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Depositional Facies and Prolific Source Rocks of a Deep Rift-Lake; The ENRECA-3 Core Well Succession, Bach Long Vi Island at The Song Hong-Beibuwan Basins Intersection

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Producing fields in the Beibuwan Basin and significant petroleum shows in the North-eastern Song Hong Basin demonstrate an active petroleum system relying on oil-prone lacustrine syn-rift source rocks of Eocene–Oligocene age. However, the sparse well information available shows highly variable syn-rift successions with very different depositional facies and highly variable source rock parameters. In order to strengthening current exploration models the Danish-Vietnamese ENRECA- re-search team drilled a 500 m deep core well on the Bach Long Vi Island located at the intersection between Song Hong and Beibuwan basins to obtain reliable and detailed information on the composition of the syn-rift succession (Fig. 1). This presentation focuses on the depositional facies of the syn-rift succession with emphasis on the formation of source rocks, reservoir rocks and carrier beds. The Neo-gene Bach Long Vi inversion structure forms a small island in the Gulf of Tonkin with exposures of Oligocene(?) syn-rift sediments comprising oil-prone, organic-richlacustrine mudstones interbedded with sandstones (Fig. 2). The island thus provides a unique geological window in to the deeply buried source rock facies in the Song Hong and BeiBuwan basins.

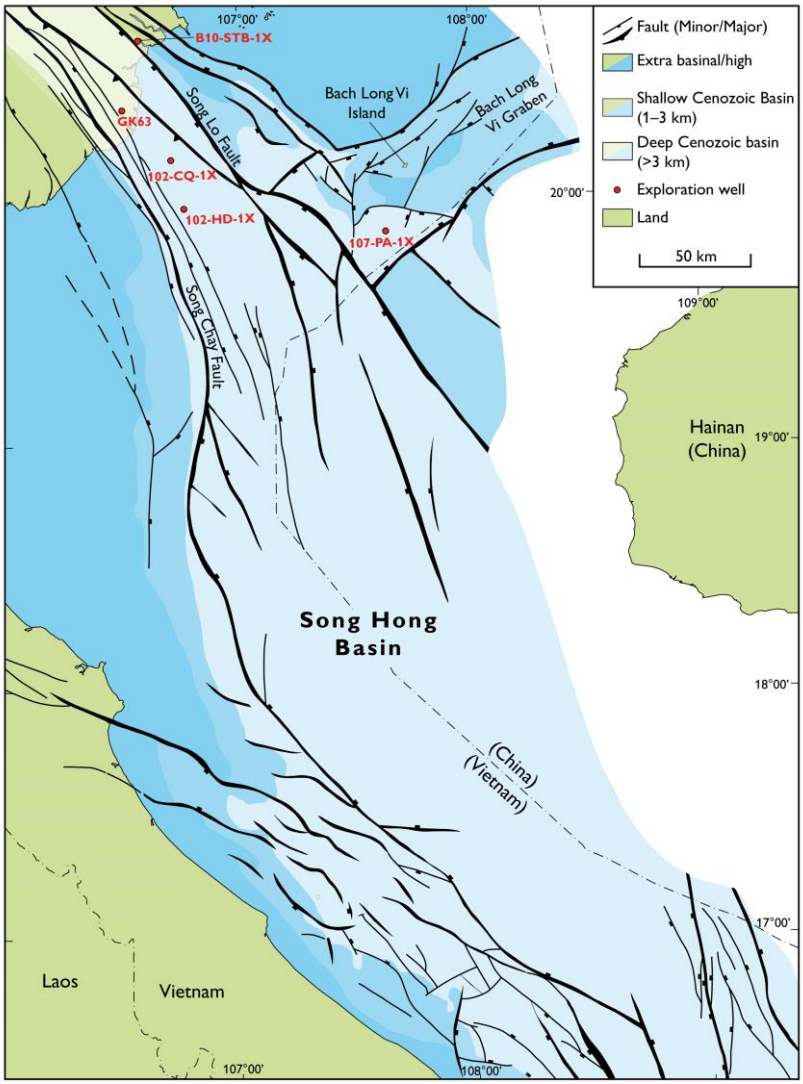

Fig. 1. Outline map of the Song Hong Basin, offshore northern Vietnam, with the location of Bach Long Vi Island in the NE-SW trending Bach Long Vi Graben.

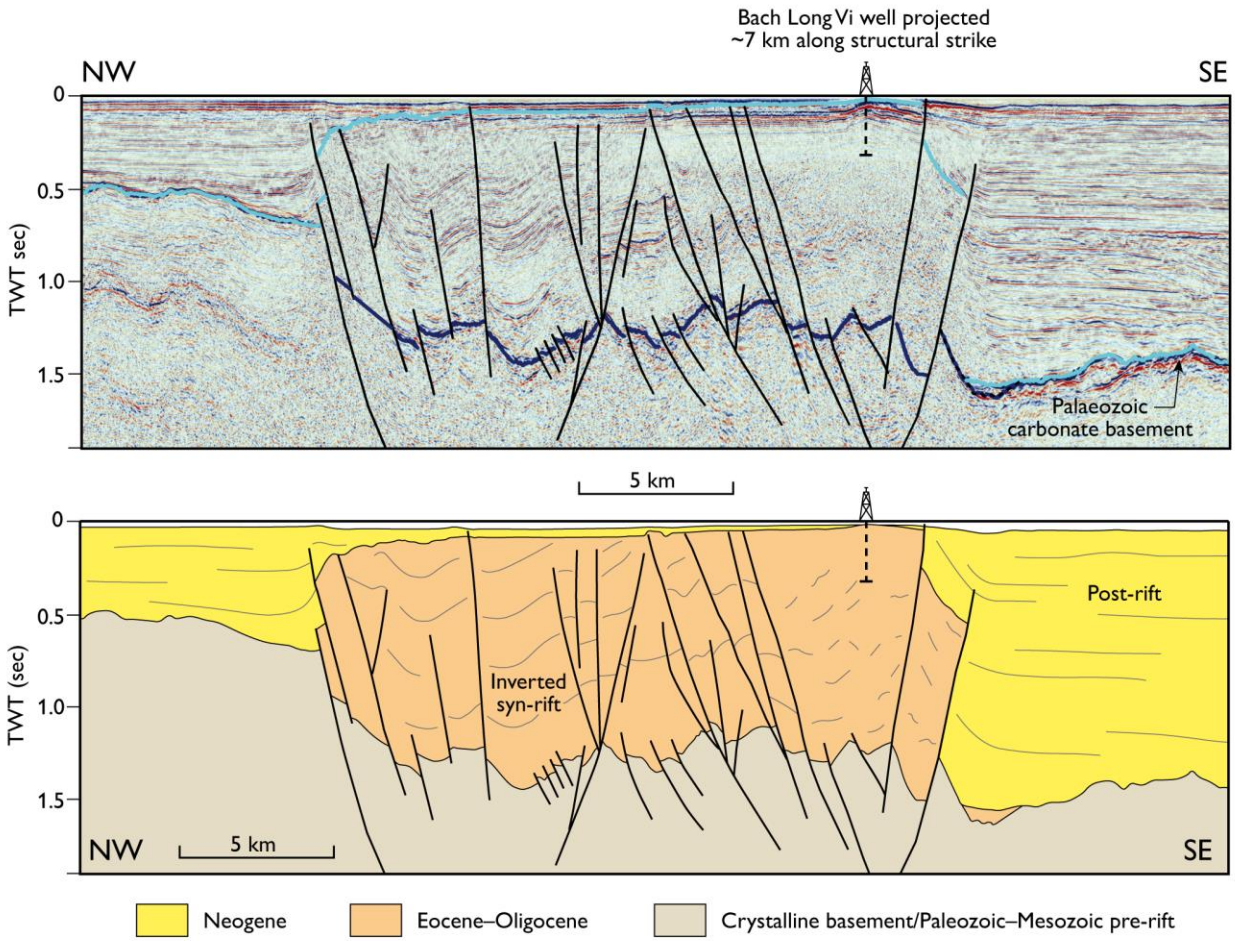

Fig. 2. NW–SE trending seismic section and interpreted geo-section across the Bach Long Vi Graben. The graben is strongly inverted and forms a prominent "pop-up" structure. The relative position of the ENRECA-3 well has been projected to the profile.

The core well obtained 500 m of syn-rift sediments consisting of mudstones and sandstones organized in a number of facies associations with specific composition and source rock characteristics. The sandstones are quartz-rich, very fine to coarse grained arkoses that were deposited by sediment gravity flows including low- and high-density turbidites, hybrites and debris flows. Visual porosity is mostly good except for the debris flows. The mudstones show a minimum net source rock thickness of 233 m with an average TOC content of 2.91 wt.% and an average HI of 575 mg HC/g TOC. Bioturbation is almost absent except for very small burrows related to sandy gravity flows. The mudstones represent deposition from pelagic mud, mud turbidites and possible hyperpycnal flows. Common soft sediment deformation structures (ball and pillows, slump folds, sandstone injectites, mudstone flames and deformed rip-up clasts) and the sediment gravity flows indicate episodes of rapid sedimentation in a soft-bottomed basin. The sedimentary facies, the large amount of fresh-water algae, the absence of marine signals and signs of subaerial exposure indicate that the deposition occurred in a deep, elongated, narrow and subsiding freshwater graben with a large organic production. Oxygen deficiency at the lake-bottom, and near-absence of a benthic fauna facilitated preservation of organic-rich mudstones.

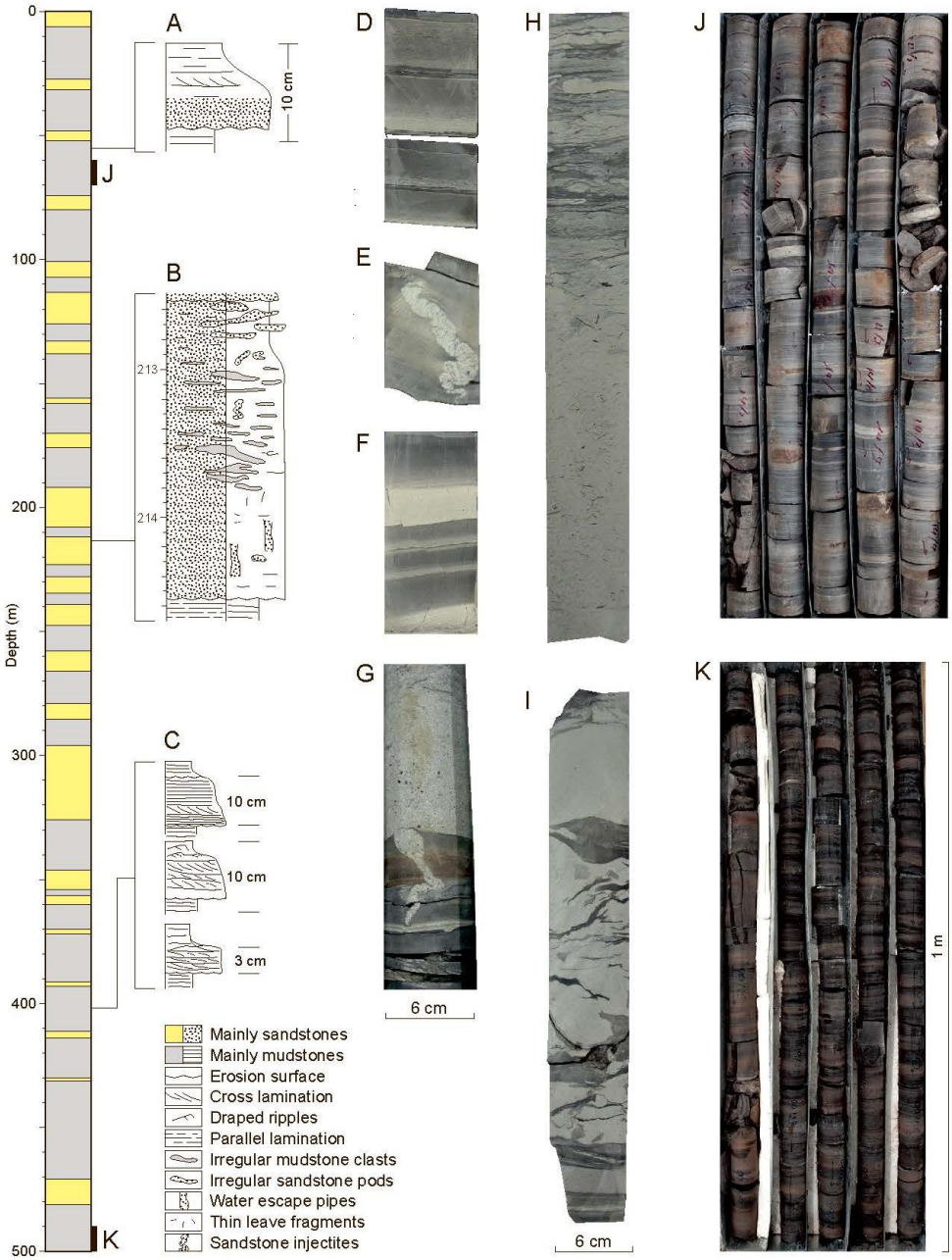

Fig. 3. ENRECA-3 well. Lithological log (left) showing ca. 163 m of sandstone dominated intervals (yellow) interbedded with intervals dominated by mudstones (grey). Thin-bedded turbidites of Bouma Tabcde (A) and Tcde (C). (B) Thick density-current deposit (hybride bed) with water escape structures, floating rip-up clasts of mudstones and pods of sandstones. (D & F) Core pieces of thin-bedded fine-grained turbidites; (E) Sandstone injected into soft mud and later compacted; (G) Grey mudstones with thin sandstones and brownish concretion and injected sand below a density-current sandstone deposit; (H) A thick sandstone dominated density-current deposit with delicate leave fragments in the lower half; (I) Sandstone with mudstones clasts formed by a density-current or sand injected in mudstones. (K) Dark grey to black, highly oil-prone mudstones alternating with light grey to greyish/brownish mudstones with a lower and varying generation potential. (J) Light grey mudstones

alternating with thin fine-grained sandstones and brownish cemented layers and concretions. The mudstones are highly oil prone.

The grain size and sorting of the sandstones suggests that the sand was supplied and sorted by river processes prior to the re-sedimentation by density currents, and the absence of pebbles suggest that the faulted rift-margins and shoulders did not supply material to the basin. The very different composition of the ENRECA-3 succession compared to other well sections in the area suggests a complex relationship between structural development, drainage patterns, sediment entry points, anoxia etc. that need further investigations before a well-constrained predictive exploration model can be generated. However, the occurrence of thick world class source rocks for oil generation is very encouraging for the local petroleum potential as well for hydrocarbon plays elsewhere in the region relying on presence of mature lacustrine source rocks deep in the syn-rift successions.

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