Corrosion testing of materials in geothermal steam

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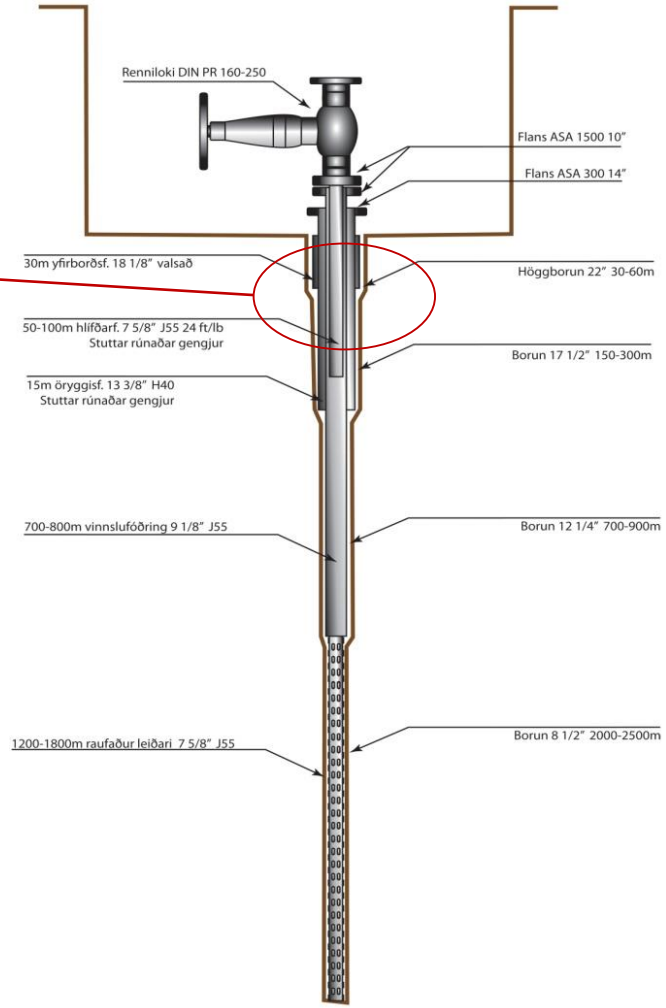
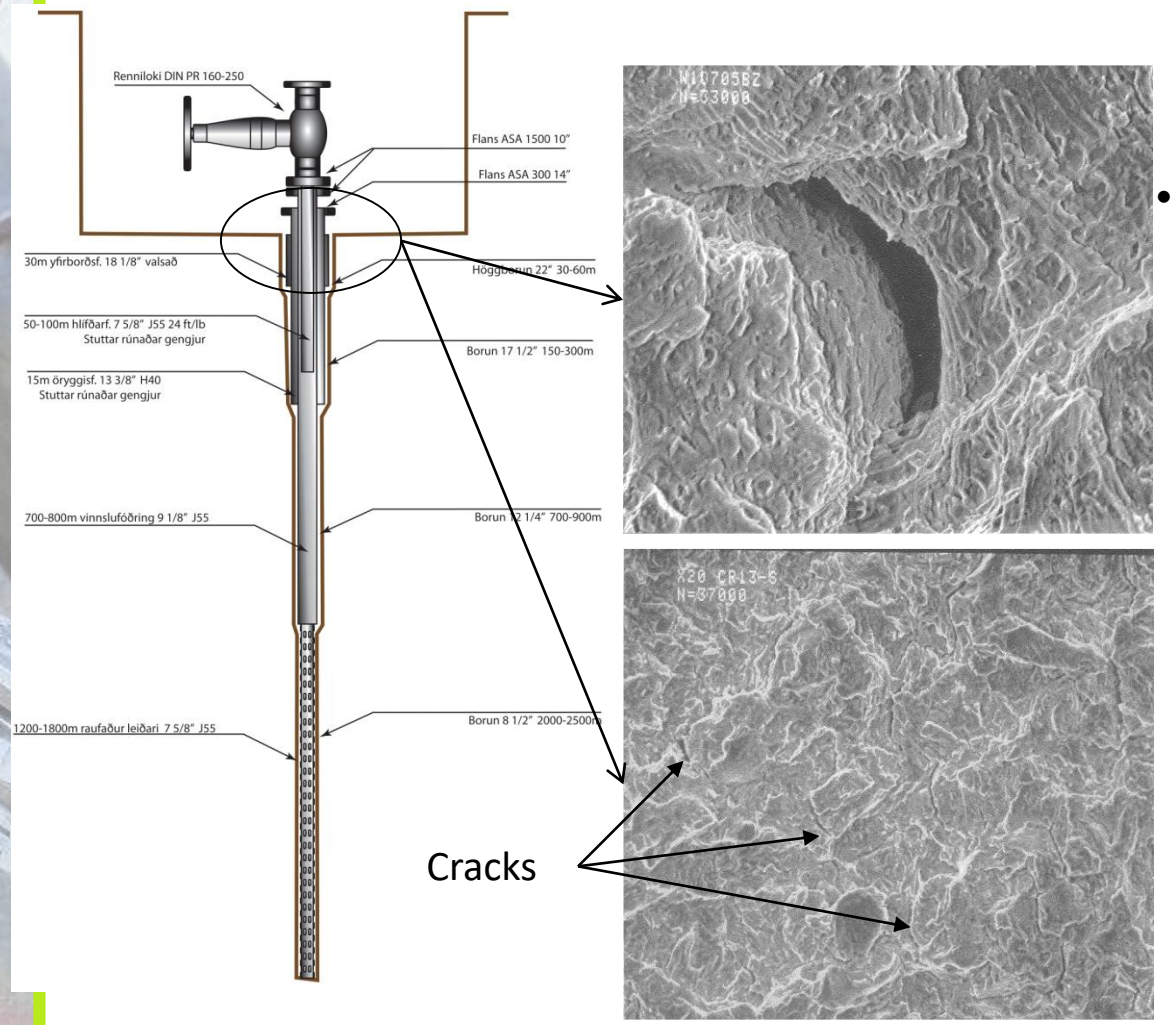
The GeoWell project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654497

Geothermal Well Materials and design!

Production casing



Geothermal Drilling experience



- Complex cemistry ➔ Complex material problems

Microvoid in stainless steel

Chemical reaction between geothermal gas and steel surface gives:

$H_2S + M \rightarrow MS + 2H^+ + 2e^-$

M (Fe, Mn)

Formation of Hydrogen molecules in microvoids gives pressure up to 2000 bar resulting in cracks inside material.

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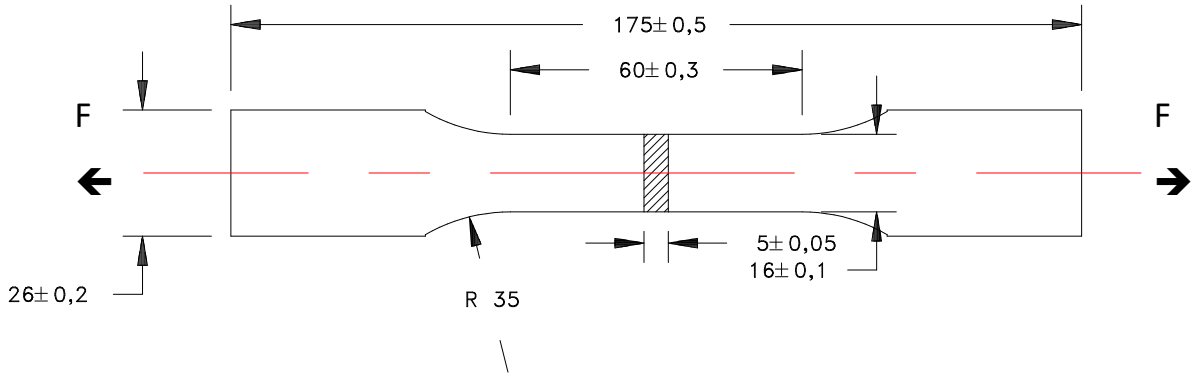
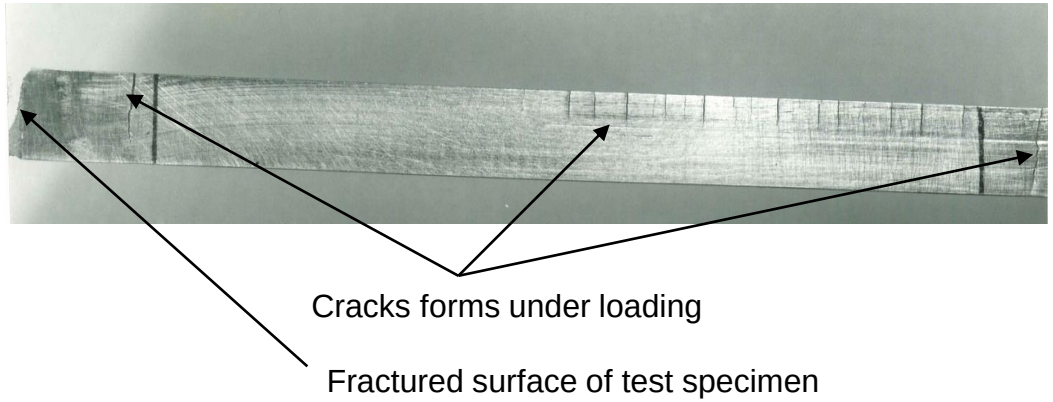
Geothermal drilling experience.



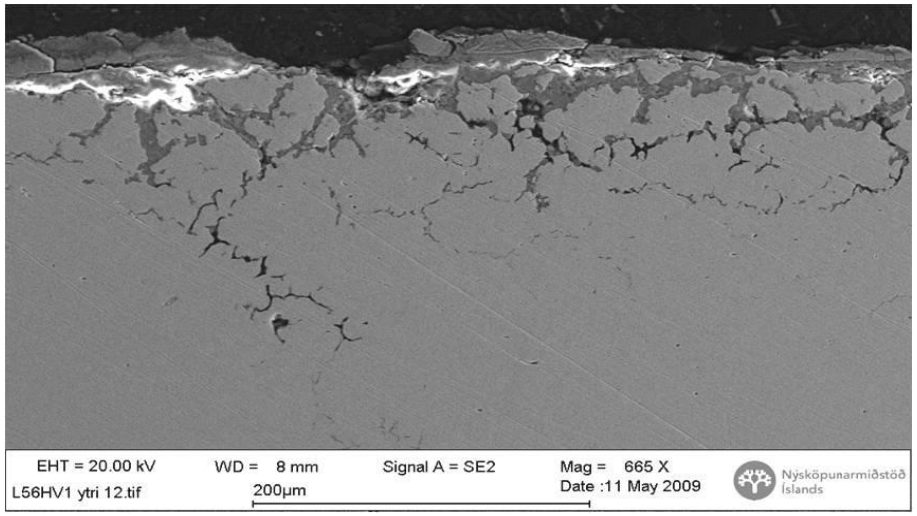


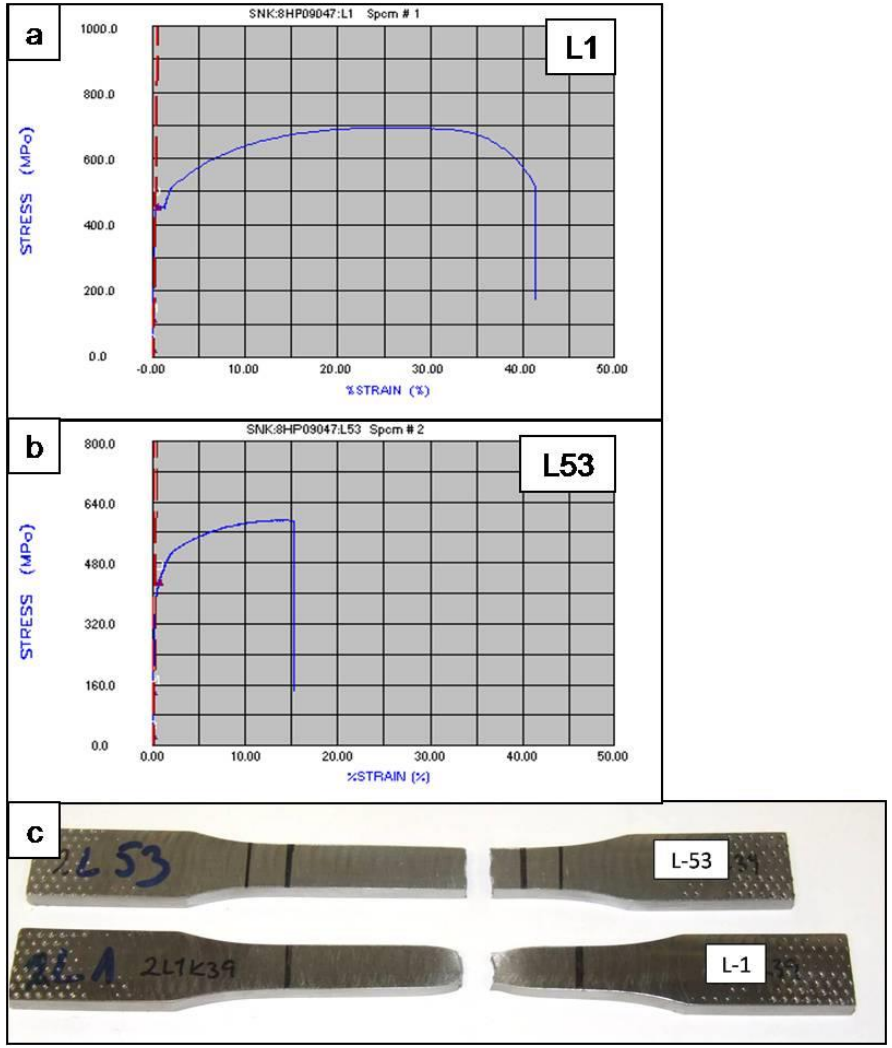
- Testing of material after several years in service:
- Impact strength reduced significantly
- Material ability to take elongation under load reduced significantly

Geothermal well K39 – Krafla Geothermal field

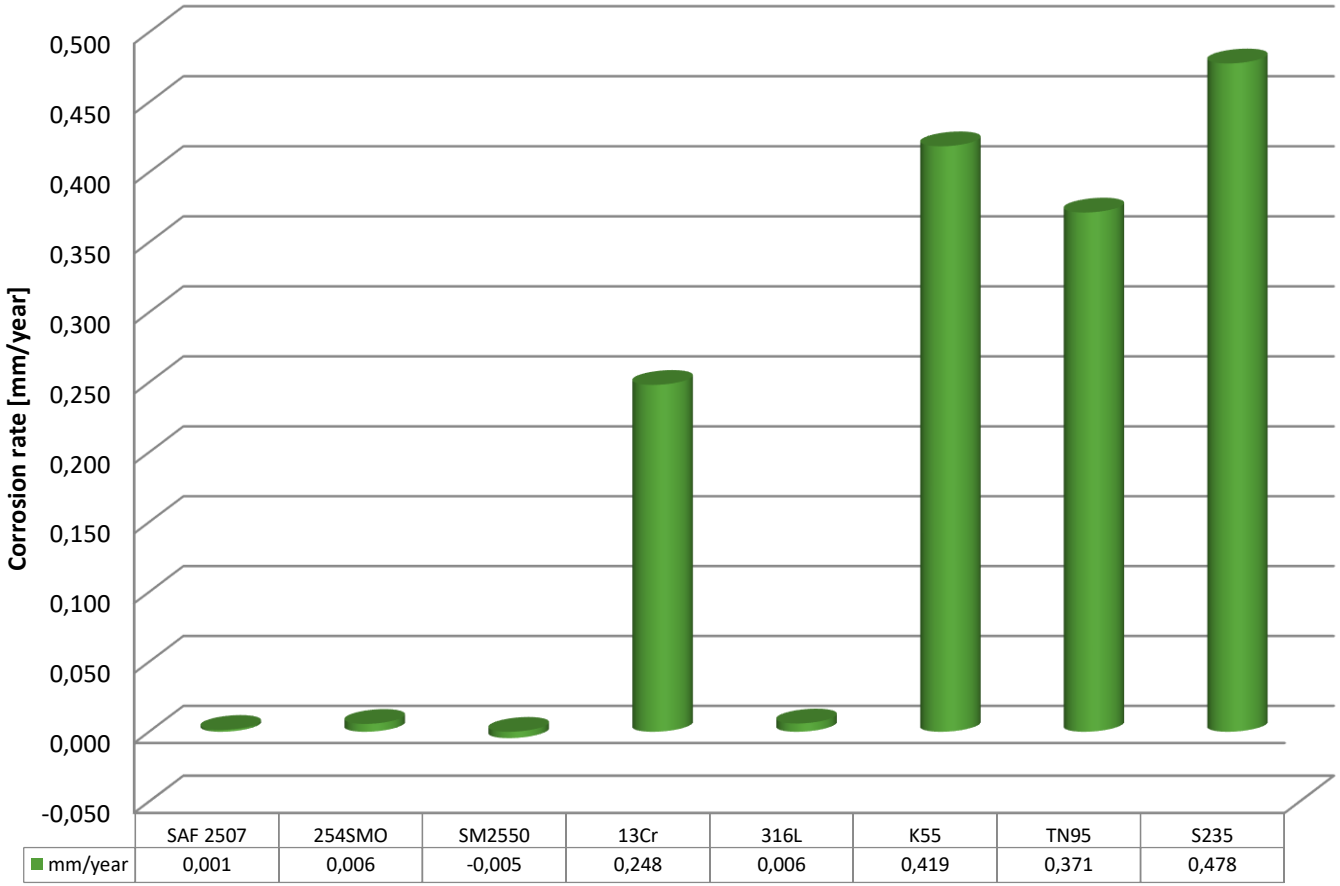
Krafla K-39 Depth 1600 m

Corrosion and Tensile testing K-39





Corrosion rate in the IDDP-1 well



	SAF 2507	254SMO	SM2550	13Cr	316L	K55	TN95	S235
mm/year	0,001	0,006	-0,005	0,248	0,006	0,419	0,371	0,478

Materials tested: Cladded and stand alone

	Sample ID	Material type	Cladding	Base material	Type	Cladding method	Full thickness (mm)	Cladding th. (mm)	Supplier
Cladded	CL02	Austenitic SS	254 SMO	P355NH / SA-516 Gr.70	Plate 300x300 mm	Explosion	12,8	3	Explomet
	CL03	Austenitic SS	SS 316L	P355NH / SA-516 Gr.70	Plate 300x300 mm	Explosion	12,8	3	Explomet
	CL04	Duplex SS	Duplex 2507	P355NH / SA-516 Gr.70	Plate 300x300 mm	Explosion	12,8	3	Explomet
	CL05	Nickel alloy	Inconel 625	P355NH / SA-516 Gr.70	Plate 300x300 mm	Explosion	12,8	3	Explomet
	CL06	Nickel alloy	C-276	P355NH / SA-516 Gr.70	Plate 300x300 mm	Explosion	12,8	3	Explomet
	CL09	Austenitic SS	SS 316L		Plate 150x400x32+3	Roll-bounding	35	3	Industeel / ArcelorMittal
	CL10	Duplex SS	Inconel 825		Plate 150x400x10+3	Roll-bounding	14,8 mælt	3	Industeel / ArcelorMittal
	CL11	Nickel alloy	Inconel 625	X65	Pipe ø342,9x22,2+3,0	Metallurgical	25,2	3	Butting
		Material type		**Base material**	**Type**		**Full thickness (mm)**		**Supplier**
Stand alone	SA01	Carbon steel		API K55	13 3/8" 68lb/ft casing		12,2		LV/IDDP-1
	SA05	Austenitic SS		B66					Sandvik
	SA06	Nickel alloy		Hastelloy C-22HS					Haynes International
	SA08	Titanium		Grade 9					Timet
	SA10	Nickel based alloy (SS)		UR 625	500x500		10		Industeel / ArcelorMittal
	SA14	Duplex SS		UR2507	297X210		6		Industeel / ArcelorMittal
	SA17	Austenitic SS		254 SMO					SINTEF

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High temperature Autoclave testing

- Testing in 210° and 450°C at the same time in the same steam conditions
  - Steam at 210°C from wellhead with 20 bar pressure through autoclave at well head conditions
  - Temperature raised to 450°C with geothermal steam flowing through the autoclave
- Same set of materials at both temperatures
  - Cladded noble material on carbon steel base material
  - Stand alone materials

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Testing at well head temperature and pressure

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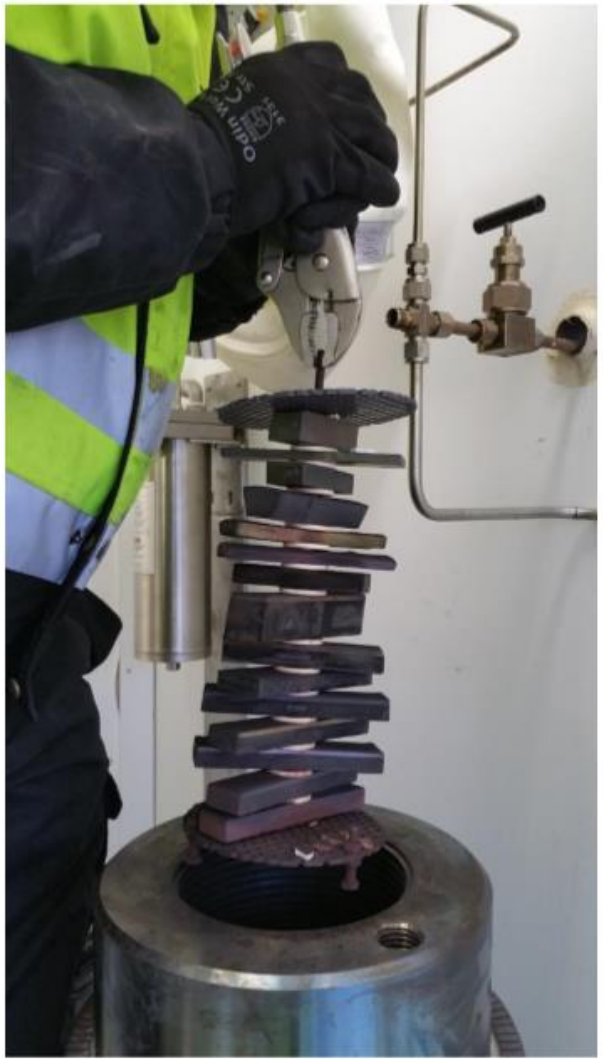
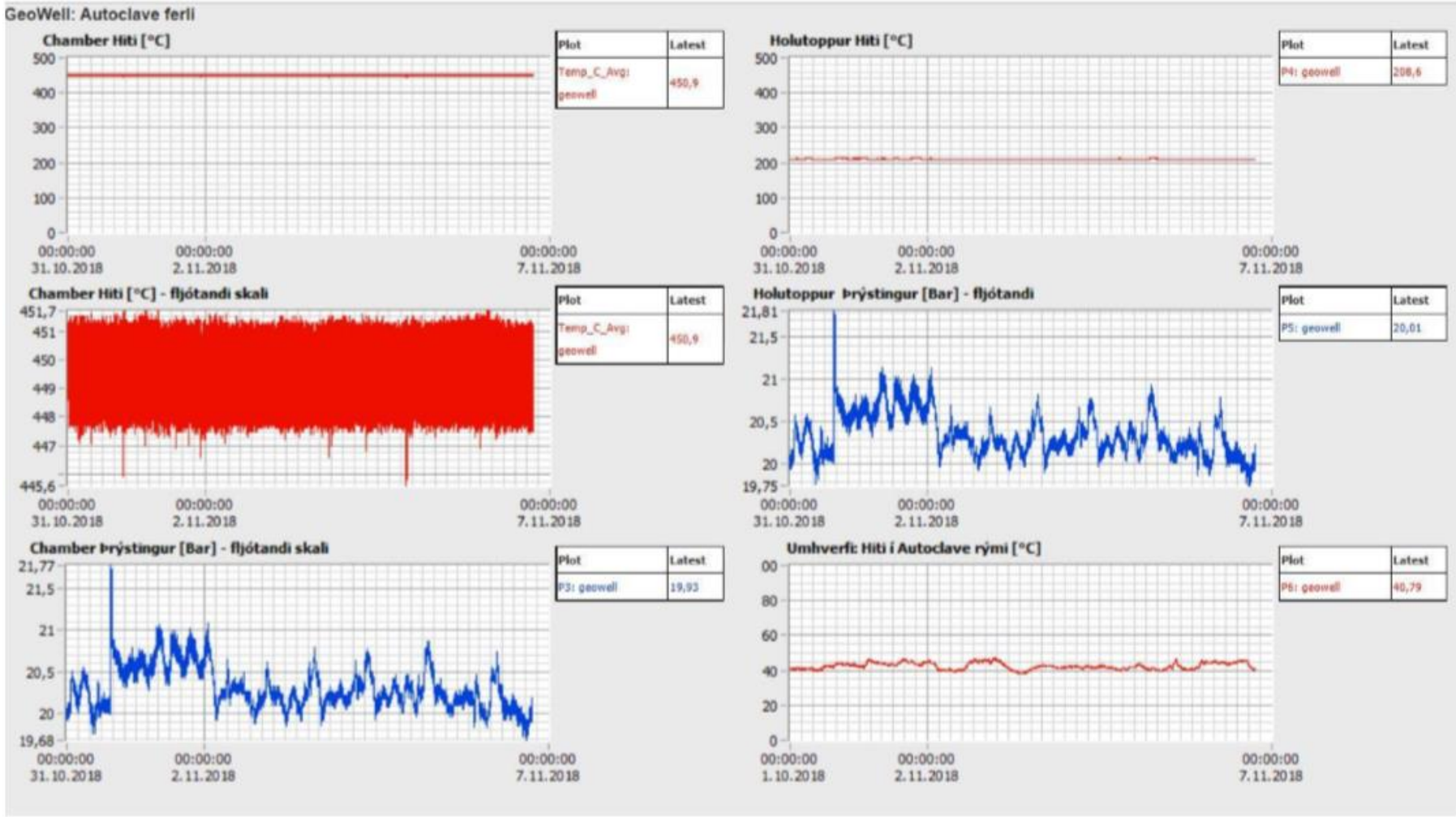
Testing in Autoclave at 450°C and 20 bar



Geothermal steam wented through the autoclave

Temperature and pressure



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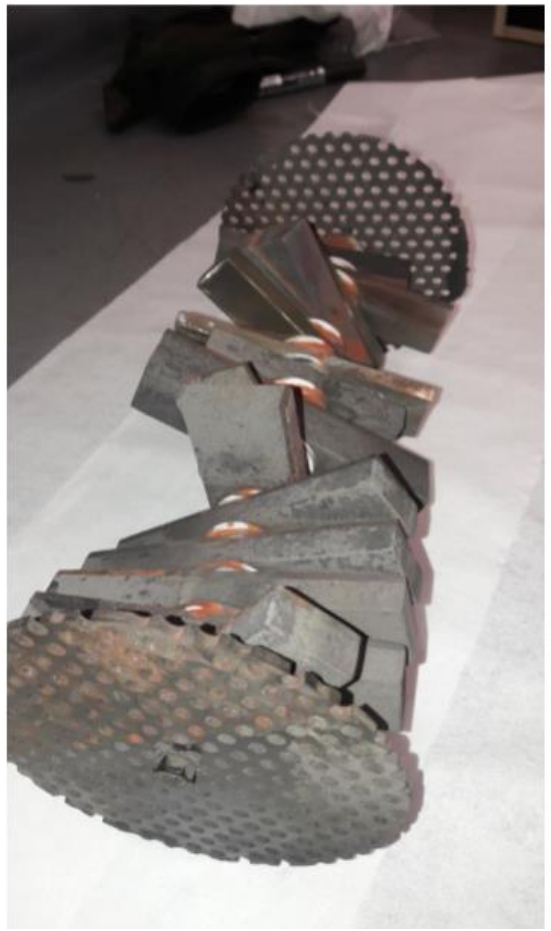
Sample racks after testing

210°C at 20 bar



450°C at 20 bar

Samples from 450°C ready for analysing


Thank you for your attention!