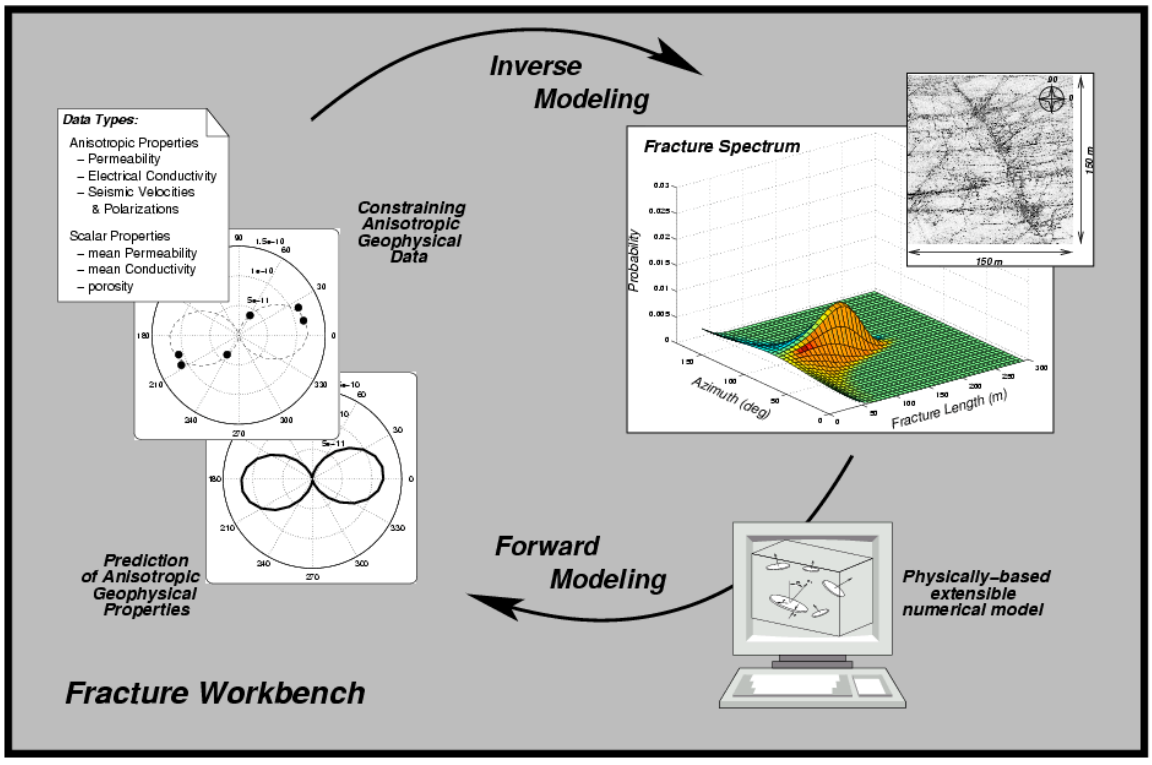
Fracture Network Attributes Determination from Geophysics

FWB: Fracture WorkBench

An interactive software platform designed to support modeling of the geophysical and flow properties of **fracture networks**. The Fracture Workbench (**FWB**) connects a statistical distribution of fractures with varying size, aperture, and orientation, to the tensor properties of a resulting anisotropic medium. These properties include permeability, electrical conductivity, as well as velocity and polarization of seismic waves (with shear-wave splitting). **FWB** is fully 3 dimensional, designed as an interactive software tool with both forward- and inverse- modeling components. In addition, fracture properties can be expressed in terms of applied regional tectonic stresses.



The forward modeling allows the determination of the geophysical properties of a system knowing the fracture network density, fracture orientations, sizes, and apertures, as well as elastic stiffness values for each fracture. In practical terms, the fracture geometry is treated statistically, where the geometry of a fracture system is represented

by a probability density function or 'fracture spectrum.' This 'spectrum' depends on several independent variables, such as the length and orientation of the fracture plane.

One advantage of **FWB** over other methodologies is that it is physically based and amenable to robust performance and predictive simulations and sensitivity analyses. It allows the user to manipulate trial fracture distributions and to immediately view the predicted behavior of the distribution. The user may also simultaneously manipulate fracture distribution, observational variables, and the orientation of the intersecting sampling plane for the purpose of optimization or to easily view 3-D predictions in 2-D space.

FWB also contains an inverse modeling component, which allows the user to predict, under various assumptions, the fracture distributions that could give rise to a particular set of observed geophysical properties such as permeability, electrical conductivity, and seismic velocities. The input consists of a set of observed and measured values, an initial fracture density (typically zero, or fracture-free), and an inverse algorithm. The output consists of a fracture spectrum model, as well as statistical parameters that quantify how well the predicted values match the observed ones. The result is a very flexible and powerful quantitative platform for investigating the geophysical and flow consequences of fracture systems. Because fracture inverse modeling is inherently non-unique, we provide a set of five inverse algorithms that minimize different error norms (estimates of prediction misfit) as well as different model norms. Each of these fits all of the data within their respective errors, if possible, while extremizing other quantities. A second feature we have partially implemented is a mechanism to apply a known bias to the inverse process that allows the user to arbitrarily weigh parts of the fracture distribution.

Fracture WorkBench Applications

Improved Fractured Reservoir Characterization and
Environmental and Groundwater Management Tool.

Forward Modeling:

- Prediction
- Sensitivity Analysis Studies

Inverse Modeling:

- 3-D Seismic Interpretation
- Quantification of Electrical Resistivity and Anisotropy
- Integration of Geophysical Data with Well Tests and 'Soft' Constraints
- Improved Dual-Porosity Model Constraints

The design of **FWB** is advantageous in that it allows the greatest feasible separation between it's major components including (1) the number and type of the independent variables governing the fracture spectrum, (2) the numbers and types of geophysical properties observations used to constrain the inverse, (3) the physics (particular forward model) that predicts an observation's value as a function of a fracture distribution, (4) the inverse algorithms, and (5) the numerous display, editing, and input/out modules. This design makes it practical to readily incorporate new observational types or different physics in a way that takes advantage of all of the other features of **FWB**.