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# Evidence of Tethyan continental break-up and Alpine collision in the Argentera-Mercantour Massif, Western Alps

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1 **TITLE**

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3 **Evidence of Tethyan continental break-up and Alpine collision in the Argentera-Mercantour**

4 **Massif, Western Alps**

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## Introduction

Morbid obesity has recently reached epidemic proportions worldwide<sup>1</sup> and bariatric surgery (BS) has been shown to be the only therapeutic means leading to long-term sustained weight loss<sup>2</sup>. Furthermore, obesity is associated with non-alcoholic fatty liver disease (NAFLD) that may proceed to non-alcoholic steatohepatitis (NASH), cirrhosis with end-stage liver disease and/or hepatocellular carcinoma (HCC)<sup>3</sup>. In parallel to the exponential increase of BS, liver transplant surgeons may be confronted with patients with such background<sup>4</sup>. While biliopancreatic diversion with duodenal switch (BPD-DS) is an uncommon bariatric procedure, for its technical difficulties and increased risk of postoperative complications, it may still be possible to come across for transplant surgeons. In this paper, we report the case of a patient with a previous history of BPD-DS who became a candidate to liver transplantation (LT) because of HCC complicating hepatitis C related liver cirrhosis.

## Case Report

A 51-year-old Caucasian man was referred to our department for a chronic entero-cutaneous fistula complicating a BPD-DS for morbid obesity done 6 months earlier in another center. His past medical history included blood hypertension, dyslipidemia, type 2 diabetes, hypothyroidism, hepatitis C and a NAFLD related liver cirrhosis. Hepatitis C (genotype 1b) was first detected in the '90s and treated by Interferon, while cirrhosis was diagnosed in 2000. In 2006, the patient underwent a transjugular intrahepatic portosystemic shunt (TIPS) for portal hypertension. In 2010 he underwent a laparoscopic sleeve gastrectomy (SG) for morbid obesity (weight: 160 kg; height: 183 cm; BMI: 47.7 kg/m<sup>2</sup>). A systematic second step DS was done at one year (weight: 120 kg; height: 183 cm; BMI: 35.8 kg/m<sup>2</sup>) by the same surgeon. The postoperative course was complicated by a leak at the duodeno-ileostomy, which required surgical treatment with laparotomy. In 2012, the patient was admitted in our department for chronic leak with a BMI of 24.8 kg/m<sup>2</sup> and underwent surgical revision of the duodeno-ileostomy that was not effective as the chronic leak recurred (Fig.1). In 2013, two HCCs, in segment III and VII were found on follow-up imaging (Fig.2). No extra-hepatic metastases were present. The patient met the Milan criteria and was enlisted for LT. Radio-frequency ablation (RFA) was performed while awaiting for LT. When added on the transplant list, the patient had no nutrient

deficiencies and had an albumin level of 38.5 g/L (normal range 35.0-52.0), a vitamin B9 level of 8.3 ng/mL (normal range 3.0-18.0) and a vitamin B12 level of 323 pg/mL (normal range 200-1000). The measurement of psoas area at L3 showed slight sarcopenia with the right area of 1392 mm<sup>2</sup> and the left area of 1282 mm<sup>2</sup> (Fig.3)<sup>5</sup>. He finally underwent LT in September 2014 (MELD = 12) with a duct-to-duct biliary reconstruction. At the time of LT, the enterocutaneous fistula tract was resected and the anastomosis fashioned again on fresh tissues. The postoperative period was uneventful and the patient was discharged on day 21. Pathology of the native liver revealed liver cirrhosis, 50% microscopic steatosis, two entirely necrotic HCCs of both 15 mm and a third one of 16 mm. The patient was given calcium, iron, and vitamin supplementation along with immunosuppressive treatment (tacrolimus (8–12 ng/mL up to month 4, then 6–10 ng/mL during months 4–12, then 4–8 ng/mL after 12 months), mycophenolate mofetil and prednisone). To date, the patient is currently alive and disease-free at 9 years from his first BS and 5 years from LT (weight: 75.5 kg; height: 183 cm; BMI: 22.5 kg/m<sup>2</sup>). His most recent nutritional state presents an albumin level of 32.6 g/L and a sarcopenic state with a right psoas area of 986.6 mm<sup>2</sup> and a left area of 829.1 mm<sup>2</sup> (Fig.3).

## Discussion

In 2016, procedures performed for morbid obesity reached the 200.000 level in the US and this rate will probably continue to increase as obesity is on the rise<sup>6,7</sup>. BS has been proven to be the most effective and sustainable treatment for obesity and its comorbidities such as hypertension, diabetes, obstructive sleep apnea and dyslipidaemia<sup>2</sup>. On the same slope, NAFLD concerns more than 30 % of Americans. Indeed, NASH has become the second indication for LT in the US<sup>8</sup>. Although there is some evidence that BS may improve NASH lesions<sup>2,9</sup>, end-stage liver disease and/or HCC may still occur. Given that, it should be considered that more and more LT will be done in patients with history of BS because of the wide diffusion of the latter. Whether obesity is a relative contraindication for LT, due to the risk of postoperative morbidity and the reduction of long-term survival, is still a matter of debate<sup>10,11</sup>. However, as NAFLD is becoming the main indication for LT, the management of obesity treatment and LT is critical and the impact of prior BS on LT needs more clarity.

55 Idriss *et al* studied the impact of prior BS on candidacy for LT and found an increased risk of death on the waiting list and a higher rate of delisting in patients with Roux-en-Y Gastric Bypass (RYGB)<sup>12</sup>. Malabsorptive mechanisms involved in RYGB might induce more important malnutrition and/or a sarcopenic state, which can contribute to worse outcomes while being on the waiting list and after LT patients. Indeed, the patient herein presented showed before LT psoas muscle area slightly below the range accepted to define the sarcopenic state<sup>5</sup>. Two years after LT sarcopenia worsened as the psoas  
60 muscle area decreased of approximately 30% on CT scan. Indeed, it is well known that proteic malnutrition is a complication of biliopancreatic diversions techniques including the DS.

The unavoidable worsening of sarcopenia may be explained by the malabsorption due to BPD-DS in addition to the surgical stress linked to LT as well as the following immunosuppressive therapy<sup>13</sup>. Probably, the patient could have taken advantage of a rehabilitation programme before LT. As a  
65 matter of fact, evidence for the benefits of nutrition intervention associated with resistance exercise in improving skeletal muscle strength and mass is growing. Healthier dietary patterns, such as adequate intake of protein, vitamin D, antioxidants and long-chain polyunsaturated fatty acids seem to benefit on muscle mass and function<sup>14</sup>. Anyway, this shortcoming could serve as a future suggestion to consider the possible benefits of nutritional supplementation in patients with sarcopenia before a  
70 demanding surgical intervention such as LT.

However, most patients with a history of BS listed for LT have currently a SG<sup>2</sup>. Indeed, SG is considered by most the procedure of choice in patients with liver cirrhosis that are or may become candidates to LT<sup>15</sup>. Restrictive procedures have less protein malnutrition and micronutrient deficiencies than malabsorptive procedures avoiding any limitations linked to the intestinal bypass,  
75 and that is why it might be a better choice before LT. Moreover, Safwan *et al* studied 11 patients that had previous BS and stressed that, in case of RYGB and BPD-DS, endoscopic access to the biliary tree in case of biliary complications, that were as high as 27% in his series, is often impossible<sup>16</sup>. In our patient, a duct-to-duct reconstruction was done but no postoperative complication occurred.

After a bariatric procedure, a rare but authentic complication to BS remains the possibility of acute or  
80 chronic liver failure, even more after BPD-DS, mainly due to bacterial overgrowth and protein

deficiency<sup>17,18</sup>. Nonetheless, this complication stays rare with much fewer liver-damages after BPD-DS than after jejunioileal bypass (JIB). In a recent review of the literature, we found that BPD with or without DS may lead to acute liver failure although only 17 cases were found over the last 18 years<sup>17</sup>. After a BPD-DS, Geertz *et al* recommend following these patients strictly with routine monitoring of  
85 liver tests and adequate supplementation<sup>18</sup>. The possibility to lengthen the common channel should be considered at the time of LT or later if malabsorption impairs postoperative course. In the case herein reported, we chose not to alter the bariatric anatomy as the patient underwent LT for HCC and not because of BS related LF. Interestingly, the short common channel did not affect the immunosuppressive treatment. Indeed, Tacrolimus is also absorbed in the colon<sup>19</sup>.

90 This case report indicates that LT can be safely performed in the setting of a BPD-DS. Indeed, while the patient fulfilled the Milan criteria, known to be associated with optimal survival results after LT, one might have been tempted to decline LT favouring alternative therapeutic options because of the theoretical risk of complications linked to the BPD with DS. Excellent results were obtained in our patient because he was on a regular nutritional follow-up after LT, had compensated liver cirrhosis,  
95 and was managed by a team experienced in both LT and BS<sup>20</sup>. Close monitoring of vitamins, minerals and nutritional status is mandatory in the setting of patients with a history of BS undergoing LT in parallel to the level of immunosuppressive drugs.

## Conclusion

BS is expanding its range of activity over the years and takes on more and more role in the scene of  
100 transplantology. To our knowledge, this is the first case of BPD-DS followed by LT for HCC. While the malabsorptive component of BS adds risk, it should not be a reason for liver surgeons to retreat, particularly if associated with a well-planned physical and nutritional rehabilitation.

## Acknowledgements

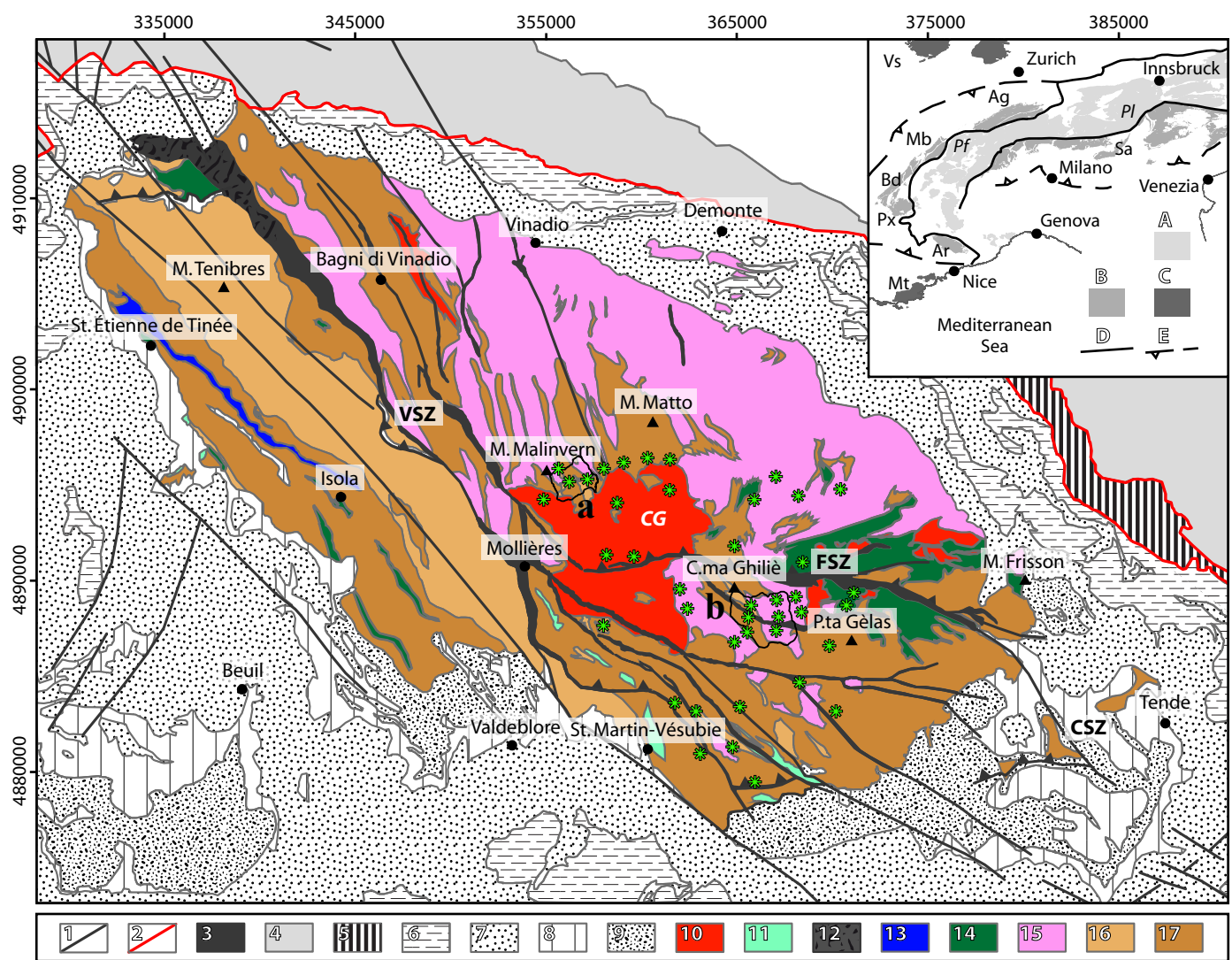
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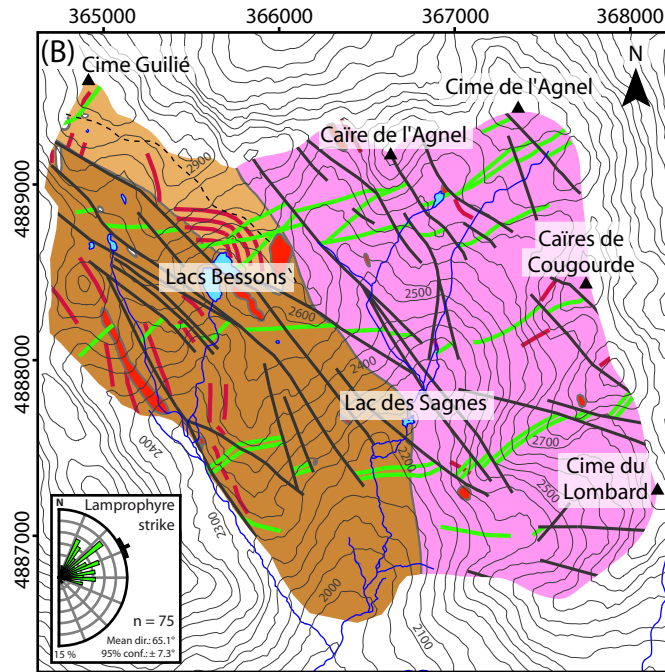
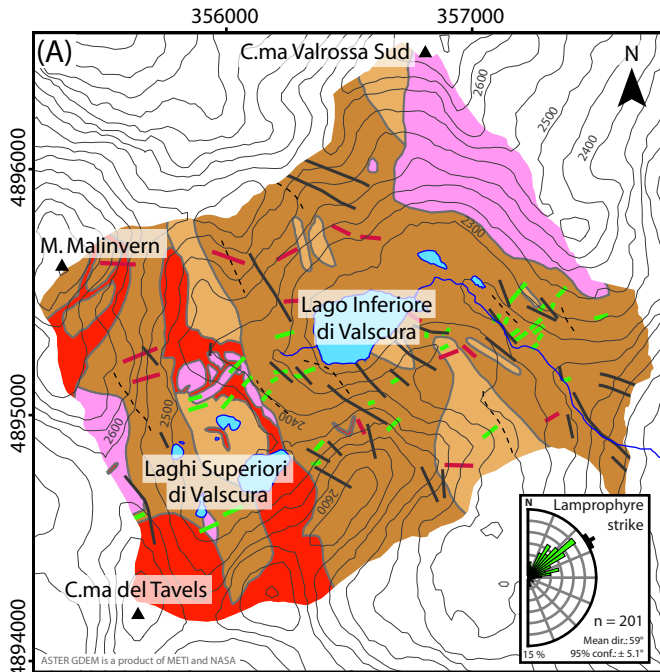
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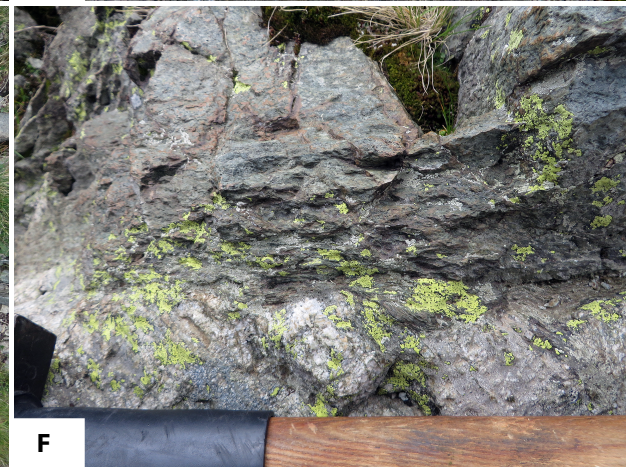
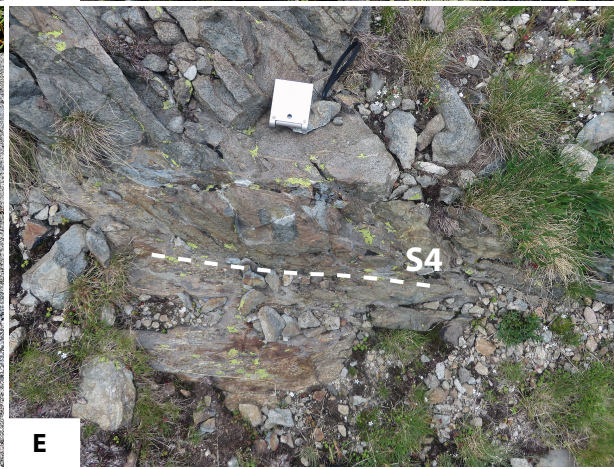
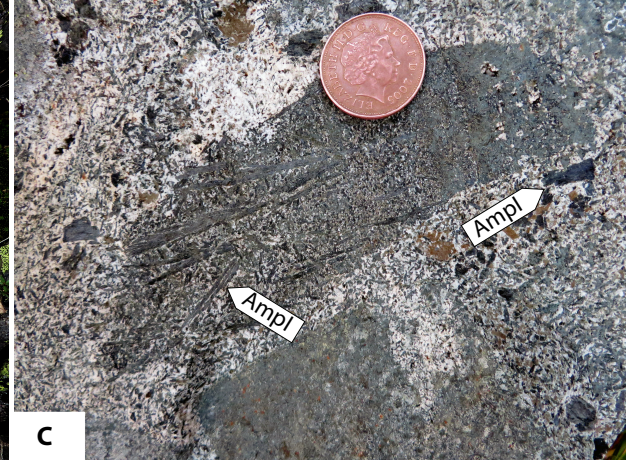
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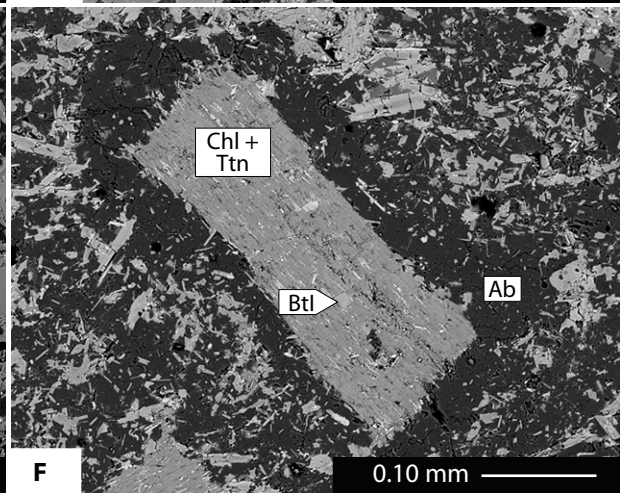
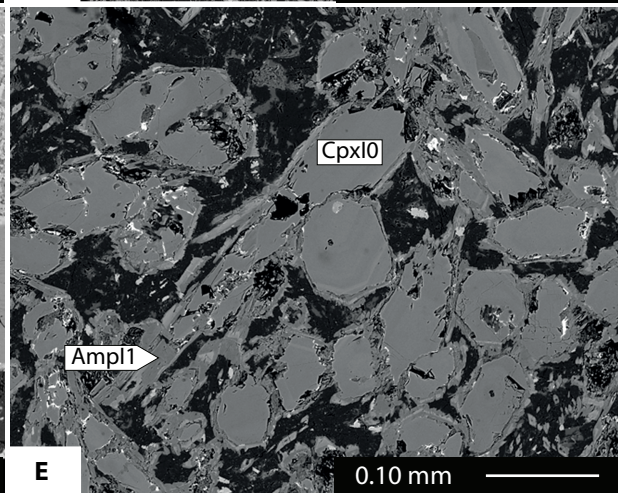
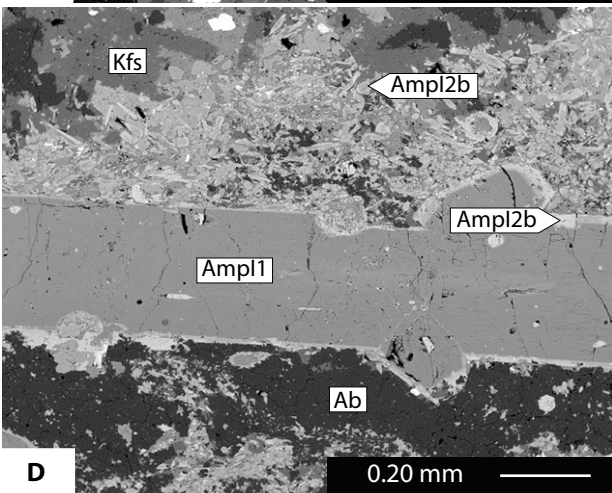
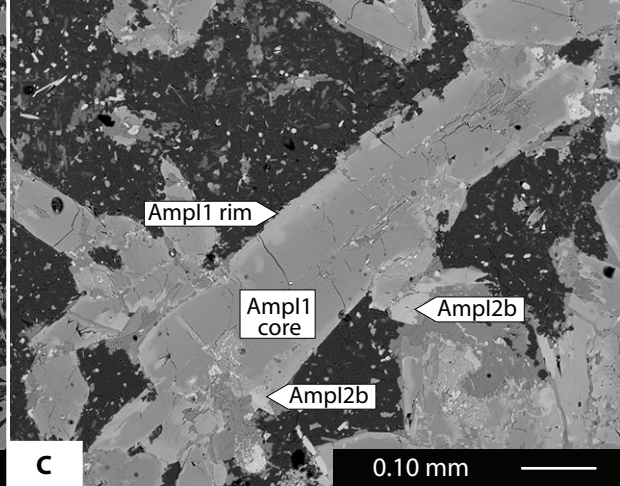
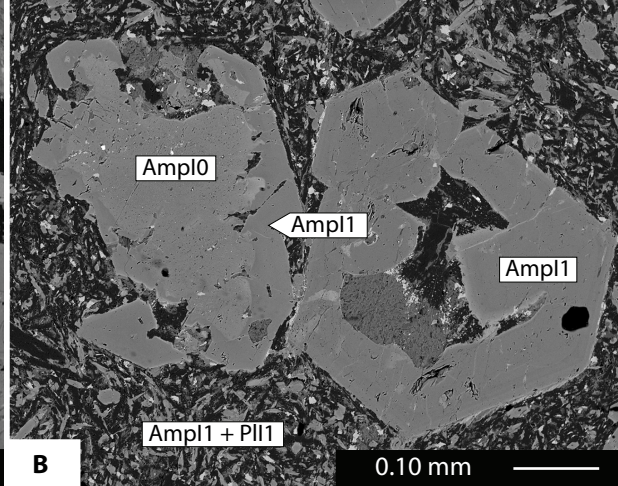
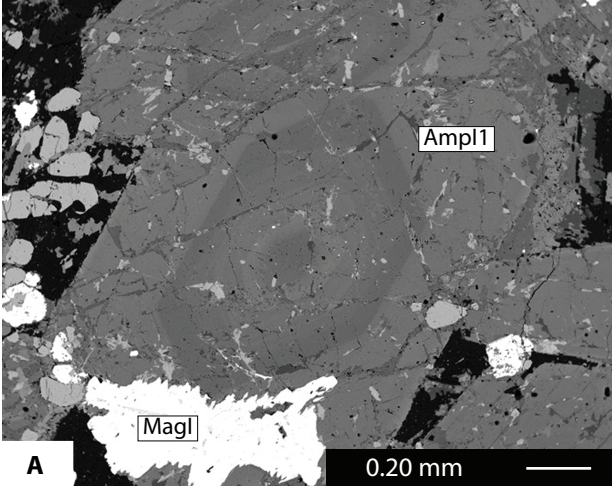
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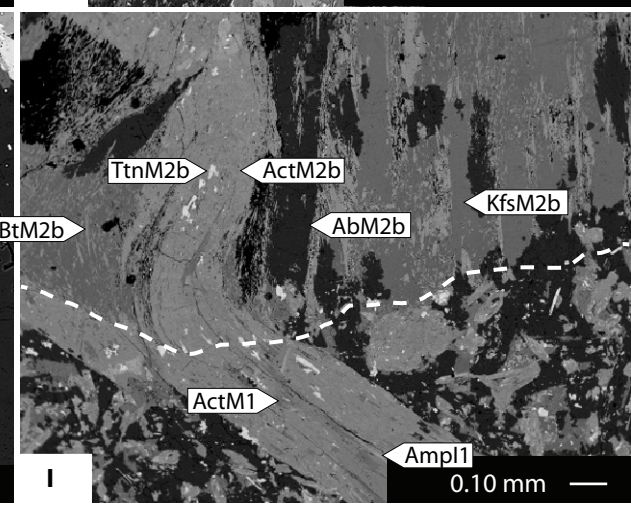
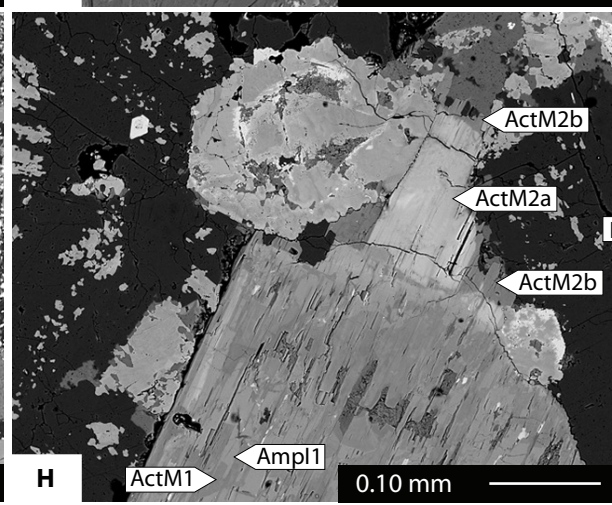
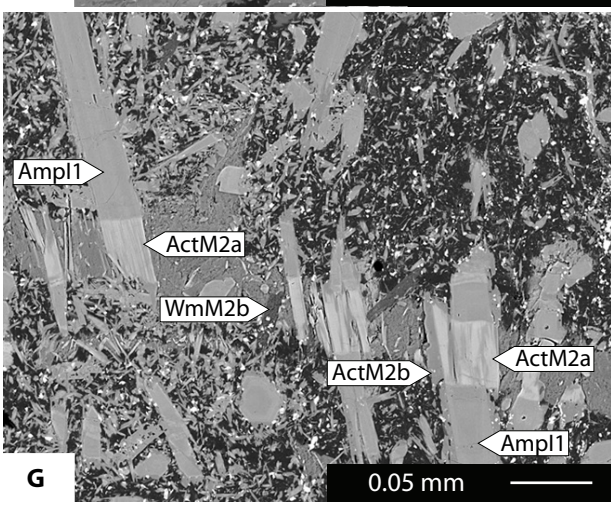
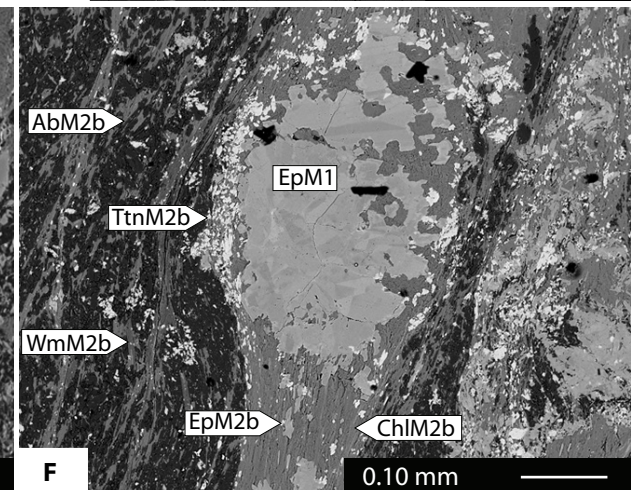
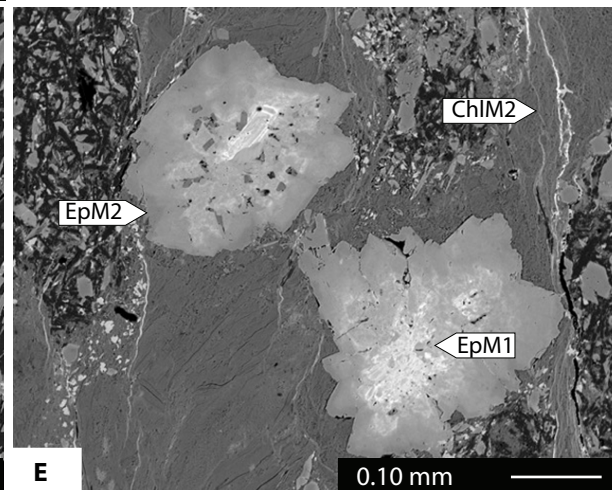
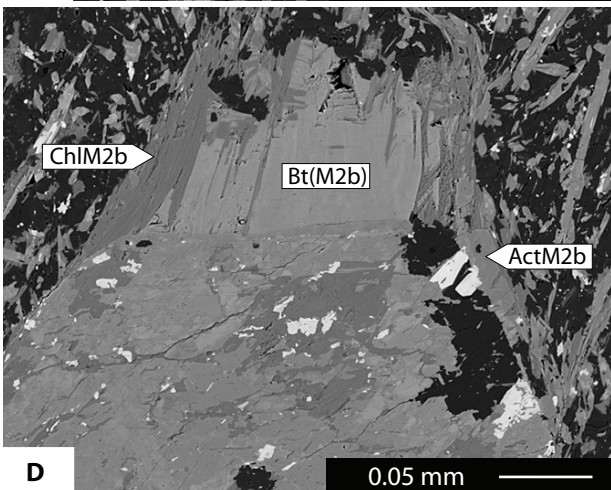
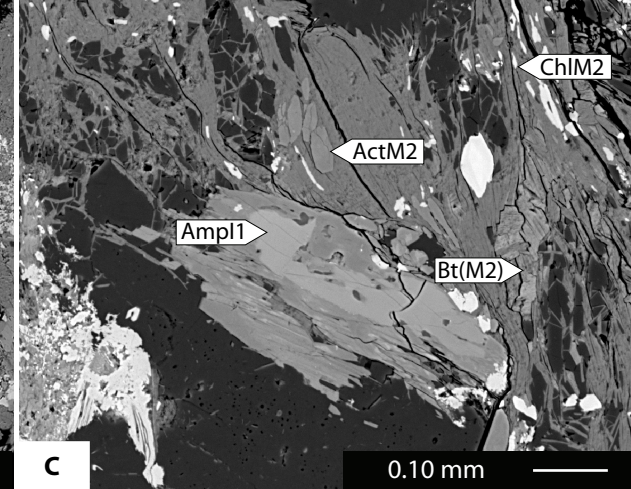
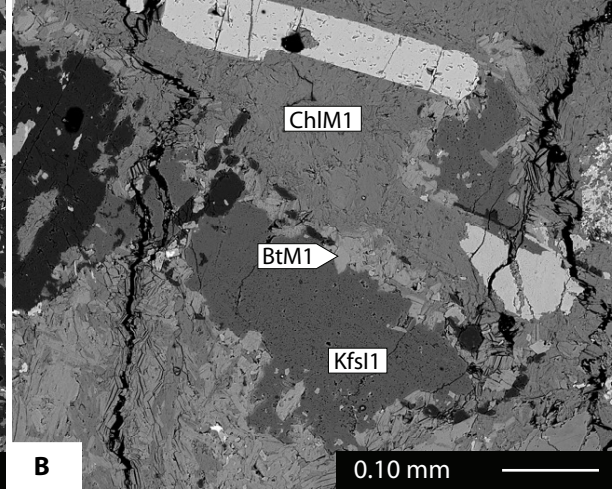
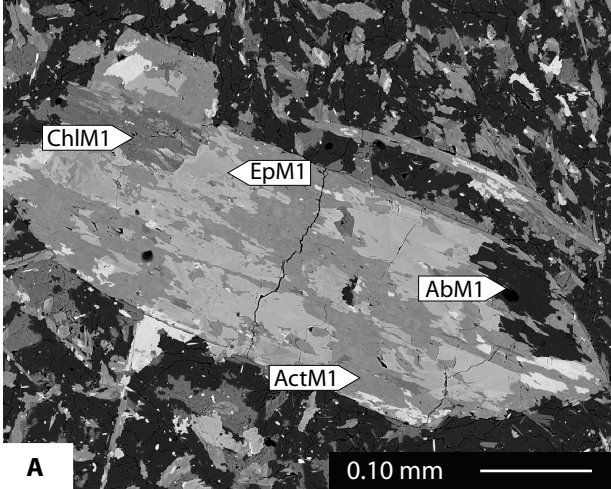


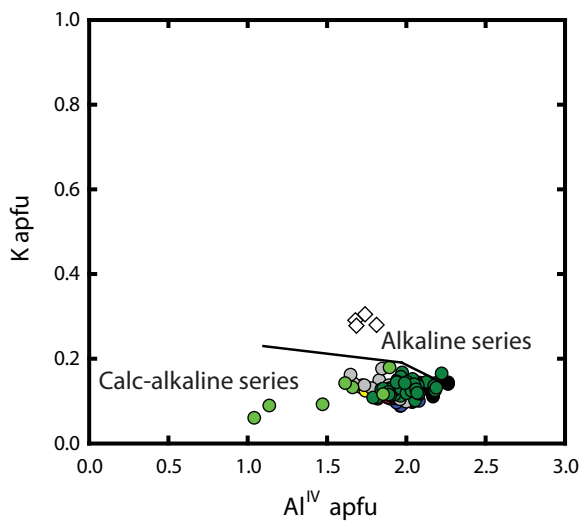
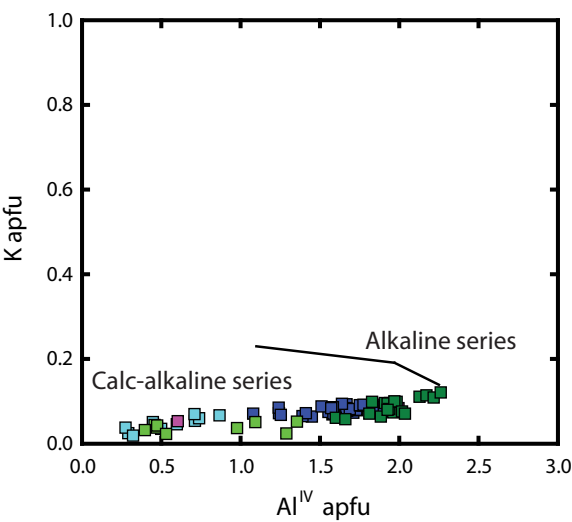
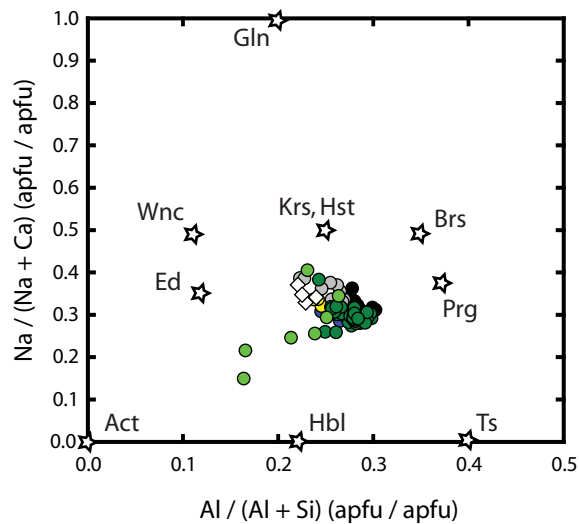
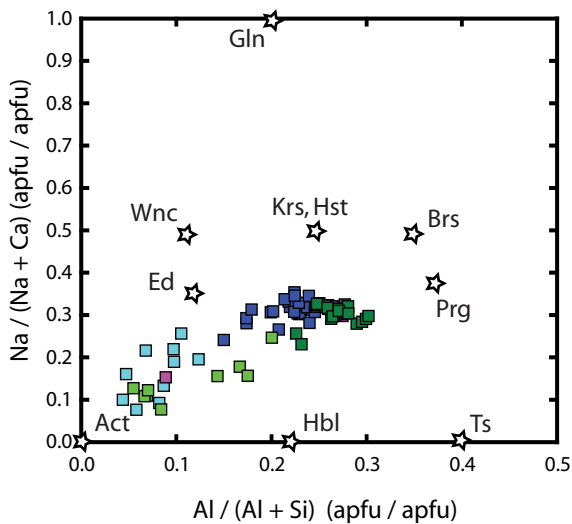
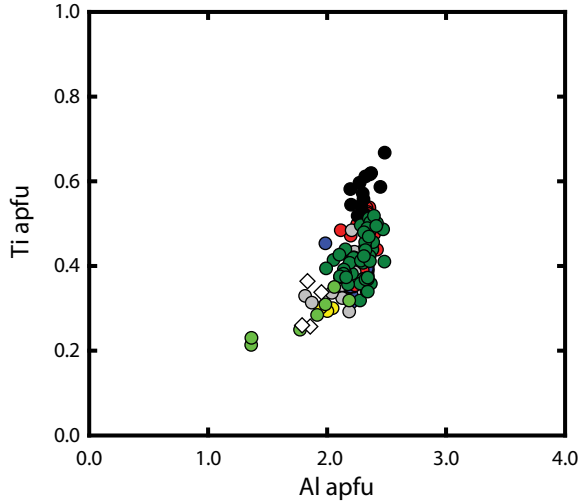
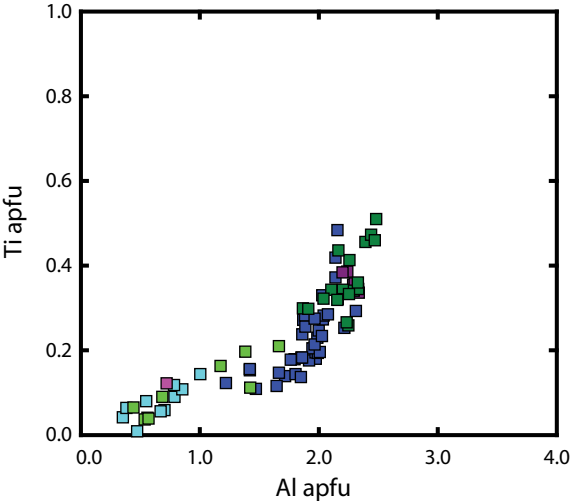










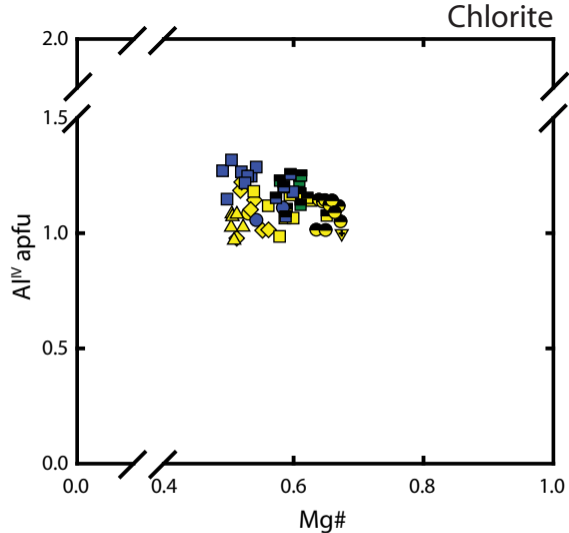


### Valscura

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- Amp2a, appinite
- Amp1, leuco-appinite
- Amp2a, leuco-appinite
- Amp1, spessartite
- Amp2a, spessartite

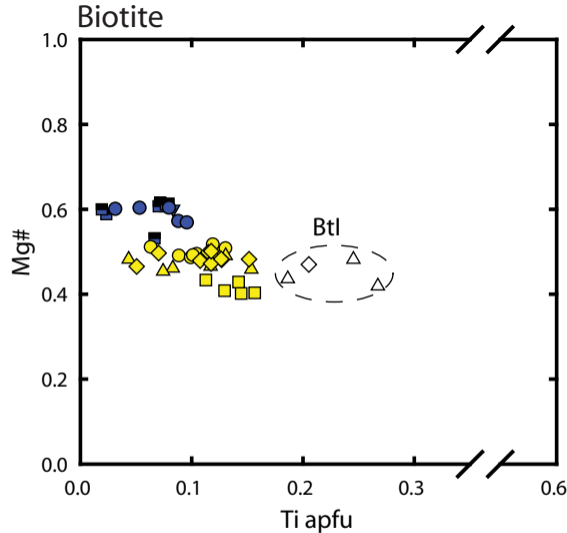
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- Amp1 core, appinite
- Amp1 core, comb layered appinite
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- ◇ Amp2b, leucocratic vein
- Amp1 core, spessartite
- Amp1 rim, spessartite



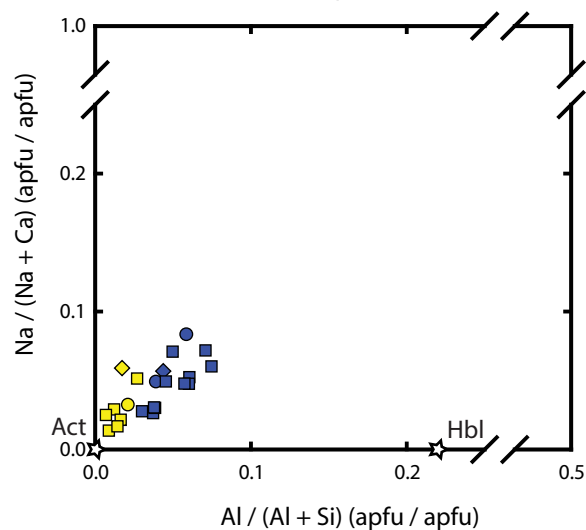
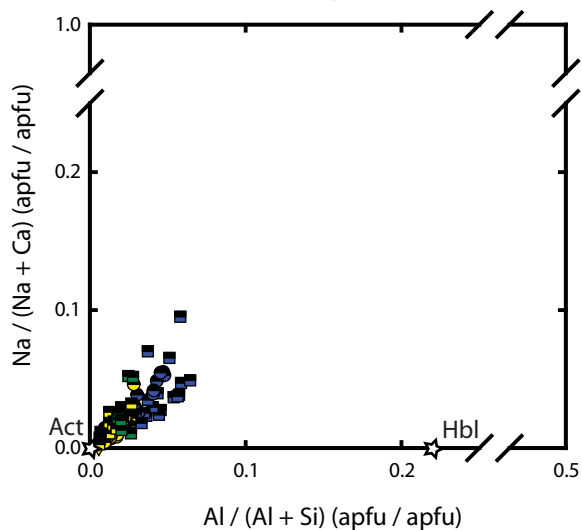
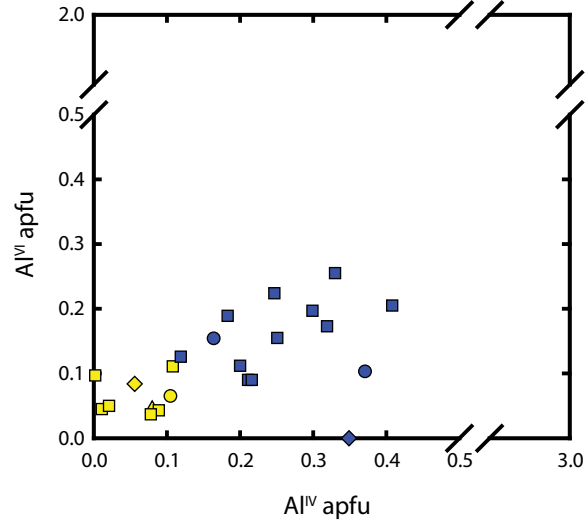
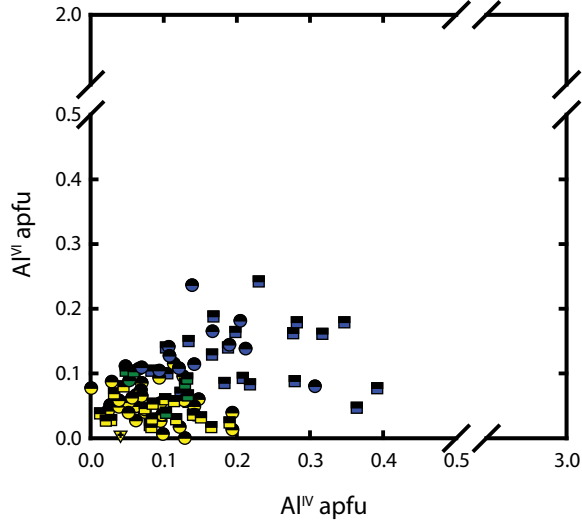
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#### Haut Boréon

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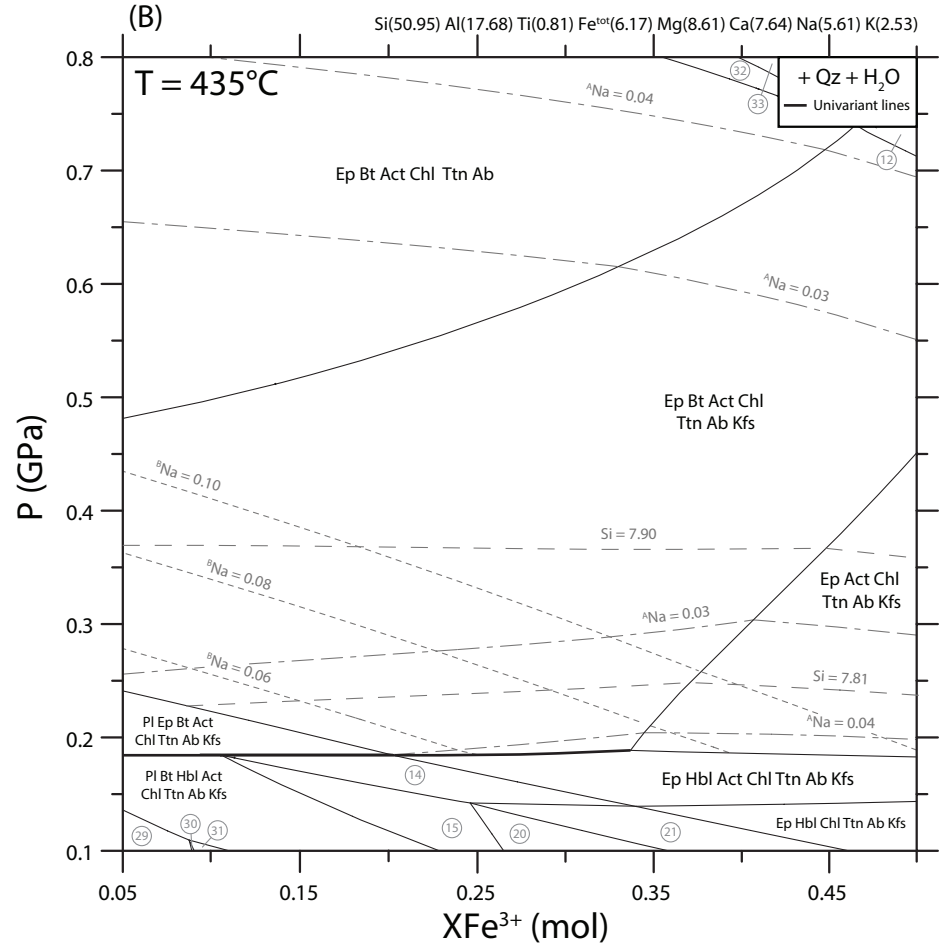
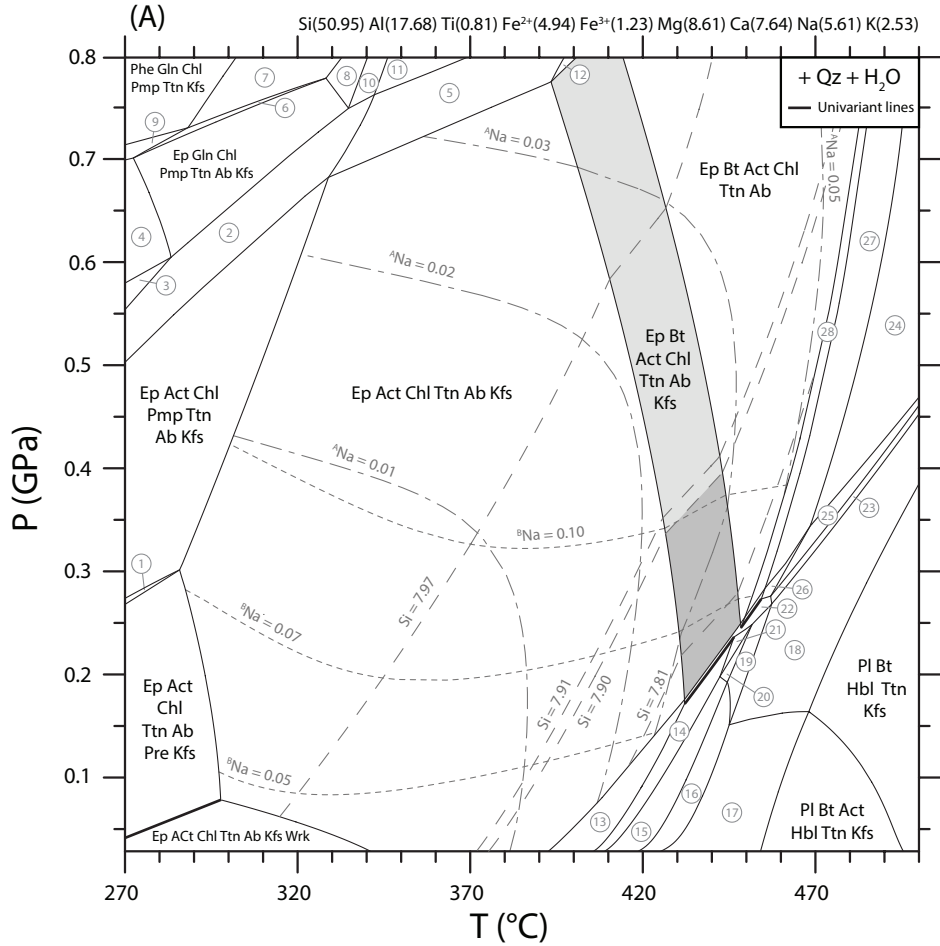
### Valscura

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- AmpM1, appinite
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- AmpM2a, spessartite
- AmpM2a, appinite
- AmpM2b, spessartite
- AmpM2b, appinite

### Haut Boréon

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- AmpM1, appinite
- AmpM1, comb layered appinite
- AmpM2, spessartite
- AmpM2, appinite
- ◆ AmpM2 comb layered appinite





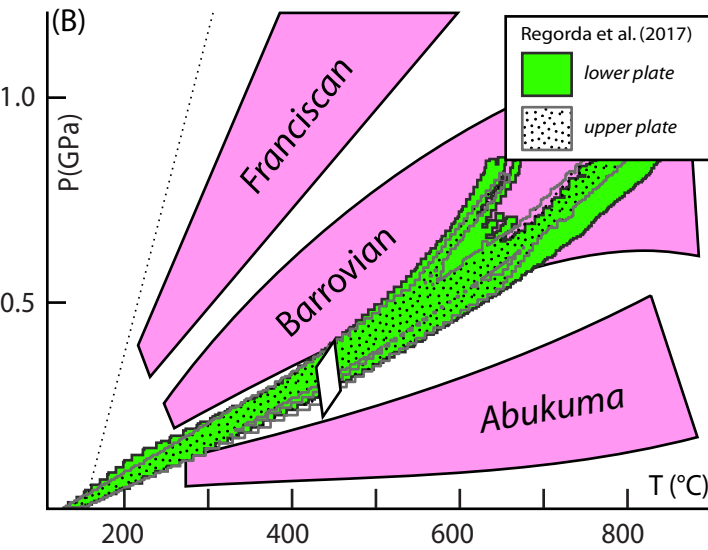
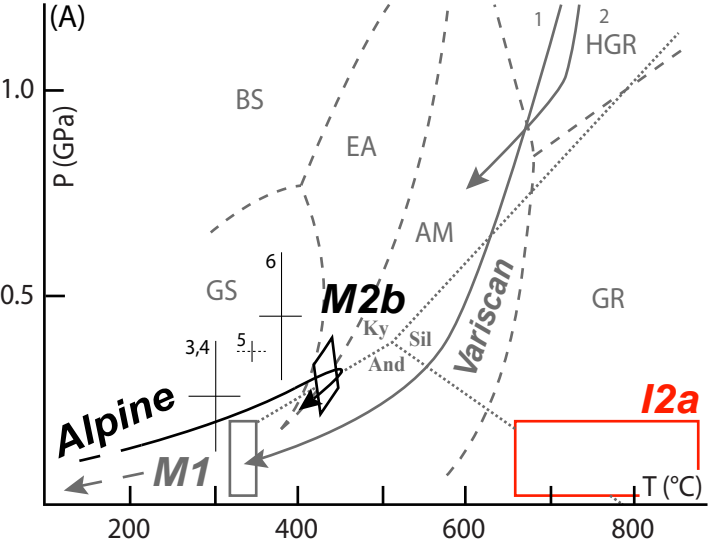
1 Ep Act Chl Pmp Ttn Pre Ab Kfs  
 2 Ep Gln Act Chl Pmp Ttn Ab Kfs  
 3 Gln Act Chl Pmp Ttn Ab Kfs  
 4 Gln Chl Pmp Ttn Ab Kfs  
 5 Ep Gln Act Chl Ttn Ab Kfs  
 6 Ep Phe Gln Chl Pmp Ttn Ab Kfs

7 Ep Phe Gln Chl Pmp Ttn Kfs  
 8 Ep Gln Chl Pmp Ttn Kfs  
 9 Phe Gln Chl Pmp Ttn Ab Kfs  
 10 Ep Gln Act Chl Pmp Ttn Kfs  
 11 Ep Gln Act Chl Ttn Kfs  
 12 Ep Bt Gln Act Chl Ttn Ab Kfs

13 PI Ep Act Chl Ttn Ab Kfs  
 14 PI Ep Hbl Act Chl Ttn Ab Kfs  
 15 PI Hbl Act Chl Ttn Ab Kfs  
 16 PI Bt Hbl Act Chl Ttn Ab Kfs  
 17 PI Bt Hbl Act Ttn Ab Kfs  
 18 PI Bt Hbl Ttn Ab Kfs

19 PI Bt Hbl Chl Ttn Ab Kfs  
 20 PI Hbl Chl Ttn Ab Kfs  
 21 PI Ep Hbl Chl Ttn Ab Kfs  
 22 PI Ep Bt Hbl Chl Ttn Ab Kfs  
 23 PI Ep Bt Hbl Ttn Ab Kfs  
 24 Ep Bt Hbl Ttn Ab

25 PI Ep Bt Hbl Ttn Ab  
 26 PI Ep Bt Chl Hbl Ttn Ab  
 27 Ep Bt Hbl Chl Ttn Ab  
 28 Ep Bt Hbl Act Chl Ttn Ab  
 29 PI Bt Hbl Act Chl Ttn Ab  
 30 PI Bt Hbl Act Ttn Ab  
 31 PI Bt Hbl Act Ttn Ab Kfs  
 32 Ep Bt Gln Act Chl Ttn Ab  
 33 Ep Bt Gln Chl Ttn Ab



<u>STAGE</u>	<u>GENESIS</u>	<u>MINERAL ASSEMBLAGE</u>
I0	igneous	Amp, Cpx
I1 (core, rim)	igneous	Amp, Pl, Qz, Kfs, Mgt, Ilm, Ap, Bt
I2 (a,b)	late-igneous	Ab, Amp
M1	subsolidus, hydrothermal	Ab, Act, Bt, Chl, Ep, Hem, Kfs, Py, Qz, Ttn
M2 (a,b)	subsolidus, syn-D4	Act, Bt, Chl, Ep, Kfs, Pl, Qz, Ttn, Wm

<u>Site</u>	<u>Rock type</u>	<u>Generation</u>	<u>Si</u>	<u>Al<sup>IV</sup></u>	<u>Ti</u>	<u>Al<sup>VI</sup></u>	<u>Mg#</u>	<u>Ca</u>	<u>Na</u>	<u>K</u>
Valscura	Appinite	Ampl1	<b>6.00 - 6.92</b>	<b>1.08 - 2.00</b>	<b>0.11 - 0.48</b>	<b>0.14 - 0.38</b>	<b>0.56 - 0.71</b>	<b>1.57 - 1.88</b>	<b>0.51 - 0.91</b>	<b>0.07 - 0.11</b>
		(37 data)	6.36 ± 0.21	1.64 ± 0.21	0.23 ± 0.09	0.26 ± 0.05	0.64 ± 0.04	1.71 ± 0.08	0.79 ± 0.08	0.08 ± 0.01
		Ampl2a	<b>7.13 - 7.73</b>	<b>0.28 - 0.87</b>	<b>0.01 - 0.14</b>	<b>0.06 - 0.17</b>	<b>0.42 - 0.64</b>	<b>1.37 - 1.86</b>	<b>0.15 - 0.48</b>	<b>0.02 - 0.07</b>
		(10 data)	7.45 ± 0.20	0.55 ± 0.20	0.08 ± 0.04	0.11 ± 0.03	0.55 ± 0.07	1.58 ± 0.16	0.31 ± 0.10	0.05 ± 0.02
	Leuco-appinite	Ampl1	<b>6.01 - 6.05</b>	<b>1.95 - 2.00</b>	<b>0.34 - 0.39</b>	<b>0.25 - 0.36</b>	<b>0.67 - 0.71</b>	<b>1.81 - 1.87</b>	<b>0.78 - 0.87</b>	<b>0.08</b>
		(5 data)	6.03 ± 0.02	1.97 ± 0.02	0.36 ± 0.02	0.30 ± 0.04	0.69 ± 0.02	1.84 ± 0.02	0.82 ± 0.04	-
		Ampl2a	<b>7.40</b>	<b>0.60</b>	<b>0.12</b>	<b>0.12</b>	<b>0.75</b>	<b>1.81</b>	<b>0.33</b>	<b>0.05</b>
	(1 data)	-	-	-	-	-	-	-	-	
	Spessartite	Ampl1	<b>5.74 - 6.46</b>	<b>1.60 - 2.26</b>	<b>0.26 - 0.51</b>	<b>0.20 - 0.34</b>	<b>0.57 - 0.78</b>	<b>1.72 - 1.96</b>	<b>0.59 - 0.87</b>	<b>0.06 - 0.12</b>
		(19 data)	6.04 ± 0.16	1.96 ± 0.16	0.36 ± 0.07	0.27 ± 0.04	0.70 ± 0.05	1.86 ± 0.06	0.79 ± 0.07	0.09 ± 0.02
Ampl2a		<b>6.65 - 7.60</b>	<b>0.40 - 1.36</b>	<b>0.04 - 0.21</b>	<b>0.05 - 0.31</b>	<b>0.53 - 0.70</b>	<b>1.23 - 1.94</b>	<b>0.16 - 0.58</b>	<b>0.02 - 0.05</b>	
(9 data)		7.22 ± 0.37	0.78 ± 0.37	0.11 ± 0.06	0.15 ± 0.09	0.62 ± 0.07	1.73 ± 0.21	0.29 ± 0.13	0.04 ± 0.01	
Haut Boréon	Appinite	Ampl1 core	<b>5.92 - 6.12</b>	<b>1.88 - 2.08</b>	<b>0.31 - 0.45</b>	<b>0.10 - 0.33</b>	<b>0.54 - 0.64</b>	<b>1.69 - 1.91</b>	<b>0.81 - 0.94</b>	<b>0.09 - 0.13</b>
		(34 data)	6.03 ± 0.05	1.97 ± 0.05	0.38 ± 0.03	0.26 ± 0.04	0.67 ± 0.05	1.87 ± 0.04	0.84 ± 0.03	0.11 ± 0.01
	Melanocratic spessartite	Ampl1 core	<b>5.74 - 6.06</b>	<b>1.94 - 2.26</b>	<b>0.41 - 0.67</b>	<b>0.19 - 0.37</b>	<b>0.55 - 0.68</b>	<b>1.84 - 1.94</b>	<b>0.79 - 1.05</b>	<b>0.10 - 0.14</b>
		(17 data)	5.94 ± 0.09	2.06 ± 0.09	0.54 ± 0.07	0.25 ± 0.05	0.62 ± 0.03	1.89 ± 0.03	0.89 ± 0.06	0.12 ± 0.01
		Ampl1 rim	<b>6.03 - 6.41</b>	<b>1.59 - 1.97</b>	<b>0.23 - 0.48</b>	<b>0.15 - 0.35</b>	<b>0.41 - 0.62</b>	<b>1.73 - 1.88</b>	<b>0.85 - 1.10</b>	<b>0.10 - 0.18</b>
		(15 data)	6.16 ± 0.12	1.84 ± 0.12	0.37 ± 0.06	0.28 ± 0.05	0.50 ± 0.05	1.81 ± 0.04	0.98 ± 0.08	0.14 ± 0.02
		Ampl2b	<b>6.19 - 6.32</b>	<b>1.68 - 1.81</b>	<b>0.26 - 0.36</b>	<b>0.11 - 0.15</b>	<b>0.25 - 0.34</b>	<b>1.71 - 1.79</b>	<b>0.86 - 1.01</b>	<b>0.28 - 0.31</b>
		(4 data)	6.27 ± 0.05	1.73 ± 0.05	0.30 ± 0.05	0.13 ± 0.01	0.28 ± 0.04	1.75 ± 0.03	0.93 ± 0.05	0.29 ± 0.01
	Comb-layered appinite	Ampl1 core	<b>5.87 - 6.18</b>	<b>1.82 - 2.13</b>	<b>0.33 - 0.54</b>	<b>0.20 - 0.35</b>	<b>0.48 - 0.68</b>	<b>1.81 - 1.94</b>	<b>0.78 - 0.92</b>	<b>0.11 - 0.14</b>
		(27 data)	6.00 ± 0.09	2.00 ± 0.09	0.45 ± 0.06	0.28 ± 0.04	0.60 ± 0.06	1.89 ± 0.04	0.86 ± 0.04	0.12 ± 0.01
Ampl1 rim		<b>6.26 - 6.28</b>	<b>1.72 - 1.74</b>	<b>0.29 - 0.30</b>	<b>0.21 - 0.33</b>	<b>0.44 - 0.47</b>	<b>1.76 - 1.81</b>	<b>0.85 - 0.91</b>	<b>0.12 - 0.14</b>	
(3 data)	6.27 ± 0.01	1.73 ± 0.01	-	0.27 ± 0.05	0.45 ± 0.02	1.79 ± 0.02	0.89 ± 0.02	0.13 ± 0.01		
Spessartite	Ampl1 core	<b>5.78 - 6.21</b>	<b>1.79 - 2.22</b>	<b>0.32 - 0.52</b>	<b>0.13 - 0.38</b>	<b>0.51 - 0.75</b>	<b>1.79 - 1.96</b>	<b>0.66 - 1.11</b>	<b>0.10 - 0.17</b>	
	(48 data)	6.00 ± 0.10	2.00 ± 0.10	0.41 ± 0.05	0.27 ± 0.05	0.68 ± 0.05	1.87 ± 0.04	0.80 ± 0.06	0.13 ± 0.01	
	Ampl1 rim	<b>6.10 - 6.96</b>	<b>1.04 - 1.90</b>	<b>0.21 - 0.35</b>	<b>0.21 - 0.32</b>	<b>0.37 - 0.71</b>	<b>1.70 - 1.90</b>	<b>0.31 - 1.16</b>	<b>0.06 - 0.18</b>	
(7 data)	6.47 ± 0.31	1.53 ± 0.31	0.28 ± 0.05	0.28 ± 0.04	0.58 ± 0.10	1.82 ± 0.06	0.72 ± 0.27	0.12 ± 0.04		

<u>Site</u>	<u>Rock type</u>	<u>Generation</u>	<u>Si</u>	<u>Al<sup>IV</sup></u>	<u>Ti</u>	<u>Al<sup>VI</sup></u>	<u>Mg#</u>	<u>Ca</u>	<u><sup>B</sup>Na</u>	<u><sup>A</sup>Na</u>	<u>K</u>
Valscura	Appinite	AmpM1	<b>7.81 - 8.00</b>	<b>0.00 - 0.19</b>	<b>0.00 - 0.02</b>	<b>0.00 - 0.12</b>	<b>0.43 - 0.76</b>	<b>1.91 - 2.00</b>	<b>0.00 - 0.08</b>	<b>0.00 - 0.03</b>	<b>0.00 - 0.01</b>
		(35 data)	7.92 ± 0.05	0.08 ± 0.05	-	0.06 ± 0.03	0.70 ± 0.06	1.97 ± 0.02	0.02 ± 0.01	0.01 ± 0.01	-
		AmpM2a	<b>7.95</b>	<b>0.05</b>	<b>0.01</b>	<b>0.09</b>	<b>0.53</b>	<b>1.97</b>	<b>0.03</b>	<b>0.01</b>	<b>0.01</b>
		(1 data)	-	-	-	-	-	-	-	-	-
		AmpM2b	<b>7.69 - 7.94</b>	<b>0.06 - 0.31</b>	<b>0.00 - 0.02</b>	<b>0.07 - 0.24</b>	<b>0.44 - 0.77</b>	<b>1.90 - 1.96</b>	<b>0.02 - 0.09</b>	<b>0.00 - 0.07</b>	<b>0.01 - 0.03</b>
	(14 data)	7.85 ± 0.06	0.15 ± 0.06	-	0.13 ± 0.04	0.67 ± 0.09	1.93 ± 0.02	0.05 ± 0.02	0.02 ± 0.02	-	
	Leuco-appinite	AmpM1	<b>7.93 - 7.96</b>	<b>0.04 - 0.07</b>	<b>0.00 - 0.01</b>	<b>0.01 - 0.07</b>	<b>0.71 - 0.72</b>	<b>1.96 - 1.98</b>	<b>0.00 - 0.04</b>	<b>0.00 - 0.00</b>	<b>0.00</b>
	(2 data)	-	-	-	-	-	-	-	-	-	
	Spessartite	AmpM1	<b>7.81 - 7.99</b>	<b>0.01 - 0.19</b>	<b>0.00 - 0.01</b>	<b>0.02 - 0.08</b>	<b>0.61 - 0.74</b>	<b>1.91 - 1.98</b>	<b>0.01 - 0.05</b>	<b>0.00 - 0.05</b>	<b>0.00 - 0.01</b>
	(17 data)	7.91 ± 0.05	0.09 ± 0.05	-	0.04 ± 0.02	0.70 ± 0.04	1.96 ± 0.02	0.02 ± 0.01	0.01 ± 0.01	-	
		AmpM2a	<b>7.87 - 7.97</b>	<b>0.03 - 0.13</b>	<b>0.00 - 0.02</b>	<b>0.03 - 0.10</b>	<b>0.49 - 0.75</b>	<b>1.86 - 1.98</b>	<b>0.02 - 0.08</b>	<b>0.00 - 0.05</b>	<b>0.00 - 0.01</b>
	(9 data)	7.91 ± 0.04	0.09 ± 0.04	-	0.08 ± 0.03	0.66 ± 0.09	1.95 ± 0.04	0.04 ± 0.02	0.01 ± 0.01	-	
	AmpM2b	<b>7.61 - 7.92</b>	<b>0.08 - 0.39</b>	<b>0.00 - 0.03</b>	<b>0.05 - 0.24</b>	<b>0.55 - 0.74</b>	<b>1.78 - 1.98</b>	<b>0.01 - 0.10</b>	<b>0.00 - 0.10</b>	<b>0.01 - 0.07</b>	
(21 data)	7.79 ± 0.09	0.21 ± 0.09	-	0.13 ± 0.05	0.68 ± 0.04	1.93 ± 0.05	0.04 ± 0.02	0.03 ± 0.03	0.02 ± 0.01		
<b>All</b>	AmpM1	<b>7.81 - 8.00</b>	<b>0.00 - 0.19</b>	<b>0.00 - 0.02</b>	<b>0.00 - 0.12</b>	<b>0.43 - 0.76</b>	<b>1.91 - 2.00</b>	<b>0.00 - 0.08</b>	<b>0.00 - 0.05</b>	<b>0.00 - 0.01</b>	
(53 data)	7.91 ± 0.06	0.09 ± 0.05	-	0.05 ± 0.03	0.70 ± 0.05	1.97 ± 0.02	0.02 ± 0.01	0.01 ± 0.01	-		
<b>All</b>	AmpM2b	<b>7.61 - 7.94</b>	<b>0.06 - 0.39</b>	<b>0.00 - 0.03</b>	<b>0.05 - 0.24</b>	<b>0.44 - 0.77</b>	<b>1.78 - 1.98</b>	<b>0.01 - 0.10</b>	<b>0.00 - 0.10</b>	<b>0.01 - 0.07</b>	
(35 data)	7.81 ± 0.09	0.19 ± 0.09	-	0.13 ± 0.05	0.68 ± 0.07	1.93 ± 0.04	0.05 ± 0.02	0.03 ± 0.02	0.02 ± 0.01		
Haut Boréon	Appinite	AmpM1	<b>7.89</b>	<b>0.11</b>	<b>0.00</b>	<b>0.06</b>	<b>0.58</b>	<b>1.97</b>	<b>0.03</b>	<b>0.04</b>	<b>0.01</b>
		(1 data)	-	-	-	-	-	-	-	-	-
		AmpM2	<b>7.63 - 7.83</b>	<b>0.17 - 0.37</b>	<b>0.00 - 0.01</b>	<b>0.10 - 0.15</b>	<b>0.63 - 0.70</b>	<b>1.87 - 1.90</b>	<b>0.07 - 0.08</b>	<b>0.02 - 0.10</b>	<b>0.01 - 0.03</b>
	(2 data)	-	-	-	-	-	-	-	-	-	
	Melanocratic spessartite	AmpM1	<b>7.92</b>	<b>0.08</b>	<b>0.01</b>	<b>0.05</b>	<b>0.63</b>	<b>1.95</b>	<b>0.03</b>	<b>0.01</b>	<b>0.01</b>
	(1 data)	-	-	-	-	-	-	-	-	-	
	Comb-layered appinite	AmpM1	<b>7.94</b>	<b>0.06</b>	<b>0.00</b>	<b>0.08</b>	<b>0.65</b>	<b>1.87</b>	<b>0.10</b>	<b>0.02</b>	<b>0.01</b>
	(1 data)	-	-	-	-	-	-	-	-	-	
		AmpM2	<b>7.63</b>	<b>0.35</b>	<b>0.01</b>	<b>0.00</b>	<b>0.63</b>	<b>1.90</b>	<b>0.07</b>	<b>0.04</b>	<b>0.03</b>
	(1 data)	-	-	-	-	-	-	-	-	-	
	Spessartite	AmpM1	<b>7.89 - 7.99</b>	<b>0.01 - 0.11</b>	<b>0.00 - 0.02</b>	<b>0.04 - 0.11</b>	<b>0.46 - 0.68</b>	<b>1.87 - 1.95</b>	<b>0.03 - 0.07</b>	<b>0.00 - 0.04</b>	<b>0.00 - 0.02</b>
	(6 data)	7.94 ± 0.04	0.06 ± 0.04	-	0.06 ± 0.03	0.56 ± 0.08	1.93 ± 0.03	0.04 ± 0.02	0.01 ± 0.01	-	
	AmpM2	<b>7.59 - 7.88</b>	<b>0.12 - 0.41</b>	<b>0.00 - 0.02</b>	<b>0.09 - 0.26</b>	<b>0.52 - 0.70</b>	<b>1.90 - 1.97</b>	<b>0.03 - 0.08</b>	<b>0.02 - 0.09</b>	<b>0.01 - 0.07</b>	
(11 data)	7.75 ± 0.08	0.25 ± 0.08	-	0.16 ± 0.05	0.64 ± 0.05	1.93 ± 0.02	0.05 ± 0.02	0.05 ± 0.02	0.02 ± 0.02		
<b>All</b>	AmpM1	<b>7.89 - 7.99</b>	<b>0.01 - 0.11</b>	<b>0.00 - 0.02</b>	<b>0.04 - 0.11</b>	<b>0.46 - 0.68</b>	<b>1.87 - 1.97</b>	<b>0.03 - 0.10</b>	<b>0.00 - 0.04</b>	<b>0.00 - 0.02</b>	
(9 data)	7.94 ± 0.04	0.06 ± 0.04	-	0.06 ± 0.02	0.58 ± 0.07	1.93 ± 0.03	0.05 ± 0.02	0.01 ± 0.01	-		
<b>All</b>	AmpM2	<b>7.59 - 7.88</b>	<b>0.12 - 0.41</b>	<b>0.00 - 0.02</b>	<b>0.00 - 0.26</b>	<b>0.52 - 0.70</b>	<b>1.87 - 1.97</b>	<b>0.03 - 0.08</b>	<b>0.02 - 0.10</b>	<b>0.01 - 0.07</b>	
(14 data)	7.73 ± 0.08	0.26 ± 0.08	-	0.15 ± 0.06	0.64 ± 0.04	1.92 ± 0.02	0.06 ± 0.02	0.05 ± 0.03	0.02 ± 0.01		

<u>Site</u>	<u>Rock type</u>	<u>Mineral</u>	<u>T (°C)</u>		<u>P (GPa)</u>	
			<u>R10</u>	<u>R10</u>	<u>M16</u>	
Valscura	Appinite	Ampl1	<b>785 - 1009</b>	<b>0.11 - 0.52</b>		
			920 ± 52	0.30 ± 0.09		
		Ampl2a	<b>666 - 759</b>	<b>0.03 - 0.08</b>	<b>0.07 - 0.18</b>	
			714 ± 34	0.06 ± 0.02	0.12 ± 0.03	
	Leuco-appinite	Ampl1	<b>1001 - 1021</b>	<b>0.44 - 0.54</b>		
			1009 ± 8	0.49 ± 0.04		
		Ampl2a	<b>738</b>	<b>0.05</b>	<b>0.13</b>	
Spessartite	Ampl1	<b>927 - 1066</b>	<b>0.30 - 0.68</b>			
		1008 ± 38	0.48 ± 0.11			
	Ampl2a	<b>665 - 875</b>	<b>0.04 - 0.21</b>	<b>0.08 - 0.12</b>		
		749 ± 84	0.09 ± 0.06	0.10 ± 0.01		
Haut Boréon	Appinite	Ampl1 core	<b>947 - 1021</b>	<b>0.33 - 0.57</b>		
			1005 ± 14	0.48 ± 0.05		
	Melanocratic spessartite	Ampl1 core	<b>998 - 1036</b>	<b>0.48 - 0.74</b>		
			1013 ± 12	0.56 ± 0.06		
		Ampl1 rim	<b>958 - 1001</b>	<b>0.40 - 0.48</b>		
			978 ± 11	0.47 ± 0.02		
	Comb layered appinite	Ampl1 core	<b>951 - 1034</b>	<b>0.40 - 0.64</b>		
			1002 ± 23	0.53 ± 0.07		
		Ampl1 rim	<b>929</b>	<b>0.31</b>		
	Spessartite	Ampl1 core	<b>971 - 1043</b>	<b>0.38 - 0.70</b>		
1011 ± 18			0.52 ± 0.08			
Ampl1 rim		<b>840 - 962</b>	<b>0.14 - 0.37</b>			
		916 ± 45	0.27 ± 0.08			

<b>Site</b>	<b>Mineral</b>	<b>T (°C)</b>			<b>P (GPa)</b>	
		<u>C88</u>	<u>J91</u>	<u>B13</u>	<u>G98</u>	<u>G98</u>
Valscura	ChlM1	<b>260 - 371</b>	<b>261 - 372</b>	<b>251 - 367</b>		
		297 ± 26	298 ± 27	309 ± 37		
	AmpM2b				<b>370 - 435</b>	<b>0.09 - 0.21</b>
					394 ± 18	0.15 ± 0.03
Haut Boréon	ChlM1	<b>250 - 331</b>	<b>256 - 336</b>	<b>220 - 354</b>		
		285 ± 23	290 ± 23	300 ± 43		
	AmpM2b				<b>359 - 435</b>	<b>0.12 - 0.23</b>
					405 ± 20	0.17 ± 0.03