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Parasequence-Scale Sedimentology and Reservoir Architecture of a Late Mesozoic Fluvial-Lacustrine Interface, Southeast Mongolia

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Late Mesozoic synrift strata of southeastern Mongolia are mainly perilacustrine facies that form both reservoir and source rock units in the East Gobi basin (EGB) subsurface. These systems are analogous to other Cretaceous and younger intracontinental rift basins in the China-Mongolia border region, including the hydrocarbon-rich Songliao basin. Basin margin exposures in the EGB record multiple lake level fluctuations during Late Jurassic—Early Cretaceous time. These expansion/contraction cycles resulted in complex lateral and vertical relations between anoxic lacustrine source/seal facies, and coarser grained fluvial-deltaic hydrocarbon reservoir rocks. Linked studies of a basin margin outcrop tied to a basin center core offer complementary views of these relationships.

About 3 km of synrift strata are exposed along the northern edge of the EGB, due to inversion of basin fill during middle Cretaceous transpression. Within the rift megasequence, three sequences (SR1-SR3) formed in response to climatic and structural controls on sedimentation. The lowermost synrift sequence (SR1) fines upward quickly from alluvial-braided fluvial conglomerate into fluvial and marginal lacustrine facies (Fig. 1). The middle and upper parts of the SR1 sequence exposed at Har Hotol are characterized by a series of 30—50 m.-thick depositional packages that typically contain basal thinly-bedded shale and siltstone, overlain by progressively upward-coarsening and thickening lenticular sandstone beds.

The lowermost of these parasequence-scale packages is arrayed in a unique set of amphitheater-style outcrops with excellent three-dimensional exposures, permitting detailed study of a preserved fluvial-lacustrine interface (Fig. 2). Outcrop investigations include photopanorama mapping and correlated measured sections, followed by interpretation of lithofacies and architectural elements. The results reveal complex sedimentologic and geometric relations, including highly lenticular sand-filled channels and a rapid lateral transition (<600 m) from fluvial sandstone into prodelta lacustrine mudstone. Asymmetric current ripples, climbing ripples, and soft sediment deformation are pervasive features, consistent with the changing hydraulics and sediment instability typical of marginal lacustrine environments. This parasequence is interpreted as a prograding perilacustrine delta, which was eventually overwhelmed by input of volcaniclastic detritus. Similar progradational cycles occur at least 13 times at the Har Hotol locality, indicating that repeated shifts in the lacustrine shoreline

characterized Upper Jurassic sedimentation in this area. Results also demonstrate the high degree of vertical and lateral lithologic heterogeneity in this hydrocarbon reservoir analog, and highlight the utility of outcrop-based studies for subsurface reservoir visualization and prediction.

Detailed study of 365 meters of conventional core recovered from the EGB complements this outcrop reservoir characterization with a lengthy vertical succession revealing the transition from fluvial and marginal lacustrine strata to profundal lacustrine facies during Early Cretaceous time (Fig. 1B). Many of the lithofacies observed in outcrop are present in the core, although a few differences are of note. First, fluvial and deltaic sections include coarser grain sizes than observed in the Har Hotol delta parasequences, probably reflecting closer proximity to source and generally coarser (higher-gradient) depositional systems. A profundal lacustrine sequence is also recognized in the core, and includes Fe-Mg carbonate strata and laminated mudstone not observed at Har Hotol. These micritic mudstone units are likely sources for EGB oil based on biomarker oil-source correlations. The core also affords improved recognition of small-scale features including trace fossils, ripples, and root traces, due to better preservation in the unweathered subsurface samples. Finally, core descriptions can be tied to well-log records and correlated across the basin, demonstrating that the lacustrine unit is widespread (at least 40 km extent), and may in fact constitute a new synrift sequence (SR4).

The results presented here hold both encouraging and cautionary implications for exploration in synrift deltaic-lacustrine reservoirs. On the positive side, evidence for a shifting lake margin predicts that multiple, stacked deltaic sandstone targets will form in close proximity to potential source lacustrine facies. The presence of adequate up-dip stratigraphic seal may be a risk on a larger scale, because deltaic sand packages likely transition laterally into fluvial and alluvial facies. However, basal lacustrine beds observed in the Har Hotol parasequences appear to represent major lake margin expansions, with transgressive mudstone units flooding fluvial deposits over significant distances, thus sealing and compartmentalizing each shoaling cycle. Although the individual sand bodies exposed at Har Hotol are relatively thin, more promising fluvial-deltaic systems may be found in other areas of the basin or in younger parts of the sequence (as seen in the core), where sediment supply and subsidence favored the development of larger or higher-gradient drainage networks.

The EGB outcropping delta and core sequences illustrate heterogeneous reservoir analogs, where sandstone bodies are not only highly lenticular and laterally discontinuous in cross-section, but also show pronounced thickness variation in the transport direction. Communication between preserved channels is jeopardized by the development of significant fine-grained interdistributary deposits or lacustrine shales. Finally, a persistent challenge to reservoir quality lies in the immature compositions of these sandstones, which have highly volcaniclastic lithologies, and associated zeolite cements (e.g., analcime), that significantly reduce porosity. Many of these lithic and geometric heterogeneities are below the resolution of commonly used exploration methods (e.g., seismic reflection data, and well-log correlation), indicating that development of outcrop-based models is critical to successful reservoir prediction in similar lacustrine-deltaic systems.

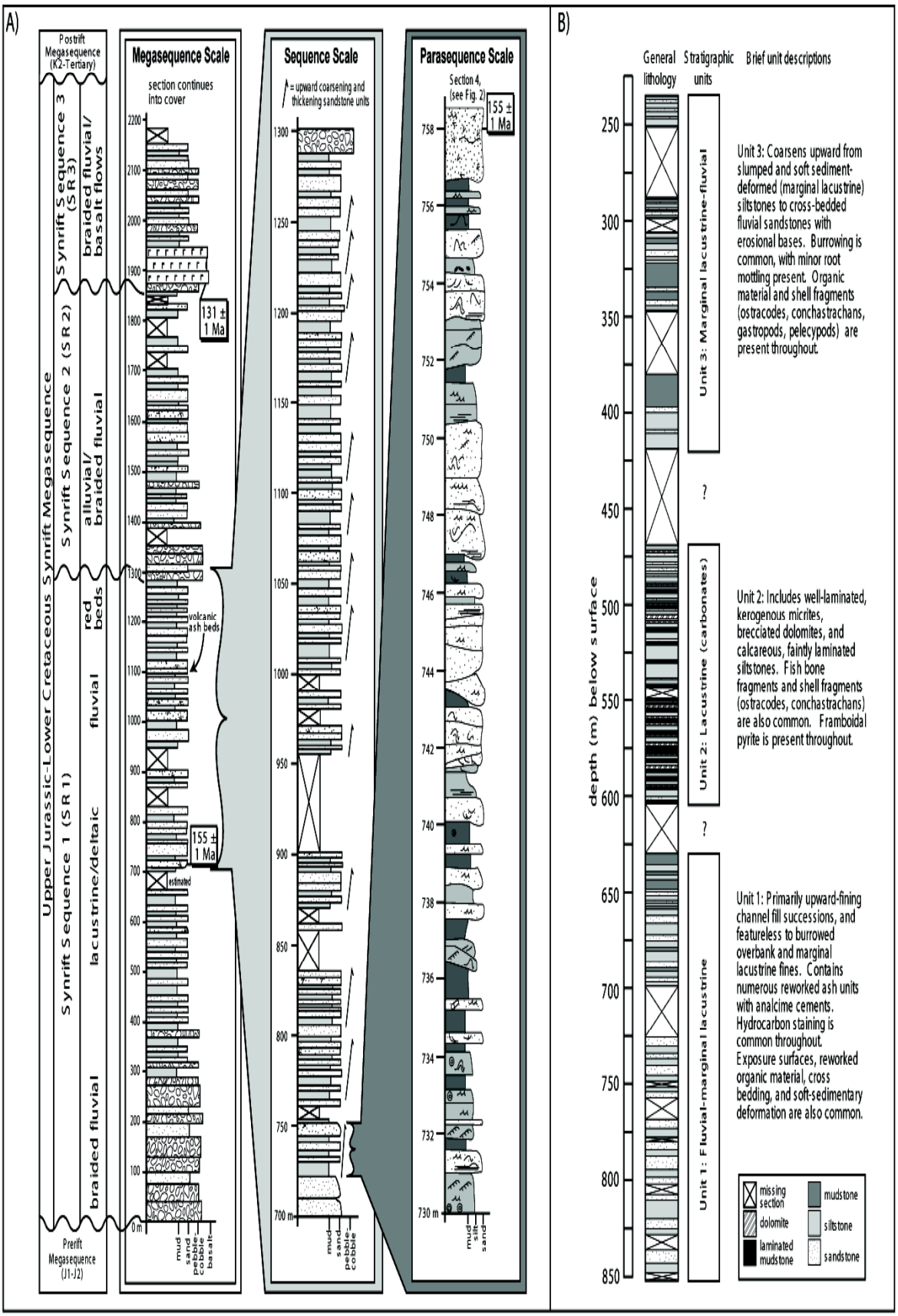

Fig. 1A) Three stratigraphic sections of synrift strata along the northern margin of the East Gobi basin. Increasing levels of detail are shown from megasequence to sequence and parasequence-scales. Radiometric ages in boxes are from ash units ($^{40}Ar/^{39}Ar$, biotite separates). See Fig. 2 for key to sedimentary structures. B) General lithology log and descriptions from an EGB core, showing subsurface examples of fluvial-lacustrine reservoir and source rocks.

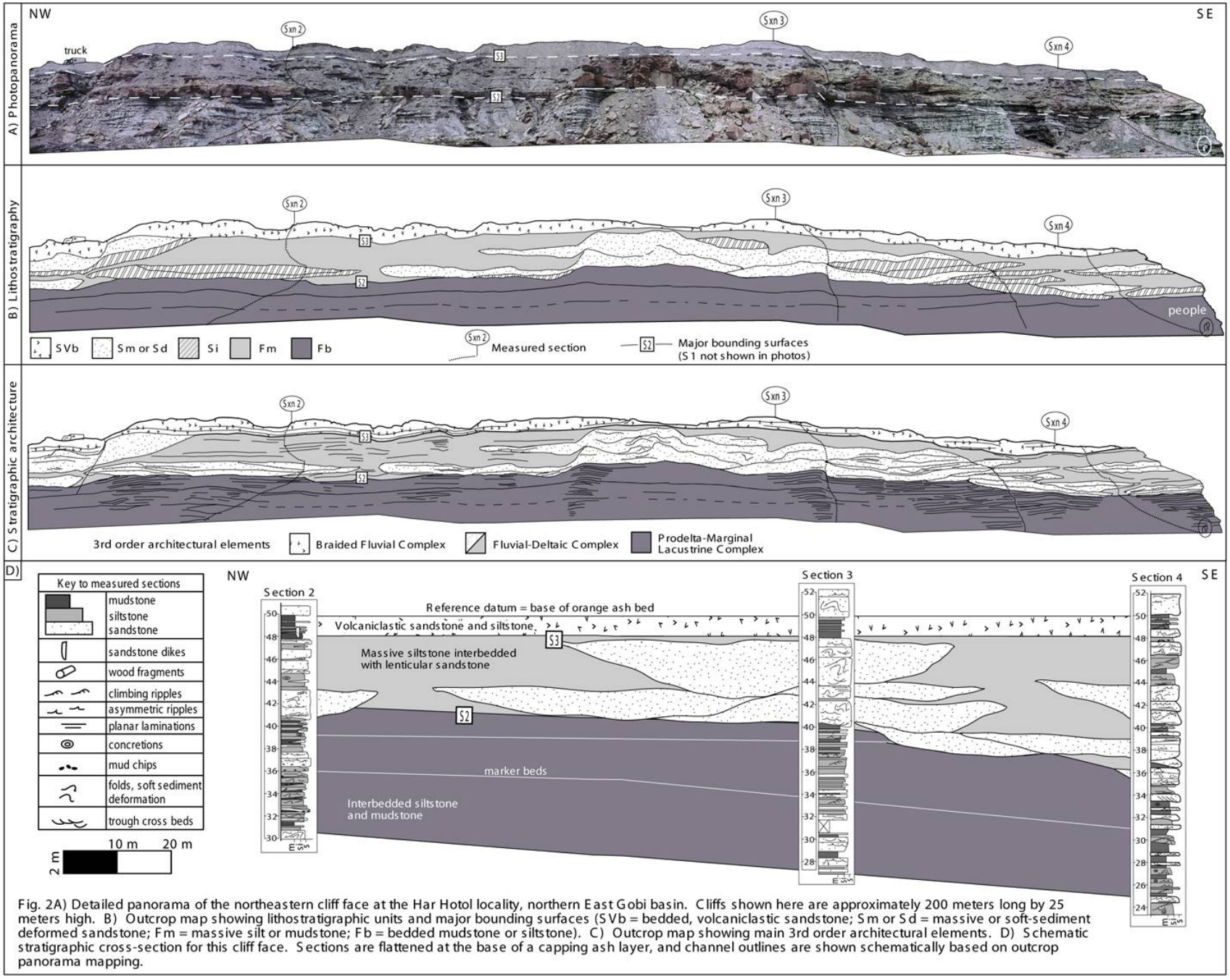

Fig. 2A) Detailed panorama of the northeastern cliff face at the Har Hotol locality, northern East Gobi basin. Cliffs shown here are approximately 200 meters long by 25 meters high. B) Outcrop map showing lithostratigraphic units and major bounding surfaces (SVb = bedded, volcaniclastic sandstone; Sm or Sd = massive or soft-sediment deformed sandstone; Fm = massive silt or mudstone; Fb = bedded mudstone or siltstone). C) Outcrop map showing main 3rd order architectural elements. D) Schematic stratigraphic cross-section for this cliff face. Sections are flattened at the base of a capping ash layer, and channel outlines are shown schematically based on outcrop panorama mapping.

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