New Methods for Tracking Regional and Global Crustal Changes Using the Geochemical Record of Magmatic Rocks and Their Derivative Sediments

Final Report 2022

UEFISCDI PCCF 2016_14

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Products

Over 60 high profile publications in Q1 journals

Over 85 peer reviewed publications total

Student, postdoc first authors and authors

New user friendly code for applications (GAME)

Public databases of magmatic rocks for the Andes and Carpathians

Progress in regional geology of the following areas: Apuseni, Calimani-Gurghiu-Harghita

Dissemination of geology to highschools and non scientific venues

New analytical techniques developed for project and beyond

New laboratory facility at U Bucharest

International Collaboration

- Collaborated with 17 groups over the course of the project
- Participated at 22 international conferences
- Articles co authored with 424 individual foreign authors and 45 non project members from Romania
- Articles co authored with researchers from 27 countries
- 15 foreign presentations at high profile institutions and conferences as guest/invited lecturers

Field work

- Field mapping and expeditions carried out in the following parts of the Carpathians: Persani-Mountains, Calimani-Gurghiu Harghita region, Retezat Mountains, Fagaras Mountains, Apuseni Mts.
- Field mapping carried out in Mongolia (Gobi Tianshan) Western US (Arizona, Nevada, Utah), the central Andes (Argentina and Chile)

Dissemination

- Promoted geology at High-schools in Bucuresti, Craiova, Sibiu, Abrud, Brad
- Toured with several K-12 children groups the Romanian national Geologic Museum
- Promoted the project in interviews for Stiinta si Tehnica, Edupedu.ro, Radio Romania Cultural
- Promoted project results and the UEFISCDI at major geological international conferences such as Goldschmidt, Geological Society of America, American Geophysical Union, European Geoscience Union, CBGA Association, IAVCEI Association.

Dissemination efforts: touring with children at the Romanian National Geologic Museum;
Conferences during the week of Geology, october 2022.

Doctoral and MS students, Teaching

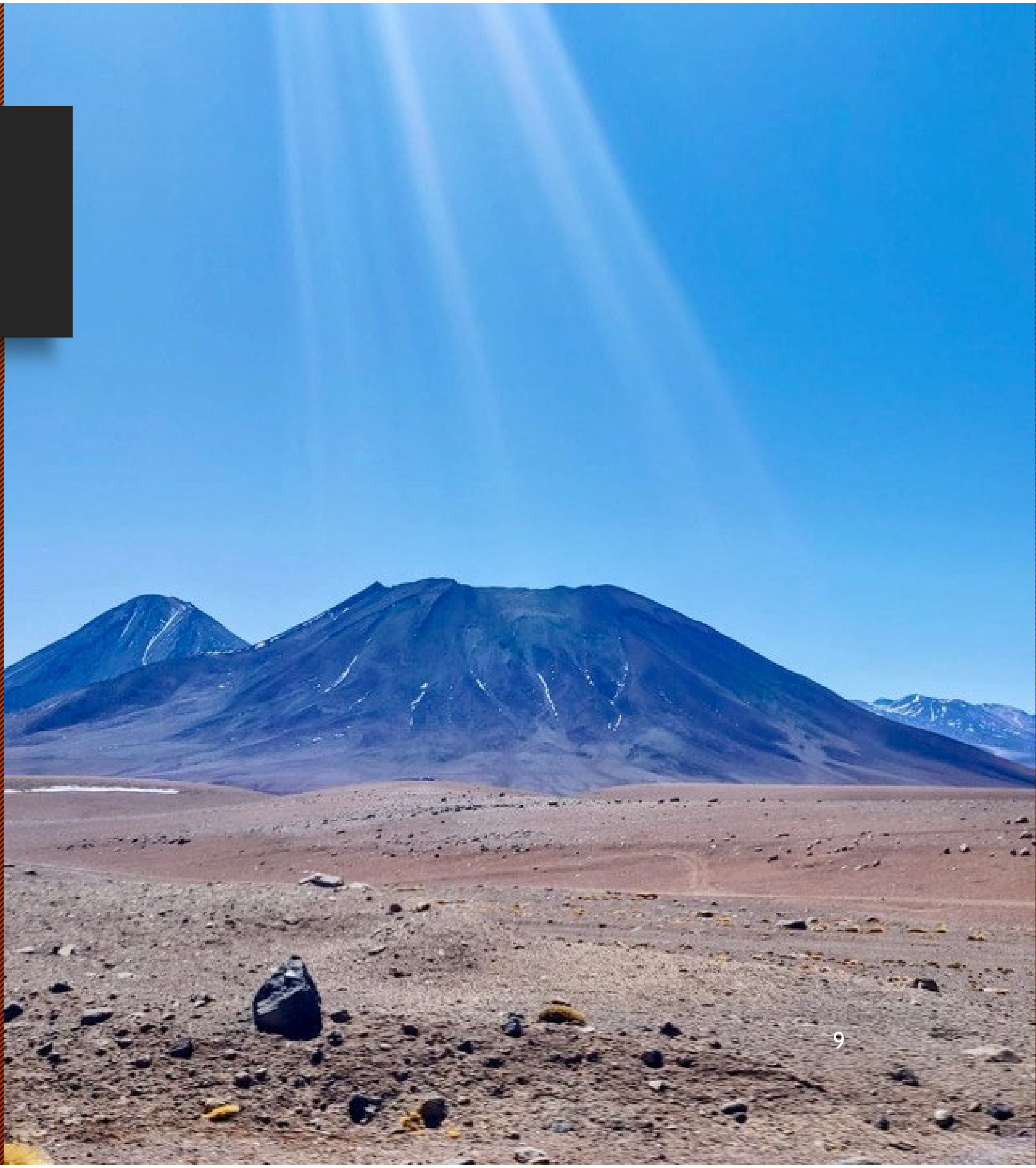
- 5 PhD students trained in this project
- 2 postdocs directly collaborated and worked on the project
- New MS course „Regional Tectonics" and new course „Tectonic Petrology" taught at University of Bucharest since 2020
- Over 10 undergraduate students engaged in field work in the Carpathinas during the course of this project

Work-packages

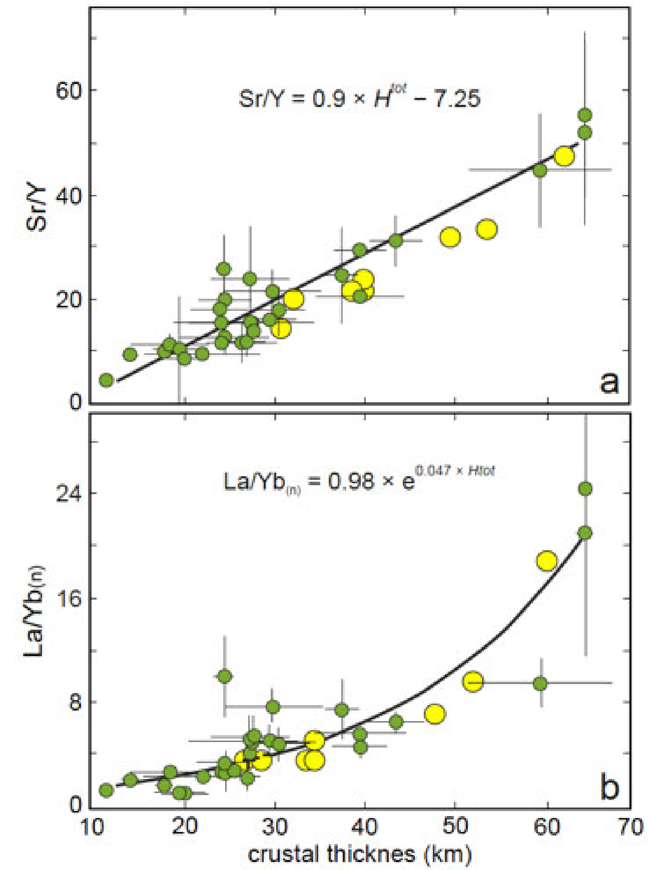
- 1. Calibrations
- 2. Whole rock applications in subduction
- 3. Applications to collision
- 4. Extending to zircon
- 5. Beyond zircon: titanite

Pathway for project execution

- A first order understanding why geochemistry of arc rocks follows crustal thickness and elevation
- Real world correlations in modern day arcs help us reconstruct thickness of crust and paleo-elevations in the continental crust
- We can do that within-orogens or globally with detrital data
- Examples that test our models
- Examples from the geologic past
- Easing data manipulation with an app – GAME

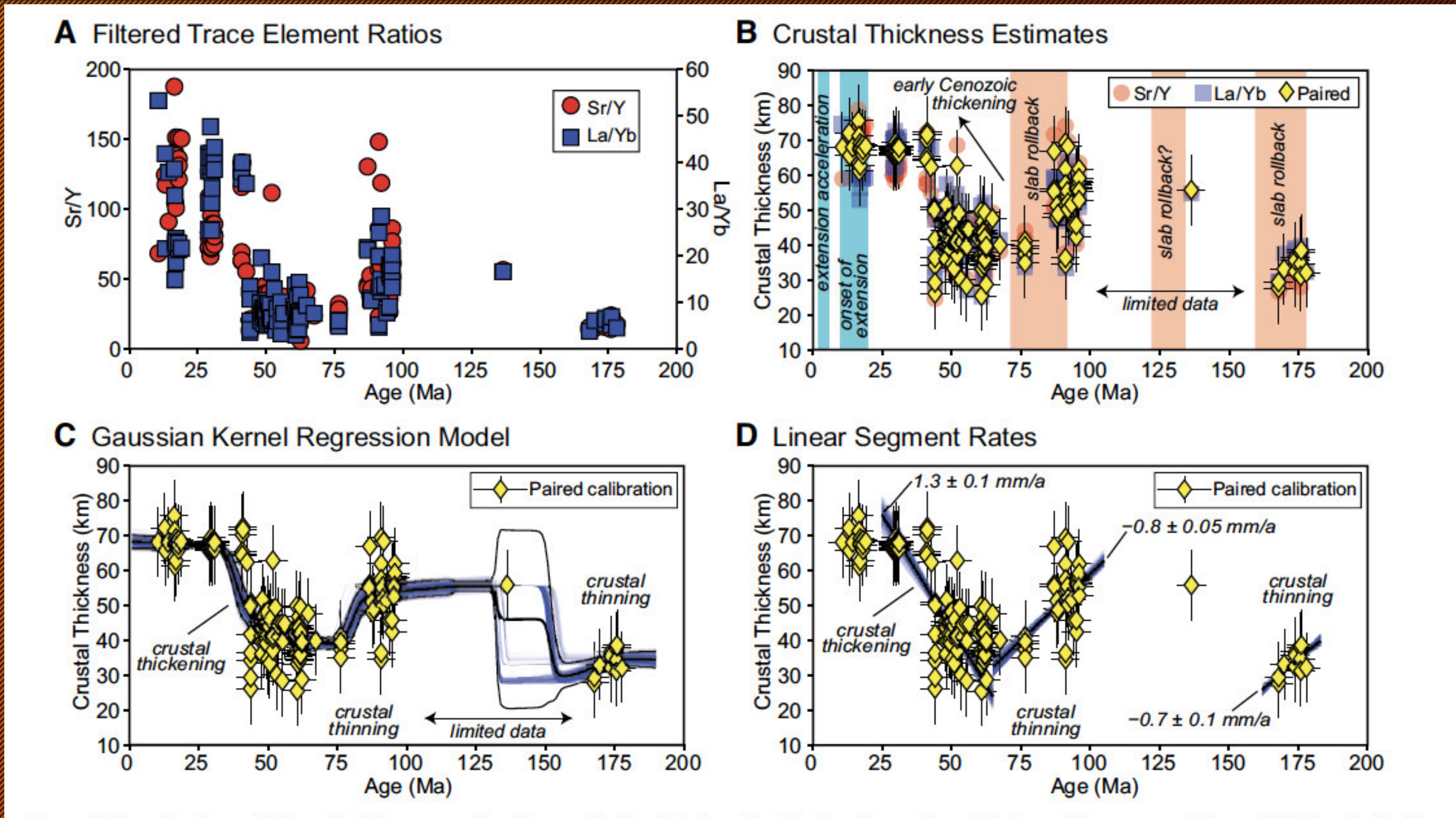


Our earlier efforts just prior to proposal submission



Profeta et al., 2015; Chapman et al., 2015

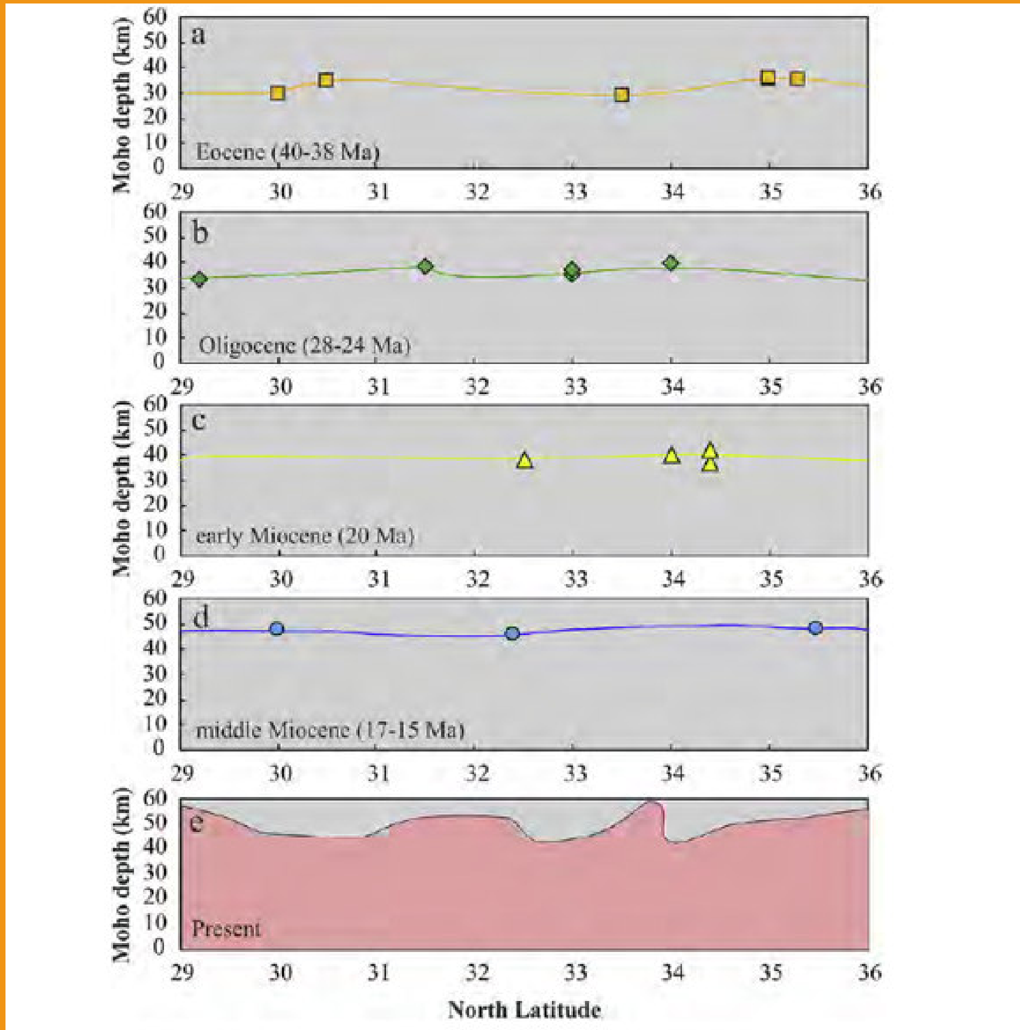
New Application s – Mohometry on Tibet



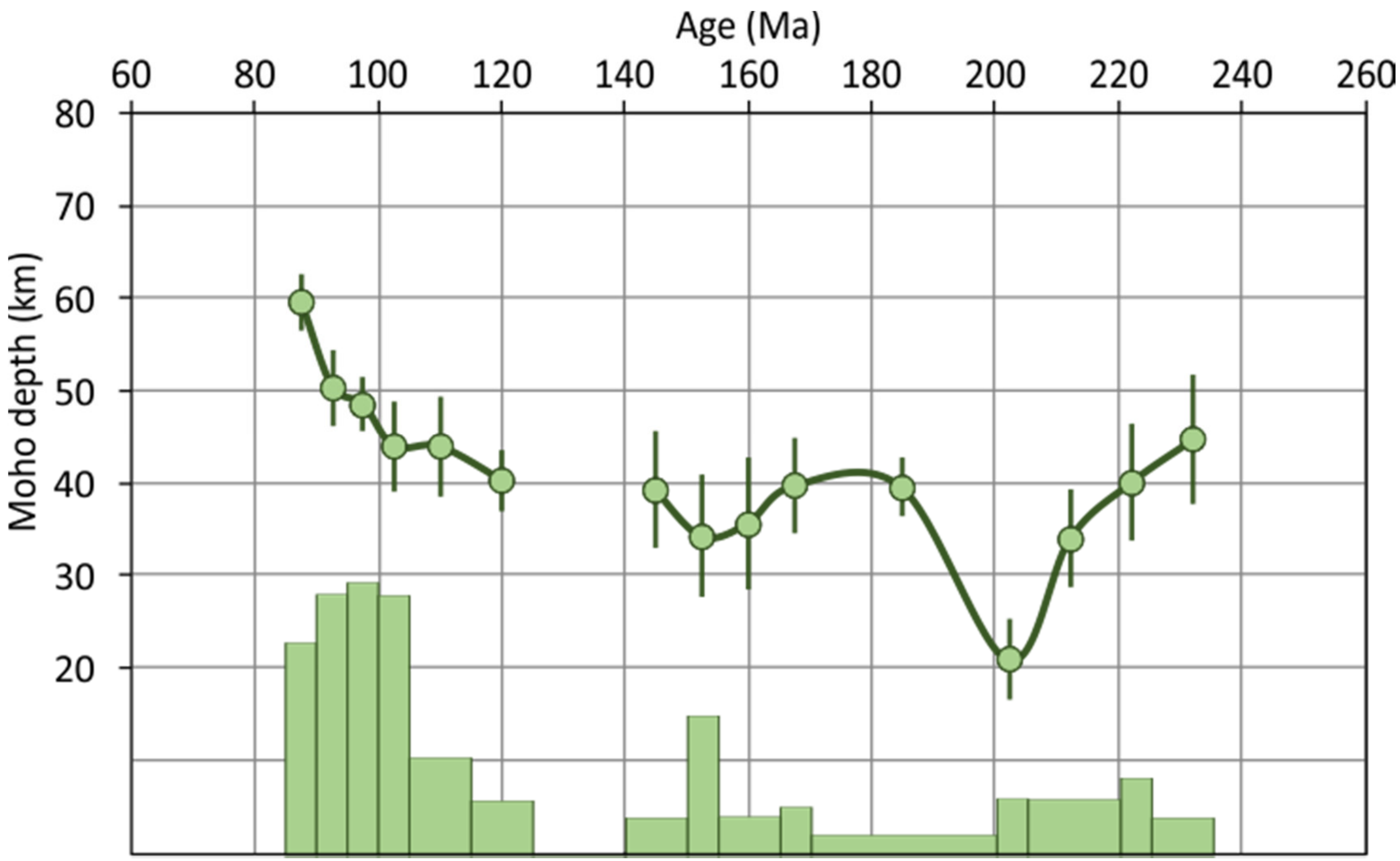
Sundell et al., 2021

Mohometry in Iran-

Chaharlang, Ducea et al., 2021



Mohometry of the Sierra Nevada



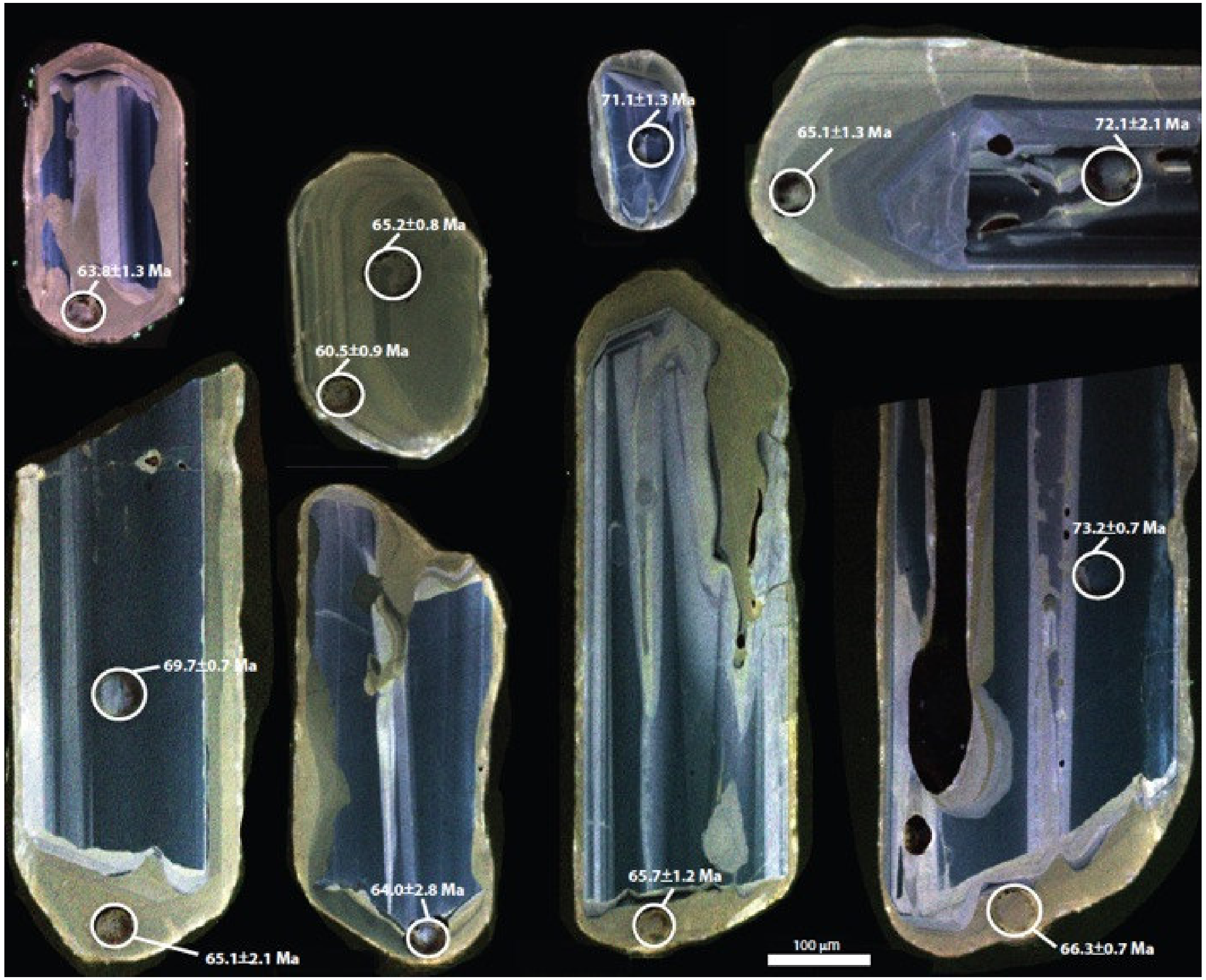
Luffi and Ducea, 2022

And many other examples published by us

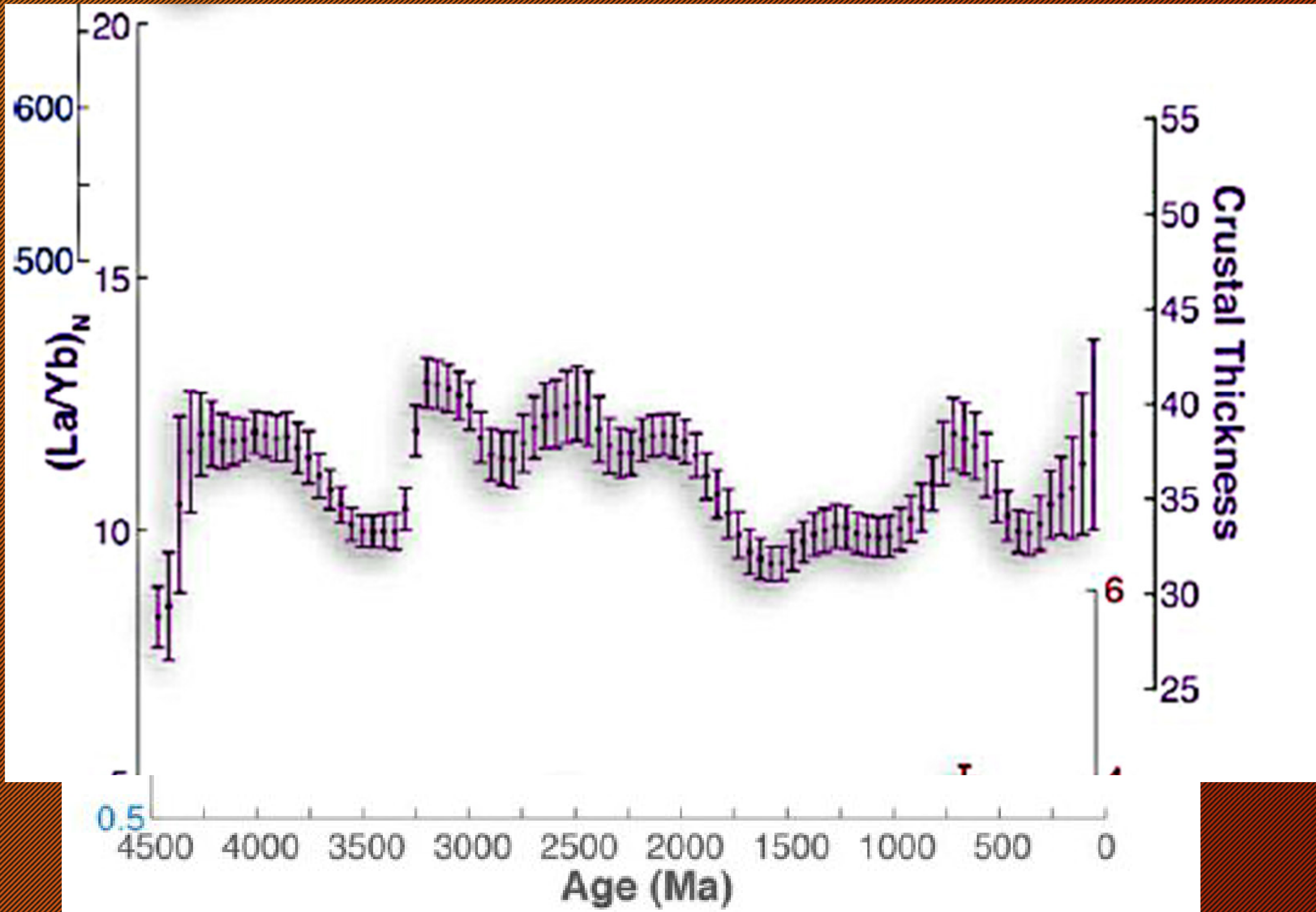
- Central Andes
- Mongolia
- Tibet
- Western North America
- Romania
- Mainland China
- Ancient orogens of Morroco and Tunisia

… onto mineral mohometry next

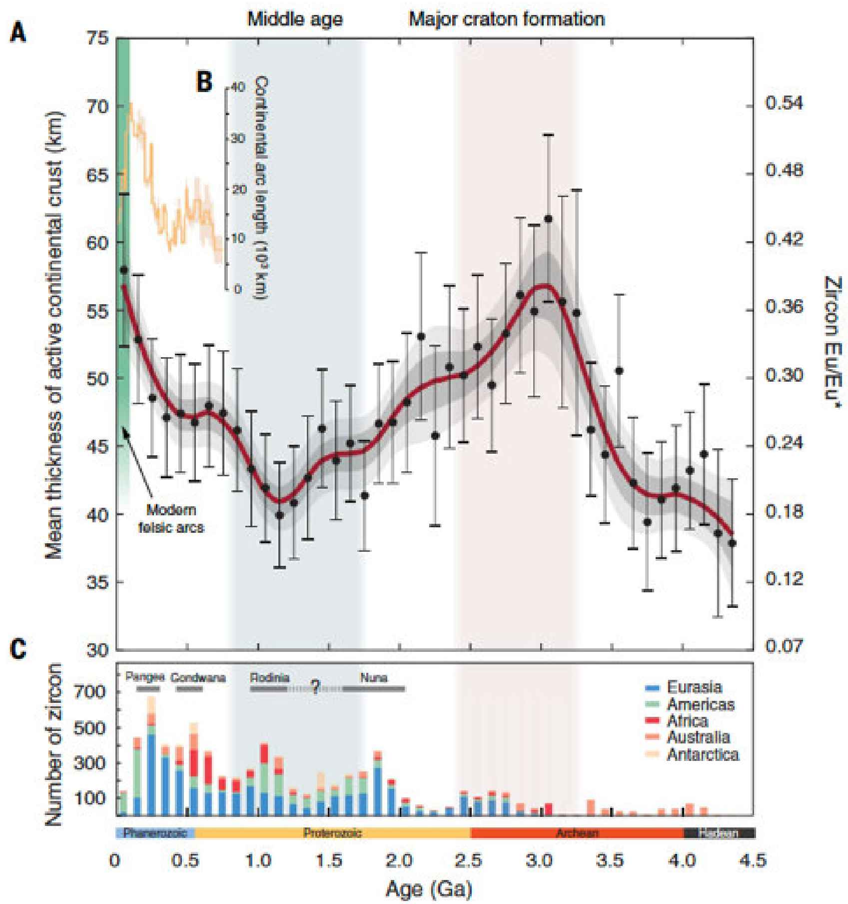
Zircon Proxies



Balica et al., 2020

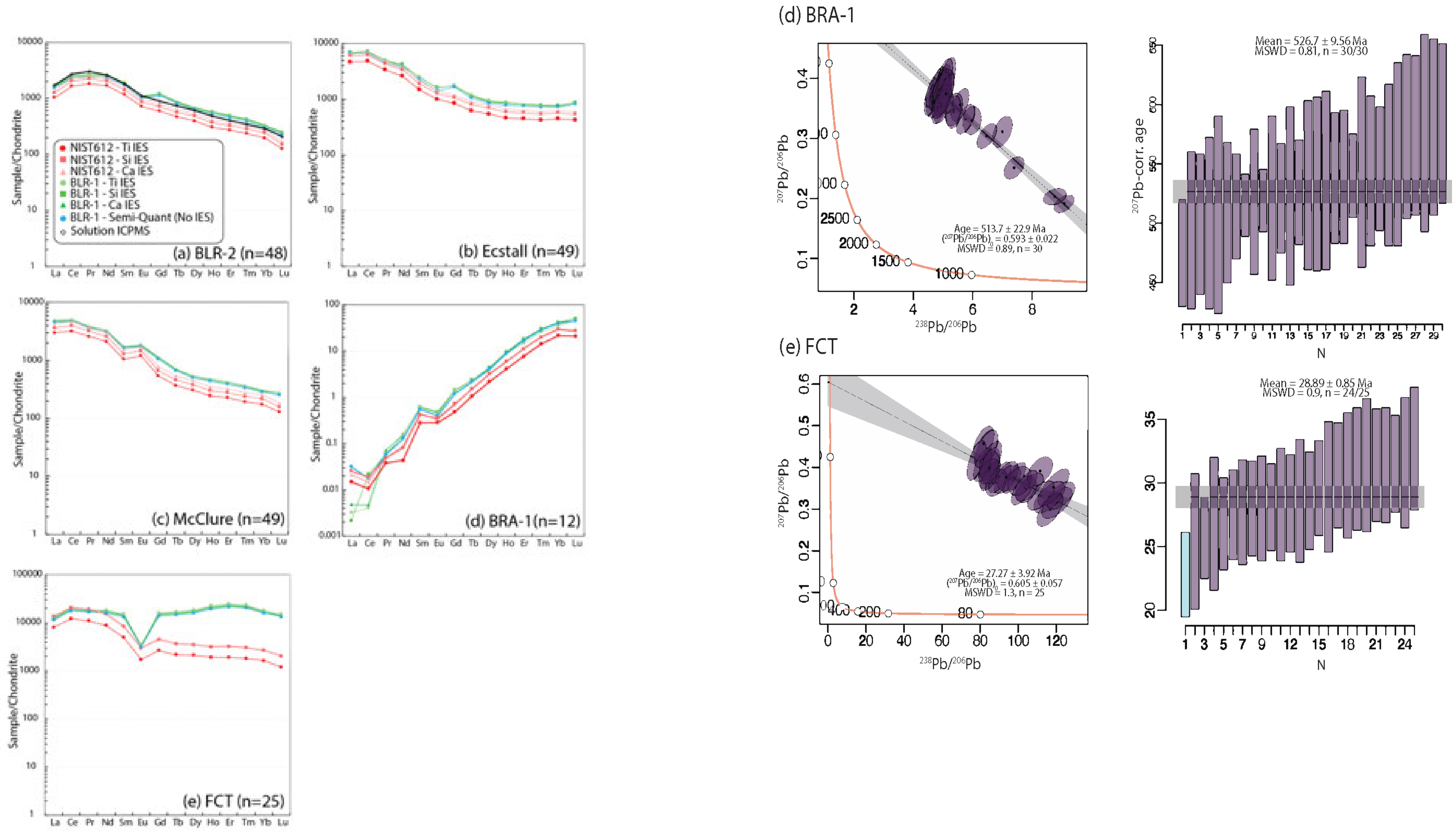


Global crustal thickness over time (Balica et al,., 2020)



Tang et al., 2021

New Petrochronology tools: Titanite comes in focus



Barla et al., 2022

New Mohometers and Paleoaltimeters

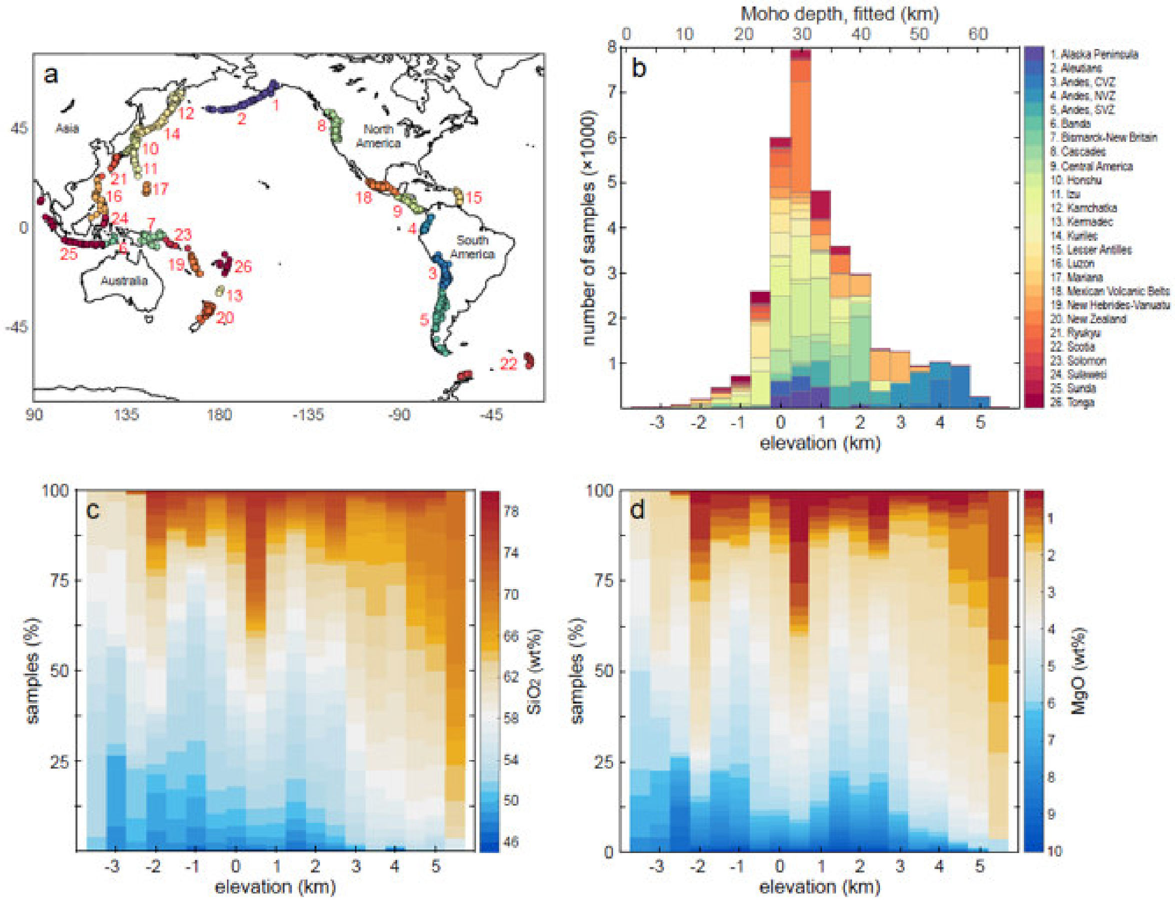
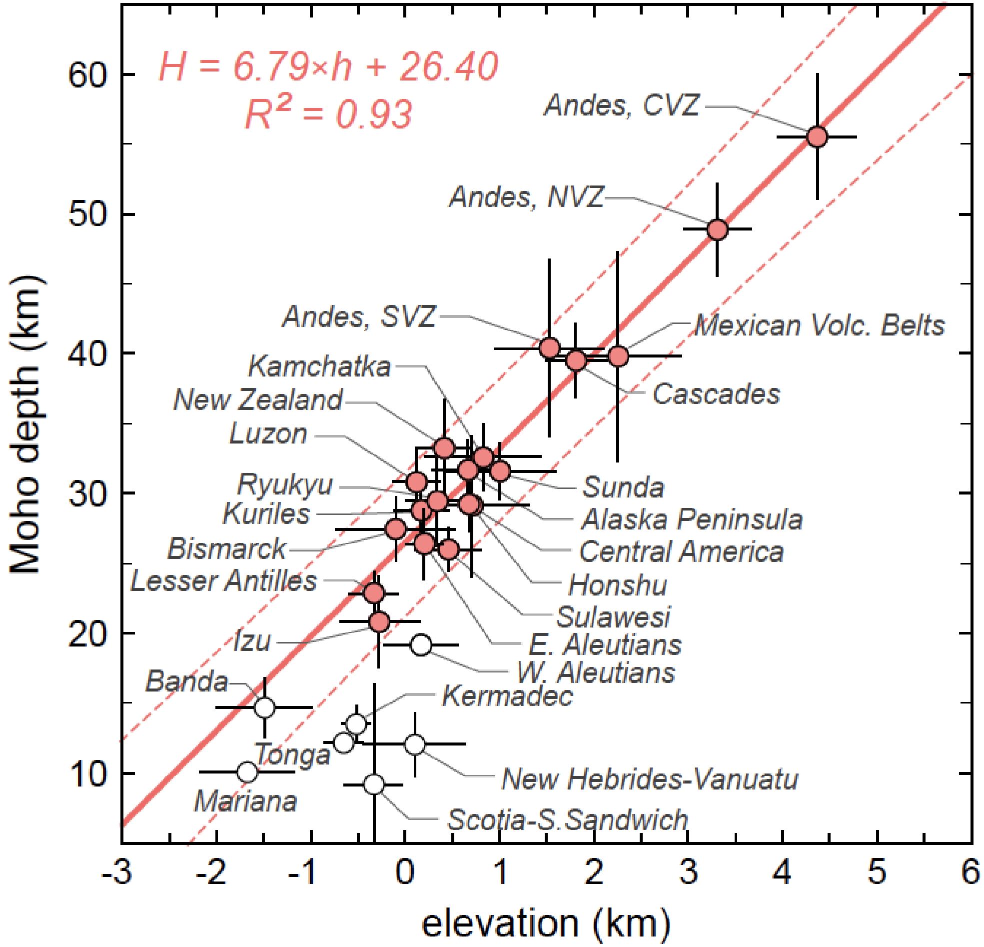
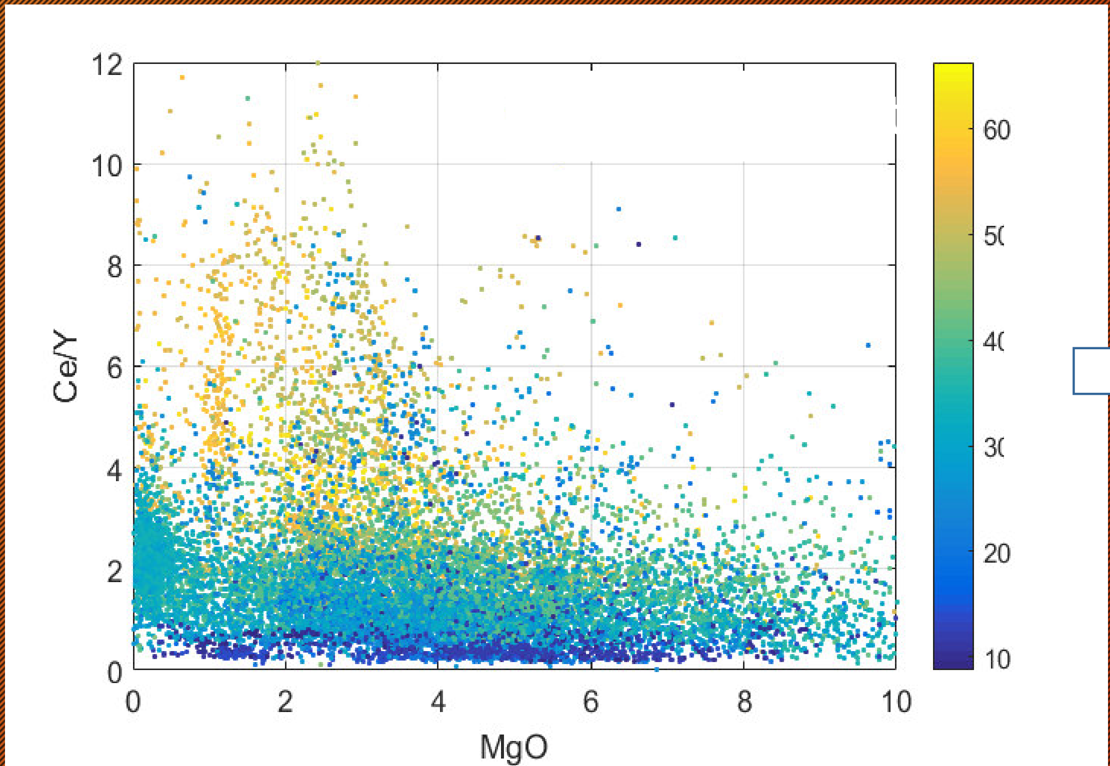


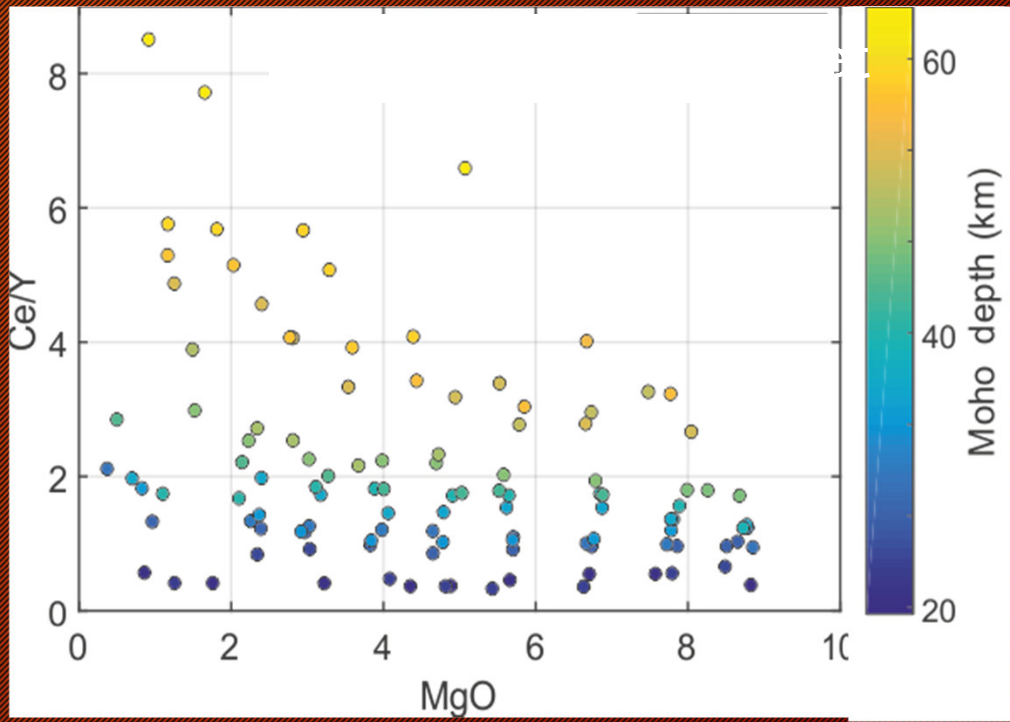
Figure 12. Global arc data set: (a) geographic distribution; (b–d) stacked histograms showing the distribution of sampled elevations as a function of arc segments (b), (c) SiO_2, and (d) MgO. Moho depth in panel (b) is fitted to elevation using Equation 17. Numbering of arc segments in panel (a) corresponds to list in panel (b). Abbreviations: CVZ—Central Volcanic Zone, NVZ—Northern Volcanic Zone, SVZ—Southern Volcanic Zone.

Global elevation crustal thickness correlations



Data filtering techniques





A new technique for fractionation dependent mohometers (Luffi and Ducea, 2022)

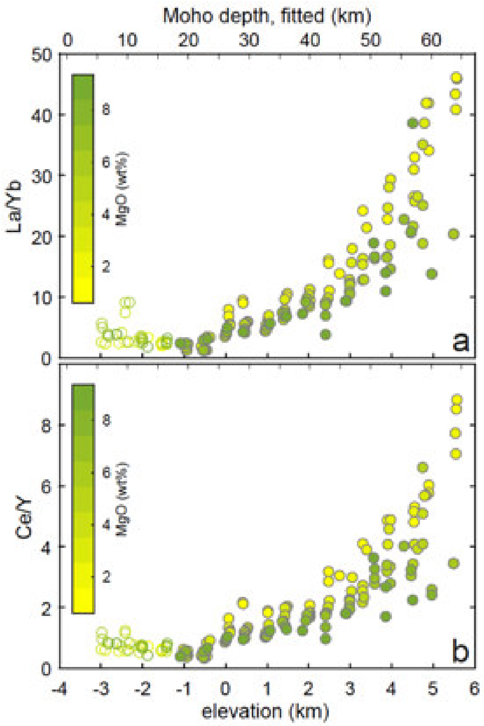
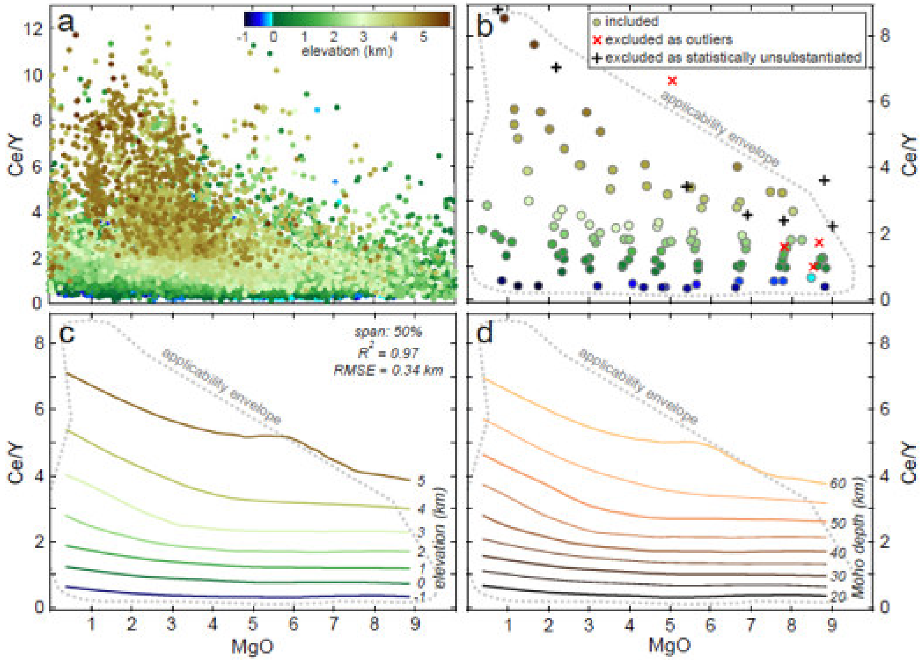
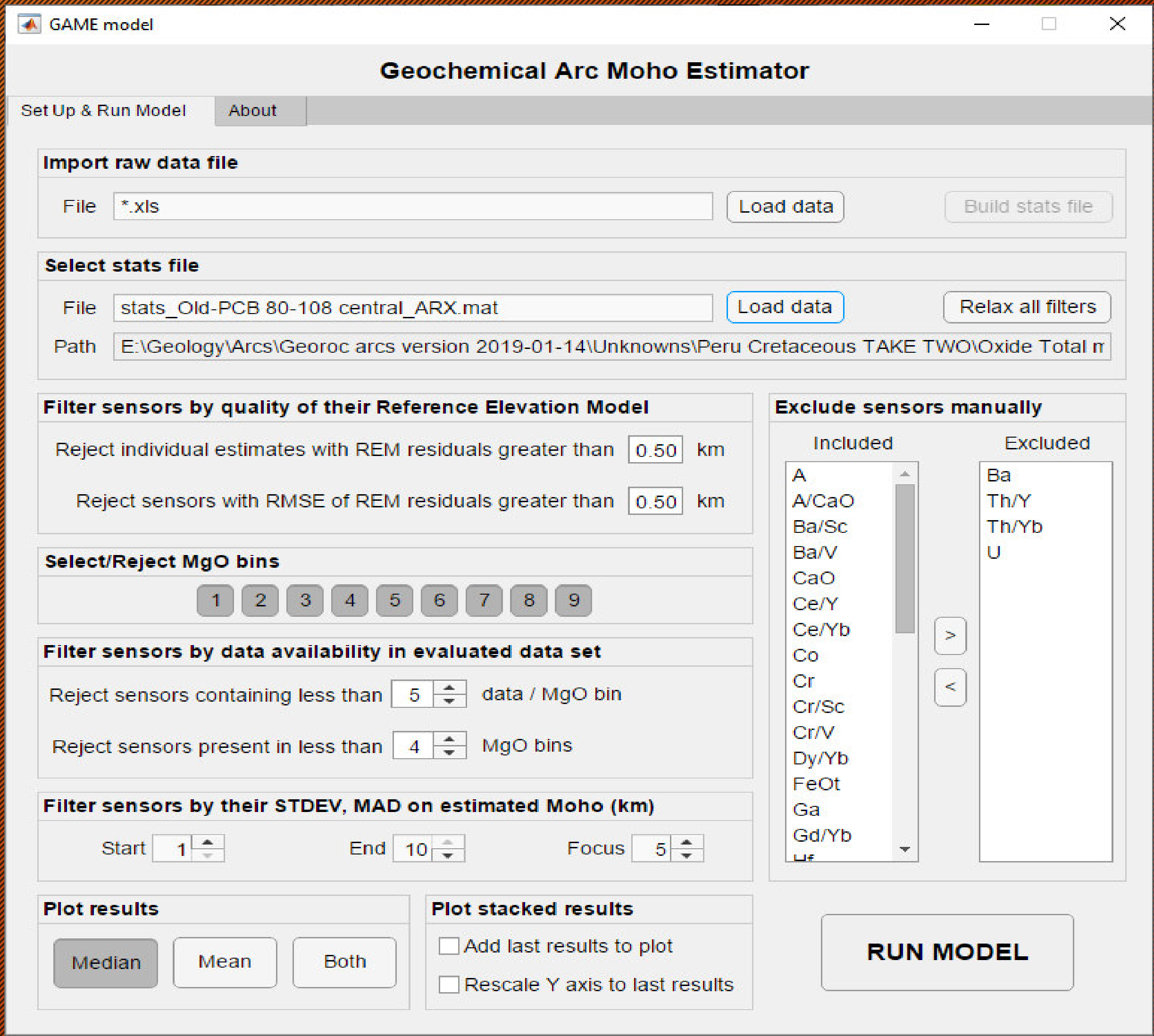


Figure 15. MgO-binned median La/Yb (a) and Ce/Y (b) versus elevation and Moho depth (fitted using Equation 17). The two ratios are representative of a series of chemical parameters of which sensitivity to crustal thickness variations is important in arcs thicker than 15–20 km but becomes insignificant in thinner arcs and thus cannot distinguish these (empty symbols) at any MgO.



GAME- a MATLAB code for project results



Results- Example, Vanuatu Arc, New Hebrides

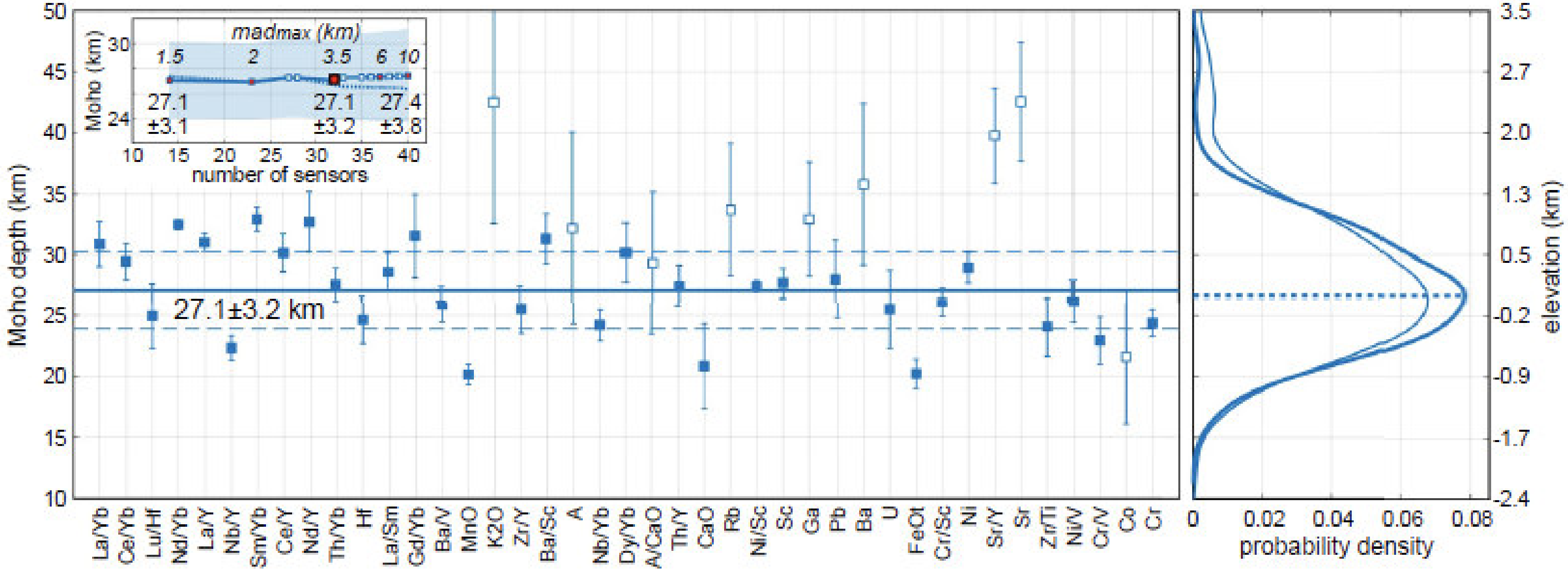
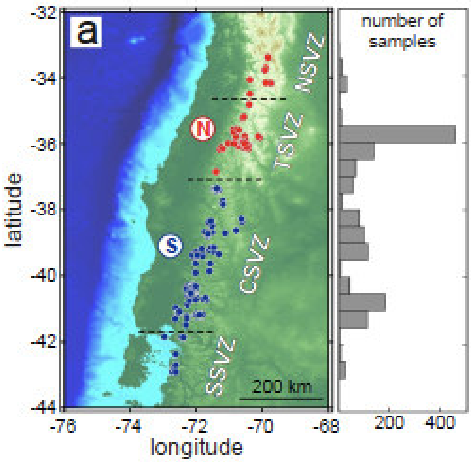
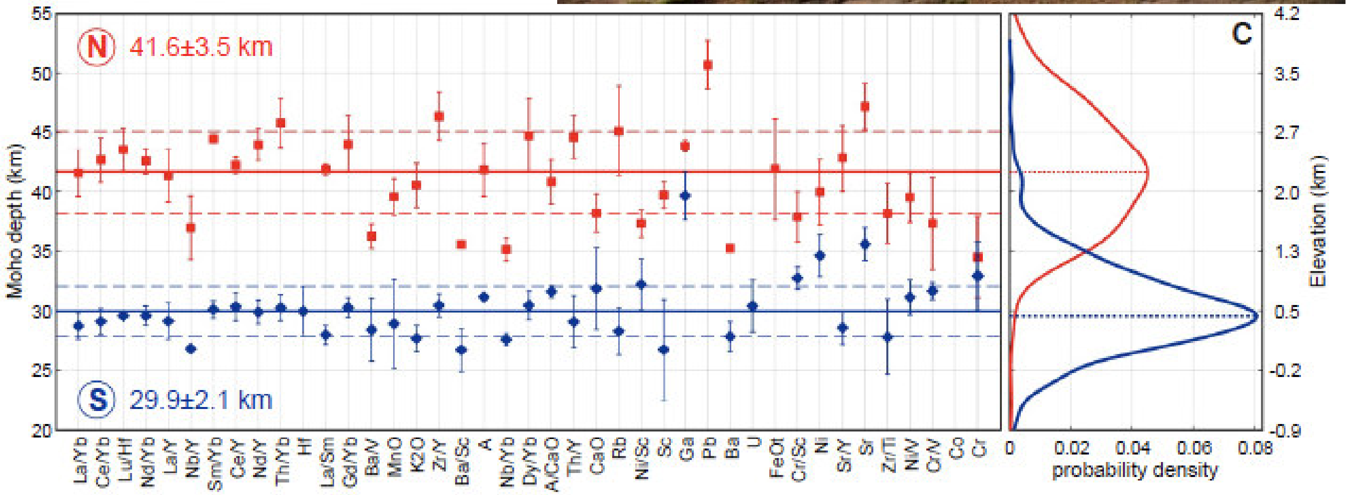


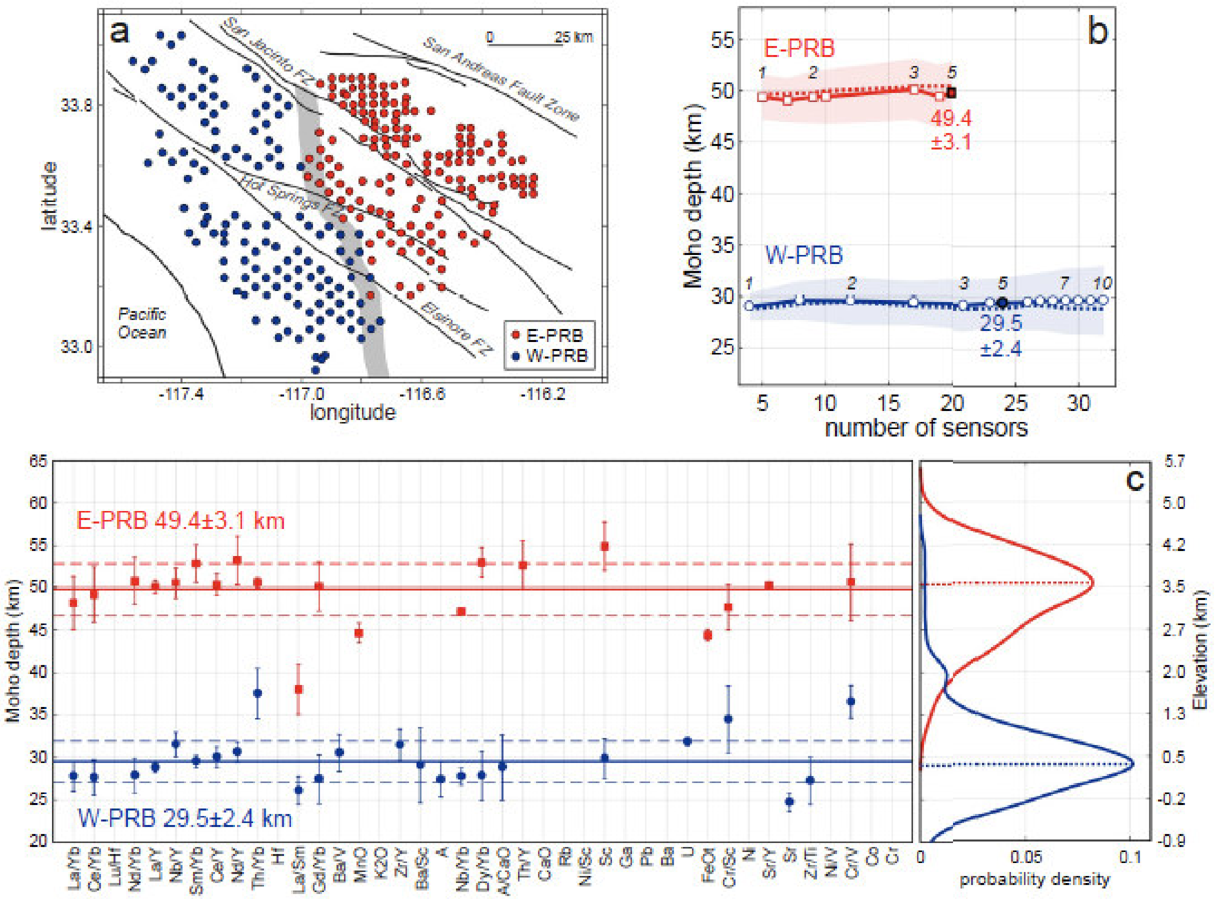
Figure 24. Chemical mohometry of the New Hebrides–Vanuatu arc. Left panel: $H_X \pm MAD_X$ estimates of individual mohometers. Estimates shown as filled symbols were obtained using $\epsilon_{max} = 0.75$ km, $rmse_{max} = 0.5$ km, and $mad_{max} = 3.5$ km; $H_M \pm MAD_M$ are shown as continuous and dashed horizontal lines, respectively. Empty symbols indicate additional estimates that are obtained by relaxing ϵ_{max}, $rmse_{max}$, and mad_{max} to 1.5, 1, and 10 km, respectively. Right panel: probability density distribution of individual estimates obtained in the two cases (thicker curve corresponds to the restricted setup); dotted line marks the peak of the curves. Inset in left panel shows the effect of mad_{max} on $H_M \pm MAD_M$ (continuous line and shaded band), and peak of probability density distribution (dotted line) at $\epsilon_{max} = 0.75$ km and $rmse_{max} = 0.5$ km. Selected mad_{max} (in italics) and resulting $H_M \pm MAD_M$ values are shown for reference. For example, setting mad_{max} to 1.5 km retains 14 mohometers, which yield $H_M \pm MAD_M = 27.1 \pm 3.1$ km. Further details and discussion in text.

Example – Andes Mts.

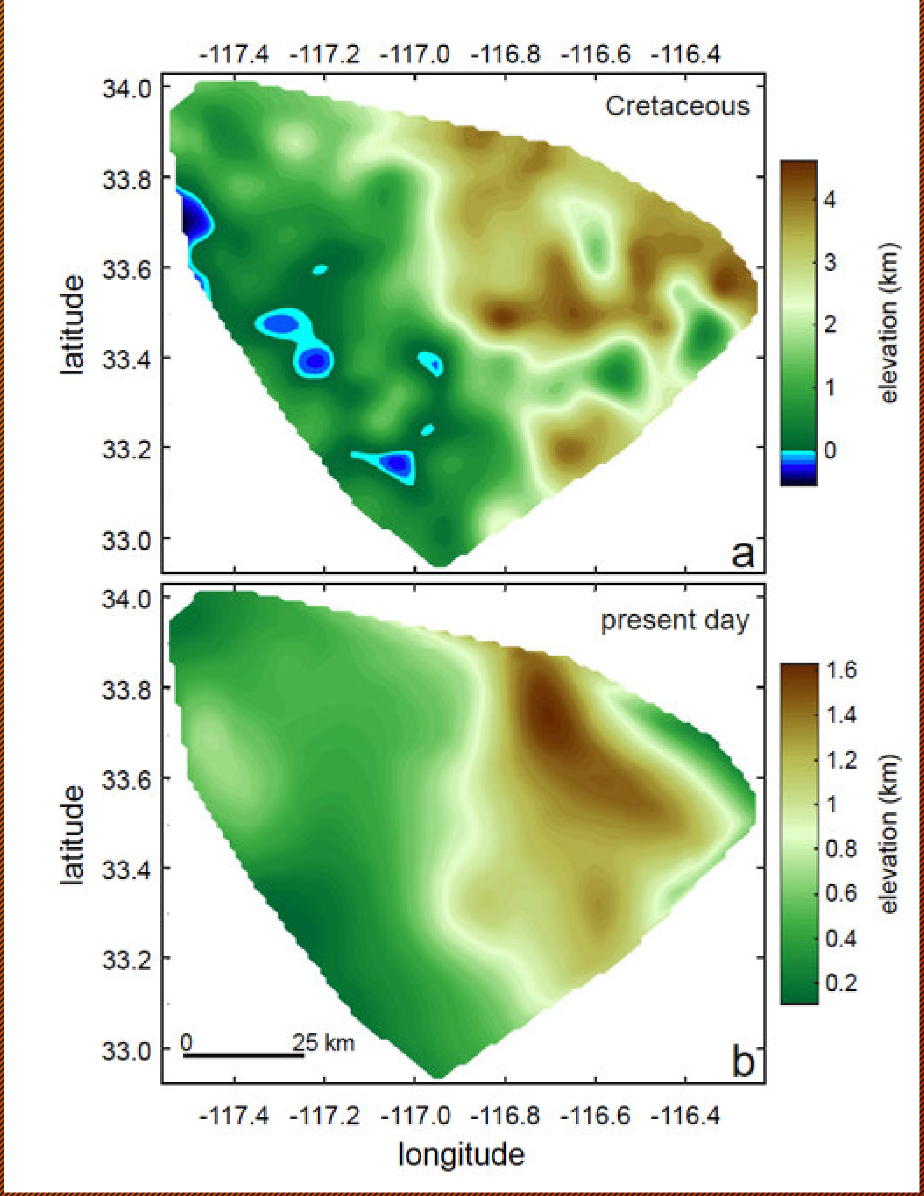




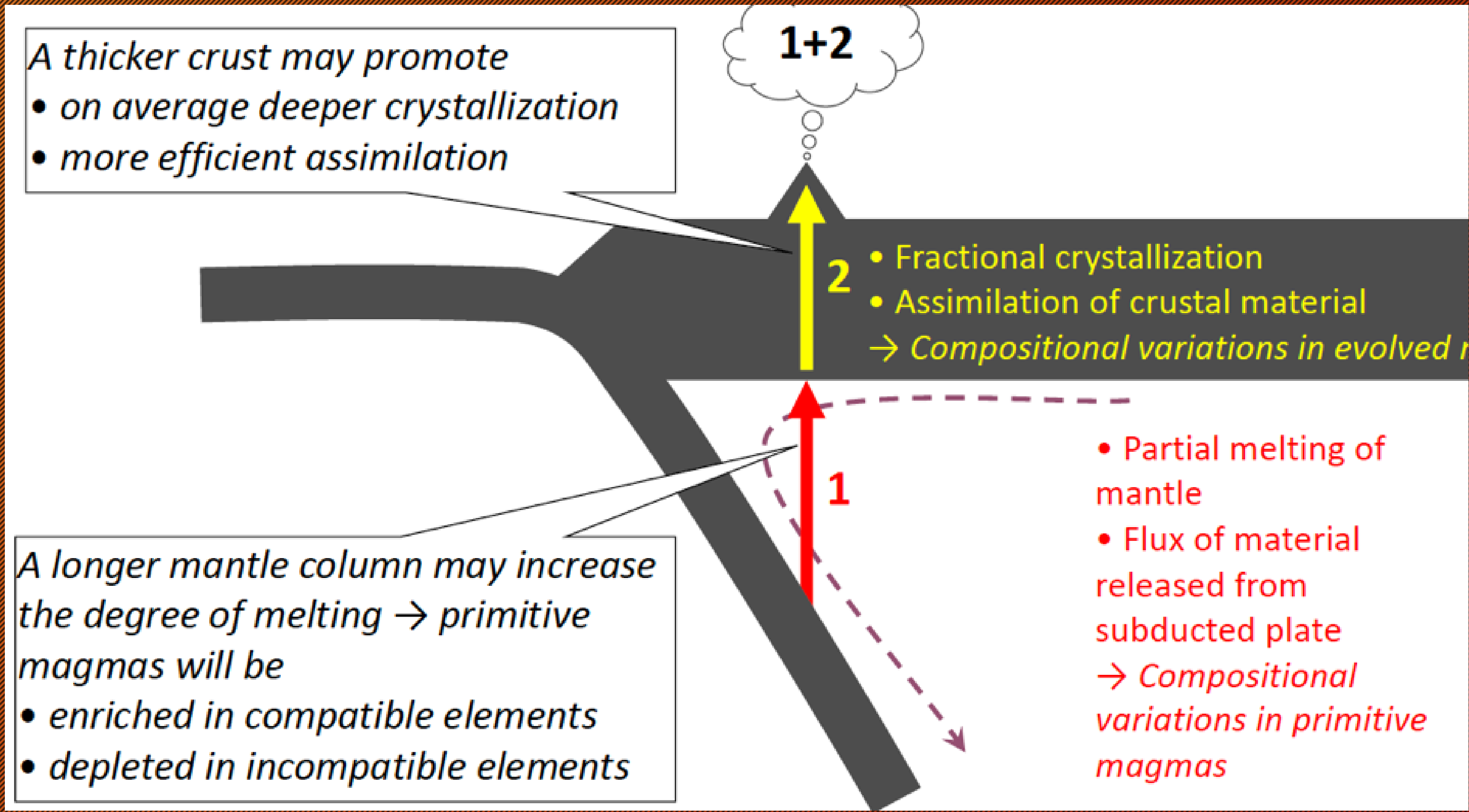
Peninsular Ranges, Baja, Mexico



Applications to **paleo-elevation, Baja**



What causes mohometers to work ?



Role of various elements in the mantle and crust

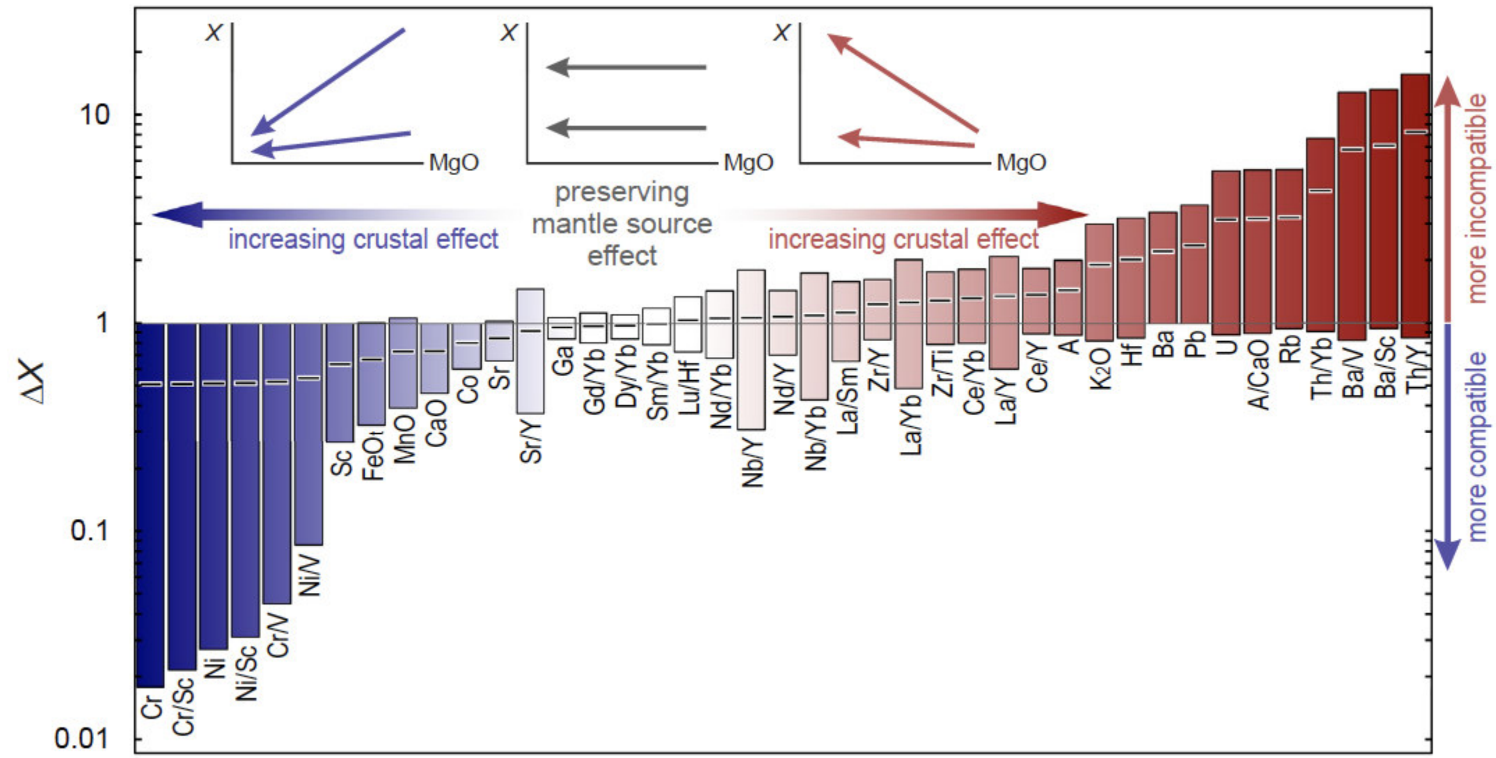
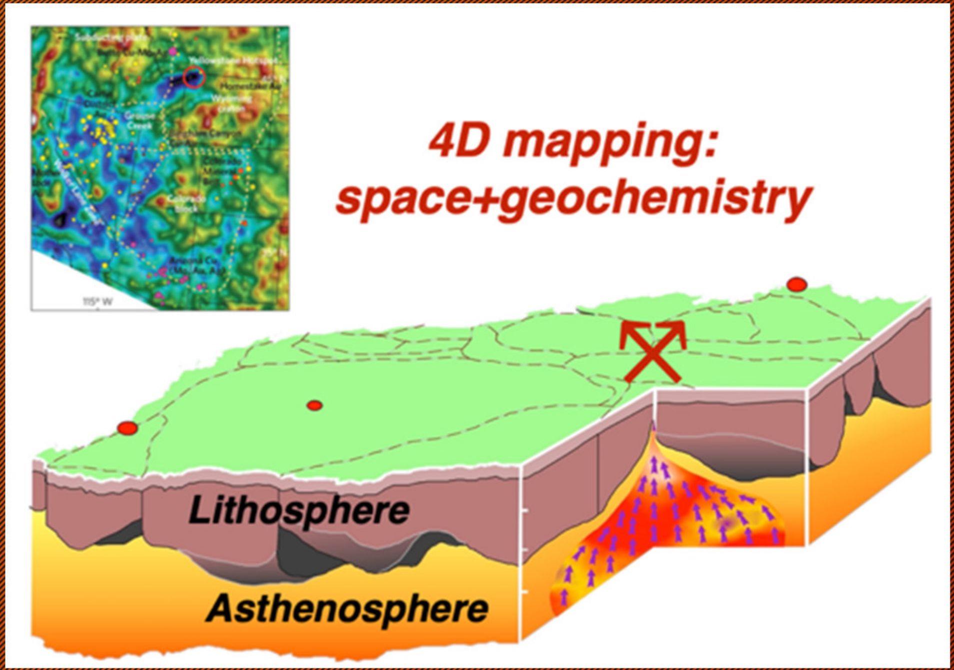


Figure 29. Total variability intervals of mohometers, ΔX, sorted by their midpoint value (marked on each bar). The resulting order mirrors the variable effect of crustal differentiation on the behavior of mohometers as shown. Inset diagrams schematically illustrate the different MgO–X trends of compatible, incompatible, and neutral mohometers.

Luffi and Ducea, 2022



Economic deposits are not random, they depend on crustal architecture

Thicker crust is correlated with most copper deposits

- Our future efforts (beyond this project) are to be applied to understanding ore deposit distribution in space and time

Conclusions

- Chemical mohometry is now a mature tool in petrotectonics
- Over 40 geochemical mohometrs are available and can be combined into providing a robust set of estimations for paleo crustal thickness
- Since continental crust is usually in isostatic equilibrium, crustal thickness is proportional with elevation; estimates of paleo-elevations are of great interest in the community
- The Matlab app GAME is an aid for ingesting data and generating paleo moho and paleo elevation calculations
- We have a good overall understanding what processes generate (either in the crust or mantle) the correlations we see in natural samples.