Developments in Geothermal Drilling

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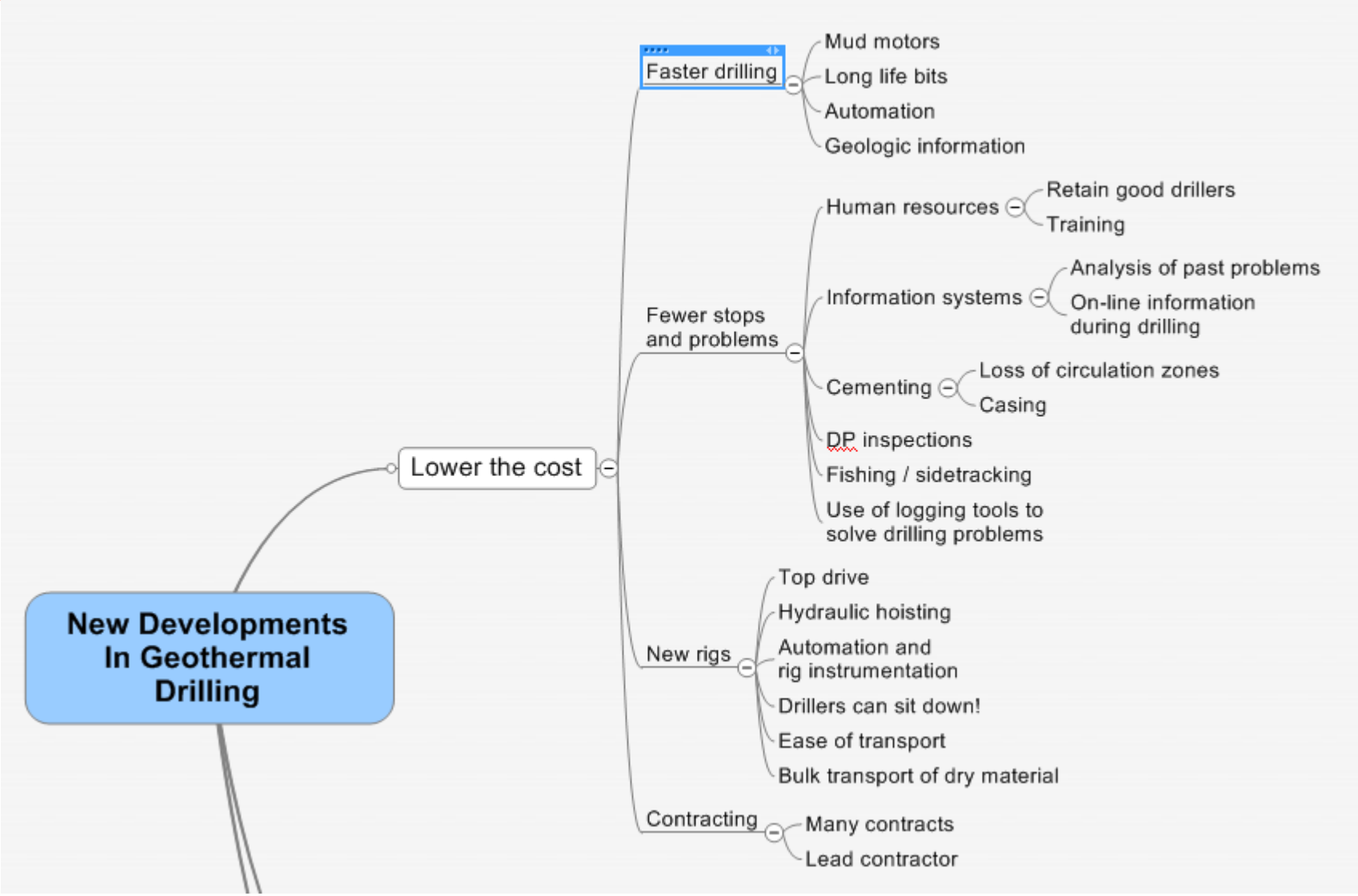
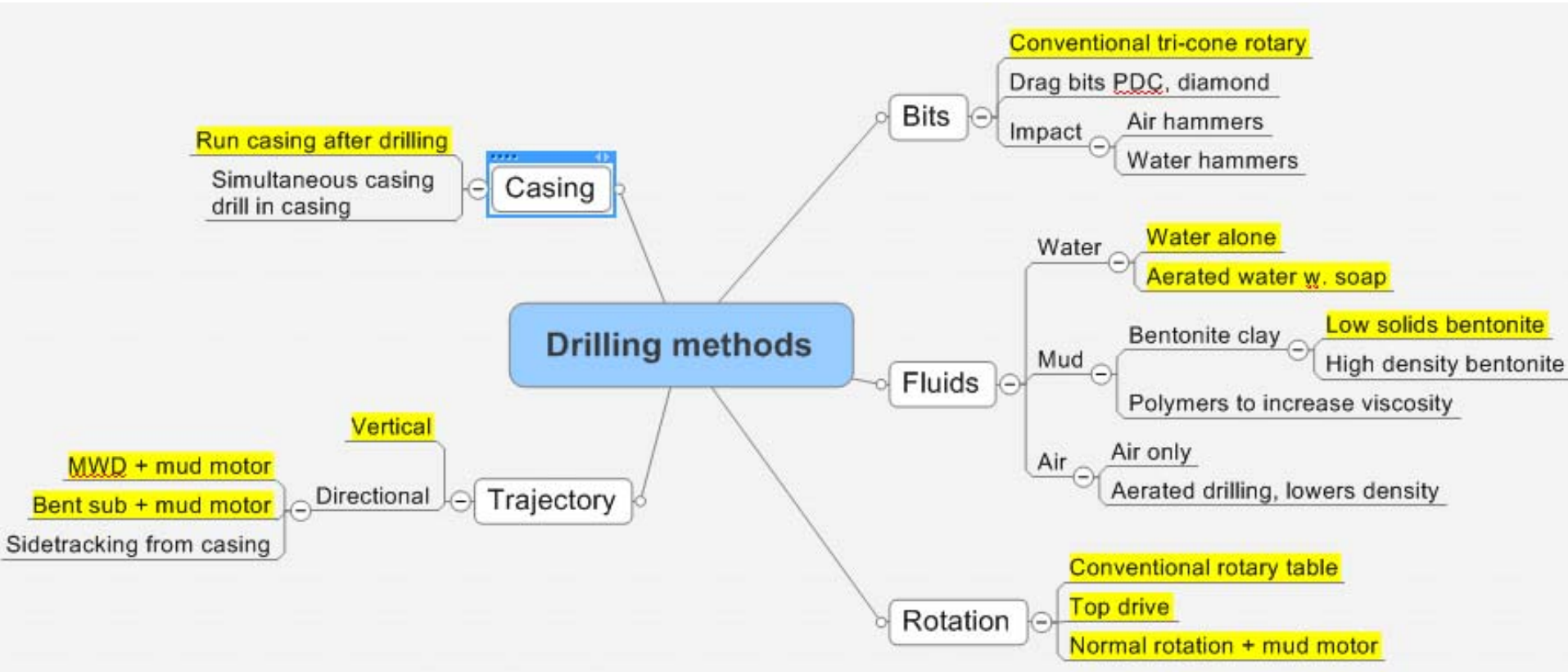
Outline


New Developments In Geothermal Drilling
Lower the cost
Faster drilling
Mud motors
Long life bits
Automation
Geologic information
Fewer stops and problems
Human resources
Retain good drillers
Training
Information systems
Analysis of past problems
On-line information during drilling
Cementing
Loss of circulation zones
Casing
DP inspections
Fishing / sidetracking
Use of logging tools to solve drilling problems
New rigs
Top drive
Hydraulic hoisting
Automation and rig instrumentation
Drillers can sit down!
Ease of transport
Bulk transport of dry material
Contracting
Many contracts
Lead contractor

Geothermal drilling methods



Various methods found in geothermal drilling.
Yellow indicate the most common ones.

Icelandic Geothermal Drilling Industry

National companies for:

- Jardboranir hf. for drilling deep wells. 4 drilling contractors in all.
- Cementing, fishing etc. done by the drilling contractor.
- Iceland GeoSurvey for geoscientific services and logging.
- Consulting engineering companies for tendering and supervision.

International companies for:

- Mud motors, MWD.
- Aerated drilling.

Pre-drilling with a truck mounted rig

-Surface casing 60-90 m, drilled dia. 24“- 28" with air-hammers.

Water used as drilling fluid whenever possible.

Only large losses are cemented (>10 l/s).

No delays due to coring. No cores taken.

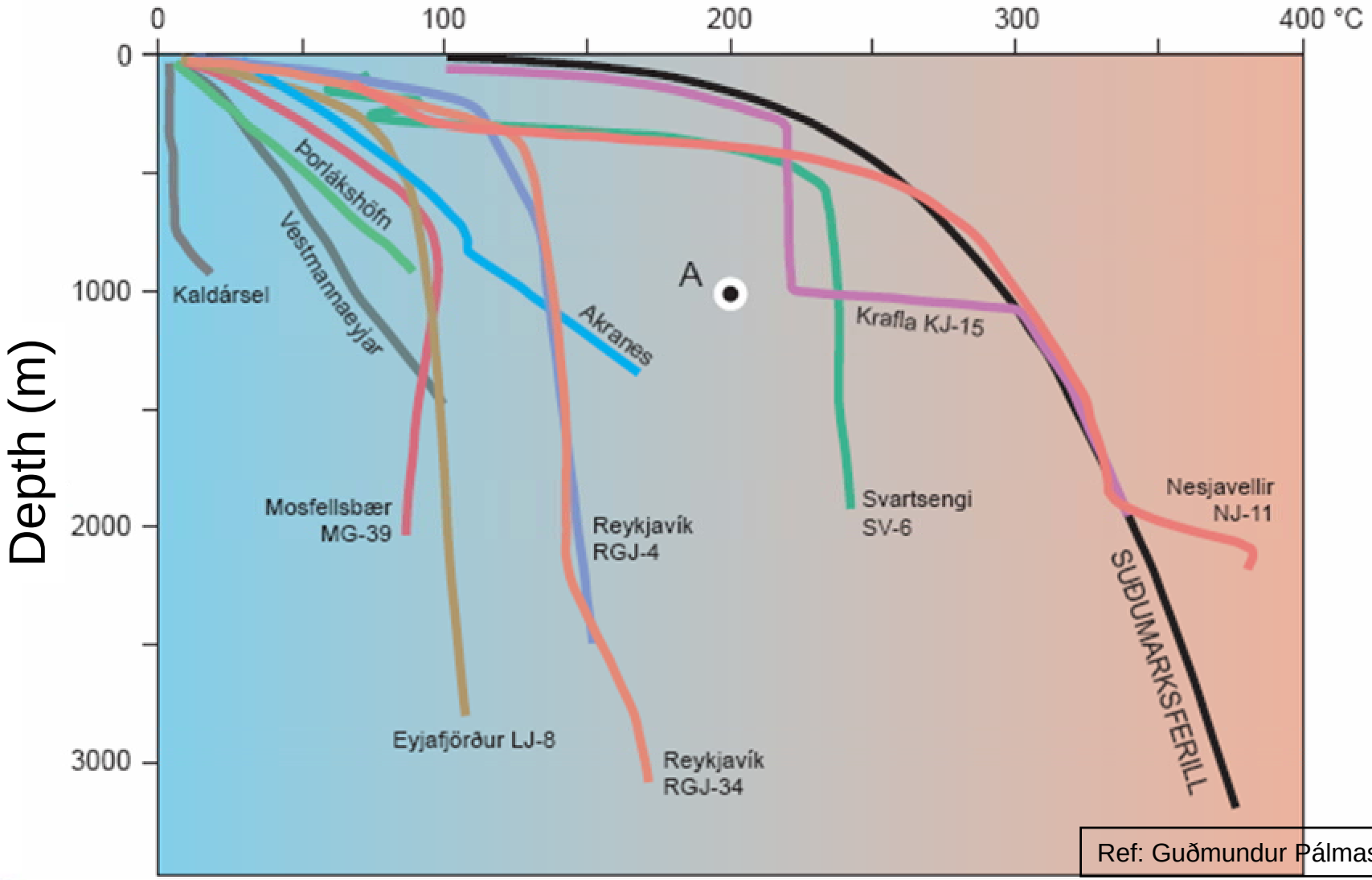
Logging or testing only at casing points.

Rigs and crew only drill geothermal wells.

Geothermal drilling rigs in Iceland

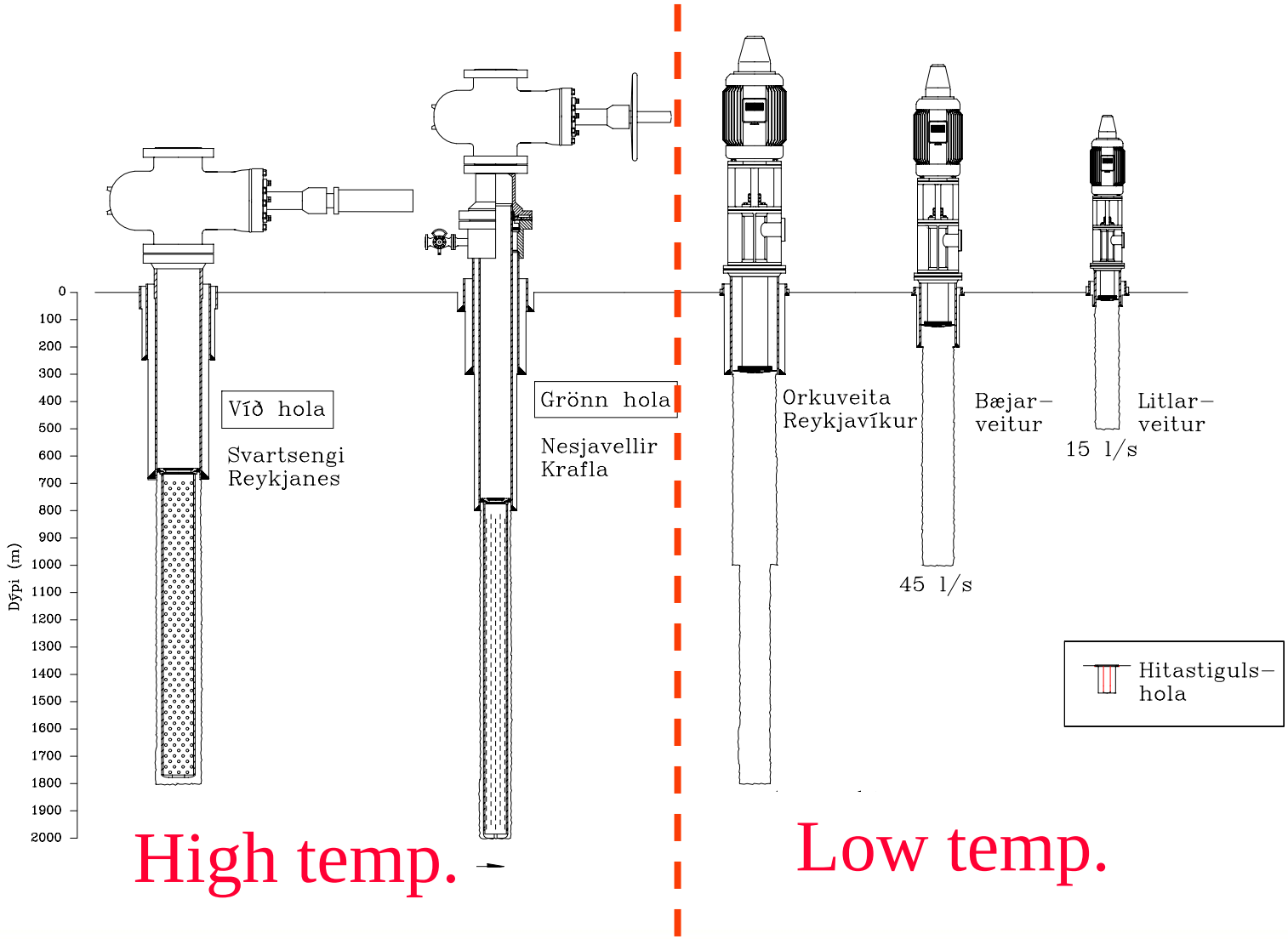
Óðinn JB	4000 m
Geysir JB	4000 m
Jötunn JB	3300 m
Sleipnir JB	2400 m
Nýr bor RFS	1600 m
Saga JB	1350 m
Trölli RFS	1100 m
Langþr. RFS	600 m
Glámur RFS	600 m
Einráður RFS	500 m
Ýmir JB	1000 m
Hrímnir JB	300 m
Alvarr	300 m
Trítill RFS	120 m

Temperature profiles - ICELAND



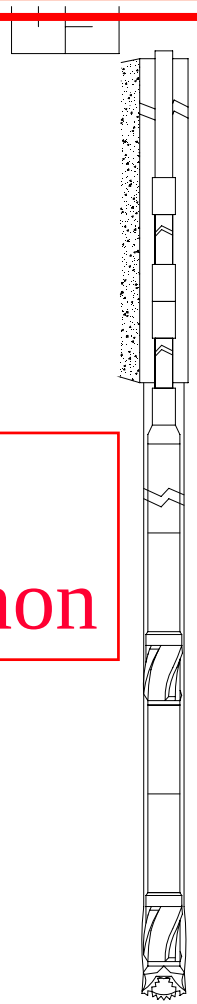
Ref: Guðmundur Pálmason

Casing profiles of Icelandic geothermal wells

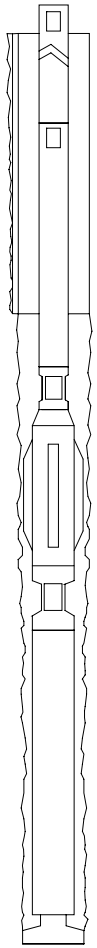


Drilling methods used in Iceland

Most common

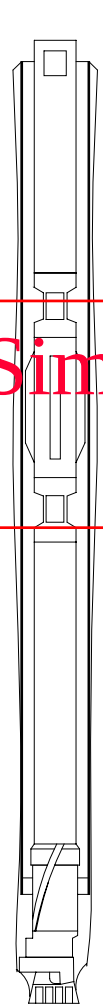


Rotary

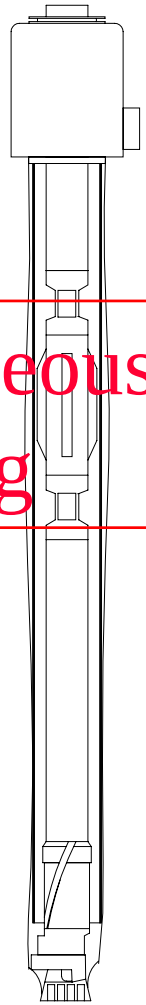


Hammer

Simlutaneous casing

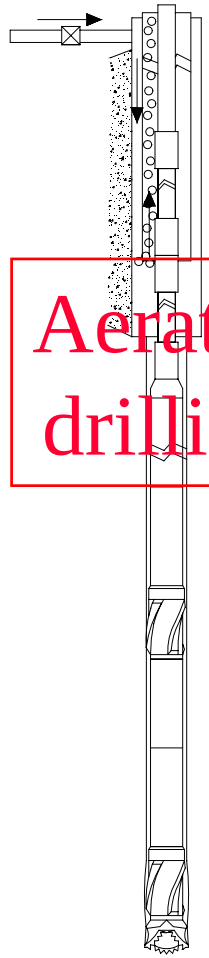


Odex



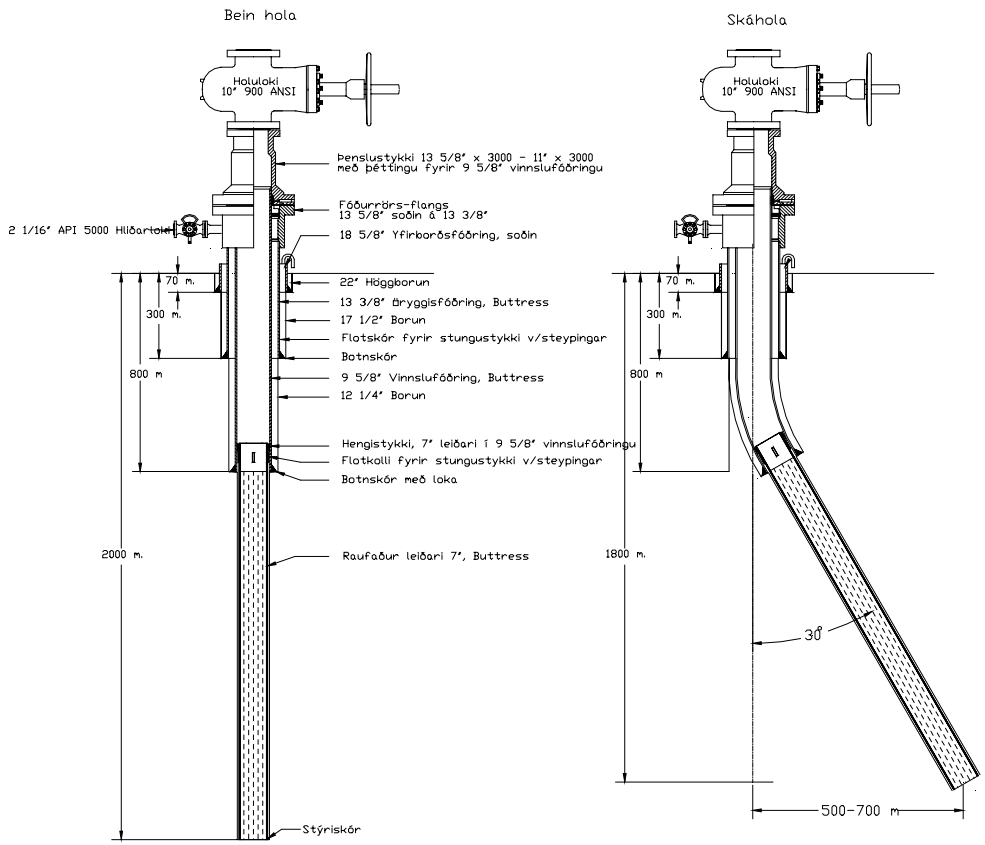
Holte

Aerated drilling



Pressure bal.

Vertical vs. directional drilling



Hlnr.:	Fj?ldi:	Heiti:	Efni:	St?r?: A4
		ÍSOR Grens?svegi 9 108 Reykjavík Telf. 91-696000		Snið 2000 m. háhitaholu. Föðringar og holutoppur.
Mkv.:	Hanna?: SLJ	Dags.: 17.04.1994	Teikning nr.: JHD-VFR-8715-SLJ 94.02.0029.ACAD.T	Bla? nr.:

The casing programmes are virtually the same. The build-up starts at the kick off point (KOP) at 300-500 m.

Inclination of 30-40° is common in geothermal wells.

Main Types of Low Temp. Wells

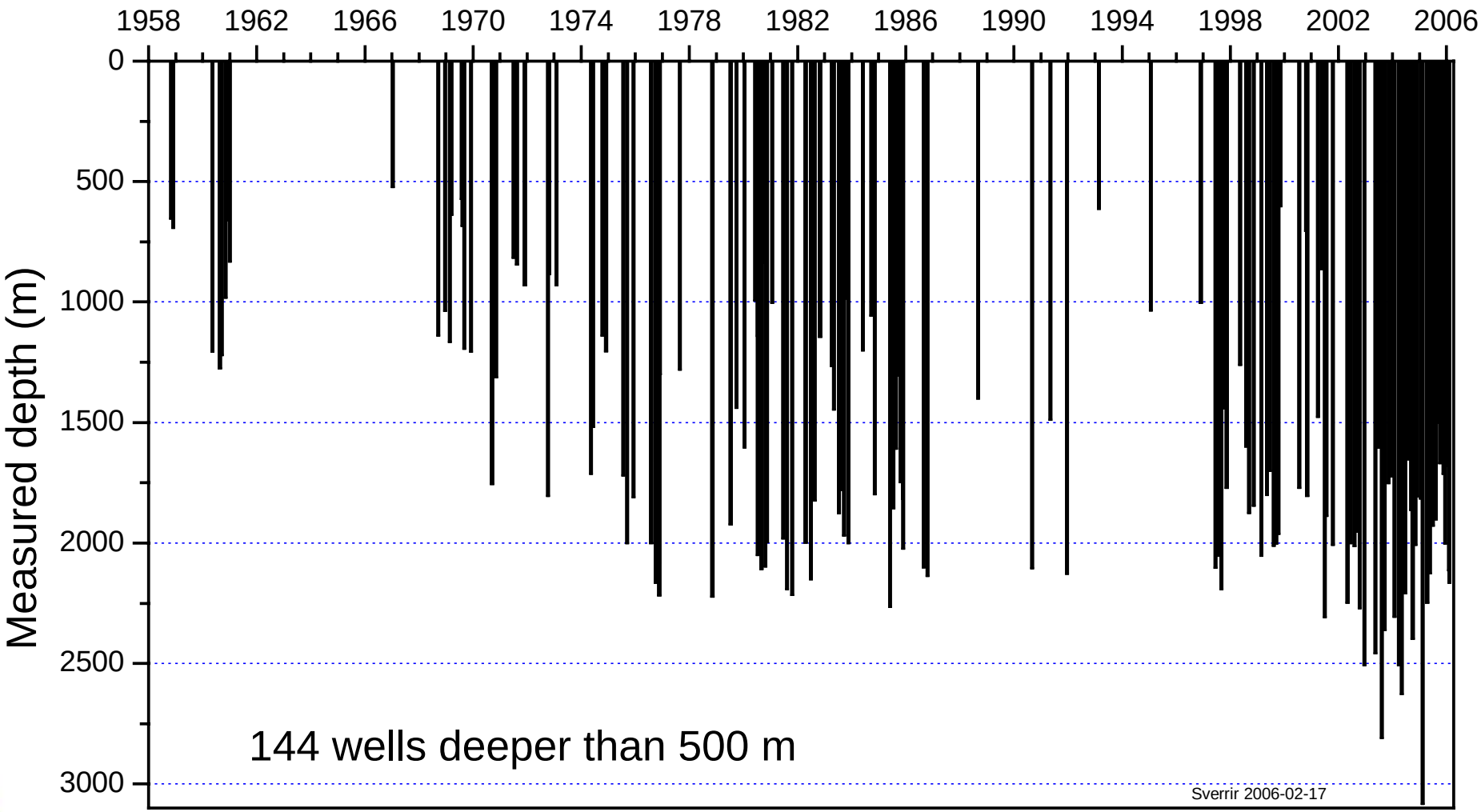
- Temperature gradient wells
  - Depth 40-100 m (used in Iceland for exploration)
  - Well diameter 3-4", plastic liner HDPE where needed

  Cost 150 €/m
- Production wells
  - Depth 400-2000 m
  - Casing sizes, mainly three diameters for production casing 14", 10 3/4" and 8 5/8" or 7 5/8".
  - Casing depth í 150-800 m. Barefoot - no liner.
  - Cost 500-1000 €/m

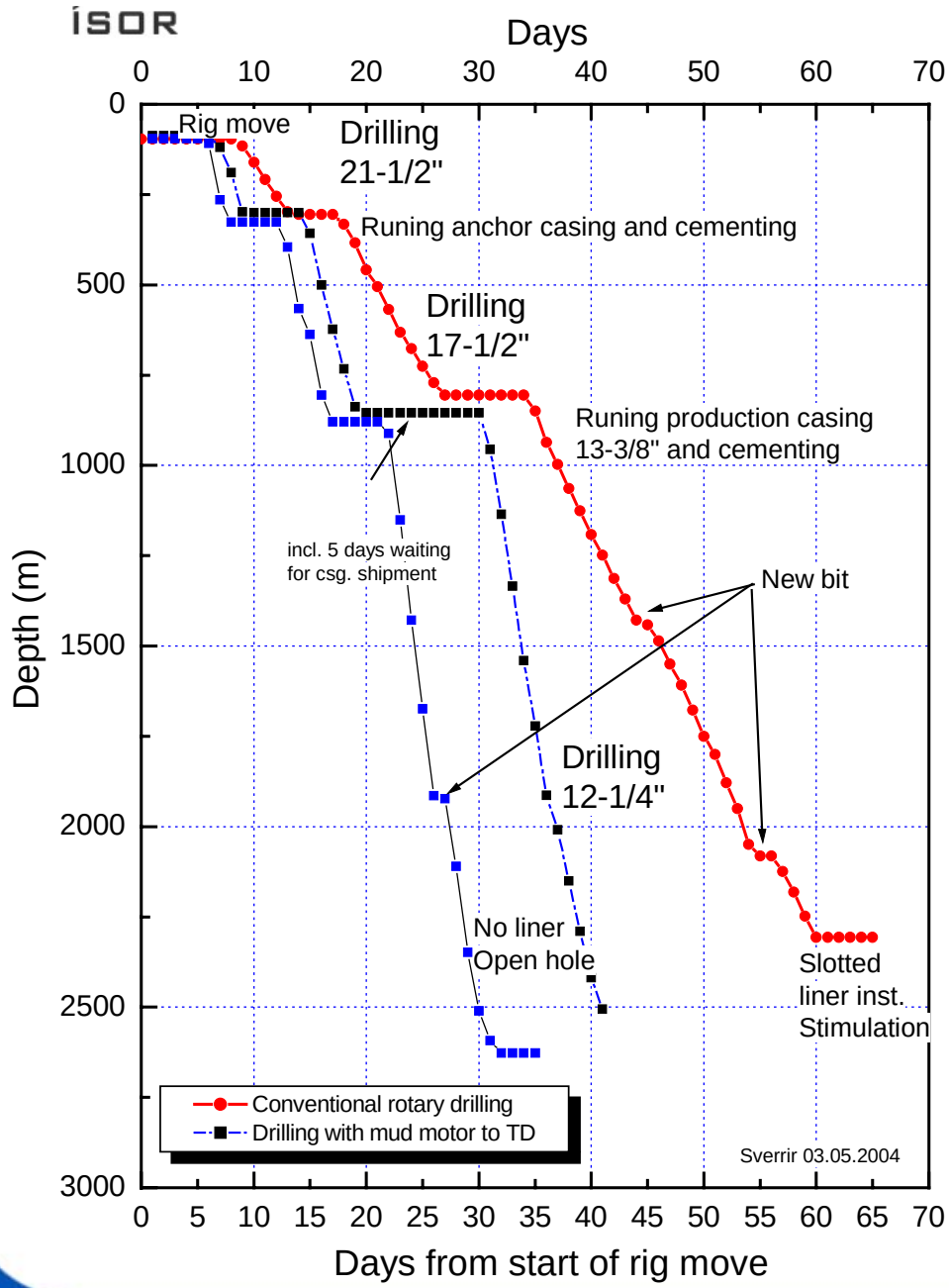
Main Types of High Temp. Wells

- Typical well profile:
  - Depth of well 1200-2800 m
  - Production casing depth 600-1100 m
  - Production casing dia. 9-5/8", liner 7" or 7-5/8"
  - Cost 1200-1800 €/m. For 2500 m, 4 million €
- Large diameter well profile:
  - Depth of well 1200-3000 m
  - Production casing depth 600-850 m
  - Production casing dia. 13-3/8", liner 9-5/8" or barefoot
  - Cost 1500-2000 €/m

HT drilling activity in Iceland



Drilling progress – days vs. depth



Note:
Doubling of ROP when drilling with mud motor.

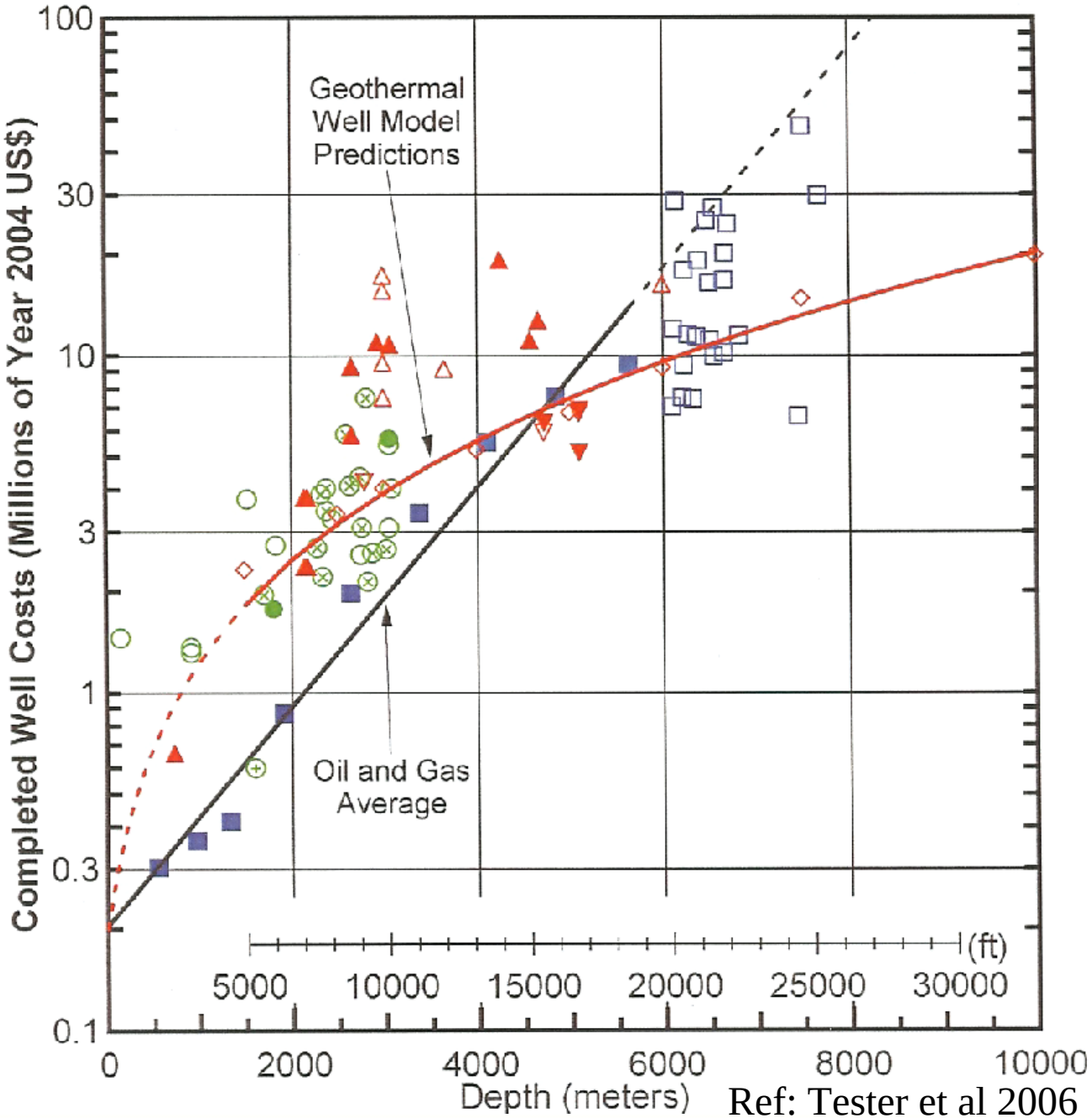
Trouble free drilling.

Few bit changes.

Well Cost

2500 m well
2.5 million €
in 2004, now
~3.5 million €

Geothermal wells are more expensive than oil and gas wells of the same depth



Ref: Tester et al 2006

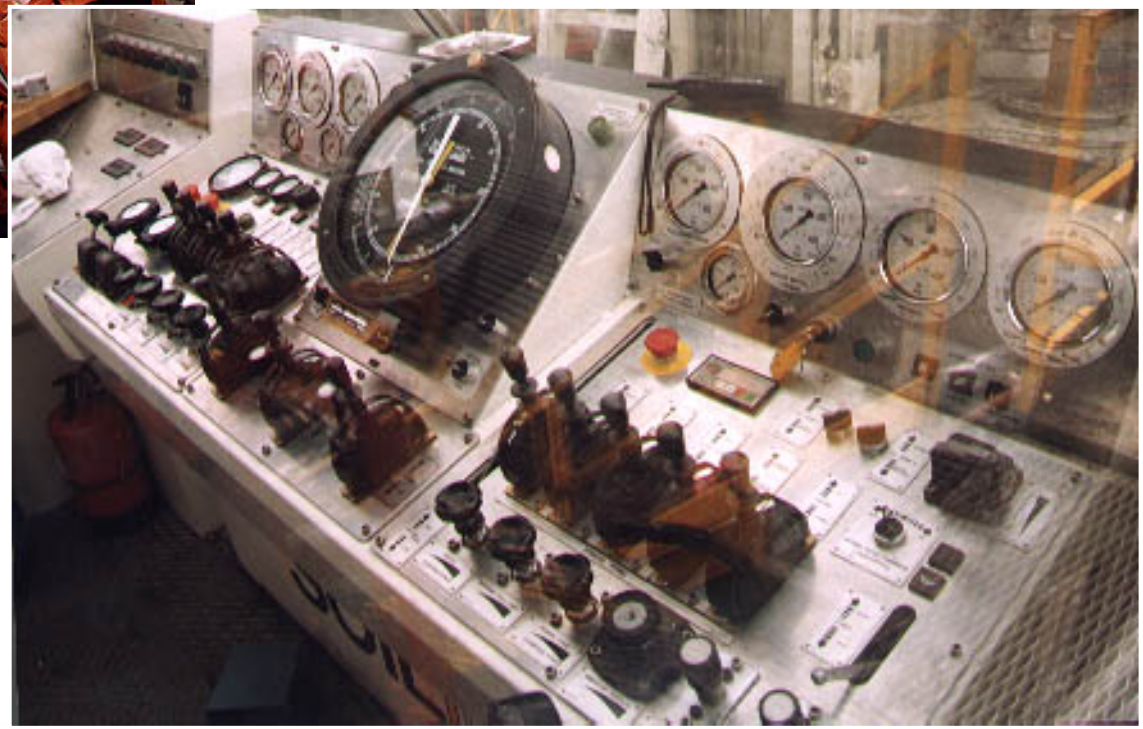
The cost is higher due to:

- Directional drilling with a mud motor and measurement while drilling (MWD) and gyro.
- Drilling rig with a top-drive.
- Aerated drilling fluid. Extra compressors.
- Using premium casing connections.
- Using cementing services from the oil industry.
- Logging services from the oil industry.
- Mobilization for only a few wells.

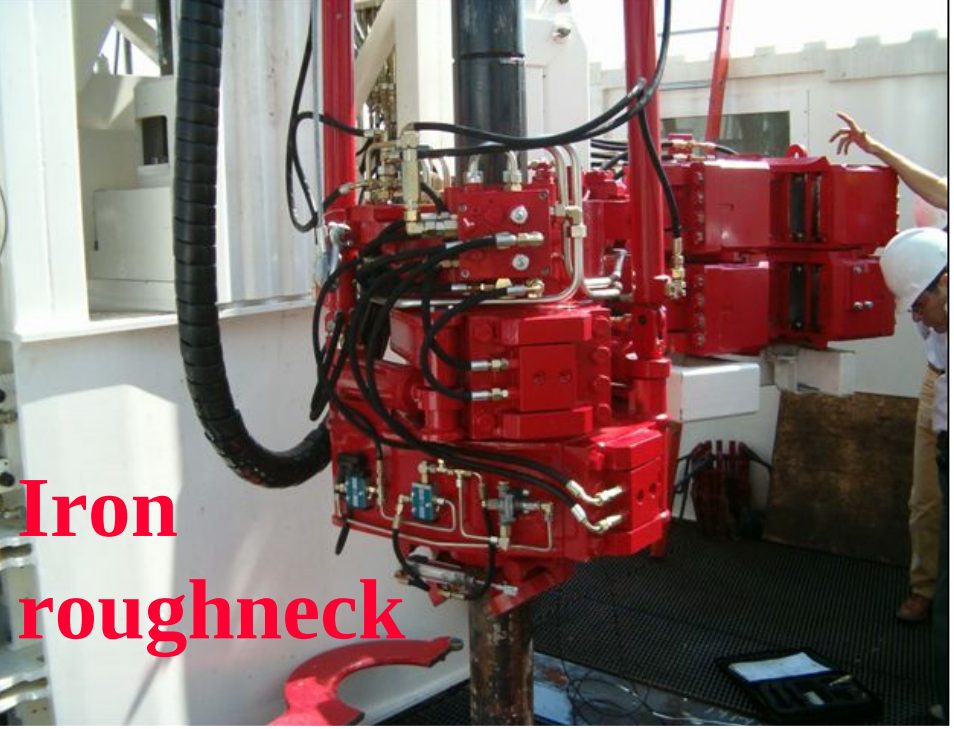
Rig control consoles

← Old type:
SCR-DC motor contr.
Rig with rotary table.

New: →
All hydraulic rig.
Iron roughneck.



Jarðboranir hf.

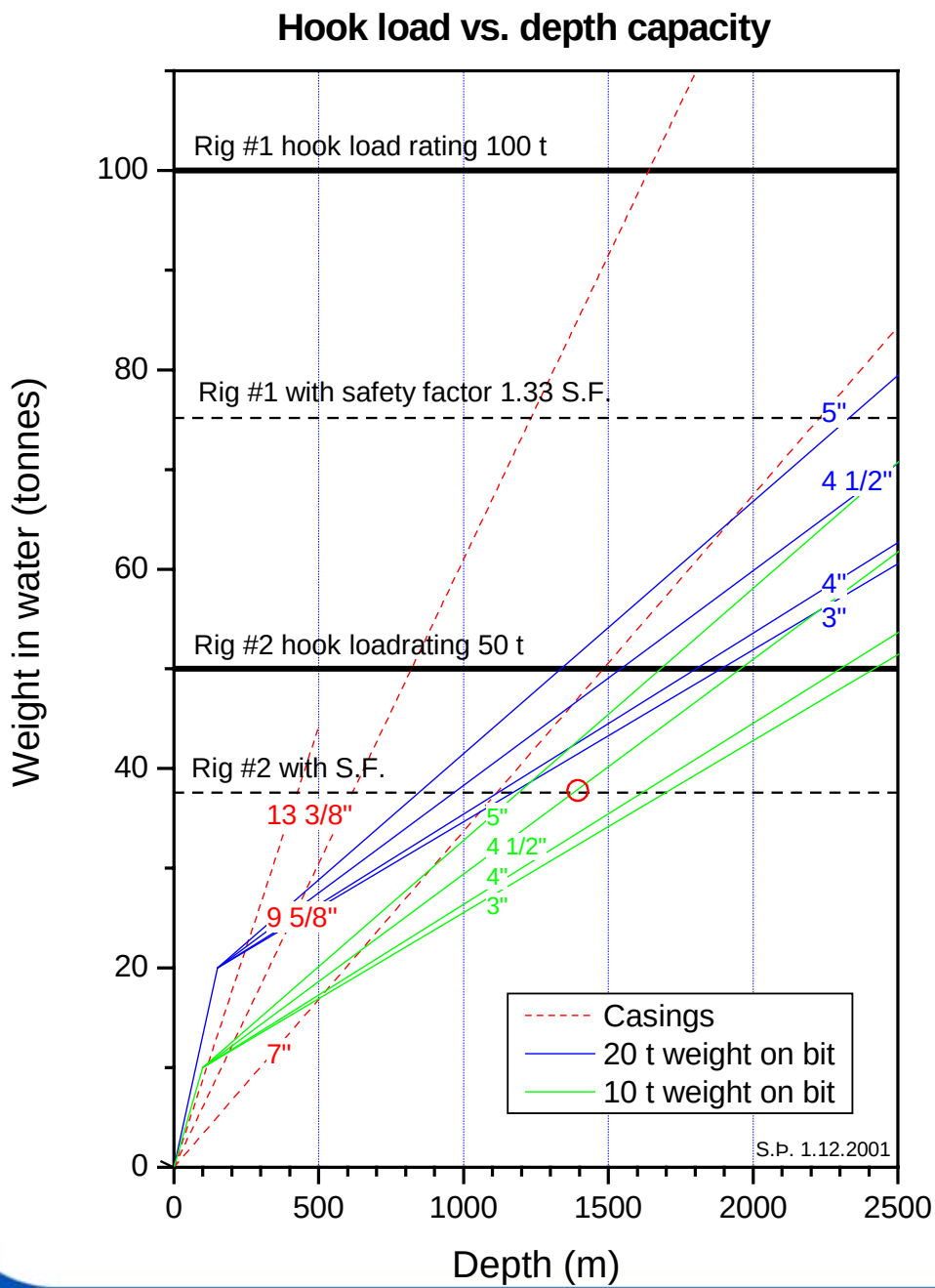


Iron roughneck

Top drive

Jarðboranir hf.

Hook Load vs. Depth



The diagram shows how deep a rig can drill, based on the hook load rating.

Example.
100 tons rig can reach
2300 m with 5" drillpipe
2700 m with 4-1/2" dp

200 t

Jarðboranir hf.


100 t
SOILMEC
JARÐBORANIR
SLEIPNIR
Jarðboranir hf.


50 t
Jarðboranir hf.

Cementing unit - from drilling contr.

Three Cement Tanks, 50 m^3 each

CROWN single skid cementing unit.

The unit is comprised of a high-pressure pumping system, recirculating mixing system, all required controls, instrumentation and a hydraulic system to drive fluid handling and mixing.

The system includes CAM - Continuous Automatic Mixing, which is a computer operated cement density control system with features like:

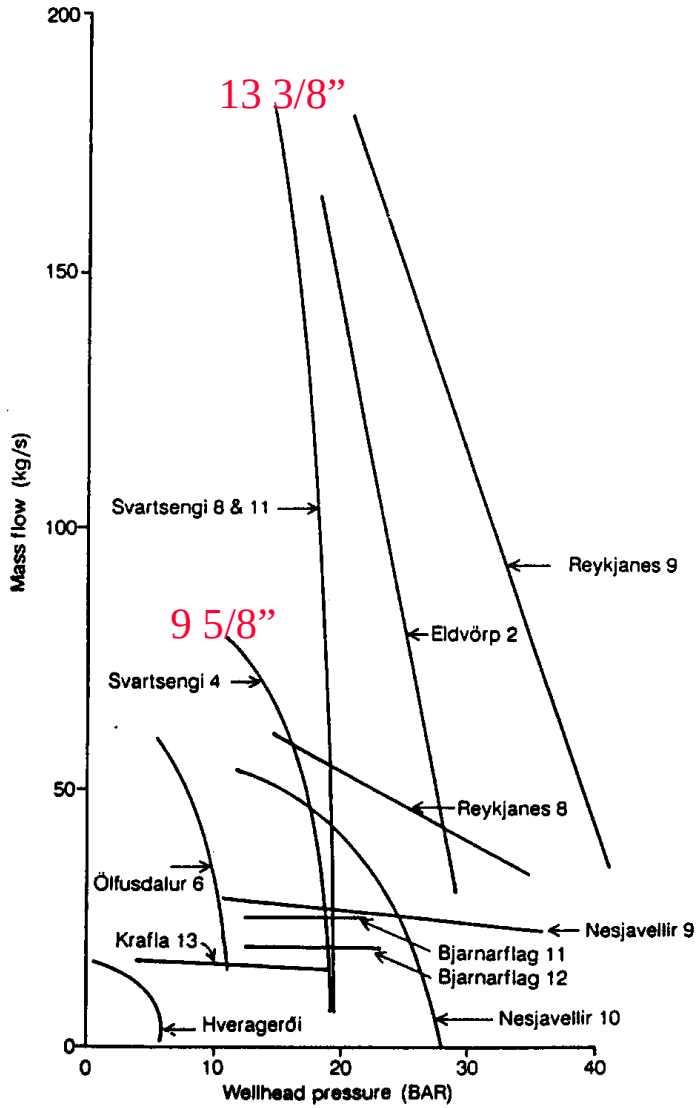
Automatic Density Control

Pre-job system check

Real time data storage of density, pump rate, total volume and pressure

Stores three cement slurry designs

Output curves for wells in Iceland



Icelandic bid forms

Drilling of a vertical geothermal well to 2500 m

Cased to: 50 m/ 450 m/ 1000 m/ TD 2500 m

Number	Work Item	Unit	Unit price	Quantity	Sum total
III.1	**Transportation**				
III.1.1	Preparations, mobilisation and demobilisation	total	0	1 0	
III.1	**Transportation**	**Total:**			**0**
III.2	**Specific site preparation for drilling**				
III.2.1	Site preparation changing from pre-drilling to drilling(cellar, mı	total	0	1 0	
III.2	**Specific site preparation for drilling**	**Total:**			0
III.3	**Drilling of a straight vertical well**				
III.3.1	**Drilling operation:**				
III.3.1-A	Drilling with ø 24” drill bit				
	Fixed price	total	0	1 0	
	Price per meter drilled	m	0	50 0	
III.3.1-B	Drilling with ø17½” drill bit				
	Fixed price	total	0	1 0	
	Price per meter drilled	m	0	400 0	
III.3.1-C	Drilling with ø12¼” drill bit				
	Fixed price	total	0	1 0	
	Price per meter drilled	m	0	550 0	
III.3.1-D	Drilling with ø8½” drill bit				
	Fixed price	total	0	1 0	
	Price per meter drilled	m	0	1,500 0	
III.3.1	**Drilling operation:**	**Total:**			0
III.3.2	**Casing runing services**				
III.3.2-A	ø18 5/8” casing	m	0	50 0	
III.3.2-B	ø13 3/8” casing	m	0	450 0	
III.3.2-C	ø9 5/8” casing	m	0	1,000 0	
III.3.2-D	ø7” liner	m	0	1,500 0	
III.3.3	**Casing runing services**	**Total:**			0

Some “Problems” of Geothermal Drilling

1. High cost of geothermal wells.
2. Well sites in protected areas. Permitting.
3. Large loss of circulation zones.
4. Drilling “blind” after total loss of circulation.
5. Slow drilling in hard lava formations.
6. Well stability during drilling.
7. Wells with low permeability / low output.
8. High pressures while drilling through a steam cap.
9. Temperature limitations of logging tools.

Conclusions

- New top-drive rigs with “iron roughnecks”, directional drilling + MWD and instrumentation are a part of a modern drilling operations.
- Better environment: noise, wastes, mud disposal.
- Big diameter casings are required for large flows.
- Incentive drilling contracts have lead to improved drilling efficiency.
- Standardized well designs and uninterrupted drilling operations will lead to lower costs.

REMINDER: ENGINE Workshop (WP4)

See you in Reykjavík, June 28-29

Drilling cost effectiveness

and

feasibility of high-temperature drilling