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Mechanical buckling of oceanic lithosphere and subduction zone morphology

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We present a new concept of the physical background of the global-scale distribution of plate subduction zones, especially around the Pacific ocean, using structural mechanics theory such as those presented by Huang (1964) etc.

According to the compilation by Watts (2001), the elastic layer thickness of oceanic lithosphere is approximately 25km for the 30Ma lithosphere, and is approximately 60km for the 130 - 140Ma.

Assuming the earth' s radius of 6.371 x 10^3 km, and the Poisson ratio of 1/3, etc., in the case of great-circle shape of the global subduction zones with the uniform slab age of 130-140Ma, the result of Huang (1964) suggests that the preferable wave number, parallel to the circumferential direction, of global spherical buckling becomes approximately 12. In other words, the classical result of Huang (1964) suggests the preferable spherical buckling wavelength of the great-circle subduction zone with the 130-140Ma slab is approximately 3.3×10^3km. For the spherical buckling of younger slab than 130-140Ma for the great-circle subduction zone, the preferable spherical buckling wavelength is smaller than approximately 3.3×10^3km.

Whereas, referring to a recent numerical simulation study on the spherical buckling by Mahadevan et al. (2010), we can suggest that the preferable spherical buckling wavelength of the great-circle subduction zone for the 130-140Ma and 30Ma slab are approximately 1.7×10^3km and 9×10^2km, respectively.

However, the above estimation might not be conclusive, because these models don't incorporate dynamic influence originated from the vertical slab extent (especially, whether stagnated at 660km depth, or not), and the ambient mantle flow regime, etc.

In addition, if a certain local portion along the subduction zone segment, during the bucking mode change of subducting lithosphere, has been mechanically fixed to the mantle frame, the forthcoming morphological transforming process of the trench - arc - back-arc system will be constrained by the non-moving site.

In general, the geometrical change of subduction zone due to the spherical shell deformation would provide the instantaneous and long-term responses on various fields of geodesy, geophysics, geology and mineral physics, etc.

We also suggest that the above dynamics is applicable on the other terrestrial planets with plate tectonics.

Keywords: subduction zone, oceanic lithosphere, buckling, spherical shell