

Scale and corrosion inhibition in the Netherlands and France

Hans van ‘t Spijker, Pierre Ungemach

Geofluid

1. Corrosion and scaling issues

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4. Scaling and corrosion issues in the NL

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Corrosion and scaling issues

- General (uniform) corrosion
- Pitting corrosion
- Crevice corrosion
- Underdeposit corrosion
- Galvanic c)orrosion
- Impingement
- Stress corrosion cracking (SCC)
- Erosion
- Corrosion by microbacteria

	Average Corrosion Rate		Maximum Pitting Rate (See Paragraph 2.5)	
	mm/y[A]	mpy[B]	mm/y	mpy
Low	<0.025	<1.0	<0.13	<5.0
Moderate	0.025-0.12	1.0-4.9	0.13-0.20	5.0-7.9
High	0.13-0.25	5.0-10	0.21-0.38	8.0-15
Severe	>0.25	>10	>0.38	>15

[A] mm/y = millimeters per year
[B] mpy = mils per year

Corrosion and scaling issues

Precipitation (deposition of solids)

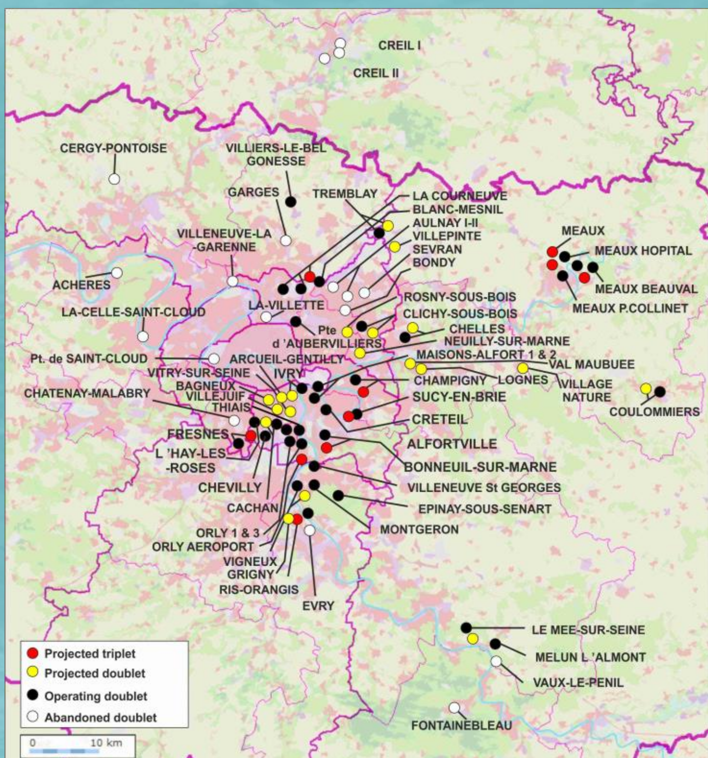
Earth Energy (Geothermal Heat Pumps)	
Component	Examples
Calcium carbonate	•Various sites
Iron oxides	•Various sites
Low and medium-enthalpy fluids	
Component	Examples
Calcium carbonate	•Oradea and Ciumeghia (Romania), Balcova (Turkey), Saidene (Tunisia) N. Kessani and Nigrita (Greece),
Iron oxides	•Nigrita (Greece)
Iron sulphide salts [in association with corrosion]	•Dogger Basin (France)
High- enthalpy fluids	
Component	Examples
Calcium carbonate	•Kizildere (Turkey),Miravalles (Costarika), Latera (Italy), Cerro Prieto (Mexico), East Mesa, Nevada (USA), Krafla (Iceland)
Silica (and metal-silicates) [usually associated with small or medium TDS]	•Svartsengi and Nesjavellir (Iceland), Dixie Valley (USA), Matsukawa, Otake and Onuma (Japan), Berlin (El Salvador)
•Heavy metal sulphide salts (with silica and metal-silicates) [associated with high TDS]	•Salton Sea (USA), Milos Island (Greece), Asal Wells (Djibouti)
•Oxides (and sulphide salts)	•Reykjanes (Iceland)

Corrosion and scaling issues

	Salton Sea, California	Broadlands 1, N. Zealand	Hot Springs, Utah	Kilauea, Hawaii	Krafla, Iceland	Kizildere (W15), Turkey	Klamath Falls, Oregon	Dogger, Paris Basin, France	Nigrita, Greece	Pijnacker, The Netherlands
pH	5.7	8.3	-	7.1	7.2	8.0	8.4	6.2	6.8	5.9
Temp.,°C	214	270	260	190	220	138	80	73	59	80
TDS (g/L)	182	3.8	7.4	15.8	1.0	2.4	0.7	15	2.5	101
Na	42700	1060	2320	4930	193	1192	205	3700	529	38150
K	6500	150	461	756	20	135	4.3	60	89	230
Ca	18200	5	8	358	1.5	1.9	26	630	160	4900
Mg	570	0	2	0.3	0.03	0.2	0.5	150	105	860
Fe	180	0.2	1	0	0.02	0	0.3	0.5	1.1	39
Pb	59	-	-	0	0	-		-	-	<1
Cl	112000	1700	3860	8970	26	46	51	7980	162	69850
SO_4^{2-}	6	40	72	24	194	631	330	775	130	13
HCO_3^-	220	300	232	18	328	-	35	335	2200	
As	22	5	4	0.1	-	-	-	-	0.5	
B	480	7	-	4.3	-	24	-	5	4.6	30
SiO_2	1150	600	563	750	383	356	48	14	38	12

Scaling and corrosion in Paris basin

Urban heating since the 1980s

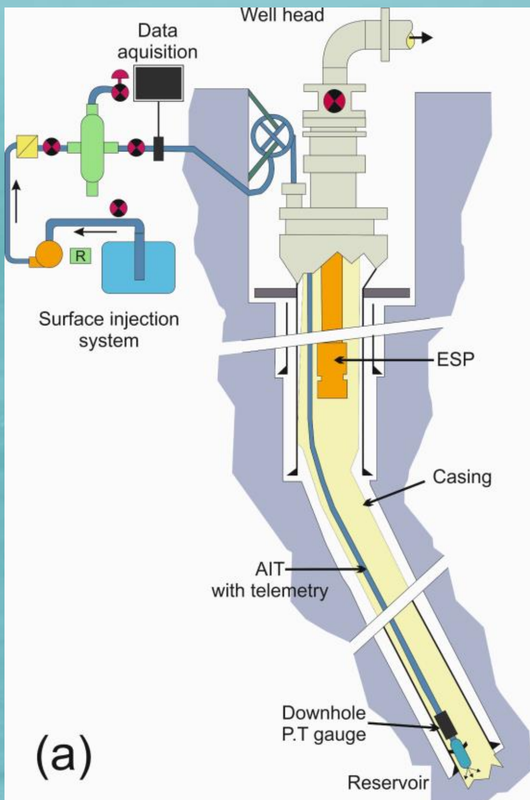


Scaling and corrosion in Paris basin

Conditions	Corrosion issues	Scaling issues
TDS ~ 15 g/l	Harsh (sour) conditions → Film forming amines injected	Mostly Pyrite (FeS_2) formation due to enhanced [Fe] concentration by corrosion
[Fe] =0.5 mg/l	Sulphide reducing bacteria → biocide injection	
CO_2 and H_2S → Sour		
T = 65-90 ºC		
Bubble point ~3-10 bar		

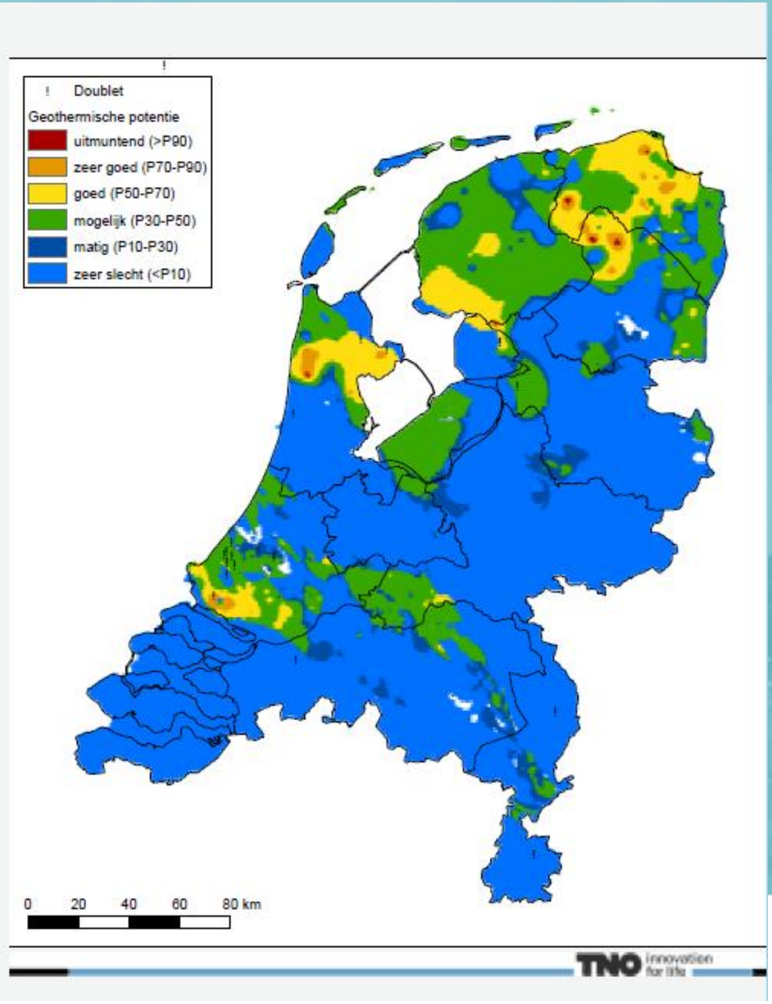
Corrosion causes [Fe] increase, and thus results in pyrite scale formation
→ Corrosion control is of utmost important

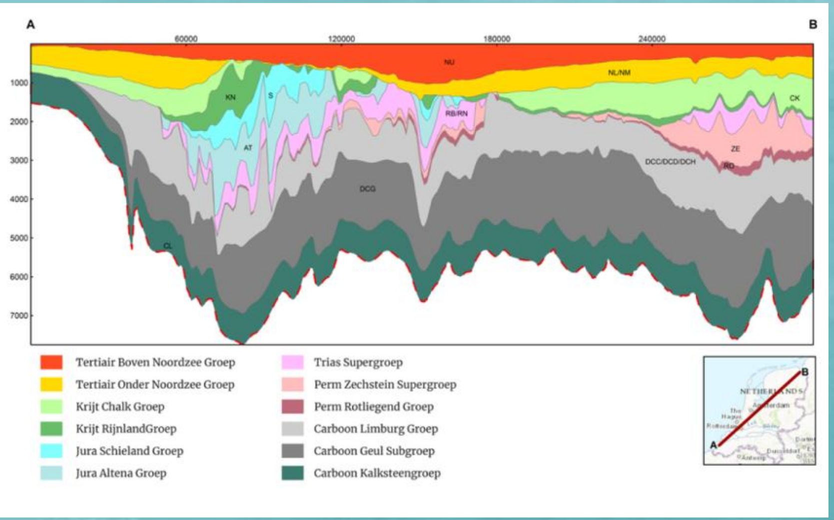
Scaling and corrosion in Paris basin

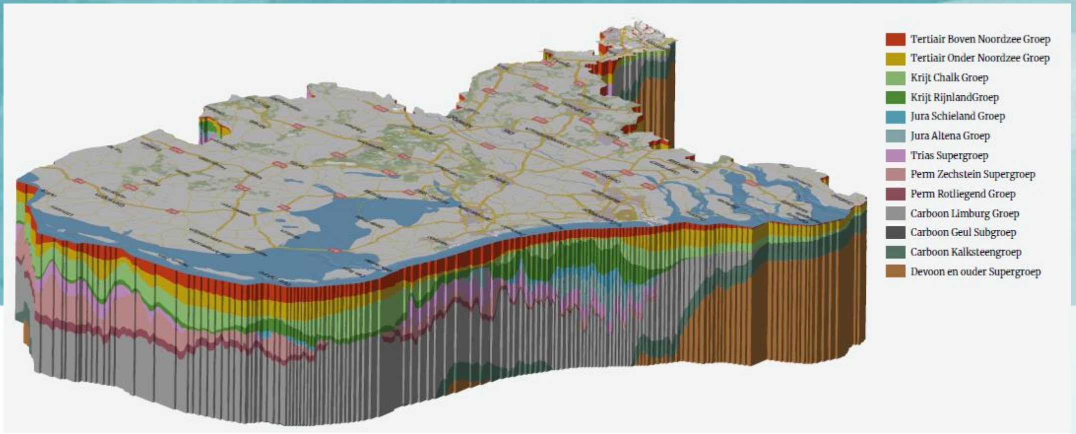


AIT line (propriety GPC)

Scaling and corrosion in Netherlands







Scaling and corrosion in Netherlands

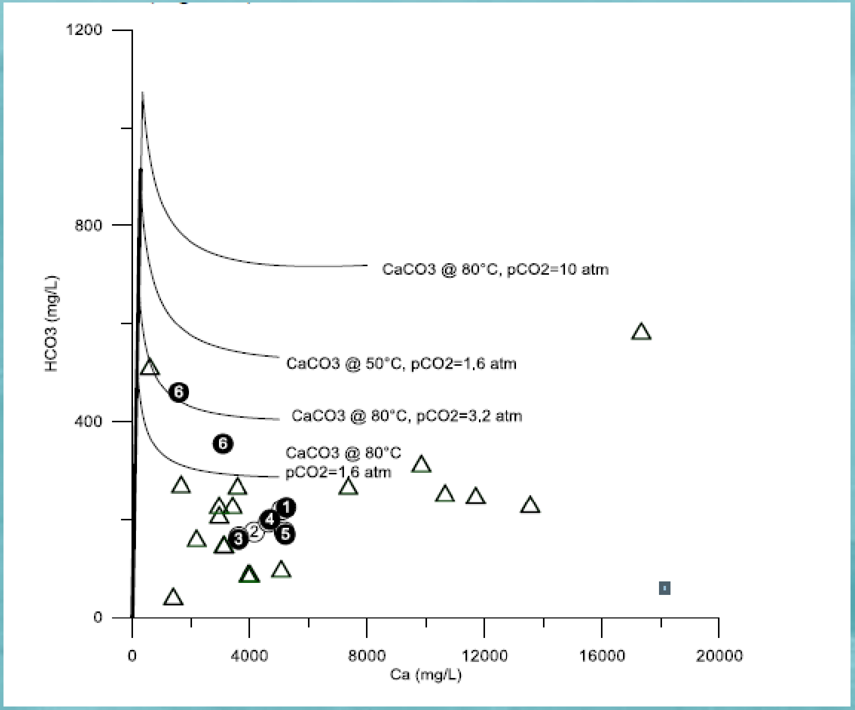
So far, geothermal energy is mostly developed by greenhouse owners

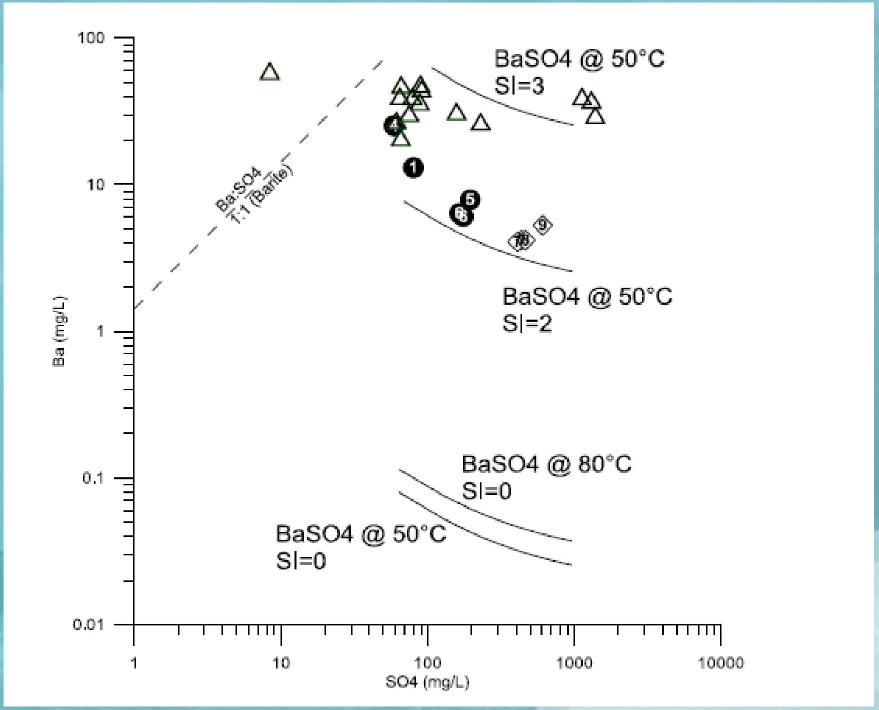
Scaling and corrosion in Netherlands

Conditions	Corrosion issues	Scaling issues
TDS ~110 g/l	Galvanic corrosion in early wells	Mostly calcite and siderite deposition
[Fe] =30 mg/l Traces Pb	Pitting corrosion?	→ increase pressure in surface installation
Gas composition is mainly CH_4, N_2, CO_2	Erosion (cavitation) of couplings	
T = 80-100 ºC	Pb deposition	
Traces of oil, aromatics		
Bubble point ~20-40 bar		

Scaling and corrosion in Netherlands

Scaling and corrosion in Netherlands

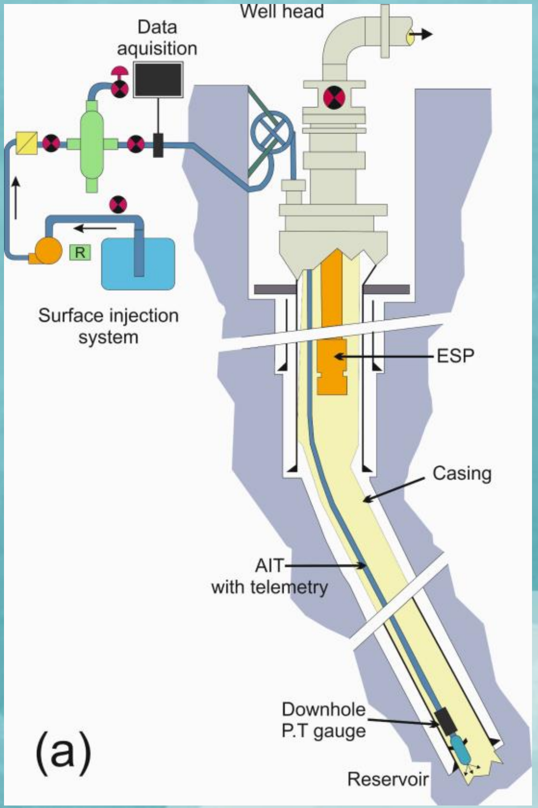




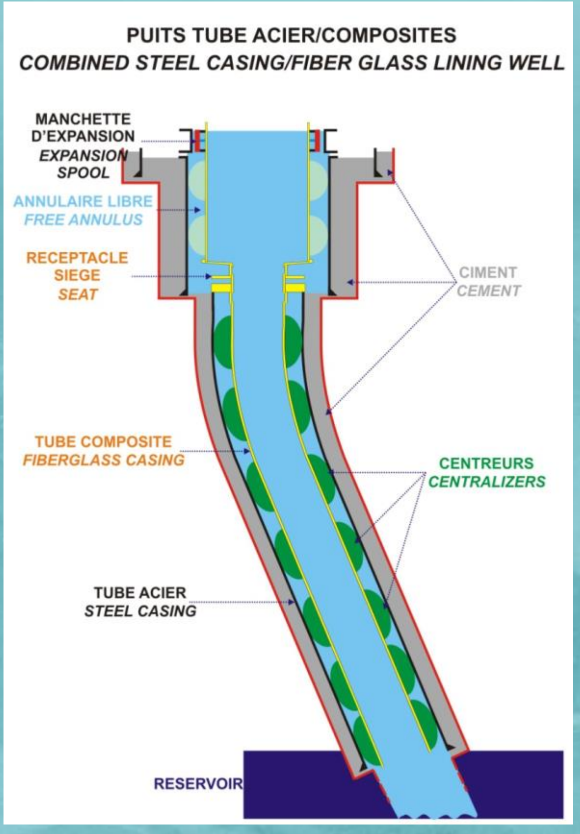
How to mitigate corrosion and scaling

Corrosion mitigation

- Use suitable corrosion inhibitors (filming amines)
    - Test efficiency of products
    - Monitor corrosion rate
- Inject inhibitor downhole
- Option: Use GRE liners
- Option: Use high steel grades



How to mitigate corrosion and scaling



Patent GPC

Installation in Bonneuil

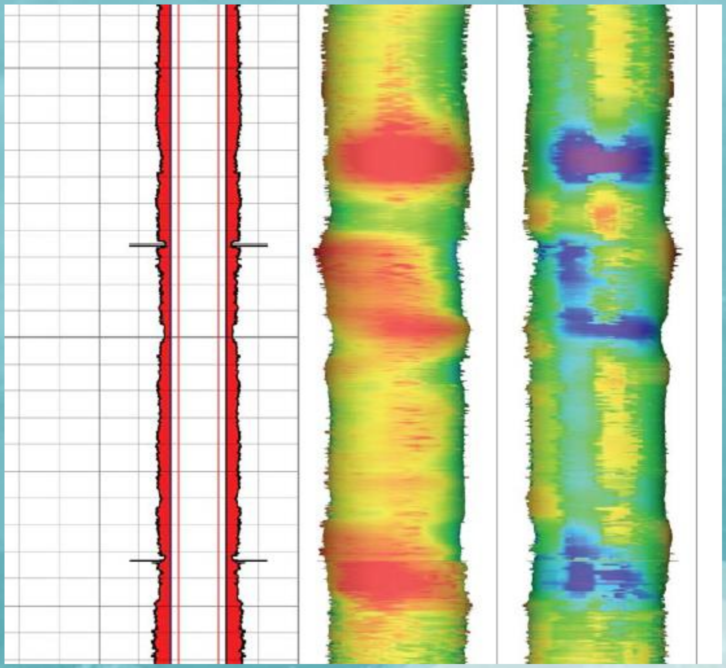
How to mitigate corrosion and scaling

Scaling mitigation

- Estimate scaling risks (e.g PHREEQC)
- Determine minimum injection temperature in injection well
- Prevent CO_2 degassing
- Inject inhibitor product
  - Carbonate scale deposition at depth
  - Most other scales (e.g. sulfate, silicate) at surface before HX

Monitoring

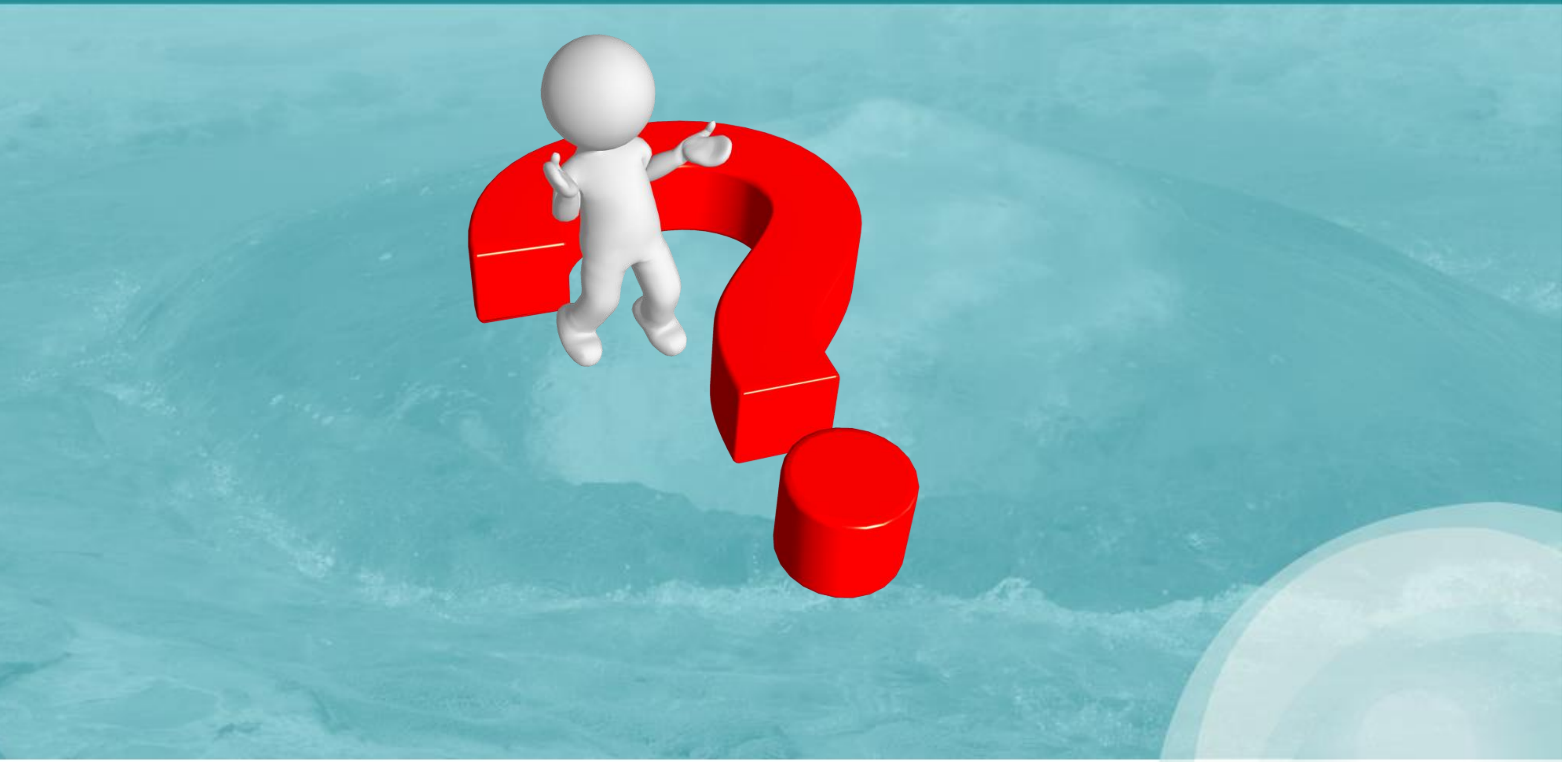
Corrosion Monitoring	Accuracy
Well logging	+++
Coupons analysis	++
Iron content	++
Corrator (LPR)	~
Test kits	++



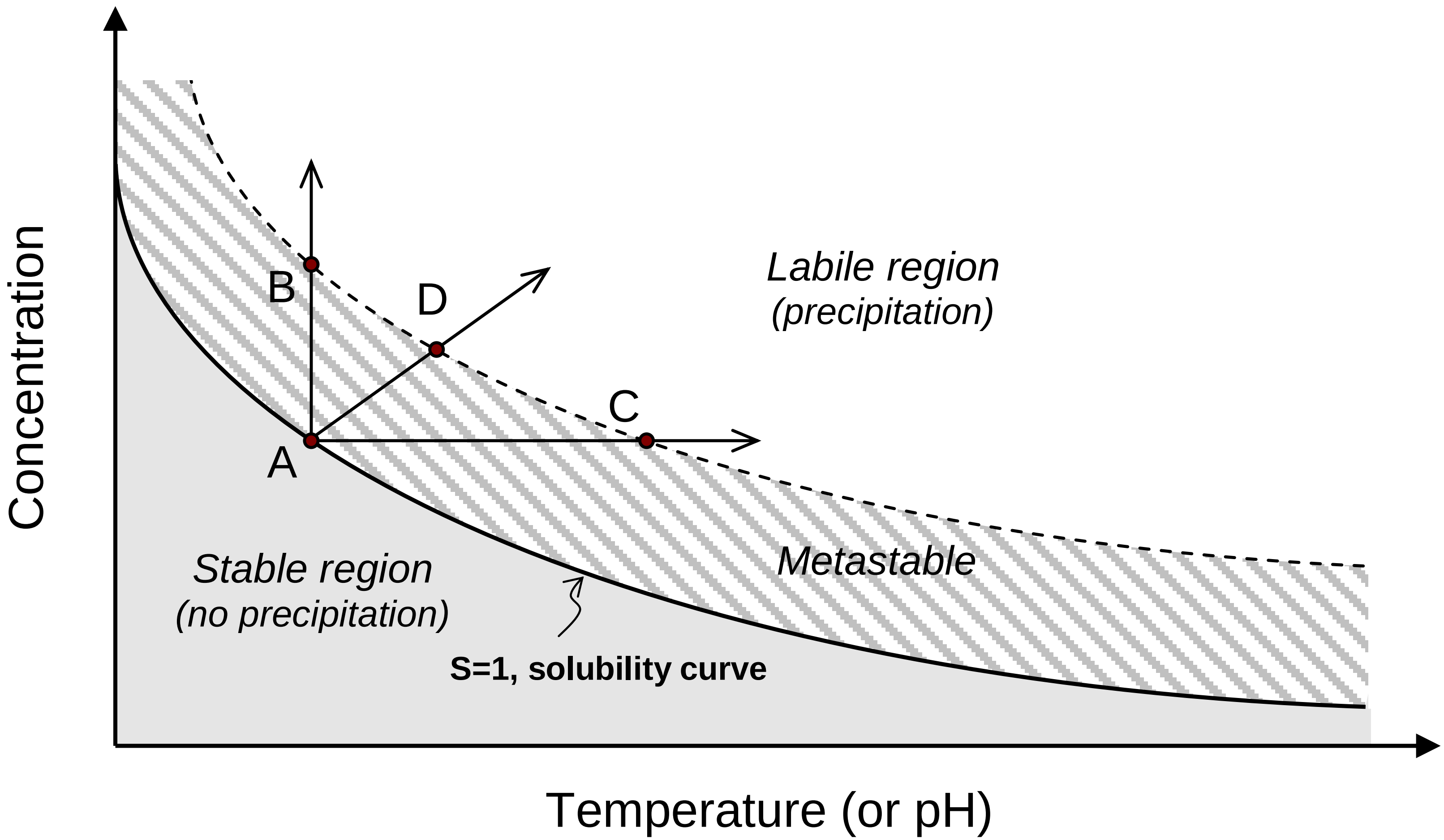
Monitoring

Scale monitoring	Accuracy
Well logging	+++
Coupons analysis	++
Deposit analysis (XRF, XRD, SEM,….)	++
Corrator (LPR)	~
Monitor ionic concentrations	++
Measure chemical parameters (pH, …)	+
Monitor particle concentration	+

GEOFLUID



SCALING SOLUBILITY.
SUPERSATURATION DIAGRAM



$Ca^{2+} + CO_3^{2-} \Leftrightarrow 2CaCO_3$ (solid)

Langelier-Saturation-Index (LSI)

LSI = pH-pHs

pHs = (9.3 + A + B)-(C+D)
where :

A = [log(TDS)-1]/10	TDS in mg/L
B = -13,12 x log θ + 34,55	θ, temperature in K
C = log[Ca 2+]-0,4	Ca^{2+} as mg/L $CaCO_3$
D = log [alkalinity)	alkalinity as mg/L $CaCO_3$