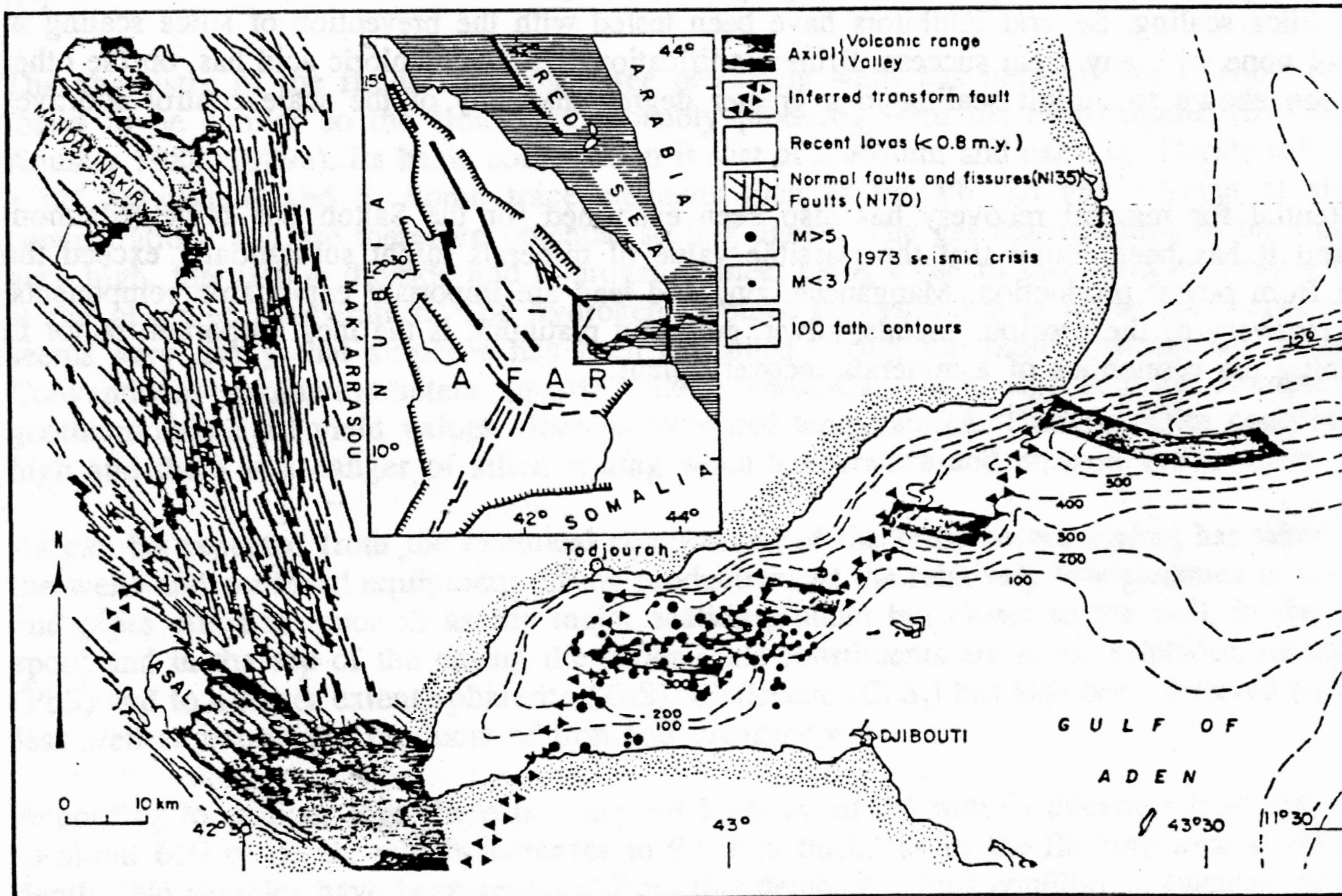
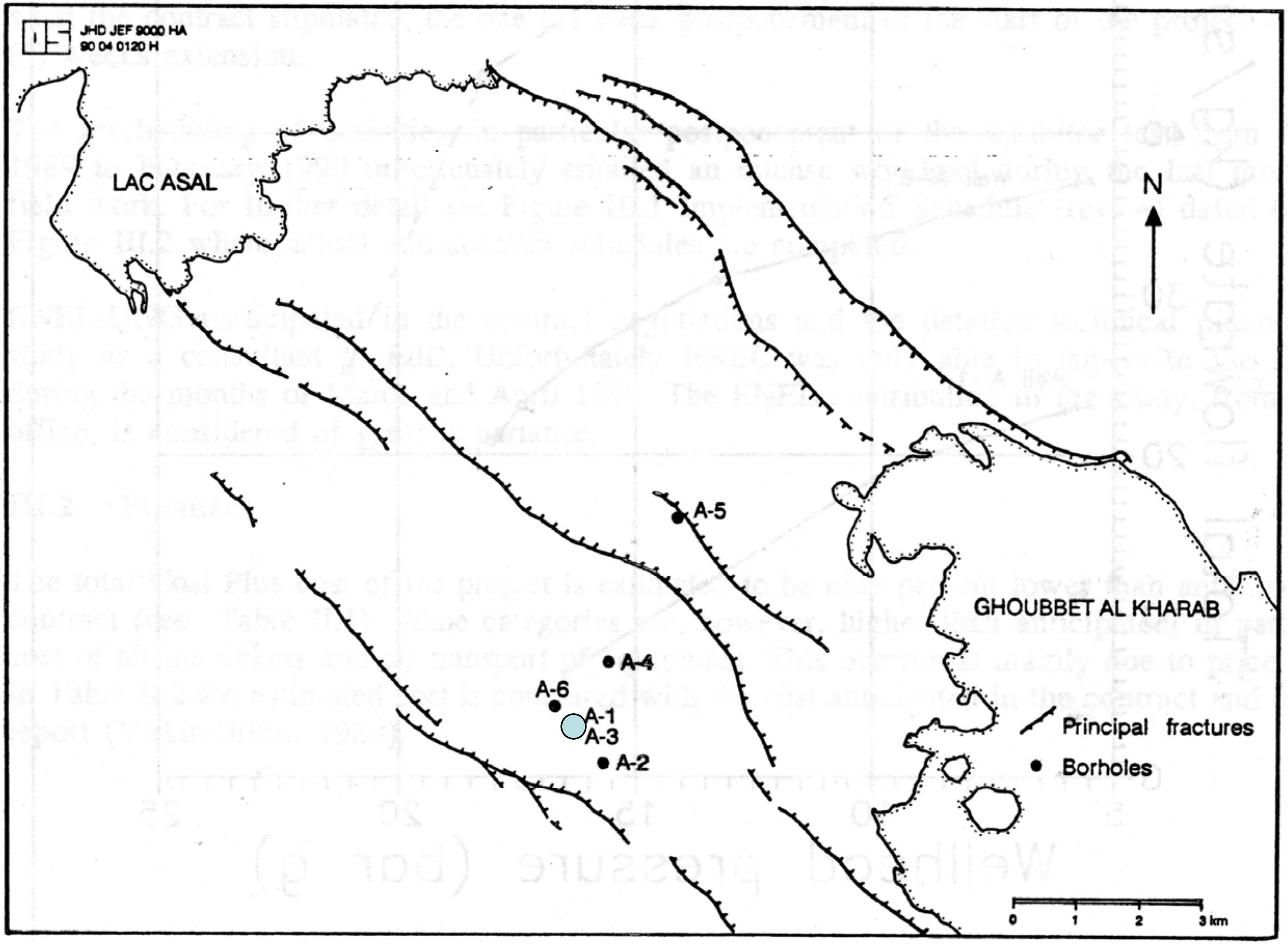
WELL TESTS IN ASAL, DJIBOUTI AND POSSIBLE CONTINUED EXPLORATION

Halldór Ármannsson,
Ómar Sigurðsson,
Matthías Matthíasson and
Knútur Árnason

Area. Gulf of Tadjoura. Axial zones and transformative faults (Courtillot et al. 1974)



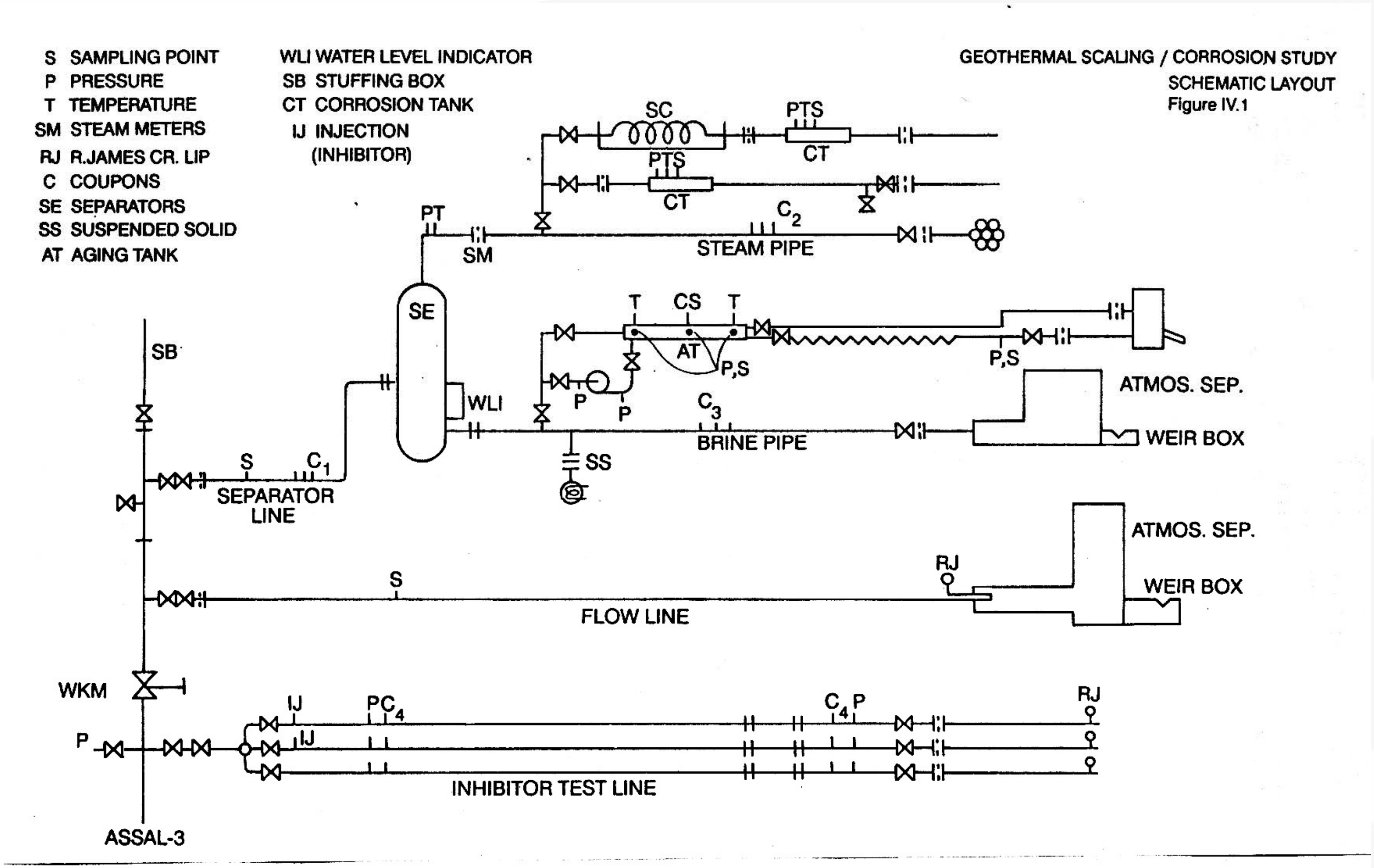
Wells in the Assal area



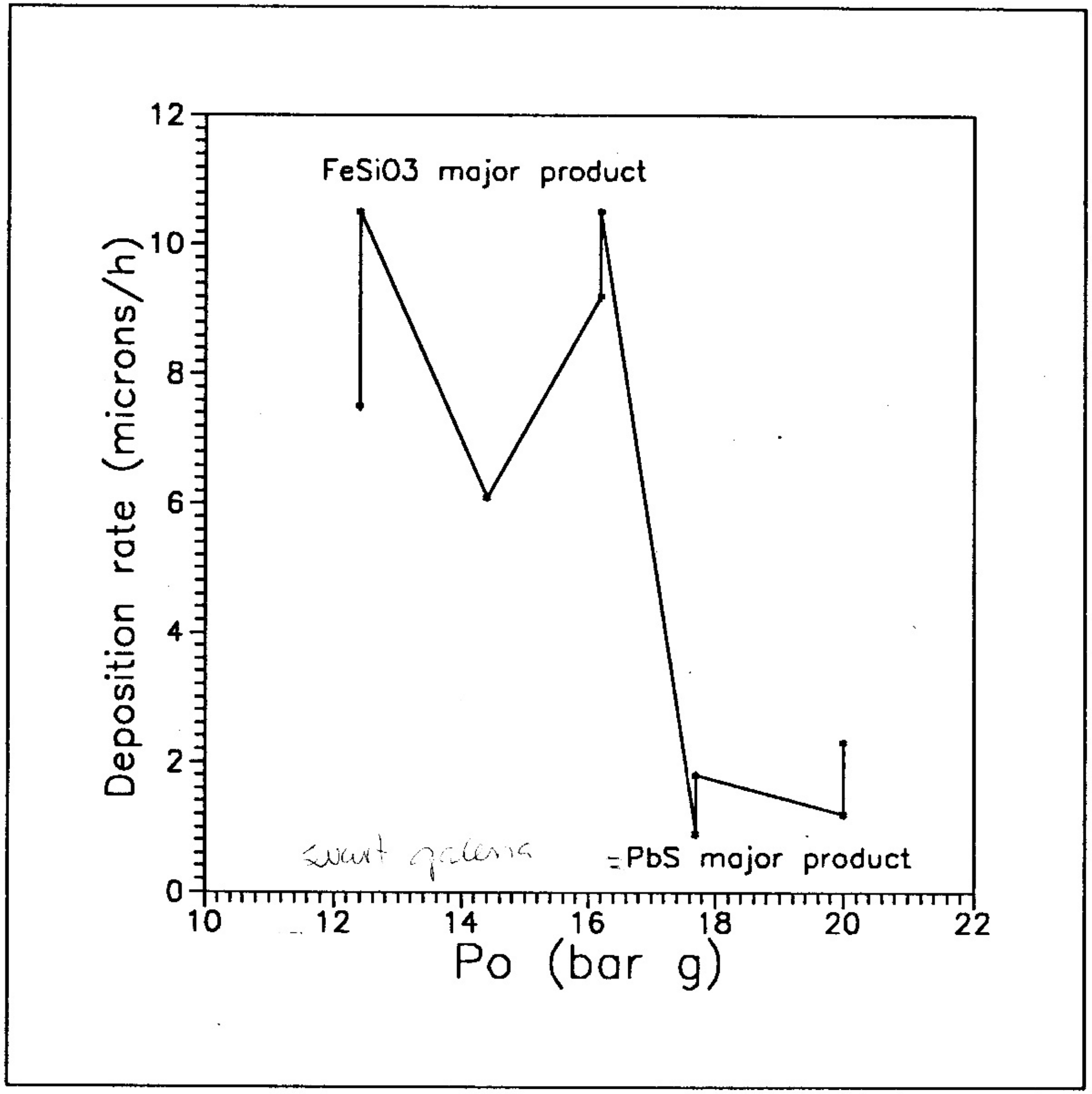
GEOTHERMAL STUDY 1989-1990
Asal 3 flow test

- Enthalpy and flow
- Chemistry of fluid
- Deposition and corrosion
- Reservoir properties
- Conversion systems

Asal-3: Layout of test apparatus

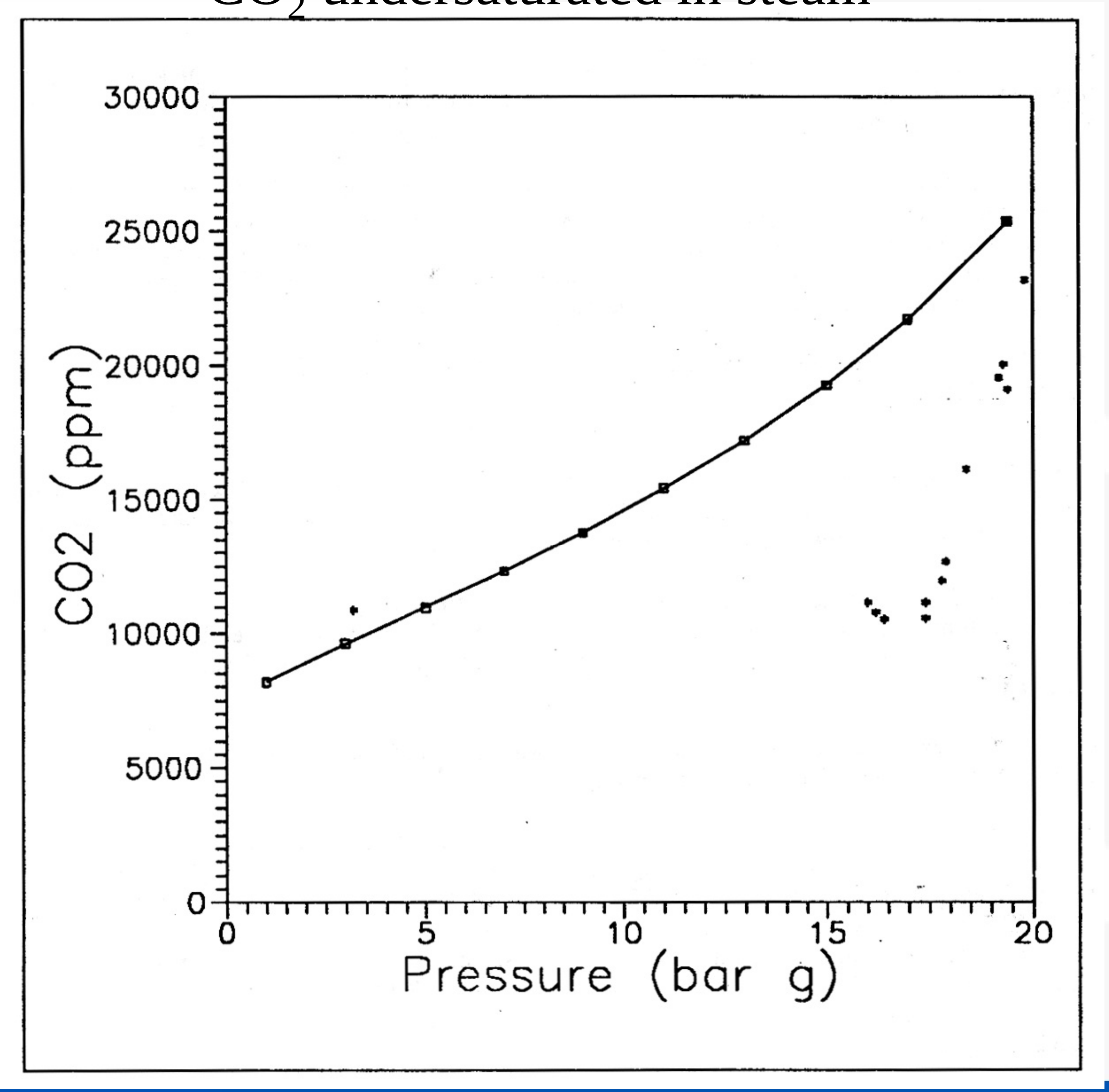


Major deposits: Sulphides (Galena, sphalerite, chalcopyrite); iron silicates <18 bar g)



Djibouti: Deposition at different pressures

Carbonate found in deposits (CO_2:0.56 -2.17%, probably as siderite). CO_2 undersaturated in steam



NADAR INHIBITORS AGAINST SULPHIDES

Inhibitor	N-4093	N-1008
Description	Brown, viscous liquid. S.G:1.14. Sequestering agent for heavy metals	Amber-yellow liquid. S.G: 1.20. Sequestering agent against Ca, Mg salts & SiO_2
Composition	Aqueous solution of polymers with carbosillic and sulphonic functions	Aqueous solution of carbosillic polymer
Pseudo-scale basic composition	Fe-Si	$CaCl_2$

DOSAGE PUMPS FOR SULPHIDE INHIBITORS

PSEUDO SCALES (iron silicates, calcium chloride)

CORROSION TEST
SOME MATERIALS TESTED

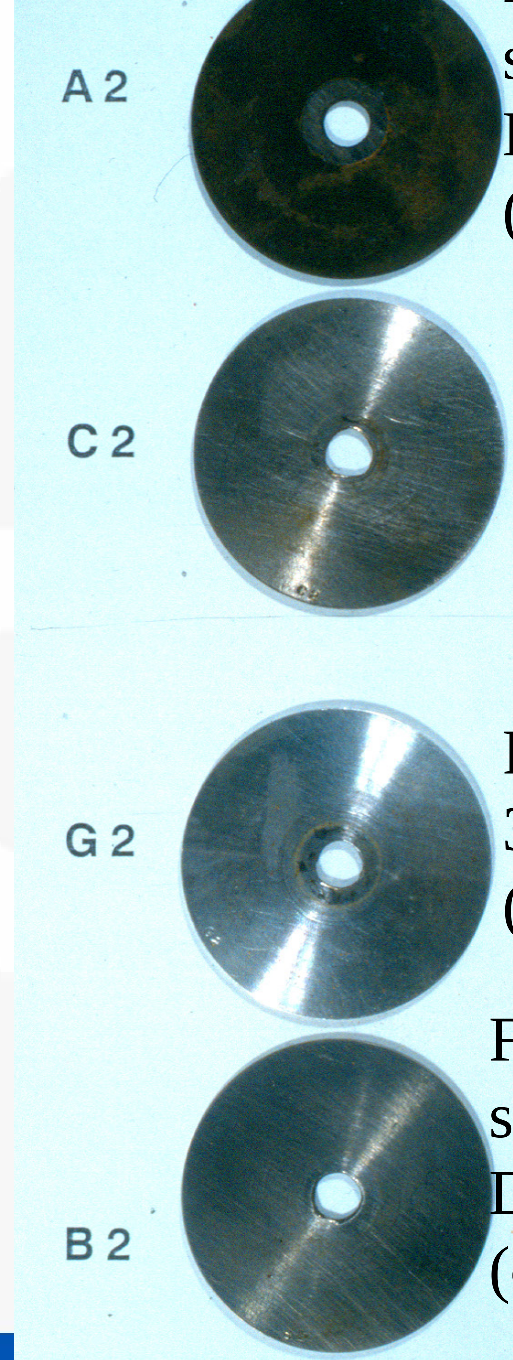
Material	*Typical use*
Stainless steel (304,316,405,2205,904L, 254SMO)	Turbine blade, condenser lining
12CrMo stainless steel, welded and unwelded	Turbine blade
13%CrMo stainless steel	Turbine blade
17-4PH steel, welded and unwelded	Turbine blade
CrMoNiV steel	Turbine shaft
CrMoV steel	Turbine rotor
CrMoNi steel	
Carbon steel	Turbine casing
Mild steel	Pipe, casing
Ti alloy	Condenser lining

Fuji, 13% Cr
stainless steel
DIN X 20 Cr 13
(uncondensed steam)

Virkir-Orkint
CrNiMo steel
30 CrNiMo 8
(DIN 17200)
(uncondensed steam)

Fuji CrMoNiV
steel
DIN 30 CrMoNiV 5 11
(uncondensed steam)

Fuji Stainless steel
405
(uncondensed steam)



Fuji CrMoNiV
steel
DIN 30 CrMoNiV 5 11
(condensed steam)

Fuji Stainless steel
405
(condensed steam)

Fuji Stainless steel
304L
(condensed steam)

Fuji, 13% Cr
stainless steel
DIN X 20 Cr 13
(condensed steam)

CORROSION IN UNCONDENSED STEAM

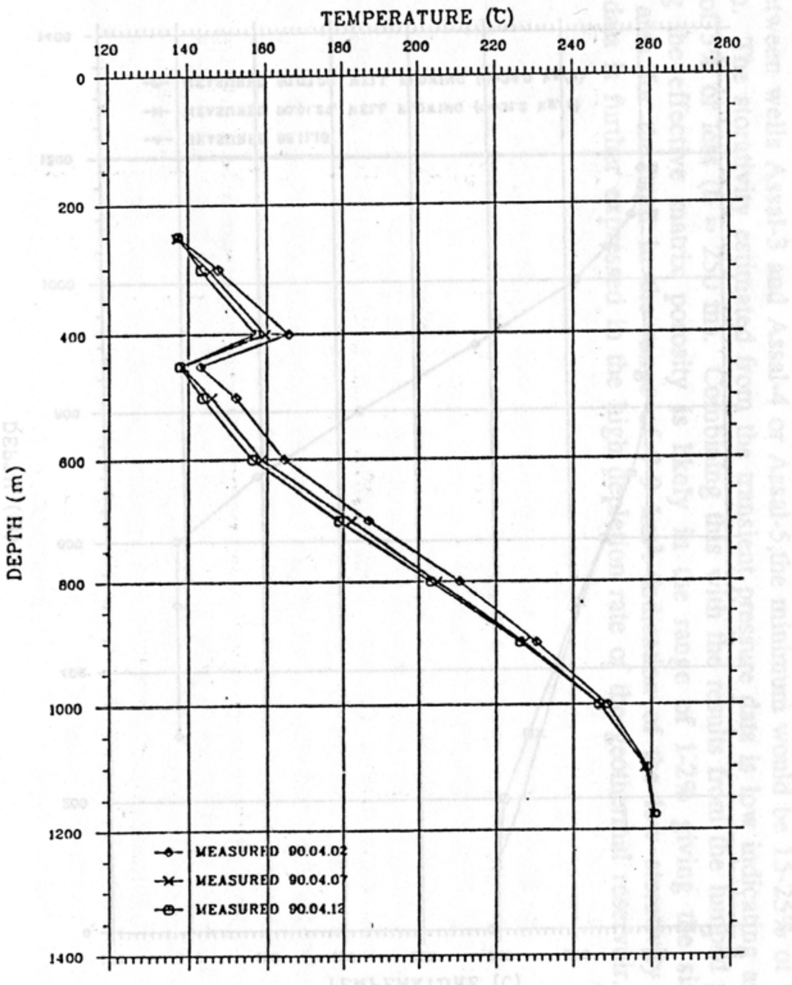
Material	Weight change %	Visual signs	Fe %	Al %	Si %	S %
CrMoV	+0.05	Many small pits	43.0	2.2	43.1	0.9
Ti alloy	+0.31	Uncorroded	22.2	9.5	34.5	0.8
CrNiMo	+0.22	Few small pits	13.3	1.3	81.1	0.7
Mild	+0.43	Small even corrosion	44.5	1.2	39.1	2.3
CrMoV	-0.06	Slight pitting	28.9	0.2	26.2	0.6
CrMoV coated CHEMIFLAKE EV70	-0.44	Cracked coat, base metal corroded				

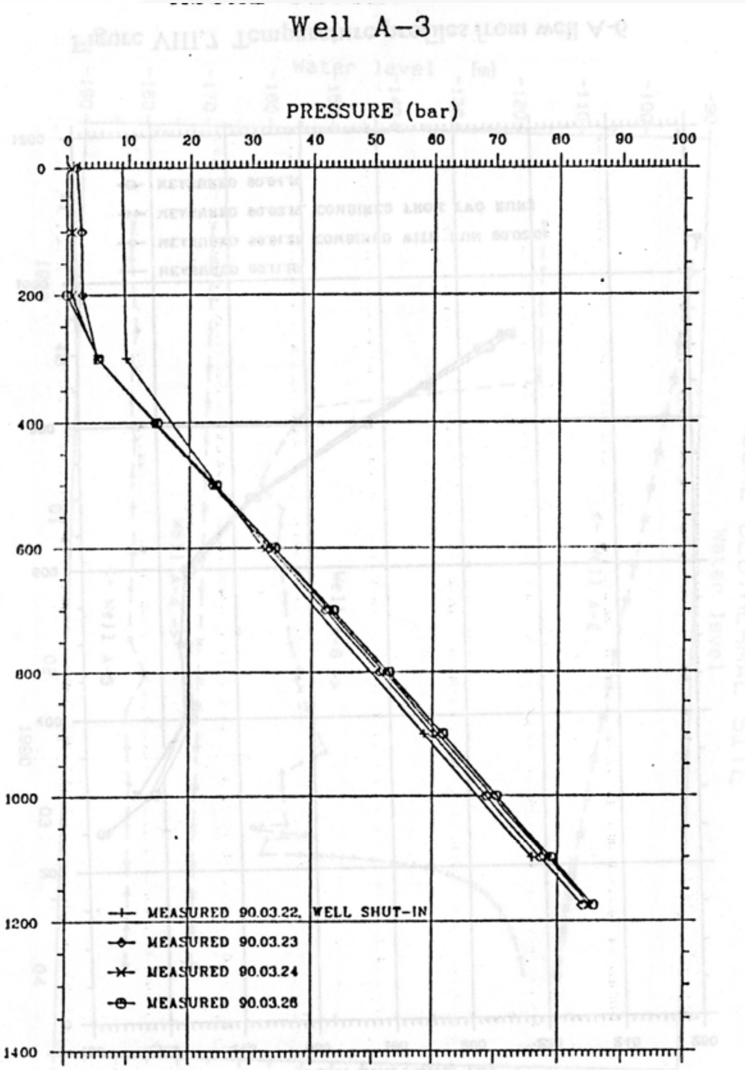
CORROSION IN CONDENSED STEAM

Material	*Weight change %*	*Visual signs*	*Fe %*	*Al %*	*Si %*	*S %*
CrMoV	-4.61	Even corrosion	45.5	0.2	0.1	27.3
St. 405	+0.19	Uncorroded	88.0	0.5	1.5	4.5
Mild	-2.04	Small even corrosion	56.6	7.6	0.2	33.0
CrMoV welded	-2.79	Even with small pitting, pronounced in heat affected zone	61.9	0.1	0.2	36.2

CORROSION RATES IN CONDENSED STEAM

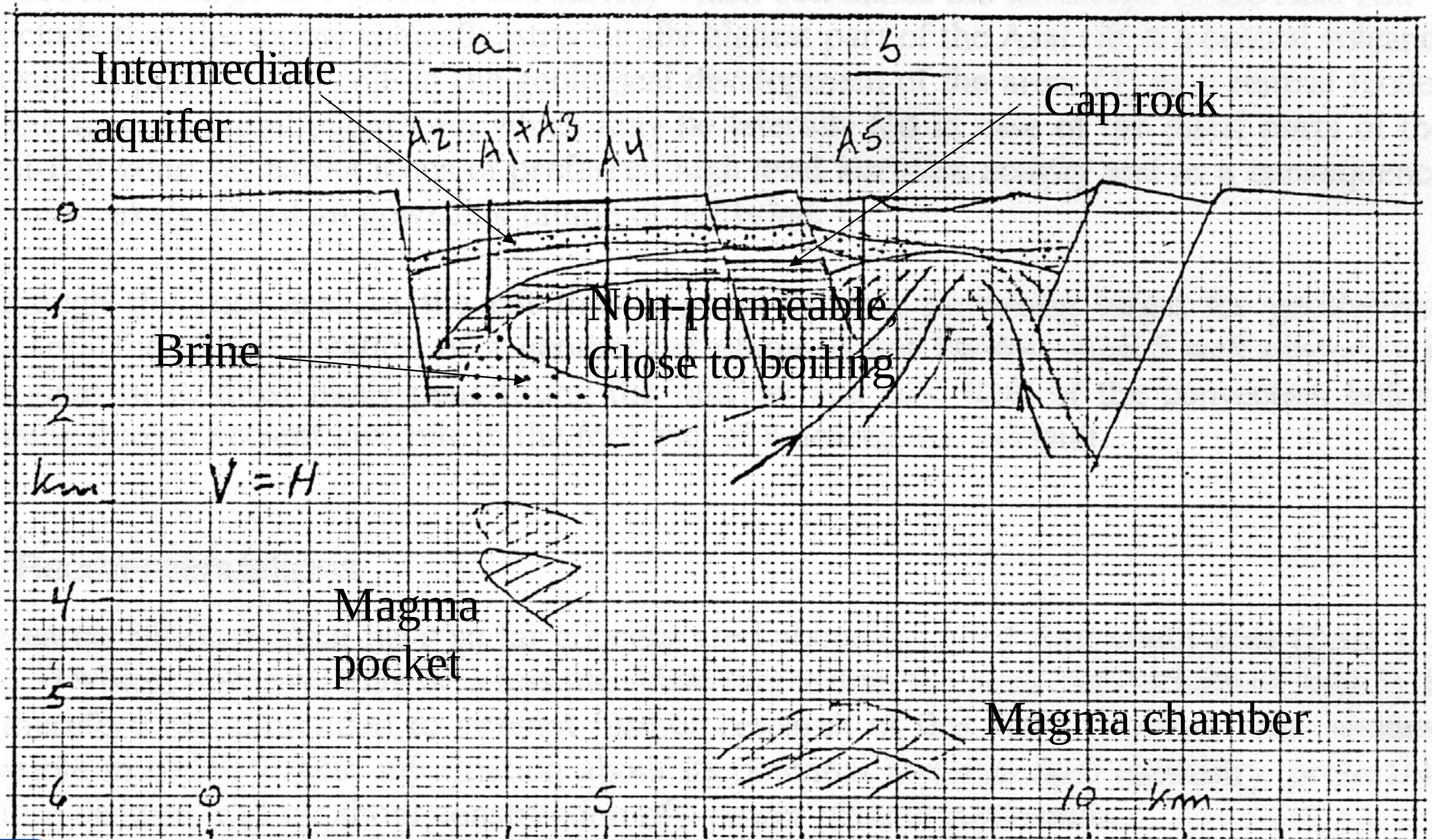
Steel type	*Corrosion rate mm/year*
DIN CrMoNiV 5 11	0.28
Carbon steel JIS SS41 (Fuji)	0.28
Mild steel (No. 37)	0.29
30 CrNiMo 8	0.22
CrMoV 10325MGB	0.34
Carbon steel JIS SS41 (MHI)	0.15

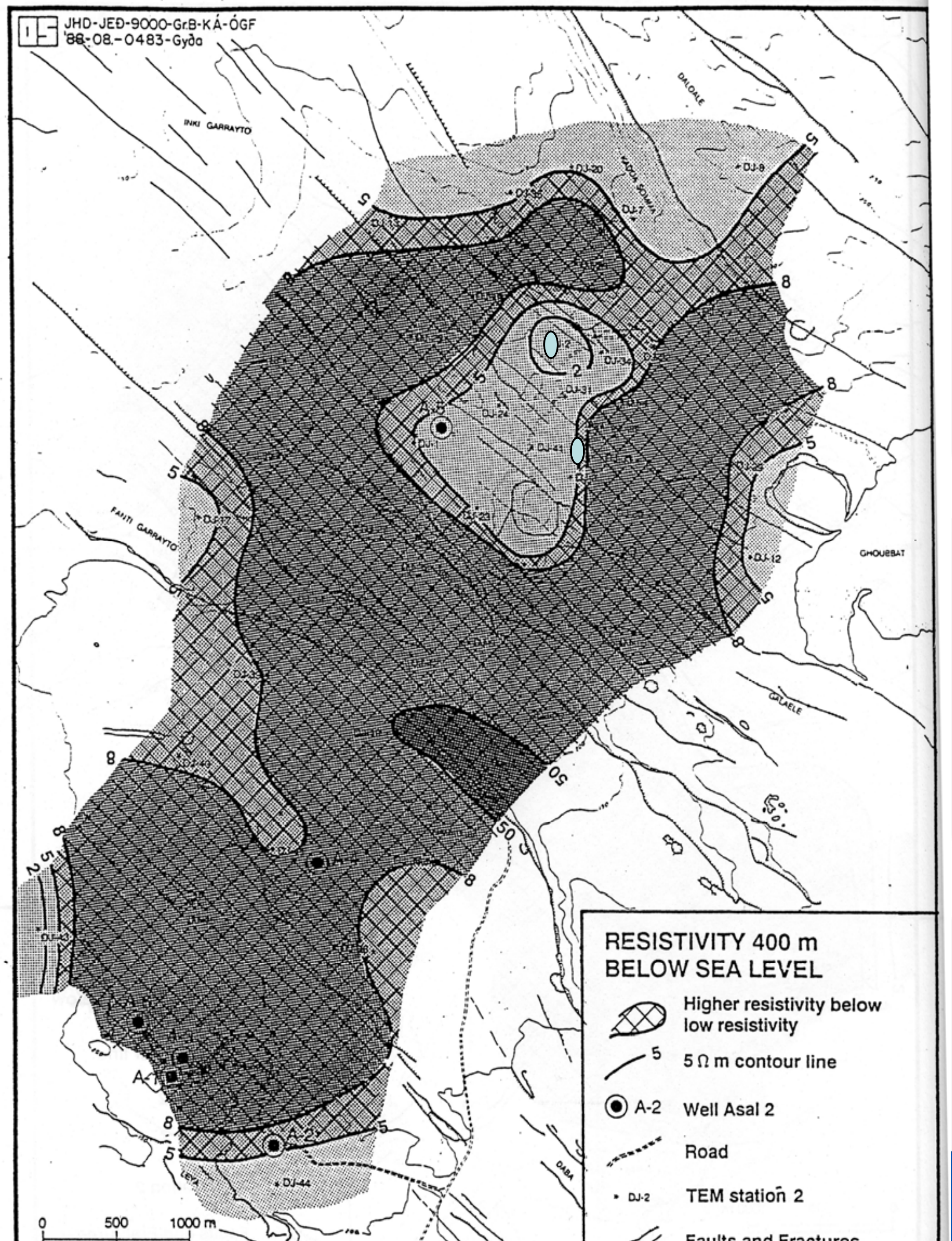




Asal-3: Temperature and pressure profiles

Model: Magma pocket and chamber heat source; a) and b) two reservoirs. Wells A 1-5 shown (BRGM 1982, modified by Sæmundsson 1988)





RESISTIVITY SURVEY
(June 1988)

Upflow zone of geothermal fluid under Lava Lake

A sudden drop in the water table is observed along a narrow belt crossing the central Asal rift between Asal-5 and Lava Lake, implying a low permeability zone, probably due to self-sealing by secondary minerals

Cap rock above the geothermal upflow zone

CONCLUSIONS

- Asal-3: 18- 20 and 16 -18 bar g. Average flow 31.6 kg/s, mean enthalpy 1070 kJ/kg. Decline over 93 days 25-28%
- Fluid Na Ca Cl, pH 4-5. TDS: 115.300-120.700 mg/l. moderate gas
- Scaling: Sulphides > 16 bar g. 6-fold increase below → iron silicates
- Inhibitors prevent sulphide scales but form pseudo scales (calcium chloride)
- Steam not corrosive
- Pressure drawdown 6.5 and 4.5 bar in Assal-3 and Assal-6 respectively. Reservoir permeability thickness product (kh) 7-11 Dm, storativity low → average porosity ≤ 5%. Drainage area for well: 7-9 km^2. High depletion rate
- Single flash or Single flash binary condensing turbine/generator unit
- Geology, geophysics: Upflow under Lava Lake, barrier between Lava Lake and Asal-5

RECOMMENDATIONS

- Run existing wells at > 18 bar g to avoid iron silicate scaling. Continue work on inhibitors to prevent sulphide scaling
- Drill well into permeable 130°C system at 4-500 m depth and test the fluid
- Drill a deeper well at Lava Lake as suggested by results of geological and geophysical studies. Add to geophysical studies

CORROSION COUPON TES