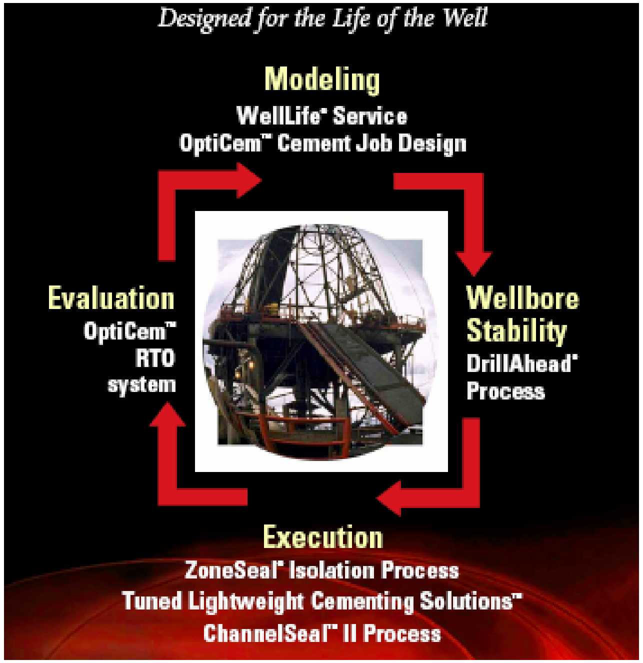
GEOTHERMAL ENERGY UTILIZATION ASSOCIATED WITH OIL & GAS DEVELOPMENT

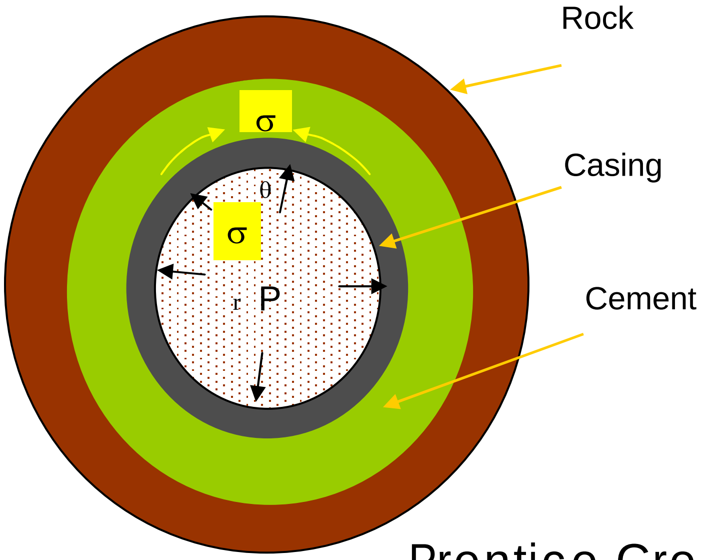
June 12-13, 2007

Southern Methodist University

Dallas, Texas

Geothermal Prospects
Well Investigations and Considerations
Long Term Well Integrity





Prentice Creel, PE

Halliburton

Well Considerations and Investigations for Future Developments

- Future developments in utilizing current wells for Geothermal Energy should include
  - the evaluation and appraisal of the prospects currently available
- Idea qualifying and investigative requirements of a prospect well would be
  - its current production status
  - its completion history
  - its workover history
  - and any diagnostics performed on the integrity of the well's zonal isolation
- With numerous wells now having depleted resources in hydrocarbon and drilled into wet formation temperatures of 225 ºF or greater, they will become possible candidates for Geothermal Resources.

What's Available

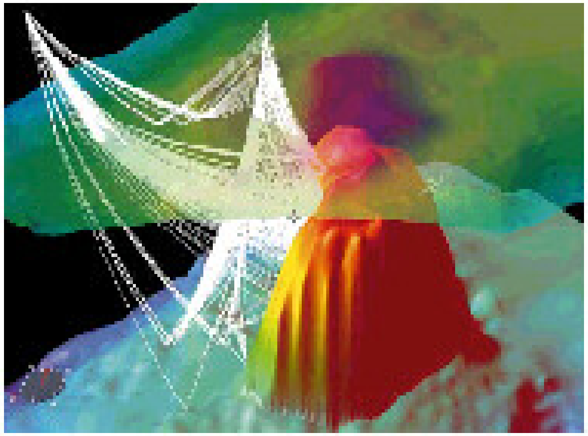
- Collective Well Files
  - Histories of completions
  - Workovers
  - injection and production data
  - cost sheets
  - regulatory requirements and compliances met
  - problems addressed and solutions used
- Scrutiny can give indications of economical levels
  - Needed repairs or well deterioration conditions
- Often files are digitized giving a much faster and beneficial way to research wells

What's Available – Cont'

- Types of Data and Well History Available
  - Structured data collections
    - Some with reservoir conceptual modeled performance and evaluations/characterizations
  - Utilization of commercial software in capturing the performance and descriptions in graphical analysis, schematics, charts, data bases, etc.
  - Internal and External Networking Systems with data archives and communications linkages
- Other Resources
  - State Governments if they have produced the data
  - DOE if still assisting the Energy Sector
  - Commercial Resources – data at a cost

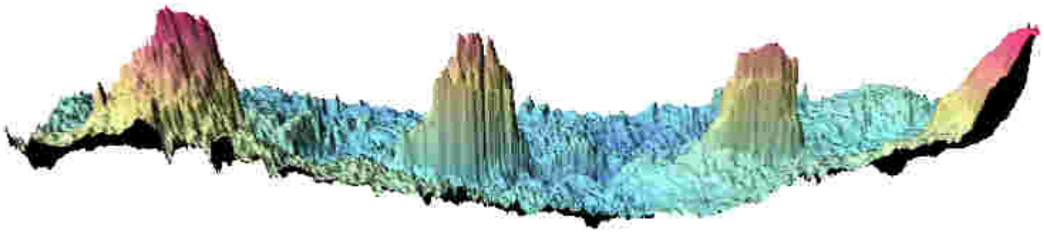
Data Collection

- Existing Data
  - Geological Description and Reservoir Understanding
  - Production and Injection History
  - Completion History and Well Construction
  - Production Equipment and Facilities
- Additional Data for Better Understanding
  - Production Tests
  - Tracers
  - Cased Hole Logging
  - Injection Analysis
  - Down Hole Video
  - Research and Developments



Data - Geological Description

- Depositional Environment
- Reservoir Geometry
- Fluid Saturation Distributions & Contacts
- Faults and Barriers
- Stratigraphic Boundaries
- Sedimentary (Laminates, Cross Bedding)
- Microscopic (Clays, Texture, Pore Geometry)
- Temperature Resources - Data



Current Casing Parameters

- Was the casing string cemented to surface ?
- Is there cement behind the casing ?
- Where are water influx intervals ?
- Where are fragile intervals with possible associated fractures ?
- What is the extent and length of casing with erosion, pitting, and leaks ?
- What is needed to give an extended well-life with production considerations or sources of new economic benefits

Considerations on Casing Repairs – Determine the Initial Construction

- Loss Circulation and Influxes
  - Focal Point Definitions
  - Diagnostics
  - Applicable technologies
- Deviations in Hole Placement
  - Horizontal
  - Multi-lateral
- Temperatures and Pressures
  - Accurate testing on slurries – API Specifications
- Fracturing and Communication
  - Natural and Induced – Hydrostatic Conditions
  - Cross-flows [water – gas] and Potentials of Deteriorative Affects
- Subsidence and Stability of Strata
  - Clay, Shale, Salt Sections, etc.
- Up-front involvement – Proactive in addressing conditions – WellLife

Addressing Completion Methods
Past & Present

- Cemented Casing with Perforated Intervals
- Open Hole Completions
- Gravel Pack Completions
- Slotted Liners
- Deviated & Horizontal Wells
  - Cased & Cemented
  - Slotted Liners
  - Open Hole Completions
  - Drilling Orientations
    - Lateral or Transverse

Repairing Wells for Long Term Zonal Isolation and Integrity

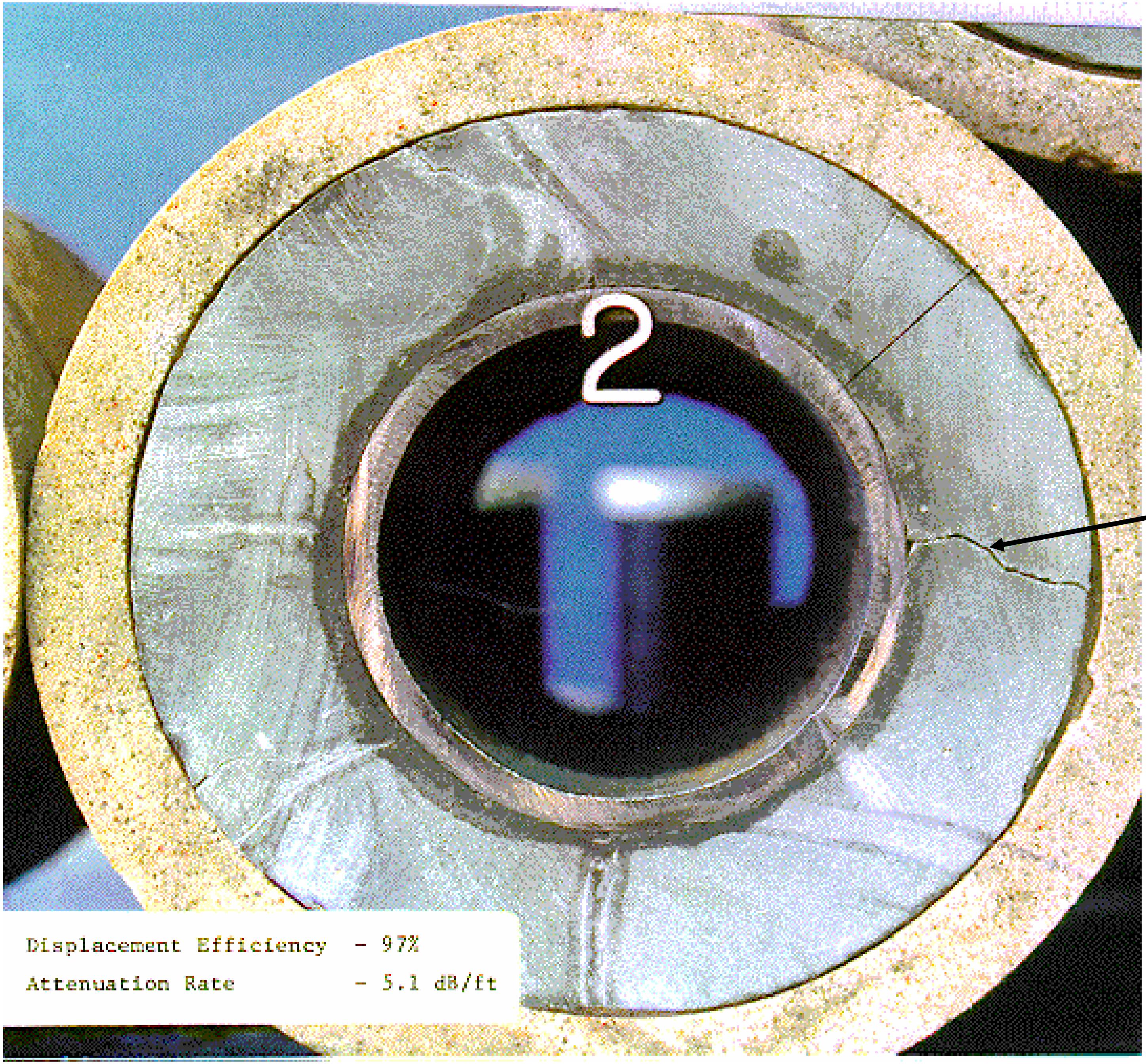
OBTAINING A GOOD ANNULAR SEAL

- Complete planning with the aid of accurate job models
- Proper well cleanout and drilling fluid preparation
- Proper centralization of the pipe
- Proper volumes and design of spacer
- Effectively designed slurries
- Pipe movement
- Continuous pumping
- Maximum flow rates
- Zero closed-in pressure during WOC time

Lack of Integrity and its Causes

Production Operations

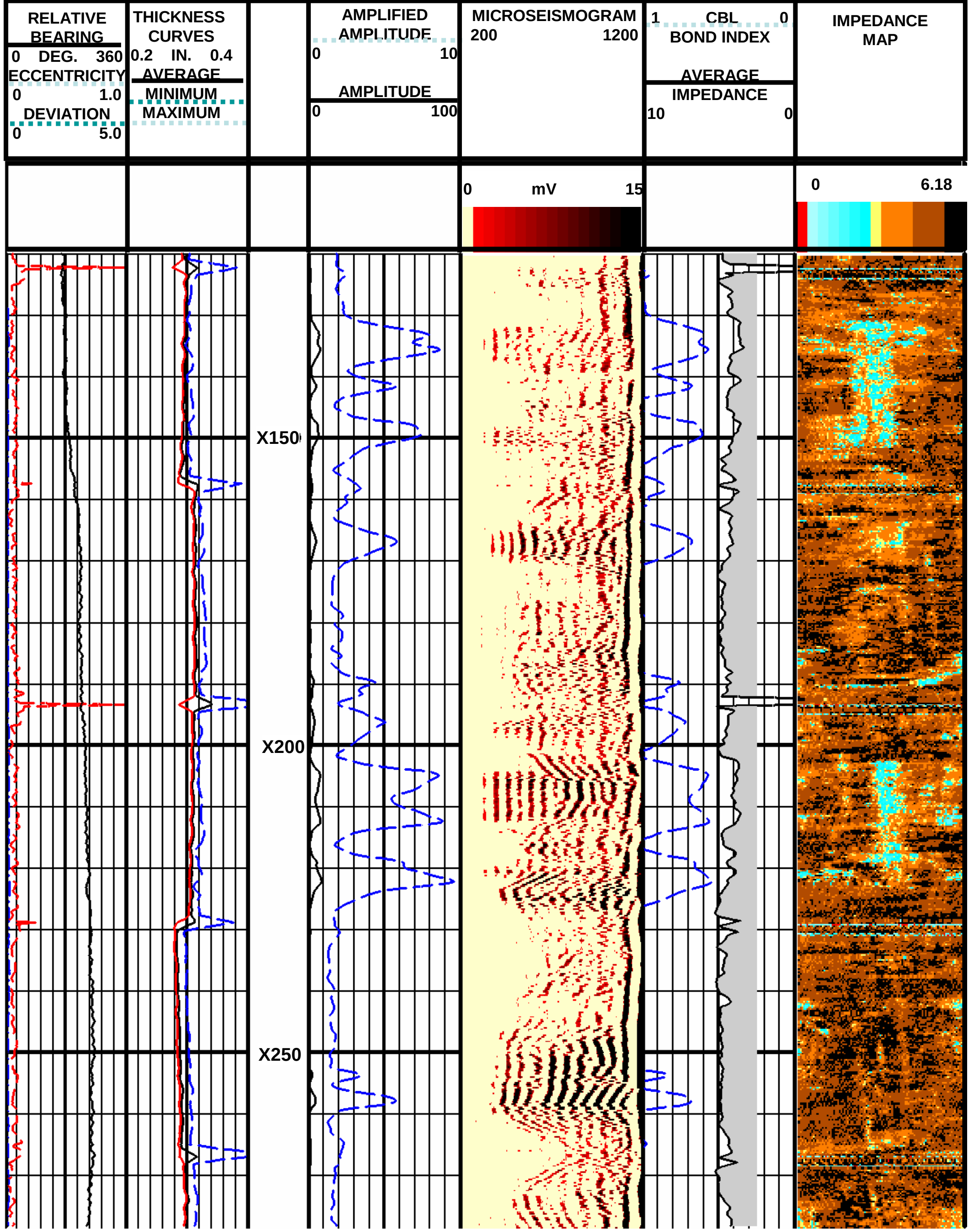
- Influxes continuing following primary cementing
- Annular pressure differences causing cross-flows
- Casing pressure cycling during the well's productive life
- Perforating and initial acid breakdowns
  - Cracking cement sheaths
  - Removal of formation barriers
- Stimulation treatments going out of zone
- Injectants dissolving and eroding rocks



Cracked Cement Sheath

How does one use this information?

- Time – Lots of data and limited resources to evaluate
- Define what is needed to accomplish the desired long well-life for Geothermal Recovery
  - Initial Completion details and data give basis to estimate the well-life potential
  - Compare the completion details and data to what is referred to as the Best Practices
  - Query the completion information to determine if any problems were existent during the primary drilling and cementing operations
  - Investigate Well Bond-Logs and if needed run latest technology to gain a 360º view of the casing annulus
  - Study the well histories such as pin-hole-leaks or metal corrosion problems

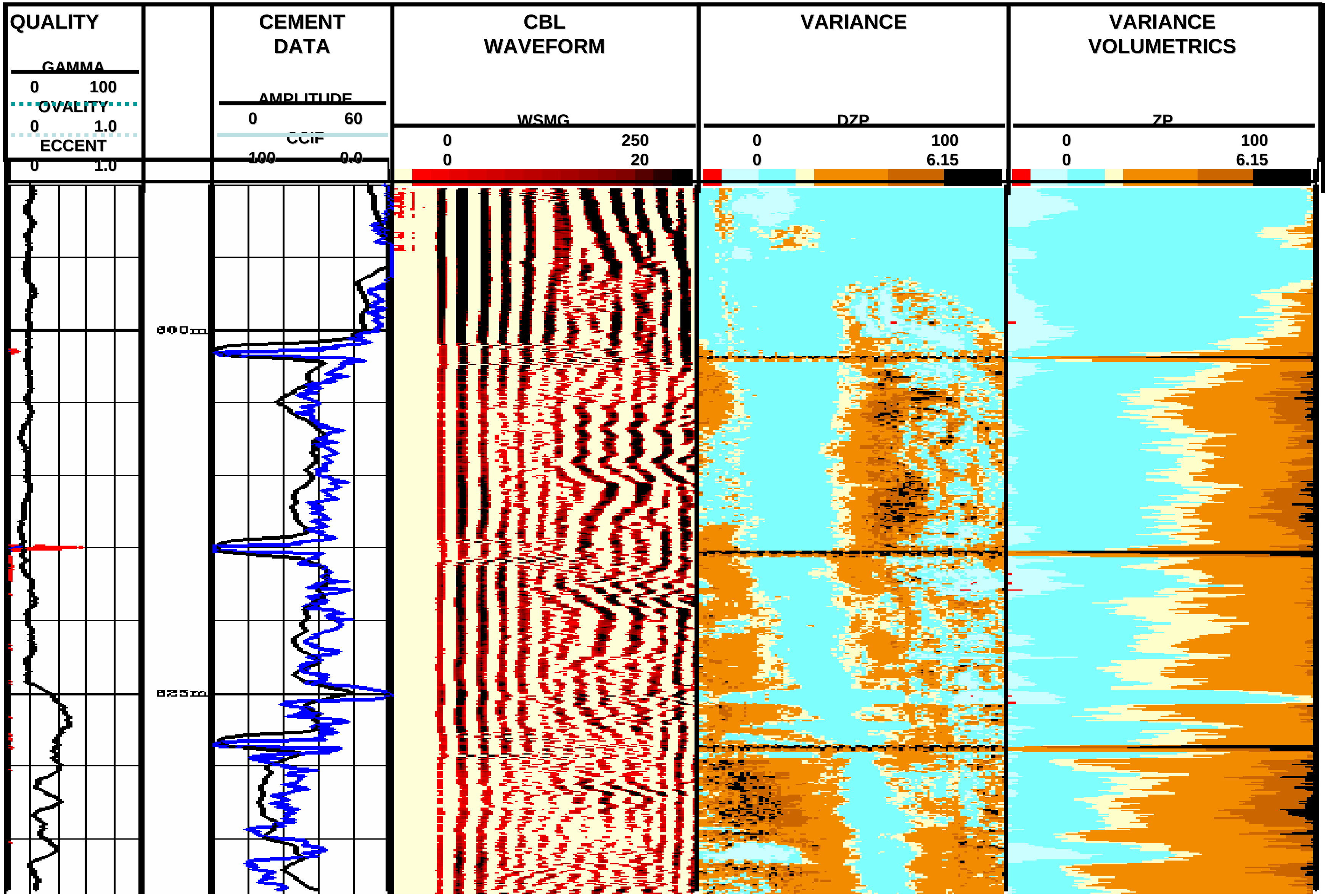


Ultra-Sonic Image Logs

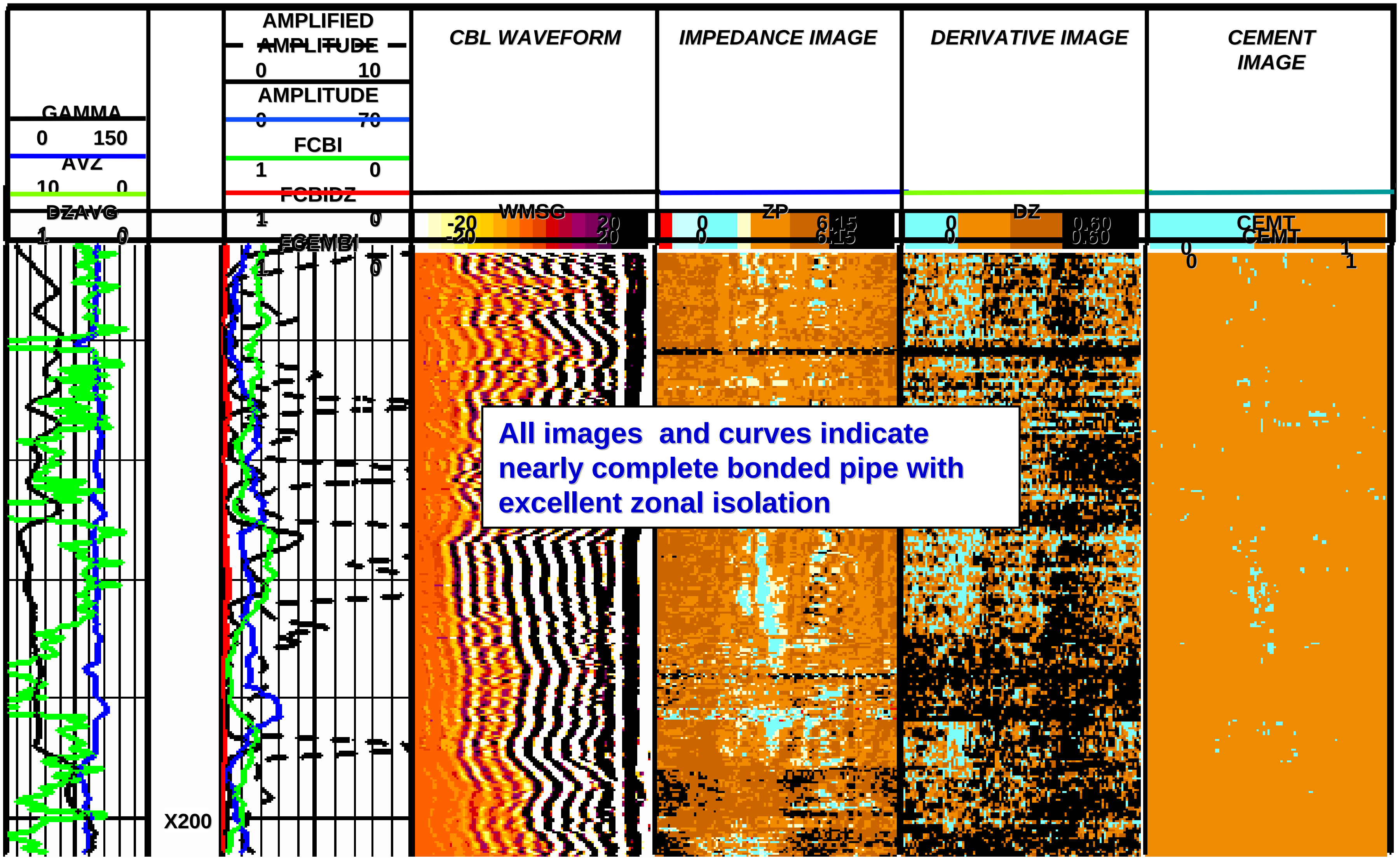
- Rotating Transducer for 360^0 Measurements Aid in Channel Identification
- Evaluate Pipe to Cement Bond
- Cement Image Display From Acoustic Impedance or Variance for Improved Interpretation

SPE # 55649

Example of Cement Evaluation Logs



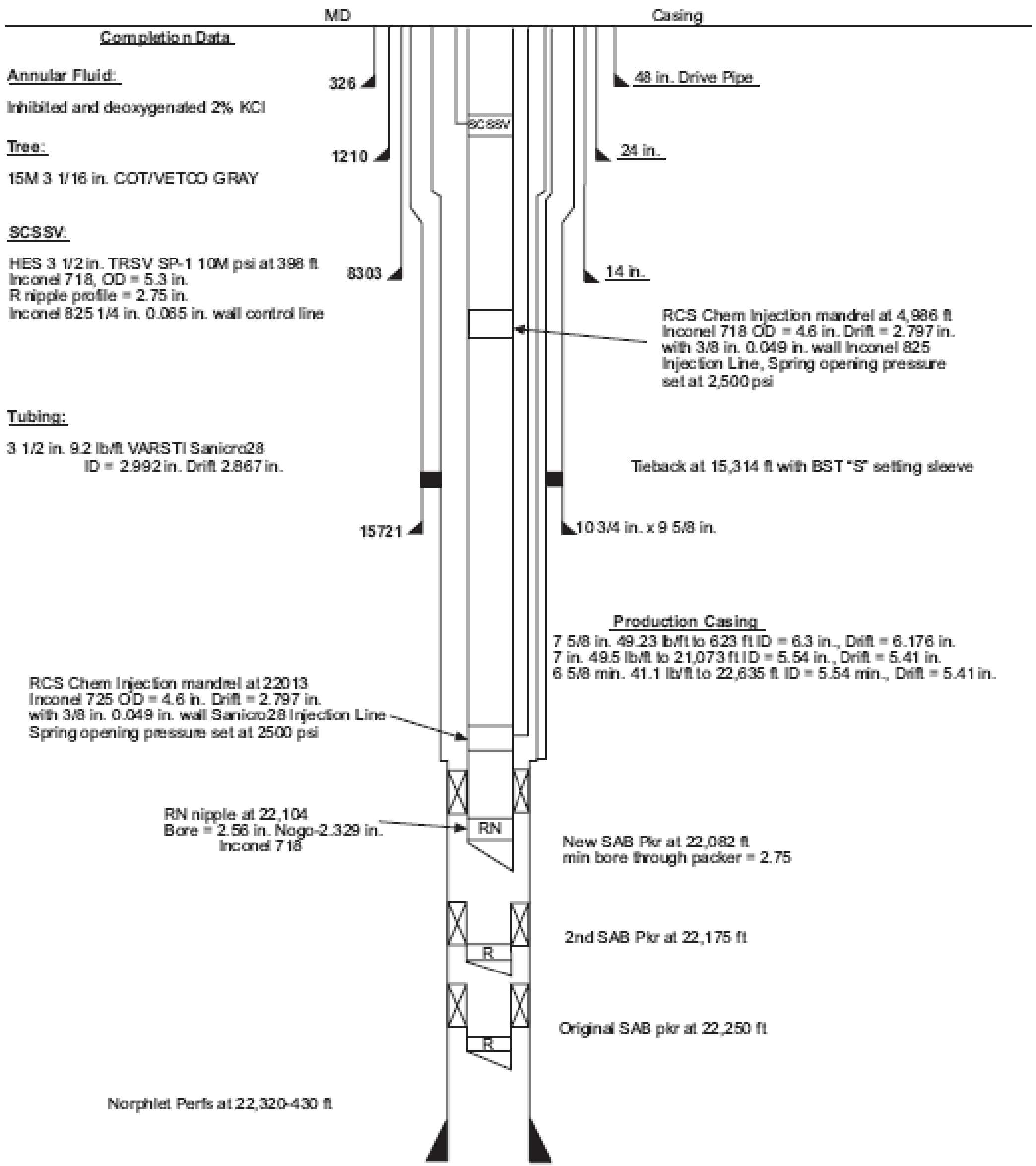
Foamed Cement Analysis in Bonded Pipe



Understanding the Complexities of the Well Completion

- Typical norm is that deeper and hotter wells have much more complex completion techniques and equipment
  - Temperature gradients vary within the areas being investigated for Geothermal Energy Resources. Depth Gradients can be from 0.75 degrees F per 100 ft up to 2.3 degrees F per 100 ft as an example [surface 75 ºF]
  - Pressure gradients can vary from 0.1 psi/ft up to 0.95 psi/ft
  - Reservoir stresses can vary from supporting a hydrostatic load from 0.20 to 0.85 psi/ft
  - Designs for completion called for multiple casing strings for well control and pressure restrictions

Example of a schematic showing a well's completion and casing depths



Example well has:

Conductor Casing

Surface Casing

Intermediate Casing

Drilling Intermediate

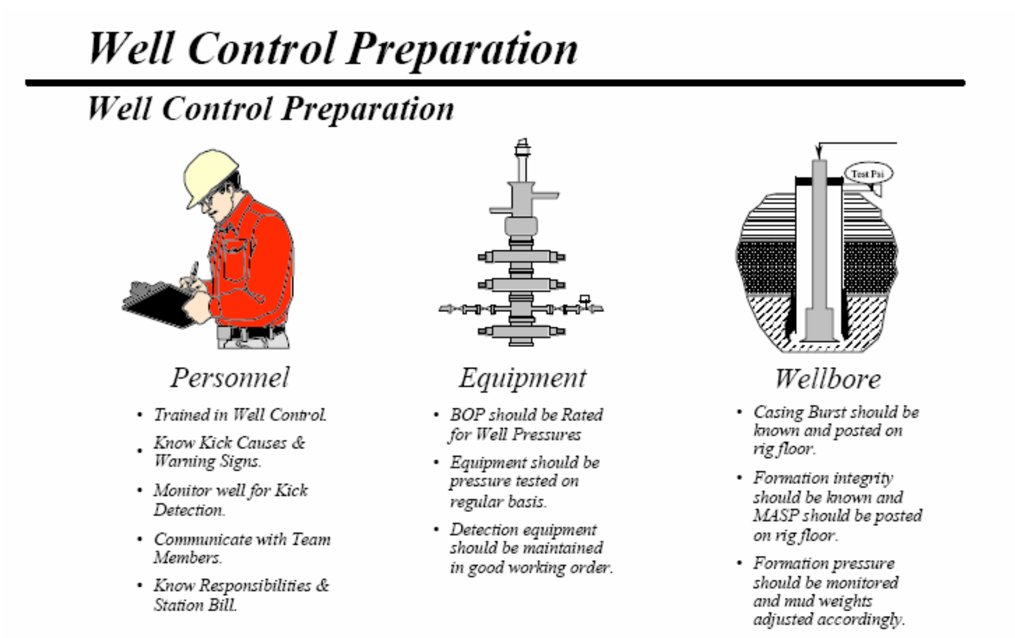
Production Liner

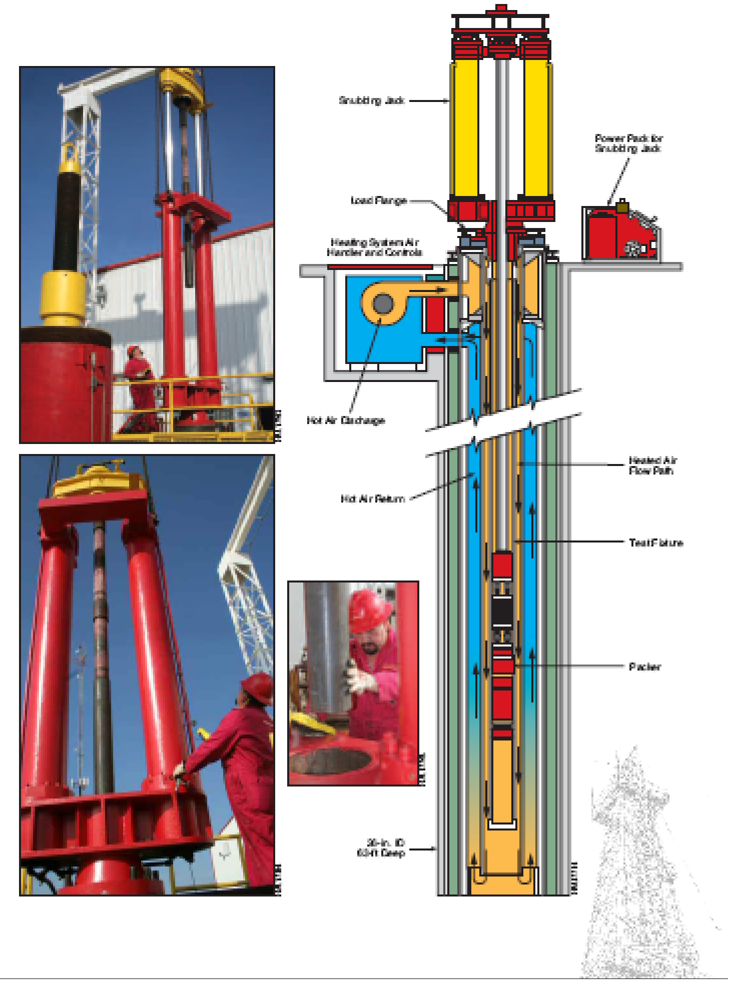
Various Completion Tools

How to Establish Well Integrity if Re-Entering a Well

- Determine the best possible ways to achieve and maintain long-life wellbore integrity and structure
  - Full Liner run into well for structure repair and gaining integrity
    - Often needed due to deterioration of current casing strings
  - Understand what the “focal points” are and their existence
    - location and pressure restrictions
  - Determine the optimal slurry and what technique of placement would best achieve a total annular isolation
  - Perform an evaluation using the “best practices steps” in the approach towards any construction or re-construction

Entering a Wellbore



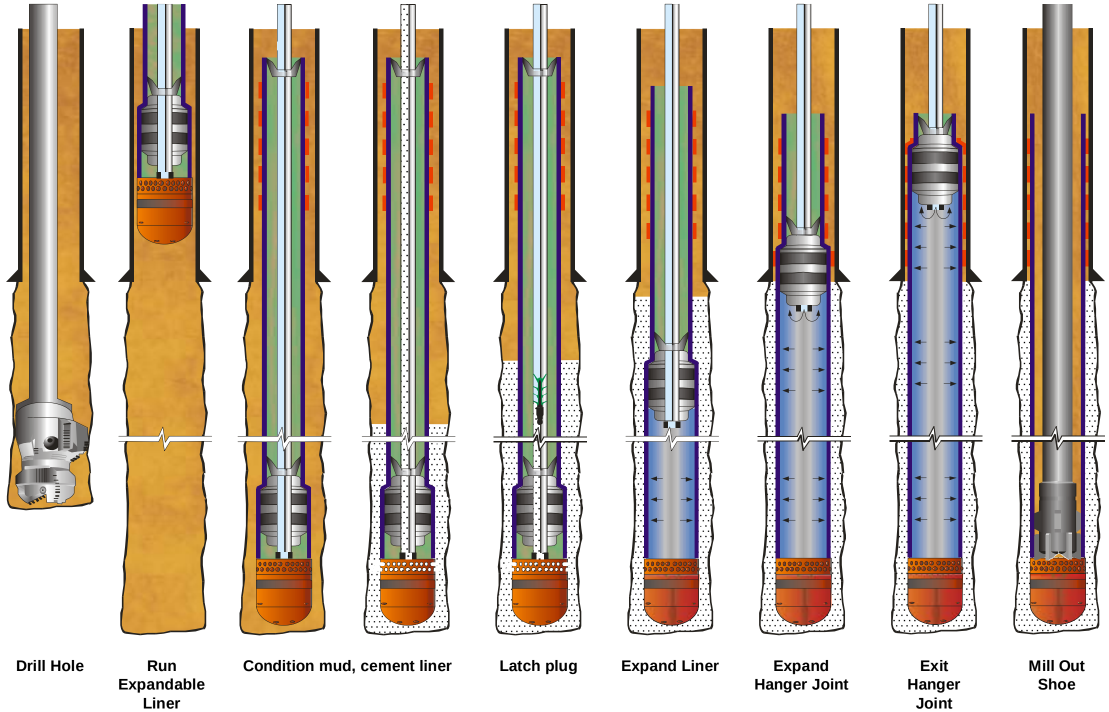


Emerging Technologies in Wellbore Stabilization

- Expandable Casings-Liners
  - Allows the operator to run in a casing or liner with clearances and then use an expansion device to enlarge the casing or liner up to the ID of the initial casing in the well
  - Can use corrosive prevention materials or cement placed in annulus prior to expansion

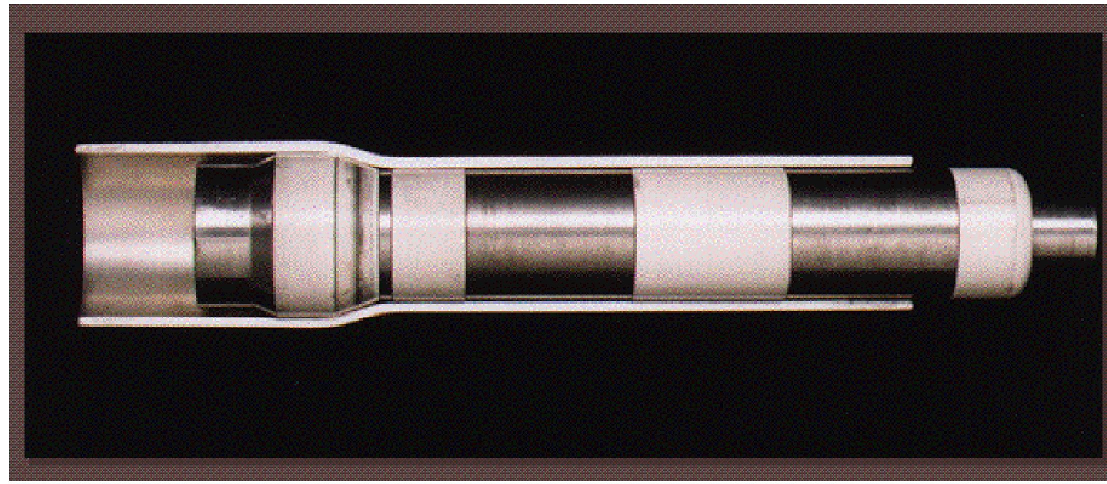
Emerging Technologies in Wellbore Stabilization

Enventure OHL™ System

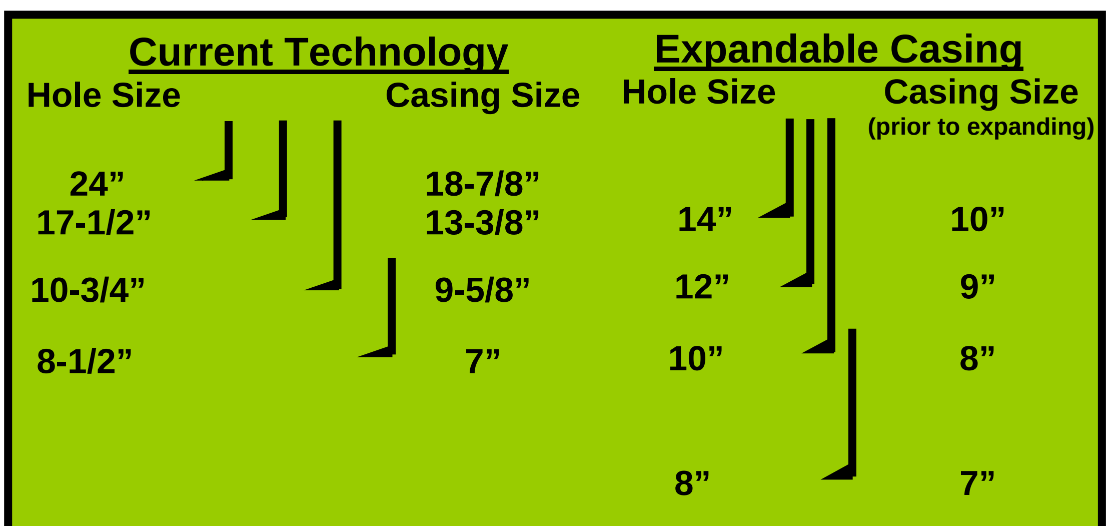


ENVENTURE
SET. The Standard.™

Expandable Casing - Products and Services



Cross section of expanded pipe and pig



Emerging Technologies in Wellbore Stabilization

- Easywell Swellable Casing Packer Technology
  - Utilizes a swellable packer run on casing or liner
  - Ability to swell when left static in either Oil or in Water
  - Capable of gaining a high pressure seal in annulus at designed points where the Easywell Packer elements were placed

Swellpacker™ isolation system

easywell

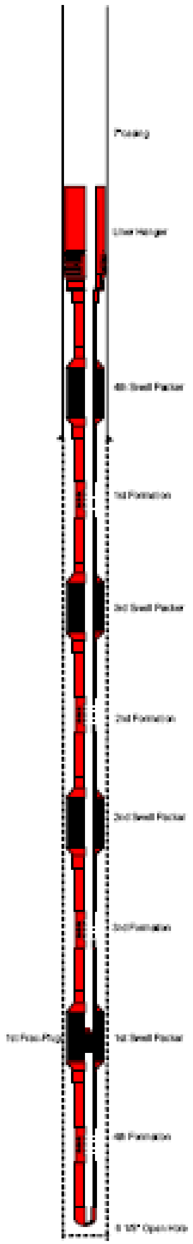


Figure 1 – Casing Run

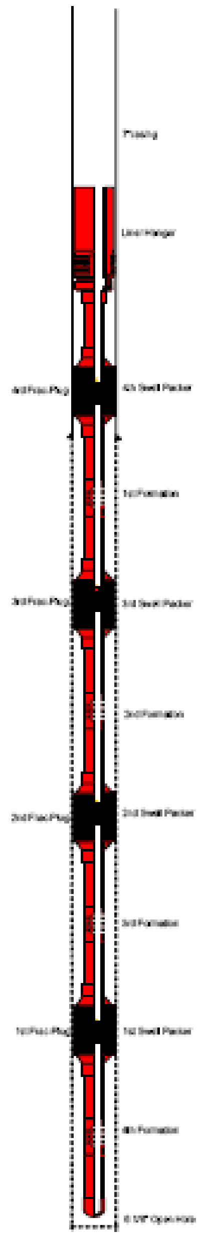
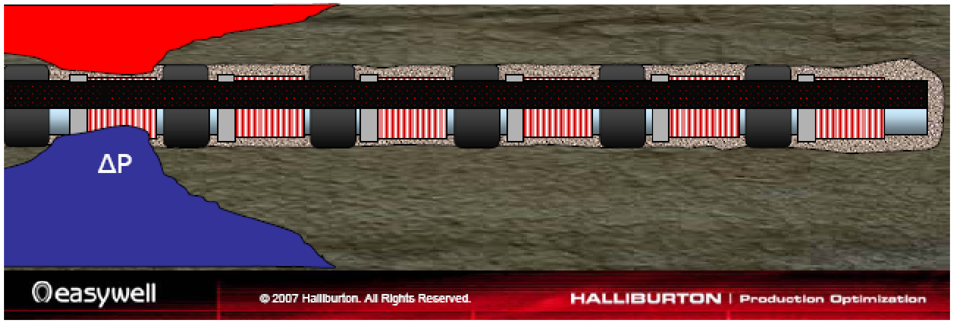


Figure 2 – Configuration after all Fracs

Emerging Technologies in Wellbore Stabilization

Easywell Packer System can be run in either a vertical or horizontal completion

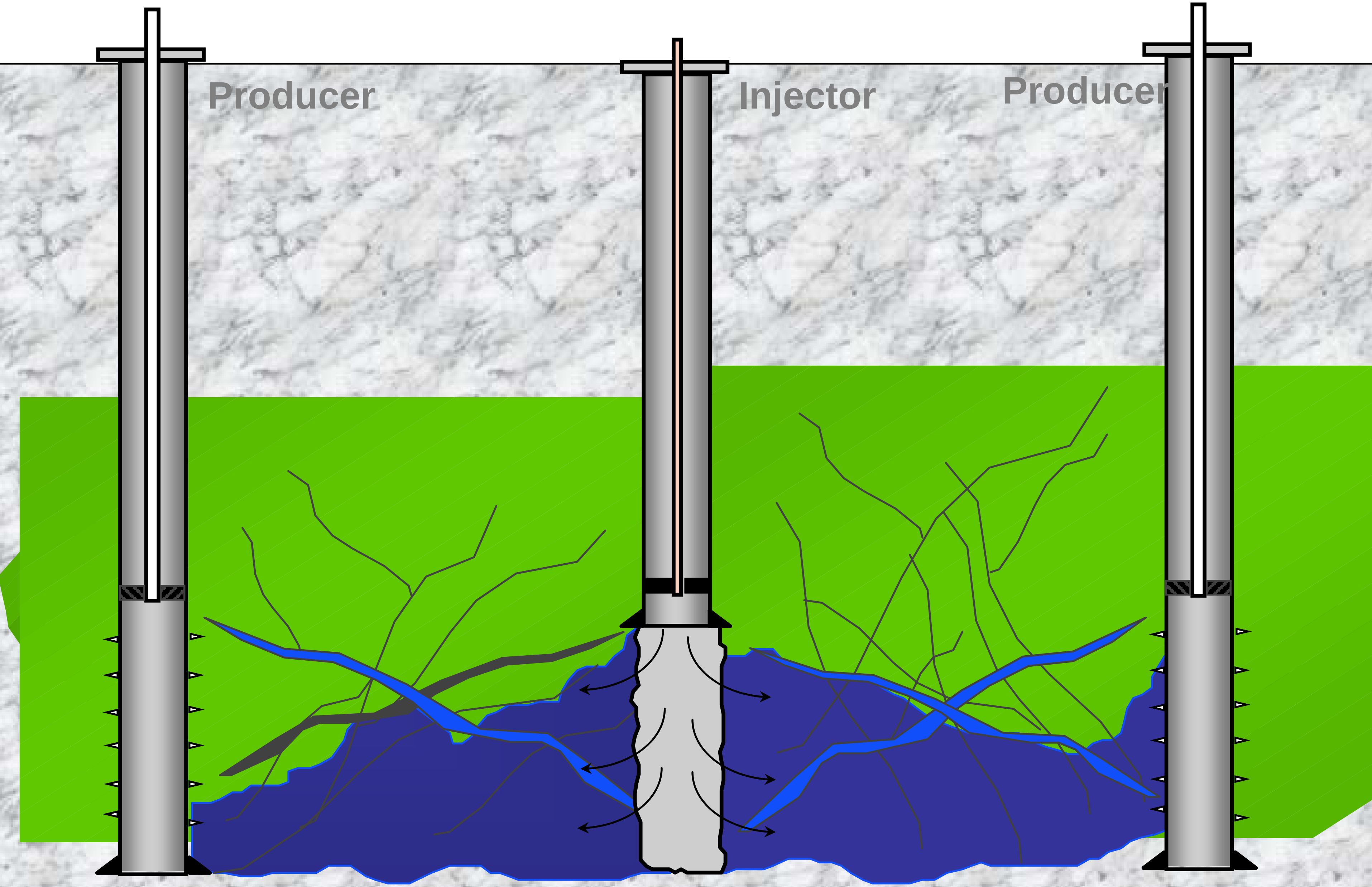
- Homogenous, low drawdown reservoir
  - Frictional flow
  - Toe-heel effects



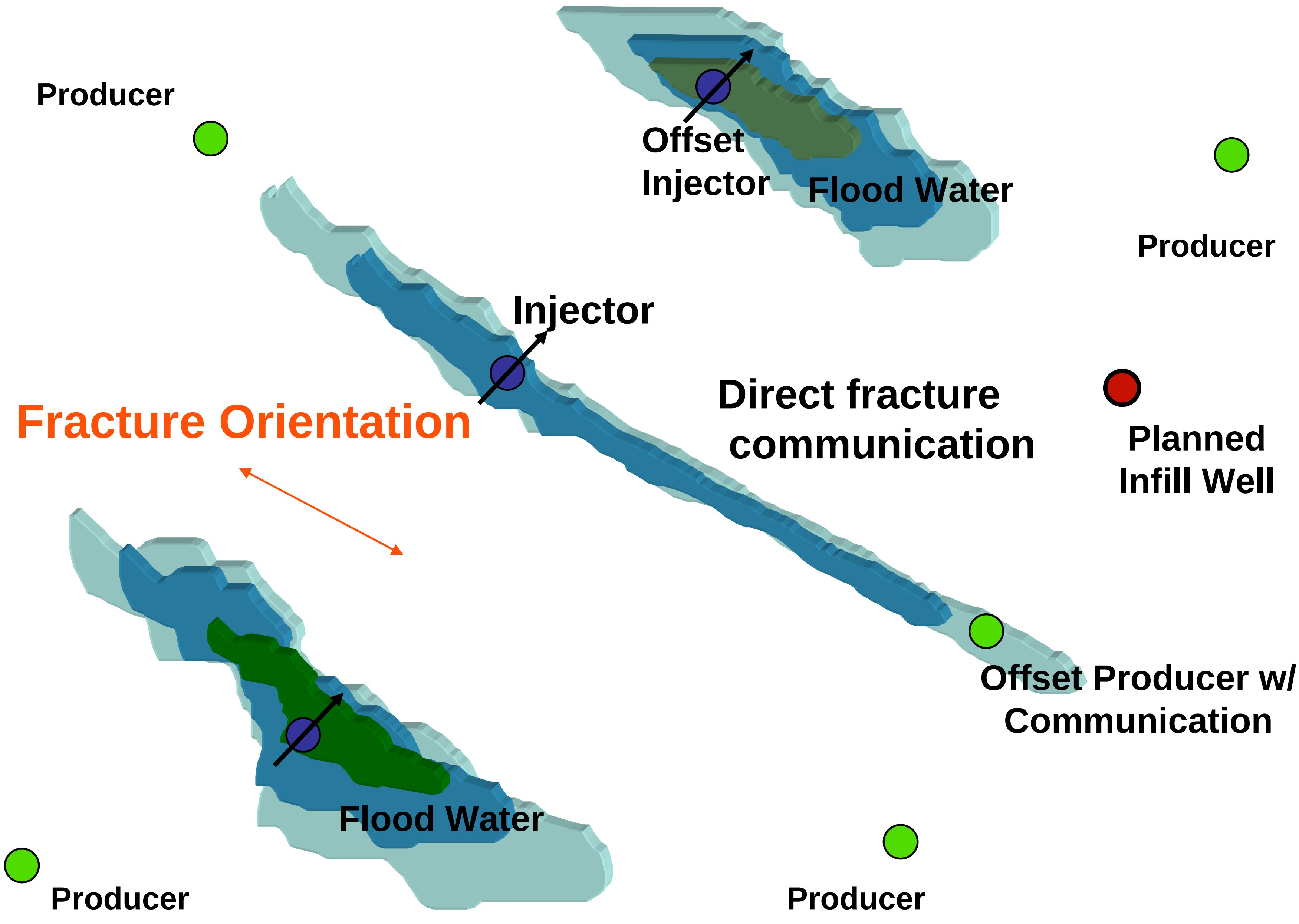
Objectives on Well Integrity Management

- Create value by extending the economic life of the well and optimizing the hydrocarbon produced, through fit for purpose well construction and repair
- Engineer sealant properties for the wellbore, reservoir and loading conditions
- Design suitable sealant from services' portfolio
- Deliver the sealant – simulation analysis via OptiCem®
- Monitor, Control and Document the well performance, in RealTime
- Dual possibilities at end of normal well-life production
  - Geothermal resources
  - Heat exchange for lifting assist via electricity generation

Fractures/Fissures and Faults occurring in Reservoirs



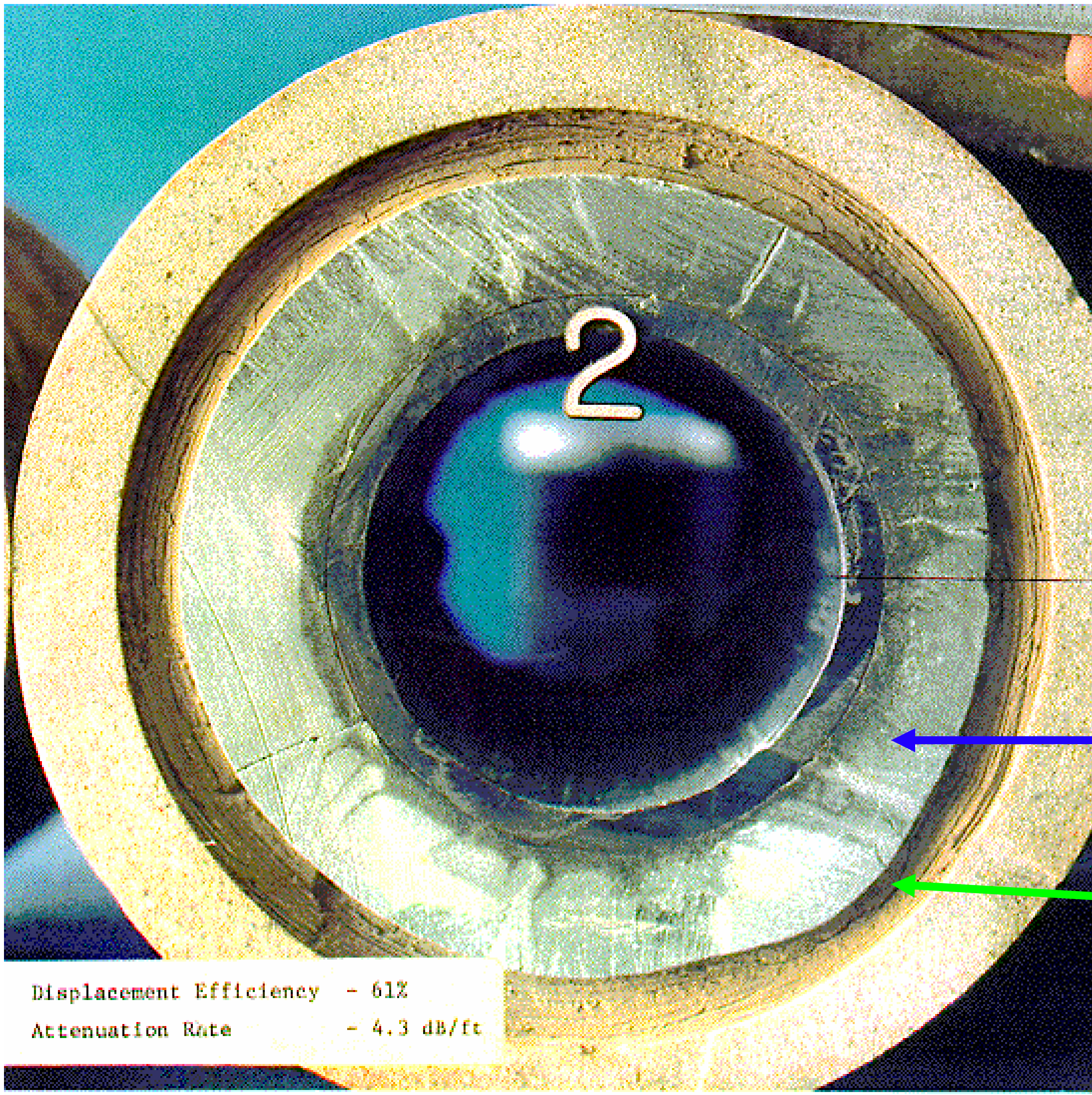
Flooded Field with Fracture Communication



Remedial Technologies

Wellbore Integrity Solutions for extended Well-life

Analysis of Results on Casing Integrity



- Bond Log
- Measure Displacement Efficiency

Cement

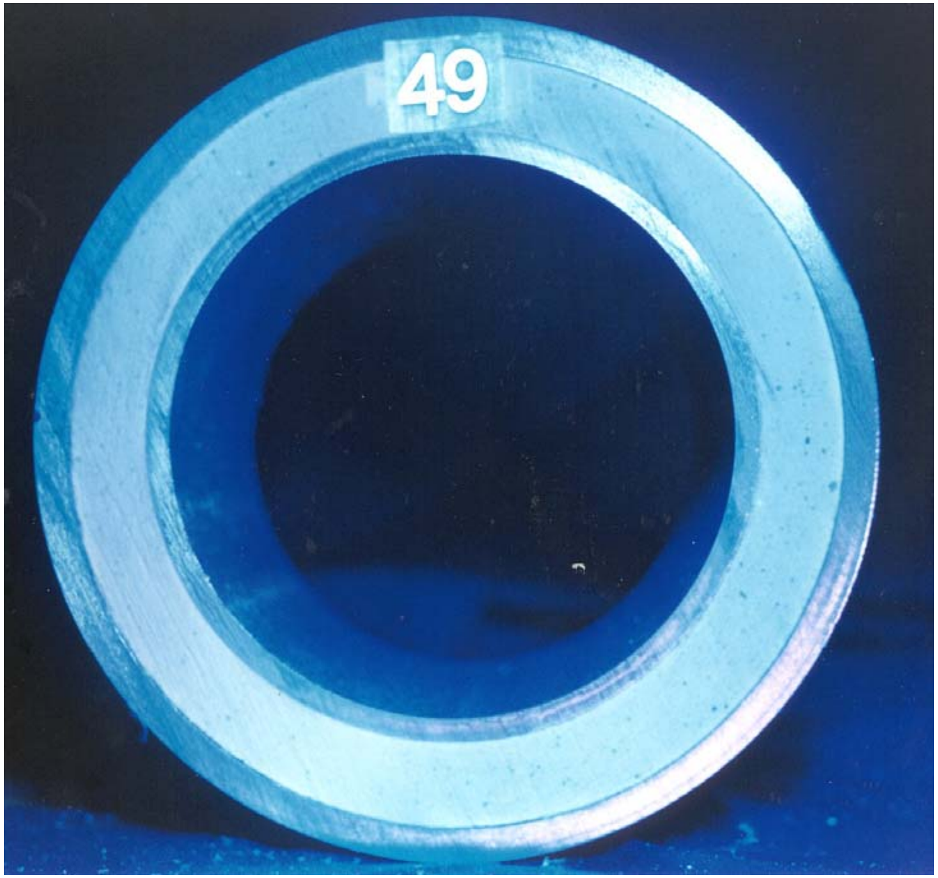
Mud Filter Cake

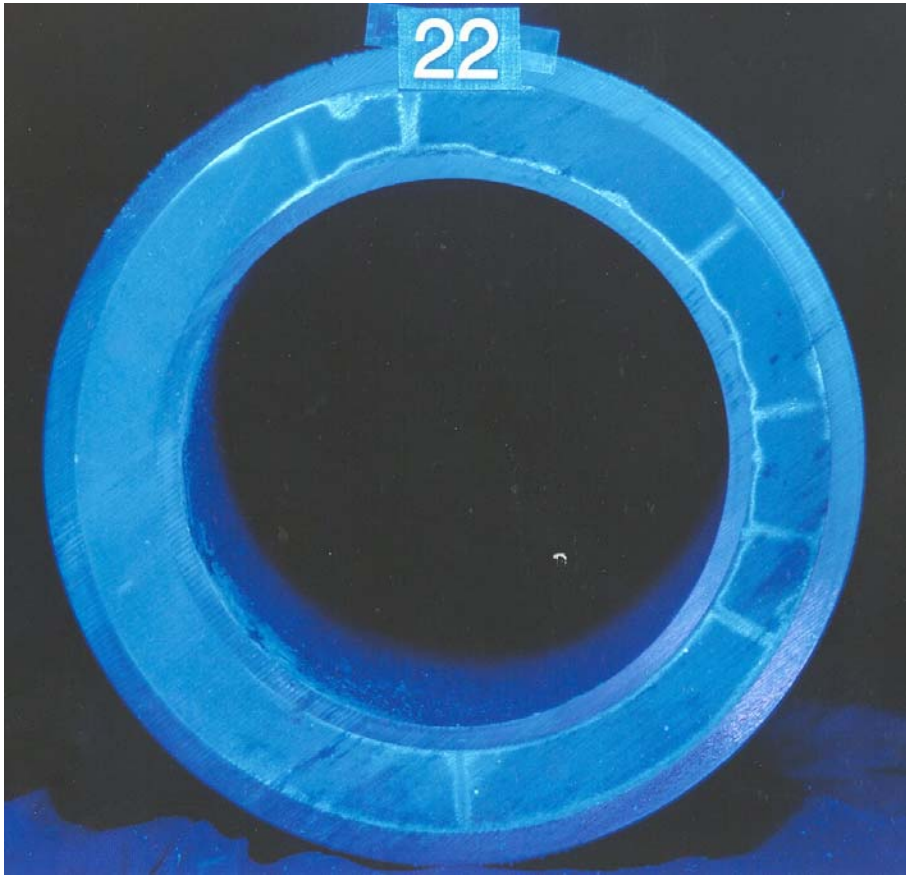
Casing Cementing Parameters
“Making a Decision”

- Is it easier to fix an invasion or loss circulation problem by changing directions annular placement is conducted ?
  - Where are gas influx intervals ?
  - Where are water influx intervals ?
  - Where are fragile intervals with possible associated fractures ?
- What is the extent and length of problem zones ?
- What is the easiest way to achieve zonal isolation ?
- What attributes are needed to achieve a successful remedy ?

Best Practices: Find and utilize the focal points in applications and placement methods

ZoneSeal vs Conventional Cement



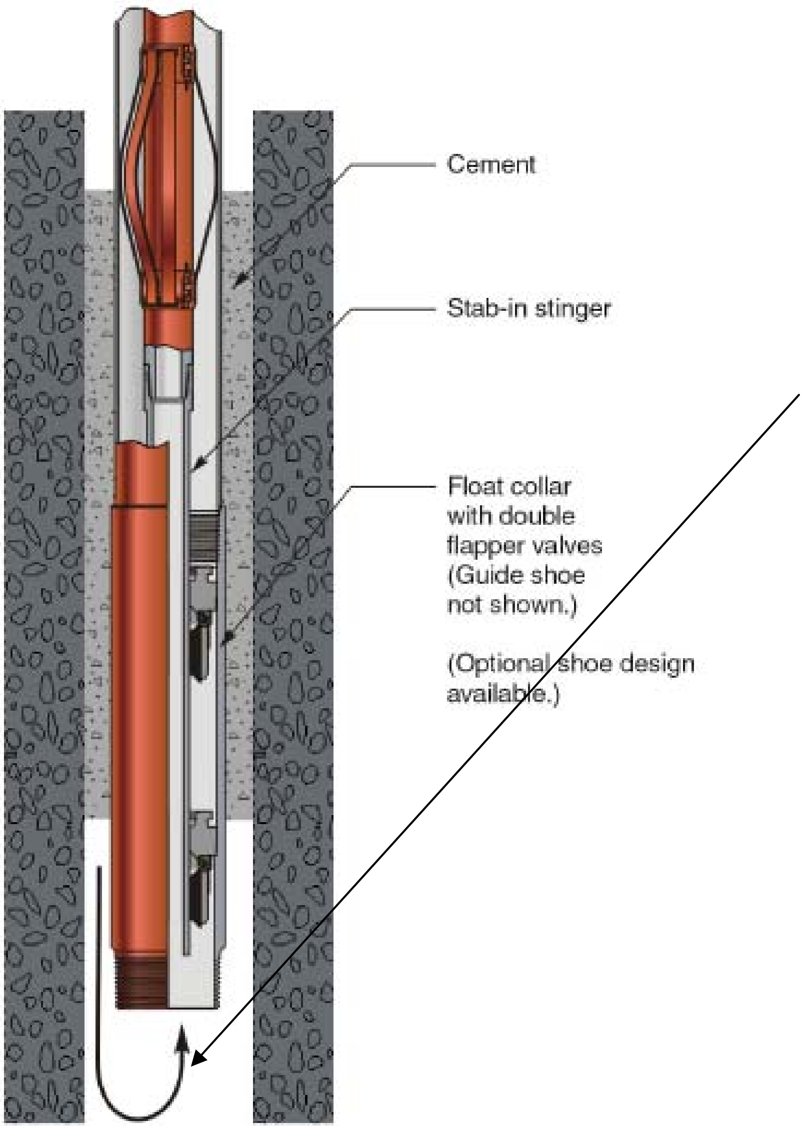


Cementing High Temperature and Pressure Wells

- General Issues
  - Zonal Isolation
  - Support Casing
  - Temperature Cycling
  - Low Fracture Gradient Formations
  - Exposure to Steam
  - Variable Hole Sizes
  - Long Well Life

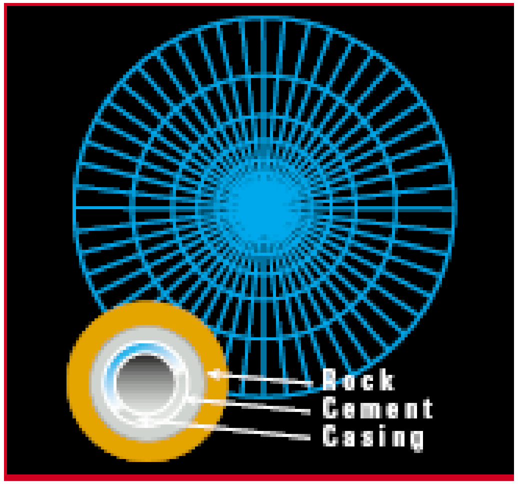
- Specific Issues
  - High Steam Pressure
    - > Fracture gradient
    - 550 to 600 deg. F.
  - Frequent Cycling
    - 10 to 15 cycles per year
  - Long Pay Interval
    - ~1/3 of total well depth
    - Maintain zonal isolation for 2 or 3 intervals
      - 5 to 10 years each

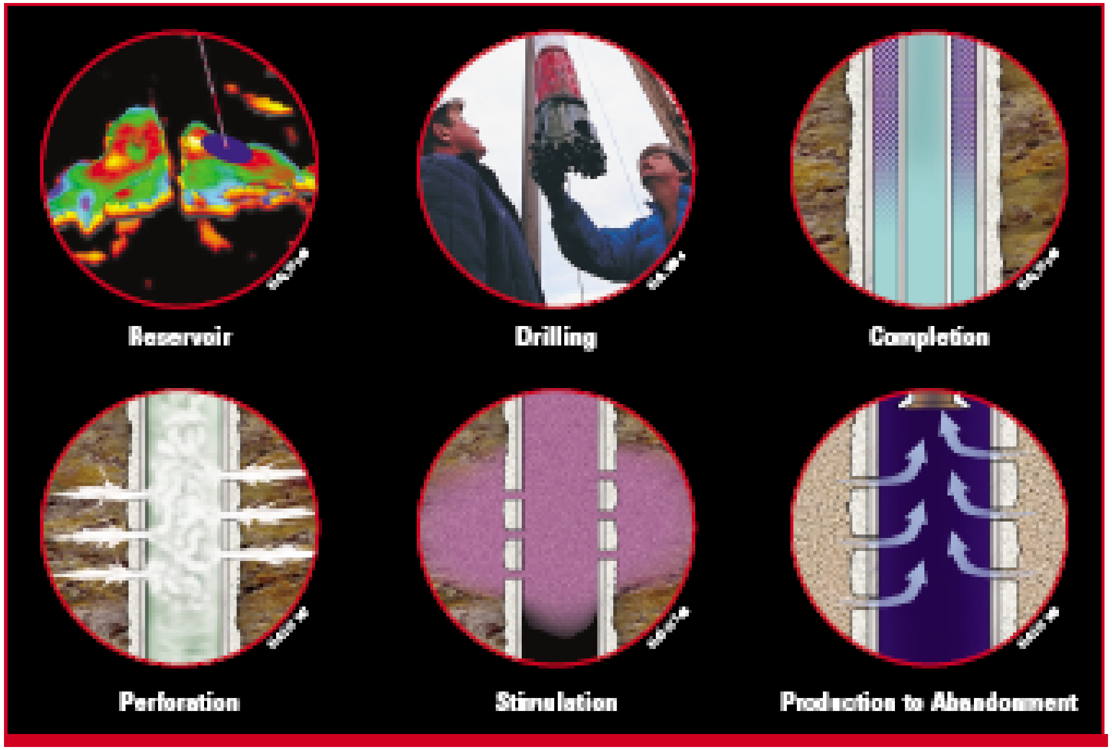
Reverse Circulating Cement Designs



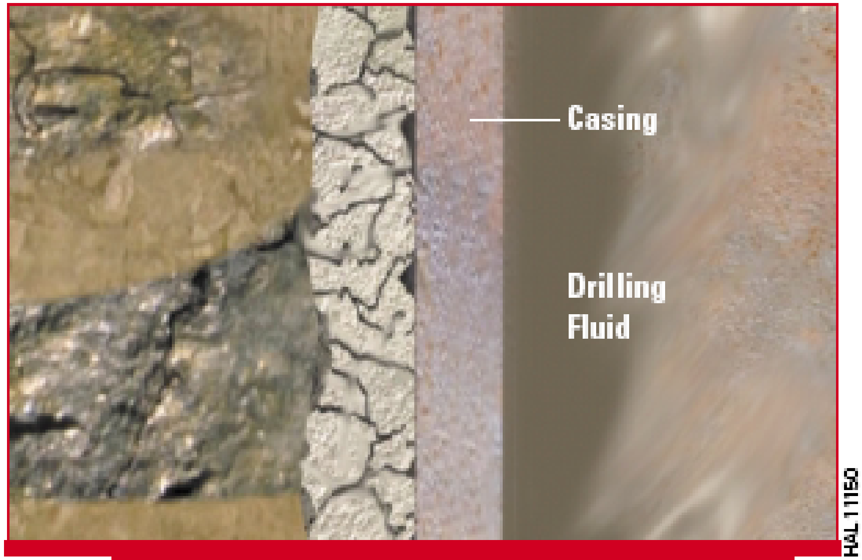
- Utilizing what the well gives you to make a better annular seal
- Utilization of energized slurries means it does not care which direction it is placed

Life of the Well Events

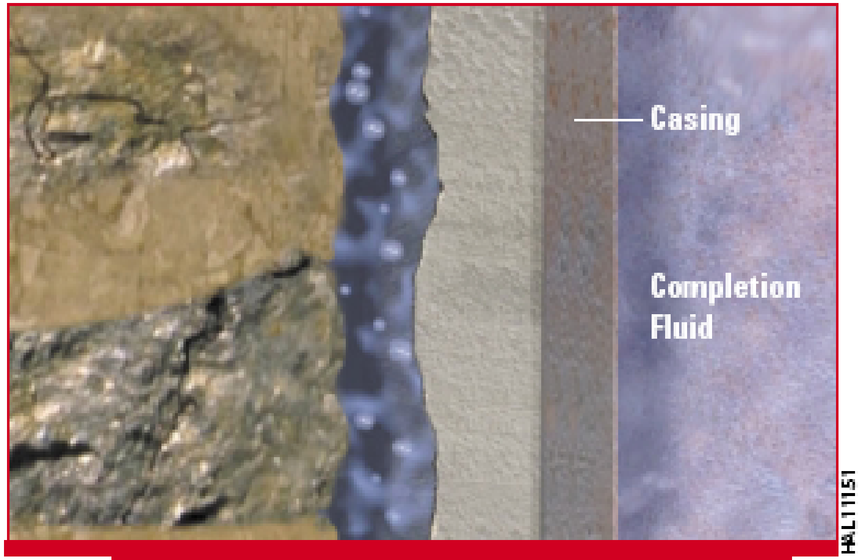




Modes of Annular Sealant Failure



Above is a graphic depiction of a cement sheath that has shattered due to extreme pressure effects encountered during a fracturing operation. Depending on the length and location of the crush zone, interzonal communication could be a distinct possibility.

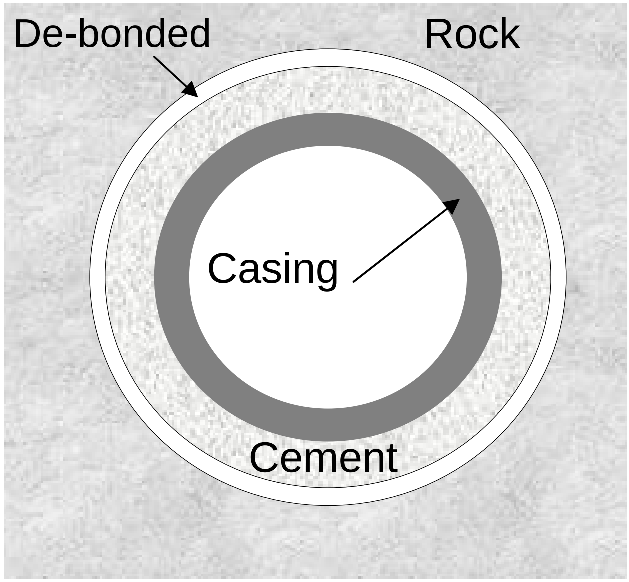


This scenario depicts debonding of the cement sheath due to casing contraction caused by replacing a heavy-weight drilling fluid with a light weight completion fluid.

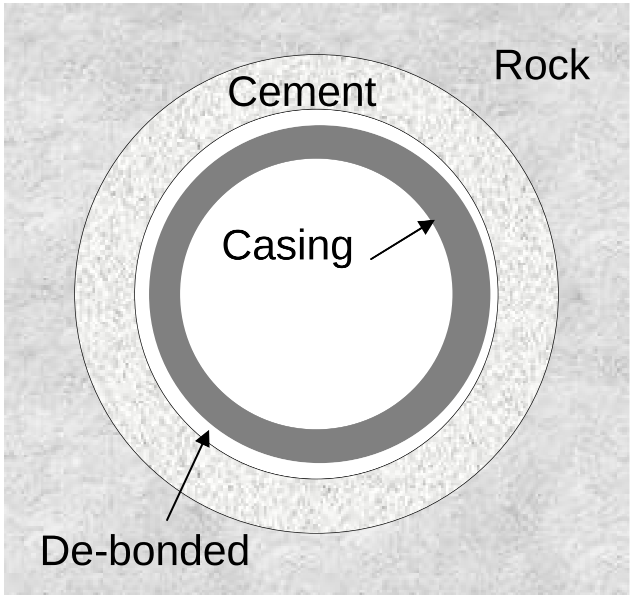
Modes of Cement Failure

- De-bonding

@ rock-cement interface

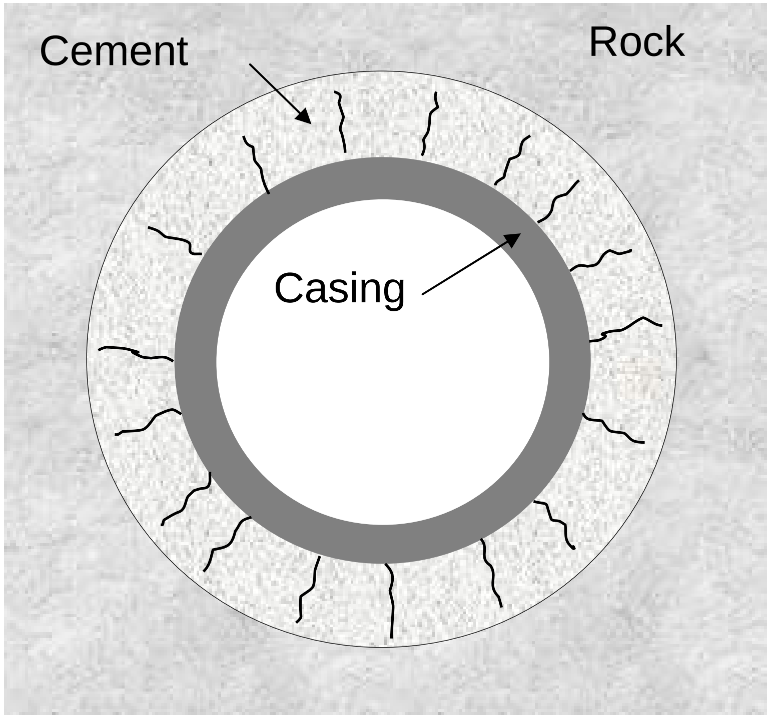


@ cement-casing interface

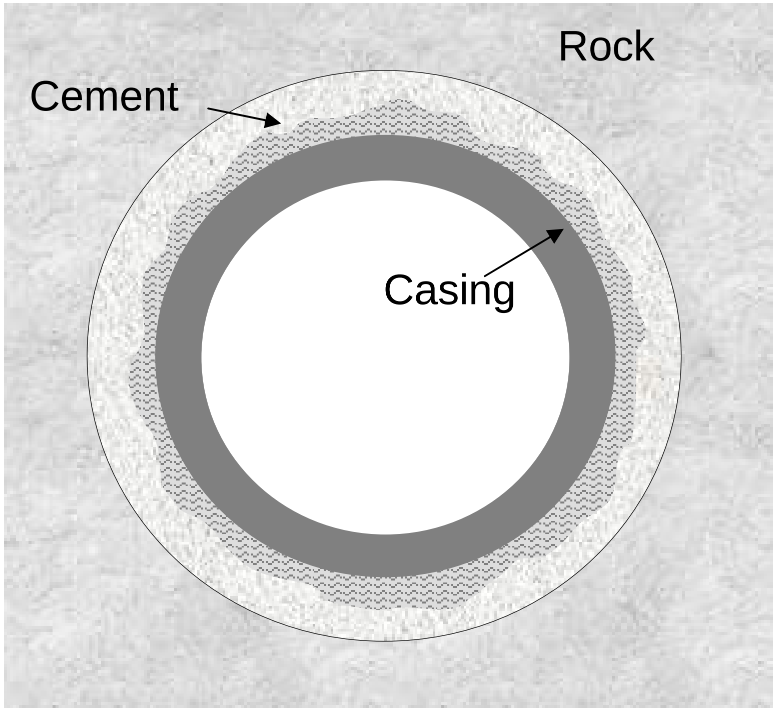


Modes of Cement Failure

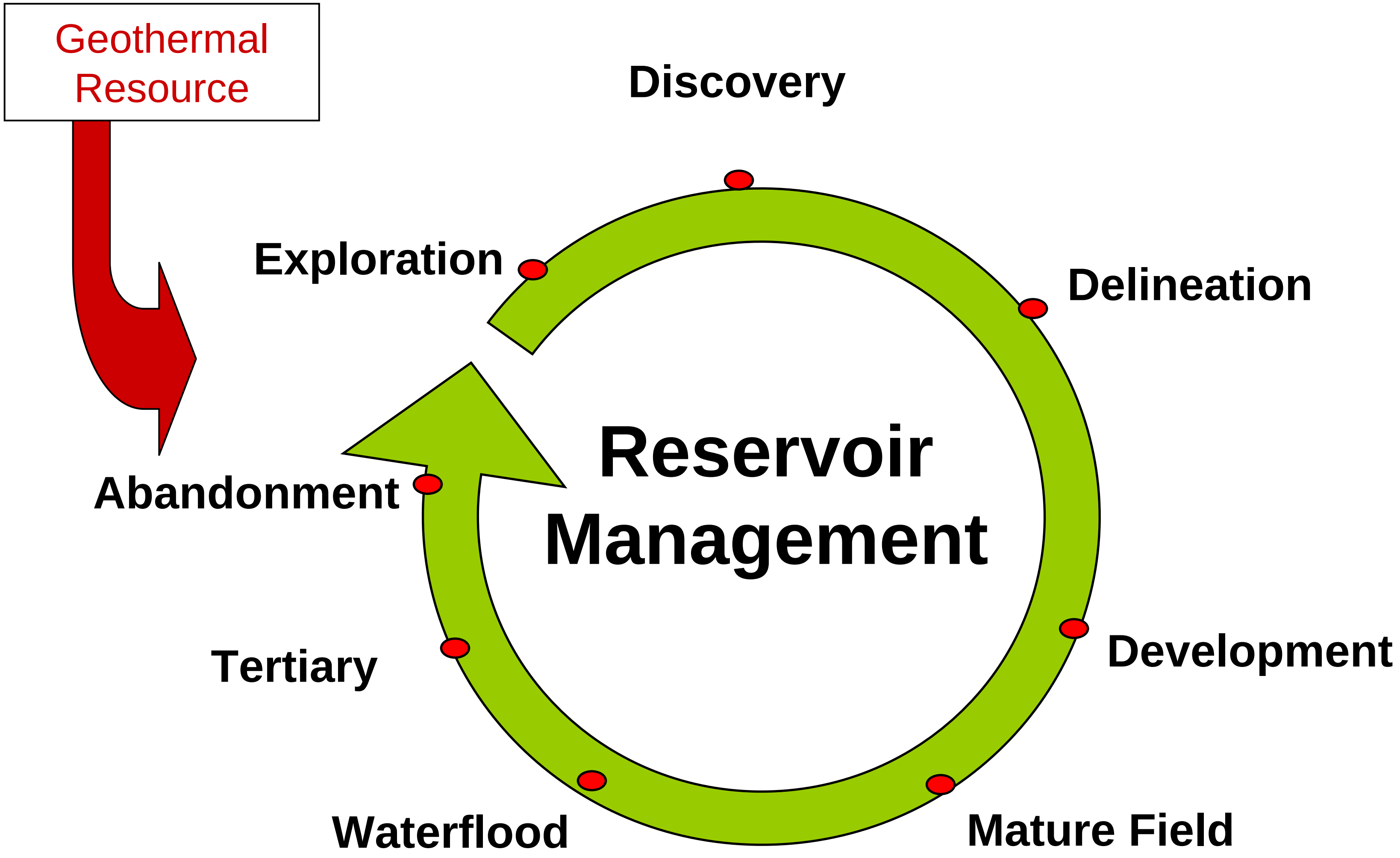
- Cracks



- Deformation



Reservoir Life Cycle



PRODUCTION


WHO NEEDS
OIL?
I RIDE THE BUS

Bossier well abandoned

ODESSA AMERICAN

June 8, 2007 - 2:29PM

MIDLAND Company announced that it had temporarily abandoned the David Barton À1, an exploratory well in its Winnsboro prospect in Richland Parish, La. targeting the middle and lower Bossier formation at a depth of approximately 14,500 to 17,500 feet.

While drilling at a depth of about 12,500 feet, the company encountered a strong water flow which it was unable to drill through without excessive risks and problems. As a result, the company temporarily abandoned the well without testing the “pressured” portion of the Bossier formation.

The company is currently re-evaluating how best to test the target section of the Bossier formation in this area. Other options may include obtaining and evaluating additional 2-D or 3-D seismic data.