The lower crust as a volatile reservoir: new constraints from the Talkeetna arc (Alaska)

Matthieu Sanchez (1), Véronique Le Roux (1,2), Laurette Piani (1), Peter H. Barry (2), Mike R. Hudak (3)

(1) Centre de Recherche Pétrographiques et Géochimiques, Université de Lorraine, CNRS, France (2) Woods Hole Oceanographic Institution, MA, US ; (3) Williams College, MA, US

This presentation participates in OSPP — Outstanding Student & PhD candidate Presentation contest

Poster abstract

1 Global flux of volatiles, ingassing or outgassing?

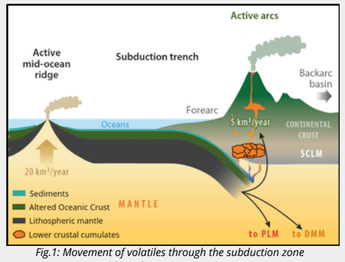


Fig.1: Movement of volatiles through the subduction zone (modified after Bekaert et al., 2021)

- **Subduction zones** are the primary pathway for **recycling volatiles** into the Earth's interior. Current models focus on volatile release through volcanism, often overlooking potential retention in **lower crustal cumulates**.
- We quantify **H_2O** and other volatiles (CO_2, S, Cl, F) in Nominally Anhydrous Minerals (**NAMs**) from the intraoceanic **Talkeetna arc section** (Alaska) using Secondary Ion Mass Spectrometry (**SIMS**).
- Our goal is to **assess the volatile storage capacity** of the lower crust and its implications for the **global volatile mass balance**.

Can the lower crust of arcs represent a significant, yet overlooked, reservoir in the global volatile mass balance?

→ **Net global ingassing of H_2O?**

→ **Need to study lower crustal cumulates**

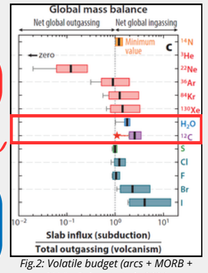


Fig.2: Volatile budget (arcs + MORB + PLM) ; Bekaert et al., 2021

2 Talkeetna intraoceanic arc section (Alaska)



Fig.4: Stratigraphic column of the Talkeetna arc section

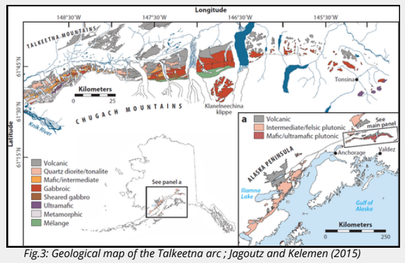
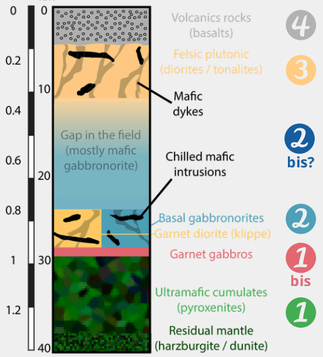


Fig.3: Geological map of the Talkeetna arc ; Jagoutz and Kelemen (2015)



- Emplaced during the early **Jurassic (210 - 180 Ma)**
- Accreted to the North American plate in the Cretaceous
- Undergone **tectonic uplift and tilt 50Ma ago**

→ **One of the two most well exhumed arc sections in the world**

3 Samples and analytical methods

LG-SIMS NANCY

Adcumulate texture with equigranular crystal growth

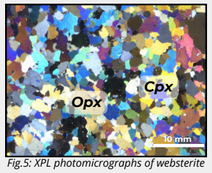


Fig.5: XPL photomicrographs of websterite

LG-SIMS IMS1280 - HR2



Fig.6: LG-SIMS at CRPG, Nancy, France

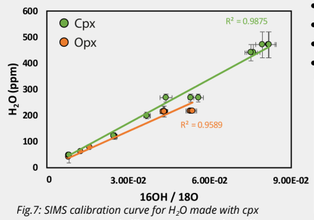


Fig.7: SIMS calibration curve for H_2O made with cpx and opx standards of differents concentrations (1)

- $P_{chamber}$: **5 x 10^{-10} mbar**
- Primary beam: Cs^+ / 2nA
- Background = **5.5 ppm H_2O**
- Spot size = 10 to 5 µm

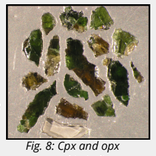


Fig. 8: Cpx and opx mounted in indium

SIMS (volatiles) + **EPMA** (major) + **LA-ICPMS** (trace)

n = 271

4 High H_2O contents in pyroxenes → magmatic origin of volatiles?



Ultramafic · Basal Gabbro · Garnet Gabbro · Garnet Diorite · ○ CPX · △ OPX

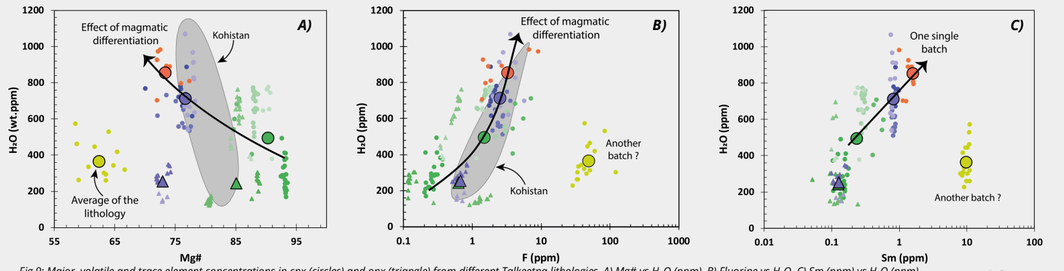


Fig.9: Major, volatile and trace element concentrations in cpx (circles) and opx (triangle) from different Talkeetna lithologies. A) Mg# vs H_2O (ppm), B) Fluorine vs H_2O, C) Sm (ppm) vs H_2O (ppm)

→ **Clinopyroxene from the arc lower crust can store H_2O concentrations up to 1000 ppm**

→ **All cumulate lithologies of Talkeetna are derived from a single batch of hydrous melt**

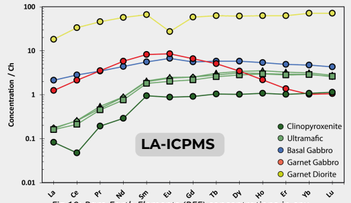


Fig.10: Rare Earth Elements (REE) concentrations in cpx

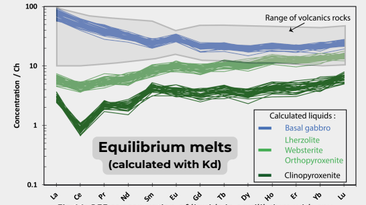


Fig.11: REE concentration of liquids in equilibrium with cpx

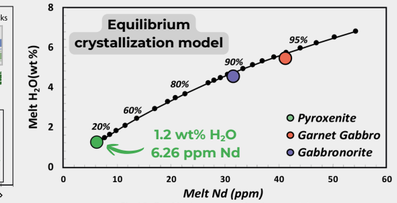


Fig.12: Equilibrium crystallization model

→ **A primary melt can reach around 6 wt% H_2O after 95% crystallization**

5 Budget of the lower crust of Talkeetna

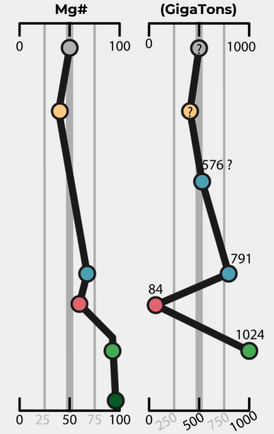


Fig. 14: A) Whole-rock Mg#, B) H_2O concentrations in NAMs from different lithologies

Estimated proportions of lithologies in the lower crust of Talkeetna (2) :

- **Mafic gabbronorite → 30 %**
- **Basal gabbronorite → 22 %**
- **Garnet gabbro → 5 %**
- **Ultramafic → 18 %**

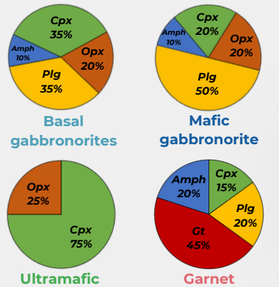


Fig. 13: Modal proportions of each lithologies

6 The lower crust: an overlooked reservoir in the global volatile mass balance

- Based on volume and concentration estimates, we quantify the **contribution of the lower arc crust** to the **global volatile mass balance**

Lower arc crust may store 1 to 9 % of slab-derived H_2O*

- Lower crustal cumulate storage represents a **non-negligible volatile reservoir** and **must be considered** to obtain a more exhaustive estimation of the global volatile flux balance

** Estimates in progress*

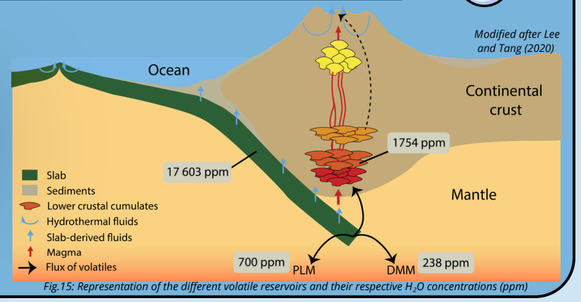


Fig.15: Representation of the different volatile reservoirs and their respective H_2O concentrations (ppm)

References

D.V. Bekaert, S.J. Turner, M.W. Broadley, J.D. Barnes, S.A. Halldórsson, J. Labidi, J. Wade, K.J. Walowski, P.H. Barry. 2021. Subduction-Driven Volatile Recycling: A Global Mass Balance. Annual Review Earth and Planetary Sciences. 49:37-70

Oliver Jagoutz, Peter B. Kelemen. 2015. Role of Arc Processes in the Formation of Continental Crust. Annual Review Earth and Planetary Sciences. 43:363-404.

(2) Rezeau, H., Jagoutz, O. E., Beaudry, P., Izon, G., Ono, S., & Kelemen, P. B. (2022, December). Sulfur isotope fractionation during arc crust formation and differentiation: Evidence from the Talkeetna island arc, south-central Alaska. In AGU Fall Meeting Abstracts (Vol. 2022, pp. V42G-0138)

Cin-Ty A. Lee, Ming Tang, How to make porphyry copper deposits, Earth and Planetary Science Letters, Volume 529, 2020, 115868, SSN 0012-821X

SIMS standards (1)

Kumamoto, K. M., Warren, J. M., & Hauri, E. H. (2017). New SIMS reference materials for measuring water in upper mantle minerals. American Mineralogist, 102(3), 537-547.

Peslier, A. H., Luhr, J. F., & Post, J. (2002). Low water contents in pyroxenes from spinel-peridotites of the oxidized, sub-arc mantle wedge. Earth and Planetary Science Letters, 201(1), 69-86.

Mosenfelder, J. L., & Rossman, G. R. (2013). Analysis of hydrogen and fluorine in pyroxenes: I. Orthopyroxene. American Mineralogist, 98(5-6), 1026-1041.

Mosenfelder, J. L., & Rossman, G. R. (2013). Analysis of hydrogen and fluorine in pyroxenes: II. Clinopyroxene. American Mineralogist, 98(5-6), 1042-1054.

matthieu.sanchez@univ-lorraine.fr