Genesis of spodumene bearing pegmatites in the Austroalpine unit (Eastern Alps): isotopic and geochemical investigations

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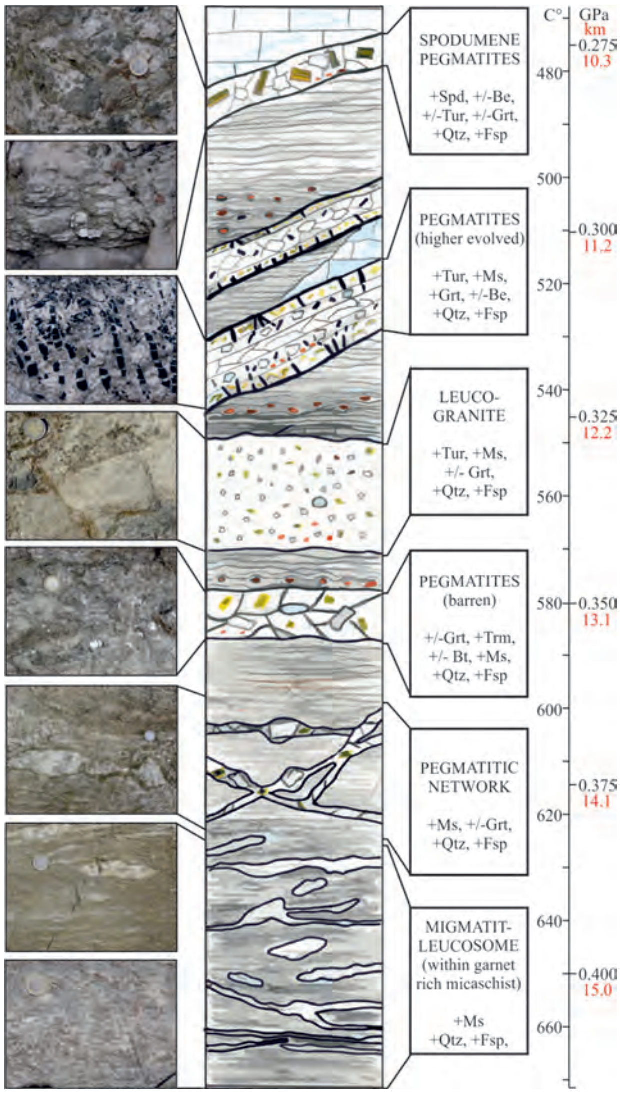
Introduction

In the Austroalpine unit of the Eastern Alps, spodumene bearing pegmatites spread heterogeneously over an E–W distance of more than 400 km. They are always associated with barren pegmatites with Permian crystallisation ages. According to Schuster & Stüwe (2008) the Permian event is triggered by lithospheric extension, causing crustal basaltic underplating, and high temperature-low pressure metamorphism and intense magmatic activity within the crust. During this study Permian pegmatites and leucogranites and their relations to the country rocks are studied. Further isotopic and geochemical measurements were performed on pegmatites and country rocks to investigate the genesis of the spodumene bearing pegmatites.



Text-Fig. 1.
Genetic model of Permian pegmatites.

Field observations

Permian pegmatites occur in three different domains (Text-Fig. 1): (1) In structurally lower parts networks of pegmatitic patches, narrow pegmatitic dykes and larger feldspar dominated pegmatites occur in aluminosilicate bearing, garnet rich micaschists and paragneisses with indications of initial anatexis. The pegmatitic patches have a maximum thickness of a few centimeters. Field relationships indicate that associated pegmatitic dykes were formed by accumulation of melt from the patches. According to data from surrounding micaschists and paragneisses this level stayed in a depth of c. 18 km and experienced high-amphibolite facies metamorphic conditions (~ 0.4 GPa and 650° C; e.g. Stöckert, 1987; Habler & Thöni, 2001) during the Permian event. (2) Structurally higher domains are characterised by concordant barren pegmatites with mineral assemblages of feldspar, quartz, muscovite, garnet and tourmaline and inhomogeneous leucogranitic bodies with pegmatitic striae. (3) Evolved pegmatites occur as partly discordant dykes in structurally uppermost levels. Feldspar, quartz, muscovite, garnet and tourmaline form the common assemblage, but additionally spodumene and beryll are present. Very rarely tiny grains of cassiterite, columbite and REE-minerals have been found. According to the presence of contemporaneously formed garnet in surrounding micaschists and paragneisses pegmatites intruded in upper greenschist facies (~ 0.3 GPa at 500° C) crustal levels at c. 10 km depth.

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Isotopic and geochemical investigations

New Sm/Nd garnet ages from three spodumene bearing pegmatites (264–268 Ma) and leucogranites (276–288 Ma) are in the range of data from barren pegmatites (264–273 Ma; Thöni et al., 2008). Initial eNd and $^{87}Sr/^{86}Sr$ values calculated for 260 Ma are typically -8.0 and 0.714 for pegmatites, whereas those from the surrounding metapelites are -10 and 0.72 respectively. The difference may be due to melt generation from paragonite rich white mica, quartz and plagioclase whereas biotite, muscovite and garnet stayed in the country rock.

Whole rock geochemical data on micaschists and paragneisses from different Austroalpine complexes yield concentrations of 30–150 ppm Li, 0.5–4 ppm Ta, 0.2–1 ppm Tl, 1–10 ppm Sn and Na_2O/K_2O ratios of 0.2–1.9. In strongly deformed pegmatites and leucogranites concentrations of 20–650 ppm Li, 0.7–11 ppm Ta, 0.3–2.1 ppm Tl, 6–26 ppm Sn and Na_2O/K_2O ratios of 0.2–1.9 were determined. This indicates low fractionation coefficients between country rocks and pegmatites of less than 10 for these elements. However, analyses from large spodumene-pegmatite samples from the Weinebene (Göd, 1989; Mali, 2004) are characterised by fractionation coefficients of 10 to 100.

LA-ICP-MS trace element analyses on muscovites show progressively decreasing K/Rb ratios from the pegmatitic patches and feldspar dominated pegmatite dykes (88–470), towards the leucogranitic bodies (63–193) to the spodumene pegmatites (16–149). Similar trends can be seen in the K/Tl and K/Cs ratios. Even if the ratios often scatter in a wide range within individual pegmatitic dykes, the data argue for continuous fractionation trends from the pegmatitic patches to the spodumene bearing pegmatites. Li concentrations in muscovite are 21–478 ppm in barren pegmatite, 72–533 ppm in leucogranites and 375–1,744 ppm in spodumene pegmatites (e.g. Mali, 2004). With respect to the pegmatite classification diagrams of Černý & Burt (1984) the muscovites from the barren pegmatites mostly plot in fields of muscovite-class pegmatites. Those from the leucogranites and spodumene pegmatites reach the fields of moderately evolved pegmatites, but they are far away from highly fractionated pegmatites. Garnet from barren pegmatits contains 78–130 ppm Li (e.g. Habler et al., 2007), whereas garnet from spodumene pegmatites shows 220–1,200 ppm Li.

Conclusion

Field observations, geochronological data and geochemical analyses indicate a cogenetic formation of barren pegmatites, spodumene bearing pegmatites and leucogranites within the Austroalpine basement during the Permian HT/LP event. Pegmatitic patches developed by anataxis of micaschists and paragneisses at ca. 0.4 GPa and 650° C. Melt accumulation caused formation of feldspar dominated pegmatites and some leucogranitic bodies. Spodumene pegmatites crystallised at conditions of ca. 3 GPa and 500° C. With respect to the country rocks Li, Sn, Tl and Ta concentrations in barren pegmatites are enriched by a factor of less than 10 and by a factor of 10 to 100 in the most evolved spodumene pegmatites. According to Černý & Burt (1984) they represent moderately fractionated pegmatites.

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