

Natural Fracture Systems Studies

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CONTRACT INFORMATION

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Schedule and Milestones**FY92 Program Schedule**

	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Data Assessment															
Methodology Development															
Applications Development															
Report Compilation															

OBJECTIVES

The objectives of this program are
(1) to develop a basinal-analysis methodology for natural fracture exploration and exploitation, and (2) to determine the important characteristics of natural fracture systems for use in completion, stimulation, and production operations.

BACKGROUND INFORMATION

Natural fractures are the critical production mechanism in many of the tight reservoirs in the western US. If these fracture systems are to be exploited, it is necessary to determine where fractures exist, what their characteristics are, and how the fractures interact with the reservoir

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geometry, in situ stresses, and other factors. Natural-fracture basinal analysis provides a means for obtaining such a characterization.

Successful stimulation and production of these reservoirs also requires a knowledge of the properties of the fracture systems, such as stress sensitivity and damage propensity. These factors need to be evaluated through a combination of field and laboratory work, in which individual fractures (lab) and fracture systems (field) are studied.

PROJECT DESCRIPTION

Natural-fracture basinal analysis begins with studies of fractures in outcrop, core and logs in order to determine the type of fracturing and the relationship of the fractures to the lithologic environment. Of particular interest are the regional fracture systems that are pervasive in western US tight sand basins. Regional fractures are created by anisotropic stress fields, usually under conditions of high pore pressure (Lorenz et al., 1991). In such systems, fractures tend to be primarily unidirectional, and thus poorly interconnected (Lorenz and Finley, 1991). This facet of western US tight gas reservoirs has been one of the primary causes of poor success in obtaining economic production from tight reservoirs.

Understanding the natural fracture system requires an understanding of the basinal mechanics, including depth of burial (subsidence and uplift), tectonic stresses and strains, lithification, thermal maturation and gas generation. Many of these elements must be estimated by examining the basin on a megascopic scale to determine basement features, faults, structure, lineaments, topography, and other basin

characteristics. In addition, these features may locally alter the stress field and reorient the natural fractures or cause multiple fracture sets to be formed. Such locales are typically excellent sites for fracture production. Even without multiple fracture sets, a reoriented stress field often provides enhanced hydraulic-fracture effectiveness.

A methodology for applying this analysis is being developed, with the goal of providing a structure for rationally characterizing natural fracture systems basin-wide. Such basin-wide characterizations can then be expanded and supplemented locally, at sites where production may be favorable. Initial application of this analysis is to the Piceance basin where there is a wealth of data from the Multiwell Experiment (MWX), DOE cooperative wells, and other basin studies conducted by Sandia, CER Corporation, and the USGS (Lorenz and Finley, 1989, Lorenz et al., 1989, and Spencer and Keighin, 1984). Such a basinal approach has been capable of explaining the fracture characteristics found throughout the southern part of the Piceance basin and along the Grand Hogback.

RESULTS

The basic methodology for constructing a basinal analysis is shown schematically in Figure 1. There is a "toolbox" of techniques that can be used to provide information on the current stress in the basin, the paleo-stress in the basin, the type and timing of fracturing, and the fracture conductivity. Most of these techniques rely on empirical information obtained from core, outcrop, and wellbore tests. The synthesis of these data, however,

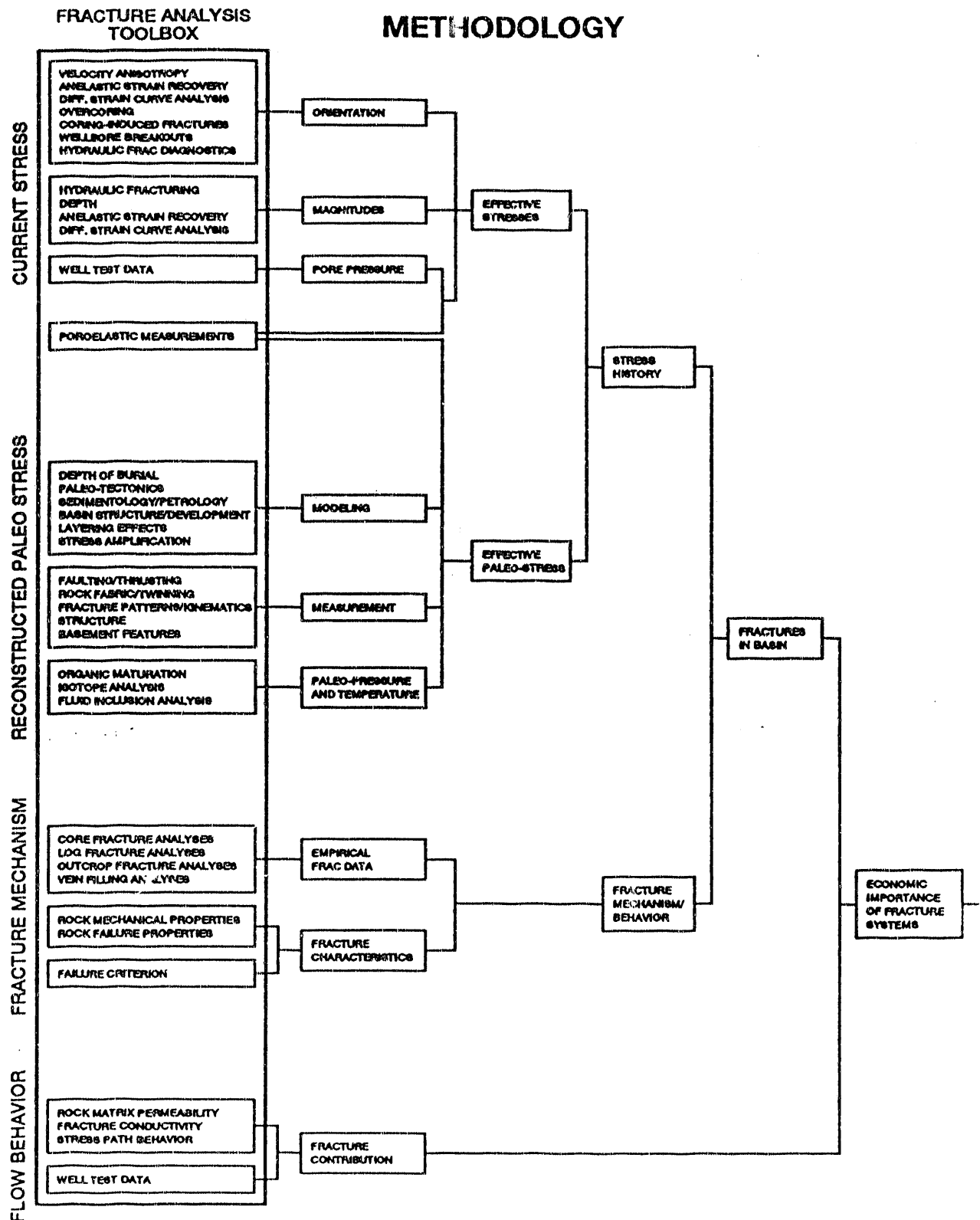


Figure 1 Methodology for natural-fracture basinal analysis

will often require considerable analytical capabilities. The primary objective of this analysis is to determine the stress history of the basin (Lorenz, 1984, Warpinski, 1989), the fracture susceptibility of the rocks of interest, and the resultant characteristics of the natural fractures, if they are created.

Regional fractures, which are the most pervasive fractures found in these basins, are formed under an anisotropic stress field, usually in the presence of elevated pore pressures. The high pore pressures effectively destress the rock so that failure occurs at much smaller deviatoric stress levels. There are three ways in which the stresses can change and thus induce fracturing, and the knowledge of the particular mechanism allows the explorationist to determine where fracture is likely to occur. First, the maximum horizontal in situ stress can increase, as for example near a thrust belt. Such a situation likely occurred in the vicinity of MWX as a result of the White River thrust. Second, the minimum stress can decrease, as in an extensional environment. Figure 2 shows an example of the effect of subsidence on the Upper Cretaceous strata in the foredeep adjacent to the Idaho/Wyoming thrust belt. This subsidence has resulted in an extension of the rocks at depth and suggests why north-south fracturing is pervasive in the western Green River basin. Third, the pore pressure can increase, as might occur due to gas generation. An increase in pore pressure levels has been an important element in the fracturing of all western tight sand basins.

An understanding of the fracture system that exists at depth is impossible without some empirical data from wellbores. The MWX and SHCT experiments have provided over 4000 ft of vertical and 380 ft of horizontal core, respectively, that have been invaluable in characterizing the

fracture systems (Lorenz and Hill, 1991). Data from these wells have provided information on spacing, width, vertical distribution, mineralization, porosity, and other parameters.

The natural fracture system is only of practical use if it has sufficient initial conductivity, and if it retains sufficient conductivity during production and drawdown. Fractured core plugs are studied in the lab to determine flow characteristics, poroelastic behavior (effects of both stress and pore pressure), and overall geomechanical response. To date, three Mesaverde natural fractures have been characterized. Results of these tests are shown in Figure 3. One of these fractures was planar, and as a result, highly stress- and pore-pressure sensitive. Turbulence factors were also found to be highly stress sensitive. A second fracture, taken from the Cozzette sandstone at the Slant Hole Completion Test (SHCT), was mineralized with somewhat vuggy porosity, and was found to be only slightly stress sensitive. Turbulence factors were also variable. The third sample, also taken from the Cozzette at the SHCT, had a vuggy mineralization with no stress or pore pressure dependence.

The more conductive fractures are also the least stress-sensitive fractures, but these highly conductive fractures are nearly unidirectional. The key to the stress sensitivity of the reservoir probably is in the characteristics of the fracture interconnections. Based upon field data from MWX, it is likely that the interconnections are through the lower-conductivity, higher-stress-sensitivity fractures. The differences in the behavior of these three samples demonstrates how important it is to understand the mechanical behavior of the natural fractures found in the reservoir.

Strain from Lengthening Line to Hypotenuse

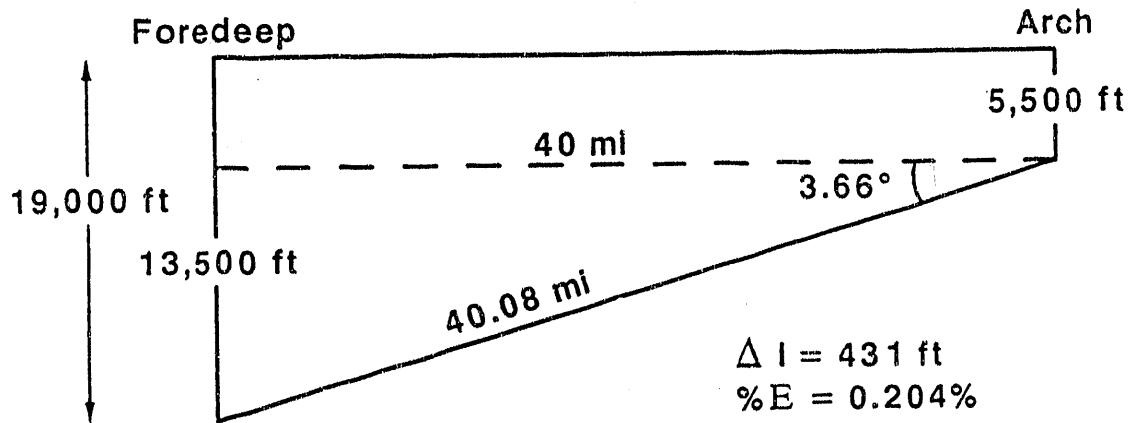


Figure 2 Geometry of extensional strain due to asymmetric subsidence

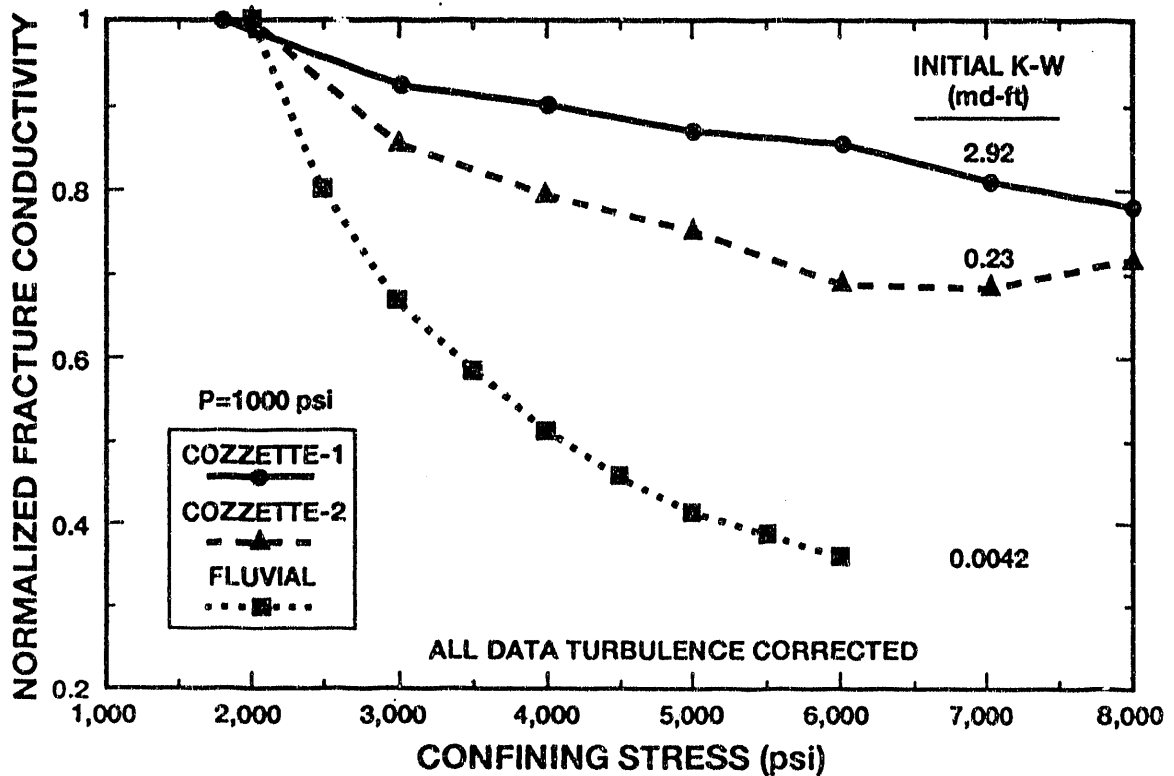


Figure 3 Stress sensitivity of fracture conductivity as a function of initial conductivity

FUTURE WORK

Future work includes the completion of a document containing the basinal-analysis methodology, an application of the methodology to the Piceance basin, and additional tests and measurements of fracture characteristics and properties. The methodology is prepared in a general fashion, with reference to various basins for examples. A specific application to the Piceance basin will also be prepared for inclusion in the methodology. This application shows how the extensive measurements that were made at the MWX site can be extrapolated through-out the basin.

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