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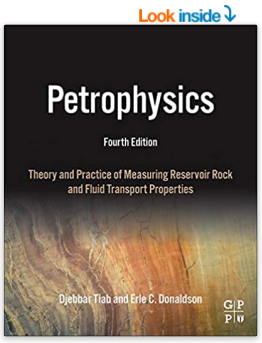

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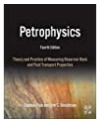
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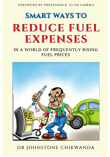

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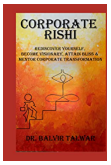

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About the Author

Djebbar Tiab is the Senior Professor of Petroleum Engineering at the University of Oklahoma, and Petroleum Engineering consultant. He received his B.Sc. (May 1974) and M.Sc. (May 1975) degrees from the New Mexico Institute of Mining and Technology, and his Ph.D. degree (July 1976) from the University of Oklahoma-all in petroleum engineering. He is the Director of the University of Oklahoma Graduate Program in Petroleum Engineering in Algeria. At the University of Oklahoma, he taught fifteen different petroleum and general engineering courses including: well test analysis, petrophysics, oil reservoir engineering, natural gas engineering, and properties of reservoir fluids. Dr. Tiab has consulted for a number of oil companies and offered training programs in petroleum engineering in the USA and overseas. He worked for over two years in the oilfields of Algeria for Alcore, S.A., an association of Sonatrach and Core Laboratories. He has also worked and consulted for Core Laboratories and Western Atlas in Houston, Texas, for four years as a Senior Reservoir Engineer Advisor.

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The total oil in place in this naturally fractured reservoir is:

$$N_{ot} = 80.05 \times 10^6 + 25.54 \times 10^6 = 105.6 \times 10^6 \text{ STB}$$

This total oil volume is correct, assuming the porosity partitioning coefficient is the same in the entire reservoir. This is highly unlikely in naturally fractured formations, where porosity varies over short distances.

FRACTURE INTENSITY INDEX

Tension stress causes rock failure along major faults, giving rise to fracture porosity (ϕ_f), and fractures of decreasing width (w_f) and length (h_f) and frequency of occurrence (FII) away from the fault plane, as shown in Figures 8.13 and 8.14[33]. Thus, permeability is much more affected by fracture dimensions than the matrix or total porosity. The curve-fit equations of the lateral distance to the surface of the fault with respect to FII for both upthrown and downthrown blocks are as follows:

Upthrown block:

$$d_{LU} = \frac{1000}{42\text{FII}^2 - 0.02.43} \tag{8.21a}$$

Downthrown block:

$$d_{LD} = \frac{1000}{9.44e^{\text{FII}} - 9.3} \tag{8.21b}$$

where

d_{LU} = lateral distance to the fault for upthrown block, ft
d_{LD} = lateral distance to the fault for downthrown block, ft
FII = fracture intensity index, fraction

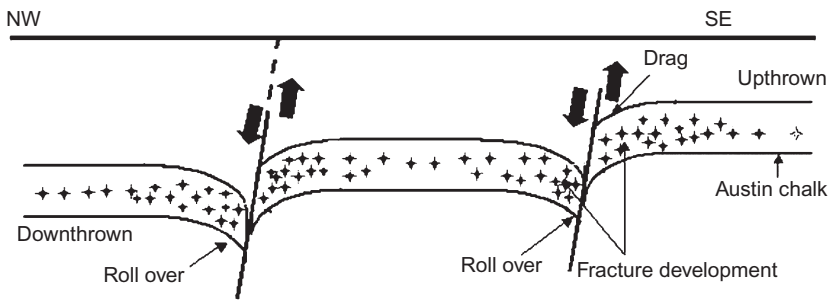

FIGURE 8.13

Frequency of occurrence of natural fractures near major faults [33].

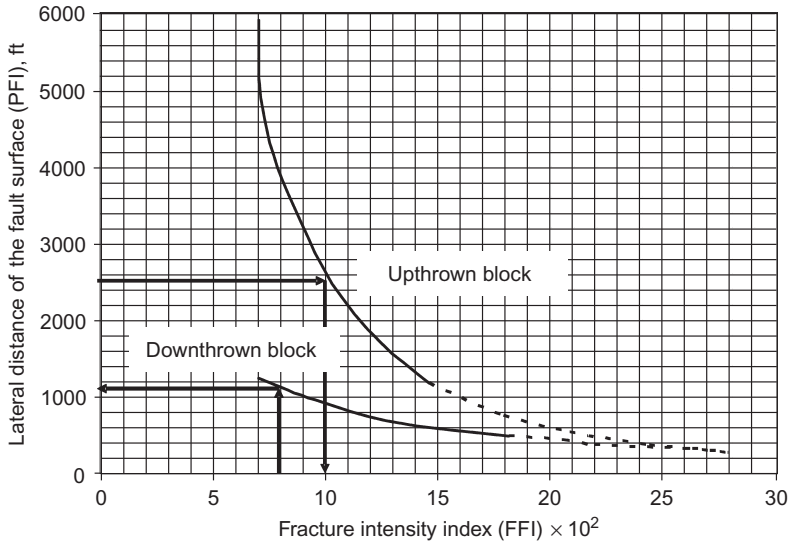

FIGURE 8.14

Fault proximity index (FPI) as a function of fracture intensity index (FII) in Austin chalk [33].

Assuming the drilling fluid used is nonconductive, the *in situ* value of the fracture intensity index (FII) is estimated from:

$$\mathrm{FII} = \frac{(1/R_{xo}) - (1/R_t)}{(1/R_{mf}) - (1/R_w)} \tag{8.22}$$

Equation (8.21a) ($R^2 = 0.989$) is applicable for a distance range of 250 to 5000 ft and an FII range of 7-25%, and Equation (8.21b) ($R^2 = 0.998$) is applicable for a distance range of 250 to 1250 ft and an FII range of 7-25%. These correlations were developed from well-log data obtained by Pirson near the Luling-Mexia fault in the Austin chalk. The primary application of these two correlations is in the exploration stage and when the presence of a nearby fault is known a priori from seismic data, as they provide only an order of magnitude of the distance to the fault. It is important to emphasize that (a) FFI is influenced by several factors, including the number of fractures and fracture geometry, and (b) not all natural fractures are the result of faulting.

The following equations can be used to estimate fracture width and fracture permeability in a type 1 naturally fractured reservoir:

$$w_f = \frac{0.064}{\phi_t}[(1 - S_{iw})FII]^{1.315} \tag{8.23a}$$

$$k_f = 1.5 \times 10^7 \phi_t [(1 - S_{wi})FII]^{2.63} \tag{8.23b}$$

where porosity, FII, and irreducible water saturation are expressed as fractions, and fracture width and fracture permeability in cm and mD, respectively. The fracture porosity can be directly estimated using the following empirical correlation [15]: