SUPPLEMENTARY MATERIAL

OVERRIDING PLATE SHORTENING AND EXTENSION ABOVE SUBDUCTION ZONES: A PARAMETRIC STUDY TO EXPLAIN FORMATION OF THE ANDES MOUNTAINS

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Geological Society of America Bulletin (2008)

METHODS

1. CHOICE OF SUBDUCTION ZONES

A total of 24 mature subduction zones were investigated (see Table S1 for the complete list). All subduction zones incorporated in the study show Wadati-Benioff zone seismicity down to a depth that exceeds 150 km, except Cascadia, Makran, Mexico and South Shetland. Some subduction zones have a poorly developed or relatively short seismic slab (Betic-Rif, Cascadia, Halmahera, Hellenic, Lesser Antilles-Puerto Rico, Manila, Makran, Mexico, parts of South America, South Shetland, Trobriand, Venezuela). For all these slabs except South Shetland a distinct and longer slab geometry has been imaged in tomography models (van der Hilst and Mann, 1994; Bostock and VanDecar, 1995; Bijwaard et al., 1998; Wortel and Spakman, 2000; Gutscher et al., 2002; Hall and Spakman, 2002; VanDecar et al., 2003). Also, all subduction zones have a well-defined trench morphology, except Betic-Rif, Calabria, Cyprus and Hellenic.

Incipient subduction zones (fourteen in total) were not taken into account in the calculations. All incipient subduction zones show Wadati-Benioff zone seismicity to a depth not exceeding ~150 km (except maybe Philippine) and formed not earlier than 5 Myr ago. Incipient subduction zones are not yet self-sustaining (Gurnis et al., 2004; Schellart, 2005), because the negative buoyancy force of the short slab is small. Subduction is essentially passive and results predominantly from the motion of the surrounding plates and microplates.

2. REFERENCE FRAME DEPENDENT PARAMETERS

2.1. Calculating overriding plate, subducting plate and trench velocity

The major overriding plates and subducting plates (and potential microplates) that were used to calculate the trench-perpendicular overriding plate velocity ($v_{OP\perp}$) and trench-perpendicular subducting plate velocity ($v_{SP\perp}$) for each subduction zone are listed in Table S1. The trench-perpendicular trench migration velocity $v_{T\perp}$ was calculated from summation of the overriding plate velocity (+ a potential microplate), the rate of arc/backarc deformation and the rate of accretion/erosion ($v_{T\perp} = v_{OP\perp} + v_{OPD\perp} + v_{A\perp}$). More details on calculating $v_{T\perp}$ can be found in Schellart et al. (2007, 2008). The velocities $v_{OP\perp}$, $v_{SP\perp}$ and $v_{T\perp}$ are particularly dependent on the choice of reference frame. For this reason, calculations were done in seven reference frames to get an understanding of how much the rates are dependent on the choice of reference frame and to investigate if, despite differences, one can still extract common patterns that might be present in different reference frames. The reference frames used were the Indo-Atlantic hot spot reference frame (O'Neill et al., 2005), a global hotspot reference frame (Gordon and Jurdy, 1986), the Pacific hotspot reference frames of Wessel et al. (2006) and Gripp and Gordon (2002), the no-net-rotation reference frames of Argus and Gordon (1991) and Kreemer et al. (2003) and the Antarctic plate reference frame of Hamilton (2003). The velocities are only slightly dependent on the choice of relative plate motion model, where calculations in the geophysical relative plate motion model of DeMets et al. (1990) and DeMets et al. (1994) are very similar to the ones in the geodetic relative plate motion model from Kreemer et al. (2003). All reference frames were combined with the model from DeMets et al. (1994) and Kreemer et al. (2003), except the no-net-rotation reference frames and the global hotspot reference frame.

In the hotspot reference frames, plate motion relative to the hotspots is averaged for the last 10 Myr (Gordon and Jurdy, 1986; O'Neill et al., 2005), 5.8 Myr (Gripp and Gordon, 2002) and 5.89 Myr (Wessel et al., 2006), while in the no-net-rotation reference frames plate motions are averaged for the last 3 Myr (Argus and Gordon, 1991) or represent current plate motions (Kreemer et al., 2003). The relative plate motion model from DeMets et al. (1994) is averaged for the last 3 Myr.

3. REFERENCE FRAME INDEPENDENT PARAMETERS

3.1. Calculating overriding plate deformation rate

The trench-perpendicular overriding plate deformation rate ($v_{OPD\perp}$) was mostly calculated from published rotation parameters for the motion of arc blocks with respect to the main overriding plate (or potential microplate). In some cases only average extension or shortening rates of the backarc/arc region were available. The plates, microplates and arc blocks used in the study are listed in Table S2.

The component of overriding plate trench-perpendicular deformation was compiled from previous investigations, in which such rates were determined mainly from geodetic investigations but also from geological or geophysical investigations (Table S1). In the geodetic data set 24 out of 28 $v_{OPD\perp}$ are based on geodetics, while the remaining 4 are based on geology/geophysics. In the geological data set 15 out of 28 $v_{OPD\perp}$ are based on geology/geophysics, while the remaining 13 are based on geodetics. Thus, the geodetic data set for $v_{OPD\perp}$ rates is most complete. Most geodetic rates are often comparable with rates determined from geological and geophysical investigations. The most important exception is for the Calabrian subduction zone, where geodetic investigations imply a current extensional rate in the overriding plate of only 0.2 cm/yr (Serpelloni et al., 2005), while geological investigations imply an average of 6 cm/yr for the last 4 Myr (Rosenbaum et al., 2004). Other less profound exceptions are the Betic-Rif subduction zone, South Shetland subduction zone and the Cascadia subduction zone (see Table S1). For four subduction zones only estimates based on geology/geophysics are available. For one (Andaman), quantification of the deformation rate is based on tectonic reconstructions. For the remaining three (Mexico, Kamchatka, Izu-Bonin), the deformation rates are determined from geological investigations, but the deformation rates are so low (< 0.2 cm/yr) that inclusion of the rates hardly affects trends observed in the diagrams.

Positive velocities of overriding plate deformation point to extension (i.e. backarc/intra-arc extension or backarc spreading). Negative velocities point to overriding plate shortening. For most subduction zones the overriding plate close to the trench is either extending or neutral. Very high trench-perpendicular backarc opening rates (6 – 15 cm/yr) are found behind the Tonga, New Hebrides, New Britain and Scotia arcs. Significant trench-perpendicular overriding plate shortening is only observed in Central South America, Japan and southern Manila with comparatively low rates (-3 – 0 cm/yr).

3.2. Calculating slab width and lateral slab edge distance

Slab width was calculated for all the major subduction zones on Earth. The width was calculated primarily from the plate tectonic model of Bird (2003), in which the width of the subduction zone plate boundary (i.e. the trench-parallel extent of the boundary) serves as a proxy for the slab width. All subduction zones have a well-defined trench morphology, except the Betic-Rif, Calabria, Cyprus and Hellenic subduction zones. Slab edge distance (D_{SE}) is the distance of the centre of a trench segment to its closest lateral subduction zone (slab) edge.

A number of wide subduction systems consist of adjoining arc systems, e.g. Nankai-Ryukyu, Tonga-Kermadec-Hikurangi, Mexico-Central America, New Britain-San Cristobal-New Hebrides (Melanesia), Burma-Andaman-Sumatra-Java-Banda (Sunda), Kamchatka-Kuril-Japan-Izu-Bonin-Mariana (Northwest Pacific). These systems were determined to consist of one single continuous slab, because the seismic and tomographic signature for each subduction system implies that the slab is continuous across individual arc cusps (Isacks et al., 1968; Yamaoka et al., 1986; Jarrard, 1986; Gudmundsson and Sambridge, 1998; Bijwaard and Spakman, 1998; Wortel and Spakman, 2000; Kennett and Gorbatov, 2004). Obviously, the existence of small sub-vertical slab tears, gaps and slab windows (i.e. with a horizontal length scale < 150 km) in all the subduction zones investigated can never be ruled out, but the limited extent will guarantee that their impact on the kinematics and dynamics of subduction will be limited. Therefore, these subduction zones can be considered as single entities.

A number of subduction zones are connected to former subduction zones that are now collision zones, for which a clear slab geometry is still discernable from focal mechanisms and/or tomography. These slab segments were included in the slab width and D_{SE} calculations. The Sunda slab continues eastward for ~1400 km as the Banda slab, where Australia is colliding with Timor (Bijwaard et al., 1998; Milsom, 2001) and northward for ~1250 km as the Burma slab, where India is colliding with Eurasia (Bijwaard et al., 1998; Rao and Kalpna, 2005). The Hellenic slab continues northwestward for ~800 km as the Dinarides slab, where the continental crust of the Adriatic promontory is colliding with Eurasia (Wortel and Spakman, 2000). The New Britain and Trobriand slabs both continue westward for ~400 km underneath the New Guinea collision zone (Cooper and Taylor, 1987; Hall and Spakman, 2002). The Lesser Antilles-Puerto Rico slab continues westward for ~550 km as the Hispaniola slab, where the Bahamas block is colliding with Hispaniola (Mann et al., 2002). The collision zones described above, including other collision zones with discernable slab geometries such as Carpathians, Solomon and Himalayas, were not included in the calculations.

3.3. Calculating trench-parallel ridge/plateau/continental crust distance

The trench-parallel distance from a subduction segment to the closest aseismic ridge/plateau/continental crust intersecting the trench (D_R) was calculated for all the subduction zones. A number of subduction zones do not have any aseismic ridge/plateau/continental crust intersecting the trench (e.g. Scotia), and these subduction zones are therefore not included in Fig. 2L.

3.4. Calculating convergence velocity

The trench-perpendicular convergence velocity $v_{C\perp}$ was calculated from the relative motion between the major overriding plate (+ potential microplate) and the major subducting plate (+ potential microplates), thus $v_{C\perp} = v_{OP\perp} + v_{SP\perp}$, where trenchward plate motion is positive. These velocities are independent of the choice of reference frame. The velocities are only slightly dependent on the choice of relative plate motion model, where calculations in the geophysical relative plate motion model of DeMets et al. (1994) and DeMets et al. (1990) are very similar to the ones in the geodetic relative plate motion model from Kreemer et al. (2003).

3.5. Calculating subduction velocity

The trench-perpendicular subduction velocity $v_{S\perp}$ was calculated from the relative motion between the major overriding plate + potential microplate + overriding plate deformation + accretion/erosion (i.e. $v_{T\perp}$) and the major subducting plate + potential microplate (i.e. $v_{SP\perp}$), thus $v_{S\perp} = v_{T\perp} + v_{SP\perp}$. The subduction velocity thus represent the rate at which the subducting plate disappears into the mantle. The subduction velocity is independent of the choice of reference frame. The velocities are only slightly dependent on the choice of relative plate motion model, because calculations in the geological relative plate motion model of DeMets et al. (1994) and DeMets et al. (1990) are very similar to the ones in the geodetic relative plate motion model from Kreemer et al. (2003). For a number of subduction zones, the velocities are also dependent on the overriding plate deformation model, be it the geodetic model or the geological model. For most subduction zones which experience overriding plate deformation the difference is small, but for some (e.g. Calabria, Scotia, South Shetland, Betic-Rif), the difference can be several cm/yr.

3.6. Trench accretion/erosion rate

The trench accretion/erosion rate ($v_{A\perp}$) for the mature subduction zones is shown in Table S1. Rates vary between -0.5 and 0.6 cm/yr. The rates for erosion and accretion have been obtained for a large part from the review paper by Clift and Vannucchi (2004). The most significant tectonic erosion rates have been documented for Japan (-0.3 cm/yr), northern and central South America (-0.3 cm/yr), Tonga (-0.4 cm/yr) and Scotia (-0.5 cm/yr). The most significant accretion rates have been documented for southern South America (0.3 cm/yr), Lesser Antilles (0.3 cm/yr), Hellenic (0.5 cm/yr) and Andaman (0.6 cm/yr). For a large number of subduction zones, the rate of accretion/erosion has been determined, whilst for some it is only inferred based on comparative geology and tectonic setting with respect to other subduction zones for which the rate is known. For a total of 11 subduction zones, no calculated rates or estimated rates are available yet, resulting in a reduction of data points from 244 to 190. In particular, no data points are available for the New Britain-San Cristobal-New Hebrides subduction zone, which is good for a total of 22 data points and which is probably undergoing erosion along (most of) its length.

3.7. Subducting plate age

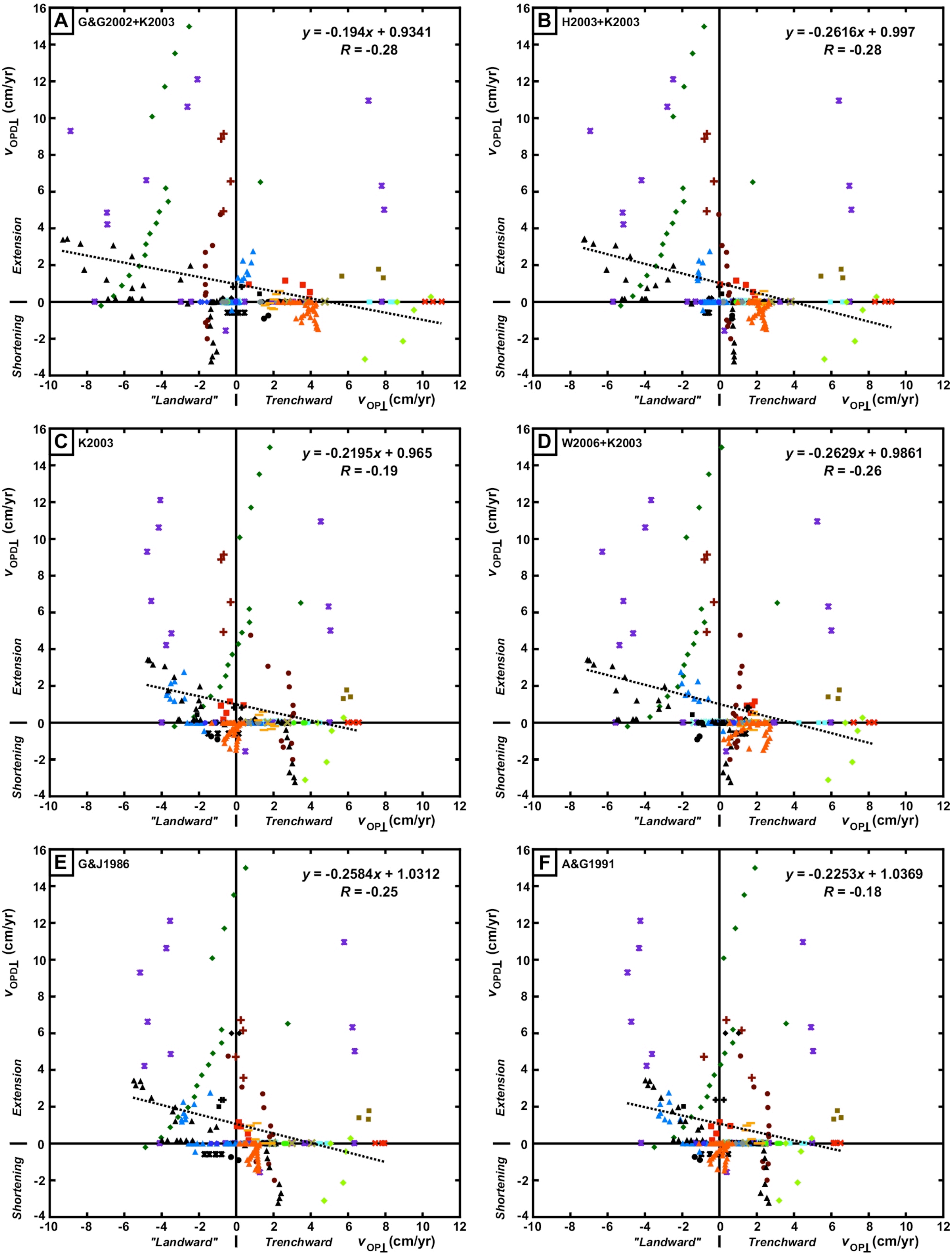
The subducting plate age (A_{SP}) at the trench was obtained from numerous published sources (see Table S1) and was averaged for the 200 km trench segments.

3.8. Slab dip angle

Shallow slab dip angles (θ_S, averaged over a depth range of 0-125 km) and deep slab dip angles (θ_D, averaged over a depth range of 125-670 km) were obtained for the subduction zones from the published literature (Yokokura, 1981; Jarrard, 1986; Yamaoka et al., 1986; Gudmundsson and Sambridge, 1998; Lallemand et al., 2005; Reyners et al., 2006; Chatelain et al., 1993; Lebrun et al., 2000; Kopp et al., 1999; Lallemand et al., 1998; Hall and Spakman, 2002; Abdelwahed and Zhao, 2007; Bostock and VanDecar, 1995; Ibáñez et al., 1997; VanDecar et al., 2003; Pérez et al., 1997; Gutscher et al., 2002; Wortel and Spakman, 2000; Papazachos et al., 2000; van Hinsbergen et al., 2005; Piromallo and Morelli, 2003; Ben-Avraham et al., 1988; Bijwaard et al., 1998; Mann et al., 2002; Alinaghi et al., 2007), and were averaged for the 200 km trench segments. Note that from a total of 244 subduction segments, 227 θ_S and 176 θ_D could be obtained.

3.9. Subduction zone polarity

The subduction zone azimuth with respect to the geographical north was calculated for the individual trench segments of each subduction zone. For more details the reader is referred to Schellart (2007).


A G&G2002+K2003
y = -0.194x + 0.9341
R = -0.28
B H2003+K2003
y = -0.2616x + 0.997
R = -0.28
C K2003
y = -0.2195x + 0.965
R = -0.19
D W2006+K2003
y = -0.2629x + 0.9861
R = -0.26
E G&J1986
y = -0.2584x + 1.0312
R = -0.25
F A&G1991
y = -0.2253x + 1.0369
R = -0.18
v_OPD⊥ (cm/yr)
Extension
Shortening
"Landward"
Trenchward
v_OP⊥ (cm/yr)

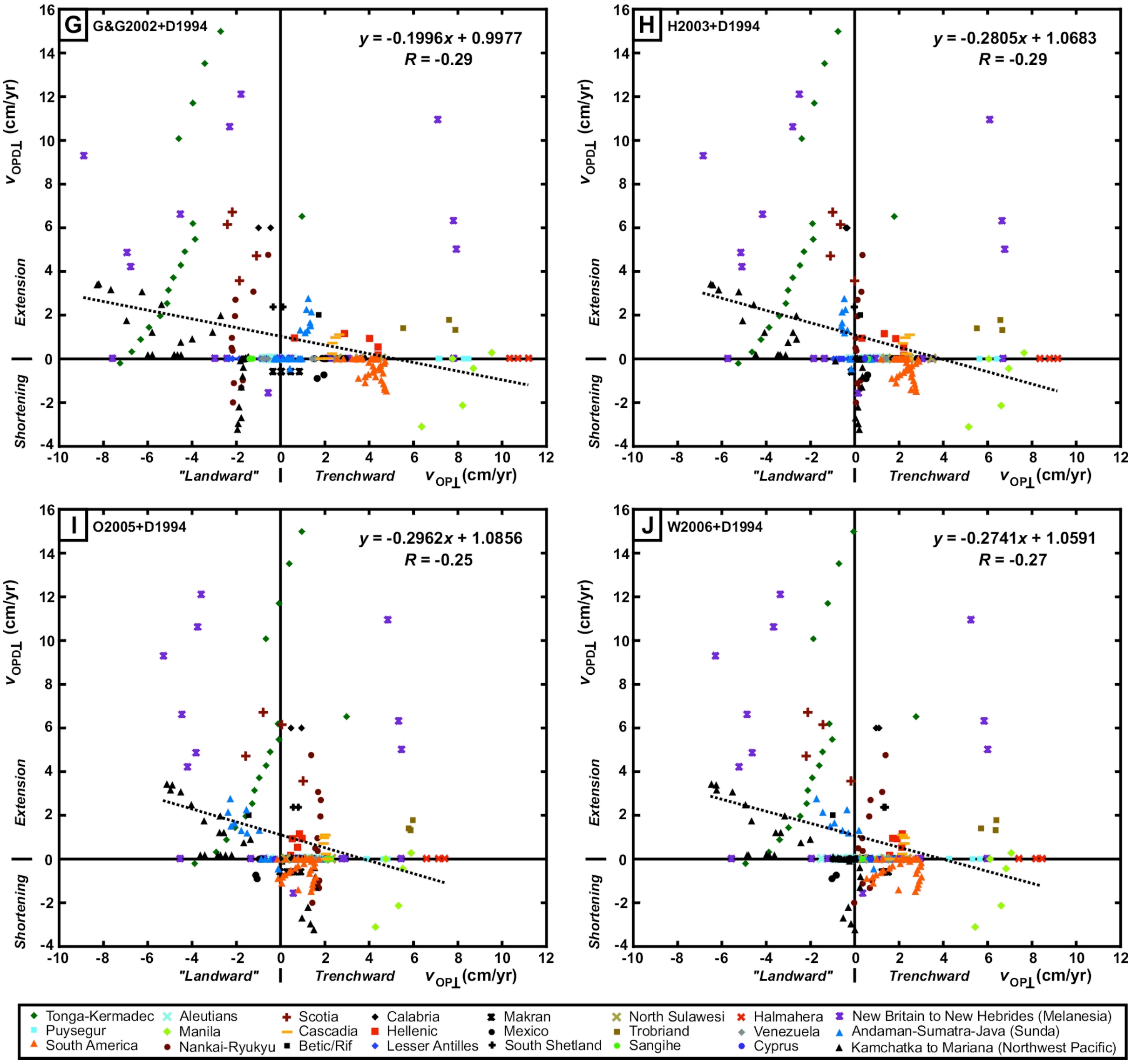


Fig. S1. (Previous page and above) Diagrams illustrating the relationship between the trench-perpendicular overriding plate velocity ($v_{OP\perp}$; trenchward plate motion is taken as positive) and the trench-perpendicular overriding plate deformation rate ($v_{OPD\perp}$; extension is positive, shortening is negative) in different global reference frames and with different relative plate motion models and overriding plate deformation data sets, i.e. geodetic with Kreemer et al. (2003) or geological with, for example, DeMets et al. (1994). Models in Figs. 1A-D make use of the geodetic data set, while models in Figs. 1E-J make use of the geological data set. The models are: (A) Pacific hotspot (Gripp and Gordon, 2002 and Kreemer et al., 2003); (B) Antarctic plate (Hamilton, 2003 and Kreemer et al., 2003); (C) no-net-rotation (Kreemer et al., 2003); (D) Pacific hotspot (Wessel et al., 2006 and Kreemer et al., 2003); (E) global hotspot (Gordon and Jurdy, 1986); (F) no-net-rotation (Argus and Gordon, 1991); (G) Pacific hotspot (Gripp and Gordon, 2002 and DeMets et al., 1994); (H) Antarctic plate (Hamilton, 2003 and DeMets et al., 1994); (I) Indo-Atlantic hotspot (O'Neill et al., 2005 and DeMets et al., 1994); (J) Pacific hotspot (Wessel et al., 2006 and DeMets et al., 1994). Note that the Indo-Atlantic hotspot model combined with Kreemer et al. (2003) is plotted in Fig. 1A of the paper.

TABLES

Table S1. Subduction zone data.

Subduction system	Slab width (km)	Subducting plate age A_{SP} (Ma)	Trench ⊥ overriding plate deformation rate $v_{OPD\perp}$ (cm/yr)	Motion of arc block with respect to overriding plate / microplate to calculate $v_{OPD\perp}$	Subducting plate (+microplate) to calculate $v_{SP\perp}$	Overriding plate (+microplate) to calculate $v_{OP\perp}$	Tectonic accretion (>0) or erosion (<0) $v_{A\perp}$ (cm/yr)
Betic-Rif [Be]	450	~155 (1)	0.44 [A]	BE-EU (2)[§]	AF	EU	?
Calabria [Cb]	300	>80 (3)	0.2 [B]	CB-EU (4)[§]	AF	EU	?
South Shetland [Sh]	450	14-23 (5)	~0.8 [C]	SL-AN (6)[§]	AN	AN	?
North Sulawesi [Sl]	500	42 (7,8)	~0		EU-SU (9)[§]	EU-SU-MS (9-11)[§]	?
Halmahera [Ha]	500	~45 (12)	~0		EU-SU-MS (11,9)[§]	AU-BH (10)[§]	?
Cyprus [Cy]	500	>80 (3)	0		AF	EU-AT (13)[§]	?
Puysegur [Pu]	750	22-83 (14)	0		AU	PA	?
Scotia [Sc]	800	26-82 (15)	4.9 – 9.1 [D]	SW-SC (16)[§]	SA	AN-SC (16)[§]	-0.5 (17)
Sangihe [Sa]	850	~45 (12)	~0		EU-SU-MS (11,9)[§]	EU-SU (9)[§]	?
Trobriand [Tr]	900 [¶]	~30 (18)	1.3 – 1.8	WL-AU (19)[§]	PA-SO (10)[§]	AU	?
Makran [Mk]	900	~85 (20)	~ -0.6	MK-EU (21)[§]	AR	EU	0.2 (22)
Manila [Mn]	1000	15-32 (23)	-3.1 – 0.3	(LU)-PS (11)[§]	EU-SU (9)[§]	PS	-0.15 (22)^
Cascadia [Cs]	1400	1-11 (24)	-0.4 – 0.6 [E]	(OR/OL/NV)-NA (25)[§]	JF	NA	0.2 (22)
Venezuela [Ve]	1550	~90 (26)	~0		CA	SA-ND (10)*	?
Hellenic- [Hl] (Dinarides) [Di]	1700 [$]	>80 (3)	0.2 – 1.2	AS-AT (13)[§]	AF	EU-AT (13)[§]	0.5 (22)
Nankai- [Na]	2250	15-29 (27)	-2.0 – -1.0	TK-AM (28)[§]	PS	EU-AM (9)[§]	0.1 (22)
Ryukyu [Ry]		38-131 (29)	0.4 – 4.8	ON-YA (30)[§]	PS	EU-YA (9)[§]	-0.3 (22)^
Lesser Antilles- [An]	2450 [#]	81-100 (1,31)	0		SA/NA	CA	0.3 (22)
Puerto Rico- [Pr] (Hispaniola) [Hp]		81-120 (1)	0		NA	CA	0.3 (22)
Mexico- [Me]	3100	5-16 (32)	~0.02	ME-NA (33)*	RI/CO	NA	-0.1 (34)
Central America [Am]		15-25 (32)	-0.9 – 0	(PM-)CA (10)[§]	CO	NA-CA (9,35)[§]	-0.3 (36)
Aleutian- [At]	3400	37-55 (37)	0		PA	NA	0.1 (22)
Alaska [Ak]		53-63 (37)	0		PA	NA	0.3 (22)
Tonga- [To]	3550	~82-110 (38)	5.1 – 15.0	TO-AU (39)*[§]	PA	AU	-0.38 (40)
Kermadec- [Ke]		~82-110 (38)	2.0 – 6.2	KE-AU (10,41)*[§]	PA	AU	-0.15 (22)^
Hikurangi [Hk]		~110-120 (38)	-0.2 – 1.4	KE-AU (10,41)*[§]	PA	AU	-0.15 (22)^
Melanesia:	4400 [¶]						
New Britain- [Br]		~30 (18)	-1.6 – 9.3	SB-PA (42)[§]	AU-SO (10)[§]	PA	?
San Cristobal- [Cr]		~1-70 (43)	~0		AU-(SO/WL) (10)[§]	PA	?
N New Hebrides- [Hb]		~58-66 (43)	~0		AU	PA	?
C New Hebrides- [Hb]		~67-70 (43)	~0 – 4	NH-AU (44)[§†]	AU	AU	?
S New Hebrides [Hb]		~35-45 (45)	4.2 – 12.1	NH-AU (44)[§†]	AU	AU	?
Northwest Pacific:	6550						
Kamchatka- [Ka]		~90-100 (37)	0 – 0.1	KA-OK (46)*	PA	EU-OK (9)[§]	-0.3 (22)^
Kuril- [Ku]		~100-130 (37)	-1.3 – 0	(OK-)AM (9)[§]	PA	EU(-OK) (9)[§]	-0.3 (22)^
Japan- [Jp]		~130-134 (47)	-3.2 – -2.2	OK-AM (9)[§]	PA	EU-AM (9)[§]	-0.3 (48)
Izu-Bonin- [Iz]		~130-146 (47)	~0 – 0.175	IB-PS (49)*	PA	PS	-0.2 (22)^
Mariana [Mr]		~146-156 (50)	-0.1 – 3.4	MA-PS (10)*[§]	PA	PS	-0.1 (22)^
South America:	7400						
Colombia- [Co]		13-30 (38)	~0		NZ	SA-ND (10)*	-0.3 (48,51)
Peru- [Pe]		22-44 (52)	-0.7 – 0.0	PE-SA (10,53)*[§]	NZ	SA	-0.3 (48,51)
Bolivia- [Bl]		44-52 (52)	-1.5 – -0.8	AP-SA (54,10) [§]	NZ	SA	-0.3 (55)
Chile [Ch]		1-51 (52,56)	-1.3 – 0.0	(CH)-SA (10,53)*[§]	NZ/AN	SA-(SC) (10)*[§]	0.3 (22)
Sunda: (Burma-) [Bu]	7850 [‡]						
Andaman- [Ad]		~70-90 (38)	-0.4 – 2.8	BU-SU (10)*	IN	EU-SU (9)[§]	0.6 (22)
Sumatra- [Sm]		43-100 (38)	0		AU	EU-SU (9)[§]	0.2 (22)
Java- [Jv] (Banda) [Ba]		~100-160 (38)	0		AU	EU-SU (9)[§]	0.2 (22)

Table S1. Data for all subduction zones on Earth including (trench-parallel) subduction zone width (which serves as a proxy for slab width) (column 2), Subducting plate age at the trench (A_{SP}) (column 3), trench-perpendicular overriding plate deformation rate $v_{OPD\perp}$ (column 4), overriding plate (or microplate) - arc block circuit used to calculate $v_{OPD\perp}$ (column 5), subducting plate (+microplate) used to calculate $v_{SP\perp}$ (column 6), overriding plate (+microplate) used to calculate $v_{OP\perp}$ (column 7) and accretion/erosion rate ($v_{A\perp}$) (column 8). Note that the convergence velocity $v_{C\perp}$ between the overriding plate and subducting plate can be calculated from combining $v_{OP\perp}$ and $v_{SP\perp}$, i.e. $v_{C\perp} = v_{OP\perp} + v_{SP\perp}$ with trenchward plate motion taken as positive, and is reference frame independent. Note that the trench velocity $v_{T\perp}$ can be calculated from combining $v_{OP\perp}$, $v_{OPD\perp}$ and $v_{A\perp}$, i.e. $v_{T\perp} = v_{OP\perp} + v_{OPD\perp} + v_{A\perp}$, where trench retreat is taken as positive. Note that the subduction velocity $v_{S\perp}$ can be calculated from combining $v_{T\perp}$ and $v_{SP\perp}$, i.e. $v_{S\perp} = v_{T\perp} + v_{SP\perp}$. Subduction zone width was primarily calculated from the plate tectonic model of Bird (2003). Note that the Nankai-Ryukyu subduction zone only has one slab edge, as the northeast side of the subduction zone abuts with the northwest Pacific slab. Plate, microplate, and arc block/arc deformation zone abbreviations, indicated in columns 5-7 by a unique two-letter abbreviation characterized by two capitals, can be found in Table S2. The segments in between brackets in column 1 (Banda, Burma, Dinarides, Hispaniola) are collision zones. In the first column the two-letter unique abbreviation for each subduction zone (capital followed by lower case) is given in between the square brackets. Abbreviations in column one: N—north, C—central, S—south. Numbers in parentheses in columns 3 and 5-8 point to the following references: 1—Müller and Roest (1992); 2—Fernandez et al. (2007); 3—Catalano et al. (2001); 4—Serpelloni et al. (2005); 5—Lawver et al. (1995); 6—Taylor et al. (in review); 7—Nichols and Hall (1999); 8—Hall (2002); 9—Kreemer et al. (2003); 10—Bird (2003); 11—Rangin et al. (1999); 12—Evans et al. (1983), Bader and Pubellier (2000); 13—McClusky et al. (2000); 14—Sutherland (1995), Gaina et al. (1998); 15—Barker and Lawver (1988), Livermore et al. (2005); 16—Smalley Jr. et al. (2007); 17—Vanneste and Larter (2002); 18—Joshima and Honza (1987), Joshima et al. (1987); 19—Tregoning et al. (1998); 20—Hutchison et al. (1981); 21—Nilforoushan et al. (2003); 22—Clift and Vannucchi (2004); 23—Briais et al. (1993); 24—Wilson (1993); 25—McCaffrey et al. (2007); 26—Kerr and Tarney (2005); 27—Sdrolias et al. (2004); 28—Mazzotti et al. (2001); 29—Hilde and Lee (1984), Deschamps et al. (2000), Deschamps and Lallemand (2002); 30—Nishimura et al. (2004); 31—Müller et al. (1997); 32—Manea et al. (2005), Protti et al. (1994), DeMets and Traylen (2000); 33—Suter et al. (2001); 34—Mercier de Lépinay et al. (1997), Vannucchi et al. (2004); 35—Pérez et al. (2001); 36—Vannucchi et al. (2001); 37—Hilde et al. (1977); 38—Sdrolias and Müller (2006); 39—Bevis et al. (1995), Zellmer and Taylor (2001); 40—Clift and Macleod (1999); 41—Wright (1993), Darby and Meertens (1995), Wallace et al. (2004); 42—Tregoning et al. (1999); 43—Schellart et al. (2006); 44—Taylor et al. (1995), Calmant et al. (1997); 45—Sdrolias et al. (2003); 46—Kozhurin et al. (2006); 47—Sager et al. (1988); 48—von Huene and Lallemand (1990); 49—Seno et al. (1993); 50—Handschumacher et al. (1988); 51—Clift et al. (2003); 52—Tebbens and Cande (1997), Tebbens et al. (1997); 53—Oncken et al. (2006); 54—Norabuena et al. (1998), Bevis et al. (2001); 55—Laursen et al. (2002); 56—Yáñez et al. (2001).

[§]Based on geodetic data.
*Based on geological and/or geophysical data.
[¶]From this width, ~400 km stems from the westward continuation of the slab below New Guinea (Cooper and Taylor, 1987).
[$]From this width, ~800 km stems from the northwestward continuation of the slab below the Dinarides (Wortel and Spakman, 2000).
[#]From this width, ~550 km stems from the westward continuation of the slab below Hispaniola (Mann et al., 2002).
[†]Australia is both the subducting plate and the overriding plate.
[‡]From this width, ~1400 km stems from the eastward continuation of the slab below the Banda arc and ~1250 km from the northward continuation of the slab below the Burma arc (Bijwaard et al., 1998; Milsom, 2001; Rao and Kalpna, 2005).
[A]Geodetic investigations indicate a present day extensional rate of only 0.44 cm/yr (Fernandes et al., 2007), while geological investigations indicate an extensional rate of 2 cm/yr (200 km of extension averaged over the last 10 Myr) (Gutscher et al., 2002).
[B]Geodetic investigations indicate a present day extensional rate of only 0.2 cm/yr (Serpelloni et al., 2005), while geological investigations indicate an average extensional rate of 6 cm/yr for the last 4 Myr (Rosenbaum et al., 2004).
[C]Geodetic investigations indicate a present day trench-perpendicular opening rate of 0.7-0.9 cm/yr (Taylor et al., in review), while geological investigations imply an opening rate of 2.4 cm/yr based on an average calculated from ~35-50 km of extension from ~1.3-4 Ma to Present (Lawver et al., 1995).
[D]Geodetic investigations indicate a present day trench-perpendicular opening rate of 4.9 – 9.1 cm/yr (Smalley Jr. et al., 2007), while geophysical investigations indicate a trench-perpendicular opening rate of 3.6 – 6.7 cm/yr (Thomas et al., 2003).
[E]Geodetic investigations indicate a present day extensional rate of up to 0.6 cm/yr in the south and shortening of up to 0.4 cm/yr in the north (McCaffrey et al., 2007), while geological investigations imply an extensional rate of 0-1.2 cm yr in the south (Wells et al., 1998).
^Not constrained but inferred from comparative geology and tectonics (Clift and Vannucchi, 2004). These rates have been incorporated in the calculations presented in Fig. 3F in the paper, but have not been incorporated in the $v_{T\perp}$ and $v_{S\perp}$ calculations.

Table S2. Two-letter abbreviations for plates, microplates and arc blocks.

Plate abbreviation	Plate	Microplate abbreviation	Microplate	Arc block / sliver / deformation zone abbreviation	Arc block / sliver / deformation zone
AF	Africa	AM	Amuria	AP	Altiplano
AN	Antarctica	AT	Anatolia	AS	Aegean Sea*
AR	Arabia	BS	Banda Sea	BE	Betic-Rif*
AU	Australia	MS	Molucca Sea	BH	Birds Head
CA	Caribbean	ND	North Andes	BU	Burma
CO	Cocos	OK	Okhotsk	CB	Calabria*
EU	Eurasia	RI	Rivera	CH	Chile*
IN	India	SC	Scotia	IB	Izu-Bonin*
JF	Juan de Fuca	SO	Solomon	KA	Kamchatka*
NA	North America	SU	Sunda	KE	Kermadec
NZ	Nazca	YA	Yangtze	LU	Luzon*
PA	Pacific			MA	Mariana
PS	Philippine Sea			ME	Mexico*
SA	South America			MK	Makran*
				NH	New Hebrides
				NV	Northern Vancouver Island*
				OL	Olympic*
				ON	Okinawa
				OR	Oregon*
				PE	Peru*
				PM	Panama
				SB	South Bismarck
				SL	South Shetland
				SW	Sandwich
				TK	Tokai South Kanto*
				TO	Tonga
				WL	Woodlark

Table S2. Abbreviations for plates, microplates, arc blocks, arc slivers and arc deformation zones. Note that these entities are represented with two capitals (following Bird, 2003). Note that for subduction zones, collision zones and incipient subduction zones a two-letter abbreviation with one capital followed by a lower case is used.

*Arc blocks, arc slivers and arc deformation zones with relatively diffuse deformation.

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