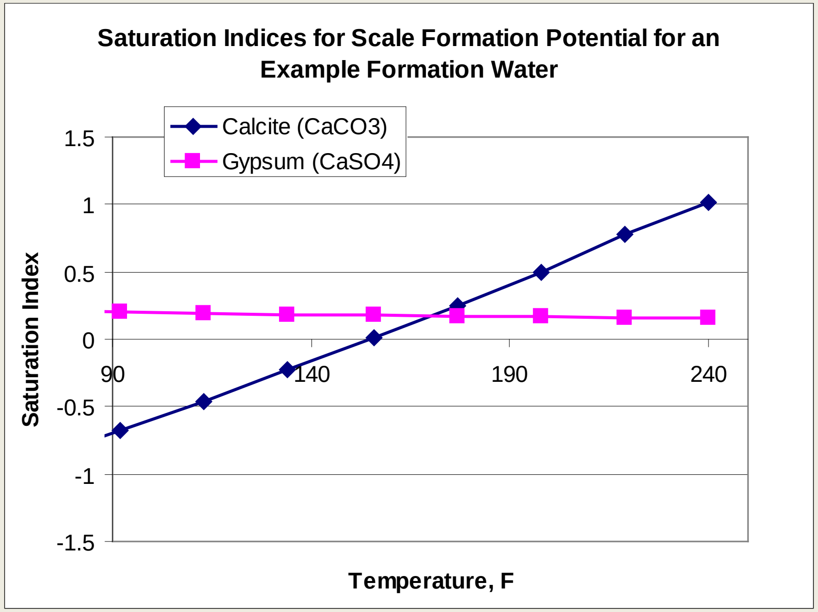
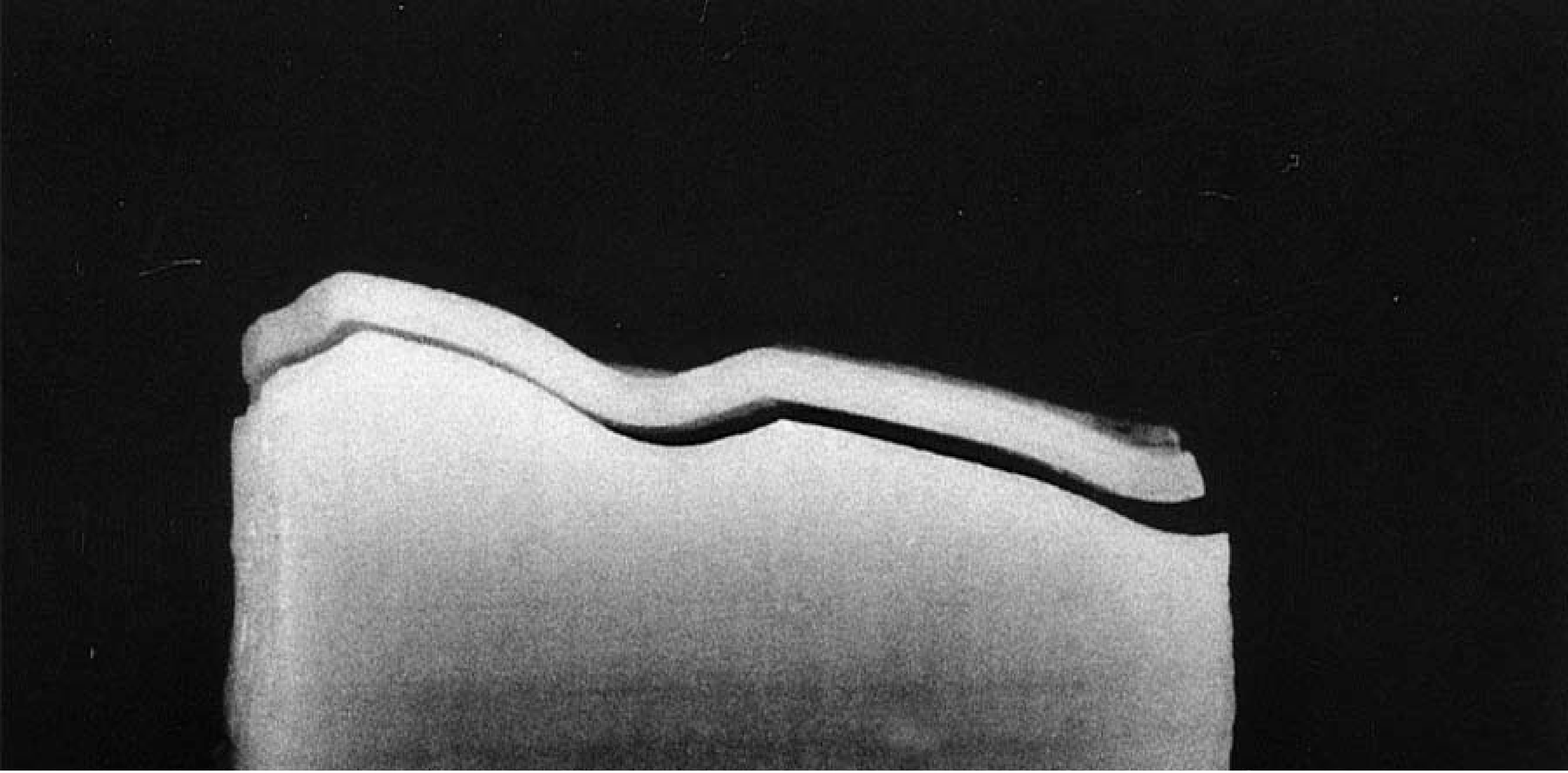
Scales

- Usually a precipitate from a brine that becomes saturated with a material due to a change in the flowing fluid conditions within a well.
- Scale precipitation may be driven by mixing incompatible waters, but can also be caused by out-gassing, shear, turbulence, and temperature and pressure loss – upsets in the flowing equilibrium.

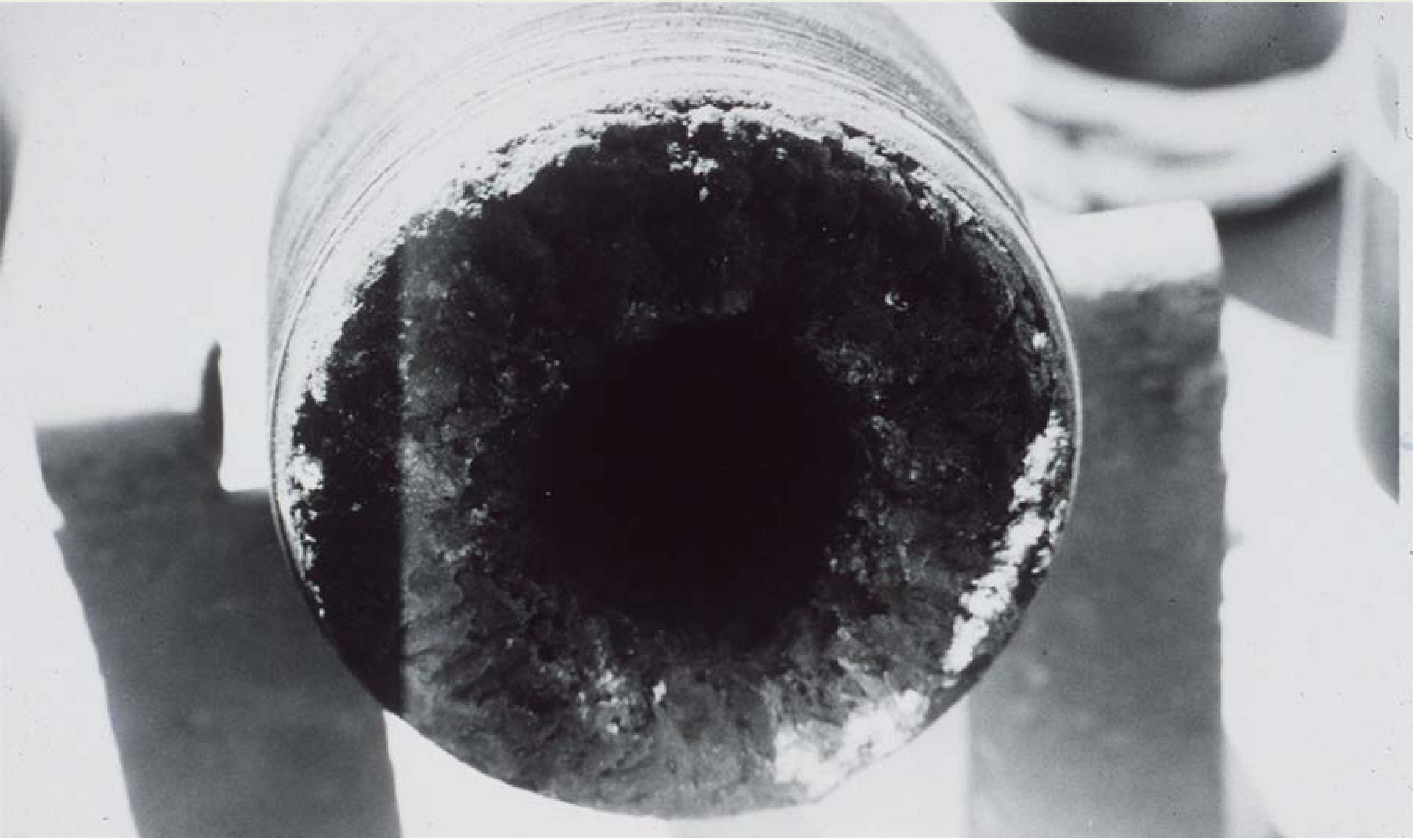
Scales

- calcium carbonate - upset driven
- calcium sulfate - mixing waters, upset, CO_2
- barium sulfate - mixing waters, upset
- iron scales - corrosion, H_2S, low pH, O_2
- rarer scales - heavy brines





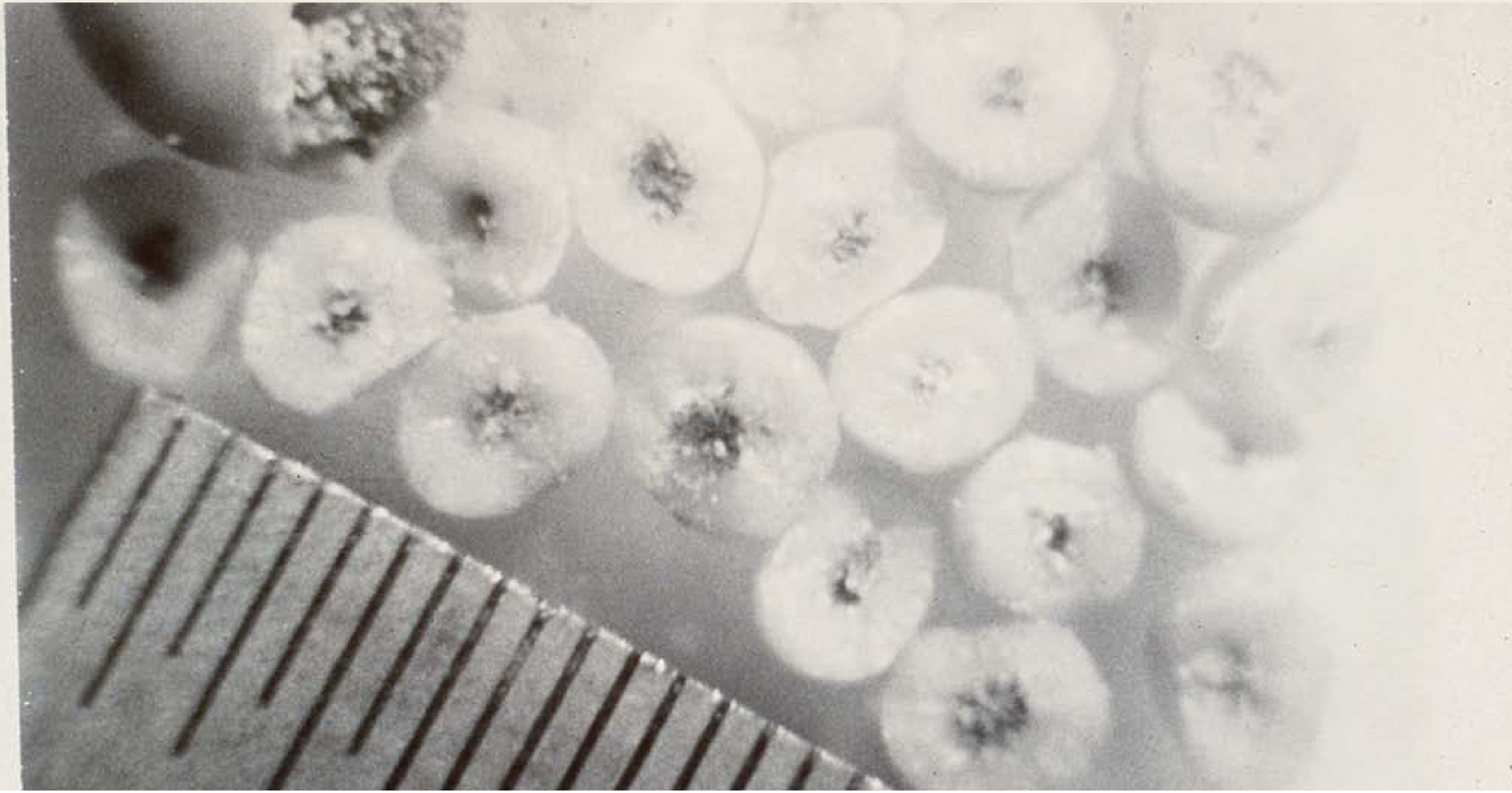
Some scales form in layers, often driven by an "upset" in the flow dynamics of the system. These deposits can form almost anywhere, on any surface, but the deposits are usually just downstream of the location of an upset in the flow system. The location of the scale is often an indicator of what is causing the precipitation.



Calcium sulfate scale from slow growth in a high water cut reservoir.

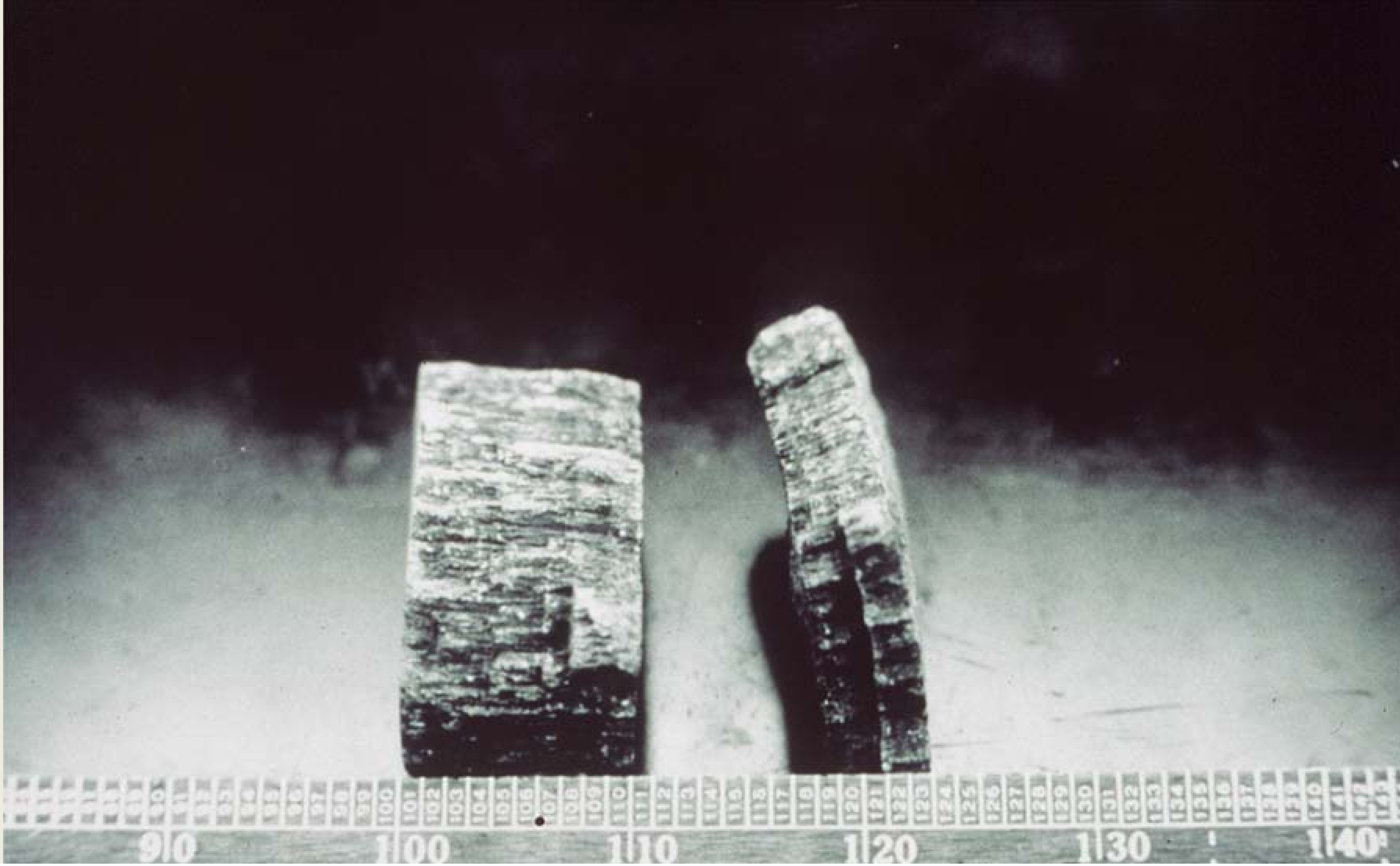
A rapidly formed deposit of calcium sulfate formed after an acid was mixed with a scale dissolver chemical that had removed a deposit of calcium sulfate scale at the perforations.

Calcium Sulfate scale that completely blocked a section of downhole tubing – this piece was from a connection.



A very unusual form of calcium carbonate scale – small pellets – 1/8” or 3 mm of carbonate scale formed around a grain of sand. Bailed from an East Texas well with natural flow (strong water drive) and significant rolling water in the bottom. When the pellets got so heavy they could not be supported, they sank. Oil Well Pearls?

Calcium sulfate crystals removed from a flow line in West Texas.



Barium Sulfate deposition from topsides piping on a North Sea platform in the early 1990's. The scale was not radioactive, but was nearly pure $BaSO_4$. There was almost no reaction in several days in a test with the best EDTA and DPTA Barium dissolvers.

NORM Scales

- NORM is Naturally Occurring Radioactive Material
- Scales which form concentrates of various naturally occurring radionuclides (NOR’s), present in almost all of the earth’s crust.
- NOR’s present in water, gas, sludge and scale.

What’s Radioactive?

- Uranium series ^{238}U and ^{226}Ra
- Thorium series, ^{232}Th
- Potassium ^{40}K

- And their gamma-ray emitting products.

Scale Location

- at pressure drops - perfs, profiles
- water mixing points - leaks, flood breakthru
- outgassing points - hydrostatic sensitive
- shear points - pumps, perfs, chokes,
- gravel pack - formation interface

Why Does Scale Form?

- **Sulphates:**

  $Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$

  FW SW

  - **Mixing of Incompatible waters (e.g. Formation and Sea water)**
  - **e.g. when Sea water breaks through in a production well already containing Formation water**
  - **e.g. When injecting Sea water into a Reservoir water Leg, or in the presence of Connate or Formation water**

Temperature and Pressure

- Carbonate is **Less Soluble** with increasing temperature and **Reducing Pressure**
- Sulphates tend to be more soluble with increasing temperature and pressure (**less of an effect**)
- These are general rules, but there are exceptions...each scale needs to be evaluated under prevailing conditions
- Increasing salinity tends to increase solubility of both

Scale Prediction

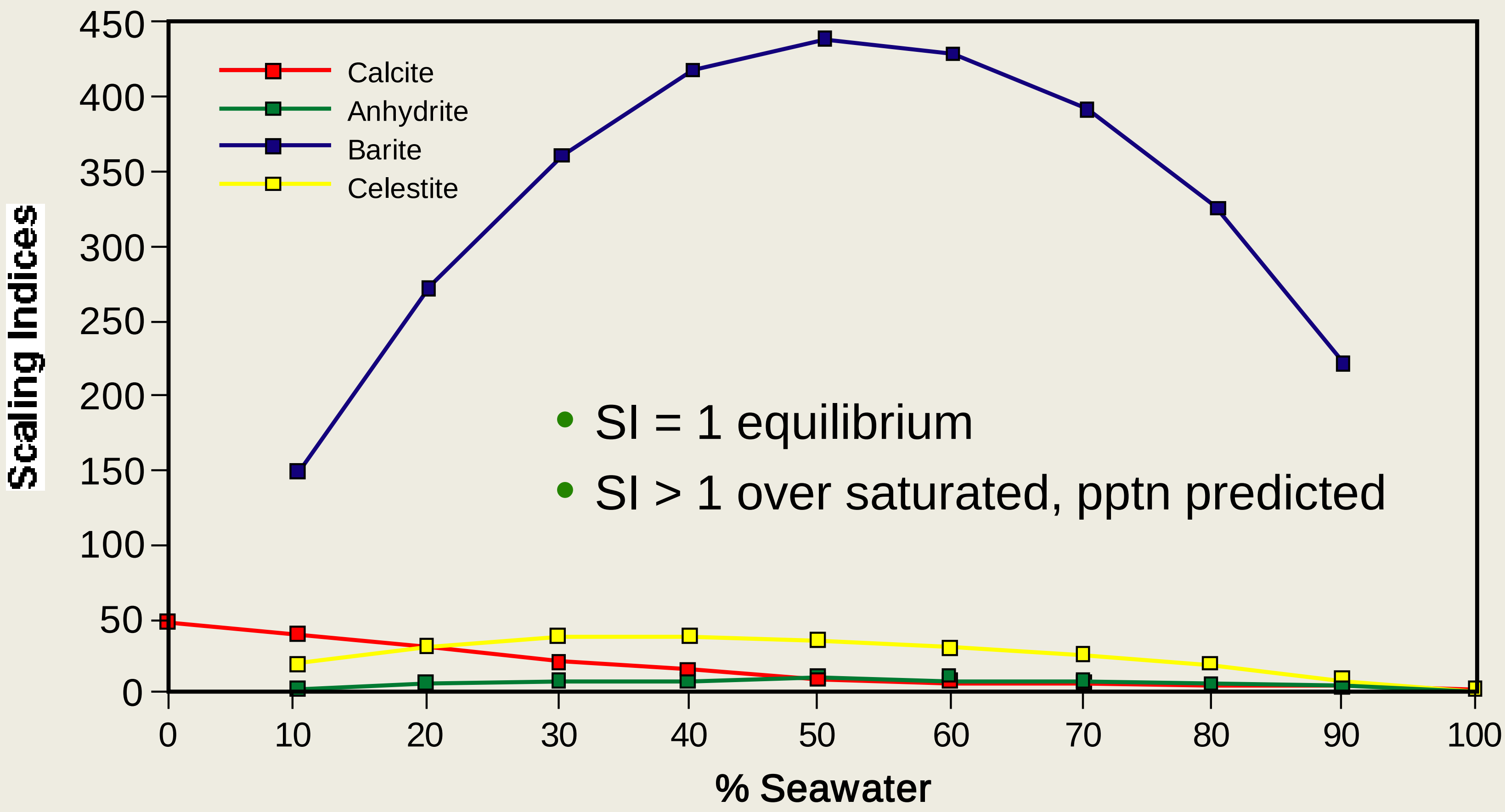
- Chemical models - require water analysis and well conditions
- Predictions are usually a “worst case” - this is where the “upset” factor comes in.
  - added shear - increased drawdown, choke changes, etc.
  - acidizing
  - venting pressure

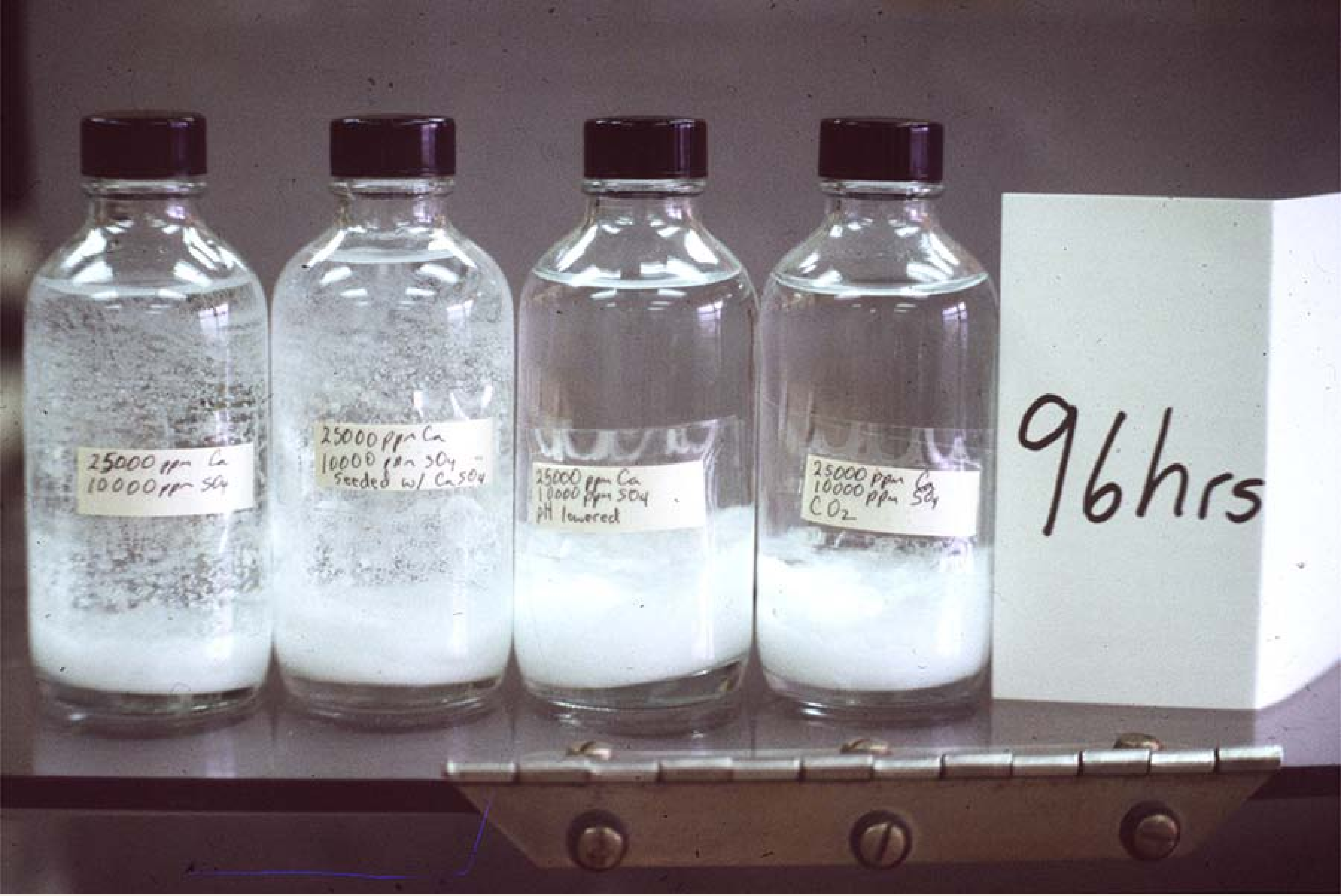
Water Composition

Concentration (ppm)

Ion	Sea Water	Forties	Miller	Gyda	Prudhoe Bay
Na	10890	29370	28780	65340	8000
K	460	372	1830	5640	83
Mg	1368	504	115	2325	84
Ca	428	2808	1060	30185	180
Sr	8	574	110	1085	24
Ba	0	252	1050	485	4
Cl	19700	52360	47680	167400	11500
SO_4	2960	0	0	0	10
HCO_3	124	496	2090	76	2222

Example of North Sea Scaling Indices for Formation / Sea Water Mixture





Calcium sulfate growth rates for various stimulation methods (upsets).

How do we Control Scale?

- **Inhibition**
  - Downhole
  - Subsea
  - Topsides
- **Stop mixing of incompatible waters**
  - PWRI Vs SWI (Harding)
  - Use De-Sulphated sea water (Marathon)
  - Train segregation (Bruce, ETAP)
- **Remedial Action**
  - Chemical Dissolution
  - Mechanical Removal

How Do They Work?

- **Crystal Modifiers**
  - These chemicals are believed to work predominantly by retarding crystal growth.
  - Promote the formation of small crystals, which act as nucleation sites, yet prevent them from becoming large enough to precipitate from solution
  - The initial nucleation reduces the supersaturation of the solution quickly
  - The large molecules attach to active crystal growth planes and block growth in one particular direction

How Do They Work

- **Threshold Inhibitors**
  - These chemicals inhibit predominantly by preventing crystal nucleation
  - They stop the ions from aggregating together and in effect delay scale formation

Inhibitor Deployment
Above the Packer

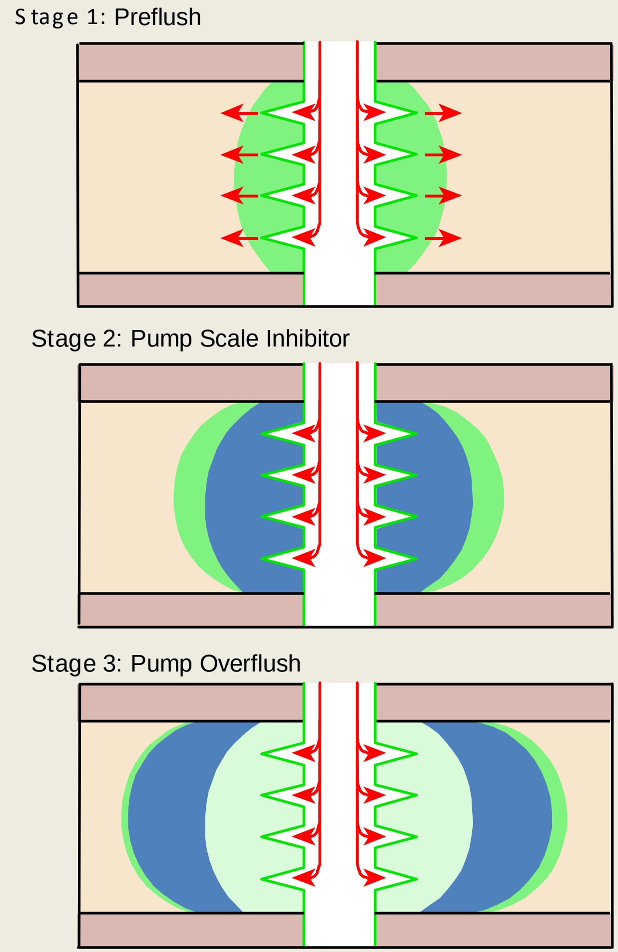
- **Continuous Injection via Chemical Injection Control Line (Macaroni string)**
  – Well integrity (leak path)
  – Increases well completion running times (rig costs?)
  – Blockage issue
- **Continuous Injection via Gas Lift**
  – Atomisation and Gunking issue
  – Orifice to Packer Volume

Inhibitor Deployment
Below the Packer

- Matrix squeezes with scale inhibitor
  - Adsorption and Absorption
  - Precipitation squeezes
- Impregnated proppant (short lived)
- Continuous Inhibition from capillary
- Inhibitor placement in the rat hole

Scale Inhibitor Squeeze Treatments

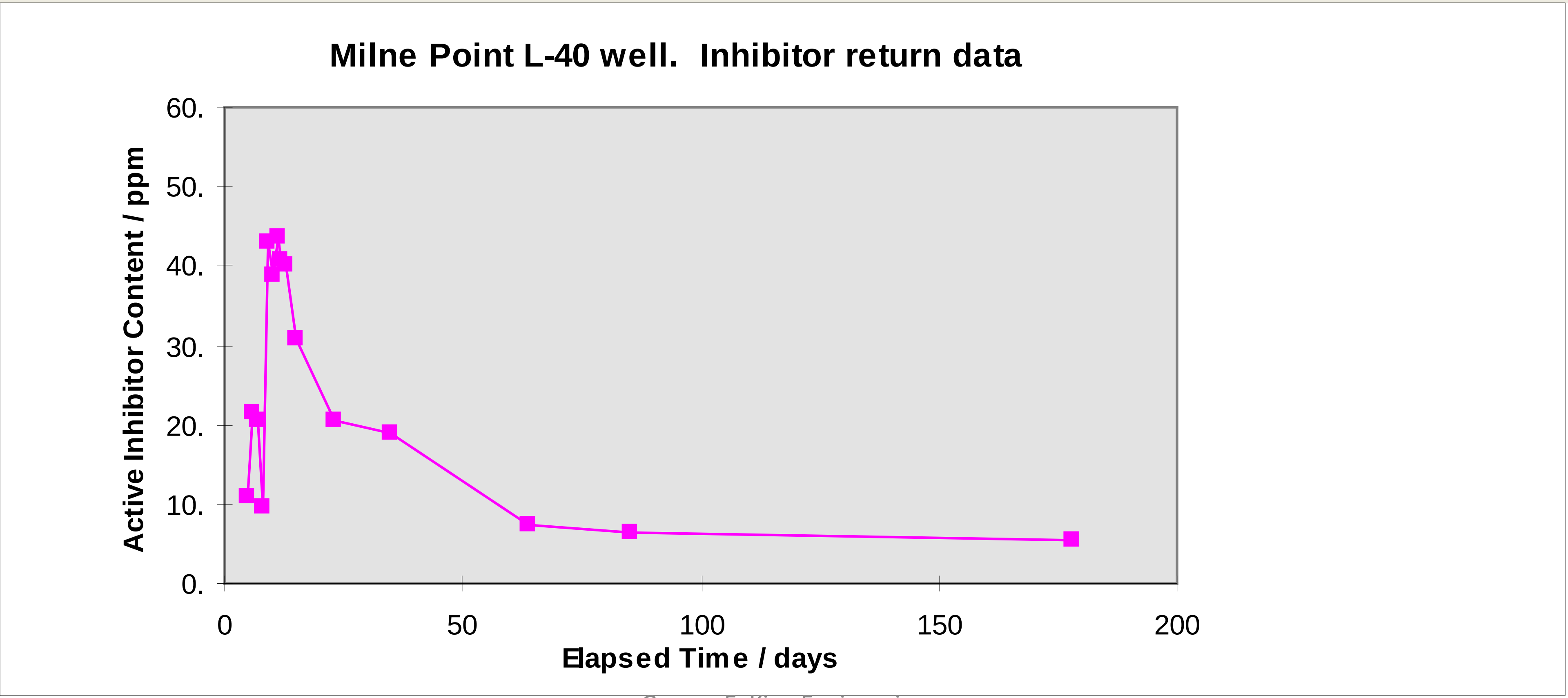
- **Bull heading**
  - Chemicals pumped directly down well (rate 3-30 bpm)
- **Pre-flush flush**
  - typical vol. 50bbls
  - maximize contact with rock and minimizes near well bore damage
- **Main treatment**
  - typical vol. 50 – 500 bbls of actual chemical required for inhibition, mixed in compatible fluid.
- **Overflush**
  - typical vol. 50 to over 1000bbls
  - ensures deeper placement of chemicals



Stage 4: Shut in
Stage 5: Return the well to production - inhibitor is slowly released into the well.

Inhibitors can be squeezed into the formation, returning slowly. There is a “threshold” level of inhibitor needed to prevent scale in a specific well system. When the inhibitor level falls below the threshold, scale can form.

Optimizing inhibitor squeeze design can change the useful inhibitor life from a few weeks to 12 to 18 months.



Scale Removal

- Calcium Carbonate - HCl, EDTA
- Calcium Sulfate - EDTA and converters
- Barium Sulfate mixtures - PDTA and EDTA
- Pure Barium Sulfate - mechanical
- Thick deposits of any sulfate scale - mechanical removal

Scale Removal

- **Chemical Dissolution – Scale Dissolvers**
    - Carbonates
        - Mineral Acids (e.g. HCl, Acetic Acid) and EDTA and DPTA
    - Calcium Sulfate
        - Chelants (e.g. EDTA and DPTA based) and Converters (strong bases)
    - Barium Sulfate – treat only scale mixtures, too slow on pure $BaSO_4$ under pressure.

- **Mechanical Removal**
    - Milling with carefully selected mills – also watch the hydraulics.
    - Under-reaming under restrictions (under-reamers are slower than mills).
        - Multiple trips in tapered diameter completion string
        - Problems with nipple profiles
    - Jetting with Solid Beads (e.g. abrasives) – tubing damage potential is moderate to high.
    - Shock (e.g. String Shot) – 1 to a maximum of 4 strands of 90 grain RDX.

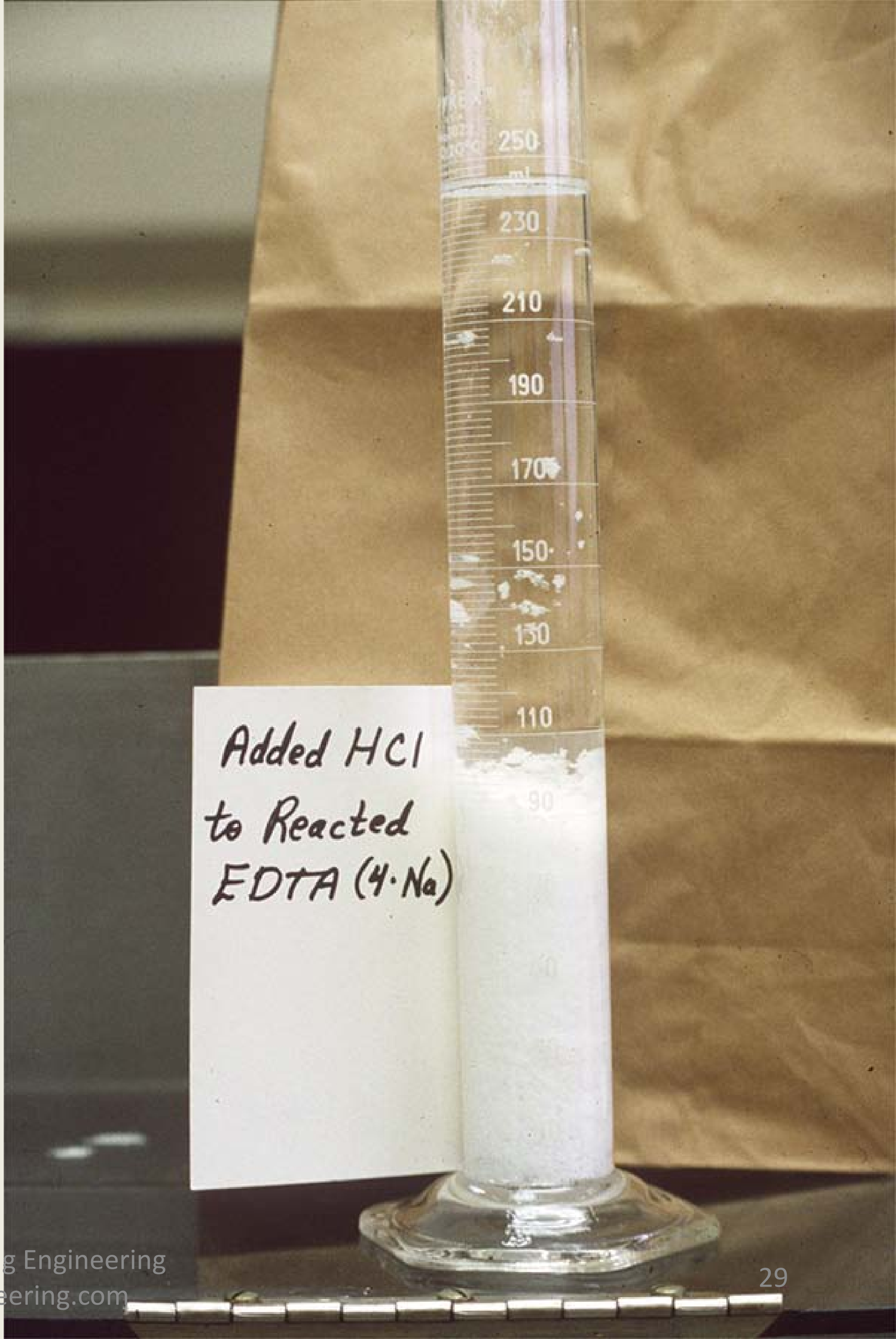
Scales

- calcium carbonate - upset driven
- calcium sulfate - mixing waters, upset, CO_2
- barium sulfate - mixing waters, upset
- iron scales - corrosion, H_2S, low pH, O_2
- rarer scales - heavy brines create zinc and other metal sulfides.

Problems with over-running the dissolver or converter with acid – the resulting reaction can re-precipitate everything!

Calcium sulfate scale precipitated from a scale dissolver solution of EDTA when treated with 15% HCl..

Most dissolvers and converters cannot hold the by-products in solution as pH drops.



Sale – Know Why.

- Scales precipitate due to fluid mixing, upsets in flowing conditions, cooling, heating, corrosion, acidizing and other factors. Understand why.
- Is it easier to prevent the scale or remove it once it has formed? It depends on the individual well conditions, e.g., access, cost, impact, etc.