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Evidence for Multiple-Phase Mass Transport During Hydrocarbon Vertical Migration

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Understanding mass transport mechanics, or how each hydrocarbon group migrates from the reservoir formation to the surface, is essential for integrating near-surface hydrocarbon data with seismic survey data, subsurface geological information, and geomorphological data

Migration Mechanisms: Work on vertical migration mechanisms during the past decade has increased our understanding of how hydrocarbons may be transported from petroleum reservoirs to the surface. While current vertical migration models deal with low-molecular-weight hydrocarbons migrating as gases (Arp, 1992) (Klusman and Saeed, 1996), medium to heavy weight petroleum hydrocarbons also are present at the surface (Hebert, 1988) (Brooks, *et al*, 1986) (Brooks and Kennicutt, 1988). Some heavier hydrocarbons are not sufficiently volatile for significant quantities to be transported as a gas phase[1]. In addition, comparing Figures 1 and 2 shows one offshore example where light hydrocarbon surface expressions were quite different from heavy hydrocarbon surface expressions (Belt and Rice, 1996a, 1996b). Different surface patterns suggest light and heavy hydrocarbons possibly migrate to the surface through different pathways. One explanation for migration through different pathways is different migration phases.

The "other phase" occurring in vertical migration may be liquid. Certainly, liquid hydrocarbon seeps have been documented offshore (Kennicutt, *et al*, 1988) and less frequently, on land. Possibly, less-than-visible quantities of heavy hydrocarbons migrate to the surface by similar vertical migration mechanisms. This paper addresses preliminary results of on-going

[1] A phase refers to a pure material or a single homogeneous mixture of materials. For example, miscible gases form a single phase and miscible liquids form a single phase. Two immiscible liquids, e.g., hexane and water, form two phases.

research investigating causes for different surface expressions of light and heavy petroleum hydrocarbons.

Gas-Phase Migration: Gas-phase migration is the vertical migration of low-molecular-weight hydrocarbons referred to as paraffins. Paraffins are composed of both straight-chained hydrocarbons, or normal paraffins, and branch-chain hydrocarbons, or isoparaffins. Paraffins are the second most common component found in petroleum, after cycloparaffins (Hunt, 1979a). Low- molecular-weight paraffins can vertically migrate through both microfractures and macrofractures. Therefore, seismic survey data and subsurface isopach maps indicate the trend and spacial extent of petroleum bearing formations that can be integrated with mapped low-molecular-weight hydrocarbon concentrations greater than background.

Evidence for Liquid-Phase Vertical Migration: Hydrocarbons, possibly vertically migrating as a liquid phase, include medium- and heavy-molecular-weight hydrocarbons such as aromatics, polynuclear aromatics, and cycloparaffins. Cycloparaffins, which are the most abundant hydrocarbons in petroleum, are present only as cyclopentanes, cyclohexanes, and cycloheptanes (Hunt, 1979b). Current data indicate medium- and heavy-molecular-weight hydrocarbons require larger conduits, or macrofractures, in the form of faults or joints. This requirement for larger fractures is consistent with a different, possibly liquid, phase migration. Anomalous mapped concentrations indicate the near-surface location of seeping fractures. Therefore, seismic survey data, subsurface geological structure maps, and geomorphological data from drainage patterns should be thoroughly evaluated to help confirm and locate these structural migration pathways in the subsurface.

Modeled Examples: Both offshore and land examples illustrate the integration of gas phase migration and possibly liquid phase migration with seismic survey data, subsurface structure and isopach data, and geomorphological information. Land examples are more complex than offshore due to vertical migration through a water table plus migration above the water table. Selected examples characterize integration and multi-phase vertical migration at both the reconnaissance and detailed phases of a prospect.

Figure 1. Offshore light weight hydrocarbon distribution

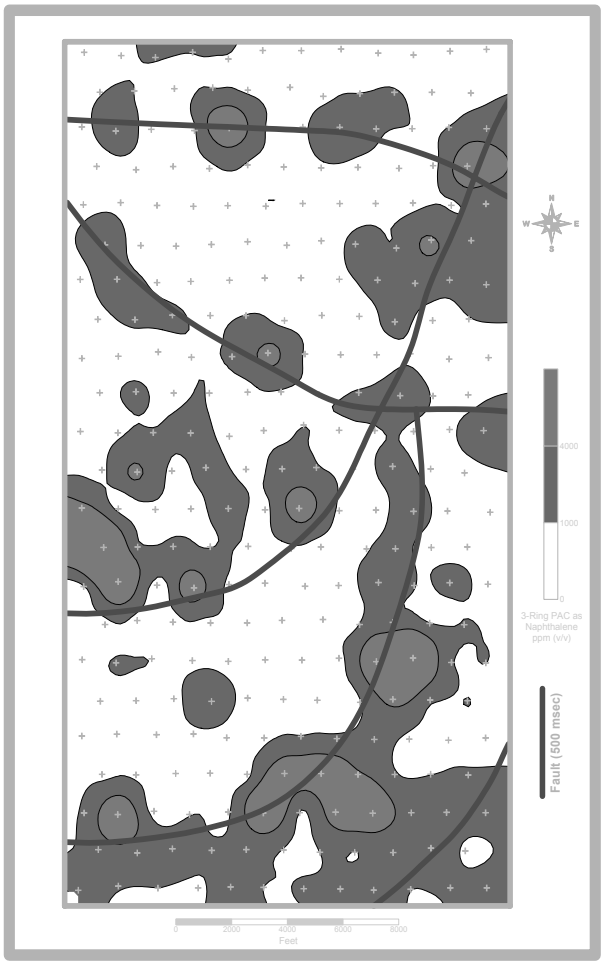

Figure 2. Offshore medium weight hydrocarbon distribution

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