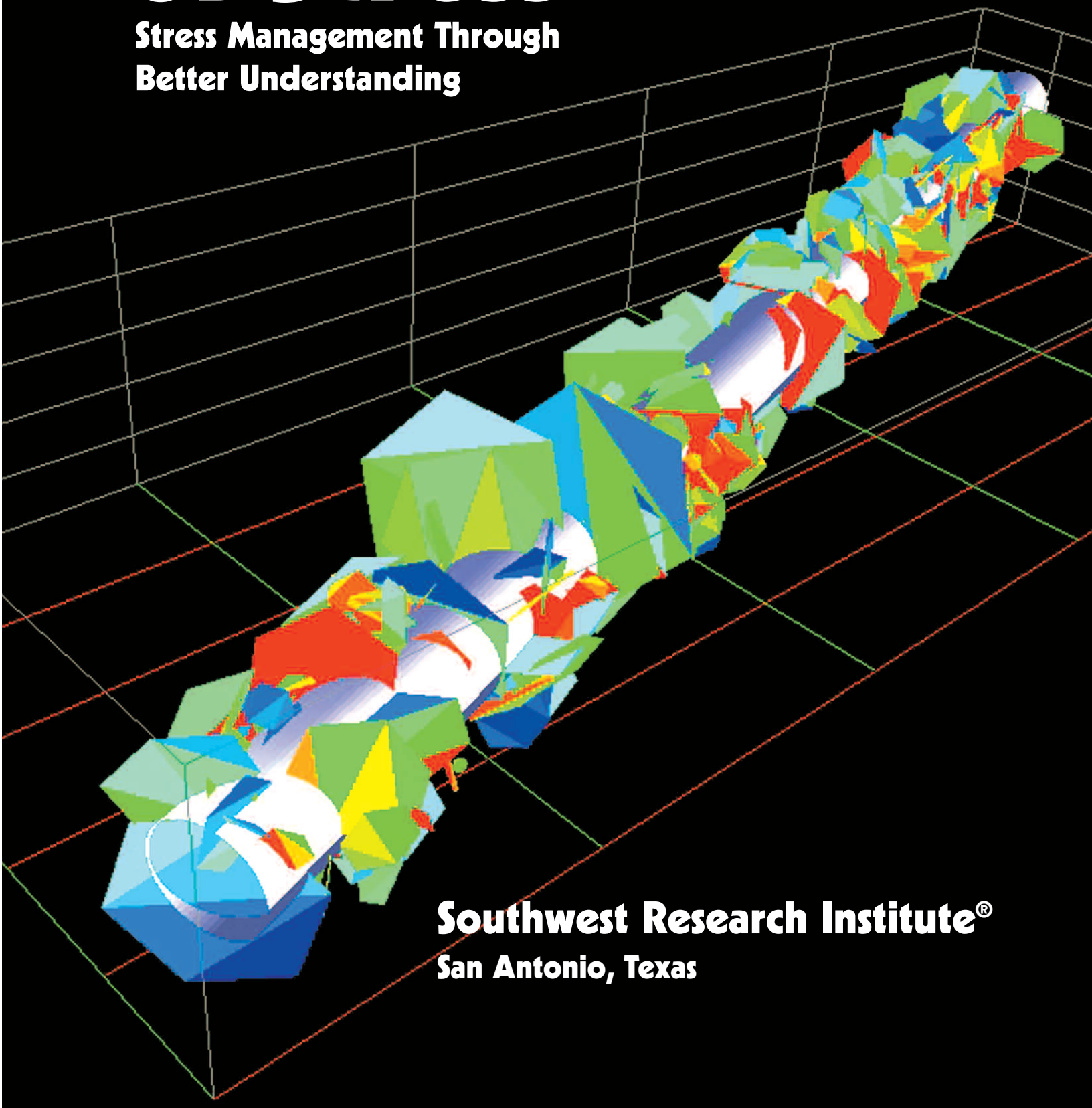
3DStress®

Stress Management Through Better Understanding



Southwest Research Institute®
San Antonio, Texas

3DStress

Southwest Research Institute

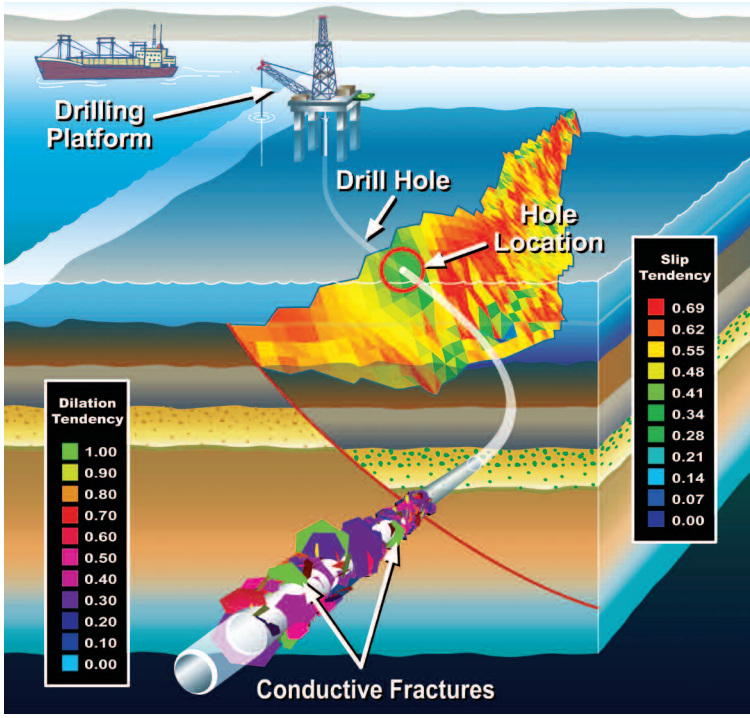
Founded in 1947 as an independent, nonprofit research and development organization, Southwest Research Institute provides a significant research, engineering, and testing resource for industry, business, and government. The Institute uses a multidisciplinary, integrated approach to solving complex problems in science and applied technology. As part of a long-held tradition, patent rights arising from sponsored research at the Institute are often assigned to the client. SwRI generally retains the rights to Institute-funded advancements.

About the cover: 3DStress colors fractures intersecting a tunnel according to their slip tendency.

Because Southwest Research Institute (SwRI) is a multidisciplinary research and development organization, its scientists and engineers develop highly functional approaches to solve scientific and technical problems.

The SwRI-developed 3DStress® is an advanced software tool to interactively analyze the tendency for faults and fractures to slip or dilate, based on a user-specified three-dimensional (3D) stress state. Evaluating stresses and their effects on faults and fractures is crucial to an improved understanding of:

- Fault reactivation
- Earthquake hazard
- Fault and fracture transmissivity
- Fault and fracture mineralization paths
- Fault-sealing behavior
- Tunnel and well-bore stability
- Structural geology interpretations



3DStress provides an interactive tool for determining stresses on faults and fractures, used in assessing traps, planning wells, and characterizing faults and fractures in hydrocarbon and geothermal reservoirs.

The 3DStress software program provides a powerful tool for predicting:

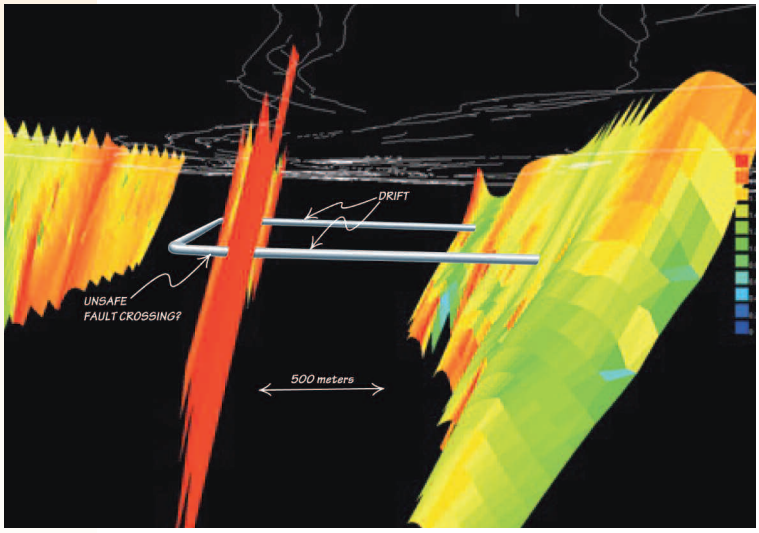
- Fault sealing
- Hydrocarbon migration routes
- Potential fracture controlled permeability

Uses of the 3DStress software include:

- Oil and gas prospect risk assessment
- Slip vector calculation for three-dimensional reconstructions
- Production planning strategy for fractured reservoirs
- Stress-state sensitivity analysis
- Well bore and tunnel stability analyses

The Institute-developed 3DStress software features:

- Interactive graphical user interface
- Multiple levels of data input, including:
  - Tabular fault and fracture orientation data
  - Fault trace maps
  - Well-bore data
  - Density and fluid pressure gradients
  - Three-dimensional seismic reflection interpretations
  - Three-dimensional stress volume information
- Estimation of slip and dilation tendency
- Mohr circle tool for stress analysis
- Failure envelope tool for rock property analysis



The SwRI-developed 3DStress is also used in evaluating stability of drifts and other underground excavations in faulted and fractured rock.

3DStress software displays faults and fractures in three-dimensional space and colors them based on the following criteria:

Slip tendency: the ratio of the shear stress to the normal stress on a fault or fracture surface:

$$T_s = \tau / \sigma_n$$

Dilation tendency: the likelihood for a fault or fracture to dilate based on the three-dimensional stress conditions and is computed as:

$$T_d = \frac{(\sigma_1 - \sigma_n)}{(\sigma_1 - \sigma_3)}$$

Leakage factor: similar to dilation tendency, but the leakage factor takes into account detailed information on fluid pressure and tensile strength of fault-zone or fracture-filling material.

$$\textit{Leakage factor} = \frac{P_f}{(\sigma_n - T)}$$

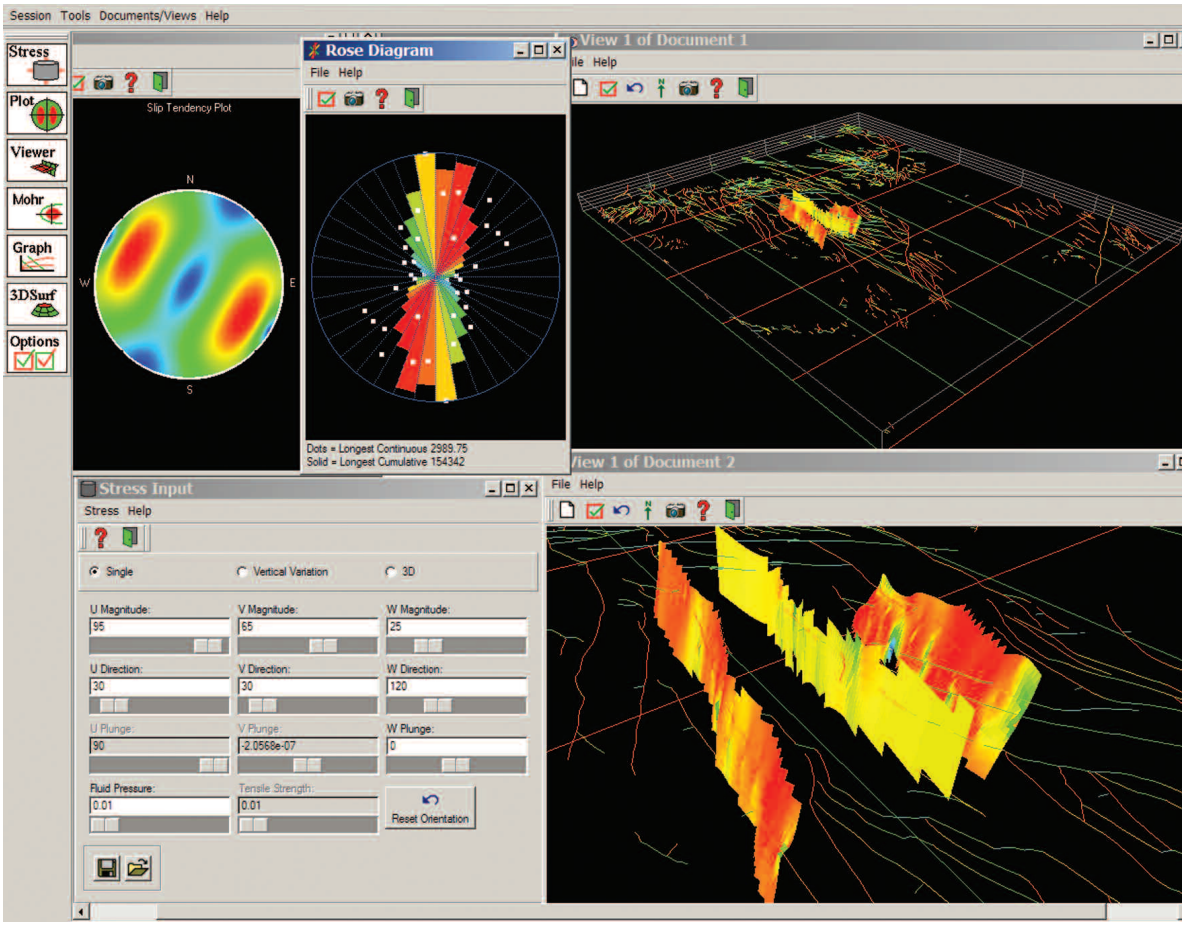
Slip direction: In addition to slip and dilation tendency, 3DStress computes the expected slip directions on faults and fractures, information that is crucial for accurate restorations, fault seal, and permeability analysis.

3DStress Interactivity

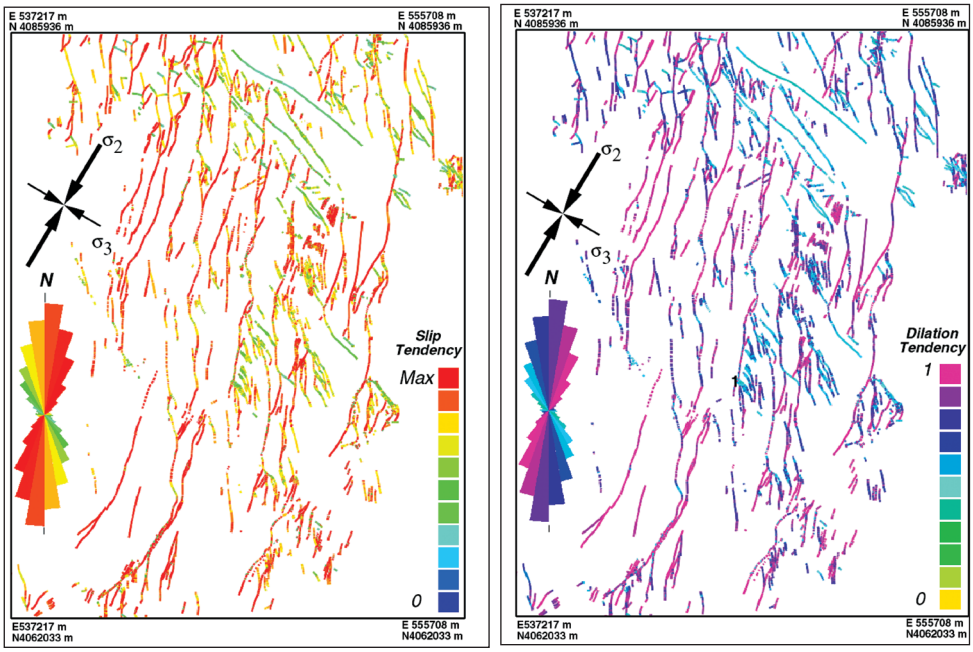
To provide an environment for effective interpretation, the software offers a variety of interactive tools, including:

- A user interface for interactive control of the input stress orientations and magnitudes
- Display of two-dimensional trace maps, and three-dimensional cutoff lines and surface representations of faults and fractures colored by slip or dilation tendency, or leakage factor
- Control of the stress field, with faults and fractures displayed
- A lower hemisphere equal-angle stereographic projection that displays fracture and fault orientations, which are colored based on the computed slip tendency, dilation tendency, or leakage factor
- User-defined stress fields to compute the likelihood of fault slip or fracture dilation based on the orientation of the fault or fracture

In complexly faulted areas, 3DStress can be used to distinguish fault populations and faults that may have formed contemporaneously during past stress conditions. Alternatively, 3DStress can be used to interpret the contemporary stress field by interactively optimizing the slip tendency and slip directions on known active faults or to identify faults that are likely to be active or inactive in a known stress field.



Users can interactively control the stress field and view the results on the displayed faults and fractures.



In these fault maps of Yucca Mountain, Nevada, the slip tendency (left) and dilation tendency (right) are calculated using the present day stress field. The combination of visual display map and the length-weighted rose diagram provides a powerful interpretation tool for geoscientists.

Southwest Research Institute is an independent, nonprofit, applied engineering and physical sciences research and development organization using multidisciplinary approaches to problem solving. The Institute occupies more than 1,200 acres and provides nearly two million square feet of laboratories, test facilities, workshops, and offices for more than 3,000 employees who perform contract work for industry and government clients.

Benefiting government, industry and the public through innovative science and technology

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