Serge Lallemand & Diane Arcay

1. Subduction stage

immature — mature

SI reached stage:
a. Incipient diffuse → b. Incipient localized → c. Achieved → d. Self-sustained
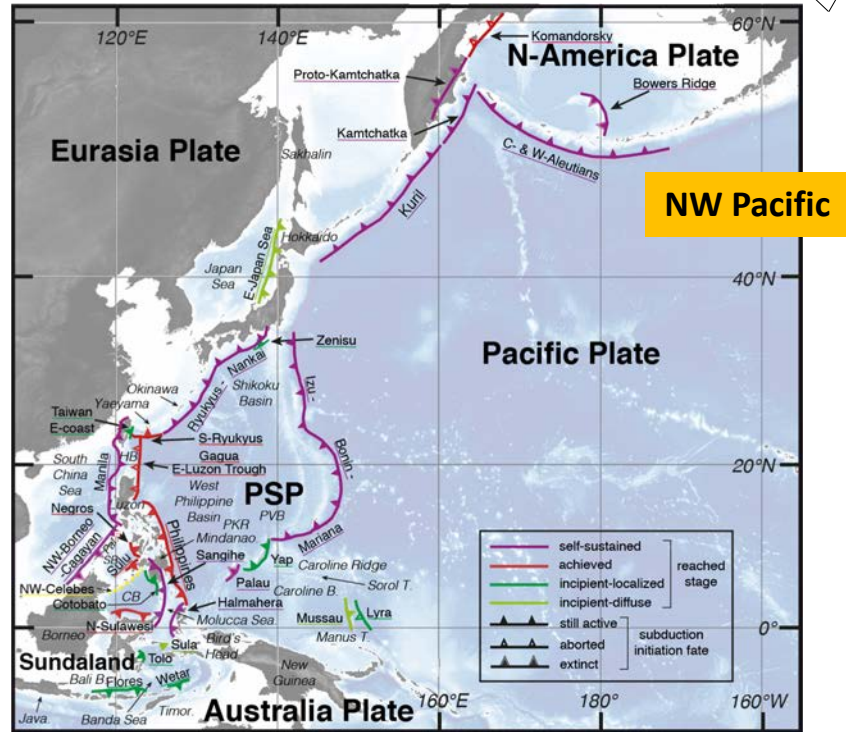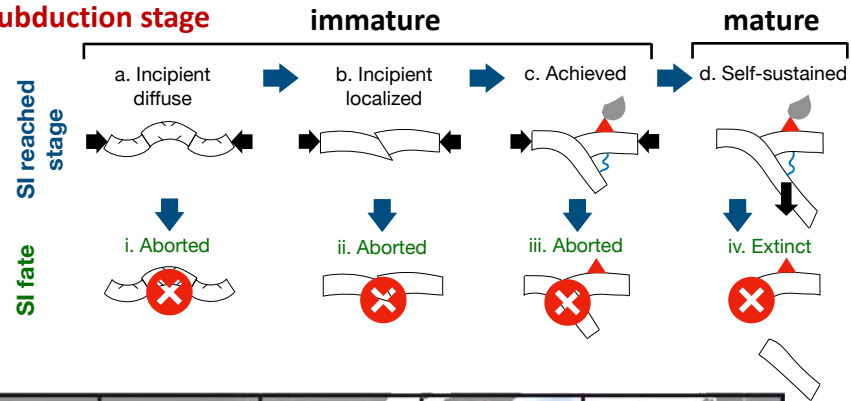
SI fate:
i. Aborted ii. Aborted iii. Aborted iv. Extinct

→ 70 Cenozoic subduction initiation cases (70,350 km): 41 immature + 29 mature (2/3 still active)

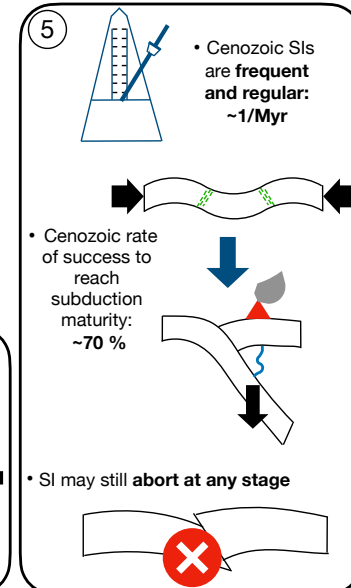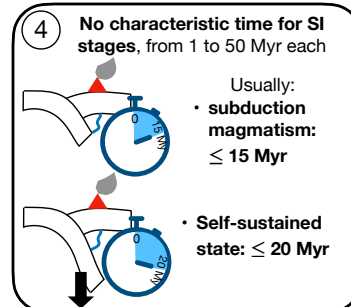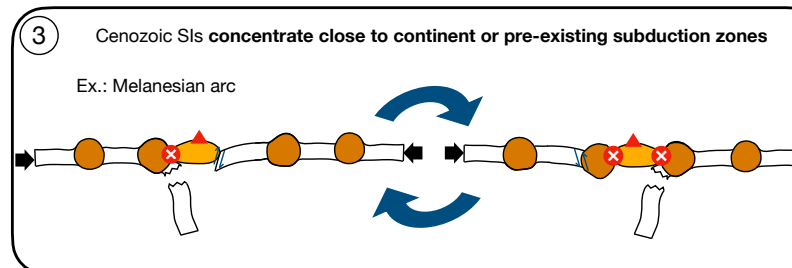**2. Geodynamic setting**   at (or far from) an ocean-continent/arc transition (rifted margin, TF, SC ...) ?
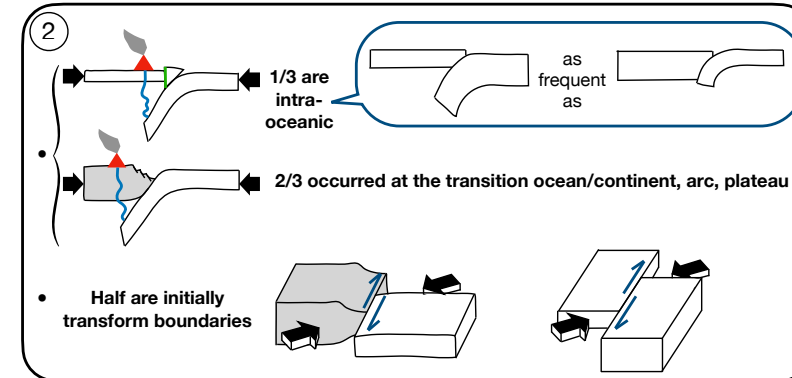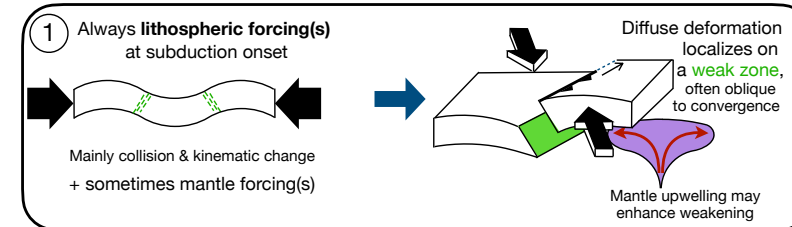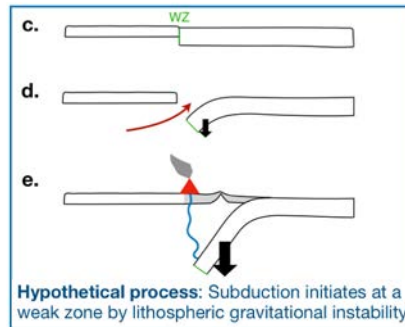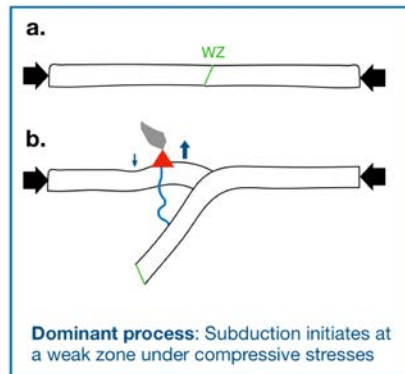
3. SI triggers   lithospheric (collision, kinematic change ...) and/or mantle (plume ...) forcing?

4. SI deformation modes and spatial expression   change in fault kinematics or not, flip, jump, lateral propagation, TF conversion ... ?
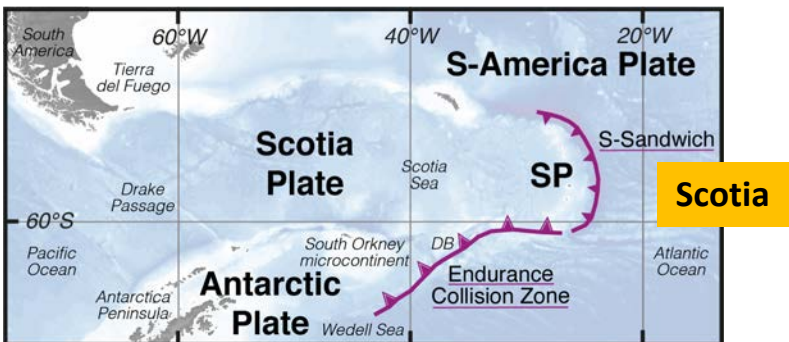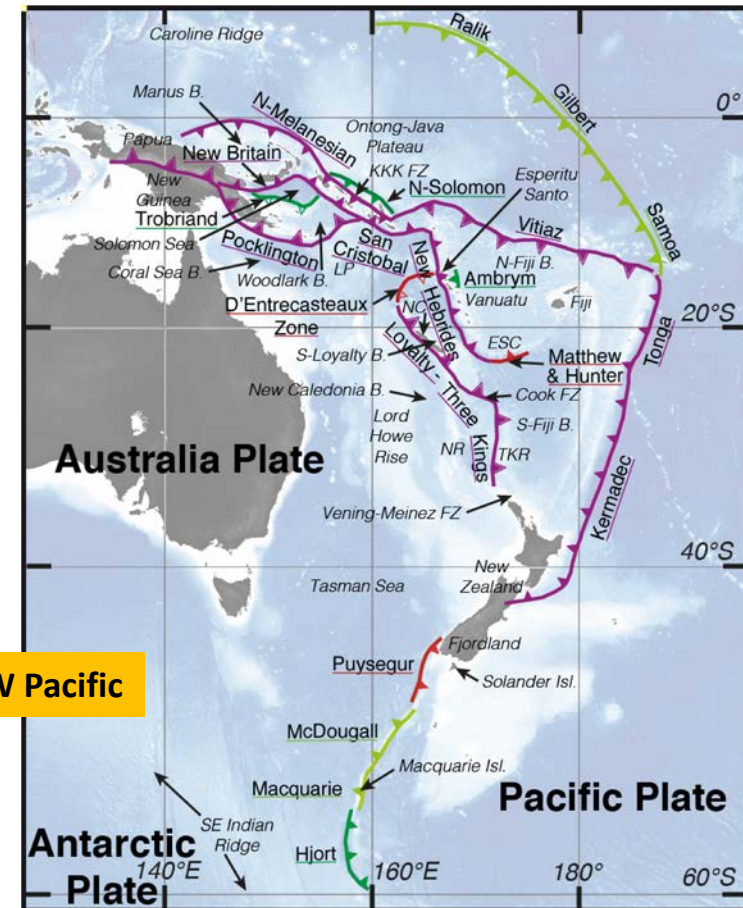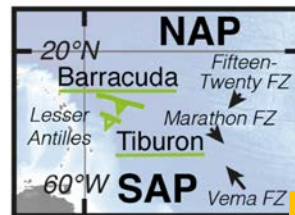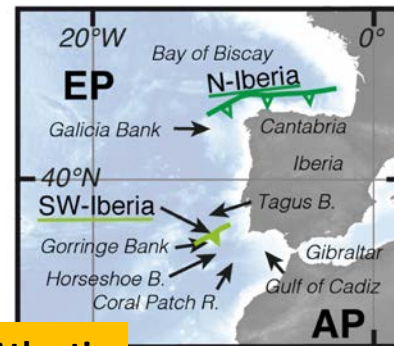
5. SI age and duration of each stage

6. Age of subducting and overriding plates at SI

7. State of stress at SI

NW Pacific

Map labels: Komandorsky, N-America Plate, Bowers Ridge, Proto-Kamchatka, Eurasia Plate, Sakhalin, Kamchatka, C.- & W.-Aleutians, E-Japan Sea, Kuril, Hokkaido, Japan Sea, Pacific Plate, Zenisu, Nankai, Okinawa, Yaeyama, Shikoku Basin, Izu, Taiwan E-coast, Ryukyus, S-Ryukyus, Gagua, HB, E-Luzon Trough, West Philippine Basin, Bonin, PSP, Manila, South China Sea, Luzon, PKR, Mindanao, PVB, Mariana, Negros, Sangihe, Yap, Caroline Ridge, NW-Borneo, Cagayan, Philippines, Palau, Caroline B., Sorol T., Sulu, Halmahera, Mussau, Lyra, NW-Celebes, Cotobato, Molucca Sea, N-Sulawesi, Sula, Bird's Head, Manus T., Sundaland, Bali B., Flores, Wetar, Tolo, New Guinea, Java, Banda Sea, Timor, Australia Plate

Legend — reached stage: self-sustained, achieved, incipient-localized, incipient-diffuse; subduction initiation fate: still active, aborted, extinct

a. (WZ)
b.
Dominant process: Subduction initiates at a weak zone under compressive stresses

c.
d. (WZ)
e.
Hypothetical process: Subduction initiates at a weak zone by lithospheric gravitational instability

① Always **lithospheric forcing(s)** at subduction onset
Mainly collision & kinematic change + sometimes mantle forcing(s)
Diffuse deformation localizes on a **weak zone**, often oblique to convergence
Mantle upwelling may enhance weakening

② 1/3 are **intra-oceanic**   as frequent as
2/3 occurred at the transition ocean/continent, arc, plateau
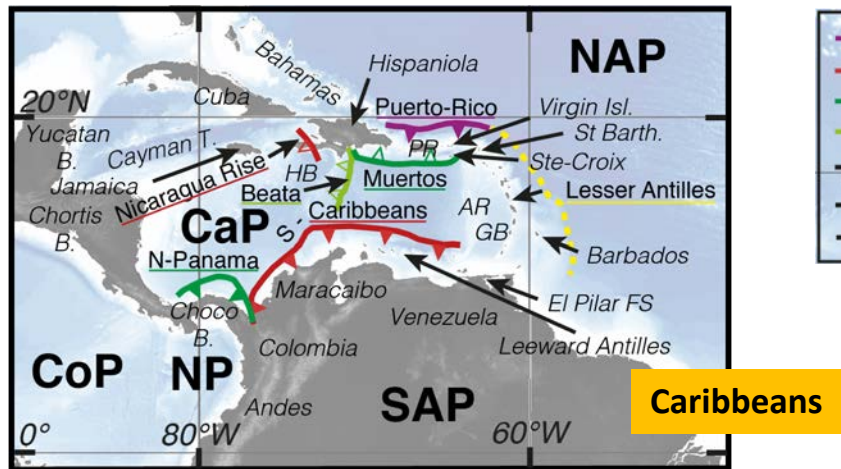**Half are initially transform boundaries**

③ Cenozoic SIs **concentrate close to continent or pre-existing subduction zones**
Ex.: Melanesian arc

④ **No characteristic time for SI stages**, from 1 to 50 Myr each
Usually:
• subduction magmatism: ≤ 15 Myr
• Self-sustained state: ≤ 20 Myr

⑤ • Cenozoic SIs are **frequent and regular**: ~1/Myr
• Cenozoic rate of success to reach subduction maturity: ~70 %
• SI may still **abort at any stage**

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Additional display material

Present-day location of the 70 subduction zones initiated during the Cenozoic
(the **NW Pacific** area is in the main presentation slide)

		Triggers						
		Lithospheric forcing				Mantle forcing		
↓ SI settings	SI forcings →	Local or nearby collision	Far-field kinematic change	Delamination	Sedimentary loading	Plume- or SC- induced	Mantle flow - triggered	Slab breakoff - triggered
Geodynamic settings — At OCT	Rifted margin (including rear-arc)	Proto-Kamtchatka, Kuril, S-Ryukyus, Zenisu, Taiwan E-coast, Philippines, Flores, Wetar, Sula, Sulu, N-Sulawesi, Tolo, Sangihe, Halmahera, N-Melanesian, Vitiaz, New Britain-San Cristobal (incl. S-Solomon), Trobriand, New Hebrides, Ambrym (incl. Pentecost-Maeowo), S-Caribbeans, W-Mediterranean, Gibraltar, Calabria, N-Maghrebides (Alboran to Sicily)	E-Japan Sea, S-Ryukyus, NW-Borneo - Cagayan, Pocklington, New Britain-San Cristobal (incl. S-Solomon), Trobriand, New Hebrides, Loyalty - Three Kings, N-Iberia, SW Iberia (incl. Gorringe), Endurance Collision Zone	S-Caribbeans, SW Iberia (incl. Gorringe), N-Maghrebides (Alboran to Sicily)	Philippines, Sula, N-Sulawesi, Tolo	Pocklington	E-Japan Sea, NW-Borneo - Cagayan, Sangihe, Halmahera, New Hebrides, Endurance Collision Zone, Gibraltar, Calabria	Taiwan E-coast, N-Melanesian, N-Maghrebides (Alboran to Sicily)
	Transform margin (including ocean-continent STEP fault)	S-Ryukyus, Zenisu, Manila, Philippines, Sula, Sangihe, Halmahera, Banda (incl. Seram), S-Caribbeans, Muertos, Puerto-Rico, Nicaragua Rise, Carpathians, W-Mediterranean, Gibraltar, Calabria, N-Maghrebides (Alboran to Sicily)	E-Japan Sea, S-Ryukyus, Manila, Negros, Cotobato, NW-Borneo - Cagayan, Tonga-Kermadec, Puysegur, Puerto-Rico, SW Iberia (incl. Gorringe)	Tonga-Kermadec, S-Caribbeans, SW Iberia (incl. Gorringe), N-Maghrebides (Alboran to Sicily)	Cotobato, Philippines, Sula, Tonga-Kermadec	Manila, Negros, Tonga-Kermadec	E-Japan Sea, NW-Borneo - Cagayan, Sangihe, Halmahera, Tonga-Kermadec, Gibraltar, Calabria	Puerto-Rico, N-Maghrebides (Alboran to Sicily)
	Former subduction zone	Komandorsky, Kamtchatka, Cascadia, New Britain-San Cristobal (incl. S-Solomon), New Hebrides, Sunda, Banda (incl. Seram)	Ryukyus-Nankai, New Britain-San Cristobal (incl. S-Solomon), New Hebrides, Tonga-Kermadec	Tonga-Kermadec	Tonga-Kermadec	Cascadia, Tonga-Kermadec	New Hebrides, Tonga-Kermadec	Ryukyus-Nankai
	Ridge flank (terrane)	Cascadia, N-Solomon, S-Caribbeans, N-Panama, Muertos, Nicaragua Rise, Beata Ridge				Cascadia		
Geodynamic settings — Far from OCT	Transform fault / Fracture zone (including oceanic STEP fault)	C- & W-Aleutians, Bowers Ridge, Gagua - E-Luzon Trough, Yap, Mussau, Samoa-Gilbert-Ralik, Matthew & Hunter, Carpathians	Gagua - E-Luzon Trough, Izu-Bonin-Mariana, Yap, Palau, Lyra, Mussau, Samoa-Gilbert-Ralik, Matthew & Hunter, d'Entrecasteaux, Tonga-Kermadec, Puysegur, McDougall, Macquarie, Hjort, Saint Paul, Romanche, Barracuda, Tiburon, S-Sandwich	Samoa-Gilbert-Ralik, Tonga-Kermadec, S-Sandwich	Tonga-Kermadec	Izu-Bonin-Mariana, Yap, Palau, Lyra, Mussau, Matthew & Hunter, Tonga-Kermadec, Saint Paul	Tonga-Kermadec, S-Sandwich	Izu-Bonin-Mariana
	Spreading center	C- & W-Aleutians, Bowers Ridge, Yap, Cascadia	NW-Borneo - Cagayan, Yap, Loyalty - Three Kings, Puysegur, McDougall, Macquarie, Hjort, Endurance Collision Zone			Yap, Cascadia	NW-Borneo - Cagayan, Endurance Collision Zone	
	Oceanic normal fault (including detachment fault)	C-Indian Ocean, Beata Ridge, W-Mediterranean						

SI reached stage : incipient-diffuse, incipient-localized, achieved, self-sustained - Present SZ status : active, aborted (when self-sustained stage was never reached), extinct

Classification of areas where subduction initiated during the Cenozoic. Lines indicate the geodynamic setting at the time of subduction initiation. STEP = Subduction-Transform Edge Propagator; OCT = Ocean-Continent Transition. Columns list the subduction triggers at initiation sorted in two groups depending on whether the driving forces are lithospheric or originate from the mantle. SC = Spreading Center. Note that some SZs satisfy several settings or triggers either because there were multiple settings or triggers acting simultaneously or because initial settings or triggers are debated. Colors indicate the subduction initiation stage reached by the system (see legend at the bottom of the table). If SI stops before reaching stage 4 = self-sustained, we consider that the process aborts, the name of the SZ is then underlined. If SI stops after stage 4, we consider that the subduction is extinct; the name of the SZ is then double-underlined.

		Deformation spatial expression								
		Flip (polarity reversal)	**Jump (same polarity)**	**Lateral propagation**	**Tectonic uplift**	**SC conversion**	**TF conversion**	**NF/DF conversion**	**Buckling**	**SZ reactivation**
Deformation mode — fault reactivation	*Change in fault kinematics*	C- & W-Aleutians, Bowers Ridge, Proto-Kamtchatka, Kuril, E-Japan Sea, Philippines, NW-Borneo - Cagayan, Flores, Wetar, N-Sulawesi, Tolo, N-Melanesian, Vitiaz, Pocklington, Samoa-Gilbert-Ralik, New Britain-San Cristobal (incl. S-Solomon), New Hebrides, Ambrym (incl. Pentecost-Maeowo), Loyalty - Three Kings, Tonga-Kermadec, N-Panama, Muertos, Nicaragua Rise, W-Mediterranean, N-Maghrebides (Alboran to Sicily)	Zenisu, Gagua - E-Luzon Trough, Sulu, Yap, Trobriand, Sunda, S-Caribbeans, Nicaragua Rise, W-Mediterranean	S-Ryukyus, Manila, Negros, Cotobato, Philippines, Sula, Sulu, Sangihe, New Britain-San Cristobal (incl. S-Solomon), Vitiaz, Matthew & Hunter, d'Entrecasteaux, Puysegur, Hjort, Banda (incl. Seram), S-Caribbeans, N-Panama, Puerto-Rico, Endurance Collision Zone, S-Sandwich, W-Mediterranean, Gibraltar, Calabria, N-Maghrebides (Alboran to Sicily)	Zenisu, Gagua - E-Luzon Trough, McDougall, Macquarie, Hjort, Muertos, Beata Ridge, Saint Paul, Romanche, SW Iberia (incl. Gorringe), Barracuda, Tiburon	C- & W-Aleutians, Bowers Ridge, NW-Borneo - Cagayan, Yap, d'Entrecasteaux, Loyalty - Three Kings, Puysegur, Hjort, Beata Ridge	E-Japan Sea, Gagua - E-Luzon Trough, Manila, Negros, Cotobato, NW-Borneo - Cagayan, Sangihe, Halmahera, Izu-Bonin-Mariana, Yap, Palau, Lyra, Mussau, Samoa-Gilbert-Ralik, Matthew & Hunter, Tonga-Kermadec, Puysegur, McDougall, Macquarie, Hjort, Sunda, Banda (incl. Seram), Puerto-Rico, Saint Paul, Romanche, SW Iberia (incl. Gorringe), Barracuda, Tiburon, Carpathians, W-Mediterranean, Gibraltar, Calabria, N-Maghrebides (Alboran to Sicily)	E-Japan Sea, Mussau, C-Indian Ocean, Beata Ridge, N-Iberia, N-Maghrebides (Alboran to Sicily)	Zenisu, Samoa-Gilbert-Ralik, Ambrym (incl. Pentecost-Maeowo), C-Indian Ocean, Barracuda, Tiburon	
	Same fault kinematics	N-Melanesian, Vitiaz, Pocklington, New Britain-San Cristobal (incl. S-Solomon), New Hebrides, Ambrym (incl. Pentecost-Maeowo)	Komandorsky, Kamtchatka, Trobriand, Sunda	New Britain-San Cristobal (incl. S-Solomon), Vitiaz					Ambrym (incl. Pentecost-Maeowo)	Komandorsky, Kamtchatka, Ryukyus-Nankai, Halmahera, N-Melanesian, Vitiaz, Pocklington, New Britain-San Cristobal (incl. S-Solomon), New Hebrides, Ambrym (incl. Pentecost-Maeowo), Sunda
	Fault(s) neoformation	C- & W-Aleutians, Bowers Ridge, Taiwan E-coast, Philippines, Tolo, Samoa-Gilbert-Ralik, N-Solomon, Ambrym (incl. Pentecost-Maeowo), Tonga-Kermadec, N-Panama, Muertos, Nicaragua Rise, W-Mediterranean	Zenisu, Cascadia, N-Solomon, Trobriand, Sunda, Nicaragua Rise, W-Mediterranean	Taiwan E-coast, Cotobato, Philippines, Sula, Sangihe, Matthew & Hunter, N-Panama, Puerto-Rico, W-Mediterranean	Zenisu, Muertos	C- & W-Aleutians, Bowers Ridge	Cotobato, Sangihe, Halmahera, Mussau, Samoa-Gilbert-Ralik, Matthew & Hunter, Tonga-Kermadec, Sunda, Puerto-Rico, W-Mediterranean	Mussau	Zenisu, Taiwan E-coast, Samoa-Gilbert-Ralik, Ambrym (incl. Pentecost-Maeowo)	Halmahera, Ambrym (incl. Pentecost-Maeowo), Tonga-Kermadec, Sunda

SI reached stage : incipient-diffuse, incipient-localized, **achieved**, *self-sustained* - Present SZ status : active, aborted (when self-sustained stage was never reached), extinct

Deformation style at subduction initiation. Lines indicate the deformation mode at the time of subduction initiation. Columns list the spatial expression of the deformation at initiation. SC = Spreading Center; TF = Transform Fault; NF/DF = Normal Fault or Detachment Fault; SZ = Subduction Zone. Note that some SZs satisfy several settings or triggers either because there were multiple settings or triggers acting simultaneously or because initial settings or triggers are debated. Colors and underlining codes are the same as in previous Table.

Below is an example of data processing (respective age and nature of subducting and overriding plates at the time of subduction initiation). The manuscript, submitted next month at Earth-Science Reviews, will provide details for each subduction initiation occurrence as well as an analysis of various characteristics (see slide 1) and some conclusions related to the physics of the processes.
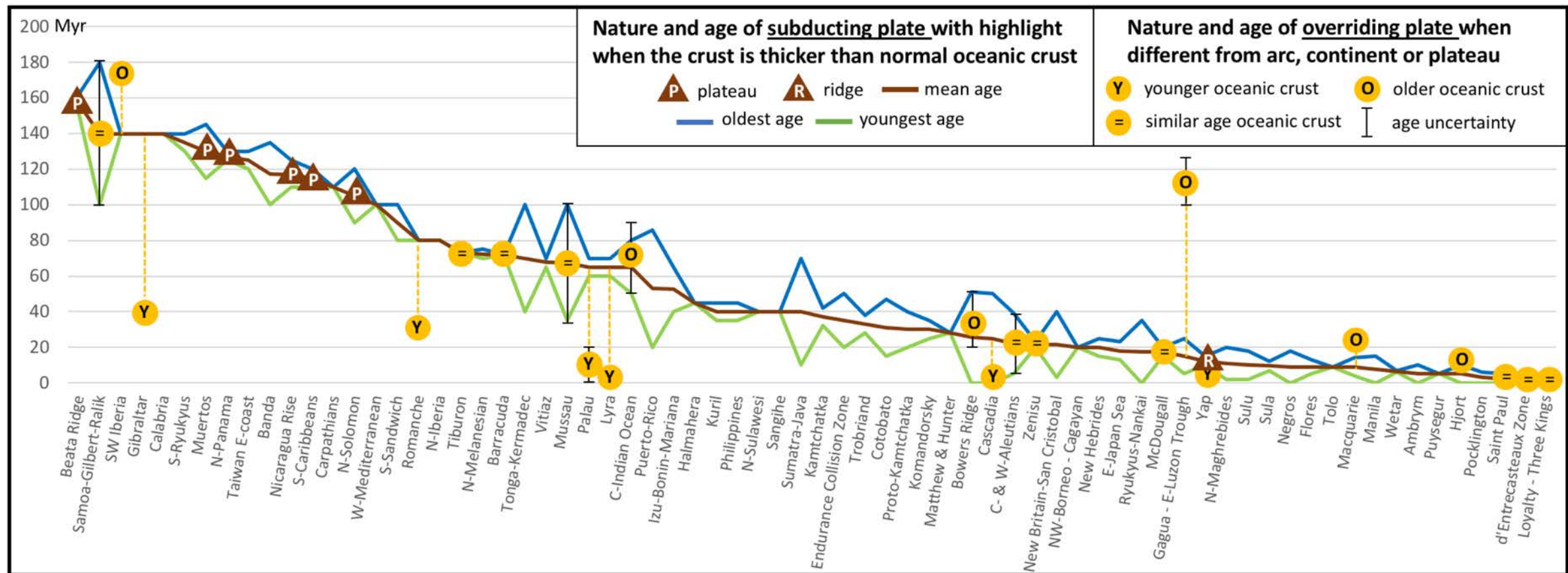
Distribution of ages of subducting plates in Ma and in descending order. When the oceanic crust is thicker than normal, the label P or R means plateau or ridge. A majority of overriding plates have an arc or a continental composition. For those having a typical oceanic composition, their age appears with yellow dots. O, Y and = mean that the overriding plate is respectively older, younger or has a similar age than the subducting plate. The length of the yellow dotted lines increases with the age contrast between the overriding and the subducting oceanic plates.