Characterization of Carriers for Hydrocarbon Migration: An Example from the Dongying Sag, Bohai Bar Basin, China*

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Abstract

Secondary hydrocarbon migration in carriers and reservoirs is a highly heterogeneous process (Harms, 1966; Berg, 1975; Schowalter, 1979), which restricts mostly the quantity and position of hydrocarbon accumulations. At a microscopic scale, the occurrence of migration depends on the importance of driving force relative to resistances of carriers, so that random distribution of pores and pore throats will cause uneven selection of a migration pathway (Lenormand et al., 1988; Hirsch and Thompson, 1995; Luo, 2007). And such heterogeneity will be enhanced by heterogeneous porous media comprising the carriers at various scales (Luo, 2011). Hence, quantitative analysis of hydrocarbon migration should consider not only the driving force but also the properties and characteristics of carrier beds (England et al., 1987).

Based on our previous attempts at quantitative researches on migration paths and pathways, the authors propose in this work a concept of carrier formation (Figure 1a) for realizing the characterization of migration carriers, by taking the scale of migration and maneuverability into account. The carrier formation is defined as a lithologic formation, beneath a regional seal, that offers the paths for hydrocarbon migration in a certain geological period when hydrocarbon migration process happened. Such a carrier formation may contain a few or multitudinous permeable geological bodies, hydraulically connected among themselves.

In order to characterize the hydraulic transmissibility of a detrital sediment carrier at the basin scale, such a carrier formation is vertically separated, by a grid, into quadrate prisms. The petrophysics properties of all the strata in one prism may be marked on the upper-surface stratum (element) by using geostatistic methods, then the carrier formation may be modeled as a 2D layer (Figure 1b). After then, all the treatments for characterizing the carrier formation's transmissibility will be done on the layer.

Discussion

The previous works, including the methods used in reservoir characterization and the authors' understanding on migration pathways, were synthesized. A working procedure for characterizing carrier formation was set up and used in migration studies. The working procedure includes 5 processes:

1) determining the thickness and domain of carrier formation and separating the formation into quadrate prisms,
2) determining the sand bodies property in each prism and constructing the 2D carrier layer model,
3) analyzing the geometrical connectivity among sand bodies in the carrier model,
4) analyzing the hydraulic connectivity among sand bodies in the carrier model, and
5) characterizing the carrier formation.

The permeability was considered as the conformable parameter in the characterization, purposing to establish a carrier frame composed of carrier formations, faults, as well as carriers associated with unconformities.

The authors studied migration carriers in the Dongying Sag of the Bohai Bay Basin, China, and attempted to establish a methodology to characterize them. The abundant subsurface data of this field was used to characterize the opening and closing processes of faults to reconstruct the temporal-spatial relationship between faulting and fluid flow during the critical moment of source-rock maturation and accumulation (Zhang et al., 2010). Diagenetic study of sandstone carriers and their hydraulic connectivity for hydrocarbon migration indicates that sandstone permeability can be used to effectively quantify the hydraulic connectivity of the carrier system. Spatial juxtaposition among sandstones and connecting open faults was identified to construct the 2D framework of compound sandstone-fault carrier system in the area of major secondary migration.

Next, hydrocarbon migration pathways within the reconstructed carrier system during the principal migration-accumulation period were simulated on the basis of current understanding of migration process in the Paleogene petroleum systems (Figure 2), using our Mig-MOD migration simulator (Luo, 2011). The major migration pathways of variable directions and distance and quantity of migrated hydrocarbon through the pathways were interpreted from the model results, using a new mass-balance method. The method takes into account the distribution of simulated pathways and estimates the hydrocarbon loss during migration. The interpretation indicates that hydrocarbons could have migrated over a long distance outside of the source domain in the center of the depression to areas beyond discovered oil fields (Figure 2). These areas are new exploration targets.

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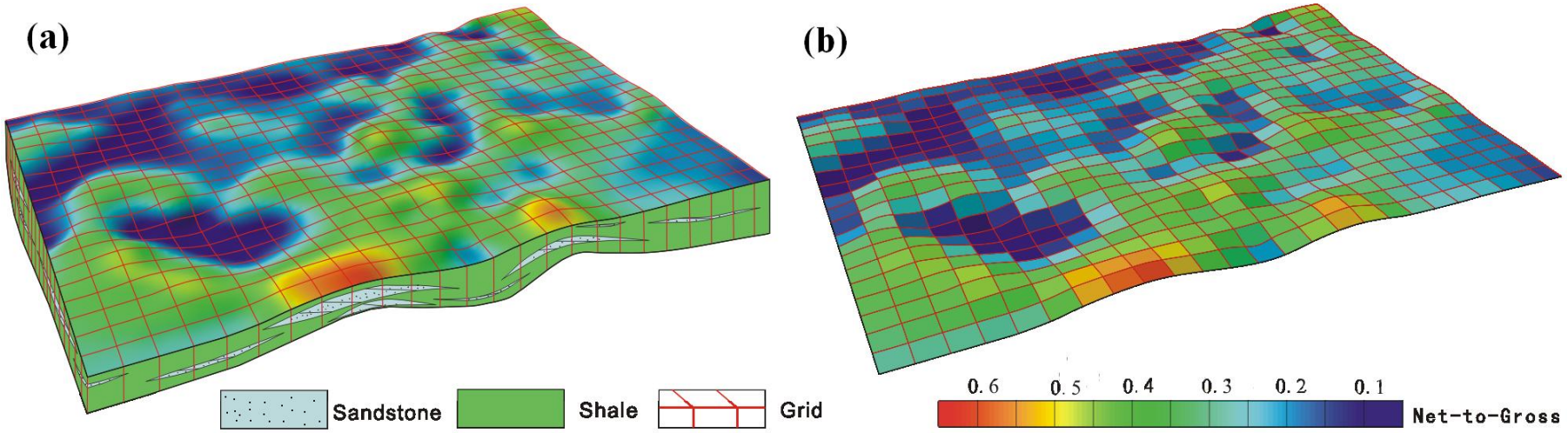

Figure 1. The distribution of sandstone bodies and the corresponding carrier formation model.
(a) Sandstone bodies distribution model characterized by elemental stratum columns with a grid;
(b) The 2D carrier formation model characterized by net-to-gross sand.

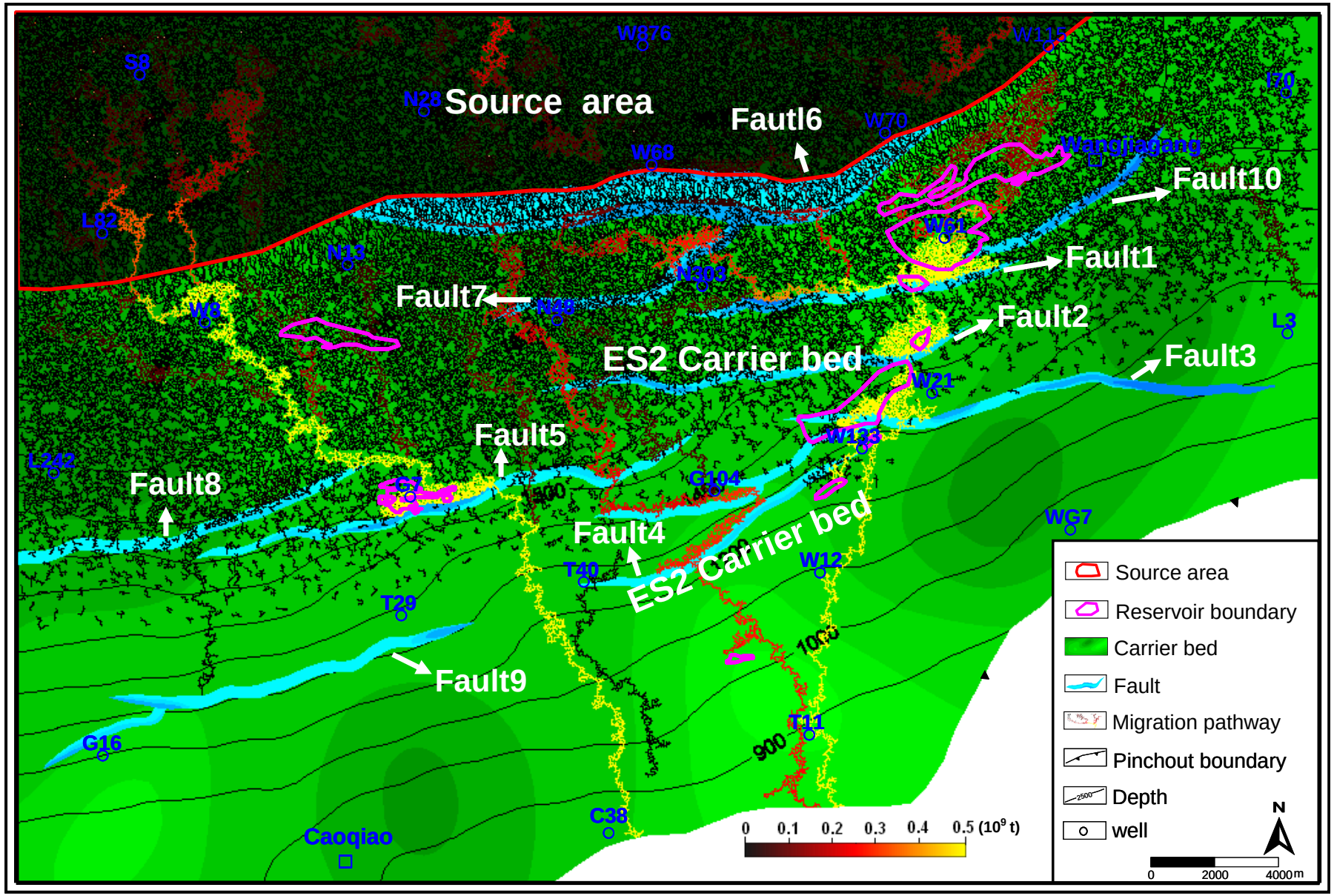

Figure 2. Application of a characterized carrier formation model in HC Migration modeling in the Dongying Sag. Both faults and carrier formation in the composite carrier framework are characterized by permeability. Mig-MOD, a software that couples the source, driving forces, and carrier, was used to simulate the migration pathways in the 2D carrier framework model.