Tectono-stratigraphic Framework and Tertiary Paleogeography of Southeast Asia: Gulf of Thailand to South Vietnam Shelf*

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Search and Discovery Article #30246 (2012)
Posted September 24, 2012

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG International Conference and Exhibition, Singapore, September 16-19, 2012, AAPG©2012

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Abstract

The structure and stratigraphy for many of the rift basins in the Gulf of Thailand and southern Vietnam shelf are individually well understood. However, the understanding of the region as a whole, and the relationships from one basin to another, is less clear. Regional paleogeography maps help portray the structural and stratigraphic evolution of the basins, and when constructed with precise chronostratigraphic control, provide a constraint to the interpretations of the facies distributions in individual basins.

Accurate basement maps are key to understanding the tectonic framework. A number of published and proprietary maps of the pre-Tertiary exist, and all are different, some substantially so. Well data, seismic data and published/proprietary maps were used to hand contour basement across the region. A contour interval of 200 m was used to further constrain the maps. There are 22 Tertiary rift basins in the region (Figure 1), although some of the basins are composite basins consisting of several coalesced rift basins.

Well data, seismic data and published/proprietary maps were also used to hand contour the top of the synrift section across the region using a contour interval of 100 m (Figure 1). The age of the top synrift section varies across the map area from Middle Oligocene in the east to Early Miocene in the northwest.

Palaegeographical maps for the Oligocene and Miocene extending from the Gulf of Thailand to the Vietnam Shelf were constructed based on the succession of sequences of Morley, Swiecicki and Dung (2011). The stratigraphic framework shown in Figure 2 is color coded by the basin's tectonic activity at the time, rifting, transitional from rift to post-rift, post-rift, and inversion.

Paleogeography

Deposition during the Early Oligocene Rupelian (~28-34 Ma) including the Tien Cau (Nam Con Son Basin), Belut and Gabus (West Natuna Basin), and Seismic Groups M and Formation 0 (in South and North Malay Basin) consisted of extensive freshwater lakes and/or swamps with widespread alluvial, fluvial, and lacustrine shoreface systems developed along rift basin margins (Figure 3). In Late Oligocene Chattian (~25-28 Ma), brackish incursion extended into the Nam Con Son Basin of South Vietnam, and resulted in deposition of extensive brackish water coals in that region (Cau Formation). *Florshuetzia* acmes in the eastern NCS indicate a coastal mangrove environment. During the first half of the Chattian, fresh water lacustrine systems continue to prevail across the rest of the region (Figure 4).

Near the end of the Chattian, repeated *Miliammina fusca* occurrences in the Udang Formation indicate that brackish water transgressions are now reaching the Natuna Basin and the southern Malay Basin. The cyclicity observed in the Natuna Basin is not observed in the Malay Basin, although this has not yet been studied biostratigraphically in a manner which would allow the cyclicity to be seen and may be masked there due to deeper water conditions (Figure 5).

Widespread latest Oligocene flooding (~24 Ma), due to the sea level rise of the Late Oligocene thermal maximum, resulted in deposition of a thick marine shale (2 seismic loops) that extended through the Nam Con Son (Lower Dua) and West Natuna Basin (Barat), into the North Malay Basin (Seismic Group K and Trengganu Shale). *Miliammina* acmes dominate over fresh water algal assemblages indicate a brackish sea irrespective of sea level. No change in salinity from high to low sea levels implies there is an effective sill between the Nom Con Son and Natuna basins (Figure 6).

The Early Miocene Aquitanian (~ 21-23 mya) was characterized by slow intermittent transgression, with marine influence extending to the southernmost Malay basin at ~22 Ma (Dua and Arang and Seismic Groups J and I). The Malay Basin remained brackish (Figure 7) until the Burdgalian (Figure 8).

In the Middle Miocene, coinciding precisely with the highest sea levels of the ‘Middle Miocene thermal maximum’, open marine conditions were widespread from offshore Vietnam (Mang Cau Formation) and throughout West Natuna (Arang) and the southern Malay Basin (Seismic Group H and F). In the southern Malay Basin, the occurrence of some planktonic assemblages indicates that the water depths were reaching middle neritic. Restricted tidally-influenced marine conditions extended northward through to the North Malay (Formation 2D), and the Khmer basins. We see the first evidence for marine influence in the Pattani Basin during sea level highstands (Figure 9).

By the Late Miocene to Early Pliocene Messinian/Zanclean (3-7 mya) open marine conditions prevail across most of the Gulf of Thailand. Water depths are most-likely similar to present-day water depths of 50 to 70 meters. Deep water conditions occur in the Nam Con Son Basin (Figure 10).

Conclusions

These regional paleogeography maps can provide insight into the source and reservoir potential of the Tertiary rift basins. Algal-rich synrift lacustrine shales are proven source rocks in most of the rift basins (Figure 11). Several of the western basins were inundated with synrift clastics and did not develop lacustrine source facies. In the Nam Con Son Basin, the synrift lacustrine shales are proven, but deeply buried and generally over-cooked and therefore not a viable source rock for portions of the basin.

Both the Malay and the Nam Con Son basins have younger coaly source rocks that have contributed to the petroleum system (Figure 12). These coaly source rocks were deposited in both coastal mangroves and in extensive tidal estuarine/upper coastal plain peat swamps. In the Nam Con Son Basin the coaly source rocks are Oligocene to Early Miocene in age. In the Malay Basin the coaly source rocks are Middle Miocene in age.

Two depositional systems prevalent in the study area are conducive to the development of stratigraphic traps: tidal deltas and anastomosing river systems. Stratigraphic traps associated with anastomosing rivers are prevalent in the Pattani and North Malay basins (Figure 13). In the Malay and Nam Con Son basins, stratigraphic traps associated with tidal bars are prevalent.

Reference

Morley, R.J., T. Swiecicki, and ThuyThi-Pham, Dung, 2011, A sequence stratigraphic framework for the Sunda region, based on integration of biostratigraphic, lithological and seismic data from Nam Con Son Basin, Vietnam: Proceedings, Indonesian Petroleum Association Thirty-Fifth Annual Convention & Exhibition, May 2011, 22 p.

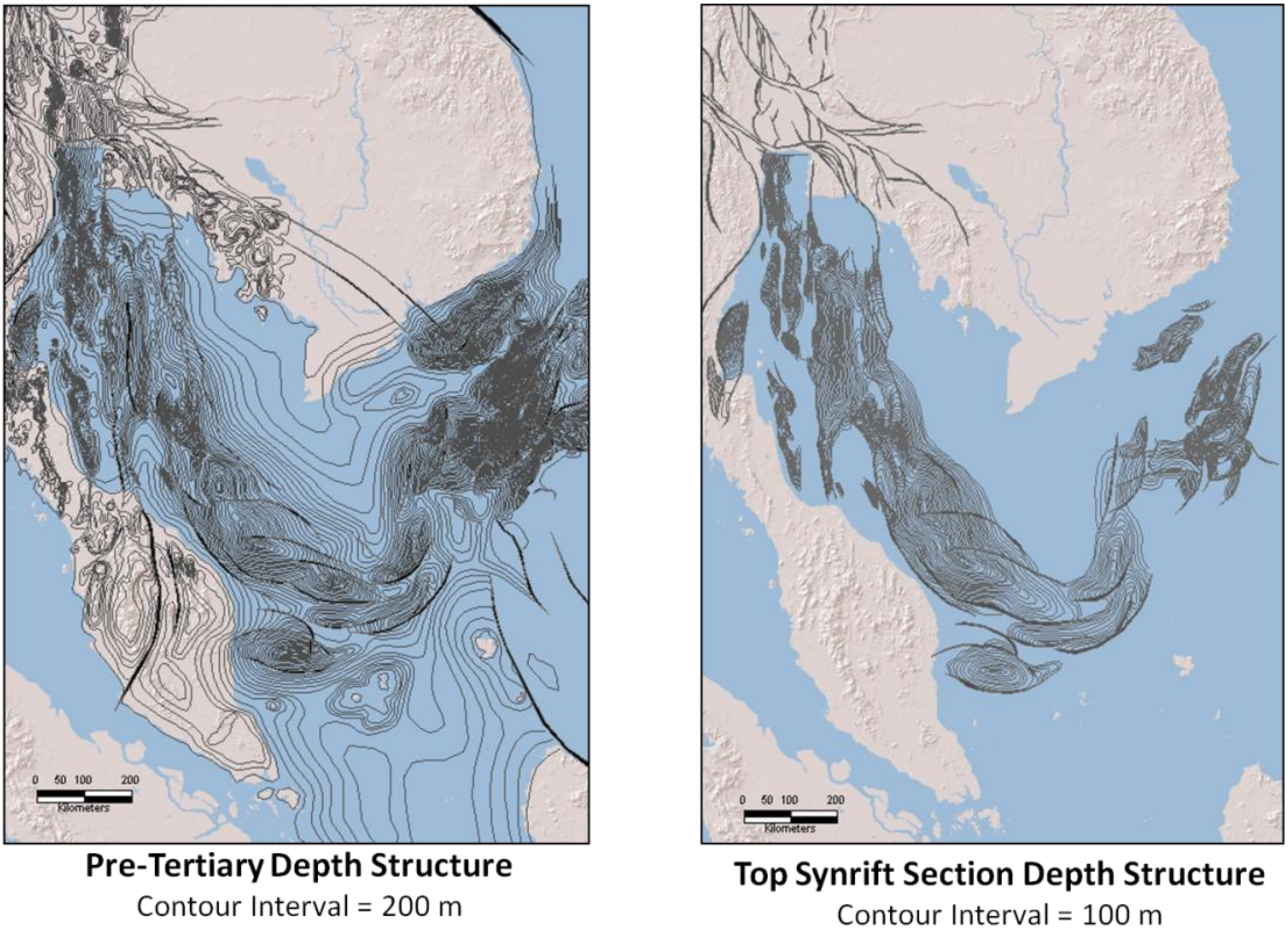

Figure 1. Depth structure maps for the pre-Tertiary and the top of the synrift section.

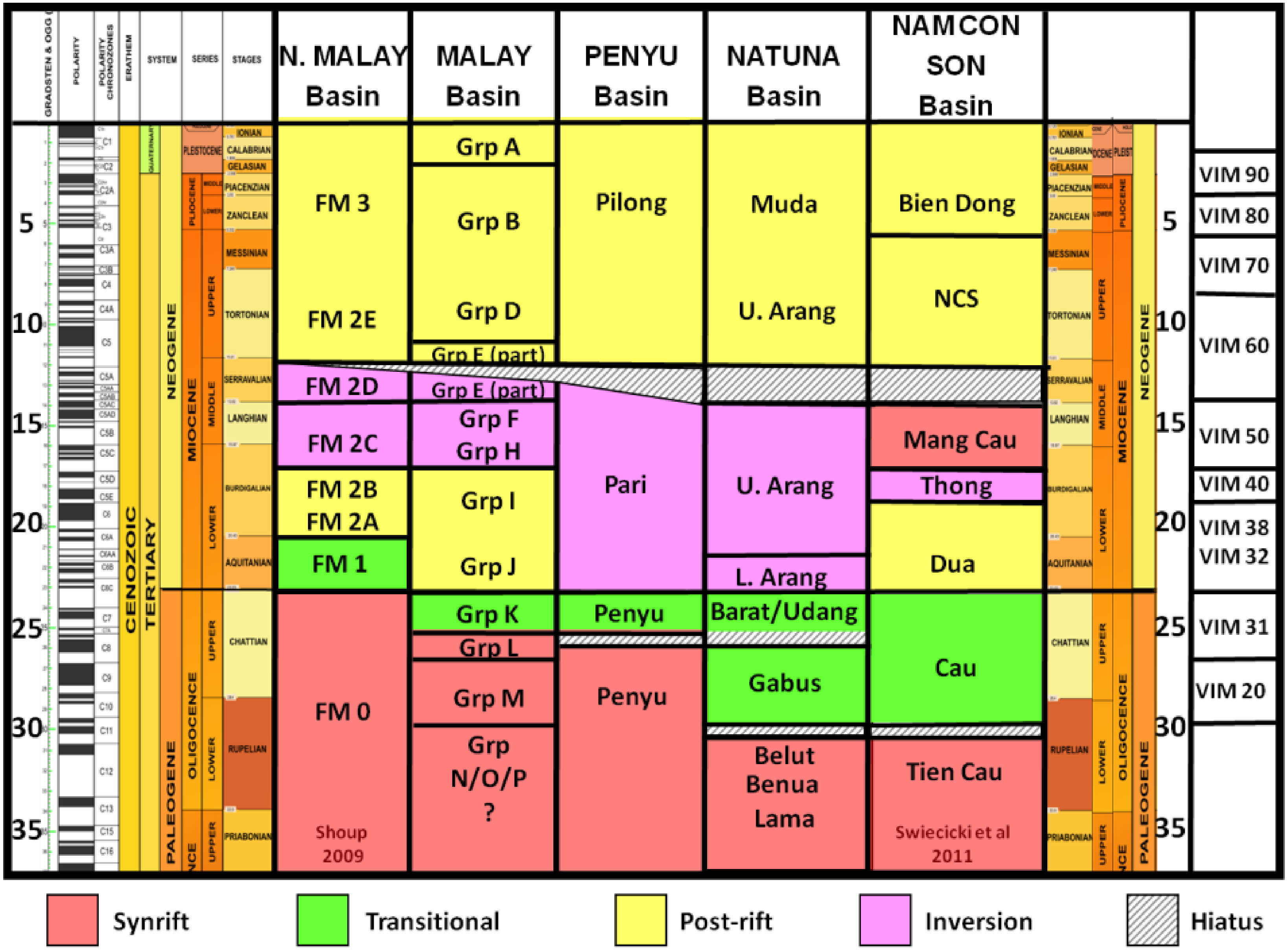

Figure 2. Stratigraphic framework and correlations.

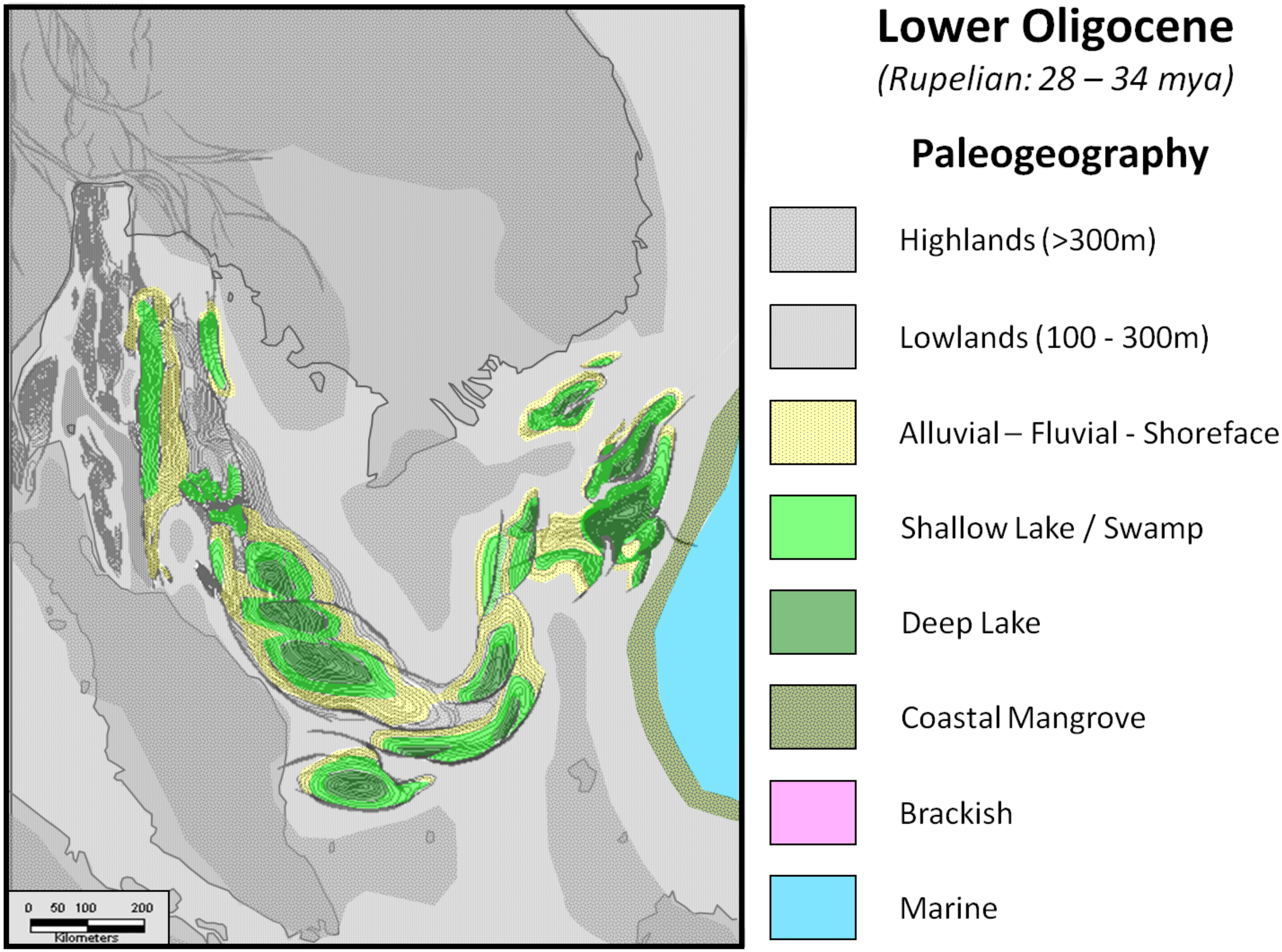

Figure 3. Lower Oligocene (Rupelian) paleogeographic map.

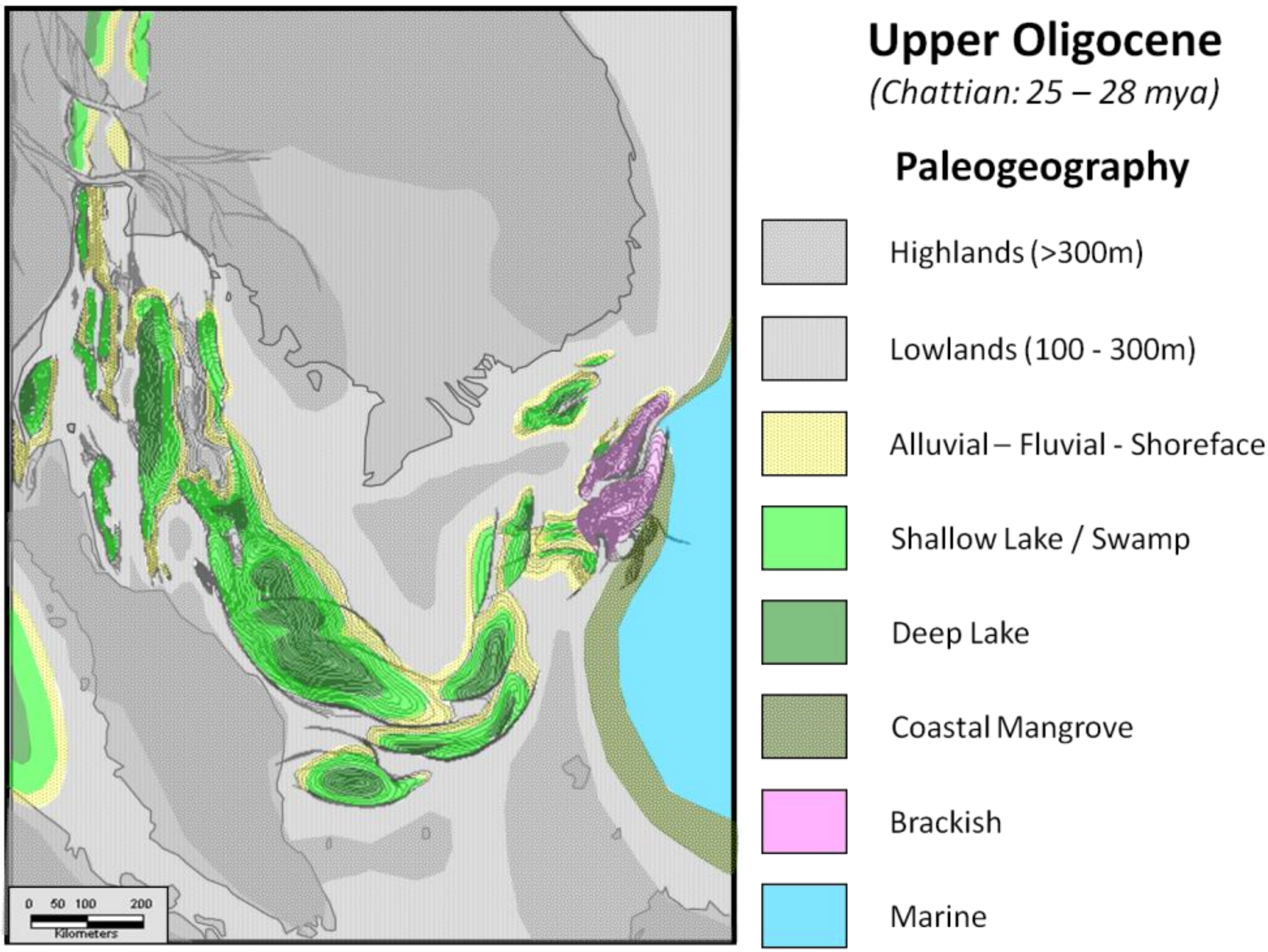

Figure 4. Upper Oligocene (Chattian) paleogeographic map.

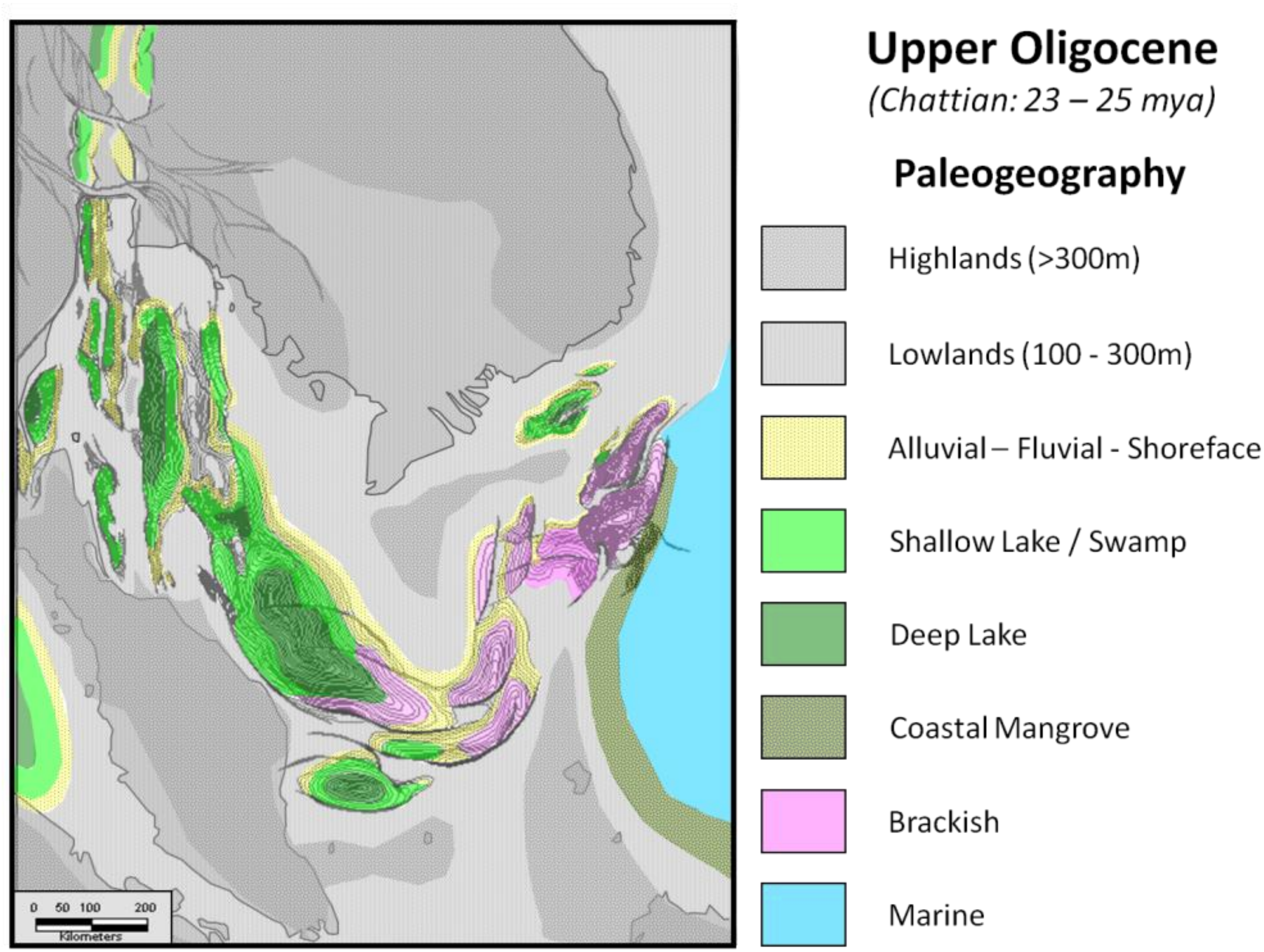

Figure 5. Upper Oligocene (Late Chattian) paleogeographic map.

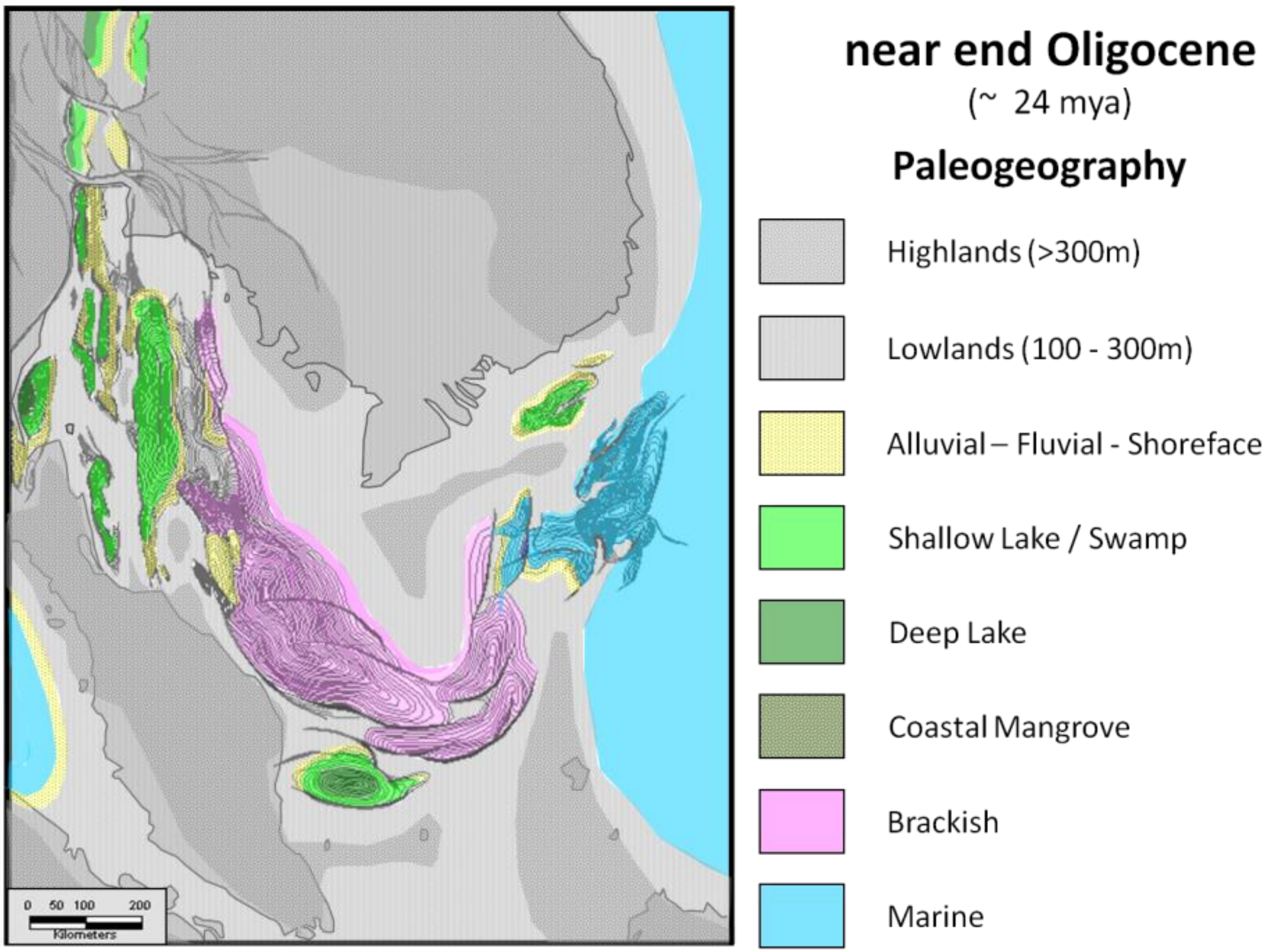

Figure 6. Near end of Oligocene thermal maximum (~24 mya) paleogeographic map.

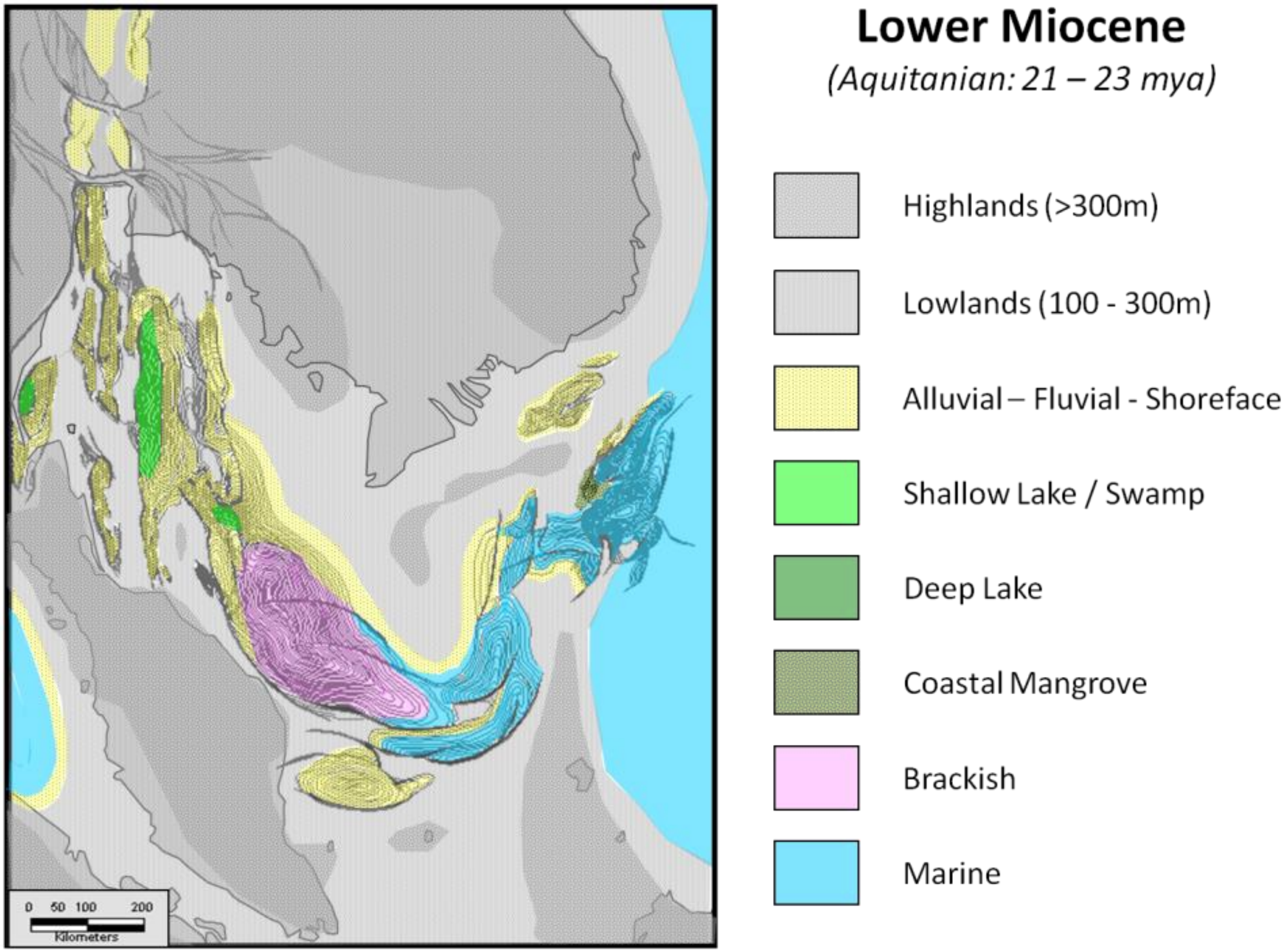

Figure 7. Early Miocene (Aquitanian) paleogeographic map.

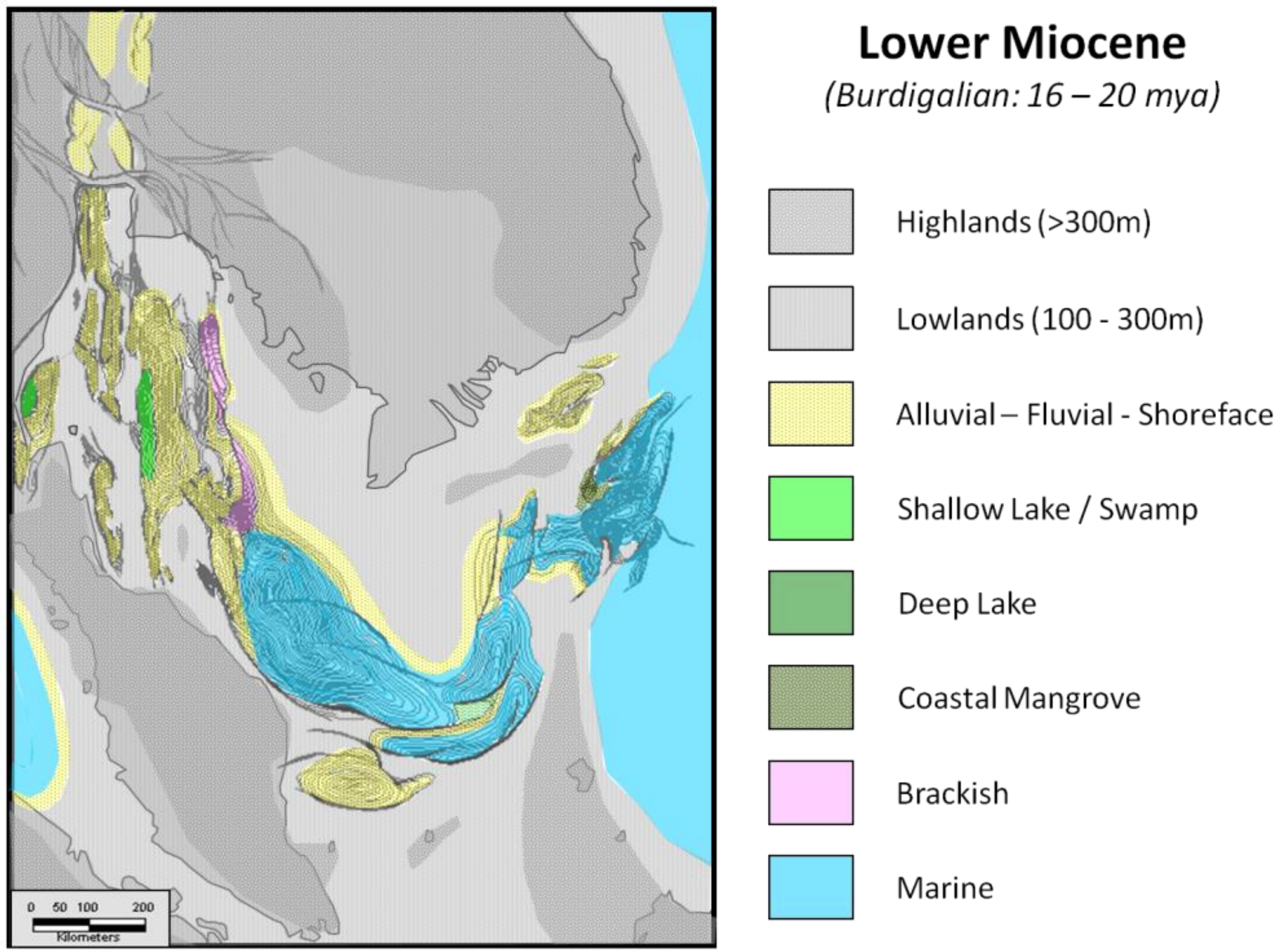

Figure 8. Early Miocene (Burdigalian) paleogeographic map.

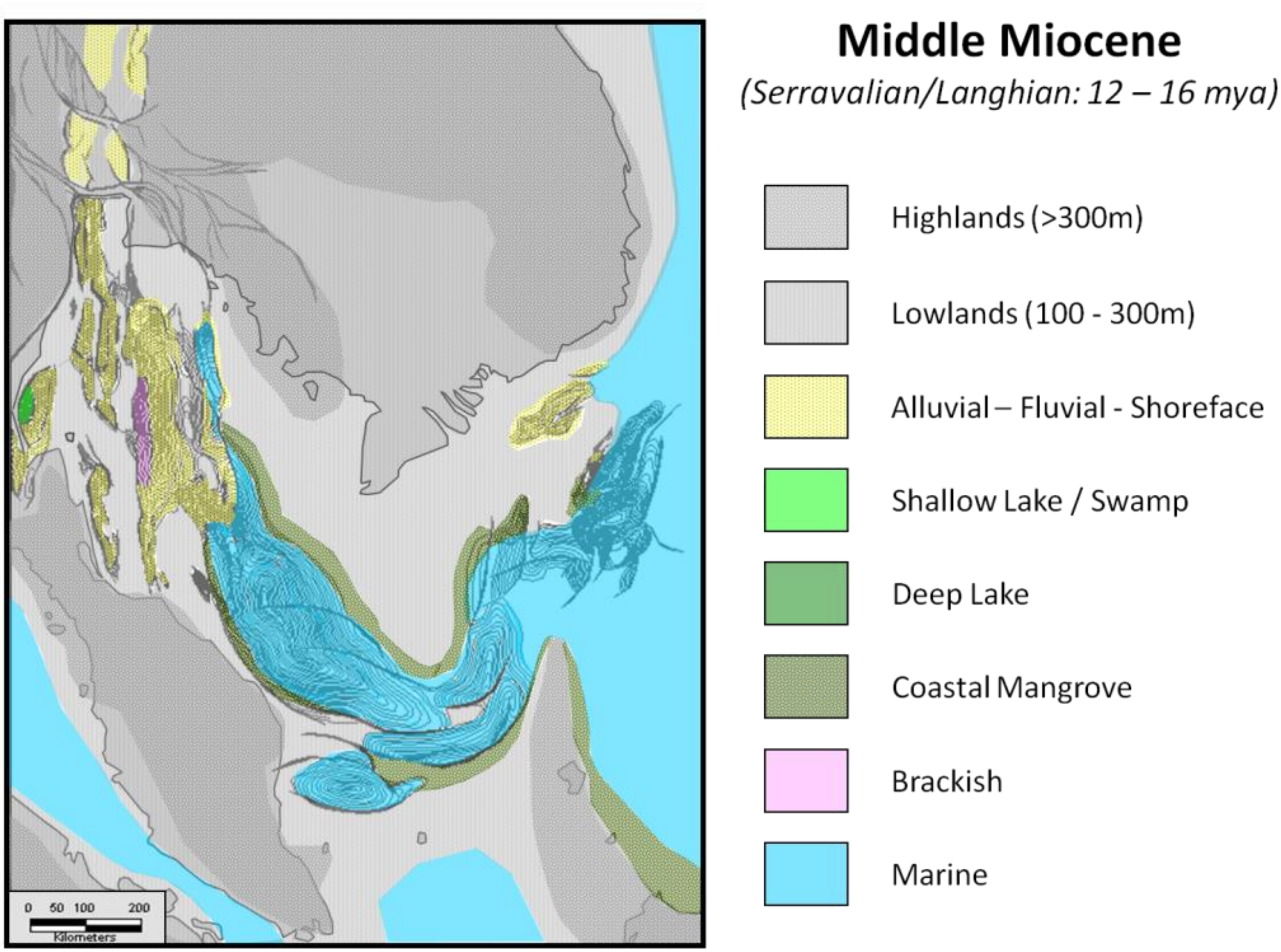

Figure 9. Middle Miocene (Serravalian/Langhian) paleogeographic map.

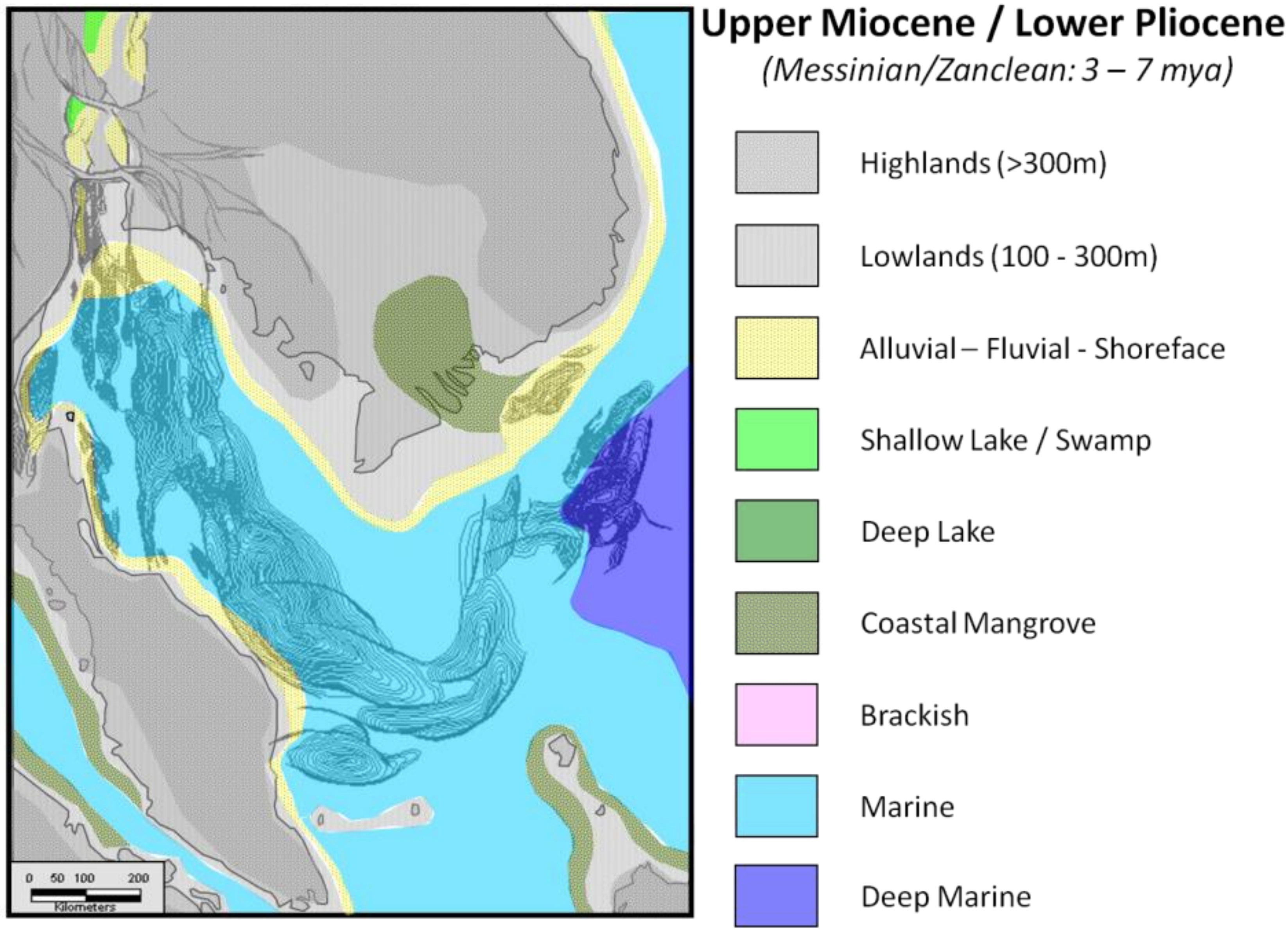

Figure 10. Late Miocene (Messinian/Zanclean) paleogeographic map.

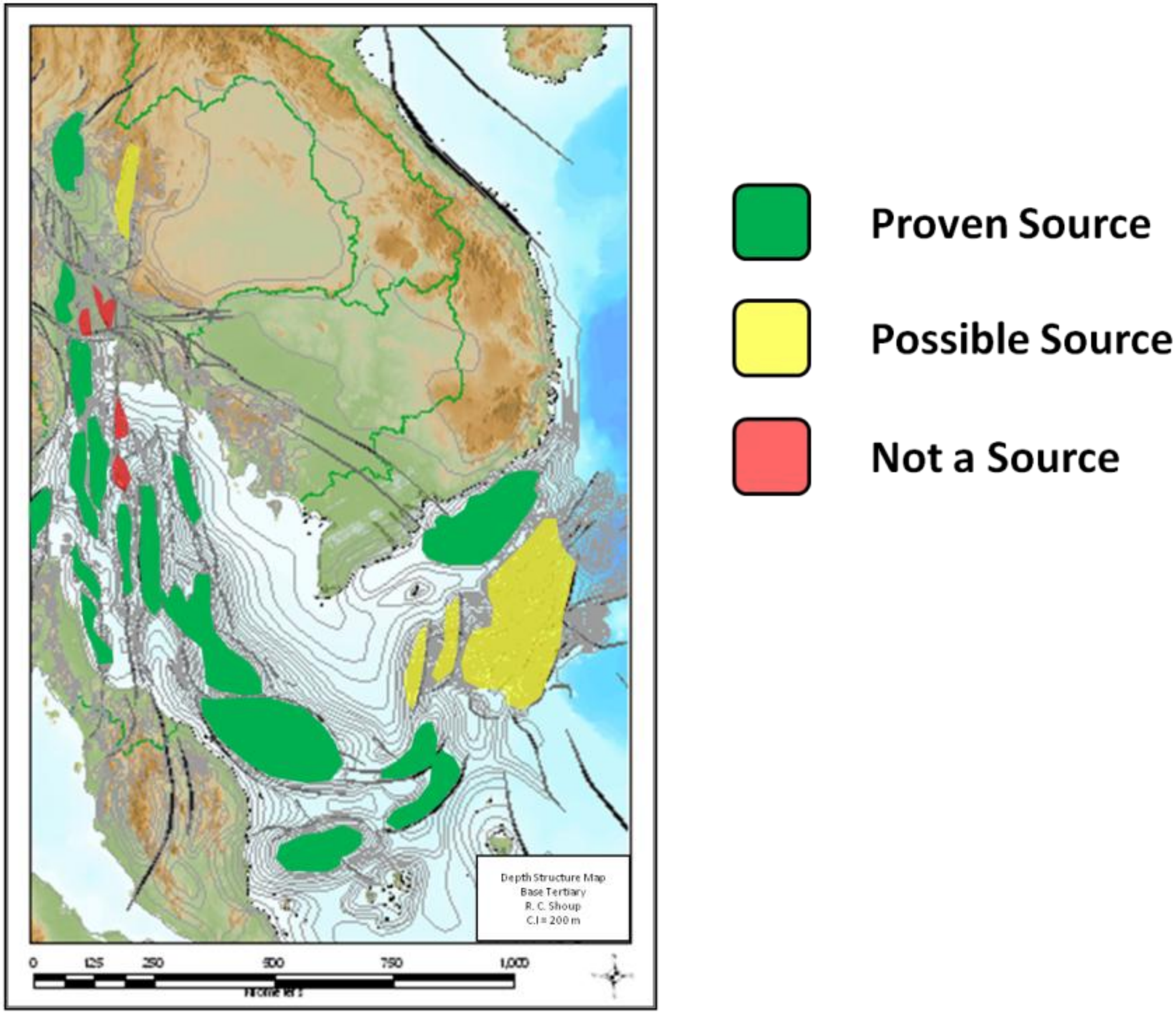

Figure 11. Source rock potential, synrift lacustrine source rocks.

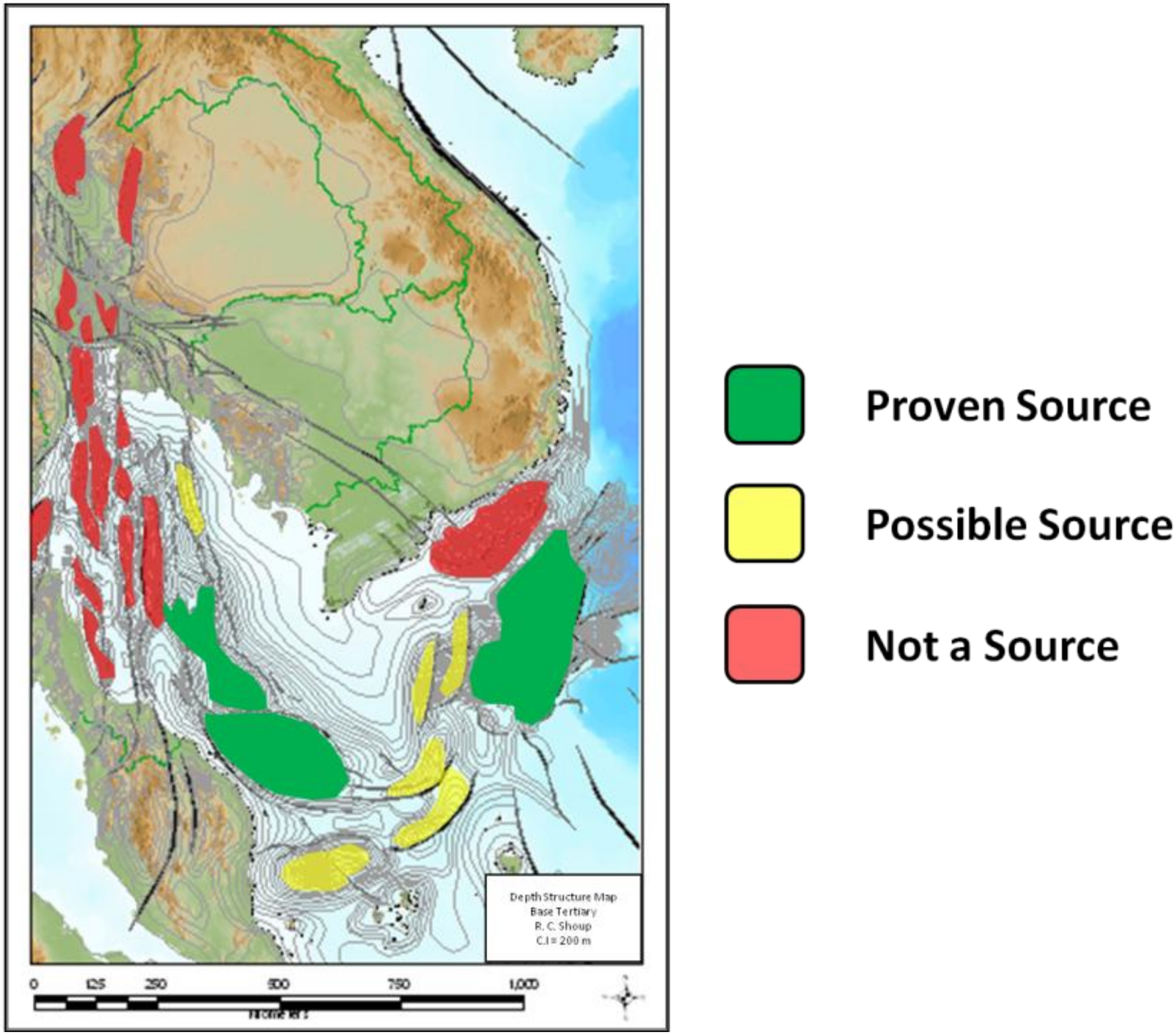

Figure 12. Source rock potential, post-rift coaly source rocks.

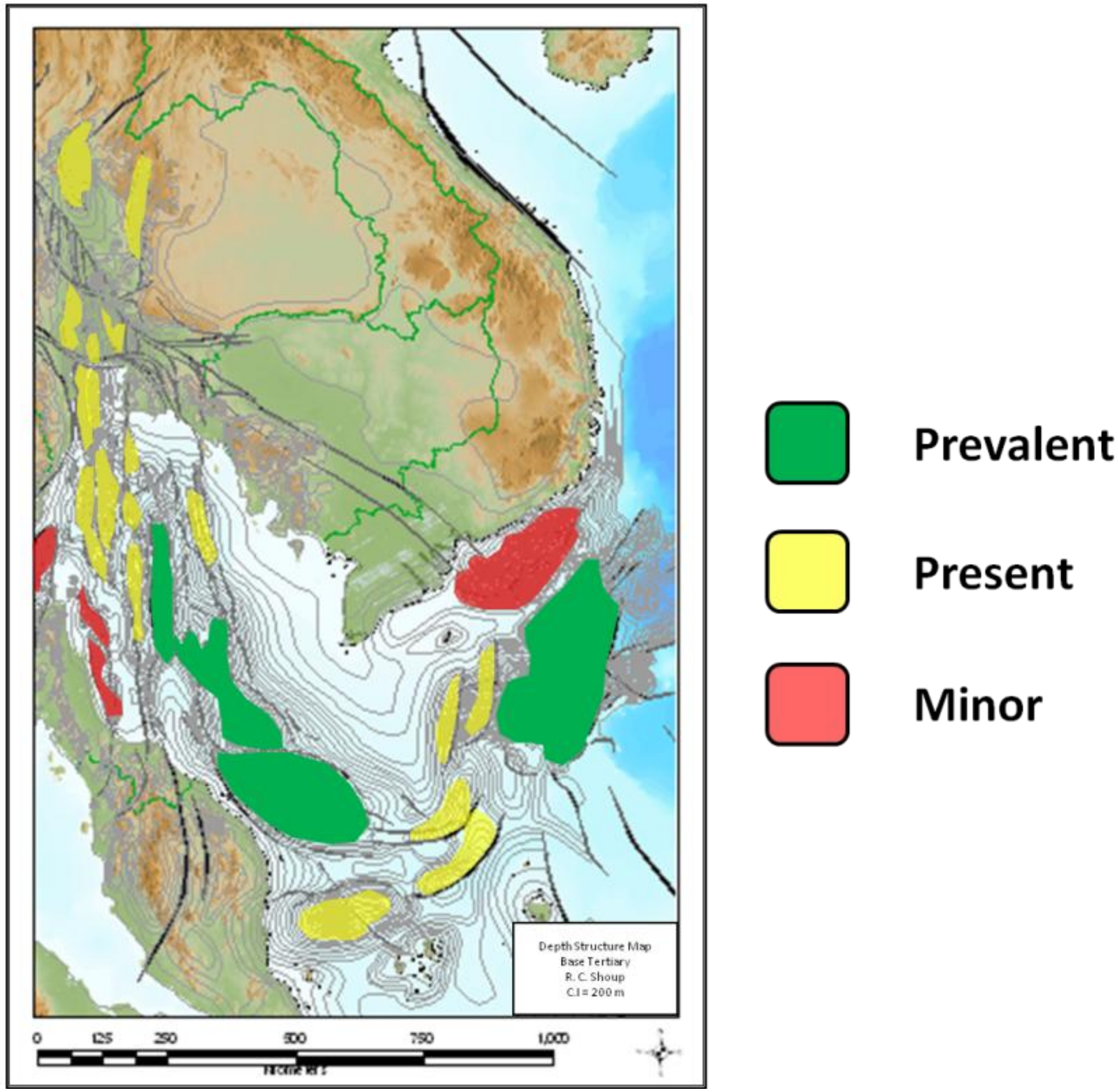

Figure 13. Stratigraphic trap potential.