Integrated Investigation of Fault-Controlled Hydrocarbon Migration, Ship Shoal 274 Field

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Ship Shoal 274 is a complexly faulted oil- and gas-producing field that serves as a natural laboratory for the study of fault-controlled hydrocarbon migration at regional to compartmental scales through analysis of geochemical, geophysical, geological and production data. Specific problems addressed in this study are how regional patterns of hydrocarbon migration relate to structural development of the field and the extent to which faults compartmentalize production.

Ship Shoal 274 and adjoining blocks lie in the Louisiana OCS, Gulf of Mexico; their geology is characterized by Plio-Pleistocene sediments crosscut by large- and small-displacement faults. Production occurs in both the footwall and the hanging wall of a large-displacement arcuate fault (A, see Figure 1) near its junction with a N-S trending fault (B). Small-displacement (50 ft. or less) faults in the footwall and hanging wall of the A fault form two sets, one that parallels the A fault and one that parallels the B fault; it is believed that these faults formed concurrently with faults A and B, respectively. Both A and B faults formed in response to salt movement and are salt cored at depth. Based on crosscutting relationships and paleontologic data, it appears that movement occurred first on fault A, while fault B and associated synthetics and antithetics were more recently active.

Map patterns of whole-oil chemistry suggest that evolving routes of hydrocarbon migration tracked structural development of the field (Figure 1). Oil with a whole-oil chemistry consistent with that of a parent

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oil, along with associated gas, is found throughout the field, and in particular, appears to lie along trends bounded by small-displacement faults of the A family. Fractionated oils and condensates with an isotopic signature similar to that of the parent oil are found proximal to the B fault and along trends bounded by faults of the B family, along with late-stage gas with a distinct isotopic signature (possibly derived from a separate source). In particular, fractionated oils, condensates, and late-stage gas are localized along faults antithetic to B. This pattern of hydrocarbon geochemistry is explained by early migration of oil and gas up the A fault, perhaps during active deformation, followed by late-stage migration of gas up the B fault (and possibly the NW-SE trending section of the A fault), resulting in oil fractionation and remigration along associated small-displacement faults, as shown in Figure 2.

Hydrocarbon distribution patterns such as gas emplaced downdip from oil are consistent with this model for reservoir charge. Such patterns must be maintained by reservoir compartmentalization. For three sands, detailed maps of oil- and gas-charged compartments bounded by small-displacement faults were made from amplitude and edge-detection analysis of seismic data. One of these, of the G sand, is shown schematically in Figure 1. Size of fault-bound compartments was estimated from the maps, then compared to drainage areas modeled from production data for wells producing from these compartments. For thin discontinuous sands, predicted fault-bound compartment size closely matches drainage area. For thicker sands such as the G sand, predicted compartment size is much less than calculated drainage area for some wells (Figure 1). For these compartments, it is inferred that small-displacement faults are ineffective barriers to cross-fault migration of juxtaposed sands over production time scales. This model could be used to predict drainage areas for oil and gas compartments located by seismic attribute mapping that were not drilled into previously.

In summary, at a regional scale, evolving migration patterns tracked structural history, and recently active faults acted as the most likely conduit for hydrocarbon flow. Large and small faults formed a network of migration pathways, and vertical and horizontal migration within the field was controlled by effective directional permeability of faults and/or juxtaposition. Applications of this study to risk mitigation include

- prediction of previously untapped compartments,
- prediction of oil/gas type based on existing patterns, and
- prediction of effective compartment size from analysis of fault-seal effectiveness.

Figure 1. Schematic map of the G sand, Ship Shoal blocks 274 and 293. Large-displacement faults A and B and related small-displacement faults are shown in black. Three-dimensional patterns of oil geochemistry are projected onto the G sand and are shown in shades of gray (as indicated by the key). Large circles indicate

calculated drainage area from G-sand production data for wells shown by small circles (the small white circle indicates a gas-producing well and the small black circle indicates an oil-producing well).

Figure 2. Schematic 3-D model of changing patterns of hydrocarbon migration, Ship Shoal 274 and vicinity. Faults A and B and associated synthetic and antithetic small-displacement faults are represented by curved surfaces. Above, black arrows indicate early migration of parent oil up faults of the A family. Below, black arrows indicate late migration of gas up faults of the B family and the NW-SE trending section of the A fault and its associated antithetics.

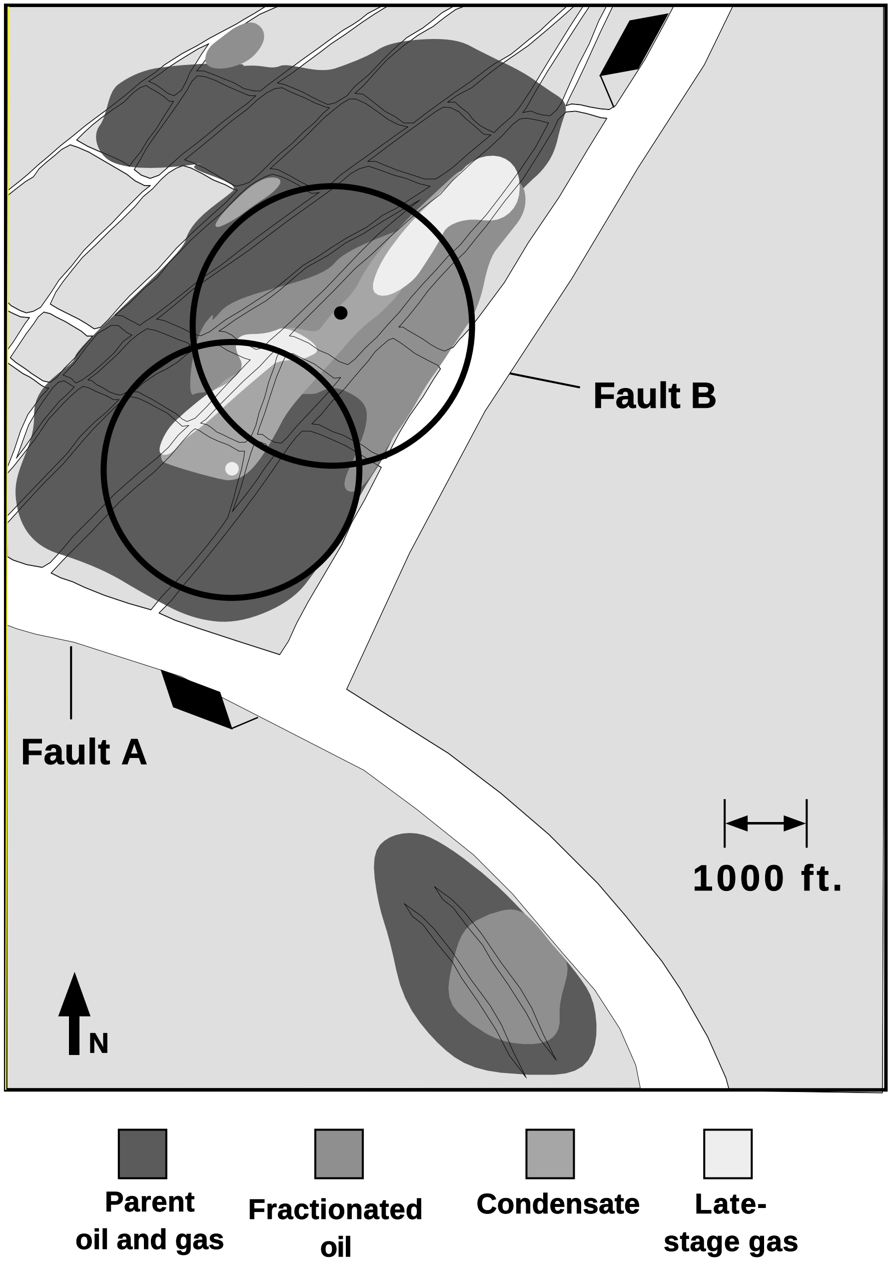

Figure 1

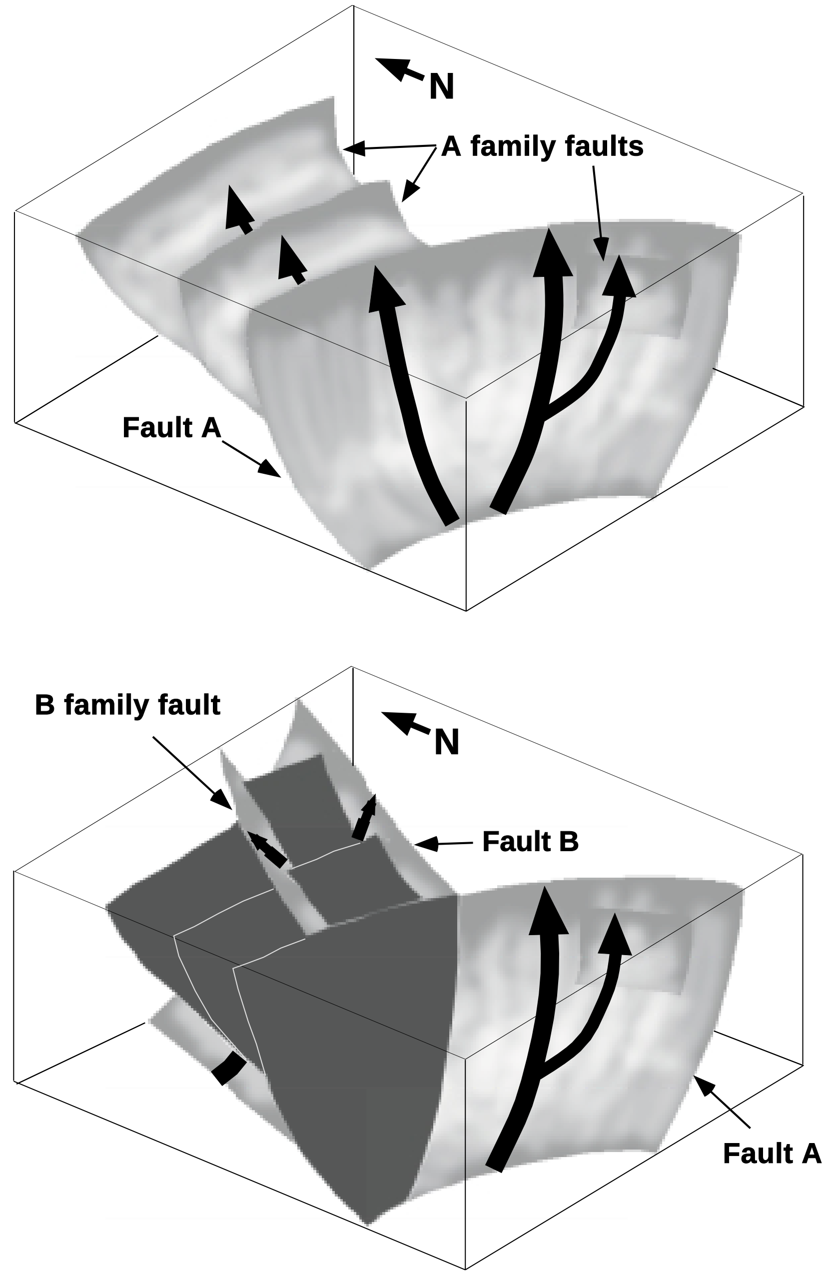

Figure 2