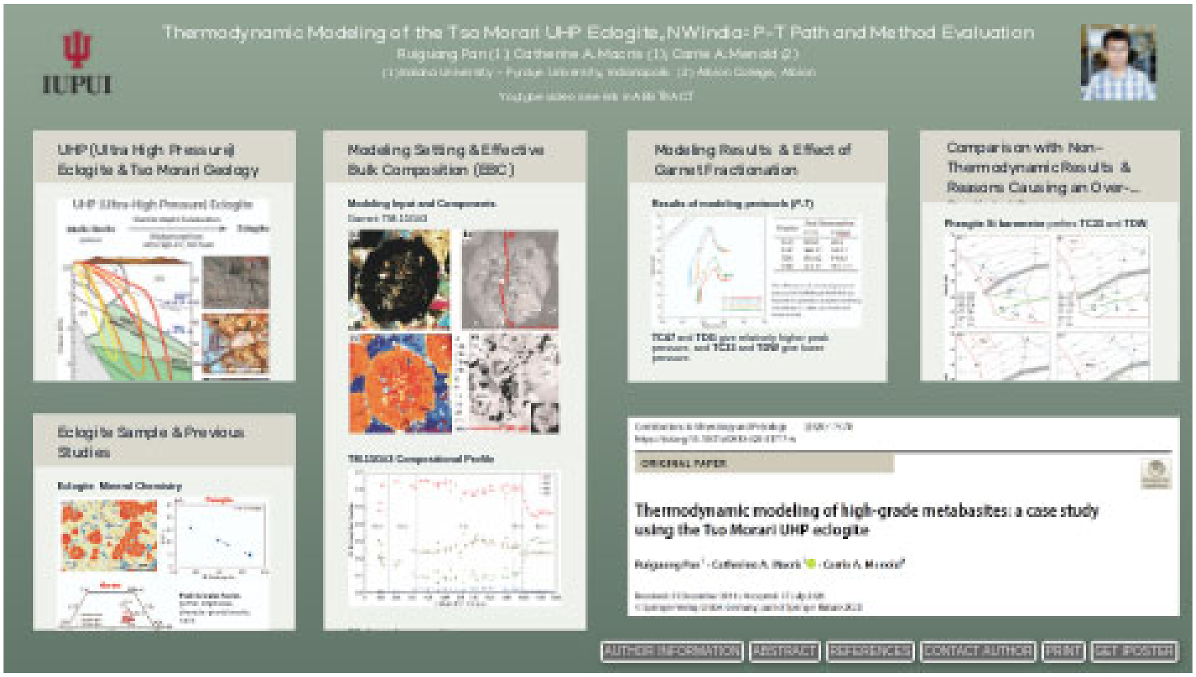
Thermodynamic Modeling of the Tso Morari UHP Eclogite, NW India: P-T Path and Method Evaluation



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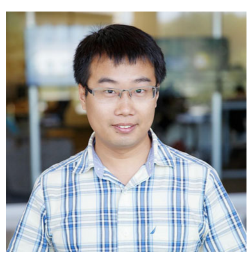
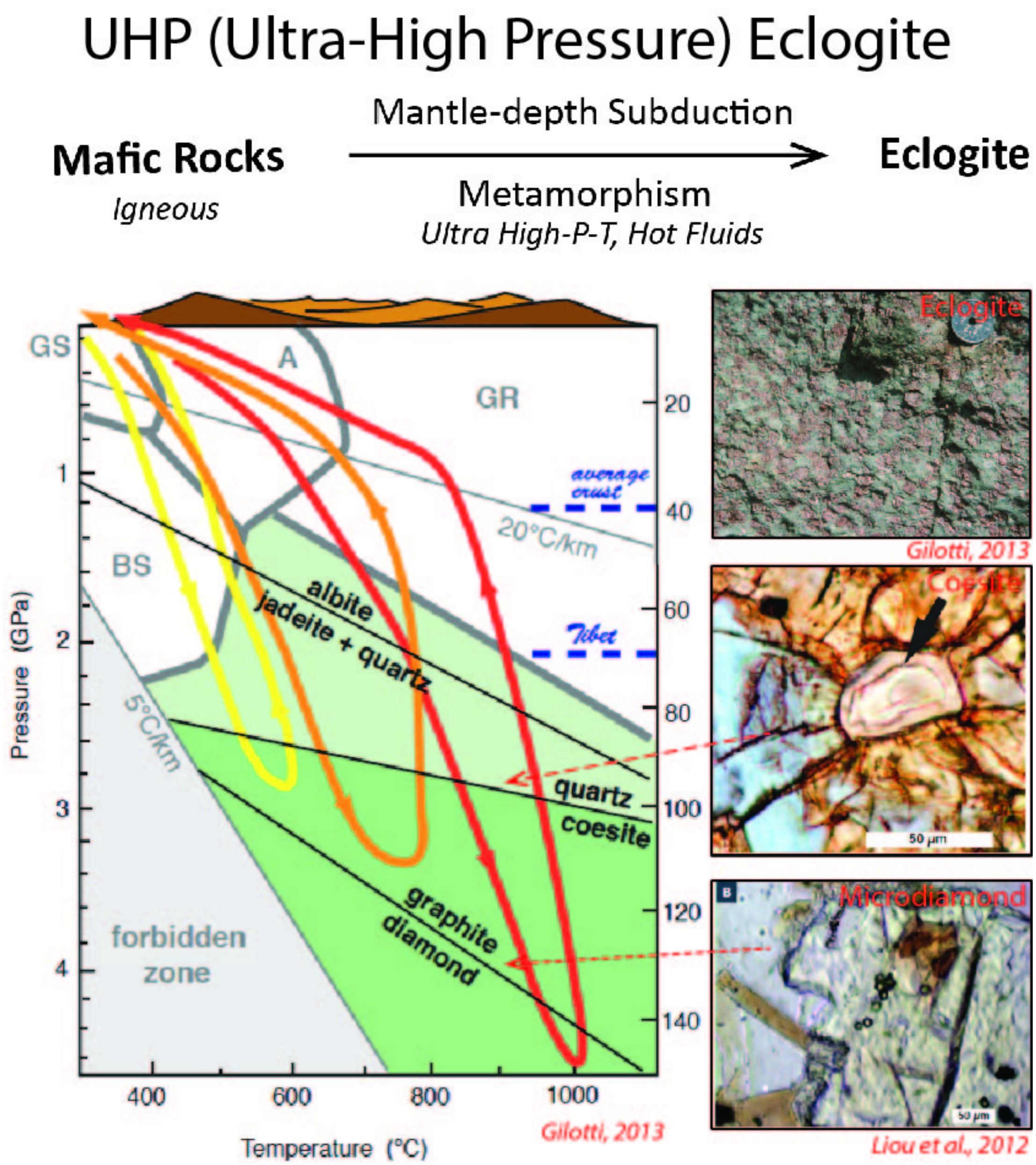
Youtube video see link in ABSTRACT



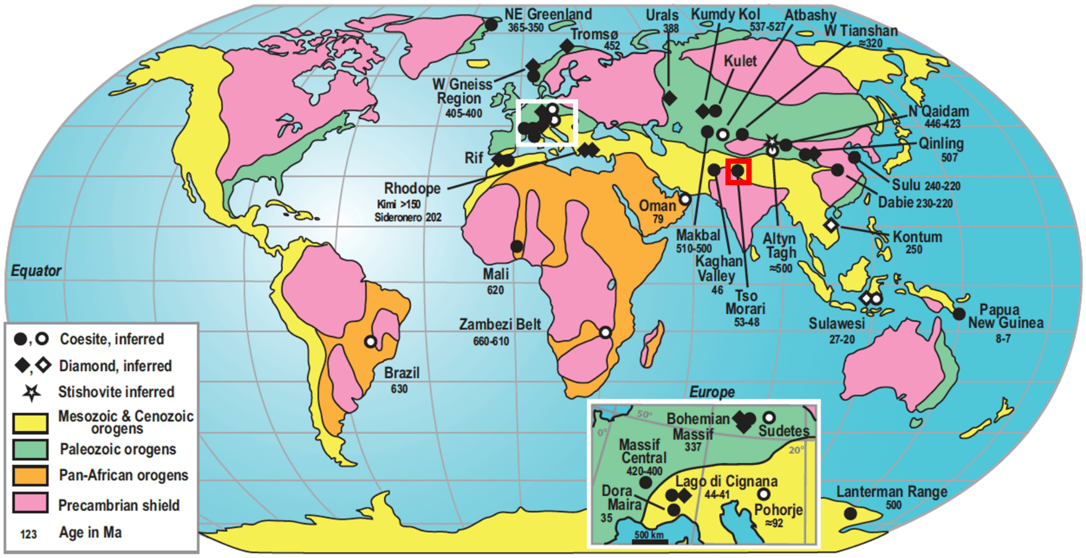
PRESENTED AT:

UHP (ULTRA HIGH PRESSURE) ECLOGITE & TSO MORARI GEOLOGY



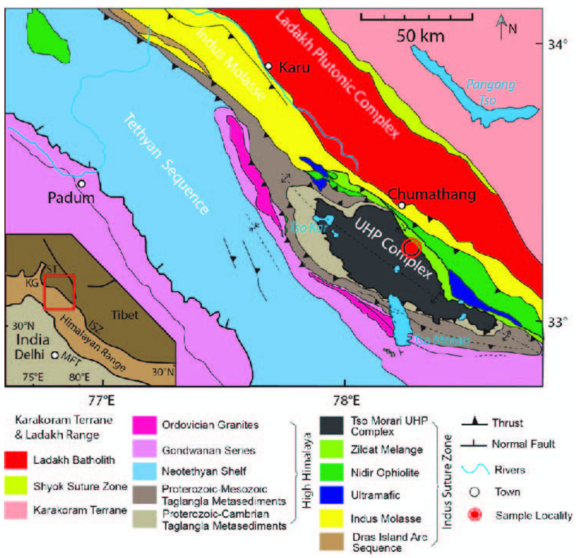
- Original **mafic rocks** are subducted to mantle depth; ultra-high **P-T-Fluids**; UHP **eclogites**.
- **Coesite** and **microdiamond** are indicator minerals for UHP metamorphism.

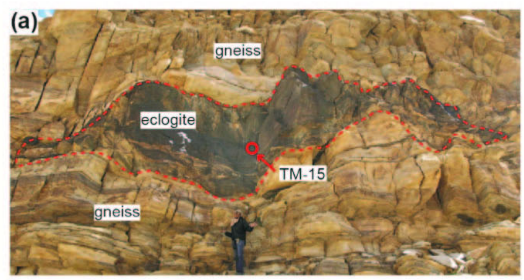
Worldwide distribution of UHP terranes



Gilotti 2013

Geologic Setting





Within the Himalaya orogeny

The Tso Morari UHP eclogite is hosted in the Puga gneiss as a boudin

- **Tectonics**: Within the Himalaya orogeny; North:Tibetan plateau; South: India continent.
- **Eclogites** are hosted as boudin in gneiss. Eclogite in darker color; Gneiss in lighter color.

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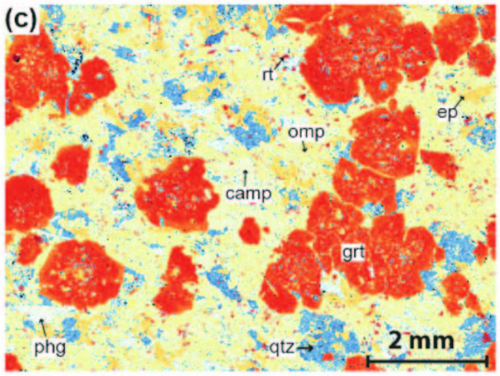
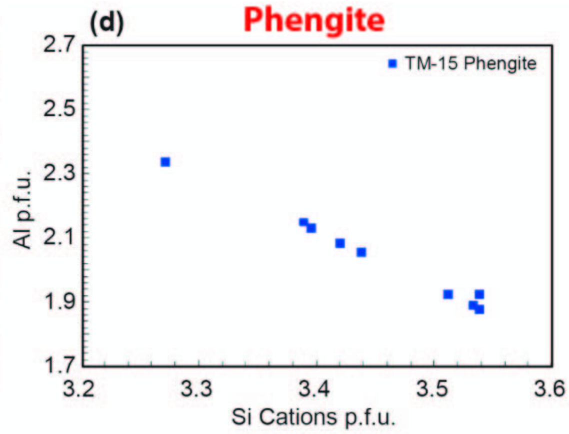
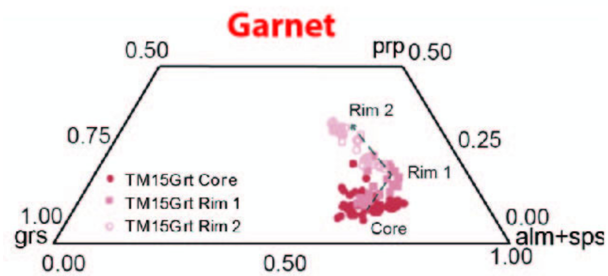
ECLOGITE SAMPLE

Eclogite Mineral Chemistry







Peak Eclogite Facies:
garnet, omphacite, phengite, quartz/coesite, rutile.

Eclogite TM-15: from the center of eclogite boundin, and showing least retrograde overprinting.

Garnet: growth zonation with high-Fe-Ca core to high-Mg rim.

Phengite: Maximum Si p.f.u.: 3.54.

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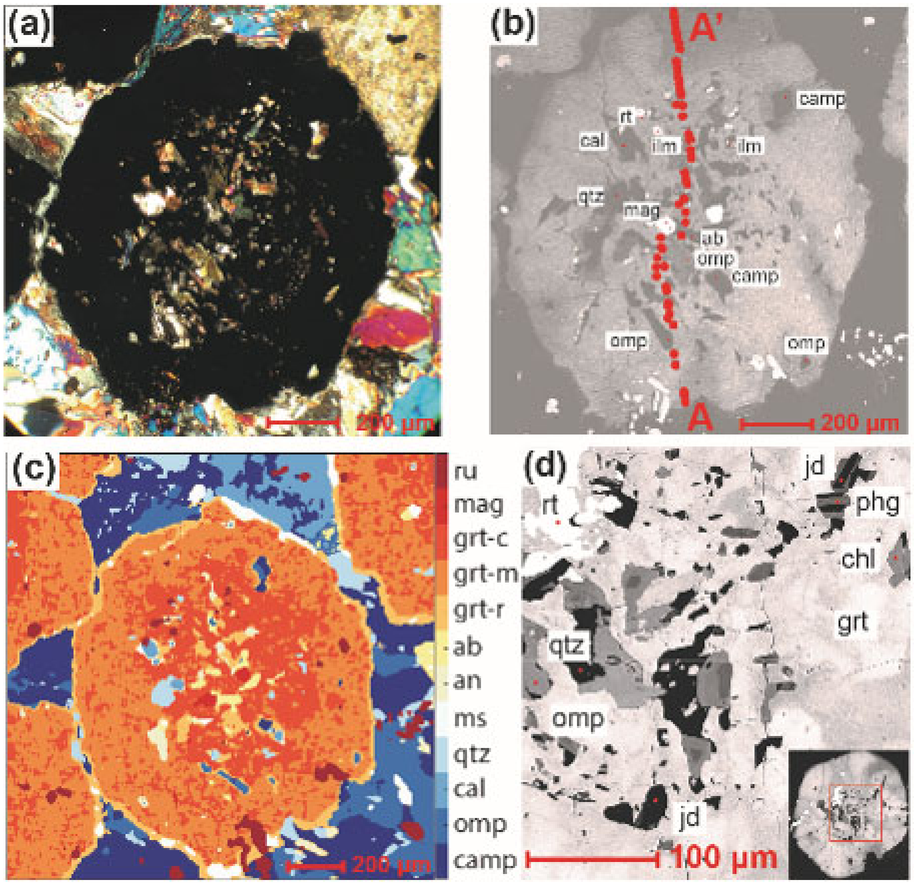
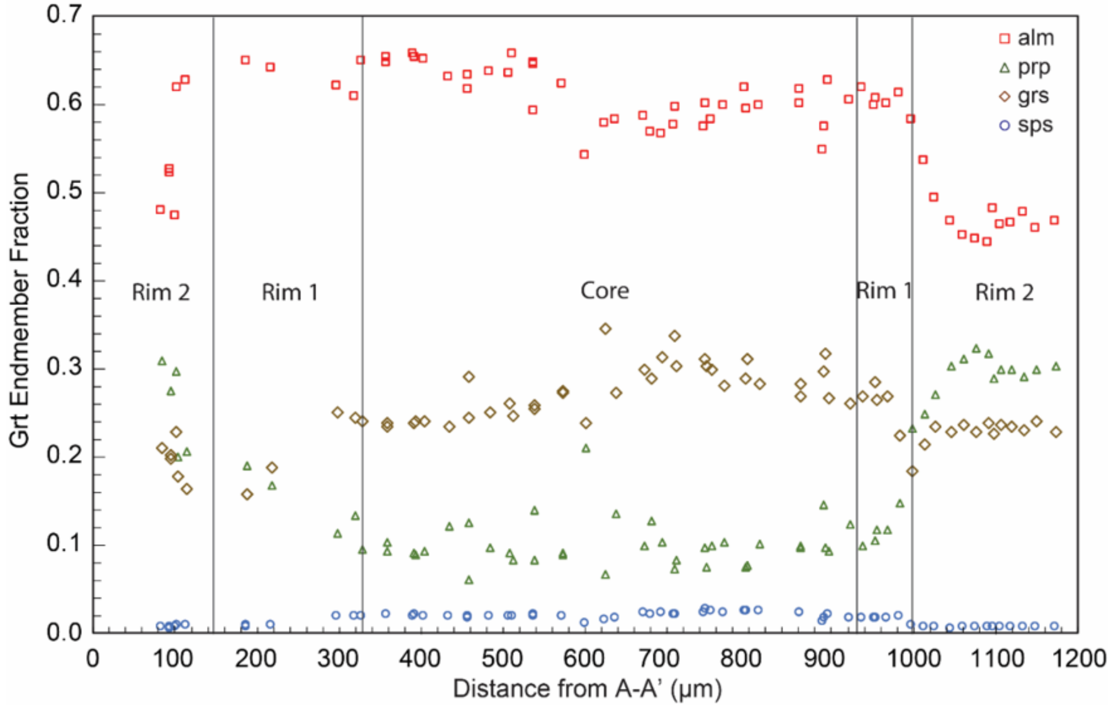
MODELING SETTING

Modeling Input and Components

Garnet: TM-15G#3



TM-15G#3 Compositional Profile



Whole-rock composition

Table 3 Eclogite major element whole-rock geochemistry from Tso Morari sample TM-15, reported in wt%

Sample	SiO_2	TiO_2	Al_2O_3	FeO^a	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI %	Sum
TM-15	45.53	2.37	15.06	11.92	0.19	7.27	10.3	2.79	0.57	0.24	2.74	96.22

[a]Total iron expressed as FeO

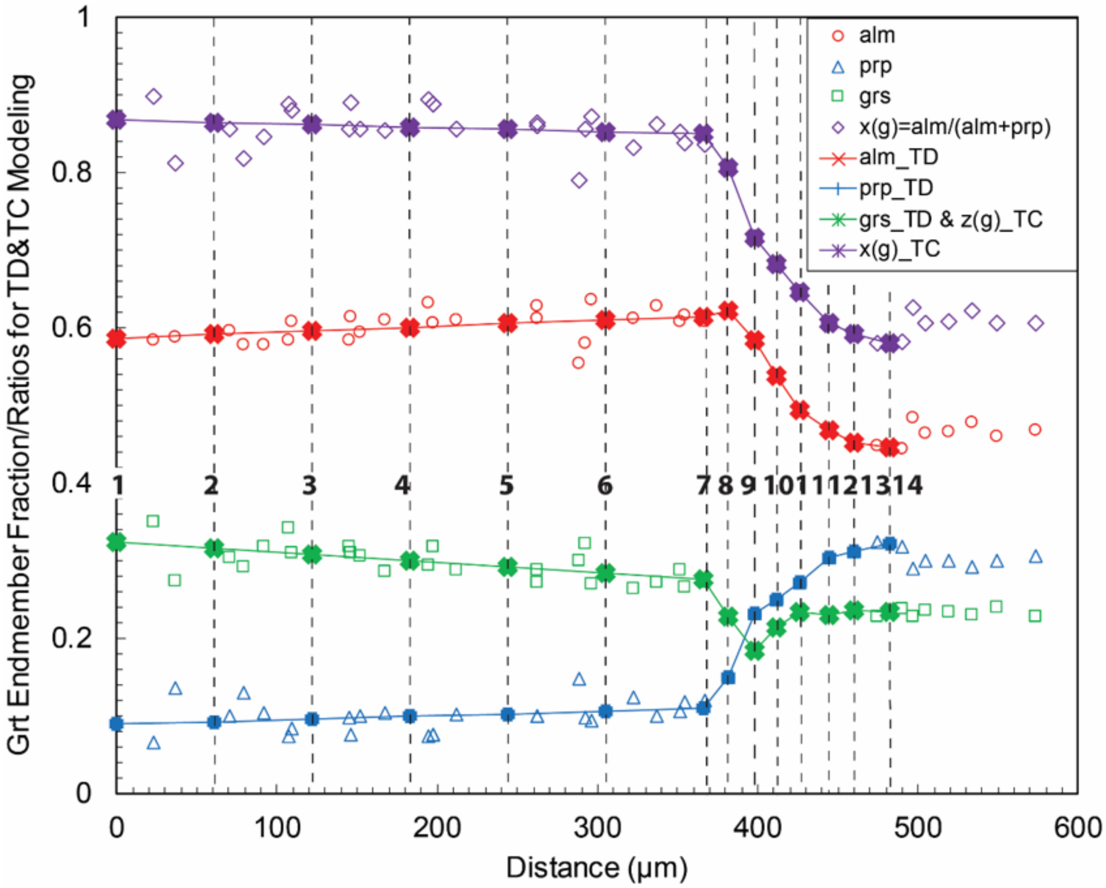
Thermodynamic Modeling Setting

Program: THERMOCALC (TC) vs. Theriak-Domino (TD);

Thermodynamic dataset: ds 55 vs. ds 62;

Garnet *a-X*: White et al. (2007) vs. White et al. (2014);

Garnet prograde growth simulation



14 fractionation steps were performed for garnet (TM-15G#3) prograde growth.

Four Trials: TC33, TC47, TDG, and TDW

Program	Thermo-dataset	Grt *a-X* relations[a]	Major Grt *a-X* relation parameters (*W*/kJ)					
			$W_{(alm-prp)}$	$W_{(alm-grs)}$	$W_{(prp-grs)}$	a_{prp}	a_{alm}	a_{grs}
TC33	ds 55	W07	2.5	10	45	1	1	3
TC47	ds 62	W14	2.5	5	31	1	1	2.7
TDG	ds 62	W14	2.5	5	31	1	1	2.7
TDW	ds 62	W07	2.5	10	45	1	1	3

[a]W07: White et al. (2007); W14: White et al. (2014a)

For instance, the TC33 protocol uses TC program, ds 55 dataset, garnet *a-X* relations from White et al., 2007;

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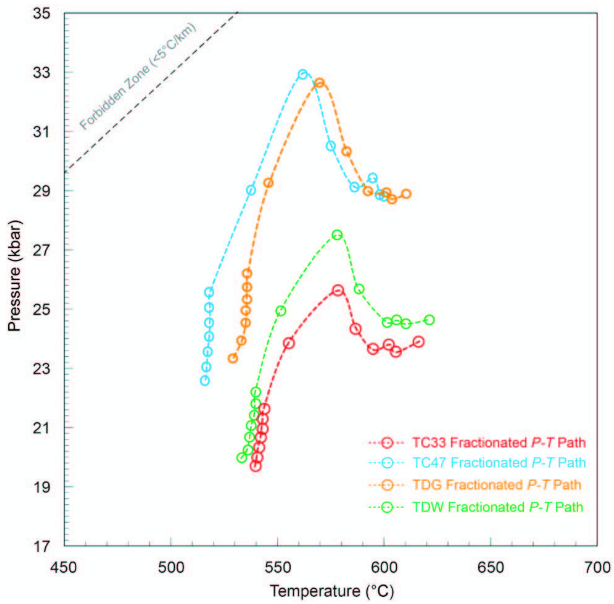
MODELING RESULTS & EFFECT OF GARNET FRACTIONATION

Results of modeling protocols (*P-T*)

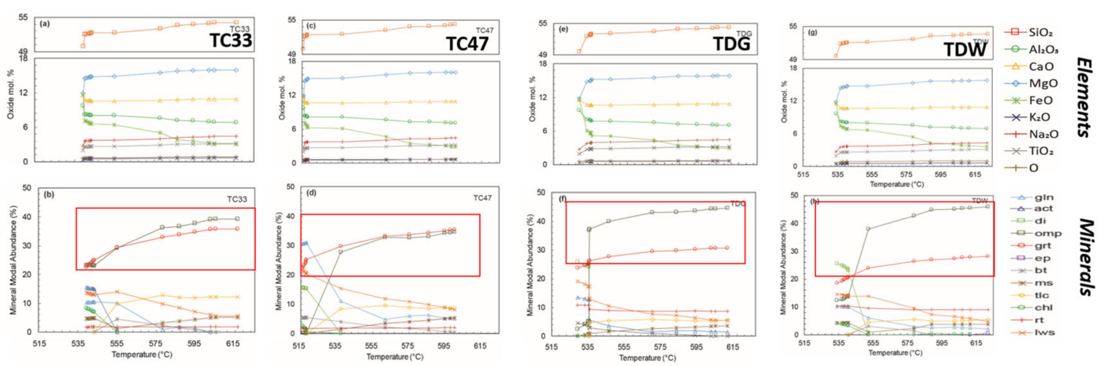


Program	Peak Metamorphism	
	T (°C)	*P* (kbar)
TC33	565±8	26±1
TC47	544±15	34±1.5
TDG	551±12	34±1.5
TDW	563±13	28.5±1.5

The differences of calculated pressures between TC33/TDW and TC47/TDG are beyond the generally accepted modeling uncertainty (± 1 kbar, 2σ; Powell and Holland 2008)

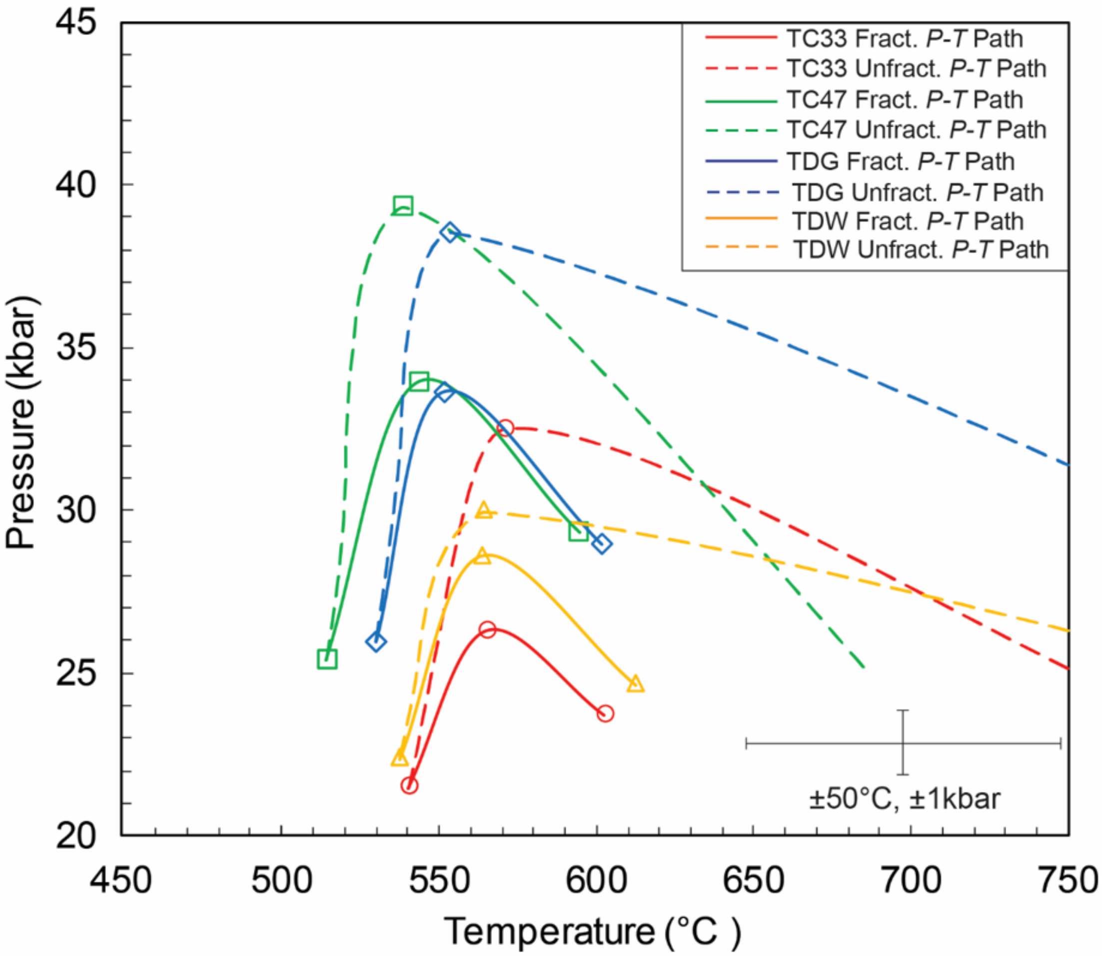
TC47 and **TDG** give relatively higher peak pressure, and **TC33** and **TDW** give lower pressure.

Results of elements & minerals evolution



- Same results in major element evolution.
- TC predicts a higher proportion of garnet but lower omphacite than TD.

Garnet fractionation effect on peak metamorphic *P-T* predictions



- Models that do not incorporate the garnet fractionation effect result in peak pressure predictions **~5 kbar higher** than those that do.
- **Garnet fractionation** effect can not be ignored.

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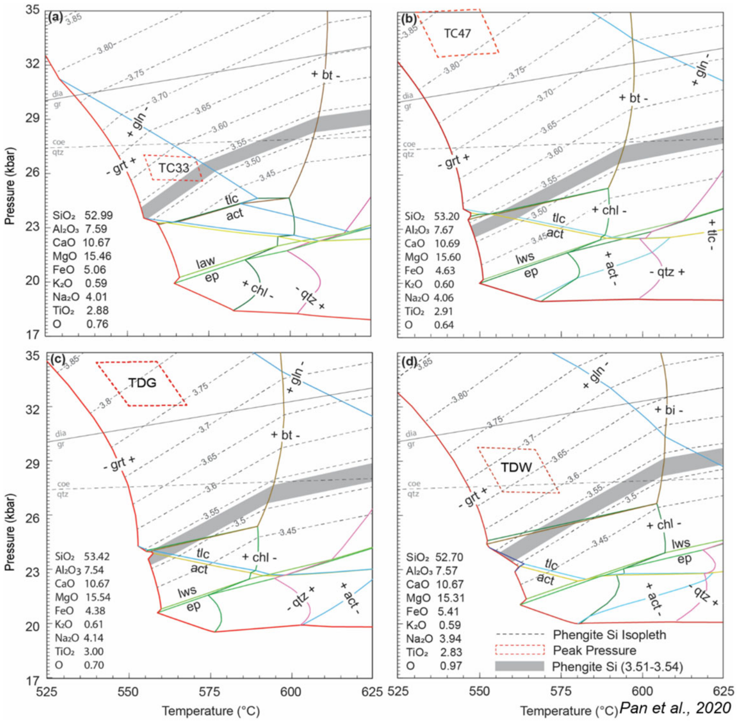
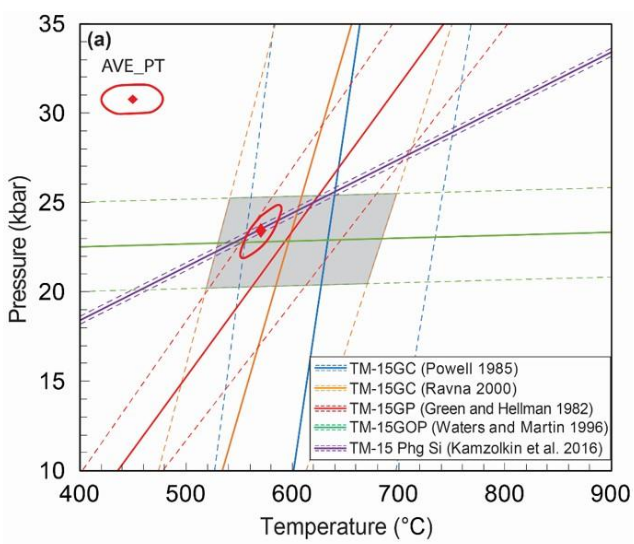
COMPARISON WITH NON-THERMODYNAMIC RESULTS & REASONS CAUSING AN OVER-PREDICTED PRESSURE

Phengite Si barometer prefers **TC33** and **TDW**;



Conventional thermobarometry: ~520–700 °C and ~20–26 kbar;



TC3.33 AVE_PT from the garnet rim was 572 ± 15 °C and 23.3 ± 1.2 kbar;

Reasons causing an over-predicted pressure

Comparison of thermodynamic modeling parameters and results for TC33, TC47, TDG, and TDW in this study

Program	Thermo-dataset	Grt *a*-*X* relations[a]	$W_{(alm-prp)}$	$W_{(alm-grs)}$	$W_{(prp-grs)}$	a_{prp}	a_{alm}	a_{grs}	*T* (°C)	*P* (kbar)
			Major Grt *a*-*X* relation parameters (*W*/kJ)						Peak Metamorphism	
TC33	ds 55	W07	2.5	10	45	1	1	3	565±8	26±1
TC47	ds 62	W14	2.5	5	31	1	1	2.7	544±15	34±1.5
TDG	ds 62	W14	2.5	5	31	1	1	2.7	551±12	34±1.5
TDW	ds 62	W07	2.5	10	45	1	1	3	563±13	28.5±1.5

[a]W07: White et al. (2007); W14: White et al. (2014)

The modification of the **garnet *a-X* relation parameters (from White et al. (2007)** to White et al. (2014)) plays a big role in the over-predicted pressures in TC47 and TDG.

TC33 and TDW are more realistic considering all non-thermodynamic results.

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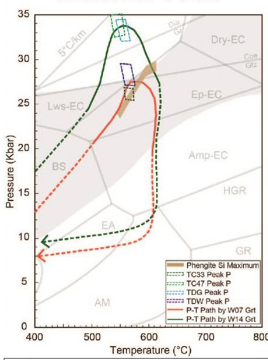
Preferred *P-T* Path



- The pressure calculated using garnet *a-X* relations of White et al. (2014) (green dashed line) is beyond the *P-T* conditions of slab surfaces.
- Our preferred *P-T* path (red dashed line) calculated using garnet *a-X* relations of White et al. (2007).

Conclusions

- The thermodynamic models using the *a-X* relations for garnet (White et al., 2014) predict a higher metamorphic peak pressure than the modeling results using White et al. (2007).
- In metabasites, peak pressure will be significantly over-predicted in the non-fractionated case.
- The peak pressures predicted by the TC33 and TDW modeling (26 ± 1 kbar at 565 ± 8 °C and 28.5 ± 1.5 kbar at 563 ± 13 °C, respectively) are preferred.
- This study illustrates the importance integrating modelling results with petrographic observations to obtain a geologically meaningful interpretation.

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Thermodynamic modeling of high-grade metabasites: a case study using the Tso Morari UHP eclogite

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ABSTRACT

The development of thermodynamic modeling techniques and availability of updated thermodynamic databases and activity-composition (*a-X*) relations, call for an evaluation of modeling pressure-temperature (*P-T*) paths of metabasites. In this study, eclogite from the Tso Morari UHP terrane, NW India, is used as a representative metabasite to compare *P-T* paths generated from the widely used THERMOCALC (TC) and Theriak-Domino (TD) programs. We also evaluate the effect of using the most updated thermodynamic database ds 62 (Holland and Powell 2011) relative to an older version ds 55 (Holland and Powell 1998), and the most updated garnet *a-X* relations of White *et al.* (2014) (W14) relative to an older version of White *et al.* (2007) (W07), while accounting for the effect of garnet fractionation. The following modeling protocols were assessed: (1) TC33: TC v3.33 with ds 55 and garnet *a-X* relations of W07; (2) TC47: TC v3.47 with ds 62 and garnet of W14; (3) TDG: TD with ds 62 and garnet of W14, and (4) TDW: TD with ds 62 and garnet of W07. TC47 and TDG modeling protocols yield a similar peak metamorphic *P-T* of 34 ± 1.5 kbar at 544 ± 15 °C and 551 ± 12 °C, respectively; while TC33 and TDW modeling yield similar peak *P-T* results: 26 ± 1 kbar at 565 ± 8 °C and 28.5 ± 1.5 kbar at 563 ± 13 °C, respectively. Results indicate that all four modeling protocols generally provide consistent thermodynamic simulations regarding metamorphic compositional and temperature evolution; however, the pressure generated by protocols using W14 (TC47 and TDG) is 5–8 kbar higher than that predicted by protocols using W07 (TC33 and TDW). The difference in peak pressure results for the modeling protocols (TC47 and TDG vs. TC33 and TDW) are beyond the suggested uncertainty using mineral isopleth thermobarometry in pseudosections: ± 50 °C and ± 1 kbar at 2σ (Powell and Holland 2008). This study illustrates that the choice of garnet *a-X* relations can affect predictions of peak pressure regardless of program choice, as well as the need of comparison between modeling predictions and petrological observations.

Youtube Video Record:

[VIDEO] https://www.youtube.com/embed/mDj3ypowGN8?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

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