Mineralogy and petrology of Fe-Mn phosphates from the Varuträsk pegmatite, Sweden.

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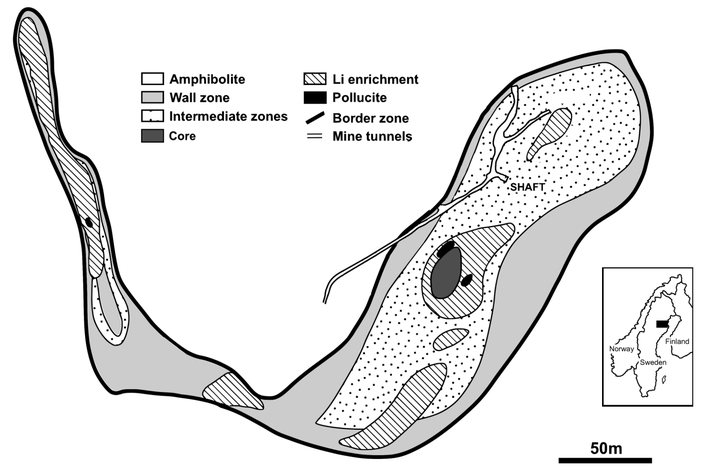
Introduction

- The **Varuträsk pegmatite** (Sweden) is a **well-zoned** and **extremely differentiated** pegmatite of the **petalite subtype**. Due to the historical importance of the pegmatite, **phosphates samples** stored in the Swedish Museum for Natural History, as well as new samples collected on the field have been re-investigated.
- Why studying phosphates ? They are **important pretrogenetic indicators** due to their relatively narrow stability fields compared to silicates.

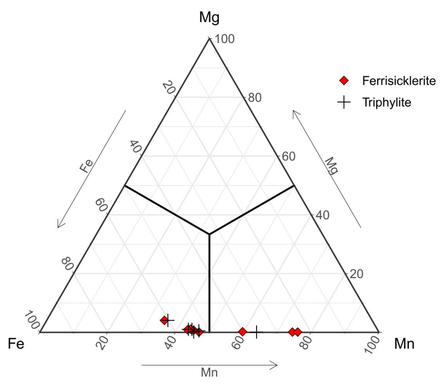


Modified from Siegel et al., 2016

Triphylite-lithiophilite assemblages

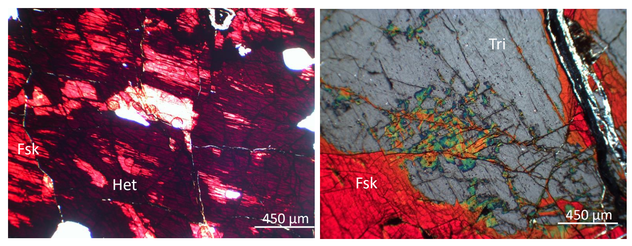
Fe oxidation and Li leaching

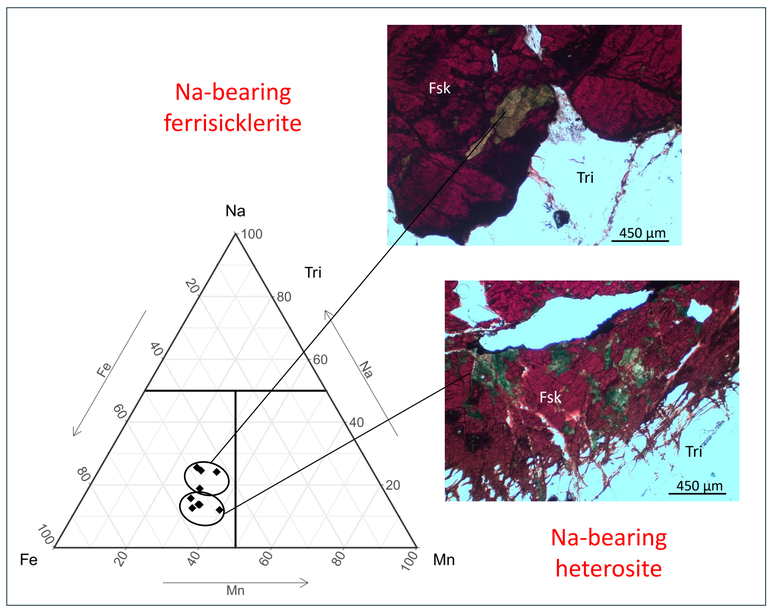
- Fe/Mn ratio of primary triphylite is preserved

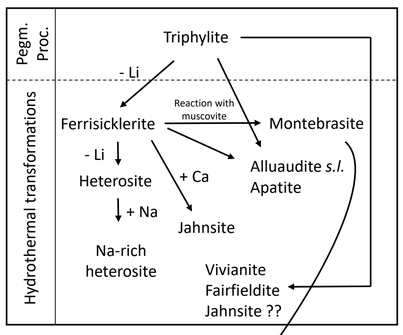


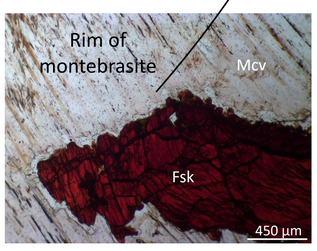
Mineral	IMA List of Minerals, December 2022	New end-member formulae
Triphylite	$LiFe^{2+}(PO_4)$	$LiFe^{2+}(PO_4)$
Lithiophilite	$LiMn^{2+}(PO_4)$	$LiMn^{2+}(PO_4)$
Heterosite	$Fe^{3+}(PO_4)$	$Fe^{3+}(PO_4)$
Purpurite	$Mn^{3+}(PO_4)$	$Mn^{3+}(PO_4)$
Sicklerite	$LiMn^{2+}(PO_4)$	Discredited
Ferrisicklerite	$Li_{1-x}(Fe^{3+},Mn^{2+})(PO_4)$	Discredited
Simferite	$Li(Mg,Fe^{3+},Mn^{3+})_2(PO_4)_2$	$LiMg(PO_4)$
Karenwebberite	$NaFe^{2+}(PO_4)$	$NaFe^{2+}(PO_4)$
Natrophilite	$NaMn^{2+}(PO_4)$	$NaMn^{2+}(PO_4)$

Lyalina, L. M. et al., 2023









Replacement of triphylite by **jahnsite s.l.**

$X(2)M(1)M(2)_2M(3)_3{}^{+2}(PO_4)_4(OH)_2{\cdot}8H_2O$

	19640141 (1)	19640141 (2)	19884465	19884455 (1)	19884455 (2)	19884455 (3)	19884455-2 (2)	19884455-2 (3)
Fe^{3+} (M2)	0.49	0.90	-	0.42	0.55	0.55	0.57	
Mg (M2)	0.18	0.09	-	0.02	0.07	0.21	0.30	0.05
Fe^{2+} (M2)	0.65	0.14	-	**1.56**	**1.38**	0.36	-	
Mn^{3+} (M2)	-	-	0.50	-	-	-	-	0.77
Mn^{2+}(M2)	**0.67**	**0.87**	**1.50**	-	-	**0.89**	**1.13**	**1.18**
Ca (M2)	-	-	-	-	-	-	-	-
Σ (M2)	1.99	2.00	2.00	2.00	2.00	2.01	2.00	2.00
Fe^{3+} (M1)	-	-		-	-	-	-	-
Mg (M1)	-	-		-	-	-	-	-
Fe^{2+} (M1)	-	-		0.28	-	-	-	-
Mn^{2+}(M1)	**1.00**	**1.00**	0.10	0.14	**1.00**	**0.80**	**0.75**	0.38
Ca (M1)	-	-	**0.90**	**0.58**	-	0.20	0.25	**0.62**
Σ (M1)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mn^{2+} (X)	-	**0.33**	-	-	**0.62**	-	-	-
Ca (X)	**0.69**	0.2	**0.77**	**0.73**	0.18	**0.70**	**0.61**	**0.60**
Na (X)	0.1	-	0.01	0.16	0.02	0.04	0.07	-
K(X)	-	-	-	0.11	0.08	-	-	-
□ (X)	0.21	0.47	0.22	-	0.10	0.26	0.32	0.4
Σ (X)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

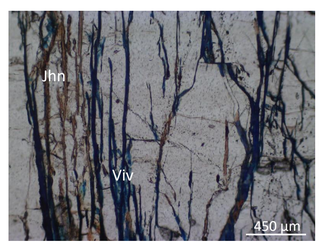
- Jahnsite-(CaMnMn)
- Jahnsite-(MnMnMn)
- Jahnsite-(CaCaMn)
- Jahnsite-(CaCaFe)
- Jahnsite-(MnMnFe)

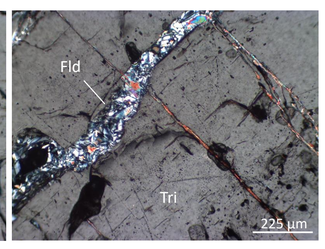
Frequently associated with **vivianite**

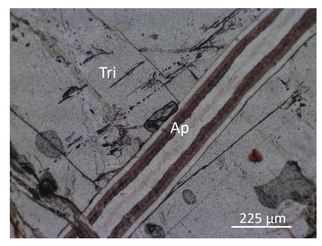
$(Fe^{2+}_{2.16}Mn_{0.84})_{3.00}(PO_4)_2{\cdot}8H_2O$

and **fairfieldite**

$Ca_{2.00}(Mn_{0.81}Fe_{0.19})_{1.00}(PO_4)_2{\cdot}2H_2O$







Zoned fracture of apatite

From the border to the core :

- Cl contents (0.11% → 4.97%)
- F contents (3.28% → 0.63%)

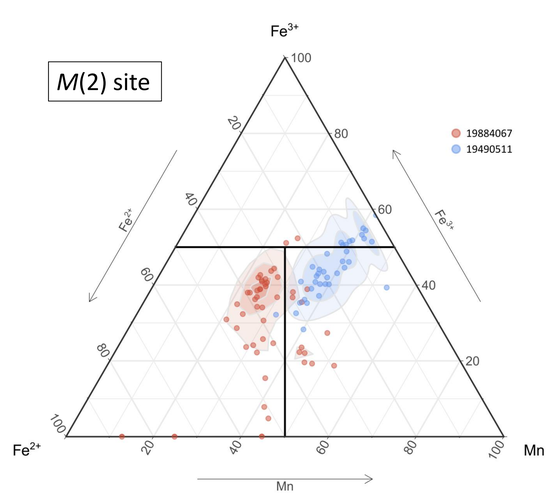
Alluaudite-rich assemblages

Simplified structural formula

$A(2)'A(1)M(1)M(2)_2(TO_4)_3$

Mineral name	New ideal formula
Hagendorfite	$Na_2MnFe^{2+}Fe^{3+}(PO_4)_3$
Varulite	$Na_2Mn_2Fe^{3+}(PO_4)_3$

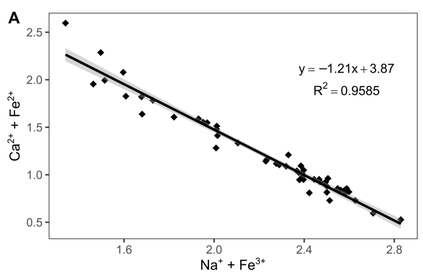
Hatert (2019)

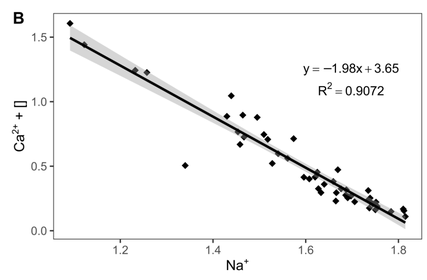


Oxydation mechanisms

$^{A2}Na^+ + {}^{M2}Fe^{2+} \rightarrow {}^{A2}[] + {}^{M2}Fe^{3+}$

Fransolet et al. (1985, 1986, 2004)

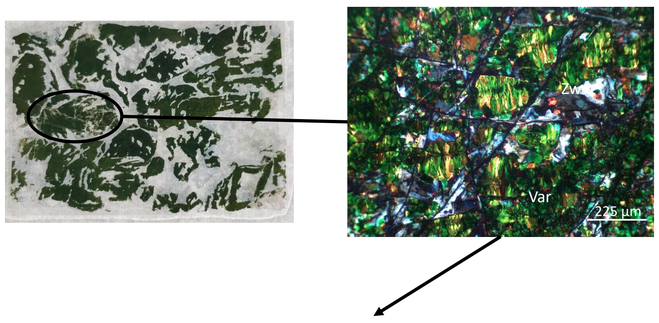




$^{A1}Na^+ + {}^{M2}Fe^{3+} \rightarrow {}^{A1}Ca^{2+} + {}^{M2}Fe^{2+}$

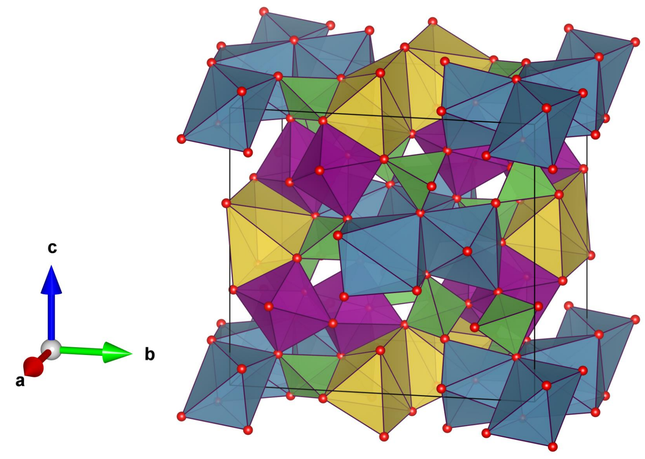
$^{A1}Na^+ + {}^{A2}Na^+ \rightarrow {}^{A1}Ca^{2+} + {}^{A2}[]$

→ Coupled heterovalent substitutions



Residual grains of lithiophilite and zwieselite
→ Alluaudite formed during **Na-metasomatism processes**

Potential new species



Caryinite : $NaCaCaMn_2(AsO_4)_3$

Empirical formula obtained from 6 microprobe analyses

$(Pb_{0.50}Na_{0.30}[]_{0.17}K_{0.03})(Ca_{0.54}Na_{0.46})(Ca_{0.64}Mn_{0.36})(Mn_{1.46}Mg_{0.52}Fe_{0.02})(AsO_4)_3$

→ $(Pb_{0.5}\square_{0.5})CaCaMn_2(AsO_4)_3$

a = 6.88 ; *b* = 13.21 ; *c* = 11.57

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emc² 18–23 August 2024
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