

Université de Liège  
Faculté des Sciences  
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Laboratoire de Minéralogie



# Crystal chemistry and geothermometric applications of primary pegmatite phosphates

Frédéric Hatert

PEG2013, May 28th, 2013



# - Content

- 1. Introduction**
- 2. Primary triphylite-type phosphates**
- 3. Sarcopside exsolutions**
- 4. Alluaudites and wyllieites**
- 5. Conclusions**

# Fe-Mn phosphates in pegmatites



**Buranga pegmatite, Rwanda**

**Sapucaia pegmatite, Brazil**





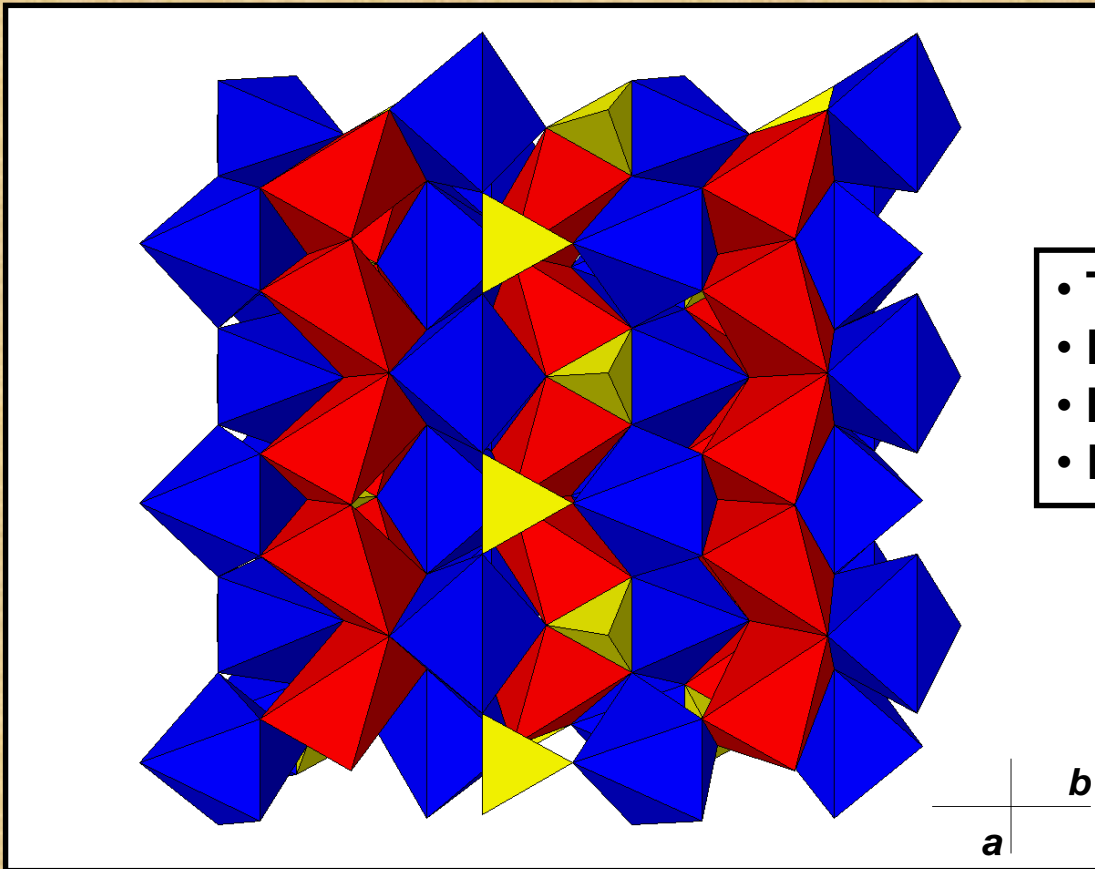
# Evolution of Phosphate Science



- **P. Quensel, B. Mason (1937-1957)**: First hypotheses on pegmatite phosphates genesis
- **D.J. Fisher (1955-1965)**: Crystal chemistry of alluaudites, fillowites, arrojadites
- **P.B. Moore (1965-1981)**: Crystal structure refinements of many phosphate minerals

- **F. Fontan, A.-M. Fransolet, P. Keller (1972-)**: Crystal chemistry, petrography, genesis of pegmatite phosphates

# Primary phosphates with the olivine structure



- Triphylite,  $\text{LiFe}^{2+}(\text{PO}_4)$
- Lithiophilite,  $\text{LiMn}(\text{PO}_4)$
- Natrophilite,  $\text{NaMn}(\text{PO}_4)$
- Karenwebberite,  $\text{NaFe}^{2+}(\text{PO}_4)$

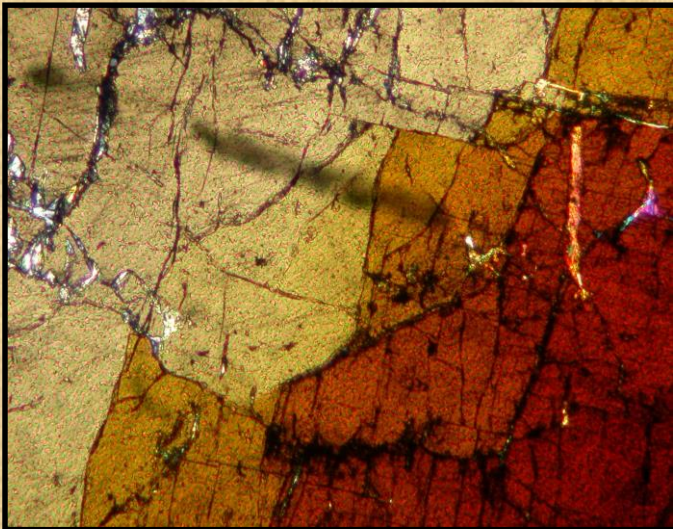
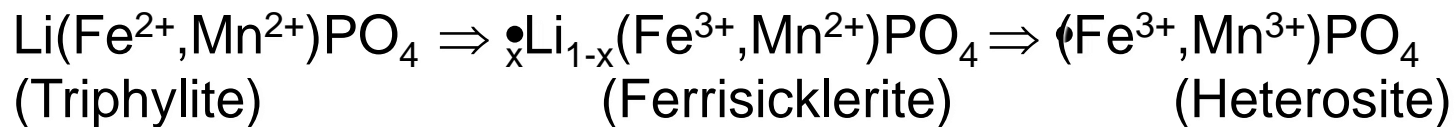
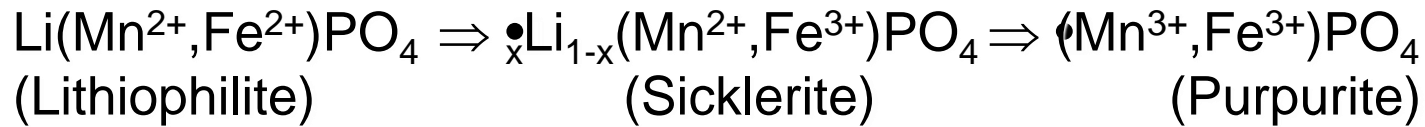
**S.G. *Pmnb***

**$a = 6.092$ ,  $b = 10.429$ ,  $c = 4.738 \text{ \AA}$**

**Red octahedra: M1 (Li, Na)**

**Blue octahedra: M2 ( $\text{Fe}^{2+}$ , Mn, Mg)**

# The « Quensel-Mason » sequence





## Questions:

- ➔ **A. Is the « Quensel-Mason » sequence a progressive oxidation process ?**
- ➔ **B. Is ferrisicklerite of primary or secondary origin ?**
- ➔ **C. Which are the stability fields of karenwebberite and marićite ?**

# A. The oxidation of triphylite-lithiophilite

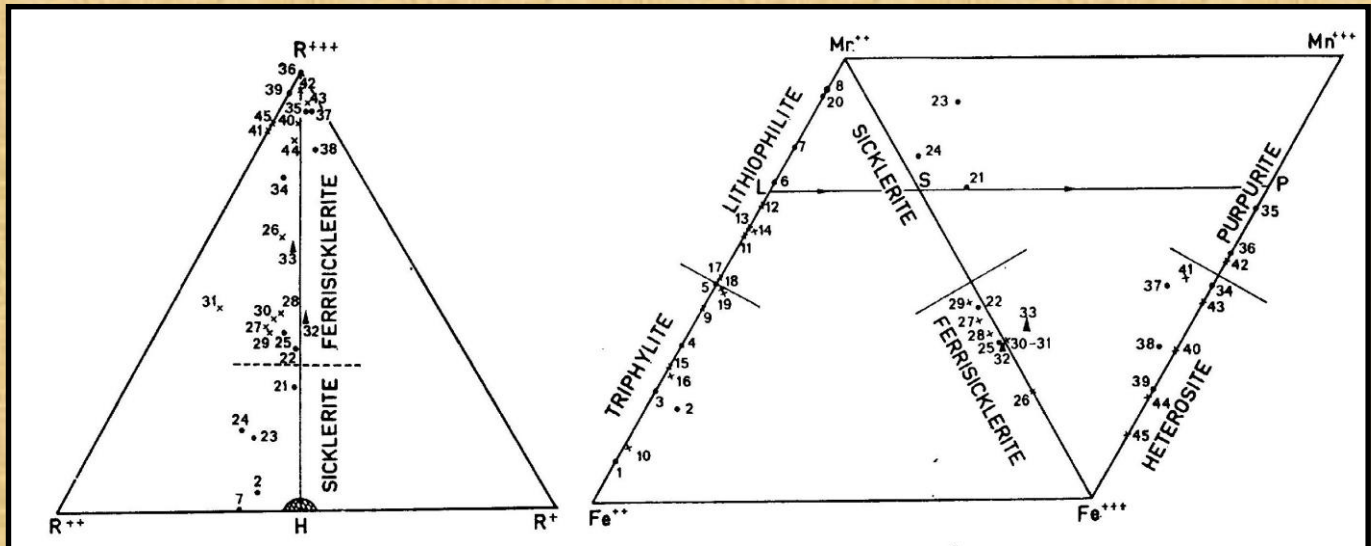


La ferrisicklélite des pegmatites de Sidi Bou Othmane  
(Jebilet, Maroc)

et le groupe des minéraux à structure de triphylite

par FRANÇOIS FONTAN \*, PAUL HUVELIN \*\*, MARCEL ORLIAC \* et FRANÇOIS PERMINGEAT \*.

1976

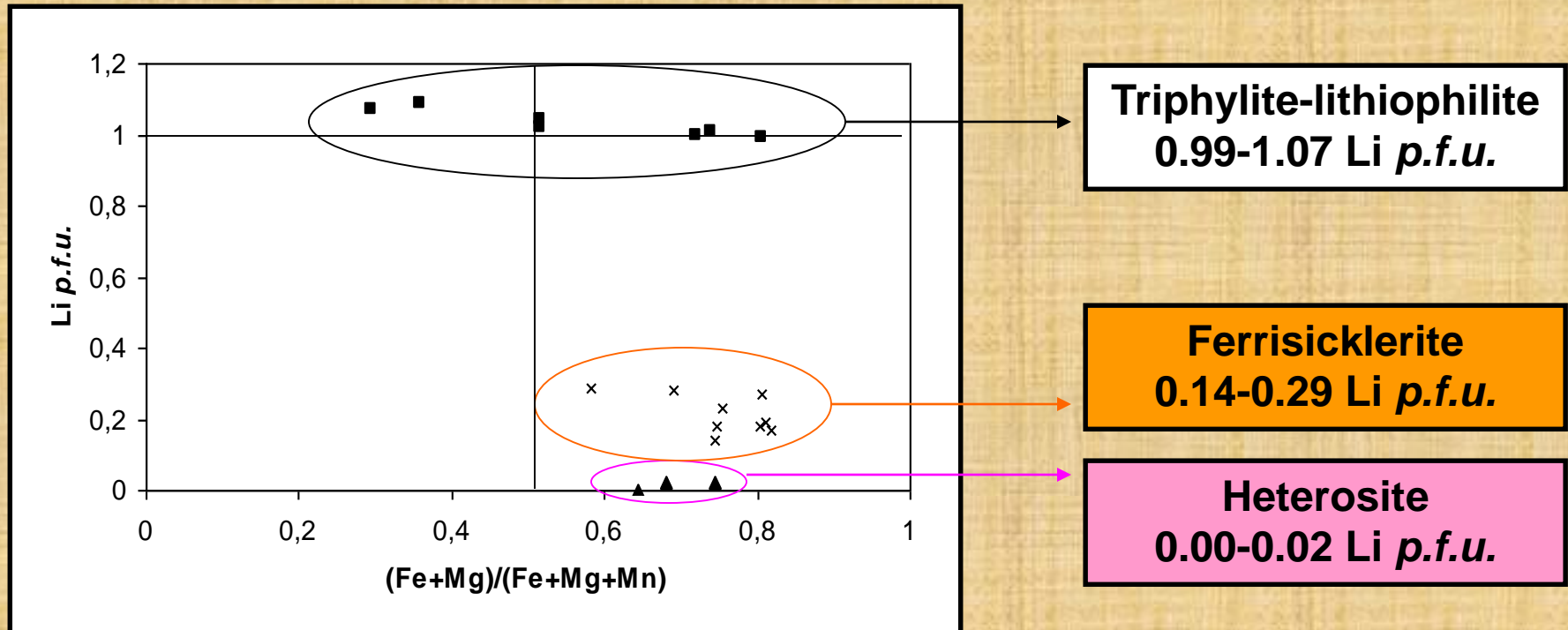


**This oxidation is not a continuous process!**



# A. SIMS analyses of natural samples

## SIMS and crystal-structure analysis of 19 samples



**Heterosite may contain up to 0.21 wt. % Li<sub>2</sub>O, and ferrisicklerite may show a low Li-content of 1.31 wt. % Li<sub>2</sub>O**



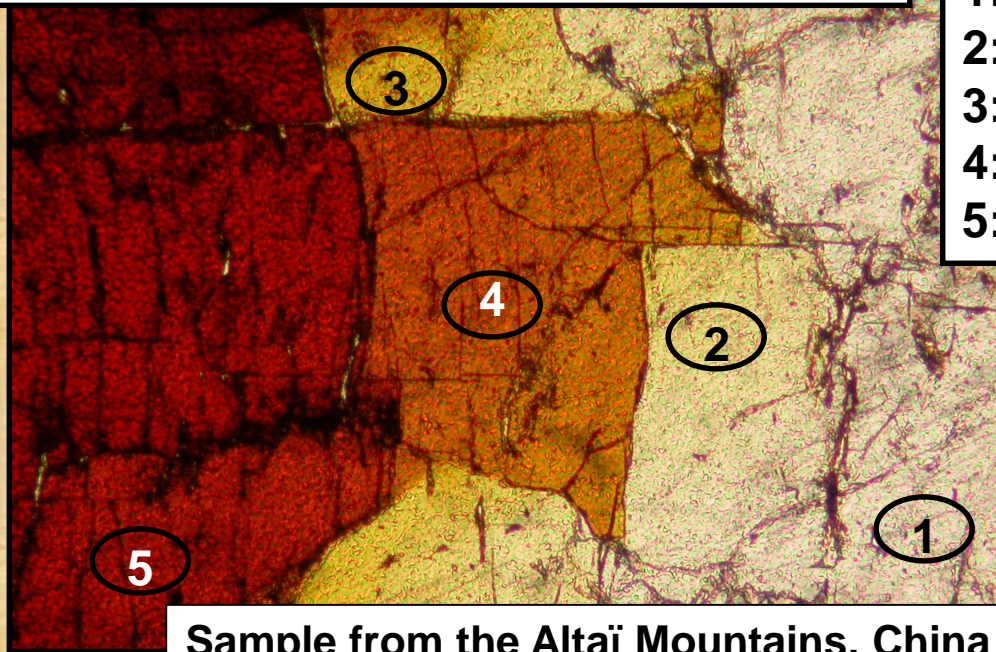
**Close Li-contents!**

# A. The lithiophilite-sicklerite series

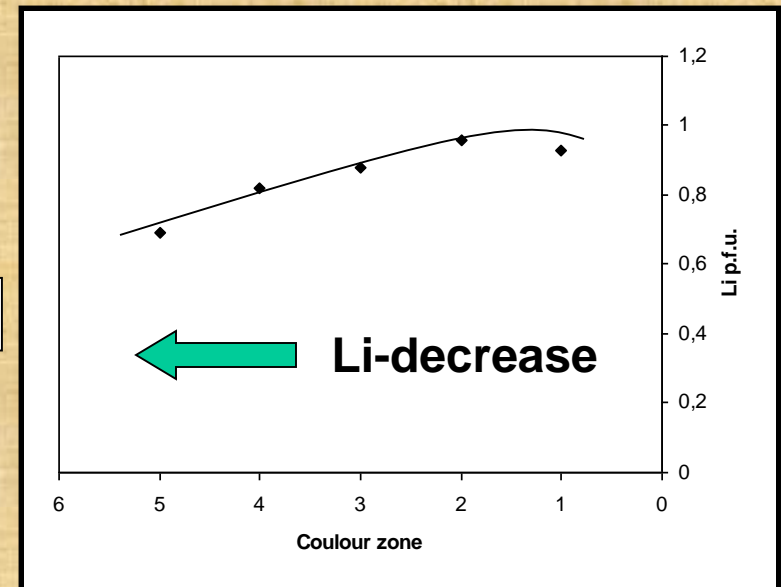
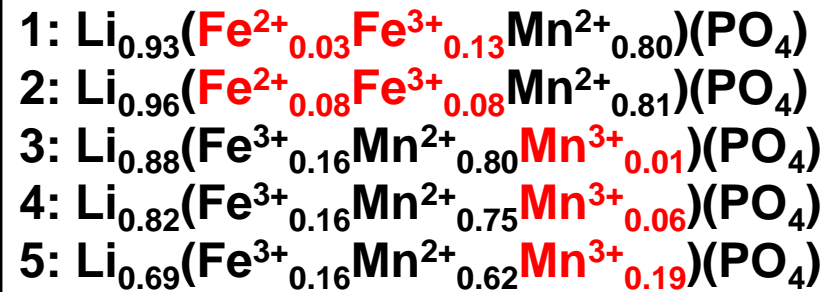
## A STRUCTURAL STUDY OF THE LITHIOPHILITE-SICKLERITE SERIES

FRÉDÉRIC HATERT<sup>§</sup>

Laboratoire de Minéralogie, B18, Université de Liège, B-4000 Liège, Belgium



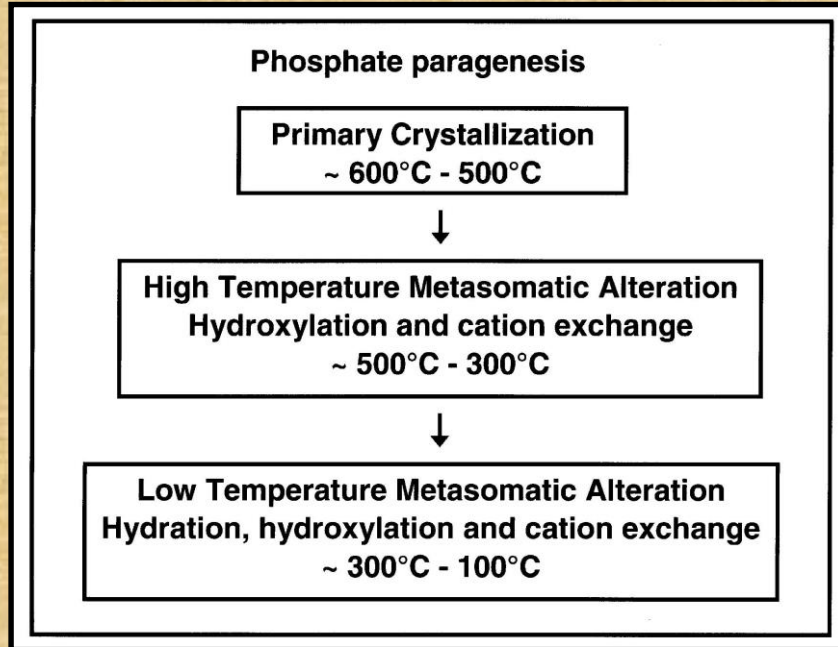
Sample from the Altaï Mountains, China



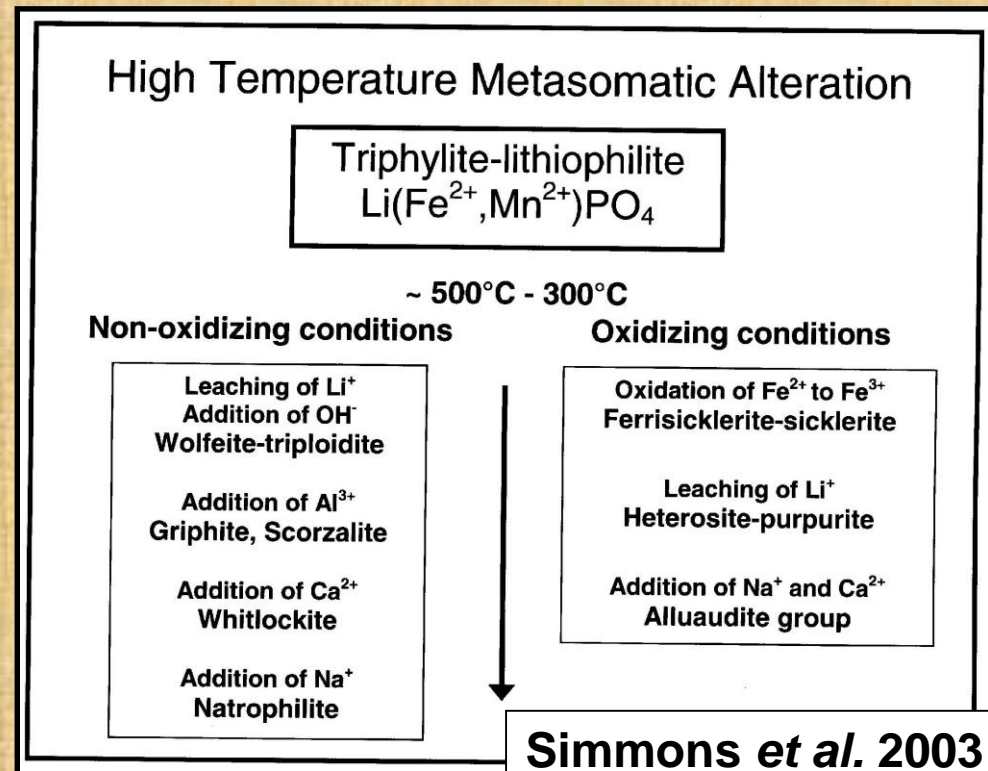
- The transition from lithiophilite to sicklerite is progressive
- The change in colour is due to the presence of  $\text{Mn}^{3+}$



## B. The stability of ferrisicklerite



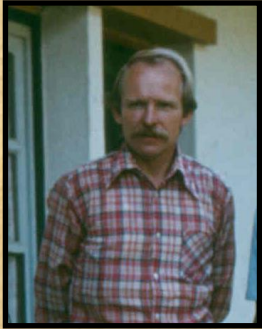
- Crystallization temperatures of ferrisicklerite?
- Degree of oxidation?



### Preliminary hydrothermal experiments

- 200-600°C, 1-3 kbar
- Low  $f\text{O}_2$ : triphylite
- High  $f\text{O}_2$ :  $\text{LiFe}^{3+}\text{PO}_4(\text{OH})$

## B. The stability of ferrisicklerite

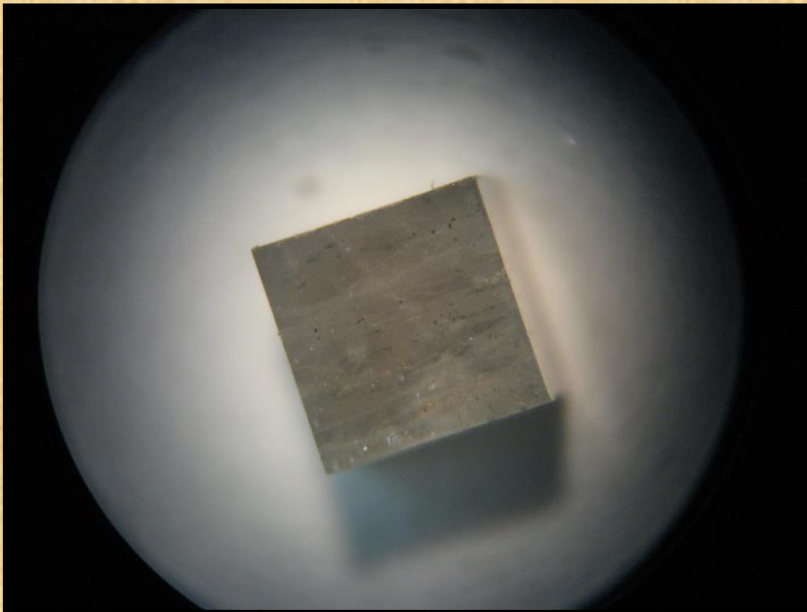


Sample 9706.41, Palermo, N.H., USA  
Collection Paul Keller, Stuttgart

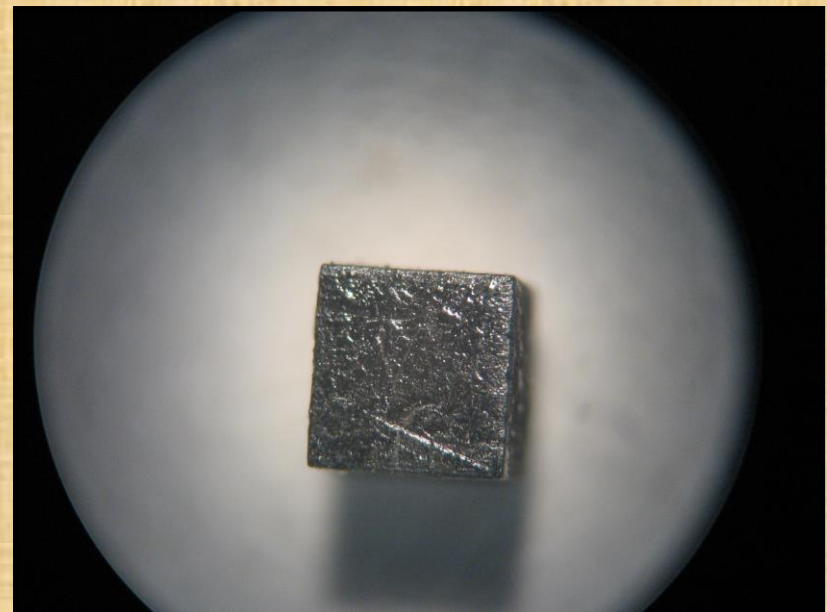
X  $\text{LiFePO}_4$  = 0.74(1)    **100%  $\text{Fe}^{2+}$**   
X  $\text{LiMnPO}_4$  = 0.21(1)  
X  $\text{LiMgPO}_4$  = 0.05(1)

0.1n HCl, 21mg  $\text{KMnO}_4$ , 120°C, 28 d

**Before run**



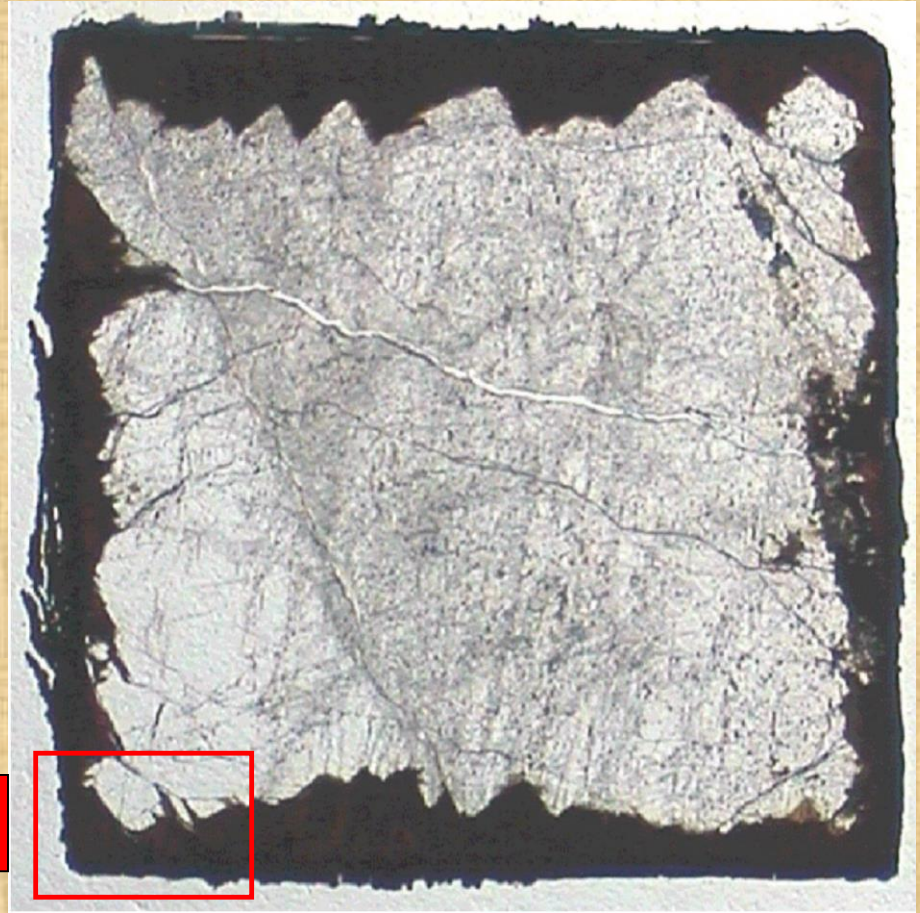
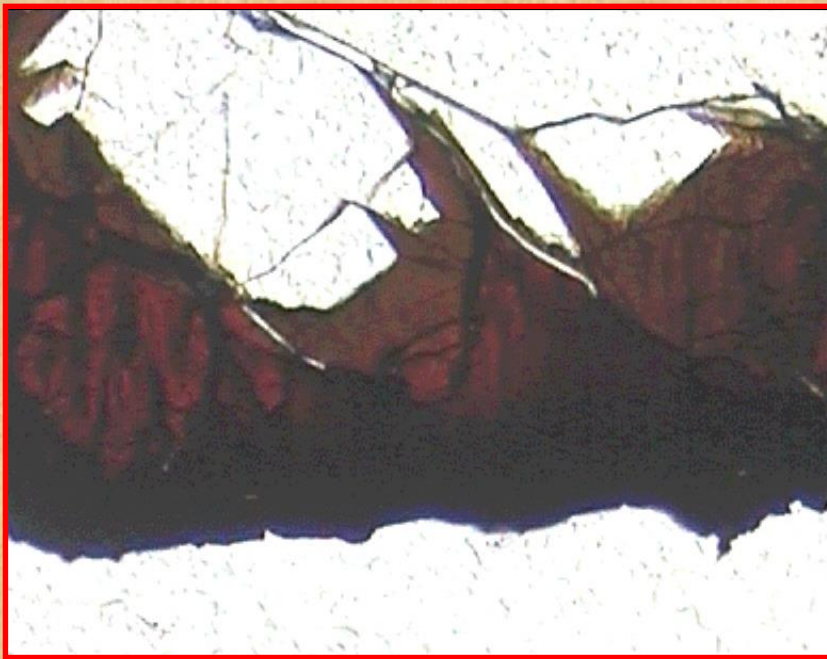
**After run**

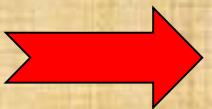




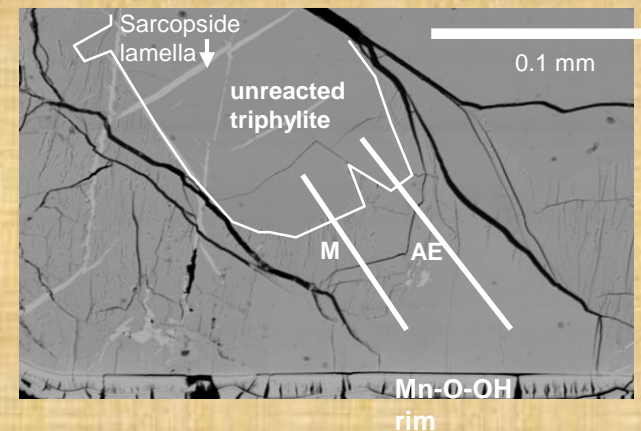
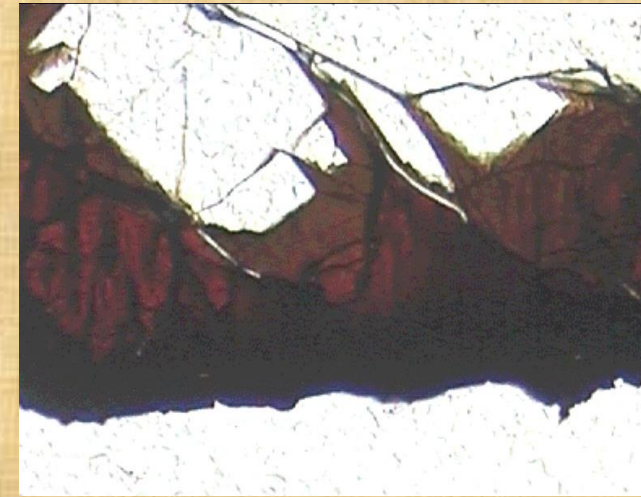
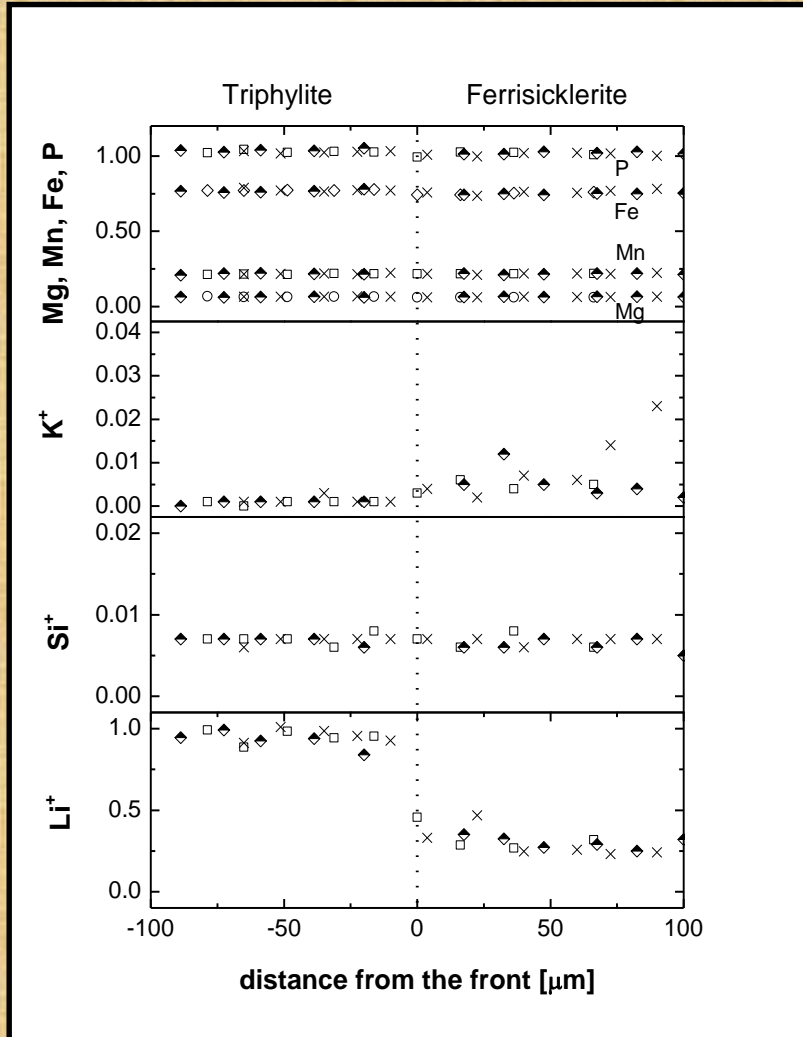
## B. The stability of ferrisicklerite

- First hydrothermal synthesis of ferrisicklerite
- At very low temperature
- Under a very high  $fO_2$



 Ferrisicklerite is a low temperature metasomatic alteration mineral (?)

# B. The stability of ferrisicklerite



**Sharp contact between triphylite and ferrisicklerite!**

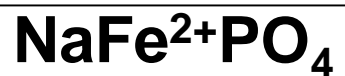


# C. Karenwebberite, a new mineral...

*American Mineralogist, Volume 98, pages 767–772, 2013*

**Karenwebberite,  $\text{Na}(\text{Fe}^{2+}, \text{Mn}^{2+})\text{PO}_4$ , a new member of the triphylite group from the Malpensata pegmatite, Lecco Province, Italy**

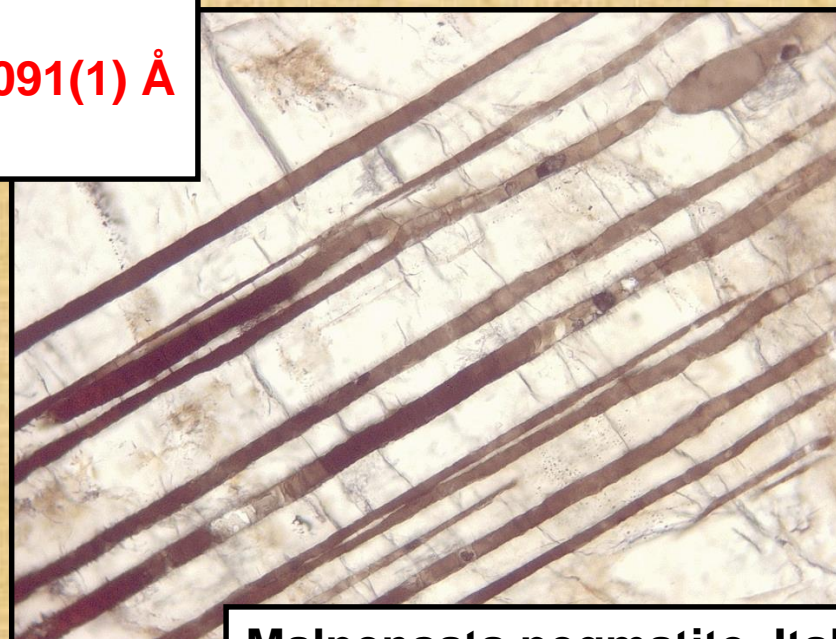
**PIETRO VIGNOLA,<sup>1</sup> FRÉDÉRIC HATERT,<sup>2,\*</sup> ANDRÉ-MATHIEU FRANSOLET,<sup>2</sup> OLAF MEDENBACH,<sup>3</sup>  
VALERIA DIELLA,<sup>1</sup> AND SERGIO ANDÒ<sup>4</sup>**



**$a = 4.882(1)$ ,  $b = 10.387(2)$ ,  $c = 6.091(1)$  Å**  
***Pbnm***

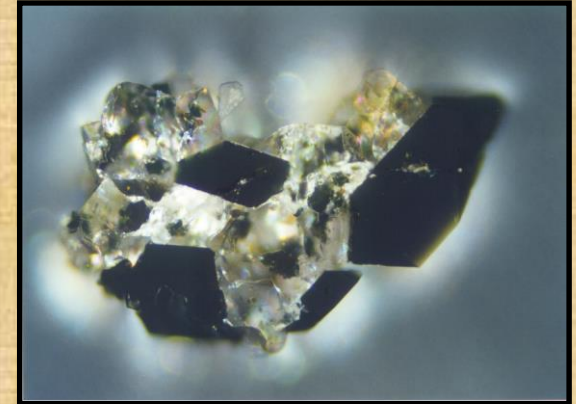
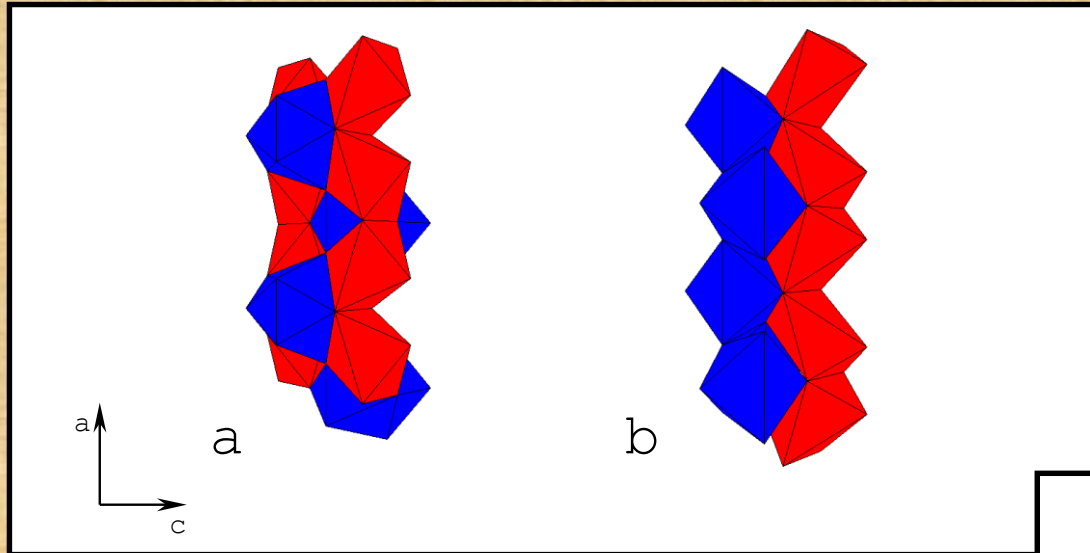


**Karen Louise Webber**

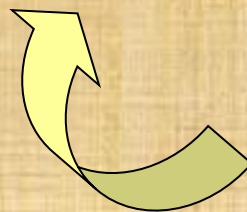
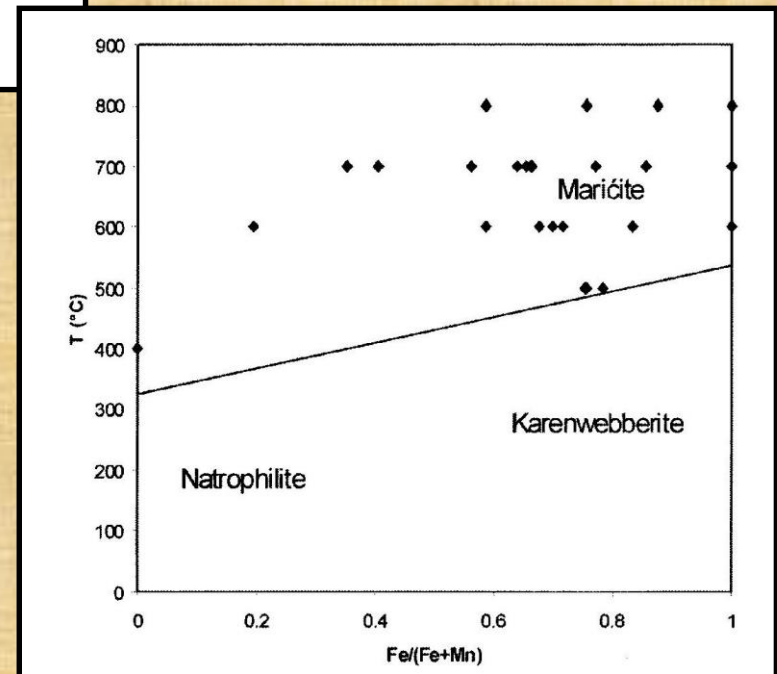


**Malpensata pegmatite, Italy**

# C. The stability of karenwebberite

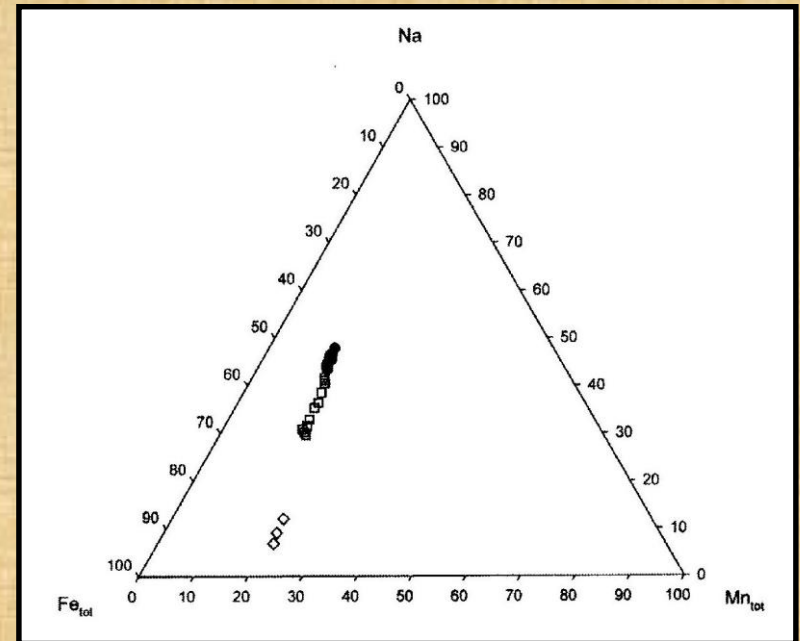
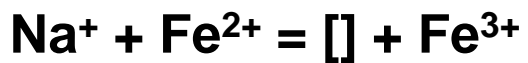
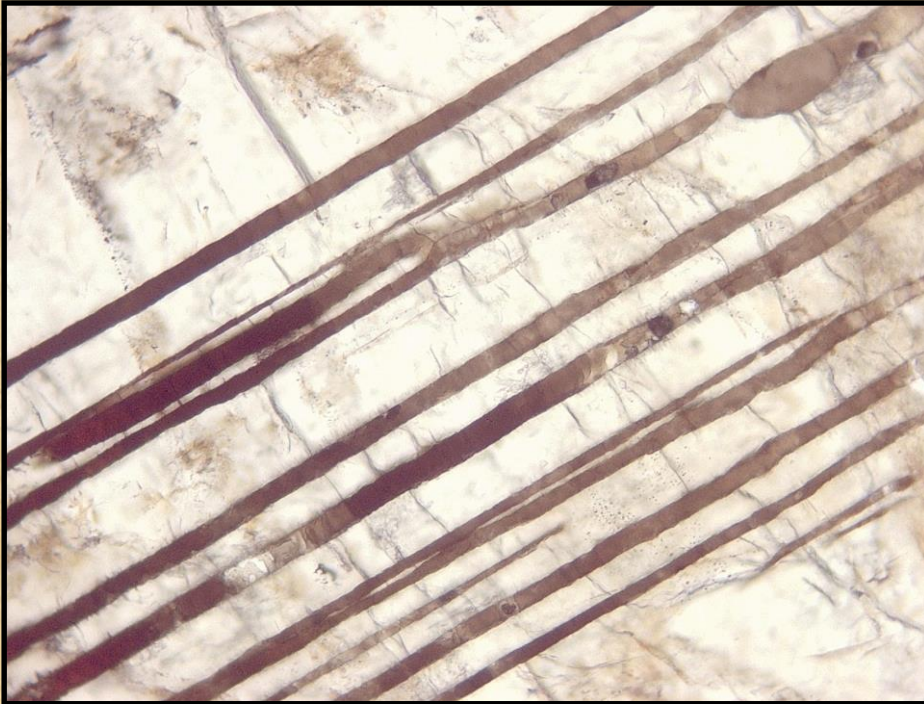


- **Marićite is the high temperature polymorph of karenwebberite**
- **Transition temperature ~ 500°C**





# C. The oxidation of karenwebberite



**Progressive oxidation towards Na-bearing ferrisicklerite!**

# The sarcopside structure

## Sarcopside

$$a = 6.088(1) \text{ \AA}$$

$$b = 4.814(1) \text{ \AA}$$

$$c = 10.484(2) \text{ \AA}$$

$$\beta = 89.42(3)^\circ$$

$$\text{S.G. } P2_1/c$$

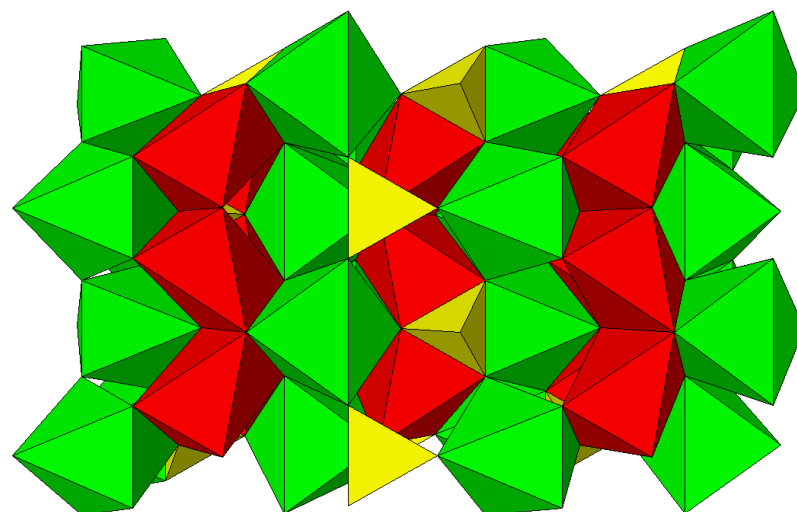
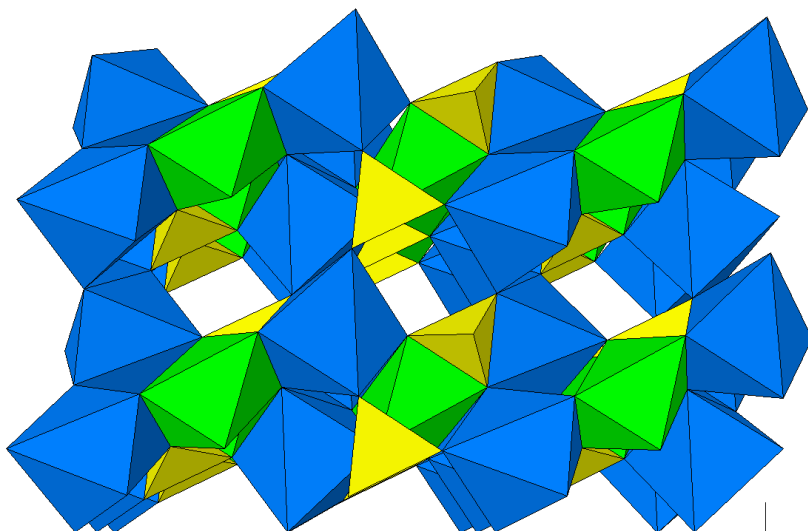
## Triphylite

$$a = 5.987 \text{ \AA}$$

$$b = 10.286 \text{ \AA}$$

$$c = 4.690 \text{ \AA}$$

$$\text{S.G. } Pmnb$$



- Topologically identical crystal structures
- 50 % of M(1) positions are vacant in sarcopside



# The triphylite + sarcopside assemblage

## Intercroissances et inclusions dans les associations graftonite-sarcopside-triphylite

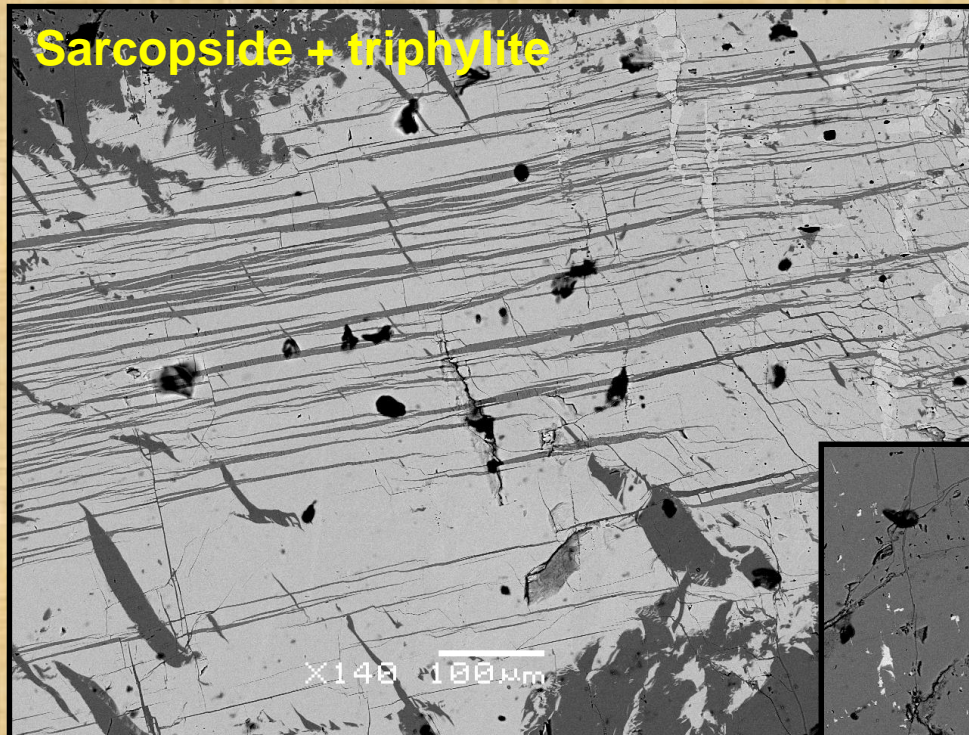
par ANDRÉ-MATHIEU FRANSOLET,  
Institut de Minéralogie, Université de Liège (1).

Fransolet, 1977





# The triphylite + sarcopside assemblage



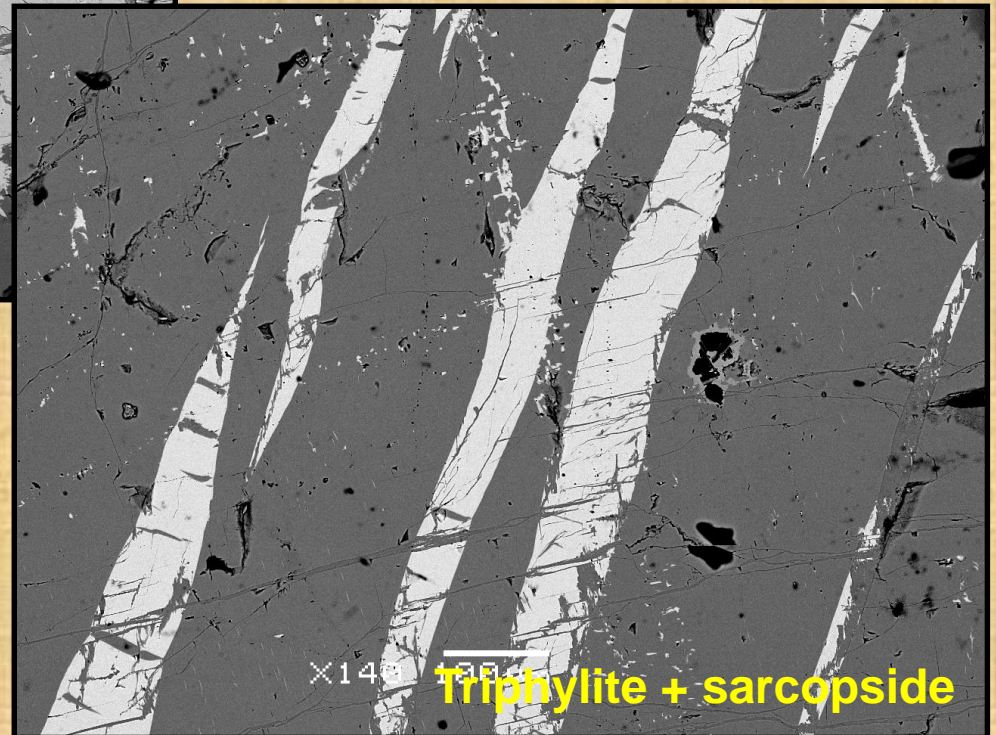
**Cañada pegmatite,  
Spain**

**Lamellar textures**



**EXSOLUTIONS!!**

**Sarcopside  $(\text{Fe,Mn})_3(\text{PO}_4)_2$**



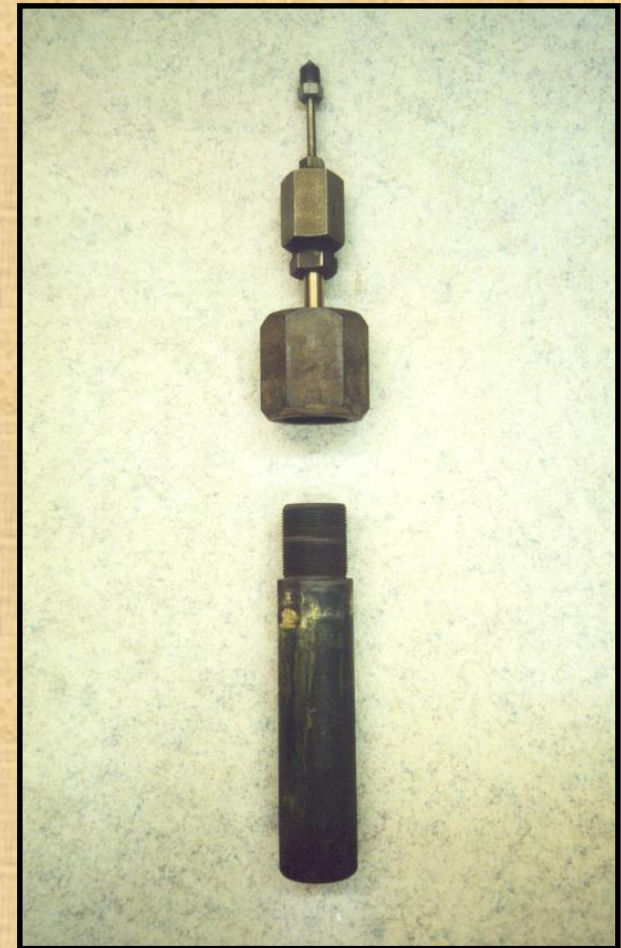
**Pictures: E. Roda Robles**



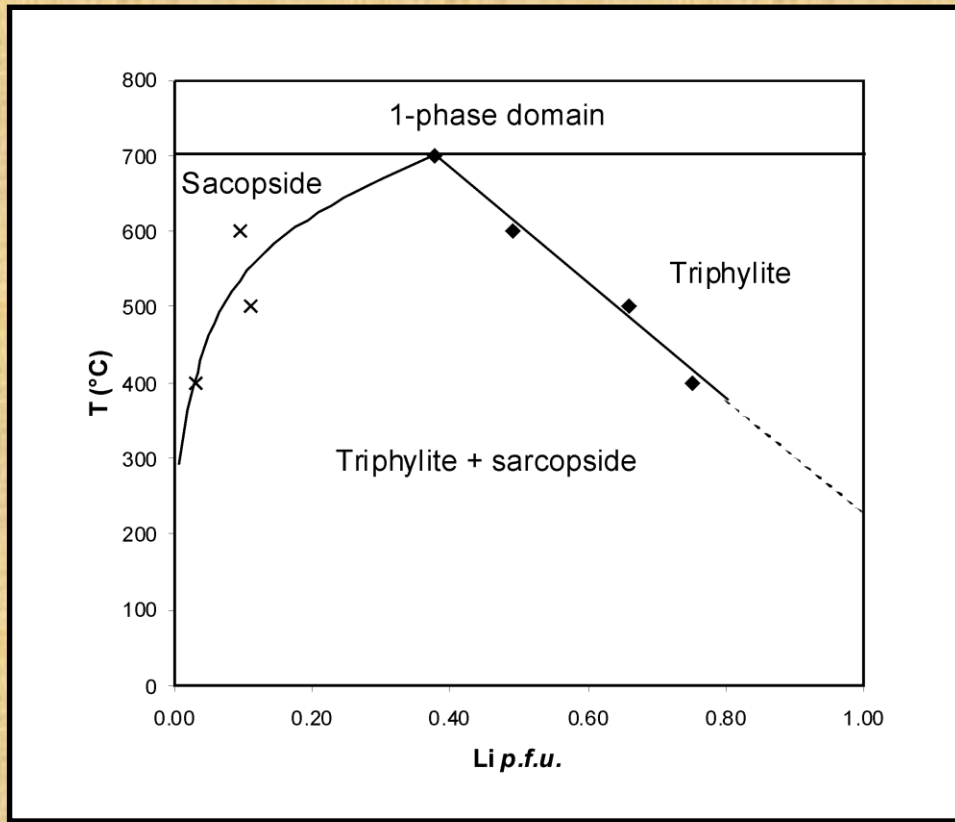
# Stability of the triphylite + sarcopside assemblage



- Hydrothermal synthesis
- Tuttle-type cold-seal bombs
- $T = 400-700 \text{ }^{\circ}\text{C}$
- $P = 1 \text{ kbar}$



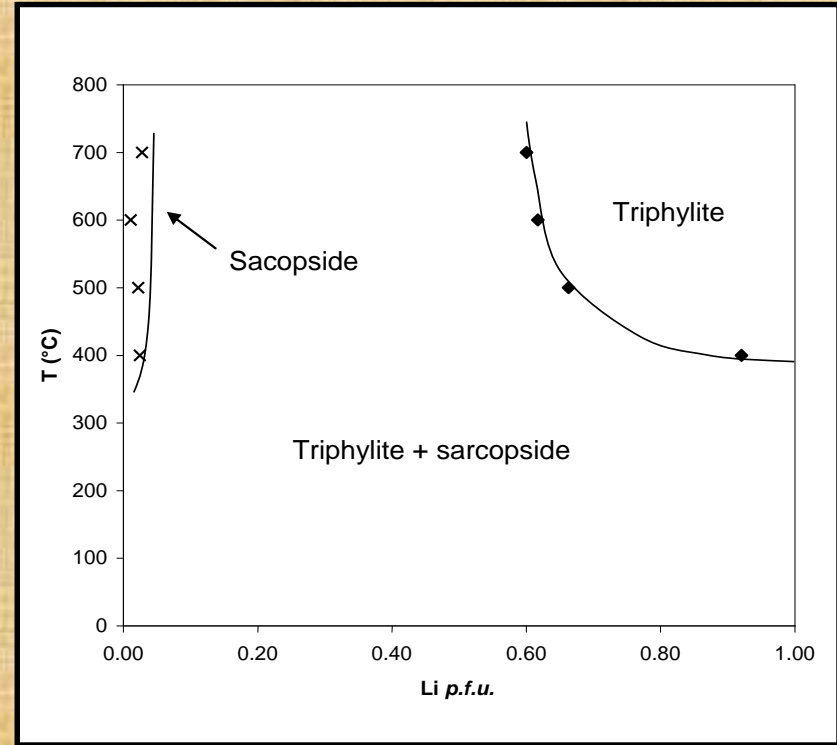
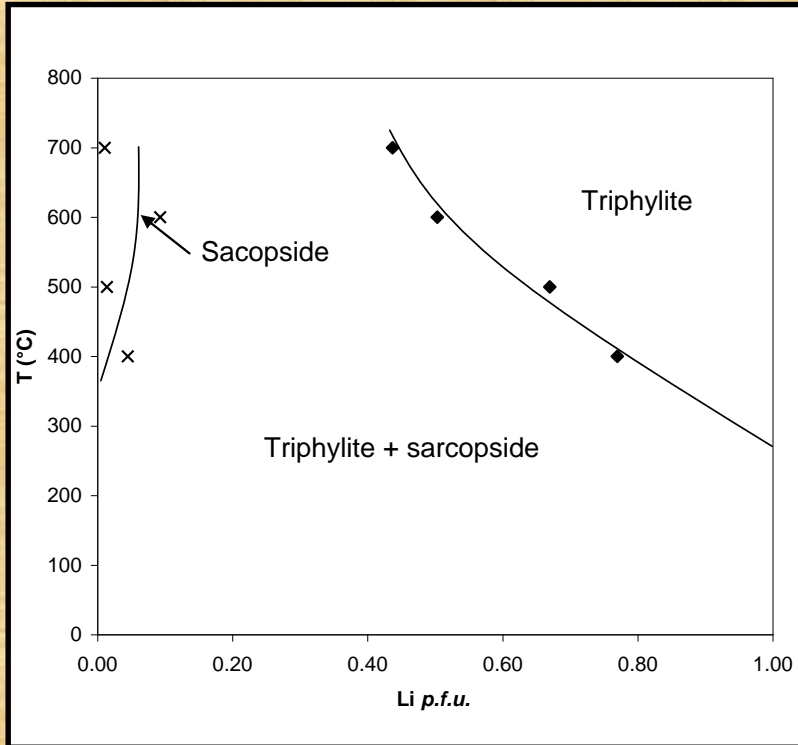
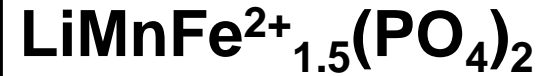
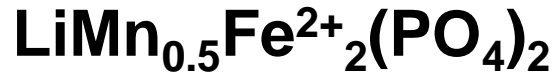
# Stability of the triphylite + sarcopside assemblage



- **Decrease of the Li-content of triphylite, from 0.72 *a.p.f.u.* at 400°C, to 0.48 *a.p.f.u.* at 600°C**
- **Increase of the Li-content of sarcopside, from 0.01 *a.p.f.u.* at 400°C, to 0.05 *a.p.f.u.* at 600°C**
- **1-phase domain above 700°C**



# Triphylite-sarcopside phase diagrams

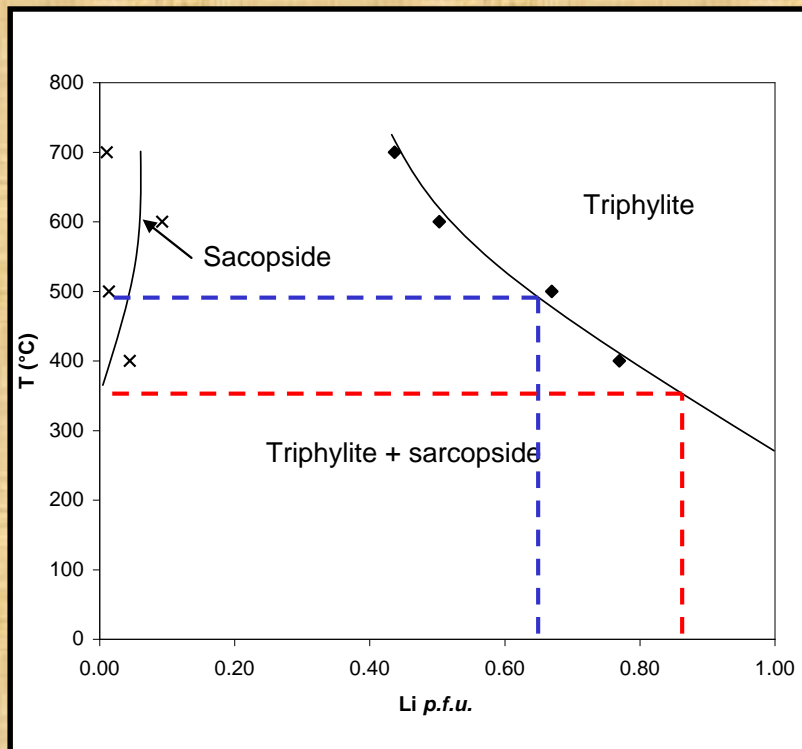


The Li-content of triphylite decreases with temperature



**Geothermometer!**

# Calculation of crystallisation temperatures for natural assemblages



**Fe/(Fe+Mn) ratio of natural triphylites and sarcopsides close to 0.800**



**Phase diagram for the  $\text{LiMn}_{0.5}\text{Fe}^{2+}_2(\text{PO}_4)_3$  starting composition**

**Cañada**

**35 % sarcopside and 65 % triphylite**

**T ~ 500°C**

**Tsoabismund**

**15 % sarcopside and 85 % triphylite**

**T ~ 350°C**



# Zavalíaite, a new mineral...

**ZAVALÍAITE,  $(\text{Mn}^{2+}, \text{Fe}^{2+}, \text{Mg})_3(\text{PO}_4)_2$ , A NEW MEMBER OF THE SARCOPSIDE GROUP  
FROM THE LA EMPLEADA PEGMATITE, SAN LUIS PROVINCE, ARGENTINA**

FRÉDÉRIC HATERT<sup>§</sup>

*Laboratoire de Minéralogie, Département de Géologie, Université de Liège, Bâtiment B18,  
Sart Tilman, B-4000 Liège, Belgium*

ENCARNACIÓN RODA-ROBLES

*Departamento de Mineralogía y Petrología, Universidad del País Vasco/EHU, Apdo. 644, E-48080 Bilbao, Spain*

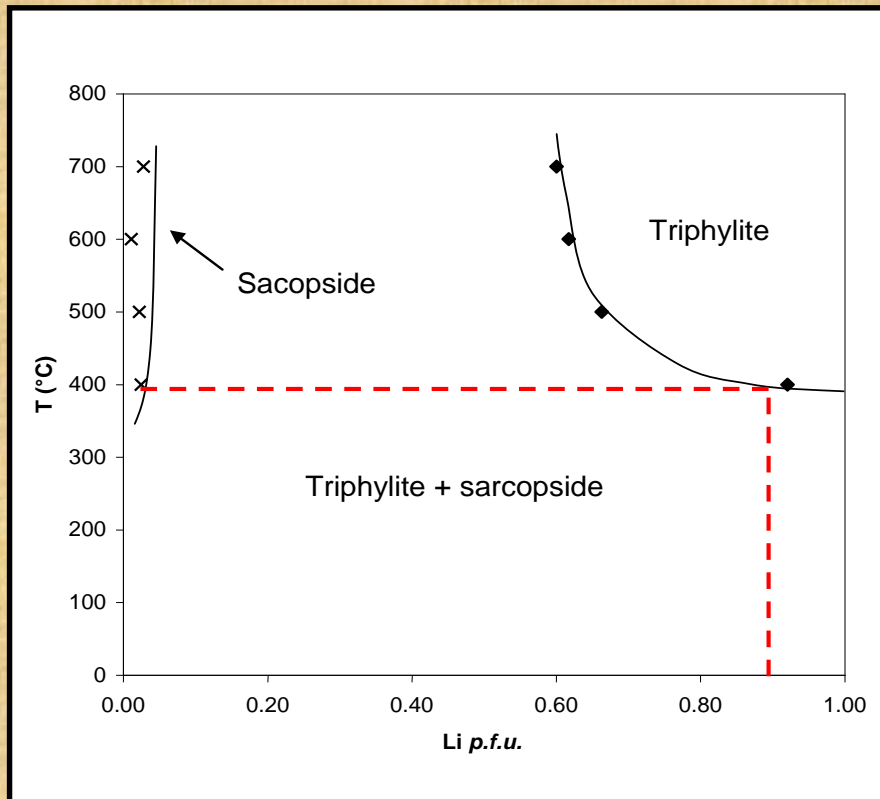
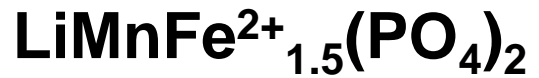
**$a = 6.088(1) \text{ \AA}$   
 $b = 4.814(1) \text{ \AA}$   
 $c = 10.484(2) \text{ \AA}$   
 $\beta = 89.42(3)^\circ$   
S.G.  $P2_1/c$**



**Florencia Márquez Zavalía**



# The stability of zavaliaite?



**Fe/(Fe+Mn) ratio of lithiophilite  
and associated zavaliaite close  
to 0.43-0.48**



**Phase diagram for the  
 $\text{LiMnFe}^{2+}_{1.5}(\text{PO}_4)_3$  starting  
composition**



**10 % zavaliaite and 90 %  
lithiophilite**



**$T < 400^{\circ}\text{C}$**



# The alluaudite supergroup



Ferrorosemaryite, Rubindi, Rwanda

## Wyllieite group ( $P2_1/n$ )

Wyllieite:  $\text{Na}_2\text{MnFe}^{2+}\text{Al}(\text{PO}_4)_3$

Rosemaryite:  $[\text{NaMnFe}^{3+}\text{Al}(\text{PO}_4)_3]$

Ferrowyllieite:  $\text{Na}_2\text{Fe}^{2+}_2\text{Al}(\text{PO}_4)_3$

Ferrorosemaryite:  $[\text{NaFe}^{2+}\text{Fe}^{3+}\text{Al}(\text{PO}_4)_3]$

Qingheiite:  $\text{Na}_2\text{MnMgAl}(\text{PO}_4)_3$

Qingheiite-( $\text{Fe}^{2+}$ ):  $\text{Na}_2\text{Fe}^{2+}\text{MgAl}(\text{PO}_4)_3$

## Alluaudite group ( $C2/c$ )

Alluaudite:  $[\text{NaMnFe}^{3+}_2(\text{PO}_4)_3]$

Ferroalluaudite:  $[\text{NaFe}^{2+}\text{Fe}^{3+}_2(\text{PO}_4)_3]$

Hagendorfite:  $\text{Na}_2\text{MnFe}^{2+}\text{Fe}^{3+}(\text{PO}_4)_3$

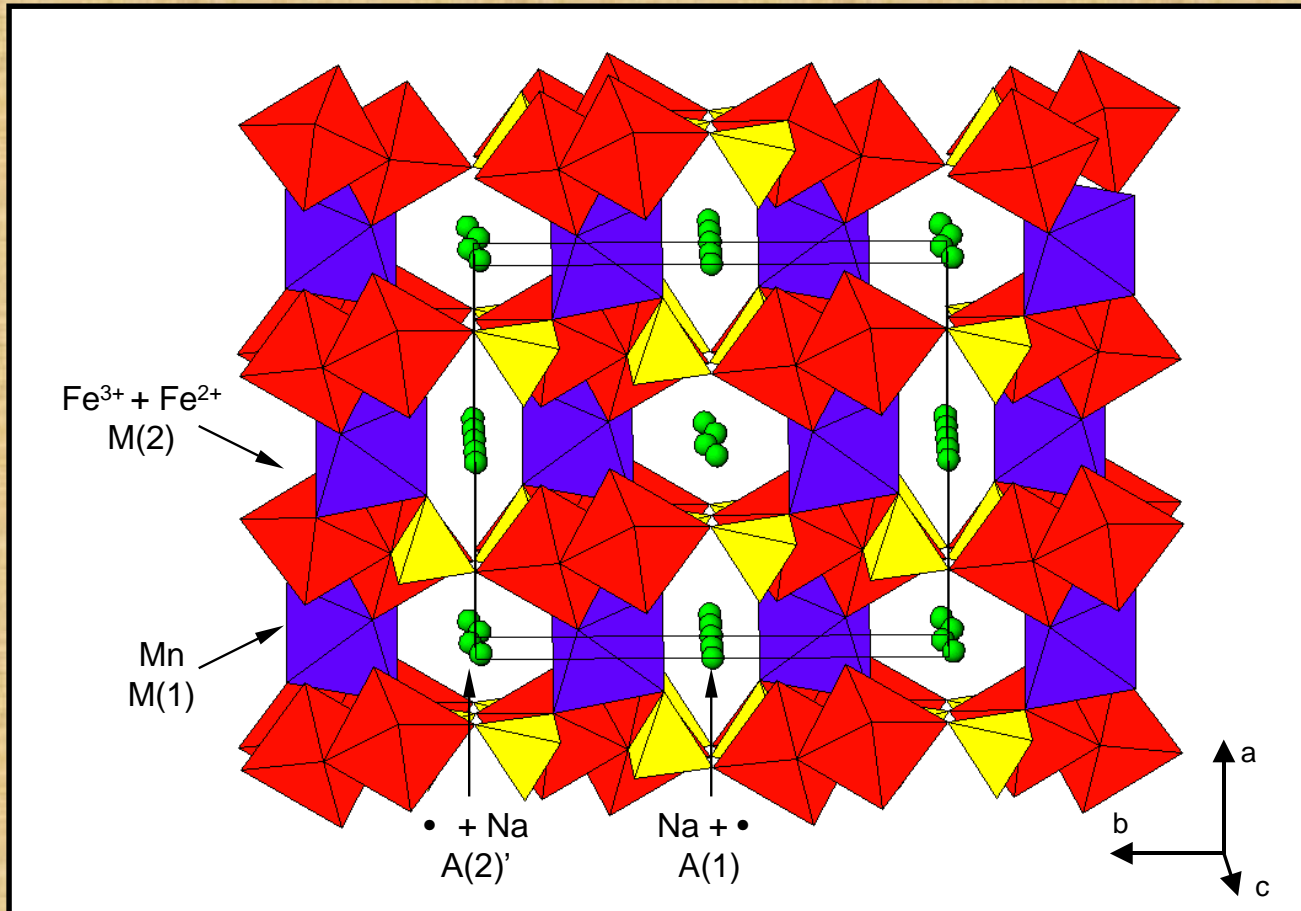
Ferrohagendorfite:  $\text{Na}_2\text{Fe}^{2+}_2\text{Fe}^{3+}(\text{PO}_4)_3$

Varulite:  $\text{Na}_2\text{Mn}_2\text{Fe}^{3+}(\text{PO}_4)_3$



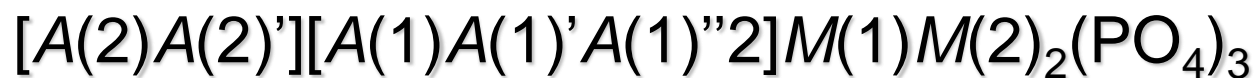
Alluaudite, Buranga, Rwanda

# The alluaudite structure



- A(2)'**: gable disphenoid
- A(1)**: distorted cube
- M(1)**: very distorted octahedron
- M(2)**: distorted octahedron

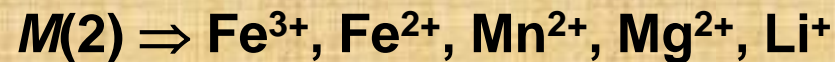
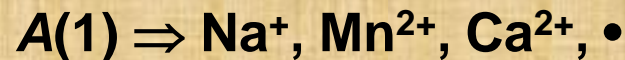
***C*2/*c*, Z = 4**





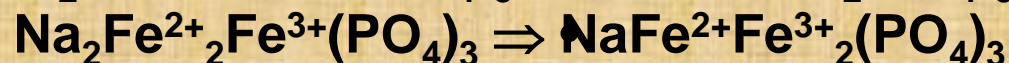
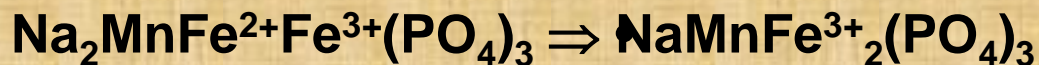
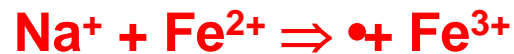
# Crystal chemistry of natural alluaudites

- Moore & Ito (1979)



- Fransolet *et al.* (1985, 1986, 2004)

### Oxidation mechanism:



# Crystal chemistry of synthetic alluaudite-type compounds

## • Solid state synthesis in air

- T = 800-950 °C
- P = 1 bar

Na-Mn-Fe<sup>3+</sup> (+ PO<sub>4</sub>) system

Role of Li<sup>+</sup>

Role of Cd<sup>2+</sup> and Zn<sup>2+</sup>

Role of In<sup>3+</sup> and Ga<sup>3+</sup>

## Experimental

## • Hydrothermal synthesis

- Tuttle-type cold-seal bombs
- T = 400-800 °C
- P = 1-5 kbar

Na-Mn-Fe<sup>2+</sup>-Fe<sup>3+</sup> (+ PO<sub>4</sub>) system

*American Mineralogist, Volume 90, pages 653–662, 2005*

Crystal chemistry of the hydrothermally synthesized Na<sub>2</sub>(Mn<sub>1-x</sub>Fe<sub>x</sub><sup>2+</sup>)<sub>2</sub>Fe<sup>3+</sup>(PO<sub>4</sub>)<sub>3</sub> alluaudite-type solid solution

FRÉDÉRIC HATERT,<sup>1,2,\*</sup> LEILA REBBOUH,<sup>3</sup> RAPHAËL P. HERMANN,<sup>3</sup> ANDRÉ-MATHIEU FRANSOLET,<sup>1</sup>  
GARY J. LONG,<sup>4</sup> AND FERNANDE GRANDJEAN<sup>3</sup>



# Cationic distribution

Cation	Ionic radius (Å)		Site			
	[VI]	[VIII]	A(2)'	A(1)	M(1)	M(2)
Ag <sup>+</sup>	1.15	1.28	X	X		
Na <sup>+</sup>	1.02	1.18	X	X	X	
Cu <sup>+</sup>	0.77	-	p	p		
Li <sup>+</sup>	0.76	0.92	p	p		
Ca <sup>2+</sup>	1.00	1.12	p	p	p	
Cd <sup>2+</sup>	0.95	1.10		p	X	p
Mn <sup>2+</sup>	0.830	0.96	p	p	X	X
Fe <sup>2+</sup>	0.780	0.92			X	X
Co <sup>2+</sup>	0.745	0.90			X	X
Zn <sup>2+</sup>	0.740	0.90			X	P
Cu <sup>2+</sup>	0.73	-		p		
Mg <sup>2+</sup>	0.720	0.89			X	X
In <sup>3+</sup>	0.800	0.92			p	X
Fe <sup>3+</sup>	0.645	0.78		p		X
Ga <sup>3+</sup>	0.620	-				p
Cr <sup>3+</sup>	0.615	-				p
Al <sup>3+</sup>	0.535	-				p

X : Complete occupancy of the site  
p : Partial occupancy of the site

**Solid-state synthesis  
and hydrothermal  
experiments**



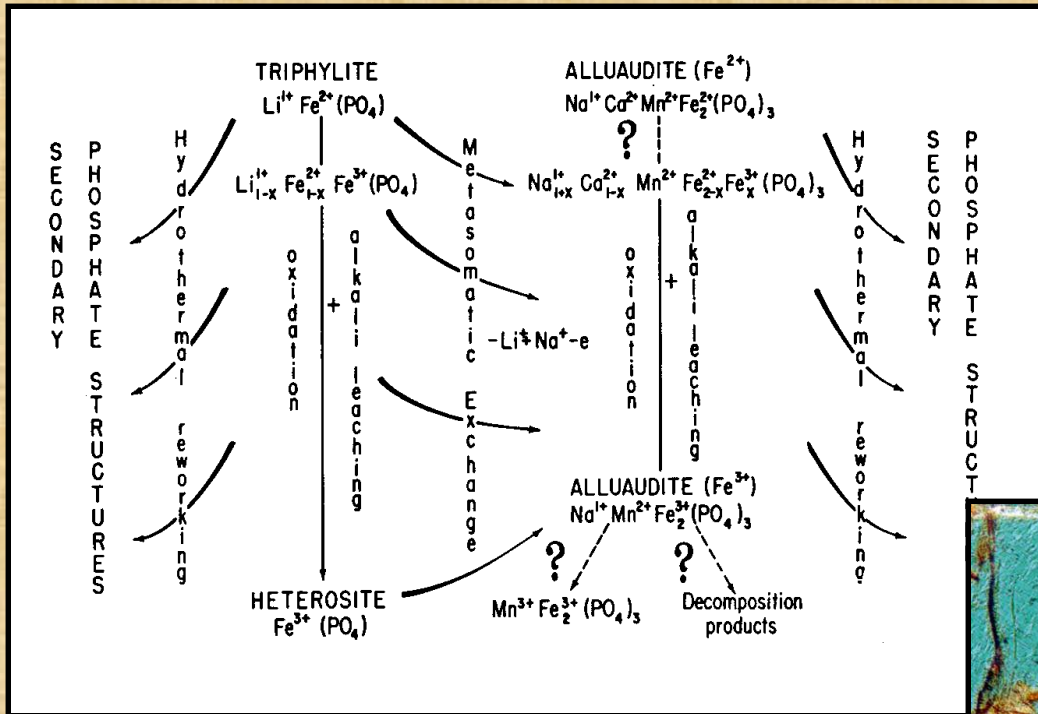
**X-ray structure  
refinements**

Crystal chemistry of the divalent cation in alluaudite-type phosphates:  
A structural and infrared spectral study of the  $\text{Na}_{1.5}(\text{Mn}_{1-x}\text{M}^{2+}_x)_{1.5}\text{Fe}_{1.5}(\text{PO}_4)_3$   
solid solutions ( $x = 0$  to  $1$ ,  $\text{M}^{2+} = \text{Cd}^{2+}, \text{Zn}^{2+}$ )

Frédéric Hatert\*

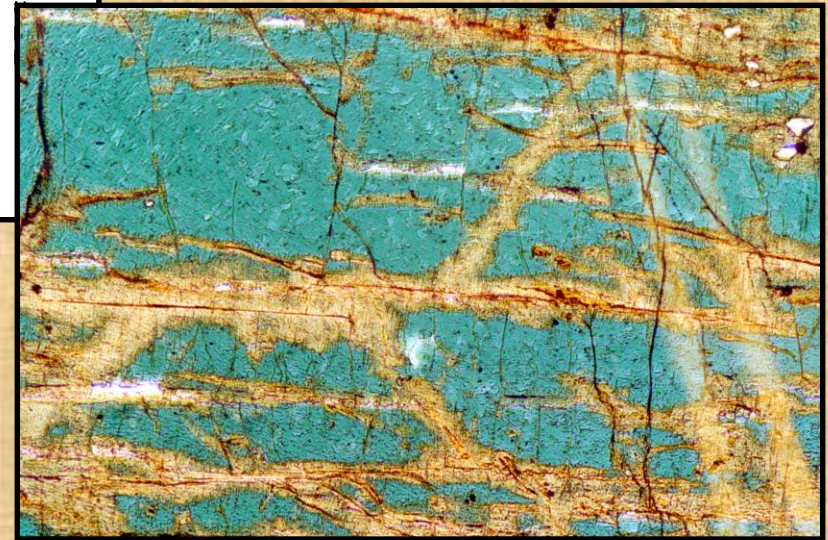
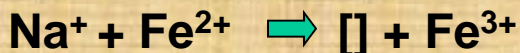
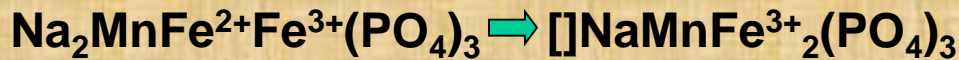
Laboratoire de Minéralogie, Université de Liège, Bâtiment B18, B-4000 Liège, Belgium

# The stability of alluaudites?



- Secondary origin
- Primary origin

## Oxidation mechanism



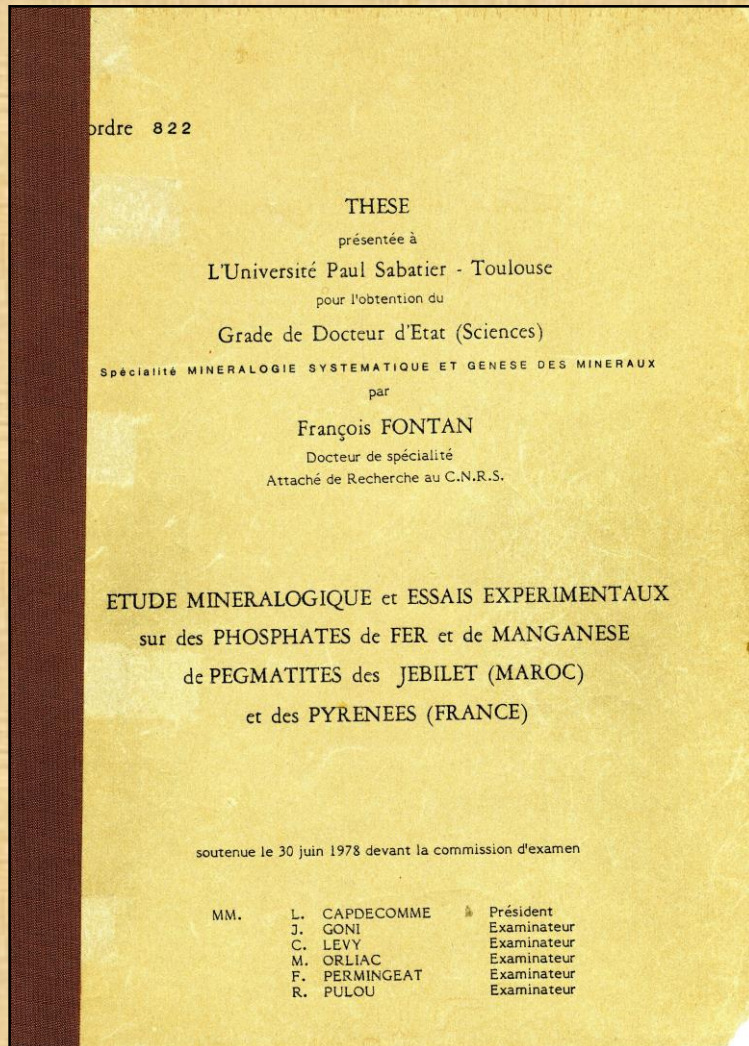
Alluaudite, Kibingo pegmatite, Rwanda



# First experiments...



**Fontan, 1978**



4/ Conclusion - Stabilité de la structure alluaudite.

Ces expériences, associées à celles réalisées sur la graf-tonite, montre que la structure alluaudite admet de très larges variations de composition chimique.

Cette structure, stable à haute température, est stable également à basse température. En effet, dans certaines pegmatites contenant des phosphates de fer et de manganèse, on observe fréquemment un remplacement métasomatique de phosphates des séries de la sicklérîte, de la triphylite et de l'hétérosite par de l'alluaudite, ce remplacement se faisant essentiellement par apport, sans doute hydrothermal, de sodium et de calcium et départ de lithium ; en outre, au cours de l'altération météorique supergène, les sicklérïtes et triphylites résiduelles perdent facilement leur lithium, tandis que l'alluaudite sodocalcique reste inaltérée. Notons d'ailleurs, que les alluaudites sodocalciques, paraissent plus stables que les alluaudites lithiques puisque celles-ci n'ont jamais été rencontrées dans la nature. A Sidi Bou Othmane, par exemple, il s'est formé à partir des solutions pegmatitiques, une triphylite qui s'est transformée en ferrisicklérïte et non une alluaudite lithique. Le fait que l'on obtienne de l'alluaudite par simple chauffage à 620°C de la ferrisicklérïte, montre que les phosphates de Sidi Bou Othmane ont cristallisé à une température inférieure à 620°C. L'étude de la transformation thermique de la graf-tonite en alluaudite nous avait déjà permis d'estimer à 700°C la température maximale de cette cristallisation.

# First hydrothermal synthesis...

TABLEAU 40

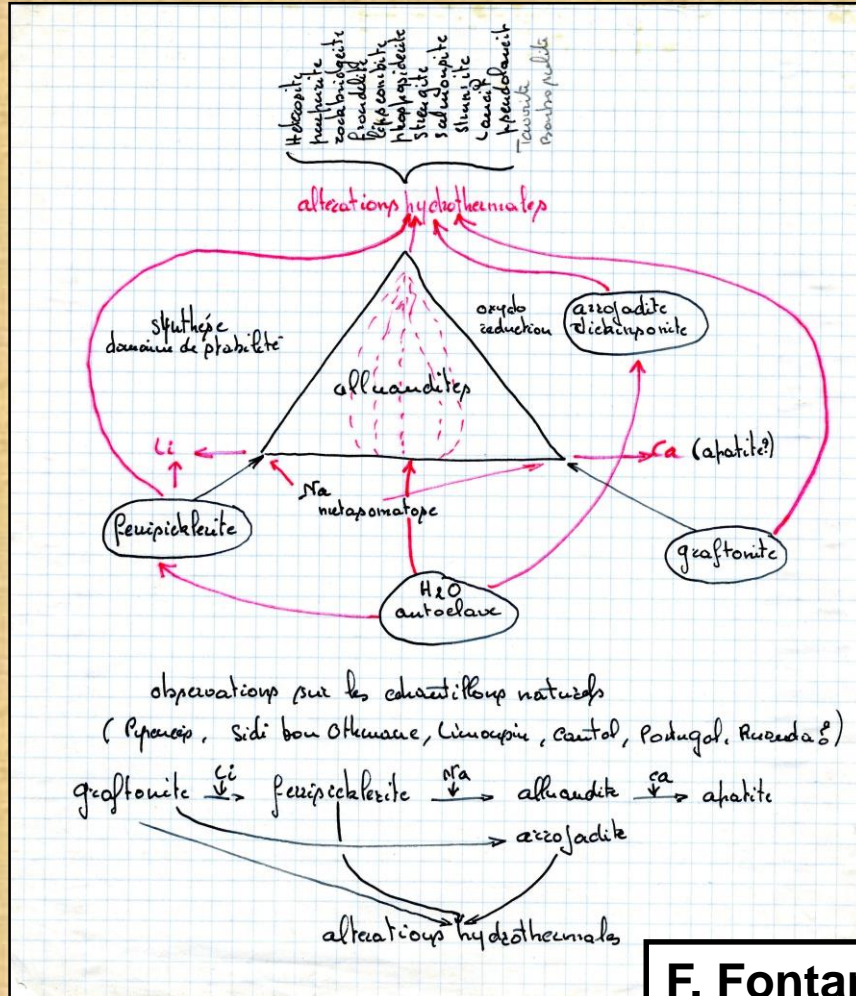
c : Concentration du thio-sulfate t : température	Li <sub>2</sub> O %	P <sub>2</sub> O <sub>5</sub> %	MnO %	FeO %	Na <sub>2</sub> O % passant en F.	Phosphates obtenus
c : 4,24 g/l	t = 150°C	3,0 %	16,0	6,5	-	LIPSCOMBITE
	t = 200°C	3,4 %	12,0	1,5	-	LIPSCOMBITE + <u>ALLUAUDITE</u>
	t = 250°C	2,3 %	2,9	1,1	0,8	<u>ALLUAUDITE</u>
c : 8,50 g/l	t = 150°C				-	LIPSCOMBITE
	t = 200°C	3,1	12,6	2,7	0,3	LIPSCOMBITE + <u>ALLUAUDITE</u>
	t = 250°C	3,3	7,1	2,1	0,9	<u>ALLUAUDITE</u>
c : 17,0 g/l	t = 150°C	3,3	16,7	6,8	0,5	LIPSCOMBITE + <u>ALLUAUDITE</u>
	t = 200°C	3,6	13,5	2,0	0,7	<u>ALLUAUDITE</u>
	t = 250°C	3,5	8,8	2,9	2,2	<u>ALLUAUDITE</u>
10 cm <sup>3</sup> H <sub>2</sub> O	t = 150°C	1,3	n.d.	3,2	-	LIPSCOMBITE
	t = 200°C	2,1	12,0	1,5	-	LIPSCOMBITE
	t = 250°C	1,6	9,6	0,2	-	LIPSCOMBITE

PROPORTION D'ELEMENTS LESSIVES SUR 100 mg DE FERRISICKLERITE ET  
PHOSPHATES OBTENUS APRES PASSAGE EN AUTOCLAVE DURANT 48 HEURES.

Fontan, 1978



# Alluaudites occupy a crucial position in the genesis of pegmatite phosphates



F. Fontan, archives

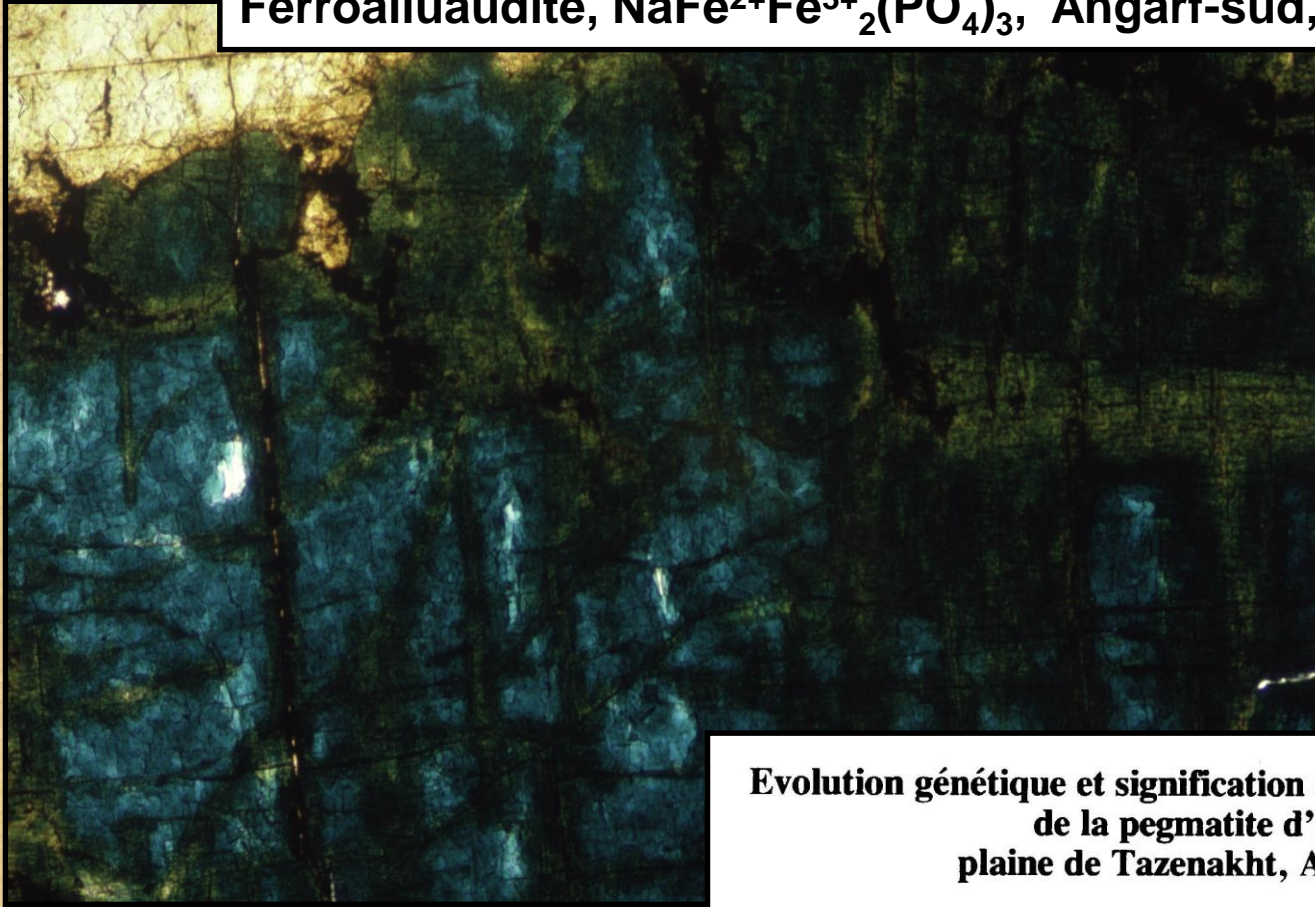
## Questions

- ➔ **A. Stability of Fe-bearing alluaudites?**
- ➔ **B. Stability of Fe-Mn-bearing alluaudites ?**
- ➔ **C. Stability of the alluaudite + triphylite assemblage ?**
- ➔ **D. Stability of wyllieites?**



# A. Fe-rich alluaudites

**Ferroalluaudite,  $\text{NaFe}^{2+}\text{Fe}^{3+}_2(\text{PO}_4)_3$ , Angarf-sud, Morocco**



**Evolution génétique et signification des associations de phosphates  
de la pegmatite d'Angarf-Sud,  
plaine de Tazenakht, Anti-Atlas, Maroc**

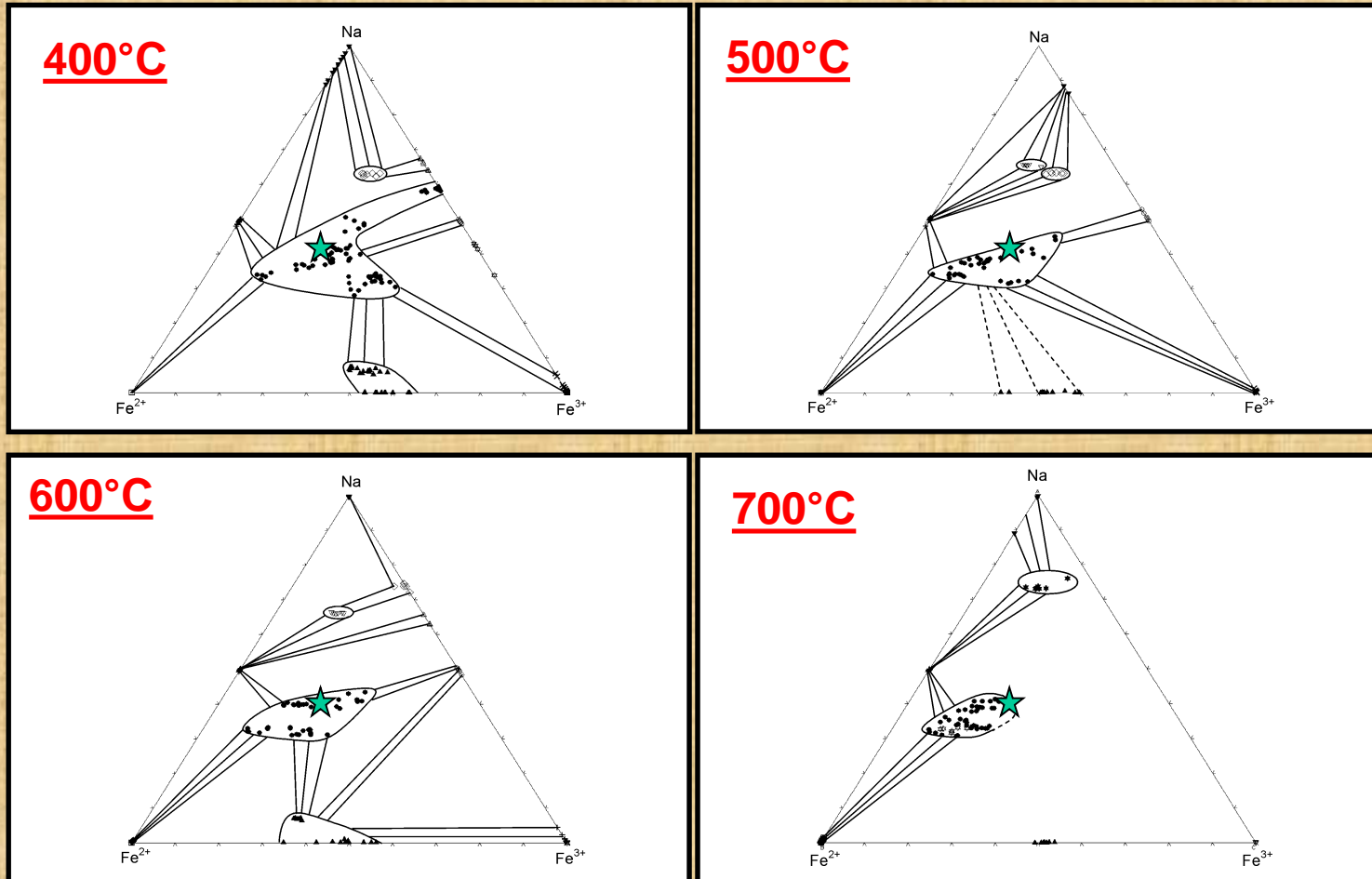
par ANDRÉ-MATHIEU FRANSOLET <sup>(1)</sup>, KURT ABRAHAM <sup>(2)</sup> et JEAN-MARIE SPEETJENS <sup>(1)</sup>

<sup>(1)</sup> Institut de Minéralogie, Université de Liège, Place du Vingt-Août, 9, B-4000 Liège (Belgique).

<sup>(2)</sup> Institut für Mineralogie, Ruhr-Universität Bochum,  
Universitätsstrasse 150, Postfach 10 21 48, D-4630 Bochum-1 (Westdeutschland).

# A. The Na-Fe<sup>2+</sup>-Fe<sup>3+</sup> (+ PO<sub>4</sub>) system

★ = Ferroalluaudite from Angarf-sud, Morocco



**Cristallisation between 400 and 600°C → primary origin**



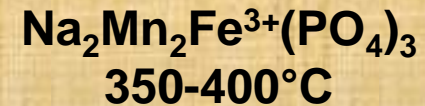
# B. The $\text{Na}_2(\text{Mn}_{1-x}\text{Fe}^{2+}_x)_2\text{Fe}^{3+}(\text{PO}_4)_3$ solid solution

- Low T  $\Rightarrow$  alluaudite
- High T  $\Rightarrow$  “X-phase”
- Mn  $\Rightarrow$  fillopite  $[\text{NaMn}_4(\text{PO}_4)_3]$

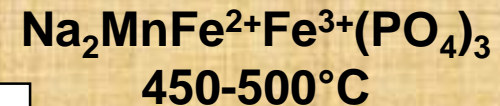
No maricite  $[\text{NaFePO}_4]$  in  
pegmatites



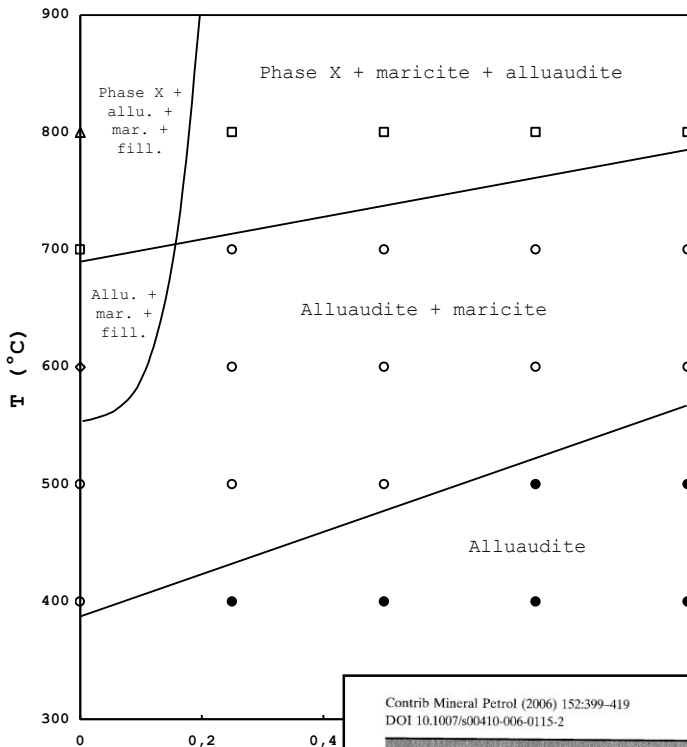
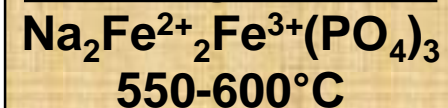
Varulite



Hagendorfite



Ferrohagendorfite



Contrib Mineral Petrol (2006) 152:399–419  
DOI 10.1007/s00410-006-0115-2

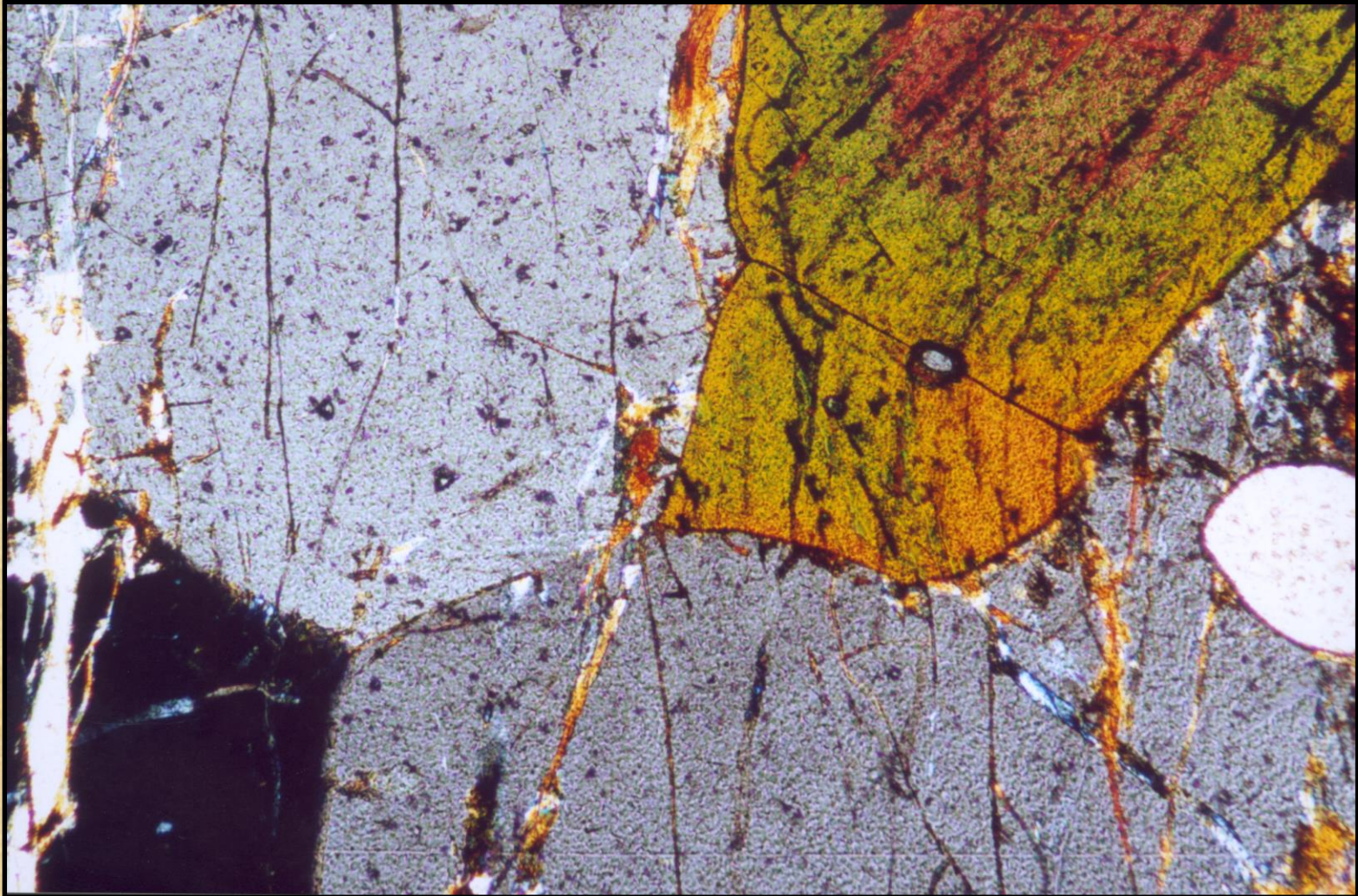
ORIGINAL PAPER

The stability of primary alluaudites in granitic pegmatites:  
an experimental investigation of the  $\text{Na}_2(\text{Mn}_{2-2x}\text{Fe}_{1+2x})(\text{PO}_4)_3$   
system

Frédéric Hatert · André-Mathieu Franolet ·  
Walter V. Maresch

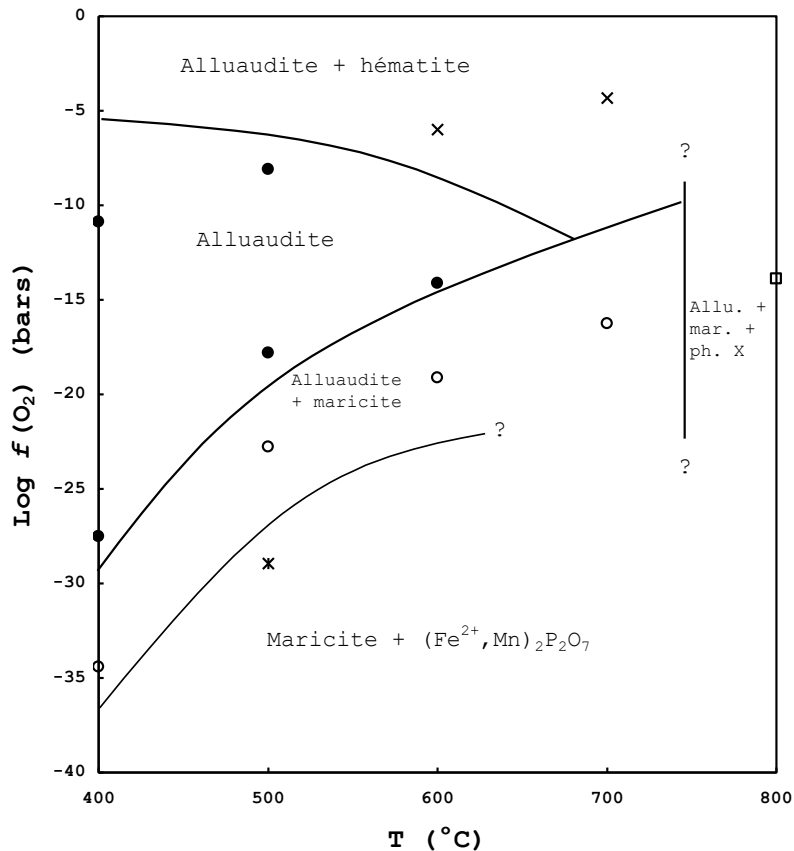


## B. The alluaudite + fillowite assemblage





# B. $\text{Na}_2\text{MnFe}^{2+}\text{Fe}^{3+}(\text{PO}_4)_3$



**Composition of primary  
alluaudite**

**Temperature and oxygen  
fugacity can be  
constrained**

## C. The triphylite + alluaudite assemblage

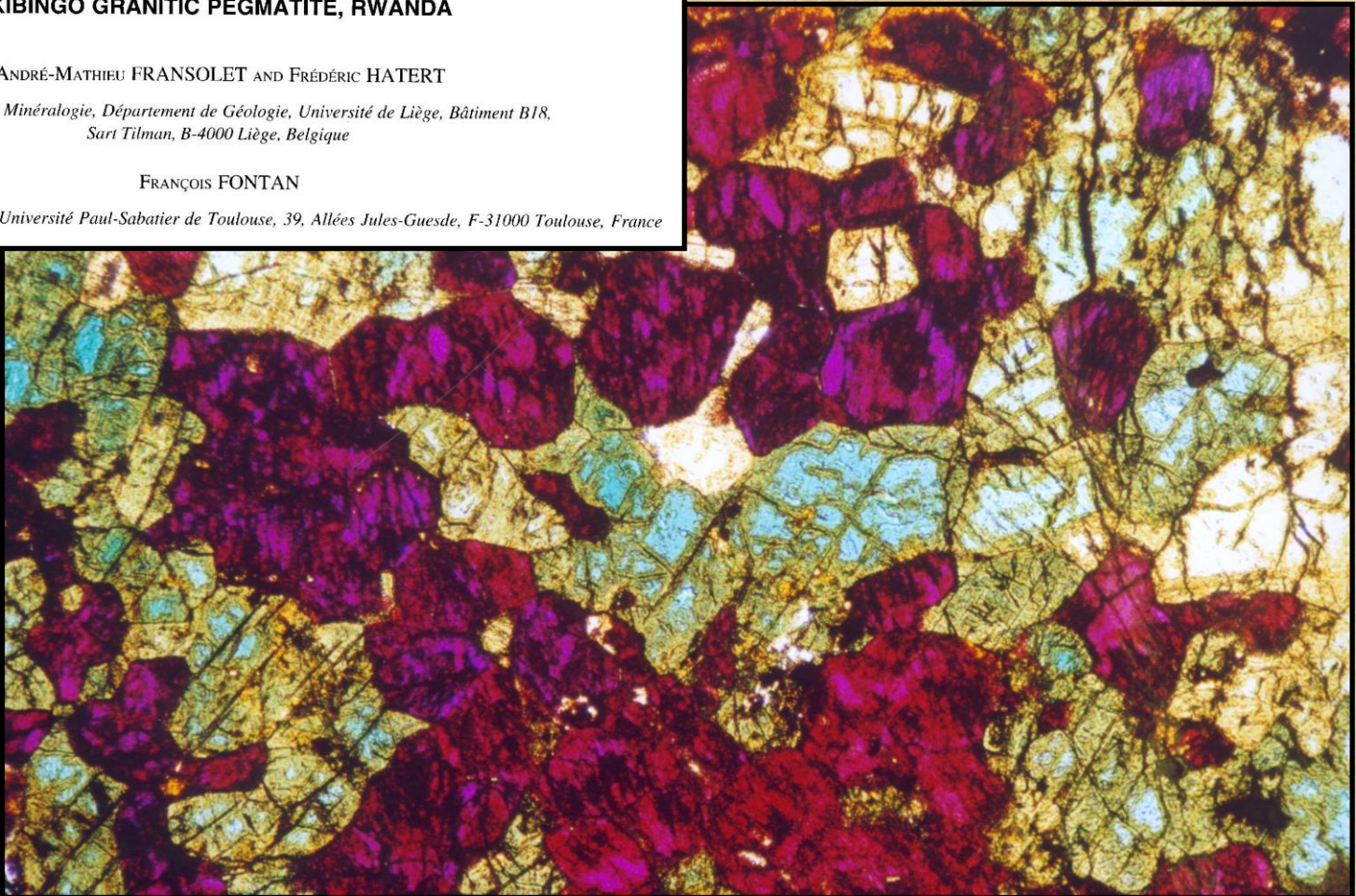
**PETROGRAPHIC EVIDENCE FOR PRIMARY HAGENDORFITE  
IN AN UNUSUAL ASSEMBLAGE OF PHOSPHATE MINERALS,  
KIBINGO GRANITIC PEGMATITE, RWANDA**

ANDRÉ-MATHIEU FRANSOLET AND FRÉDÉRIC HATERT

*Laboratoire de Minéralogie, Département de Géologie, Université de Liège, Bâtiment B18,  
Sart Tilman, B-4000 Liège, Belgique*

FRANÇOIS FONTAN

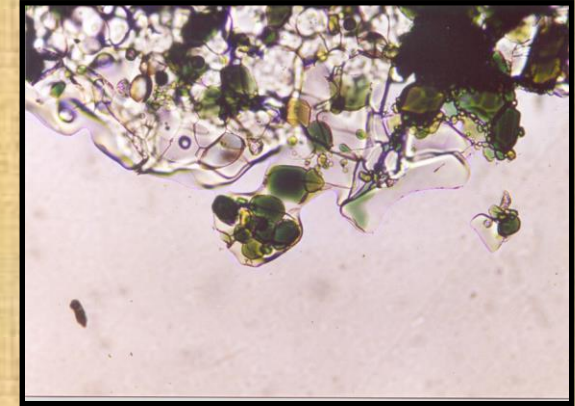
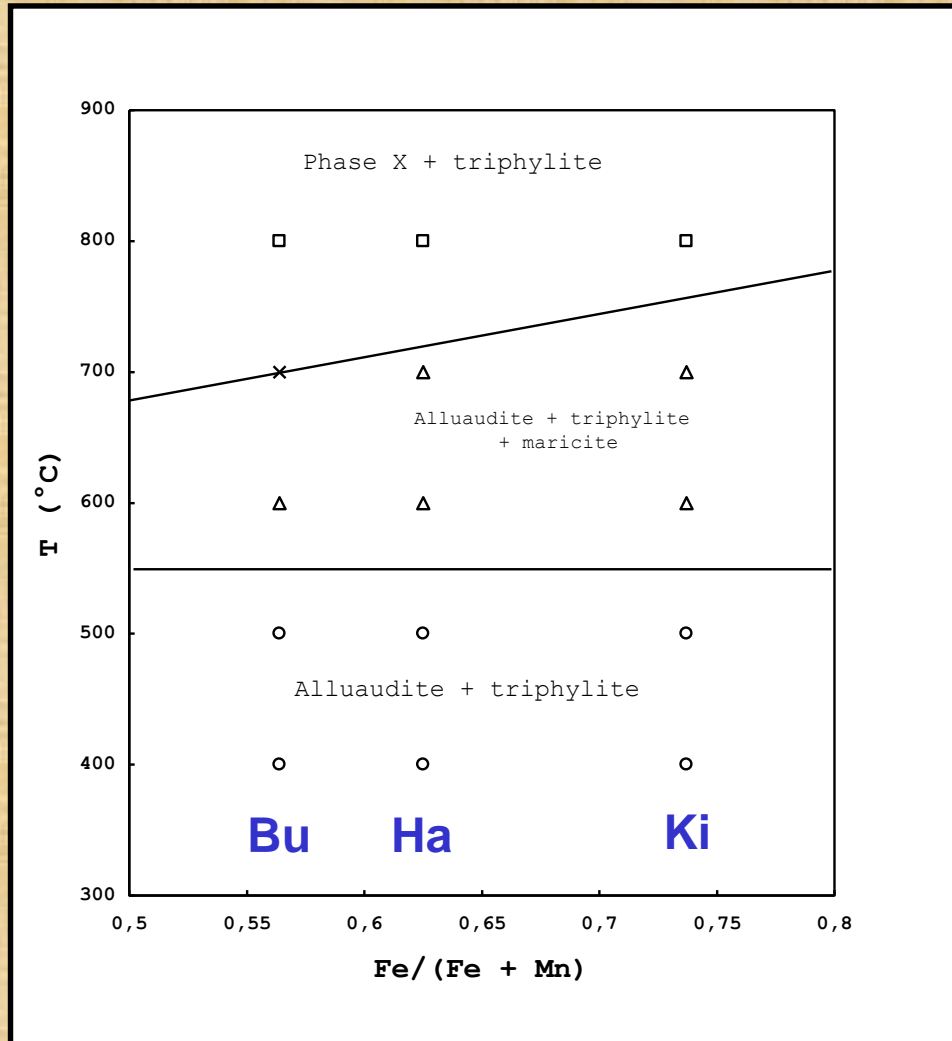
*Laboratoire de Minéralogie, Université Paul-Sabatier de Toulouse, 39, Allées Jules-Guesde, F-31000 Toulouse, France*



**Hagendorfite, alluaudite, and heterosite, Kibingo pegmatite, Rwanda**



# C. Stability of the triphylite + alluaudite assemblage



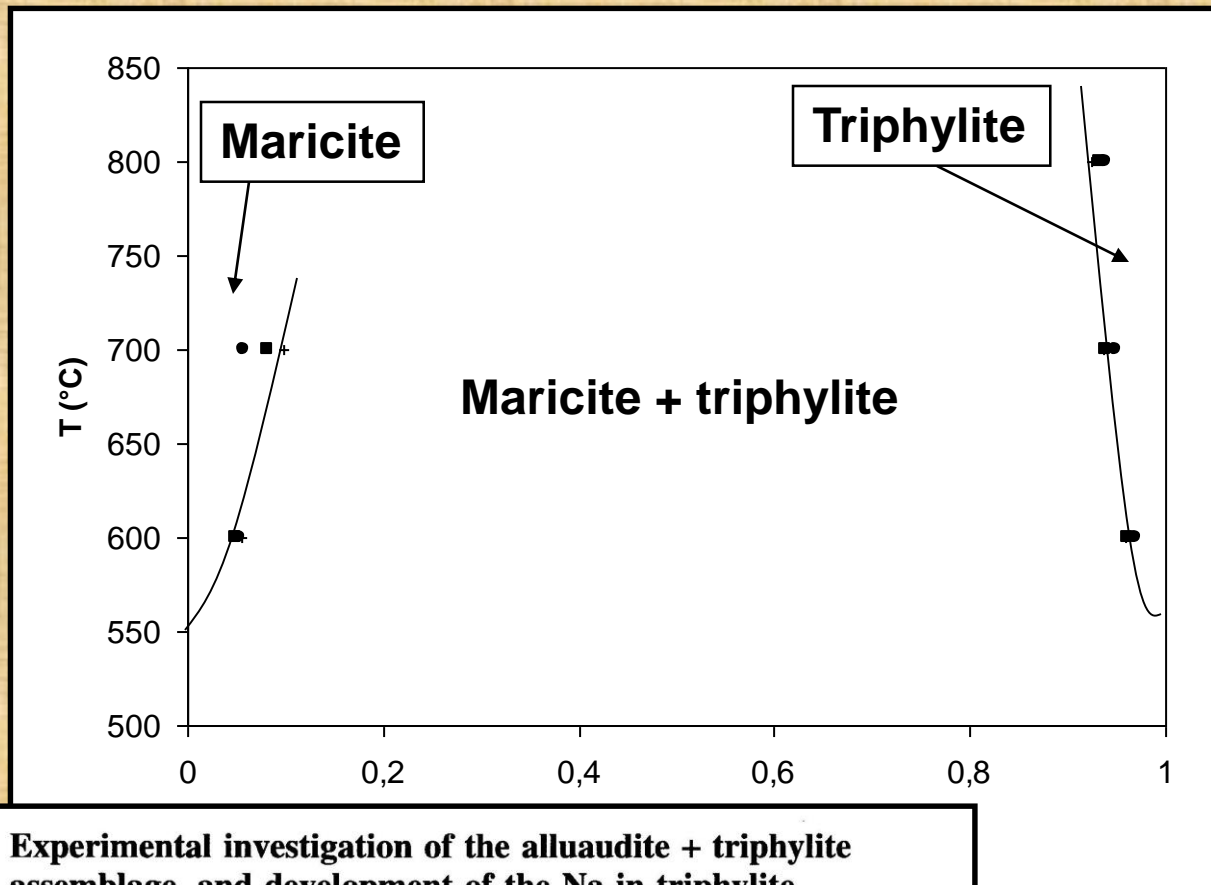
No maricite in pegmatites



Alluaudite + triphylite  
assemblage stable up to  
500-600 °C

Bu = Buranga, Rwanda  
Ha = Hagendorf-Süd, Germany  
Ki = Kibingo, Rwanda

## C. The Na-in-triphylite geothermometer



**Experimental investigation of the alluaudite + triphylite assemblage, and development of the Na-in-triphylite geothermometer: applications to natural pegmatite phosphates**

Frederic Hatert · Luisa Ottolini ·  
Peter Schmid-Beurmann

• In triphylite, Na can reach 0.08 *a.p.u.f.* at 800°C

• In maricite, Li can reach 0.10 *a.p.u.f.* at 700°C

• No partitioning below ca. 550°C

**Geothermometer!**

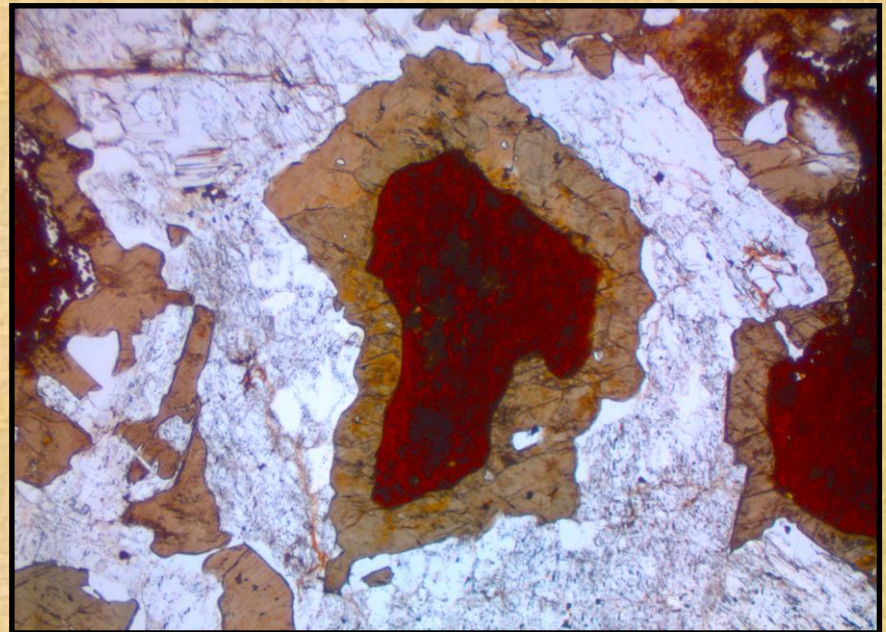


## D. Stability of wyllieites?

**Qingheite-(Fe<sup>2+</sup>), Na<sub>2</sub>Fe<sup>2+</sup>MgAl(PO<sub>4</sub>)<sub>3</sub>, a new phosphate mineral from the Sebastião Cristino pegmatite, Minas Gerais, Brazil**

FRÉDÉRIC HATERT<sup>1,\*</sup>, MAXIME BAIJOT<sup>1</sup>, SIMON PHILIPPO<sup>2</sup> and JOHAN WOUTERS<sup>3</sup>

- Reaction between albite and triphylite
- High temperature hydrothermal transformations
- Factors governing the transition from alluaudites to wyllieites not clearly understood



# Conclusions



- Iron-manganese phosphates play a crucial role in the geochemical evolution of granitic pegmatites, and are very sensitive to the variations of physico-chemical parameters
- An experimental investigation of alluaudites, and of the alluaudite + triphylite and triphylite + sarcopside assemblages, has provided tools which can be used to estimate the P, T, and oxygen fugacity conditions that prevailed in pegmatites



# Many thanks to...



- **André-Mathieu Fransolet (Liège)**
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- **Fabrice Dal Bo (Liège)**
  
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- **Pietro Vignola (Milano)**
- **Miguel Galliski, Florencia Márquez-Zavalía (Mendoza)**
- **Luisa Ottolini (Pavia)**
- **Peter Schmid-Beurmann (Münster)**