High Heat Flows: A Potential Risk to Hydrocarbon Charge in Deepwater Areas Off South East Brazil

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Pre-salt (early Cretaceous age) rocks are the main source of hydrocarbons in the Campos Basin, offshore S.E. Brazil and their extension into the outer, ultra-deep water parts of the basin are critical for continued exploration success. The potential for deepwater hydrocarbon reserves sourced from Pre-salt source rocks is dependent on a number of factors: one key factor being the presence of a mature source at the time when windows become available in the overlying salt to allow migration from Pre-Salt source beds through the salt barrier into the Post-Salt reservoirs. These reservoirs comprise deepwater turbidite sandstones of late Cretaceous to late Tertiary age and form the giant fields of the Campos Basin, such as Marlim, Albacora and Roncador.

The Pre-Salt source rocks within the syn-rift section comprise freshwater lacustrine shales through to transitional brackish marine or sag phase saline or hypersaline carbonates and marls (Gibbs et al., 2003). In the Campos Basin two main pre-salt source kitchens can be identified; an inboard graben which has sourced most of the hydrocarbons and an eastern outboard graben system. The presence and maturity of this latter graben system is essential for the success of the deepwater plays in the Campos and other Brazilian basins.

Reverse post-rift subsidence modelling was employed to determine the thermal history of the basin to aid constraining predictions of source maturity. The risk in the outboard graben is that the thermal model required to produce a post-rift basin, with a shallow depositional environment for salt accumulation followed by a period of rapid subsidence associated with continental breakup, must involve a period of high heat flows. These are associated with extreme thinning of the lithosphere, either during or after deposition of the salt. This period of high heat flow is separate from the thermal event that produced the original rifting, indicating that the Pre-salt sources have been influenced by two periods of elevated heat flows during the initial rifting and subsequently during the later breakup event. Critically, modelling is required to determine the timing and extent of these events and their effects on the petroleum system. Post-salt subsidence results in further hydrocarbon generation from the pre-salt sources in the outboard grabens.

Key risks are the timing and extent of this breakup related heat flow event: structural modelling in conjunction with basin modelling was used to assess the critical effects on maturation of the pre-salt source rocks.

Structural modelling used an integrated approach of flexural backstripping (or reverse post-rift subsidence modelling) and section restoration to generate sequential snapshots of section geometry from the present day back to 112 Ma, the assumed age of continental breakup (Figure 1). The beta factor profile represents the degree of whole-lithosphere thinning associated with the breakup event. Beta factor magnitude is a proxy for mantle isothermal

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perturbation and can be used to estimate the temperature and heat flow anomalies formed at top crystalline basement as a result of lithosphere scale extension.

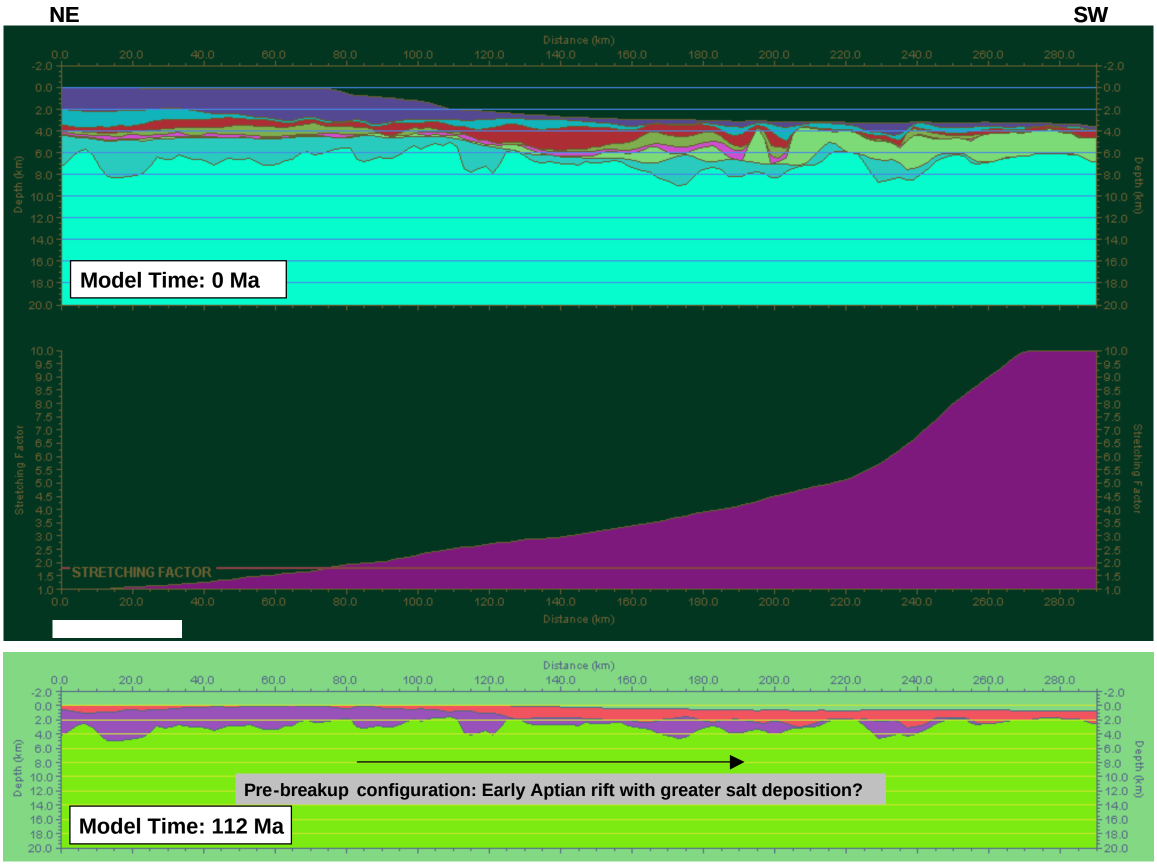

Figure 1: Present day section, backstripped and restored to 112 Ma and the beta factor used in the backstripping.

Downdip, systematic changes in top basement heat flow history occur as a result of varying beta factor (Figure 2), showing a large breakup related heat flow anomaly in the deepwater, outer parts of the basin. Basin modelling shows that this heat flow event has a major effect on the maturity of the Pre-Salt source rocks, increasing their maturity often into the gas window. Hydrocarbon generation timing is also drastically altered, with much earlier timing of charge generation. The effects on the deepwater petroleum system resulting from this heat flow event are thus critical.

In addition to the backstripping approach employed here, a second forward modeling approach is compared (Karner et al., 2003). Both models are based on a Mckenzie (1978) approach where subsidence is related to thermal relaxation of mantle isotherms following lithospheric extension. The understanding of hydrocarbon charge prediction is discussed in terms of these respective techniques while other processes such as lithospheric phase transitions (Podladchikov et al., 1994) are considered.

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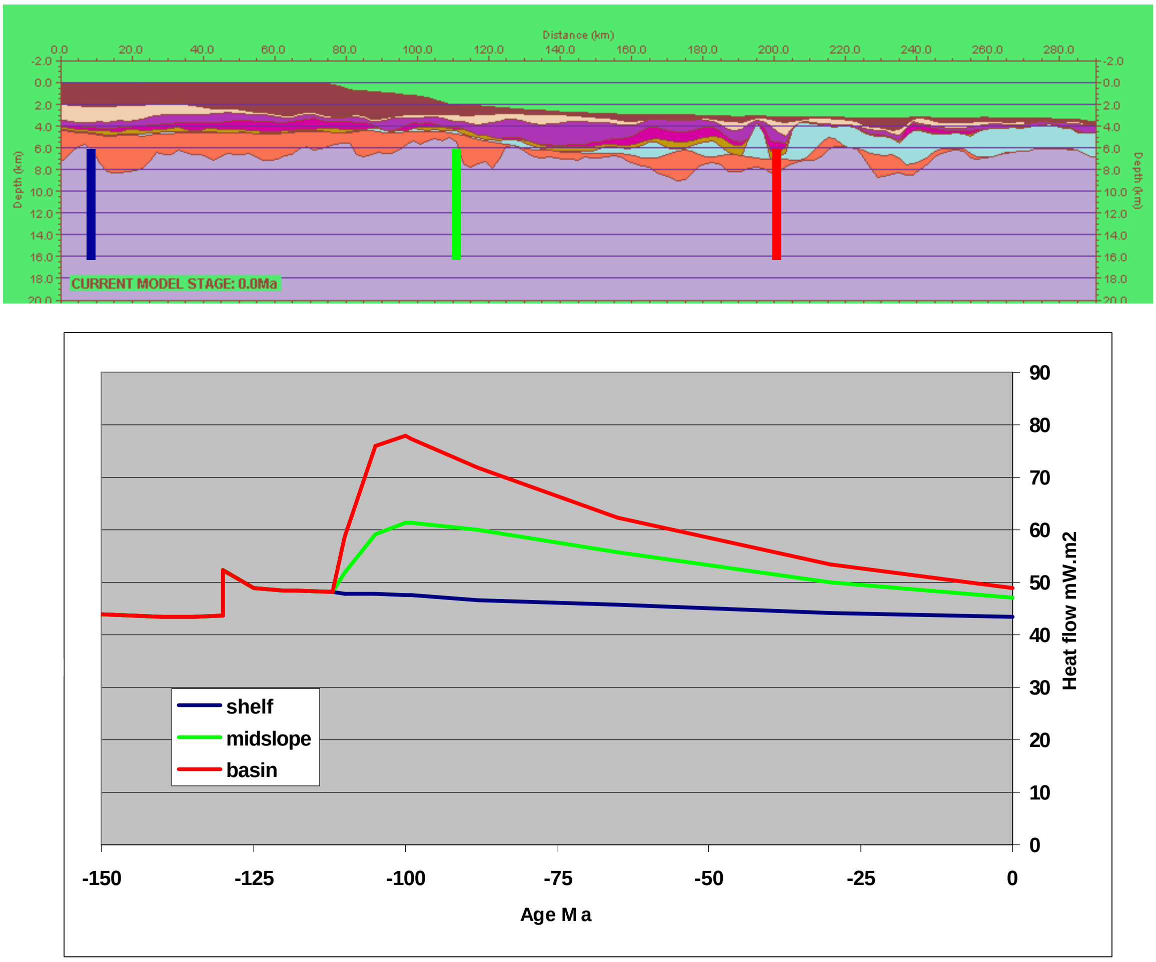

Figure 2: Downdip changes in heat flow history resulting from beta factor variation.

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