Mengxianminite $Ca_2Sn_2Mg_3Al_8[(BO_3)(BeO_4)O_6]_2$ a new borate mineral from the Xianghualing skarn, Hunan province, China

Can RAO

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Dubai, UAE April, 2016

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History of mengxianminite

- **2015 (Dec.) --- a new borate mineral, aproved by CNMNC**

INTERNATIONAL MINERALOGICAL ASSOCIATION
COMMISSION ON NEW MINERALS, NOMENCLATURE AND CLASSIFICATION

Chairman: Professor Ulf Hålenius
Department of Geosciences
Naturhistoriska Riksmuseet

Phone: +46 8 5195 4033
E-mail: ulf.halenius@nrm.se

Postal address: Box 50007, SE-10405 Stockholm, Sweden

2 December, 2015

Dear Can Rao,

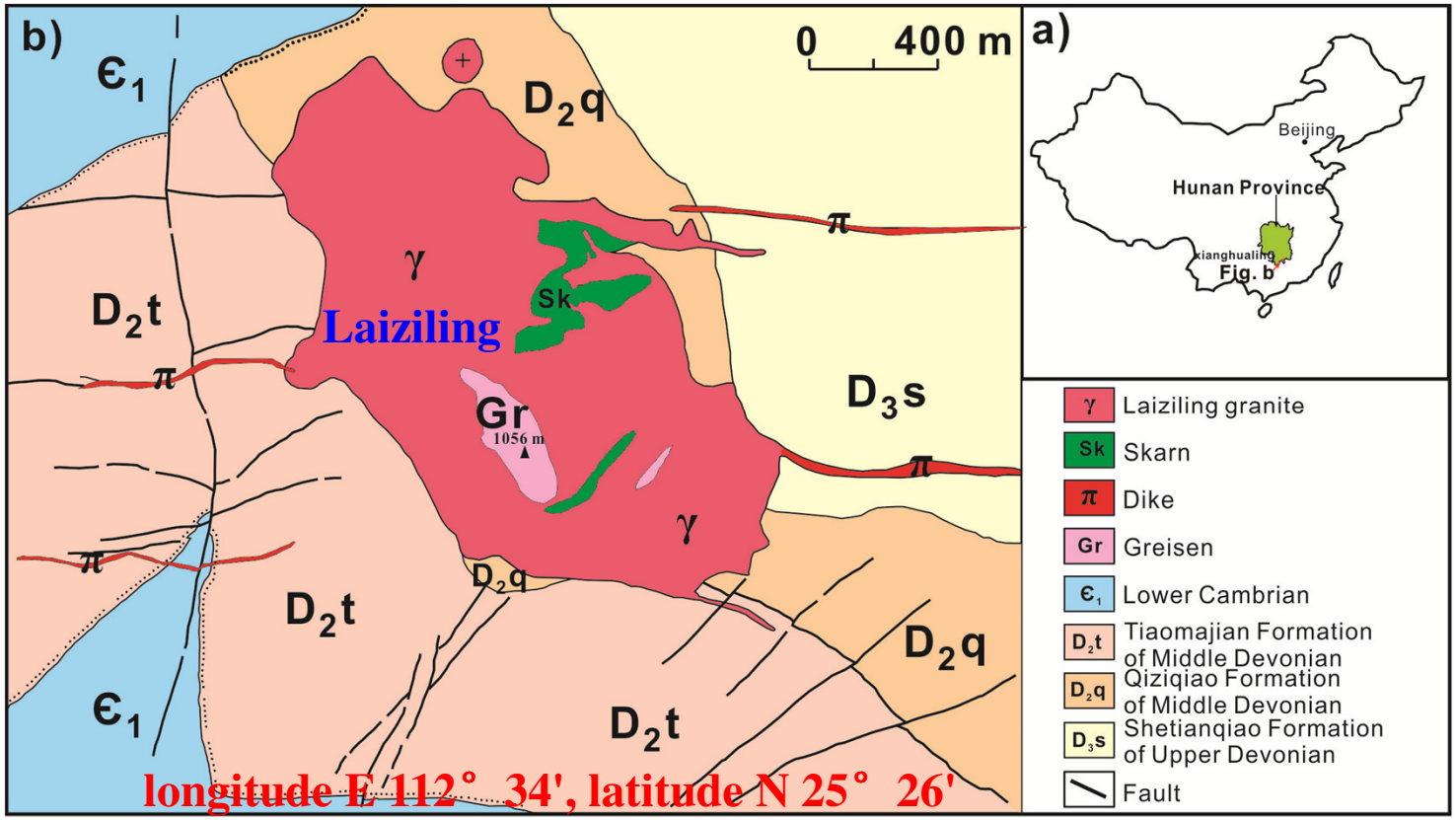
Congratulations on your new mineral, MENGXIANMINITE (2015-070)!

Outline

- Type locality
- Occurrence
- Chemical compositoin
- Crystallography
- Discussion
- Summary

Type locality

- **Xianghualing skarn**



Also the type locality of:

Hsianghualite $Ca_3Li_2Be_3(SiO_4)_3F_2$

Liberite $Li_2Be(SiO_4)$

Type locality

- **Laiziling Granite**



pegmatite zone

greisen zone

albite granite zone

leucogranite zone

protolithionite granite zone

Formation time: 155 My (Zhu et al. 2011)

Granite: Be 16ppm Sn 65ppm

Type locality

- **Contact between the granite and skarn**

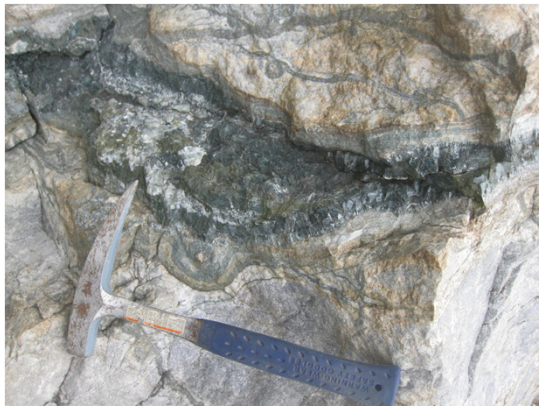


- **Keep the original shape of carbonate rocks**



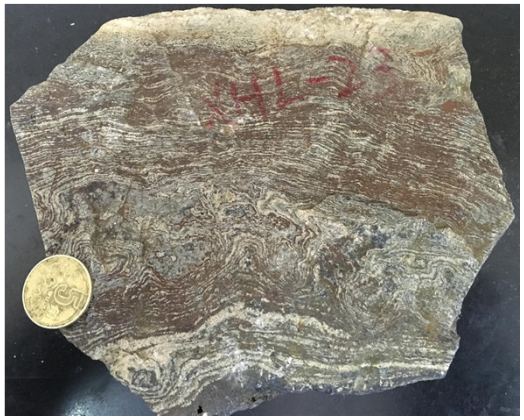
Type locality

- **Structures of the Xianghualing Skarn**

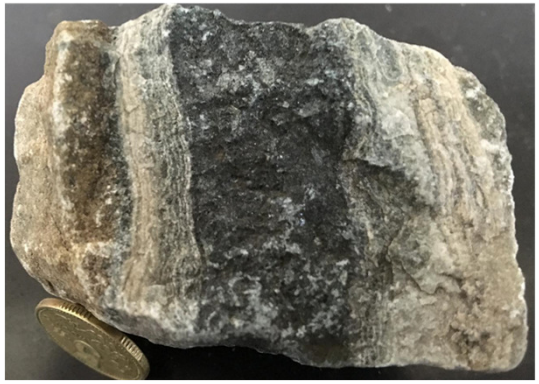


laying structure





laying and veined structure



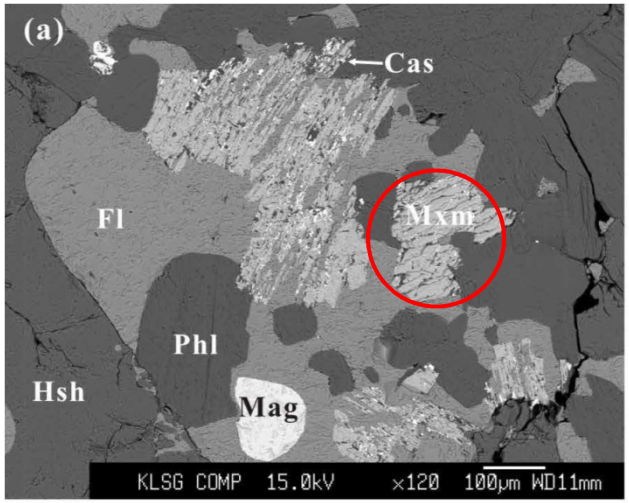


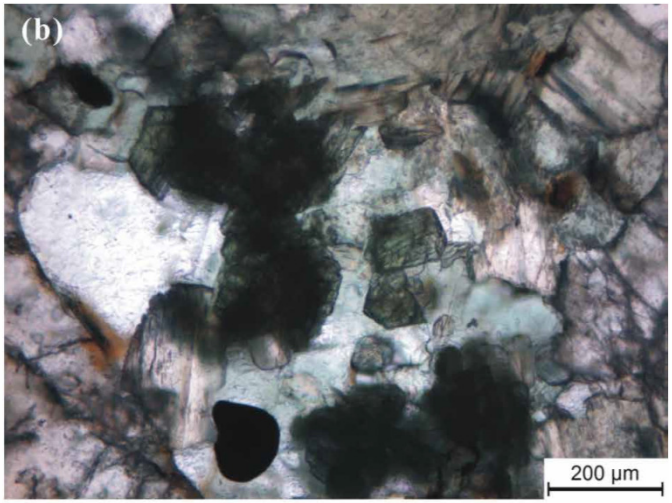


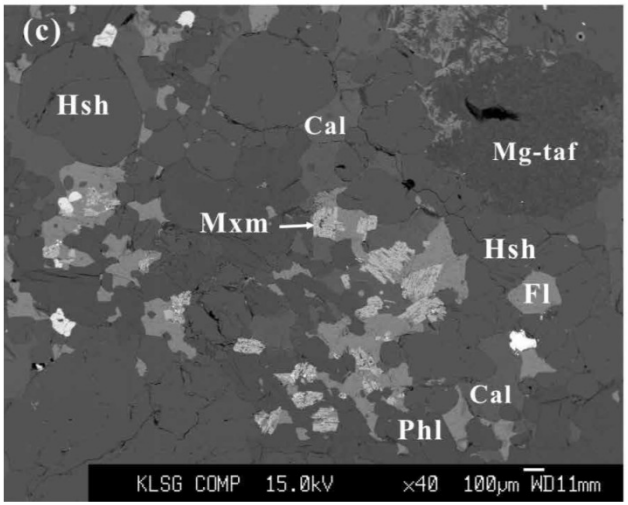
Other names: ribbon rock, stratiform skarn, rhythmically banded rock, wrigglite skarn et al.

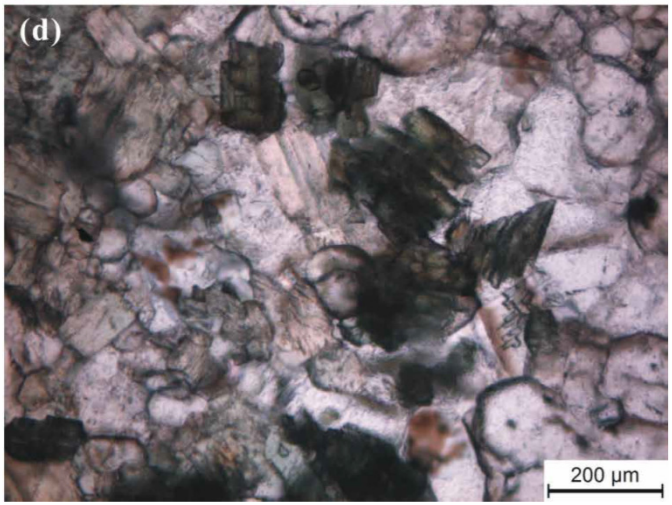
Occurrence











Subhedral-euhehral; Size: 20 to 200 μm

The associated minerals: flourite, hsianghualite, phlogopite, calcite, magnetite, and taaffeite group minerals

Chemical composition (EMPA)

	Wt.%	Range	Std. dev.		apfu
Al_2O_3	40.00	39.66-40.64	0.39	Al	8.382
SnO_2	25.96	25.46-26.54	0.44	Sn	1.841
CaO	8.56	8.11-9.18	0.43	Ca	1.629
MgO	6.57	5.86-7.75	0.74	Mg	1.740
FeO	4.83	4.58-5.24	0.23	Fe	0.718
*B_2O_3**	*6.52*	6.46-6.61	0.06	B	2.000
BeO#	*4.68*	4.63-4.76	0.04	Be	2.000
ZnO	1.81	1.21-2.24	0.38	Zn	0.237
MnO	1.23	1.09-1.42	0.13	Mn	0.185
Na_2O	1.13	0.77-1.40	0.28	Na	0.392
SiO_2	0.04	0.02-0.05	0.01	Si	0.007
K_2O	0.00	0-0.01	0.00	K	0.000
TiO_2	0.10	0.01-0.22	0.08	Ti	0.013
Total	101.42				

Empirical formula: $(Ca_{1.63},Na_{0.39})_{\Sigma 2.02}(Sn_{1.84},Zn_{0.24})_{\Sigma 2.08}$

$(Mg_{1.74},Fe_{0.72},Al_{0.38},Mn_{0.19},Ti_{0.01})_{\Sigma 3.04}Al_8[(BO_3)(BeO_4)O_6]_2$

Physical and optical properties

	Mengxianminite
cleavage	{100} perfect,{010} good
Optical	biaxial (-)
α	1.80
β	1.83
γ	1.84
density(cal.)	4.17 g/cm^3
$1 - (K_P/K_C)$	-0.036 (superior)
Fluorescent	none

Crystallography

• Pattern of Powder-XRD

$I_{obs.}$	$d_{obs.}$	$I_{calc.}$	$d_{calc.}$	*hkl*	$I_{obs.}$	$d_{obs.}$	$I_{calc.}$	$d_{calc.}$	*hkl*
-	-	74	7.604	8 0 0	100	2.375	85	2.395	14 0 2
-	-	39	4.307	7 1 1			41	2.390	6 4 0
20	4.04	41	3.998	9 1 1	-	-	55	2.330	15 3 1
17	3.63	38	3.692	11 1 1	20	2.281	11	2.280	10 4 0
35	3.00	43	3.008	16 2 0	-	-	23	2.154	14 2 2
100	2.931	78	2.902	17 1 1	15	2.071	21	2.077	16 2 2
25	2.842	46	2.858	2 0 2			10	2.065	16 4 0
		100	2.844	1 3 1	52	2.028	13	2.031	21 3 1
9	2.781	14	2.772	5 3 1	**	1.933	32	1.922	20 2 2
		22	2.762	6 0 2	15	1.859	15	1.854	4 4 2
28	2.714	16	2.706	7 3 1	35	1.807	2	1.810	9 1 3
		78	2.690	19 1 1	17	1.727	8	1.729	13 5 1
-	-	35	2.587	20 2 0			13	1.728	33 1 1
20	2.515	12	2.535	24 0 0	16	1.603	15	1.592	20 4 2
		32	2.531	11 3 1	18	1.566	71	1.570	30 2 2
29	2.475	34	2.479	0 2 2			42	1.564	30 4 0
30*	2.430	87	2.432	13 3 1	98*	1.530	18	1.534	14 6 0
-	-	60	2.408	6 2 2			10	1.531	15 3 3

* overlapping with phlogopite; ** overlapping with fluorite

(Central South University)

Crystallography

- **The measurement of single crystal strucure**

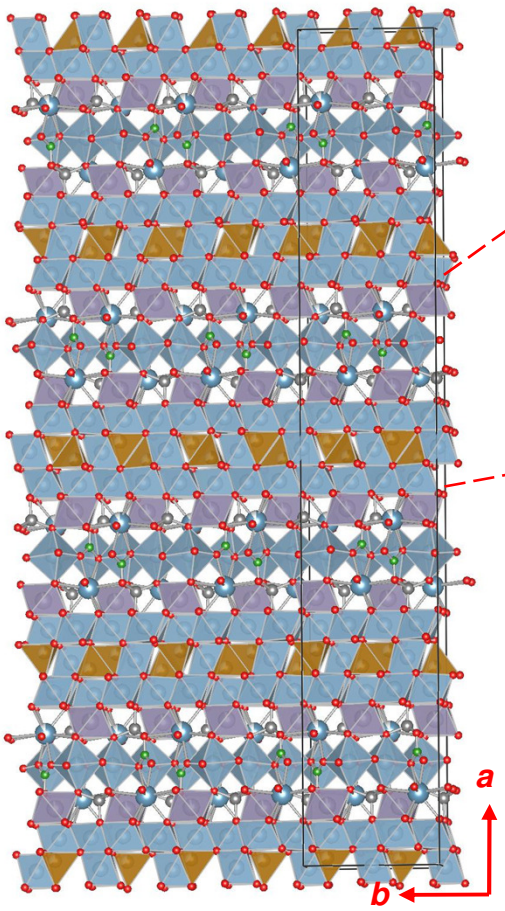
Crystallographic data and refinement parameters

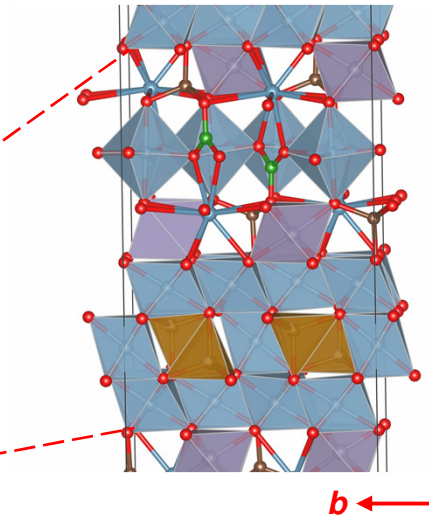
Laboratoire de Minéralogie, Université de Liège

Crystal size (mm)	0.139 x 0.108 x 0.088
Color	green
Space group	*Fdd2*
a, *b*, *c* (Å)	60.689 (3), 9.907 (1), 5.740 (1)
β (°)	90
V (Å^3)	3451.0 (3)
Z	8
D(calc) (g/cm^3)	4.170*(calc.)
$2\theta_{min}$, $2\theta_{max}$	5.36°, 57.48°
Range of indices	$-82 \le h \le 77$, $-13 \le k \le 12$, $-7 \le l \le 7$
Measured intensities	7296
Unique reflections	2062
Independent non-zero [$I > 2s(I)$] reflections	1742
μ (mm^{-1})	0.810
Refined parameters	133
R_1 [$F_0 > 2\sigma(F_0)$]	0.0467
R_1 (all)	0.0625
wR_2 (all)	0.1002
S (goodness of fit)	1.106
Max *D*/*s* in the last l.s. cycle	0.001
Max peak and hole in the final D*F* map (*e*/Å^3)	+1.09 and –0.98

Crystallography

- **Crystal structure mode**





T2 layer
O' layer
T2 layer
Module B

O layer
T1 layer
O layer
Module A

O layer: 6 AlO_6 (O)
T1 layer: 2 AlO_6 (O), 4$(Mg,Fe)O_4$ (T)
O' layer: 4 AlO_6 (O), 4 BO_3 groups
T2 layer: 2 SnO_6 (O), 2 BeO_4 (T), 2 CaO_{11}

Module A: spinel $MgAl_2O_4$

Module B: $CaSnAl(BeO_4)(BO_3)$?

Crystal structure: 4 × (module A + module B)

Crystallography

Final atomic coordinates, equivalent isotropic displacement parameters and bond valence sums

Atom	Layer	*X*	*Y*	*Z*	U_{eq}	BVS
Sn	T2	0.572539(9)	0.82974(7)	-0.6539(2)	0.00871(16)	3.76
Mg	T1	0.51026(3)	0.8332(2)	0.3372(6)	0.0096(6)	2.11
Ca	T2	0.58662(3)	0.6613(2)	-0.1488(8)	0.0169(6)	1.62
Al1	0	0.53870(4)	0.5825(3)	0.5917(13)	0.0102(5)	2.91
Al2	0	0.53869(4)	0.8324(3)	-0.1610(9)	0.0102(5)	2.91
Al3	T1	0.5	0.5	0.3366(10)	0.0105(8)	3.06
Al4	0	0.53853(4)	0.5837(3)	0.0892(12)	0.0094(6)	2.86
Al5	0’	0.62504(4)	0.4190(3)	0.0799(9)	0.0133(9)	2.61
Be	T2	0.58209(18)	0.5080(13)	0.311(2)	0.010(3)	1.86
B	0’	0.61437(15)	0.4193(11)	0.576(3)	0.012(2)	3.04
O1		0.55537(9)	0.5007(7)	0.3332(17)	0.0110(13)	1.86
O2		0.52001(9)	0.9265(7)	0.0574(14)	0.0151(17)	1.98
O3		0.59181(9)	0.4236(8)	0.5629(14)	0.0160(16)	1.93
O4		0.62724(11)	0.4761(7)	0.4044(12)	0.0178(17)	2.09
O5		0.55508(9)	0.7464(6)	0.0738(16)	0.0121(14)	1.94
O6		0.55511(9)	0.5070(7)	-0.1673(18)	0.0118(14)	1.94

Anisotropic displacement parameters for mengxianminite(Å^2)

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
Sn	0.0089(2)	0.0082(2)	0.0090(2)	0.003(3)	-0.0001(4)	0.0002(3)
Mg	0.0104(9)	0.0083(9)	0.010(1)	0.0006(9)	0.001(1)	-0.0008(8)
Ca	0.0107(9)	0.017(1)	0.023(1)	-0.002(1)	-0.000(2)	-0.0008(9)
Al1	0.009(1)	0.010(1)	0.011(1)	-0.003(2)	0.002(3)	-0.000(1)
Al2	0.010(1)	0.010(1)	0.011(1)	-0.001(1)	-0.001(2)	-0.001(1)
Al3	0.010(1)	0.012(2)	0.009(2)	0	0	0.000(2)
Al4	0.009(1)	0.008(1)	0.011(1)	-0.003(2)	-0.001(1)	0.000(1)
Al5	0.012(1)	0.016(1)	0.013(1)	0.002(1)	-0.002(2)	-0.000(1)

Crystallography

Bond distances (Å)

Sn-O3	2.208(8)	Al1-O1	1.970(10)	Al2-O1	1.951(7)
Sn-O9	2.025(9)	Al1-O2	1.927(7)	Al2-O2	1.930(8)
Sn-O6	2.052(6)	Al1-O9	1.884(7)	Al2-O9	1.883(10)
Sn-O5	2.061(8)	Al1-O12	1.945(12)	Al2-O13	1.924(7)
Sn-O10	2.056(9)	Al1-O13	1.930(12)	Al2-O5	1.880(9)
Sn-O11	2.042(7)	Al1-O6	1.861(10)	Al2-O7	1.943(9)
<Sn-O>	2.079	<Al-O>	1.920	<Al-O>	1.919
Mg-O2	1.945(8)	Al3-O2 ×2	1.900(8)	Al4-O1	1.918(10)
Mg-O12	1.943(6)	Al3-O7 ×2	1.909(9)	Al4-O12	1.924(11)
Mg-O13	1.963(5)	Al3-O12 ×2	1.893(6)	Al4-O13	1.935(12)
Mg-O7	1.931(10)	<Al-O>	1.901	Al4-O6	1.938(10)

Be

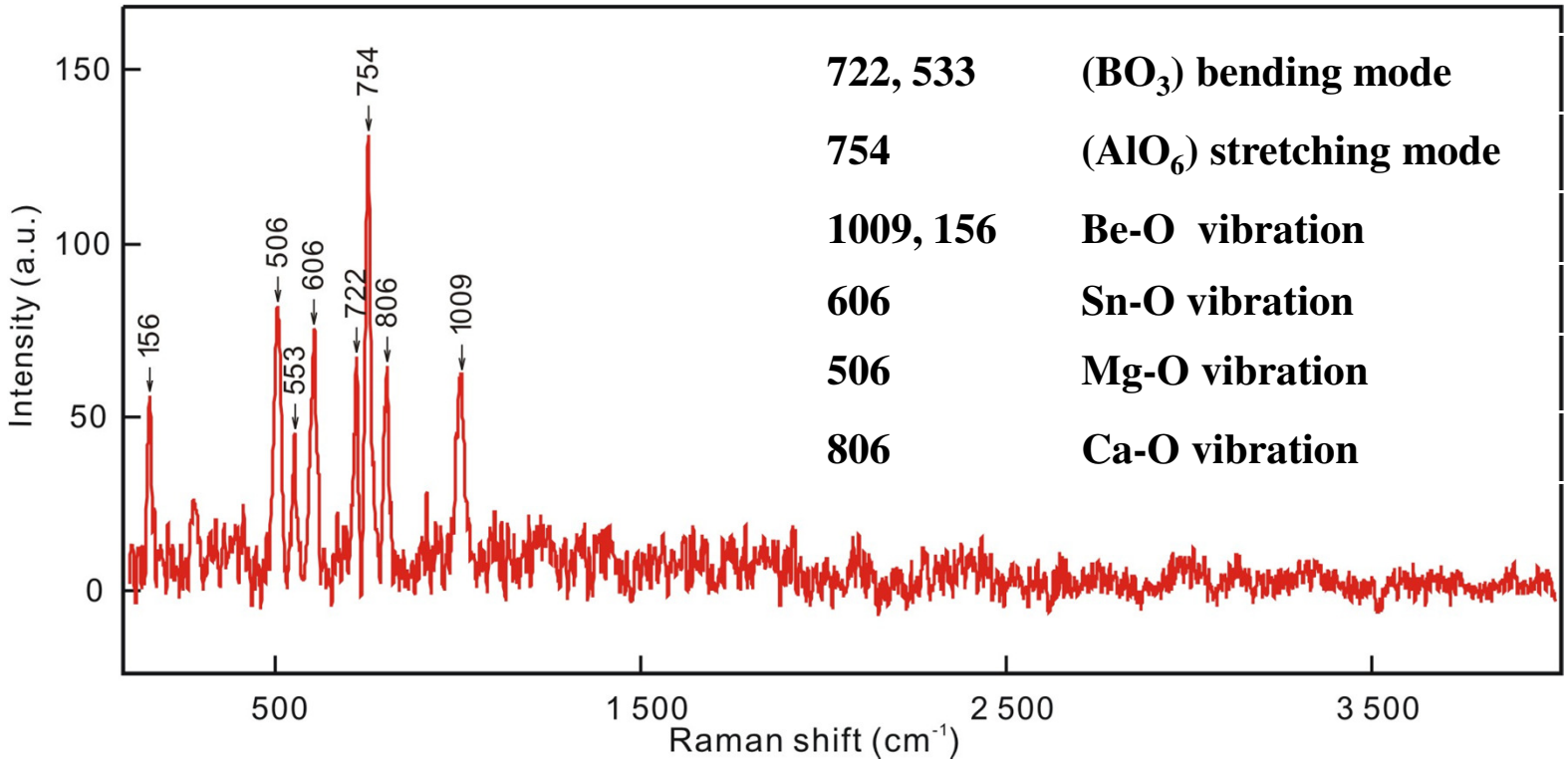
B

Discussion

- Raman spectrum
- Infrared spectrum
- Comparation with "mengxianminite"
- Origin
- Implications

Discussion

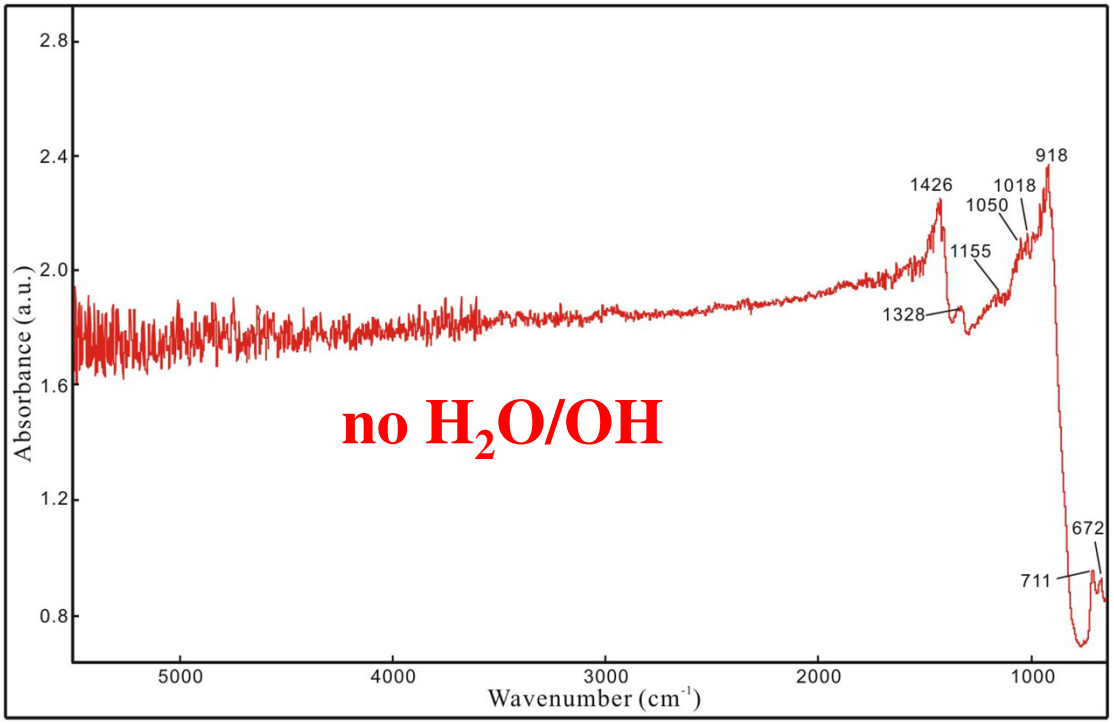
- **Raman spectrum**



722, 533	(BO_3) bending mode
754	(AlO_6) stretching mode
1009, 156	Be-O vibration
606	Sn-O vibration
506	Mg-O vibration
806	Ca-O vibration

Discussion

- **Infrared spectrum**



1426, 1328, 1155, 1050, 918	**(BO_3) stretching mode**
672	**(AlO_6) bending mode**
711	**Be-O vibration**

Discussion

- **Comparation with "mengxianminite"**

Element	Mengxianminite						"Mengxianminite" Huang et al. 1988
	1	2	3	4	5	6	
Al_2O_3 (wt%)	40.64	40.10	39.66	39.69	39.72	40.18	43.04
SnO_2	25.46	26.17	26.34	25.60	26.54	25.67	29.89
CaO	8.33	8.26	8.11	8.97	8.49	9.18	7.84
MgO	6.08	5.86	6.05	7.16	6.51	7.75	5.27
FeO	4.72	4.71	4.78	5.24	4.93	4.58	6.49
ZnO	2.24	1.84	2.17	1.21	1.81	1.57	3.39
MnO	1.33	1.18	1.42	1.11	1.24	1.09	1.18
Na_2O	1.33	1.40	1.24	0.77	1.30	0.78	1.90
SiO_2	0.03	0.05	0.02	0.05	0.05	0.04	0.26
K_2O	0.00	0.00	0.00	0.01	0.00	0.00	-
TiO_2	0.01	0.10	0.07	0.17	0.04	0.22	0
B_2O_3*	6.52	6.47	6.45	6.52	6.52	6.62	
BeO**	4.69	4.65	4.64	4.68	4.68	4.76	
Total	101.38	100.78	100.95	101.18	101.81	102.43	99.26

Discussion

- **Comparation with "mengxianminite"**

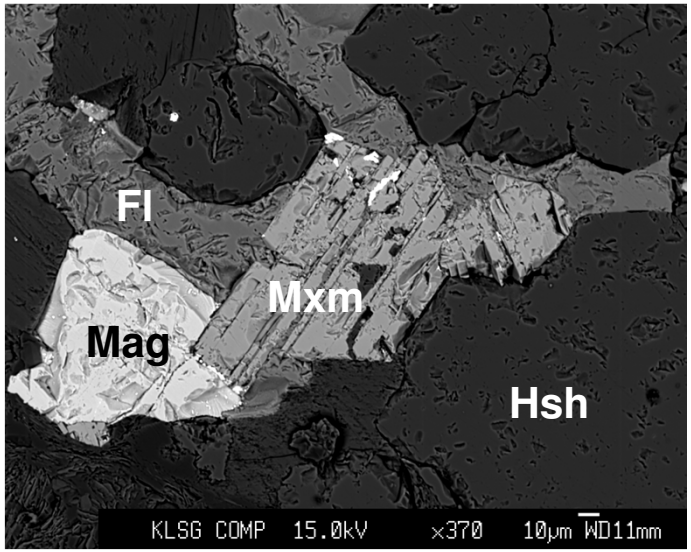
	Mengxianminite	"Mengxianminite" (Huang *et al.*, 1988)
Color	Green	Green
Structural formula	$Ca_2Sn_2Mg_3Al_8[BO_3\|BeO_4\|O_6]_2$	$(Ca,Na)_4(Mg, Fe,Zn)_5Sn_4Al_{16}O_{41}$
Space group	*F dd*2	*C* 2/*m* or *C* 2 or *C m*,,
a	60.689 (3) Å	9.903 Å
b	9.907 (1) Å	5.681 Å
c	5.740 (1) Å	30.43 Å
	α = β = γ = 90°	β = 93°
V	3451.0 (3) Å^3	1709.613 Å^3
Z	8	2
Density	4.170* g/cm^3 (calc)	3.728 g/cm^3
Biaxial	α = 1.80; β = 1.83; γ = 1.84	α = 1.791; β = 1.790; γ = 1.770
In plane polarized light	Green	Green
Dispersion	None	None
2*V*	60°	60°

The same locality ➡ The same phase

Discussion

- **Origin**

(1) F-rich condition, at late stages of the Xianghualing skarn, hydrothermal origin



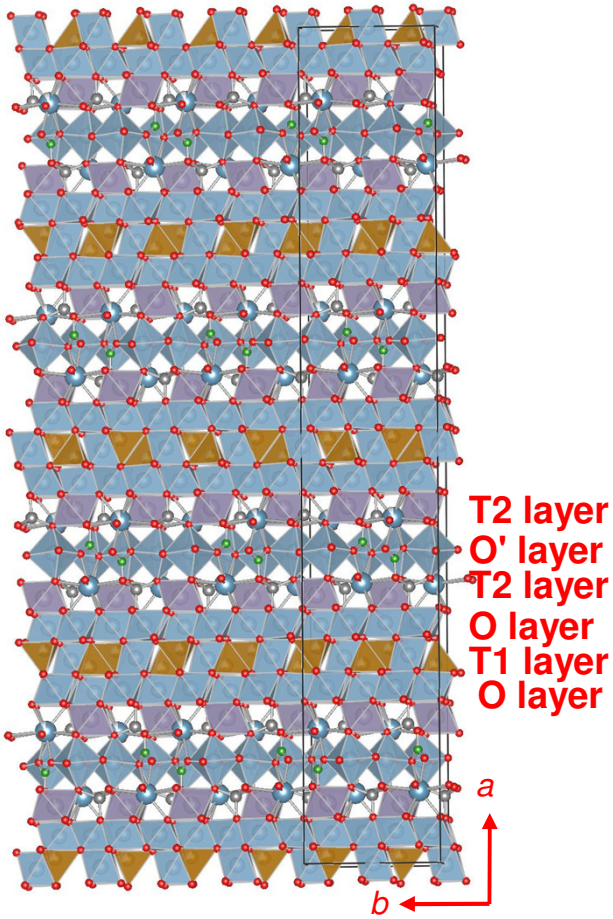
(2) Laiziling granite (with 65 ppm Sn and 16 ppm Be) provide Sn and Be

(3) The wall-rock suit (Tiaomajian formation with 284 ppm B) provide B

(4) Other Sn- and/or Be/B- bearing minerals: nigerite group minerals, cassiterite, taaffeite group minerals, chrysoberyl, hambergite, bergslagite, et al.

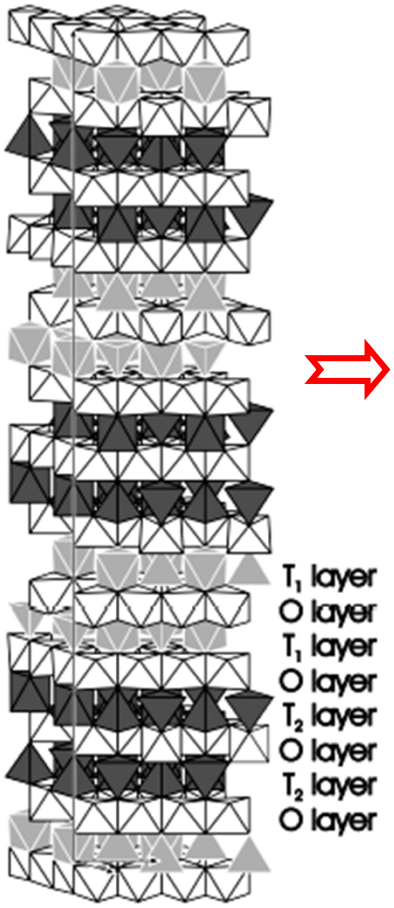
Discussion

- **Implication**



mengxianminite

4 × (O-T1-O-T2-O'-T2)



högbomite-24R

3 × (T1-O-T1-O-T2-O-T2-O)

similar to nigerite and högbomite group minerals

Hejuy C. & Armbruster T., 2002

Discussion

- **Implication**

Polysomatic series

2N1S*, *2N2S*, *2N3S*, 12*H*, 14*T*, 16*H*, 18*R*, 24*R*, 30*R*, 36*R

Nigerite group **Högbomite group**

spinel(Mg,Fe) nolanite (Sn) spinel (Mg,Fe) nolanite(Ti)

(Armbruster T., 2002)

Mineral	Chemical formula	Space group
?	$MgAl_2O_4 + 2\ CaSnAl(BeO_4)(BO_3) = Ca_2Sn_2MgAl_4[(BO_3)(BeO_4)O_2]_2$	?
?	$2MgAl_2O_4 + 2\ CaSnAl(BeO_4)(BO_3) = CaSnMgAl_3(BO_3)(BeO_4)O_4$	?
mengxianminite	$3\ MgAl_2O_4 + 2\ CaSnAl(BeO_4)(BO_3) = Ca_2Sn_2Mg_3Al_8[(BO_3)(BeO_4)O_6]_2$	F*dd2*
⋮	⋮	⋮

(Fe,Mg)/(Ti,Sn) bearing series? **$CaSnAl(BeO_4)(BO_3)$ a new polysome?**

Summary

- **One new borate mineral was found in the Xianghualing skarn, South of China**

- **Mengianminite is the first borate with both Sn and Be in nature, and with new structure type**

- **It formed under F-rich condition and at late stages of the skarn**

- **The Fe/Ti - end member of mengxianminite and other polysomatic series will be found in the future**


Your comment is
highly appreciated!
Thanks!

Mengxianminite $Ca_2Sn_2Mg_3Al_8[(BO_3)(BeO_4)O_6]_2$ a new borate mineral from the Xianghualing skarn, Hunan province, China

Can RAO

School of Earth Sciences, Zhejiang University
Hangzhou, 310027, China

Dubai, UAE April, 2016

Email:canrao@zju.edu.cn