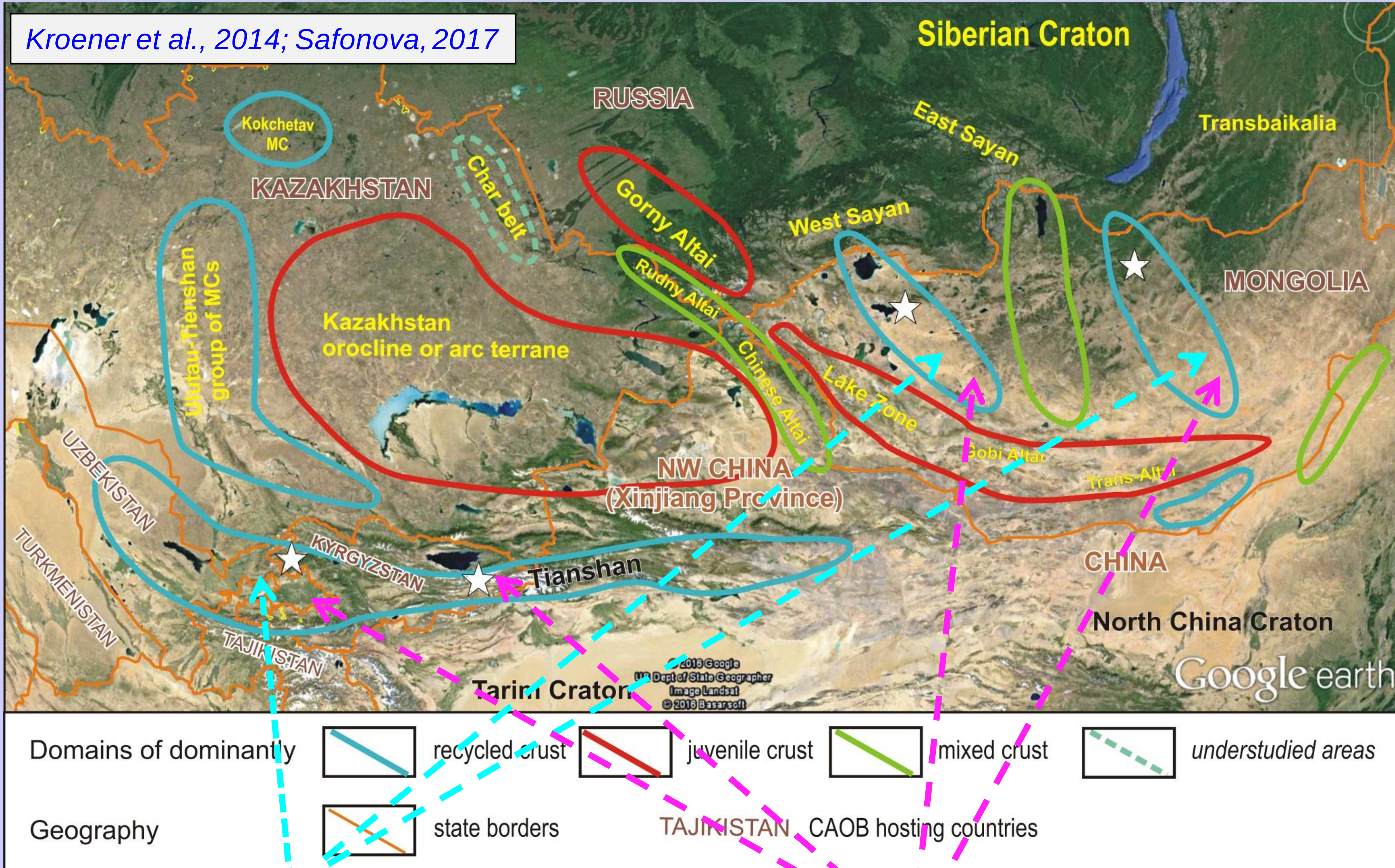
HOWEVER recent Hf-in-zircon isotope studies show a big portion of recycled crust in the CAOB



Condie&Kroener, 2013

Hawksworth et al., 2010

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

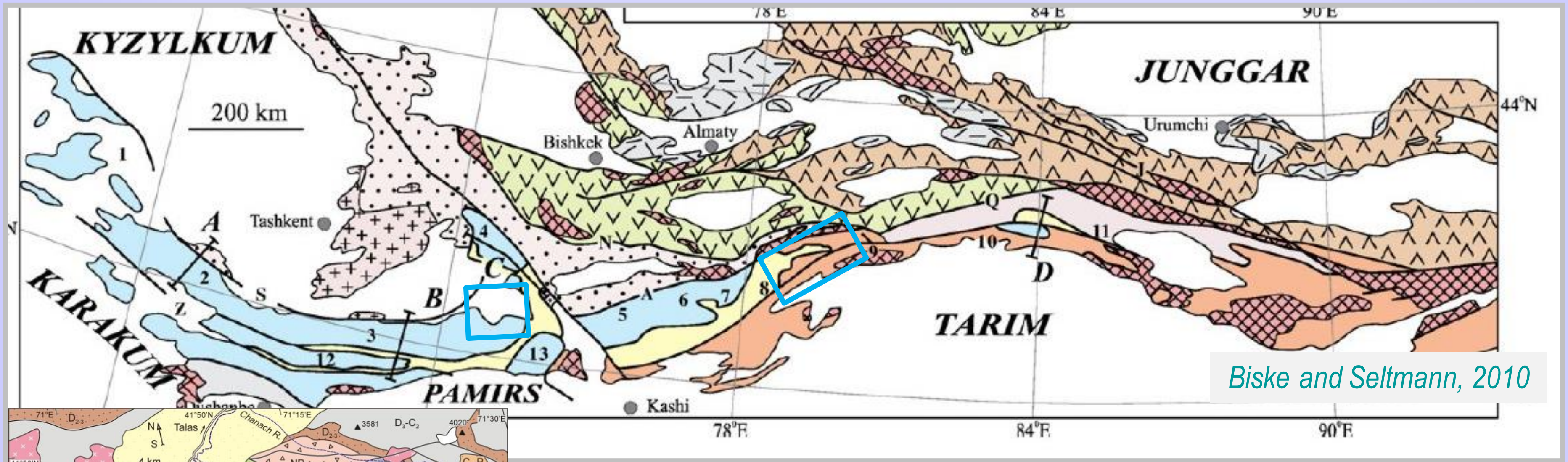


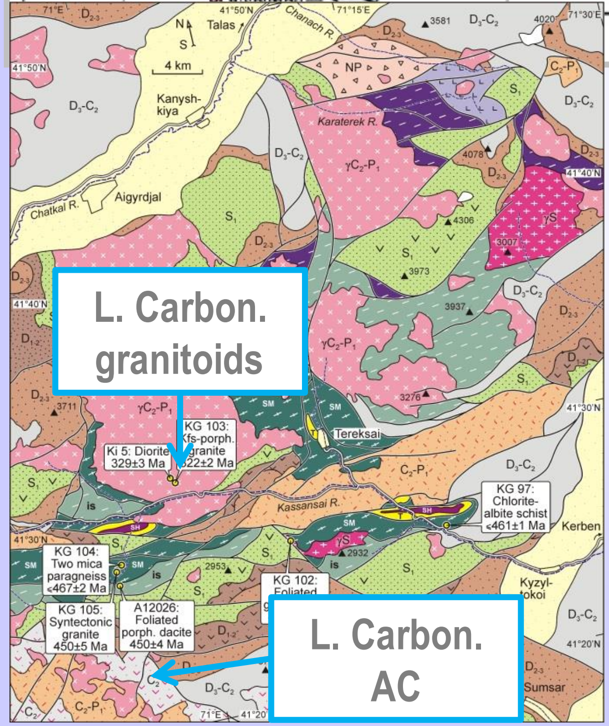
Isotope-implied recycled crust

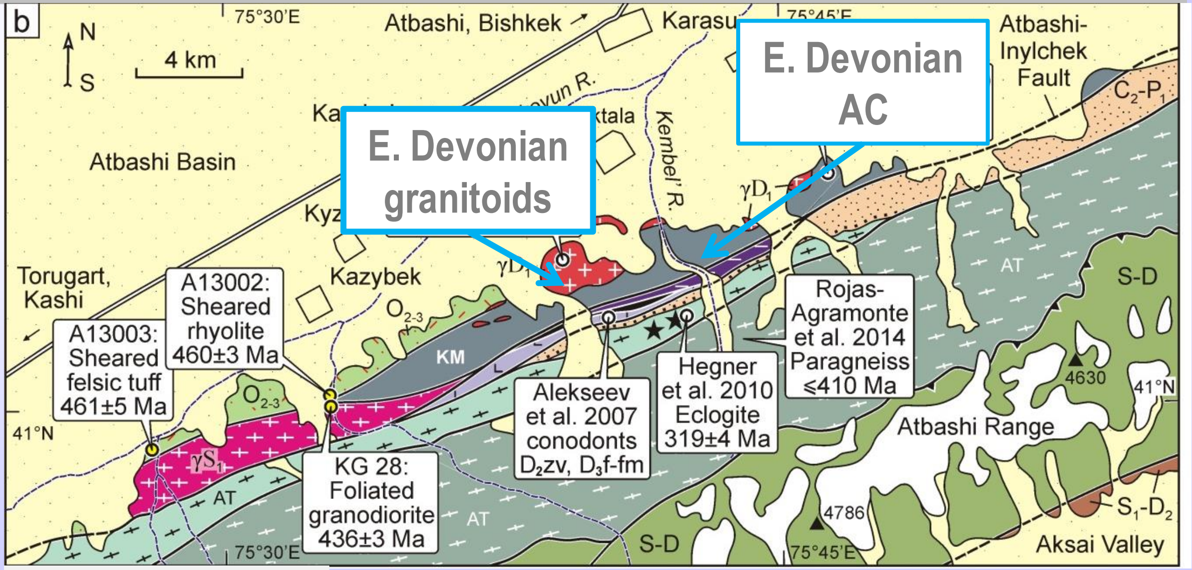
Accretionary complexes with OPS-hosted OIBs and BS

Probable cases of tectonic erosion in the CAOB

Chatkal-Kurama arc, southern Tienshan

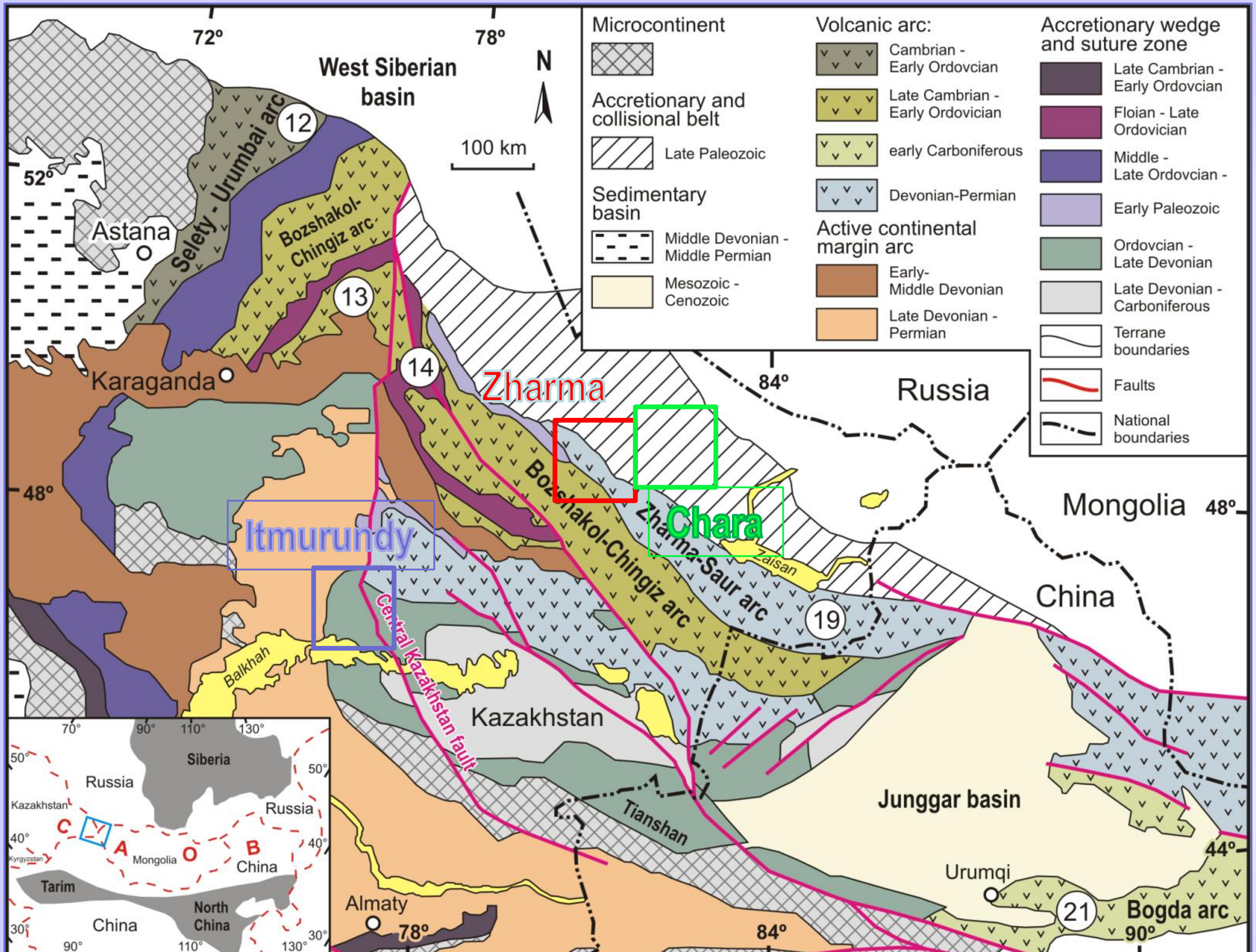






Alexeiev et al., 2016

The tectonic map of the Kazakh orocline and adjacent areas



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

Key arc terranes:

12 - Selety-Urumbai, Cambrian – early Ordovician;

13 - Bozshakol-Chingiz, late - Cambrian early Ordovician; 501-480 Ma

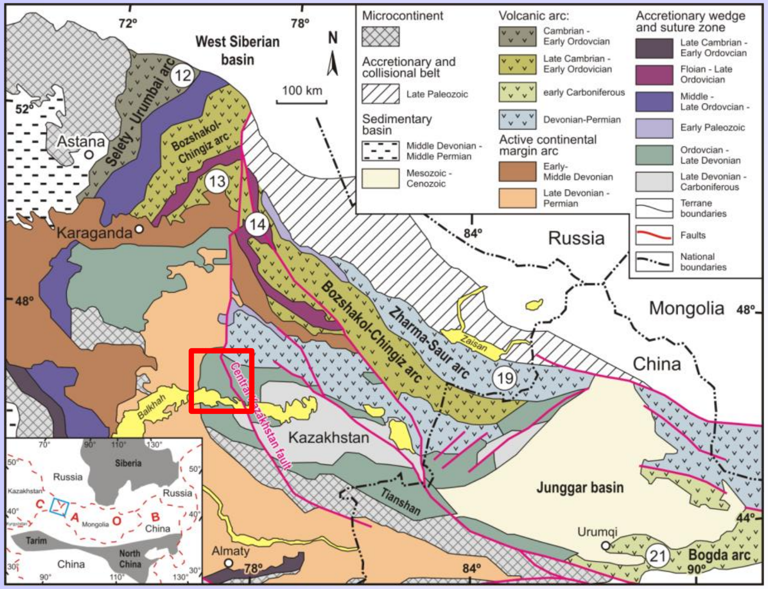
14 - Baydaulet-Aqbastau, Floian – late Ordovician

19 - Zharma-Saur - M. Devonian; 380–356 Ma

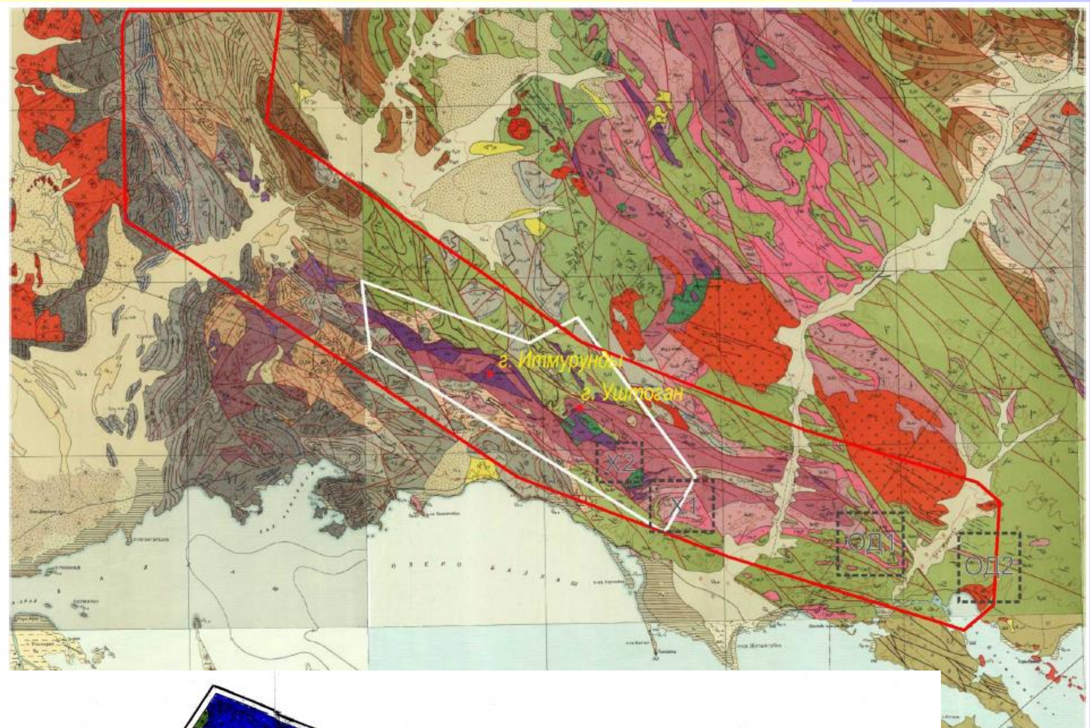
20 – Bogda, 347-315 Ma

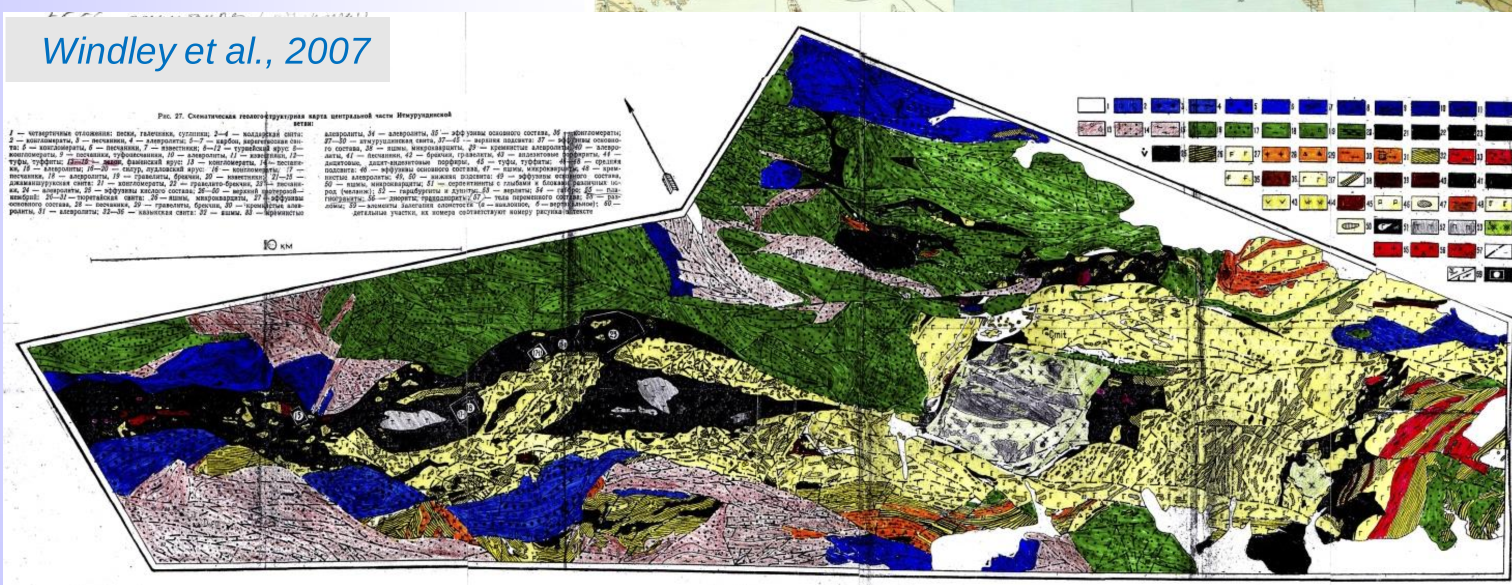
Probable cases of tectonic erosion in the CAOB

Itmurundy ophiolite belt, central Kazakhstan, Ordovician



Windley et al., 2007





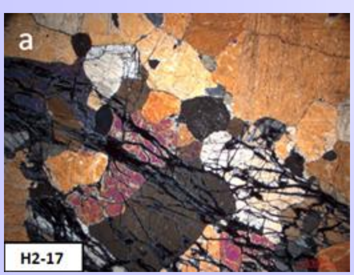
New data-1

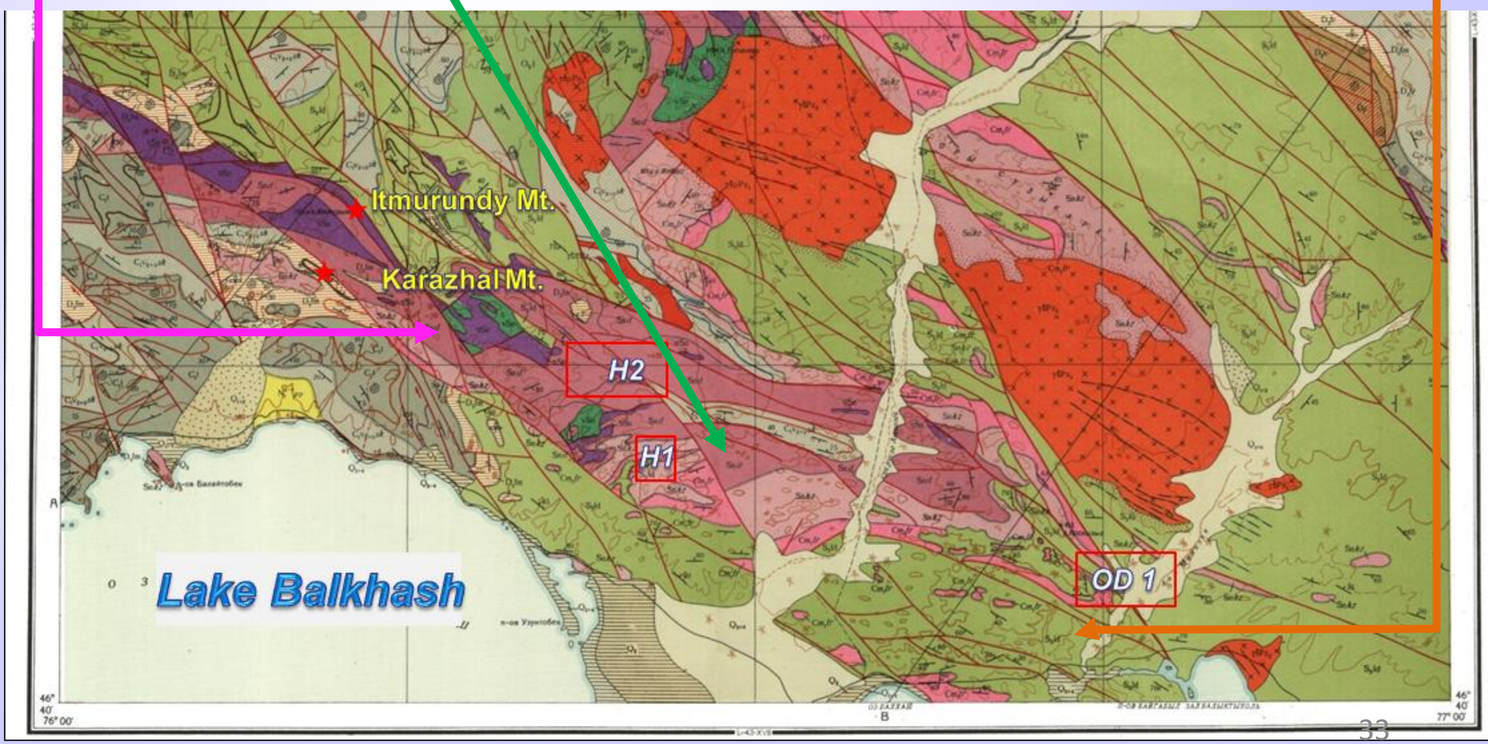
There are three major associations in the Itmurundy AC: mantle, orogenic and post-orogenic

Mantle association: ultramafics, mafics, plagiogranites

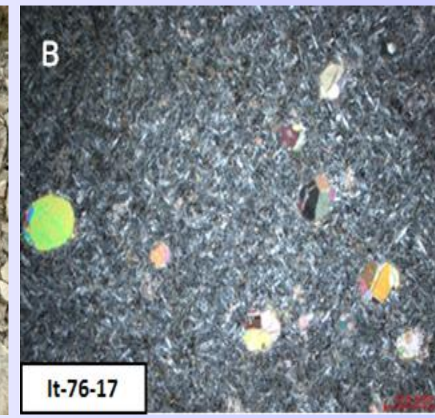
Orogenic association: accreted and supra-subduction rocks (OPS: basalt, chert, SS, sandstone) , andesibasalts, andesite

Post-orogenic association: sandstones, carbonates, felsic volcanics, conglomerates

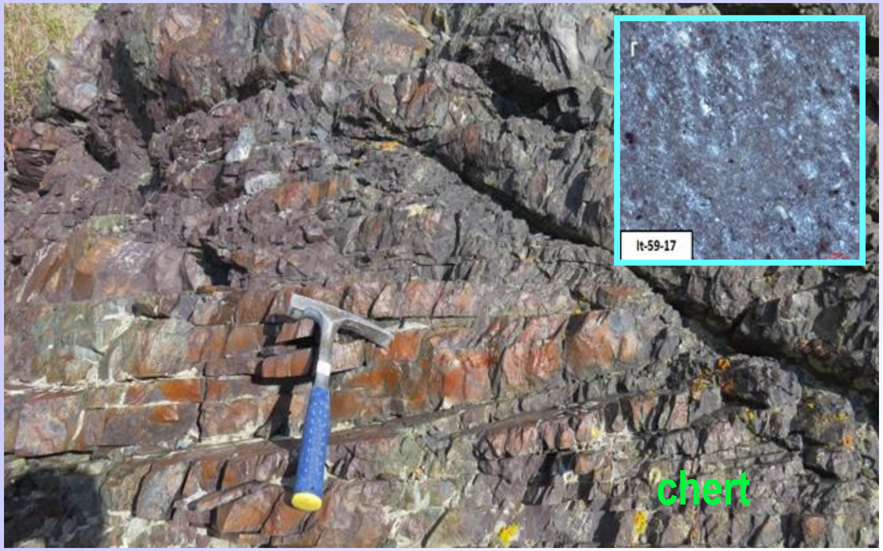


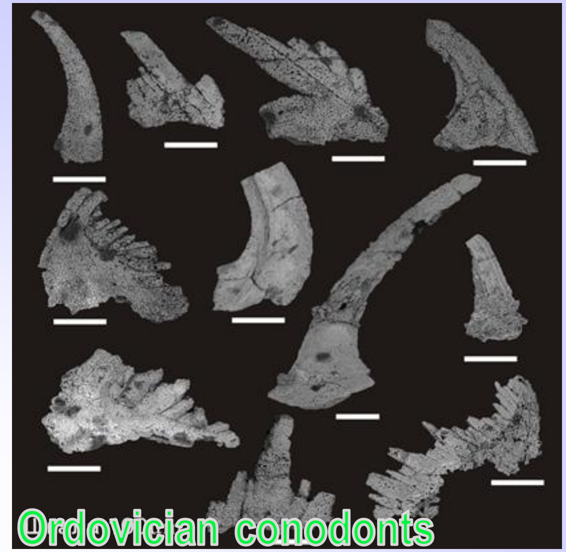


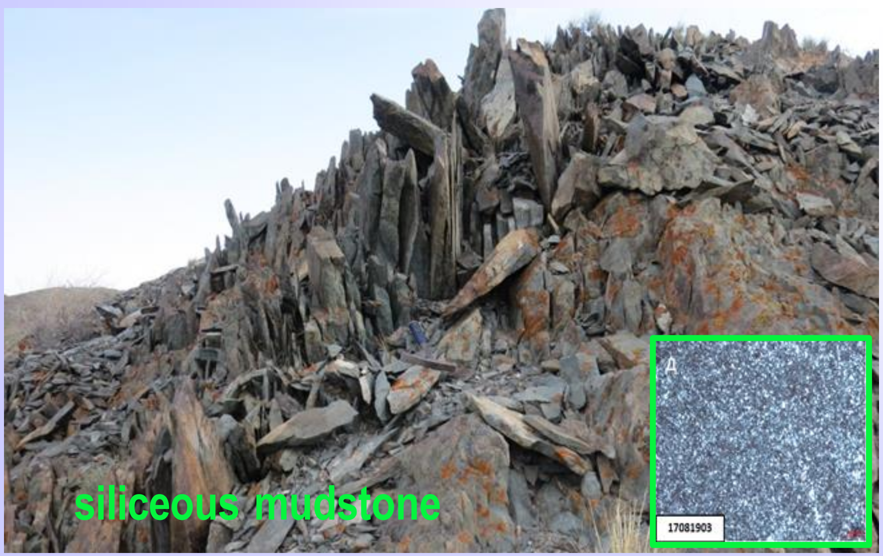
Itmurundy orogenic association: igneous rocks



Itmurundy orogenic association: sedimentary rocks

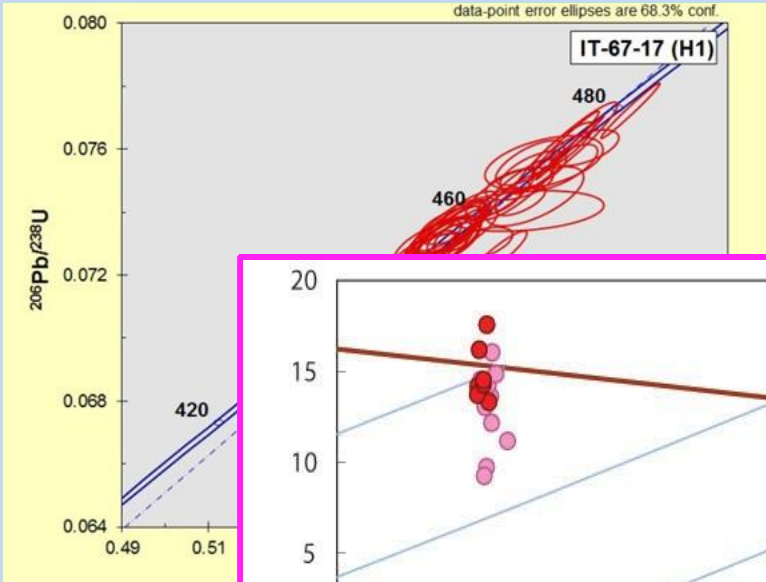


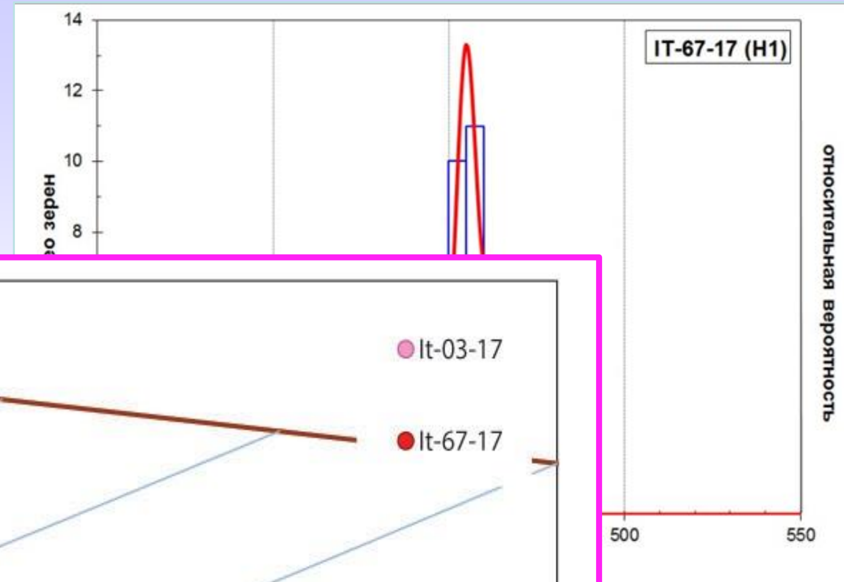


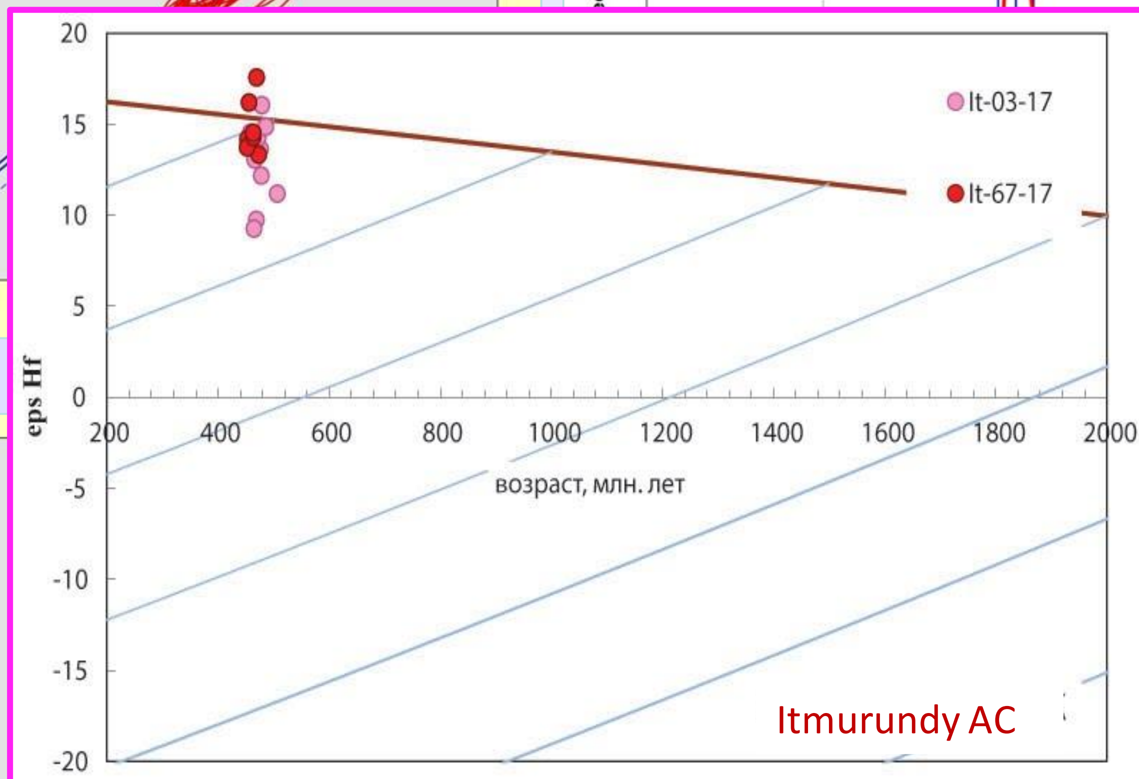


U-Pb ages of detrital zircons from Itmurundy sandstones - 1

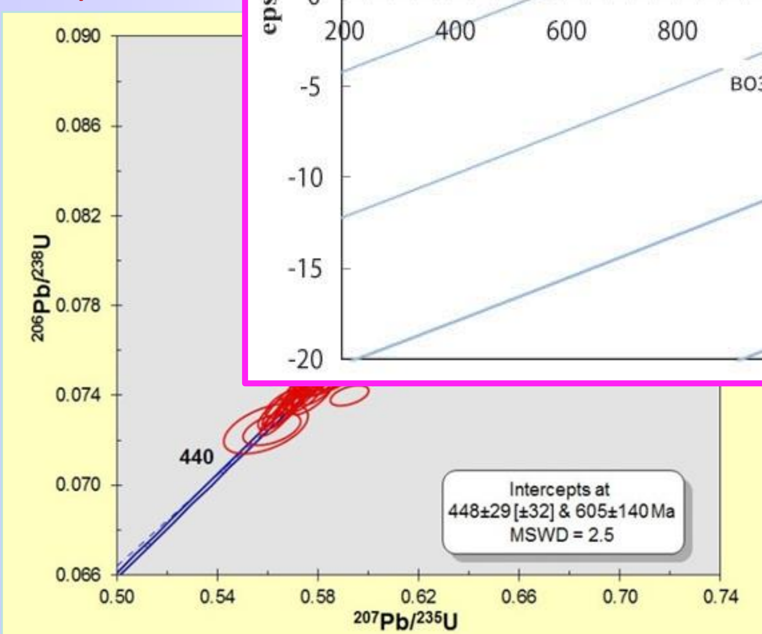
Itmurundy Fm.

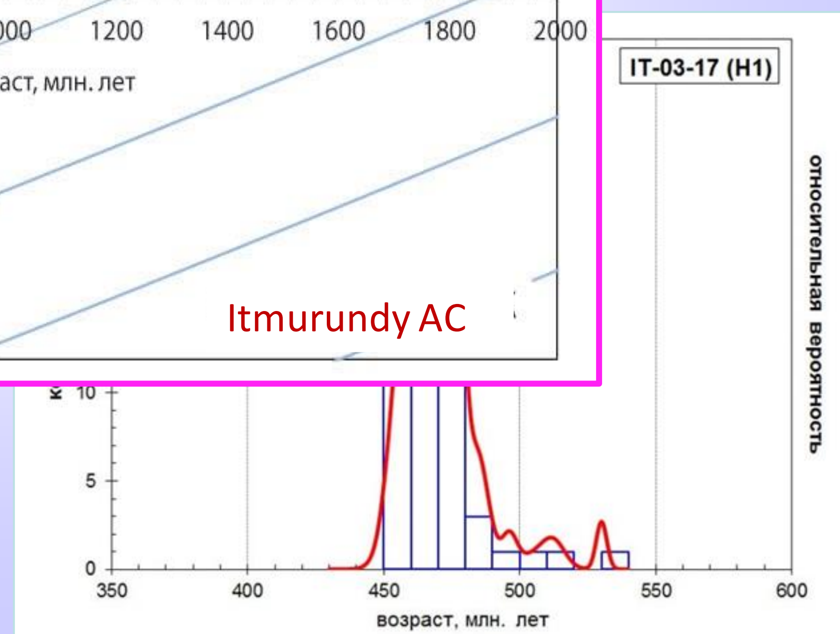






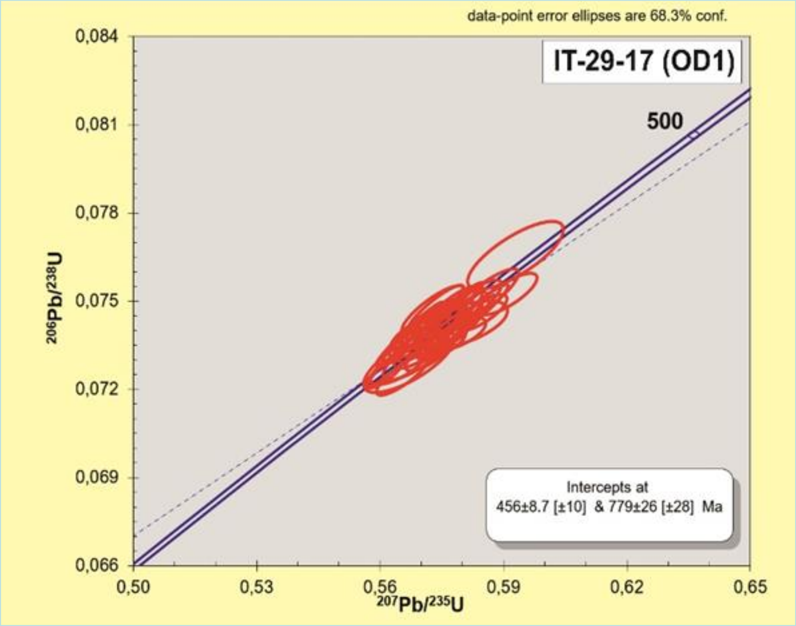
Kazyk Fm.

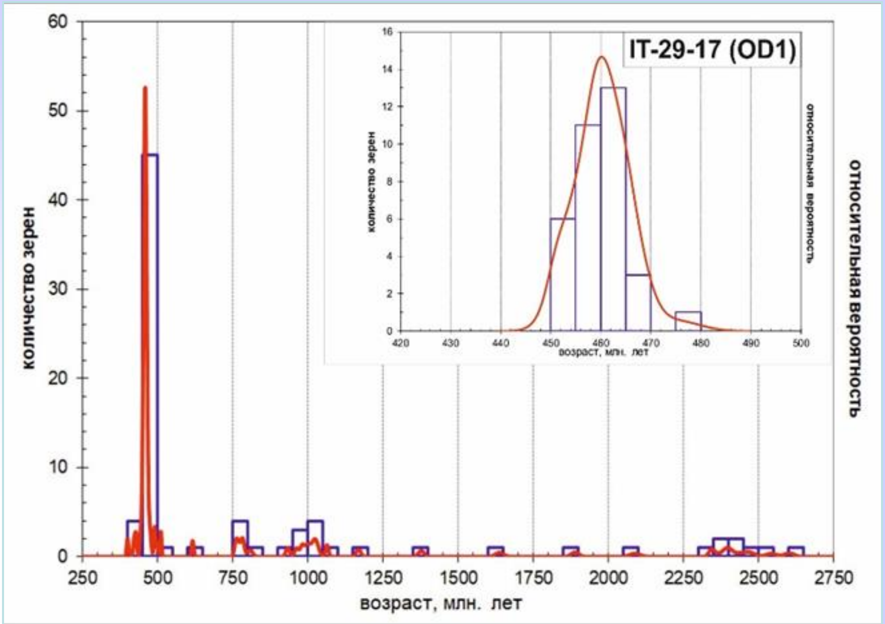


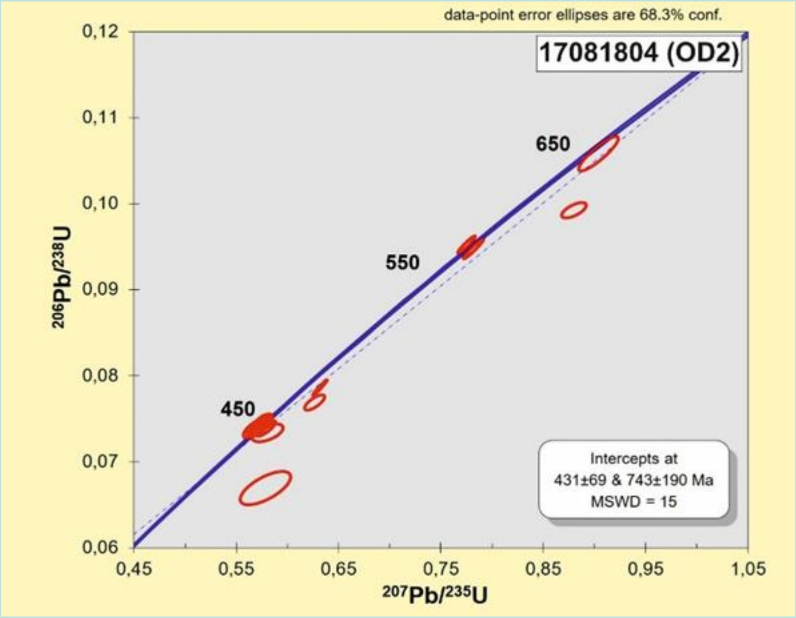


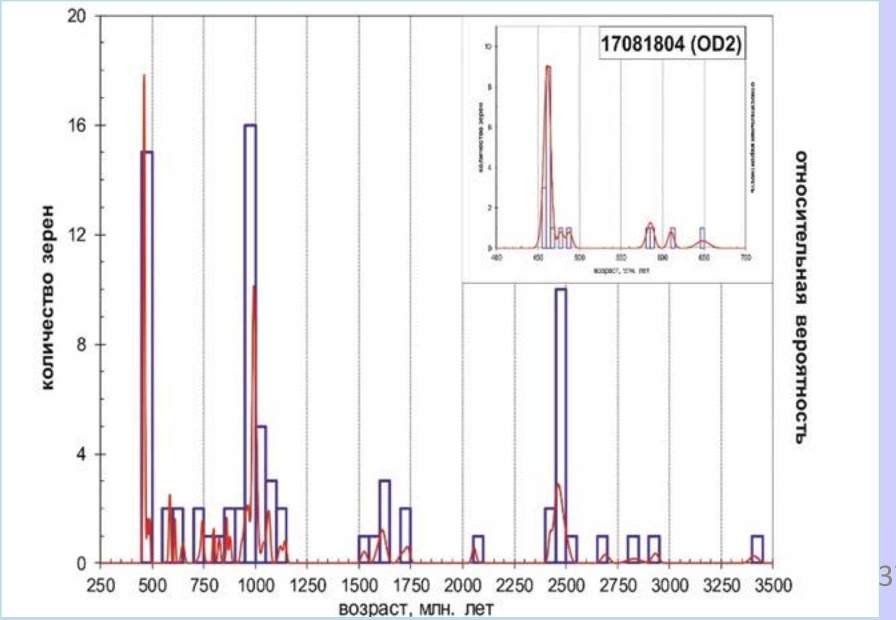
U-Pb ages of detrital zircons from Itmurundy sandstones - 2

Тюретайская свита







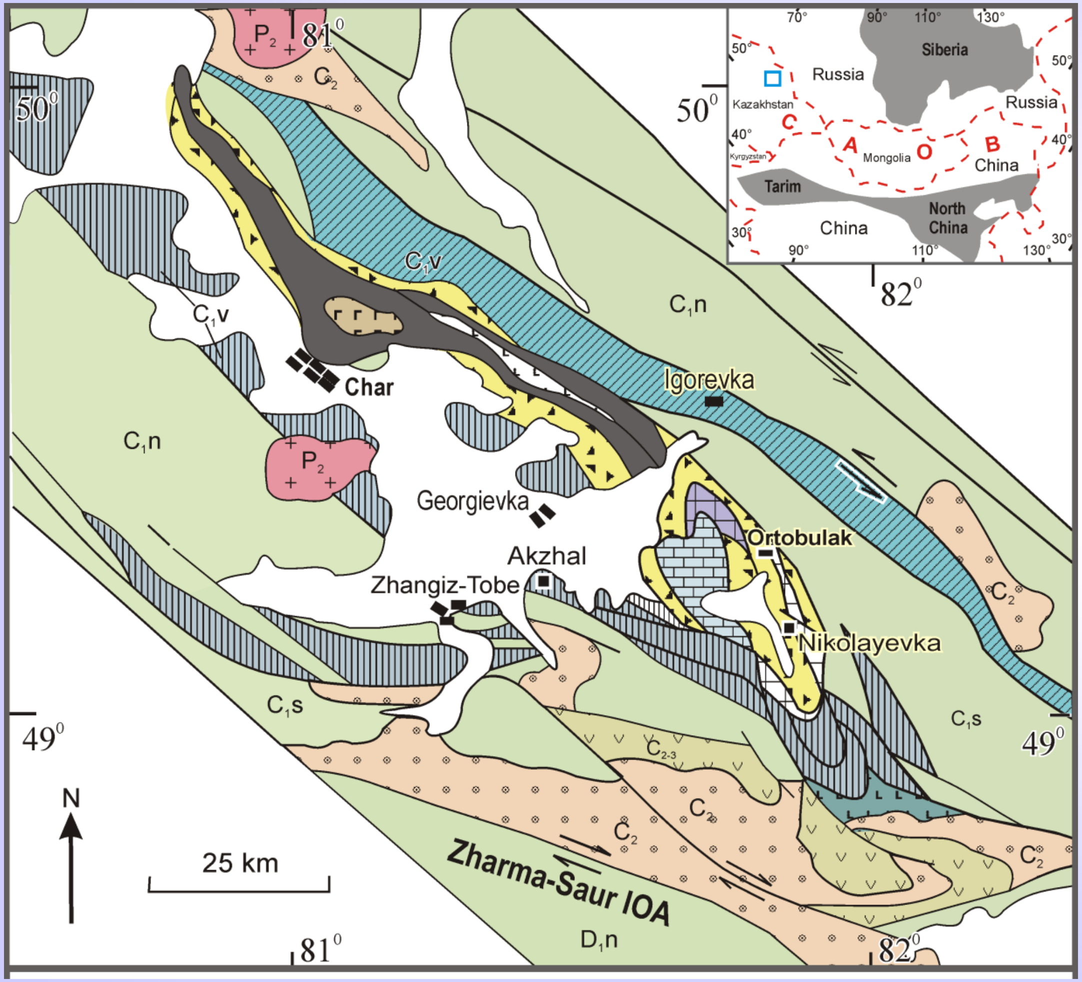


Location of sampled sandstones and their U-Pb age patterns

New data-2

Probable cases of tectonic erosion in the CAOB

Char ophiolite belt, East Kazakhstan



OPS

Safonova et al., 2012

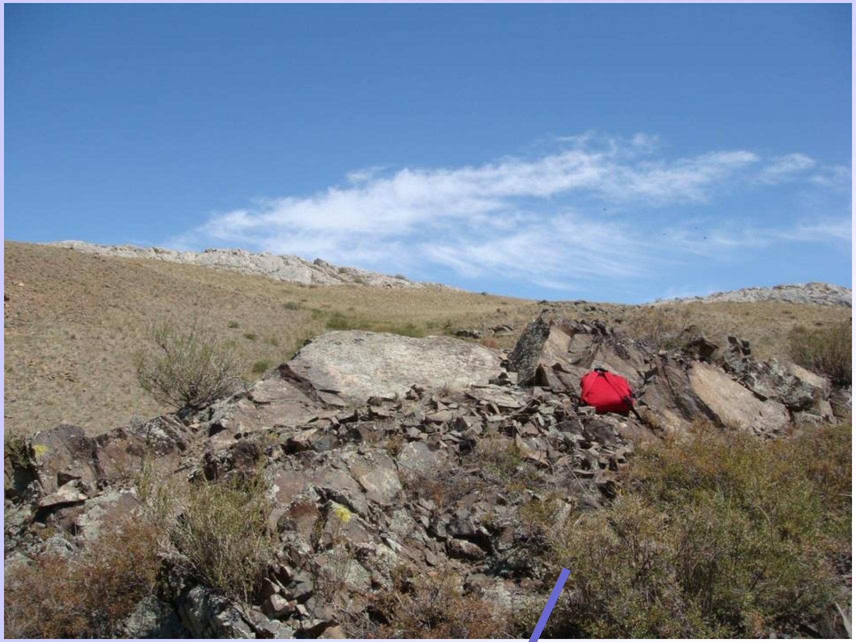
Blue-schist

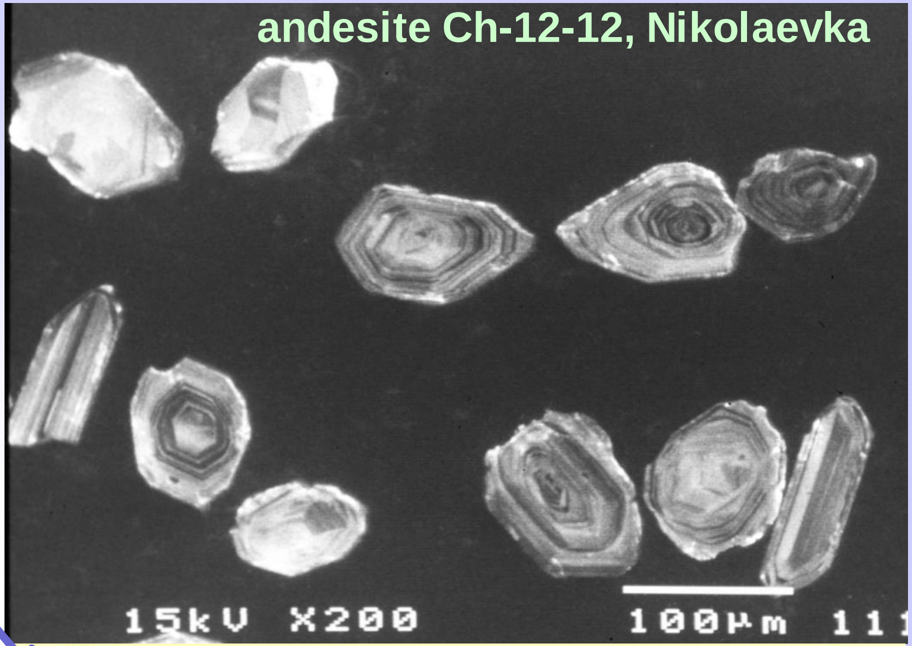
Volkova et al., 2008

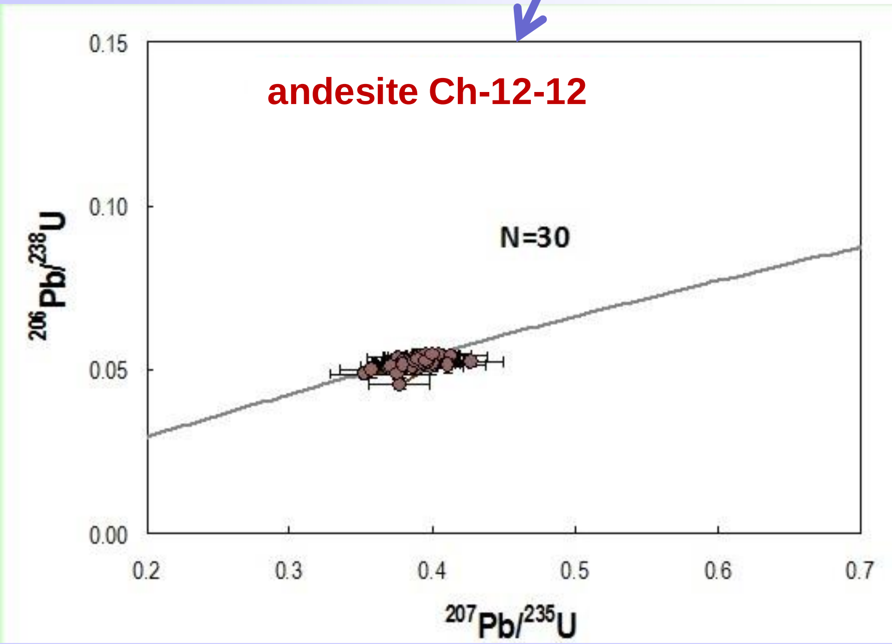
IOA

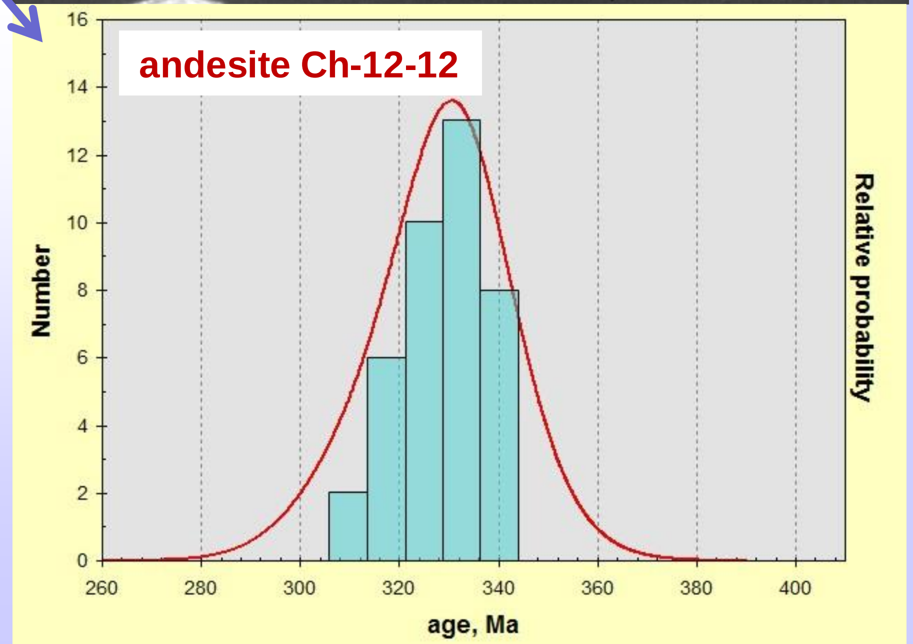
Safonova et al., 2018

Visean-Serpukhovian andesites



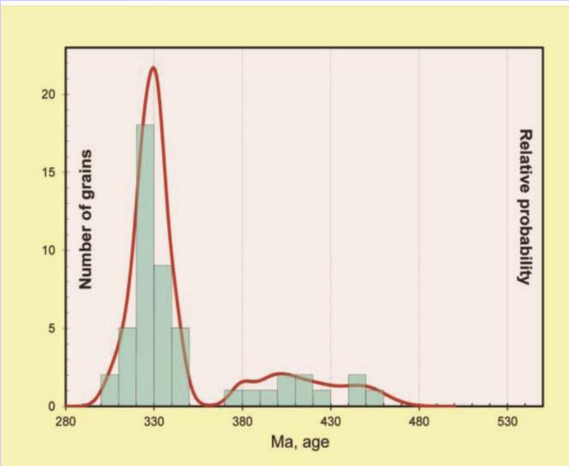




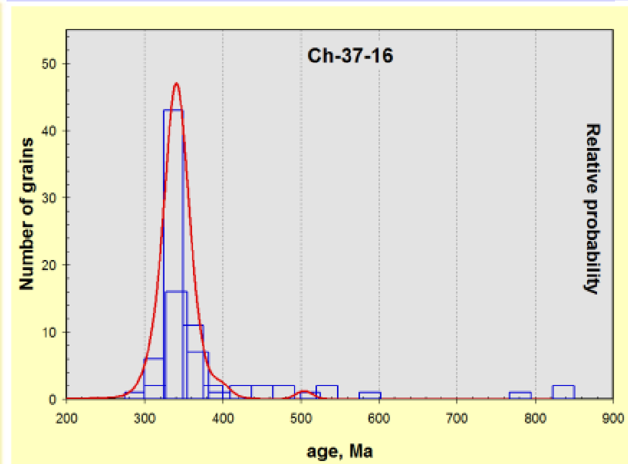


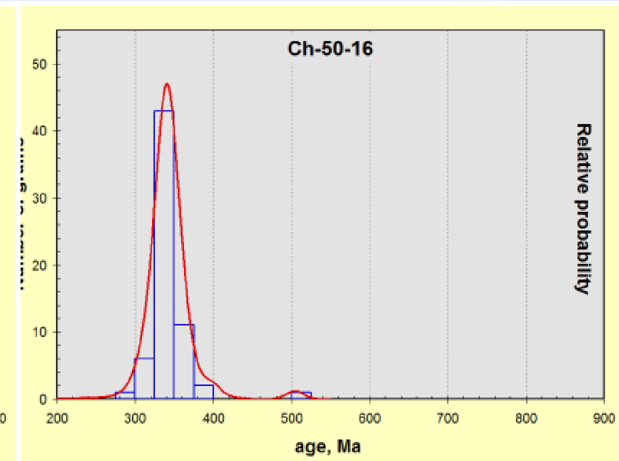
New data-3

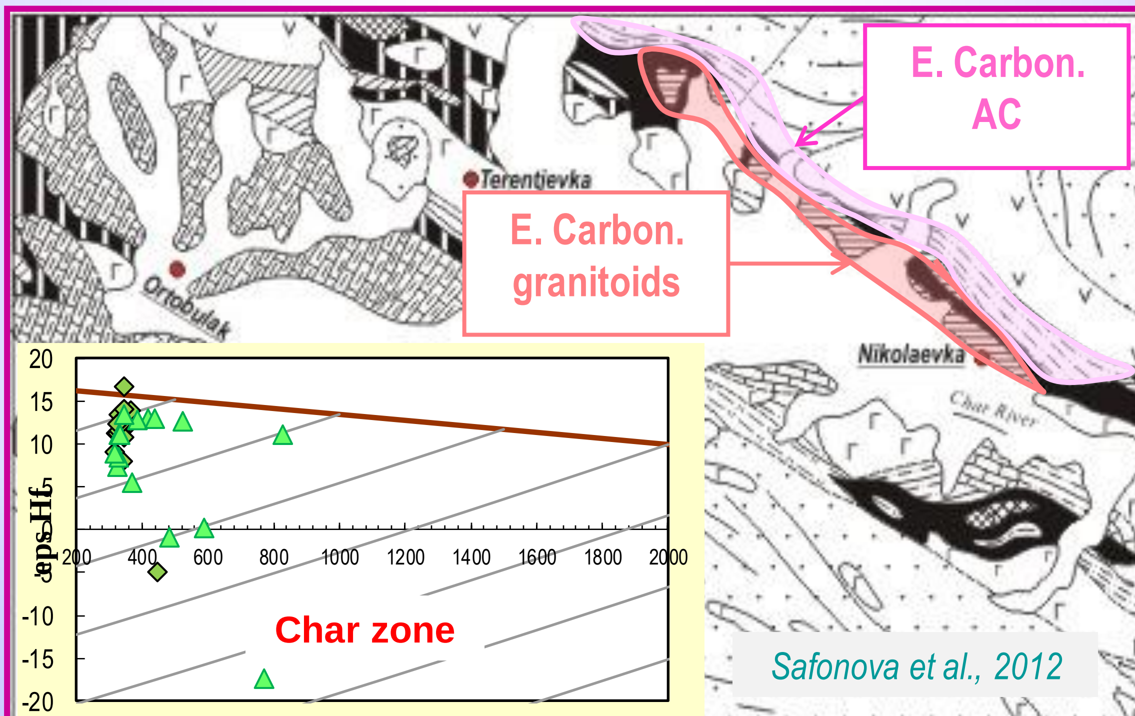
Char volcanic rocks



Char sandstones

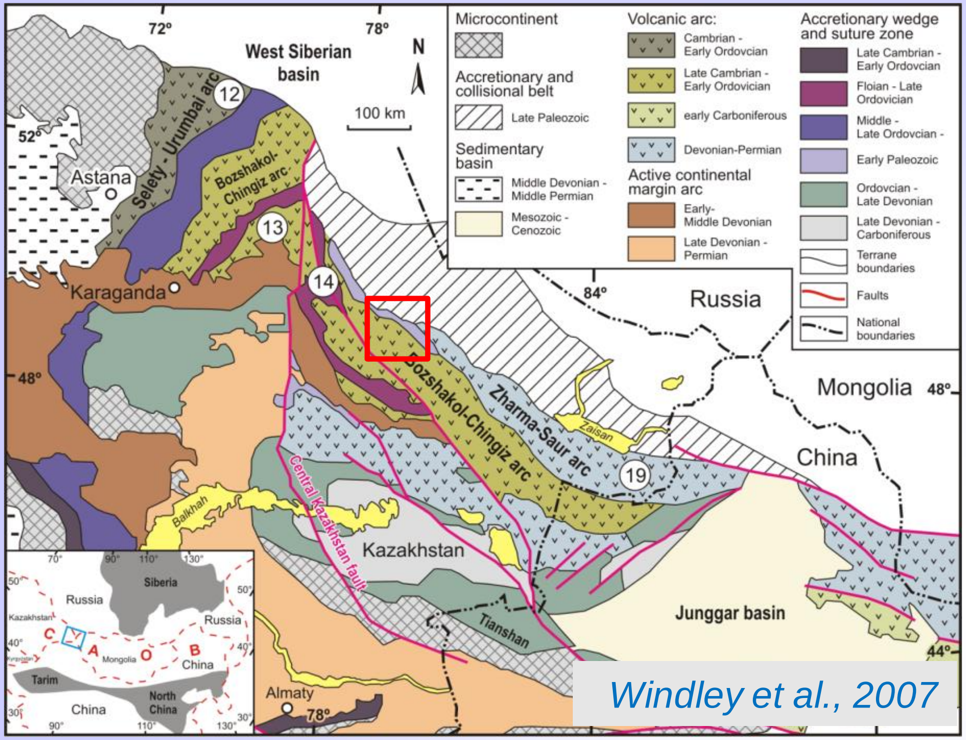




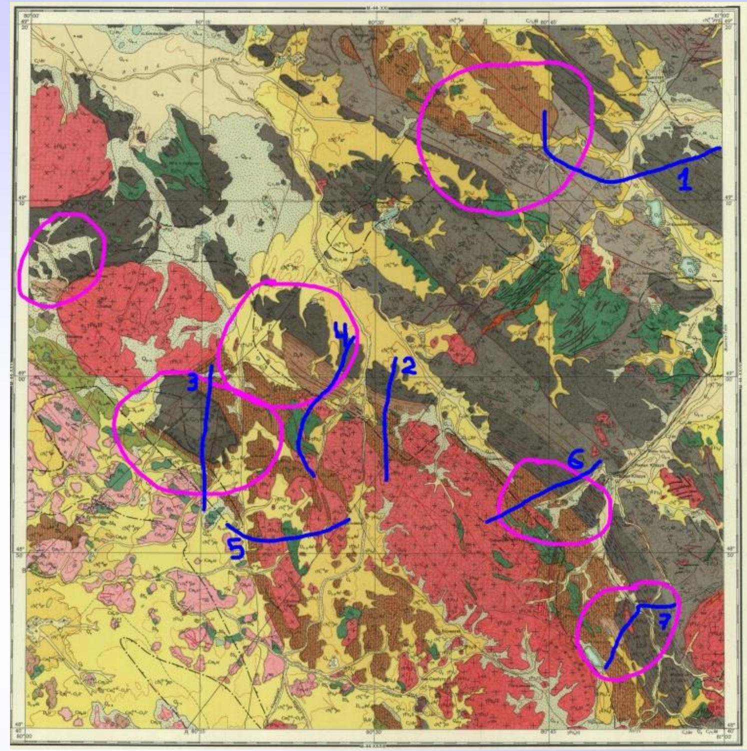


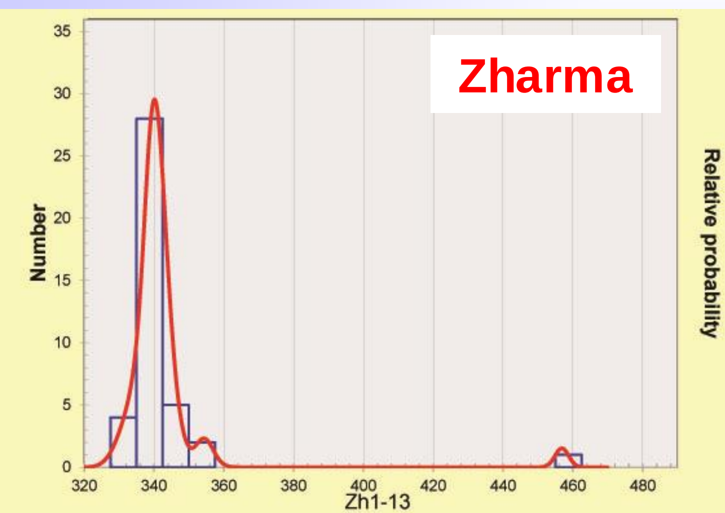
Probable cases of tectonic erosion in the CAOB

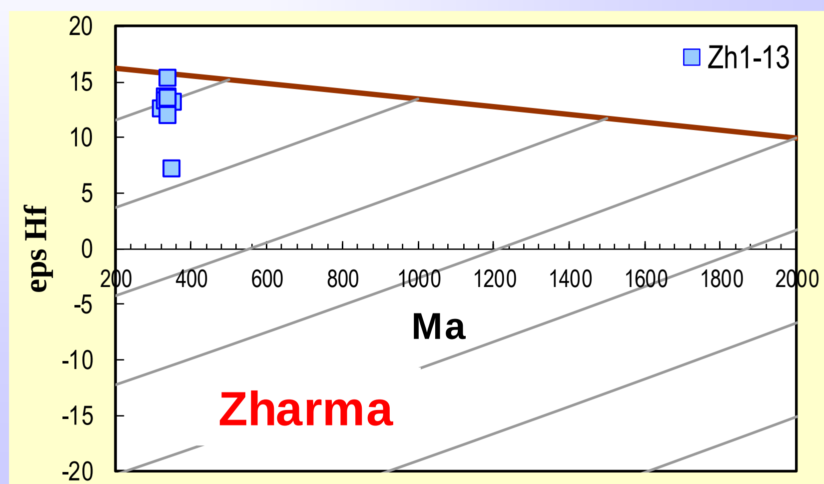
Zharma arc, East Kazakhstan



Windley et al., 2007

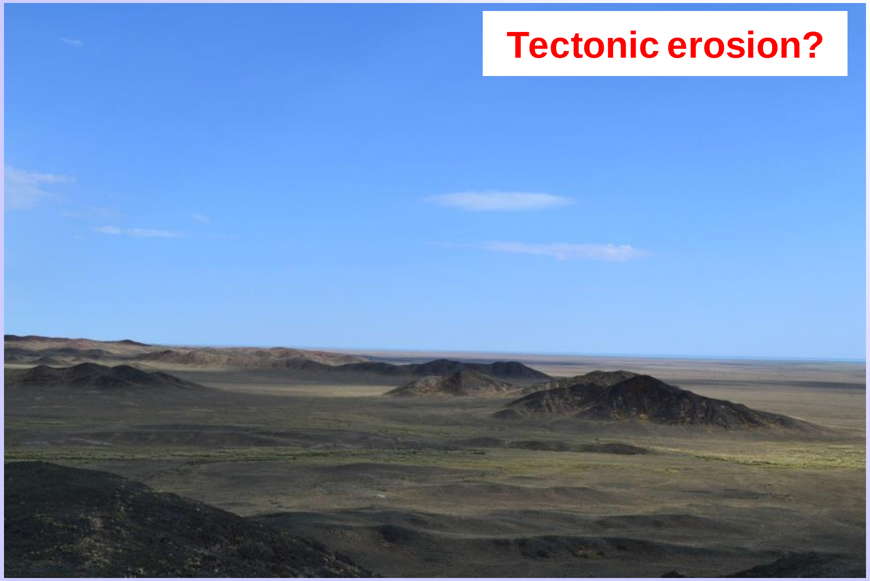






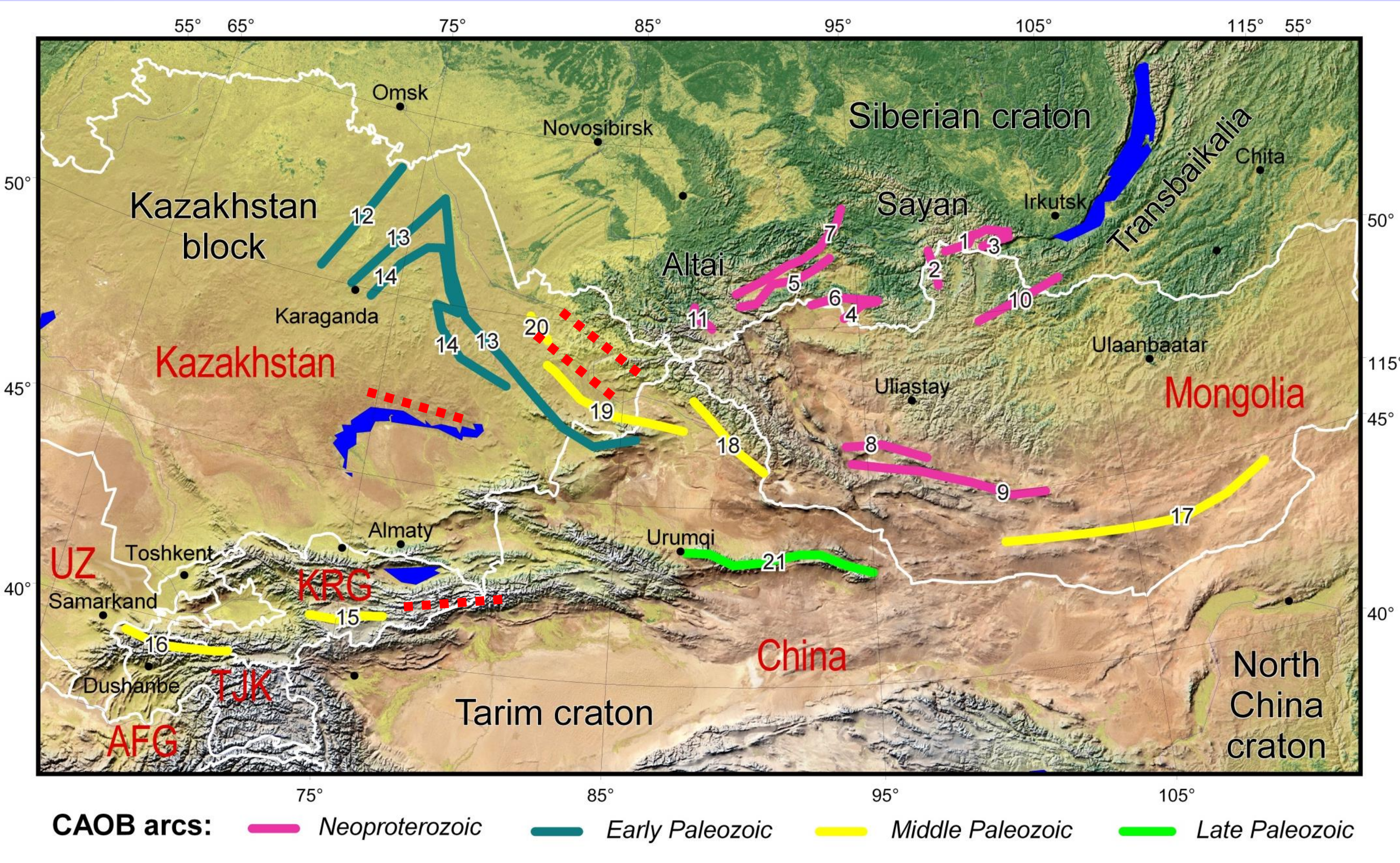
Russian Altai, L. Neoproterozoic - E. Cambrian

Itmurundy zone, central Kazakhstan, Ordovician



Char zone, E. Kazakhstan; L. Devonian – E. Carboniferous

Intra-oceanic arcs of the Paleo-Asian Ocean



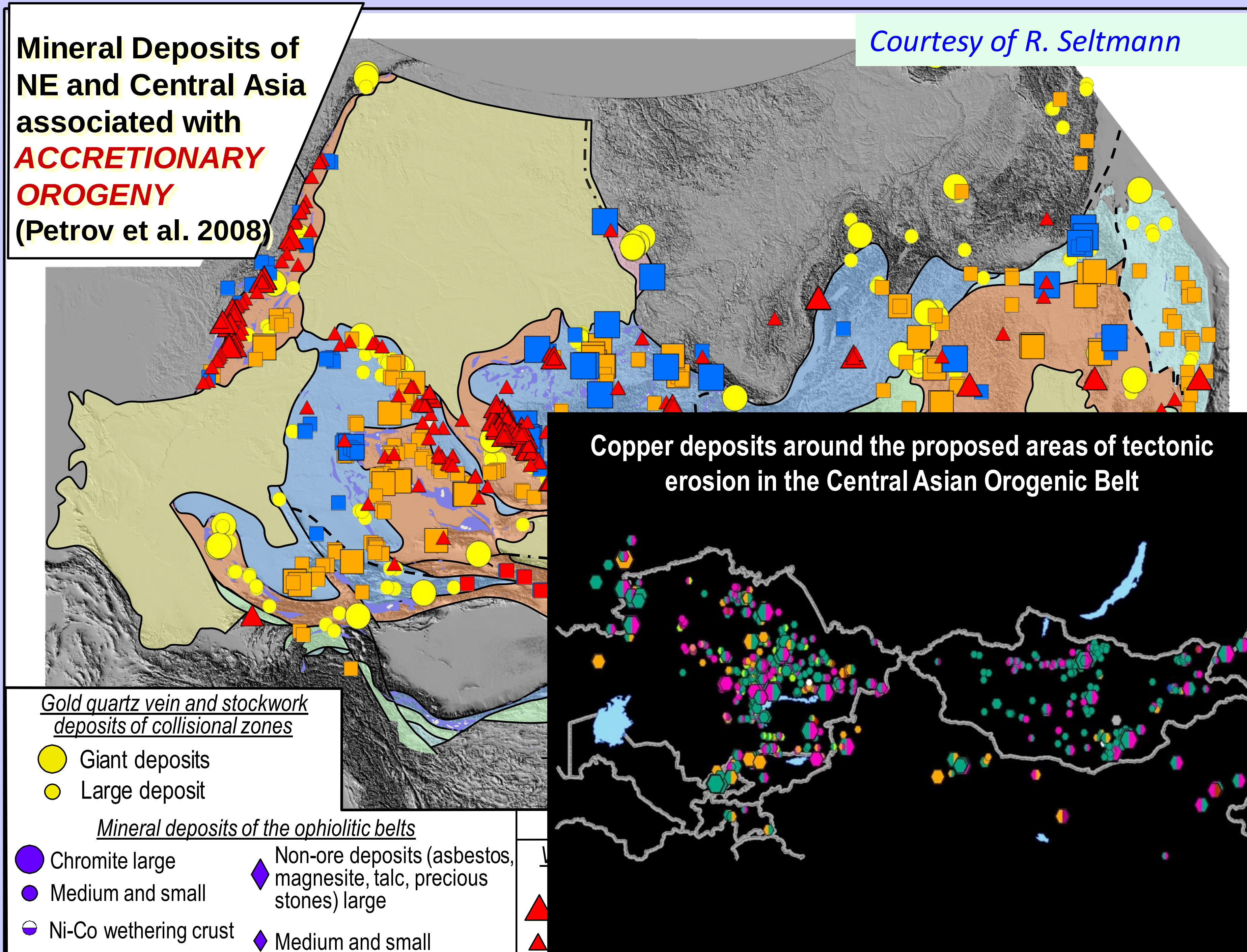
Tectonic erosion?

Safonova et al., 2017

Mineral Deposits of NE and Central Asia associated with *ACCRETIONARY OROGENY*

(Petrov et al. 2008)

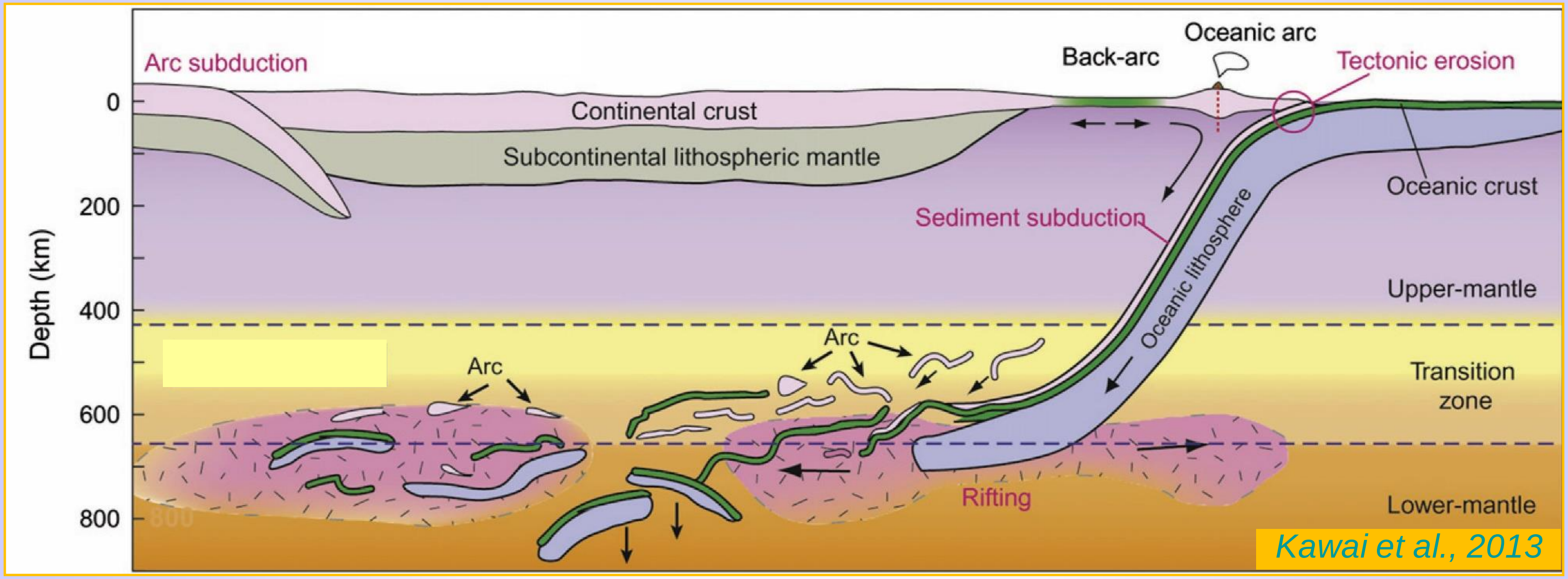
Courtesy of R. Seltmann



Copper deposits around the proposed areas of tectonic erosion in the Central Asian Orogenic Belt

New data-4

Observation #2: various materials can be tectonically eroded at P-type margins and subducted to the mantle



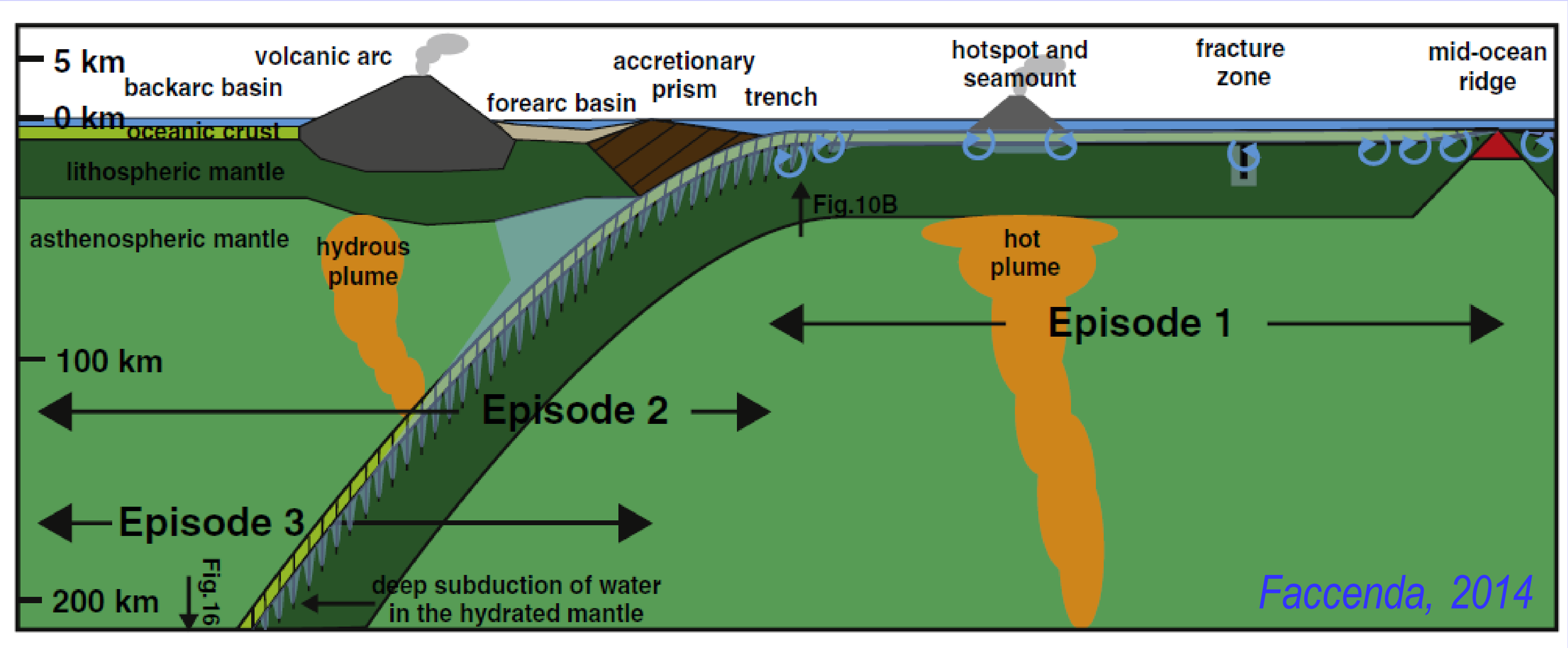
Subducting materials:

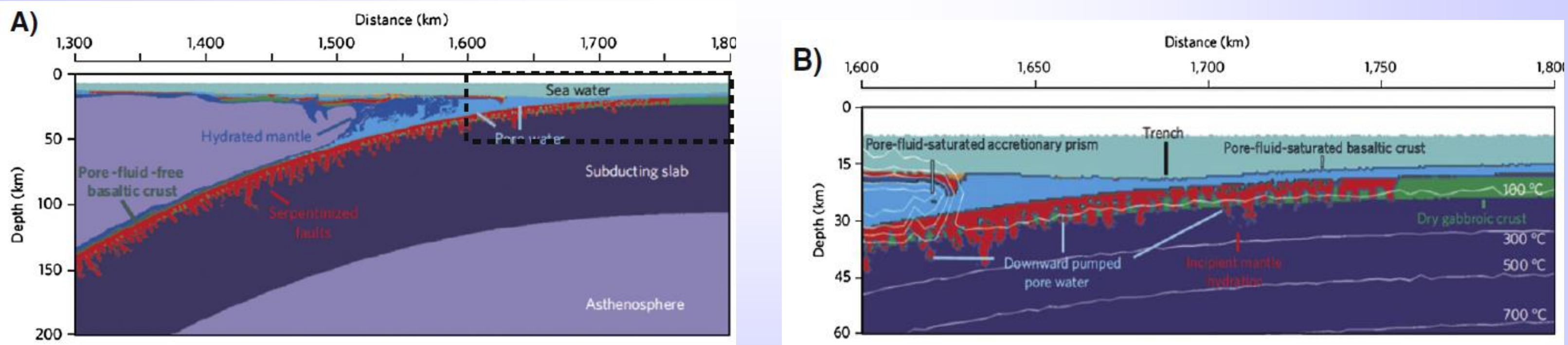
(i) **hydrated and carbonated material of oceanic crust/OPS**: source of **water and CO_2**;

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

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

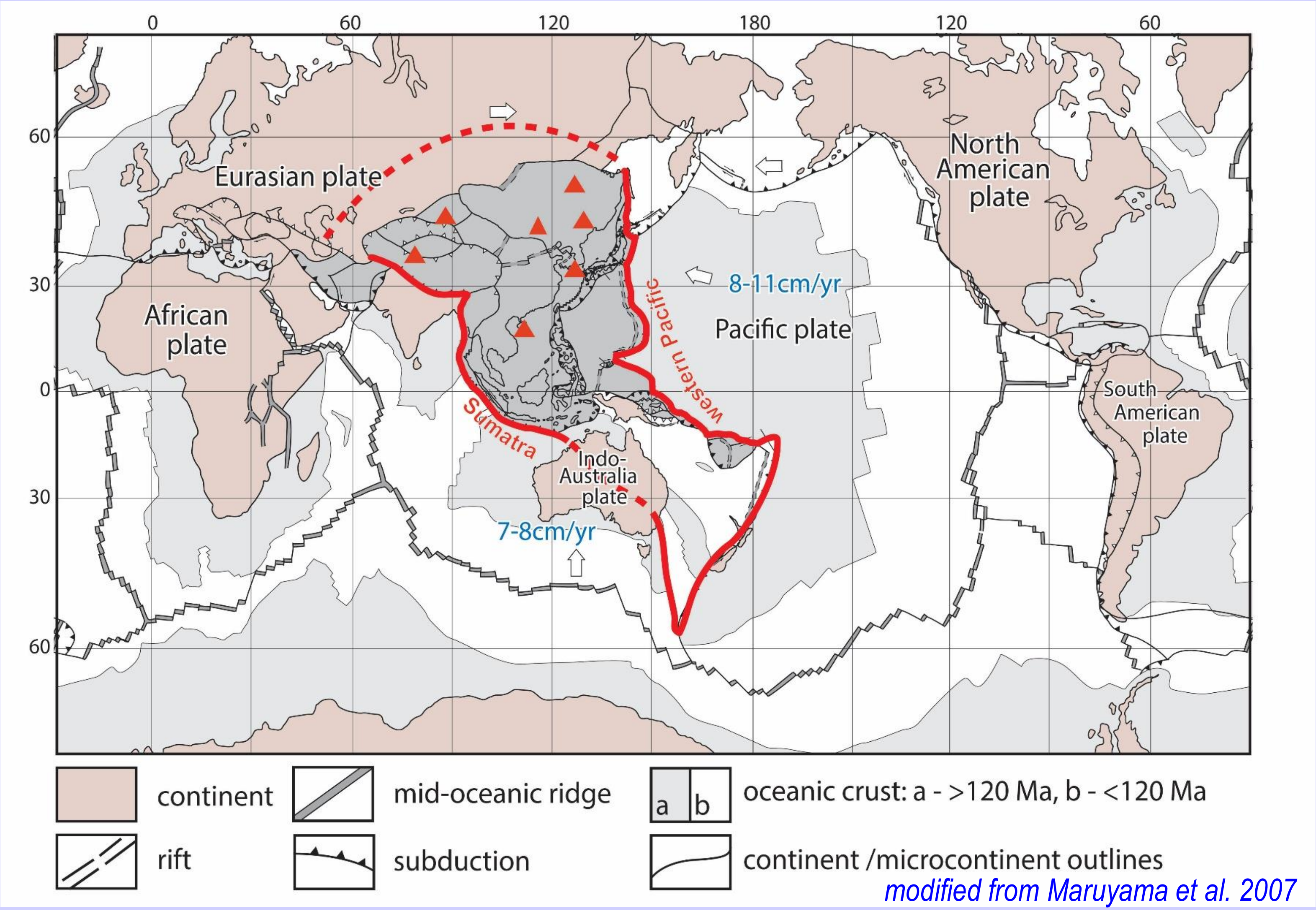
Subduction of hydrated-carbonated oceanic crust and role of water





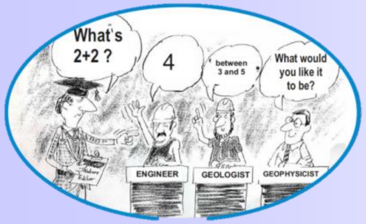
The subducting oceanic crust is saturated by hydrous minerals: serpentinites, hydrated sediments, and carbonates. In addition, subducting slabs can be bended to form fissures through which water can be supplied deeper to the lower layer of double seismic zone. This is the only way to transport water from the slab into the mantle in the form of DHMS, which can further decompose to hydrous wadsleyite and ringwoodite or release hydrous melts.

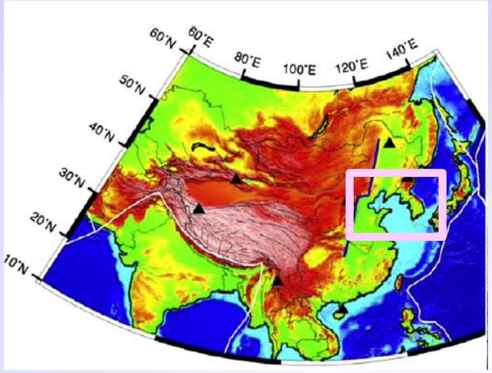
Observation #3: post-Miocene Asia has been surrounded by a double-sided subduction zone

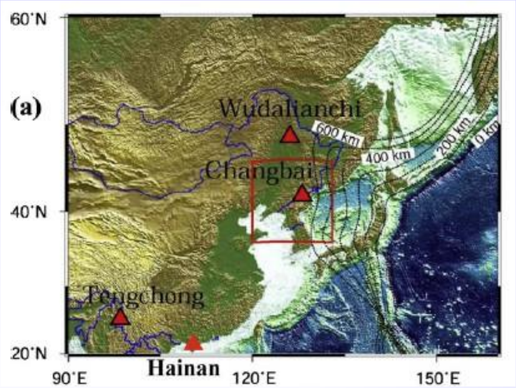


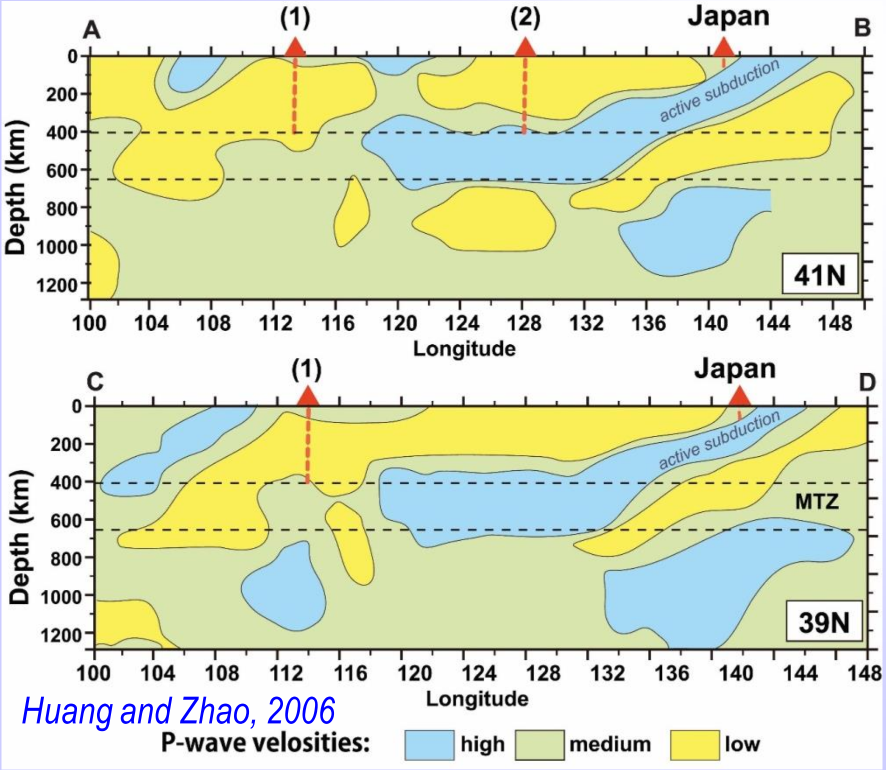
There are a lot of Cenozoic volcanoes in central and eastern Asia

Recent intra-plate volcanism of East Asia probably related to the subduction of the Pacific Plate

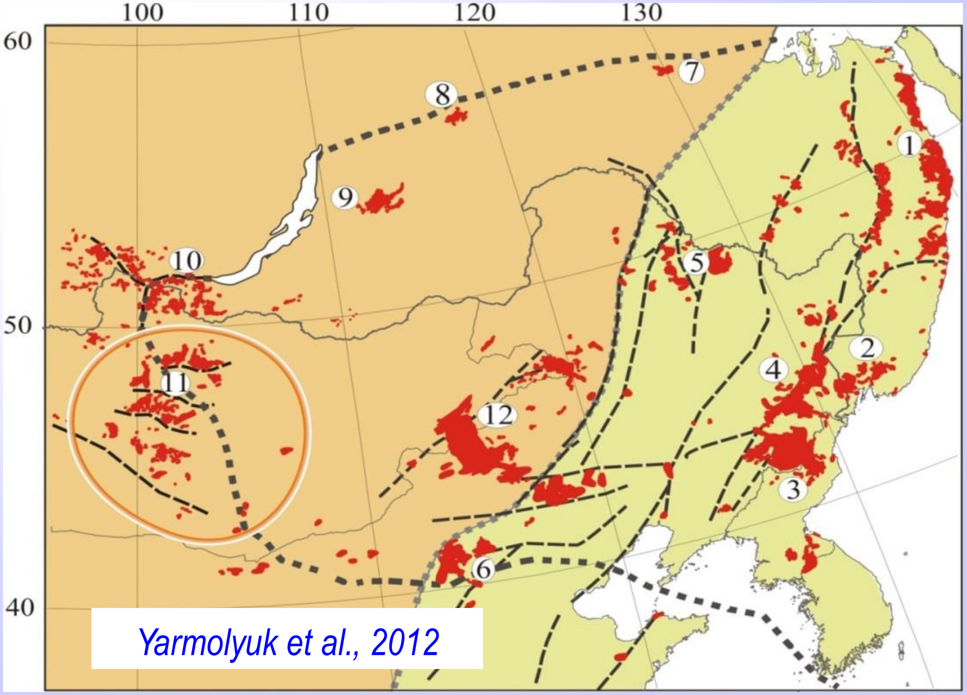






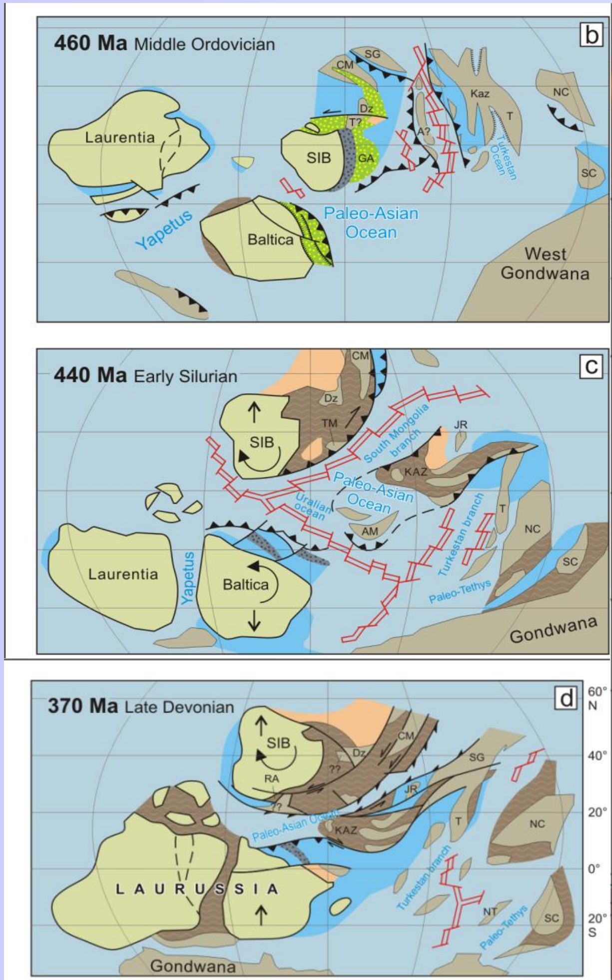


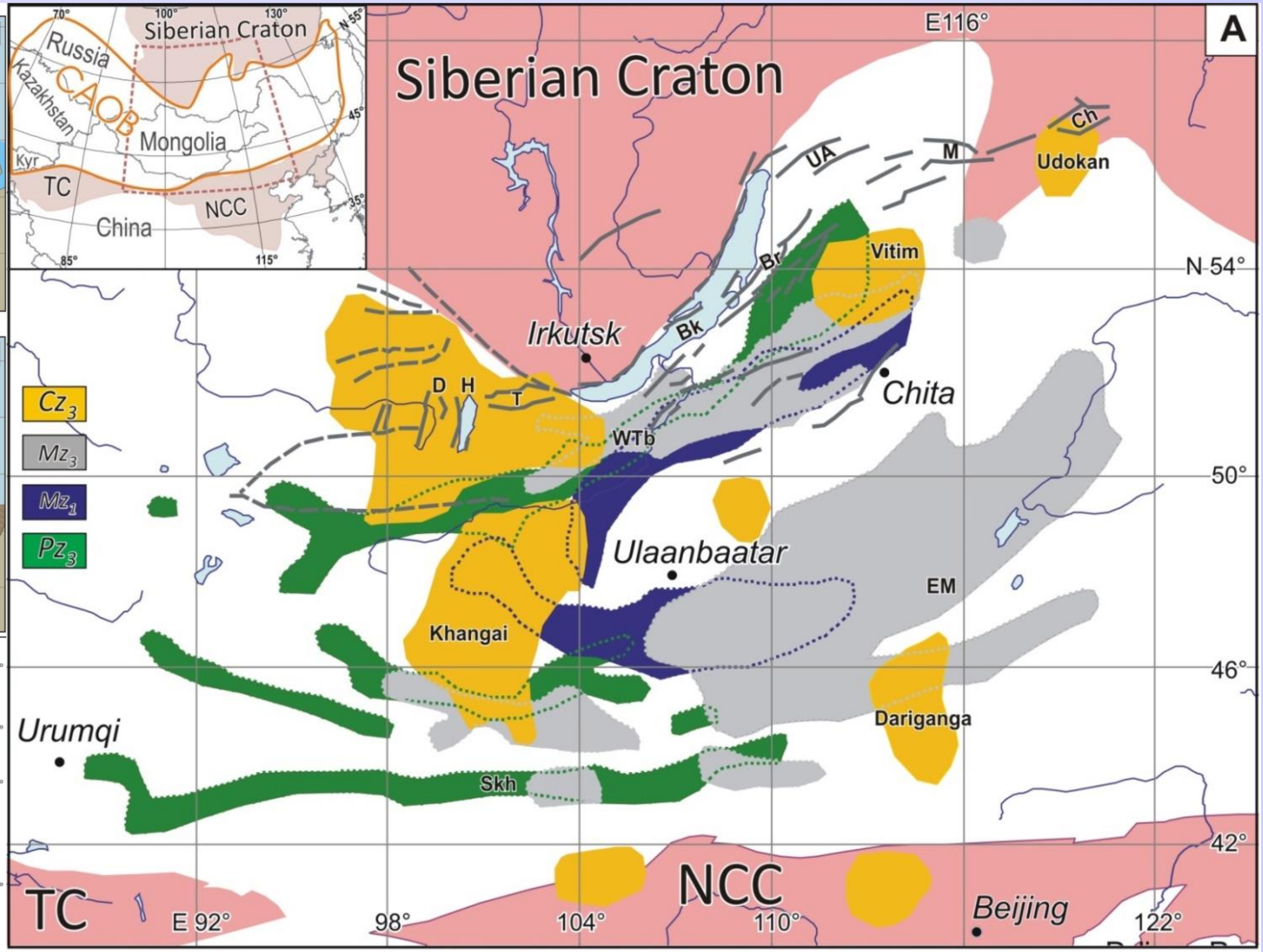
Huang and Zhao, 2006



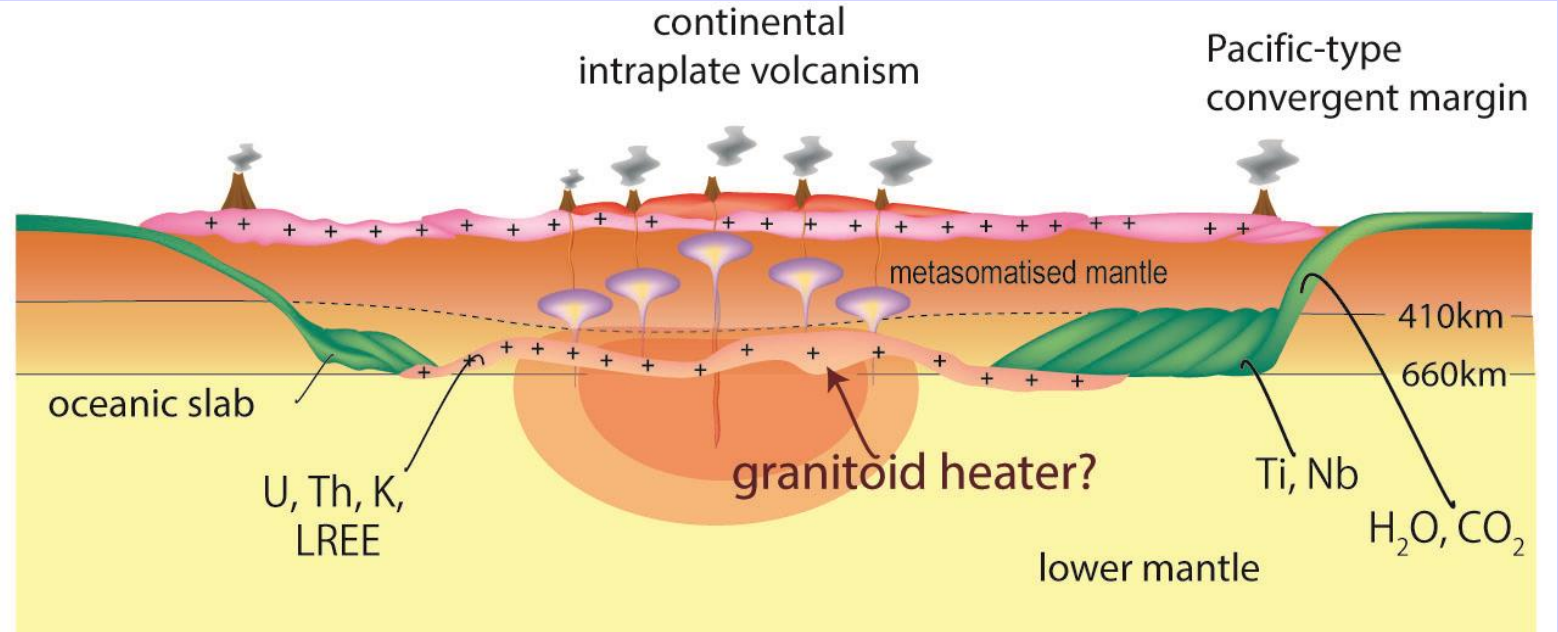
Yarmolyuk et al., 2012

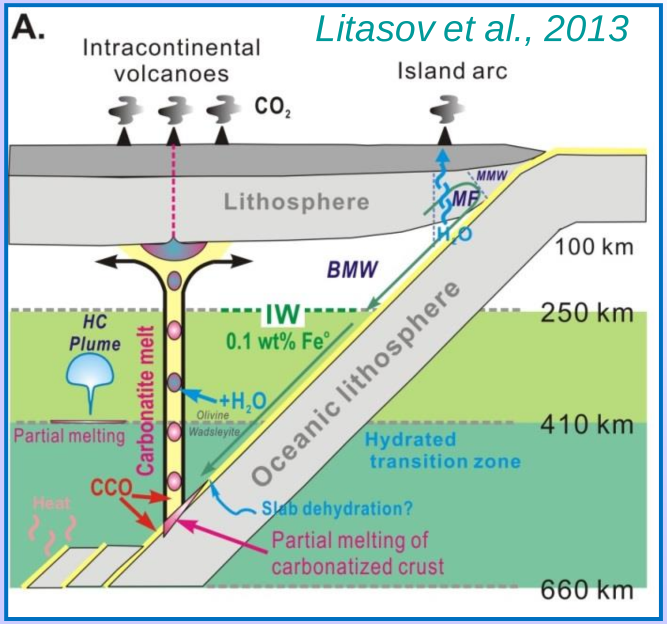
A question: any link between tectonic erosion at PAO active margins and Meso-Cenozoic intra-plate continental volcanismc fields in the CAOB

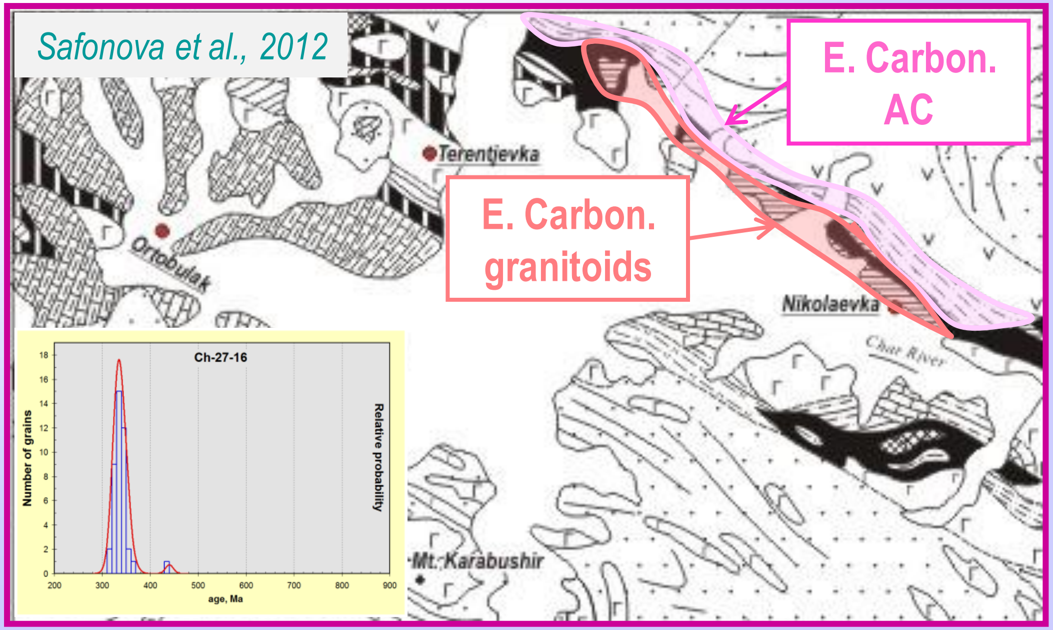




This is how P-type belts and “shallow” mantle plumes are mutually linked, but we need a new algoritm to highlight the periods of tectonic erosion







Observations and suggestions

1. Pacific-type convergent margins are places of both major crustal growth and destruction

2. Different kinds of materials can be eroded and/or directly subducted to the MTZ

3. Volatiles, MORB and arc granitoids can survive and accumulate in the MTZ

4. They can trigger mantle melting and generate mantle plumes

5. The Cenozoic intra-plate continental volcanism in East Asia is linked to the subduction of the Pacific plate

What about the Meso-Cenozoic volcanism in Central Asia?

Conclusions

The P-type Central Asian Orogenic Belt hosts numerous **intra-oceanic arc** terranes and **turbidite/greywacke** trench units.

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

Disproportions between the P-type nature of the CAOB and its "50% recycled crust" may come from the **tectonic erosion** of juvenile arc crust

The **crustal materials tectonically eroded** at P-type convergent margins of the Paleo-Asian Ocean in mid-late Paleozoic time could contribute to the **intra-plate magmatism** in the CAOB

Itmurundy Belt, central Kazakhstan

LEPOM field trips 2017