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Tidal circulation in an Early Permian epicontinental sea: insights from a mathematical modeling approach

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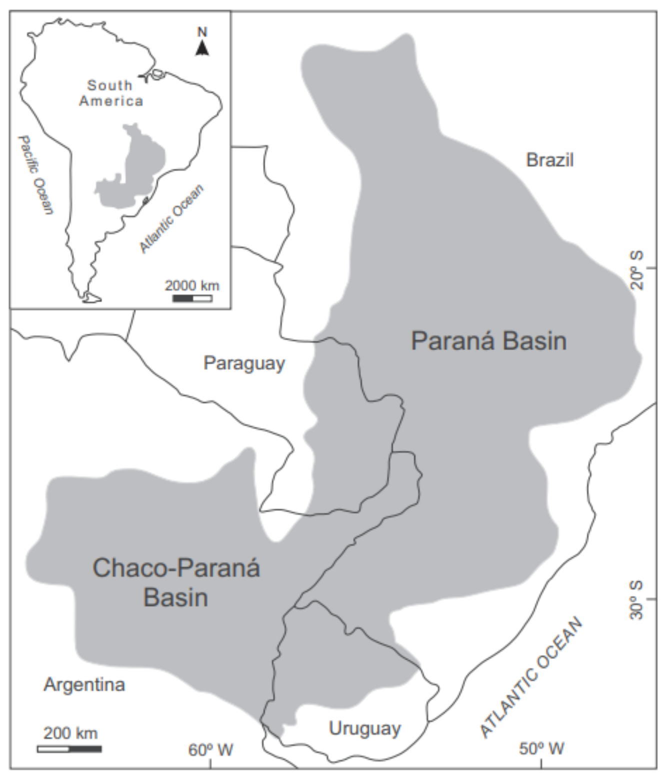

Fig. 1. Location of the Paraná Basin and its Chaco-Paraná extension (Candido et al., 2020).

- Paraná Basin → intracratonic basin (1800,000 km²);
- Rio Bonito Formation → coastal plain and shallow marine deposits;
- Palermo Formation → transitional to offshore deposits (register the drowning of coastal system).

- Guatá Sea → epicontinental sea (1200,000 km²);
- Modern analogous model: Hudson Bay.

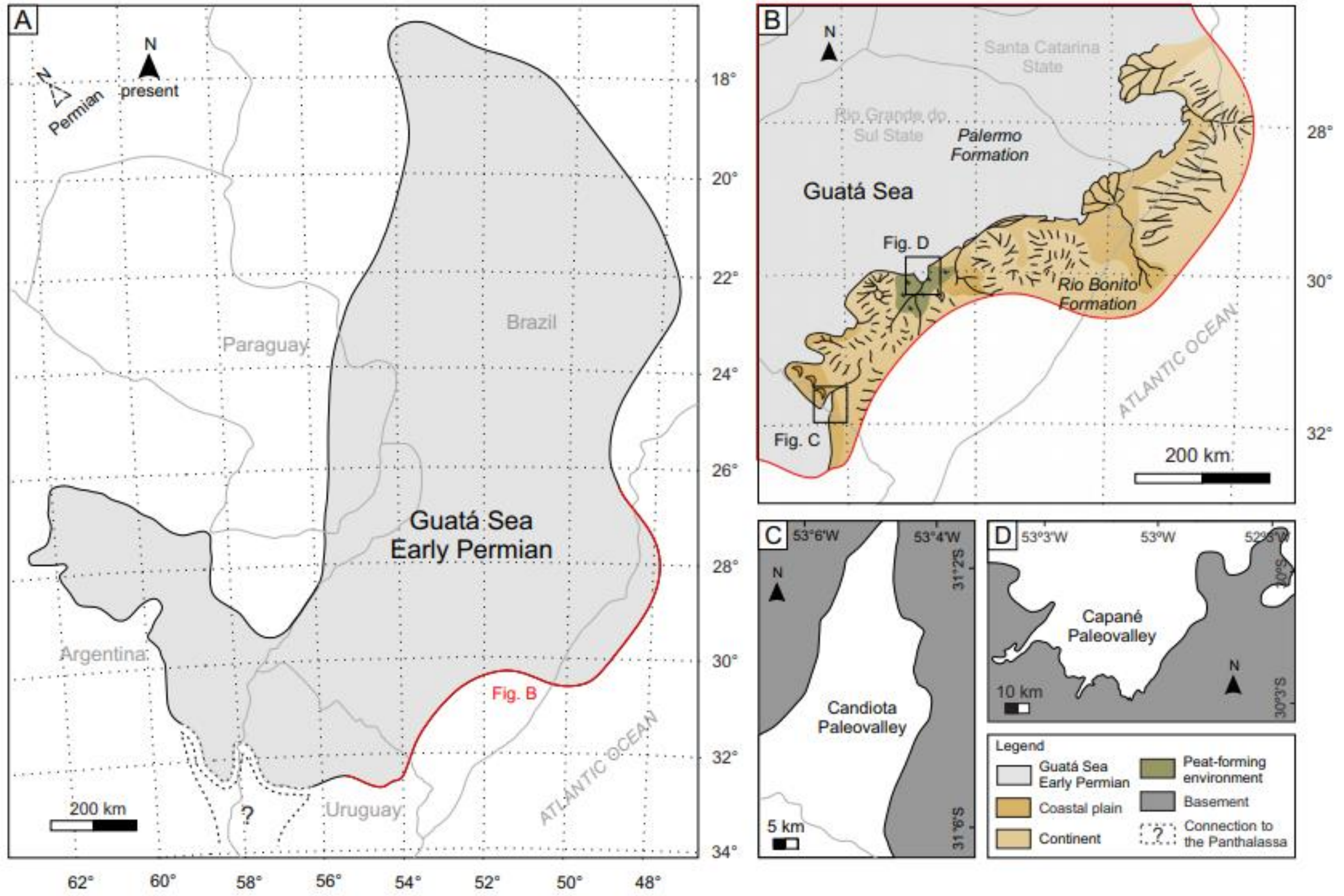

Fig. 2. A - Paleogeographic map of the Paraná Basin in the Early Permian. Guatá Sea correspond to the Palermo Formation, and the coastal plain area, the Rio Bonito Formation. Map elaborated from the paleogeography of Lavina (1992), Schneider et al. (1974), Northfleet et al. (1969), and Padula and Mingramm (1967b). The connection to the Panthalassa Ocean was likely located to the south according to Lavina (1992); B - Coastal deposits of the Rio Bonito Formation (modified from Lavina and Lopes, 1987); C - Current contour of the Candiota paleovalley (Holz, 2003); D - Current contour of the Capané paleovalley (Lopes, 1995). (Candido et al., 2020).

- Mathematical modelling approach.

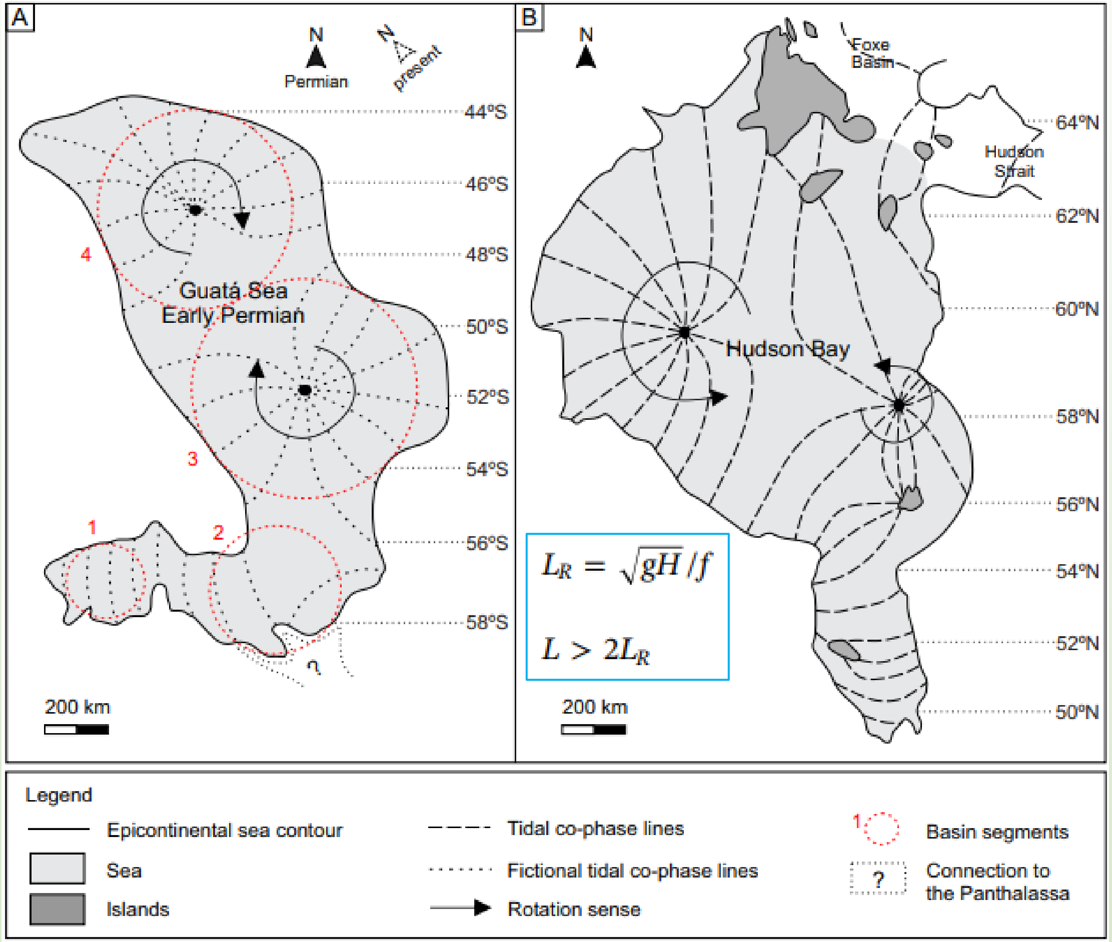

Fig. 3. Guatá Sea and Hudson Bay chart. A - Guatá Sea general physiography and potential amphidromic system (component M2), considering an average depth of 100 m. It is a speculative map. In red, the basin segments, which were used to test the possibility of formation of amphidromic systems according to their scale (1: L = 250 km, 2: L = 420 km, 3: L = 710 km; 4: L = 610 km). Note that amphidromic systems would have developed only in cells 3 and 4; B - Hudson Bay and its amphidromic system corresponding to the M2 component (Webb, 2014). (Candido et al., 2020).

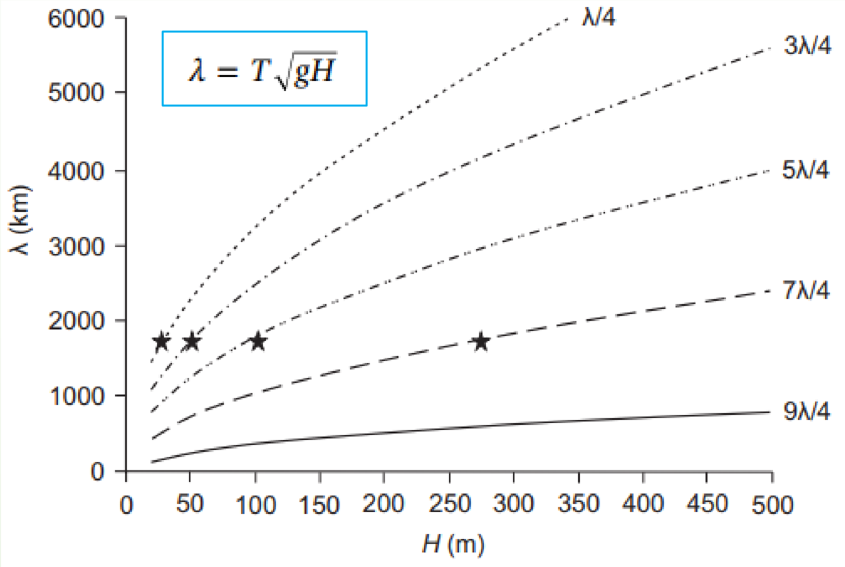

Fig. 4. Tidal wavelength (λ) and its odd multiples in relation to the basin depth (H). The stars show the water depth estimations for the basin length of 1800 km, in which resonance could occur (Candido et al., 2020).

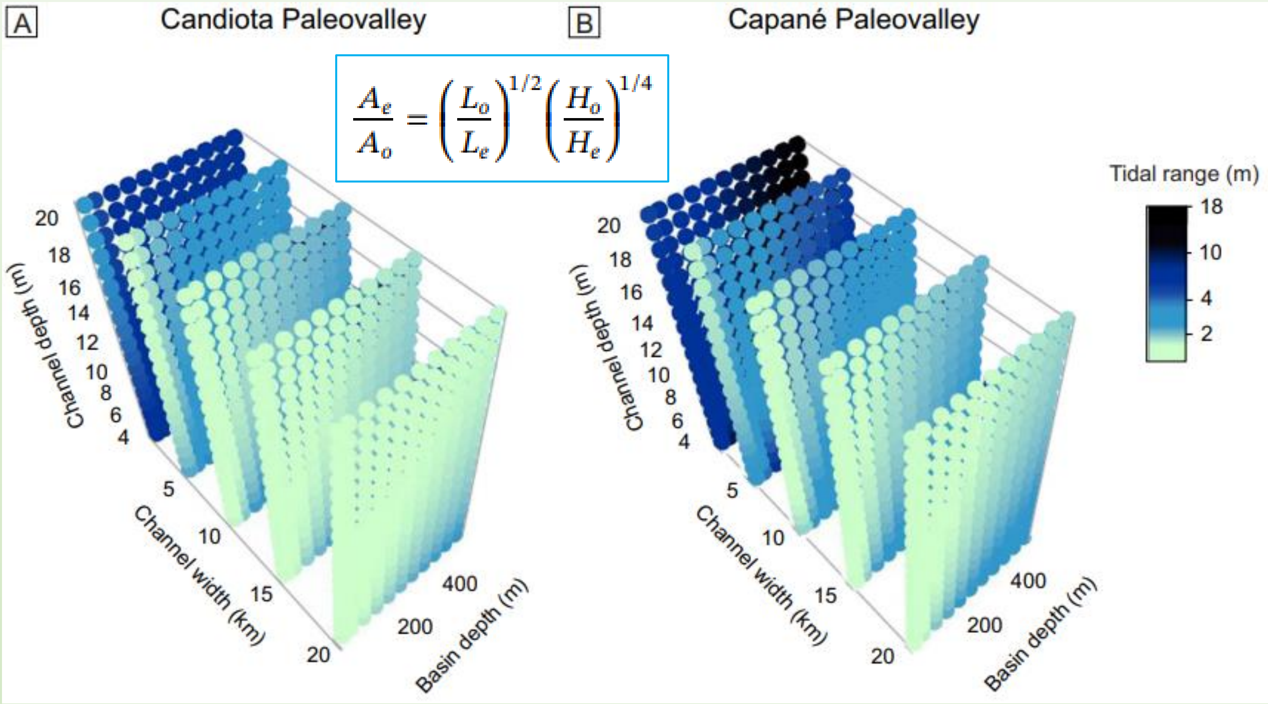

Fig. 5. Simulated tidal amplitudes at the valley's mouth, considering different scenarios for basin depth and estuary width and depth. Tides ranged up to 14 m in the Candiota valley (A) and up to 18 m in the Capané valley (B) (Candido et al., 2020).

Conclusions

- Amphidromic systems might have occurred in the Guatá Sea and influenced sediment transport and deposition along the coast and within the valleys;
- At least two amphidromic systems with tidal-bulge clockwise rotation might have been established in the Guatá Sea (considering an average water depth of 100 m);
- Tidal wave resonance was also possible in the Guatá Sea considering an average water depth of 100 m;
- Candiota valley: micro- to mesotidal amplitudes;
- Capané valley: mesotidal amplitude;
- Tidal amplification within estuaries explains the formation of large-scale tidal bar of the Rio Bonito Formation in the southern Paraná Basin.

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Tidal circulation in an Early Permian epicontinental sea: Evidence of an amphidromic system

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ABSTRACT

In epicontinental seas, as well as in oceans, amphidromic systems control tidal movement, acting on coastal dynamics and, therefore, influencing the depositional record. Inland seas were common in Pangea during the Permian. However, estimating the conditions that governed the tide in these seas is highly complex. Although Permian marine deposits are well documented on a regional scale, the tidal behavior in the epicontinental sea has not been analyzed yet. In this work, we present a theoretical perspective on the behavior of tides in the epicontinental sea of the Paraná Basin during the Early Permian (Guatá Sea), covering an area of ~1200,000 km^2. Mathematical models were applied to test the existence of amphidromic points in the basin (determined from the Rossby radius of deformation) as well as to verify the possibility of resonance. Since paleodepth is unknown and the basin tectonism is still under discussion, an estimated bathymetry from 20 to 500 m was used to cover even some unlikely scenarios. We also tested, using mathematical models, the amplification of the tide inside two paleovalleys. The obtained results were compared to Hudson Bay, considered here to be a modern analog of the Guatá Sea. According to the paleogeography, paleolatitude (Southern Hemisphere), and depositional records, the Guatá Sea had clockwise-rotation amphidromic systems. However, resonant effects may also have affected circulation, especially at sea depth below 100 m. In the simulated scenarios, the tide amplification in both valleys was variable but concentrated between micro to mesotidal amplitudes. This study presents the first contribution to the understanding of the tidal behavior of the Early Permian epicontinental sea of the Paraná Basin in the basinal context of the Gondwanan paleocontinent.