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Petroleum source-rock evaluation of upper Eocene Kopili Shale, Bengal Basin, Bangladesh

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ABSTRACT

The upper Eocene Kopili Shale occurs throughout the Bengal Basin, including in the northwestern Indian platform and deeper basin areas (e.g., Sylhet Trough) of Bangladesh. Mudrocks presumed to be equivalent to the Kopili Shale in India are known hydrocarbon source rocks. However, the source-rock potential of the Kopili Shale in Bangladesh is not well established, thus prompting the current study of abundance, character, and maturity of organic matter in Kopili Shale samples from the Bengal Basin.

Organic petrologic observations and Rock-Eval pyrolysis data indicate that organic matter in the Kopili Shale is largely terrigenous, including an admixture of type I/II (liptodetrinite, cutinite, bituminite), type III (vitrodetrinite), and type IV (inertodetrinite) macerals. Mean vitrinite reflectance values (R_o = 0.86–1.32%) and a single reliable T_{max} value (433 °C) indicate that organic matter from all sampled sections is thermally mature. Total organic carbon (TOC) contents of samples from core and outcrop are generally low (<0.6%) and thus reflect relatively poor hydrocarbon-source potential. However, TOC values of ~1.0% and S2 values from one section indicate that source potential is locally higher in the Sylhet Trough area.

An understanding of differences in Kopili source-rock potential between India and parts of the Bengal Basin will require more comprehensive comparative facies analyses.

1. Introduction

The Kopili Shale is a sequence of dark gray to black mudrocks and subordinate marlstones that accumulated in Himalayan foreland basins during the Late Eocene, purportedly in shallow marine settings (Reimann, 1993). The Eocene Kopili Formation of Assam, India, which consists of shallow marine to lagoonal shale, fine-grained sandstone, and marl streaks (Moulik et al., 2009) is a proven source-rock for both oil and gas in the well-defined Sylhet-Kopili/Barail-Tipam composite petroleum system (Wandrey, 2004). Previous workers (e.g., Shamsuddin et al., 2001) have proposed that the Kopili Shale of Bangladesh also may serve as an effective hydrocarbon-source rock that charges known and as-yet undiscovered Tertiary reservoirs in the Bengal Basin. However, owing to limited deep well control and lack of petrologic data, the source-rock potential of the Kopili Shale in this region remains poorly known. To address this problem, we initiated geochemical and petrologic studies of organic matter in core and outcrop samples of Kopili Shale that were obtained from different parts of the Bengal Basin. The objectives of the current paper are to: (1) summarize principal findings of organic carbon, Rock-Eval pyrolysis, and vitrinite reflectance analyses; (2) discuss Kopili Shale source-rock potential based on amount, type, and maturity of organic matter; and (3) compare the source potential of the Kopili Shale in the Bengal Basin with that of the equivalent Kopili Formation in Assam, India.

2. Stratigraphy and depositional history of the Bengal Basin

2.1. Stratigraphy

The Bengal Basin (Fig. 1) is a large foreland basin in which a relatively thick succession (up to 16 km) of Cenozoic sediment accumulated in response to the uplift and erosion of the Himalayas. The basin is bounded on the west by the Indian craton, on the east by the Indo–Burman ranges, and on the north by the Shillong Plateau, a Precambrian massif adjacent to the Himalayas. The basin extends southward into the Bay of Bengal and is contiguous with the Bengal deep sea fan (Fig. 1). Cenozoic strata within the basin thicken from west to east and from north to south (Uddin and Lundberg, 1999).

The Bengal Basin has two broad tectonic provinces separated by a northeast-trending hinge zone (Fig. 1): (1) the northwestern Indian platform, where a relatively thin sedimentary succession (<6 km) overlies basement rocks of the Indian Craton; and (2) the southeastern deep basin, which hosts a thicker Tertiary sedimentary sequence that overlies

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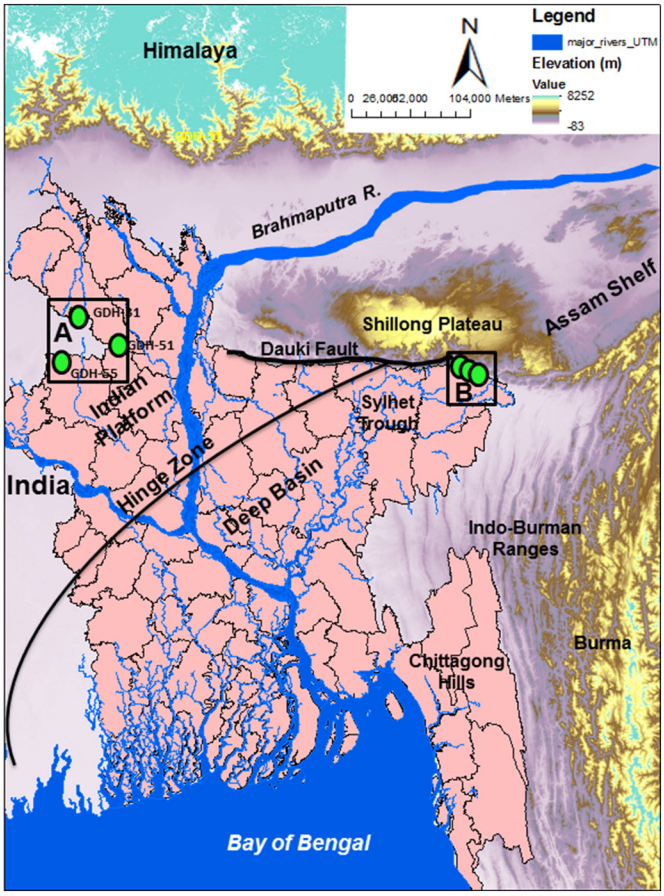

Fig. 1. Map of Bangladesh showing major features of the Bengal Basin and locations of sediment cores (A); and outcrop sections (B) examined in this study. Stratigraphic sections of (A) and (B) are shown in Fig. 2. The hinge zone that separates the stable shelf (Indian Platform) from the deep basin continues to the northeast as the Assam Shelf. Green dots represent locations from which samples have been collected for this study. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

deeply subsided basement of undetermined origin (Fig. 2). In most areas of the basin, Tertiary strata are concealed by the overlying Quaternary section. However, Tertiary strata have been uplifted and exposed locally along the northern and eastern margins of the Sylhet Trough (also referred to as the Surma Basin) of northeastern Bangladesh and in the Chittagong fold belt in eastern Bangladesh. Outcrop studies in these areas, along with limited drilling and geophysical data (Anwar and Husain, 1980), have led to a preliminary understanding of Bengal Basin lithostratigraphy (Khan and Muminullah, 1980; Fig. 2).

In the Indian platform area (Fig. 2A), Cenozoic strata overlie Precambrian basement, a thick (up to 955 m) succession of Carboniferous to Late Permian coal-bearing siliciclastic sediments of the Gondwana Group (Kuchma and Paharpur formations), and an ~500-m-thick sequence of Cretaceous flood basalts (Rajmahal Traps). The latter are overlain by marine carbonaceous sandstones and subordinate shales and marls of the Paleocene-Eocene Cherra Formation, deep-water nummulitic carbonates of the Middle Eocene Sylhet Limestone, and shallow-marine dark-gray to black, fossiliferous mudstone and subordinate marls of the Upper Eocene Kopili Shale. The Kopili Shale, which is ~30 m thick in the platform area (Banerji, 1981), is in turn overlain by sandstones and/or mudrocks of the Oligocene Barail Formation, Miocene Surma Group, and Plio-Pleistocene Dupa Tila Sandstone.

In deep basinal areas, including the Sylhet Trough (Fig. 2B), rocks older and deeper than the Middle Eocene Sylhet Limestone have not been encountered in outcrops or by drilling. Here, the Sylhet Limestone is overlain by 40–90 m of the Kopili Shale, which consists of dark-gray to black, fossiliferous mudrock and marl that grades upward into brown siltstones and very light gray sandstones with localized carbonaceous streaks. The presence of nummulites in the calcareous shale, coupled with the wavy-pinstripe and lenticular bedding, indicates a shallow marine setting with probable tidal influence. The Kopili Shale is overlain by the Oligocene Barail Group, which in the northeastern Bengal Basin is divided into the argillaceous Jenum Formation and the arenaceous Renji Formation (Fig. 2B). The Barail Group, in turn, is overlain by the lower to middle Miocene Surma Group, which includes the Bhuban and Boka Bil formations, both of which comprise alternating mudrock and sandstone packages (Uddin and Lundberg, 1999; Uddin et al., 2010). The Surma Group is unconformably overlain by the upper Miocene to Pliocene Tipam Group, which includes the Tipam Sandstone

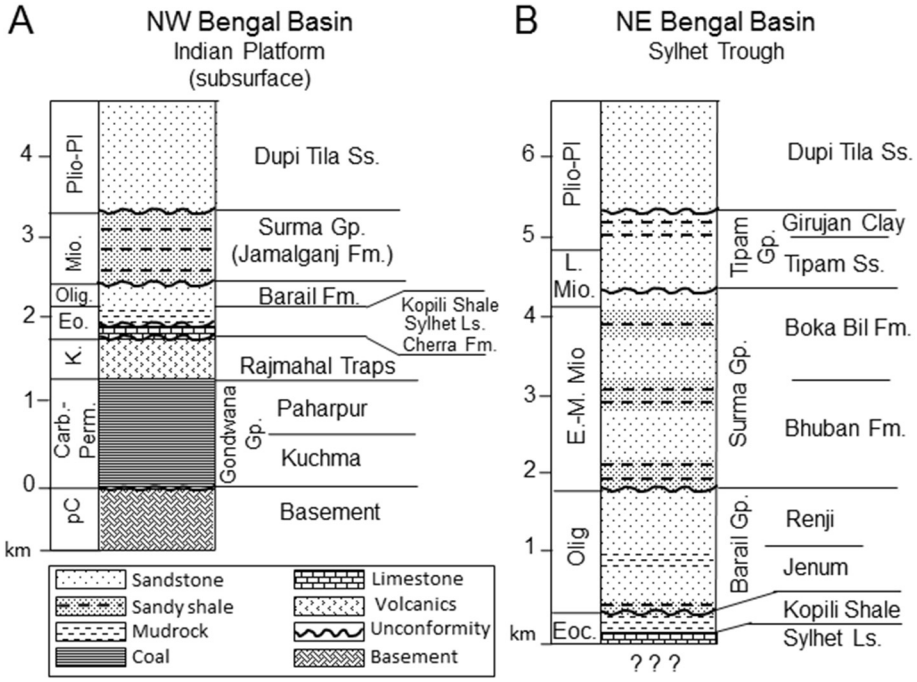

Fig. 2. Stratigraphic framework of the Bengal Basin, Bangladesh (modified from Uddin and Lundberg, 1999). Locations of A and B are shown in Fig. 1.