Sea-Floor Seeps and the Framework of Oil Generation and Migration in the Gulf of Mexico Slope

Roger Sassen, Geochemical and Environmental Research Group (GERG),
Texas A&M University, College Station, TX 77845

The Gulf of Mexico continental slope is an archetypal salt basin with multiple oil-prone source rocks ranging in age from Early Tertiary to Late Jurassic, a regionally variable thermal history, rapid vertical migration along salt and faults and extremely low trapping efficiency. The low trapping efficiency of the Gulf slope is often offset by extremely prolific Upper Jurassic source rocks with a relatively recent time of hydrocarbon charge.

Episodes of sediment loading and structural evolution cause pulsed migration from depth. Traps often receive multiple charges with variable hydrocarbon characteristics, and hydrocarbons undergo fractionation and remigration during structural modification within complex reservoir systems. Most hydrocarbons are eventually dispersed, or lost to the sea floor. For this reason, oil and gas seeps, gas hydrates, chemosynthetic communities, authigenic carbonate rock, and natural oil slicks are common across some areas of the slope. Regionally, the distribution of seeps shows a strong relation to the distribution of subsurface accumulations of oil and gas.

Within the main zones of seepage across the Gulf continental slope and shelf edge, seepage characteristics are related to structural context. Conduits for hydrocarbon migration are sometimes resolvable from depth to the sea floor on seismic profiles. Sites of seepage are definable using 3-D geophysics as sea-floor amplitudes associated with subsurface structure and irregular sea floor.

Seepage intensity in the vicinity of oil and gas accumulations is strongly controlled by structure. For example, salt movement and faulting on the edges of intrasalt basins with large source-rock drainage areas can result in significant oil and gas seepage with sea-floor modification. Examples include seeps near (1) Cooper Field on Garden Banks Block 388, (2) Jolliet Field, Green Canyon Block 184, (3) Mars Field in Mississippi Canyon Block 807, and (4) the “Venus” seep, a regional pressure release point representing

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lateral fluid flow from the vicinity of Ursa Field on Mississippi Canyon Block 810.

High-rise salt structures that have received charge can display extremely prolific seepage. The oil and gas seeps at Garden Banks Block 425, near Auger Field, serve as an example. The nature of seepage associated with sub-salt discoveries was initially unknown. However, horizontal salt sheets with sub-salt charge display edge-leakage, but more intense seepage can occur on the fractured crests of salt sheets. Thus, seeps overly some sub-salt fields. The deep Sigsbee Escarpment area also is characterized by oil and gas seeps, one example being near the BAHA well in Alaminos Canyon Block 600.

In contrast, a charged stratigraphic trap with poorly developed vertical conduits to the sea floor might at best display a modest oil seepage signature deficient in thermogenic gas. The easily detectable aromatic hydrocarbons of crude oil (PAH) accumulate over time in sea-floor sediments because they are resistant to bacterial oxidation, whereas gas is rapidly removed by bacterial oxidation.

Seep geochemistry allows mapping of oil families ahead of the drill bit, emphasizing differences in resource value. Lower Tertiary and Cretaceous source rocks are important in specific areas, but Upper Jurassic source rocks are initially characterized by high sulfur contents which decrease with increasing thermal exposure. In the broadest sense, biomarker geochemistry of oil seeps can provide regional calibration in mapping source rock maturity and timing.

Although oil and gas seeps constrain risk, seeps do not guarantee success because so many other risk factors are involved. In addition, gas-flushing sometimes creates oil seeps in association with gas fields. Prolific leakage, however, should not raise undue concern of breached seals. In contrast, the absence of seeps on the slope where potential migration conduits do exist could indicate a lack of charge, so other risk factors become moot.

The relationship between seepage and subsurface accumulations on the Gulf slope appears similar to some other oil-prone Tertiary deltas in terms of seepage (i.e., offshore Nigeria). However, it should be stressed that other hydrocarbon-prone basins can display quite different characteristics.