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Magmatic-hydrothermal transition in Mo-W granite-pegmatite-greisen systems:

Trace element chemistry of quartz, Krupka district, eastern Erzgebirge (Czech Republic)

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0. In short …

What?

We are interested in better understanding of magmatic-hydrothermal transition in silicic systems, particularly the composition of highly differentiated, volatile-rich melts and their aqueous fluids. We will investigate unique composite intrusion of granites, pegmatites, with massive silicification, greisenization and stockwork of proximal and distal quartz veins. Abundance of the siliceous rocks points to sharp chemical gradients, controlling the precipitation and/or mineralization processes that may have been facilitated by involvement of hydrosilicate (silicothermal) fluids.

How?

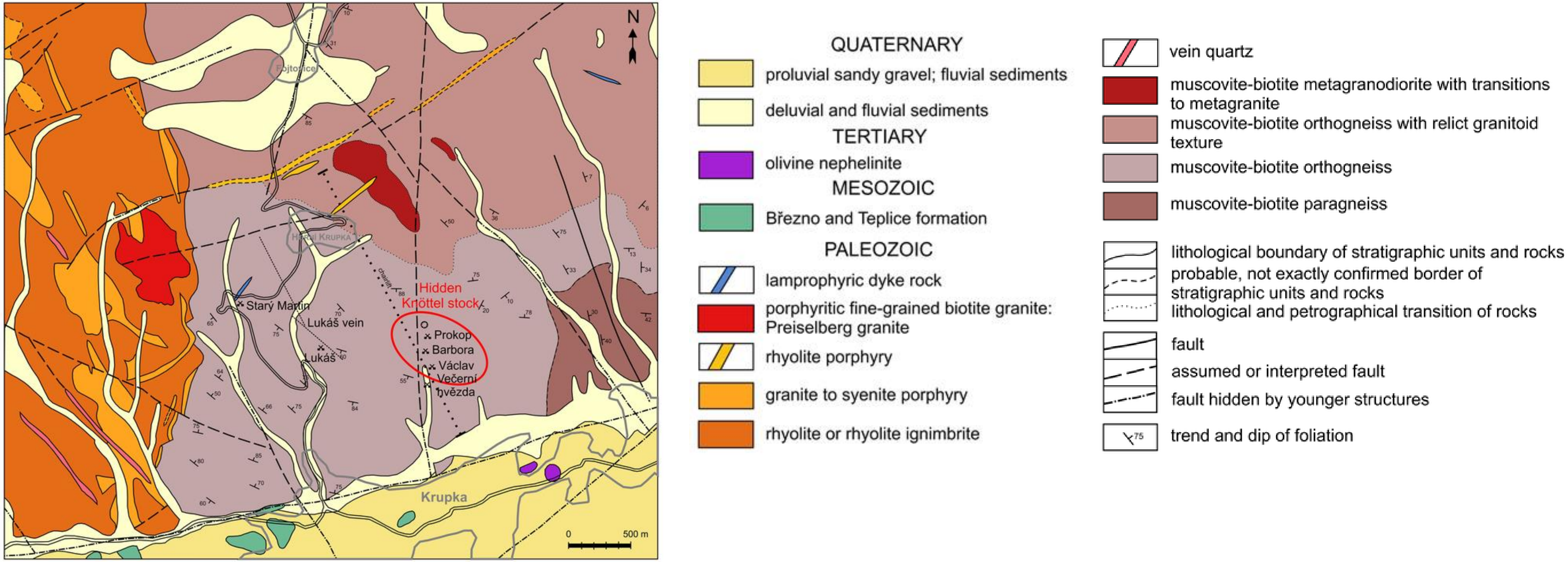
Fluid inclusions are irregularly and poorly preserved in individual rock types. We will use trace element concentrations in quartz to monitor evolution of granitic melts and magmas during emplacement, formation of pegmatites and their spatial zones, as well as magmatic *vs*. meteoric input into metasomatic and hydrothermal rocks (greisens, hydrothermal quarzites, quartz veins). This approach was complemented by Ti-in-quartz thermometry.

Then …

The Li/Ti ratios in quartz are the most robust indicators of magmatic crystallization (700–583 °C), exsolution of hydrosilicate medium (601–497 °C), formed as a disequilibrium boundary layer in front of rapidly propagating solidification front, and multistage exsolution of hydrothermal fluids (498–393 °C), producing greisens, quartz stockwork and distal quartz veins.

1. Geological setting

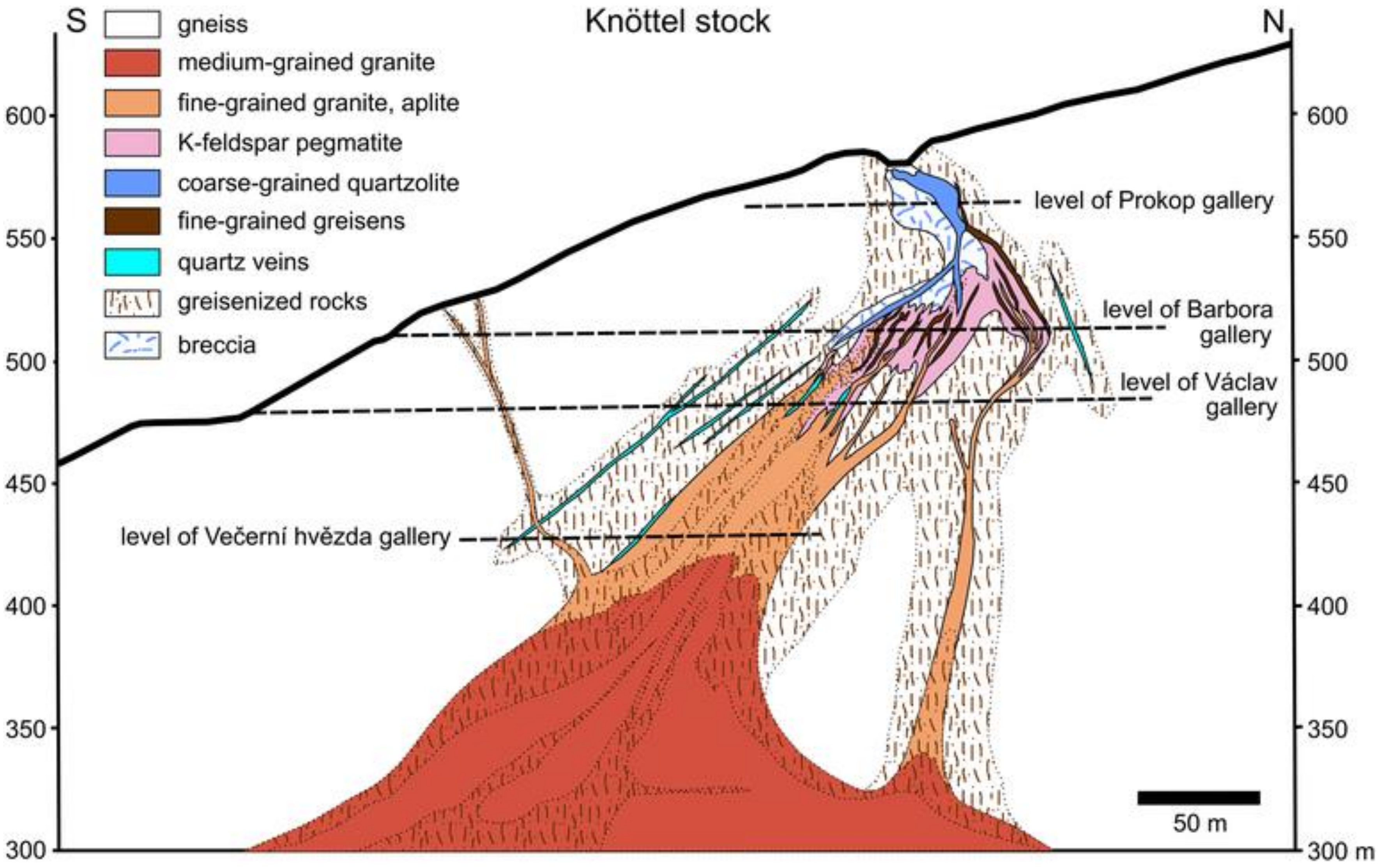
The Krušné hory/Erzgebirge province in central Europe is characterized by late Variscan, Sn-W greisen mineralization that is spatially and temporally associated with W-Mo pegmatite-greisen mineralization in its eastern part.



The granite-pegmatite-greisen stock belongs to the series of minor shallow-level intrusions (327-317 Ma), emplaced near the contact of the Teplice-Altenberg volcanic complex (caldera) with the pre-Variscan metamorphic complex (two-mica gneisses)

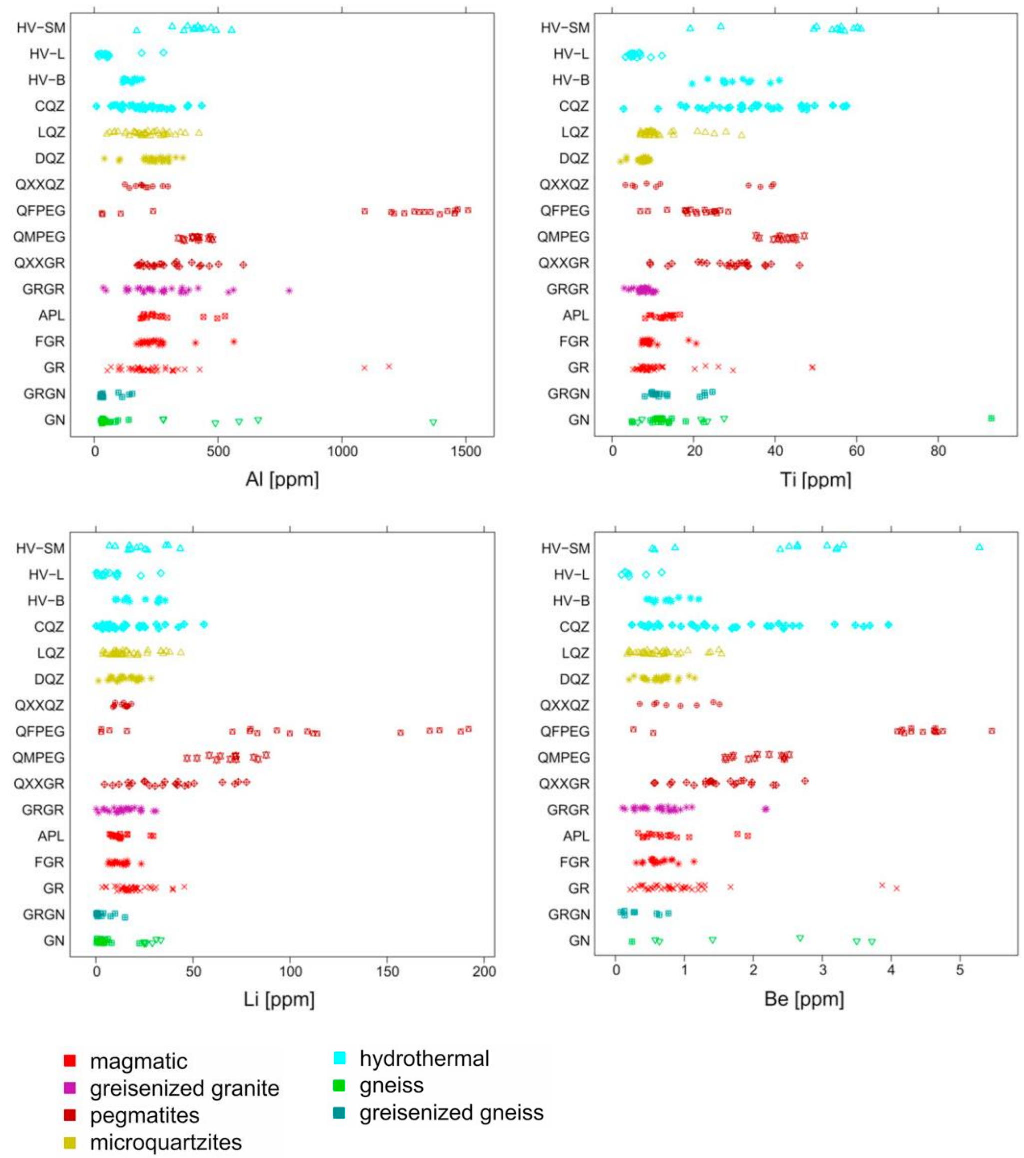
2. Geological setting

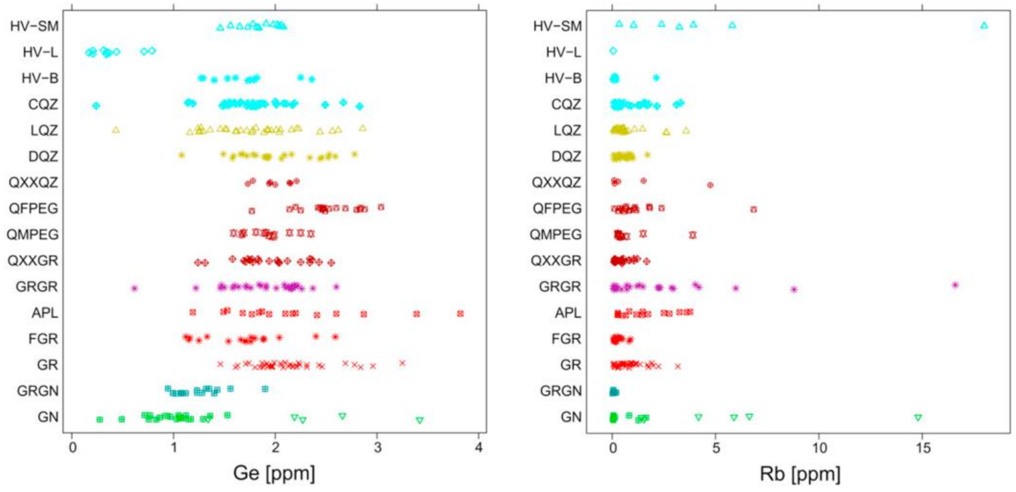
In the Knöttel district at Krupka, a complete sequence of highly differentiated Li- and F-rich granites, aplites, pegmatites, breccias, greisens, hydrothermal quartzites and late quartz veins is exposed.



3. Trace elements in quartz (in individual rock types)

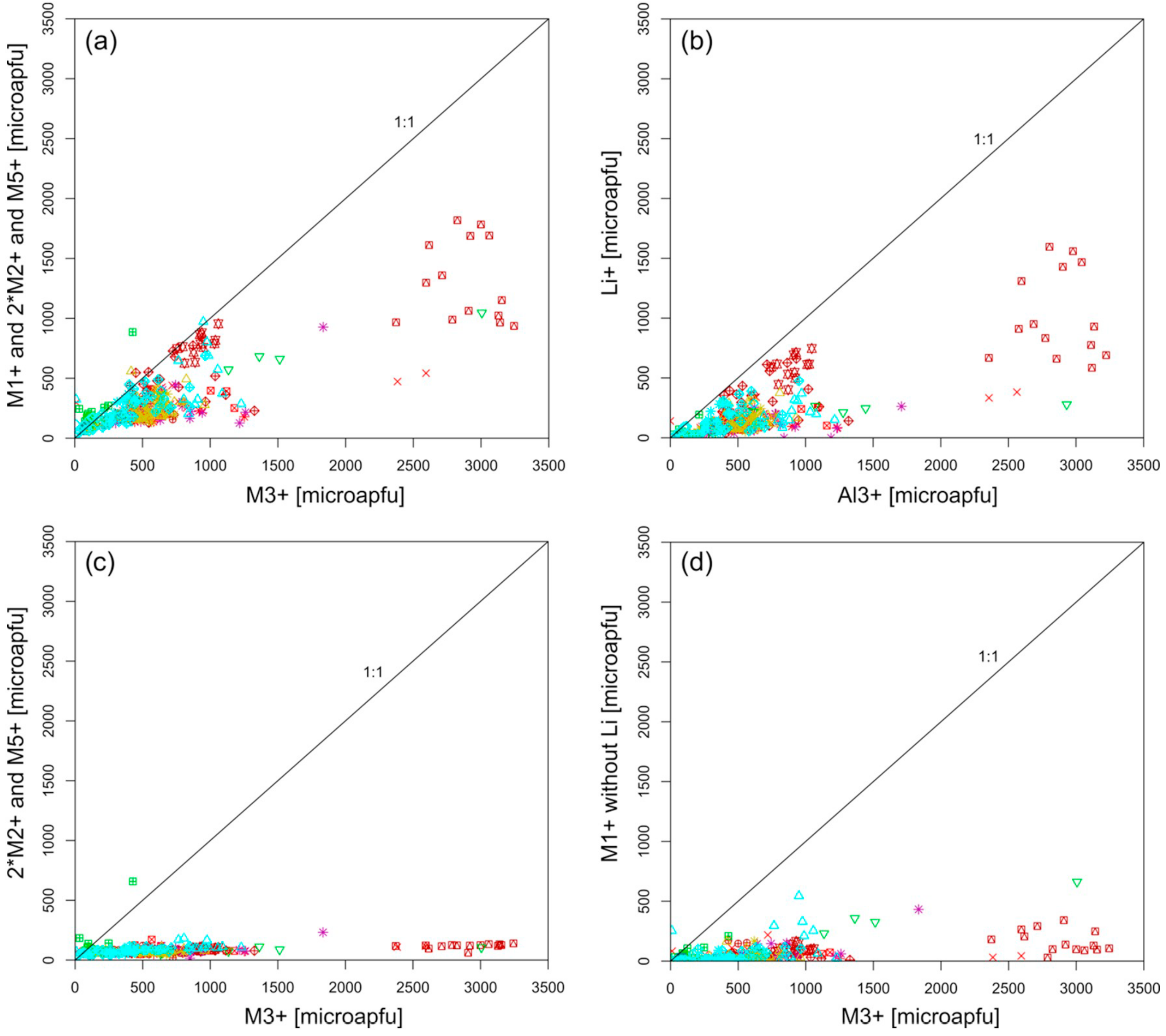
The nature of magmatic-hydrothermal transition has been investigated and interpreted by trace element composition of quartz, analyzed by laser ablation ICP-MS





Most abundant trace element in quartz in all the rock types is Al and the elements to be used for interpretation are mainly Al, Ti, Li and Be. Several element pairs correlate, e.g. Li and Al (dictated by the abundance of Li in the parental melt), Fe and Mn, Rb and Cs, Na and K, Pb and Sn as well as As and Sb.

4. Trace elements in quartz: Substitution mechanisms

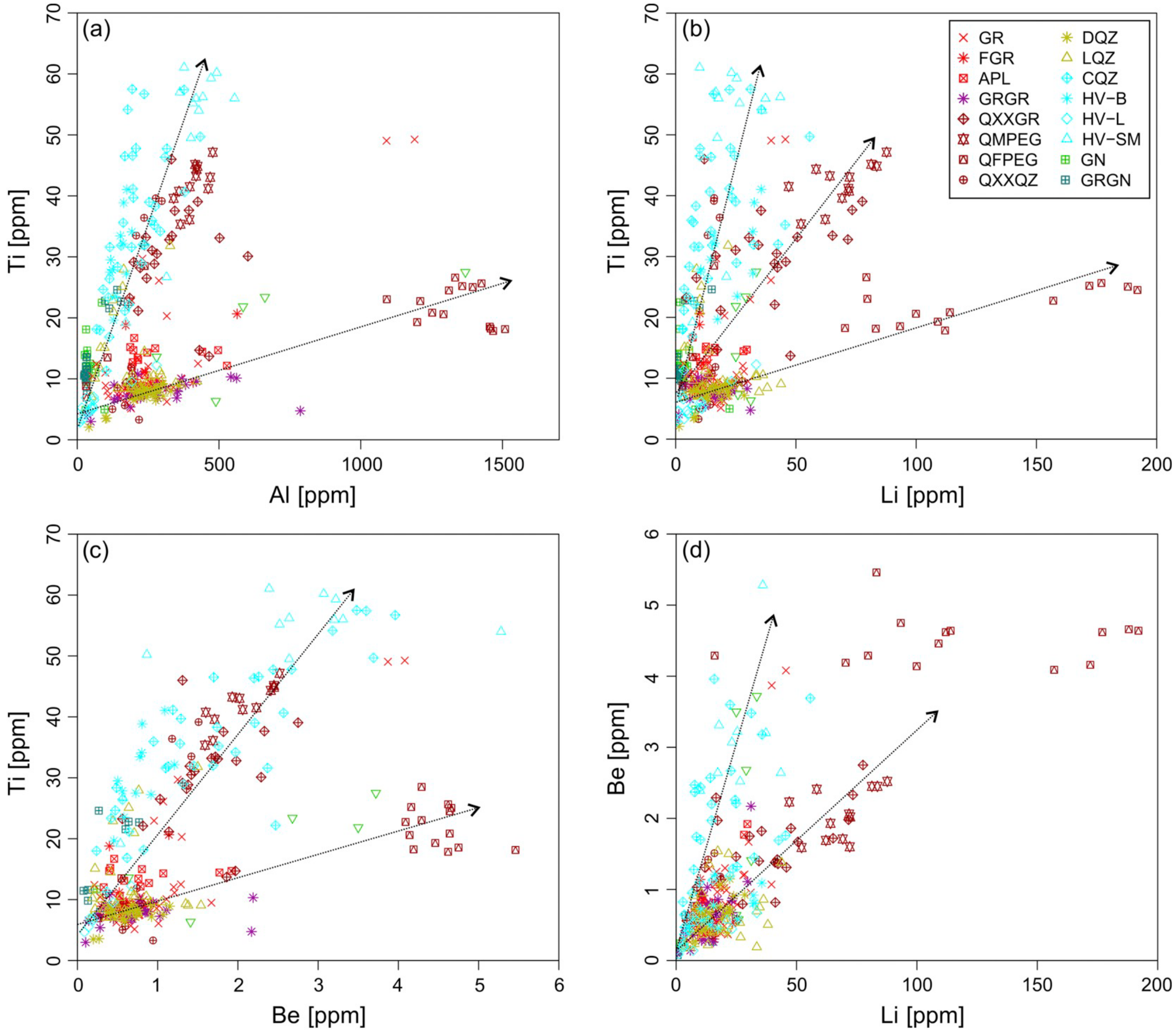


Al, B, Ge, Fe, H, K, Li, Na, P and Ti are expected to be ionic substituents in quartz. At Knöttel:
Ti^{4+} >> Ge^{4+}
Al^{3+} >> Fe^{3+}, B^{3+}
Li^{+} >> K^{+} > Na^{+} >> Rb^{+}
Minor abundances of M^{2+} and P^{5+}

The trivalent cations (mainly Al^{3+}) are balanced by
Li^{+} > K^{+} > Na^{+} > Mg^{2+} > P^{5+} > Mn^{2+} > Be^{2+}, possibly H^{+}

Dominant substitutions are:
$Si^{4+} = Li^{+}Al^{3+}$, $Si^{4+} = K^{+}Al^{3+}$, $Si^{4+} = Na^{+}Al^{3+}$

5. Ti-in-quartz thermometry



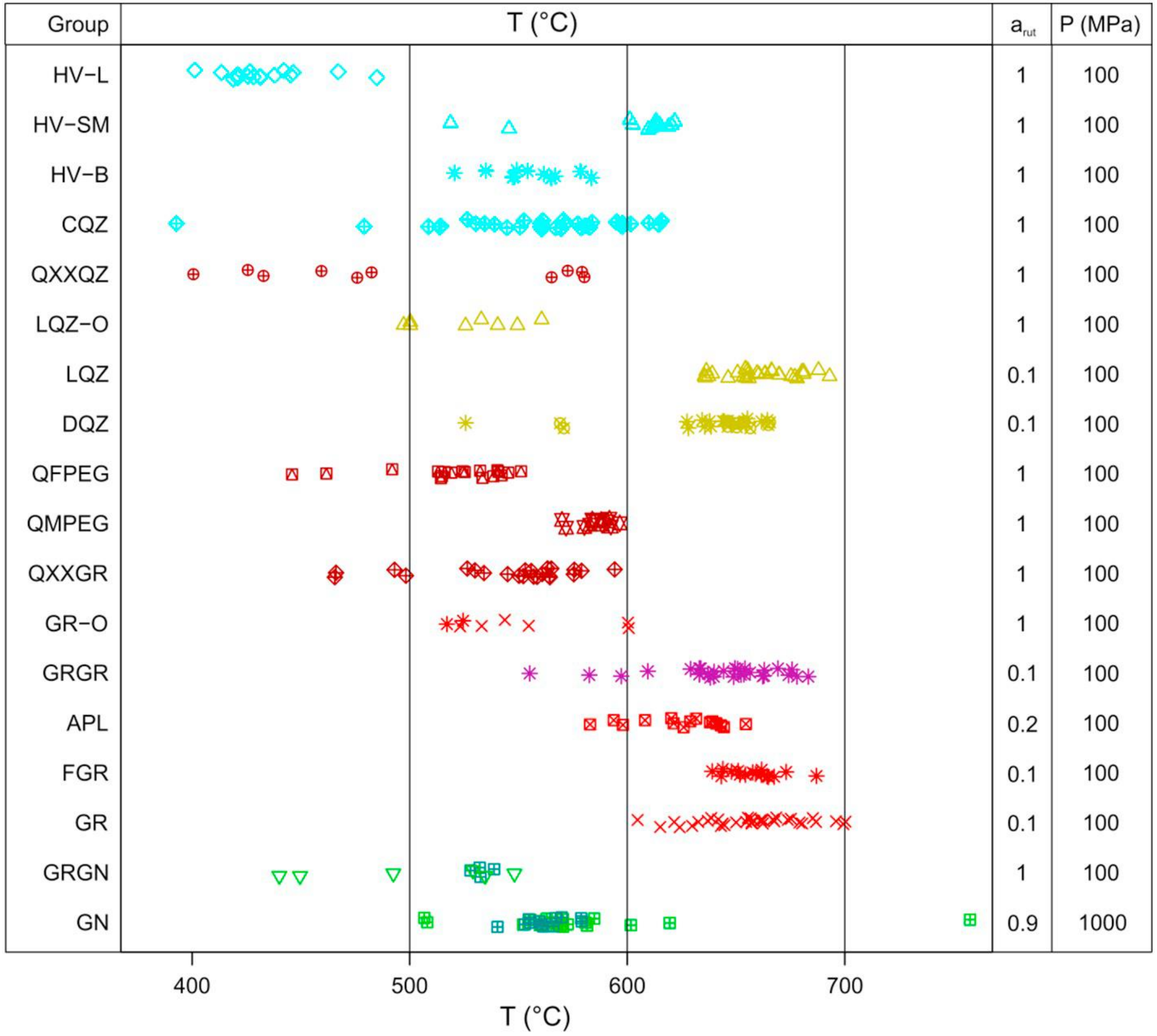
Ratios in Ti vs. Li, Be and Al in quartz define several distinct genetic trends:

(1) **magmatic, high-Li/Ti or Al/Ti trend**, which involves granites, aplites and K-feldspar pegmatites.

(2) **late-magmatic or hydrosilicate, medium-Li/Ti trend** recorded by quartz megacrysts and pegmatite-textured aggregates in granites and quartz-protolithionite pegmatite. This trend plausibly represents a hydrosilicate liquid, an H_2O- and SiO_2-rich medium that was probably formed by disequilibrium crystallization in front of rapidly propagating solidification front of highly evolved granitic melt.

(3) **hydrothermal, low-Li/Ti or Al/Ti trend** represented by a stockwork of coarse-grained hydrothermal quartzites and quartz veins, and quartz replacement in greisens.

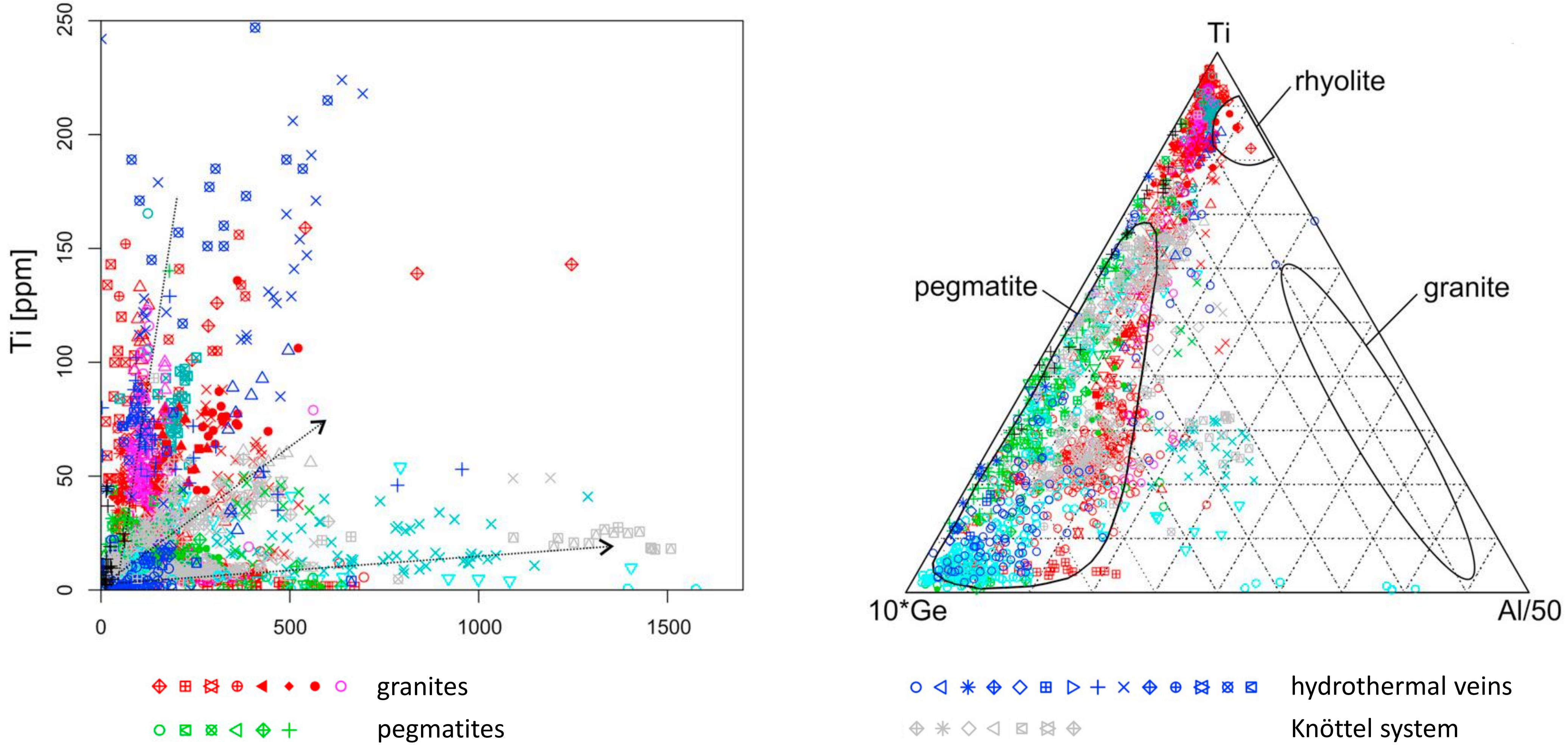
6. Ti-in-quartz thermometry



Thermal evolution of the magmatic-hydrothermal system was monitored by Ti-in-quartz thermometry. The calculated rutile activity in the granitic melts was very low (0.3–0.05) but it increased (up to 1), that is, rutile saturation in the pegmatites and the hydrothermal quartz veins.

Magmatic crystallization of the granites and aplites occurred from 700 to 580 °C, the pegmatite formation between 600 and 500 °C. The greisenization stage coincided thermally with the pegmatite crystallization, and it was followed by a late hydrothermal stage precipitating distal quartz veins at 500–390 °C.

7. Comparison with highly differentiated granite-pegmatite systems worldwide



The concentrations of Ti, Al, Ge, Li and Rb in quartz reveal that the granite and pegmatite magmas at Knöttel – and in the Erzgebirge in general – have reached extremely high Al, Li, Rb and Ge enrichment in comparison with igneous rocks worldwide and their composition approaches that of pegmatites. In addition, the Knöttel system exhibits Be enrichment in quartz, apparently linked to F enrichment, and this feature marks the Mo-W-mineralized systems globally.

Further information

Peterková T., Dolejš D. (2019). Magmatic-hydrothermal transition of Mo-W-mineralized granite-pegmatite-greisen system recorded by trace elements in quartz: Krupka district, Eastern Krušné hory/Erzgebirge. *Chemical Geology, 523, 179-202.*

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