The Weinebene pegmatite deposit

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1. Spodumene pegmatite deposits of Austria

In the Austroalpine basement about 80 spodumene ($LiAlSi_2O_6$) bearing pegmatites of Permian age are known (Fig. 1). The most prominent occurrence in Austria is the Weinebene deposit located at Koralpe in the South of Austria. Other occurrences were discovered in the areas near Haslau, St. Radegund, Übelbach, Katzbachgraben, Altes Almhaus, Wildbachgraben, Klementkogel, Hüttenberg, Falkenberg, Wölz Tauern, Millstatt Seerücken, Wöllatratten, and Defereggen valley. The Koralpe-Wölz Nappe-system hosts spodumene pegmatites in Southern Tyrol near Ratschinges and Lenkstein (KNOLL et al., 2018). Pegmatites in the Austroalpine basement, which formed during the Variscan or Eo-Alpine orogeny, do not contain any lithium mineralization.

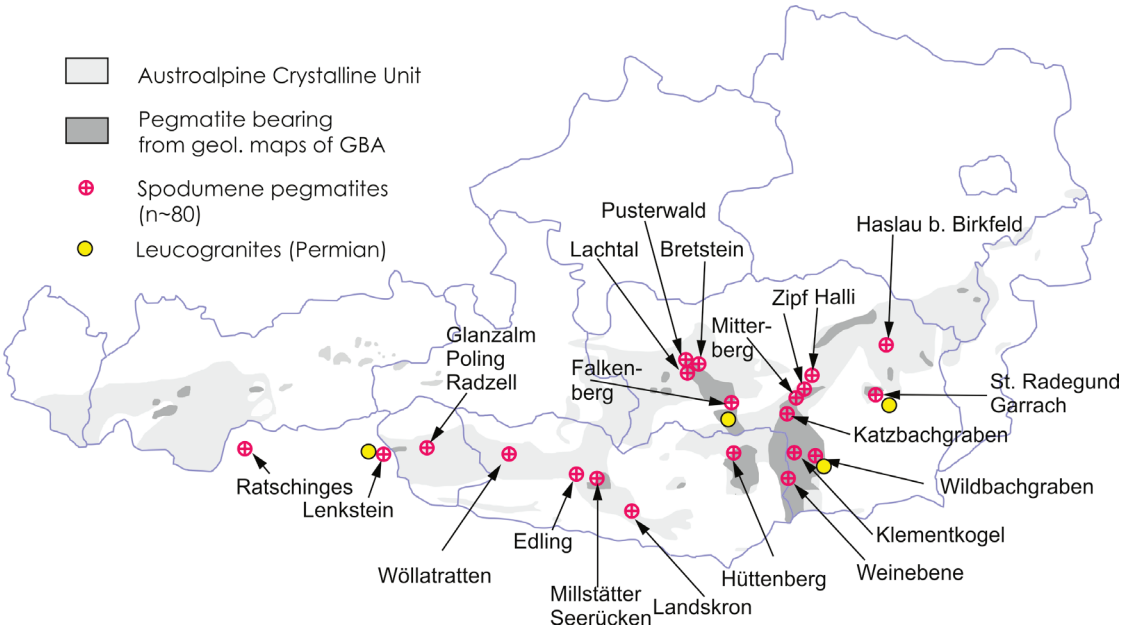

Fig. 1. Permian spodumene pegmatite and leucogranite occurrences in the Eastern Alps.

Permian pegmatites occur at different paleo-crustal levels between c. 23 km and 10 km depth. They formed at temperatures and pressures between 600–700 °C and 6–7 kbar, respectively (Fig. 2). The deepest level host rocks comprising paragneisses and micaschists show migmatitic structures and are supposed to be the source for the initial anatectic pegmatitic melt. Irregular patches of pegmatitic neosome, sometimes gradational to the host contain fine to coarse feldspar and muscovite porphyroblasts. These patches converge to pegmatite networks as well as to thin barren, concordant or discordant pegmatite dykes. At medium depths concordant, non-zoned, and barren pegmatites intruded mainly into staurolite or kyanite (paramorphs of Permian andalusite) bearing host rocks. Sometimes Permian leucogranite bodies of a few hundred meters in thickness are associated with the pegmatites. The shallowest levels embody zoned, concordant, as well as discordant pegmatite dykes that are highest evolved and spodumene bearing in some places. Spodumene pegmatites are hosted by micaschists, paragneisses, amphibolites and marbles.

Usually the mineralogical composition of the pegmatites is rather simple with albite, K-feldspar, quartz and muscovite. Tourmaline, zircon, xenotime, monazite, garnet, and biotite are present in many pegmatites. Beryl, apatite, Nb-Ta-minerals, cassiterite, Nb-rutile and other accessories are rather rare. In spodumene pegmatites, the spodumene contents are highly variable ranging from 0.1 vol.-% up to 30 vol.-%. Exocontact alteration results often in silicification and tourmalinization. In amphibolite host rocks additional growth of biotite could be observed.

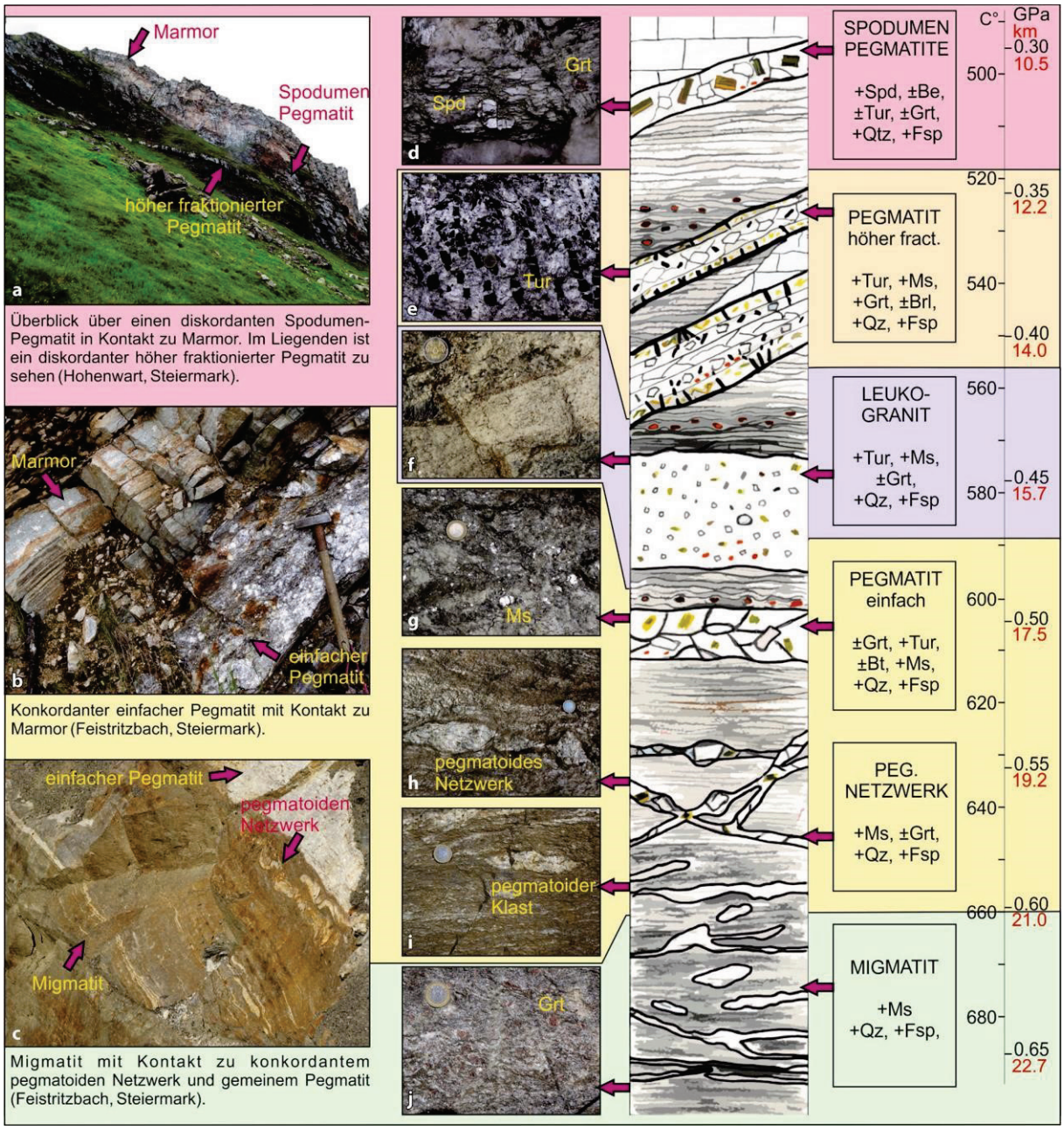

Fig. 2. Synoptic diagram showing field relations for Permian pegmatites and leucogranites in the Austroalpine unit of the Eastern Alps. Three domains (green, yellow and reddish) are distinguished (see text). Outcrop pictures of a) spodumene pegmatite, b) concordant barren pegmatite and c) migmatitic mica schist with pegmatitic networks and dykes. Compilation of typical lithologies: d) spodumene pegmatite (width of image 7 cm), e) comb structures of deformed tourmaline (width of image 37 cm), f) inhomogeneous leucogranite (width of image 20 cm), g) muscovite pegmatite (width of image 25 cm), h) deformed pegmatitic network (width of image 40 cm), i) pegmatitic patches within deformed migmatitic mica schist (width of image 30 cm), j) garnet-rich restitic paragneiss (width of image 20 cm). k) Schematic column showing the distribution of typical lithologies, magmatic assemblages and depth-pressure-temperature relations (KNOLL et al., 2021).

Whole rock geochemistry shows high contents of Si, Al, K and Na. Li_2O contents of spodumene pegmatite specimens reach ca. 2.5 wt.-% at maximum (Tab. 1). Nb and Ta contents are below 100 ppm, and Be and Sn are also below economic importance. Quartz and feldspars are suitable for glass and ceramics production due to the low Fe content.

		Zinkenschlucht	Scharnitzfeld	Weittal	untere Mittagswand	Hohenwart Südwand	Hohenwart Südwand	Edling	Weinebene Amphibolites	Weinebene Micaschist	Rieserferner
SiO_2	g/100g	73.76	73.64	73.95	65.21	72.07	70.62	73.20	74.10	74.78	76.36
TiO_2	g/100g	0.02	0.01	0.01	0.00	0.05	0.00	0.02	0.02	0.03	<dl
Al_2O_3	g/100g	16.53	16.35	15.38	22.39	17.88	18.00	18.00	15.75	15.49	15.14
FeO	g/100g	0.45	0.39	0.12	0.45	0.08	0.24	0.24	0.62	0.59	0.49
MnO	g/100g	0.14	0.11	0.08	0.15	0.13	0.05	0.01	0.08	0.06	0.06
MgO	g/100g	0.04	0.03	0.06	0.24	0.10	0.02	0.08	0.09	0.06	<dl
CaO	g/100g	0.34	0.27	0.29	0.65	0.95	0.42	0.06	0.36	0.30	0.17
Na_2O	g/100g	3.99	4.31	3.15	6.11	4.61	5.94	2.86	2.84	3.40	4.12
K_2O	g/100g	2.74	2.78	3.68	2.42	1.35	2.72	2.56	2.71	2.43	1.20
P_2O_5	g/100g	0.08	0.10	0.06	0.08	0.02	0.10	0.09	0.38	0.41	<0.01
Li_2O	g/100g	0.98	1.49	2.46	0.76	1.55	1.01	2.13	2.22	1.28	1.62
LOI	g/100g	0.82	0.82	0.82	1.59	0.42	0.56	0.80	0.51	0.78	0.59
SUM	g/100g	99.89	100.30	100.06	100.05	99.21	99.68	100.05	99.68	99.61	99.75
Pb	mg/kg	34	38	49	46	45	61	129			
Zn	mg/kg	16	17	13	35	26	66	108			
Sn	mg/kg	43	39	25	14		24		138	85	
Rb	mg/kg	401	433	706	310	247	395	350	1108	878	
Cs	mg/kg	85	20	99	28		44	16	62	25	
Ba	mg/kg	49	45	50	78	17	15	13			
Sr	mg/kg	37	33	158	49	31	22	9			
Ga	mg/kg	26	31	22	31		24				
Ta	mg/kg	15	30	51	14		3		19	24	
Nb	mg/kg	30	79	86	28	104	17		55	85	
Th	mg/kg	2	1			10	1				
U	mg/kg	8	5	2			2		6	9	
Y	mg/kg	12	6	10	8	16					
La	mg/kg	2	2		2		2				
Ce	mg/kg	5	4								
Sm	mg/kg	1	1.1	0.1	0.6		0.9				
Yb	mg/kg	0.5	0.5		0.4		0.4				
Be	mg/kg	83	99	49	42	223	52	190	59	54	
Zr	mg/kg	55	23	15	19	28	35				
Hf	mg/kg	1.9	1.6	1.3	0.9		0.7				

Tab. 1. Whole rock geochemistry of selected spodumene pegmatites (GÖD, 1989; LUECKE & UCIK, 1986; MALI, 2004; PROCHASKA, 1981).

To determine the fractionation degree, more than one thousand magmatic muscovites of host rocks, pegmatites, and leucogranites were analyzed by Laser Ablation ICP-MS (Fig. 3, CERNY 1982). In the course of fractionated crystallisation along the intrusion path of the pegmatite melt, trace elements like Li, Rb, Cs, Tl, Ga, Hf, Nb, Ta become enriched, whereas Ba and Sr are depleted. K/Rb in muscovite is a good indicator for the degree of fractionation. Muscovites of the spodumene pegmatites show K/Rb ratios < 100. Muscovite analyses of many barren pegmatites demonstrate comparable K/Rb ratios, indicating promising areas of rare element pegmatites (Fig. 4). Breakdown of staurolite and/or muscovite during anatectic melt formation is probably the source of Li. Significant enrichment of Li up to 7000 mg/kg in the melt through crystal fractionation may result in spodumene crystallization (LONDON, 2008).

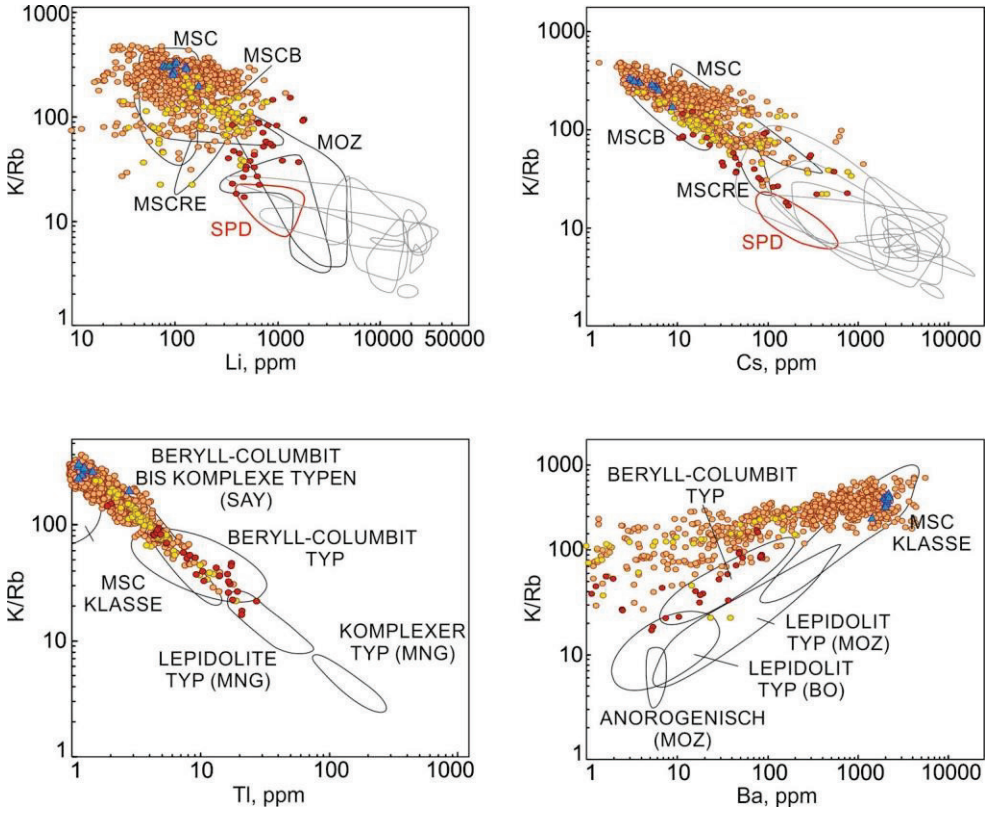

Fig. 3. Trace element composition of Permian muscovites in migmatites (blue dots), low to highly evolved pegmatites (orange dots), leucogranites (yellow dots) and spodumene pegmatites (red dots, classification after CERNY, 1982; KNOLL et al., 2021).

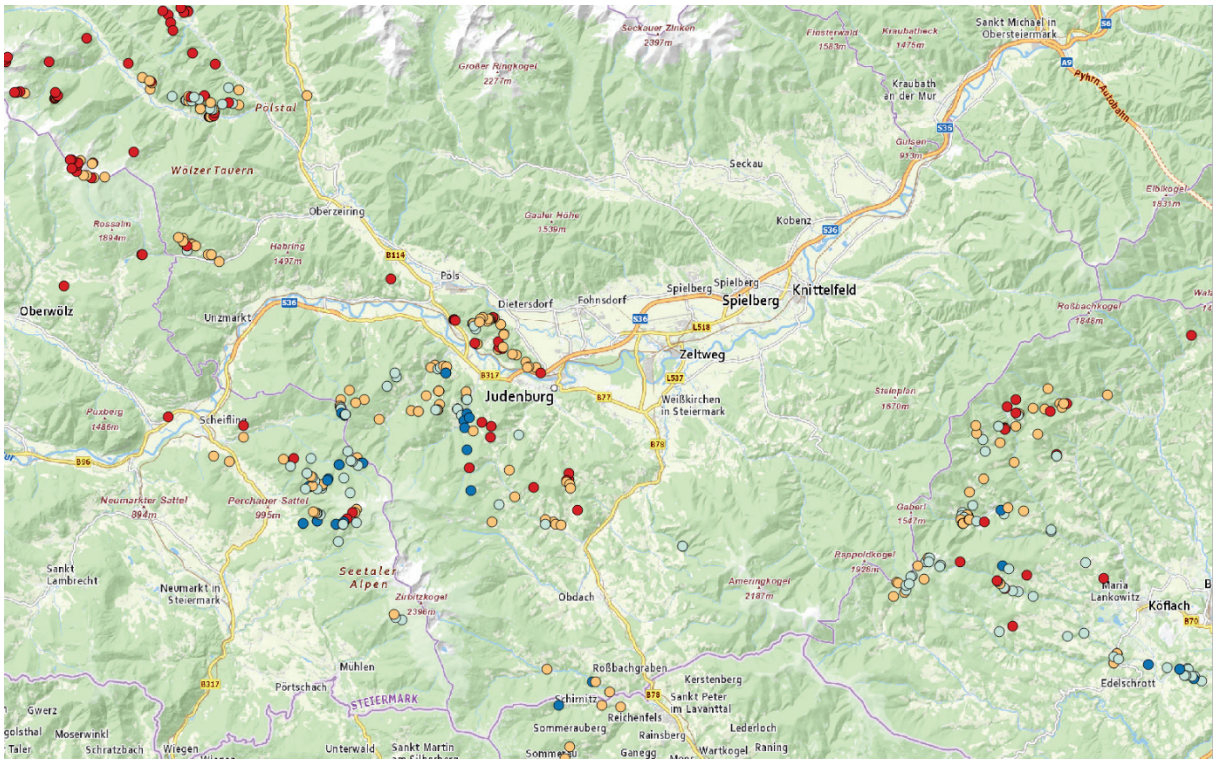

Fig. 4. K/Rb ratio of muscovite from Permian pegmatites in Styria (red 20–100, orange 101–200, green 201–300, blue > 300). Red dots indicate potential areas of spodumene pegmatite occurrences.

2. The Weinebene pegmatite deposit

Spodumene was discovered at the Weinebene about 80 years ago (MEIXNER, 1966). In 1981, Minerex, a former Austrian government company, started extensive exploration resulting in underground test mining and a pre-feasibility study in 1987. In 1988, the project was transferred to the Bleiberger Bergwerksunion mining company. 1991, the project was sold to Kärntner Montanindustrie, operating a hematite mine at Waldenstein, to secure the access to the spodumene deposit and the test mine, respectively. In 2011, Global Strategic Metals and Exchange Minerals acquired the project for € 9.7 mio plus 20 % VAT (europeanlithium.com; 13th July 2022).

The deposit is located in the Koralpe-Wölz Nappe-system of the Austroalpine basement. Host rocks are amphibolites and micaschists forming a Cretaceous anticline with a fold axis plunging to the East (Fig. 5). The amphibolites are composed of amphibole, plagioclase, few garnet, subordinate quartz as well as calcite. The micaschists comprise muscovite, quartz, garnet, biotite and plagioclase. Kyanite paramorphs after andalusite are also present. In total 15 spodumene pegmatite dykes were discovered with a persistence of up to 1500 m and with variable true thicknesses of 10 m at maximum. The amphibolite hosted pegmatites are rather coarse crystalline in contrast to the micaschist hosted pegmatites. The latter ones are classified as mylonitic spodumene pegmatite gneisses due to intense ductile deformation and recrystallization during the Alpine orogenic event. The mineral assemblage includes spodumene, quartz, albite, microcline, muscovite, beryl, black tourmaline, apatite, graphite, cassiterite, triphylite, ferrisicklerite, microlite and zircon, among a great variety of secondary minerals. The deposit is also the type locality of weinebeneite ($CaBe_3(OH)_2(PO_4)_2.4H_2O$; WALTER et al., 1990; NIEDERMAYR & GÖD, 1992).

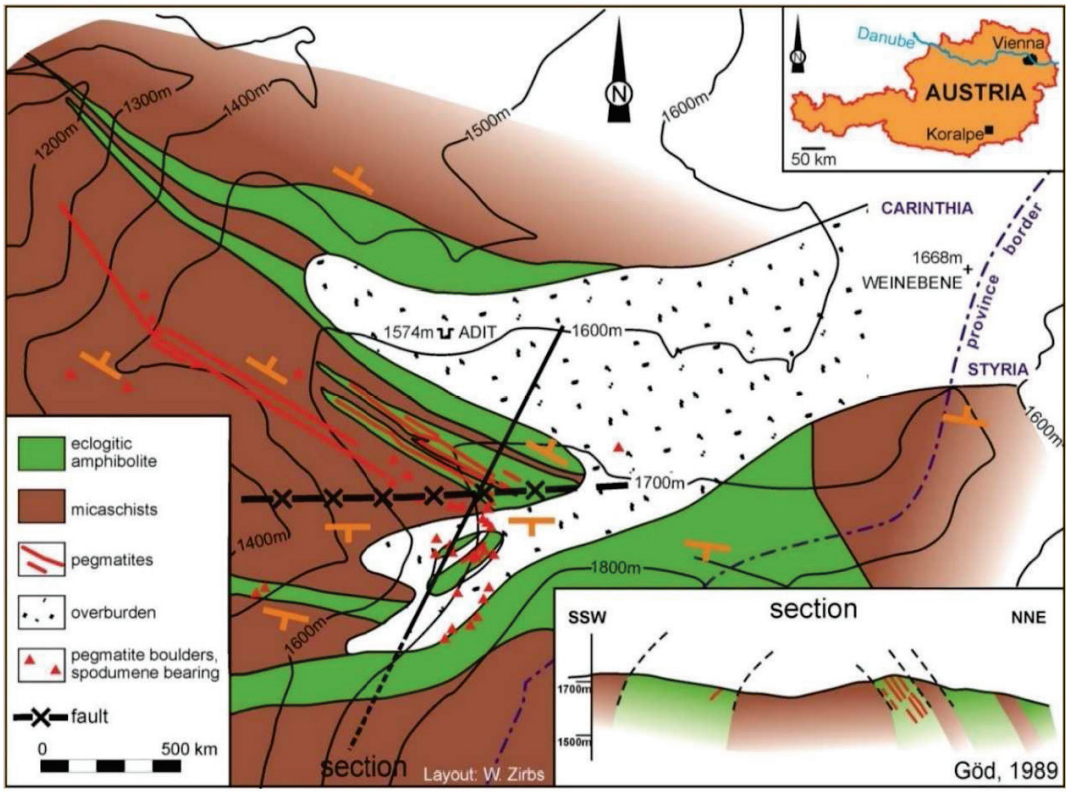

Fig. 5. Cross section of the Weinebene spodumene deposit anticline, dividing the deposit in a northern and a southern limb (GÖD, 1989).

Four decades ago, Minerex started to explore the deposit via drillings and underground test mining (Fig. 6). Since 2011, subsequent drillings were made and more than 1000 t of ore were mined for processing tests. Currently, the project is operated by European Lithium LTD, listed at Australian and European stock exchanges. In total, about 30 km of drill cores were recovered and analyzed. Based on these data, a 3D deposit model was generated for resource calculation, grade distribution and mine design. The pre-feasibility study reports JORC compliant ore resources (measured, indicated and inferred) of more than 12 mio t, grading ca. 1.0 wt.-% Li_2O. 2022, the company released an interim definitive feasibility study (DFS) update announcement on the major DFS key performance indicators including the pre-tax net present value for the accelerated case of A$ 862 million, a maximum of 20 years lifetime of the spodumene pegmatite mine with an annual ore production of approximately 770,000 t (ASX Announcement, 19th April 2022, europeanlithium.com). At full production, this results in an annual output of ca. 11,000 t LCE (Lithiumcarbonate Equivalent, europeanlithium.com, 13th July 2022).

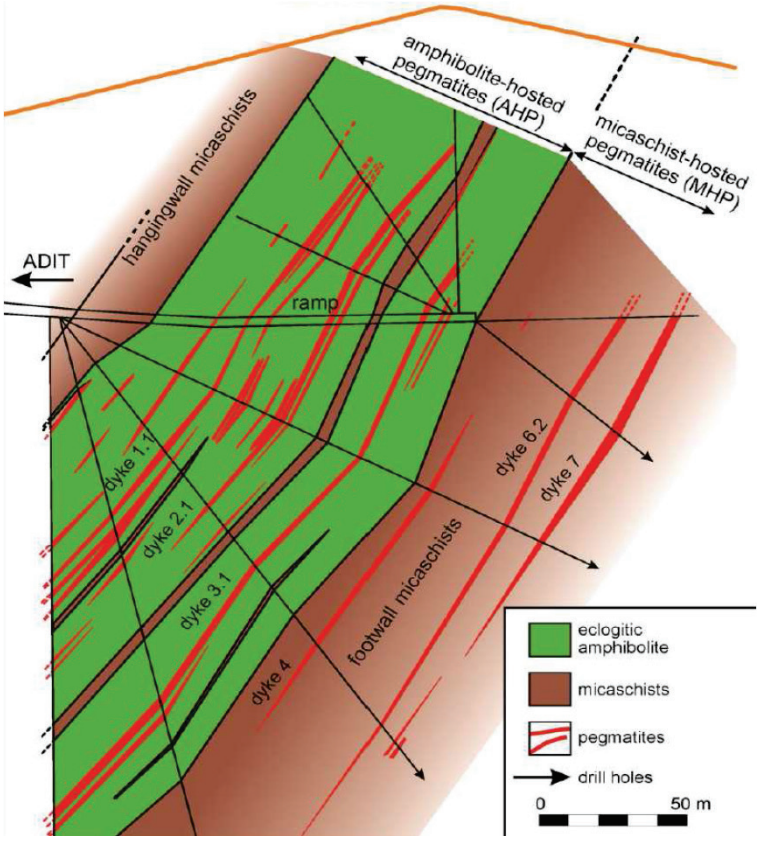

Fig. 6. Geological cross section and test mine drifts of the Weinebene deposit (GÖD, 1989).

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