

## Editorial

# Editorial for Special Issue “Accessory Minerals in Silicic Igneous Rocks”

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Although minor in abundance and typically small in size, accessory minerals are of fundamental importance in deciphering the evolutionary history of magmatic–hydrothermal systems. They inherit information from magma sources, monitor the evolution of fractionating melts, and record information on mixing/mingling/contamination of melts. Accessory minerals constitute important geochronometers and essentially govern the enrichment/depletion of economically relevant elements. Accessories act as thermobarometers and monitor the fluid regime in magmas and expelled fluids. Their textural and compositional patterns constrain the impact of rock–mineral–fluid interaction. They also monitor how intense such processes have obscured the primary composition of igneous rocks.

Relative to the enormous potential that accessory and ore minerals have in tracing geological processes, the seven papers collected in this Special Issue can only cover a small, but representative selection of key questions. They address various aspects of dating rocks and associated mineralization, using different isotopic systems and applying state-of-the-art analytical techniques. The contributions follow up with the reconstruction of the evolution of magmatic and ore-forming processes, especially focusing on the genetical relations between deposits and spatially associated felsic rocks.

Extraction of reliable information on the composition, age, and origin of accessory phases requires high-precision analytical techniques. In addition to the widely used electron-probe microanalysis (EPMA), modern analytical developments comprise, for instance, secondary ion mass spectrometry (SIMS), laser ablation-multicollector-inductively coupled mass-spectrometry (LA-MC-ICPMS), or isotope dilution thermal-ionization mass spectrometry (ID-TIMS). The reliability of data obtained from such studies is not only related to the precision of the applied methods and instruments used, but is also critically dependent on the availability of well-characterized standard material. The paper of Wu et al. [1] reports on such a standard mineral (the RW-1 monazite) as a potential new working reference material for microbeam analysis of O–Nd isotopes. The oxygen (O) and neodymium (Nd) isotope systematics of monazite has been shown to provide an effective tracer of metamorphic and hydrothermal processes, but a more widely application of monazite O–Nd isotopes is hindered by the lack of a sufficient number of standards. The isotopic data reported by Wu et al. [1], thus, constitute a step forward in increasing the availability of well-analyzed monazite standard for the analysis of O and Nd isotopes.

Monazite is not only a potential ideal geochronometer and perfect tracer of stable and radiogenic isotopes, but simultaneously the most important carrier of the light rare earth elements (LREE) and of thorium in felsic igneous rocks. In less silicic, more Ca-rich granites and granodiorites, allanite-(Ce) crystallized instead of monazite-(Ce) and takes the position of the major host of LREE and Th, commonly together with apatite (LREE) and thorite (Th). In contrast to monazite-(Ce), allanite-(Ce) is relatively more susceptible to alteration, which may give rise to a plethora of secondary phases, i.e., epidote, bastnäsite-(Ce), synchysite-(Ce) and many others. Therefore, allanite-(Ce) is little used in precisely dating rocks, but instead is considered a potential tracer of fluid-mediated overprinting processes. The contribution of Gros et al. [2] is subjected to the complex alteration characteristics of



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allanite-(Ce) entrained in composite dykes cross-cutting the Karkonosze granitoid pluton in the Variscan of Poland. Their study uses EPMA and LA-ICPMS, together with back-scattered electron (BSE) imaging, to discriminate different allanite-(Ce) populations and intragrain alteration products, and to measure their compositions. Considering the specific geochemical responses to the discrete overprinting events, the authors suggested alkaline, low-temperature and oxidized fluids being responsible for the hydrothermal processes that the dykes experienced. Moreover, Gros et al. [2] inferred a change of the fluid composition with time, developing from an early Cl-dominated fluid to a late F–CO<sub>2</sub>-rich hydrothermal solution. The results of this study underpin the importance of allanite-(Ce) in reconstructing the late- to post-magmatic, fluid-triggered history of magmatic rocks.

Accessories are by far the most prominent minerals for the purpose of inferring the age of magmatic and hydrothermal processes. U–Pb isotopic dating of monazite, xenotime, uraninite, titanite, and apatite, only to mention a few, is currently in use to obtain intrusion ages of igneous rocks. The most widely used geochronometer is, however, zircon. Zircon is generally abundant in silicic rocks, may consist of age-different growth and alteration domains, and accounts for an important, but variable budget of bulk-rock concentrations of Zr, Hf, U, and the heavy rare-earth elements (HREE). Since zircon is particularly prone to alteration, which may result in the loss of radiogenic Pb and disturbance of the isotopic system, special care has to be devoted to the identification of grains or intragrain domains appropriate for dating. Owing to this potential problem, alternative methods, which do not rely on isotopic data, would be advantageous in identifying different zircon populations that may be present in a rock. Rhyolitic rocks are particularly susceptible to contain zircon populations of different origin, and any technique that would foster the recognition of genetically different zircon would be supportive in clarifying the origin of the host rock. Prezebyło et al. [3] used the automated scanning electron microscopy mineral liberation analysis (SEM-MLA) to search for the eventual presence of different populations of zircon in a selection of late-Variscan rhyolites of central Europe. The authors successfully applied this method to infer whether the zircon crystals crystallized from the contemporary magma (autocrysts), relate to an earlier magmatic episode (antecrysts), represent un-resorbed remnants from their anatectic source of assimilated country rocks (inherited or xenocrysts), or were formed in response to the infiltration of Zr-rich external fluids. Prezebyło et al. [3] could demonstrate that each of the rhyolite localities studied in the paper has its own, special zircon fingerprint, a finding essential for streamlining the focus of forthcoming research of these rocks.

Highly differentiated, evolved (rare metal) granites are often associated with metallic ore mineralization. Key questions are the genetical relations between the granitic rock and the spatially associated mineralization, and whether it originated within a single event or involved multiply episodes of enrichment processes. Resolving these questions requires accurate dating of ore metals, i.e., Re–Os of molybdenite, U–Pb of cassiterite, or Sm–Nd of wolframite. Two papers in this special volume are dedicated to these key issues. Yuan et al. [4] studied pegmatite-hosted uranium deposits in the Shangdan uraniumiferous province of China. The authors integrated different dating methods of uraninite and coffinite with petrographic and microanalytical studies. They confirmed the magmatic origin of the U mineralization, distinguished three episodes of U circulation, and defined the physico-chemical conditions prevailing during the different stages of mineralization. Another ore mineral and isotopic system were considered to constrain the genesis of the Longshan Sb–Au deposit in the Xiangzhong metallogenic province of China. Zhang et al. [5] combined data of trace-element composition, Sm–Nd isotope dating, and Sr-isotope analysis of scheelite to infer the genetic relationship between the deposit and the surrounding granite intrusions. Since the ages of Longshan and the magmatic rocks overlap and additionally share other chemical properties, Zhang et al. [5] argued for a genetical association of the ore-forming processes with the intrusion of the granites.

Understanding the evolution of granitic melts and the pre-concentration of “critical” raw elements requires identification and compositional characterization of those mineral

species, in which the elements of interest are primarily bound. Two contributions focused on accessory minerals constituting the main carriers of Nb and Ta, but also contain significant proportions of U, Th, and the REE. The paper of Huraiova et al. [6] considered an exotic occurrence of felsic rocks, i.e., mantle-related granite xenoliths entrained in alkali basalts that intruded in response to Pliocene-Pleistocene rifting of the Carpathian back-arc basin in central Europe. The authors addressed the specific conditions of formation and the EPMA-measured composition of the columbite-fergusonite-pyroxhlore mineral association, an assemblage atypical for common calc-alkalic granites. The unusually elevated concentrations of Nb and Ta are thought to be inherited from the mafic parental magma derived from the enriched metasomatized mantle wedge, which was modified by fluids, alkalic, and carbonatitic melts liberated from the subducted slab of oceanic crust prior to rifting. Pyroxhlore-group minerals account for the major budgets of Nb and Ta in alkaline granites hosting the Katugin rare-metal deposit of East Transbaikalia, Russia. As a result of a comprehensive EMP study, Starikova et al. [7] were able to distinguish several chemical and textural types of pyroxhlore, monitoring the evolution of the ore-forming process during the transition from magmatic to hydrothermal conditions.

**Conflicts of Interest:** The author declares no conflict of interest.

## References

1. Wu, L.-G.; Li, X.-H.; Ling, X.-X.; Yang, Y.-H.; Li, C.-F.; Li, Y.-L.; Mao, Q.; Li, Q.-L.; Putlitz, B. Further characterization of the RW-1 monazite: A new working reference material for oxygen and neodymium isotopic microanalysis. *Minerals* **2019**, *9*, 583. [\[CrossRef\]](#)
2. Gros, K.; Slaby, E.; Jokobauskas, P.; Sláma, J.; Kozub-Budzyń, G. Allanite geochemical response to hydrothermal alteration by alkaline, low-temperature fluids. *Minerals* **2020**, *10*, 392. [\[CrossRef\]](#)
3. Prezebyło, A.; Pietranik, A.; Schulz, B.; Breitzkreutz, C. Towards identification of zircon populations of Permo-Carboniferous rhyolites of Central Europe: Insights from automated SEM-mineral liberation analyses. *Minerals* **2020**, *10*, 308. [\[CrossRef\]](#)
4. Yuan, F.; Jiang, S.-Y.; Liu, J.; Zhang, S.; Xiao, Z.; Liu, G.; Hu, Y. Geochronology and geochemistry of uraninite and coffinite: Insights into ore-forming process in the pegmatite-hosted uraniferous province, North Qinling, Central China. *Minerals* **2019**, *9*, 552. [\[CrossRef\]](#)
5. Zhang, Z.; Xi, G.; Mao, J.; Liu, W.; Olin, P.; Li, W. Sm–Nd dating and in-situ LA-ICP-MS analyses of scheelite from the Longshan Sb–Au deposit, Xiangzhong metallogenic province, South China. *Minerals* **2019**, *9*, 87. [\[CrossRef\]](#)
6. Huraiová, M.; Konečný, P.; Hurai, V. Niobium mineralogy of Pliocene A<sub>1</sub>-type granite of the Carpathian back-arc basin, central Europe. *Minerals* **2019**, *9*, 488. [\[CrossRef\]](#)
7. Starikova, A.E.; Bazarova, E.P.; Savel'eva, V.P.; Sklyarov, E.V.; Khromova, E.A.; Kanakin, S.V. Pyroxhlore-group minerals in the granite-hosted Katuhin rare-metal deposit, Transbaikalia, Russia. *Minerals* **2019**, *9*, 490. [\[CrossRef\]](#)