Fill'er Up, Mac...and Check the Oil: Petroleum Migration Into Pay Sands at the Mars Field, Deepwater Gulf of Mexico

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The Mars Field, located ca. 200 km southeast of New Orleans in the Mississippi Canyon OCS lease area, lies in a crescent-shaped basin bounded on the north, east, and west by a laterally-continuous salt tablet (the Antares Salt) and on the south by a deep-seated salt diapir (the Venus Salt). The structural configuration of the Mars Field is an inclined, east-plunging trough within this salt embayment. Trapping elements at Mars include structural features that involve overhung Antares Salt to the north and onlap onto the Venus Salt to the south (Mahaffie, 1994). Stratigraphic trapping elements involve the scouring and erosion of turbidite fan and channel deposits (Mahaffie et al., 1995). The largest oil pools occur on the major limb of the Mars structure adjacent to the Antares salt tablet. Smaller oil accumu-lations generally are found on the minor limb of the trough, which wraps around the northern face of the Venus Salt.

The sour oil at Mars appears to have migrated vertically into the basin from deeply buried Mesozoic source rocks via the diapiric Venus Salt, which provided entry points for petroleum charge. The oil subsequently migrated laterally into and around the Mars trough. The geometry of this structure — which in cross section is a broad syncline — initially gives the impression that oil filled Mars pay sands via a backfilling mechanism because inferred charge entry points at the Venus Salt-sediment interface occur at the top of oil columns on the minor limb. During backfilling, an increment of charge that enters at the crest of a pay zone must displace an underlying, buoyant oil column (Fig. 1). Furthermore, because large oil columns occur at Mars on the major (northern) limb of the structure, it also might seem that either backfilling is required to allow oil to spill across the trough axis towards the Antares Salt (Fig. 2), or that oil also migrated into Mars reservoirs from vertical entry points (VEPs) associated with the Antares salt tablet. However, a careful analysis of oil migration illustrates that neither backfilling mechanisms nor multiple VEPs need to be invoked to explain how crude oil migrated through the turbidite reservoirs at Mars from the Venus salt body.

The key insight comes from appreciating how the plunge of the Mars trough and the presence of permeability barriers within the turbidite reservoirs influenced lateral migration in three dimensions. Crude oil entering the basin initially migrated along the Venus Salt-sediment interface, moving up the plunge of the Mars trough from structurally low VEPs found along the face of the Venus diapir (Fig. 3). When this oil encountered an updip barrier — such as the suture between the Antares and Venus salt bodies, or impermeable mudrocks filling turbidite channel scours — it initially formed modest oil pools on the southern limb of the trough, at all times conventionally filling traps from below by displacing denser brine (Fig. 4). These oil accumulations eventually grew until they completely filled all traps on the minor limb. Subsequent incremental oil charge spilling from these traps continued to migrate laterally updip. This "fill and spill" process allowed crude oil to cross the trough axis and fill the much larger traps on the northern limb of the Mars structure without requiring backfilling or the presence of additional VEPs. Thus, the plunge of the Mars structure and stratigraphic complexities induced by turbidite flow processes focussed oil migration around the field from VEPs present only along the northern face of the Venus salt diapir.

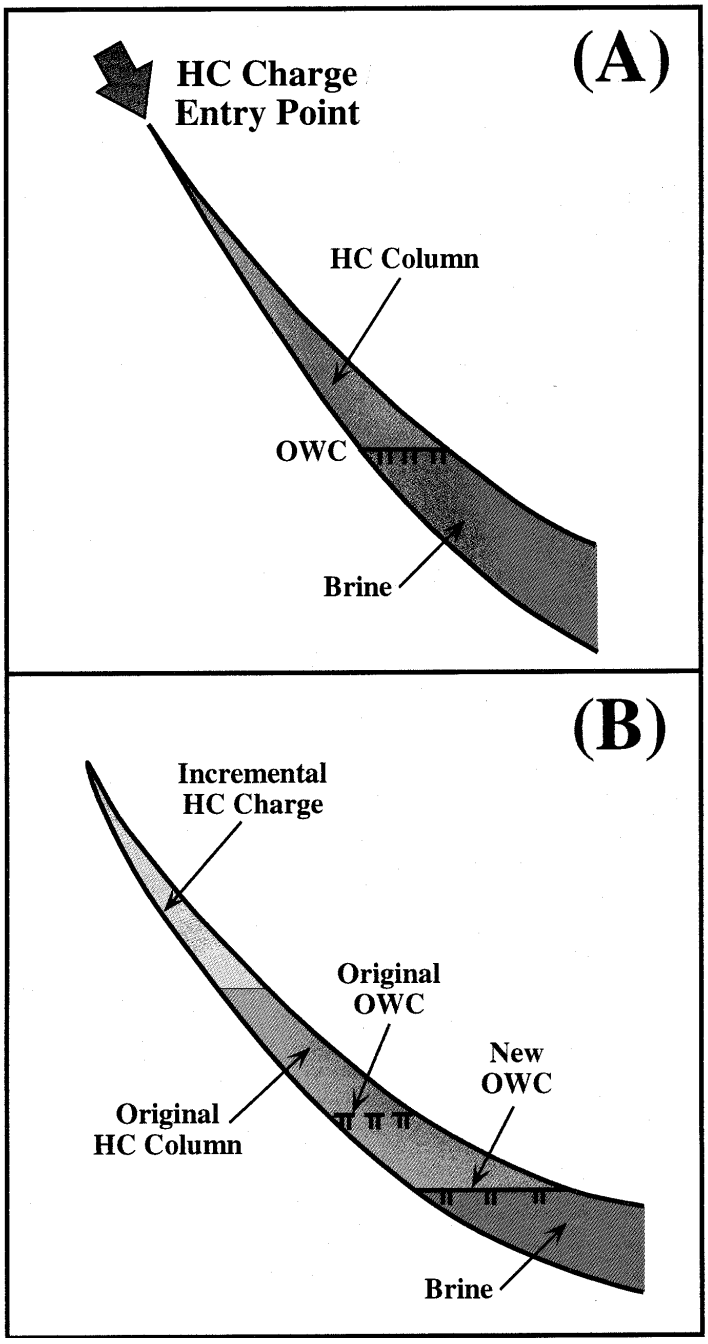

Figure 1. Backfilling charge and migration model for Mars pay sands. (A) Backfilling is required when the hydrocarbon (HC) charge entry point is located at the crest of a pay zone, significantly above the oil-water contact (OWC). (B) During backfilling, incremental HC charge (light grey) must displace a pre-existing, buoyant oil column (medium grey) into the water leg (dark grey).

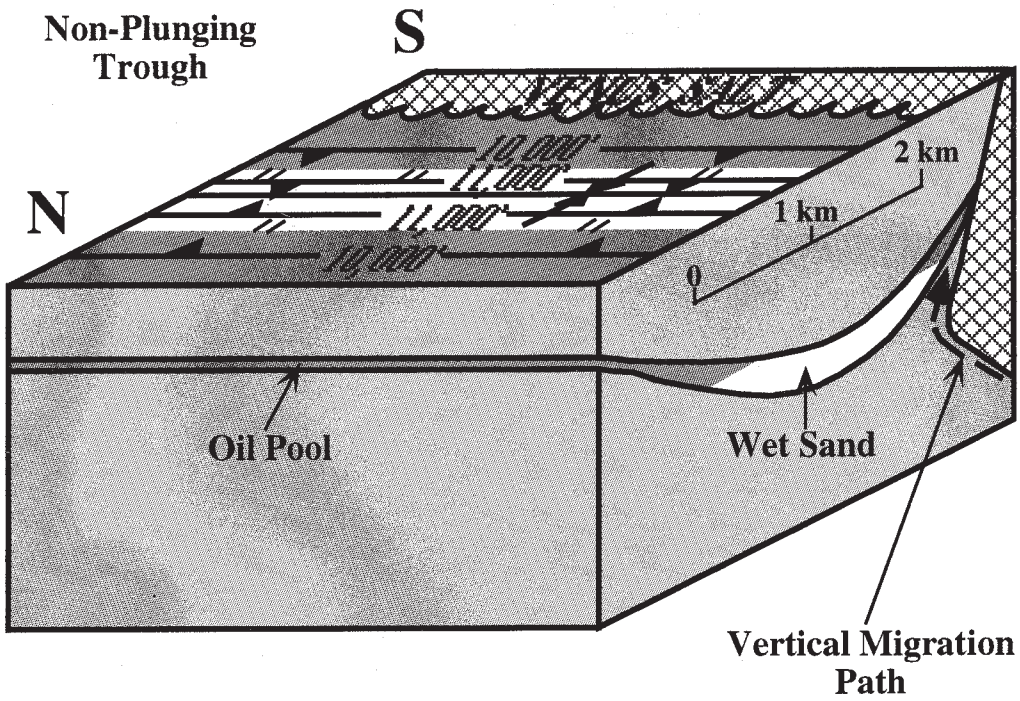

Figure 2. Mars charge mechanism for a non-plunging trough, illustrating a map view (horizontal plane) of the subsurface structure and stratigraphy. If the plunge of the Mars structure is overlooked inadvertently, it appears that oil migrating vertically along the northern face of the Venus Salt can fill salt-onlap traps only by backfilling pay sands from vertical entry points (VEPs) at their crest. Because buoyancy keeps oil columns (dark grey) nestled against the Venus Salt, massive amounts of backfilling — or the presence of additional VEPs located along the northern limb of the trough (not shown) — is required to spill oil across the trough axis to account for the presence of large oil pools on the northern limb of the Mars structure.

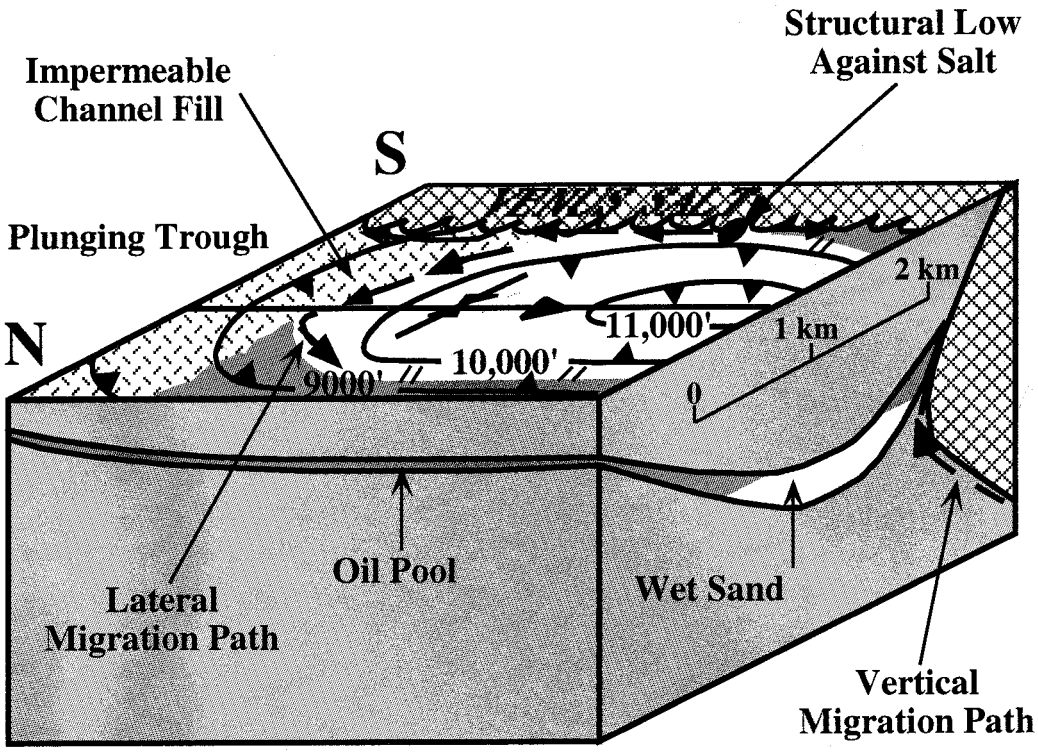

Figure 3. Mars charge mechanism for a plunging trough, illustrating a map view (horizontal plane) of the subsurface structure and stratigraphy. Oil entering a pay zone from a structurally-low vertical entry point (VEP) along the Venus Salt will migrate laterally updip along the salt-sediment interface and can cross the trough axis — filling turbidite reservoirs (dark grey) without backfilling — if permeability barriers are present.

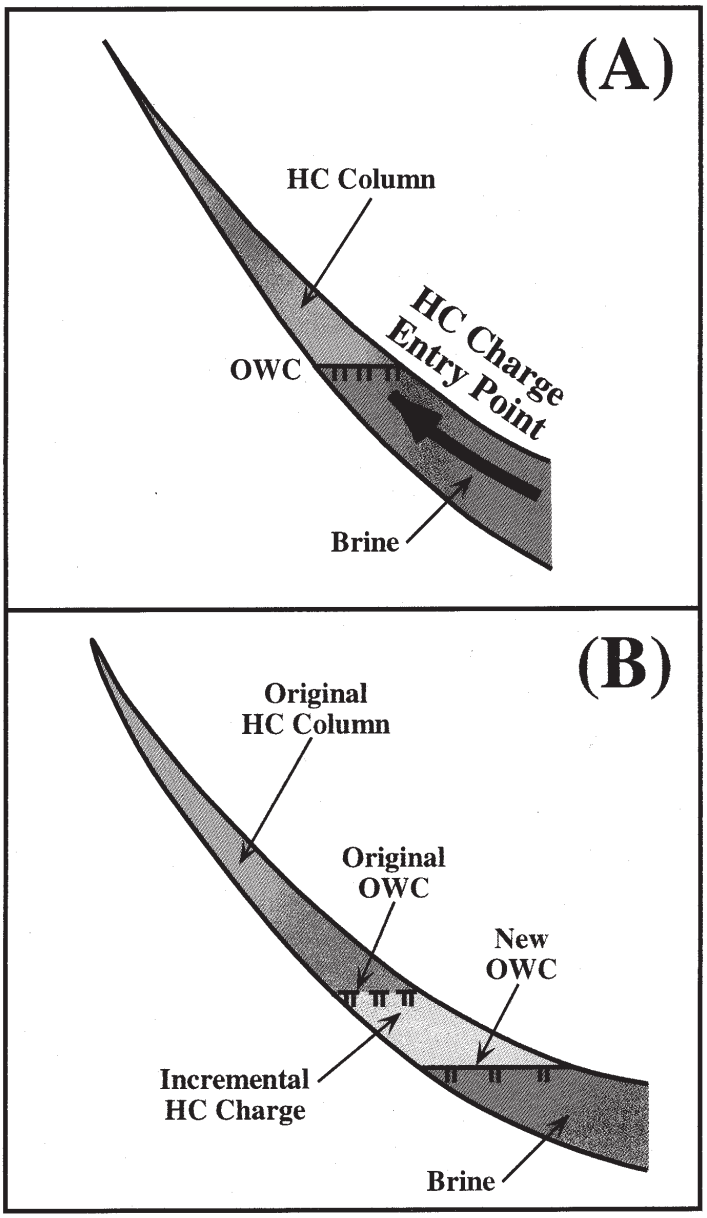

Figure 4. Conventional charge and migration model for Mars pay sands. (A) At all times, hydrocarbons (HC) migrate laterally through pay zones below the oil-water contact (OWC). (B) Incremental HC charge (light grey) migrating below a pre-existing oil column needs to displace only denser brine (dark grey) at the OWC — not a large column of buoyant oil (medium grey).

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