Combined natural and numerical-modeling constraints on subduction interface strength at deep metamorphic conditions

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1. Overview

What is the absolute viscosity range of deep subduction interfaces?

- The rheology of the subduction interface long- and short-term subduction dynamics.
- Current constraints on average subduction interface viscosity come from flow laws, overestimating the true viscosity range possible.
- Our goal is to place more precise bounds on the global range of shear zone viscosity for natural subduction shear zones at deep subduction conditions.
- We modelled the rheology of nine published shear zones to obtain a range of viscosities.

2a. Shear Zone Sources

Area	Unit	Lx (m)	Ly (m)	Map Source	P (GPa)	T (°C)	PT Source
S. California, USA	Catalina Schist	686	91	Hoover et al., 2022	1.4	650 - 750	Cisneros et al., 2022
Tien Shan, Kyrgyzstan	Makbal eclogite	354	805	Sobolev et al. 1986	2.4	550 - 610	Togonbaeva et al. 2010
Sivrihisar, E. Turkey	Halilbagi unit	1136	973	Whitney et al. 2014	2.3	475 - 520	Davis and Whitney, 2006
W. Turkey	Biga HP-slice	3205	938	Sengün et al., 2011	1.9	550 - 675	Sengün et al., 2014
Canada	Yukon-Tanana Terrane	4104	2735	Petrie et al., 2015	2.3	480 - 520	Ghent and Erdmer, 2011
N. Kazahkstan	Kulet eclogite, Kokchetav massif	6808	6658	Kaneko et al., 2000	3.2	680 - 780	Zhang et al., 2012
W. Alps	Susa Shear Zone	1608	432	Ghignone et al. 2020a	2.3	500 - 530	Ghignone et al. 2020b
Dabie-Sulu, China	Maobei HP-slice	3515	1942	Xu et al., 2006	2.6	750 - 850	Xu et al., 2006
W. Alps	Lago Superiore shear zone	53	77	Federico et al. 2007	1.6	450 - 500	Liou et al., 1998

2b. Flow Law Parameters

Unit	Sample Lithologies	n	m	r	Q* (kJ/mol)	A ($MPa^{-n}r$ um^m s^{-1})	Reference
[1] Eclogite	eclogite, metabasalt, metagabbro	3.5	0	0	403 + 27.2P	$10^{3.3}$	Zhang and Green (2007)
[2] Wet Quartz	quartzite, schist, metapelite	4	0	1^1	125	1.75 x 10^{-12}	Tokle et al. (2019)
[3] Blueschist	blueschist	2	1^2	0	383	2.97 x 10^{-11}	Tokle et al. (2022)
[4] Wet Olivine	meta-peridotite, peridotite	3.5	0	1.2^3	480 + 22P	90	Hirth and Kohlstedt (2003)
[5] Antigorite	serpentinite	3.8	0	0	0.0089 + 3.2P	$e^{-0.86}$	Hilairet et al. (2007)
[6] Aragonite	marble	5.2	0	0	249	$e^{-0.6}$	Rybacki et al. (2003)

General flow law equation. $\dot{\epsilon} = A\sigma^n \frac{f^r}{d^m} \exp\left(-\frac{Q}{RT}\right)$

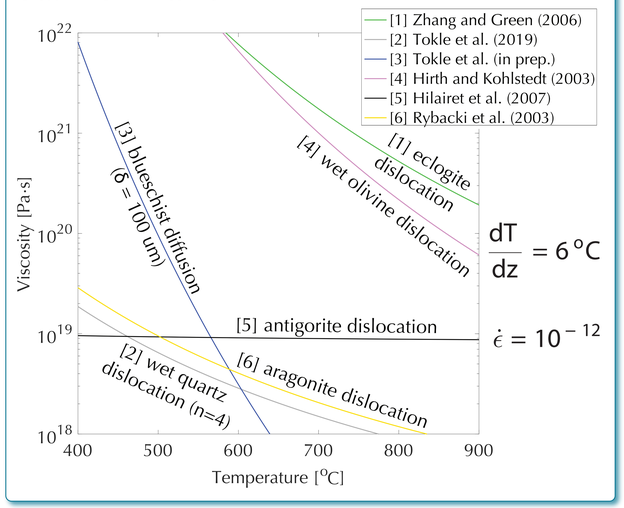
[1] Quartz water fugacity (Shinevar et al. 2015), with A1 = 5521 MPa, A2 = 31.28 MPa, A3 = -2.009 x 10-5 m^{-1}. a_{H_2O} set to 1. $f = a_{H_2O} A_1 e^{\left(-\frac{A_2 + PA_3}{RT}\right)}$

[2] For blueschist, boudin spacing δ is used instead of d, and is set at 100μm.

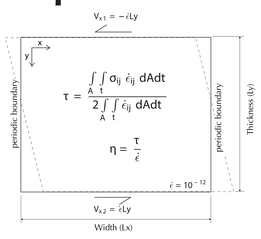
[3] Wet olivine fugacity (C_{OH}) si set at 600 MPa.

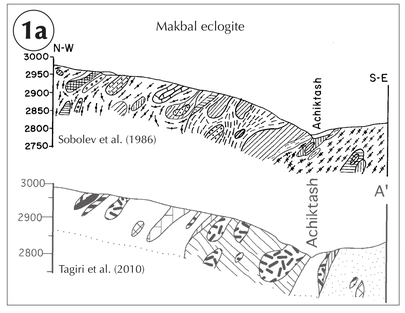
*Flow laws are reported as either activation enthalpy (Q) or as activation energy and volume (Ea + PV). Ea is kJ/mol, V is cm^3/mol.

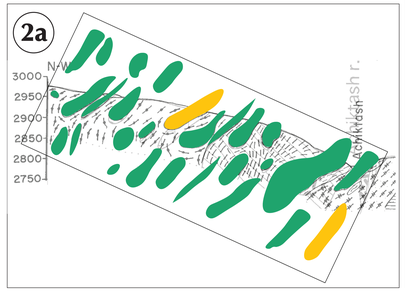
3a. Flow Laws



3b. Model Implementation





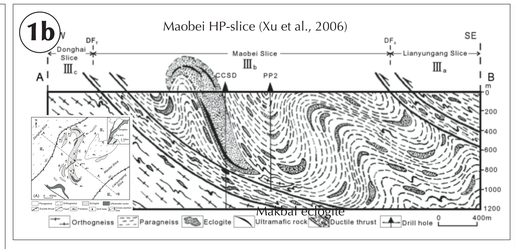


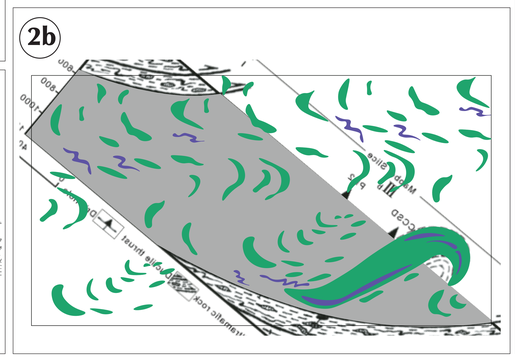
1) We chose published sections with minimal retrogressive overprint, defined shear zone width, and well-constrained PT conditions, then generated or digitized cross sections.

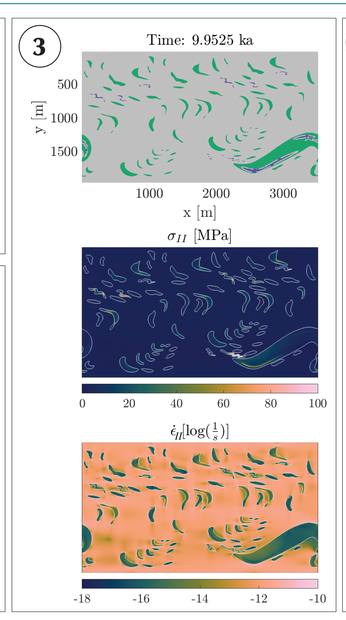
2) We extrapolated the distribution of blocks to create a rectangular section, maintaining block distribution. We oriented the sections for top-to-the-left shearing.

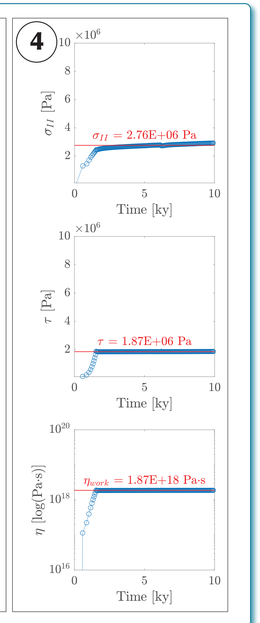
3) We ran the viscoplastic model (modified from Ruh, 2021) for ~10ky.

4) We took the median value during stable creep to represent the strength of the shea

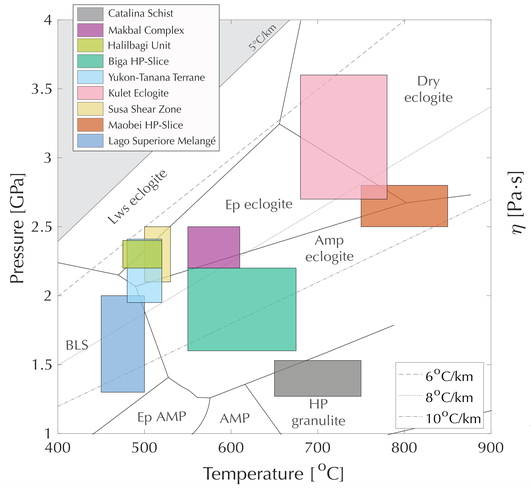


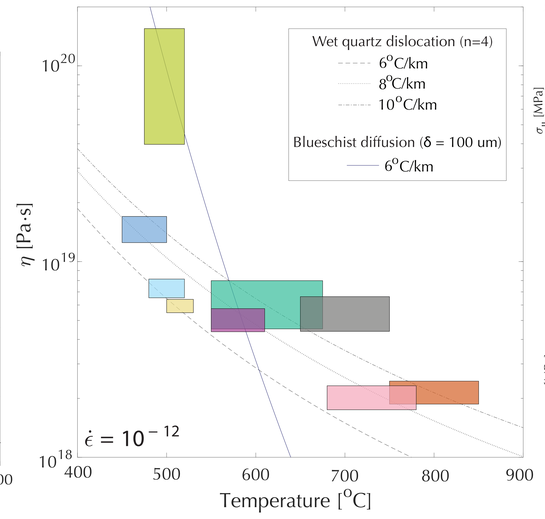


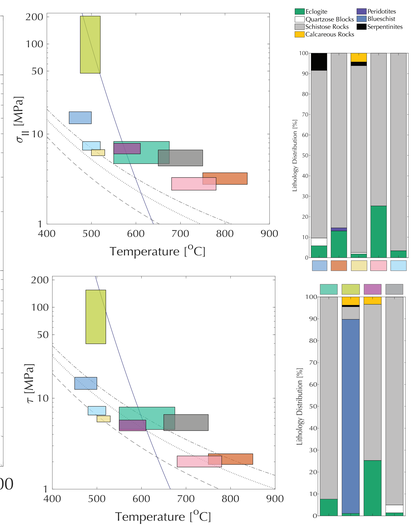




4. Results







5. Next Step

- Use plate convergence rates from plate reconstructions to set the shear velocity
- Add more non-melange sections (i.e. layered, purely weak matrix) to the analysis

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