AUREOLE

EGU General Assembly 2021

ERA-MIN 2

RESEARCH & INNOVATION PROGRAMME ON RAW MATERIALS TO FOSTER CIRCULAR ECONOMY

Sb, As and W content of magmas

Insights from geochemical databases

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brgm Geoscience for a sustainable Earth

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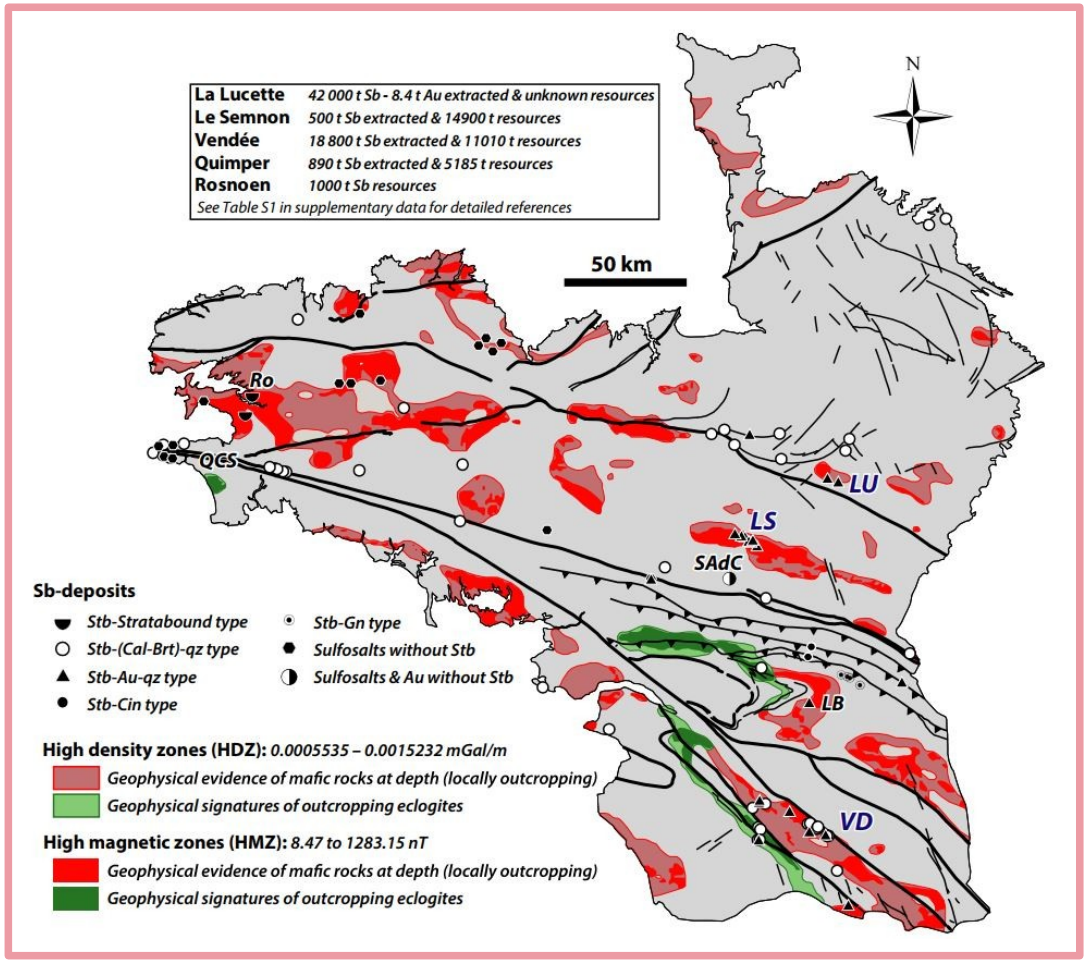
A link between mafic magmatism and Sb, Hg ± As, W, Au, Ag ore deposits?



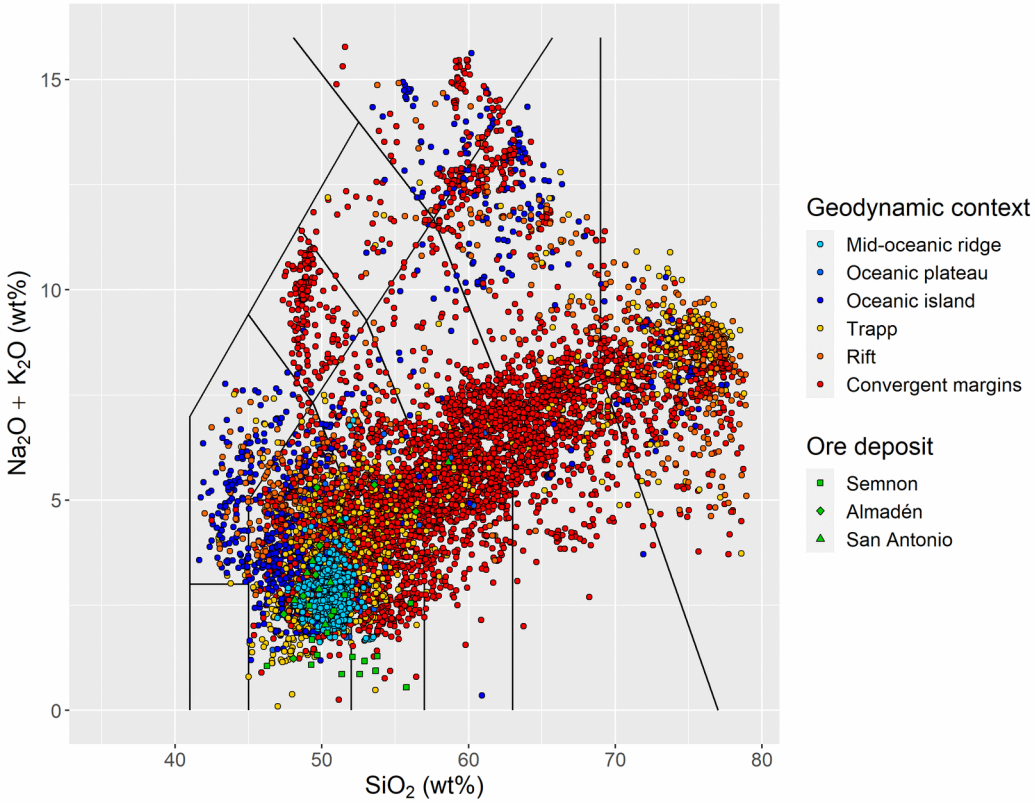
Mafic magmatism and mineralisation

- Spatial and chronological correlation (360 Ma)
- Armorican Massif, Central Iberian Zone
- No causal processes identified
- Contribution of magmas or magmatic rocks?
- Magmatic contribution: need to assess melt-fluid partitioning of targeted elements

Left: spatial link between mafic magmatism and Sb mineralisation in the Armorican Massif, France (Pochon et al. [2016]).

First issue to solve: what is the pre-degassing metal & metalloid content of magmas?
→ This study aims to answer this question

Geochemical database



Database features

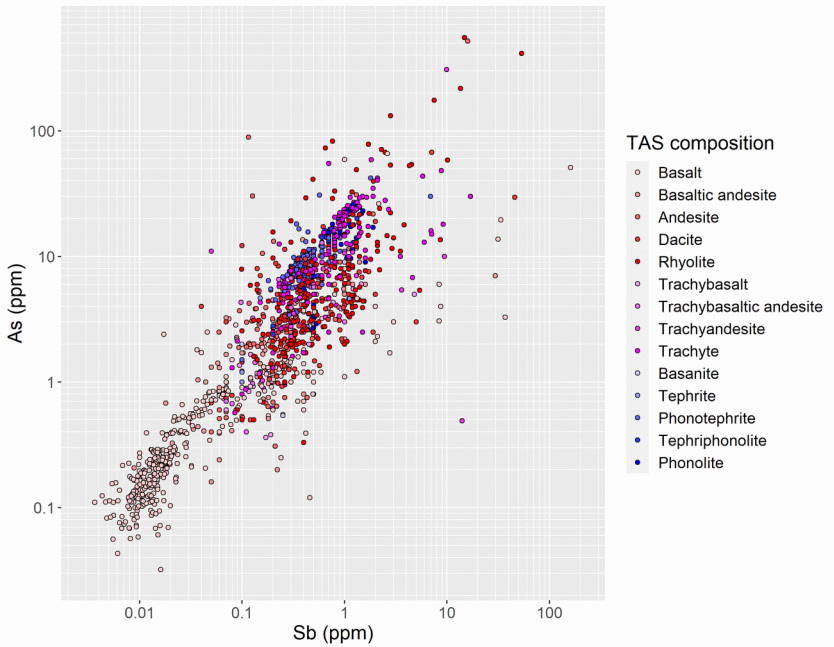
- Jenner and O'Neill [2012]
  → mid-oceanic ridge
  → glass
- GEOROC
  → 5 geodynamic contexts
  → mainly whole rock
- AUREOLE
  → 3 ore deposits
  → whole rock

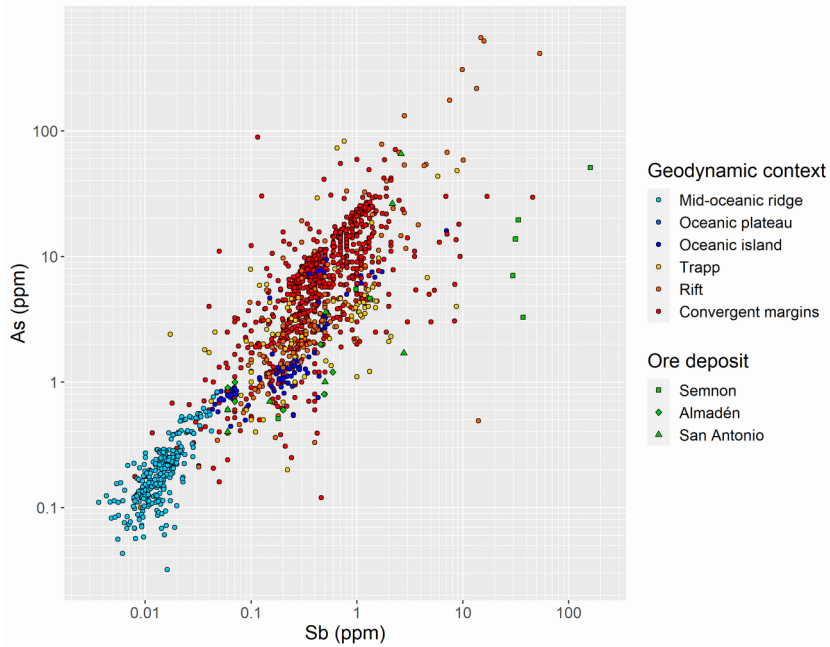
Left: database distribution in a TAS diagram.

Below: number of data points for targeted elements.

Database	All	Sb	As	W	Au	Ag	Hg
Jenner and O'Neill [2012]	602	274	326	587	109	334	
GEOROC	7214	3819	1982	3685	454	597	64
AUREOLE	33	29	24	31			15

Metalloids and metal relationships: Sb & As



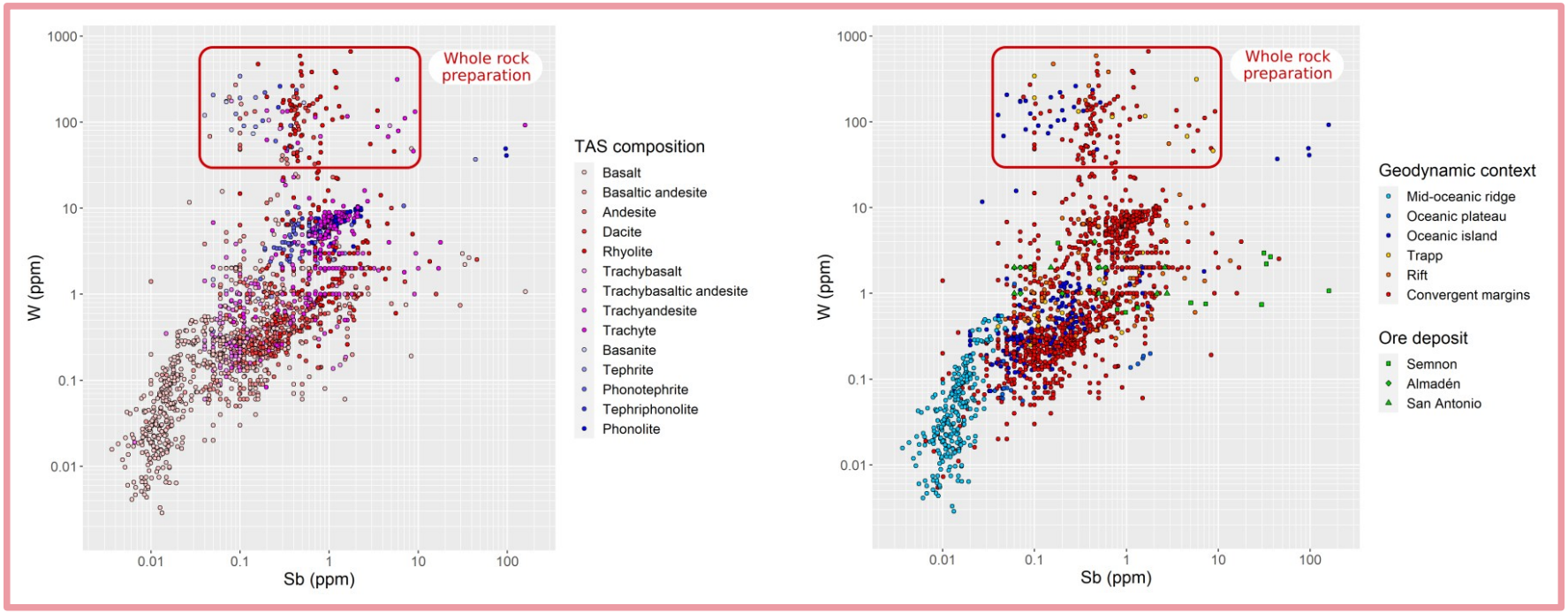


As vs Sb, with TAS compositions shown.

As vs of Sb, with geodynamic contexts shown.

- Clear positive correlation between Sb & As
- Small decorrelation between calc-alkaline and alkaline compositions
- Higher concentrations and higher variability in continental contexts

Metalloids and metal relationships: Sb & W

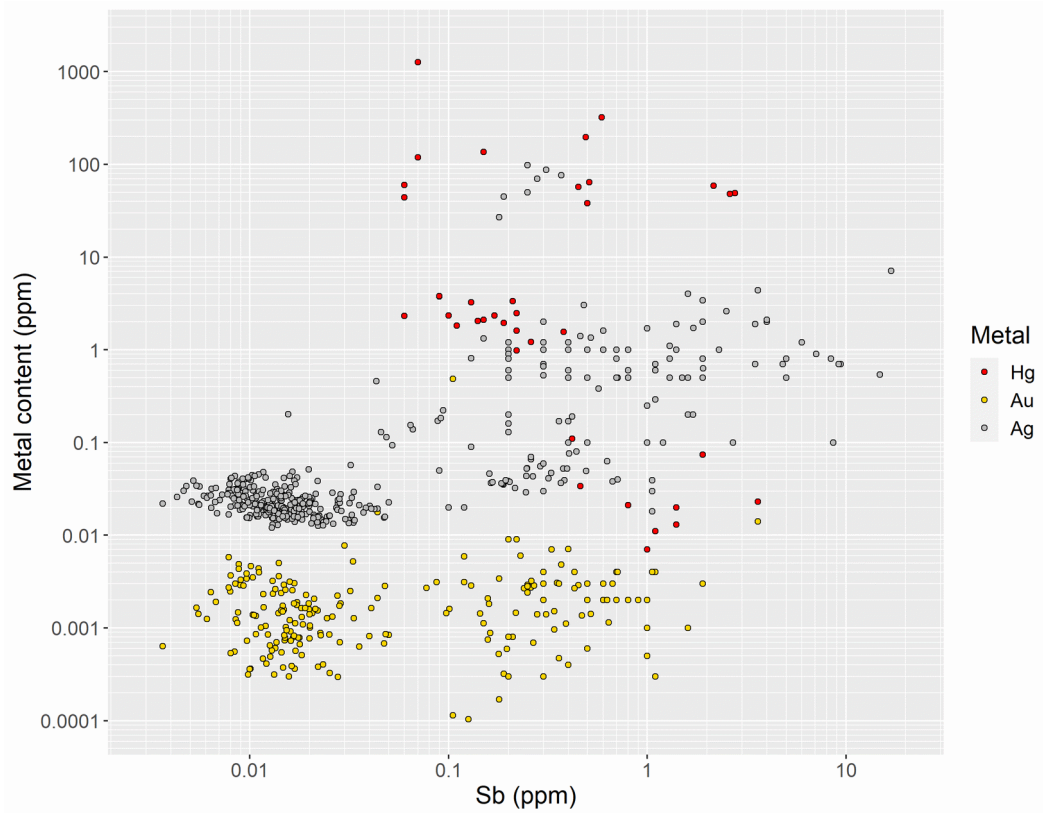


W as a function of Sb, with TAS compositions shown.

W as a function of Sb, with geodynamic contexts shown.

- Good positive correlation between Sb & W
- Globally same features than for Sb & As covariation
- Out-of-correlation W-rich group : contamination by rock grinding with W carbide?

Other metals: Hg, Au & Ag



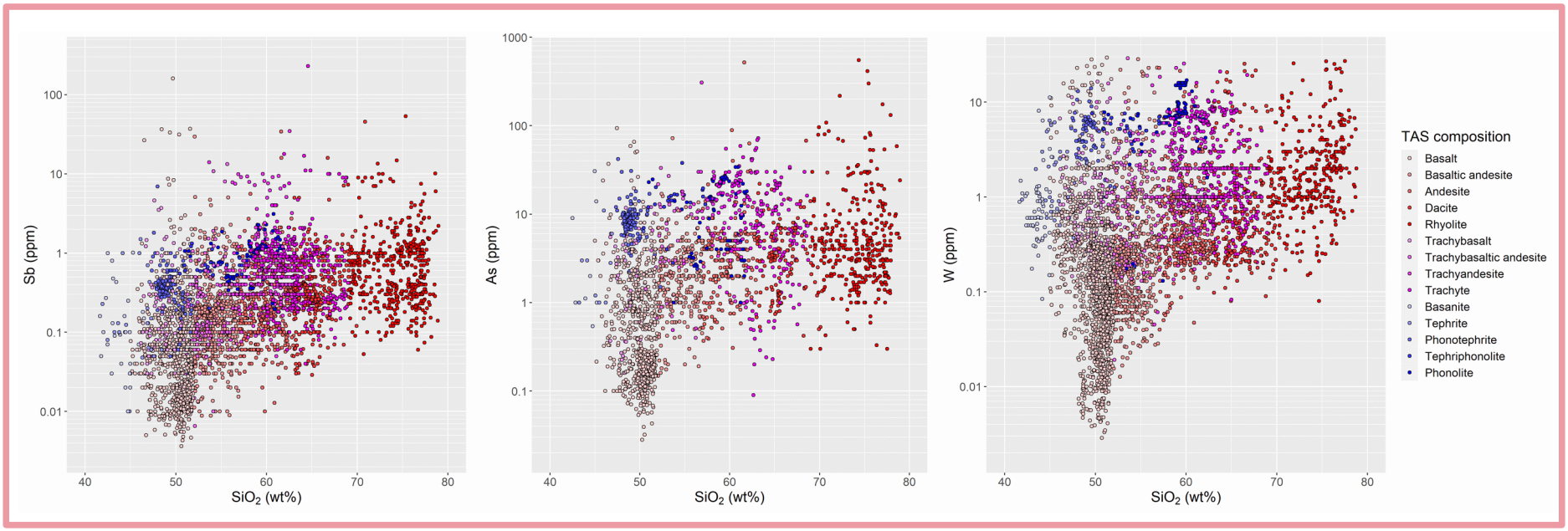
Issues with Hg, Au & Ag data

- Hg: insufficient data
- Au: no correlation with Sb-As-W group
- Ag: multivariate relationship with Sb-As-W group
- Au & Ag: not enough data to explore relationships

Left: Hg-Au-Ag concentrations as a function of Sb.

- Focus on the Sb-As-W group for this study

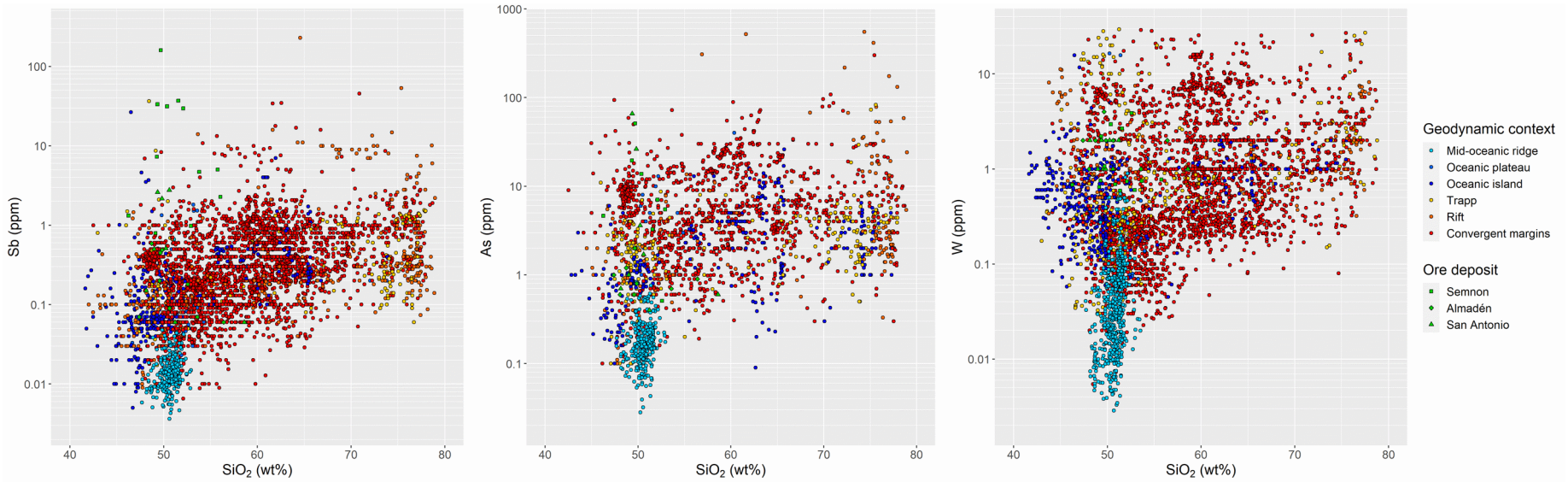
Effects of magma composition: SiO_2



Sb, As, W vs SiO_2, with TAS compositions shown.

- SiO_2: can be used as a differentiation index
- No clear relationship between Sb, As, W and SiO_2
- No clear relationship with TAS rock compositions

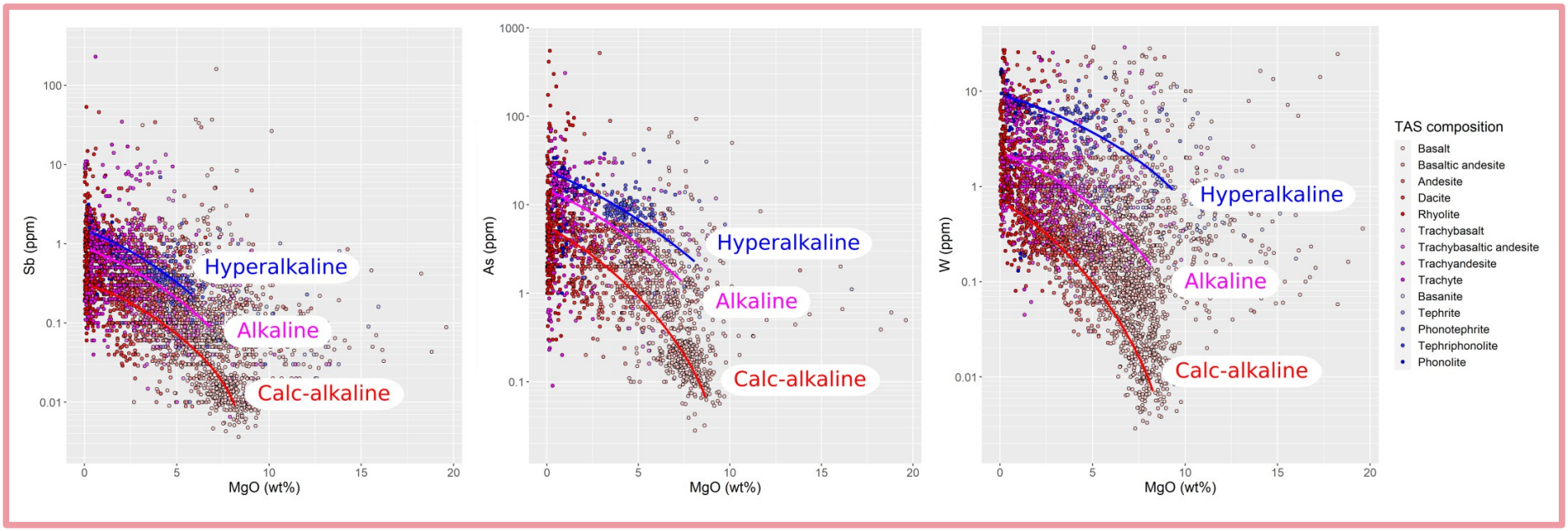
Effects of magma composition: SiO_2



Sb, As, W vs SiO_2, with geodynamic contexts shown.

- SiO_2: can be used as a differentiation index
- No clear relationship between Sb, As, W and SiO_2
- High variability within continental contexts

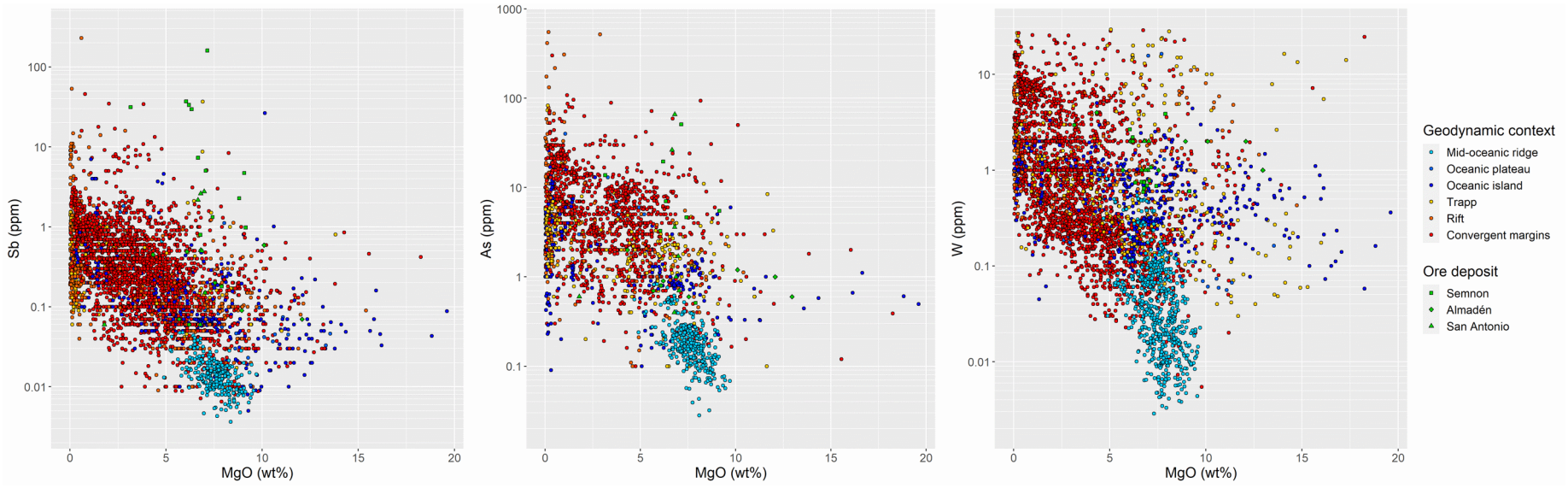
Effects of magma composition: MgO



Sb, As, W vs MgO, with TAS compositions shown.

- MgO: another way to look at differentiation
- Better relationship with MgO than SiO_2
- Higher Sb, As and W content in alkaline magmatic series

Effects of magma composition: MgO



Sb, As, W vs MgO, with geodynamic contexts shown.

- MgO: another way to look at differentiation
- Better relationship with MgO than SiO_2
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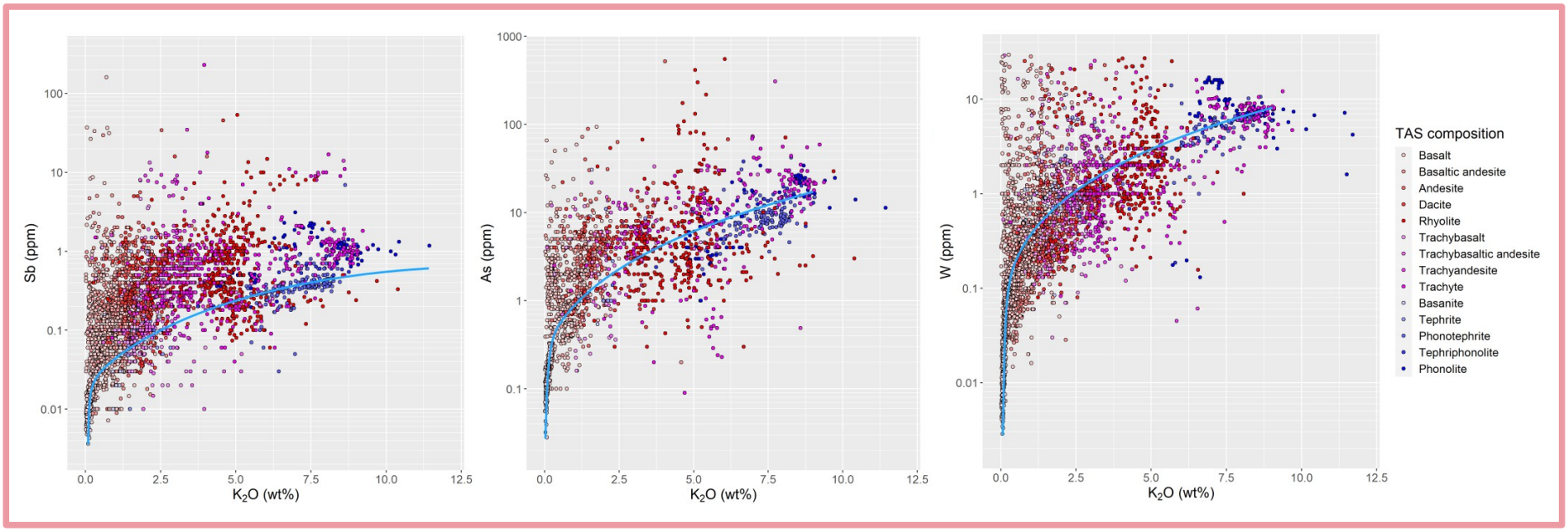
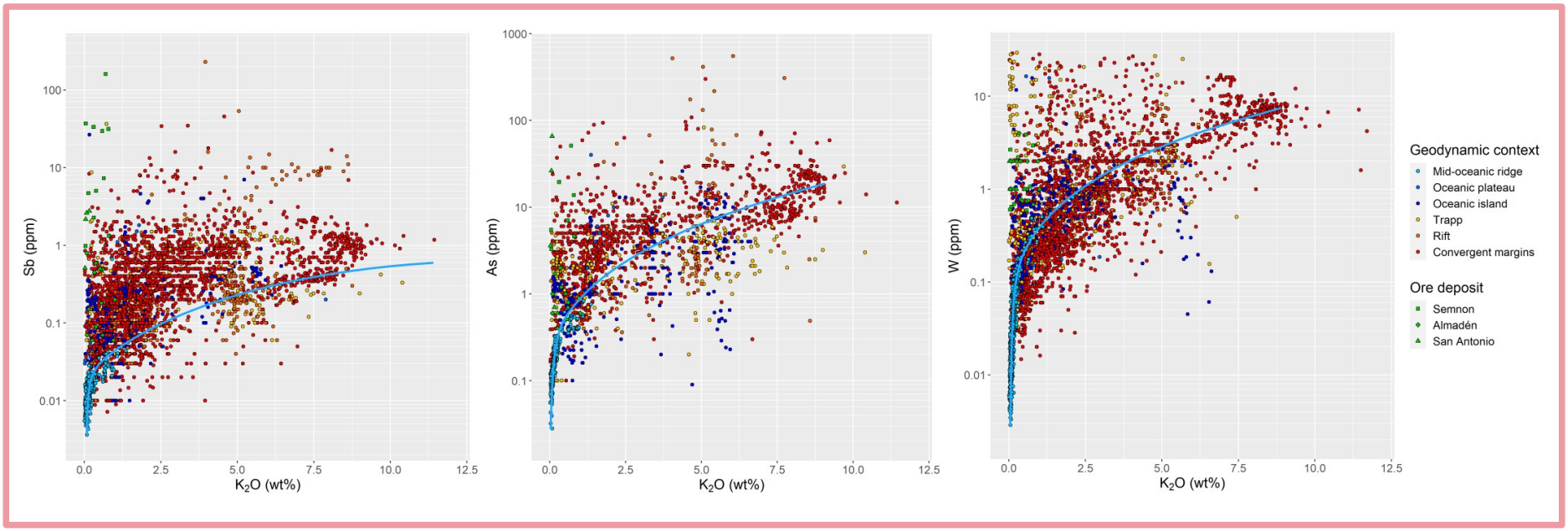
Effects of magma composition: K_2O



Sb, As, W vs K_2O, with TAS compositions shown.

- K_2O: draws a baseline → best explicative variable yet
- All TAS compositions are included in the baseline
- High out-of-baseline variability

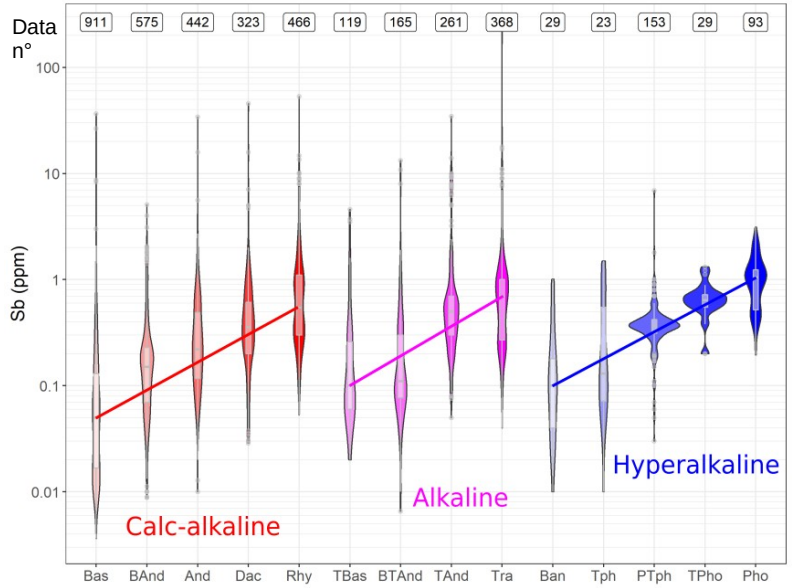
Effects of magma composition: K_2O

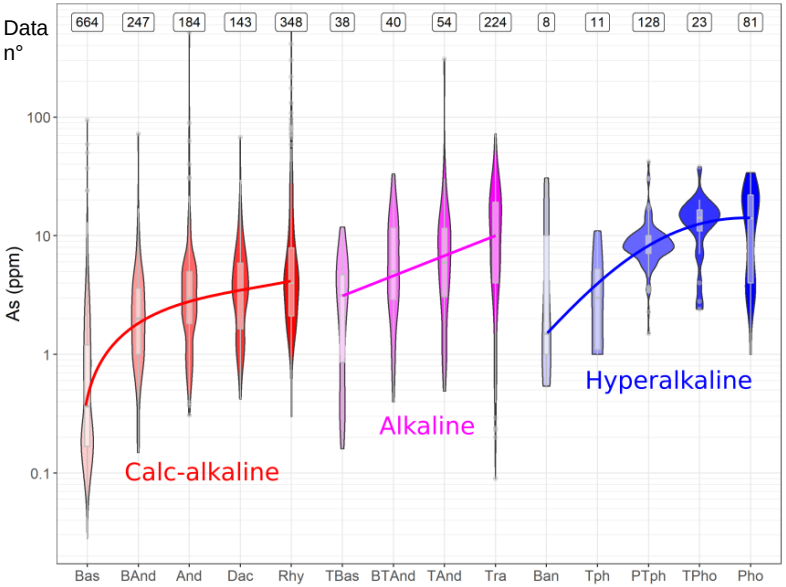


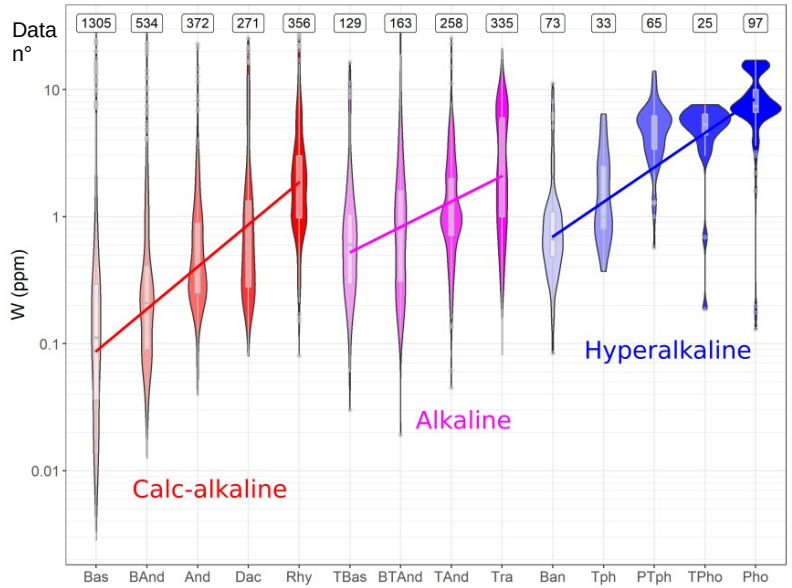
Sb, As, W vs K_2O, with geodynamic contexts shown.

- K_2O: draws a baseline → best explicative variable yet
- Mid-oceanic ridge magmas form the left part of the baseline
- Out-of-baseline variability mostly exists within continental contexts

Differentiation effect



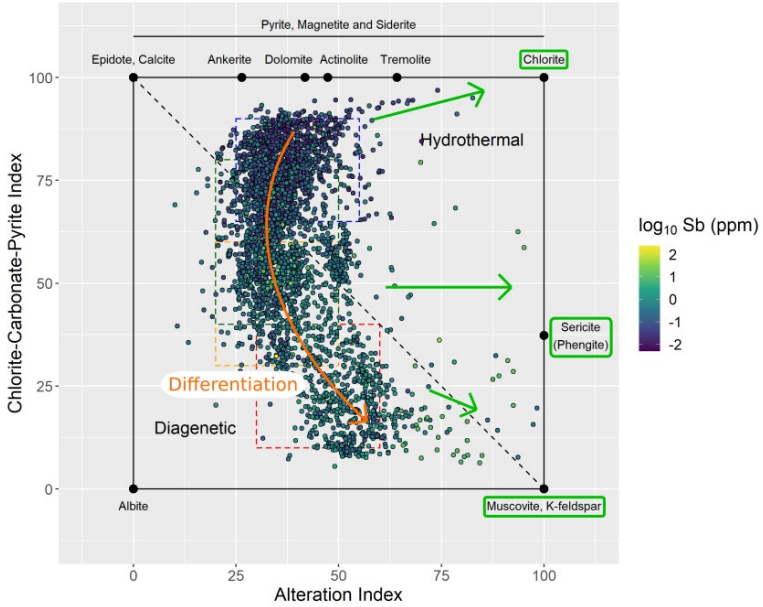


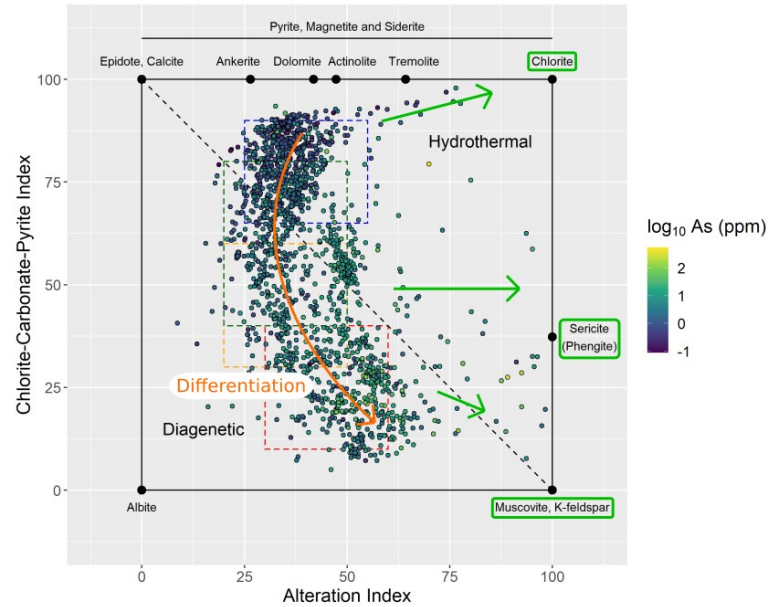


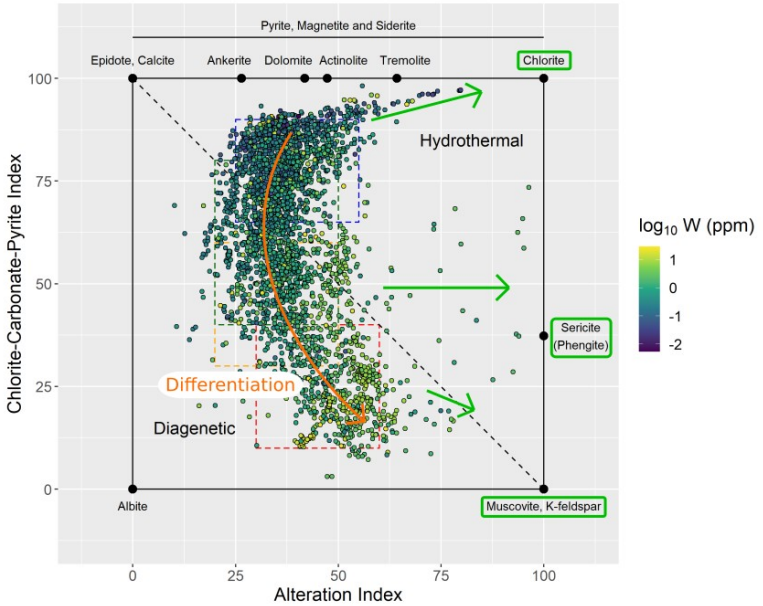
Sb, As and W distributions in TAS

- Median values increase with differentiation (fractional crystallisation)
- Higher values in alkaline series
- High variability outside of the interquartile range

Post-magmatic alteration effect



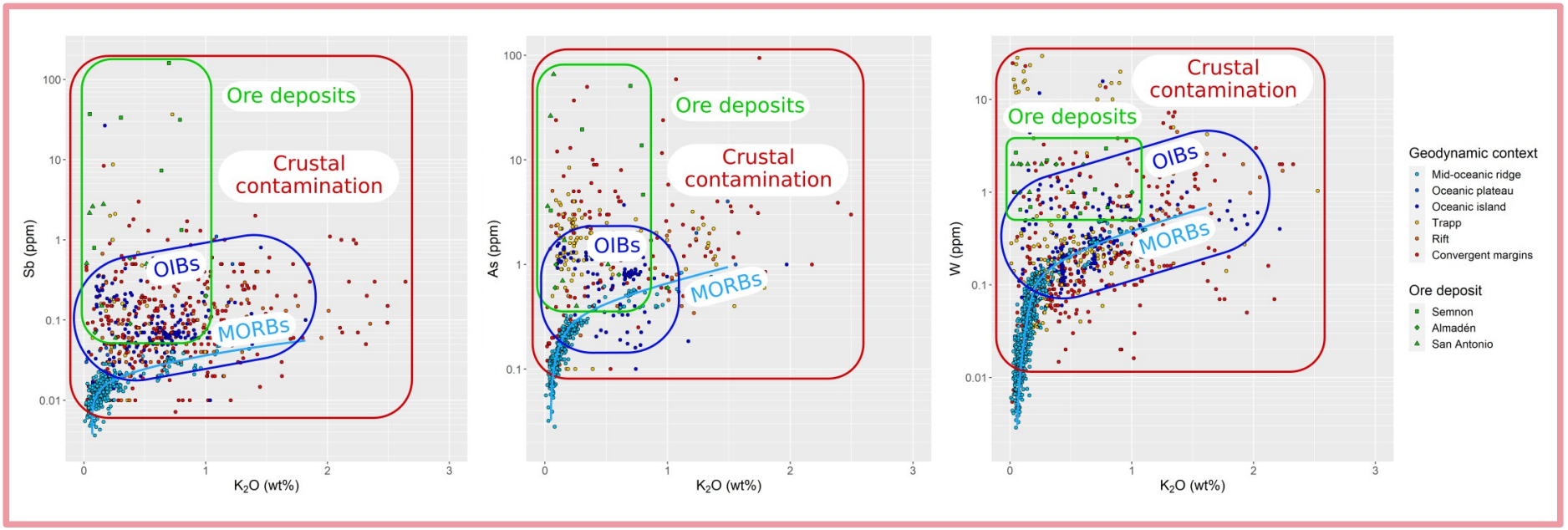




CCPI-AI diagrams

- Differentiation trend : Sb, As and W increase
- Points out of the boxes are considered altered
- Chlorite, sericite & potassic alteration
- No effect of alteration

Focus on basalts: main observations

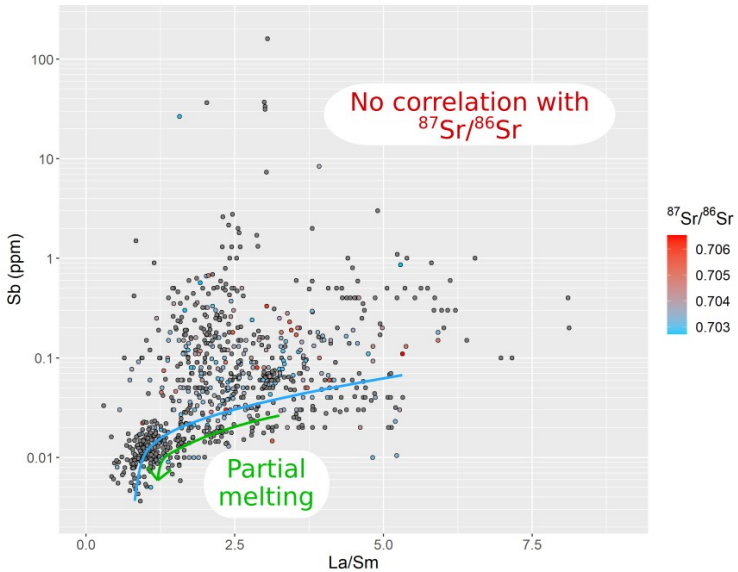


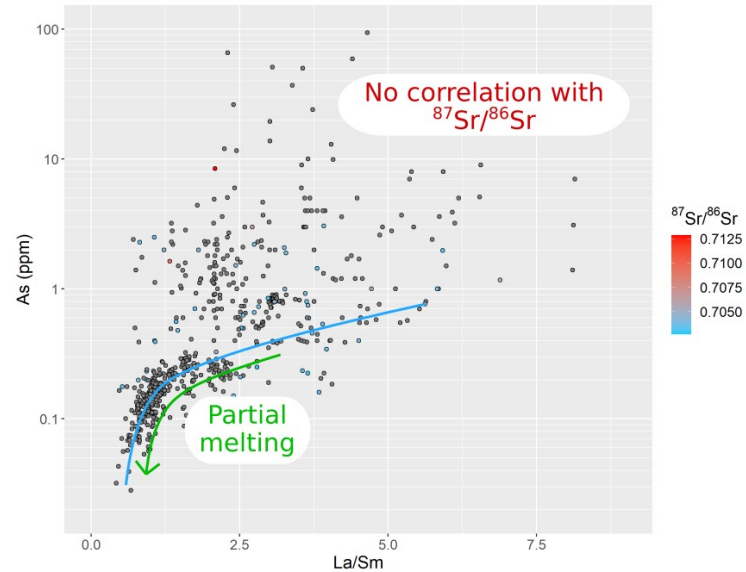
Sb, As, W vs K_2O in basalts, with geodynamic contexts shown.

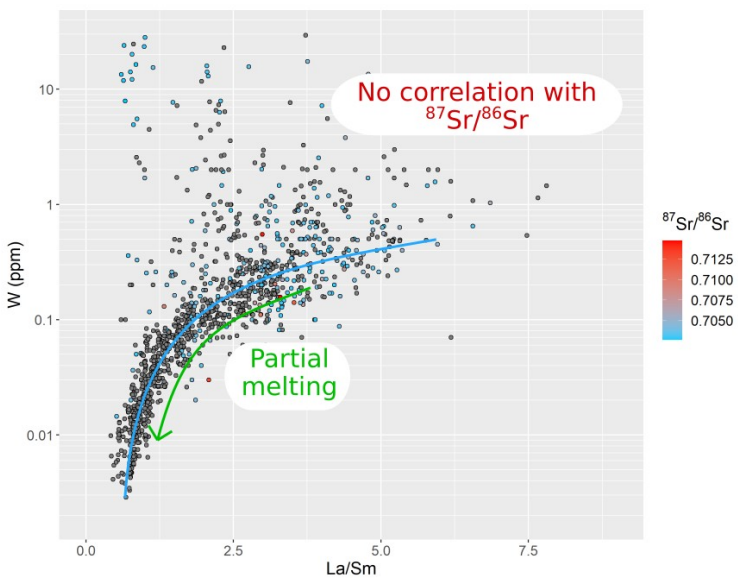
Sb, As and W in basalts

- Basalts are useful to identify processes
- Baseline variability: highlighted by MORBs
- Out-of-baseline variability: moderate in OIBs, high in continental contexts
- Deposits: above the baseline

Focus on basalts: explaining baseline variability



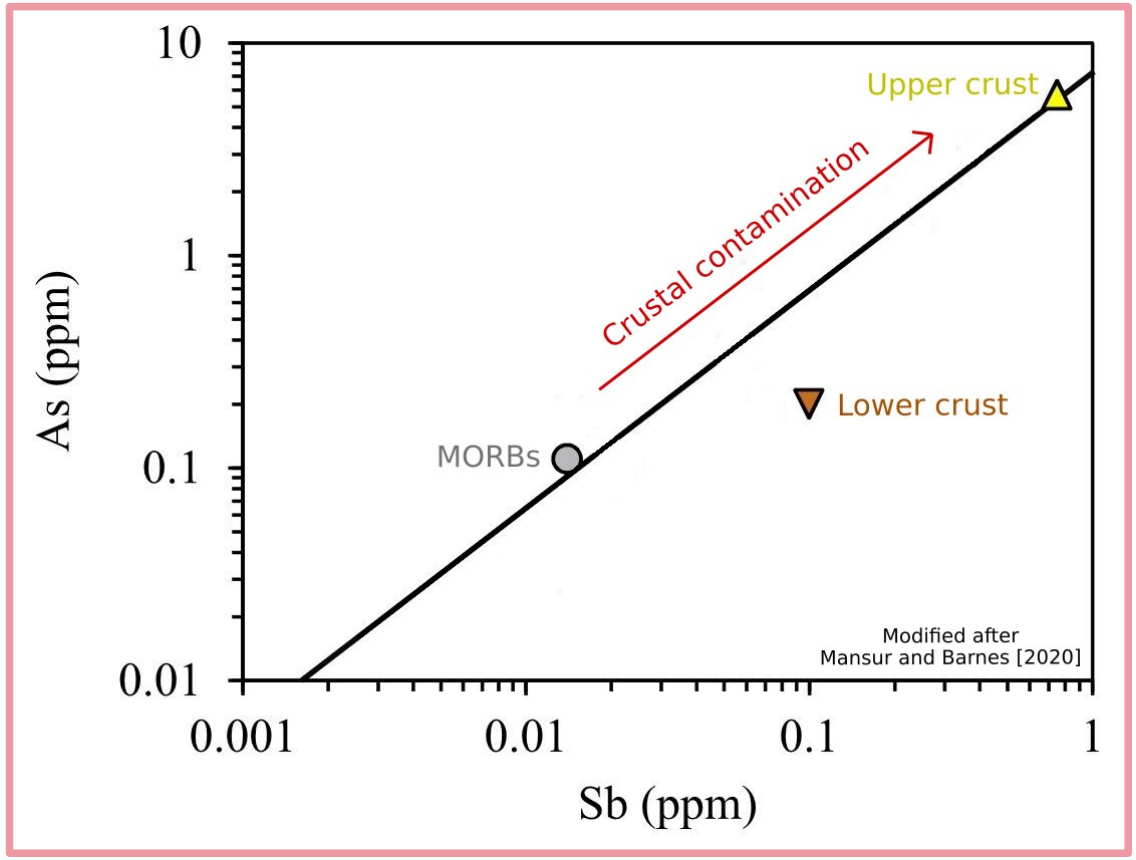




Sb, As and W vs La/Sm ratio

- Decreasing La/Sm ratio indicates increasing degree of partial melting, as the $^{87}Sr/^{86}Sr$ isotopic ratio do not suggest mantle metasomatism
- Basaltic magmas produced by lower degrees of partial melting seem to have higher Sb, As and W contents

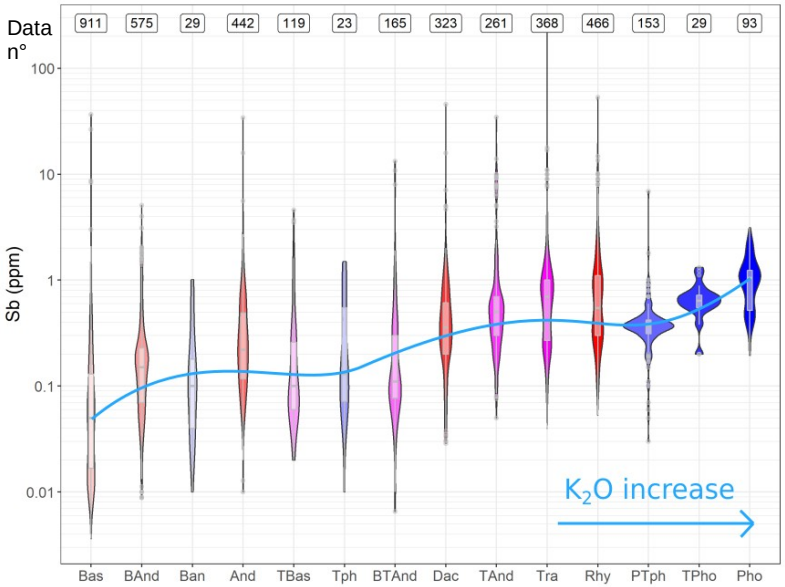
Focus on basalts: explaining out-of-baseline variability

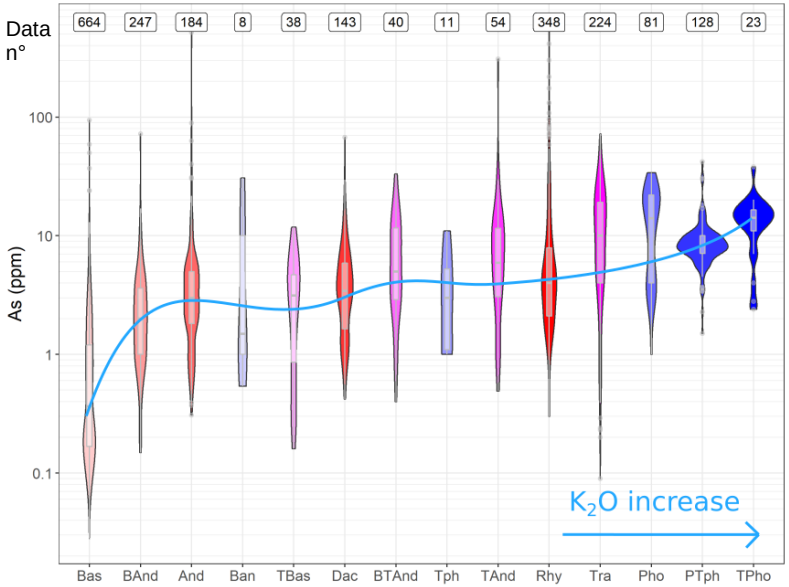


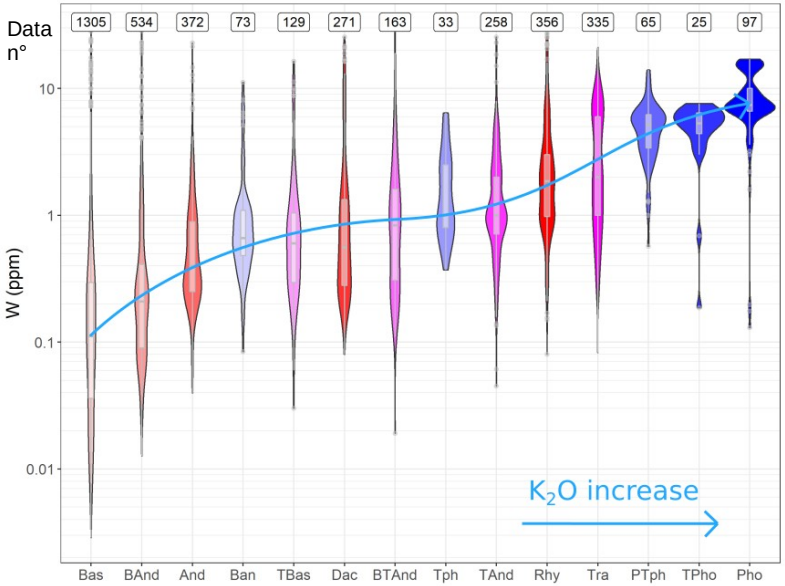
- Highest Sb, As, and W values are not tied to the baseline processes
- These values are mostly occuring within continental contexts
- This suggests the occurrence of crustal contamination, as the crust is enriched in these elements

Left: mean content of As and Sb in MORBs and continental crust.

Summarizing the K_2O trend







Sb, As and W distributions in TAS with K_2O

- Median value of Sb, As and W increases with K_2O
- This trend reflects both partial melting and crystallisation processes affecting the Sb, As and W content of magmatic rocks

Conclusion and perspectives

Conclusion

- Sb, As and W are strongly correlated in magmatic rocks
- Sb, As and W contents generally increase with K_2O content: a baseline most likely results from partial melting and crystallisation processes
  → Mantle partial melting decreases Sb, As and W contents in resulting basalts
  → Fractional crystallisation increases Sb, As and W contents along TAS series
- Out-of-baseline variability may be linked to crustal contamination, with no significant alteration effect
- Mafic melts associated with ore deposits are always above the baseline, suggesting metal enrichment through crustal contamination

Perspectives

- Investigate the crustal contamination role further (new geochemical tracers)
- Investigate fluid inclusion and melt inclusion data

References

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AUREOLE project data provided by **Pochon A.** (Le Semnon district) and **Campos H.** (Almadén and San Antonio districts).