Perspectives on cratonic and Phanerozoic deep continental lithosphere from xenoliths: geochemical, petrological, and microstructural constraints

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"intact" cratons: Slave, Siberian, Kaapvaal

"disturbed" cratons: N. China, Wyoming, Colorado Plateau

Phanerozoic mantle lithosphere - Sierra Nevada, California
Xenoliths

Dunite

Garnet harzburgite

Whole xenoliths from Lesotho kimberlite

Spinel lherzolite
Secular variation in SCLM

Artemieva, Lithos 2009
Textural variation in P-T space

Coarse granular lherzolite (Wyoming)

Sheared lherzolite (Wyoming)

Boyd, GCA 1973

Parks, Chin et al., in prep
Forming cratonic mantle

• Petrology/geochemistry, microstructures, PT path

• Combine with seismology & geophysical observations

a. Plume origin
   - Dry, “A-type” fabric
   - No subduction trace-element
   - Isotropic structure?

b. Oceanic lithosphere underthrusting and imbrication
   - Subduction/hydrous trace-element
   - Dipping structures

Lee et al., Annu. Rev. 2011

c. Arc thickening/accretion
   - Subduction trace-element
   - Dipping structures, continuity with crustal sutures?
Kaapvaal craton

Baptiste et al., Lithos 2012
Siberian craton

Fig. 9. Detailed distribution of harzburgitic garnets (defined as in Fig. 3a) within each field along the Olenek trend. Lithosphere–asthenosphere boundary (LAB) defined as in Fig. 5. The position of the LAB in two different time slices is shown at the northern end of the traverse.
Slave craton

Kopylova & Russell, EPSL 2000
No correlation in H2O and degree of melt depletion
Pyroxene H$_2$O

Compiled from various sources
Olivine CPO - Kaapvaal

Coarse granular

Fluidal

Mylonitic

Baptiste et al., Lithos 2012
Olivine CPO - Siberia

Coarse granular

Porphyroclastic

Bascou et al., EPSL 2011
Different formation mechanisms?

Doucet et al., GCA 2014
Cratonic peridotites

- Cratons vary in degree of stratification
  - Slave strongly layered
  - Kaapvaal & Siberian less layered

- With increasing depth:
  - Water content increases
  - Bimodal & axial-[010] olivine CPO increases
What can we learn from non-cratonic peridotites?
A Mesozoic example from North America

Sierra Nevada Batholith, CA
Thicken, cool, stabilize

$H_2O$ solubility*: 400 ppm
$\eta_{eff} = 10^{18} \text{ Pa s}$

$H_2O$ solubility: 80 ppm

Chin et al., G^3 2016
Melt depletion PT ≠ final PT also observed in cratons
Olivine CPO varies with depth, similar to some cratonic xenoliths.
Bulk CPO vs. intragranular microstructures

<table>
<thead>
<tr>
<th>Slip System &amp; CPO</th>
<th>Tilt Boundary</th>
<th>Twist Boundary</th>
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<tbody>
<tr>
<td></td>
<td><strong>Row 1</strong> plane // to subgrain bndry.</td>
<td><strong>Row 2</strong> rotation axis</td>
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<td>A-type</td>
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<td>[010]; requires [010] &amp; [100] screws</td>
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<tr>
<td>E-type</td>
<td>[010]</td>
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</tbody>
</table>
“E-type” subgrains dominate

- E-type — high water
- Yet bulk CPO anhydrous (A/B type) and olivine only has 10 ppm H2O
Sierran arc xenoliths

- **Depth gradient from orthorhombic CPO to weak axial-[010]**
  - Reflected in composition

- **Subgrains preserve earlier, hi-T hydrous deformation**
  - Low $T_{\text{final}}$: low $H_2O$ solubility

- Orthorhombic E-type to weak axial-[010] decreases Vp anisotropy
  ([Michibayashi et al. 2016](#))

- **Similar to cratons, with increasing depth:**
  - Water content increases
  - Bimodal & axial-[010] olivine CPO increases
Are cratons forever?

Petrofabric & geochemistry of Wyoming peridotites
Olivine CPO of Wyoming Craton xenoliths

Homestead
H00-11-16: Gt-sp lherzolite

Williams
H68-16B: Gt-sp harzburgite

B-type
axial-[010]

Parks, Chin et al., in prep
Effects of Laramide Orogeny on Wyoming Craton

- Hydration & metasomatism disturbs SCLM
- B-type, axial-[010] olivine CPOs
- High $T_{\text{REE}}$ - transient heating

Parks, Chin et al., in prep
Similarities between Archean & Phanerozoic mantle

Lee et al., Annu. Rev. 2011

coarse granular

Drier, “original” CPO?

MLD?

porphyroclastic

Wetter, modified CPO

depleted

refertilized