Hf-Nd dichotomy: constraints from felsic, mafic and ultramafic rocks in the western Dharwar Craton, India

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Introduction

The ^{176}Lu-^{176}Hf and ^{147}Sm-^{143}Nd isotope systematics are good tracers of the degree of mantle depletion and concomitant continental crust formation. They behave similarly during magmatic differentiation (***Fig.1***). However, ultramafic rocks in some Archaean cratons show discrepancies in their initial isotope ratios (εHf ≠ 2×εNd) (e.g. Nebel et al., 2014; Hoffmann et al., 2017). This 'decoupling' of Hf-Nd isotopes, if present, implies a strong heterogeneity in the Archaean mantle

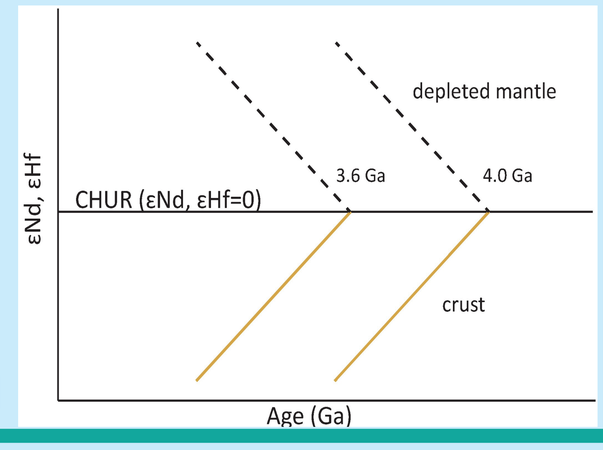
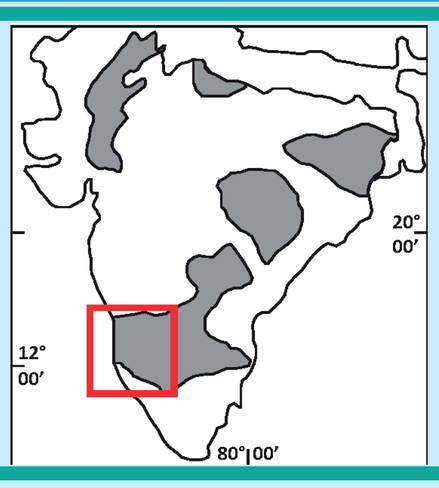


Fig.1: The chemical behaviour of ^{176}Lu-^{176}Hf, ^{147}Sm-^{143}Nd systems during magmatic differentiation

Geological background

- Western Dharwar Craton- oldest part of the continent
- basement of TTG gneisses (3.4-3.0 Ga)
- Older Sargur greenstone belt (3.3-3.1 Ga)
  Younger Bababudan greenstone belt (~3.1-2.8 Ga)
- Greenschist to lower amphibolite facies



Komatiitic rocks

- Komatiites, komatiitic basalts, olivine cumulates belong to the Sargur Group
- Ages constrained as 3.35-3.15 Ga only by Sm-Nd isotopes
- Komatiites show (rarely) spinifex texture (***Fig.3***)

Fig.2: Map of Indian sub-continent. ⊙ the five Paleoarchaean cratons ☐ the location of the western Dharwar Craton

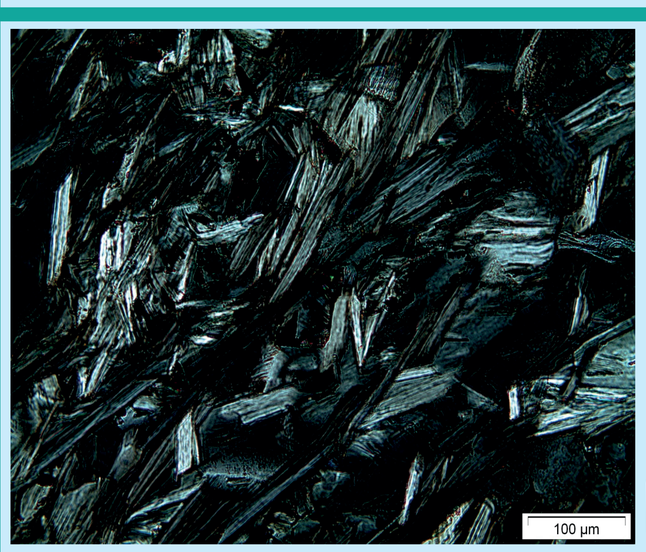


Fig.3: Spinifex texture of a komatiitic rock under crossed polars

Results and implications

- Hf and Nd isotopes of TTGs and greenstone mafic rocks show mild to significant source depletion and correlate (***Fig.4***).
- Komatiitic rocks (MgO=15-30%; Na_2O+K_2O<1; (Gd/Yb)N=0.6-1.8) show strongly depleted and 'decoupled' Hf-Nd isotope ratios (***Fig.5***).

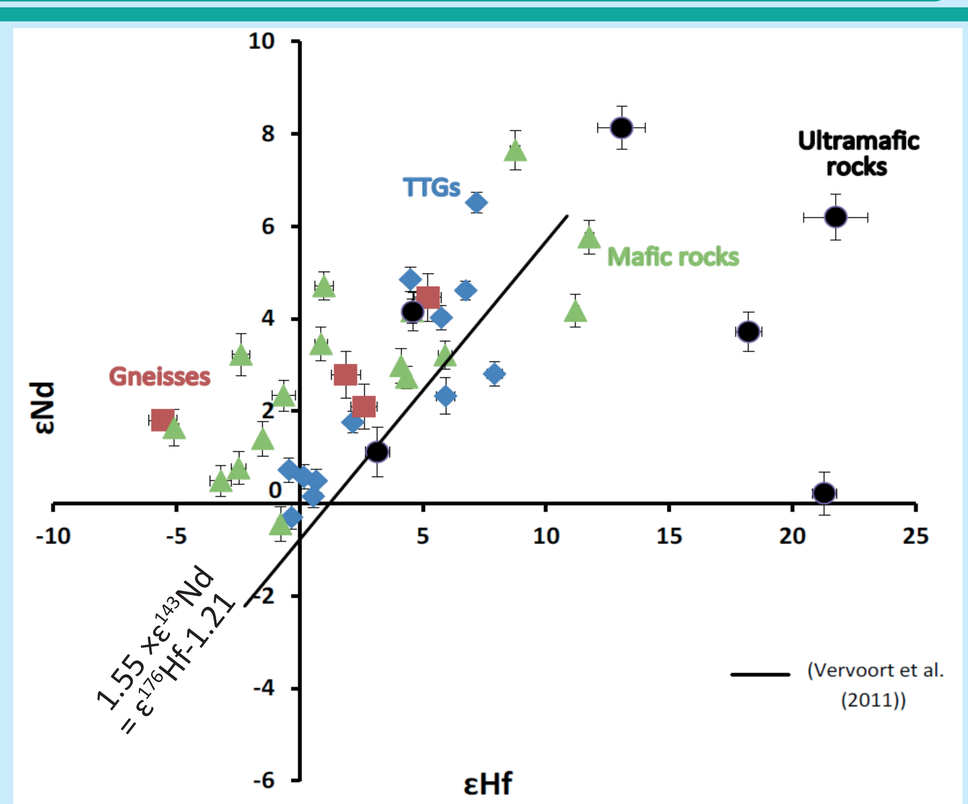


Fig.4: εHf vs. εNd of TTGs, gneisses, mafic and ultramafic rocks in the western Dharwar Craton

Ages

- The ultramafic rocks have a whole rock ^{176}Lu-^{176}Hf age of 3182±170 Ma and a ^{147}Sm-^{143}Nd errorchron age of 3655±420 Ma; Sm-Nd isochrons are mildly disturbed
- The Lu-Hf age (3204±200 Ma) agrees with the U-Pb zircon age of mafic rocks in the Sargur Group (3228±22 Ma)

Composition of the precursor

- Nd systematics show involvement of more than one source component (***Fig.6***). Ultramafic rocks show 1/Nd from ~0.5-3.5
- The source could involve a 3.6 Ga old mafic crust (Ravindran et al., 2020) and the contemporary depleted mantle

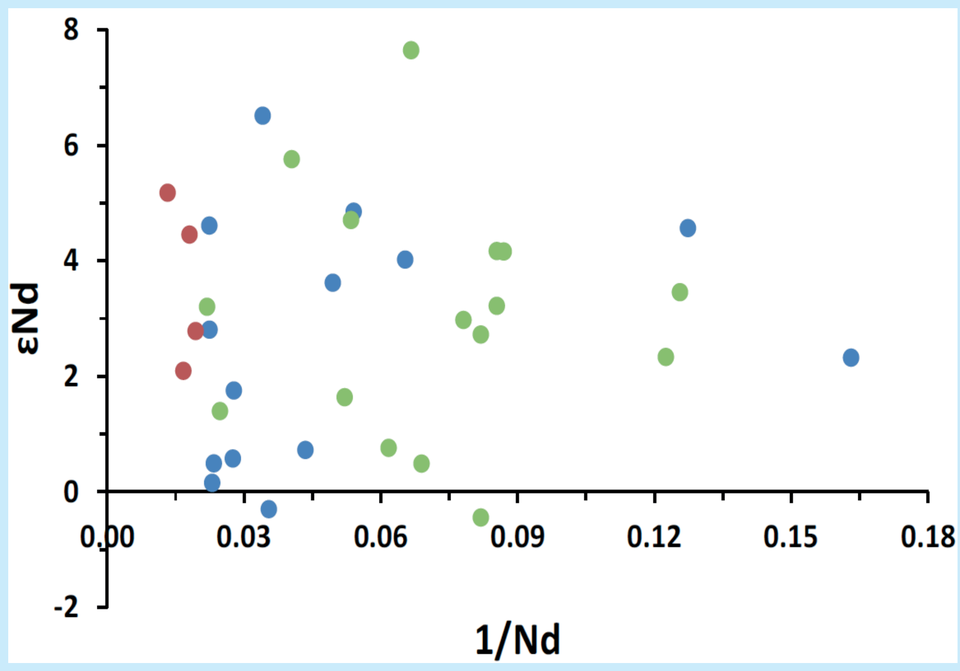


Fig.6: ε^{143}Nd vs. 1/Nd of magmatic rocks in the western Dharwar Craton. Colour codes same as in ***Fig.4***

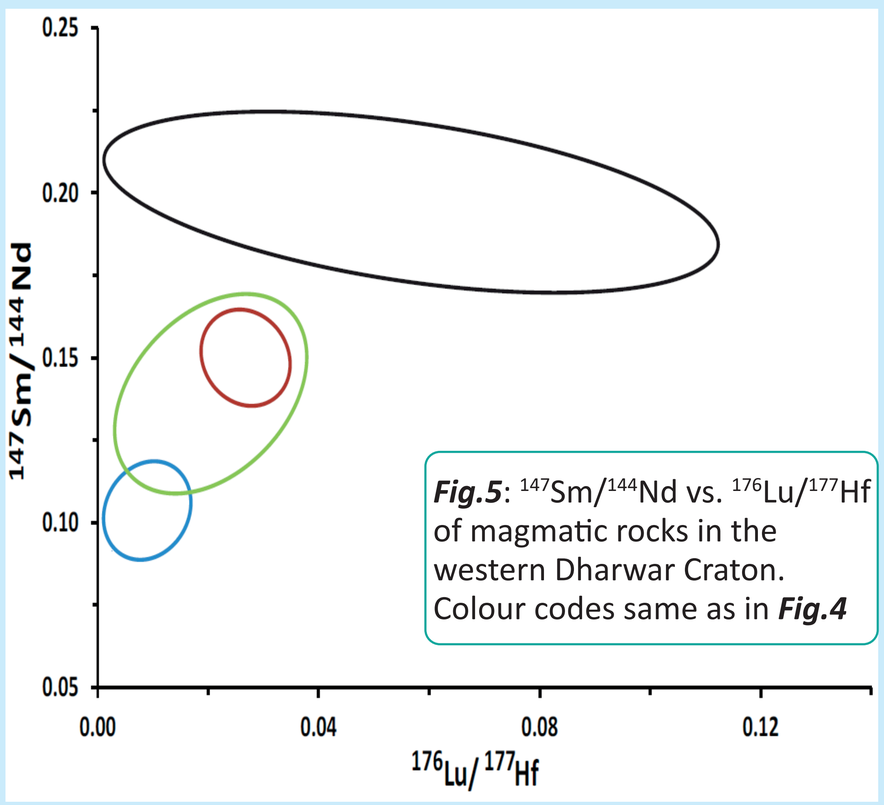


Fig.5: ^{147}Sm/^{144}Nd vs. ^{176}Lu/^{177}Hf of magmatic rocks in the western Dharwar Craton. Colour codes same as in ***Fig.4***

Nature of the Archaean mantle source

- The Hf-Nd array of mafic-felsic rocks indicate correlation in the composition of the source as expected from magmatic processes
- Some komatiitic rocks strongly deviate from the array and have highly radiogenic Hf isotope ratios. This indicates a different source for their formation with decoupled Lu-Hf/ Sm-Nd isotope systematics
- As komatiitic rocks are high temperature melts and come from a great depth, chemical layering of the early mantle might be the cause for the decoupling
- The ultramafic precursor could be the remnant of early mantle after deep differentiation

Conclusions

- The 'decoupled' Lu-Hf and Sm-Nd isotope systems in ultramafic rocks has been observed for the first time in the Dharwar Craton; mafic and felsic rocks show correlation of Hf-Nd isotopes in the source
- Large variability of Lu-Hf isotopes in komatiitic rocks ➞ heterogeneity in Archaean mantle source composition
- Komatiitic melts could be derived from remnants of early mantle differentiation at great depths (garnet-perovskite fractionation?)

References

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