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Editorial

Editorial for the Special Issue "Petrology and Mineralogy of Pegmatite Deposits"

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This Special Issue of *Minerals*, section Mineral Deposits, on the topic of "Petrology and Mineralogy of Pegmatite Deposits", was inspired by the currently growing scientific and economic interest in pegmatites. Pegmatites are variants of the more common plutonic igneous rocks, such as granites, syenites, and gabbros, which can range from coarse-grained to megacrystic and most frequently occur in rocks of a granitic composition. Granitic pegmatites can contain various critical and other rare metals, industrial minerals, and gemstones and are thus strategically and economically important for the supply of sought-after green technology metals, such as Li, REE, Si, Ta, Nb, Rb, Cs, Sn, Sc, and Be. The green-technology metal most in demand at present is Li, which is needed to meet the growing need for lithium-ion batteries (e.g., for electric vehicles and battery storage farms), and in 2022, more than 60% of the world's Li production was extracted from pegmatites.

In addition to the economic interest in pegmatites, their complex mineralogy and structure has also attracted the interest of scientists, who have been studying the various unsolved questions regarding their origin, fractionation, and crystallization. Although no commonly accepted model regarding the source of pegmatites has emerged so far, most researchers in recent decades have supported the theory that pegmatites derive from residual melts, themselves a result of the crystallization of granitic plutons. Recent findings, however, have challenged the residual melt hypothesis by indicating that pegmatites can also form via the direct, partial melting of metamorphic rocks. Pegmatites' texture has also attracted interest as what causes it is not still completely understood. Additionally, pegmatites have been of interest as they have the broadest grain-size range observed in any type of rock and may exhibit complex internal zoning or strongly directional crystal growth of combed or dendritic crystals, graphic intergrowths, and compositional layering, all of which can be particularly complex.

The first paper in this Special Issue, by Dias et al. (2022) [1], focuses on the application and calibration of a portable laser-induced breakdown spectroscope (pLIBS) to identify and analyze the Li minerals spodumene and petalite during exploration surveys. For instrument testing, samples from the Barroso–Alvão (BA) aplite–pegmatite field in Vila Real, Portugal, are investigated, and the authors establish one qualitative calibration to identify the two minerals and two more quantitative calibrations specifically made for each respective mineral. The first LIBS calibration uses Fe as Fe is the only element with intensity ratios that allow the identification of the two minerals.

In the second paper, Haase and Pohl (2022) [2] establish a petrophysical database of pegmatite ores and their wall rock to supplement and calibrate ground-based non-invasive geophysical exploration methods and deposit modeling. The database is part of an exploration toolset for mineralized pegmatite that was developed in the framework of the EU Horizon2020 project GREEN-PEG (GA no. 869274).

Petrophysical parameters measured using drill core and field samples and acquired through geophysical borehole logging are compiled in the first database for European

Pegmatite deposits, EuroPeg_PetroDB. The database is comprehensively structured with an intuitive design, and the samples in it are supplemented with meta-information. Supporting the initiative of FAIR data, EuroPeg is freely accessible on an open data repository. Barros et al. (2022) [3] study the exomorphic halos in wall rocks of Li–Cs–Ta albite–spodumene-type pegmatites of the Leinster pegmatite belt in southeast Ireland. The authors perform mineralogical characterization and whole-rock geochemical analyses of drill cores intersecting pegmatite bodies and their wall rocks. Exomorphic halos, 2–6 m thick and enriched in Li, Rb, Be, B, Cs, Sn, and Ta, are identified in both mica schists and granitic rocks adjacent to spodumene pegmatites. The authors propose that halos result from the discharge of rare-element-rich residual fluids exsolved near the end of the pegmatite crystallization process. The possibility of identifying rare-element enrichment trends through the analysis of bedrock, stream sediments, and soils introduces opportunities for mineral exploration strategies in Ireland and other locations worldwide with similar albite–spodumene pegmatites.

Rosing-Schow et al. (2022) [4] investigate the Pb isotope signatures of K-feldspar from granitic pegmatites and A-type, ferroan granitic intrusions from the late Sveconorwegian period (900–1000 Ma) in four different areas of southern Norway. The Pb isotope compositions broadly overlap with the initial compositions estimated from previously published solution TIMS whole-rock and feldspar Pb isotope analyses of late Sveconorwegian granitic plutons across the region. This suggests that magmas forming A-type granite plutons and granitic pegmatites have been derived from broadly similar source rocks, i.e., from a continental crust that initially formed in the Palaeoproterozoic period (ca. 2.10–1.86 Ga) and subsequently underwent intracrustal partial melting, differentiation, and rejuvenation via mafic underplating in the Mesoproterozoic period.

Husar and Krenn (2022) [5] utilize fluid and solid inclusions in magmatic garnet from Permian pegmatites of the Koralpe Mountains in Austria to establish the P–T conditions during pegmatite emplacement and crystallization. Densities, fluid chemistries, and mineral chemical data of fluid and solid inclusions reveal a continuous upward trend for garnet crystallization during anatexis from lower (ca. 25 km) up to middle crustal levels (12–15 km). The results indicate that amphibolite/granulite facies conditions, found at 7.6 kbar/700 °C for garnet crystallization in spodumene-free pegmatites, are significantly higher than previously suggested for pegmatite formation in the Koralpe Mountains.

Bhandari et al. (2022) [6] investigate the Yamrang pegmatite in the Ikhabu pegmatite field, in eastern Nepal. Pegmatite is Nepal's primary source of aquamarine, and based on mineralogical and geochemical studies of pegmatite and its granite wall rock, processes that have led to beryl saturation of the pegmatite melt are explained and can be used for geochemical exploration of beryl pegmatites. It is proposed that a bulk rock Be content of >10 ppm could be used as an exploration vector for beryl mineralization in the region.

Roda-Robles et al. (2022) [7] demonstrate that apatite can be used as an archive of processes occurring during the evolution of granitic magmas and as a pegmatite exploration tool. The authors' conclusions are based on a compositional study of apatite from different Variscan granites, pegmatites, and quartz veins from the Central Iberian Zone (CIZ). Manganese in granitic and pegmatitic apatite increases together with the degree of evolution, reflecting the growing amount of Mn in residual melts. However, subrounded Fe–Mn phosphate nodules, where apatite often occurs in P-rich pegmatites and P-rich quartz dykes, is likely to have crystallized from a P-rich melt exsolved from the pegmatitic melt. The low Mn and Fe contents in the apatite from the quartz veins may be attributed either to the low availability of these elements in the late hydrothermal fluids derived from the granitic and pegmatitic melts or to a high fO_2. This review also proposes that the ternary plots ΣREE-Sr-Y and U–Th–Pb of apatites, as well as Eu anomaly versus the $TE_{1,3}$ diagram, may be used as petrogenetic indicators for Li-rich pegmatites from the CIZ.

Finally, in their review, Galliski et al. (2022) [8] provide information regarding the main pegmatites occurring in the Pampean Pegmatite Province in northwest Argentina, describing the main bodies and including an estimation of their economic potential for lithium. Galliski et al. suggest that the Li-bearing pegmatites of the Pampean Pegmatite Province are predominantly caused by the fractionation of fertile S-type granitic melts produced by either fluid-absent or fluid-assisted anatexis of a thick pile of Gondwana-derived turbiditic sediments. Most pegmatites are orogenic (530–440 Ma) and developed during two overlapping collisional orogenies (Pampean and Famatinian), but a few are postorogenic (~370 Ma) and related to crustal contaminated A-type granites. The pegmatites, the authors indicate, were likely intruded in the hinterland, most frequently in medium-grade metamorphic rocks with PT conditions of ~200–500 MPa and 400–650 °C. These rocks have potential resources of up to 200,000 t of spodumene with variable grades between 5 and 8 wt.% Li_2O. The potential for discovery of additional Li resources is significant as the area has not been systematically explored.

The papers included in this Special Issue improve our knowledge regarding the mineral diversity and chemistry of pegmatites and contribute to the debate around the genesis of these rocks and their potential economic exploitation. This Special Issue is a contribution to the European Commission's Horizon 2020 innovation programme under grant agreement no. 869274, project "GREENPEG—New Exploration Tools for European Pegmatite Green-Tech Resources".

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