Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Discussion

Comment on “The potential influence of subduction zone polarity on overriding plate deformation, trench migration and slab dip angle” by W.P. Schellart

Carlo Doglioni

Dipartimento di Scienze della Terra, Università La Sapienza, Roma, Italy

ARTICLE INFO

Article history:
Received 11 December 2007
Received in revised form 22 February 2008
Accepted 27 February 2008
Available online xxxx

Keywords:
Westward drift
Subduction hinge
Trench migration

ABSTRACT

The Schellart's [Schellart, W.P., 2007, The potential influence of subduction zone polarity on overriding plate deformation, trench migration and slab dip angle. Tectonophysics, 445, 363–372.] paper uses slab dip and upper plate extension for testing the westward drift. His analysis and discussion are misleading for the study of the net rotation of the lithosphere since the first 125 km of subduction zones are sensitive also to other parameters such upper plate thickness, geometry and obliquity of the subduction zone with respect to the convergence direction. The deeper (>125 km) part cannot easily be compared as well because E- or NE-directed subduction zones have seismic gaps between 270–630 km. Moreover the velocity of subduction hinge cannot be precisely estimated and it does not equal to backarc spreading due to accretionary prism growth and asthenospheric intrusion at the subduction hinge. It is shown here that hinge migration in the upper plate or lower plate reference frames supports a general global polarization of the lithosphere in agreement with the westward drift of the lithosphere. The W-directed subduction zones appear controlled by the slab–mantle interaction with slab retreat imposed by the eastward mantle flow. The opposite E-NE-directed subduction zones seem rather mainly controlled by the convergence rate, plus density, thickness and viscosity of the upper and lower plates. Finally, the geological and geophysical asymmetries recorded along subduction and rift zones as a function of their polarity with respect to the tectonic mainstream are not questioned in the Schellart's paper, but they rather represent the basic evidence for the westward drift of the lithosphere.

1. Introduction

Schellart (2007) presented an interpretative global analysis of the slab dip and the trench migration in order to test the westward drift of the lithosphere. His paper has the merit to raise the discussion on this fundamental topic of geodynamics, but it contains a number of misleading considerations. Schellart's criticism is based on three primary interpretations such as i) the subduction hinge migrates irrespective of a geographic polarity; ii) the backarc basins open no matter of the subduction direction, and iii) there is not a systematic rule in slab dip with respect to the subduction polarity.

Schellart compares the strike of the slab and its dip, finding no relevant asymmetries and no geographical polarity signature. He then affirms that his data confute the importance of the westward drift as a primary tuning factor for subduction asymmetries.

The interpretation of the westward drift has a long history since a number of authors during the years (Rittmann, 1942; Le Pichon, 1968; Bostrom, 1971; Nelson and Temple, 1972; Moore, 1973; Shaw, 1973; Scoppola et al., 2006) proposed a global or net westward drift of the lithosphere relative to the mantle. This net rotation is indicated by independent kinematic observations such as plate motion within the hotspot reference frame (e.,g., Ricard et al., 1991; Gripp and Gordon, 2002), plate motion relative to Antarctica (Le Pichon, 1968; Knopoff and Leeds, 1972) and geological asymmetries (Doglioni, 1993, 1994). Plate velocity (Heflin et al., 2007) and seismicity decrease toward polar areas, suggesting a rotational tuning on plate tectonics.

Schellart's criticism to the westward drift has biases that have to be pointed out: 1) the strike versus dip of the slab analysis is insensitive to the study of the asymmetry between W- versus E- or NE-directed subduction zones; 2) shallow versus deep seismicity comparison: shallow slab seismicity (<125 km) is controlled by a number of lithospheric scale factors and is meaningless for the slab–mantle relationship, since the so-called mantle wind should be present in the underlying asthenosphere; the deep seismicity (>125 km) along E- to NE-directed subduction zones has a seismic gap between 250–630 km depth and cannot be simply compared to the opposite W-directed deep slabs; 3) the rates of the trench or hinge migration along W-directed subduction zones cannot be measured with sufficient accuracy (Fig. 1); 4) backarc extension of W-directed subduction zones is different from the one observed in the upper plate of the opposite subduction systems; 5) contrary to Schellart evaluation, the westward drift of the lithosphere is not computed and inferred only

---

E-mail address: carlo.doglioni@uniroma1.it.
URL: http://tetide.geo.uniroma1.it/DST/doglioni.

0040-1951/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2008.02.012

Please cite this article as: Doglioni, C., Comment on “The potential influence of subduction zone polarity on overriding plate deformation, trench migration and slab dip angle" by W.P. Schellart, Tectonophysics (2008), doi:10.1016/j.tecto.2008.02.012

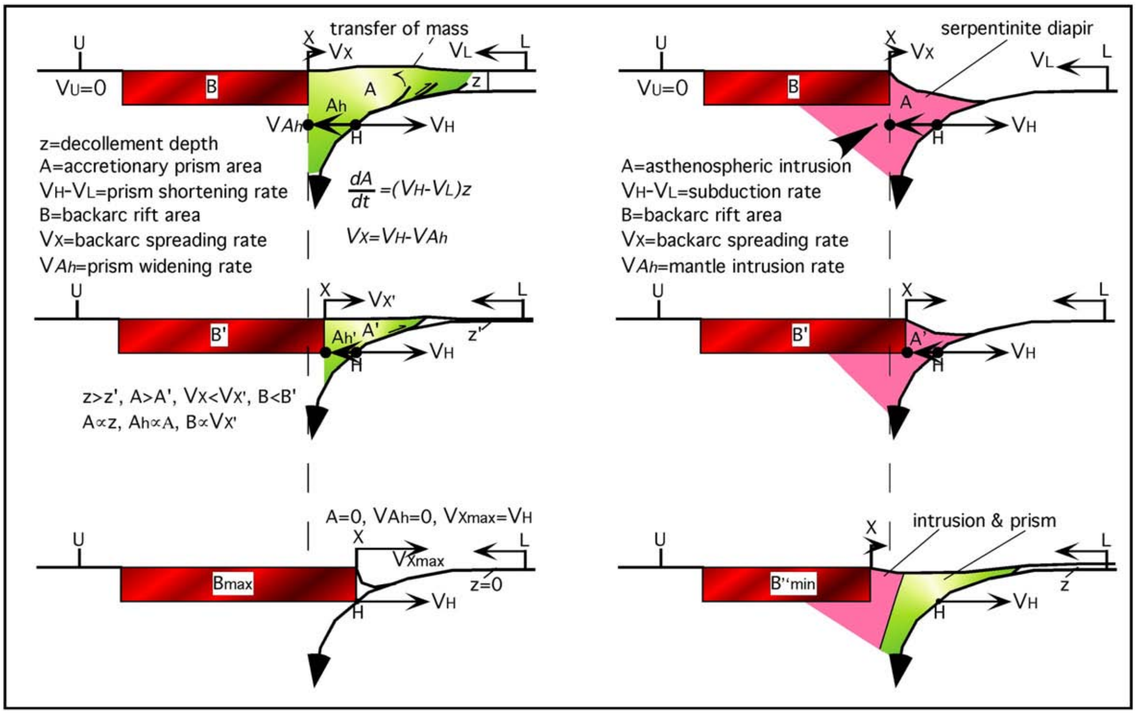

Fig. 1. In case the accretionary prism is entirely formed at the expenses of the lower plate as it occurs along W-directed subduction zones, the shortening is equal to the subduction rate ($V_S=V_H-V_L$). With given convergence (V_L) and subduction hinge (V_H) migration rates, three different cases are illustrated to the left. The deepest position of the decollement plane depth (z) of the accretionary prism determines a larger transfer of mass per unit time from the lower to the upper plate (left upper panel). This decreases the width of the backarc rift and its velocity of spreading (V_X). As a consequence, the reference point X migrates toward the foreland slower as the decollement depth and the accretionary prism width (Ah) increase. U, fixed upper plate. In the rare case of no accretion at the prism front (i.e., $z=0$ and the lower plate is entirely subducted, left lower panel), the backarc spreading should equal the velocity of the hinge ($V_X=V_H$). The left middle panel is an intermediate case. The three models to the right show the cases in which a serpentinized asthenospheric diapir wedges at the subduction hinge, or mixed with the accretion, inhibiting the opening of the backarc. Therefore, the reference point X might not be a reliable kinematic indicator of the subduction hinge migration rate when accretion and asthenospheric wedging occur, besides all the other problems discussed in the text. Therefore we might not have a reliable velocity of the subduction hinge from the backarc opening and the interpretation that W-directed slabs and their hinges may move relative to the mantle remains unconstrained.

on the basis of the asymmetry of slab dip, but it is detected by an endless list of independent kinematic, structural, morphologic, geophysical and lithologic parameters.

2. Strike versus dip of the slab

The strike or direction of any slab can be between 90° and 0° with respect to the convergence direction, i.e., as for thrust planes, from a frontal ramp (90°), to oblique ramp (e.g., 45°), to lateral ramp (0°). Following the example of structural styles where thrust planes become progressively steeper moving from the frontal, to oblique and to the lateral ramp, it can be shown that the subduction dip increases as the angle between subduction strike and convergence direction decreases. Oblique or lateral subduction zones such as the Cocos plate underneath Central America are, by geometrical constraint, steeper (>50°–70°) than frontal subduction zones (e.g., Chile <30°), like the oblique or lateral ramp of a thrust at shallow levels in an accretionary prism is steeper than the frontal ramp. Most of the world subduction zones show arcuate geometry and therefore the slabs present all possible angles with respect to the main subduction direction.

Schellart's analysis finds a dispersion of data, which is entirely expected in terms of first order signatures of subduction direction with respect to the geographic polarity. The “westward” drift of the lithosphere is a term that may generate confusion because it has not a pole of rotation coincident with the Earth's axis. It has been computed with a pole of rotation at about 55.9°S and 69.9°E (ω 0.4359°/M yr) in the deep hotspot reference frame (Gripp and Gordon, 2002), and 60.2°S and 83.7°E (ω 1.4901°/M yr) in the shallow hotspot reference frame (Crespi et al., 2007; Cuffaro and Doglioni, 2007). Therefore the subduction dip variation with respect to the westward drift of the lithosphere cannot simply be analyzed comparing east versus west subduction zones. The subduction characters (slab dip, seismicity, topography and prism signatures) have to be studied along the undulated pattern of the tectonic mainstream with the poles of rotation located in the southeast Indian Ocean. This mainstream of plate motions contains most of the possible azimuths from 0 to 360° as a function of the longitude. Moreover the aforementioned oblique and lateral subduction zones may have a further scattering in dip directions between 0 and 360°. W-directed slabs frequently have arcuate shape (Apennines, Carpathians, Banda, Marianas, Aleutians, Kurili) whereas the opposite slabs have more linear trends which direction follows the plate margin (Andes, Cordillera, Alps, Zagros, Himalayas). Therefore along an arcuate W-directed subduction zone the slab can strike from 90°E, 45°W, 0°, 45°E, to 90°W, any azimuth. The E-NE-directed subduction-related orogens have longer wavelengths but they also show arcuate geometries with a complete scatter azimuthal distribution. That is why it is better to discuss about subduction direction rather than subduction dip. Therefore the Schellart's analysis is meaningless for discriminating the slab dip versus the net rotation of the lithosphere, similarly to what was already presented by Lallemand et al. (2005).

3. Shallow versus deep seismicity comparison

Schellart argues that the slab dip is not significantly influenced by the polarity of the subduction. However his analysis is different from what was suggested in a number of alternative articles where the slab dip is measured not simply comparing E- versus W-directed subduction zones, but is measured along the undulated flow of absolute plate motions (e.g., Doglioni et al., 1999a,b, and references therein), and the definition of W- versus E- or NE-directed is rather related to

Please cite this article as: Doglioni, C., Comment on “The potential influence of subduction zone polarity on overriding plate deformation, trench migration and slab dip angle" by W.P. Schellart, Tectonophysics (2008), doi:10.1016/j.tecto.2008.02.012

subductions following or contrasting this flow. Moreover, in his analysis he subdivides the slab into a shallow (<125 km) and a deeper part (>125 km) as Lallemand et al. (2005). This subdivision is ambiguous and useless for a number of reasons. The E- or NE-directed subduction zones have mostly continental lithosphere in the upper plate and the dip of the first 125 km is mostly constrained by the thickness and shape of the upper continental plate when present, and by the angle of the slab with respect to the convergence direction as previously mentioned. The westward drift of the lithosphere implies a relative "eastward" mantle flow, which decoupling is in the asthenosphere that starts generally deeper than 100 km. Therefore the shallow part of the slab may not show such a pronounced difference dip for the various parameters affecting the slab geometry down to the base of the lithosphere. However, in the upper part of the lithosphere, we can detect a pronounced asymmetry of the foreland regional monocline (i.e., the upper part of the subduction hinge marking the onset of the subduction zone), which is in average few degrees steeper along W-directed subduction zones (Lenci and Doglioni, 2007).

Cruciani et al. (2005) carefully measured the slab dip and they demonstrated no correlation between slab age and dip of the slab. The analysis was stopped to about 250 km depth because E- or NE-directed subduction zones do not have systematic seismicity at deeper depth, apart few areas where seismicity appears concentrated between 630 and 670 km depth, close to the lower boundary of the upper mantle. The origin of these deep isolated earthquakes remains obscure (e.g., mineral phase change, blob of detached slab or higher shear stress) and therefore they could not represent the simple geometric prolongation of the shallow part of the slab. Therefore, at deep levels (>250 km) the dip of the slab based on seismicity cannot be compared between W- and E-NE-directed subduction zones, simply because most of the E- or NE-directed slabs do not show continuous seismicity deeper than 250 km. Therefore any statistical analysis on the slab dip based on seismicity cannot be done simply comparing W- and E-directed slabs because E- or NE-directed subduction zones do not have comparably deep seismicity. High velocity bodies suggesting the presence of slabs in tomographic images often do not match slab seismicity. Moreover the inference of slabs deeper than 250 km based on tomographic images is velocity model dependent and the color palette can be significantly misleading (e.g., Trampert et al., 2004; Anderson, 2006, 2007a,b). Whatever the cause is, Isacks and Barazangi (1977) described how western Pacific slabs are generally steeper than the eastern ones for most of their strike.

When comparing slabs dip between 100 and 250 km depth, and removing the oblique subduction zones as Central America, the W-directed subduction zones have far dominant steeper angles (Cruciani et al., 2005).

Lallemand et al. (2005) note that steeper slabs occur where the upper plate is oceanic, while shallower slabs occur where the upper plate is continental. However, the majority of E- or NE-directed subduction zones worldwide have continental lithosphere in the upper plate, confirming the asymmetry. Moreover subduction zones juxtapose plates of different thickness and composition generating variation in the dip. The variability of the angle of obliquity of the subduction strike with respect to the convergence direction determines a further change in the dip of the slab. Removing these issues, the W-directed subduction zones when compared to E- or NE-directed slabs still maintain a number of differences, such as they are steeper, they are deeper or at least they present a more coherent slab-related seismicity from the surface down to the 670 discontinuity, and they show opposite down-dip compression seismicity (Isacks and Molnar, 1971).

4. Subduction hinge migration

Schellart's analysis is based on trench perpendicular migration. However, along an oblique trench with respect to the subduction direction, due to stress deviation relative to the convergence direction and strain partitioning, the hinge moves obliquely, not exactly perpendicular to the trench. Lallemand et al. (2005) and Heuret and Lallemand (2005) have already studied the trench or hinge motion in a mantle reference frame, pointing for a general westward shift of all subduction hinges. Schellart (2007) again discusses the trench motion in a number of different reference frames and finds again the mobility of subduction hinges relative to the mantle. However, the velocity of the subduction hinges cannot be measured precisely, as shown in Doglioni et al. (2007), Fig. 8. The motion of the subduction hinge is for example computed assuming that it equals the amount of backarc spreading (e.g., Heuret and Lallemand, 2005). The rate can be mediated using past backarc basin magnetic anomalies or present GPS data. However, the opening of the backarc basin could have the same speed as the subduction hinge only if there was no accretion in the prism and no asthenospheric intrusion at the subduction hinge, both more or less ubiquitous processes along subduction zones. They decrease the velocity of the backarc opening with respect to the hinge migration, and partly prevent the opening of the basin. Keeping in mind this obstacle in the computation, at the moment it is practically impossible to have a realistic velocity of the subduction hinge, but we can only have a minimum velocity of it. In other words, when applying this simple concept, the velocity of the hinge along the W-directed subduction zones could be much faster, that means retreating faster to the east with respect to the upper plate, and decreasing or stopping its velocity relative to the mantle.

The subduction hinge behavior can be analyzed in three reference frames, e.g., relative to the mantle, relative to the upper plate and relative to the lower plate. In the mantle reference frame, the subduction hinge should be fixed along W-directed subduction zones and moving W- or SW-ward along the opposite subduction zones. However, due to the present limitation for constraining the hinge fixity or mobility along W-directed subduction zones, we may have further information in the other two reference frames. In the upper plate reference frame, the subduction hinges, regardless of the exact speed, we do have good constraints for most of the world subduction zones in terms of direction and versus of the hinge motion. This analysis provides an important indication supporting a global polarization because, regardless of the subduction polarity, the subduction hinges move E-ward or NE-ward directed, apart central-north Japan, where the subduction system is reverting and the backarc basin shrinking. Moreover, the general observed rule is that the hinge moves away from the upper plate along W-directed subduction zones, whereas it regularly moves toward the upper plate along the opposite E- or NE-directed subduction zones, even if there is some upper plate "backarc" extension. Assuming fixed the upper plate U (Fig. 2a,b), the subduction rate V_S is given by the velocity of the hinge H minus the velocity of the lower plate L ($V_S = V_H - V_L$). The subduction rate 1) increases the convergence rate when H diverges, and 2) decreases the convergence rate when H converges. It turns out that the subduction rate is faster or slower with respect to the convergence rate as a function of the subduction polarity, being much faster for W-directed slabs. See Doglioni et al. (2007) for a more detailed description of all subduction zones.

We can also study the behavior of the subduction hinge relative to the fixed lower plate (Fig. 2c,d). This is another very interesting case because the velocity of the subduction is given by $V_S = -V_H$. Therefore the velocity of the hinge is the same as the subduction rate. The hinge always moves toward the lower plate L, but it may move toward the lower plate faster or slower than the upper plate. The first case is typical of W-directed subduction zones, whereas the second case is the rule for the opposite subduction zones. What is relevant from this simple kinematic analysis is i) the occurrence of a steady rule of hinge behavior supporting a global tuning, and ii) it contains a dynamic information. In fact, in the setting where the subduction hinge migrates faster than the upper plate toward the lower plate, the subduction is controlled only by the slab–mantle relationship (W-directed subduction zones); in case the subduction hinge migrates slower than the upper plate toward the lower plate (E- or NE-directed subduction zones), the subduction is

Please cite this article as: Doglioni, C., Comment on "The potential influence of subduction zone polarity on overriding plate deformation, trench migration and slab dip angle" by W.P. Schellart, Tectonophysics (2008), doi:10.1016/j.tecto.2008.02.012

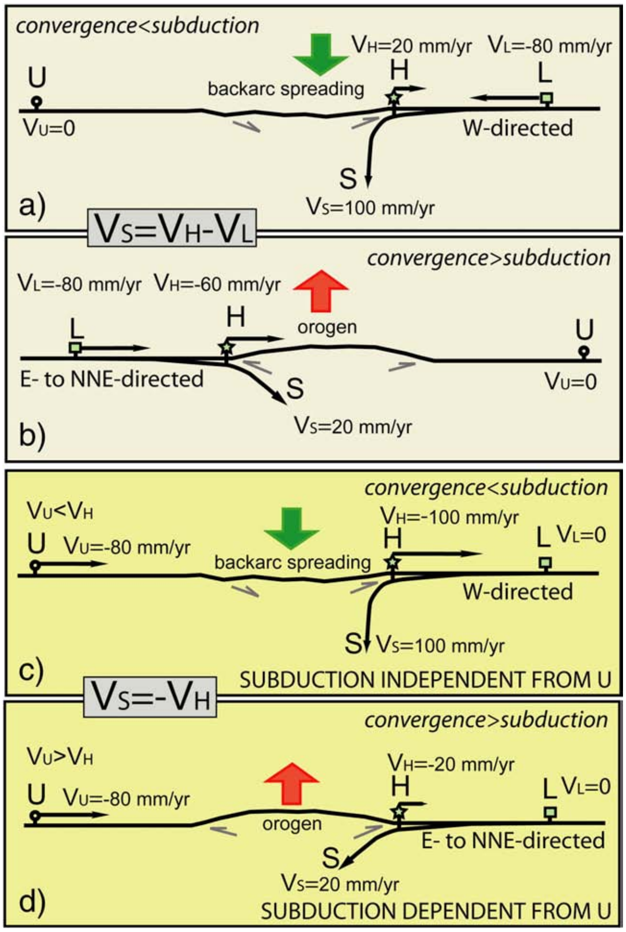

Fig. 2. Upper panels a) and b): basic kinematics of subduction zones, assuming fixed the upper plate U, a converging lower plate L, and a transient subduction hinge, H. The subduction rate S is given by $V_S = V_H - V_L$. Values are only as an example. S increases when H diverges relative to the upper plate (a), whereas S decreases if H converges (b). The movements diverging from the upper plate are positive, whereas they are negative when converging. The case a) is accompanied by backarc spreading, a low prism and is typical of W-directed subduction zones, whereas in case b) double verging and elevated orogens form and is more frequent along E- to NNE-directed subduction zones. Note that in both W- and E-NE-directed subduction zones, the hinge migrates eastward relative to the upper plate, suggesting a global tuning in subduction processes. Lower panels c) and d): kinematics of subduction zones assuming fixed the lower plate. Note that the velocity of the hinge equals the velocity of the subduction in both cases, $V_S = -V_H$. In case c) the subduction is independent from the upper plate velocity, whereas in case d) is a function of it. These opposite kinematic settings indicate different dynamic origin of the subduction, i.e., slab/mantle interaction for c), and upper/lower plates interaction for case d), a reasoning that contains the asymmetry of subduction zones.

generated only by the upper plate–lower plate relationship. This information contains a genetic and geographic asymmetry in the origin of subduction zones, regardless of the mantle (hotspot) reference frame. The E-NE-directed subduction zones are rather mainly controlled by the upper–lower plate convergence rate, plus density, thickness and viscosity of the upper and lower plates.

This basic kinematic analysis showing how the subduction rate is dependent on the far field velocity of plates and the velocity of the hinge supports the information that subduction zones are passive features and not driving plate tectonics.

5. Backarc extension

Schellart states that backarc extension is confined along W-directed subduction zones in the westward drift model. This is not true (e.g., Doglioni, 1995; Doglioni et al., 2002). The backarc extension in the Schellart's study is assumed as monogenetic. However there are profound differences between backarc spreading associated to W-directed or to E- NE-directed subduction zones (e.g., Doglioni, 1995). The first type occurs when the retreat of the lithosphere leaves an empty volume, which is replaced by the asthenosphere. This type of backarc is pervasively distributed throughout the whole upper plate, and is fast (usually >0.6 km/Ma subsidence rate, >10 km/Ma spreading rate, oceanization in few million years), eventually arriving to oceanization. It may develop with and without converge between the upper and the lower plates, and it can simply be explained as related to the slab retreat relative to the upper plate, regardless of the retreat due to slab pull or the eastward mantle flow implicit in the westward drift of the lithosphere.

The upper plate extension along the opposite E- or NE-directed subduction zones has a very different origin and cannot be compared and associated to the W-directed settings. First observation is that the extension is not widespread all over the upper plate, but confined in areas close to transfer zones. The Andaman rift formed in the area accommodating the faster SW-ward advancement of the Indonesia arc (around 60–64 mm/yr) over the Australian–Indian plates with respect to the slower (34–38 mm/yr) convergence between Eurasia and India along the Himalayas collision zone. Unlike the W-directed subduction zones backarc, it means that at least three plates (two in the hangingwall and at least one in the footwall) characterize this type of “backarc” rift. Rifting is not occurring in most of the upper plate along the Indonesia arc, such as in Flores basin. Similar settings have been proposed for the Aegean extension, where the Greece lithosphere is overriding the Africa plate faster than the Cyprus arc: the differential hangingwall velocity generates the rifting, which is not due to the loss of the subducted lithosphere (Doglioni et al., 2002; Innocenti et al., 2005). In the Aegean rift, in spite of a >40 Ma rift, the upper plate is still >20 km thick continental crust.

Therefore, backarc spreading, forms in two settings: 1) along the W-directed subduction zones where the basin opens where the asthenosphere replaces the retreated lithosphere, and 2) along the E-NE-directed subduction in which the upper lithosphere is split into two sub-plates that have a differential advancement velocity relative to the lower plate. Along the W-directed subduction zones, the hinge diverges relative to the upper plate, and the backarc spreading is given by the rate of hinge retreat, minus the volume of the accretionary prism, or, in case of scarce or no accretion, minus the volume of the asthenospheric intrusion at the subduction hinge. Since the volume of the accretionary prism is proportional to the depth of the decollement plane, the backarc rifting is inversely proportional to the depth of the decollement. Along E- or NE-directed subduction zones, few backarc basins form (e.g., Aegean, Andaman) and they can be explained by the velocity gradient within the hangingwall lithosphere, separated into two plates. The assumption that when backarc opens, the subduction hinge moves away from the upper plate is valid only for W-directed subduction zones. In fact, in the aforementioned examples of backarc spreading along E- or NE-directed subductions, the hinge converges relative to the upper plate.

6. Westward drift of the lithosphere

The presence of the net rotation of the lithosphere is detected in independent kinematic data sets (Antarctica fixed, Le Pichon, 1968; Knopoff and Leeds, 1972; deep or shallow Hotspot Reference Frames Crespi et al., 2007; Cuffaro and Doglioni, 2007) and it has no fundamental relation with respect to the slab dip. The “westward” drift is unavoidable if we accept that the Hawaii chain represents a kinematic indicator of i) decoupling between lithosphere and underlying mantle, which ii) is tuning westward the lithosphere because of the weight of the Pacific plate in the global plate motion kinematics (e.g., Ricard et al., 1991; Gripp and Gordon, 2002; Crespi et al., 2007). The “westward” drift is coherent with the dynamics of the Earth's despinning (1.7 ms/century) of 10^26 erg/year (Denis et al., 2002).

Please cite this article as: Doglioni, C., Comment on “The potential influence of subduction zone polarity on overriding plate deformation, trench migration and slab dip angle" by W.P. Schellart, Tectonophysics (2008), doi:10.1016/j.tecto.2008.02.012

Fig. 1 of Schellart's paper in which the “westward” drift model is presented for testing the process, actually it mostly corresponds (apart from a couple of wrong arrows, such as the oceanic plate dipping to the east, which is actually moving westward as shown in Doglioni et al., 2007) to the real observed velocities of plate boundaries relative to the mantle such as the westward migration of ridges (e.g., Le Pichon, 1968) and subduction zones (e.g., Garfunkel et al., 1986; Heuret and Lallemand, 2005). In other words, regardless of the dip of the slabs, the kinematic evidence is consistent with a global westward polarity of the lithosphere decoupling.

However, regardless of the dip of the slab there are a number of surface observables, which cannot be simply ignored, which are supporting a geographic polarization of the global tectonics. These are:

- The dip of the regional monocline that is in average about 6.1° for W-directed and 2.6° for E-NE-directed slabs respectively (Mariotti and Doglioni, 2000; Lenci and Doglioni, 2007).
- The subsidence rates in the foredeep and trenches of W-directed slabs are >1 mm/yr, whereas the opposite slabs have foredeep subsidence rates <0.3 mm/yr (Doglioni, 1994).
- The average topography above W-directed slabs is −1250 m, and gravimentric and heat flow values show high anomalies, whereas average topography is 1200 m, and gravimetric and heat flow values show smoother anomalies for the prisms and orogens associated to the opposite slabs (Harabaglia and Doglioni, 1998). The striking difference in topography comparing western and eastern Pacific subduction zones in spite of similar convergence rates is persistent all over the other world subduction zones. Good examples are the difference between Alps and Apennines (Carminati et al., 2004), or event more clear the decrease in elevation when moving northward from New Zealand (NE-directed subduction) to Tonga-Kermadec (W-directed subduction) (Harabaglia and Doglioni, 1998). There is not a W-directed slab with a highly elevated topography. In New Zealand there is an alpine double vergent orogen, whereas moving northward to the W-directed Pacific subduction, the system shifts to a single vergent accretionary prism and a well developed backarc basin above a steep and deep slab.
- The accretionary prisms associated with W-directed slabs are mainly composed of sedimentary cover rocks scraped off the top of the downgoing lithosphere, whereas the opposite orogens are affecting all types of crustal rocks (Garzanti et al., 2007), being the asymmetry controlled by shallow (upper crustal) versus deep (upper mantle) decollements zones respectively (Doglioni et al., 2007).
- Metamorphic *PTt* paths of the two opposite subduction zones show very different signatures. For example UHP rocks are found only along orogens associated to E- NE-directed collision zones.
- Uplift rates are about 1 mm/yr and transient moving toward the foreland to the “east” above W-directed slabs, whereas they may be faster and widening the orogen both vertically and horizontally in the opposite settings.
- Subduction related magmatism (Syracuse and Abers, 2006) comes from deeper sources along W-directed slabs than the opposite settings.
- The life span of W-directed subduction zones is generally shorter (30–40 Ma), then they revert their polarity; the opposite slabs may remain in a steady-state regime for hundreds of Ma (Doglioni et al., 1999a).
- Oceanic ridges have generally a 100–300 m shallower bathymetry in their eastern flank that can be explained as either related to dynamic topography and/or to the eastward transit of depleted mantle after the partial melting at the rift (Doglioni et al., 2003).
- Intraslab seismicity tends to be down-dip compression within W-directed slabs, whereas it is frequent in the down-dip extension in the opposite slabs.
- W-directed subduction zones rather provide about 2–3 times larger volumes of lithosphere re-entering into the mantle, and the slab is pushed down. This opposite behavior is consistent with the down-dip extension seismicity along E-NE-directed subduction zones, and the frequent down-dip compression along the W-directed subduction zones.
- The subduction rate along W-directed slabs is generally controlled by the slab–mantle relation, whereas the rate along the E-NE-directed subduction zones is rather controlled only by the upper–lower plates' convergence rate (Doglioni and Carminati, 2008).

All these asymmetries and signatures can be checked all over the world moving along the mainstream of plate motions (Doglioni, 1993; Crespi et al., 2007) and independently support the westward drift of the lithosphere much more than the poorly constrained dip of the deep slabs.

Moreover, surprisingly, along E- or NE-directed subduction zones, the slab moves “out” of the mantle, i.e., the slab slips relative to the mantle opposite to the subduction direction (Doglioni et al., 2007). Kinematically, this subduction occurs because the upper plate overrides the lower plate, pushing it down into the mantle. As an example, the Hellenic slab moves out relative to the mantle, i.e., SW-ward, opposite to its subduction direction, both in the deep and shallow hotspot reference frames (Cuffaro and Doglioni, 2007). In the shallow hotspot reference frame, upper and lower plates move “westward” relative to the mantle along all subduction zones.

This kinematic observation casts serious doubts on the slab negative buoyancy as the primary driving mechanism of subduction and plate motions (Doglioni et al., 2006a,b).

Along the W-directed subduction zones, the rate of subduction seems rather controlled i) by the hinge migration due to the slab interaction with the “easterly” trending horizontal mantle wind along the global tectonic mainstream, ii) by the far field plate velocities, and, iii) by the value of negative buoyancy of the slab relative to the country mantle.

Alternatively, E-NE-NNE-directed subduction zones have rates of sinking possibly chiefly determined i) by the far field velocity of plates, and ii) by the value of negative buoyancy of the slab relative to the country mantle.

All this indicates that subduction zones have different origin as a function of their geographic polarity, and the subduction process is more a passive feature rather than being the driving mechanism of plate motions (Doglioni et al., 2007). Subduction kinematics shows that plate velocity is not dictated by the rate of subduction. Therefore the Schellart's discussion is interesting and useful, but it does not neither disprove the westward drift of the lithosphere, nor provides a clue in understanding the driving mechanism of plate tectonics.

References

Anderson, D.L., 2006. Speculations on the nature and cause of mantle heterogeneity. Tectonophysics 416, 7–22.

Anderson, D.L., 2007a. New theory of the Earth. Cambridge University Press. ISBN 978-0-521-84959-3, 0-521-84959-4.

Anderson, D.L., 2007b. Is there convincing tomographic evidence for whole mantle convection? http://www.mantleplumes.org/TomographyProblems.html 2007.

Bostrom, R.C., 1971. Westward displacement of the lithosphere. Nature 234, 356–538.

Carminati, E., Doglioni, C., Scrocca, D., 2004. Alps vs Apennines. Special Volume of the Italian Geological Society for the IGC 32 Florence—2004, pp. 141–151.

Crespi, M., Cuffaro, M., Doglioni, C., Giannone, F., Riguzzi, F., 2007. Space geodesy validation of the global lithospheric flow. Geophys. J. Int. doi:10.1111/j.1365-246X.2006.03226.x.

Cruciani, C., Carminati, E., Doglioni, C., 2005. Slab dip vs. lithosphere age: no direct function. Earth Planet. Sci. Lett. 238, 298–310.

Cuffaro, M., Doglioni, C., 2007. Global kinematics in the deep vs shallow hotspot reference frames. In: Foulger, G., Jurdy, D. (Eds.), The Origins of Melting Anomalies: Plates, Plumes, and Planetary Processes, vol. 430, pp. 359–374.

Denis, C., Schreider, A.A., Varga, P., Zavoti, J., 2002. Despinning of the Earth rotation in the geological past and geomagnetic paleointensities. J. Geodyn. 34, 667–685.

Doglioni, C., 1993. Geological evidence for a global tectonic polarity. J. Geol. Soc. (Lond.) 150, 991–1002.

Doglioni, C., 1994. Foredeeps versus subduction zones. Geology 22 (3), 271–274.

Doglioni, C., 1995. Geological remarks on the relationships between extension and convergent geodynamic settings. Tectonophysics 252 (1–4), 253–267.

Doglioni, C., Carminati, E., 2008. Structural styles and Dolomites field trip. Mem. Descr. Carta Geol. It. 1–268.

Please cite this article as: Doglioni, C., Comment on “The potential influence of subduction zone polarity on overriding plate deformation, trench migration and slab dip angle" by W.P. Schellart, Tectonophysics (2008), doi:10.1016/j.tecto.2008.02.012

Doglioni, C., Harabaglia, P., Merlini, S., Mongelli, F., Peccerillo, A., Piromallo, C., 1999a. Orogens and slabs vs their direction of subduction. Earth Sci. Rev. 45, 167–208.

Doglioni, C., Gueguen, E., Harabaglia, P., Mongelli, F., 1999b. On the origin of W-directed subduction zones and applications to the western Mediterranean. Geol. Soc. London Sp. Publ. 156, 541–561.

Doglioni, C., Agostini, S., Crespi, M., Innocenti, F., Manetti, P., Riguzzi, F., Savascin, Y., 2002. On the extension in western Anatolia and the Aegean sea. J. Virt. Explor. 7, 117–131.

Doglioni, C., Carminati, E., Bonatti, E., 2003. Rift asymmetry and continental uplift. Tectonics 22 (3), 1024. doi:10.1029/2002TC001459.

Doglioni, C., Cuffaro, M., Carminati, E., 2006a. What moves plates? Boll. Geofis. Teor. Appl. 47 (3), 227–247.

Doglioni, C., Carminati, E., Cuffaro, M., 2006b. Simple kinematics of subduction zones. Int. Geol. Rev. 48 (6), 479–493.

Doglioni, C., Carminati, E., Cuffaro, M., Scrocca, D., 2007. Subduction kinematics and dynamic constraints. Earth Sci. Rev. 83, 125–175. doi:10.1016/j.earscirev.2007.04.001.

Garfunkel, Z., Anderson, C.A., Schubert, G., 1986. Mantle circulation and the lateral migration of subducted slabs. J. Geophys. Res. 91, 7205–7223.

Garzanti, E., Doglioni, C., Vezzoli, G., Andò, S., 2007. Orogenic belts and Orogenic sediment Provenances. J. Geol. 115, 315–334.

Gripp, A.E., Gordon, R.G., 2002. Young tracks of hotspots and current plate velocities. Geophys. J. Int. 150, 321–361.

Harabaglia, P., Doglioni, C., 1998. Topography and gravity across subduction zones. Geophys. Res. Lett. 25 (5), 703–706.

Heflin, M. et al., 2007. http://sideshow.jpl.nasa.gov/mbh/series.html.

Heuret, A., Lallemand, S., 2005. Plate motions, slab dynamics and back-arc deformation. Phys. Earth Planet. Inter. 149, 31–51.

Innocenti, F., Agostini, S., Di Vincenzo, G., Doglioni, C., Manetti, P., Savascin, Y., Tonarini, S., 2005. Neogene and Quaternary volcanism in Western Anatolia: magma sources and geodynamic evolution. Mar. Geol. 221, 397—421.

Isacks, B.L., Barazangi, M., 1977. Geometry of Benioff zones: lateral segmentation and downward bending of the subducted lithosphere. In: Talwani, M., Pitman III, W.M. (Eds.), Island arcs, Deep sea trenches and back-arc basins. Maurice Ewing Series, vol. 1. AGU, pp. 99–114.

Isacks, B., Molnar, P., 1971. Distribution of stresses in the descending lithosphere from a global survey of focal-mechanism solutions of mantle earthquakes. Rev. Geophys. 9, 103–174.

Knopoff, L., Leeds, A., 1972. Lithospheric momenta and the deceleration of the Earth. Nature 237 (12), 93–95.

Lallemand, S., Heuret, A., Boutelier, D., 2005. On the relationships between slab dip, back-arc stress, upper plate absolute motion and crustal nature in subduction zones. Geochem. Geophys. Geosyst. 6, Q09006. doi:10.1029/2005GC000917.

Le Pichon, X., 1968. Sea-floor spreading and continental drift. J. Geophys. Res. 73 (12), 3661–3697.

Lenci, F., Doglioni, C., 2007. On some geometric prism asymmetries. In: Lacombe, O., Lavé, J., Roure, F., Verges, J. (Eds.), Thrust belts and Foreland Basins: From Fold Kinematics to Hydrocarbon Systems, Frontiers in Earth Sciences. Springer, pp. 41–60.

Mariotti, G., Doglioni, C., 2000. The dip of the foreland monocline in the Alps and Apennines. Earth Planet. Sci. Lett. 181, 191–202.

Moore, G.W., 1973. Westward tidal lag as the driving force of plate tectonics. Geology 1, 99–100.

Nelson, T.H., Temple, P.G., 1972. Mainstream mantle convection: a geologic analysis of plate motion. Am. Assoc. Pet. Geol. Bull. 56, 226–246.

Ricard, Y., Doglioni, C., Sabadini, R., 1991. Differential rotation between lithosphere and mantle: a consequence of lateral viscosity variations. J. Geophys. Res. 96, 8407–8415.

Rittmann, A., 1942. Zur Thermodynamik der Orogenese. Geol. Rundsch. 33, 485–498.

Schellart, W.P., 2007. The potential influence of subduction zone polarity on overriding plate deformation, trench migration and slab dip angle. Tectonophysics 445, 363–372.

Scoppola, B., Boccaletti, D., Bevis, M., Carminati, E., Doglioni, C., 2006. The westward drift of the lithosphere: a rotational drag? Geol. Soc. Amer. Bull. 118 (1/2). doi:10.1130/B25734.1.

Shaw, H.R., 1973. Mantle convection and volcanic periodicity in the Pacific: evidence from Hawaii. Geol. Soc. Amer. Bull. 84, 1505–1526.

Syracuse, E.M., Abers, G.A., 2006. Global compilation of variations in slab depth beneath arc volcanoes and implications. Geochem. Geophys. Geosyst. 7, Q05017. doi:10.1029/2005GC001045.

Trampert, J., Deschamps, F., Resovsky, J., Yuen, D., 2004. Probabilistic tomography maps chemical heterogeneities throughout the lower mantle. Science 306, 853–856.

Please cite this article as: Doglioni, C., Comment on "The potential influence of subduction zone polarity on overriding plate deformation, trench migration and slab dip angle" by W.P. Schellart, Tectonophysics (2008), doi:10.1016/j.tecto.2008.02.012