Computing Rates and Distributions of Rock Recovery in Subduction Zones

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paper

github

Introduction

- High-pressure (HP) rocks record subduction interface behavior, but **small sample sizes of exhumed HP rocks make statistical inference weak**
- Inferring rates and distributions of rock recovery from subduction zones with statistical robustness is possible by tracing markers in geodynamic numerical models

Methods

- Classifying unlabeled markers as "recovered" or "not recovered" using their pressure-temperature (PT) traces **defines an unsupervised classification problem**
- Gaussian Mixture Model (GMM) clusters markers into groups and assign labels to GMM groups

Results

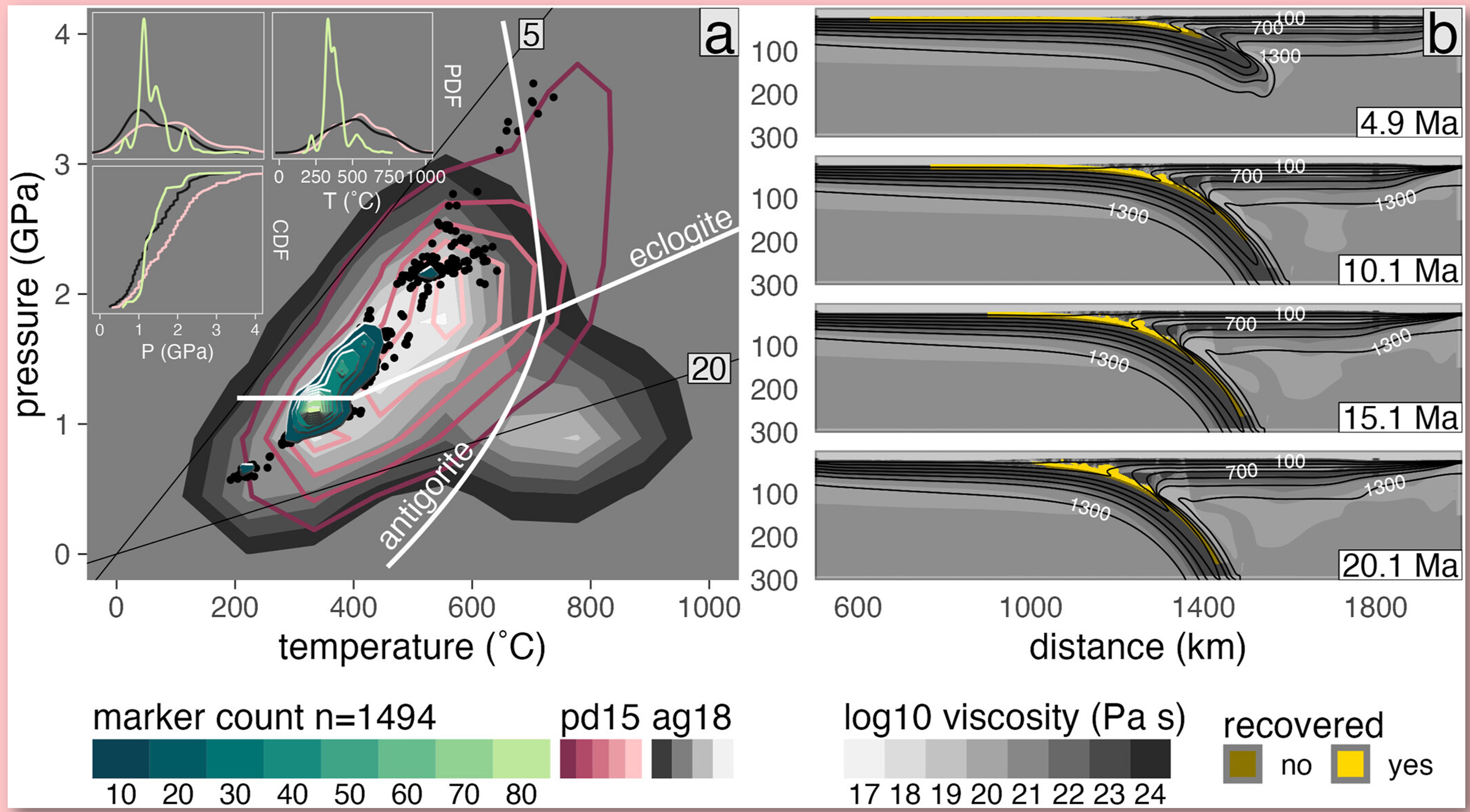
- Markers show **discrete multimodal PT distributions**
- Across 64 numerical experiments with wide-ranging initial conditions less than 1% of markers are recovered from between 1.8 and 2.2 GPa and 475–625°C

Discussion

Why might this gap occur? Four possibilities are considered:

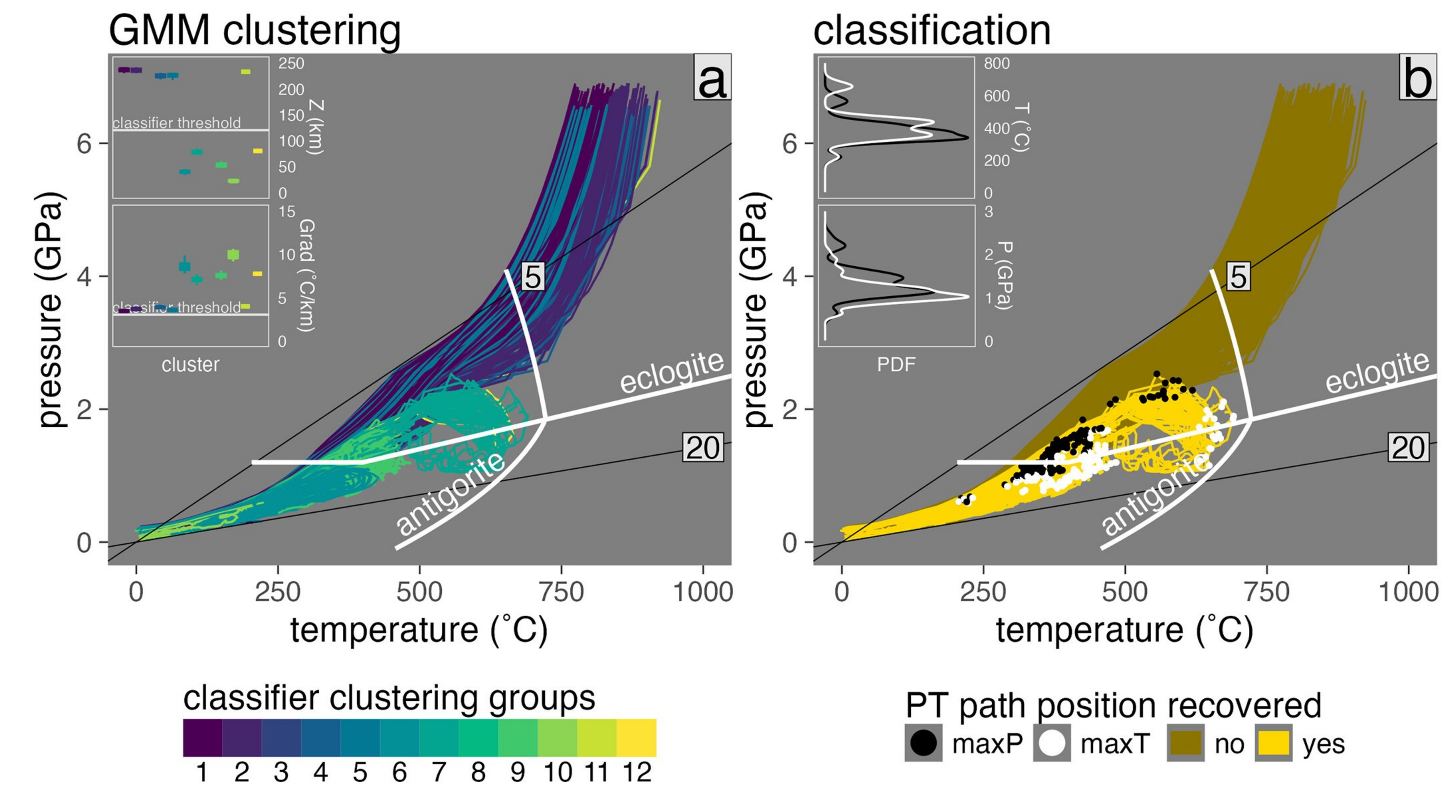
1. Numerical modeling uncertainties (e.g. rheology)
2. Petrologic uncertainties (e.g. modeling PT paths)
3. Selective sampling bias (i.e. non-random samples)
4. Geodynamic uncertainties (e.g. short-lived events)

A significant lack of markers recovered near 2 GPa and 550°C contrasts with high frequencies of natural samples near this PT condition



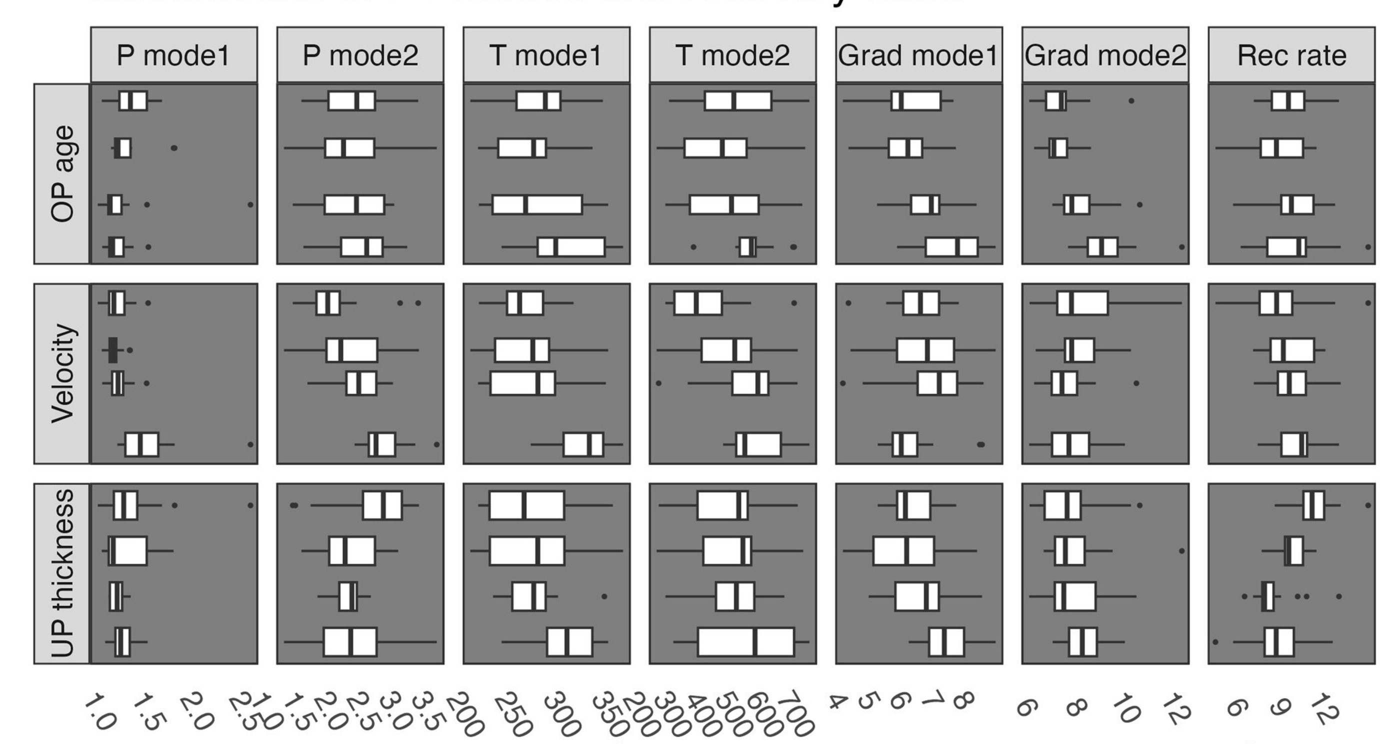
Summary of marker recovery for model cda62. (a) Pressure-temperature diagram showing the frequency of recovered markers (black points and green Tanaka contours) in comparison with the pd15 (solid red contours) and ag18 (filled gray contours) data sets. Thin lines are thermal gradients labeled in °C/km. Reaction boundaries for eclogitization of oceanic crust and antigorite dehydration are from Ito and Kennedy (1971) and Schmidt and Poli (1998), respectively. Marker counts (Tanaka contours) are computed across a 100 × 100 grid (0.04 GPa × 10°C). (insets) Probability distribution functions (top insets) and cumulative distribution functions (bottom inset) comparing P and T distributions between numerical experiments (green lines) and natural samples (pink lines: pd15, black lines: ag18). (b) Visualization of log viscosity in the model domain showing the major modes of marker recovery along a relatively thick subduction interface that tapers near the viscous coupling depth.

Explanations for an "overabundance" of natural samples around 2 GPa and 550 ˚C might include: **selective sampling of rocks** (petrological bias), **reaction overstepping** (petrological uncertainty), or **recovery/exhumation processes that are not included in numerical simulations** (modeling uncertainties)

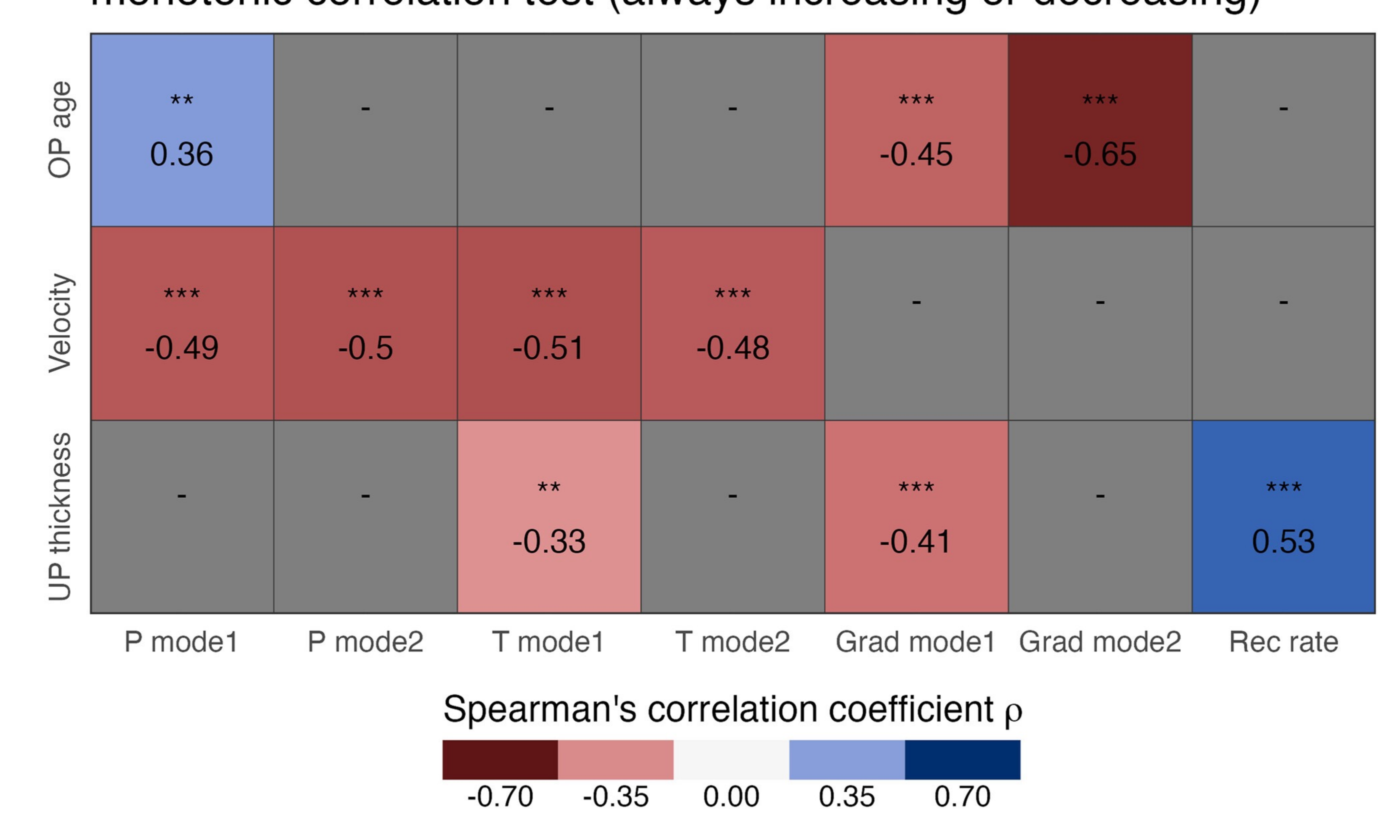


Example of marker classification. (a) Pressure-temperature (PT) diagram showing marker clusters as assigned by Gaussian mixture modeling (GMM; colored PT paths). (b) PT diagram showing marker classification results (colored PT paths) and various marker positions along their PT paths (black, white, and pink points).

distributions of PT modes and recovery rates



monotonic correlation test (always increasing or decreasing)



Open Research

All data, code, and relevant information for reproducing this work can be found at https://github.com/buchanankerswell/kerswell_et_al_marx, and at https://doi.org/10.17605/OSF.IO/3EMWF, the official Open Science Framework data repository (Kerswell et al., 2023). All code is MIT Licensed and free for use and distribution (see license details).

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