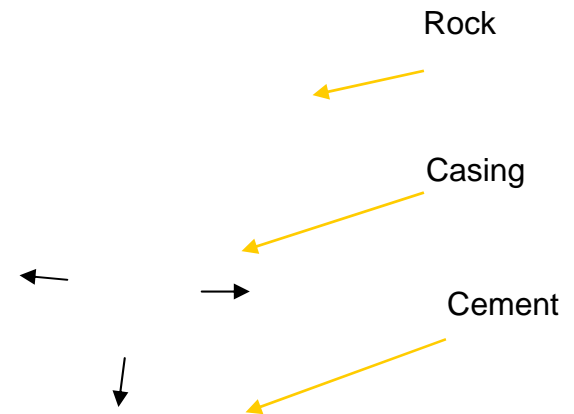
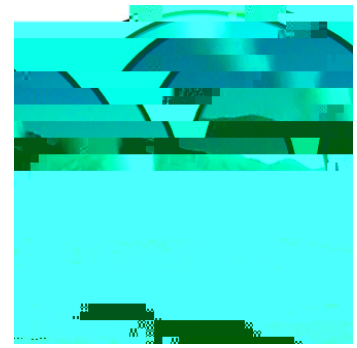


GEOHERMAL ENERGY UTILIZATION



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 °F 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

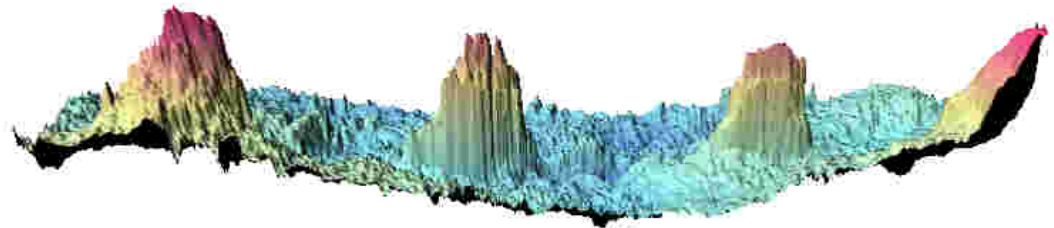
Data Collection

- ∅ 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

Addressing Completion Methods

Past & Present

Ø

Repairing Wells for Long Term Zonal Isolation and Integrity

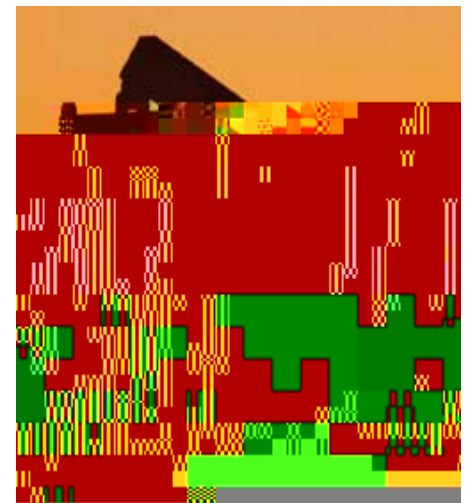
OBTAINING A GOOD ANNULAR SEAL

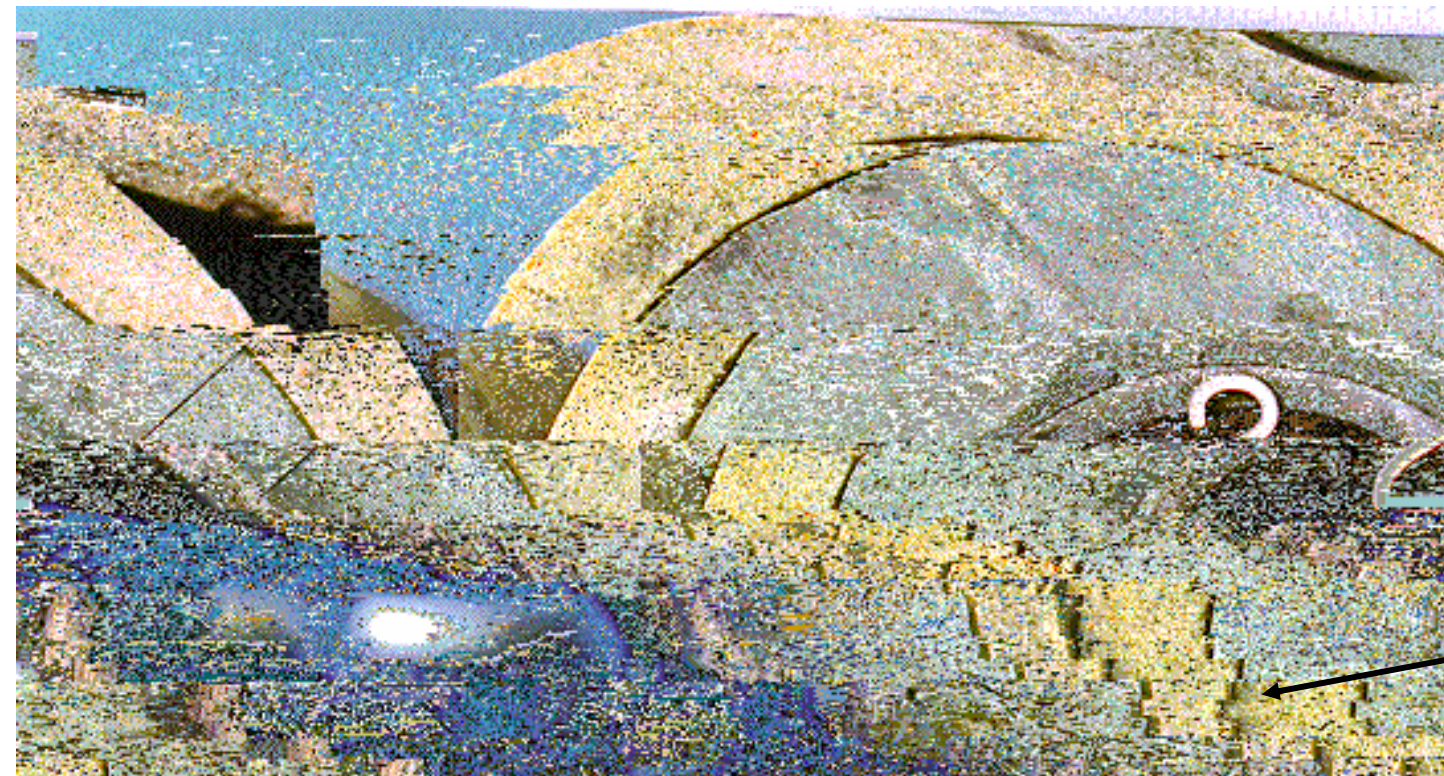
- ∅ Complete planning with the aid of accurate job models
- ∅ Proper well cleanout and drilling fluid preparation
- ∅ Proper centralization of the pipe
- ∅ Proper volumes and design of spacer
- ∅ Effectively designed slurries
- ∅ Pipe movement
- ∅ Continuous pumping
- ∅ Maximum flow rates
- ∅ Zero closed-in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





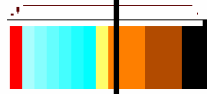
**Cracked
Cement
Sheath**



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 360° view of the casing annulus
 - ∅ Study the well histories such as pin-hole-leaks or metal corrosion problems

RELATIVE BEARING	THICKNESS CURVES	AMPLIFIED AMPLITUDE	MICROSEISMOGRAM	CBL BOND INDEX	IMPEDANCE MAP
0 DEG. 360	0.2 IN. 0.4	0 10	200 1200	1 0	
ECCENTRICITY	AVERAGE			AVERAGE	
0 1.0	MINIMUM	AMPLITUDE		IMPEDANCE	
0 5.0	MAXIMUM	0 100		10 0	



0 mV 15

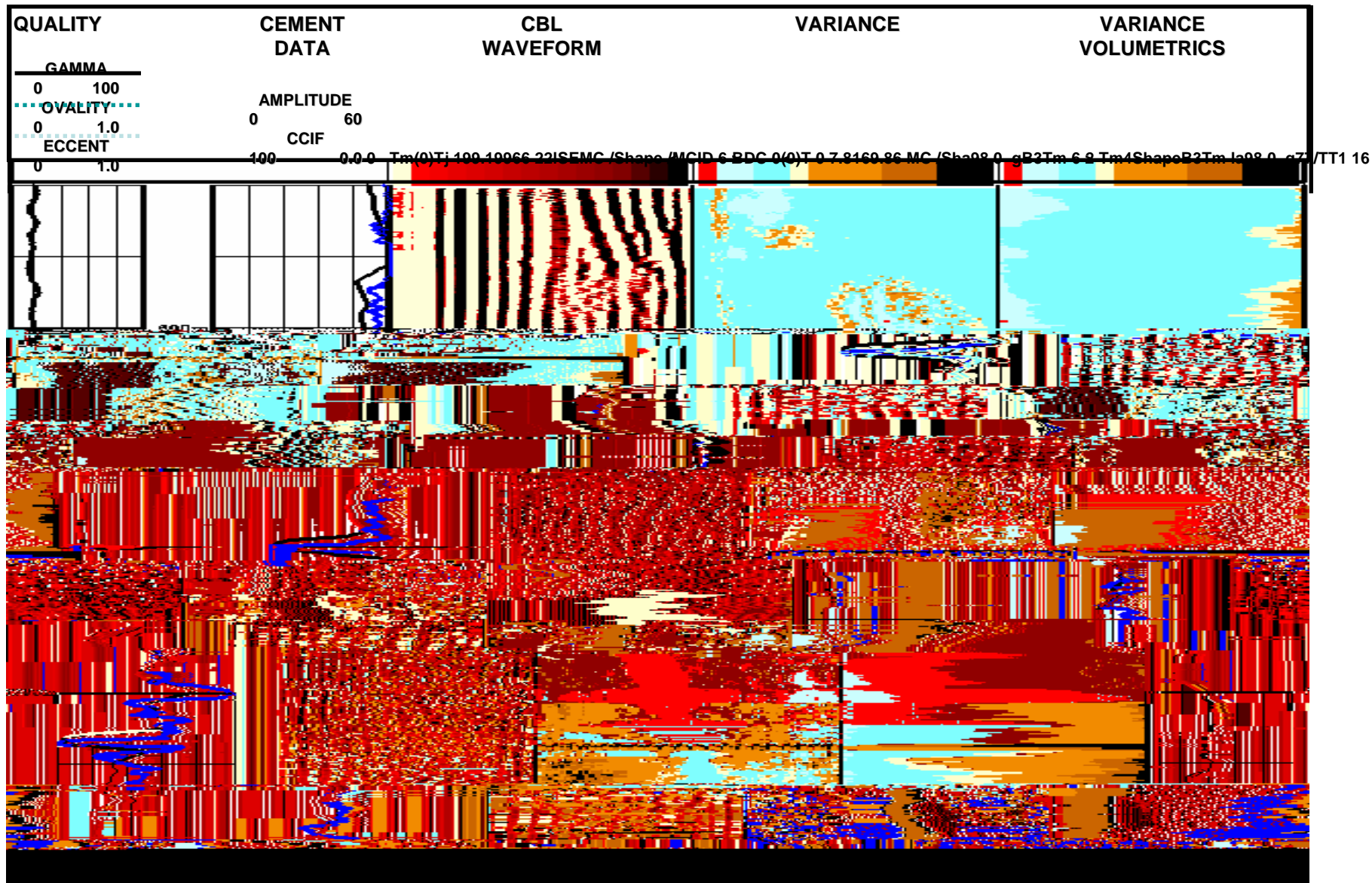


X150

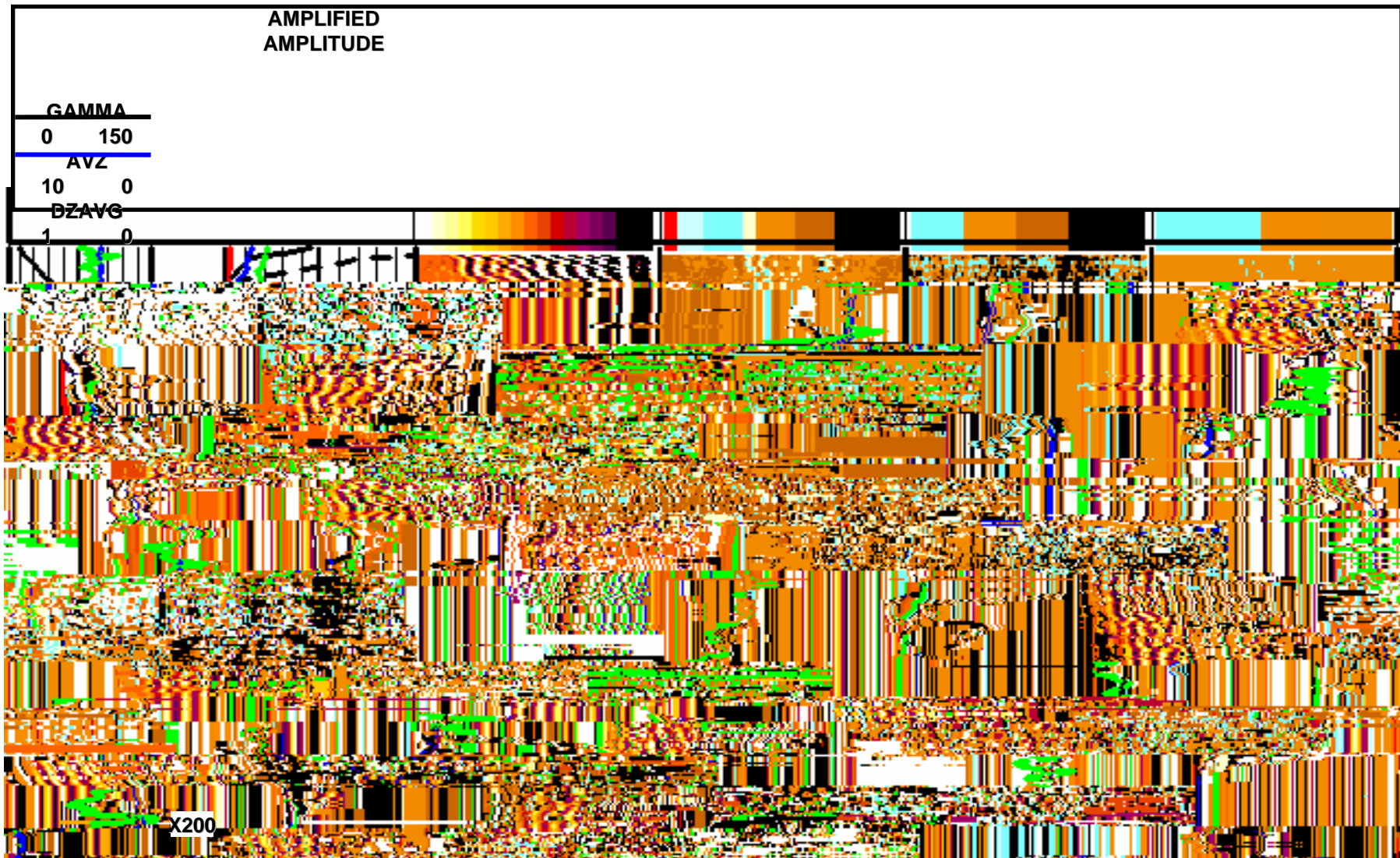
X200

X250

Example of Cement Evaluation Logs



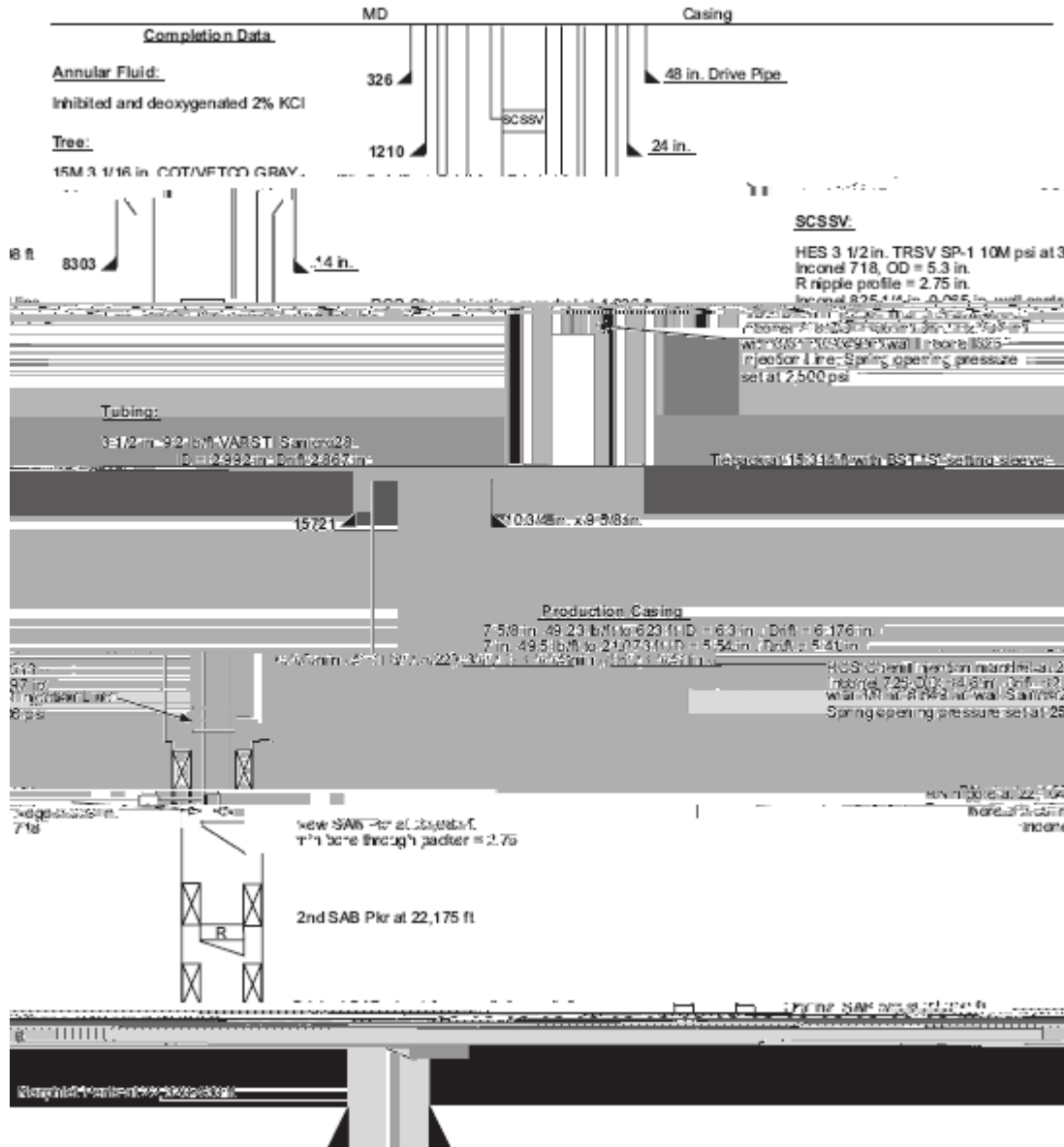
Foamed Cement Analysis in Bonded Pipe



Understanding the Complexities of the Well Completion

Ø

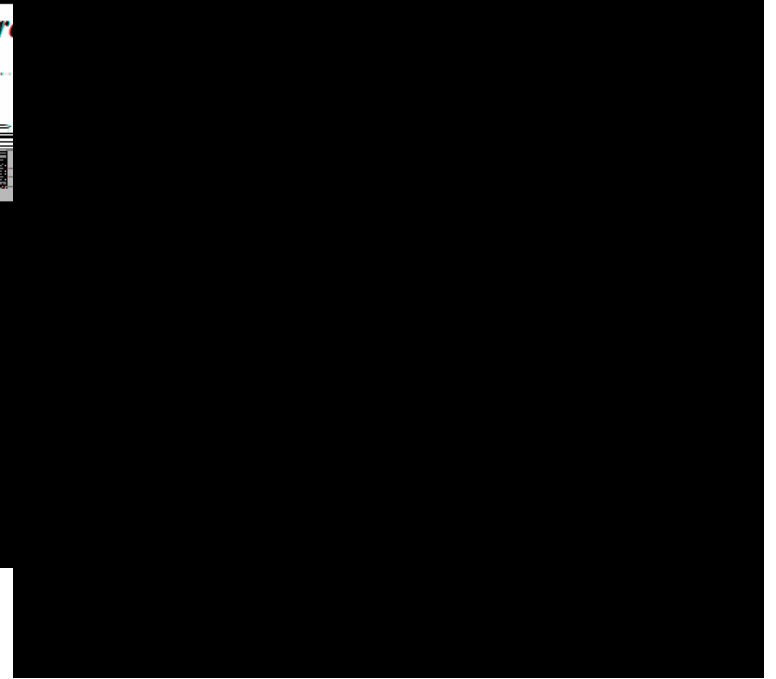
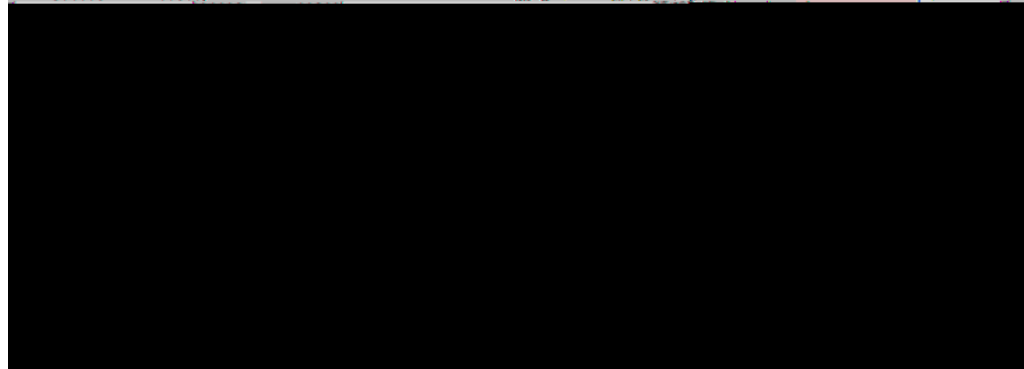
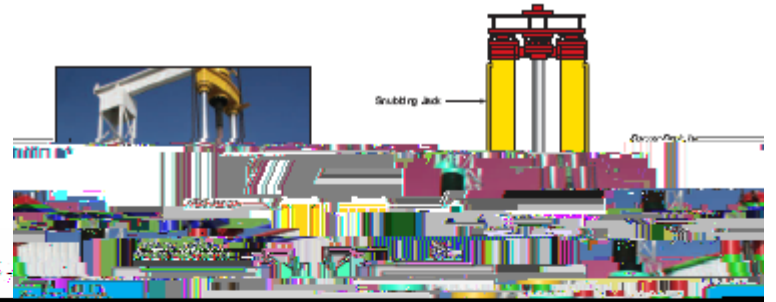
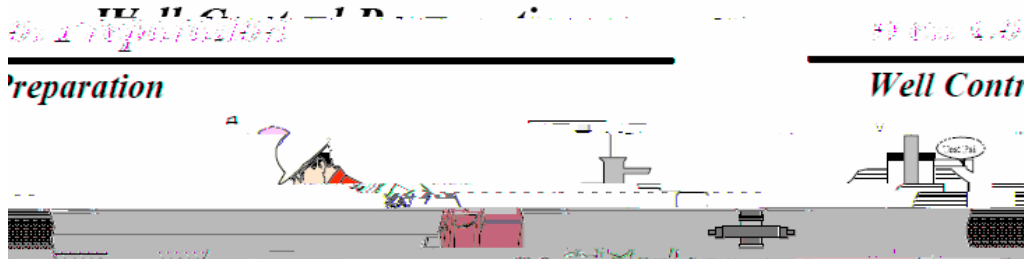
Example of a schematic showing a well's completion and casing depths



- 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

Entering a Wellbore

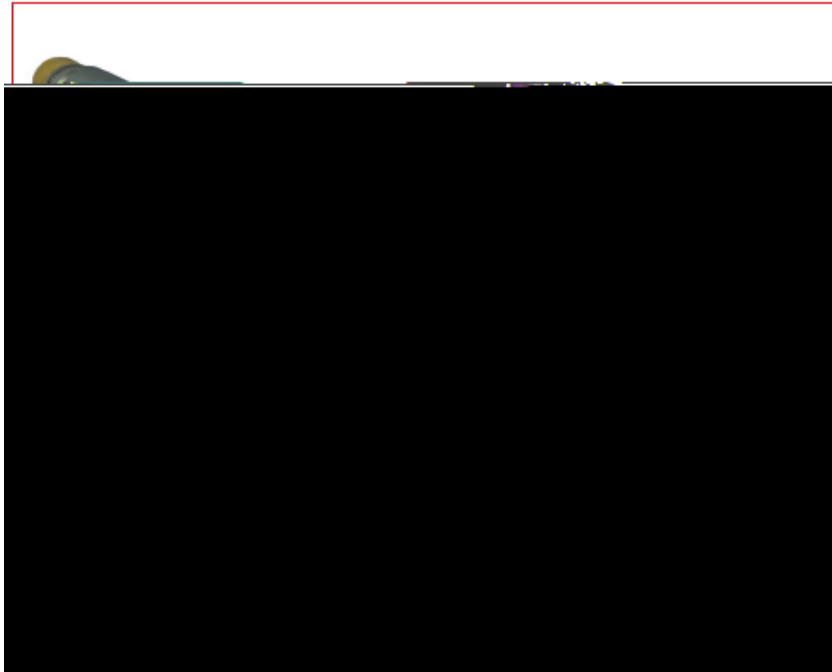


Emerging Technologies in Wellbore Stabilization

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Emerging Technologies in Wellbore Stabilization

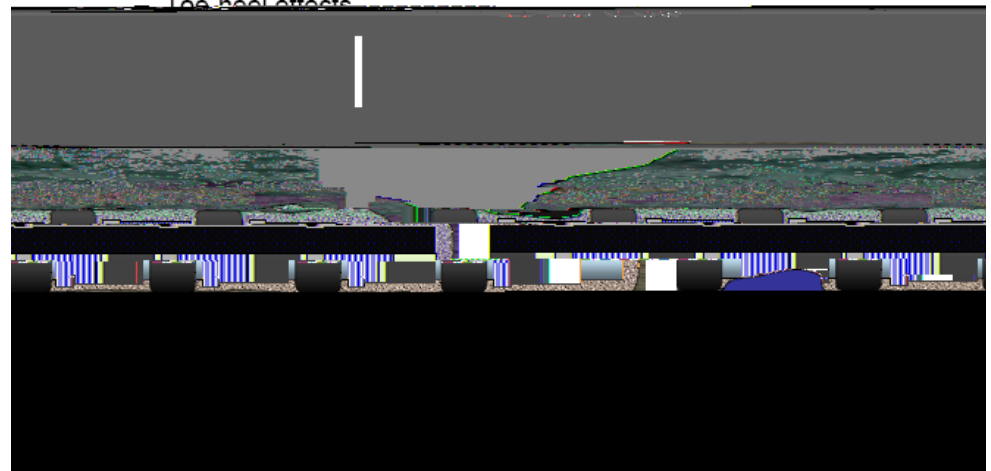
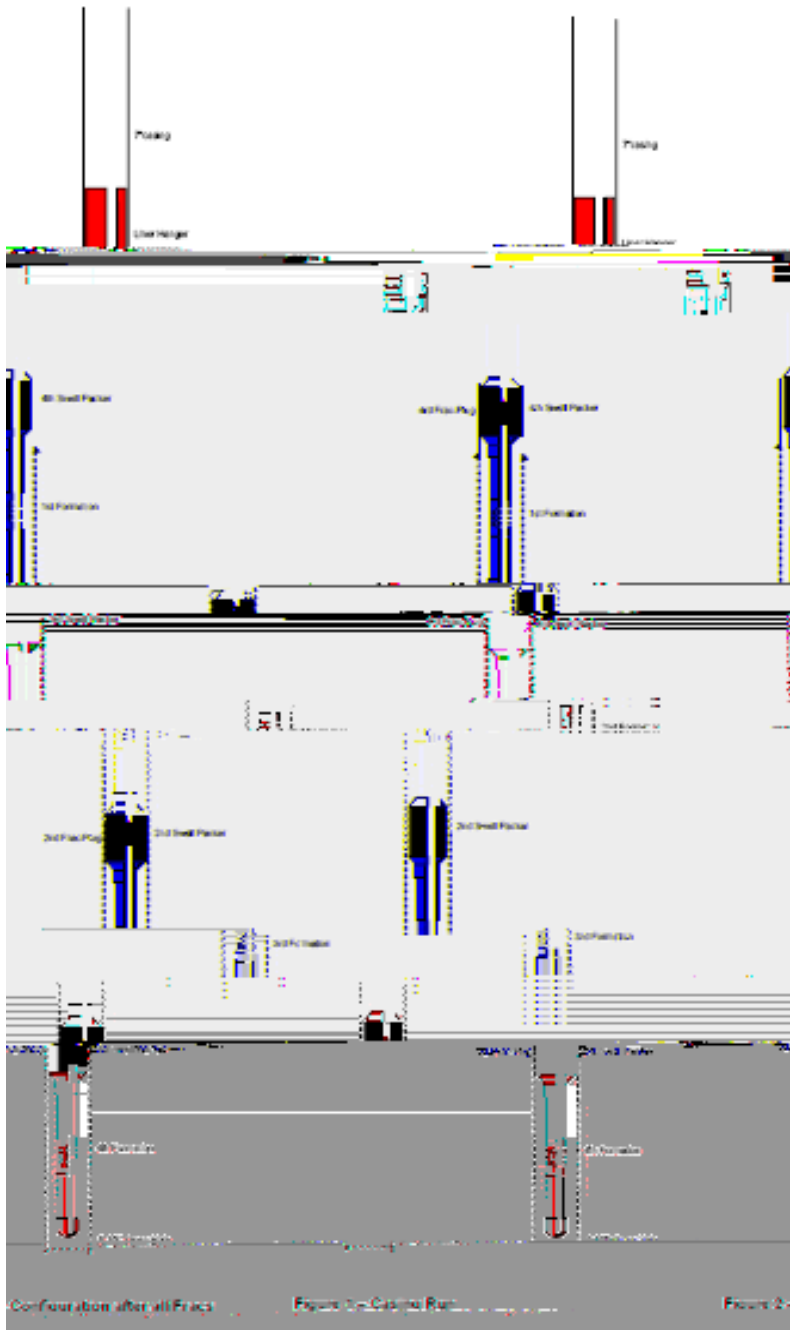
- ∅ Easywell Swellable Casing Packer Technology
 - ∅ Utilizes a swellable packer run on casing or liner
 - ∅ Ability to swell when left static in either Oil or in Water
 - ∅ Capable of gaining a high pressure seal in annulus at designed points where the Easywell Packer elements were placed



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



Remedial Technologies

Wellbore Integrity Solutions for extended Well-life



Analysis of Results on Casing Integrity

- Bond Log
- Measure Displacement Efficiency



Cement



Mud Filter Cake

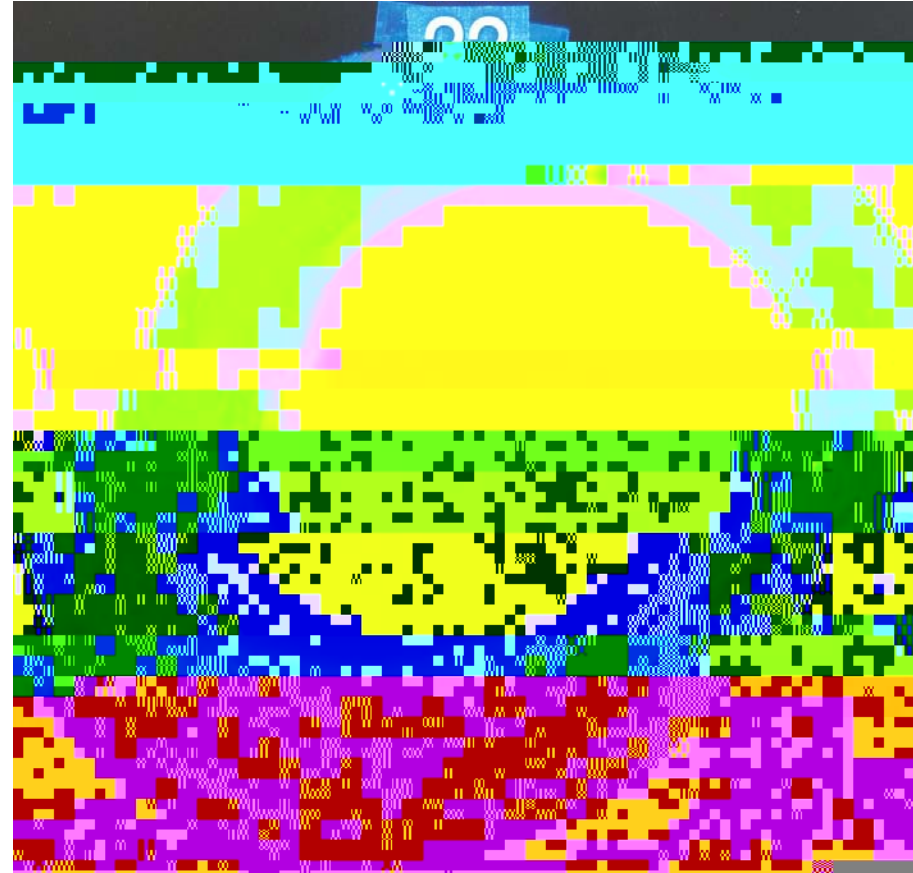
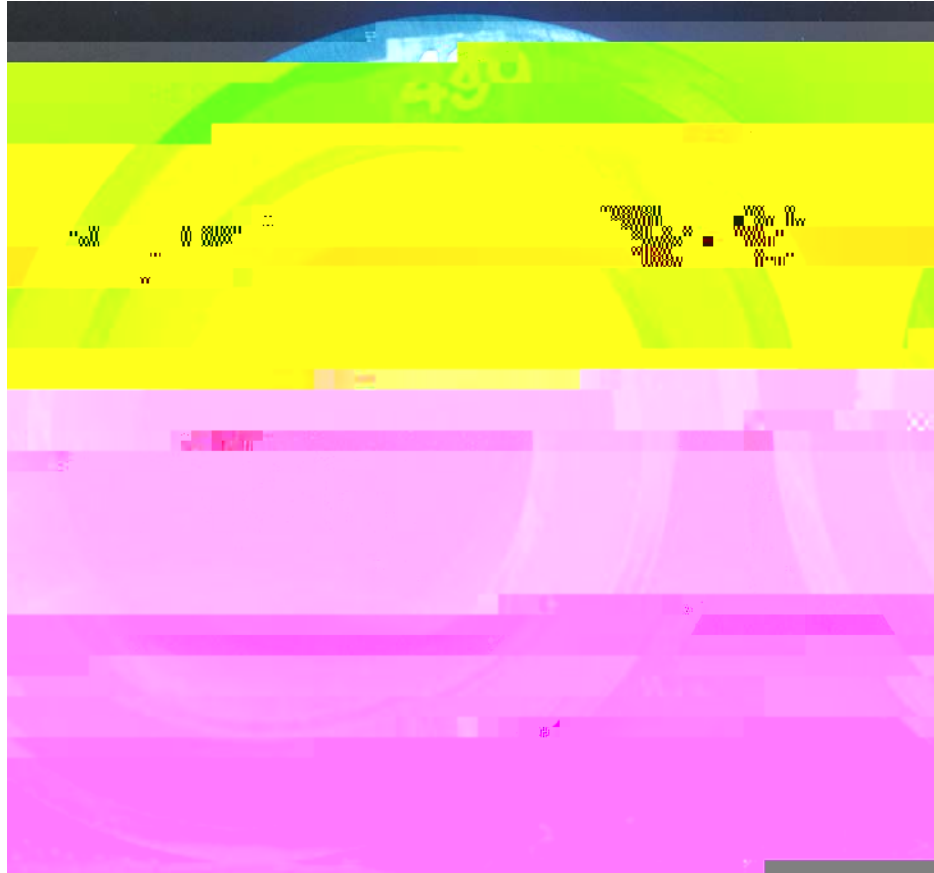
Casing Cementing Parameters

“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



Well-being

Well-being



Modes of Annular Sealant Failure

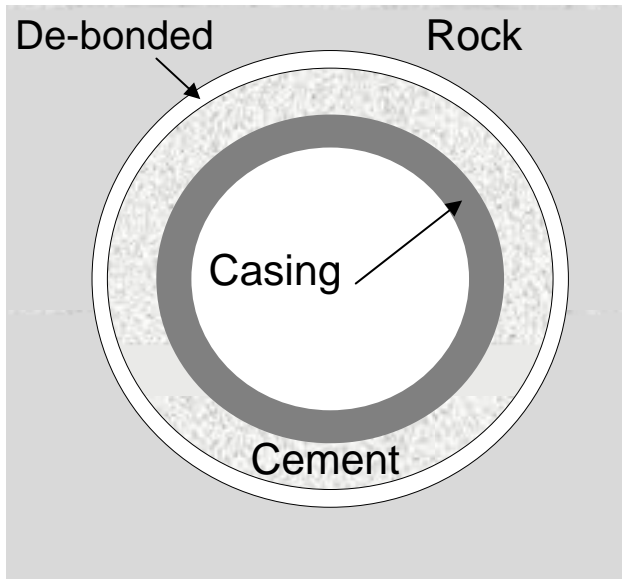
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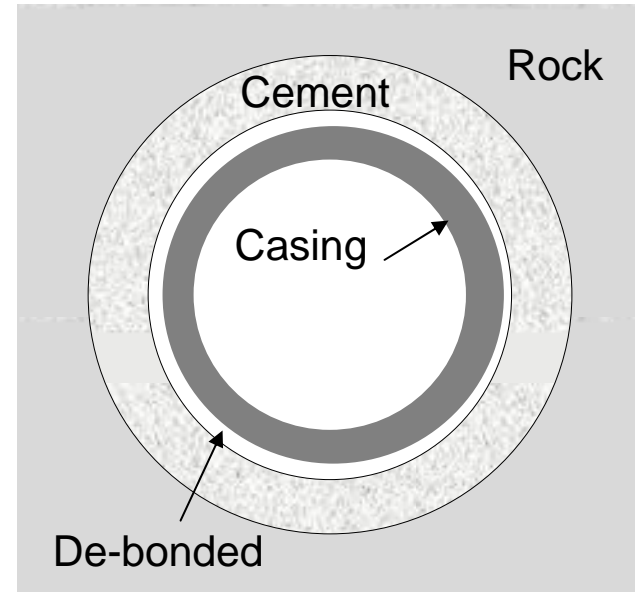
Modes of Cement Failure

- De-bonding

@ rock-cement interface



@ cement-casing interface



Reservoir Life Cycle

