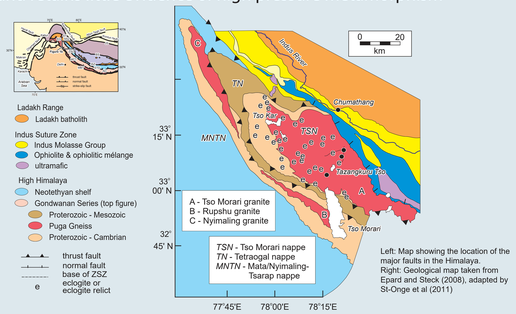
Subduction and Exhumation of the Tso Morari Region, Ladakh

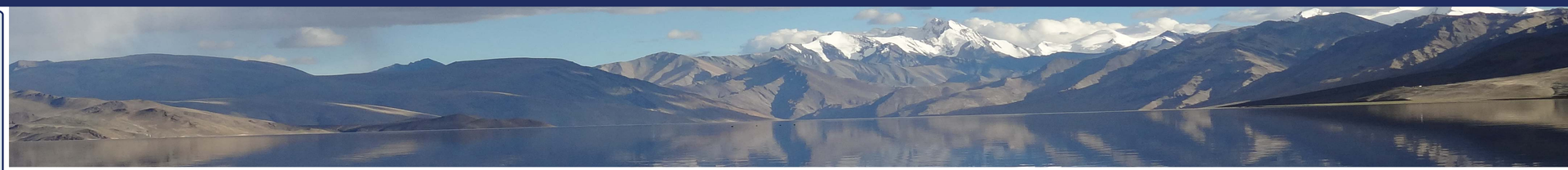
A Bidgood[1], D Waters[1], M Searle[1], N Roberts[2], Talat Ahmad[3]
1. University of Oxford 2. NIGL, BGS 3. Jamia Millia Islamia, New Delhi

1) Introduction

- The Tso Morari dome is the northernmost extent of Indian continental crust subducted to UHP conditions during early India-Asia collision
- The discovery of the mineral **coesite,** a high pressure polymorph of quartz, is evidence for **continental subduction** to pressures of around 27kbar (~90km).
- The abundant felsic material has been overprinted by amphibolite facies metamorphism and retains little evidence of high pressure metamorphism



Left: Map showing the location of the major faults in the Himalaya.
Right: Geological map taken from Epard and Steck (2008), adapted by St-Onge et al (2011)



2) Key points

- **Mafic** eclogites preserve evidence for UHP metamorphism. They comprise <1% of the outcrop and have >90% of publications.
- **99%** of the material is **felsic** with very few publications.
- The felsic material records amphibolite facies metamorphism, with **little evidence of high pressures**

Hypotheses:

1) Felsic material was never subducted to high pressure
2) Felsic material was subducted to UHP depths but didn't transform
3) Felsic material was subducted, transformed and then retrogressed

3) Outcrop relationships

Lithologies making up the dome include: metagranites, metasediments and metabasic rocks

Metasedimentary raft and intrusive contact (red) with granite gneiss.

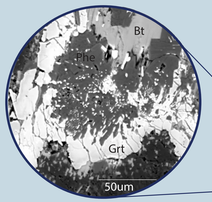
Eclogite boudin hosted in granite gneiss and metasedimentary gneiss.

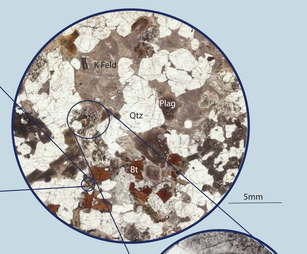
Eclogite boudins hosted in garnet mica-schist (igneous protolith)

4) Undeformed granite

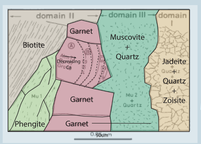
Evidence of high pressure metamorphism is preserved as coronas of garnet and phengite around igneous biotites and within cordierite pseudomorphs

Garnet + Phengite corona around biotite





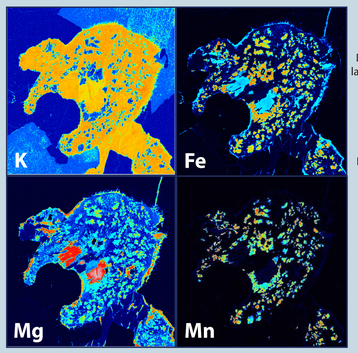
Granite assemblage:
- Biotite
- White mica
- Cordierite
- Plagioclase
- Quartz
- K feldspar



Cordierite pseudomorph consisting of phengite, phlogopite and Fe-Mg garnet

Cartoon of similar textures in the Monte Mucrone meta-quartz diorite of the Sesia Zone (Koons et al. 1987)

White Mica compositions



Magmatic alteration of Crd:
Coarse Mg-rich micas
Post magmatic pinite alteration
Metamorphic alteration of Crd:
fine grained phengite
Fe-Mg garnet
kyanite

Quartz or Coesite?

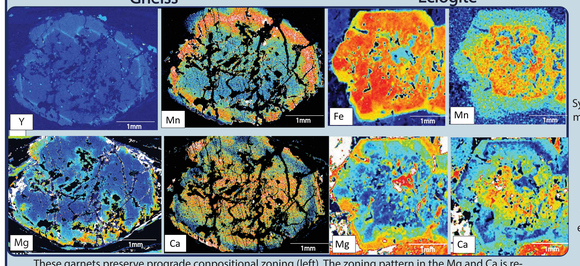
Key Points:
This is evidence of high pressure metamorphism in felsic rocks of the TM dome.

Cordierite underwent late stage magmatic alteration prior to higher pressure metamorphism

Coesite has been found in mafic eclogites in the TM dome. Most felsic rocks do not show evidence of coesite but some do.

5) Prograde garnets

Garnets are found in mica gneisses close to sheared rheological contacts.

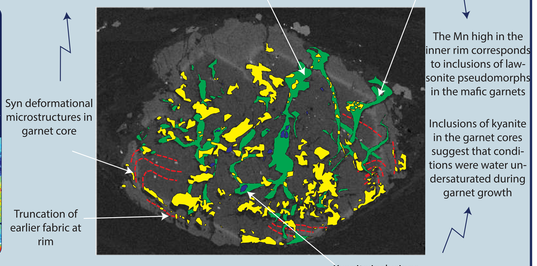


These garnets preserve prograde compositional zoning (left). The zoning pattern in the Mg and Ca is remarkably similar to the zoning seen in the mafic eclogites (right). It is in the high-Mg rims of the eclogites that coesite has been discovered.

1) Mn and Y high suggest resorption of garnet followed by new growth
2) A change from inclusion-rich to inclusion-poor garnet at this boundary
3) Appearance in mafic rocks of pseudomorphed lawsonite at this boundary

- This may be explained by the addition of water during garnet growth at high pressures

The presence of millipede structures in the garnet cores shows that a fabric developed prior to garnet core growth



Statement of the problem

- Garnet isopleths in thermodynamic models do not match the observed values; fractionation of water, garnet and the stability of minerals such as plagioclase and cpx may be important factors
- The recorded P-T conditions may reflect fluid-promoted reactions and/or deformation episodes, rather than a simple prograde to peak evolution.

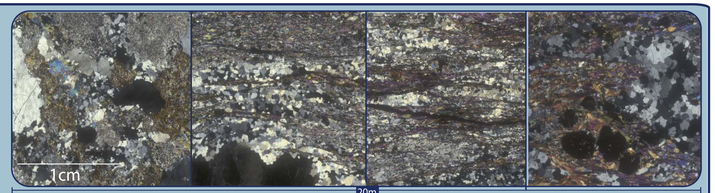
6) Conclusions and Implications

- Eclogite facies metamorphism is preserved in the metagranites of Tso Morari dome, as well as in eclogite boudins
- Bulk composition of Puga Gneiss was altered prior to prograde garnet growth with low H2O
- The Puga Gneiss and granite are the dominent rock types. The metamorphism of these rocks changes the strength of the crust.
- The timing and degree of transformation of the granites, therefore has implications for the geodynamics of the Indian margin.

7) Further work

- Determine the P-T-t history of the UHP eclogites across the dome
- Compare P-T-t paths of different lithologies
- Determine the involvement of water through time

How do you turn a granite into a garnet mica schist?



Granite → Augen gneiss → Grt-mica gneiss

How do large thrust slices of continental crust, composed mostly of Ordovician granite get subducted to depths >100 km and then returned to the surface during the India-Asia collision process?