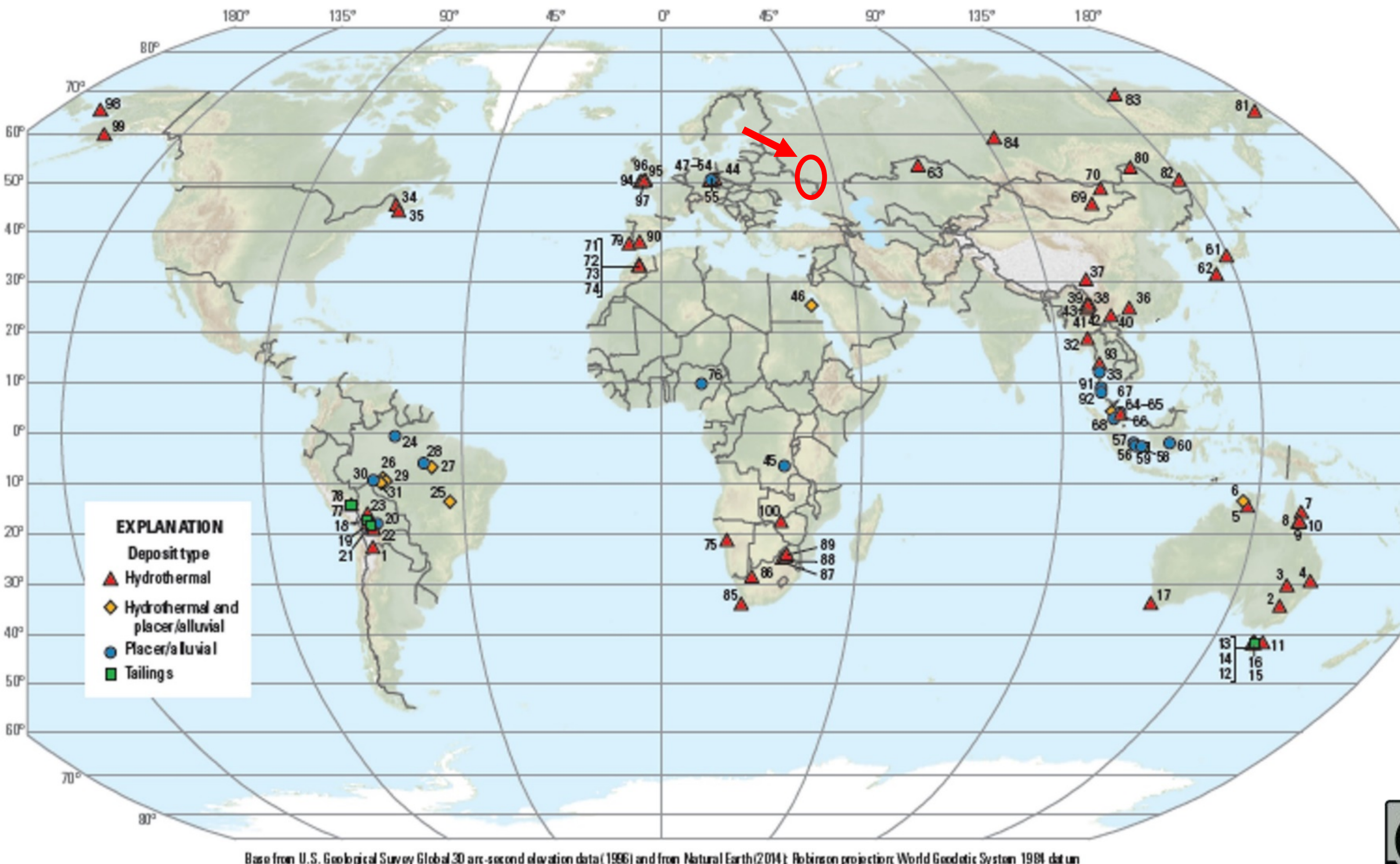
TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG

The chemical evolution from older (323–318 Ma) towards younger highly evolved tin granites (315–314 Ma)—sources and metal enrichment in Variscan granites of the Western Erzgebirge (Central European Variscides, Germany)

Tichomirowa M., Gerdes A., Lapp M., Leonhardt D., Whitehouse M. (2019)

- Erzgebirge – one of the classical tin regions of the world
- Close relationship with highly specialized granites
- Different models for formation of such highly specialized granites and tin enrichment at ore level



USGS, 2017

Figure S7. World map showing locations of major tin deposits and districts in the world, by deposit type. The numbers are keyed to the identification numbers listed in table S2.

Proposed critical enrichment processes for granite-bound tin mineralization („Sn-granites“):

- Intense sedimentary weathering (=Na, Ca, Sr depletion and Sn-W enrichment) and voluminous sedimentary rocks = source enrichment
- Melting conditions, e.g. high-temperature melting
- Extreme degrees of magmatic fractionation
- Enrichment in magmatic fluids

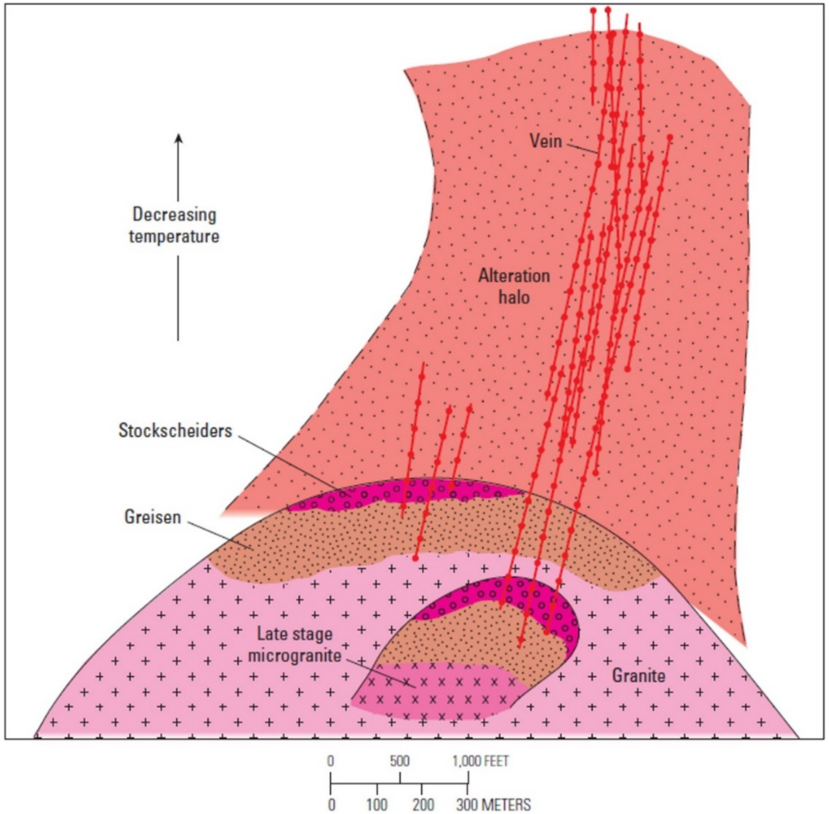


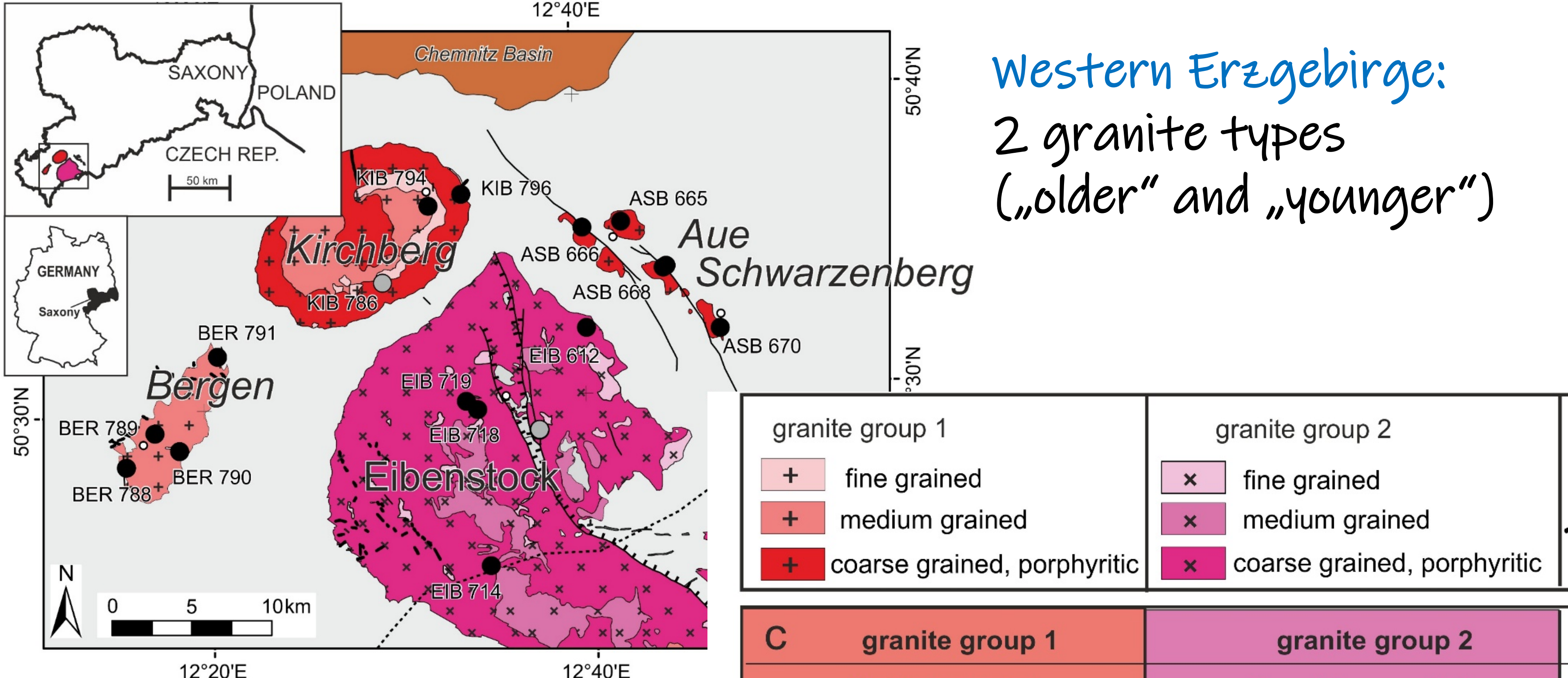
Figure S6. Schematic vertical section across a typical hydrothermal mineralized granite cupola showing salient features of a shallow granite-related tin-mineralized system. As a tin-bearing granitic magma intrudes into existing crustal rock and cools, residual metal-rich fluids left over from the crystallization of the primary igneous minerals are injected into voids and fissures within the granite and surrounding host rock, forming bodies with high concentrations of tin. After Cérný and others (2005).

Erzgebirge = ideal region to study the formation of„Sn-granites“:

- Many publications about geology, petrology, geochemistry, geochronology of Variscan granites and their host rocks
- Sequence of Variscan granite intrusions in the Western Erzgebirge established by high-precision U-Pb dating: older less fractionated granites intruded between 323 and 318 Ma (Aue-Schwarzenberg, Kirchberg, Bergen). The highly fractionated F-rich „Sn-granite“ Eibenstock intruded 5 Ma later (315-314 Ma)
- Geochemical evolution of granites can be investigated for this time interval
- Possible to establish the source of granites by combination of methods (Nd and Sr isotopes of bulk rock; Hf and O isotopes of zircons) that are resistant to extreme fractionation or hydrothermal overprint

Western Erzgebirge:

2 granite types
(„older“ and „younger“)



C granite group 1		granite group 2		
„Gebirgsgranite“ scarcely mineralized granite		„Erzgebirgsgranite“ highly mineralized granite (Sn, W)		
Older Intrusive Complex (OIC)	Inter-mediate granites	Younger Intrusive Complex (YIC)		
low-F biotite granite	low-F two-mica granite	high-F, high-P, Li-mica granite	high-F, low-P, Li-mica granite	high-F, low-P, biotite granite
ASB, KIB	ASB, BER	EIB		

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Western Erzgebirge: Identification of source rocks for Variscan granites

- comparing zircon`s $^{176}Hf/^{177}Hf$ with that of basement rocks
- comparing zircon`s $\delta^{18}O$ with that of basement rocks
- using xenocrystic zircon ages of granites (360 – 340 Ma)
- Using Nd bulk rock model ages

Conclusions:

- pure sediments and most meta-sedimentary and meta-igneous host rocks from the Cadomian basement can be excluded as major sources
- Contrary, high-grade metamorphic amphibolite- and granulite-facies gneisses are the most likely sources for Variscan granites in the Western Erzgebirge based on their zircon data (Hf and O isotopes, xenocrystic zircon ages)
- The Hf data from zircons as well as the Nd data from whole rocks do not support a substantial mantle input for these S-type granites after metamorphic homogenization.

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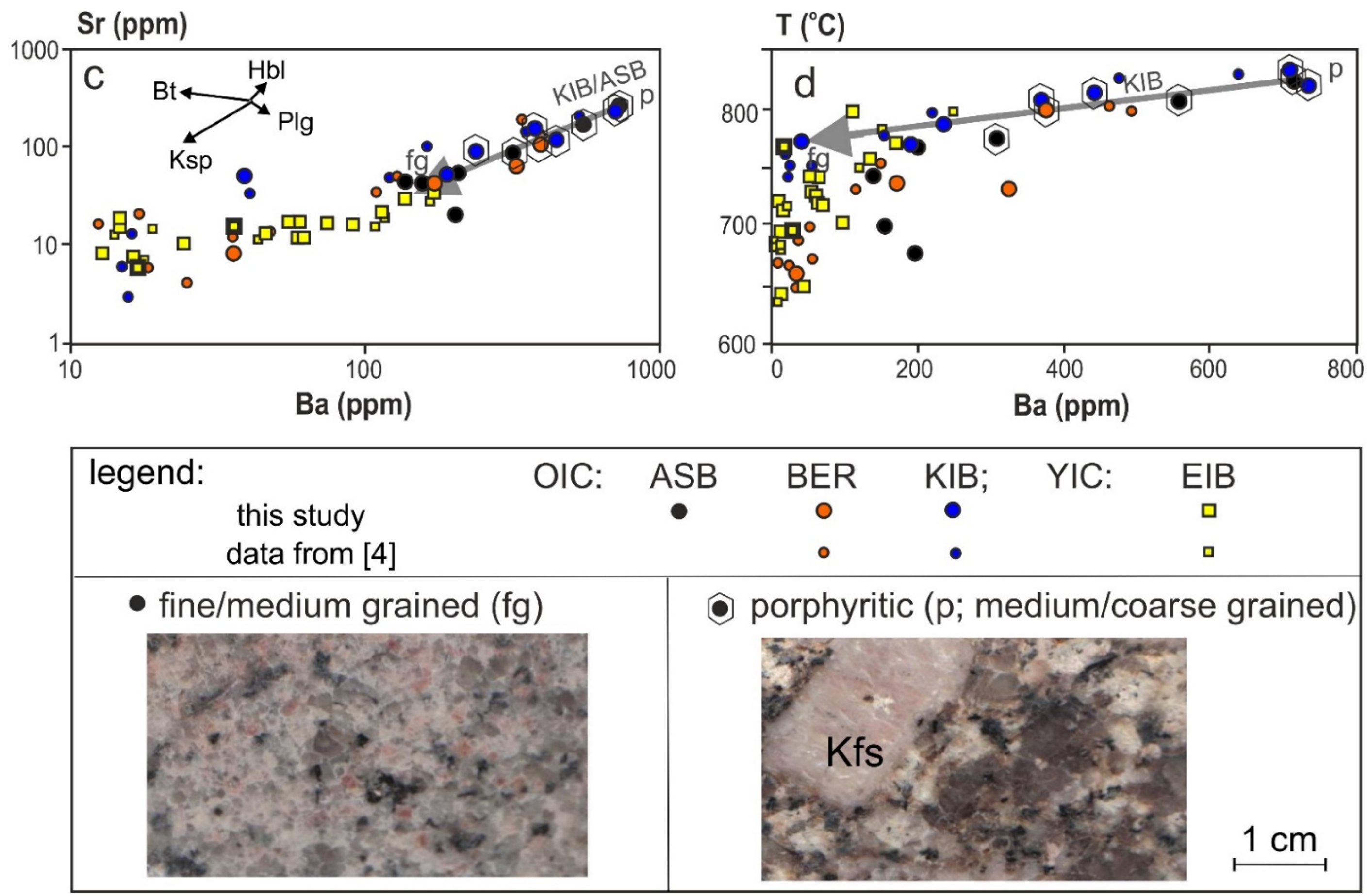
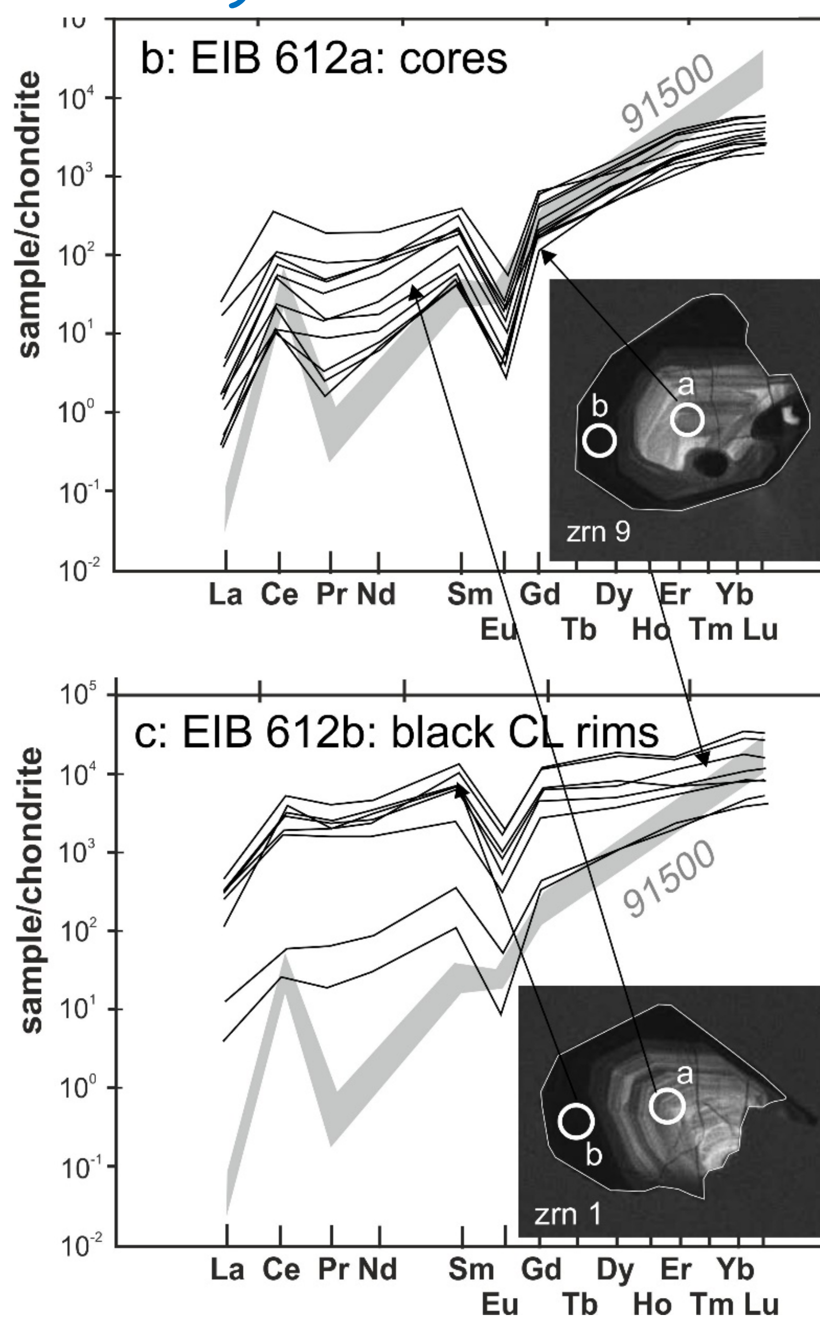
Western Erzgebirge: Melting and fractional crystallization

- The youngest most fractionated Sn-granite Eibenstock has lower melt temperatures (~750 – 700°C) compared to the older granites (Aue-Schwarzenberg, Kirchberg, Bergen)
- Fractional crystallization of biotite and plagioclase together with K-feldspar „phenocryst unmixing“ (porphyritic varieties) results in correlation lines in Harker diagrams



Western Erzgebirge: the role of fluids (greisenization)

- Extreme enrichment of several elements (e.g., Sn, W, Ta, Nb, F, Bi, Rb, Cs, F)
- Depletion of Na
- Replacement textures: dissolution of plagioclase, formation of fluorite
- Formation of zircon rims that are black in CL-images, porous, have extremely high concentration of common Pb, are enriched in LREE



Extreme enrichments by late F-rich fluids

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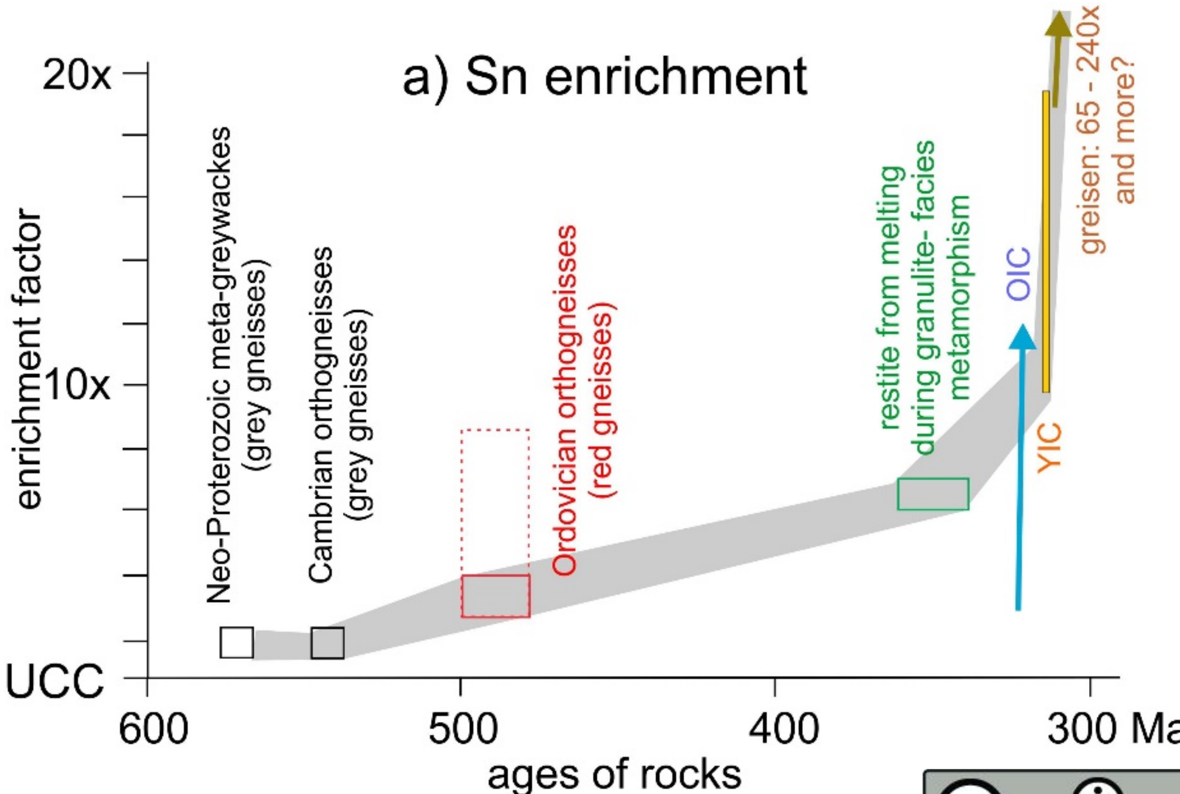
Factors Necessary for Enrichment of Sn and W to Ore Concentration

- Source rocks (= restite from high-temperature metamorphic rocks) were already enriched in Sn (probably in Ti-minerals like rutile), but ≤ 10 times compared to the Upper Continental Crust (UCC)
- Fractionation and multiple melt production (from older granites OIC starting at 323 Ma to younger granites YIC at 315-314 Ma) led to further enrichment (mean enrichment ca. 12times of UCC)
- Largest enrichment by hydrothermal fluids (greisens: 65 – 240x)!

Contrary to previous suggestions:

- sedimentary rocks cannot be source rocks
- Low Sn-enrichment in source rocks: ≤ 10 times
- Melt temperature was lower for „Sn-granite"



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