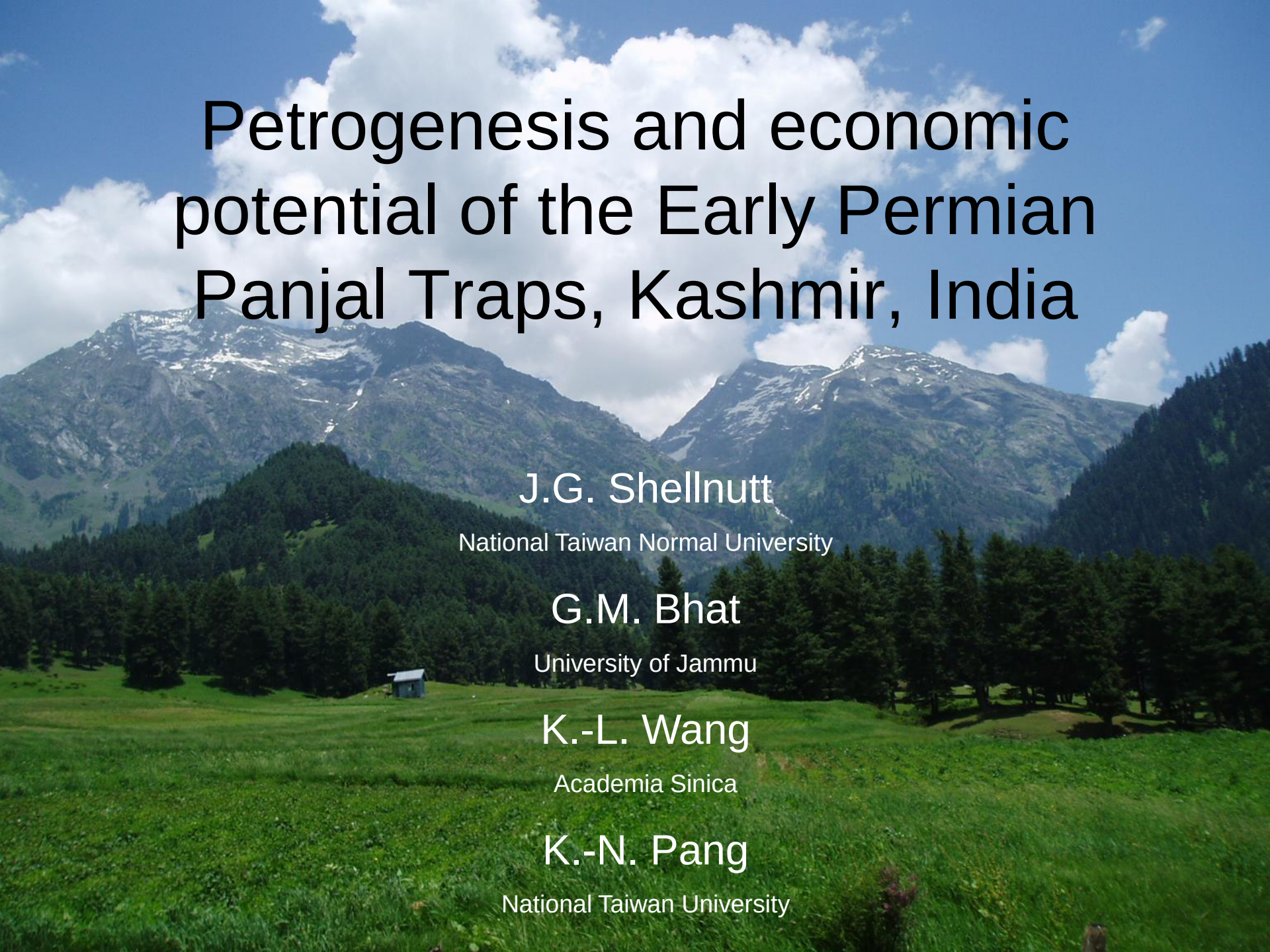

Petrogenesis and economic potential of the Early Permian Panjal Traps, Kashmir, India

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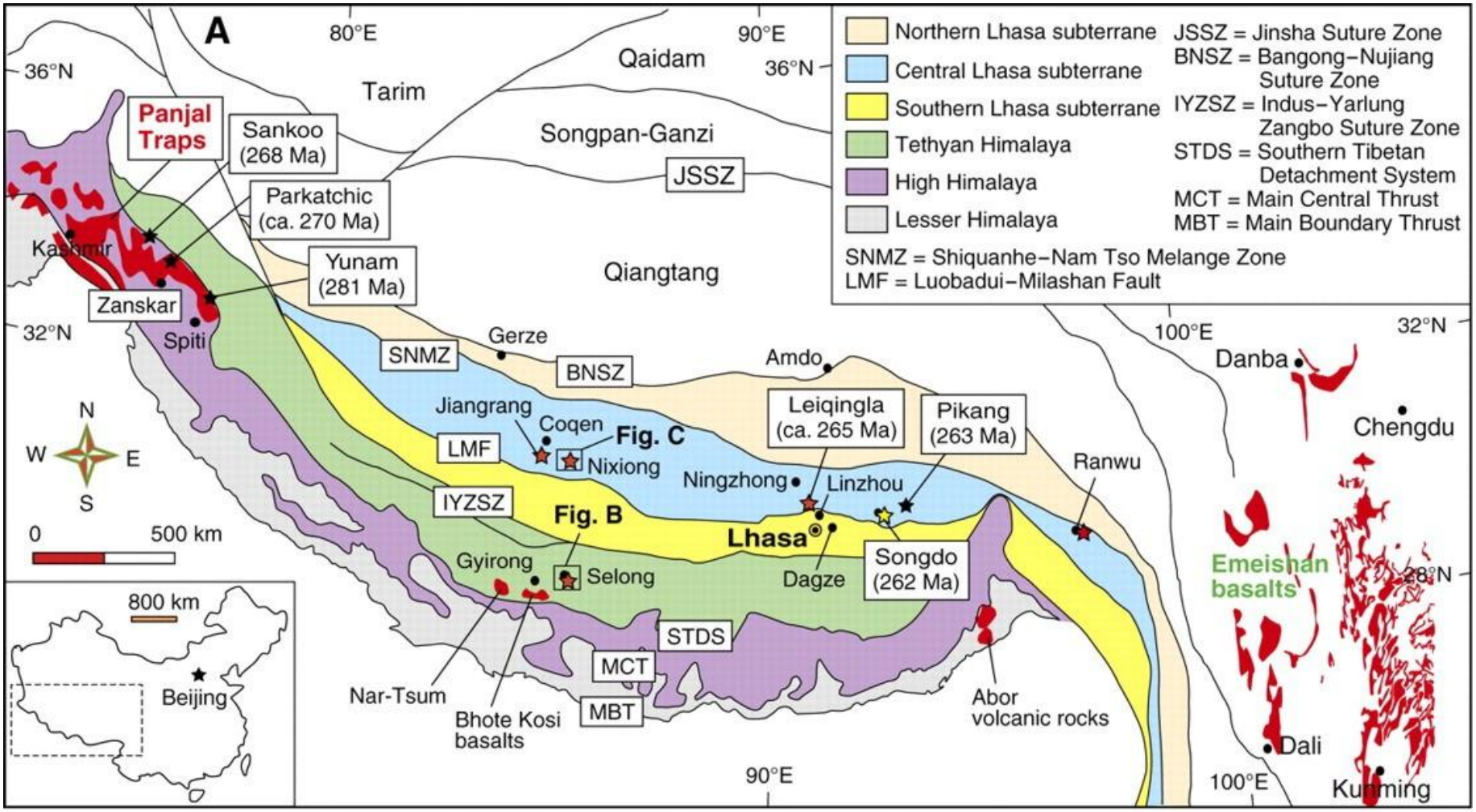
Introduction

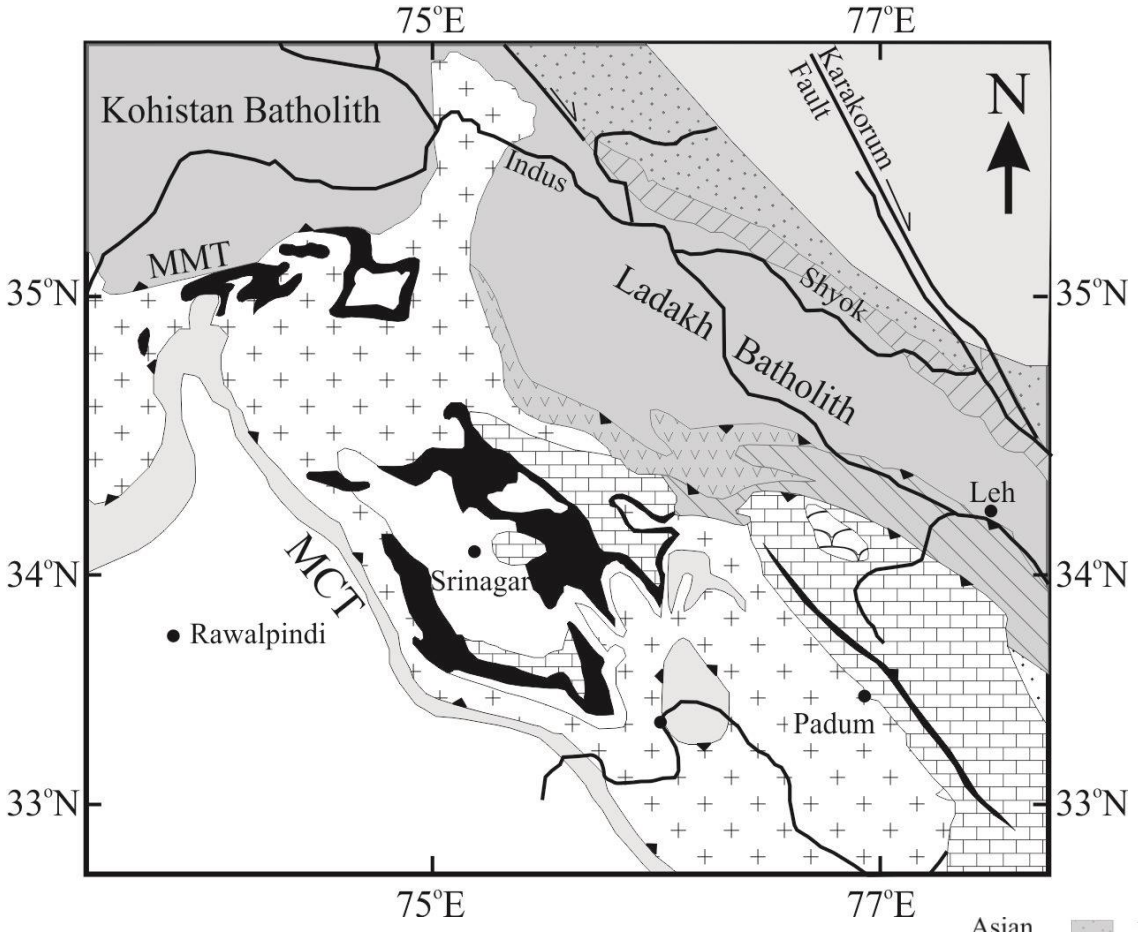
- Large igneous provinces are voluminous, temporally restricted, spatially contiguous regions of the Earth's crust that contain magmatic rocks.
- There are continental and oceanic examples.
- The continental LIPs are mostly comprised of flood basalts but there are a few which are dominated by silicic volcanic rocks.
- LIPs commonly host base metal deposits, are associated with continental break-up and often contemporaneous with mass extinctions ± climate change.



Zhu et al., 2010 GSA Bulletin

Introduction

- The Panjal Traps were one of the most debated correlations of the Permian (~290 Ma).
- They are thought to be have erupted at any time from the Late Carboniferous to Early Triassic (Nakazawa et al., 1975; Veevers & Tewari, 1995; White & Saunders, 2005; Zhu et al., 2010).
- These rocks have not been studied in 30+ years.
- The purpose of the work is to examine the likelihood of base and precious metal deposits (i.e. Ni-Cu-PGE).



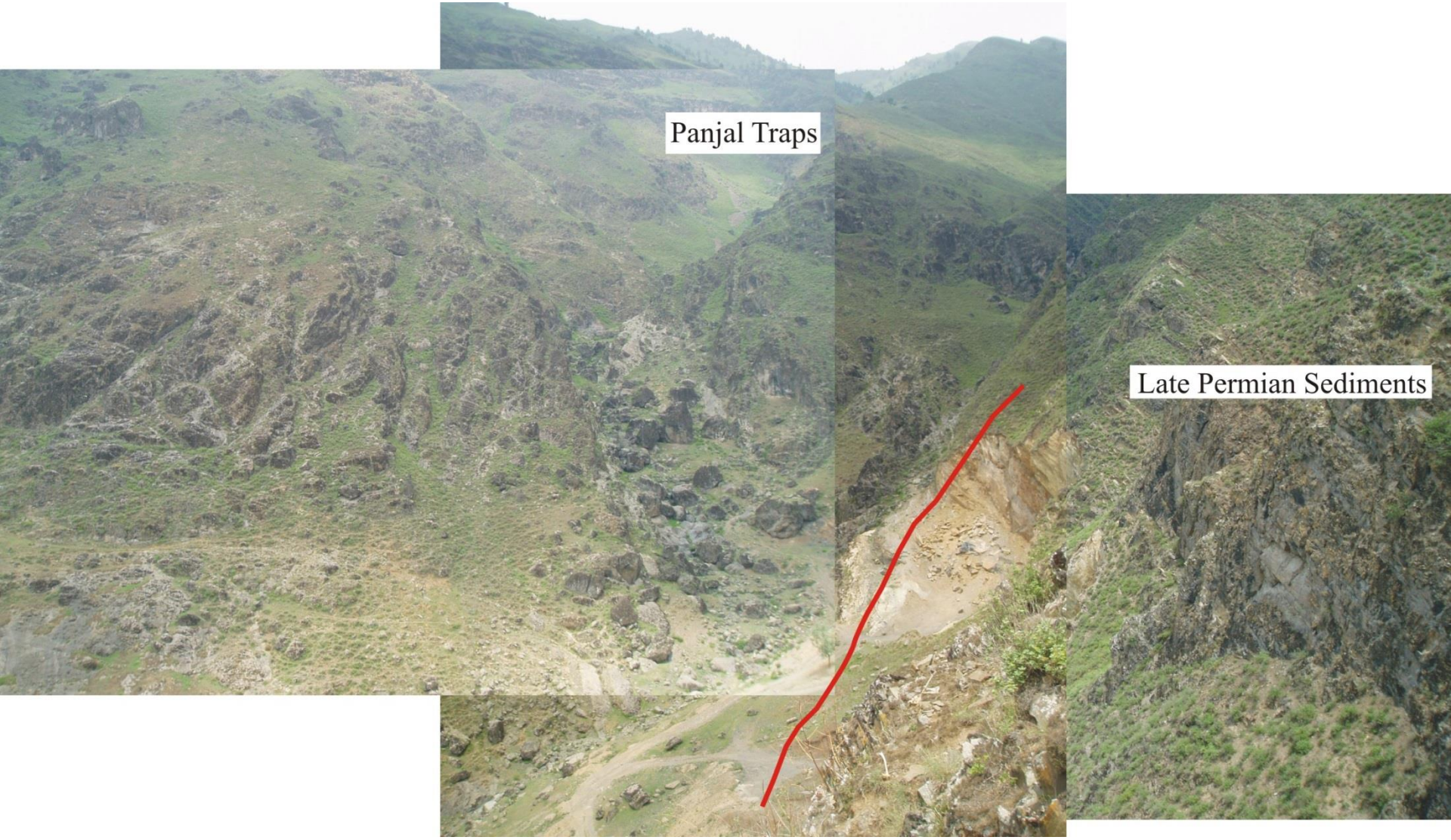
Simplified geological map of the Kashmir Valley showing the distribution of the Panjal Traps.

There are examples of massive flows, columnar jointed flows and pillow basalts.

Asian margin
- Karakoram units
- Shyok suture
- Kohistan-Ladakh units
- Dras Nindam
- IYSZ - MMT (Main Mantle Thrust)

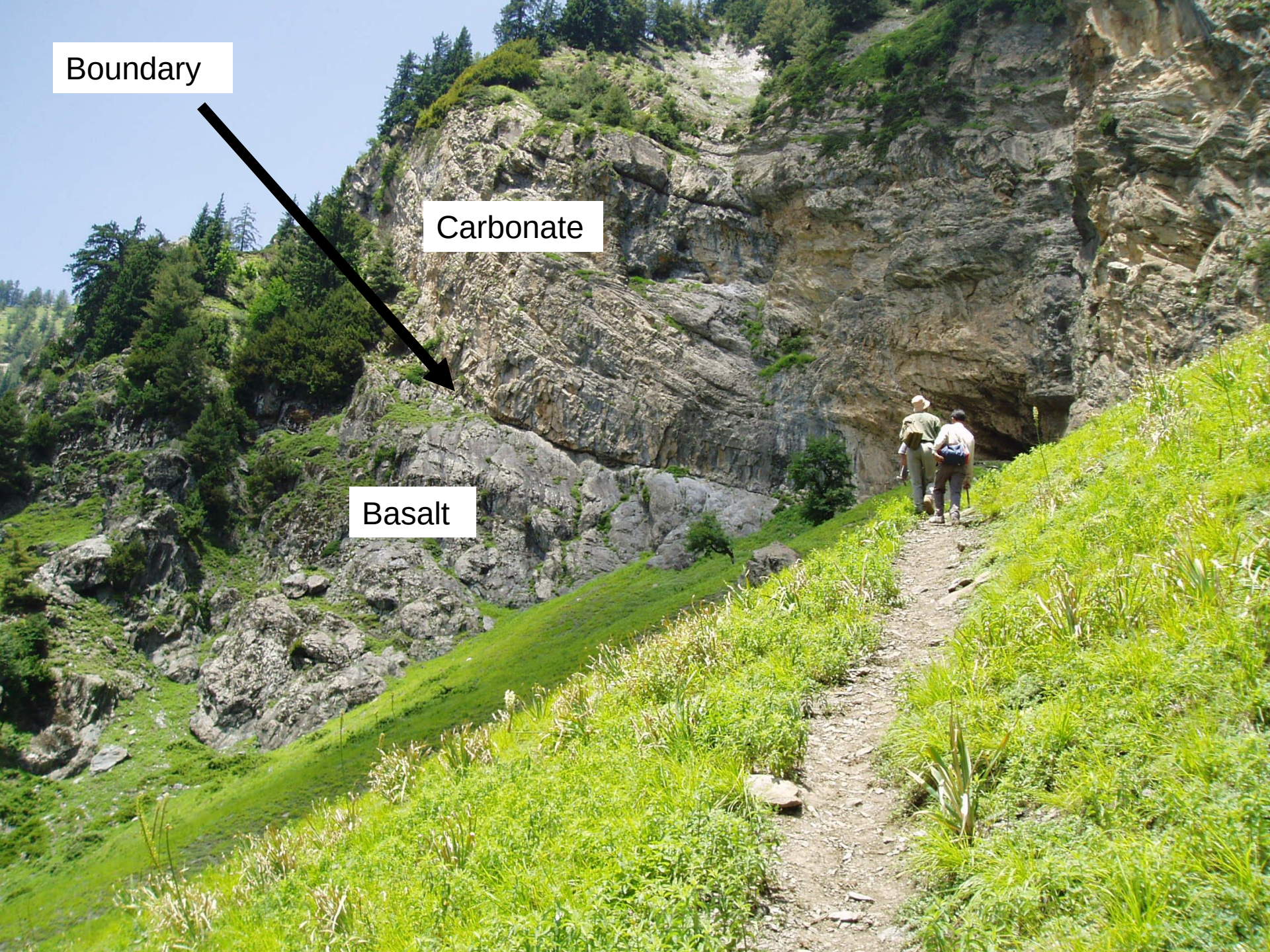
Indus-Yarlung Suture Zone
- Indus and Shergol units, Lamayuru flysch
- Ophiolites and associated melanges

Indian Platform
- Inner Paleozoic-Mesozoic metasediments
- Panjal Traps
- Precambrian-Eocene sequences
- Higher Himalaya
- MCT Main Central Thrust
- Lesser Himalaya



Guryul Ravine


Guryul Ravine

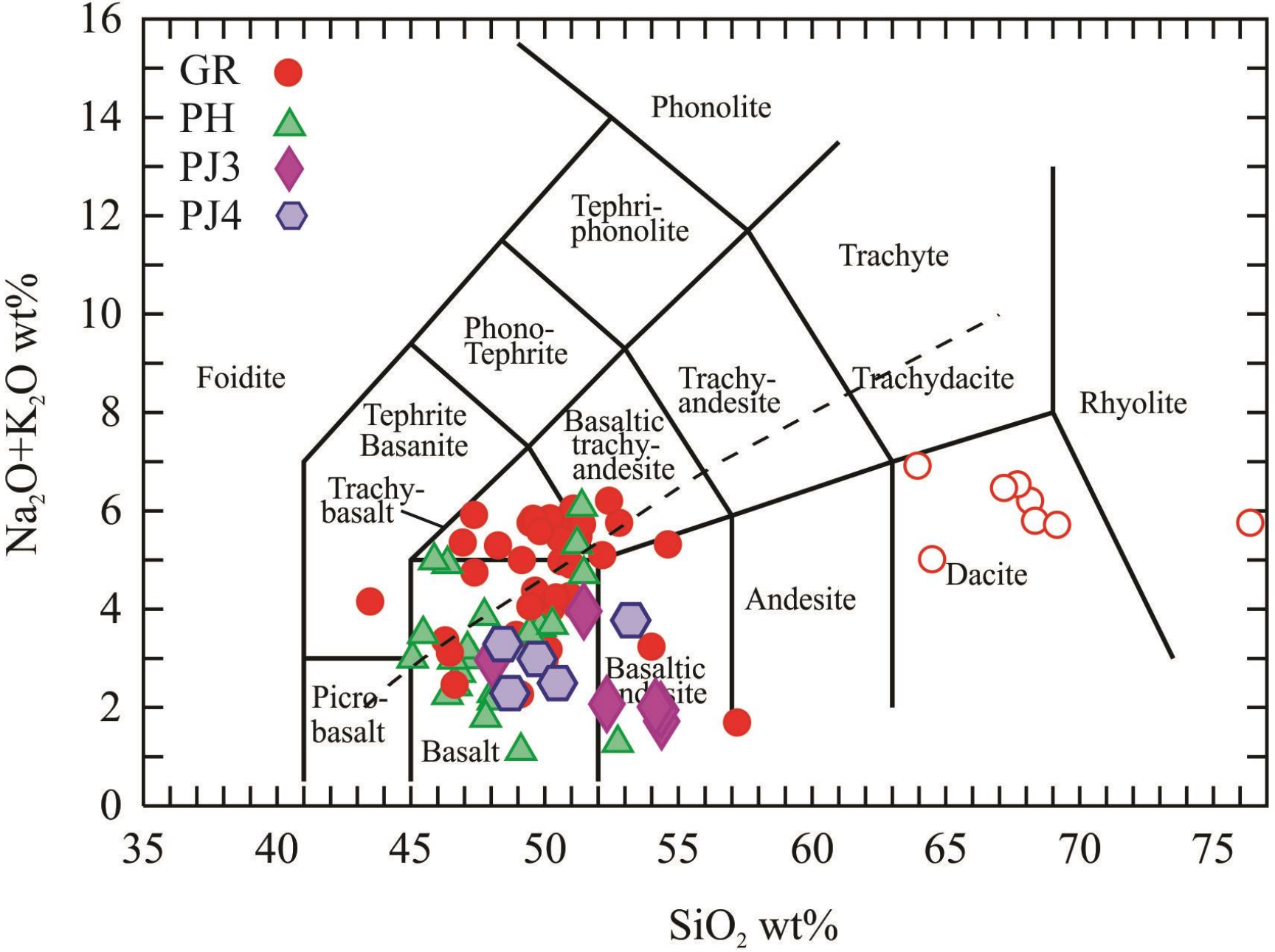

Boundary
Carbonate
Basalt

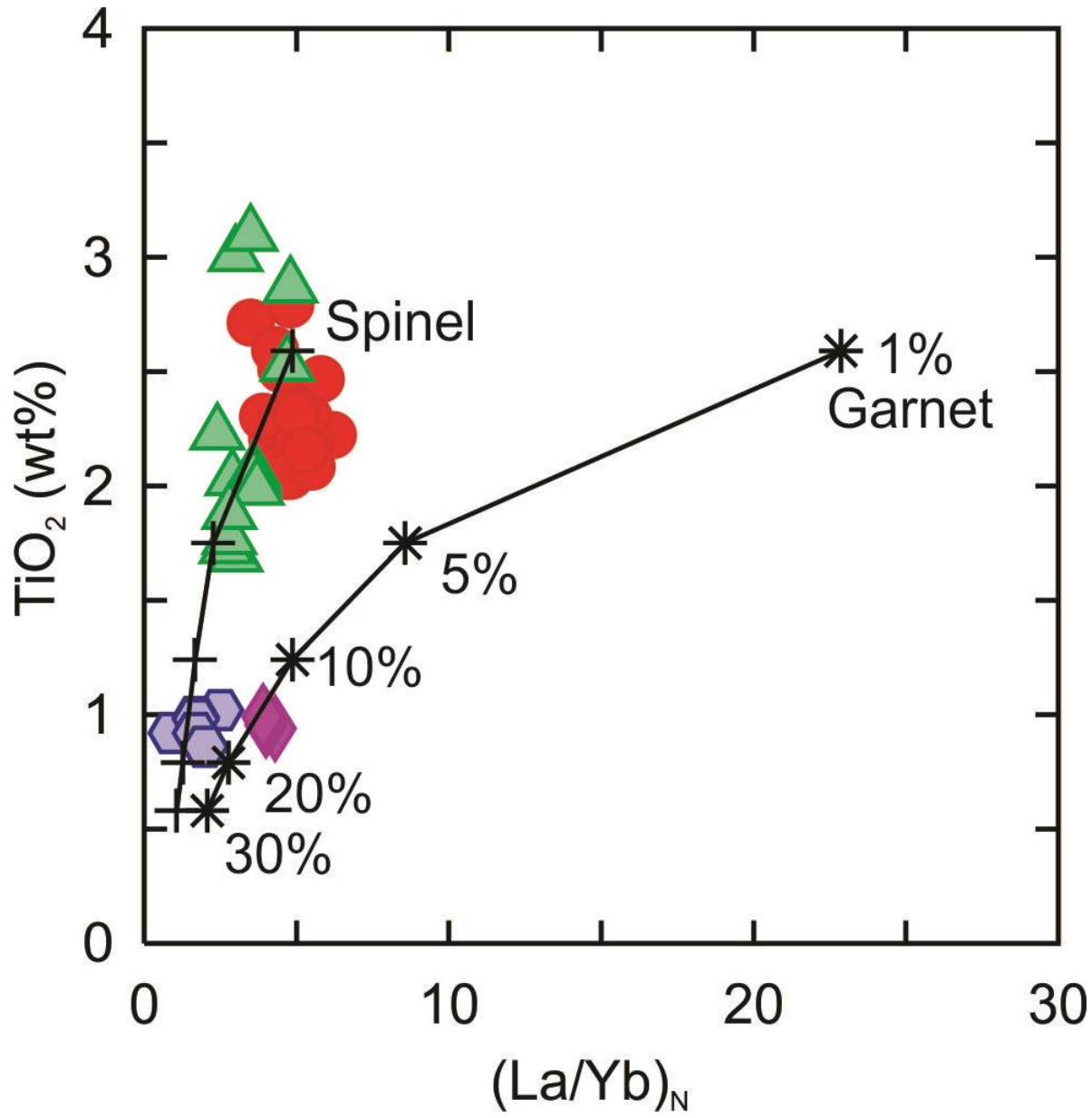

Columnar Jointing

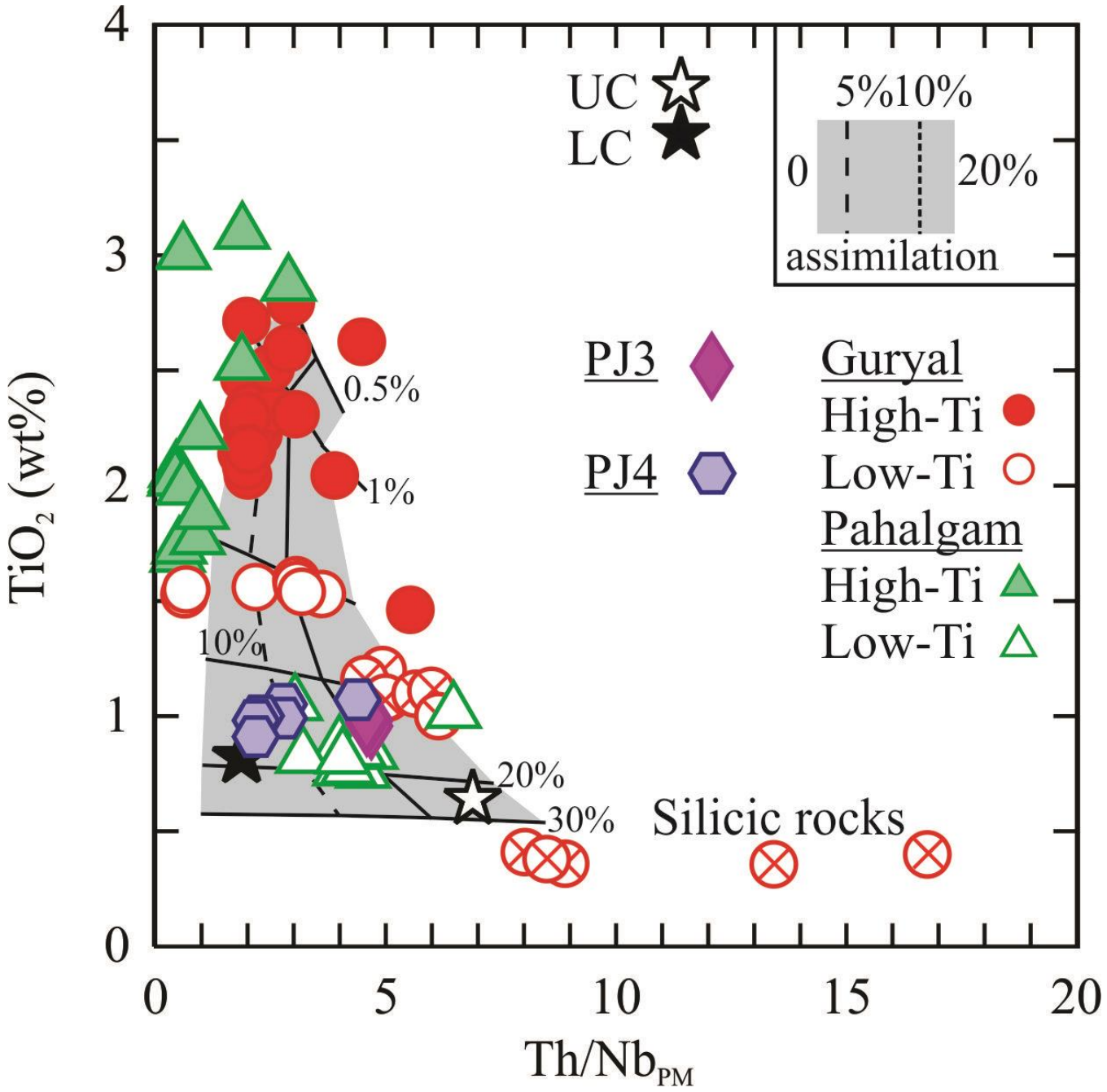

Pillow basalts

Petrogenesis of the Panjal Traps

- What is their bulk composition?
- Where did they originate from?
- Why did they form?
- What is the potential for mineral deposits?

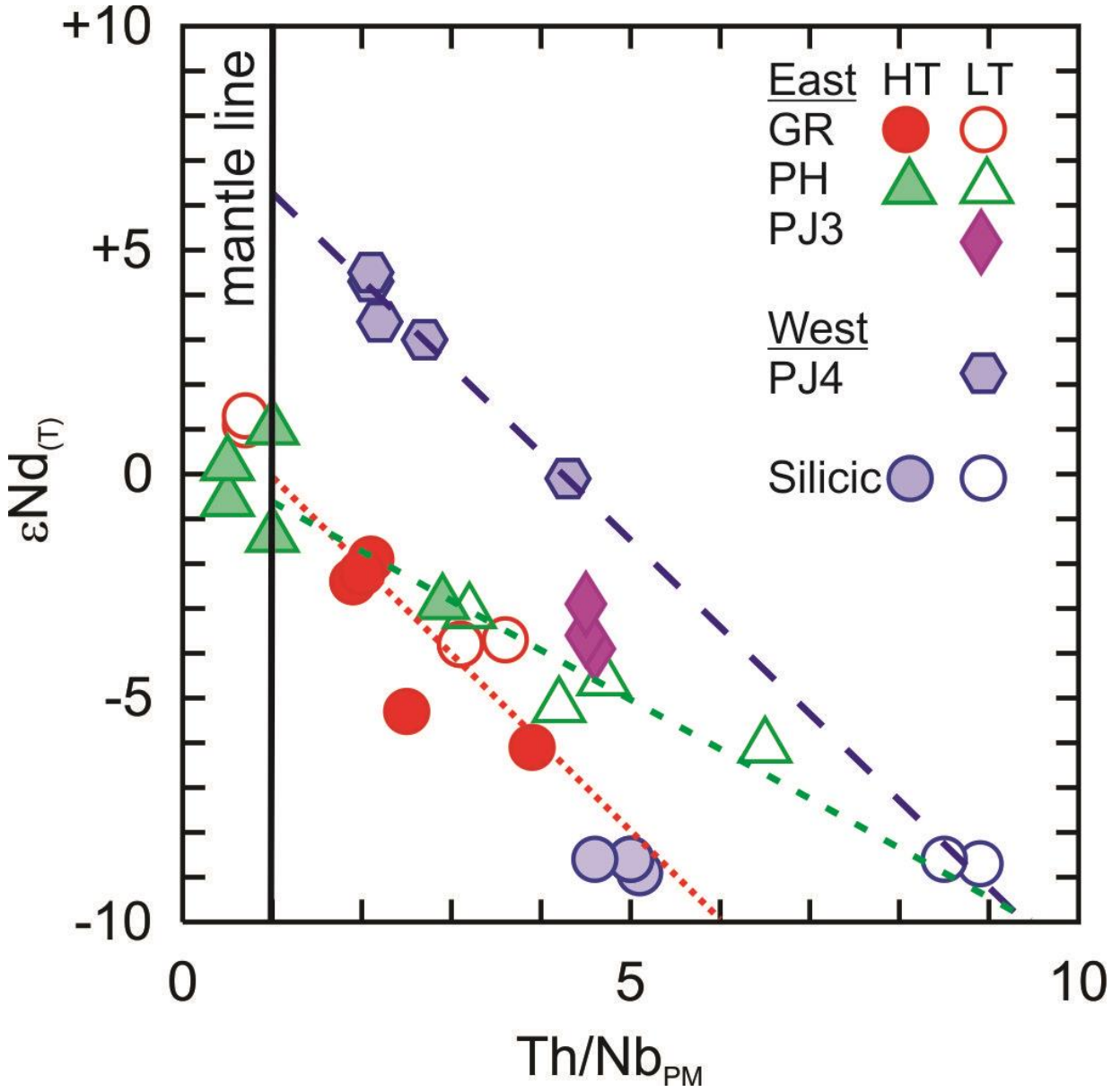

GR
PH
PJ3
PJ4
Phonolite
Tephri-
phonolite
Trachyte
Phono-
Tephrite
Foidite
Trachy-
andesite
Trachydacite
Rhyolite
Tephrite
Basanite
Basaltic
trachy-
andesite
Trachy-
basalt
Dacite
Andesite
Basaltic
Picro-
basalt
Basalt
16
14
12
10
8
6
4
2
0
35
40
45
50
55
60
65
70
75
Na_2O+K_2O wt%
SiO_2 wt%


4
3
2
1
0
0
10
20
30
TiO2 (wt%)
(La/Yb)N
Spinel
1%
Garnet
5%
10%
20%
30%


UC
LC
5%10%
0
20%
assimilation
PJ3
PJ4
Guryal
High-Ti
Low-Ti
Pahalgam
High-Ti
Low-Ti
0.5%
1%
10%
20%
30%
Silicic rocks
TiO2 (wt%)
Th/NbPM
0
1
2
3
4
0
5
10
15
20

Geochemistry Results

- The Panjal Traps are alkalic to tholeiitic continental flood basalts. There are some silicic and intermediate rocks.
- Trace element modeling indicates that 0.5% to 15% partial melting of a spinel peridotite source will reproduce the REE patterns.
- Some basalts have not been contaminated by crustal material whereas others were variably contaminated (5%-10%).
- This means the Panjal Traps are derived from a shallow mantle source and have interacted with the crust.



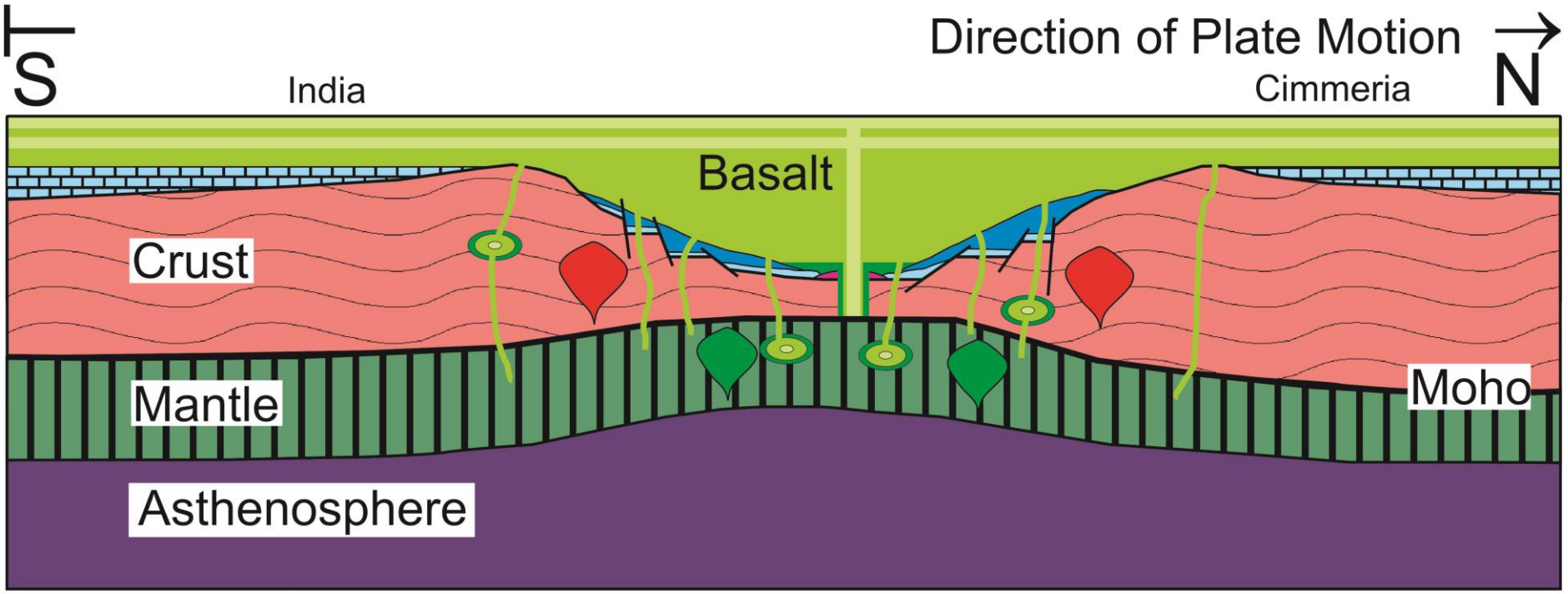
Nd isotope mixing relationship with the crust derived silicic volcanic rocks of the Panjal Traps.

Isotope Geochemistry

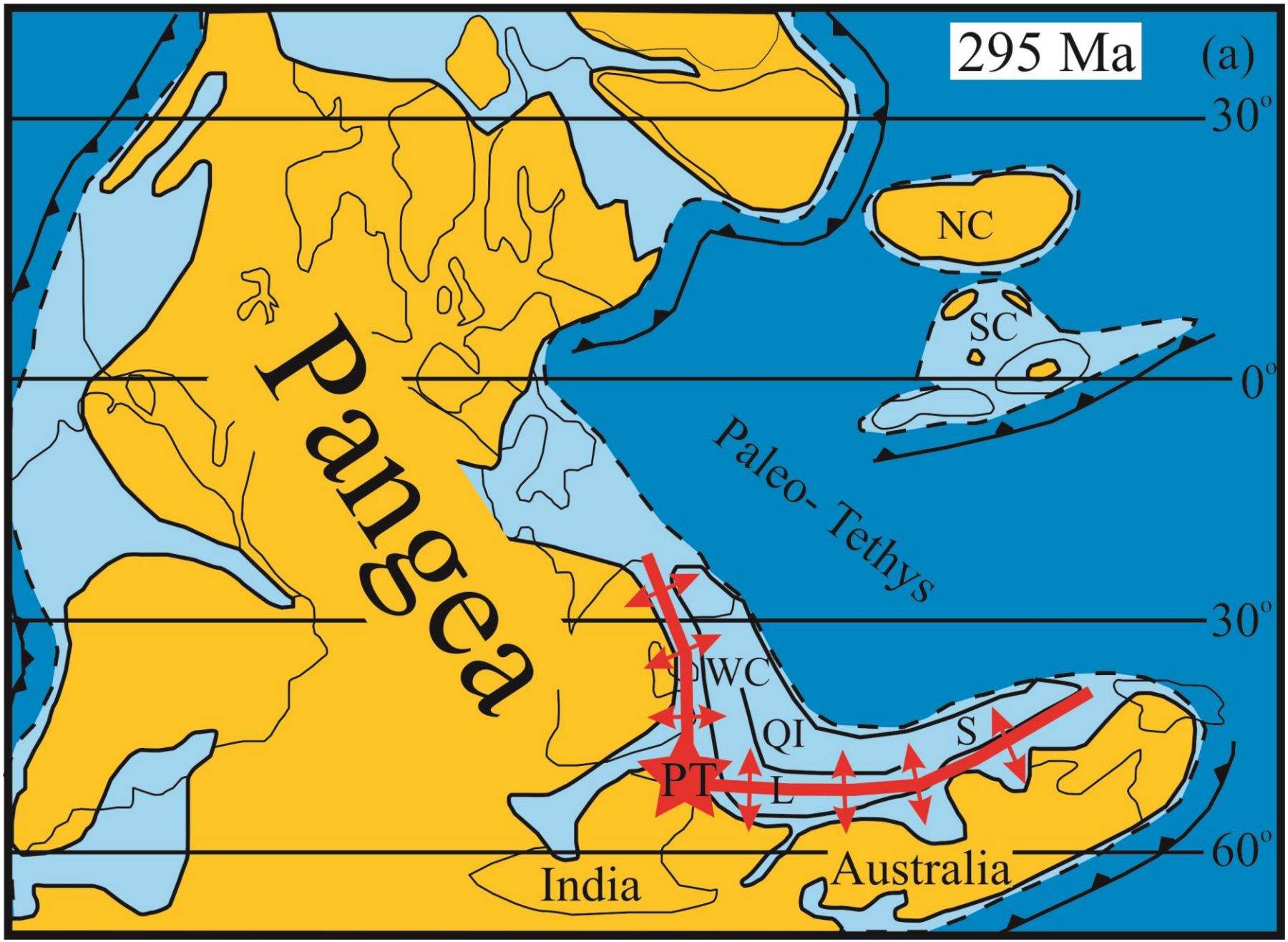
- The Nd isotope geochemistry is variable from different localities which is likely related to crustal contamination.

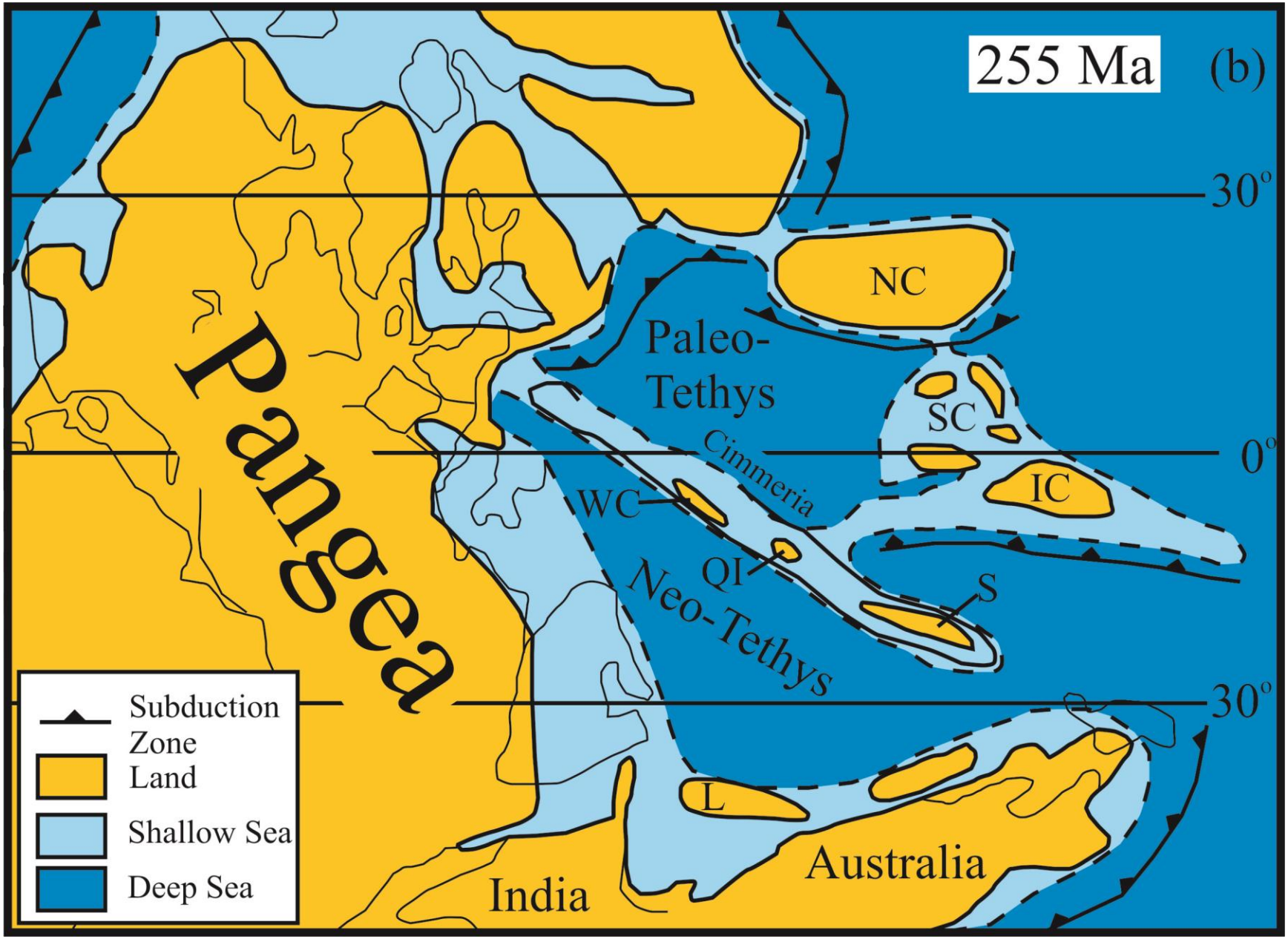
- The differences in the Nd isotopes from eastern Kashmir Valley and western Kashmir Valley suggest that the basalt piles have different sources.

- The west are more similar to E-MORB (i.e. depleted mantle) whereas the east are more similar to OIB (i.e. enriched mantle).



Passive Extension Model


295 Ma
(a)
30°
0°
30°
60°
NC
SC
Pangea
Paleo- Tethys
PWC
QI
S
PT
L
India
Australia


255 Ma
(b)
30°
0°
30°
Pangea
NC
Paleo-
Tethys
SC
Cimmeria
IC
WC
QI
Neo-Tethys
S
L
India
Australia
Subduction Zone
Land
Shallow Sea
Deep Sea

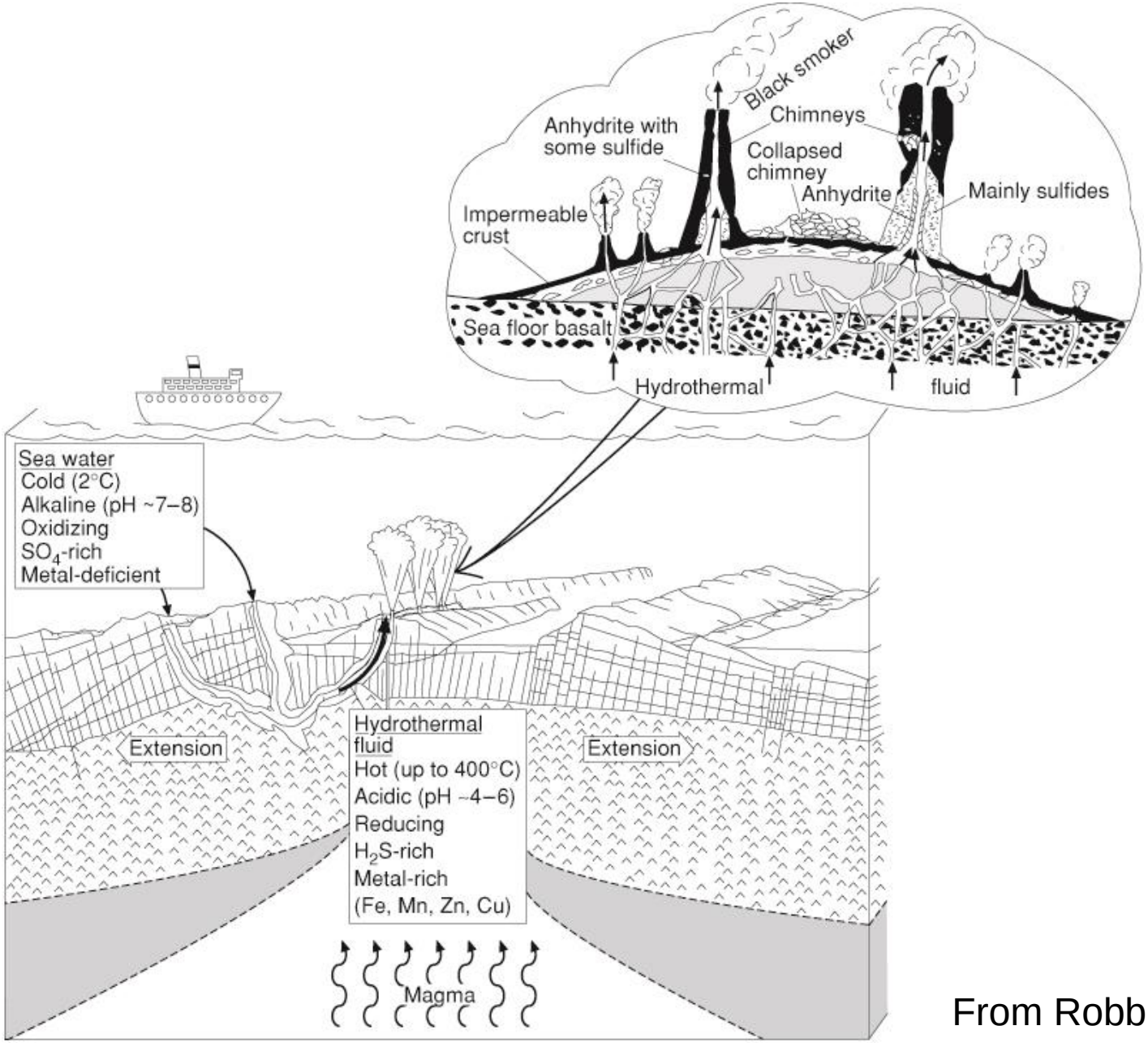
What is the potential for mineral deposits?

- The sub-aerial eruption environment is not a good place to look for mineral deposits.

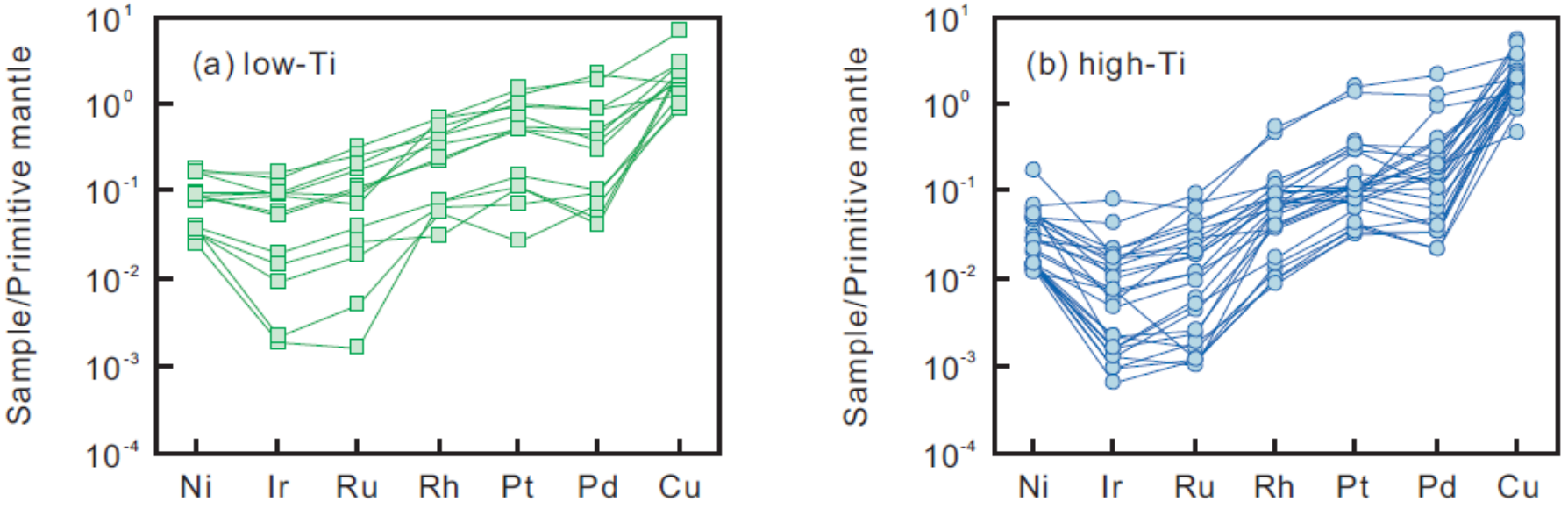
- The pillowed basalts, however, indicate a sub-aqueous environment which is a very good place to look for VMS deposits mineral deposits.

- The PGE data indicate that the basalts are depleted in sulphur and therefore sulphide deposits maybe associated with the plutonic rocks.

Formation of oceanic volcanogenic massive sulphide deposits



From Robb (2005)



Normalization of PGEs and Ni and Cu to primitive mantle values for the rocks from eastern Kashmir Valley.

Conclusions

1) The Panjal Traps are likely derived from partial melting of the lithospheric mantle.

2) The Panjal Traps are a consequence of rifting along the southern margin of the Tethys Ocean.

3) The presence of pillow basalts means that water was present during the eruption of the basalts and is favourable site for VMS deposits.

4) The depleted PGE nature of the basalts suggests sulphide minerals segregated before eruption and that there could be massive sulphide deposits within the intrusive units.