N428: Advanced Structural Methods: From Exploration to Reservoir Scale

Format and Duration
Classroom - 5 Days

Instructor(s): Lans Taylor

Summary

The course briefly introduces the definitions, classification and geomechanical concepts fundamental to structural geology in order to bring participants to common understanding and terminology. A review of the principal tectonic environments and the structures developed follows (greater emphasis can be placed on a particular structural regime where necessary). The course then focuses on description of the workflows and techniques used in structural characterization. At the seismic- to basin-scale, these methods ensure the viability of an interpretation. Restoration feeds into petroleum systems and basin modeling. Other techniques are used to predict structure in areas of poor data or at sub-seismic and reservoir scales. Workflows generally proceed from geologic description, to populating numerical models, to reservoir simulation for operational decisions.

Learning Outcomes

Participants will learn how to:

1. Categorise the geometries of geological structures ranging from faults, fractures to folds at all scales.
2. Establish rock mechanical principles and the effects of stress on geological materials.
3. Interpret structures formed under the principal tectonic regimes and in areas of salt tectonics.
4. Map and construct cross sections of a range of geological structures.
5. Validate structural interpretations with emphasis on structures developed under gravity-driven contractional regimes.
6. Perform and assess a range of structural analysis techniques and apply these to subsurface datasets.
7. Characterise the variety of natural fractures and the fracture networks developed under reservoir conditions.

Training Method

A five-day classroom course consisting of lectures and worked examples.

Who Should Attend

Geologists and geophysicists who wish to develop expertise in structural analysis methods. Greater emphasis can be given to particular structural regimes and styles and to specific aspects of analysis should the company require it.

Course Content

Day 1: Structural Styles

Description of the geometric arrangements of folds, faults, fractures, and unconformities at the seismic- to basin- scale, typically grouped by tectonic environment. We define about a dozen characteristic forms, then describe the geometry and physical attributes of individual elements within those forms.

Introductory Concepts

1. Definitions, Classification, Nomenclature

- Displacement fields and discontinuities. Folds, faults, fractures, and unconformities

2. Earth Materials / Geomechanics
   - Stress, strain, moduli. Elastic, poro-elastic, plastic, viscous, standard linear solids
3. Global Process
   - Planetary Architecture, Mantle Dynamics, Plumes and Super-Plumes. Plate Tectonics, Dynamic Topography
4. Interpretation Principles
   - Buoyancy, Regional Elevation, Horizontal Rotation vs Vertical Translation. Tectono-Stratigraphy

Day 2: Structural Styles by Tectonic Environments Part I

1. Contractional Systems
   - **Thin-Skin: Fold & Thrust Belts** - Coulomb Wedge, impact of surficial process. Thrust system behavior (vergence, ramps & flats, fault rotation, faulting sequence). Thrust system geometry (duplex, fans, wedges). Folding during thrusting (detachment, fault bend, fault propagation)
   - **Thick-Skin: Inversion and Orogenic Collapse** - Positive Inversion - Measurement: null points and growth indicies, Geometric inheritance and tectono-stratigraphy. Negative Inversion

Day 3: Structural Styles by Tectonic Environments Part II

1. Extensional Systems
   - **Thick-Skin:** Rifting - Rift models: Volcanic vs non-volcanic, post-rift thermal subsidence. Planar rotational faults in 2D: Syn-tectonic sediments, scarp degradation
   - **Thin-Skin:** Landslides, Passive Margins, and Delta Collapse. Gravitational collapse – linked extension to contraction. Listric geometry, extensional folding, crestal collapse grabens. Growth faults, syn-tectonic sedimentation, raft tectonics
   - **Extensional Faults in 3D**: Displacement profiles, relay ramps, splays, accommodation zones, fault tip folding, impact of stress anisotropy
2. Strike Slip Systems
   - **Tectonic setting.** Fault zone architecture. Fault termination and flower structures. Pull-aparts and Pop-ups
3. Salt Systems
   - **Salt Mechanics:** Passive, Active, & Reactive systems. Pillows, Walls, Diapirs: growth and collapse. Sediment salt-wall interaction, dog-tongues, radial & concentric faulting. Salt Glaciers, mini-basins, Roho & Counter-regional systems

Day 4 Structural Methods Part I

1. Mapping and Cross Section Construction Techniques
   - **Contouring methods:** triangulation, constant slope, constant curvature, kriging
   - **Surface conformity:** missing section to fault gap, fault surface contouring; Dip meter, dip domains, and projection; Structural Restoration

2. Forward vs. reverse modeling
    - Restoration template and regional elevation
3. Deformation mechanisms
    - Passive slip, flexural slip, flexural flow, plate bending, viscous flow
4. Geometric consistency
    - Line length balance: pins and kinks. Area balance: extensional and contractional fault prediction methods
    - Isostacy, crustal flexure, and thermal effects
    - Geomechanics
5. Calibration of wireline to lab studies
    - Moduli, strength
    - Determination of in-situ stress: 3D Hooke's law
    - Failure Criteria: Mohr Coulomb
6. Models of overpressure
    - Disequilibirium compaction. Chemical phase change & HC generation

Day 5 Structural Methods Part II

1. Curvature Analysis
    - Definitions: Positive, Negative, Max, Min, Mean, Gaussian
2. Plate Bending Model
3. Scale dependence
4. Dealing with faults
5. Mechanical stratigraphy, weak layers and bedding plane slip
6. Dislocation Analysis
7. Perturbed stress field concept, radar interferometry, focal plane mechanisms
8. Displacement profiles, elastic limits and the stick-slip model
9. Software considerations, ED (Badley's) vs NFP (SLB)
10. Determining boundary conditions
11. Meaningful metrics and calibration
12. Natural Fractures
13. Fracture types and classification
    - Modes I: joints, veins, dikes, stylolites, compaction and deformation bands. Mode II & III: faults, hesitation lines, horse tails, twist hackles
    - Geometry of fracture systems: Density and orientation vs connectivity and conductivity. Percolation threshold concept. Emergent aperture concept
    - Hydraulic behavior of fractures: Parallel plate, "Snow" model. Effective media
    - Geomechanical behavior of fractures: Aperture-pressure-permeability relationships. Bed-bounded model for fracture porosity and permeability
14. DFN (Discrete Fracture Models)
    - Quantification: correcting image and wireline logs.
    - Geostatistical representation.
    - Controlling Elements.

- Upscaling.
- Calibration with production