Mantle roots of major Precambrian shear zones inferred from structure of the Great Slave Lake shear zone, northwest Canada

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ABSTRACT

Preserved, ancient orogens provide important perspective on modern continental convergent zones. Relatively deep levels of these systems are exposed at the surface, and these crystalline rocks promote the recording of seismic signals from great depths. In this study, multi-azimuthal teleseismic observations reveal gently dipping discontinuities and wedge-shaped structures beneath the Great Slave Lake shear zone, Canada, which formed the Paleoproterozoic convergent boundary between the Archean Slave and Rae cratons during assembly of the Nuna supercontinent. This ancient shear zone experienced two distinct tectonic phases. An early convergence phase involved intracontinental underthrusting of the Slave craton beneath the Rae margin with little evidence of subduction. A later phase was characterized by brittle strike-slip faulting. Receiver functions exhibit discontinuities that imply the latter faults to be listric in the crust. A high-velocity layer below the Moho may mark eclogitic residues of melts that formed “calc-alkaline” granitoids within the crust of the shear zone, without invoking subduction-induced melting within the mantle. Uppermost mantle discontinuities and xenolith suites from nearby kimberlite pipes together define lithological and structural geometries interpreted as two phases of wedging by the central Slave craton lithosphere, associated with either Slave craton construction or early Slave-Rae convergence. The new teleseismic data contain no direct or indirect evidence of faulting along near-vertical suturing structures within the crust or the mantle. The observed wedge-shaped cratonic margins imply that lithospheric blocks grew primarily by lateral accretion of similar blocks, with the strongest layer at 100–150 km depths. In the study area, the diamond-bearing Slave lithospheric mantle wedge underlies the entire shear zone at depths where diamonds are stable, and data indicate that the Slave craton's lithospheric mantle was intact and strong at these depths as early as 2.0–1.9 Ga, when this tectonic boundary was active.

INTRODUCTION

The three-dimensional lithospheric structure of major continental fault zones remains poorly documented worldwide. Where such faults are exposed, bedrock and geodetic mapping provide two-dimensional (2-D) surface geometry and timing constraints, and thus the resulting understanding of each fault’s tectonic evolution is limited to the uppermost crust. By default, these faults are presumed vertical throughout the lithosphere. However, deep seismic-reflection profiling has shown, through the lack of offsets in laterally continuous reflectors, that the deep crustal geometry of archetypal strike-slip faults (San Andreas, Alpine, and Great Glen faults) seldom includes simplistic vertical faults below the upper crust (Furlong et al., 1989; Brocher et al., 1994; Stern and McBride, 1998). More ancient examples are even less well understood. In Precambrian shield settings, however, the strongest lithospheric layer occurs at 50–100 km depths within the uppermost mantle (Sleep, 2009). This makes structural geometries observed at these depths (not near the surface) key factors in understanding the tectonic history and fault development, because these depths are where the overall rate of horizontal shortening will be limited during convergence.

The mechanical strength of continental lithosphere and its support of mountain belts, primarily through crustal root zones, remain active research topics (Jackson, 2002; TRANSALP Working Group, 2002). Study areas are generally neotectonic, so that earthquakes can serve as proxies for strain measurements, although many examples, such as the Himalayan and Zagros mountain belts, do involve one Precambrian shield. Subduction of intervening oceanic lithosphere and high heat flow are generally assumed in such neotectonic settings, usually from direct observations and measurements, and thus a crustal layer provides maximum horizontal strength in these settings (Jackson, 2002). In a few examples, such as the Tien Shan, intracontinental convergence occurs where deeper maximum horizontal strength possibly lies within the uppermost mantle (Vinnik et al., 2004). Our study addresses the fundamental nature of the Paleoproterozoic convergence of two Archean cratons with no relevant paleoseismicity or heat-flow regimes available from that time. Whether the convergence involved subduction or only collision of two cratons has important implications for metasomatism of the cratonic margins and their assumed strength profiles.

In this study, multi-azimuthal teleseismic observations provide insights at 40–250 km lithospheric depths within the Canadian Shield by revealing seismic discontinuities that are laterally continuous beneath the Great Slave Lake shear zone, which is the tectonic boundary between the Archean Slave craton and the Rae domain of the Churchill Province in Canada (Hoffman, 1987; Chacko et al., 2000). Few methods penetrate to mantle depths, and our analysis is thus limited largely to mapping lateral continuity and dips of seismic discontinuities as calibrated by a few geochemical studies of nearby granites and xenoliths. The consistency of lateral correlations of several seismic phases directly beneath surface traces of component Great Slave Lake shear zone faults suggests that these faults, or shear zones, cannot be near vertical. Instead, the moderately dipping discontinuities observed emphasize the prominent role of thrust and wedge tectonics during craton convergence and thus imply a great width...
for these continental orogens (Jackson, 2002). Craton boundaries and zones of concentrated strain in the uppermost crust may thus be displaced laterally hundreds of kilometers from their kinematic counterparts within the continental mantle lithosphere.

**GEOLOGICAL SETTING**

The Great Slave Lake shear zone forms the boundary between the Archean Slave and Rae cratons amid a collage of crustal elements recognized near the center of the Canadian Shield (Fig. 1; Hoffman, 1987; Ross et al., 2000). Known inherited collisional architecture resembles that of Phanerozoic analogues characterized by telescoped passive margins, foreland basins, accreted island arcs, and microcontinents. Regionally reconstructed oblique convergence of the Slave and Rae cratons during the Paleoproterozoic (2.0–1.8 Ga) assembly of Nuna (Hoffman, 1987) is consistent with the evolution of local structures observed along the cratons’ common boundary, the Great Slave Lake shear zone (Hanmer et al., 1992). Progressively from southwest to northeast, this common boundary locally trends 065°, 040°, and 020°, where it is defined by the contact between Slave craton granitoids and granitoids and orthogneisses and paragneisses of the Taltson and Thelon magmatic tectonic zone (Fig. 1). The Great Slave Lake shear zone boundary is thought to result either from a Himalayan-style collision (Hoffman, 1987), or it formed as a plate interior mountain belt with similarities to the Tien Shan of central Asia (Chacko et al., 2000). Within the 020°-trending (Thelon) boundary segment, asymmetry in metamorphic grade, foreland basins, and 2.02–1.91 Ga Thelon magmatism suggest that the Slave craton was underthrust or subducted beneath the Queen Maud block of the Rae domain (Gibb and Thomas, 1977; Tirrul and Grotzinger, 1990). The 065°-trending (Taltson) segment is expressed within predominantly 1.97–1.90 Ga granite, monzodiorite, and tonalite (Chacko et al., 2000), which was subsequently deformed into a 25-km-wide tectonic zone composed of three bands of high-grade, steeply dipping, strike-lineated mylonites collectively called the Great Slave Lake shear zone (Hanmer et al., 1992). The new teleseismic transect crosses the Slave-Rae boundary at the northern end of the 065°-trending Taltson segment (Fig. 1). The boundary zone studied here is therefore transitional between strike-lineated structures typical of the pure strike-slip deformation observed to the southwest and dip-lineated structures typical of the thrust deformation observed along the Thelon margin to the north-northeast (Fig. 1; Hanmer et al., 1992).

Most of the Great Slave Lake shear zone evolved, as indicated by observations of three general, diachronous characteristics (Hanmer et al., 1992): (1) Metamorphic grade decreased from granulite to greenschist; (2) composite mylonite width decreased as ductile deformation became brittle; and (3) mixed dip- and strike-lineated strains became predominantly strike-lineated in most areas. An early ductile, oblique convergent phase is typified by 1.98–1.924 Ga amphibolite-facies mylonites. A late brittle, dextral transpressive phase is typified by the post–1.86 Ga McDonald fault (Fig. 1). Late deformation was not entirely strike slip, as it also uplifted and exposed early granulite-facies mylonites.

Inferred subduction polarity in Himalayan-type convergence models between the Slave and Rae cratons has been based upon the higher-granulite-facies rocks observed on the Rae craton side (Hanmer et al., 1992). Within the Thelon segment, the presence of foreland basin and absence of 2.02–1.91 Ga magmatism on the Slave craton side have been interpreted to indicate that any intervening oceanic lithosphere and the Slave craton were underthrust or subducted beneath the Rae craton (Gibb and Thomas, 1977; Tirrul and Grotzinger, 1990). Differentiation of Himalayan-type subduction from Tien Shan–type underthrusting models relies on either geochemical or seismic evidence of subducted oceanic lithosphere that previously...
Great Slave Lake shear zone roots

Separation of the Slave and Rae cratons. Significant amounts of subducted oceanic lithosphere typically would introduce water into the overlying mantle wedge, and hydrate or metasomatize it into serpentinite (Bostock et al., 2002; Wiens et al., 2008), destroying primary lithologies, structures, and xenocrysts such as zircons or diamonds (Heaman and Pearson, 2010).

TELESEISMIC STUDIES

Seismic anisotropy provides the best indicators of ordered structure, sometimes called “fabric,” within subcontinental mantle lithosphere (Long and Becker, 2010) and complements identification of localized, major discontinuities by seismic methods using forward wave-scattering reconstructions or receiver functions (Vinnik et al., 2007). The multi-azimuthal anisotropy analysis as used here (Bostock, 1998; Snyder and Bruneton, 2007) requires many earthquakes; 283 earthquakes were recorded at 14 seismic observatories deployed across the Slave-Rae boundary (Fig. 1). This multi-azimuthal application strives to maximize spatial resolution. It uses Ps waves instead of Sp waves because of their shorter wavelengths (Abt et al., 2010; Levander and Miller, 2012). It analyzes all azimuths from which earthquake waves arrive and are successfully recorded, and our experience shows that at least 24 mo of records at each station are required to record sufficient earthquakes to populate 5° bins with statistically significant numbers of earthquakes (Fig. 2). Few seismic arrays are maintained this long. The spacing between array stations here is 15–25 km (Table 1), ensuring overlap in coverage at lithospheric depths. These factors combine to significantly improve sections, especially when using both radial and tangential receiver function components at selected azimuths (compare Fig. 3 with Rondenay et al., 2000; Wittlinger et al., 2009; Levander and Miller, 2012). Two previous teleseismic studies in this region include one that crossed the Great Slave Lake shear zone south of Great Slave Lake (Eaton and Hope, 2004) and another that crossed the central Slave craton (Snyder, 2008; Fig. 1). These postdated a regional Slave craton study that utilized widely spaced seismic observatories (Bank et al., 2000). We utilized results at four stations (MLON, BOXN, MGTN, KNDN) from the central Slave study of Snyder (2008), which used identical analysis and which are along strike with the new teleseismic array. The previous two surveys provide only averaged (nonazimuthal) estimates of Moho depth and fast polarization directions at three relevant locations along the Great Slave Lake shear zone (Fig. 1). The study of Eaton and Hope (2004), which crossed Great Slave Lake shear zone and McDonald fault, utilized 6 mo of earthquake records. It thus had limited azimuthal coverage with which to characterize fully the deep three-dimensional structure, but its receiver

**TABLE 1. STATIONS: LOCATION AND NUMBER OF EARTHQUAKES ANALYZED**

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude (°N)</th>
<th>Longitude (°W)</th>
<th>Elevation (m)</th>
<th>Location</th>
<th>Gap (km)</th>
<th>Start (mo/yr)</th>
<th>End (mo/yr)</th>
<th>SKS*</th>
<th>Ps*</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOXN</td>
<td>63.6522</td>
<td>109.7179</td>
<td>435</td>
<td>Box Lake</td>
<td>15</td>
<td>8/2002</td>
<td>7/2007</td>
<td>57</td>
<td>175</td>
</tr>
<tr>
<td>COKN</td>
<td>63.27018</td>
<td>108.76241</td>
<td>366</td>
<td>Cook Lake</td>
<td>27.5</td>
<td>7/2008</td>
<td>5/2010</td>
<td>74</td>
<td>116</td>
</tr>
<tr>
<td>WLZN</td>
<td>63.23652</td>
<td>108.48018</td>
<td>405</td>
<td>Artillery Lake</td>
<td>20.6</td>
<td>7/2008</td>
<td>5/2010</td>
<td>52</td>
<td>128</td>
</tr>
<tr>
<td>ARTN</td>
<td>62.93693</td>
<td>107.93379</td>
<td>418</td>
<td>Fabian Lake</td>
<td>22.5</td>
<td>7/2008</td>
<td>5/2010</td>
<td>42</td>
<td>76</td>
</tr>
<tr>
<td>SNLN</td>
<td>62.83043</td>
<td>107.61020</td>
<td>364</td>
<td>W Sandy Lake</td>
<td>20.8</td>
<td>7/2008</td>
<td>5/2010</td>
<td>70</td>
<td>84</td>
</tr>
</tbody>
</table>

*Number of earthquakes used in analysis.
function analysis identified the Moho at 40 ± 2 km at the northwest end of the transect, 44 ± 2 km in the center, and 42 ± 2 km at the southeastern end (Fig. 1). The overall average fast polarization direction of all stations in the study was 049° ± 19°, but stations within the shear zone displayed characteristics of two layers having fast polarizations of ~030° and ~060°, which are assumed to represent crustal and mantle fabrics, respectively (Eaton and Hope, 2004).

NEW SEISMIC OBSERVATIONS

Receiver Functions

Receiver functions at each of the 14 stations were determined wherever at least two earthquakes could be assembled into directional 5° bins. Resultant multi-azimuthal displays reveal azimuthally consistent phases that indicate near-horizontal surfaces. Typically, the most prominent positive (red) phase present defines the Moho, here at 45 km depth beneath station HOWN; later-arriving phases were then presumed to be multiples and were ignored (Fig. 2). Laterally consistent phases with a sinusoidal pattern over a 360° azimuth range indicate dipping planar surfaces (arrows in Fig. 2). Typically, no sinusoids were fully defined, partly due to poor azimuthal coverage and partly due to polarity flips. Phases on the transverse component usually represent anisotropic structures and should exhibit phase reversals dependent on polarization direction and dip of the fabric (e.g., Levin and Park, 1997). The transverse components of a number of stations locally exhibited uppermost mantle discontinuities dipping at 25°–30° toward 260°–280° (Fig. 2). Lateral continuity is emphasized and plays a key role here, and the phase highlighted in Figure 2 was initially chosen because of its apparently consistent amplitude at back azimuths of 240°–360° on the transverse component.

Selection of bins in the northwest (295°–315°) and southeast (140°–155°) allowed construction of an unmigrated seismic cross section along the transect (Fig. 3), and this again emphasizes lateral continuity (rather than simply large amplitude) of discontinuities at larger, interstation scale lengths. A clear, positive discontinuity (Moho) appears on the radial component beneath the four observatories at both the northwest and southeast ends of the transect. A flat Moho is observed within the central Slave craton (stations MLON, BOXN, MGTN, KNDN), but it appears deeper or less distinct between stations COKN and FABN (green dots, Fig. 3C). Stations COKN and WLMN have a positive phase at 35 and 50 km and a negative (black) phase at 75 km that is observed as far as station TMBN to the southeast (purple dots on Fig. 3C). Stations SNLN through GDLN have a clear positive phase at 41–46 km (green dots on Fig. 3C).

The composite cross section of transverse components shows a series of semicontinuous phases with apparent dip to the southeast. The most consistent phase occurs as a dipole pair from ~70 km depth in the northwest at station ARTN to ~160 km depth at the southeast end of the transect (blue dots in Fig. 3D). A much less distinct phase intercepts this phase at its southern end and dips to 200 km depths near the center of

![Image of a seismic cross section with labeled stations and phases](https://pubs.geoscienceworld.org/gsa/lithosphere/article-pdf/5/6/539/3039125/539.pdf)
the transect (purple dots in Fig. 3D). Together, these two mantle discontinuities define a wedge that contacts the base of the crust where the multiple Moho discontinuities are observed. Several less-consistent phases also dip to the southeast beneath stations MLON–COKN at 40–100 km depths (yellow dots in Fig. 3D). These phases intercept a northwest-dipping phase beneath station COKN to outline another wedge-shaped geometry. This northwest-dipping seismic discontinuity on the transverse component was recognized by Snyder (2008) to occur across most of the central Slave craton.

**SKS Splitting Parameters**

Multi-azimuthal splitting estimates averaged for paired stations at the northwestern, central, and southeastern parts of the transect are distinct as compared to previous results from the central Slave using the same analysis (Snyder and Bruneton, 2007). Similar splitting parameters as determined for earthquakes recorded by adjacent stations were grouped in order to enhance statistical robustness given the relatively short time these stations were active compared to the central Slave study. Beneath stations COKN and WLMN, a single layer is estimated with an average fast polarization direction of 064° ± 11° and delay time of 1.0 ± 0.6 s (Figs. 4 and 5). Beneath SNLN, EA06, and WHFN, no single anisotropic layer was deemed appropriate, and a two-layer signature was best modeled using fast polarizations at 035° and 060° and delay times of 1.0 and 0.5 s. The pattern beneath GDLN and HOWN is indistinct, but 070° is indicated weakly. Central Slave stations (KNDN, MLON, BOXN) exhibited two-layer patterns with fast directions of 047°–050° and 005°–047° (Snyder and Bruneton, 2007).

**INTERPRETATION**

Seismic discontinuity geometries are consistent across the entire transect within the strong uppermost mantle at 50–200 km depths. These discontinuities appear paired: moderate, southeast-dipping discontinuities intersecting shallower, northwest-dipping discontinuities to form wedge shapes. Wedge tips are located at depths of 145 to 205 km (B. Kjarsgaard, 2013, personal comms). Garnet peridotite xenoliths and Cr-pyrope garnet xenocrysts are observed in kimberlites at Gahcho Kué (Kopylova and Caro, 2004) and indicates a broad chemical boundary (90–170 km) between spinel and garnet peridotite punctuated by discrete shear zones (~). Elsewhere, color lines (coded to dots in Fig. 3) synthesize where discontinuities (red or black polarity on Figs. 2–3) appear on either component beneath that station. Beneath the Slave craton, these lines are labeled Moho, H, X, and L as interpreted in Snyder (2008). Moho is traditionally assumed to represent the base of the crust. H (Hales discontinuity) is arguably the base of the spinel peridotite layer. L (Lehman discontinuity) is traditionally the base of the lithosphere and is not clearly defined by this study. Numbers are fast polarization directions modeled from SKS splitting; depths are uncertain. McDF—McDonald fault zone.

The inferred wedge-within-wedge geometry as defined by two sets of intersecting seismic discontinuities observed on transverse components implies that mantle within the northwestern wedge is continuous with mantle of the southeastern Slave craton to the northwest (Fig. 4). Mantle rocks within the wedge located beneath stations KNDN through GD LN may have affinities to either the Slave or Rae cratonic mantles, or to neither. Samples of mantle peridotite xenoliths and Cr-pyrope garnet xenocrysts are observed in kimberlites at Gahcho Kué (station KNDN). Garnet peridotite xenoliths (Kopylova and Caro, 2004) occur from depths of 155 to 195 km, with garnet xenocrysts from depths of 145 to 205 km (B. Kjarsgaard, 2013, personal obs.), and thus represent samples from the lower portion of the main (southeast) wedge. Mantle within the upper part of this wedge is immediately beneath Slave craton crust (stations MLON to ARTN). The Slave mantle lithosphere is therefore interpreted to project 140 km southeast of its crustal boundary at the surface, the McDonald fault (Figs. 1 and 4). Its wedge-shaped margin implies that mantle rocks comprising the Rae craton lie above and below, presumably thrust there during convergence of these craton. Such wedging would be expected to uplift the shallow Rae margin preferentially and can thus explain the higher-granulite-facies rocks observed there (Hammer et al., 1992).

Paired seismic discontinuities appear on the radial component receiver function at depths of 40–75 km across most of the transect, with the positive Moho (red) overlying a negative (black) discontinuity (Fig. 3). In the northwest, this pair nearly coincides at 40 km depth. Farther south, beneath stations COKN through ARTN, a possibly doubled Moho overlies a deeper (70 km) negative discontinuity. Paired positive-negative polarity discontinuities are observed southeast from there to beneath TMBN (Fig. 3). Thus, the seismic layer at depths of 40–75 km defined by these paired discontinuities apparently propagates...
seismic waves at average velocities greater than both the overlying crust and underlying mantle, based on the observed polarities. Such relatively large S-wave velocities are rare at depths less than 150 km (Ábalos et al., 2011) and could represent an ~30-km-thick sheet of Rae mantle thrust on top of a similar sheet of Slave crust. The various discontinuity geometries observed would then require very complex thrust relationships. Alternatively, the layer could consist of lower crust and mantle mineral assemblages in eclogite facies (e.g., Hynes and Snyder, 1995) interleaved at more intimate scales. Similar seismic velocity crustal structure is observed beneath the intracontinental Tien Shan orogen (Vinnik et al., 2004, 2007), the Himalayan orogen (Wittlinger et al., 2009), and the Andes (Gilbert et al., 2006). These geometries are consistent with thrusting and duplexing of lower crust on the scale of kilometers to tens of kilometers, which is more typically observed in former collisional zones (e.g., Coward, 1983).

Receiver function studies cannot detect near-vertical seismic discontinuities such as faults, but they can resolve offsets or breaks in subhorizontal discontinuities caused by faulting. Observed ductile strain associated with early displacements along the Great Slave Lake shear zone is concentrated on the seismic transect within the Talison granitoids located at the surface between stations FABN and EA06 (Fig. 4). The late brittle deformation associated with the McDonald fault occurs just northwest of station FABN. The Moho and especially the negative discontinuity at 75 km depths appear little disrupted beneath these stations, arguing against vertical faults. In contrast, neither discontinuity is clearly detected beneath station WLMN, suggesting that the Moho is disrupted by deformation concentrated here at Moho depths and implying that the McDonald and early ductile faults dip steeply to the north (Fig. 4).

The preference for two layers of distinct SKS polarizations modeled beneath stations SNLN and EA06 in the study area supports suggestions of Eaton and Hope (2004), who proposed a primary, deeper fabric oriented 060° that closely matches the strike of the southwest segment of the Great Slave Lake shear zone (065°) and nearly that of North America plate motion at 230°/050°. This general orientation characterizes the entire transect (047°–070°), and polarizations parallel with tectonic borders are also noted in modern orogens such as the Tien Shan (Vinnik et al., 2007). Where a secondary fabric is recognized, oriented 005°–047° within the Slave craton and 035° beneath the Talison arc, causative fabric probably originates at depths <145 km and <100 km, respectively. Anisotropies within the central Slave craton were modeled as less than 5% (Snyder and Bruneton, 2007), so thick layers are required. The secondary, shallower anisotropy is interpreted to relate to fabrics associated with regional fold structures and shear faults, respectively. Ductile structures formed at granulate and amphibolite facies typically have high, smooth variations in seismic properties (Law and Snyder, 1997), characteristics making them more observable by both seismic methods used here. These seismic sections would therefore preferentially highlight structures formed during the early tectonism associated with oblique convergence over steeper structures derived from late brittle faulting.

**DISCUSSION**

Gently dipping discontinuities are observed to intersect and define tectonic wedges beneath the common boundary between the Slave and Rae cratons. Although considered Paleoproterozoic in age, these presumed strike-slip structures interleave crust and mantle of two stable, directly opposed Archean lithospheric blocks, which is a new observation. This deep wedge-shaped structural geometry and seismic signature are typical of Alpine- or Himalayan-style convergence zones (Coward, 1983; Hoffman, 1987; TRANSALP Working Group, 2002; Wittlinger et al., 2009), not of strike-slip faults (Stern and McBride, 1998). Subhorizontal lineations indicate that most of the pure strike-slip strains described for rocks in this area occurred on late, brittle structures such as the McDonald fault (Hamner et al., 1992), and thus this fault has many seismic and structural similarities with the Alpine Periadriatic fault (TRANSALP Working Group, 2002). The relatively narrow (few kilometer), steep fault structures are not easily imaged by seismic techniques used here unless associated with significant steps in older marker features such as the Moho (e.g., Stern and McBride, 1998). No such steps or offsets are observed beneath the surface trace of the McDonald fault near station FABN, or elsewhere along the transect. One interpretation is that the late brittle faults are listric (Coward, 1983) and offset the Moho to the north beneath station WLMN or COKN. The alternative improbably requires that a vertical fault with cumulative dextral, strike slip with displacement equal to 70–125 km produced no steps in Moho depth. By analogy, the Alpine Periadriatic fault is presumed to carry major crustal-scale displacements, but it showed no evidence of deep
serpentinization, metasomatism, and resetting mantle overlying the subduction zone, causing introduces water and other volatiles into the Subduction of oceanic lithosphere typically produces enclaves (Fig. 3) may represent an almost identical structure, but now accompanied by the more complex architecture imaged for the first time here across the Slave-Rae boundary image. The new observations represent both geophysical and geochemical signatures that can distinguish between these two tectonic models. No high-amplitude, laterally continuous seismic discontinuities that typically indicate subducted oceanic lithosphere (e.g., Bostock, 2012) are observed at depths greater than 150 km on this transect. On the other hand, the “calc-alkaline” geochemical signature of granitoids observed farther southwest within the Taltson magmatic zone can be explained by melting of either subducted oceanic crust or the thickened and duplexed lower crust interpreted here (Chacko et al., 2000). The latter option also explains the high velocities of residual rocks in granulite or eclogite facies (e.g., Wittlinger et al., 2009). If melting of underthrust crust indeed initiated 2.02–1.90 Ga Taltson and Thelon granitic magmatism in an intraplate setting, as interpreted by this study of seismic discontinuities (Fig. 6). Following Snyder (2008), this wedge would have characteristics of his lower mantle layer (here at 50–75 and 145–205 km depths; bounded by the Moho-H and X-L discontinuities, respectively), whereas the northwestern wedge would relate to his shallower mantle layer (60–145 km depths; bounded by the H-X discontinuities) (Fig. 4). This interpretation is also consistent with the one or two layers of SKS anisotropy modeled in this study and results presented by Snyder and Bruneton (2007), where the lower layer is characterized by a fast polarization of 047°–064°, and the shallower layer is characterized by 005°–047° (Fig. 4).

The dual wedge geometries within the mantle lithosphere of the Slave craton margin also help to clarify some aspects of the original assembly of the Slave craton lithosphere (Davis et al., 2003; Snyder, 2008; Heaman and Pearson, 2010). Basement mapping indicated that a more juvenile 2.75–2.60 Ga terrane, often called the Hackett River terrane, accreted onto the 3.5–2.7 Ga central core ca. 2.65 Ga (Helmstaedt, 2009, and references therein). The new observations presented herein indicate that this juvenile terrane was wedged apart with one 40-km-thick “flake” riding on top the central Slave core and another layer underthrusting the core (Fig. 6). This accreted Hackett River terrane is interpreted to lie along the entire eastern margin of the present-day Slave craton, and its shape was thus further modified by the 1.98–1.92 Ga convergence of the Rae craton along the Thelon front.

In summary, geometric details of the Great Slave Lake shear zone and Slave-Rae boundary architecture imaged for the first time here across the entire orogeny reveal important clues about wedge-tectonic processes nearly 2 b.y. after they occurred and the host lithosphere stabilized as part of the Canadian Shield. Seismic anisotropy characteristics are typically interpreted differently in long, stable shield and neotectonic regions of continents (compare Bostock, 1998; Snyder, 2008; Vinnik et al., 2004, 2007). Nevertheless, the lack of any seismic evidence of near-vertical faults or former subduction zones favors interpretation of this major tectonic boundary as almost purely intracratonic (intraplutonic) and thus structurally more similar at a lithospheric scale to the present-day Tien Shan than to the Himalaya. Important clues are thus revealed as to how the Slave craton was originally constructed primarily via lateral accretion.

APPENDIX: TELESEISMIC METHODS

The multi-azimuthal anisotropy analysis as used here (Bostock, 1998; Snyder and Bruneton, 2007) requires many earthquakes; 283 earthquakes were recorded at 14 seismic observatories deployed across the Slave-Rae boundary
Bank, C.-G., Bostock, M.G., Ellis, R.M., and Cassidy, J.F., 2000, MERA (East Arm Project) and GEM (Diamond Project) background.

ACKNOWLEDGMENTS

We thank the Rae craton, where the strongest discontinuity, by definition, the latter strategy using primarily back azimuth distance ranges, so the two sorting strategies made little difference. The latter strategy using primarily back azimuth distance ranges, so the two sorting strategies made little difference.

Free-surface dominant, the earthquakes were grouped as in the conical displays and opens out at depth so that its radius is approximately one third of the depth.


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First, receiver functions were sorted into two groups of back azimuths (BAZ) where the majority of earthquakes occurred, 140° < BAZ < 160° and 290° < BAZ < 318°, and then they were binned according to radial distance. Sec- ond, the earthquakes were grouped as in the conical displays and opens out at depth so that its radius is approximately one third of the depth.

First, receiver functions were sorted into two groups of back azimuths (BAZ) where the majority of earthquakes occurred, 140° < BAZ < 160° and 290° < BAZ < 318°, and then they were binned according to radial distance. Second, the earthquakes were grouped as in the conical displays and opens out at depth so that its radius is approximately one third of the depth.

First, receiver functions were sorted into two groups of back azimuths (BAZ) where the majority of earthquakes occurred, 140° < BAZ < 160° and 290° < BAZ < 318°, and then they were binned according to radial distance. Second, the earthquakes were grouped as in the conical displays and opens out at depth so that its radius is approximately one third of the depth.

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