On the antipodal symmetry and seismic activity.

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Abstract. We discuss the effects of antipodal symmetry on Earth’s interior, landscape, ocean flow and seismic activity. The persistence of the (almost) antipodal symmetry in geology, geography and seismic activity strongly suggests that the forces which have been shaping out planet must satisfy (almost) antipodal symmetry. Of specific importance is the conclusion that powerful earthquakes tend to avoid large regions of deep ocean and antipodes of such regions, thus limiting epicenters of powerful earthquakes to relatively small portion of the Earth’s surface. Another important conclusion is that powerful earthquakes are typically accompanied by seismic activity not only near the epicenter but also near the antipode of the epicenter, thus allowing us to forecast, but only with certain probability, whether a set of foreshocks is going to lead to a powerful earthquake.

Key words: Powerful earthquakes, volcanic eruptions, antipodal symmetry.

The antipodal point, or simply antipode, of a point $x^o_{N/S}, y^o_{E/W}$ on the surface of the Earth is the point $x^o_{S/N}, (180 - y)^o_{W/E}$ located diametrically opposite, so that a line drawn from the one to the other passes through the center of the Earth. The antipodal shadow, or simply antipode, of a geographical place (continent, island, sea, etc.) is the set of all points antipodal to the points of the original geographical place. The map of the world with the antipodes of all continents is shown in Figure 1. Given the heterogeneity of the Earth’s structure one may not expect any kind of antipodal symmetry to hold exactly but rather approximately; that is if an event takes place at a point $x^o_{N/S}, y^o_{E/W}$ at time $T$, the corresponding antipodal event takes place not exactly at the point $x^o_{S/N}, (180 - y)^o_{W/E}$ at time $T$ but rather close to $x^o_{S/N}, (180 - y)^o_{W/E}$ at time close to $T$. We will often refer to it as almost antipodal symmetry and occasionally add the word 'almost' to 'antipodal' to emphasize lack of exactness.
Almost antipodal symmetry in seismic activity. The (almost) antipodal symmetry of seismic activity may allow to predict earthquakes and volcanic eruptions as seismic activity in a certain place may forecast seismic activity close to its antipode. Although there is no example of a pair of earthquakes with epicenters at two exactly antipodal locations, there are many which struck at almost antipodal locations at almost the same time. A random half an hour search of USGS website\(^1\) delivered the following examples of almost antipodal earthquakes: 1) magnitude 8.0 earthquake off the coast of Peru at 14.0°S, 78.0°W on December 12, 1908 at 12:08 UTC and magnitude 7.0 earthquake in Myanmar at 26.5°N, 97.0°E on December 12, 1908 at 12:55 UTC; 2) magnitude 7.3 earthquake in Argentina at 29.0°S, 62.5°W on December 7, 1912 at 22:47 UTC and magnitude 6.5 earthquake near Taiwan at 24.0°N, 121.6°E on December 11, 1912 at 18:07 UTC; 3) magnitude 7.3 earthquake in China at 29.0°N, 104.0°E on July 30, 1917 at 23:54 UTC and magnitude 6.9 earthquake in Argentina at 31.0°S, 70.0°W on July 27, 1917 at 2:52 am UTC; 4) magnitude 9.6 earthquake in Chile at 38.29°S, 73.05°W on May 22, 1960 19:11 UTC, preceded

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\(^1\)The earthquake data in this article are according to U.S. Geological Survey, Department of the Interior/USGS, [http://earthquake.usgs.gov/earthquakes/search/](http://earthquake.usgs.gov/earthquakes/search/). USGS seems to be revising their earthquakes data on a regular basis, so the magnitude of a particular earthquake in their data base may be changed at any time; earthquake data in this article is mostly as presented by USGS in February of 2015. Although the revisions are mostly small, in some cases they are fairly considerable, e. g. [http://earthquake.usgs.gov/earthquakes/eqarchives/year/mag8/magnitude8_1900_date.php](http://earthquake.usgs.gov/earthquakes/eqarchives/year/mag8/magnitude8_1900_date.php) as of January 20, 2015 states that the July 31, 1970 earthquake in Columbia was of magnitude 8.0 and the January 30, 1971 earthquake in Indonesia was of magnitude 8.1 while [http://earthquake.usgs.gov/earthquakes/search/](http://earthquake.usgs.gov/earthquakes/search/) states that the magnitudes of the two earthquakes were correspondingly 7.5 and 7.7. We will mostly use data base at [http://earthquake.usgs.gov/earthquakes/search/](http://earthquake.usgs.gov/earthquakes/search/), the parameters of some earthquakes may be expected to slightly change over time.
by a magnitude 8.2 foreshock at 37.825°S, 73.379°W on May 21, 1960 at 10:03 am UTC and a magnitude 8.6 foreshock at 38.061°S, 73.031°W on May 22, 1960 at 18:56 UTC and a few weaker ones, and magnitude 6.8 earthquake in Japan at 29.136°N, 129.957°E on May 18, 1960 at 06:35 UTC; 5) magnitude 8.7 earthquake near Alaska at 51.251°N, 178.715°E on February 4, 1965 at 05:01:22 UTC and magnitude 6.0 earthquake near South Sandwich Islands at 56.452°S, 27.043°W on January 16, 1965 at 11:33 UTC; 6) magnitude 6.2 earthquake near Peru at 18.023°S, 70.533°W on May 06, 2010 at 02:43 UTC and magnitude 6.5 earthquake near Indonesia 4.081°S, 101.069°E on May 05, 2010 at 16:29 UTC; 7) double magnitude 8.8 earthquake in Chile with epicenters at 35.95°S, 72.71°W and at 36.122°S, 72.898°W on February 27, 2010 at 06:34 UTC and magnitude 7.0 earthquake in Japan at 25.73°N, 128.652°E on February 26, 2010 at 20:31 UTC; 8) magnitude 7.3 earthquake near Sumatra at 2.433°N, 93.210°E on January 10, 2012 at 18:37 UTC and magnitude 5.0 earthquake near Ecuador at 0.740°S, 80.280°W on January 10, 2012 at 18:07 UTC; 9) magnitude 6.2 earthquake near New Zealand at 30.662°S, 178.484°W on October 11, 2013 at 21:25 UTC and a magnitude 6.6 earthquake in Greece at 35.514°N, 23.252°E on October 11, 2013 at 13:12 UTC; 10) magnitude 6.3 earthquake near Taiwan at 23.59°N, 121.437°E on October 31, 2013 at 12:02 UTC and magnitude 6.6 earthquake near Chile at 30.292°S, 71.522°W on October 31, 2013 at 23:04 UTC with a magnitude 6.2 foreshock at 35.314°S, 73.395°W on October 30, 2013 at 2:52 am UTC; 11) magnitude 7.9 earthquake near Alaska at 51.849°N, 178.735°E on June 23, 2014 at 12:53 UTC and magnitude 6.9 earthquake near Visokoi Island at 55.470°S, 28.367°W on June 28, 2014 at 23:53 UTC; and many more. It is hard to attribute these earthquakes to a mere coincidence.

There have been four magnitude $\geq 9.0$ earthquakes in 1900-2014, all were accompanied by almost antipodal seismic activity as shown in Figure 2. However the magnitude 8.9 earthquake on November 4, 1952 at 16:58:30 UTC at 52.623°N, 159.779°E was accompanied by suspicious lack of seismic activity in usually more seismically active antipodal region as shown in Figure 3. Thus the antipodal seismic activity is not assured even for high magnitude earthquakes.

In 2010-2014 five earthquakes of magnitude $\geq 8.2$ struck almost periodically separated on average by 373 days, each one of the them occurred at or close to a minimum in cosmic ray intensity as shown in Figure 4. The particulars of the earthquakes are: 1) a double earthquake of magnitude 8.8 on February 27, 2010 at 6:34 UTC in Chile at 36.122°S, 72.898°W and 35.85°S, 72.71°W;
Figure 2: Four known earthquakes of magnitude $\geq 9.0$ in 1900-2014 are shown in the left frame. The antipodal activity corresponding them is shown in the right frame, a circle with a letter 'A' denotes the strongest earthquake almost antipodal to the magnitude $\geq 9.0$ earthquake denoted by a circle of the same color. Source: [http://earthquake.usgs.gov/earthquakes/search/](http://earthquake.usgs.gov/earthquakes/search/) as of February 15, 2015.

Figure 3: Earthquakes of magnitude $\geq 5.0$ for the period of October 1, 1952 - January 4, 1953. The magnitude 8.9 earthquake on November 4, 1952 at 16:58:30 UTC at 52.623°N, 159.770°E is marked blue. The region antipodal to the earthquake’s epicenter lies South-East of South America. Source: [http://earthquake.usgs.gov/earthquakes/search/](http://earthquake.usgs.gov/earthquakes/search/) as of February 15, 2015.

2) magnitude 9.0 earthquake on March 11, 2011 in Japan at 38.297°N, 142.373°E, with the epicenter almost antipodal to the earthquakes in 1); 3) magnitude 8.6 earthquake on April 11, 2012 in Indonesia at 2.327°N, 93.063°E, followed by a magnitude 8.2 aftershock, the epicenters of both were almost antipodal to the earthquakes in 1) but quite far away from the earthquake in 2); 4) magnitude 8.3 earthquake on May 24, 2013 in the Okhotsk Sea at 54.892°N, 153.221°E was followed by two less powerful earthquakes at almost antipodal locations, one of magnitude 7.3 on July 15, 2013 at 60.857°S, 25.07°W, the other one of magnitude 7.7 on November 17, 2013 at 60.274°S, 46.401°W; 5) magnitude 8.2 earthquake on April 1, 2014 in Chile at 19.610°S, 70.769°W close to the epicenters in 1) and almost antipodal to the earthquake in 3). Figure 5 points out another interesting feature of the earthquakes. The five earthquakes of magnitude $\geq 8.2$ in 2010-2014 suggest that the time interval between two earthquakes with almost antipodal epicenters may be as long as a year or even longer; Figure 5 suggests that earthquakes may actually "split up" into several sub-earthquakes separated by a rather large time interval.
Daily average for CRI for 2010-2014. The asterisks approximately indicate the points on the graph corresponding to five earthquakes of magnitude \( \geq 8.2 \) in 2010-2014. Source: http://cr0.izmiran.rssi.ru/mosc/main.htm.

Figure 5: Earthquakes of magnitude \( \geq 8.2 \) for the period 2010-2014. The midpoint between the earthquakes marked green is at approximately \( 30^\circ N, 114^\circ E \), the midpoint between the earthquakes marked green is \( 28^\circ S, 71^\circ W \); the two midpoints are almost antipodal to each other.

It is as if the earthquakes marked blue and green were branches of the same earthquake going in opposite directions; the blue branch split up into two subbranches marked dark blue and light blue, the green branch split up into two subbranches marked dark green and light green. The earthquakes shown here appear to be parts of a single event lasting five years, at least. Source: http://earthquake.usgs.gov/earthquakes/search/ as of February 19, 2015; http://www.geomidpoint.com/.

Most of the continental area on the Earth’s surface is antipodal to oceanic regions, only \( \approx 14.7\% \) of land territory is antipodal to other land, representing approximately 4.4% of the Earth’s surface. But it is these 4.4% along which the most powerful earthquakes congregate. Figure 6 shows earthquakes of magnitude \( \geq 8.2 / \geq 8.1 \) from 1900 to 2014; it leads to a stunning conclusion that of 50/76 earthquakes of magnitude \( \geq 8.2 / \geq 8.1 \) in 1900-2014, only two/three (shown in dark green) struck far away from water and all 50/76 struck in the regions of land mass or shallow depth antipodal to regions of land mass or shallow depth or close to such regions; there is currently no explanation as to why. The western border of North America is antipodal to a large region of deep water far away from land mass or shallow water, it was struck by only 1/2 earthquakes of magnitude \( \geq 8.2 / \geq 8.1 \). High magnitude earthquakes seem to typically avoid large regions of deep water or regions antipodal to such.

Greenland and the islands of northern Canada are antipodal to land mass and used to be seismically active but no longer are. The center of the region is antipodal to a recently discovered 250-mile wide Antarctic crater in Wilkes Land, at \( 70^\circ S, 120^\circ E \).

If we look at earthquakes of lower magnitude, the number of earthquakes increases as does
Figure 6:

The upper left/right frame shows earthquakes of magnitude $\geq 8.2 / \geq 8.1$ from 1900 to 2014, the total number of earthquakes is 50/76. The frame in the second row shows map of World with height and depth. In the third and fourth rows the first frame is a portion of the antipodal map in Figure 1, the middle frame is a regular map and the last frame is an antipodal map of the region antipodal to the middle frame. The yellow circles mark earthquakes in or close to South America, their epicenters are antipodal to land mass or regions of shallow depth in Asia or close to such. The green circles mark earthquakes in land mass or regions of shallow depth in Asia and Asia-Pacific, their epicenters are antipodal to land mass or regions of shallow depth in South America or close to such. The purple and brown circles show earthquakes in or close to the polar regions, all of them occurred in or close to land mass or regions of shallow depth, and, their epicenters are antipodal to regions of shallow depth or close to such. The blue circles show earthquakes in or close to Australia, all of them were in or close to regions of shallow depth and antipodal to land mass or regions of shallow depth or close to such. The red and brown circles show earthquakes with the epicenters correspondingly at $24.9^\circ N, 63.6^\circ E$ and $62.9^\circ N, 149.5^\circ E$. The only earthquakes far from water are marked dark green. Only 9/15 earthquakes are far both from South America and its antipode, they are marked purple, blue, brown and red. The arrows point approximately to antipodal locations of the earthquakes marked by circles of the same color. Source: [http://earthquake.usgs.gov/earthquakes/search/](http://earthquake.usgs.gov/earthquakes/search/) by USGS as of February 14, 2005 and [http://www.ngdc.noaa.gov/mgg/global/relief/SLIDES/JPEGfull/](http://www.ngdc.noaa.gov/mgg/global/relief/SLIDES/JPEGfull/) by NGDC, NOAA.
their density; it becomes more difficult to sort the earthquakes out into almost antipodal pairs. Figure 7 shows earthquakes of magnitude $\geq 6.2$ in October, 2013, and how they can be broken up into pairs or triplets of earthquakes almost antipodal to each other. Even at a rather low magnitude of 6.2, it is still possible to see which earthquakes are almost antipodal to which.

![Figure 7: Earthquakes of magnitude $\geq 6.2$ in October 2013.](image)

Earthquakes of magnitude $\geq 6.2$ in October 2013. The earthquakes in the pair marked yellow and the triplets marked brown are almost antipodal to each other, they struck within 2-3 days from each other. The earth quakes in the pair marked purple struck within 10 days from each other. The earthquakes in the pairs marked orange and red had almost antipodal locations but struck within 2-4 weeks from each other. The two earthquakes marked in the Western hemisphere marked blue did not have an almost antipodal match of magnitude $\geq 6.2$, but there was an almost antipodal match of of magnitude 6.0. Source: [http://earthquake.usgs.gov/earthquakes/search/](http://earthquake.usgs.gov/earthquakes/search/) as of February 15, 2015.

The eruption of Mount Pinatubo at $15.141667^\circ N, 120.35^\circ E$ in mid-June 1991, the second largest volcanic eruption of the 20th century, was accompanied by a magnitude 7.3 earthquake on June 23, 1991 which struck almost antipodally at $26.802^\circ S, 63.349^\circ W$. The eruption was preceded by a series of smaller eruptions, the first of which on April 2, 1991 was accompanied by a magnitude 7.1 earthquake on April 5, 1991 at $5.982^\circ S, 77.094^\circ W$. The largest eruption of the 20th century was that of Novarupta in Alaska on June 6-8, 1912 but no reliable records of earthquakes at the time could be found.

We already noticed in Figure 6 that the epicenters of the earthquakes marked red, brown, purple and some green are on or close to the tectonic lines, and so are their antipodes. Are the tectonic lines antipodal to each other? Figure 8 shows major tectonic lines and how they can be divided into pairs, with some pairs comprised of tectonic lines almost antipodal to each other. The rest of the pairs are comprised of tectonic lines which could have been almost antipodal to each other but have been moved from their almost antipodal positions.

**Almost antipodal symmetry and ocean trenches.** Ocean trenches may be viewed as remnants of seismic activity long time ago; they are also subject to almost antipodal symmetry. As Figure 10 shows, all but two (New Hebrides and Kermadec-Tonga) large ocean trenches are either close to South America or to its translated antipode shown in the right frame of Figure 10. South America is also home of the South Atlantic Anomaly, where the Earth’s magnetic field attains its
Figure 8: Approximate locations of major tectonic lines. The tectonic lines are divided into pairs marked by the same letter of the same color; one line is labeled with a capital letter, the other one with a small letter. Some pairs are comprised of tectonic lines almost-antipodal to each other, others are comprised of tectonic lines which could have been almost-antipodal but were moved from their mutually almost-antipodal positions. Most tectonic lines pass through the oceans and it appears as if land masses have pushed tectonic lines to their current positions, e.g. North America has pushed the d-line southwards, Europe has pushed the eastern boundary of the h-line southwards to the middle of the p-line, South America and India have pushed both b-lines, the k-line was stopped short by Antarctica, etc. The map does not take into account the nature of each tectonic line, that is whether the plate boundary marked by the line is divergent, convergent or transform; whether there is a subduction zone along the line, whether the fault along the line is normal, reverse/thrust, strike slip, etc. The original map is from http://earthquake.usgs.gov/earthquakes/search/, also http://www.1800-sports.com/images/earthquake-epicenters.jpg.

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only minimum; is it a coincidence or the two are somehow related? Another, rather remarkable, observation is that the arc-like part of the Peru-Chile Trench near North-West cost of South America is almost antipodal to the Java Trench.

**Hot spots and almost antipodal symmetry.** Geological hotspots are volcanic regions thought to be fed by underlying mantle that is anomalously hot compared with the mantle elsewhere; they make a hotly debated subject with some strongly supporting their existence and others as strongly rejecting. Whether they exist or not is not clear, but quite a few lists of hotspots have been compiled. According to https://gsa.confex.com/gsa/2004AM/finalprogram/abstract_78207.htm, of 45 prominent or ‘primary’ hotspots, found in most hotspot compilations, 22 form antipodal pairs and 19 of the remaining 23 have volcanic centers near their antipodes.

**Almost antipodal symmetry of the geomagnetic field and ocean currents.** As one might expect the Earth’s magnetic field exhibits almost antipodal symmetry in the sense that, as Figure 11 shows, the maxima/minimum of the Earth’s magnetic field are also almost antipodal to each other: the South Atlantic Anomaly is almost antipodal to local maximum T near the Tunguska river in Siberia, and local maximum $P_N$ near the Hudson Bay is almost antipodal to local maximum $P_S$ near Antarctica. Somewhat less expected is the almost antipodal symmetry found in ocean
Figure 9: World’s largest ocean trenches. Colors of the labels carry no significance, they are solely to make the labels less confusing. The map is from https://www.cia.gov/library/publications/the-world-factbook/graphics/ref_maps/physical/pdf/world.pdf, originally from the CIA’s World Factbook.

Figure 10: The major trenches of the world are either close to South America (Peru-Chile, Middle American, Cayman, Puerto-Rico, South Sandwich) or congregate to its antipode translated to fit Eurasia (Aleutian, Kuril-Japan, Mariana, New Britain, Java, Nansci Shoto) as shown in the right frame. The only exceptions are New Hebrides and Kermadec-Tonga trenches, they run very close to the antipodes of the western boundary of Iberian Peninsula and the northwest boundary of Africa. The antipode of the Peru-Chile Trench continues the Java Trench. The left frame is from Figure 14.

currents shown in Figure 12. All but one vortices of ocean currents between $45^\circ N$ and $45^\circ S$ are almost antipodal to each other. The vortices’ average latitude is close to the tropics suggesting solar and lunar influence. What makes it unexpected is that the continents do not seem to possess antipodal symmetry.

**Almost antipodal continental fit.** It is well known that the continents almost fit each other like in a jigsaw puzzle\(^2\), we shall refer to it as the *direct continental fit*; it is illustrated in Figure 13. Figures 14, 15 show that we may also fit continents and the antipodes of the continents in a similar manner, we shall refer to it as the *antipodal continental fit*. Not only we can fit continents and their antipodes together, we may do it in more than one way. While the direct continental fit

\(^2\)http://en.wikipedia.org/wiki/Continental_drift
Figure 11: Total intensity of the Earth's magnetic field in nT. The total intensity of the Earth's magnetic field has three maxima $P_N$, near the Hudson Bay, Canada; $P_S$, between Antarctica and Australia; $T$, near the Tunguska river in Siberia; and one minimum SAA, near the center of the South Atlantic Anomaly. Source: http://www.ngdc.noaa.gov/geomag/WMM/wmm_ddownload.shtml.

Figure 12: Ocean currents as of 2004. Two vortices of ocean currents almost antipodal to each other are marked by the same letter. All but one vortices between $45^\circ N$ and $45^\circ S$ are almost antipodal to each other, vortex C has no antipodal match. Instead, vortex C, rather smallish compare to other vortices and located just South of the South Pacific Superswell, is antipodal to the Sahara Desert. Vortices at the latitudes higher than $45^\circ$ and small vortices due to terrestrial features do not have (almost) antipodal matches and are not marked here. The map was downloaded from http://commons.wikimedia.org/wiki/File:Ocean_current_2004.jpg but is originally from http://msi.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/APN/Chapt-32.pdf.

is explained by the theory of the continental drift/plate tectonics, there is no explanation of the antipodal continental fit.

At some points in the Earth's past all land mass was gathered in a single supercontinent; to satisfy the antipodal continental fit the supercontinent had to occupy about half of the Earth's surface and its boundary had to be almost antipodal to itself. Figure 16 shows that the last known supercontinent of Pangea could be approximately inscribed in a great circle with the regions inside and outside of the great circle being almost antipodal to each other. Pangea fits inside the great circle, the gaps between Pangea and the great circle shaded light purple are to be expected, as erosion and the elements make the coastline somewhat uneven. The gap between Pangea and the great circle shaded dark purple is just too large to be attributed to simple unevenness of the coastline; according to the principle of the antipodal continental fit there expected to be land mass there. Whatever might have happened to it? Could it just have sunk giving rise to the Darwin
Reconstructed Pangea, the last supercontinent known to exist, with modern continents outlined. The picture is from Wikipedia http://en.wikipedia.org/wiki/Pangaea; there are many other versions of Pangea, some are more sophisticated than others, their use is hindered by copyright issues. Some non-scientific images of Pangea may be found at 1) http://ump.berkeley.edu/geology/anim11.html, 2) http://giphy.com/gifs/trippy-breaking-apart-JEjyLjbuOjjYA, 3) http://www.metafysica.nl/wings/remy_remy1977_1.jpg, 4) http://www.preearth.net/preearth-flat.gif, 5) http://courses.washington.edu/tesc243/karakoram/pangeabreakup.gif, 6) http://baask.com/articals/sangat/birth_of_balochistan/image002.jpg, 7) http://www.preearth.net/worlds-collide.html, 8) http://www.divediscover.whoi.edu/tectonics/pangea-animation.html, 9) https://www.classzone.com/books/earth_sciences/terc/content/visualizations/es0806/es0806page01.cfm?chapter_no=visualization. 10) https://dr282zn36sxxg.cloudfront.net/datastreams/f-d%3Ac51f44cb8323a43cf7d55cea8ca0cbb2fa6e0af5b80af2d673ccae0e%2BIMAGE_THUMB_POSTCARD%2BIMAGE_THUMB_POSTCARD.1; we neither support nor reject theories associated with the images but list their web locations solely as examples of different presentations of Pangea.

Rise and the South Pacific Superswell? Could it still be sinking towards the core somewhere deep down in the mantle causing the above-average seismic activity near the Java Trench and near the western coast of South America almost antipodal to the Java Trench? At this point we may only speculate as to the nature of the missing land mass in Figure 16.

Almost antipodal symmetry of the Earth core and the core-mantle boundary. In a recent article 'Equatorial anisotropy in the inner part of Earth's inner core from autocorrelation of earthquake coda', Tao Wang, Xiaodong Song, and Han H. Xia analyzed the autocorrelation of earthquake coda measured by global broadband seismic arrays between 1992 and 2012, and found that the differential travel times of two types of Earth core-penetrating waves vary at low latitudes by up to 10 seconds. Their observation of large, up to 10 seconds, variations in the II2-I2 residuals, are illustrated in Figure 17 which also exhibits almost antipodal symmetry: the blue regions center near the poles are almost antipodal to each other as are the blue regions near the northern part of the Peru-Chile Trench and near the Java Trench; the gaps in red circles are also almost antipodal to each other. The gaps in the red circles are close to points $P_N$ and $P_S$ of Figure 11. http://www.iris.edu/gallery3/research/2006proposal/inner/IRIS05_icrot

Could the anisotropy be due to the missing land mass? Similar work by other authors provide

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3 For explanation of technical terms and details the reader is referred to the source of the file.
Figure 14: The left frame shows how continents and their antipodes almost fit together. The right frame shows how continents and their antipodes almost fit together if we remove the isthmus of Central America and bring North America and South America together; notice how well the boundary of Australia's antipode fit the boundaries of adjacent continents. The continents and their antipodes fit well on the sphere but, due to the Gauss’s Theorema Egregium described in http://en.wikipedia.org/wiki/Theorema_Egregium, cannot be unfolded onto a flat plane without distorting distances and shapes; consequently Africa’s antipode had to be broken to make the unfolding possible, the gap between the eastern border of South America and southwestern border of Africa in the left frame appears for the same reason. Another solution could have been to distort the shapes of the continents and their antipodes, which the authors chose not to do. The shapes of the continents and their antipodes were obtained from http://www.jasondavies.com/maps/clip-extent/, courtesy of Jason Davies.

Figure 15: The first frame shows how the antipode of Antarctica almost fits into the Arctic; the second frame improves the fit by moving Greenland and Alaska. The third frame shows a different fit of the antipode of Antarctica into the Arctic; the fourth frame improves the fit by moving Russian Far East, Alaska and Greenland shown in dark green. Curiously, Greenland magnified by the factor of 1.3 fits even better, its outline is shown in blue in the last frame. The images were produced with the help of http://www.jasondavies.com/maps/clip-extent/, courtesy of Jason Davies.

somewhat different results yet all show almost antipodal symmetry of one kind or another, e.g. http://www.iris.edu/gallery3/research/2006proposal/inner/IRIS05_icrot, http://www.geo.uu.nl/~deuss/research/inner-core/.

Another recent research paper exhibits the outer core-mantle boundary tomography; as
Figure 16: The first frame shows supercontinent Pangea from Figure 13. The second frame shows a circle circumscribed around Pangea, it looks a bit like an ellipse due to mapping distortions. If we assume that the region shaded yellow was made up of modern continents, its area should be about the same as the area of the Earth’s land mass today, that is about 30% of the Earth’s surface; the area of the regions shaded purple (light and dark) in the third frame could be estimated to be about 20% of the Earth’s surface. Since the area inside the circle is about half of the Earth’s surface, the circle must be a great circle or close to being a great circle; it must divide the Earth’s surface into two approximately equal hemispheres. There are many other presentations of Pangea, some are more sophisticated than others, their use is hindered by copyright issues; practically all of them lead to the same conclusion that Pangea could be approximately inscribed in a great circle with (a) chunk(s) of land mass missing.

Figure 17: Residuals of observed II2-I2 differential times (symbols) and model global predictions (color background). Observed residuals are plotted at the array locations (filled symbols) and their antipodes (open symbols). Adapted by permission from Macmillan Publishers Ltd: Nature Geoscience, Tao Wang, Xiaodong Song, Han H. Xia, Equatorial anisotropy in the inner part of Earth’s inner core from autocorrelation of earthquake coda; appeared online on 9 February 2015, http://dx.doi.org/10.1038/NGEO2354, copyright 2015; License Number 3565200880257.

Figure 18: Outer core-mantle boundary tomography, for details the reader is referred to Tanaka, S., Constraints on the core-mantle boundary topography from P4KP-PcP differential travel times, Journal of Geophysical Research, Vol. 115, B04310, doi10.1029/2009JB006563, 2010. Source of the image: http://www.iris.edu/gallery3/research/2010proposal/outer_inner_core/TanakaFig1, permission to use the image freely for personal and educational/academic purposes is granted on the web site.

shown in Figure 18, it also exhibits almost antipodal symmetry.
Almost antipodal symmetry in craters and tektites. All large ancient craters also seem to be almost antipodal to either other craters or locations which are or used to be seismically active:

1) the Chicxulub Crater at 21.4°N, 89.517°W is almost antipodal to the point right between the Shiva Crater at 18.667°N, 70.233°E and the Bedout Crater at 18°S, 119°E; 2) the Morokweng Crater at 26.4667°S, 23.533°E and the Vredefort Crater at 27°S, 27.5°E are almost antipodal to seismically active region of Hawaii centered at 21.3°N, 157.8°W; 3) Tookonooka Crater at 27.117°S, 142.83°E and Talundilly Crater nearby are almost antipodal to the Fried Egg structure in the Atlantic Ocean 150 km away from the Azores; 4) the Acraman Crater at 32.02°S, 135.45°E is almost antipodal to the Chesapeake Bay crater at 37.283°N, 76.02°W; 5) the Kara crater 69.1°N, 64.15°E is almost antipodal to the Antarctica Peninsular while the Popigai crater at 71.65°N, 111.183°E is antipodal to the tip of the Antarctica Peninsular; 6) the antipodes of the Manicouagan Crater at 51.383°N, 68.7°W, the Sudbury crater at 46.6°N, 81.183°W, and the Beaverhead crater at 44.6°N, 113°W lie on or close to the southern boundary of the Australasian Strewnfiled shown in Figure 19. The craters are believed to be left by extraterrestrial impacts, which one would expect to be random and not to exhibit any kind of pattern; however, knowing how widespread is seismic activity, one may find a currently or formerly active seismic spot pretty much anywhere making almost antipodal symmetry shown by craters somewhat of a wishful thinking. But if it is not wishful thinking; why would the largest craters, believed to be the footprints of ancient impacts by extraterrestrial bodies striking the Earth quite randomly, show almost antipodal symmetry? Could the craters be remnants of some terrestrial activity?

Figure 19 itself exhibits almost antipodal symmetry in the sense that the centers of the
North American and Australian strewn fields are almost antipodal to each other; the Ivory Coast Strewn Field is not almost antipodal to any strewn field. Tektites are believed to be the relics of ancient impacts by extraterrestrial bodies, but then why would the centers of the two largest tektite strewn fields be almost antipodal to each other? Could the tektites be remnants of some terrestrial activity?

**Conclusion.** The observations discussed here point to the greater importance of the almost antipodal symmetry than is currently believed. The persistence of the almost antipodal symmetry suggests that the forces, which shaped our planet in the past and continue re-shaping it now, posses almost antipodal symmetry as well.

There is a number of theories attempting to explain almost antipodal symmetry of some phenomena, e.g. antipodal volcanism, shock dynamics; but none can explain the sheer variety of the phenomena exhibiting almost antipodal symmetry. The only forces with almost antipodal symmetry we know are the tidal forces, they exhibit themselves by creating tides at the opposite sides of the globe. Such forces are certainly present in the liquid core and viscous mantle where they should also cause tides; it is the motion of these tides which most likely is responsible for the different aspects of the antipodal symmetry discussed in this article. Since the liquid core contains electric currents, whose existence is attested to by the very existence of the geomagnetic field, the magnetic fields due to cosmic rays and solar activity, should affect it in a similar manner causing earthquakes, volcanic eruptions, etc., albeit without antipodal symmetry.

If two earthquakes with almost antipodal epicenters strike at almost the same time, we may speculate that they have the same underlying cause(s), whatever the cause(s) might be. Figure 5 might as well depict a seismic event that lasted at least five years and produced several earthquakes. That related earthquakes are separated from each other by time varying from days to months or even years, indicates that earthquakes lag their causes by considerable length of time; which, in turn, shows that any attempt to prove or disprove any correlation between earthquakes and their possible causes by direct statistics is, at best, naive and futile.

That powerful earthquakes tend to avoid large regions of deep ocean and antipodes of such regions, allows us to tell in which regions powerful earthquakes are likely to strike and which regions they avoid. That powerful earthquakes are typically accompanied by seismic activity not only near the epicenter but also near the antipode of the epicenter, allows us to forecast, but only
with certain probability, whether a set of foreshocks is going to lead to a powerful earthquake or not. At the moment both conclusions are only loosely formulated, much more work is needed to make them more precise and bring the earthquake forecast to the level of reliability of the weather forecast.

Acknowledgments.

Many illustrations in this publication are from public domain with references provided, the author would like to express his gratitude to all those who created them and those who made them available to the public. The material produced by USA federal agencies is in the public domain and may be reproduced without permission as per http://www.doi.gov/copyright.cfm under the terms of Title 17, Chapter 1, Section 105 of the US Code. Moscow Neutron Monitor at http://cr0.izmiran.rssi.ru/mosc/main.htm provided software and data to generate graphics for cosmic ray intensity. The author would like to thank Jason Davies who kindly allowed him to use the material he created.

There is no bibliography in this paper as references are provided in the text.