Continental scale shear wave splitting analysis: Investigation of seismic anisotropy underneath the Australian continent

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Abstract

The structure of the upper mantle beneath the Australian continent is investigated using teleseismic shear wave splitting to extract seismic anisotropy. Measurements have been performed on data recorded at 190 sites with portable broadband seismic recorders, spanning almost the entire surface of the continent since 1992. The average time span of the various deployments, primarily designed for surface wave tomography, is 6 months, which is rather limited for shear wave splitting analysis. However, the data set provides a full continental scale survey using the reasonably favourable distribution of seismicity to Australia. Seismic anisotropy has the potential to provide insights into the lithospheric structure and the possible mechanical coupling between the crust and the upper mantle, but prior results for Australia have indicated relatively small levels of splitting and a complex pattern. These results are confirmed with our new and far more extensive measurements across the whole continent. The pattern of seismic anisotropy from shear wave splitting beneath Australia is rather complex and is not correlated with the almost north–south absolute plate motion (APM) from recent models. Deviation of the asthenospheric mantle flow around the lithospheric roots associated with the extensive Archaean and Proterozoic zones of central and western Australia could be occurring, and so mantle flow-related anisotropy cannot be completely ruled out. Despite the limited geological outcrop, especially in Phanerozoic eastern Australia, that is almost entirely covered by sedimentary basins, some relationships can be highlighted between the orientation of the polarization plane of the fast S-waves and structural trends along, for instance, the Halls Creek orogen bordering the eastern edge of the Kimberley basin or along the New England and Lachlan fold belts in the southeastern part of the continent. Such relationships might account for anisotropy frozen in the lithosphere during post-tectonic thermal relaxation. Along the poorly constrained and controversial Tasman Line (TL), the geological boundary between Precambrian and Phanerozoic Australia, directions of anisotropy measured at some stations located in the close vicinity of the ‘line’ appear to exhibit a curvilinear trend somewhat similar to that of the TL, suggesting that fossil deformation associated with the TL might be recorded in the pattern of seismic anisotropy.

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Keywords: Seismic anisotropy; Lithosphere; Australian continent; Shear wave splitting; Mantle flow; Anisotropy frozen in the lithosphere; Crust/mantle coupling

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1. Introduction

The analysis of seismic anisotropy has been extensively developed over the last decade to emerge as a powerful tool for studying structure in the upper mantle (see [1] and [2] for review). The anisotropic parameters are assumed to be closely related to the crystallographic fabrics developed in the upper mantle due to past and present deformation. Comparison of shear wave polarization anisotropy from core phases and surface geology can provide insights into the mechanical coupling between the crust and the upper mantle.

Seismic anisotropy is a phenomenon analogous to the crystallographic birefringence of calcite: when a polarized S-wave propagates across an anisotropic medium, it is split into two quasi S-waves with perpendicular polarization that propagate with different velocities. Measuring seismic anisotropy at a seismological station yields two parameters: $\phi$, the orientation of the polarization plane of the faster S-wave and $dt$, the delay between the arrival times of the fast and slow split waves. The splitting measurements are commonly performed on core-refracted shear waves such as SK(K)S or PK(K)S. These phases are generated from a P-to-S conversion at the core–mantle boundary (CMB) and are thus polarized along the radial direction as they enter the mantle. The phases arrive at the station with a nearly vertical incidence, and anisotropy measured at the Earth’s surface thus represents a vertically integrated effect of anisotropy from the CMB to the surface, with no indication of the depth location of the anisotropy source. Source-side contamination, however, is avoided. Petrophysical studies suggest that anisotropy is mostly located in the upper mantle, between the 410 km olivine–spinel phase transition and the Moho [1–3]. Some small contributions from the D\textsuperscript{''} layer [4], the lower mantle [5] and the crust [6–8] can nevertheless not be ruled out.

Olivine is the most abundant and deformable mineral in the upper mantle; it develops a lattice preferred orientation (LPO) that might result either from the active deformation of the asthenospheric mantle that accommodates or causes the absolute plate motion (mantle flow related anisotropy) [9,10], or was imposed during past deformation, and then was “frozen” in the lithosphere during post-tectonic thermal relax-
and to complement the results previously obtained by [17], which mainly deal with the eastern part of the continent.

2. Region under study

The Australian continent has experienced a complex tectonic evolution over the past 4.6 Gy that may be expected to have left some imprints on the lithospheric mantle (see [18,19] for review). The tectonic evolution of the various Precambrian cratonic blocks has been influenced by a combination of lateral lithospheric deformation, and vertical lithospheric accretion, perhaps by mantle plumes. The three main cratonic blocks (North, West and South Australian cratons) formed at ca. 1830 My and resulted from the collision between individual blocks. The Pilbara and Yilgarn cratons joined along the Capricorn orogen during the early Proterozoic to form the West Australian craton. The assemblage of the proto-Gawler and proto-Curnamona blocks along the Kimban orogen shaped the South Australian craton. Various small Precambrian blocks such as the Kimberley, Pine Creek and Tennant Creek inliers collided along sutures like the King Leopold and Halls Creek orogens, and resulted in the formation of

Fig. 1. Location of the 190 instrumented sites. Symbols represent the deployments they are related to. The names of the stations for which results are discussed in the text are indicated. The dashed line represents the Tasman Line as suggested by [22]. The main geological provinces mentioned in the text are located (AB=Arunta block; AFo=Albany Fraser orogen; AmB=Amadeus Basin; Co=Capricorn orogen; Cu=Curnamona block; FP=Fleurieu Peninsula; GC=Gawler craton; HCo=Halls Creek orogen; KB=Kimberley basin; KLo=King Leopold orogen; Ko=Kimban orogen; LFB=Lachlan fold belt; MB=Musgrave block; MIB=Mount Isa block; NEFB=New England fold belt; PB=Pilbara block; PC=Pine Creek; TC=Tennant Creek; TFS=Tamar Fracture System; YCB=Yilgarn cratonic block).
the North Australian craton (see Fig. 1 for the location of the various geological units). Active tectonics between 1300 and 1100 My led to the amalgamation of Proterozoic Australia. The North, South and West Australian cratons, previously part of large continental landmasses that may have respectively included North America, East Antarctica and Greater India, ended up shaping an early component of the Rodinia supercontinent. The West and North cratonic blocks accreted and then collided with the South Australian craton along the Albany Fraser orogen. The Centralian Superbasin formed between 830 and 750 My over the junction of the three cratons, and was followed by the breakup of Rodinia at ca. 750 My.

The Palaeozoic belts located in the eastern part of the continent (e.g. the New England and Lachlan fold belts, see Fig. 1) developed mainly in a backarc environment with transient episodes of accretionary tectonism related to west-dipping subduction. Passive margins preserved on the east, west and south coasts of the Australian continent formed as a result of Gondwana breakup.

The boundary between Precambrian and Phanerozoic Australia has been interpreted to follow the “Tasman Line” (TL), whose definition has been primarily based on the separation of geological outcrops of Precambrian and younger basement [20], and, to a lesser extent, on gravity and magnetic anomalies. This concept has been extensively discussed and argued, with various authors suggesting different positions for the TL (see [21] for review and Fig. 1 for location). The recent work of [21] however concluded that even if based on geophysical data and geological lineaments believed to define a given age and tectonic origin, the TL, as defined by many authors (e.g. [22–25]), may in fact result from a number of sources that vary in age, protolith, and degree of deformation/metamorphism. In this view there is, therefore, no basis for the interpretation of a coherent supracrustal Tasman ‘Line’.

The contrast between eastern and western Australia is however the most striking result in surface wave tomographic studies (see [26, 27] for the latest results, but also [28, 29]) and is present from at least 75 to 200 km depth: a very strong contrast in seismic shear wavespeed is indeed imaged beneath the eastern and western parts of the continent. Shear wavespeeds faster than the continental average extend to at least 200 km in the cratonic zone to the west of 140°E. There is no clear relationship between the eastern extension of this anomaly and any of the various locations of the Tasman Line (e.g. [22–25]): it is in close agreement with the original TL defined by [20] in northern Queensland down to 100 km depth (see Fig. 1 for location), and all over Queensland from 100 to 150 km depth. At 150 km depth however, the NE–SW trend along the edge of the Curnamona province is in closer agreement with more recent suggestions [22], [24], the southernmost connection of the TL to the Tamar Fracture system in Tasmania is markedly different between different authors. Below 150 km depth, the boundary is mainly oriented NS along 140°E, and does not correlate with any definition of the TL. Around 25°S however, a small indentation within the shape of the anomaly might be related to the lines suggested by [22] or [24].

The results of surface wave tomography for mantle structure are not simply related to the suggested location of the TL from crustal information; the contrast between western Precambrian and eastern Phanerozoic Australia is nonetheless undisputed.

3. Method

Shear wave splitting measurements have been performed using the Silver and Chan algorithm [30],
which consists of minimizing the energy on the transverse component by rotating and time shifting the traces. The energy on the transverse component is automatically evaluated for many candidate values of \( \phi \) and \( dt \) (with respective increments of 1° and 0.05 s) to retrieve the pair of values that best removes influence of anisotropy. This method assumes that anisotropy is located in a single horizontal layer.

Individual results have been sorted in 4 categories (good, fair, poor and null) following [14] and are based on: (1) the quality of the initial signal (signal-to-noise ratio and interferences with other phases), (2) the ellipticity of the particle motion in the horizontal plane when anisotropy is present, (3) the linearization of the particle motion by anisotropy removal, (4) and the waveform coherence between the fast and slow split shear waves. Measurements satisfying the four criteria, producing similar pulse shapes and linear particle motion after correction along with fairly small error ellipses were rated as “good”, while those meeting only three criteria were rated as “fair”. A poor measurement only fulfills two criteria and a null measurement does not show any energy on the transverse component associated with the arrival of the core phase of interest on the radial component; this may be due either to an absence of anisotropy or to an initial polarization of the incoming shear wave parallel or orthogonal to the fast anisotropic direction.

The quality of the data has been visually inspected and only traces showing sharp arrivals of the core phases, very distinct from the surrounding noise, have been kept. The influence of time windowing and filtering has systematically been checked. When used, the filter was a Butterworth pass-band with lower limit equal to 0.03 Hz and upper limit varying from 0.25 to 0.75 Hz.

To increase the robustness of the results compared to the analysis of single events, we have used the method of [31] (hereafter referred to as WS) to compute global solutions. The WS method consists of simultaneously processing multiple events, at a single station, by normalizing and summing individual error surfaces. For those stations showing either no correlation between backazimuthal variations or splitting parameters that are more complex than the splitting predictions for a single anisotropic layer with a vertical symmetry axis, global solutions have been computed. In order to assess the validity of these results, we also used the same data to compute global solutions using the cross-convolution method of [32] (ML in the following). Unlike the WS method which defines individual errors on both anisotropic parameters, the estimate of the errors in the ML method is performed through the use of a misfit parameter \( R \) based on the match between the transverse and radial components after correction (see [32] for details). Smaller \( R \) indicates better solutions. Only those results that are coherent between the two methods have been plotted in Fig. 3b as grey bold lines and listed in Table 1.

4. Observations and discussion

Surface wave tomographic studies including azimuthal anisotropy suggest a two-layer system of anisotropy beneath Australia [33–36]: in the upper layer, directions of anisotropy are approximately oriented east–west in [33,34], and more or less randomly in [35], whereas in the bottom layer, directions of anisotropy appear to be north–south, parallel to the absolute plate motion (APM) in each model.

The main challenge in studying core-refracted shear waves is the lack of vertical resolution. The anisotropy measured at the surface has been acquired on the way from the CMB to the surface; the splitting parameters therefore represent an integrated measurement and we need to consider whether a lithospheric or an asthenospheric source, or a combination of both, may account for the observed anisotropy.

4.1. Asthenospheric source of anisotropy

In the study case of a decoupling between a “flat” lithospheric plate and the underlying upper mantle, simple asthenospheric flow would lead to splitting parameters very coherent over large geological domains that differ in both age and structure: the orientation of the polarization plane of the fast S-wave would be parallel to the APM, and the amplitude of the delay time would be rather constant in each domain. At the Australian continental scale however, considering the results as a whole, the directions of anisotropy obtained from shear wave splitting appear to be very scattered. Previous evidence accounting for an asthenospheric contribution comes from observation of shear wave splitting for
Fig. 3. Measured directions of the orientation plane of the fast shear-wave. (a) Good and fair measurements. The length of each line is proportional to the delay time. (b) Null measurements associated with the results of the multiple-events method (grey bold lines, with the length of the lines proportional to the delay time. When a slight difference exists between the global solutions computed either with the WS or the ML method, we represent the results issued from the WS method). Crosses denote the absence of splitting: each branch is either parallel or perpendicular to the backazimuth of the incoming waves and represents a possible direction of anisotropy. The dashed line represents the Tasman Line as defined by [22]. Light grey arrows represent the APM defined by the HS2-Nuvel1 model [37], black arrows represent the APM calculated from the HS3-Nuvel1A model [37] and dark grey arrows the APM calculated from the T22A model [38]. The inset displays measurements obtained at the permanent stations from various studies: [46] (black lines show backazimuths of null shear wave splitting), [9] (grey lines), [42] (inset for Geoscope station CAN: left diagram represents the azimuth of each fast split shear wave for one good (black) and one fair (grey) measurement, while the right diagram represents the null directions).
refracted S-waves beneath northern Australia [37]: the authors explained the observed discrepancy between measurements resulting from waves travelling through the low velocity zone, the transition zone, and through the top of the lower mantle in terms of transverse isotropy located within the low velocity zone under the unusually thick mantle lid beneath north Australia. In the present study, we cannot highlight any simple relationship between the orientations of the polarization plane of the fast S-wave and the APM of Australia determined either from the HS2-Nuvel1 [38], HS3-Nuvel1A [39] or T22A [40] models (arrows on Fig. 3). Following one school of thought [9,10], if APM is nevertheless envisioned as the main source of anisotropy, we have to consider rather complex deviations of the mantle flow around the cratonic keels of the various continental domains to reconcile the scattered directions of anisotropy measured at the surface and the APM. Results from surface wave tomography of the Australian continent suggest that the topography of the lithosphere–asthenosphere boundary may well be rather complex [28,29]. This could account for such deviations of the mantle flow, and an asthenospheric contribution is therefore not ruled out.

4.2. Lithospheric source of anisotropy

Due to the limited amount of reliable measurements performed at each station, related to the short time span of recording, together with the sedimentary cover overlying the Palaeozoic basement almost in the entire eastern part of the continent, no direct correlation is observed between the measured orientation of the polarization plane of the fast S-waves and the mapped superficial structures. It is therefore impossible to assert that anisotropy frozen in the lithosphere is the main source of anisotropy.

With a closer look at the data, some correlations can however be seen, especially (1) in the Kimberley region, (2) in the southern part of the Yilgarn cratonic block, and (3) along the southeastern margin of the continent (see Fig. 1 for location).

In the Kimberley block (KB, Fig. 1), the directions of anisotropy measured within the framework of the KIMBA experiment (July–Oct. 1997 then May–Oct. 1998, white diamonds on Fig. 1) show various orientations. Results from surface wave tomography of the Australian continent suggest that the topography of the lithosphere–asthenosphere boundary may well be rather complex [28,29]. This could account for such deviations of the mantle flow, and an asthenospheric contribution is therefore not ruled out.

### Table 1

Multiple event parameters calculated for those stations showing no important variations in the splitting parameters with respect to the backazimuth

<table>
<thead>
<tr>
<th>Station</th>
<th>Lat (°)</th>
<th>Lon (°)</th>
<th>WS method</th>
<th>Error (±°)</th>
<th>dt (s)</th>
<th>Error (s)</th>
<th>ML method</th>
<th>dt (s)</th>
<th>Error (s)</th>
<th>Nb of phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARMA</td>
<td>−30.42</td>
<td>151.63</td>
<td>162.00</td>
<td>12.50</td>
<td>0.65</td>
<td>0.18</td>
<td>147.00</td>
<td>0.80</td>
<td>0.24</td>
<td>3</td>
</tr>
<tr>
<td>KA03</td>
<td>−15.93</td>
<td>127.25</td>
<td>64.00</td>
<td>8.50</td>
<td>0.84</td>
<td>0.18</td>
<td>64.00</td>
<td>0.88</td>
<td>0.11</td>
<td>2</td>
</tr>
<tr>
<td>KB14</td>
<td>−18.19</td>
<td>127.82</td>
<td>48.00</td>
<td>4.00</td>
<td>1.60</td>
<td>0.26</td>
<td>42.00</td>
<td>1.24</td>
<td>0.47</td>
<td>4</td>
</tr>
<tr>
<td>SB09</td>
<td>−32.28</td>
<td>146.85</td>
<td>8.00</td>
<td>3.00</td>
<td>1.12</td>
<td>0.14</td>
<td>7.00</td>
<td>1.16</td>
<td>0.25</td>
<td>3</td>
</tr>
<tr>
<td>STK</td>
<td>−31.88</td>
<td>141.60</td>
<td>53.00</td>
<td>7.50</td>
<td>0.45</td>
<td>0.10</td>
<td>52.00</td>
<td>0.45</td>
<td>0.12</td>
<td>3</td>
</tr>
<tr>
<td>TL01</td>
<td>−18.00</td>
<td>141.64</td>
<td>24.00</td>
<td>4.00</td>
<td>0.64</td>
<td>0.14</td>
<td>27.00</td>
<td>0.72</td>
<td>0.27</td>
<td>3</td>
</tr>
<tr>
<td>TL03</td>
<td>−20.15</td>
<td>139.41</td>
<td>117.00</td>
<td>22.50</td>
<td>0.16</td>
<td>0.18</td>
<td>101.00</td>
<td>0.16</td>
<td>0.15</td>
<td>4</td>
</tr>
<tr>
<td>TL04</td>
<td>−21.68</td>
<td>140.97</td>
<td>7.00</td>
<td>6.50</td>
<td>0.52</td>
<td>0.08</td>
<td>10.00</td>
<td>0.52</td>
<td>1.02</td>
<td>2</td>
</tr>
<tr>
<td>WP15−16</td>
<td>−31.21</td>
<td>121.09</td>
<td>64.00</td>
<td>10.50</td>
<td>0.60</td>
<td>0.12</td>
<td>63.00</td>
<td>0.68</td>
<td>0.25</td>
<td>4</td>
</tr>
<tr>
<td>ZB11</td>
<td>−28.85</td>
<td>152.25</td>
<td>182.00</td>
<td>4.00</td>
<td>1.04</td>
<td>0.12</td>
<td>179.00</td>
<td>1.04</td>
<td>0.55</td>
<td>5</td>
</tr>
</tbody>
</table>

Multiple event parameters have been calculated using both the Wolfe and Silver [31] and Menke and Levin [32] methods. $R$ is a misfit parameter issued from the ML method and based on the match between the transverse and radial components after correction: the smaller the $R$, the better the solution.
Fig. 4. Zoom on region 1 (see Fig. 3 for location) superimposed on the geological map of the Kimberley region (obtained from the Geological Survey of Western Australia website). Null and fair measurements are respectively represented as black crosses and grey lines. Stations whose results are discussed in the text are indicated. (a) Good and fair measurements. (b) Null measurements.
fold belts and the basin, measurements performed highlight null results. Results are coherent between the stations in this region and if anisotropy is detected, the fast anisotropic direction is either oriented N 30° E or N 120° E, approximately parallel to the network of faults mapped within the basin (Fig. 4). At those stations located within the basin and along the King Leopold orogen however, only one or two measurements have been considered as reliable per station; it may therefore have little physical meaning and does not allow any straightforward interpretation. Along the Halls Creek fold belt, results obtained at station KB14 are coherent: 4 measurements have been performed on 3 events with different backazimuths (120.9–194.3°), leading to a well-constrained global solution (φ = 48 ± 4°, dt = 1.6 ± 0.26 s with the WS method, and φ = 42°, dt = 1.24 s, R = 0.47 with the ML method). Measurements performed at station SC06 confirm those obtained by [17] and highlight a direction of anisotropy (20° < φ < 38°) that coincides with the NNE trend of the major shear zones that separate the Kimberley from the central Arunta block [17]. The results obtained at SC01 are also in good agreement with those performed by [17]: one good measurement led to φ = 18 ± 14.5° and dt = 0.28 ± 0.08 s. Unlike [17] however, no reliable measurements have been kept at station SC03, except three very coherent null measurements showing either the absence of anisotropy along the ray path or two possible orientations of the polarization plane of the fast S-wave: N 64° E or N 154° E.

In the southern part of the Yilgarn cratonic block, two main directions of anisotropy are observed on both sides of 30° S latitude (Fig. 5). The N 40/50° W directions of anisotropy observed north of this line are parallel to some regional faults (Fig. 5a). South of 30° S latitude, a set of 10 stations recorded the same event (day 00341, latitude 39.57° S, longitude 54.80° E, depth 30 km, magnitude 7.5). The coherence between the individual results per station is particularly striking (Fig. 5b) because it extends over 600 km, whereas the pattern of anisotropy from shear wave splitting is usually expected to vary in continental areas that experienced long and complex history such as Precambrian platforms. All stations indeed exhibit a null result which corresponds either to an absence of anisotropy beneath the stations or to the polarization plane of the fast S-wave oriented N 45/50° E or N 40/45° W (Fig. 5c). A N 40/45° W orientation of the polarization plane of the fast S-wave would approximately match the global NW–SE trend of the faults in the southwestern part of the Yilgarn craton; however, despite the good consistency of the results at the deployment scale, no firm interpretation can be envisaged on the basis of a single measurement per station.

In the southeast of the continent, stations ZB11, ARMA, CNB and YB02 (see Fig. 1 for location) highlight directions of anisotropy almost parallel to the structural trend of the New England and Lachlan fold belts (Fig. 3); i.e. NNE–SSW within the New England fold belt (stations ZB11 and ARMA) and more NE–SW along the Lachlan fold belt (stations CNB and YB02). These measurements may account for anisotropy frozen in the lithosphere during the post-tectonic thermal relaxation related to the formation of the Palaeozoic Lachlan and New England fold belts. The results obtained at station ZB11 moreover confirm those previously measured by [17], accounting for a global solution of φ = 182 ± 4° and dt = 1.04 ± 0.12 s with the WS method, and φ = 179°, dt = 1.04 s and R = 0.55 with the ML method. CNB (−35.315°; 149.363°) is a permanent station deployed and maintained by Geoscience Australia. Data processed at this station however correspond to a time span of recording of only 6 months, for the sake of comparison with the other data presented in this study. Good measurements performed at CNB (Fig. 6) on 3 core-refracted phases related to 2 events with different backazimuths (6.0° and 129.5°) give consistent directions of φ (N 55° E, N 22° E, N 27° E), whereas the same events recorded at the nearby (<40 km) permanent GEOSCOPE station CAN (−35.321°; 148.999°) were of rather poor quality and did not allow us to perform any measurement. More strikingly, studies taking into account several years of data recorded at station CAN reveal a well constrained apparent isotropy for SKS and similar phases (see [41–43] and inset in Fig. 3). The lateral resolution reached through studying core phases arriving at a station with a near vertical incidence is around 30 km. The inconsistency in terms of splitting parameters observed at CAN and CNB stations is therefore very interesting. No conclusion can be highlighted in view of only three good measurements,
meaningful change of elastic properties in the vicinity of a large number of measurements covering a long time span and/or a wide range of back-azimuths. It seems however that we may have a meaningful change of elastic properties in the vicinity of Canberra, on a scale of a few tens of kilometres.

Fig. 5. Zoom on region 2 (see Fig. 3 for location) superimposed on the geological map of the southern part of the Yilgarn craton (obtained from the Geological Survey of Western Australia website). (a) Good (black lines) and fair (grey lines) measurements. (b) Null measurements. The dashed line represents the 30° S parallel. (c) Example of the consistency between the different null measurements obtained for the same event recorded at different stations within the framework of the WACRATON deployment.
Similar features have been observed at the portable Kimberley array in South Africa, significant changes in shear wave splitting being observed over scales of <35 km [44]: such small-scale variations might therefore represent a more common situation than is currently appreciated. On the basis of this anomaly, a third long-term station will be installed beginning of 2005 in the same region, in order to study this peculiar local feature of anisotropy and see whether it is well constrained or just a question of probability related to the backazimuths of the events recorded during a 6 month period.

In their study, [17] reported directions of anisotropy in eastern Australia that exhibit a curvilinear trend somewhat similar to the poorly constrained and controversial “Tasman Line” (TL), delimiting the Proterozoic shields of central Australia and the Phanerozoic regions of the Tasman fold belt in eastern Australia. To some extent, we agree with the statement of [17], especially since we measured additional directions of anisotropy at stations SB05, SB01, SA04 and TL04 (see Fig. 3), located in the close vicinity of the proposed TL as defined by [22], directions that are locally parallel to the trend of the line.

The TL and the Trans European Suture Zone (TESZ) in Europe both represent geological features separating Proterozoic from Phanerozoic terranes; we could therefore have expected to observe a behaviour of the seismic waves along the TL similar to the one

![Fig. 6. Shear wave splitting measurements performed at station CNB on two different events highlighting good (a) and very good (b and c) results. Studies taking into account several years of data recorded at the nearby (~40 km) permanent GEOSCOPE station CAN conclude a net isotropic behaviour.](image-url)
reported on both sides of the TESZ. Along the Sorgenfrei–Tornquist Zone (STZ), the northwestern part of the TESZ, results of SKS shear wave splitting have shown that azimuthal anisotropy directions seem to follow the trend of the STZ [45]. These observations are consistent with alignment of mantle rocks parallel to the trend of the STZ which may have taken place during large-scale transcurrent motion along the STZ and that were subsequently frozen in the lithosphere. In our study, we however do not observe such a parallelism between the orientation of the polarization plane of the fast S-waves and the structural trend of the Tasman Line.

The Tasman Line project is designed to be operational until at least April 2005, and only 1 yr of data has yet been analyzed. We therefore expect to record more useful data to be able to investigate whether the Tasman Line could be analogous to the TESZ in Europe, and to determine the role it played during the formation of the Australian continent. The preliminary results seem encouraging. The recent review of [21] suggests however that previously proposed Tasman “lines”, even if based on geophysical data, might result from the association of lineaments or structural units of different ages that experienced different deformation and metamorphism, and therefore do not form a ‘line’ sensu stricto, as is the case in northern Europe.

Another interesting feature to report is common discrepancies between measurements performed on SKS and SKKS phases at stations SB01 and SB05. The ray paths followed by SKS and SKKS phases are different in the lower mantle and D\textsuperscript{W} layer, and almost superimposed in the upper mantle. This kind of discrepancy might therefore account for the potential location of anisotropy within the lower mantle and/ or the D\textsuperscript{W} layer.

Finally, we report stations showing clear evidence of isotropy. Measurements performed on various events covering a reasonable range of backazimuths at stations SC08 (backazimuth of 54.4° and 162.8°), SD09 (101.8°<baz.<148.5°), ZB12 (89.6°<baz.<132.8°) and YE02 (87.7°<baz.<143.7°) exhibit null results accounting for an absence of anisotropy underneath those stations. Looking at the geographical distribution of the stations (Fig. 1), it appears that stations YE02 and ZB12 are located in the vicinity of the isotropic permanent CAN station. The clear and consistent results obtained at station CNB and accounting for a direction of the polarization plane of the fast S-wave oriented ~30°, parallel to the structural trend of the Lachlan fold belt, are therefore even more intriguing and definitely require further investigation.

5. Discussion and conclusions

We retrieved shear wave splitting parameters at 118 of 190 sites temporarily equipped with broadband seismological stations deployed all over the Australian continent since 1992. Despite the impressive amount of stations covering the entire continent together with the large potential of seismicity to be recorded in Australia, the short time span of recording of most of the stations (average of 6 months) together with the sedimentary cover preventing outcrop in a large part of the Phanerozoic eastern Australia, did not allow us to highlight any clear and coherent pattern of anisotropy from shear wave splitting at the continental scale. However, due to the complex tectonic evolution of the Australian continent that begun 4.6 Gy ago, together with the presence of large cratonic blocks deeply rooted in the upper mantle, the lithosphere–asthenosphere boundary might well be rather complex, and mantle-flow related anisotropy can therefore not be completely ruled out: deviation of the mantle flow around the cratonic keels, leading to a complex pattern of anisotropy at the surface, might still be envisioned. This idea is supported by the results of surface wave tomography that may suggest a rather complex lithosphere–asthenosphere boundary.

At a regional scale, some evidence of fast split S-waves being polarized in planes oriented parallel to the local structural trends (southeastern coast and along the Halls Creek orogen, for instance) may account for anisotropy frozen in the lithosphere during post-tectonic thermal relaxation.

It seems therefore difficult to interpret the complex pattern of anisotropy from shear wave splitting beneath Australia in terms of either mantle-flow related anisotropy or anisotropy frozen in the lithosphere: a contribution from both the lithospheric and sublithospheric mantle is likely. The duration of most of the deployments is not sufficient for us to
be able to pin down the contribution from each source of anisotropy by, for instance, performing 2-layer modelling of the anisotropy. The current Tasman Line project is however designed to last for at least 2 yr (2003–2005) and aims at recording events simultaneously on both sides of the Tasman Line, the controversial boundary between the Precambrian western and Phanerozoic eastern Australia. Only 1 yr of data has been included in the present study. The forthcoming data should allow us to build a reliable database on both sides of the Tasman Line and to better constrain the preliminary results, which appear to exhibit a curvilinear trend sub-parallel to the structural trend of the Tasman Line and therefore suggestive of fossil anisotropy frozen in the lithosphere.

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