SE Asia

Backarc Basins

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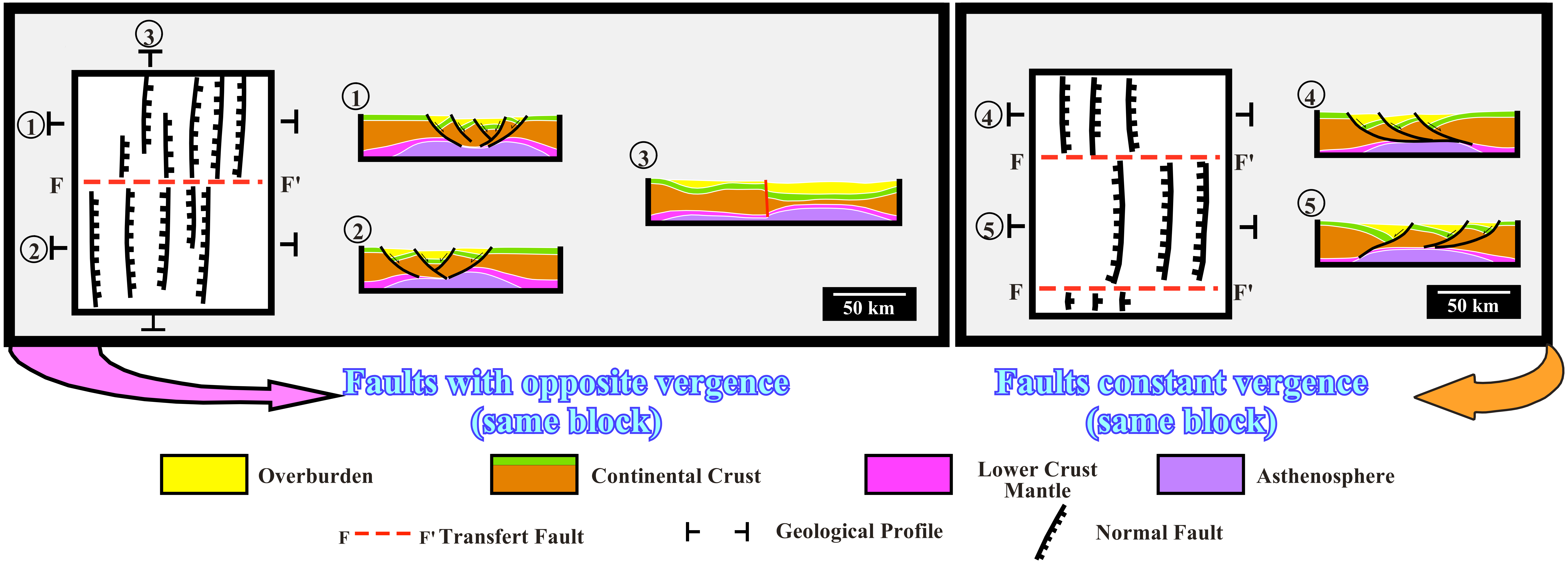
Back-arc Rifting Phase

1) Formation of Grabens

2) Formation of Half-grabens



During the rifting phase of a back arc basin, the continental crust is lengthened by normal faults and filling up, in association with a differential subsidence, by non-marine sediments either fluvial deltaic or continental. Marine deposits are possible, but they are exceptional. The extension of the crust is induced by listric normal faults (faults flattenning in depth). Very often such a fault end in transfert zones, These faults are often incorrectly interpreted as strike slip faults. Generally, they are localized in pre-existing fracture or discontinuity zones. These geological sketches, taken from A. Bally (1985), allow explorationists to tentatively correct a large number of obsolet and fallacious seismic interpretation that have been proposed on Indonesian seismic lines. Frequently, organic-rich lacustrine deposits, that is to say, potential source-rocks, are deposited during the rifting phase particularly when the rate of extension is higher than the rate of sedimentation as explain later. The recognition and mapping of transfer faults is a key to map the potential petroleum systems.

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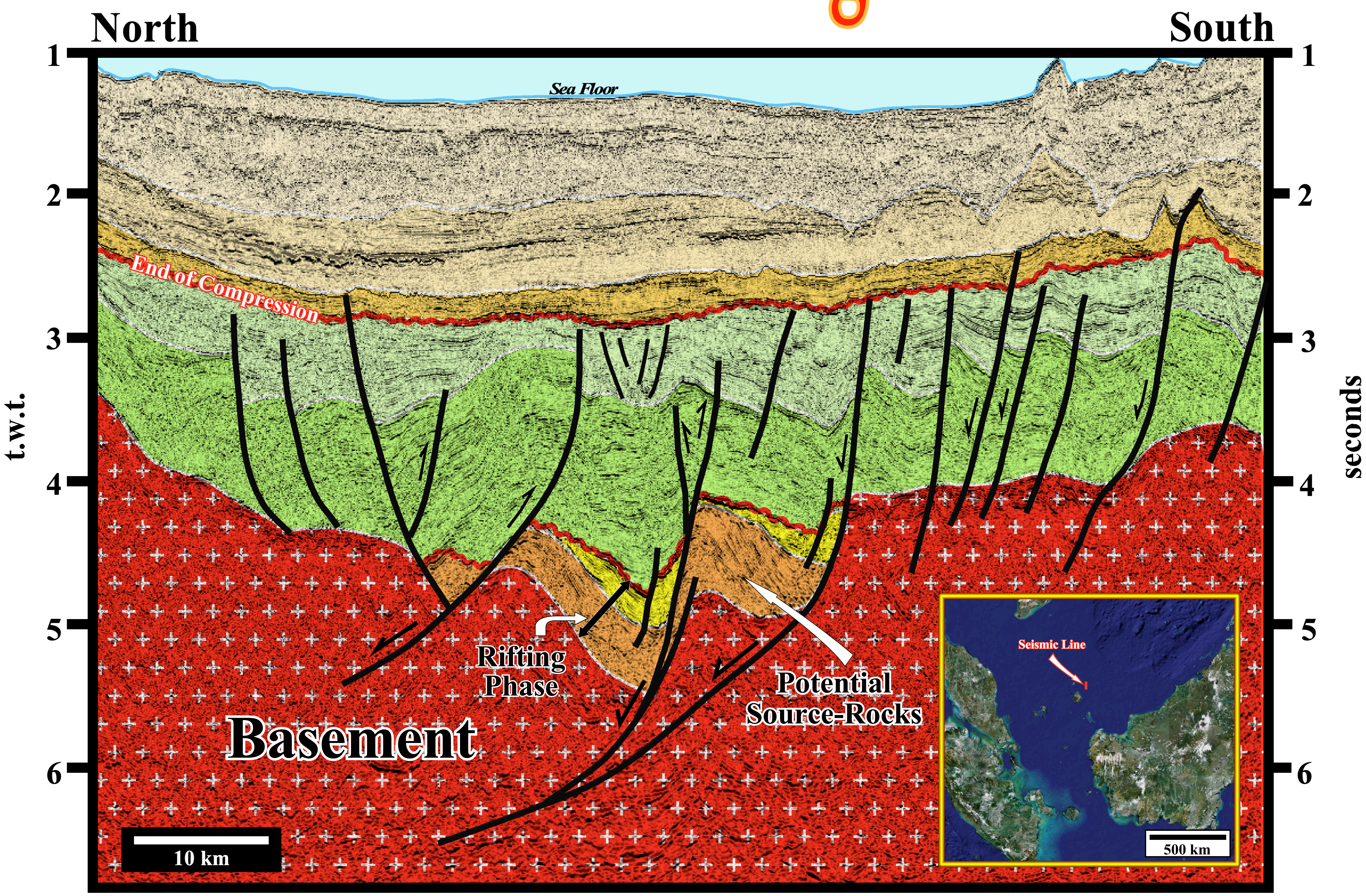
Back-arc Rifting Phase



In this tentative interpretation (all seismic interpretations proposed in these notes are just conjectural interpretations which should be tested in order to progress by trial and errors), of seismic line from the offshore Indonesia, the rifting phase of the back-arc basin is easily recognized in the central part of the line, where listric normal fault created half grabens in the continental crust. The lengthening associated with the relative movement of the faulted blocks gave accommodation for deposition of non-marine sediments and, likely, to organic-rich lacustrine shales. Such a potential source-rocks are probably associated with the deepest orange seismic interval since its internal configuration is parallel, that is to say, shaleprone (see next).

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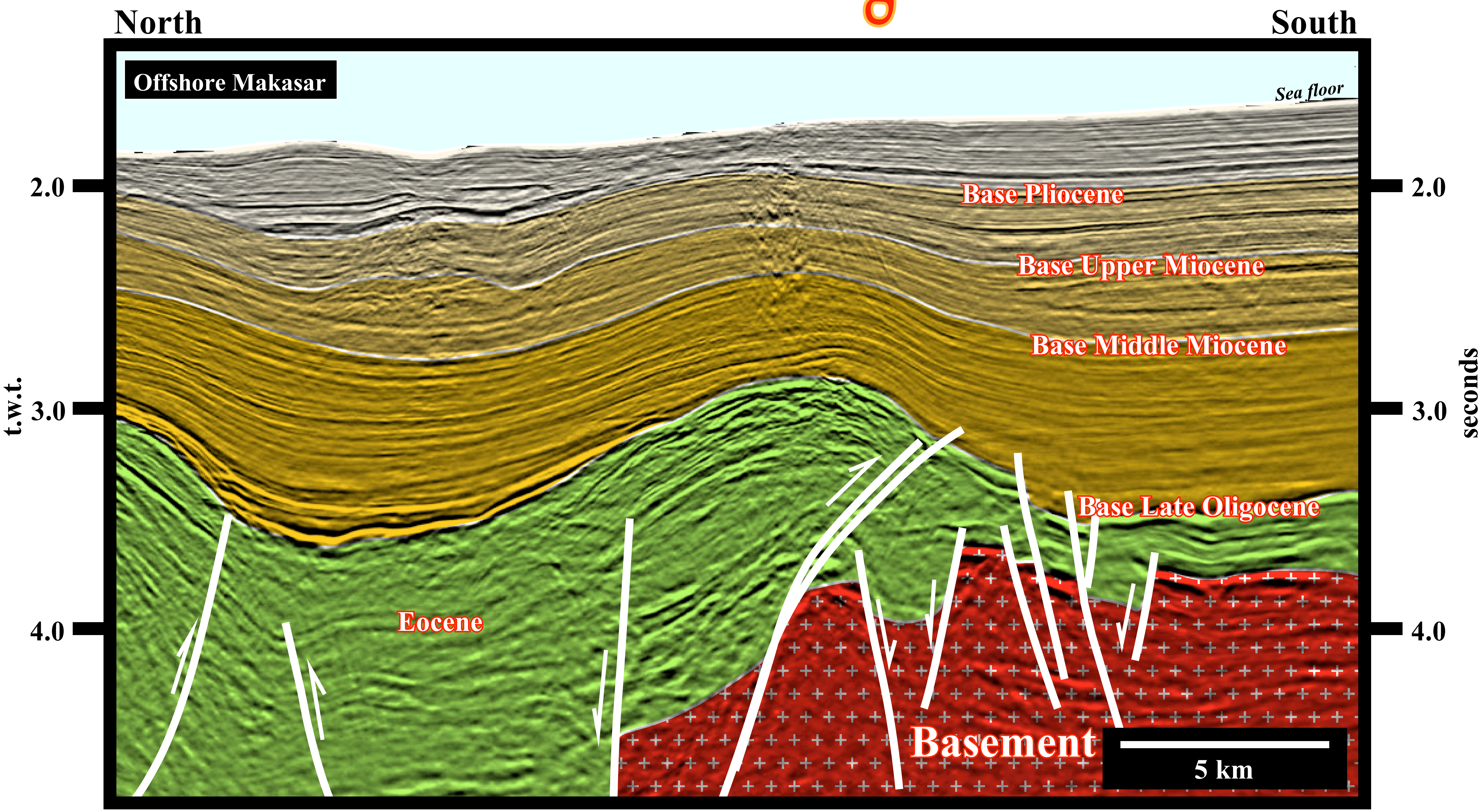
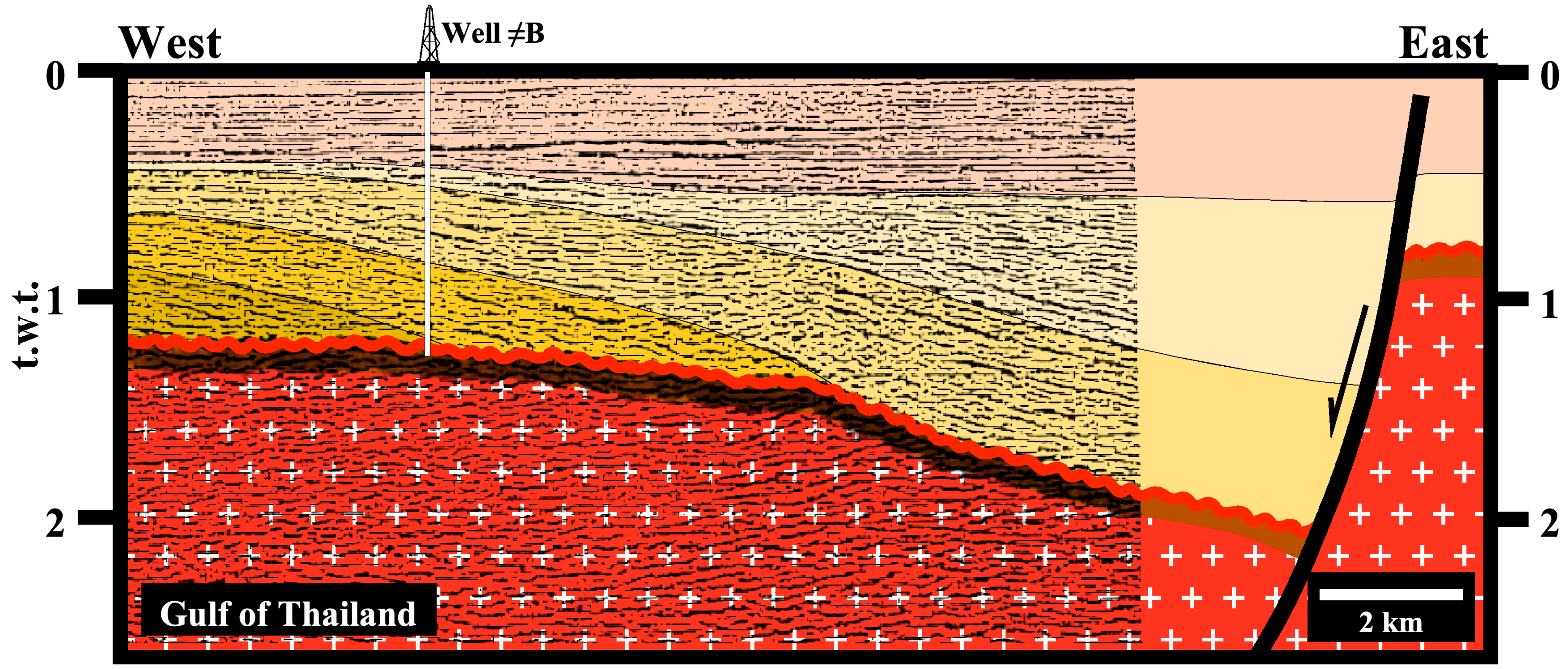
Back-arc Rifting Phase

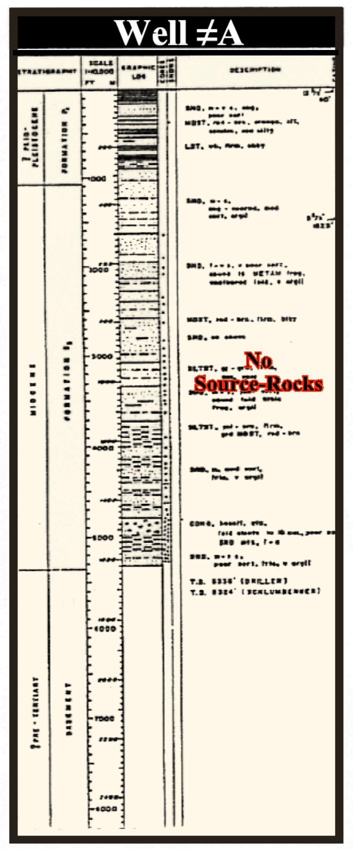


In this tentative interpretation of a seismic line, the Eocene lengthening of the back-arc north Makassar area is easy recognized under the seismic interval of the sag phase and non-Atlantic margin sediments. As illustrated, a Neogene compressional tectonic regime, reactivated the normal faults developed during the rifting phase were reactivated creating large anticline structures particularly when the direction of the maximum effective stress was orthogonal to the strike of the faults.

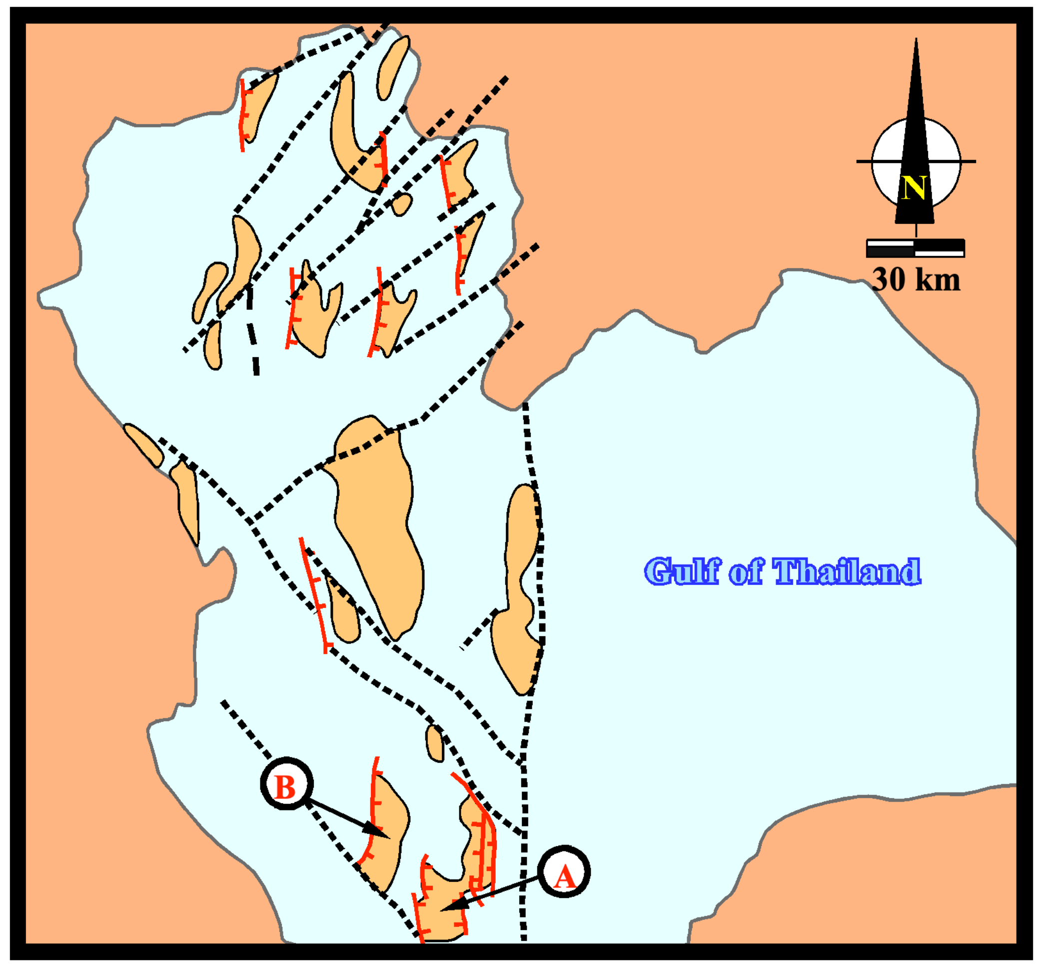
Back-arc Basin Source-Rocks

Seismic Line A

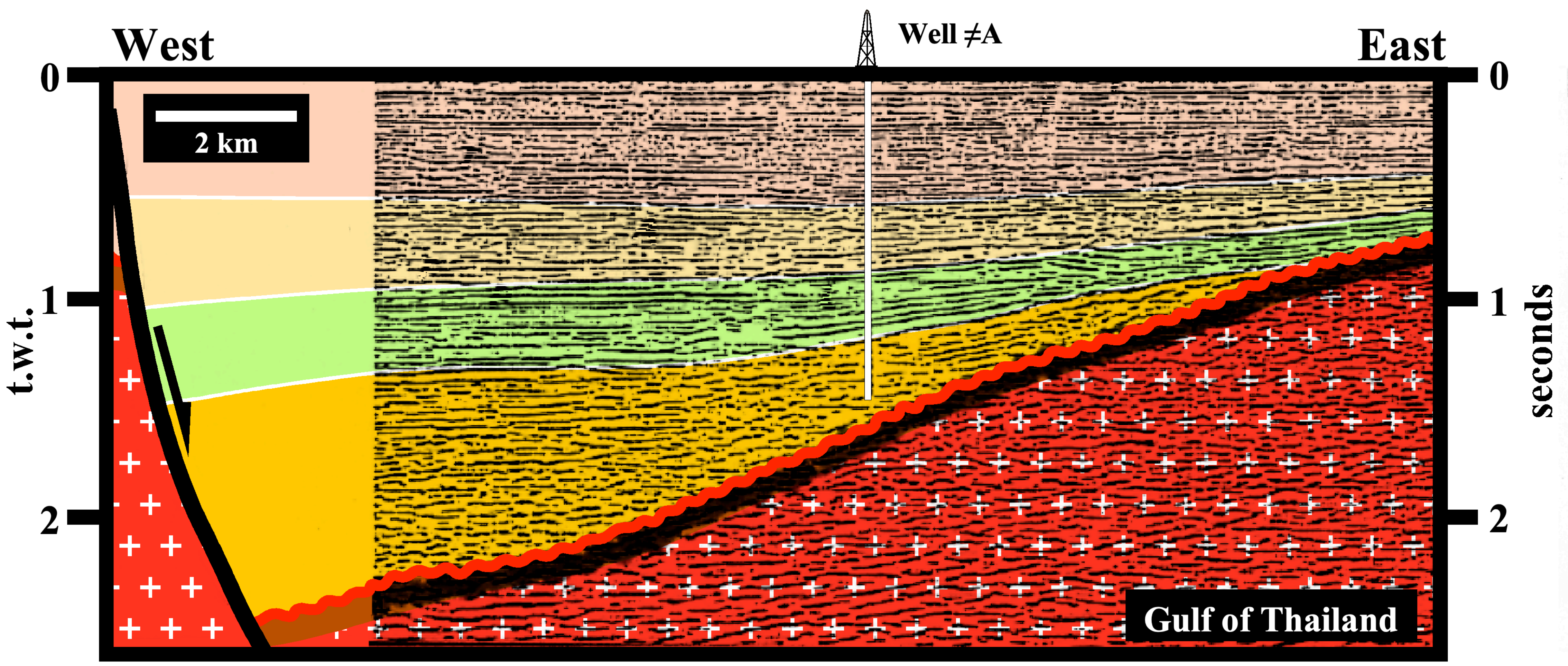


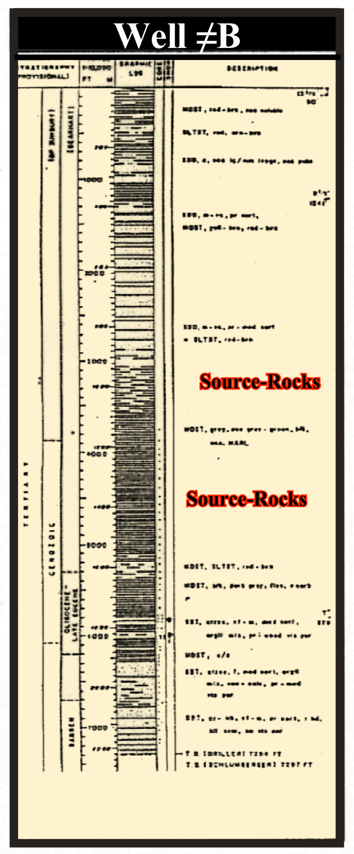


Location Map



Seismic Line B





The main generating petroleum subsystems of the back-arc basins is associated with the lacustrines shales deposited during the rifting phase. Beside favorable climatic conditions, the organic-rich lacustrine shales, deposited in the half-grabens, obey to the following geological conditions: (i) the half-grabens must be large enough to avoid a predominant transversal filling, i.e. terrigeneous influx from the norders of the basin; (ii) the rate of extension should not be balanced by the rate of filling, that is to say, to get lacustrine shales a lake in a *sina qua non* condition; (iii) the terrigeneous influx should not fill all available space for the sediments created by the subsidence, in other words, the seismic intervals of the rift-type basin should not present all a divergent internal configuration.

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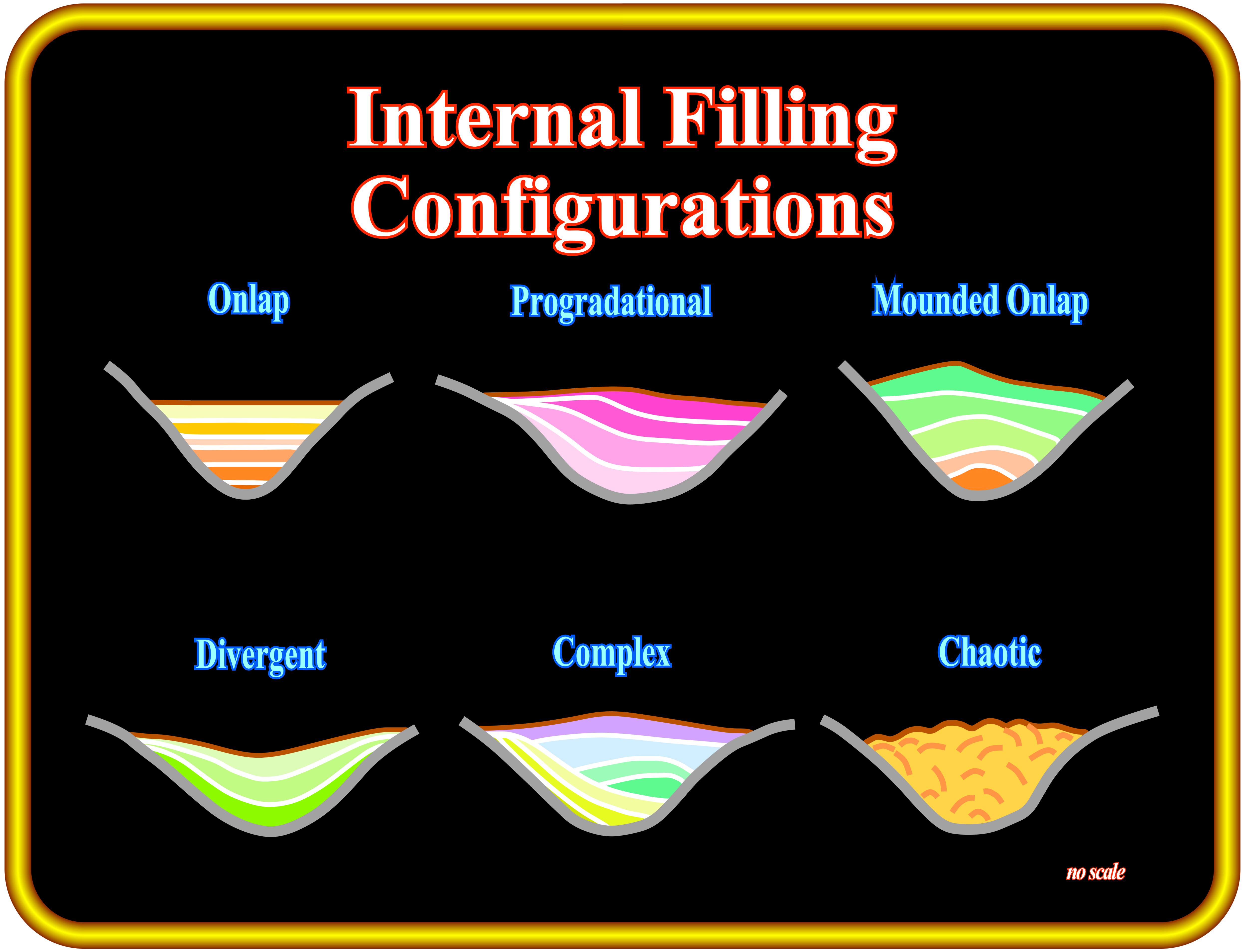
Back-arc Basin Source-Rocks



In rift-type basins, several filling configurations are possible. However, just two allow the development of large enough lakes to avoid lateral filling and to consent the deposition of organic-rich lacustrine shales: (i) the onlap filling, with a parallel internal configuration and (ii) the mounded onlap filling, which is a variation of the first one. At the onset of an onlap filling, a significant water depth is created (rate of the extension higher than the rate of filling). Then, as sedimentation takes place, the water depth decreases. In contrast, during a divergent filling, the water depth stays always unimportant: At each accommodation increasing deposition takes place. Summing up, in an onlap filling, the water depth of sediments charging the initial bathymetric anomaly becomes smaller to the top, while in a divergent filling the water depth is constant and small because there is no initial bathymetric anomaly.

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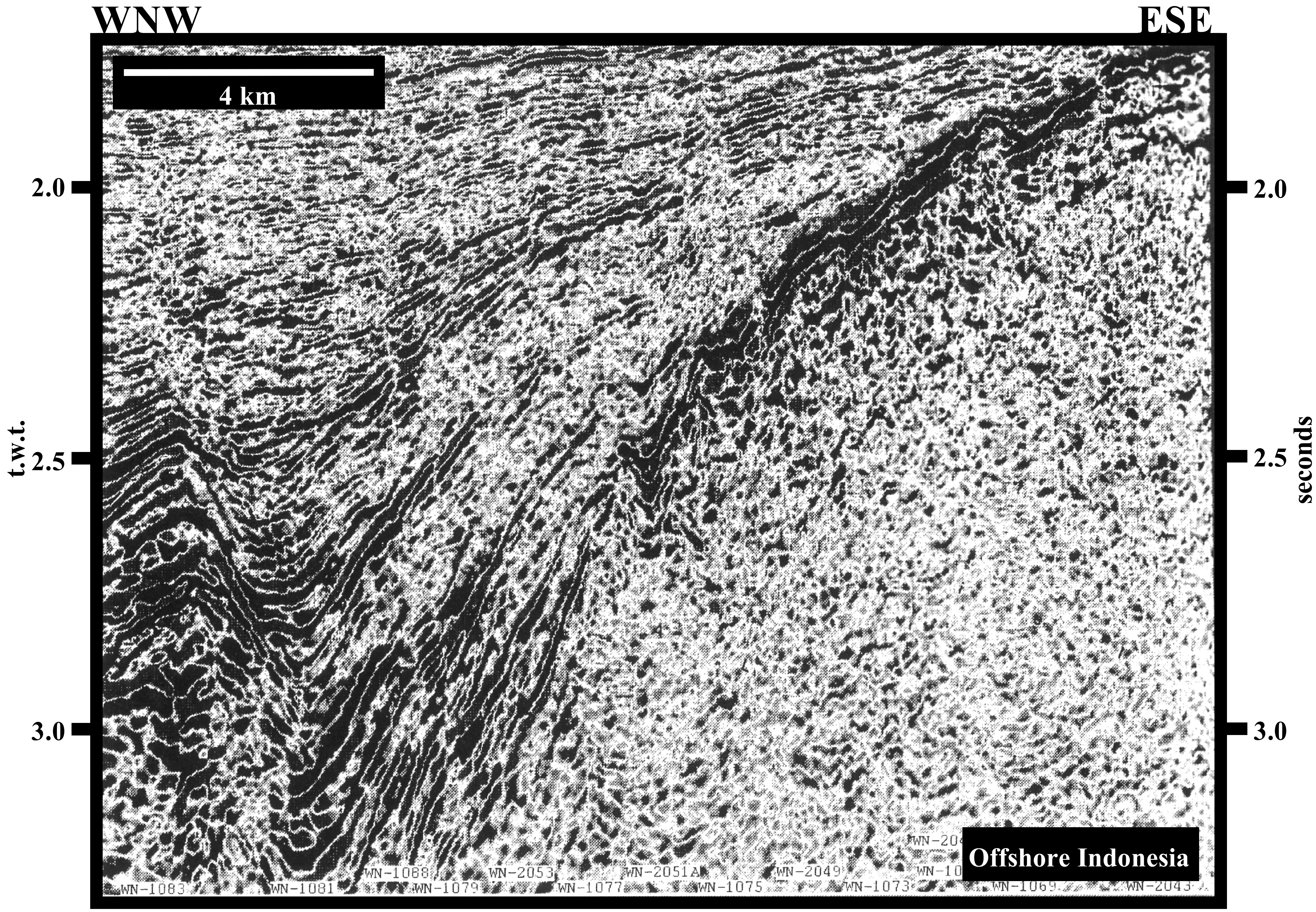
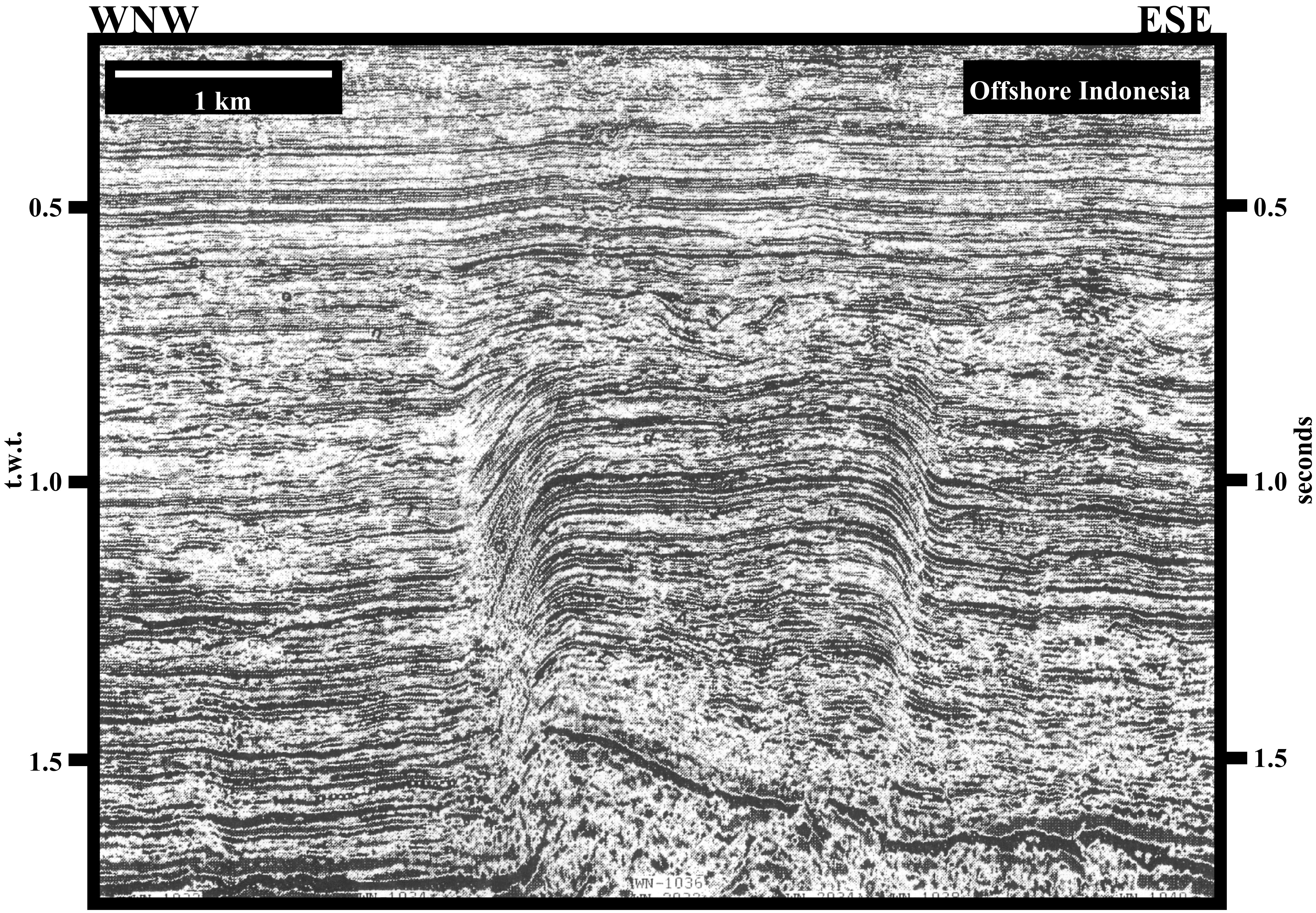
Back-arc Basin Source-Rocks



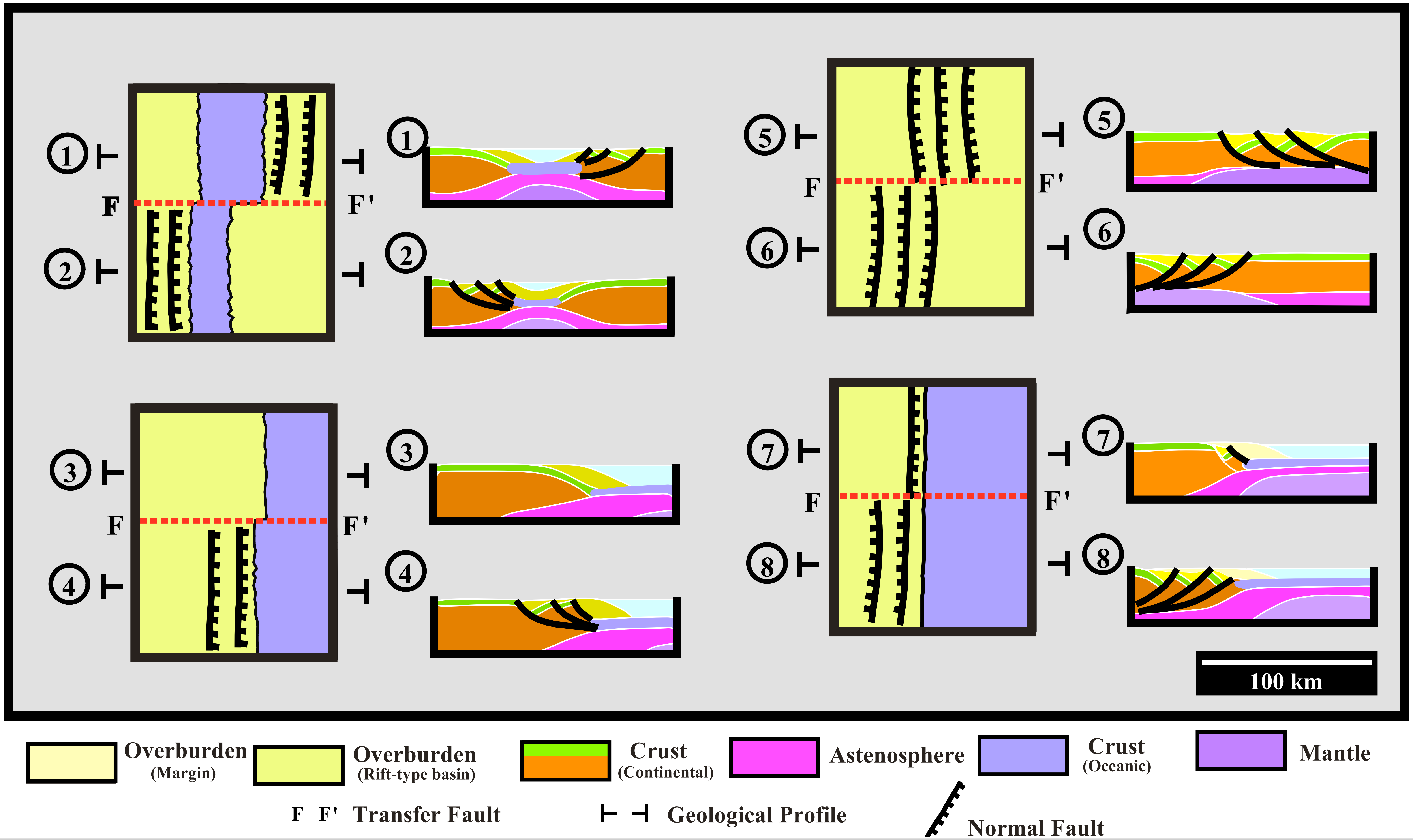
On this seismic line, within the rift-type basin, the probability of find organic-rich sediments (lacustrine), which could be considered as a potential generating petroleum sub-system, is quite small. The internal configuration of the sediments filling the half-graben is without any doubt divergent. The seismic intervals thick toward the normal fault bordering the half-graben, which means that the extension was, every time, balanced by deposition. Under such a conditions, the facies of the sediments has is likely sandprone.

Back-arc Basin Source-Rocks



In spite of the fact that the rift-type basin is here completed inverted, it is quite easy to realize that the seismic interval composed by the infilling sediments has a parallel internal configuration. Such a geometry suggests that the depositional water depth of the sediments filling the original half-graben was decreasing as sedimentation took place. In such a geological conditions, there is a significant probability that lacustrine organic-rich sediments were deposited, in this half-graben, during the rifting phase of the back-arc basin.

Back-arc Margin Phase



When the extension during the sag phase is big enough oceanisation takes place with individualization of new lithospheric plates and formation of new oceanic crust, which can be subaerial in the onset of the oceanization. The geological profile of these non-Atlantic margins is function of the breakup model and the orientation of the breakup zone breakup. These sketches explain quite well how the geometry of the sediments of a back-arc basin, with oceanisation, can change from each side of a transfer fault. In addition, as depicted, it is easy to understand that the hydrocarbon potential can be completely difference when a transfer fault is crossed.

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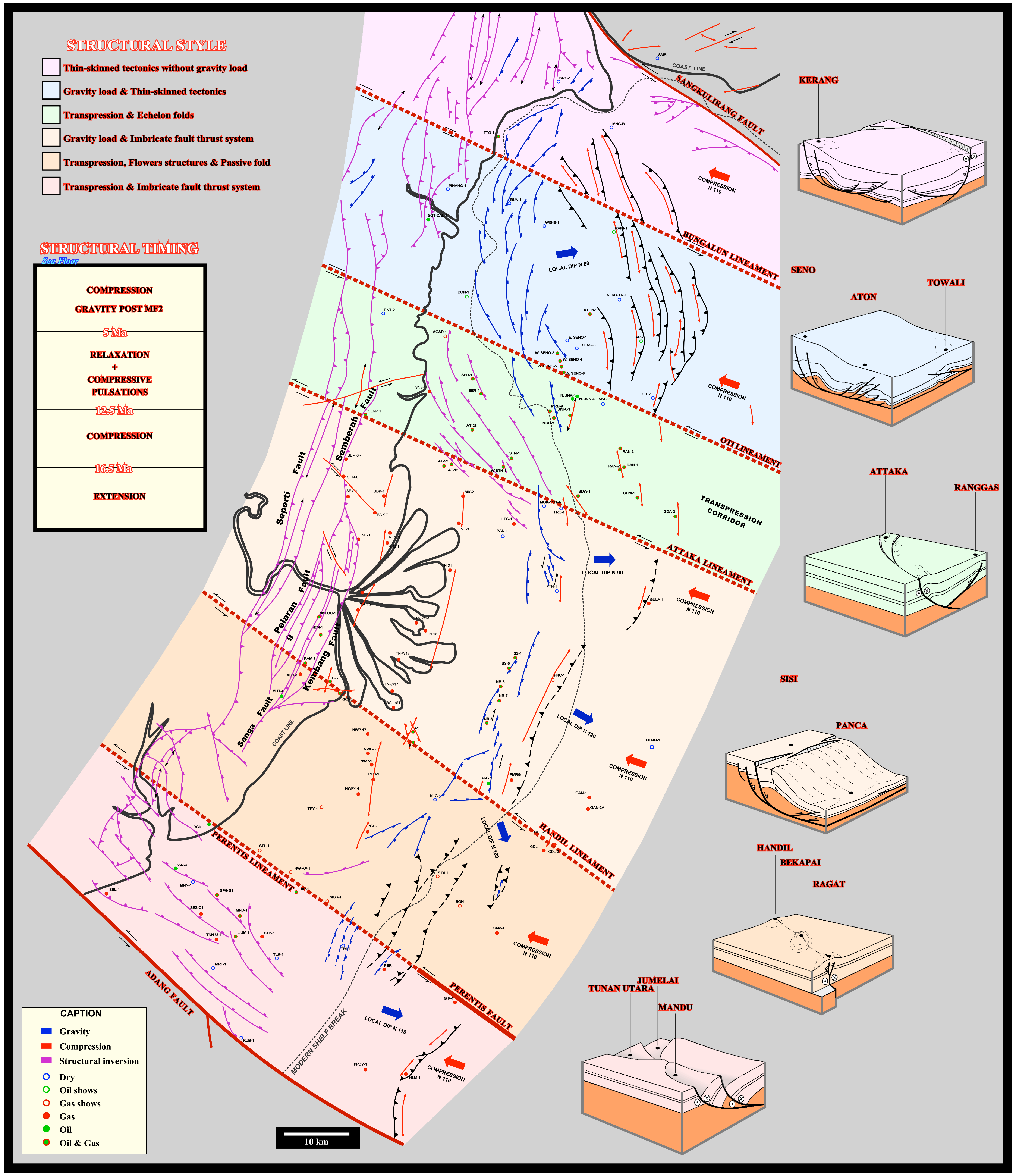

Back-arc Fracture Zones

(Kutei Basin)

As depicted here, the six structural provinces, in which the offshore Mahakan (Kutei basin) can be subdivided, are limited by tectonic lineaments related to the major transfert faults affecting the substratum and controlling the rift-type basins developed during the rifting phase (and the new formed oceanic crust). Even assuming that the main generating petroleum system (source rocks) is associated with the sag phase or with the non-Atlantic margin, i.e. that it is independent of the potential source rocks of the rift-type basins, one can say that the deep transfer faults, which, often, correspond to reactivated old fracture zones, control the migration entrapment petroleum subsystem of this offshore. In fact, these geological tectonic provinces correspond roughly to petroleum provinces.

Regional Tectonic Evolution

(North Australia / SE Asia)

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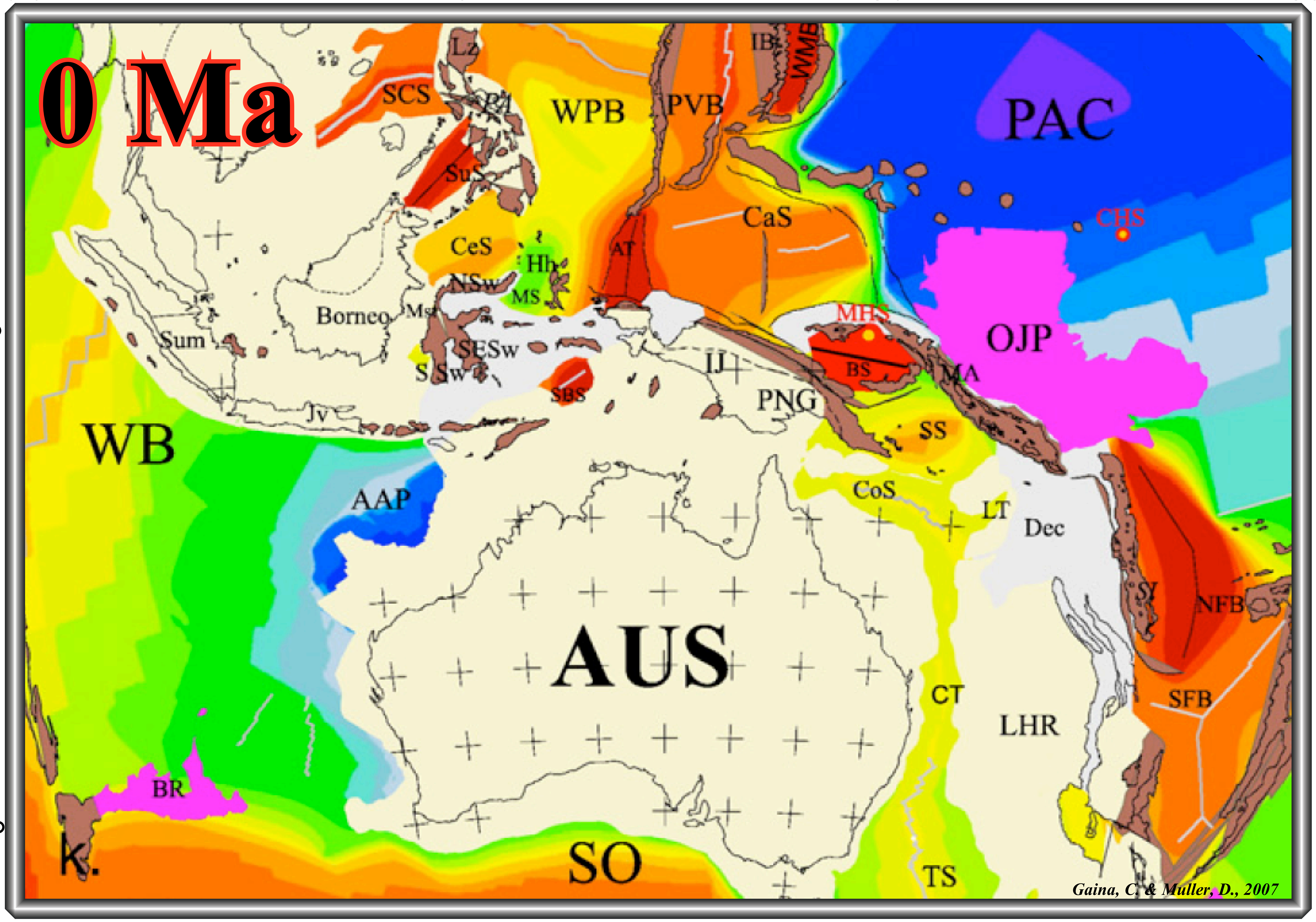
Present Time

AUS- Australia
PAC- Pacific Ocean
IND- Indian Plate
EUR- Eurasia
LUZ- Luzon
NCR- North Caroline Basin
NLB- North Loyalty Basin
NCS- North China Sea
NPB - North Philippine Plate
NSW- North Sulawesi Arm
SPB- South Philippine Plate
SLB- South Loyalty Basin
SIL- Solomon Island
SCR- South Caroline Basin
SI- Sulu Island Arc
WB- Wharton Basin
SO- Southern Ocean
WPS- West Philippine Sea
PVB- Parece Vela Basin
WMB- West Marianne Basin
Su - Sulu Sea
CeS- Celebes Sea
MSt- Makassar Strait
MS- Molucca Sea
SBS -South Banda Sea

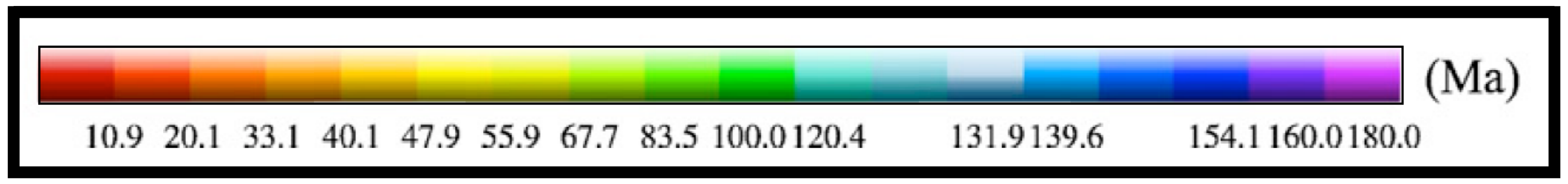
90° 120° 150° 180°

0° 0°



-30° -30°

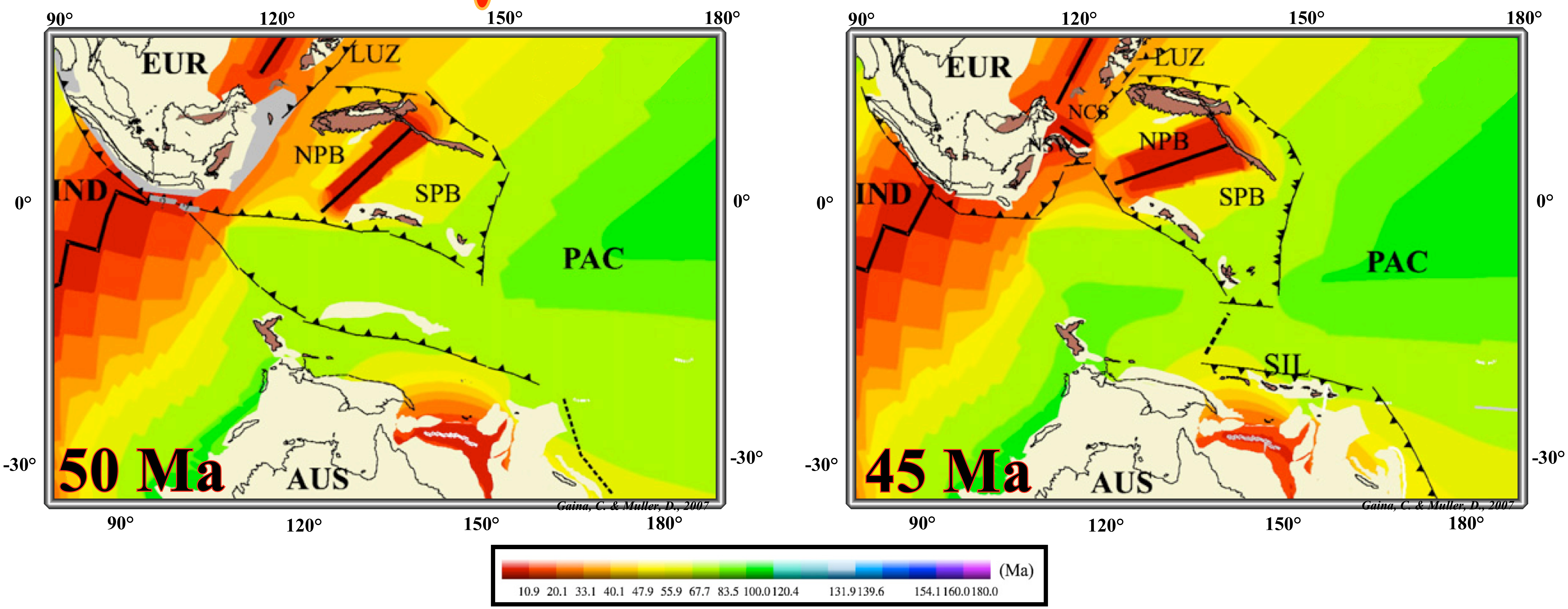
90° 120° 150° 180°



Legend

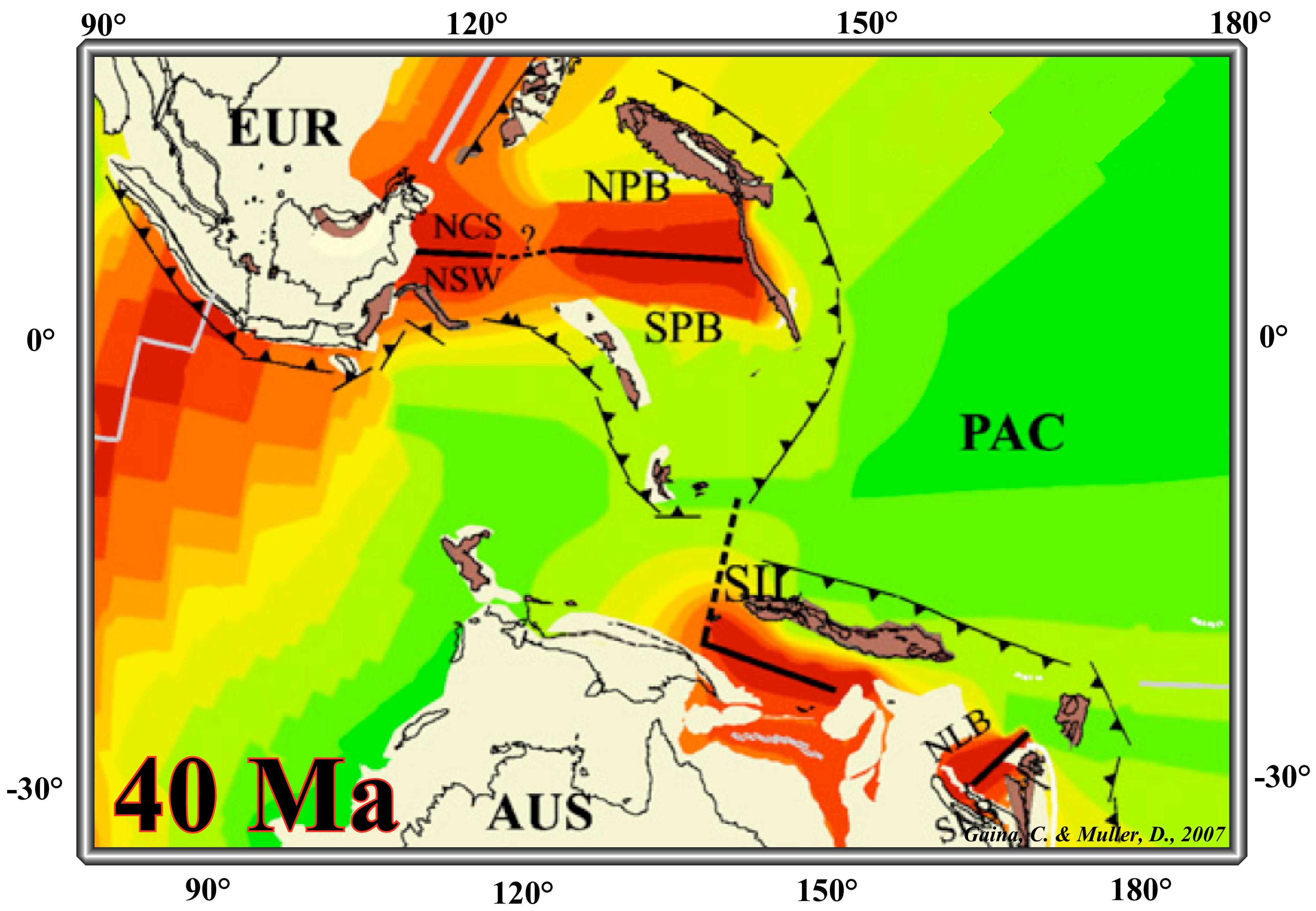
- Continental Blocks
- Present day Coastline
- Insufficient data
- Active plate boundaries
- Active plate boundaries
- Large Igneous Provinces
- Island Arcs
- Hotspots

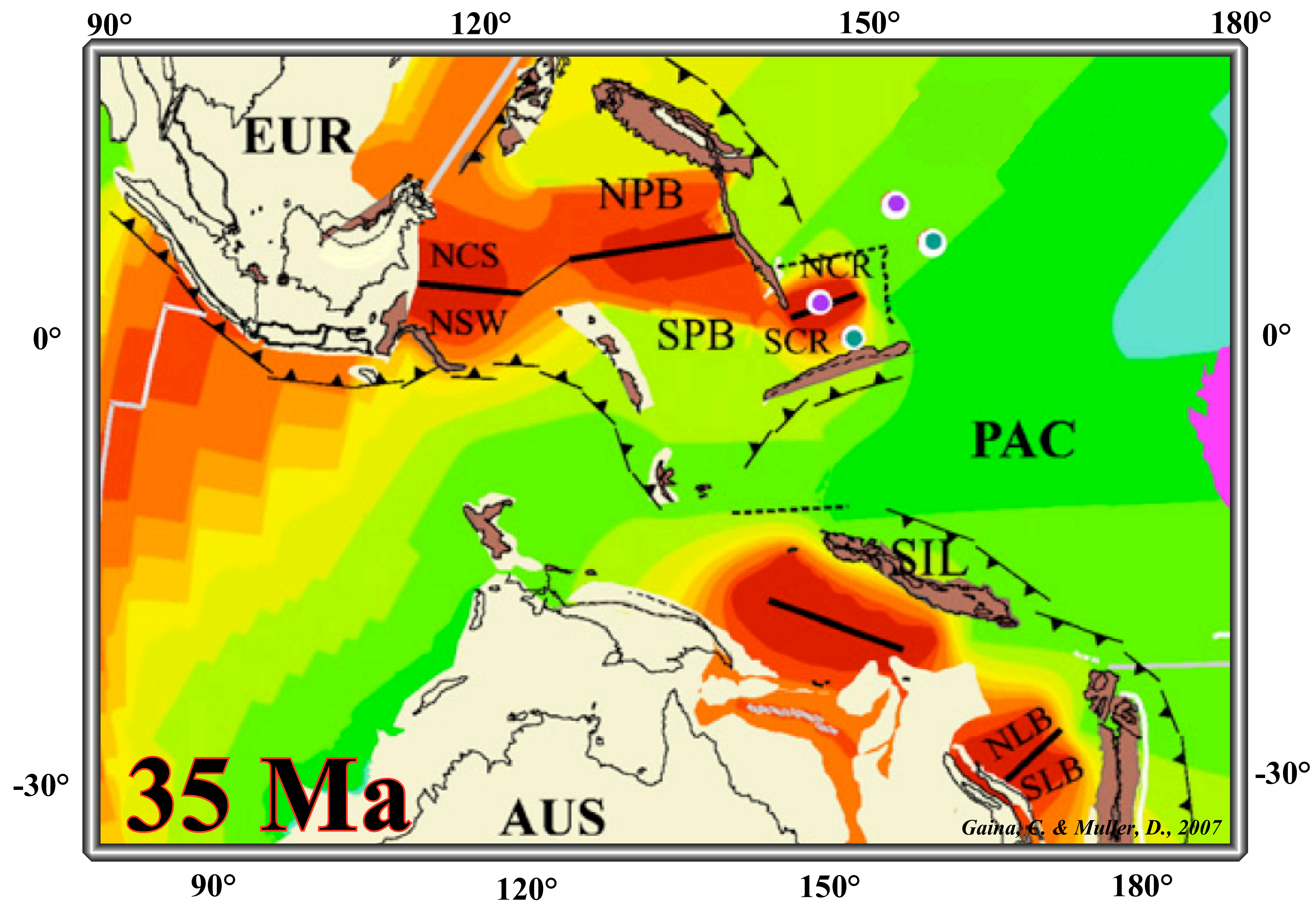
Early Eocene - Middle Eocene

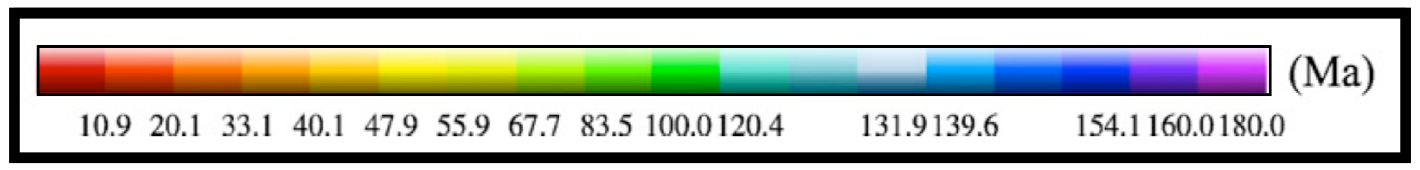


At the beginning of the Late Cretaceous the N and E margins of AUS switched from active to passive margins due to a change in the absolute motion of the PAC. A scenario of continuous K/T subduction along Indonesia, based in mineral ages of Barisan Mountains, seems to be corroborated by seafloor magnetic anomalies in the eastern Indian Ocean. Despite the suggestion that subduction under E. Java terminate in Early Cenozoic due to a collision with an AUS derived terrane, all other data support long-lived Sunda-Java subduction since the Late Cretaceous. In the early Cenozoic a series of trenches was initiated in the W. Pacific and a new back-arc basin, the western Philippine sea was formed. Several tectonic events, both in the Indian and West Pacific realms appear to cluster around mid-Eocene time. The presence of a single northward subduction zone NW of AUS under the Philippine Sea plate, where old Pacific crust subducted rapidly, might have determine the change in the northward movement of the AUS at higher speed at about 44 Ma. Shortly after 50 Ma, due to the rearrangement of the location of the northward subduction under the Philippine plate and Sundaland, a new trench formed south of northern arm of Sulawesi and a new back-arc (Celebes Sea basin) started opening west of the West Philippine Sea. The southward subduction of the PAC under the NE AUS gradually created the Melanesian Arc by arc volcanism.

Middle Eocene - Upper Eocene

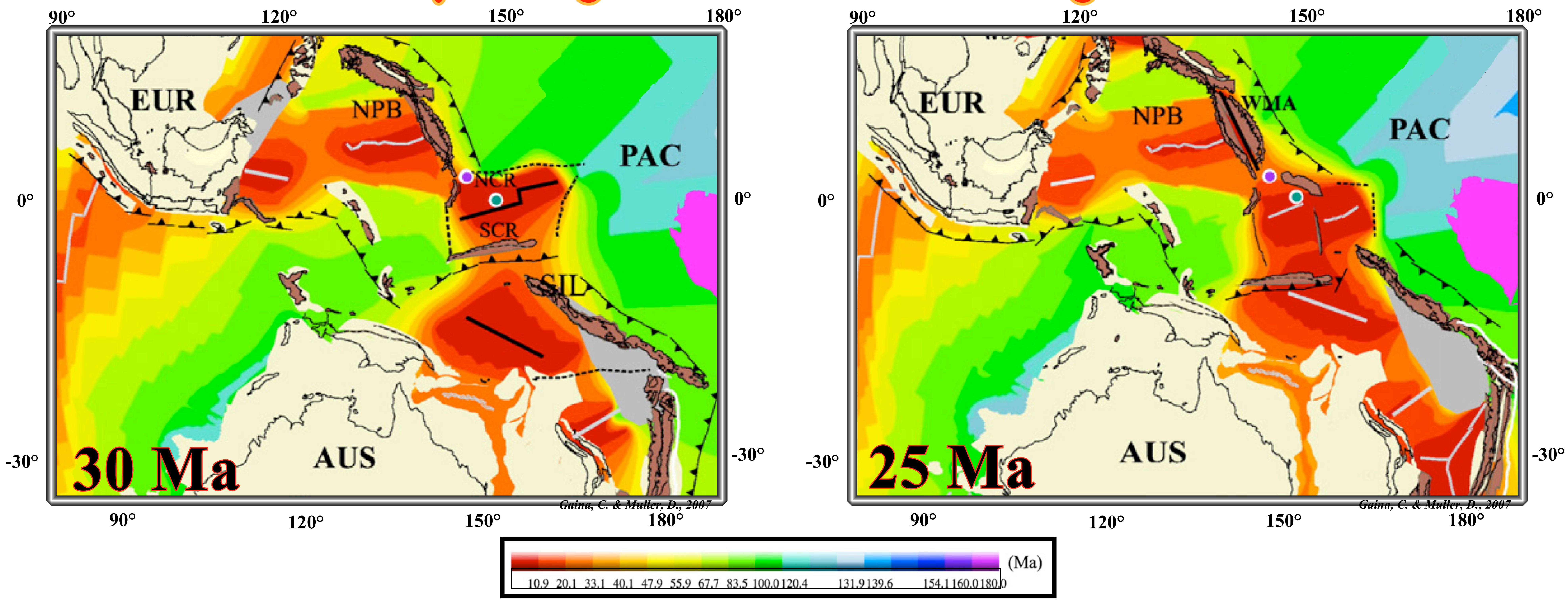






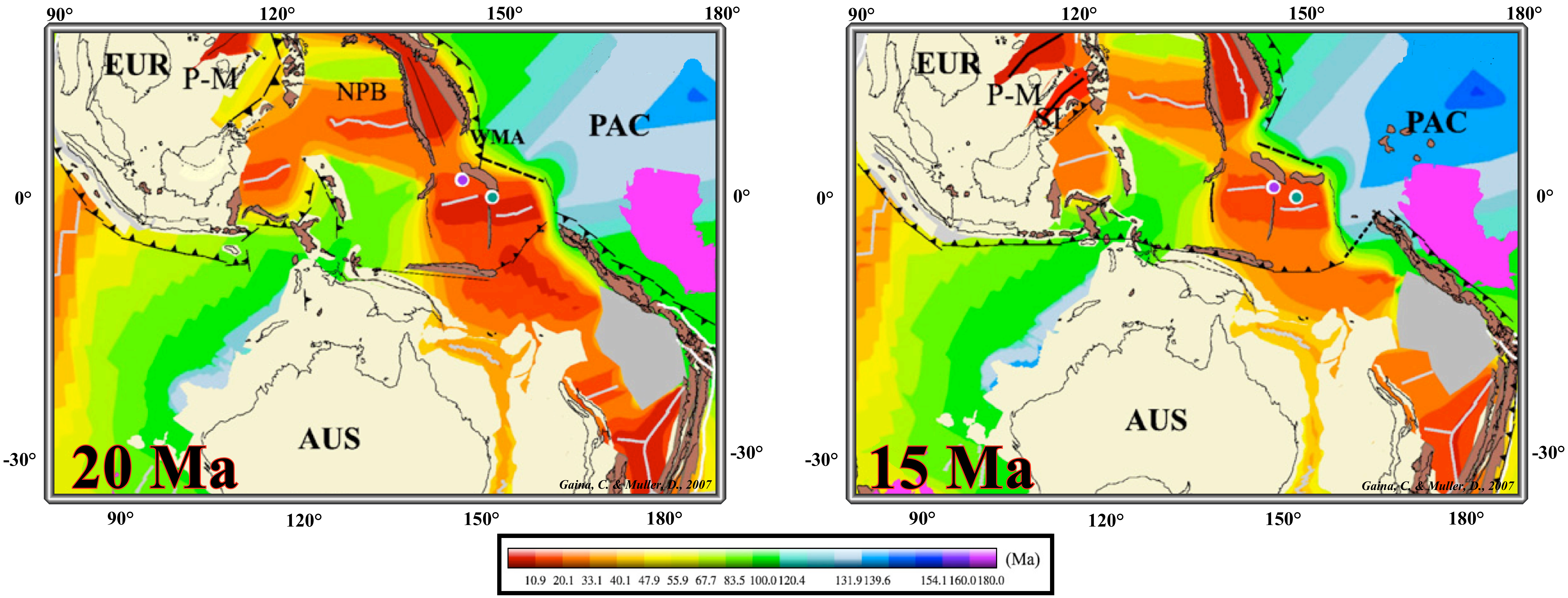
At this time, two subduction zones were present N of AUS with opposed polarities. In the NE southward subduction led to the opening of the Solomon Sea and in NW northward subduction, under the Philippine Sea arc, consumed old Pacific crust. The two subduction zones were probably connected ba a transform fault. The northward subduction under the Philippine arc created another volcanic chain, the Caroline arc, and around 36 Ma, seafloor spreading started in the west and at 34 Ma in the east Caroline basin. During the evolution of the Caroline Sea basin, the two trenches may acted as convergent boundaries. The Palau Arc probably has the same origin as the Palu-Kyushu Ridge, which is situated east of the west Philippine Sea basin and has been formed around Eocene time by subduction related volcanism. Seafoor spreading slowed down considerably in the West Philippine Basin 35.3 Ma and finally ceased before 30 Ma. Although there is no direct evidence for the exact timing of cessation of seafloor spreading in the Celebes Sea, it has been proposed that sea floor spreding ceased in this basin after the formation of magnetic anomaly 16 (35 Ma) in a similar fashion as in the West Philippine basin.

Early Oligocene - Late Oligocene



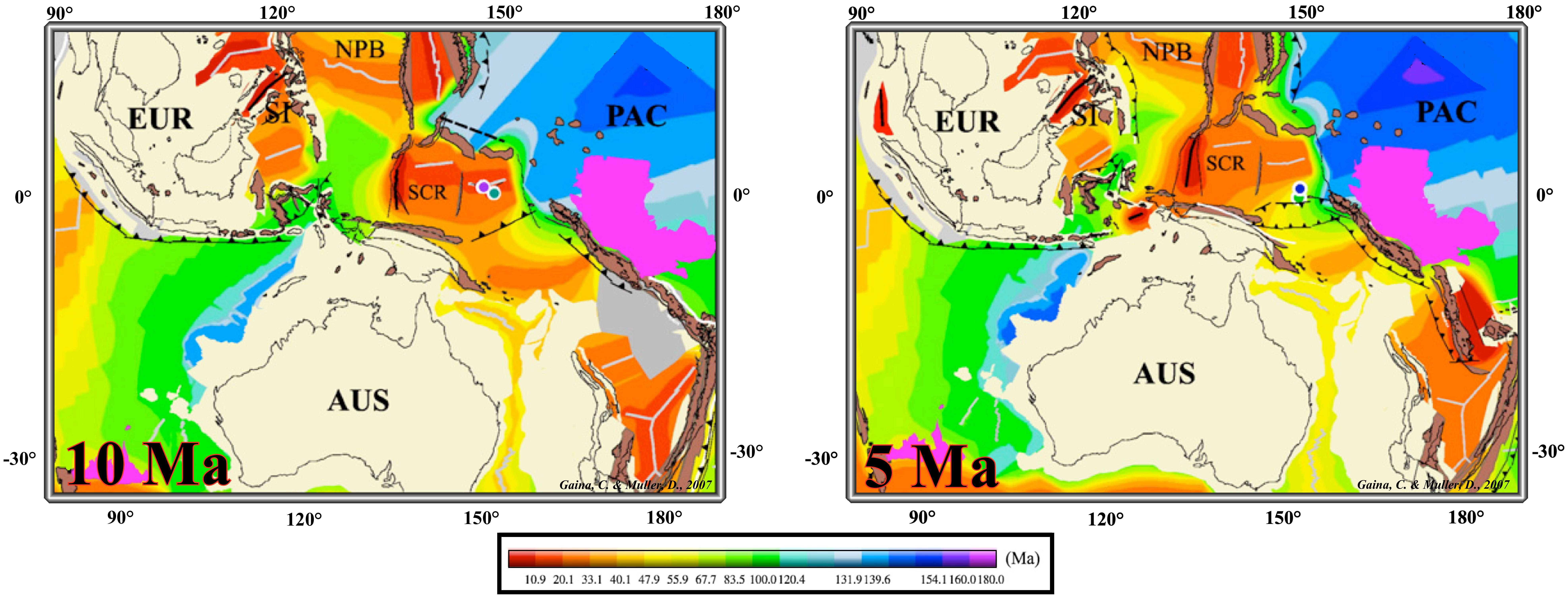
At around 30Ma seafloor spreading in the WPB ceased and the Parece Vela Basin began forming to the east with a spreading direction perpendicular to the older magnetic lineations from WPB. Seafloor spreading in the two sub-basins of the Caroline plate followed different patterns: in the eastern sub-basin symmetric seafloor spreading formed ENE-WSW oriented blocks, whereas in the western sub-basin, several northward directed ridge jumps created a highly asymmetric oceanic fabric. The rapid northward motion of AUS due to seafoor in the Southern Ocean and the northward pull of the subducted slab under the Philippine Sea plate, decreased the distance between the two tectonic plates considerably and eventually led to collision at around 25 Ma. The proximity of the Ontong Java Plateau at around 25 Ma will also preclude the subduction rollback that led to the clockwise rotation of the Melanesian arc and the formation of Solomon Sea. The Southern boundaries of the Philippine and Caroline plates change from trenches to strike-slip faults. The paleomagnetic data of Borneo suggests that it experienced an approximative 51° of counterclock rotation in particular from Early to Middle Miocene. However, other suggest that Borneo counterclock rotation cannot be larger than 25° in order to account for a minimum displacement relative to Java and Sumatra.

Early Miocene - Middle Miocene



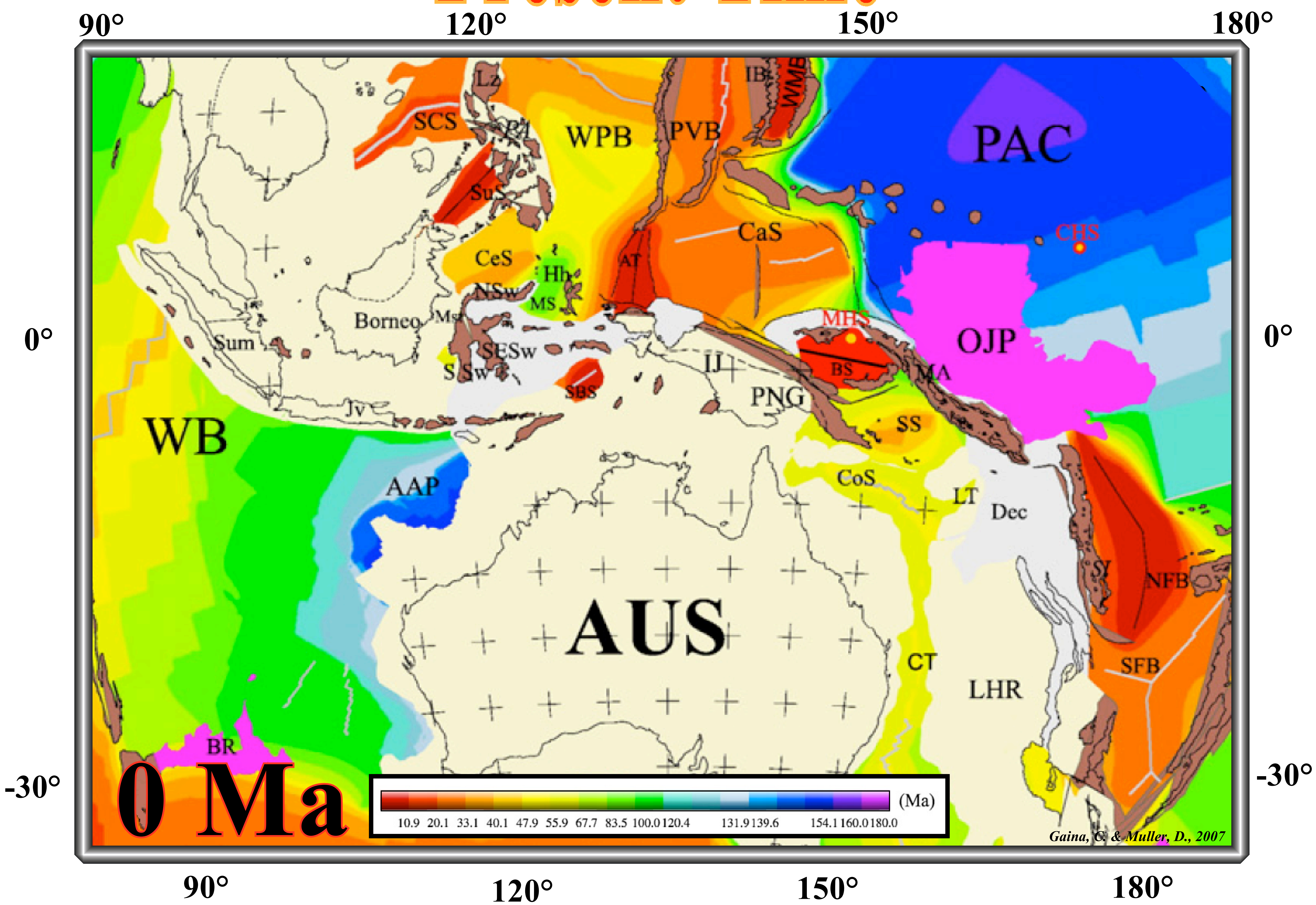
Following several million years of soft docking between the Ontong Java Plateau and the Melanesian Arc, the northwestward direceted subduction gradually stopped and reversd its polarity, probably around 12 Ma. The Melanesian Arc became part of the Pacific plate and the Solomon Sea oceanic crust was subducted under the newly formed trench. West of the Philippine Sea plate, the Celebes also decreased in size, as a new subduction zone created north of the North Sulawesi arm, probably after collidin with the northern margin of Australia. Part of the northern Celebes Sea might have also being subducted northward due to the opening of the Sulu Sea in the Middle Miocene.

Late Miocene - Pliocene



The northern margin of the northward moving Australian plate experienced extensive compressional and strike-slip regimes due to the continuing clockwise rotation of the Philippine and Caroline plate and the subduction under the westward moving Pacific plate. This resulted in the accretion of the Caroline Arc and ophiolite subduction to the northern Papua New Guinea, thrust faulting in PNG's Mobile Belt and the almost complete subduction of the Solomon Sea and Molucca Sea under the Pacific plate and the Philippine and Celebes sea respectively. Slap pull led to the opening of the Woodlark basin east of the New Guinea, which is now subducting under the South Solomon Trench, and new back-arc basin (The Bismark Sea) started to form north of the New Britain as a consequence of a newly formed trench (The Manus trench).

Present Time



The northwestard boundary of the Caroline plate with the Philippine and Parece Vela basins (the Palau and Yap trenches) and probably the Marianne basin (at the Marianne trench) display unusually deep bathymetry (7000-10000 m) for plate boundaries with rediced subduction activity. The resistance of viscous asthenosphere against vertically subducting slabs or a rapid rollback of the subducting Caroline plate has been invoked to account for these anomalous depth. Northwestward subduction of the Australian plate along the Banda trench and soutward subduction of Bird^s head microplate along Ceram trench led to the opening of the North and South Banda basins between 12.5 and 3.5 Ma. Subduction along Timor trough decreased gradually and is considered to be almost inactive in the present day.