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# Complex shallow mantle beneath the Dharwar Craton inferred from Rayleigh wave inversion

Kajaljyoti Borah,[1] S. S. Rai,[1] Keith Priestley[2] and V. K. Gaur[3,4]

[1]*National Geophysical Research Institute, Uppal Road, Hyderabad* 500 007*, India. E-mail: kajalborah1979@gmail.com*
[2]*Bullard Laboratories, Cambridge University, Cambridge CB*3 0*EZ, United Kingdom*
[3]*Indian Institute of Astrophysics, Bangalore* 560034*, India*
[4]*CSIR Fourth Paradigm Institute, Bangalore* 560034*, India*

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## SUMMARY

The 3-D shear velocity structure beneath South India's Dharwar Craton determined from fundamental mode Rayleigh waves phase velocities reveals the existence of anomalously high velocity materials in the depth range of 50–100 km. Tomographic analysis of seismograms recorded on a network of 35 broad-band seismographs shows the uppermost mantle shear wave speeds to be as high as 4.9 km s$^{-1}$ in the northwestern Dharwar Craton, decreasing both towards the south and the east. Below ∼100 km, the shear wave speed beneath the Dharwar Craton is close to the global average shear wave speed at these depths. Limitations of usable Rayleigh phase periods, however, have restricted the analysis to depths of 120 km, precluding the delineation of the lithosphere–asthenosphere boundary in this region. However, pressure–temperature analysis of xenoliths in the region suggests a lithospheric thickness of at least ∼185 km during the mid-Proterozoic period. The investigations were motivated by a search for seismic indicators in the shallow mantle beneath the distinctly different parts of the Dharwar Craton otherwise distinguished by their lithologies, ages and crustal structure. Since the ages of cratonic crust and of the associated mantle lithosphere around the globe have been found to be broadly similar and their compositions bimodal in time, any distinguishing features of the various parts of the Dharwar shallow mantle could thus shed light on the craton formation process responsible for stabilizing the craton during the Meso- and Neo-Archean.

**Key words:** Composition of the mantle; Surface waves and free oscillations; Seismic tomography; Cratons; Asia.

## 1 INTRODUCTION

Cratons are extraordinary areas of continental lithosphere that have exhibited long-term stability against deformation. While the processes of their formation and preservation remain a matter of continuing enquiry, it is clear that their lithospheric structures must be so constituted as to fulfil the following two requirements throughout their history: (i) the ability to maintain a net positive balance between the opposing effects of chemical and thermal buoyancy and (ii) a total yield stress that is greater than those exerted by mantle convection. The latter, in turn, requires a thick root acquired through a cumulative process as well as high viscosity and elevated solidus by expulsion of bound molecular water. Worldwide investigations of mantle xenoliths from cratonic regions have shown that the subcrustal cratonic mantle lithosphere (SCML) consists primarily of olivine with an unusually high proportion of Mg# minerals and low Ca, Al oxides (Bernstein *et al.* 1997), even as the high Mg hosts vary from the orthopyroxene-rich harzburgites of the Kaapvaal craton (Boyd & Mertzman 1987) to the refractory dunites of Greenland (Bernstein *et al.* 1997). However, the particular thermo-mechanical mechanism responsible for sequestering the large amounts of anhydrous lighter derivatives from the parental peridotites to form the cratonic lithosphere is a matter of debate. The two main hypotheses advanced to explain this segregation process, ones that require an efficient melting regime, assume: (i) extensive partial melting with melt and volatiles being extracted under extreme conditions within the head of a hot mantle plume and (ii) repeated reprocessing at subduction margins of the depleted oceanic mantle (Lee 2006; Arndt *et al.* 2009; Lee *et al.* 2011) which, in the Archean, would probably have a higher proportion of Forsterite, Fo#91–93. The first of these predicates a zonally differentiated pattern horizontally mediated by the distance to the plume edge and vertically by the distance above the solidus. The latter might be expected to retain the vestiges of the original stratification produced by higher levels of partial melting with decreasing depth, as well as of extensive harzburgite enrichment such as dipping interfaces of stacked oceanic mantle (Bostock 1998; Lavender *et al.* 2005). This paper presents the results of an experiment designed to discern these features in the shallow cratonic