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On the global aspects of the almost-antipodal symmetry on the Earth

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ABSTRACT
We discuss the manifestations of antipodal symmetry in Earth's geology, geography and seismic/tectonic activity.

Key words: Symmetries on Earth surface, antipodal symmetry, seismic activity, tectonic activity.

PREAMBLE

In this paper we discuss almost antipodal symmetry, a phenomenon yet unexplained by modern science. Although it is in full view for all to see, it has not even been reported in scientific literature. The *antipodal point*, or simply *antipode*, of a point $\lambda°N/S$, $\varphi°E/W$ on the surface of the Earth is the point $\lambda°S/N$, $(180 - \varphi)°W/E$ 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 geographic place (continent, island, sea, etc.) is the set of all points antipodal to the points of the original geographic place. The map of the world with the antipodes of all continents is shown in Figure 1. Because of Earth's heterogeneity, exact antipodal symmetry is not very likely to be observed whereas almost antipodal symmetry is observable. The exact definition of 'almost antipodal' events should depend on the maximum allowable deviation from exact antipodality. However, in this paper, we say that two events are 'almost antipodally symmetric' or are 'almost antipodal' if one event takes place at a point $\lambda°N/S$, $\varphi°E/W$ at time T, while the other one takes place close to point $\lambda°S/N$, $(180 - \varphi)°W/E$ at time close to T with rather loosely defined 'close'.

The most well-known example of almost antipodal symmetry is tides, which at any given moment of time appear at two locations almost antipodal to each other. The antipodal symmetry on Earth has attracted attention of many a scientist. In his book S. Warren Carey (1976), vividly explained the importance of antipodal symmetry.

The almost antipodal symmetry also surfaced in the discussion of hotspots. According to the statistical analysis performed on three published distributions of hotspots, 26 to 37 percent of hotspots form almost antipodal pairs, provided no more than 700 km deviation from exact antipodality is allowed, [Rampino et al., 1992].

Almost antipodal symmetry in seismic activity

Almost antipodal symmetry is known to manifest itself in seismic activity (USGS Earthquake Archives, 2017), and geographic location of volcanoes and craters:
1) 1912/12/11 earthquake at 24.0°*N*, 121.6°*E* and 1912/12/07 earthquake at 29.0°*S*, 62.5°*W*; **2)** 2001/01/26 earthquake at 23.42°*N*, 70.23°*E* and 2001/01/29 earthquake at 24.05°*S*, 115.4°*W*; **3)** 2002/05/28 earthquake at 24.07°*N*, 122.26°*E* and 2002/05/28 earthquake at 28.94°*S*, 66.8°*W*; **4)** 2012/01/10 earthquake at 2.43°*N*, 93.21°*E* and 2012/01/10 earthquake at 0.74°*S*, 80.28°*W*; **5)** the 2015/04/15-21 eruption of Tungurahua at 1.47°*S*, 78.44°*W* and the 2015/04/6-12 eruption of Sinabung at 3.17°*N*, 98.39°*E*, followed by 2016/03/02 earthquake at 4.95°*S*, 94.33°*E* and 2016/04/16 earthquake at 0.35°*N*, 79.93°*W*; **6)** the eruption of Pinatubo at 15.142°*N*, 120.35°*E* in June 1991 and the 1991 increase in activity in a prolonged 1990 - 1995 eruption of Sabancaya at 15.78°*S*, 71.85°*W* ; accompanied by earthquakes at 13.11°*S*, 72.19°*W* on 1991/07/06; at 15.68°*N*, 121.17°*E* on 1990/07/16; and at 11.76°*N*, 121.9°*E* on 1990/06/4; **7)** craters Morokweng at 26.47°*S*, 23.53°*E* and Vredefort at 27°*S*, 27.5°*E* and seismically active region of Hawaii centered at 21.3°*N*, 157.8°*W*; **8)** the southernmost volcano Erebus at 77.53°*S*, 167.15°*E* and the northernmost volcano Beerenberg at 71.08°*N*, 8.16°*W*; **9)** seven of the most powerful earthquakes in 1900 - 2016 were accompanied by almost antipodal seismic activity as shown in Table 1; and much more. As we look at earthquakes of lower magnitude, the number of earthquakes increases, it becomes more difficult to figure out which earthquakes are almost antipodal to which. Even major vortices of ocean currents between 45°*N* and 45°*S* are almost antipodal to each other, as shown in Figure 2.

Of course, not all earthquakes, volcanoes and craters occur almost antipodally; but the almost antipodal symmetry is so prominent in seismic activity that several

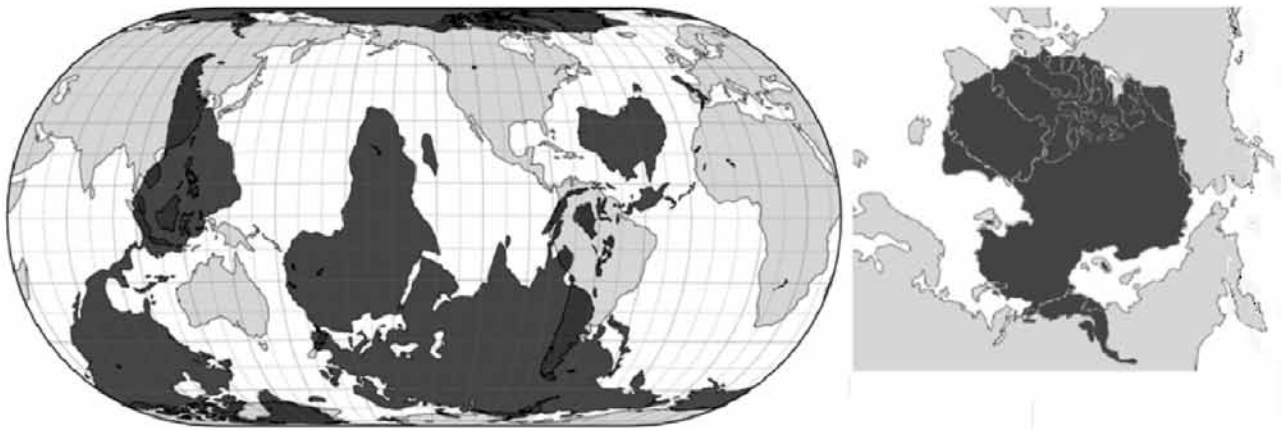

Figure 1. The continents are shown in light gray, the antipodes of the continents are shown in dark gray, (Davis, 2017 web link)

Table 1: Almost antipodal seismic activity corresponding to the most powerful earthquakes of 1900-2016. Coordinates are rounded off to the nearest tenth of a degree. Only M ≥ 7.0 fore/aftershocks are listed.

Magnitude, date, location, and surrounding seismic activity of the most powerful earthquakes	Almost antipodal seismic activity corresponding to these earthquakes
M=8.6 on 2012/4/11 at 2.3^{o}N, 93.^{o}E	M=7.4 on 2012/3/20 at 16.5^{o}N, 98.2^{o}W
M=9.1 on 2011/3/11 at 38.3^{o}N, 142.4^{o}E five M ≥ 7.0 fore/aftershocks	M= 6.9 in 2011/2/11 at 36.4^{o}S, 73.^{o}W
M=8.8 on 2010/2/27 at 36.1^{o}S, 72.9^{o}W two M ≥ 7.0 aftershocks	M=7.0 on 2010/2/26 at 25.9^{o}N, 128.4^{o}E
M=8.6 on 2005/3/28 at 2.1^{o}N, 97.1^{o}E	M=6.0 on 2005/4/11 at 7.3^{o}S, 77.9^{o}W
M=9.1 on 2004/12/26 at 3.3^{o}N, 96^{o}E M=7.2 aftershock	M=7.2 on 2004/11/15 at 4.7^{o}N, 77.5^{o}W
M=8.7 on 1965/2/4 at 51.3^{o}N, 178.7^{o}E	M=6.0 on 1965/1/16 at 56.5^{o}S, 27.^{o}W
M=9.2 on 1964/3/28 at 60.9^{o}N, 147.3^{o}W	M=7.8 on 1964/5/26 at 56.3^{o}S, 27.7^{o}W
M=9.5 on 1960/5/22 at 38.1^{o}S, 73.4^{o}W five M ≥ 7.0 fore/aftershocks	M=6.5 on 1960/5/18 at 29.2^{o}N, 130^{o}E M=8.0 on 1960/3/20 at 39.9^{o}N 143.2^{o}E
M=8.6 on 1957/3/9 at 51.5^{o}N, 175.6^{o}W four M ≥ 7 aftershocks	M=6.0 on 1957/5/12 at 60.5^{o}S, 24.3^{o}W
M=9.0 on 1952/11/4 at 52.6^{o}N, 159.8^{o}E	M=6.5 in 1952/4/15 at 56.5^{o}S, 25.8^{o}W M=6.4 on 1952/6/19 at 53.7^{o}S, 54.2^{o}W
M=8.6 on 1950/8/15 at 28.4^{o}N, 96.4^{o}E	M=7.1 on 1950/8/14 at 27.5^{o}S, 62.8^{o}W
M=8.6 on 1946/4/1 at 53.5^{o}N, 162.8^{o}W	M=6.4 on 1946/10/26 at 60.5^{o}S, 35.2^{o}W
M=8.8 on 1906/1/31 at 1^{o}N, 79.4^{o}W	M=7.8 on 1907/1/4 at 1.9^{o}N, 94.2^{o}E

theories have been put forward to explain it, e.g. antipodal volcanism, shock dynamics, (Jonathan, 2005, Meschede et al., 2011, Retailleau et al., 2014, Real and Cormier, 1980). The theories, however, explain the almost antipodal symmetry of local features/events, i.e. features/events occupying only small regions of the Earth's surface. Here we demonstrate that the almost antipodal symmetry exhibits itself also on the planetary scale.

Almost antipodal continental fit.

Most of the land mass on the Earth's surface is antipodal to oceanic regions, only ≈ 14.7% of land is antipodal to other land, representing approximately 4.4% of the Earth's surface. According to (Harrison and Christopher, 1966), the present antipodal arrangement of continents and oceans has less than 1 chance in 14 of being caused by a random

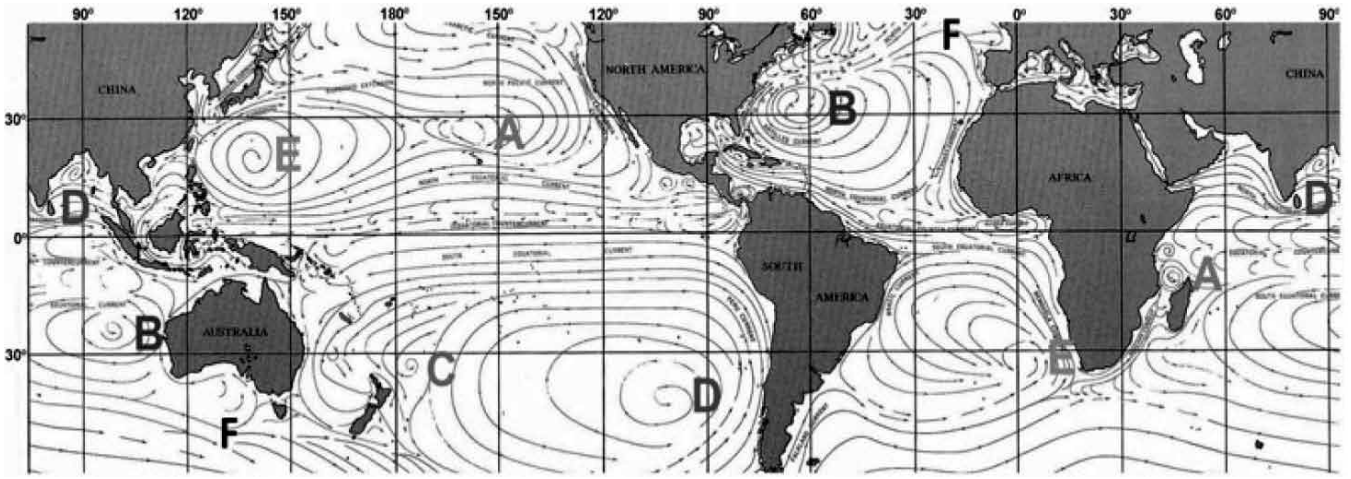

Figure 2. Ocean currents as of 2004. Of the nine major vortices between 45°N and 45°S, eight occur in four almost antipodal pairs marked by letters A, B, D,E. Only vortex C does not have an almost antipodal match. There is also a pair of vortices marked by F, only one of which is below 45°, (Ocean Currents: web link, 2017).

process, the unknown origin of such an arrangement is often referred to as antipodal puzzle, (Leak, 2011). But, there is more to it.

As Figure 3 shows the antipodes of continental shelves of Africa and Eurasia shown in frame 1 fit the continental shelves of North America and Europe shown in frame 2 adjacent to them in a jigsaw-puzzle-like manner. In other words, the boundaries of the continental shelves of Africa and Eurasia shown in frame 1 are almost antipodally symmetric to the boundaries of the continental shelves of North America and Europe shown in frame 2. The images are in Mercator projection, we can use its properties described in (Wikipedia. Mercator projection, 2017) to derive an approximate quantitative relationship governing the positioning of continental shelves: if (λ, φ) are the latitude and longitude of a point on the continental shelves in frame 1; $(-\lambda, \pi - \varphi)$ are the latitude and longitude of its antipode; (Λ, Φ) are the latitude and longitude of the point in frame 2 where $(-\lambda, \pi - \varphi)$ is moved; then the quantities

$$L = \frac{1-\sin\lambda}{1+\sin\lambda} \cdot \frac{1-\sin\Lambda}{1+\sin\Lambda} > 0, \; F = \frac{\phi-\pi}{\cos\lambda} - \frac{\Phi}{\cos\Lambda} \quad (1)$$

stay approximately the same for all points on the continental shelves in frame 1.

The antipodes of Australia and Tasmania may be fit between the east coast of North America and the isthmus of Central America on one side and Africa and the Iberian Peninsula on the other side somewhat differently from Figure 3 as shown in Figure 4.

In a similar jigsaw-puzzle-like manner illustrated in Figure 5, the continents of the Arctic shown in frame 2 fit the antipode of the continental shelf of Antarctica shown in frame 1; and not in one but in two different ways. In other words, the continental boundaries of the Arctic shown in frame 2 are almost antipodally symmetric to the boundaries of the continental shelf of Antarctica shown frame 2.

Figures 3 and 5 differ in one significant way: in Figure 3 the antipodes of continental shelves are matched to continental shelves, whereas in Figure 5 the antipode of the Antarctica continental shelf is matched to the continents rather than continental shelves of the Arctic. From the human perspective it would be much nicer if the Nature matched the antipodes of continental shelves to continental shelves or the antipodes of continents to continents rather than mixing them up, yet the Nature does not care about our perspective and does as she pleases; and why she does so modern Geophysics cannot explain. One possible explanation might be that the determining factor is not the depth but the distance from the center of the Earth, the points at the same depth at latitude λ are approximately

$$R_{eq} - \sqrt{\frac{\left(R_{eq}^2\cos\lambda\right)^2 + \left(R_{po}^2\sin\lambda\right)^2}{\left(R_{eq}\cos\lambda\right)^2 + \left(R_{po}\sin\lambda\right)^2}} \approx 21.3777\sin^2\lambda \; km$$

closer to the center of the Earth than the points at the equator; $R_{eq} \approx 6,378.137\ km$, $R_{po} \approx 6,356.7523\ km$ are correspondingly the equatorial and polar radii.

The phenomenon illustrated in Figures 3 and 5 is superficially similar to the jigsaw-puzzle-like fitting of the adjacent continental shelves in the theory of Continental Drift/Plate Tectonics going back to 1596, when Abraham Ortelius noticed that the shapes of continents on the opposite sides of the Atlantic Ocean, most notably Africa and South America, seem to fit together. The observation was discussed by numerous scientists for three Centuries until in 1912 Alfred Wegener put all their ideas together to what is now known as the theory of Continental Drift, [Wikipedia-Continental drift, 2017]. Continental Drift had not been completely accepted until 1950s when it was finally validated and expanded into Plate Tectonics. Continental Drift/Plate Tectonics is most likely cause of

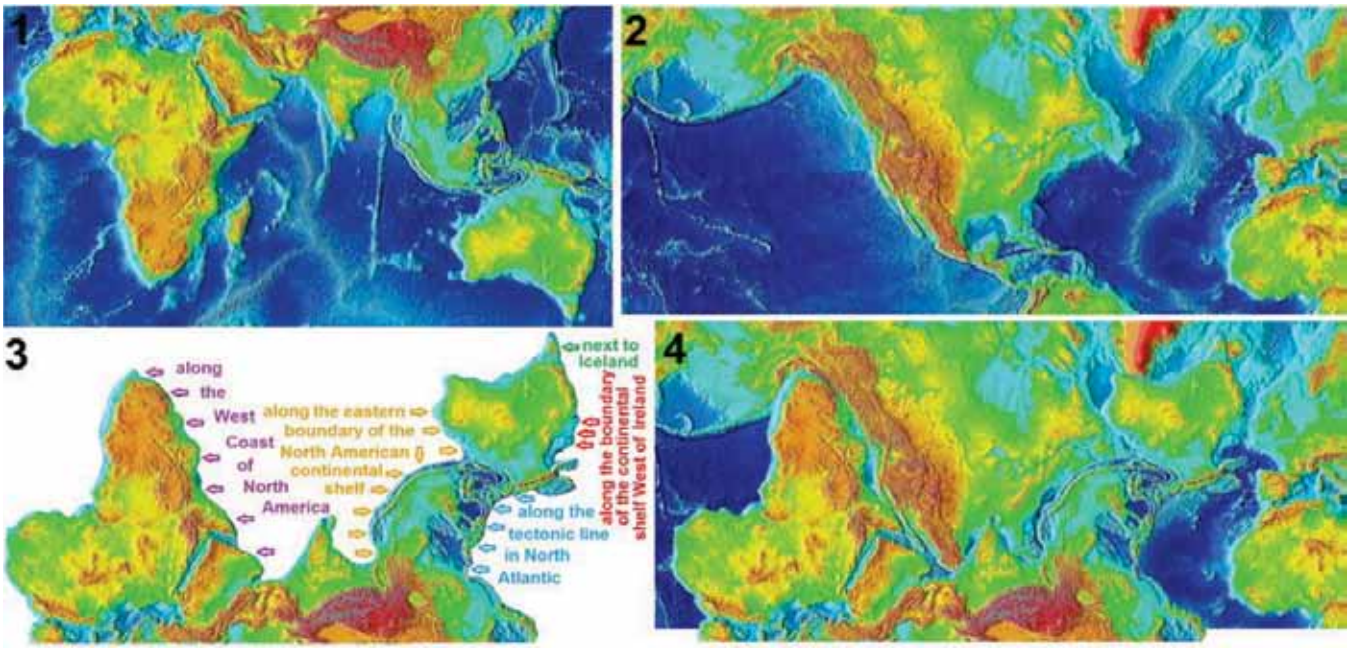

Figure 3. Frame 1 shows a map of the region containing Africa, southern Eurasia, the islands of South Pacific Asia, and Australia. Frame 2 shows a map of North America and the adjacent regions of the Pacific and Atlantic. Frame 3 shows the antipode of the continental shelves in frame 1. In frame 4 the image from frame 3 is superimposed on frame 2; the colored labels in frame 3 indicate which boundaries in frame 2 correspond to the boundaries of frame 3 indicated by the arrows of the same color. The images are in Mercator projection, (NOAA, 2017).

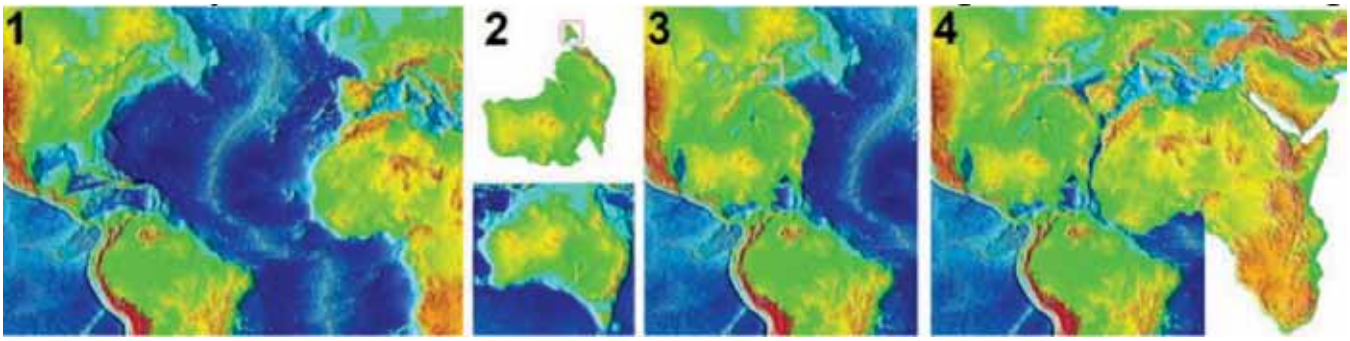

Figure 4. The antipodes of Australia and Tasmania fit between the east coast of North America and Central America on one side and Africa and the Iberian Peninsula on the other side.

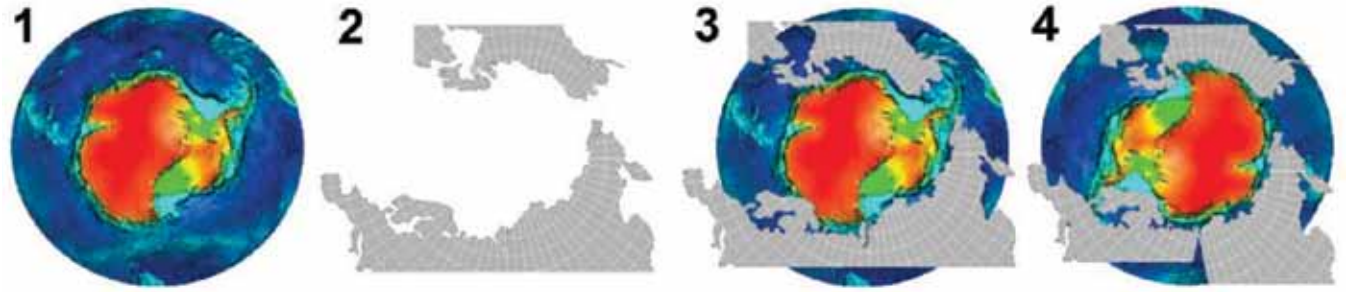

Figure 5. Frame 1 shows the antipode of Antarctica continental shelf (NOAA Maps, web link), frame 2 shows the contours of the Arctic continents. Frames 3, 4 show how the contours of the Arctic continents wrap around the antipode of the Antarctica continental shelf shown in frame 1 in two different ways.

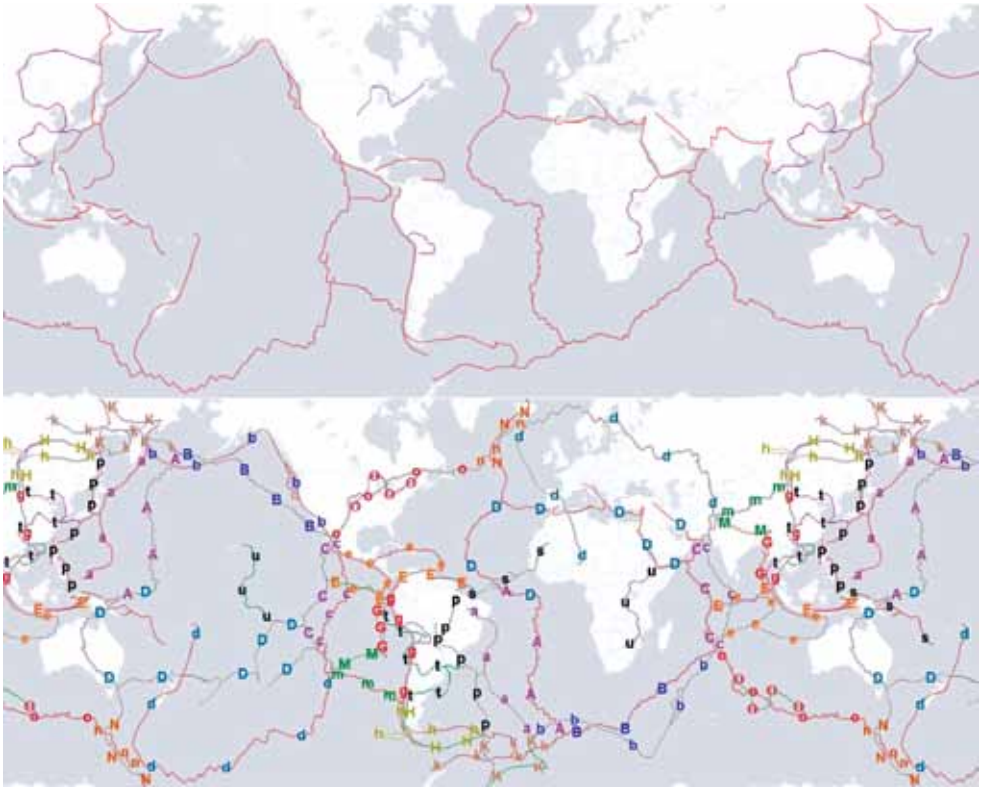

Figure 6. The top frame shows major tectonic lines in maroon according to (USGS: Earth quake Archives, 2017); and major rift lines in purple according to (Gaba web link, 2017). The bottom frame adds the antipodes of the major tectonic lines in dark grey, the antipodes of the long rift lines in green; and letter labels to show which line corresponds to which. A tectonic/rift line and its antipode are labeled by the same letter either small or capital; two tectonic/rift lines almost antipodal to each other are labeled by the same letter with one labeled by a small letter and the other one by the equivalent capital letter. Some tectonic/rift lines slightly overlap. Some almost antipodal pairs look remarkably alike: 'a' and 'A', 'b' and 'B', 'c' and 'C', 'd' and 'D', 'h' and 'H', 'n' and 'N'. Lines in pairs 'e' and 'E', 'g' and "G', 'k' and 'K', 'm' and 'M' are almost antipodal to each other. The 'o' line is considerably longer than its almost antipodal match the 'O' line running along the Saint Lawrence rift system, Midcontinent rift system and the eastern border of the North American Mountains. The 'p','t', 's', 'u' lines do not seem to have antipodes; the antipode of the 'u' line goes all the way to Hawaii. The antipode of the 'e' line by Australia fits between Australia and Indonesia.

why in Figures 3 and 5 the almost antipodal boundaries are removed from exactly antipodal positions.

Figures 3 and 5 involve all continents/continental shelves and their boundaries with the exception of South America and the eastern border of Eurasia from Japan to Kamchatka. There are several ways to match the antipode of the boundary of South America to the eastern border of Eurasia, yet none is as good or as natural as in Figures 3 and 5.

Almost antipodal symmetry of major tectonic and rift lines

The major tectonic and rift lines also exhibit almost antipodal symmetry, as demonstrated in Figure 6. What is truly remarkable is 1) the similarity of some lines, e.g. 'a' and 'A', 'b' and 'B', 'c' and 'C', 'd' and 'D', 'h' and 'H', 'n' and 'N'; 2) that the loops comprised of 'M', 'G', 'E', 'C' lines is almost antipodal to the loop comprised of 'm', 'g', 'e', 'c' lines; 3) how nicely the antipode of the 'e' line fits between Australia and Indonesia.

DISCUSSION

Although it has been known for quite a while that some earthquakes strike almost antipodally, and even a few theories have been suggested, the global aspects of the almost antipodal symmetry on the Earth's surface somehow have been overlooked despite being in full view for all to see. The observations discussed here point to the greater importance of the almost antipodal symmetry in the physical laws which shaped our planet in the past and continue re-shaping it now. There are a number of theories attempting to explain almost antipodal symmetry of some phenomena, e.g. antipodal volcanism, shock dynamics; but none can explain almost antipodal symmetry on the planetary scale. The only presently-known forces with almost antipodal symmetry are the tidal forces producing

tides at the opposite sides of the globe. Such forces are certainly present in the liquid core and viscous mantle where they also create tides; it is these tides which are responsible for the different aspects of the antipodal symmetry discussed in this article.

CONCLUSION

There are clear signatures of the almost antipodal symmetry in many geo-phenomena. Research needs to be continued to determine the causes of the almost antipodal symmetry. We hope our paper will encourage more research by specialists.

ACKNOWLEDGEMENTS

Even though some people may disagree with the presented facts, we would like to thank the anonymous reviewer and Chief Editor for agreeing to publish the material. We hope it will incite a healthy interaction on the subject and lead to better understanding of the role of the antipodal symmetry in the structure of the Earth and natural phenomena regularly occurring in different parts of the Earth.

Compliance with Ethical Standards:

The authors declare that they have no conflict of interest and adhere to copyright norms.

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