Drilling Fundamentals III

Introduction to Drilling Technology

Volker Wittig

International Geothermal Centre Bochum, Germany

Table of content

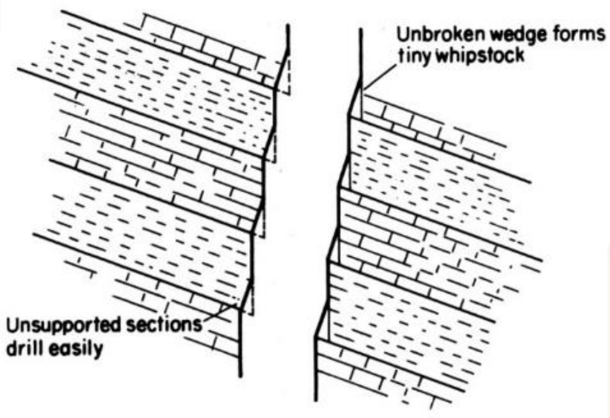
1. Brief History of Drilling
2. Drilling Rig and Auxiliary Equipment
3. Coiled Tubing
4. Drill String
5. Drill Bits
6. New Drill Bit Solutions
7. Basics of Rock Mechanics
8. Casing
9. Cementation
10. Drilling Fluid
11. Well Control
12. **Directional Drilling**
13. **DTH Hammer Technology**
14. **Logging, Geotechnical Drilling and Site Investigation**
15. **Reporting, HSE, Economics**
16. **Practical Exercises**

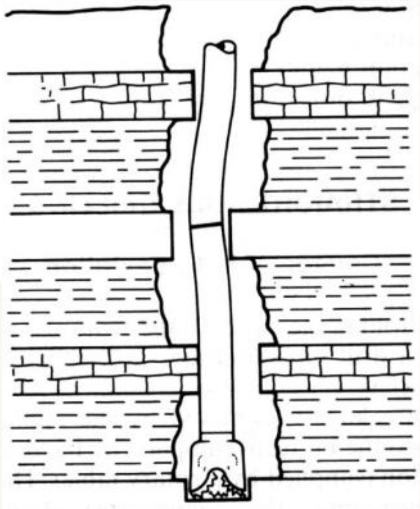
Directional Drilling

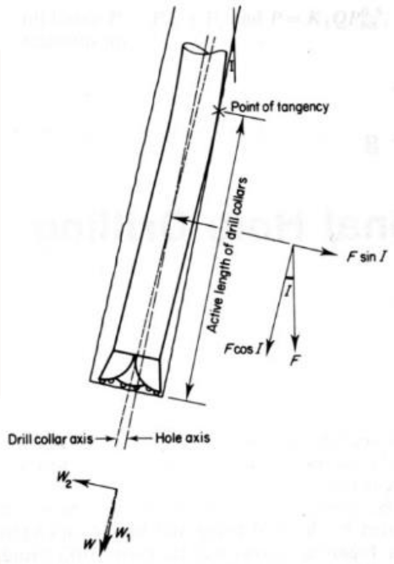
Causes of well trajectory changes :

Deviation from the vertical well axis e.g.:

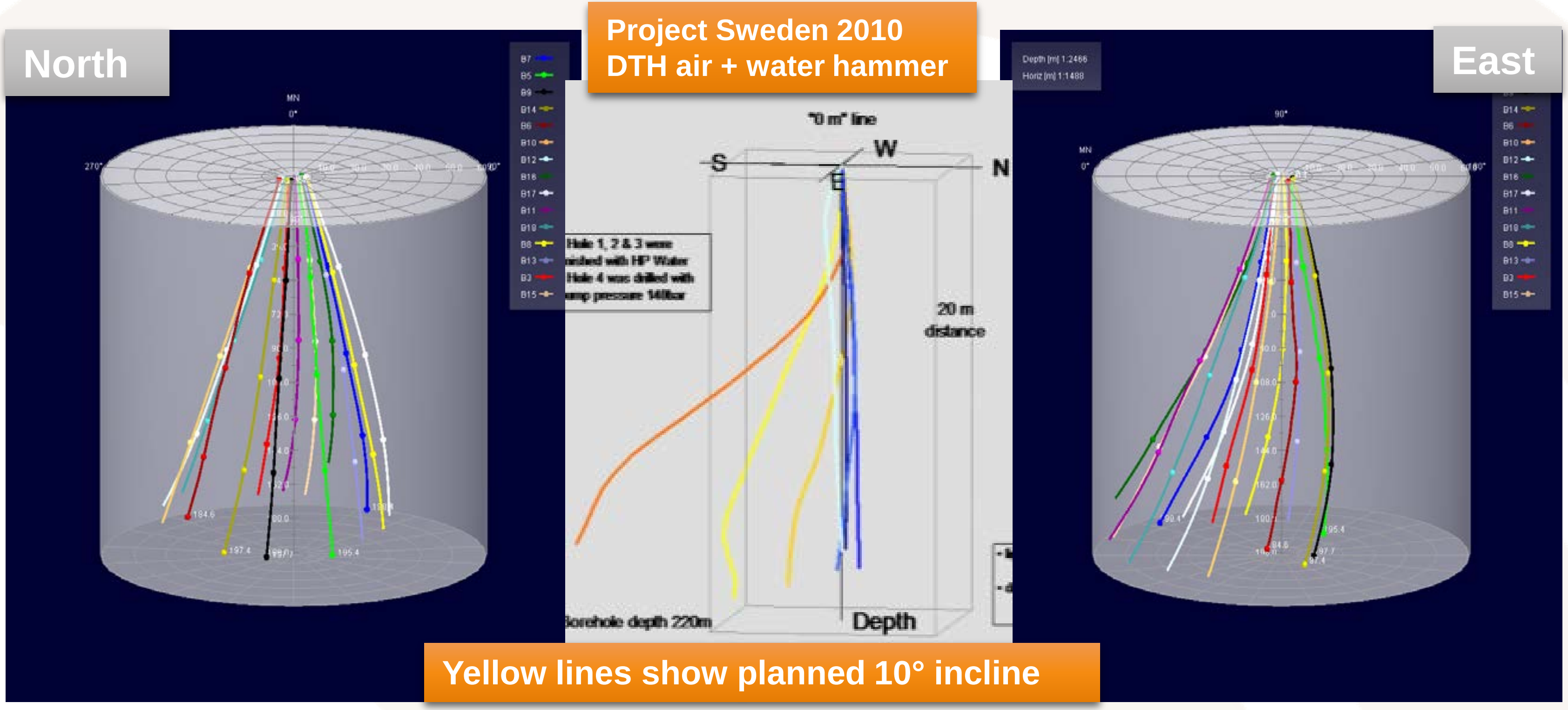
- Steep, inclined layering of geological planes
- Change of rock hardness
- (Too) high WOB (bit pressure) → "bending" of the drill string -



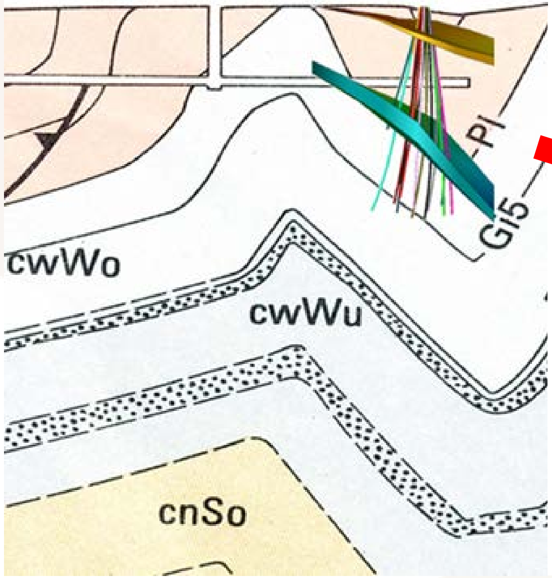


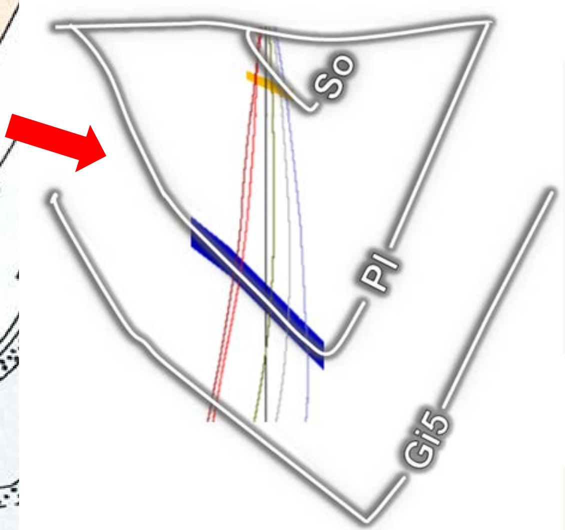


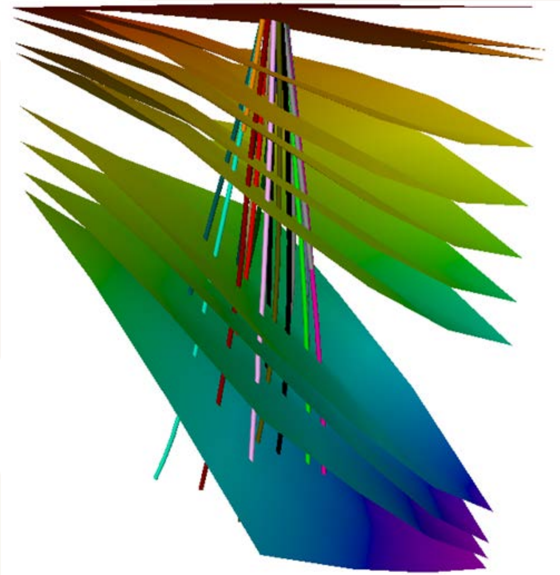
Well trajectory: “straight” drill path



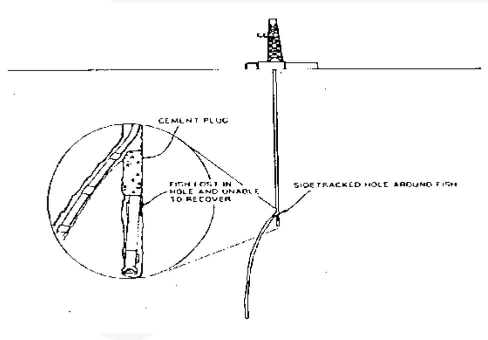
Well trajectory : deviation through Geology



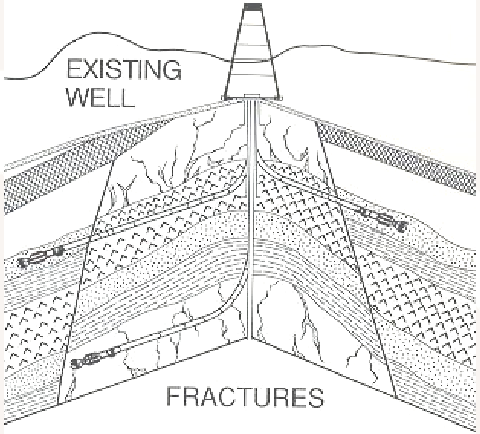




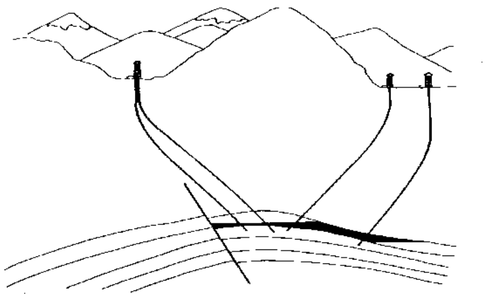
Trajectory changes - other



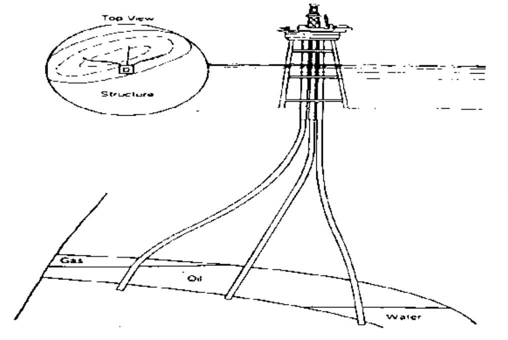
Side-tracking after unsuccessful fishing operations



Use an existing hole for more drilling targets

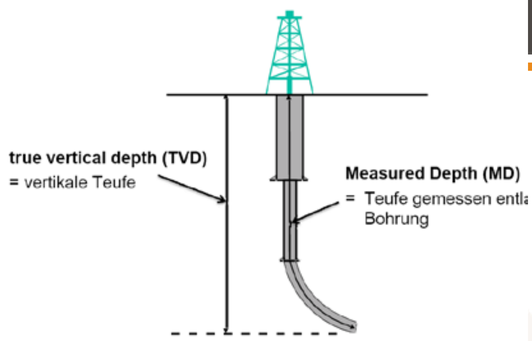


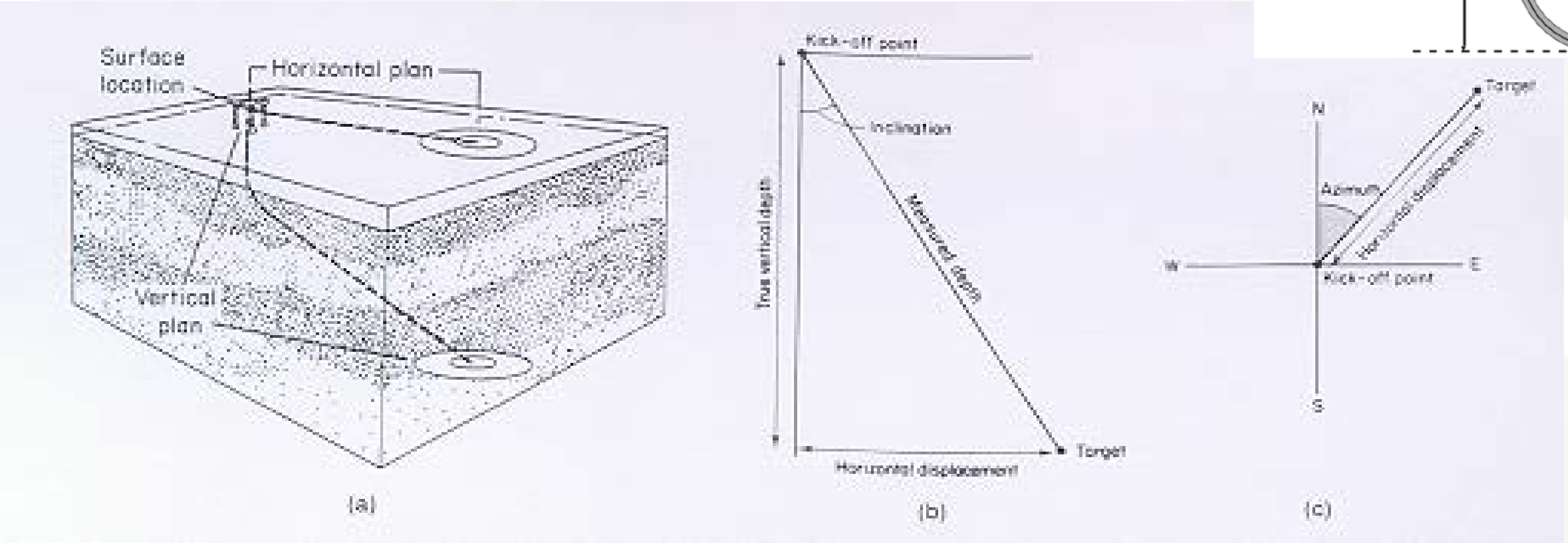
"Obstacles“, such as buildings, protected areas etc.



Development of reservoir from one drill pad

Trajectory of directional well

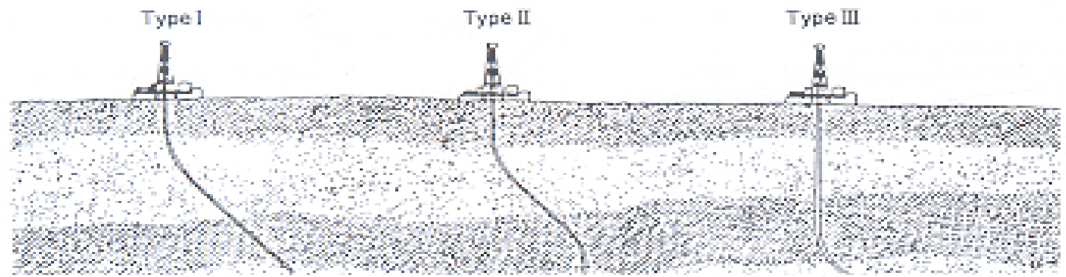




Directional drilling: a. three-dimensional view, b. Vertical section, c. Horizontal section. (Rabia, H. 1985; p153)

Types of well trajectory

- **Vertical hole:** no intentional deviation of the hole from the vertical axis
- **Directional well type 1**: “J” type, kick off in low vertical depth, directional drilling with constant inclination angle to the target (reservoir)
- **Directional well type 2:** "S" type, kick off in low vertical depth, directional drilling with constant inclination angle; redirection to vertical
- **Directional well type 3:** like type 1, but kick off at greater depth



Types of directional wells (Rabia, H. 1985; p154)

Kick-off methods - Whipstock

Whipstock characteristic:

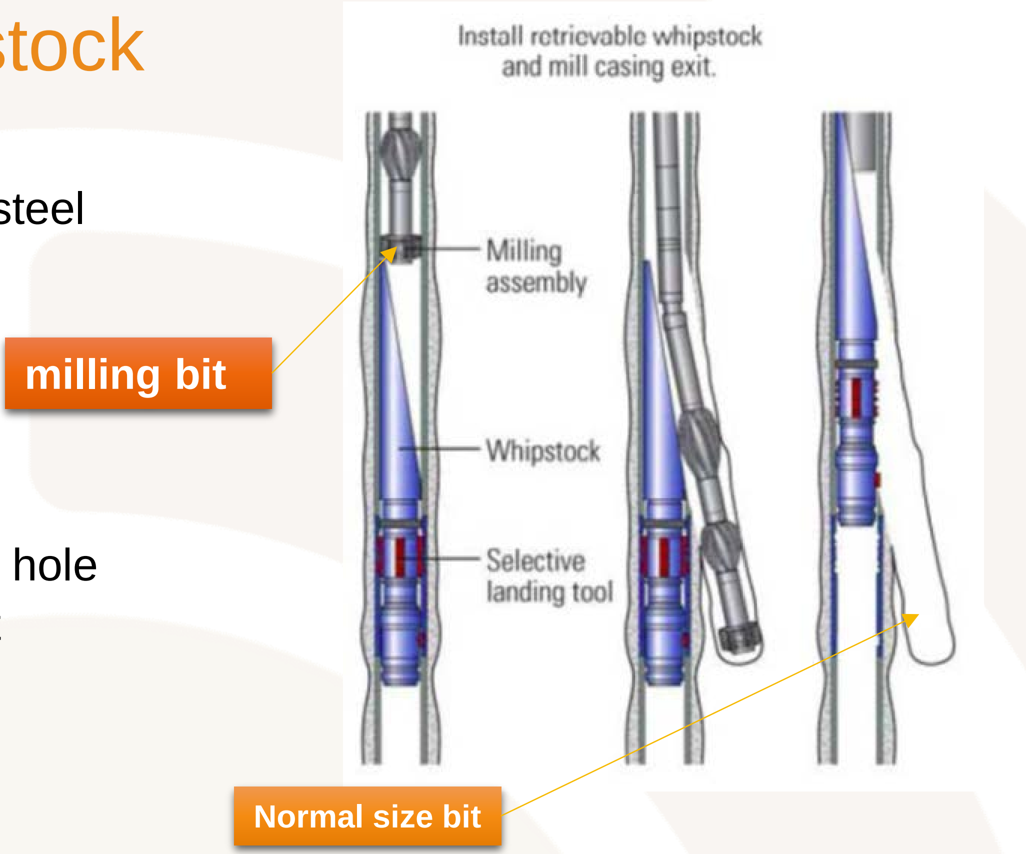
- made of manganese or chrome-nickel steel
- oldest directional drilling technique
- reliable, but time consuming

Operation method :

- Set a whipstock
- Use small bit to mill + drill new, inclined hole
- commence drilling with reg. size drill bit

Problem:

- Maintaining the allowable inclination



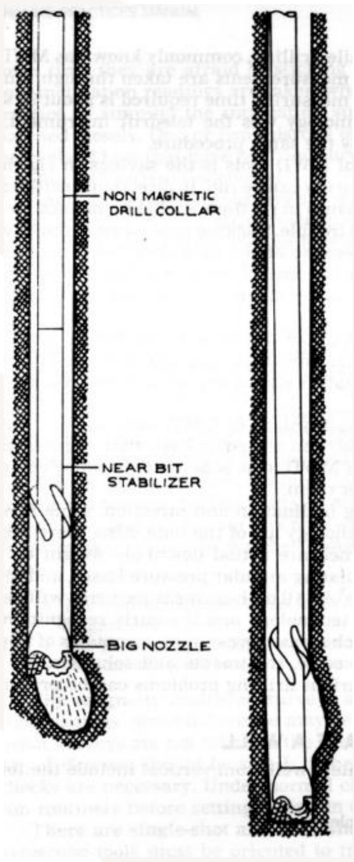
Kick-off methods – jetting

Directional drilling with direct use of drill bit’ jets

Dependent on the formation hardness:

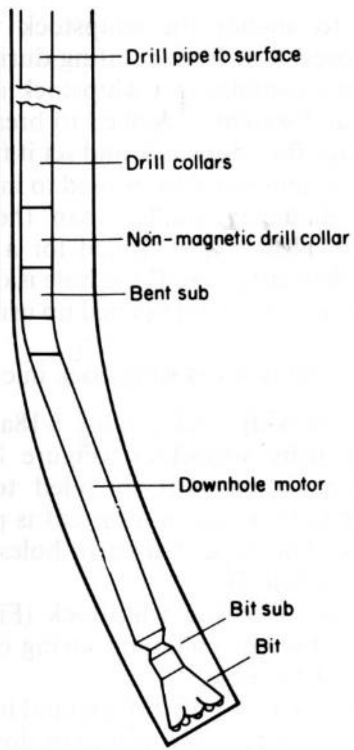
- ideal for soft formations
- unsuitable for non or weakly consolidated formations

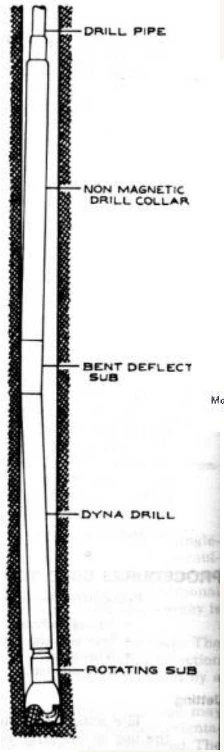
Problem: Maintaining the max. permissible inclination

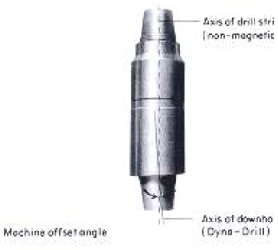


Kick-off with down hole motors

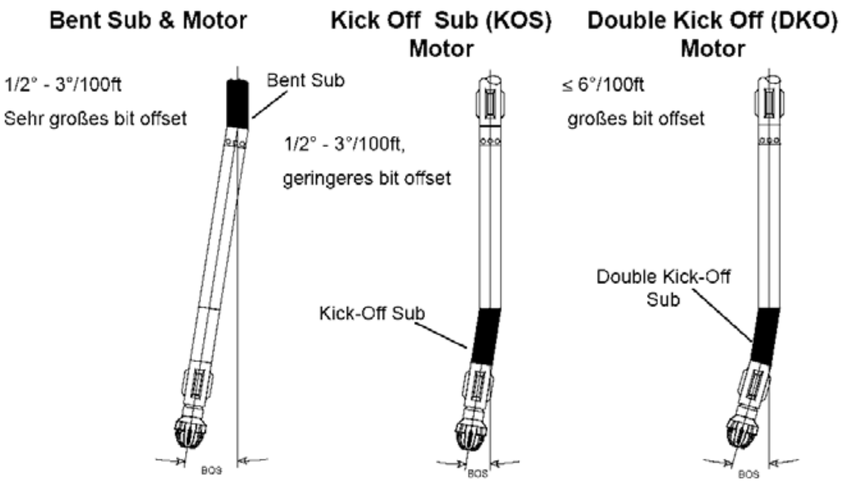
Directional drilling with down hole kick-off motors and bent sub.



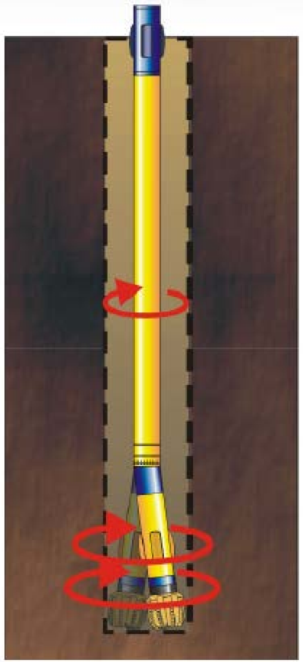


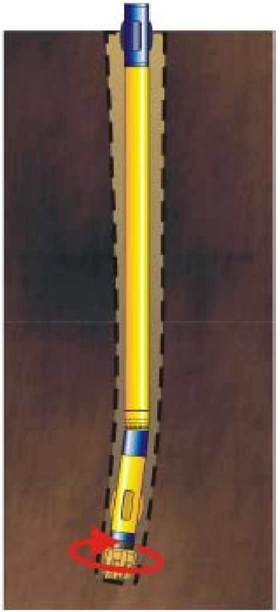


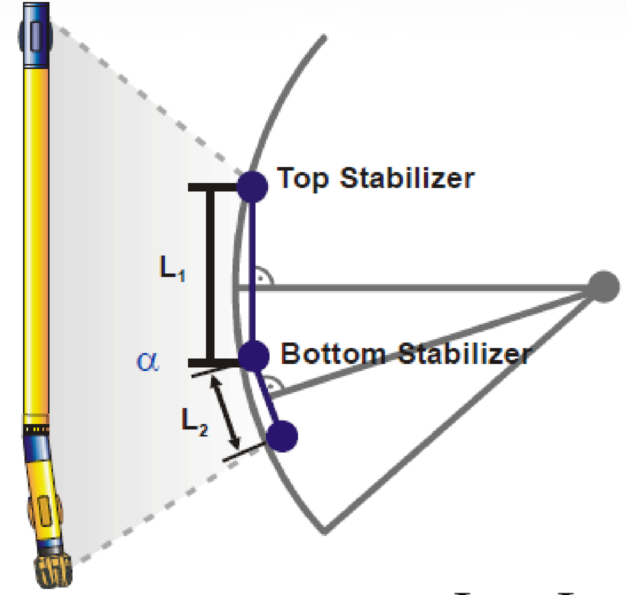
Bent sub. (Rabia, H. 1985



Steerable down hole motors







$$R = \frac{L_1 + L_2}{2 \cdot \sin \alpha}$$

Steerable Motor Drilling

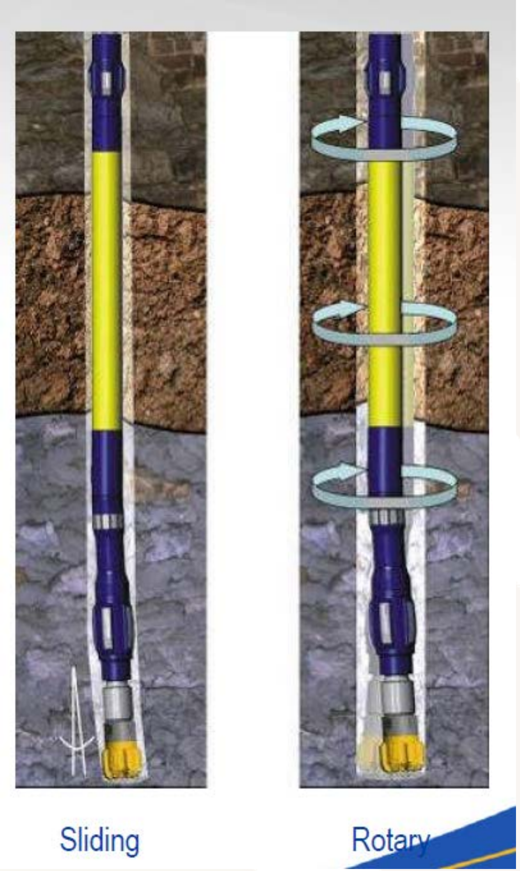
Steerable Motor Drilling

Pros

- High ROP when rotating ahead
- Power directly at the bit
- LWD partially decoupled from bit dynamics
- Good PDC bit operating parameters

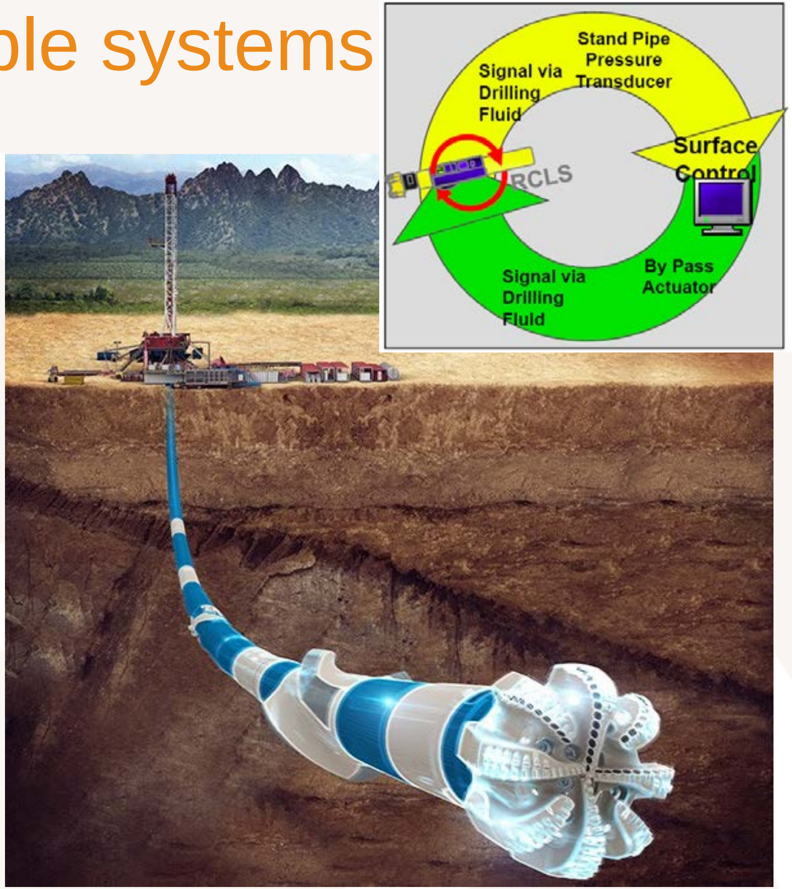
Cons

- **Sliding for directional control:**
  - **Low ROP**
  - **Hole cleaning issues**
  - **Torque & drag issues**
- **Not downhole adjustable**
- **Drill string RPM limited by motor bend**
- **Over gauge hole in rotary mode**
- **LWD sensor spacing from bit**

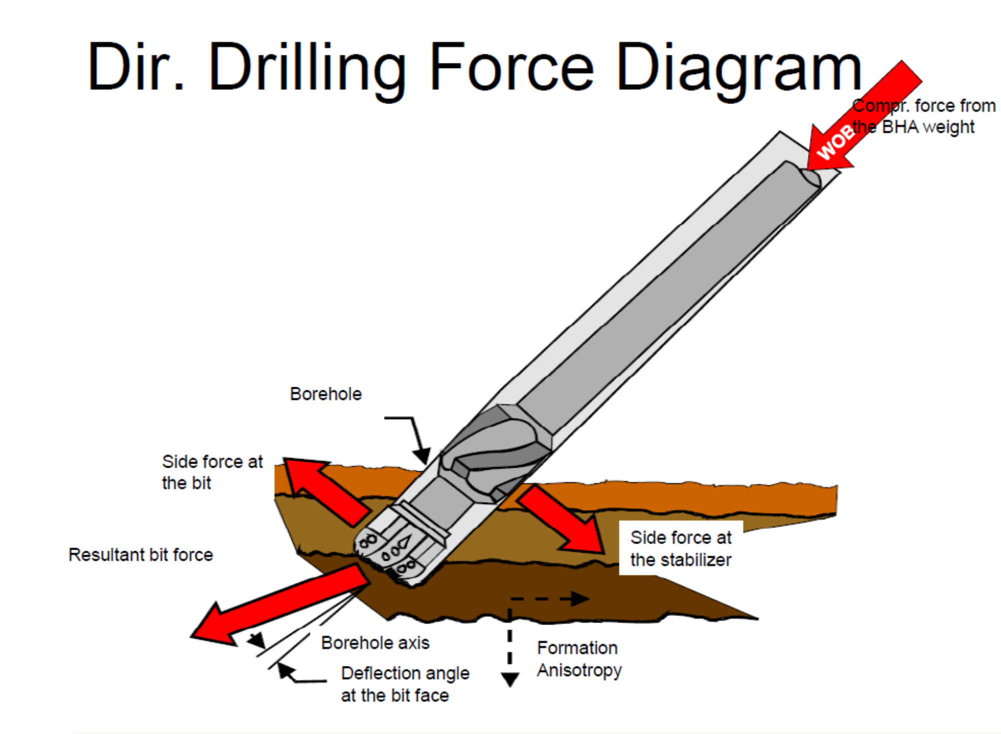


down hole motors – rotary steerable systems

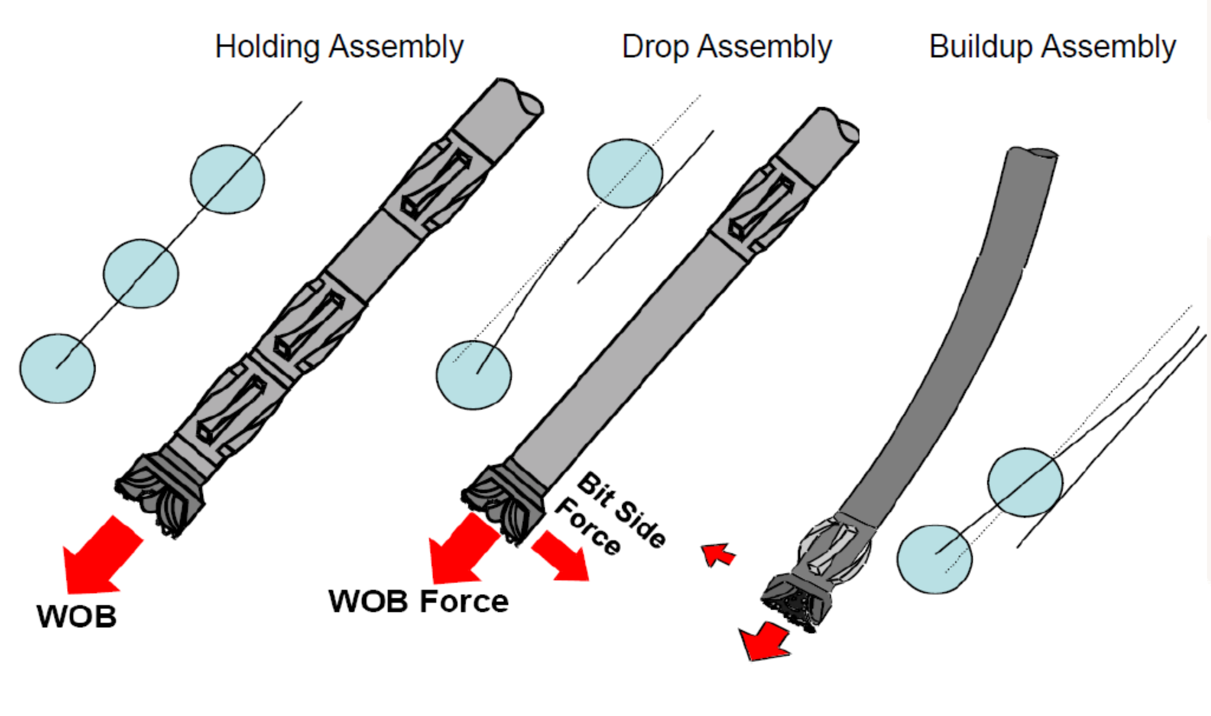
- A direct drill bit drive
- Most modern technology
- Very precise alignment
- High dimensional accuracy
- No additional roundtrips
- No problems with cutting sedimentation
- Tilt angle: 0.5 - 2.5 °
- Slope transition controllable while drilling
- Combination with MWD tools



BHA : forces during inclined drilling operations

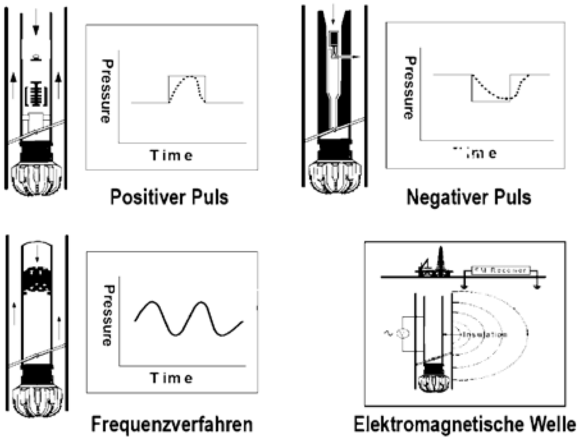


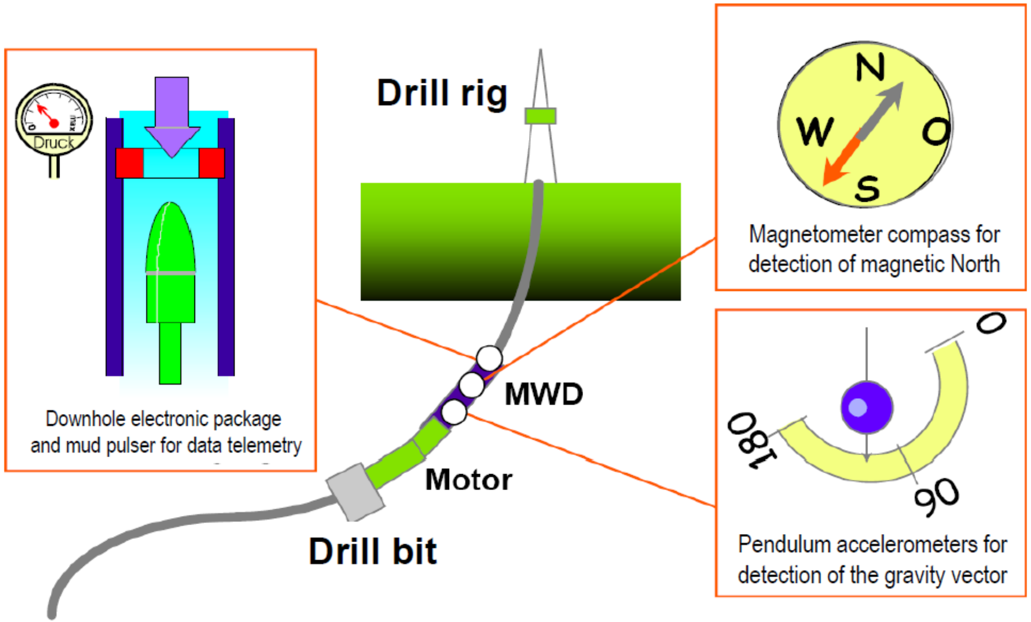
BHA directional changes through stabilizers



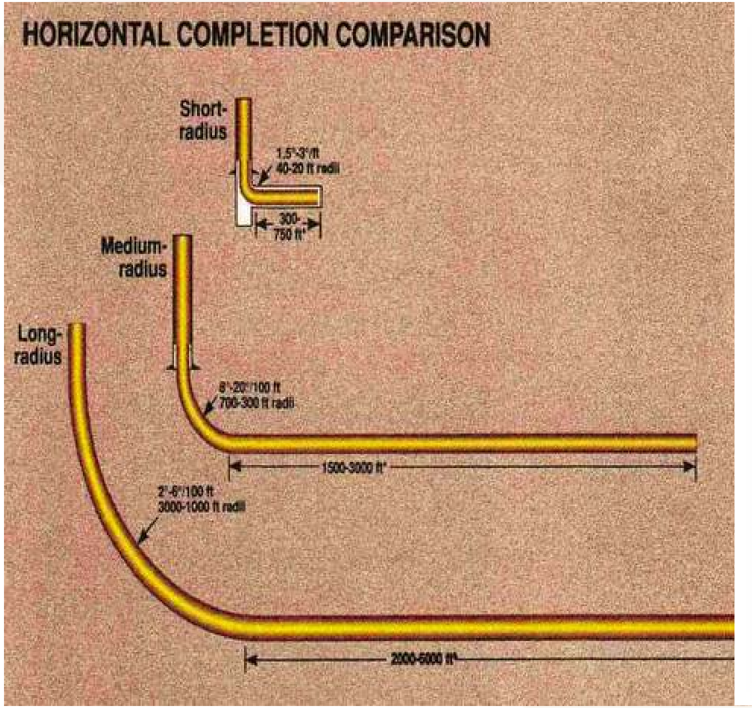
MWD – measurement while drilling and data transfer

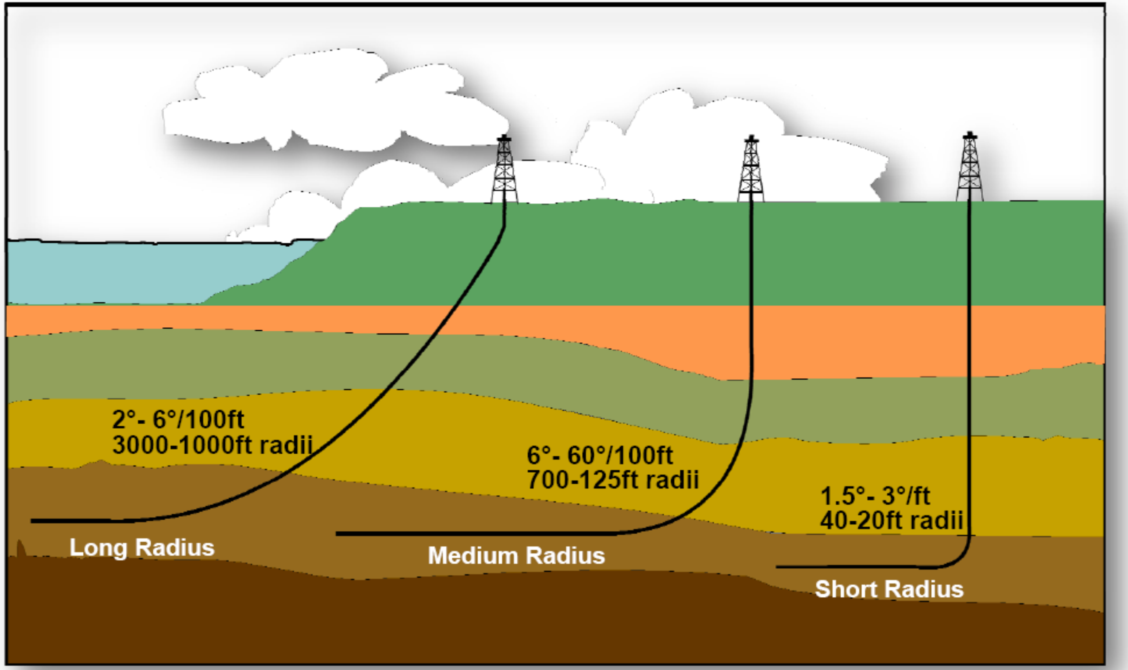
Mud pulse telemetry





Directional drilling : curvature + completion geometry



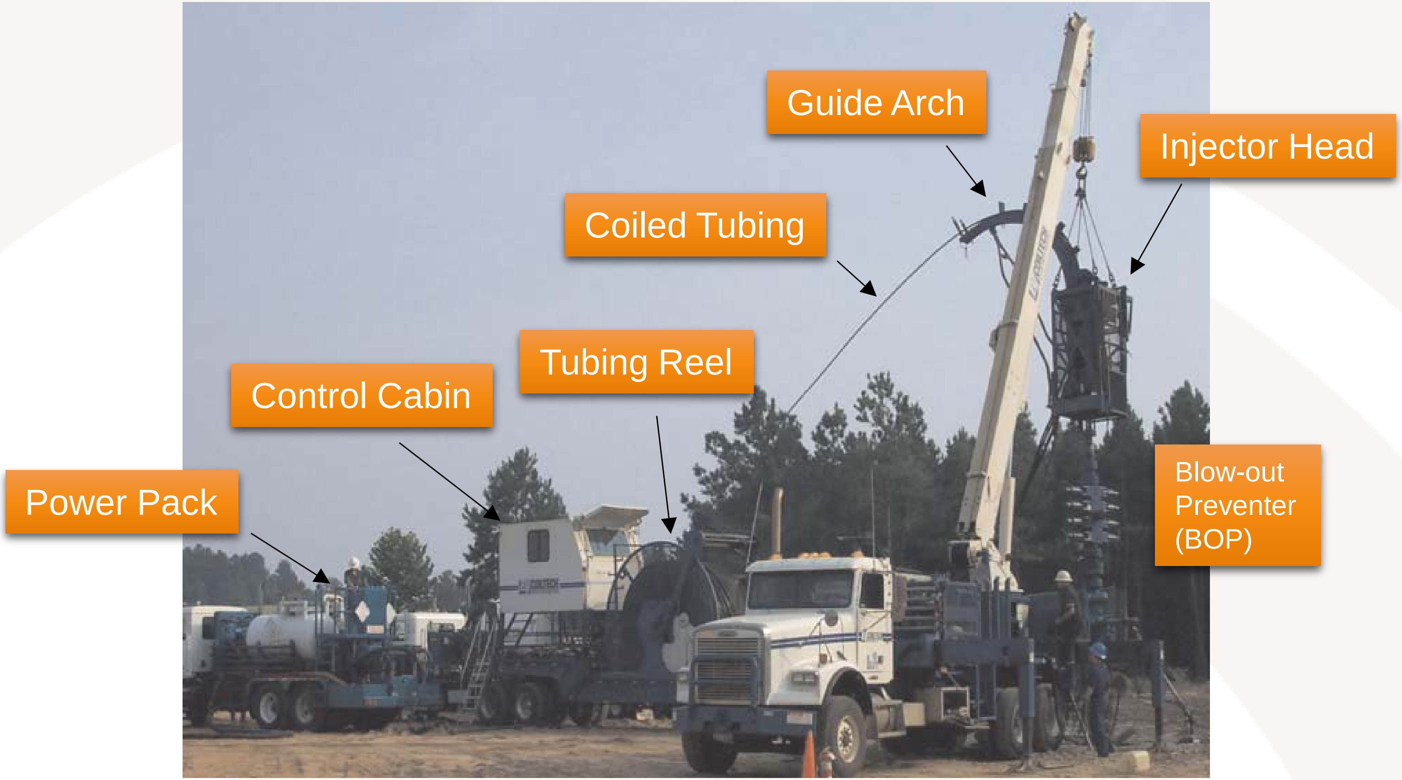


AutoTrak eXpress – Base Level RSS Service Rotary Steerable System (Baker Hughes)

- Automated 3D Rotary Steerable Drilling
- Standard Directional /Gamma MWD service
- Easy-to-operate downlink

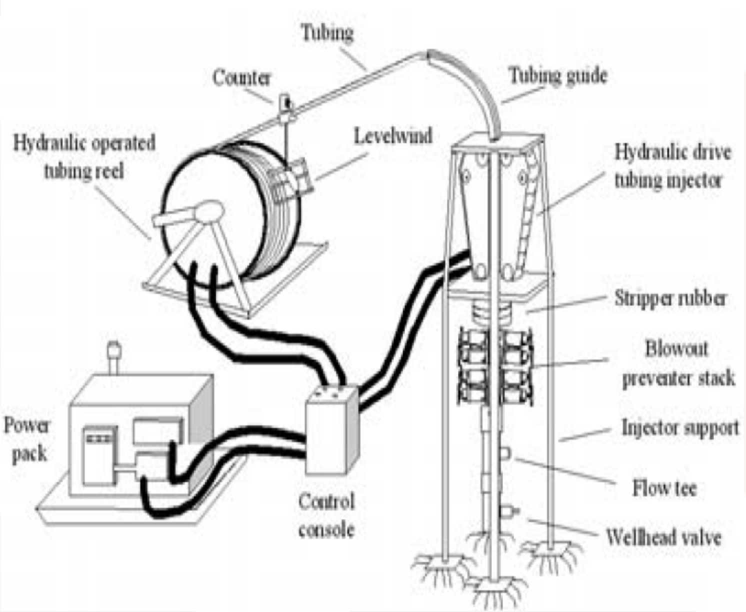
Coiled Tubing

Coiled Tubing Drilling Technology

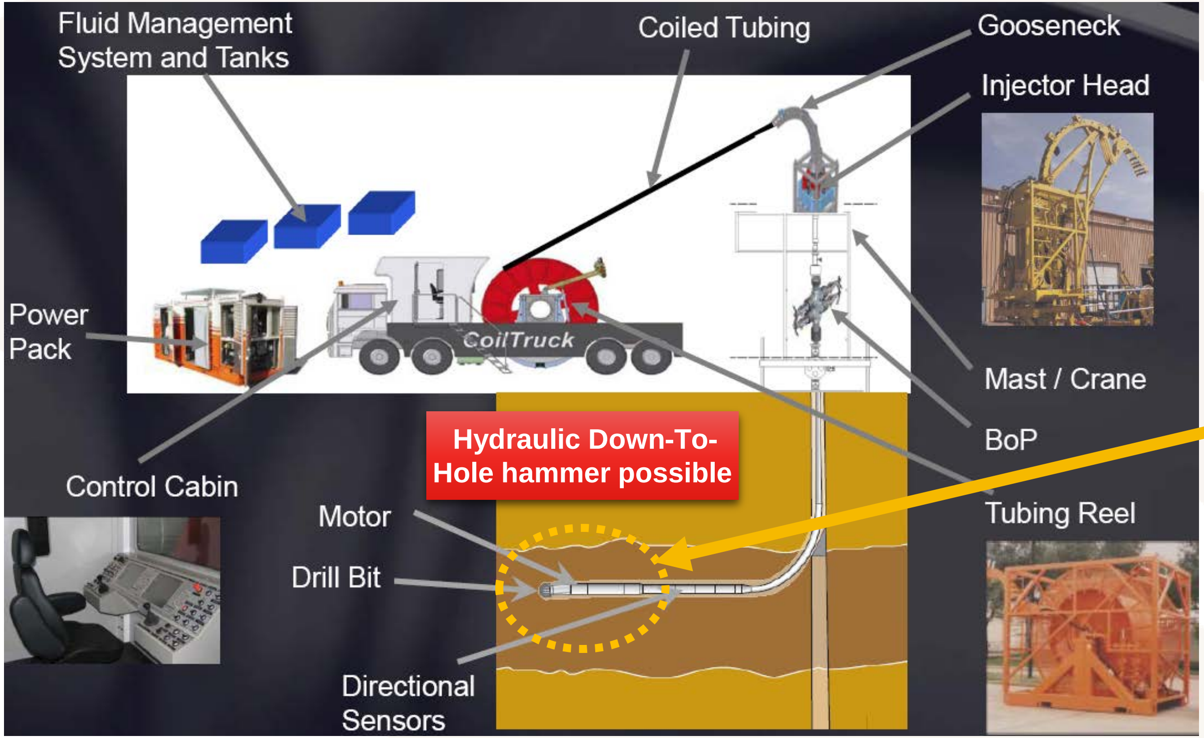


Coiled Tubing Drilling Technology

- More than 3 decades standard in oil & gas industry for service / intervention work
- Fast, short trip times, continuous operation
- experience with DTH hammer drilling in hard rock
- feasibility for „grass root“ drilling
- conductor, surface casing with BOP possible

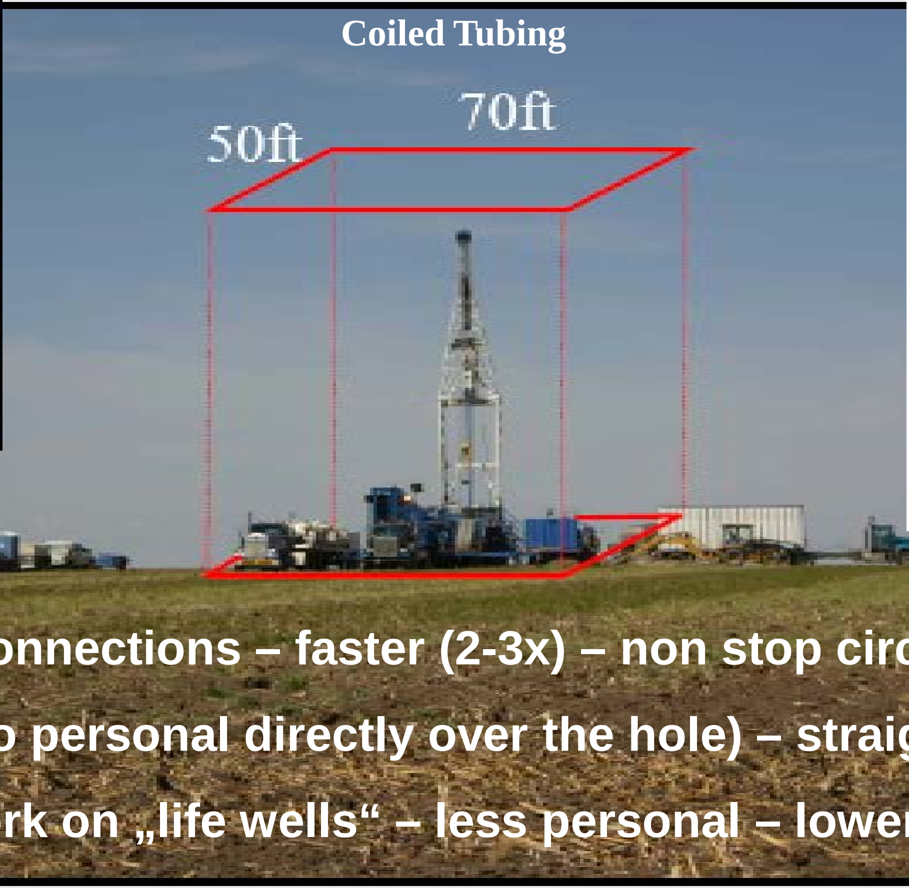


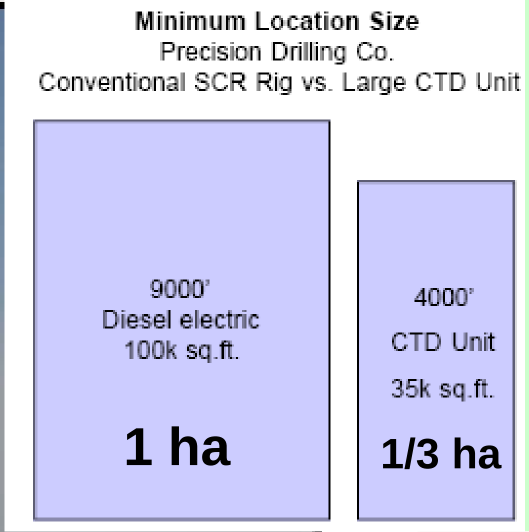
Coiled Tubing Drilling Technology



Hydraulic Down-To-Hole hammer drills 5 x faster than tri-cone or PDC bits

Coiled Tubing





No connections – faster (2-3x) – non stop circulation

safer (no personal directly over the hole) – straight drilling

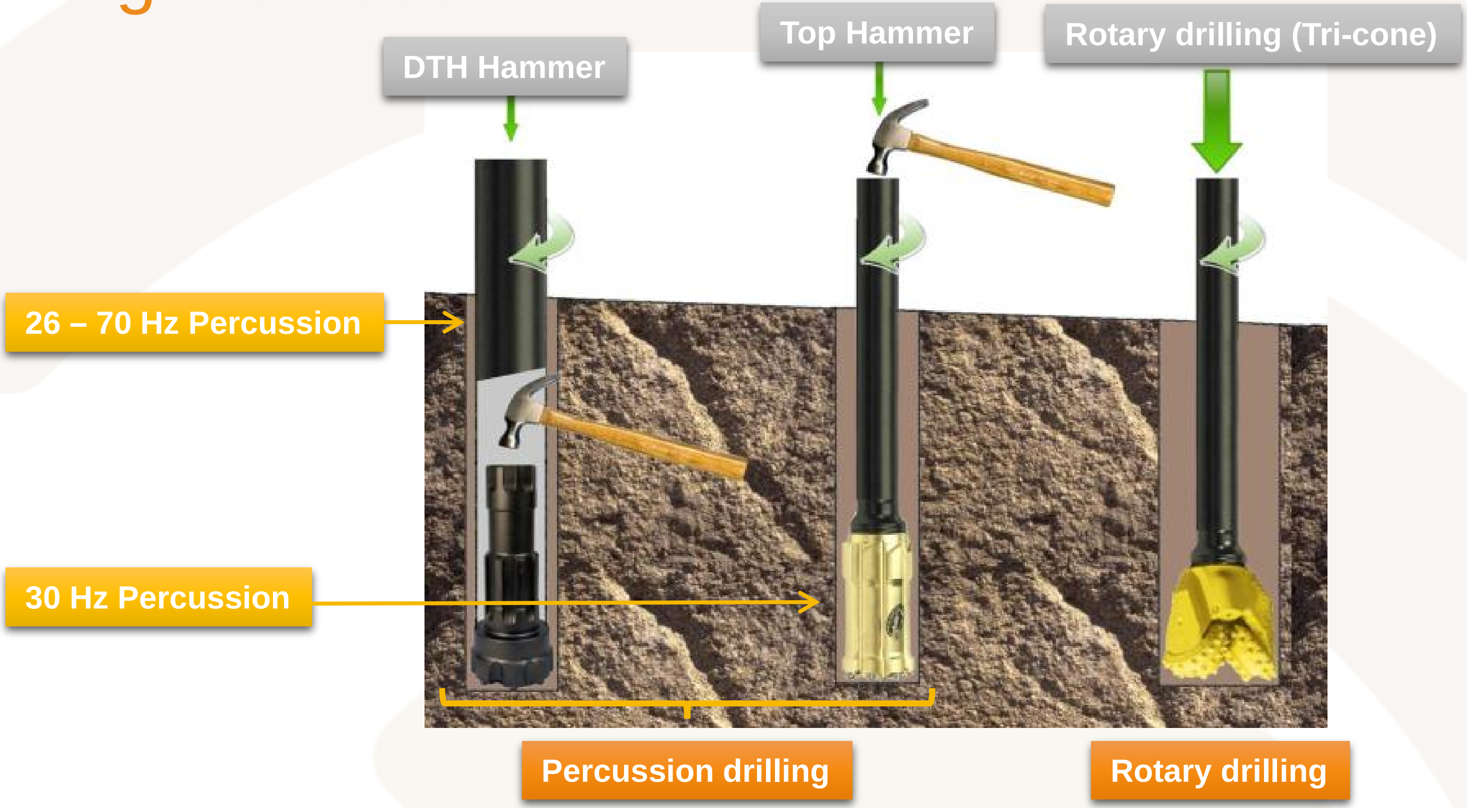
Work on „life wells“ – less personal – lower cost

Hybrid drilling rig

Down-The-Hole
DTH Hammer drilling

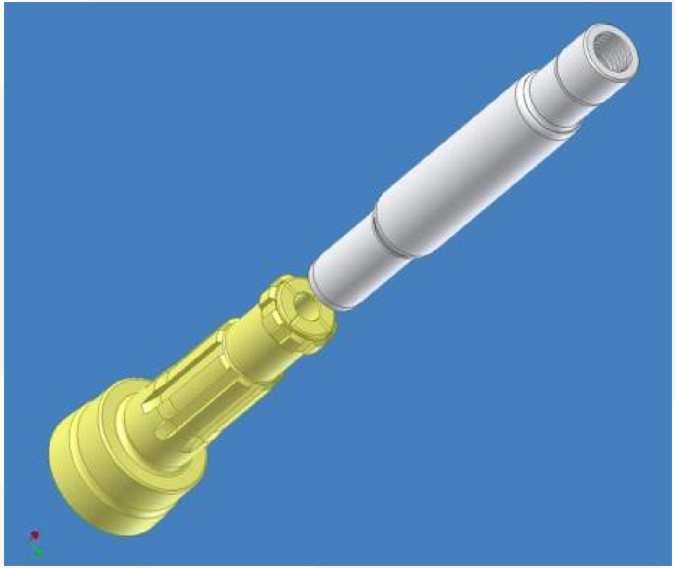
air + water / mud

Drilling methods



DTH water Hammer

- **High power output due to incompressible fluid**
- **high blow frequency**
- **< 70 Hz**



Water DTH Hammer

Two moving parts

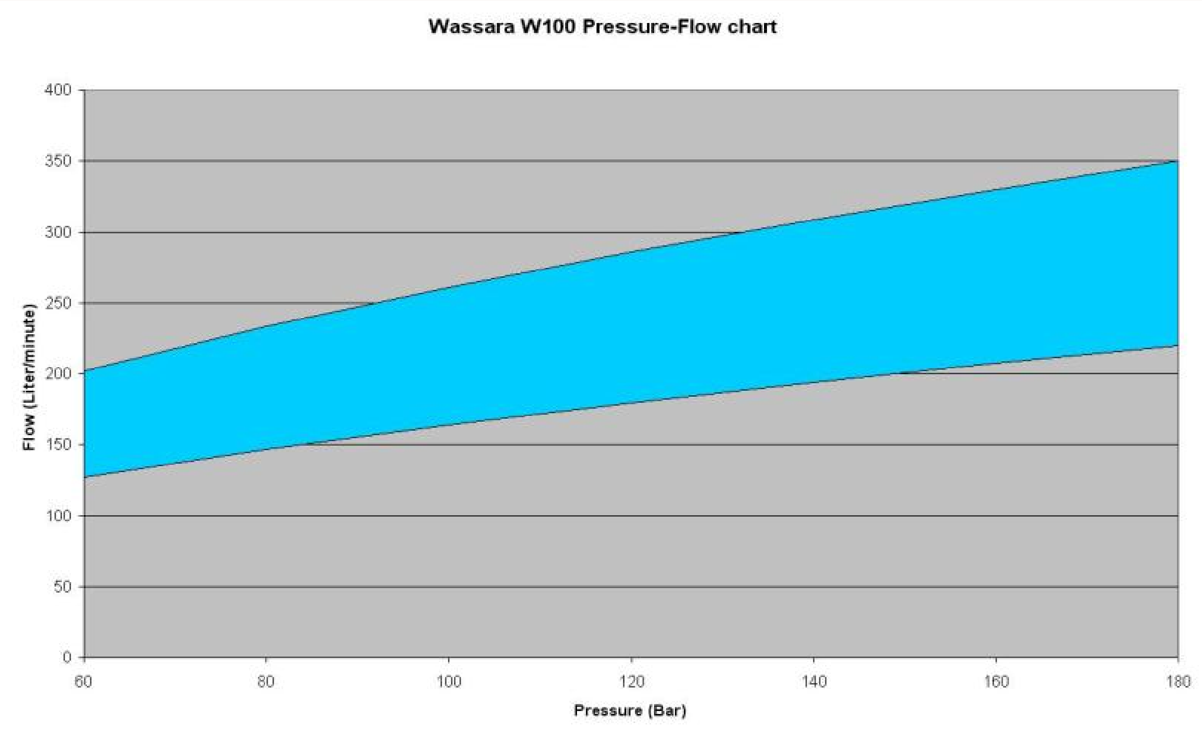
Piston

Valve

Data sheet for DTH Water Hammer W100

Hole dimension:	**Ø108-130 mm**
Hammer weight:	**56.5 kg**
Piston weight:	**8.7 kg**
Flow:	**220-350 ltr / min**
Pressure:	**< 180 Bar**
ROP:	**1 m / min in iron ore**
	0.7 m / min in granite
Blow frequency:	**65 Hz**
Output power:	**26 kW**
Installed pump power:	**110 kW**

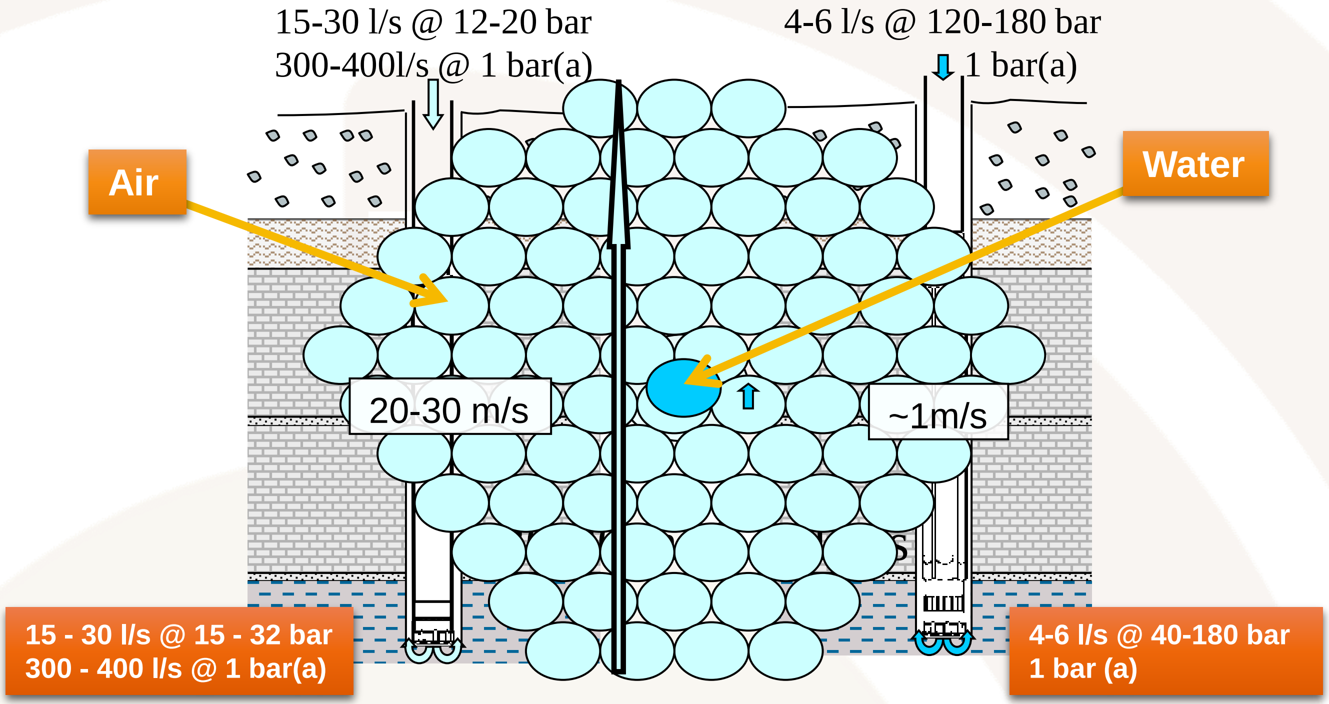
Wassara W100 Pressure vs. Flow chart



Water and Air DTH Hammer

Air (gas) is compressible:

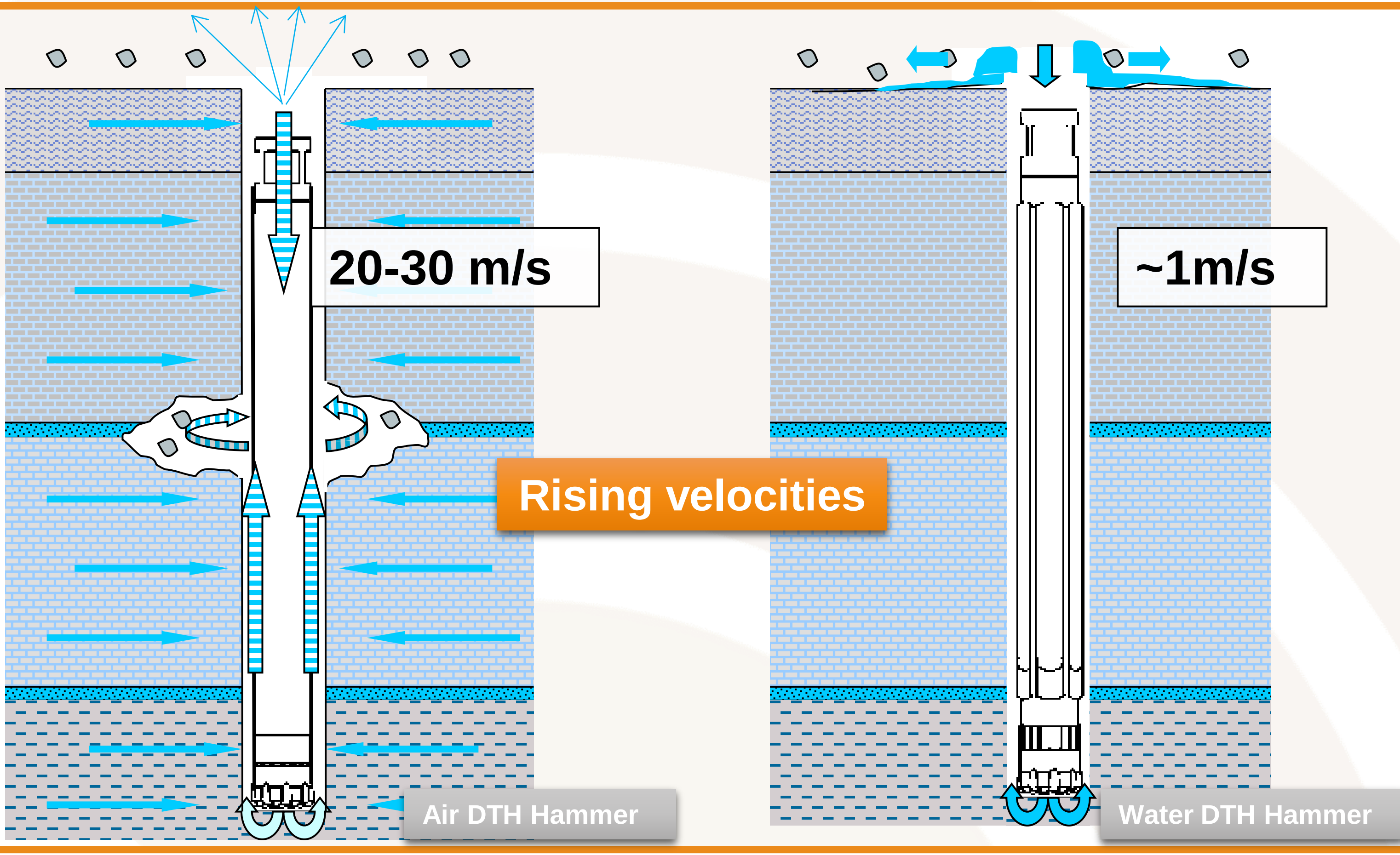
- approx. 3 – 4 x more power required
- very high return rates of cuttings
- depth limitation due to low specific density of air



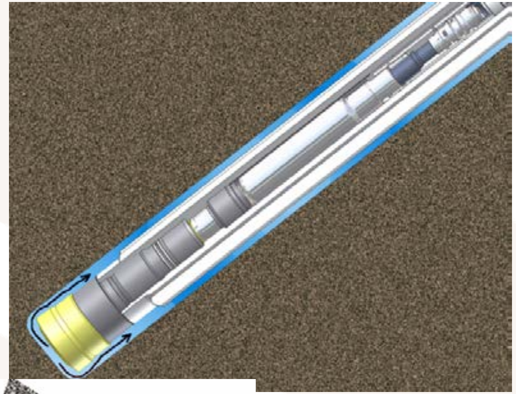
Rising velocity of the returns:

Large caverns voids, erosion

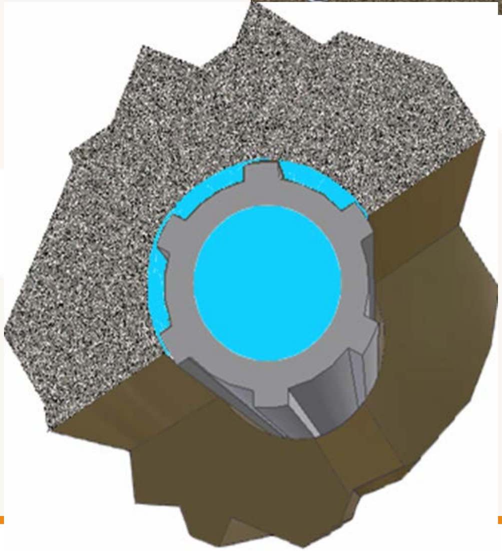
“Explosions” possible ground water will be pumped (“geyser”)



Water DTH Hammer

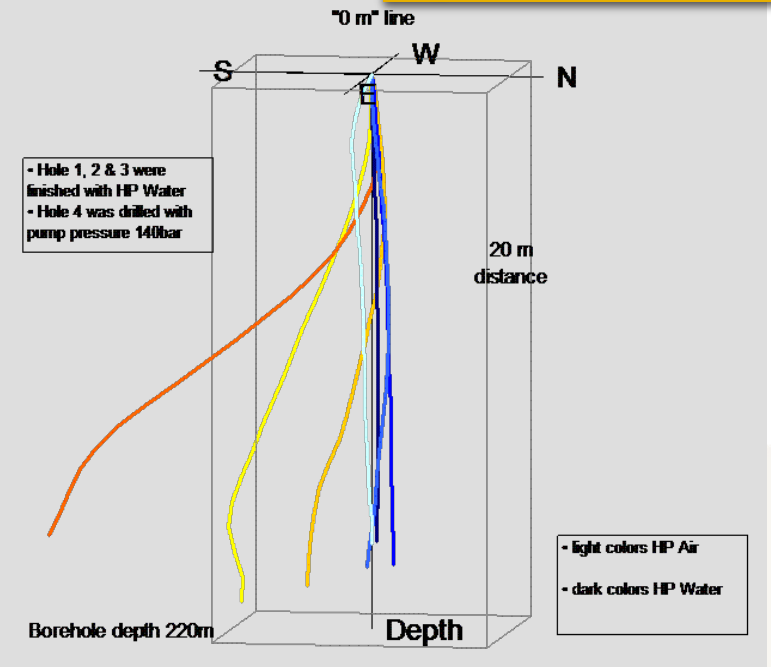


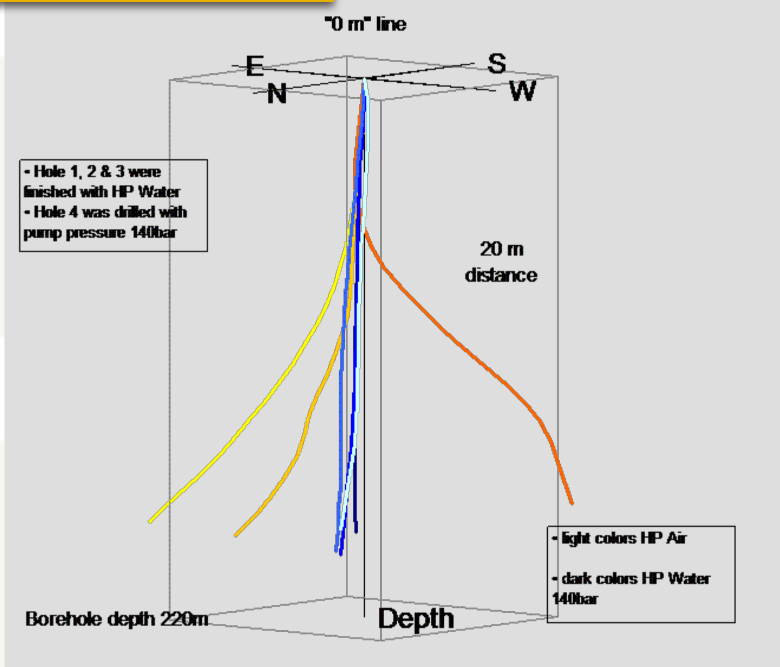
Straight holes by stabilized piston case with low clearance requirements due to fluid (water) flow instead of expanding gas



DTH Fluid Hammer – deviation from vertical axis

light colors: DTH air - dark colors: DTH water

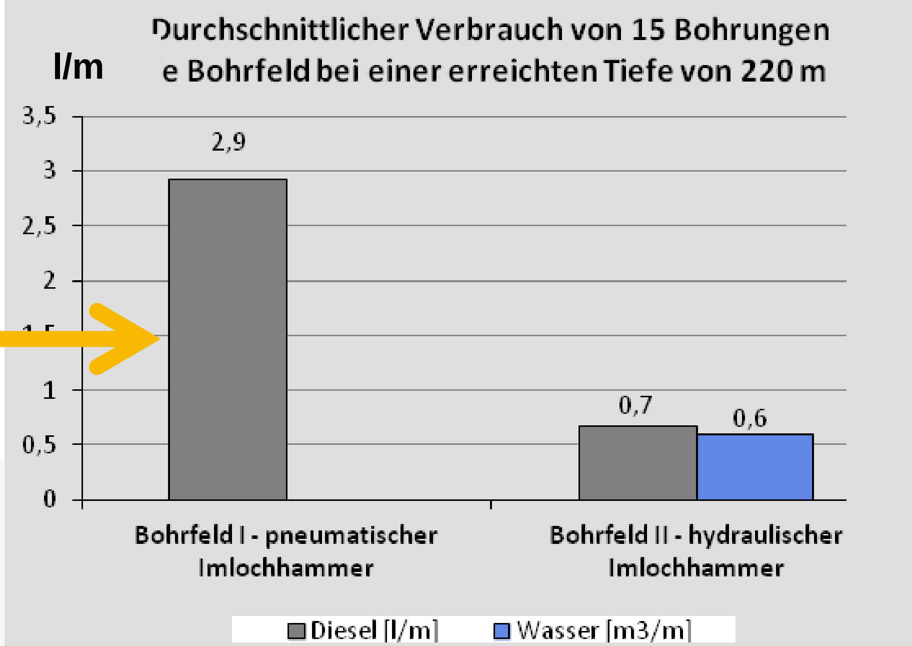




Comparison of DTH Hammers

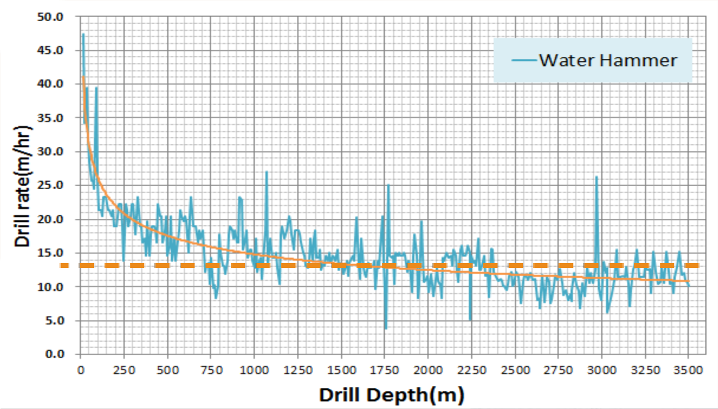
ROP approx. 0,7 m/min in > 250 MPa rock

DTH air hammer (compressor) requires 4 x more energy than DTH water hammer



Today: deep drilling with DTH Water hammer + Recirculation

- depth over 3.500 m; ROP >10 m / hr
- in Granite; 8 ½ in open hole; South Korea



No.	DISCRIPTION
1	Connection Sub
2	Cut-off block
3	Upper seal case
4	Valve
5	Valve Guide
6	Piston
7	Tube
8	Lower seal case
9	Bit Guide ring
10	Bit Guide ring A
11	Bit Guide Chuck
12	Hammer Bit

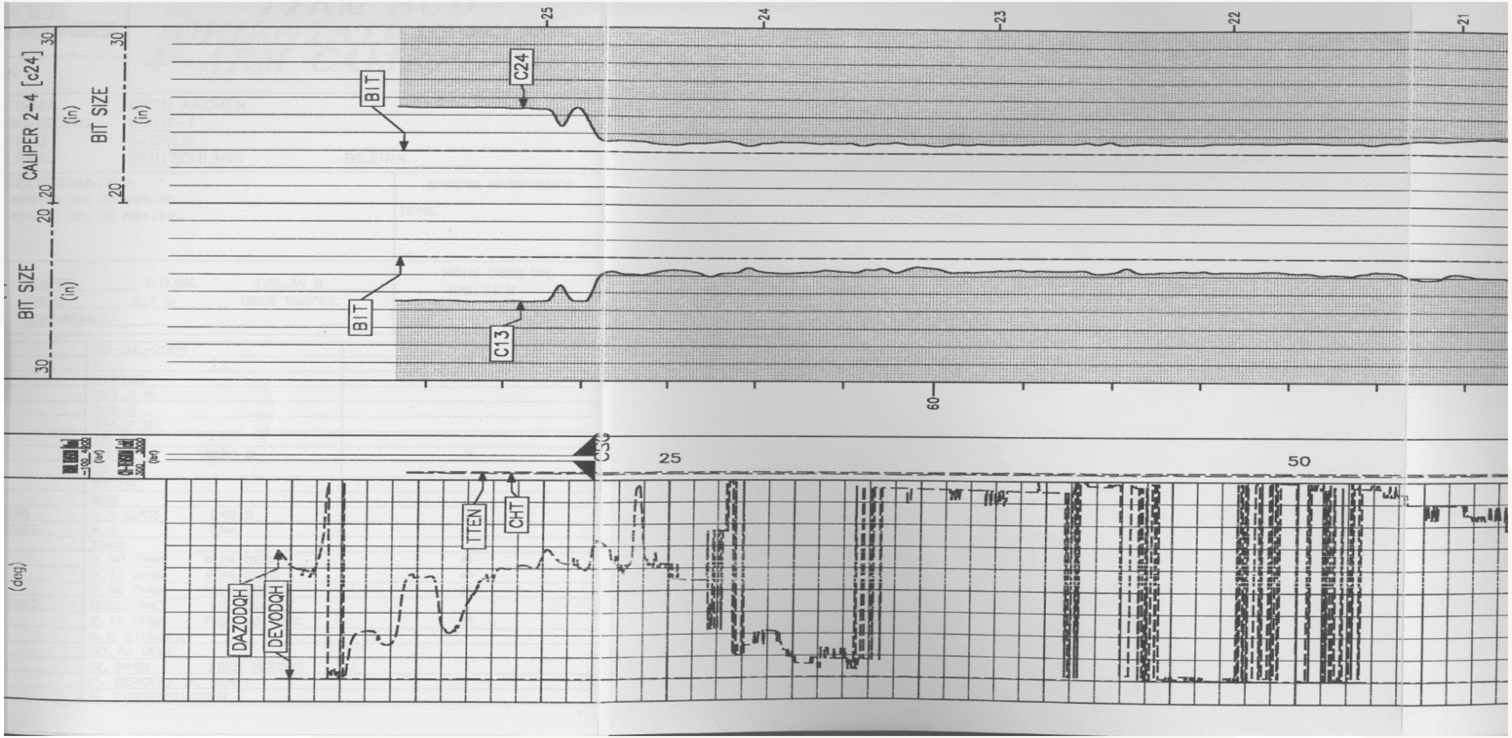
Logging, Coring , Geotechnical drilling

Logging truck

Wire-line measuring tools

- Check drilling / hole results
- Wireline, post run drilling
- Caliber Cal, diamter
- Cement – Bond – Log (CBL)
- Temperate (Temp)
- Deviation + Azimuth
- Gamma
- Televiewer
- Etc.

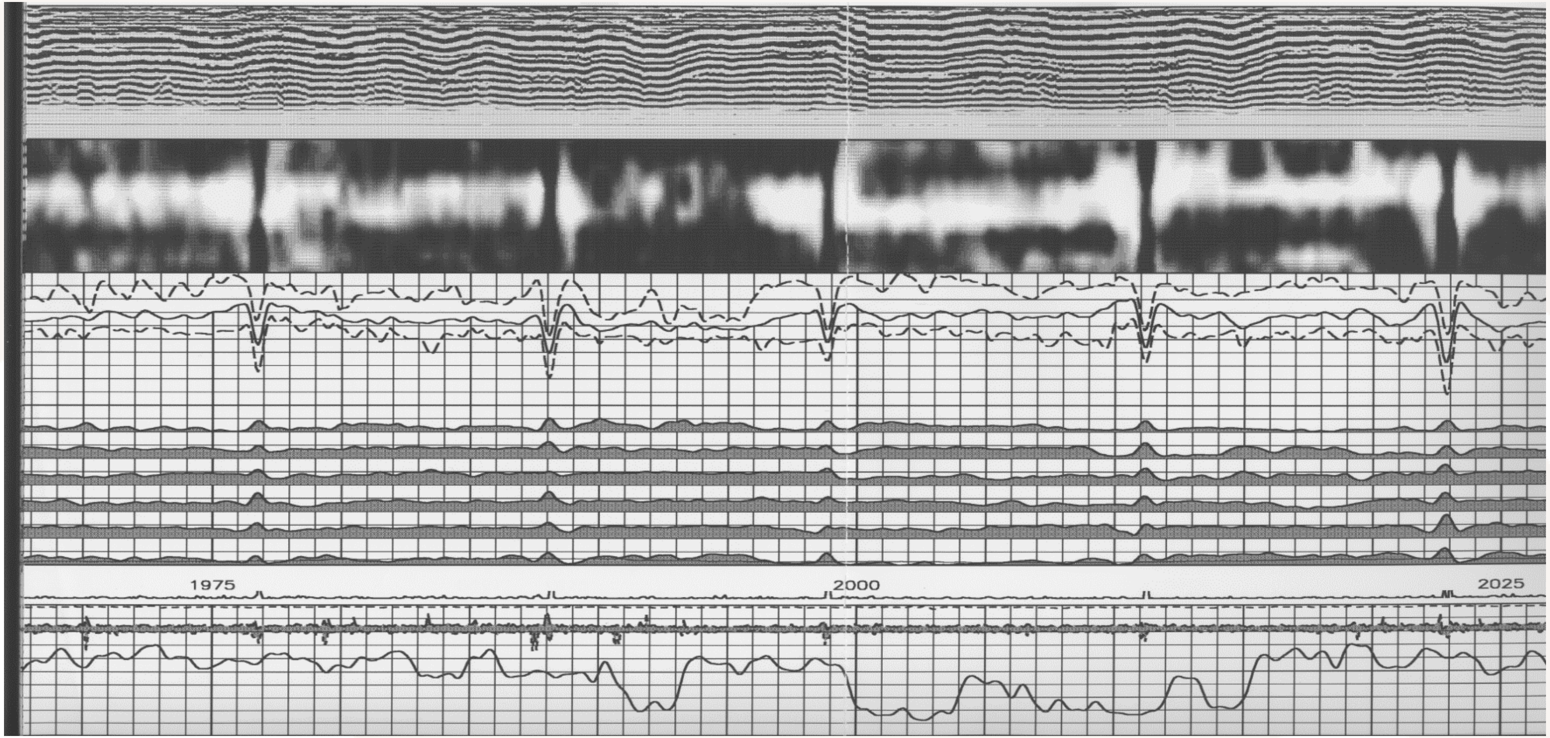
Caliper - example



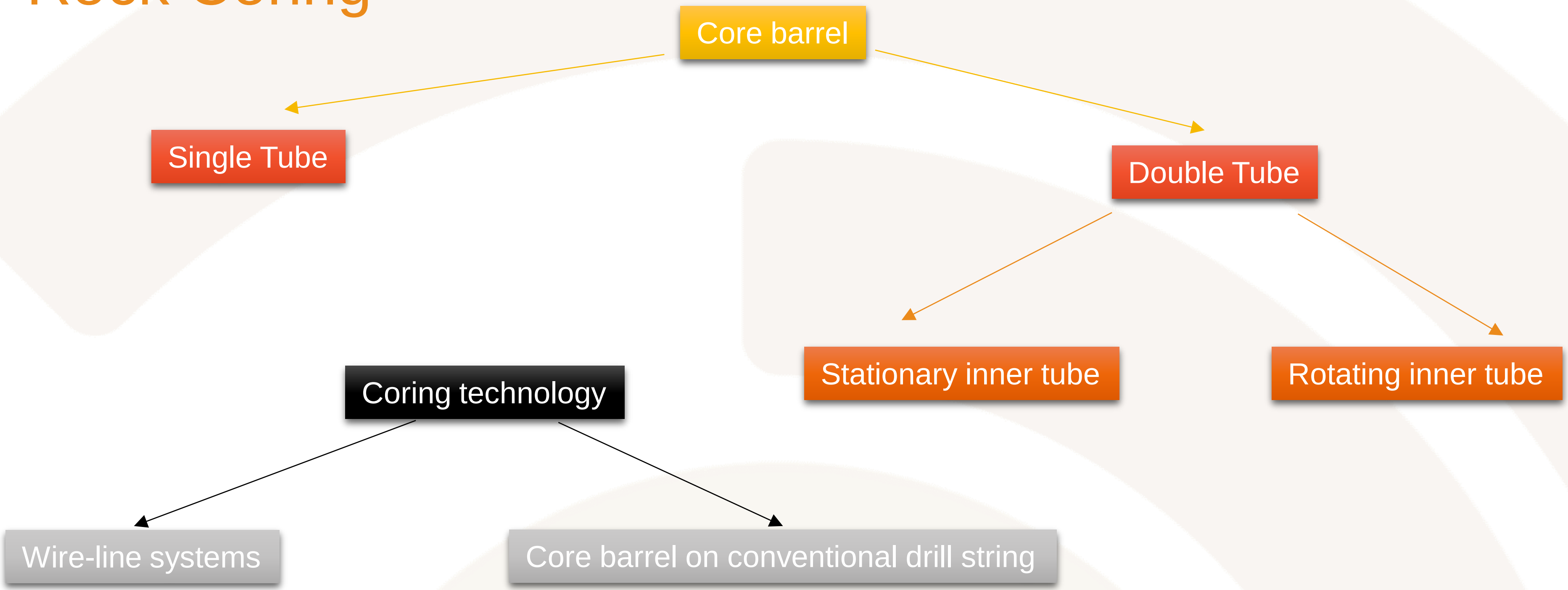
Cement bond logs - Acoustic logs

- Proper cement placement between the well casing and the formation is essential:
  - To support the casing (shear bond)
  - To prevent fluid from leaking to the surface
  - hydraulic bond: to isolate producing from water bearing zones
- Acoustic logs provide the primary means for evaluating the mechanical integrity and quality of the cement bond

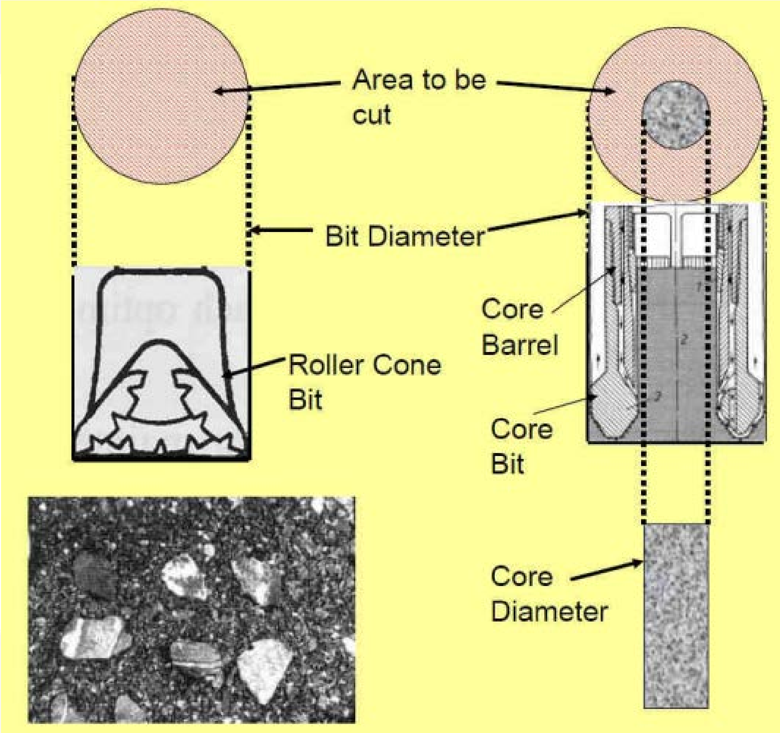
Cement Bond Log (CBL) – example



Rock Coring


Core barrel
Single Tube
Double Tube
Stationary inner tube
Rotating inner tube
Coring technology
Wire-line systems
Core barrel on conventional drill string

Conventional rotary drilling vs. coring

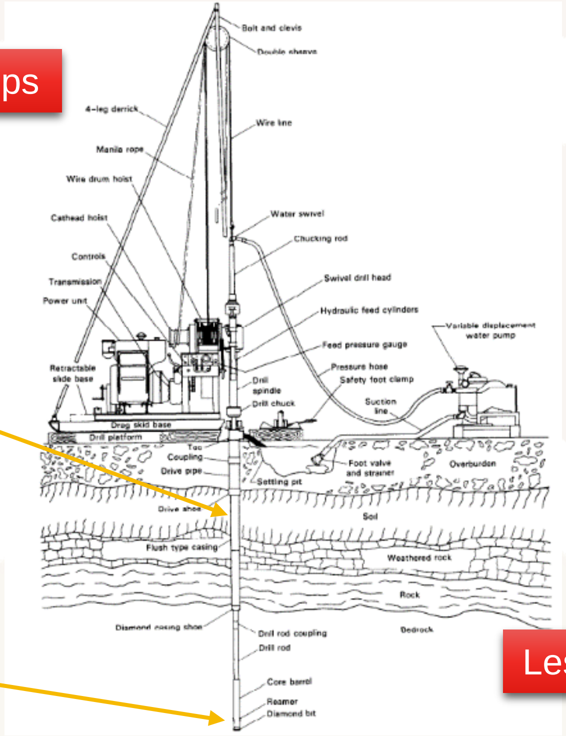


Diamond coring exploration system

No large mud pumps

Drill pipe might be used as casing

Diamond core bit



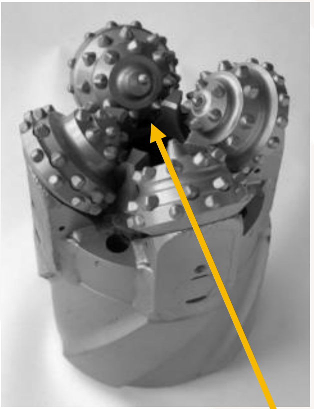
Less rig power

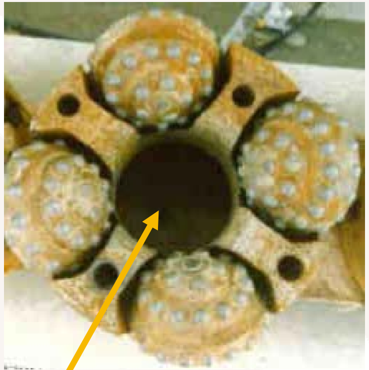
Core bits types

Diamond core bits

PDC core bits

4-Roller cone core bit





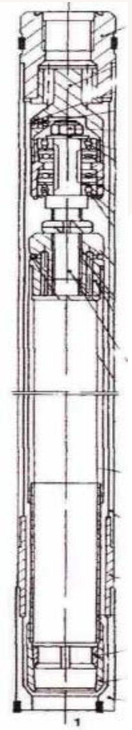
Space for core sample

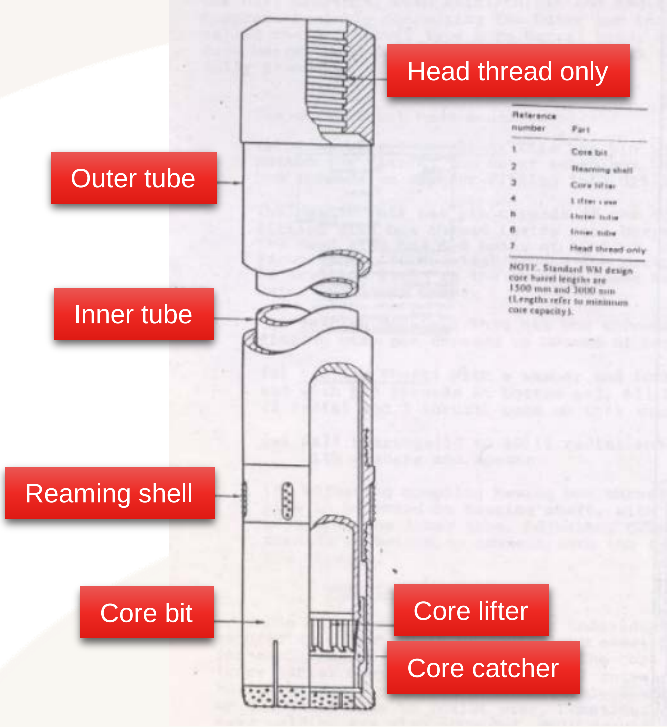
Core barrel disassembly and storage

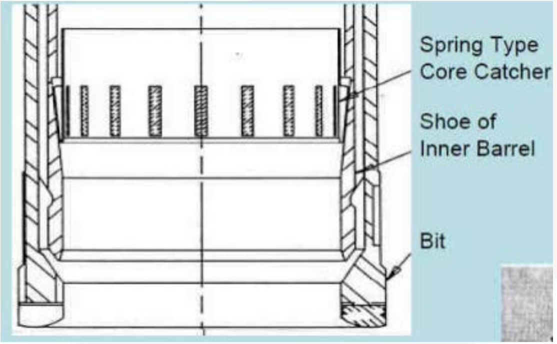
Core sample

Storage in wooden baskets

Dual tube coring barrel system





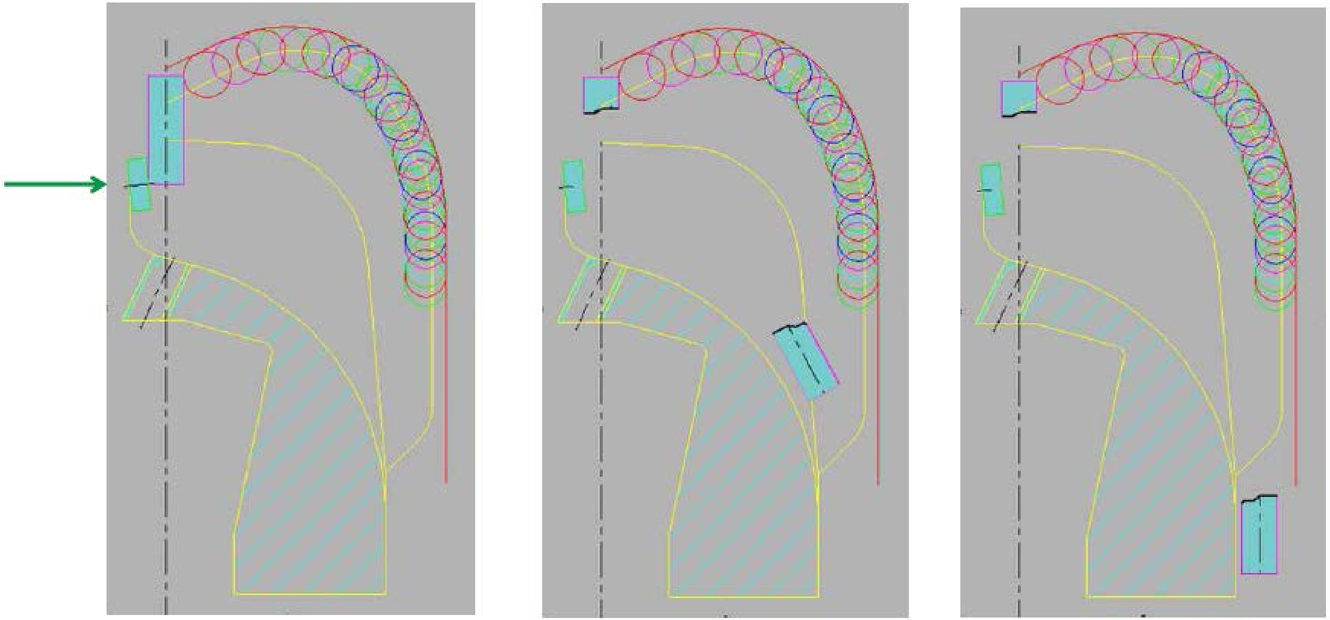


New coring solutions – microCORE

MicroCORE™ - Product Definition

- Fixed Cutter Drill Bits (PDC, Dual, Impregs)
- Partner: Total S.A. DBR (patent holder)
- Purpose: Generate micro-cores of formation while drilling
  - Increase the cutting efficiency → ROP
  - Improve the cuttings quality for formation assessment
- Applications:
  - Conventional development drilling program
  - Hard rocks, HPHT conditions
  - ERT
  - Impregnated application
  - Exploration
  - Driving System: Rotary-Motor-RSS-Turbine
  - Horizontal Applications

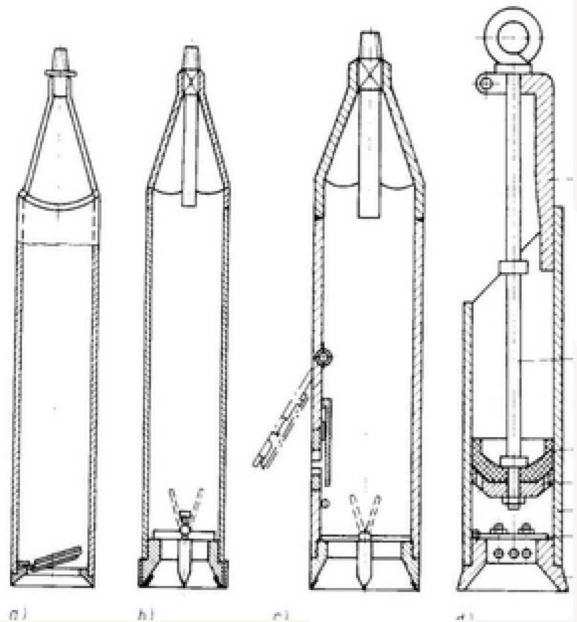
New coring solutions – microCORE



New coring solutions – microCORE

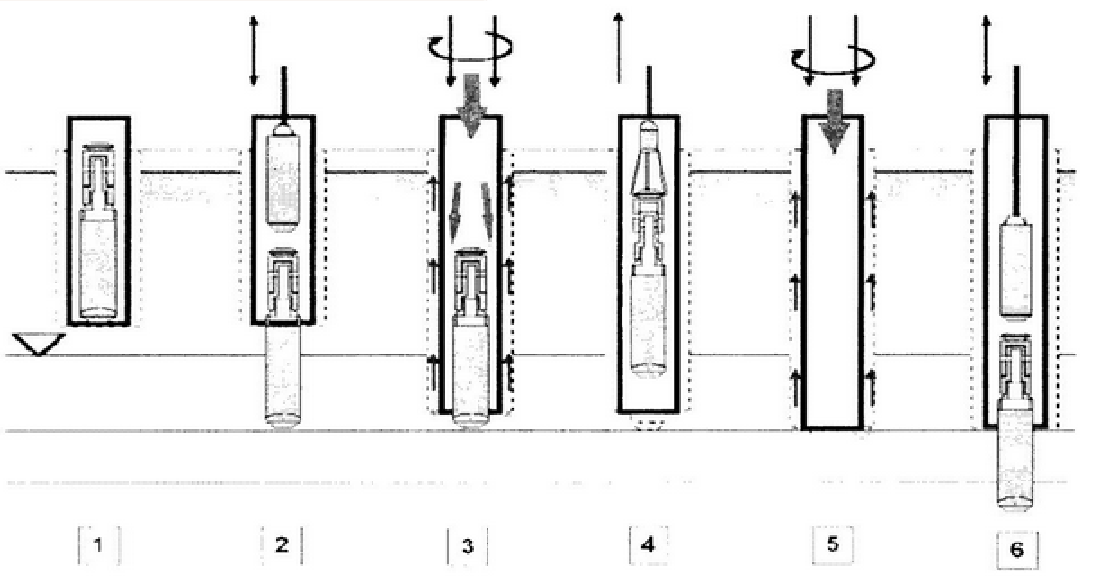
Geotechnical drilling tools

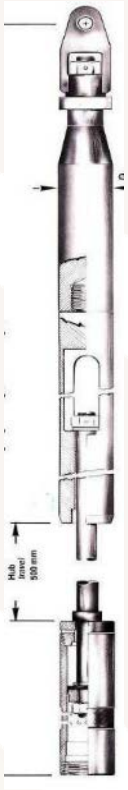
Cable „dry“ drilling technology

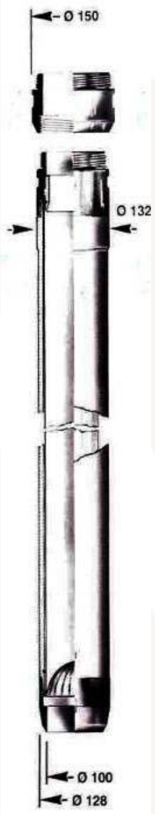


Cable drilling tools

Percussion and cable drilling tools







Geotechnical drilling

Top drive hammers

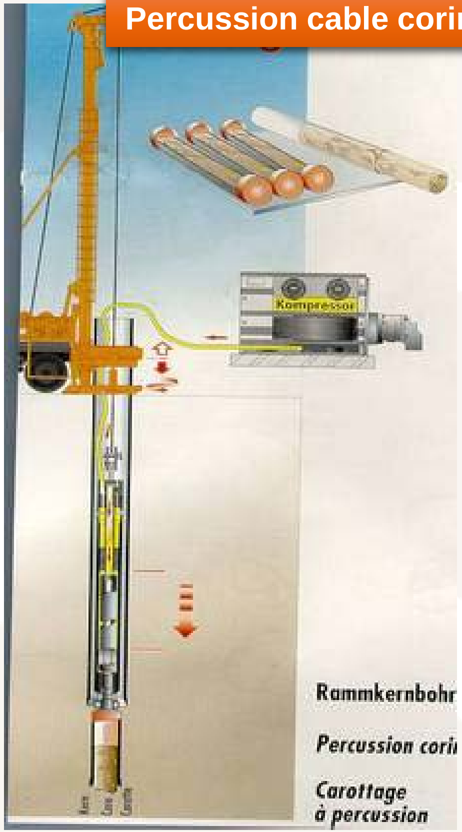
Direct push

No rotation

Rotation

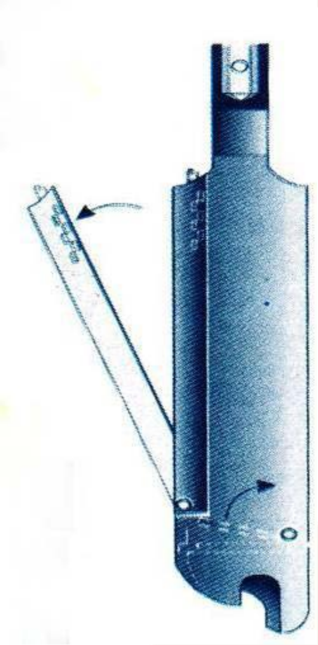
No drill mud system

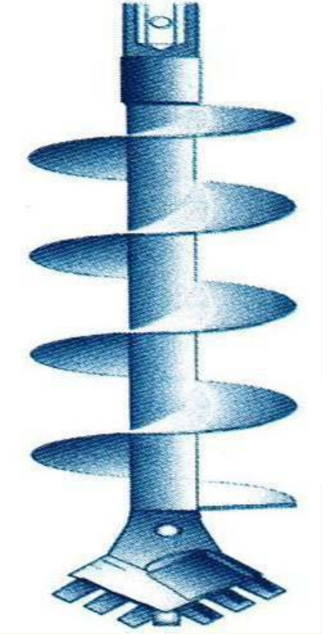
Percussion cable coring tool

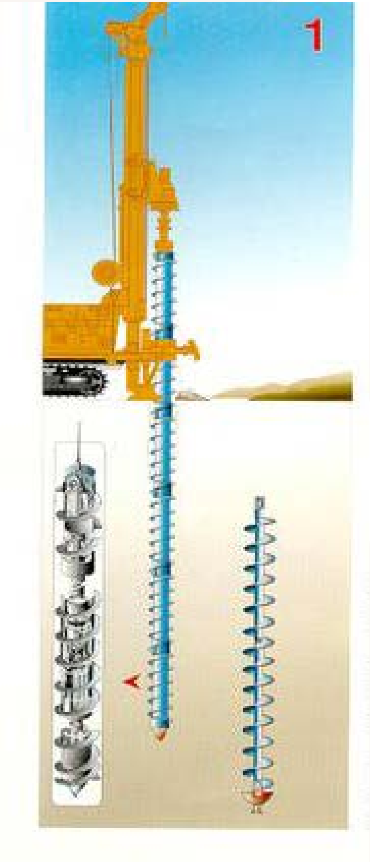


Casing drilling

Geotechnical Drilling: augering

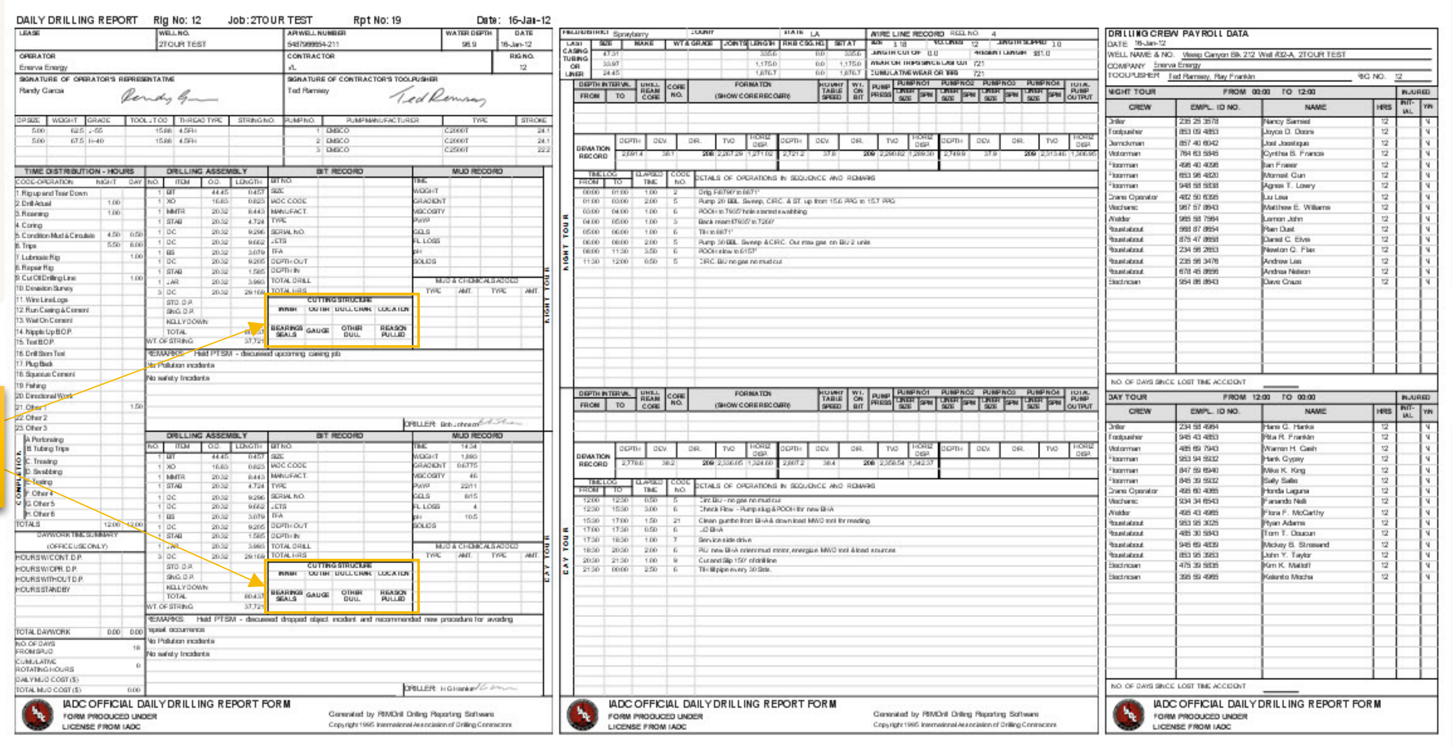






Reporting, HSE, Economics

Daily Drilling Report – IADC report form



DAILY DRILLING REPORT Rig No: 12 Job: 2TOUR TEST Rpt No: 19 Date: 16-Jan-12

LEASE | WELL NO. 2TOUR TEST | API WELL NUMBER | WATER DEPTH | DATE 16-Jan-12

OPERATOR Enerva Energy | CONTRACTOR | RIG NO. 12

SIGNATURE OF OPERATOR'S REPRESENTATIVE: Randy Garcia | SIGNATURE OF CONTRACTOR'S TOOLPUSHER: Ted Ramsey

TIME DISTRIBUTION - HOURS | DRILLING ASSEMBLY | BIT RECORD | MUD RECORD

CUTTING STRUCTURE: INNER | OUTER | DULL CHAR | LOCATION | BEARINGS SEALS | GAUGE | OTHER DULL | REASON PULLED

REMARKS: Held PTSM - discussed upcoming casing job. No Pollution incidents. No safety incidents.

DETAILS OF OPERATIONS IN SEQUENCE AND REMARKS

DRILLING CREW PAYROLL DATA

NIGHT TOUR FROM 00:00 TO 12:00 | DAY TOUR FROM 12:00 TO 00:00

IADC OFFICIAL DAILY DRILLING REPORT FORM
FORM PRODUCED UNDER LICENSE FROM IADC

IADC Dull Grade System

BHA and directional drilling reports

ADVANTAGE String Report - Run #3

BAKER HUGHES INTEQ

Operator	Jardboranir	Fields	Reykjanes	Facility	Thor
Well	IDDP-2	Wellbore	IDDP-2	Rig	Thor

Job IDDP-2

String Components

#	Component	S/N	Mfr	Gauge OD in	OD in	ID in	FN OD in	FN Len. m	Thread	Length m	Total Len m
12	HWDP x 8	Tally	Jardboranir		5	3			(PB) DSHT50 - DSHT50	76.27	208.76
11	Sub - X/O	PMC0616	Jardboranir		6 3/4	3			(PB) DSHT50 - NC50	1.23	132.49
10	Drill collar	Tally	Jardboranir		6 3/4	2 13/16			(PB) NC50 - NC50	8.99	131.26
9	Accelerator	CW1503366-4	NOV		6 3/4	2 13/16			(PB) NC50 - NC50	8.05	122.27
8	Drill collar x 3	Tally	Jardboranir		6 3/4	2 13/16			(PB) NC50 - NC50	27.92	114.22
7	Jar	474-651287-00	NOV		6 1/2	2 13/16			(PB) NC50 - NC50	5.98	86.30
6	Drill collar x 6	Tally	Jardboranir		6 3/4	2 13/16	6 3/4		(PB) NC50 - NC50	55.76	80.32
5	Stab - string	ST515	Jardboranir	8 3/8	6 3/4	2 13/16	6 3/4	0.92	(PB) NC50 - NC50	2.25	24.56
4	MWD - NaviTrak	ZDHP 10506170	INTEQ		6 3/4	2 3/4	6 3/4	0.62	(PB) NC50 - NC50	10.36	22.31
3	Stab - string	ST240	Jardboranir	8 1/4	6 3/4	2 13/16	6 3/4	0.78	(PB) NC50 - NC50	2.06	11.95
2	Motor - steerable	115579697	INTEQ	8 3/8	6 3/4	5	6 3/4	0.52	(BB) NC50 - NC50	9.65	9.89
1	Bit - insert - roller cone	5247871	Baker Hughes	8 1/2	8 1/2				4 1/2 Reg	0.24	0.24

12 String components with a total length of 208.76 m.

Run Details

Run #	Depth In m	Depth Out m	Time In	Time Out	Total Dist m	Rotate Distance m	Slide Distance m	Buoyed BHA Wt tonne	Buoyed Wt below jars tonne
3	3000.00		14/Sep/2016 05:40			0.00	0.00	23.5	11.1

Bit Details

Size in	Type/Mfr	Nozzles in/32	TFA in^2	I	O	D	L	B	G	O	R	In MD/TVD m	Out MD/TVD m	Progress m	Time hours	TBR
8 1/2	VMG-44CDX2 / Baker Hughes	3x24	1.3254						I			3000.00/2998.14	/			

Motor Details

Size in	Type/Mfr	S/N	ΔPress bar	Rotating hours	Sliding hours	Deflection deg
6 3/4	Ultra XL INTEQ	115579697	10.000			0.600 AKO

Stabilizer Details

Comp. #	Description	Distance to Bit m	Spiral Type	Blade Type	Blade OD in	Blade Length mm	Blade Width in
5	Stab - string	23.435	Spiral	Integral	8 3/8	406.4	2 7/8
3	Stab - string	10.99	Spiral	Integral	8 1/4	355.6	2 1/2
2	Motor - steerable	0.92	Straight	UBHS (Screw-On)	8 3/8	152.4	2 1/4

Page 1

Actual Wellpath Report

IDDP-2 (RN-15)
Page n of nn

BAKER HUGHES

REFERENCE WELLPATH IDENTIFICATION

Operator	Jardboranir HF	Slot	Slot#RN-15
Area	Iceland	Well	IDDP-2 (RN-15)
Field	Reykjanes	Wellbore	IDDP-2 (RN-15)
Facility	RN-15 (IDDP-2) Thor		

WELLPATH DATA (28 stations)

MD [m]	Inclination [°]	Azimuth [°]	TVD [m]	Vert Sect [m]	North [m]	East [m]	DLS [°/30m]	Comments
0.00	0.000	N/A	0.00	0.00	0.00	0.00	0.00	
988.00	0.000	N/A	988.00	0.00	0.00	0.00	0.00	Inc=0.75
1189.00	0.000	N/A	1189.00	0.00	0.00	0.00	0.00	Inc=1
1684.00	0.000	N/A	1684.00	0.00	0.00	0.00	0.00	Inc=1.25
1774.00	0.000	N/A	1774.00	0.00	0.00	0.00	0.00	Inc=1.5
1822.00	0.000	N/A	1822.00	0.00	0.00	0.00	0.00	Inc=1.25
1899.00	0.000	N/A	1899.00	0.00	0.00	0.00	0.00	Inc=1.25
2015.00	0.000	N/A	2015.00	0.00	0.00	0.00	0.00	Inc=1
2433.00	0.000	N/A	2433.00	0.00	0.00	0.00	0.00	Inc=1.5
2527.00	2.470	343.120	2526.97	-1.38	1.94	-0.59	0.79	
2555.10	2.570	346.170	2555.04	-2.25	3.13	-0.91	0.18	
2583.60	2.330	344.040	2583.52	-3.12	4.31	-1.23	0.27	
2612.00	2.230	338.540	2611.90	-3.86	5.38	-1.59	0.25	
2641.00	2.370	347.620	2640.87	-4.66	6.49	-1.92	0.40	
2669.00	2.400	337.580	2668.85	-5.44	7.59	-2.27	0.45	
2698.00	2.160	341.960	2697.82	-6.18	8.68	-2.67	0.31	
2736.00	2.350	326.740	2735.80	-7.01	10.01	-3.32	0.49	
2756.00	2.140	324.290	2755.78	-7.35	10.65	-3.76	0.35	
2785.00	1.910	275.370	2784.76	-7.37	11.14	-4.56	1.75	
2814.00	3.300	251.490	2813.73	-6.54	10.92	-5.83	1.79	
2843.00	3.760	230.370	2842.68	-5.02	10.05	-7.36	1.42	
2872.00	5.570	221.120	2871.58	-2.75	8.38	-9.01	2.02	
2901.00	7.140	217.500	2900.40	0.42	5.89	-11.04	1.68	
2929.00	7.930	213.710	2928.16	4.07	2.90	-13.17	1.00	
2958.00	9.630	197.340	2956.83	8.43	-1.08	-15.00	3.11	
2981.00	10.630	203.650	2979.47	12.42	-4.86	-16.43	1.95	
3024.00	11.340	236.000	3021.72	20.17	-10.86	-21.53	4.27	
3053.00	12.920	228.380	3050.07	25.81	-14.61	-26.32	2.32	

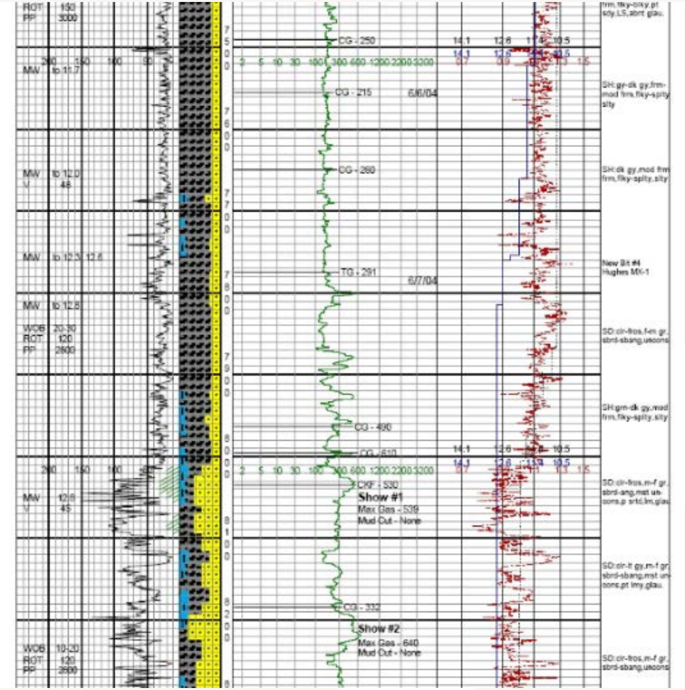
HOLE & CASING SECTIONS - Ref Wellbore: IDDP-2 (RN-15) Ref Wellpath: IDDP-2 (RN-15)

String/Diameter	Start MD [m]	End MD [m]	Interval [m]	Start TVD [m]	End TVD [m]	Start N/S [m]	Start E/W [m]	End N/S [m]	End E/W [m]
21in Open Hole	0.00	300.00	300.00	0.00	300.00	0.00	0.00	0.00	0.00
18.625in Casing	0.00	300.00	300.00	0.00	300.00	0.00	0.00	0.00	0.00
17.5in Open Hole	300.00	804.00	504.00	300.00	804.00	0.00	0.00	0.00	0.00
13.375in Casing	0.00	799.50	799.50	0.00	799.50	0.00	0.00	0.00	0.00
12.25in Open Hole	804.00	2507.00	1703.00	804.00	2506.99	0.00	0.00	1.20	-0.36

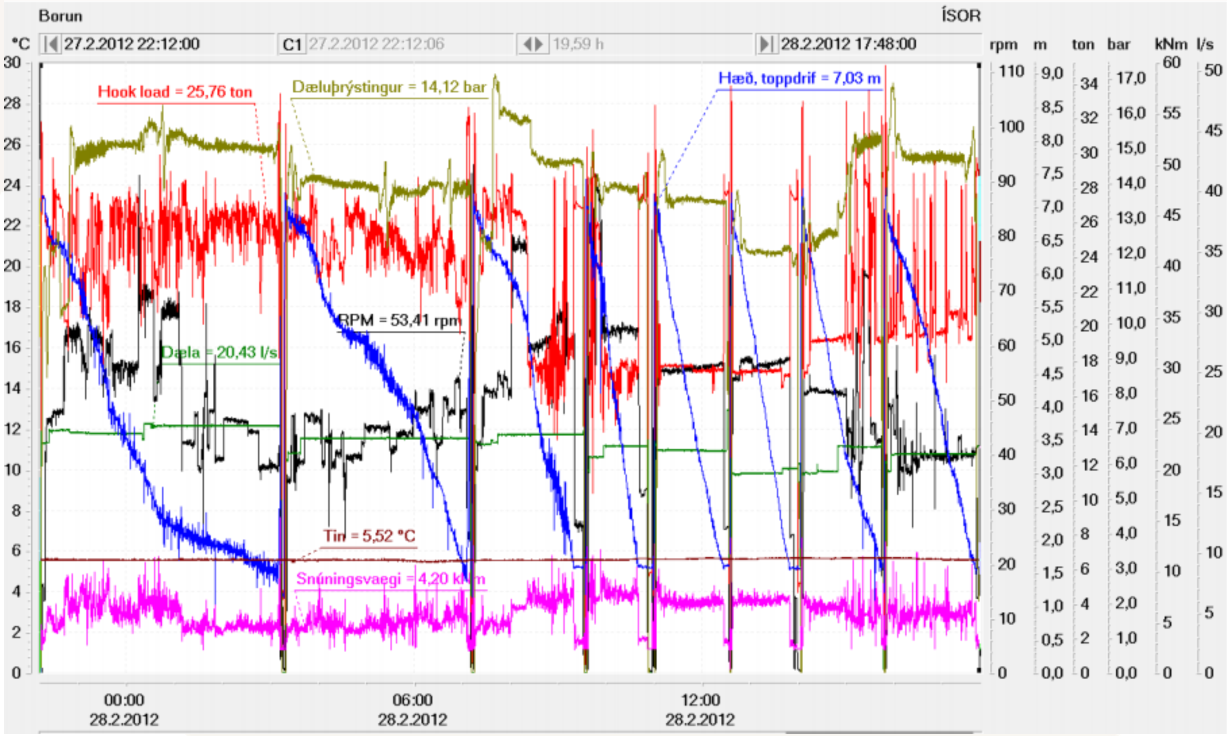
WELLPATH COMPOSITION - Ref Wellbore: IDDP-2 (RN-15) Ref Wellpath: IDDP-2 (RN-15)

Start MD [m]	End MD [m]	Positional Uncertainty Model	Log Name/Comment	Wellbore
0.00	2433.00	Drift Indicator - Inclination Only (Actual Survey)	RNJ-15 Anderdrift surveys 12 1/4" (988-2433m)	IDDP-2 (RN-15)
2433.00	2981.00	BHI NaviTrak (Standard)	12 1/4 BH NaviTrak	IDDP-2 (RN-15)
2981.00	3053.00	BHI NaviTrak (Standard)	8 1/2" BH NaviTrak (m)	IDDP-2 (RN-15)

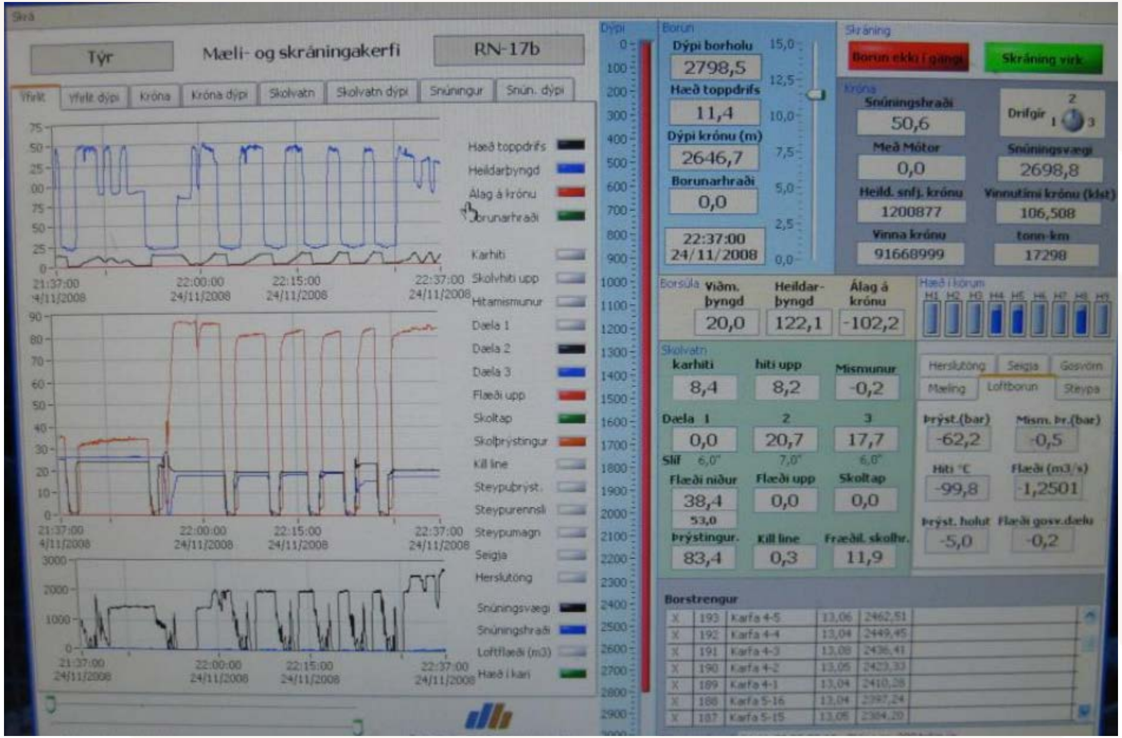
Mud logging service + reporting



Drilling parameters – e.g. Iceland / ISOR



Drilling parameters at the rig



HSE - Personnel at rig site

Rig crew:

- Drilling foreman (Toolpusher) – 2 in rotation
- Party chief (Driller)
- Assi-Driller
- 2-4 rig workers (Roughnecks)
- Rig electrician – 2 in rotation
- Rig blacksmith

Clients:

- Company man

…and service companies:

- Mud engineer and technician
- Sampler and mud logger
- Directional driller and surveying engineer
- Casing running services
- Cementation services
- Fishing company
- Logging-Service
- Stimulation service (Frac/Acidizing)
- Well testing services, etc.

§ legal stuff : rig site falls under the Mining Law

- The federal Mining Law (**BBergG**) – security of resources, security of businesses and prevention of
- hazards;
- General Mining Regulation (**ABBergV**) – governs work safety and health
- Drilling Regulation* **(BVOT)** – special directives for the drilling operation, must be accessible at
- the drilling operation site.

- **Further laws** apply during drilling operations:
- Bundesimmisionsschutzgesetz (BImSchG); Anlagenverordnung
- (VAwS); Betriebssicherheitsverordnung (BetrSichV); Arbeitszeitgesetz (ArbZG);
- Elektro-Bundesbergverordnung (ElBergV); TA‘s Luft und Lärm; Gefahrstoffverordnung (GefStoffV);
- Kreislaufwirtschafts- und Abfallrecht für Bergbaubetriebe; Wasserhaushaltsgesetz (WHG) …

General rules at the rig site

- Advance notification of your arrival, make visit appointment;
- Reverse parking – in emergency escape direction;
- Report to tool pusher, sign into visitor´s book;
- Wear/use the appropriate personal protective equipment (PPE);
- Observe the warning sign and instructions;
- Respect explosive protection instructions;
- Watch out for construction traffic and hovering crane loads;
- Absolutely no drugs, no smoking and no alcohol!

Personal protective equipment (PPE)

- Safety hat (observe expiration date)
- Safety boots
- Safety goggles
- Non inflammable fabrics in working clothing
- Noise protective ear covers
- If applicable: climbing gear (for levels >1 m)
- Work gloves

Ex-zones - ignitable atmospheres

- On the rig floor around the mouth of the borehole;
- At the mud line in the rigs substructure;
- At the mud shakers;
- On the entire mud tank system;
- At the exhaust side of the degasser.

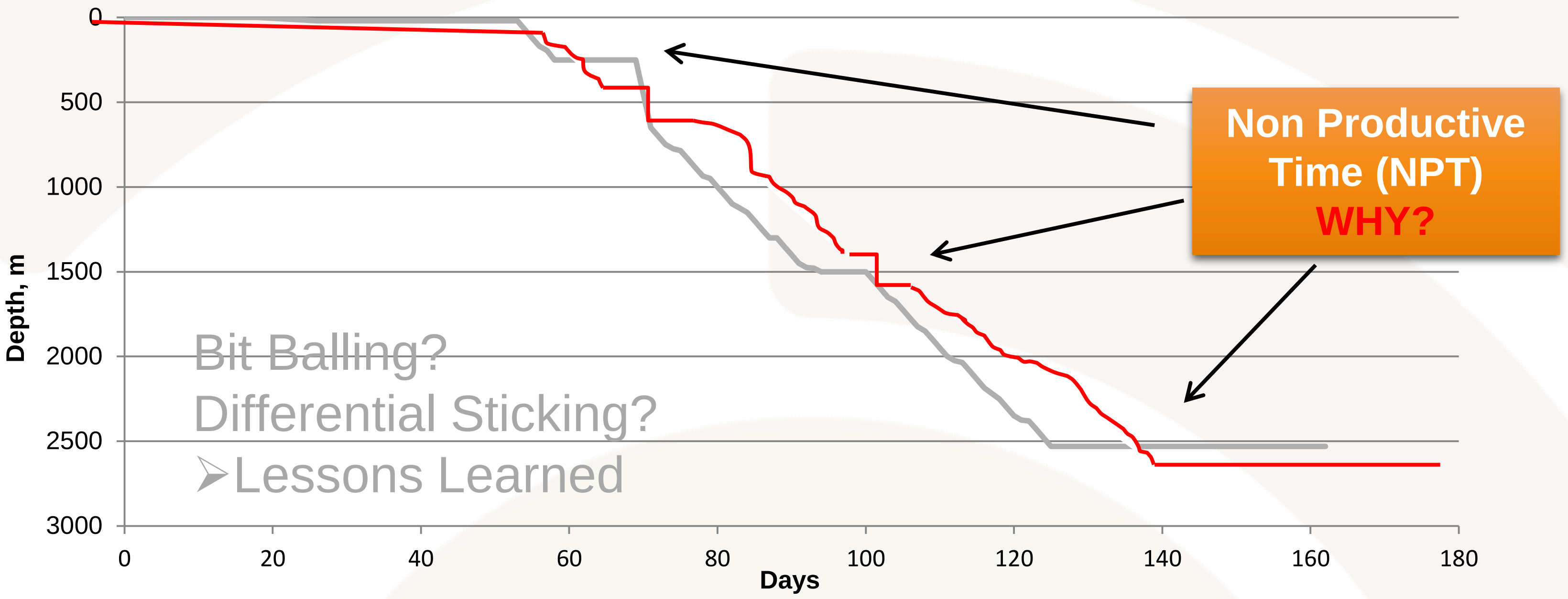
- In Ex-zones ……
- Only Ex-approved electrical machinery can be operated;
- No open fire, - no lighters and matches to be carried;
- No mobile phone to be carried or operated;
- Working overalls to be certified acc. to EN 1149;
- Welding, soldering or cutting only after written approval.

Other general hazards

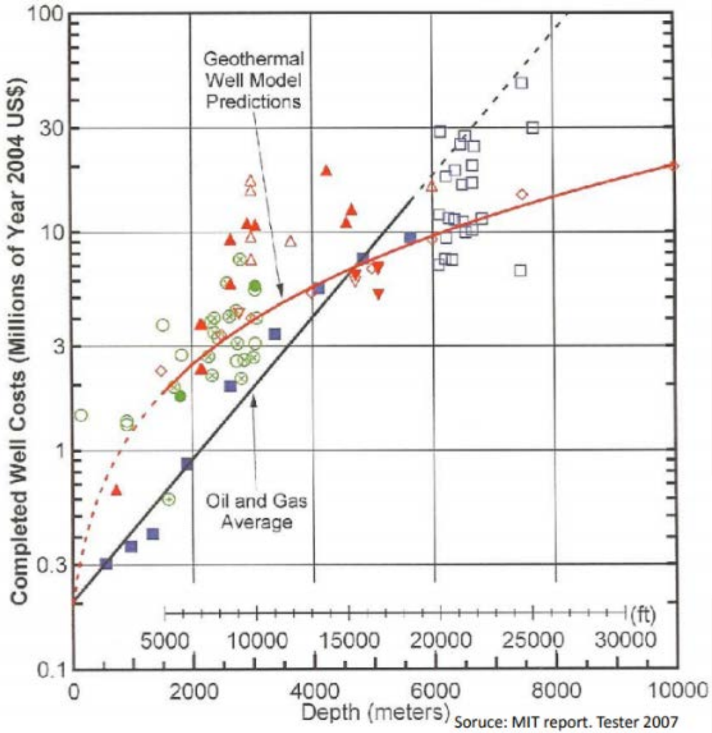
- Machinery parts can be hot – i.e. hydraulic motors,
- oses, mud line, wires and cables.
- Slippery surfaces are common from spoiled mud;
- Exiting liquids or hydraulic oil can be under high ressure;
- Watch out for hovering loads and moving parts;
- In upcoming heavy storms, the well has to be secured nd the rig site evacuated;
- At high winds, the rigs hook load ratings has to be reduced or maybe even the rig evacuated;
- falling parts from working overhead heights (i.e. working on the rig´s mast)

economics

Time-Depth diagram



Well cost

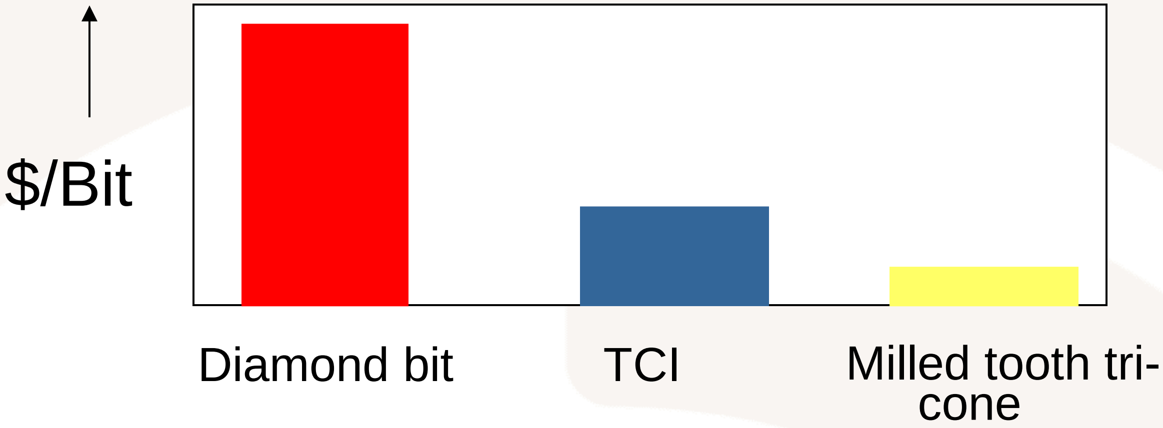


Soruce: MIT report. Tester 2007

Geothermal directional drilling – costs

	Conventional Steering System	RSS with downhole motor	
Dayrate (Rig, Mud Logging, Mud Engineering)	X	X	€/day
Directional Service	0.38 X	1.06 X	€/day
Total Dayrate	**1.38 X**	**2.06 X**	**€/day**
Section Length	1,100	1,100	m
Gross ROP	48	102	m/day
Days to Drill	23	11	days
Total Cost	**31.63 X**	**22.22 X**	**€**
Saving		**9.41 X**	**€**

Drill bit cost



- One drill bit may cost from 10.000 to 150.000 US $
- Bit cost may total 5 to 10 % of drilling costs
- Bit cost may influence 75% of total drilling cost (penetretion rate, tripping operations)

Thank you very much

Questions please ….

Exercise II: Cost per Foot (CPF) calculation

Determine the drilling Cost per Foot (CPF) using the following data:

- Drill bit (lost in hole) cost = 32,000 $
- Drilling time = 50 hours
- Tripping in time = 5 hours
- Tripping out time = 4.5 hours
- Rig rental cost = $3500/hour
- Auxiliary costs (incl. drilling crew, drilling fluid) = $900/hour
- Drilled interval = 5000 ft

Exercise II: Cost per Foot (CPF) calculation – solution

$$CPF = \frac{C_b + C_f(t_b + t_t + t_s)}{\Delta D}$$

CPF = (32,000 + [(3,500 + 900)* (50 + 4.5 + 5)]) ÷ 5000

CPF = **59 $ per foot**