What is the Story on Microseepage?

Many people have heard of macroseepage, but few people have heard about microseepage or understand the microseepage mechanism.

As most of us know, the term **Macroseepage** refers to **visible oil and gas seeps**. Macroseeps are very localized areas containing large concentrations of hydrocarbons that are restricted to the termination of faults, fractures, and outcropping unconformities or carrier beds. These visible seeps have led to the discovery of many of the world's important oil and gas producing areas (Link, 1952; Macgregor, 1993), see **Figure 1**.

In **Microseepage**, hydrocarbon compounds pervade the overlying seal and migrate vertically through the stratigraphic sequence to the surface. The leakage is not massive, as with a breach of a structural closure. This process is distinct from the movement of hydrocarbons along breaching faults or fracture swarms (i.e. macroseepage), with its consequent surface expression of an oil or gas seep (Silliman, 2005).

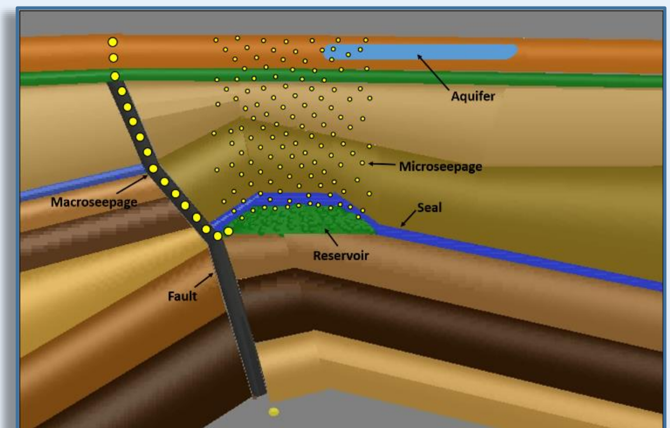

Figure 1.

Due to vapor pressure limitations, typically only volatile or semivolatile hydrocarbons are expected above the water table. The existence of microseepage is supported by a large body of empirical evidence (Price, 1986; Klusman, 1993; Klusman and Saeed, 1996; Matthews, 1996).

Research and field studies suggest that the dominant migration medium is **continuous-phase, buoyancy-driven gas flow** within carrier and reservoir rocks and capillary imbibition in the transition from sources and seals into carrier rocks.

The migration of hydrocarbon compounds is nearly vertical in direction, so that surface expressions of these compounds overlay the subsurface accumulations. In this manner, detection of thermal hydrocarbons provides a valuable exploration capability (Silliman, 2005). Surprisingly, migration rates are fairly dynamic, ranging from less than 1 meter per day to tens of meters per day (Arp, 1992; Abrams, 1992)

Why should I care about anything but macroseepage?

Macroseepage is important because it denotes the presence of a petroleum system and the biomarker data can address depositional environment, age, maturity, etc. However, macroseeps are not omnipresent. Microseep data provides additional information such as structural boundaries, faults, hydrocarbon movement, reservoir depletion affects, field sweet spots (i.e. areas of higher pressure, porosity, and net pay) and can identify several liquid signatures denoting multiple sources.

Since oil contains compounds out to ~C_{45}, why is microseepage only analyzed up to C_{20}?

While most microseepage analyses analyze only C_1 – C_5, Amplified Geochemical Imaging analyzes C_2 – C_{20}. The primary limiting factor for the C_{20} monitoring is the volatility of the hydrocarbon compounds themselves. C_{20} is the approximate limit beyond which hydrocarbon compounds no longer partition into the gas phase, thus preventing their transport through the reservoir seal.

If traditional methods report a detection limit of parts per million (ppm) for microseepage, then how can AGI report a detection limit of parts per billion (ppb)?

The AGI sampler, see **Figure 2**, contains a specially engineered oleophilic (i.e. oil loving) adsorbent encased in a microporous membrane. These membrane pores are small enough to prevent soil particles and water from entering, but are large enough to allow hydrocarbon molecules to pass through. The result is an ultrasensitive technology that is approximately 1,000 times more sensitive than traditional methods.

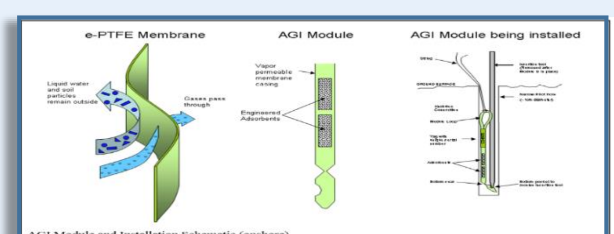

Figure 2.

How do larger molecules migrate through over-pressured zones and aquifers?

Literature postulates molecular movement through pervasive microfractures as free phase flow (Brown, 2000). However, the strong fracture control postulated does not concur with empirical data which does not produce the sort of surface patterning predicted by this model. It is important to note that the microfracture network, as a whole, is not coupled to ground-water flow paths since downstream deflection of surface signatures cannot be established. Larger molecules would presumably carry in solution with the light gases (including both hydrocarbons and CO_2 in places). It is also important to note that in aquifers lateral movement occurs in centimeters per day, while vertical buoyancy of the hydrocarbon molecule occurs at meters per day.

What is the effect of dipping porous beds on the migration of heavier components? Would heavier components tend to migrate along the bed top rather than directly upward?

Empirical data shows apical anomalies corresponding to reservoir projections against high-angle reverse faults for instance, or stratigraphic plays where porous formations truncate along basin flanks. This again points to the decoupling of microseepage flow paths from poro-perm migration pathways.

In a real sense, microseepage can be thought of as a separate, “tertiary” migration mechanism, in the movement of petroleum systems. Any tendency to link microseepage into traditional secondary migration processes ends up being problematic with reservoir preservation through time. Microseepage is documented from a variety of reservoir studies current day, implying the mechanism is stable over geologic time. If the process had overlap with secondary migration, the system would lead to reservoir depletion long ago. If microseepage could be captured in effect when crossing poro-perm pathways, it would likely never be observed at the surface since active basins usually have porous formations somewhere above generating source sections.

Does microseepage occur in fields with very heavy oils, especially given your C_{20} threshold?

Yes! Typically heavy oil signatures are a result of biodegradation and, thus, the loss of gaseous light-end components. The result is a heavy oil signature where the majority of the heavy oil signature emanates beyond C_{20}. However, there are still numerous compounds in the heavy oil signature that elute between C_{12}-C_{20} that provide sufficient signal for detection and mapping. Projects conducted by AGI in Peru (available upon request), Argentina, and Venezuela have demonstrated the ability to detect the microseepage of heavy oils.

Does microseepage occur through “perfect” seals such as thick salt sequences or frozen tundra?

Yes! One case study (available upon request) conducted in the Red Sea entailed ~8,000 ft of salt and anhydrite. Given the extensive thrusting, faulting, and thick salt sequence, seismic data was difficult to interpret. **Figure 2** shows a cross section of the field along with a stratigraphic column and an oil signature derived at the surface via microseepage. Another case study performed in Western Siberia (available upon request) was performed through frozen tundra. Both a condensate and normal API oil were detected at the surface as a result of microseepage. A well drilled subsequent to the survey confirmed 80 m of net oil pay at ~3,000 m resulting in an EUR of 340 million barrels of oil.

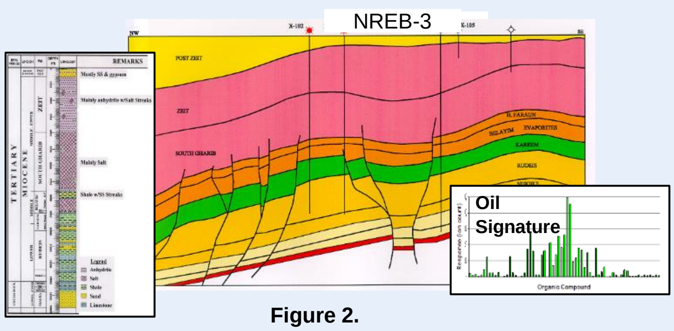

Figure 2.

Do you see source rock effects? That is, do generating source rocks also give a vertical migration signature?

Yes, this is an interesting question and one of the reasons for liking the Brown 2000 model of microseepage. Empirical data seems to indicate enhanced hydrocarbon levels in areas of migration / generation, the microfracture / continuous gas flow model is easier to accept than micro-bubble / capillary overpressure models for microseepage. It appears that reservoirs are discerned from general migration pathway / source rock areas by the coherence of surface anomalies. Reservoirs yield broader and stronger anomalies than the other conditions. This distinction may be a function of the volume of hydrocarbons in place.

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