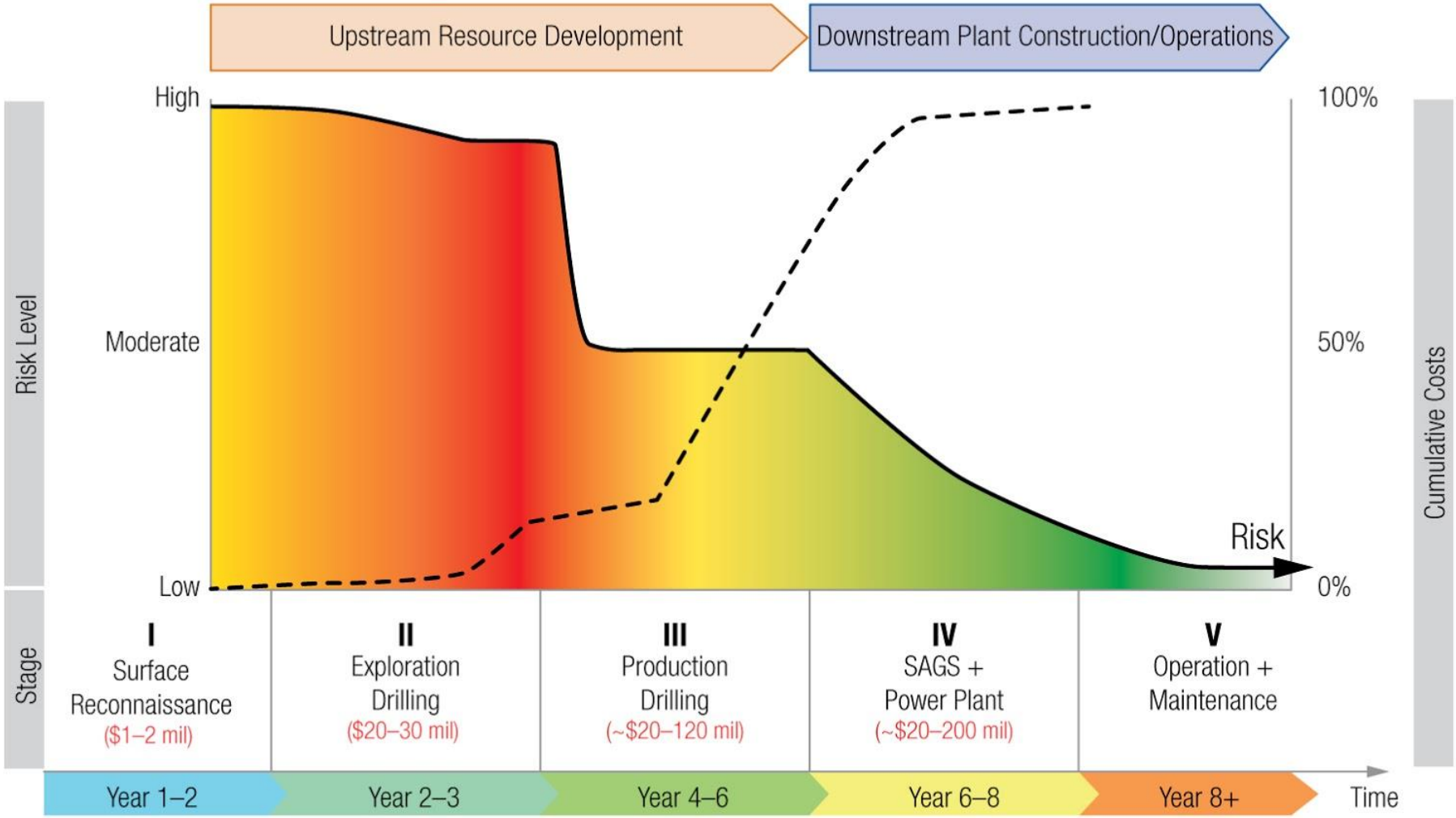
Svartsengi Power Station, Iceland

Overview of modern well-logging technology

Yiqiao Song, Schlumberger

@ARPA-e workshop : Operating at Extremes: Tools for Enhanced Geothermal Systems

Geothermal field development



Source: Adapted from Geothermal Handbook (ESMAP 2012).

Petroleum Field Development

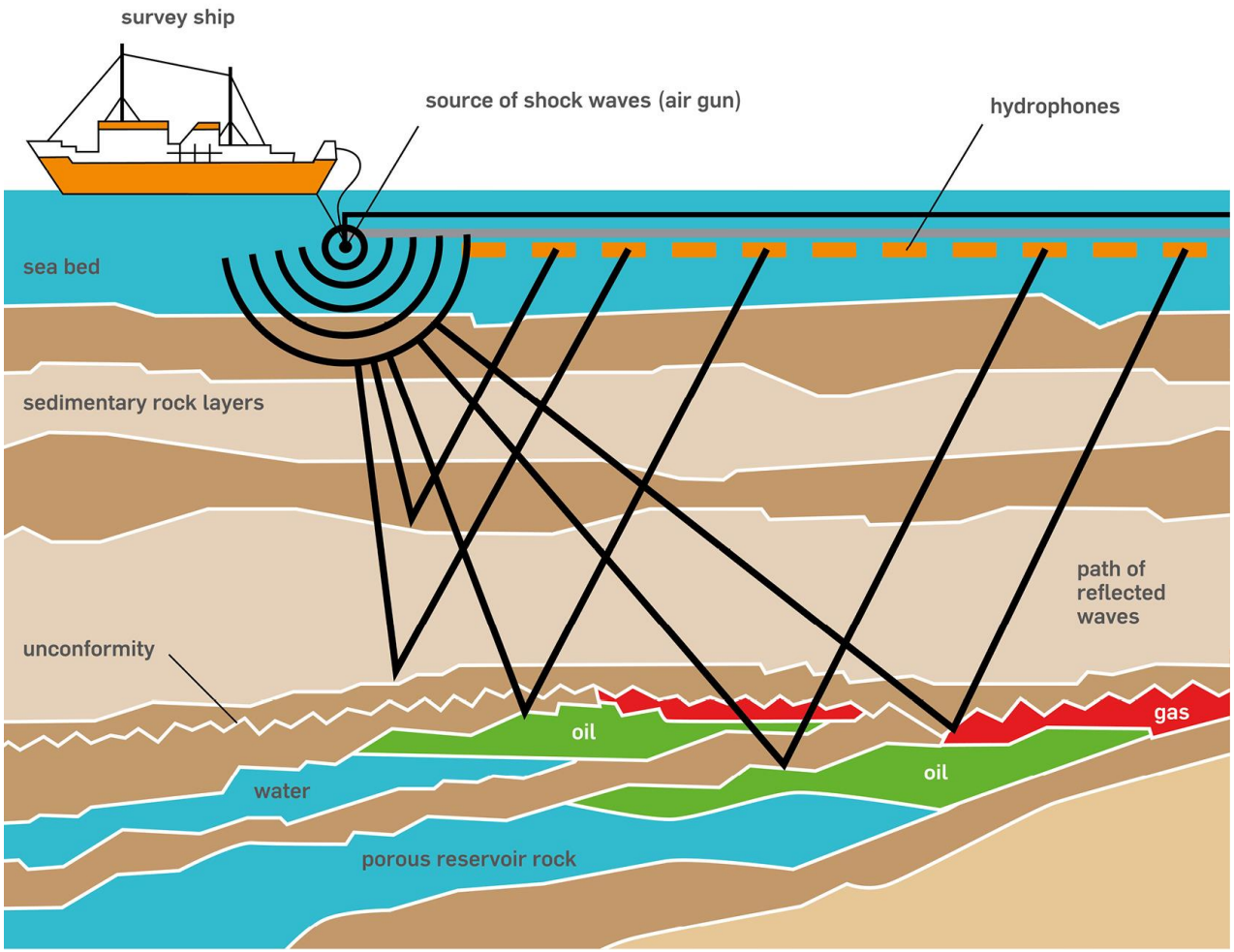
Exploration	Appraisal	Development	Production
Are there hydrocarbons?	What is the size?	Drill wells	Maintain
➢ Gather information ➢ 1 or 2 wells drilled	➢ Assess characteristics ➢ Understand subsurface dynamics ➢ Multiple well drilled, dependant on field size and seismic data	➢ Drilling Production & Injection wells	➢ Drilling more Production & Injection wells ➢ Infield drilling ➢ Well repair & Workover

50 years

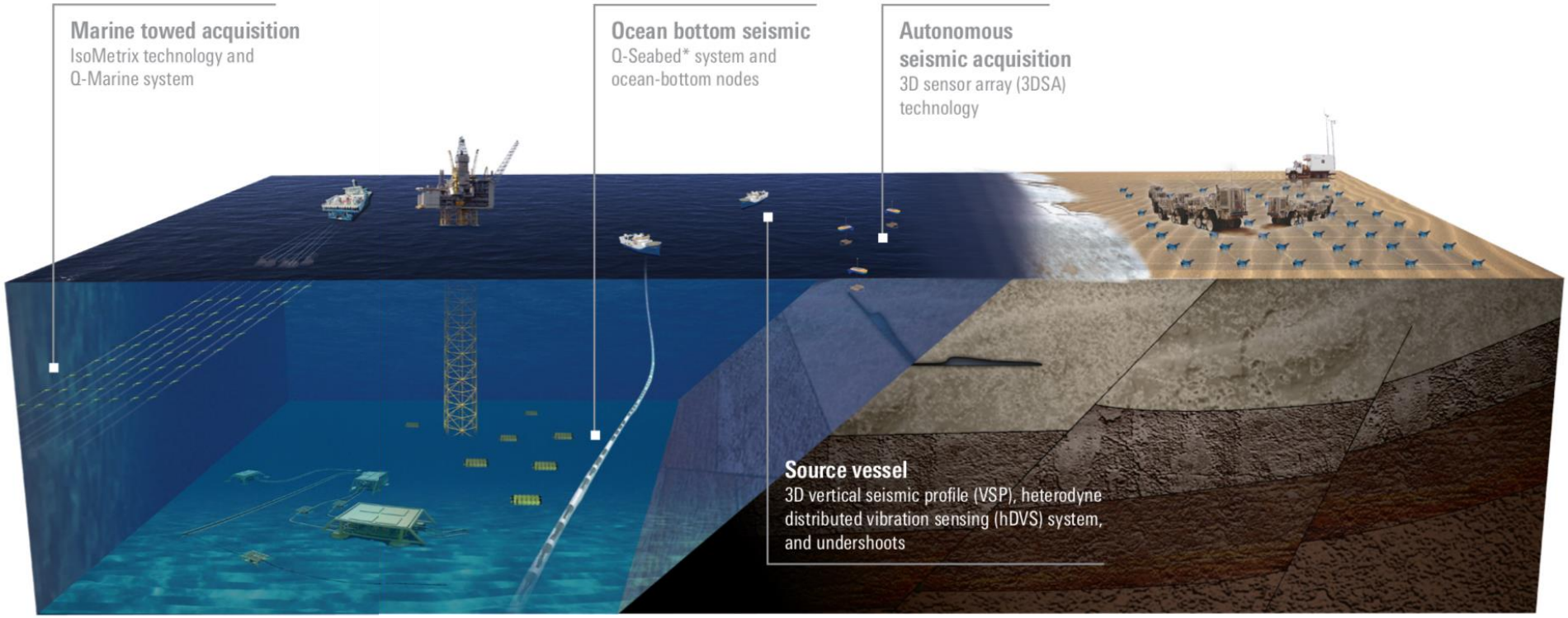
Measurement need

- Reservoir
  - Geology
  - Petrophysics (porosity, perm, saturation)
  - Well testing
- Operational
  - Drilling, LWD
  - Completion, cement
  - Production logging, permanent sensors

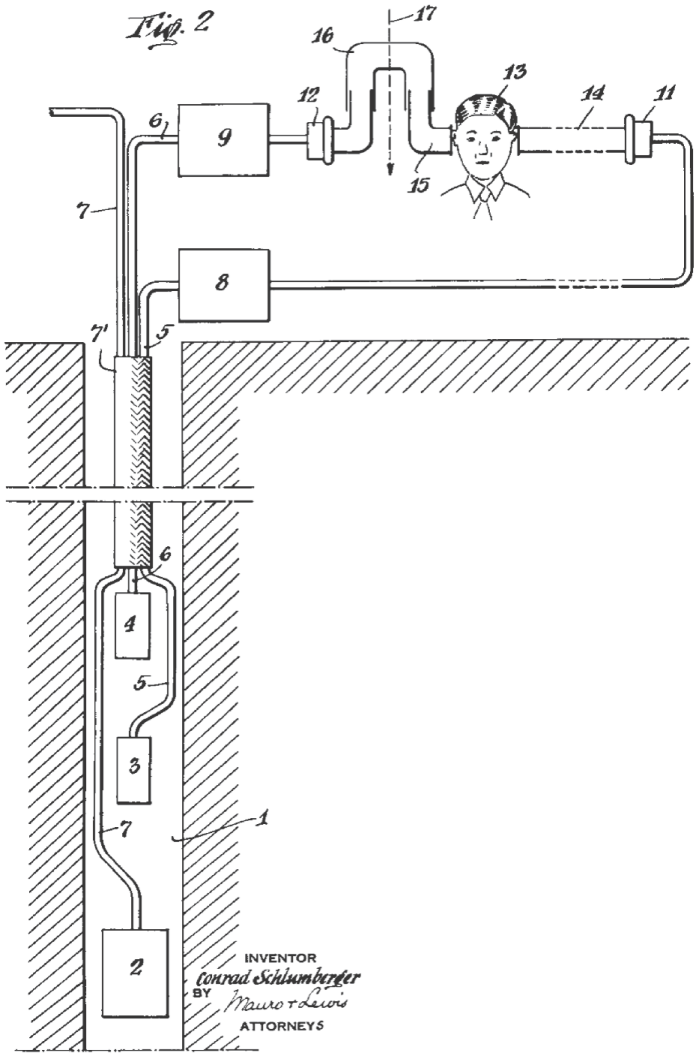
Seismic survey

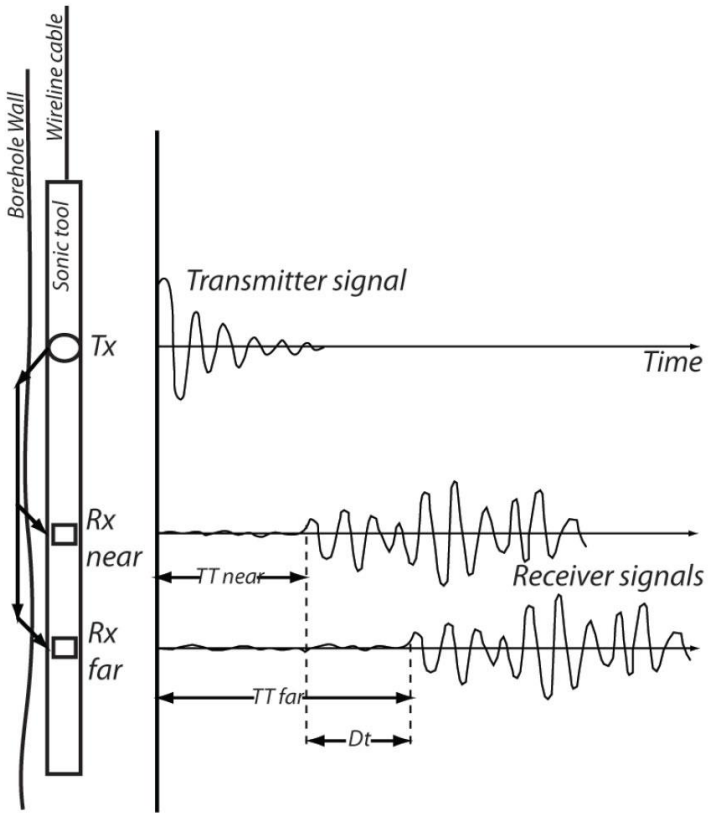


Seismic data acquisition



Sound velocity





Sonic Scanner

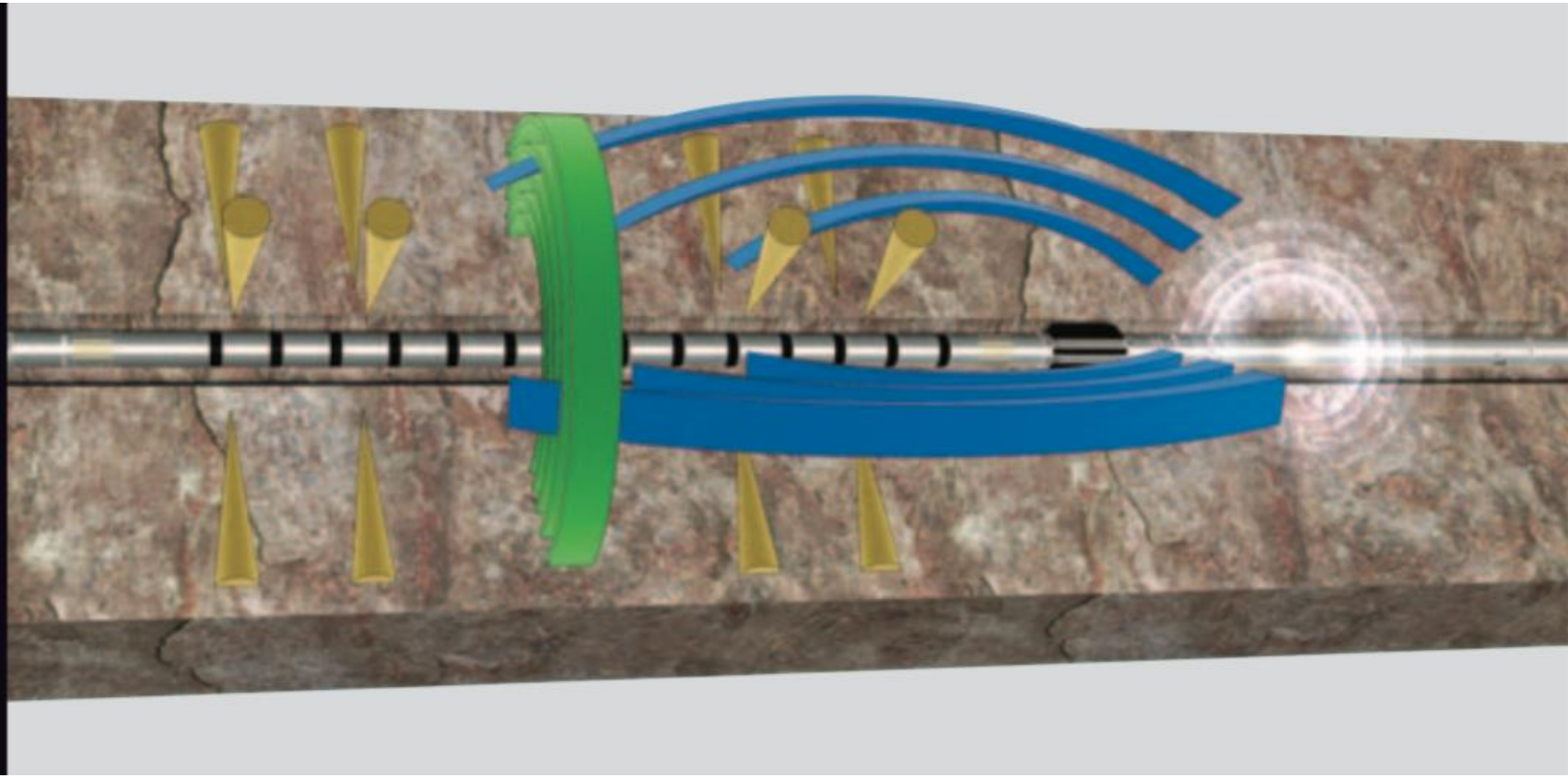


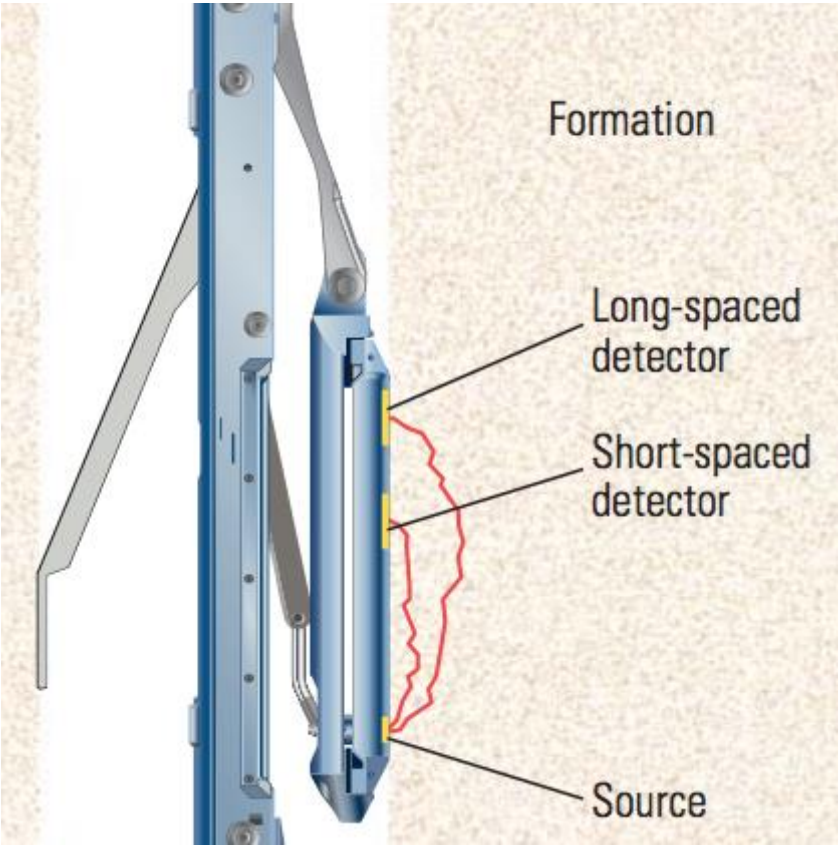
Figure 1. The Sonic Scanner tool provides the benefits of axial, azimuthal, and radial information from both the monopole and the dipole measurements for near-wellbore and far-field slowness information.

Nuclear Methods

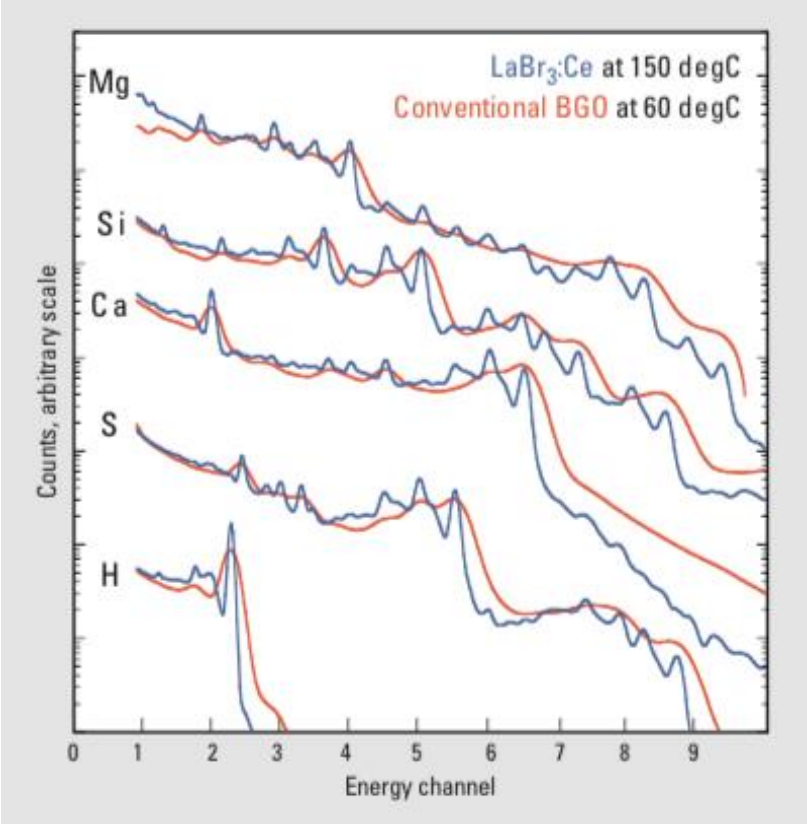
- Gamma ray and neutron

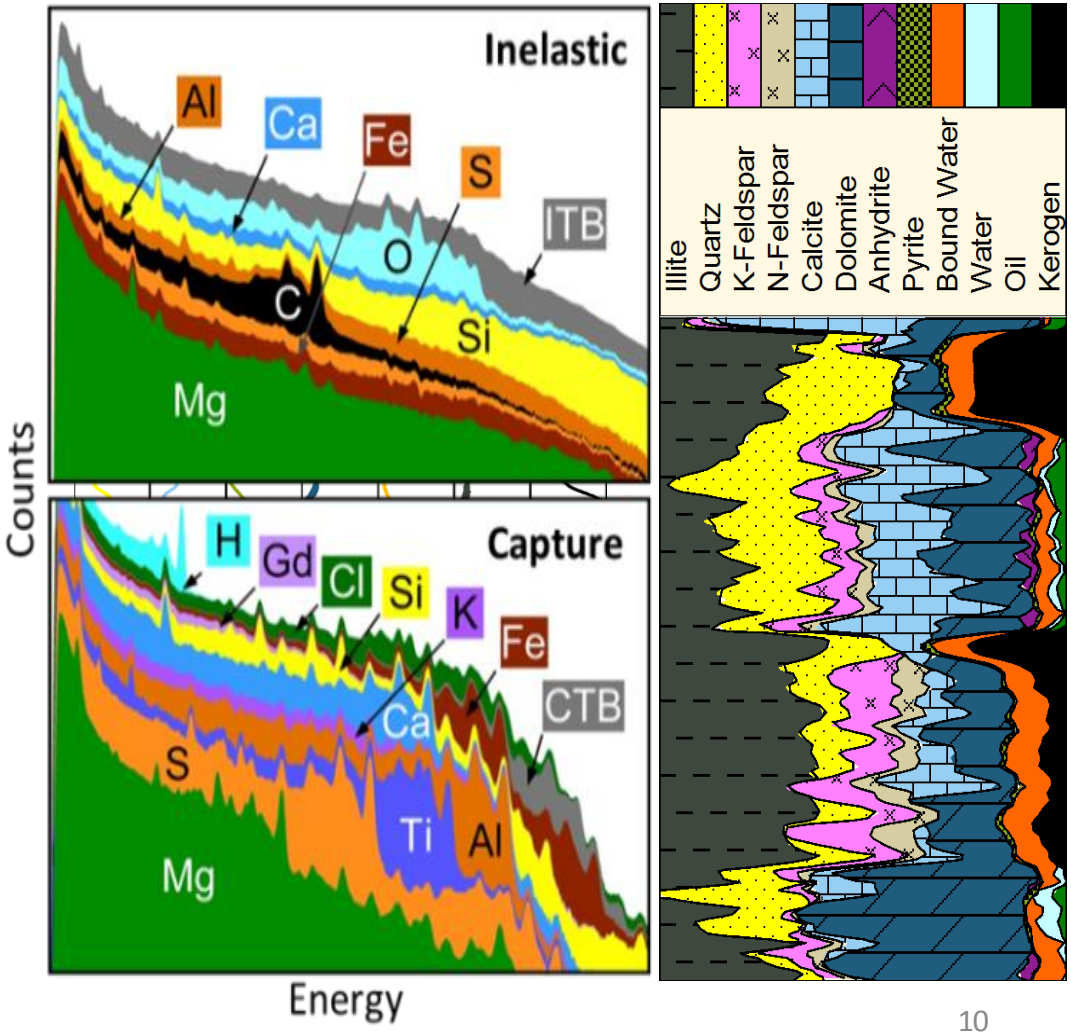
- Rock matrix density
- Porosity

- Mineral composition



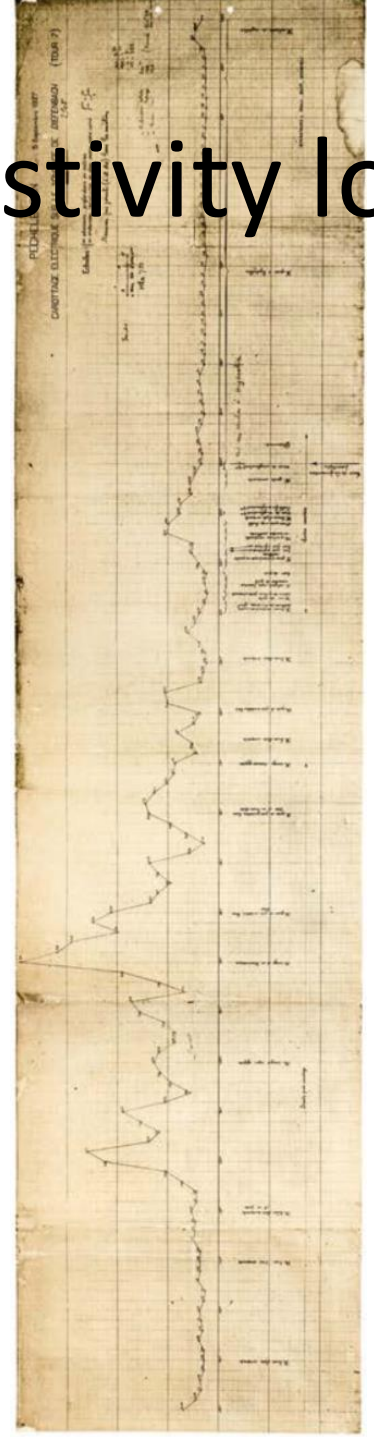
Lithology and TOC: Litho Scanner

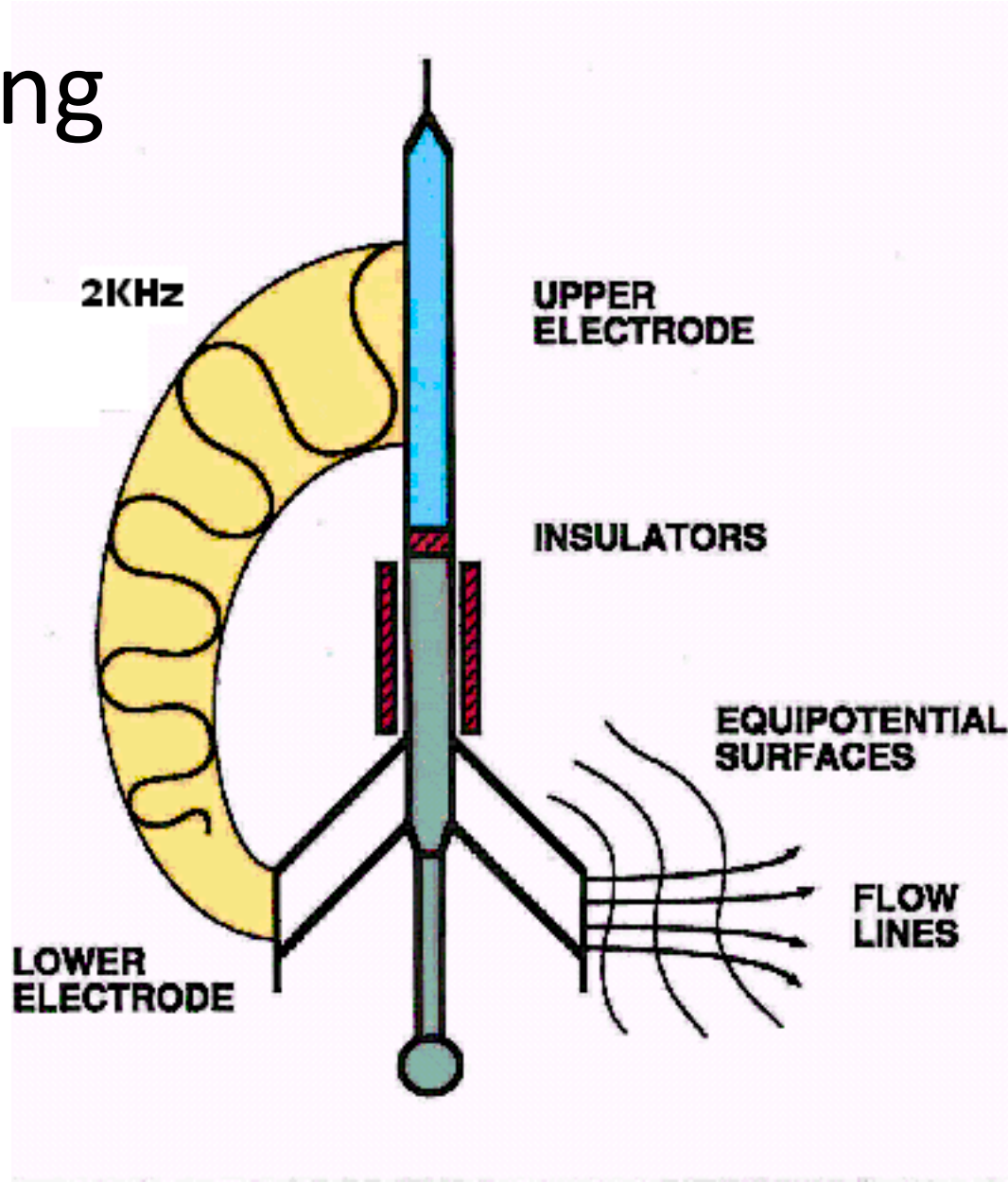




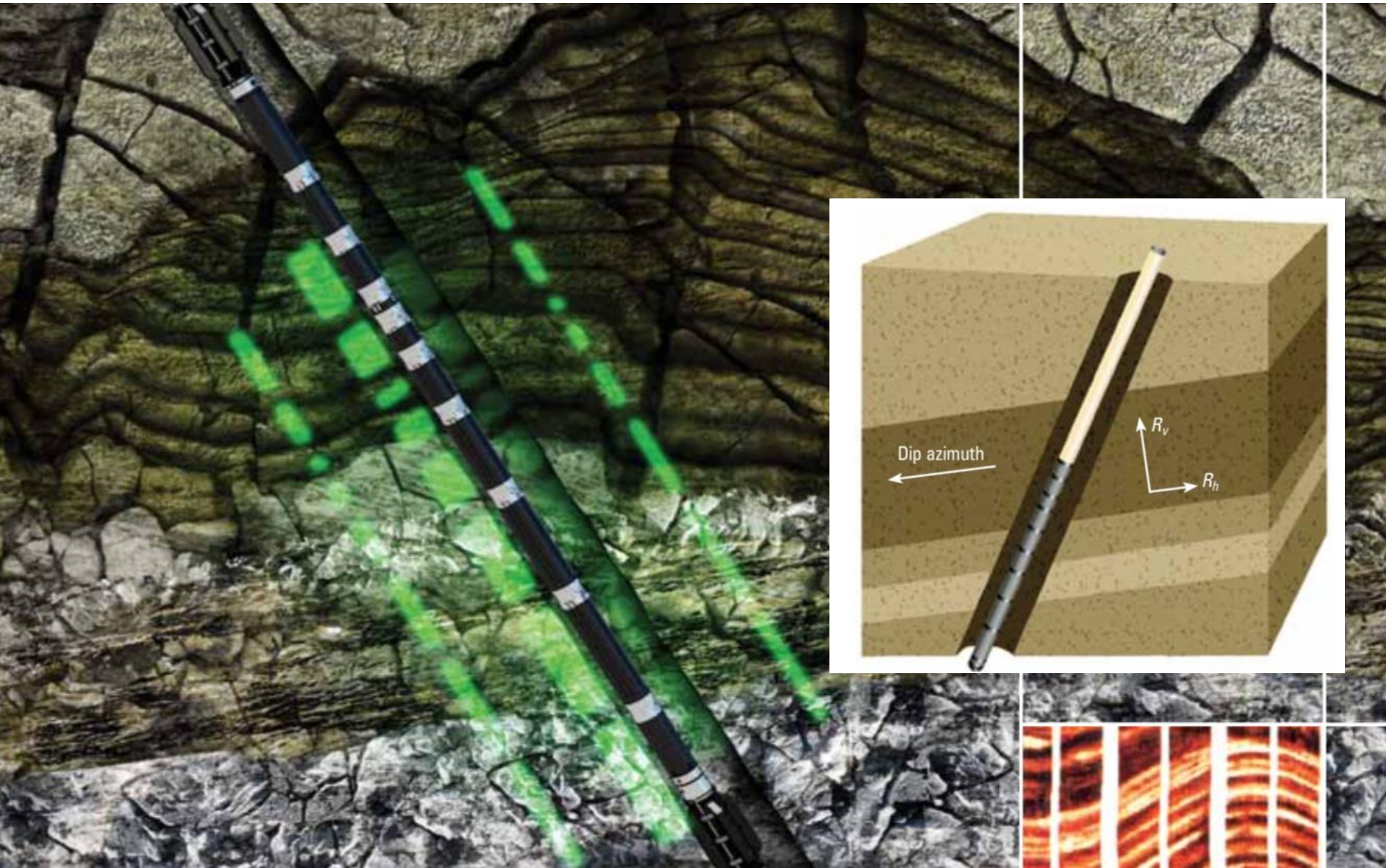
Resistivity logging

First Wireline log in a oil well was recorded in Pechelbronn, France, on September 5, 1927

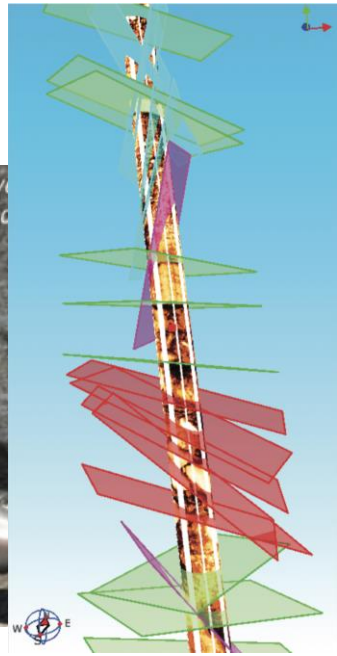


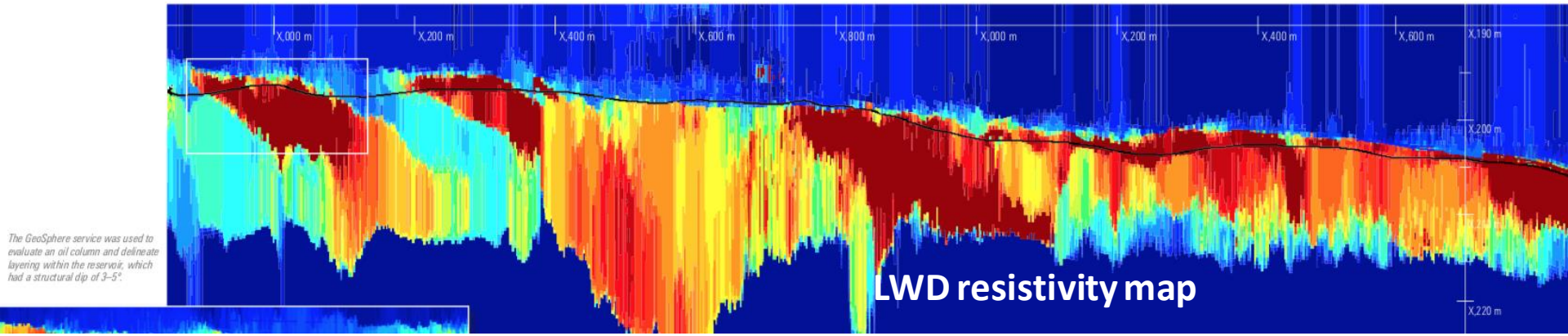


3D Resistivity



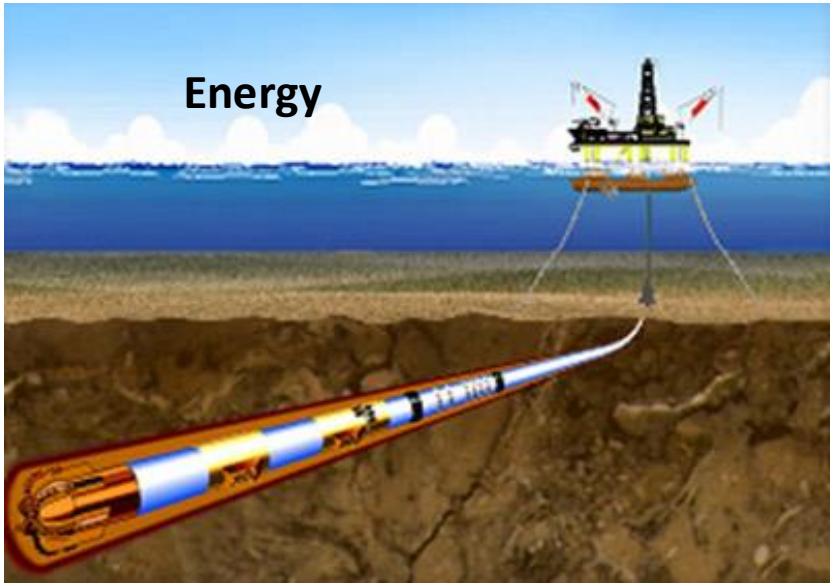
Resistivity Imaging





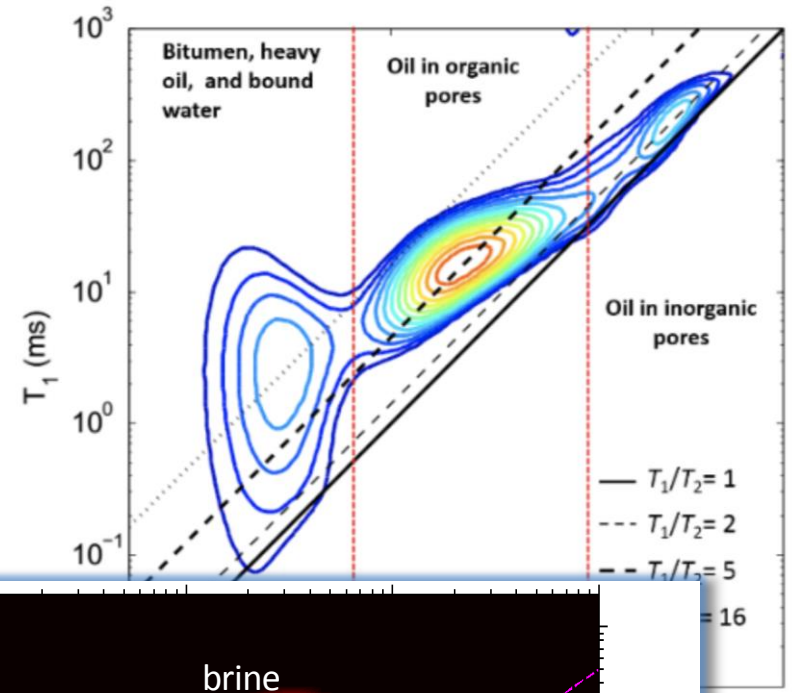
The GeoSphere service was used to evaluate an oil column and delineate layering within the reservoir, which had a structural dip of 3–5°.

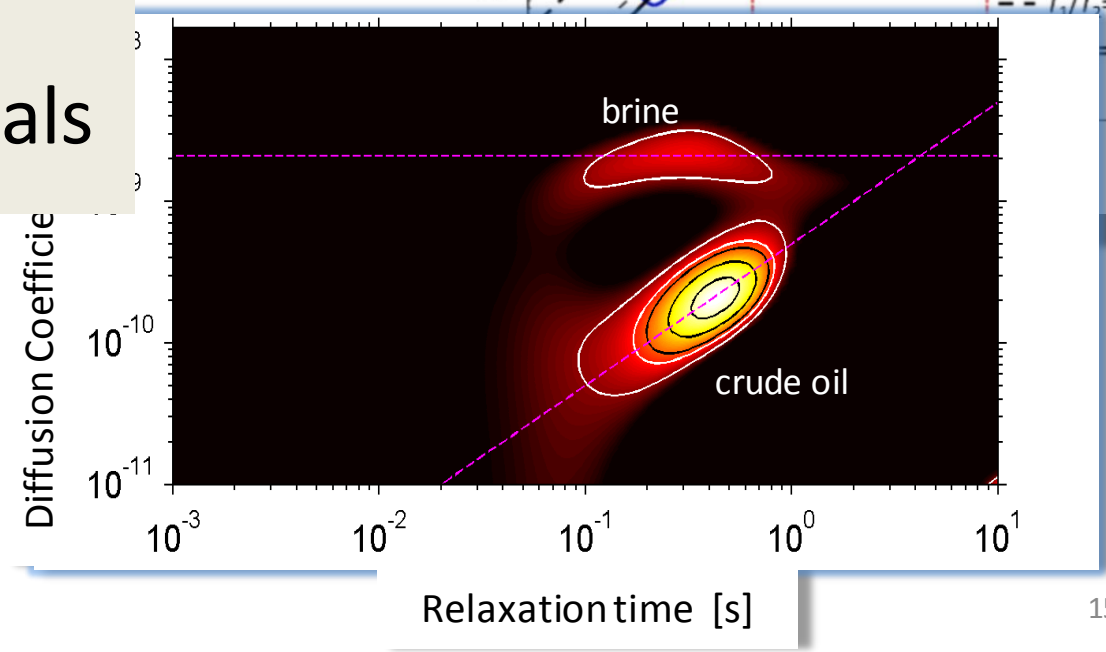
Magnetic Resonance



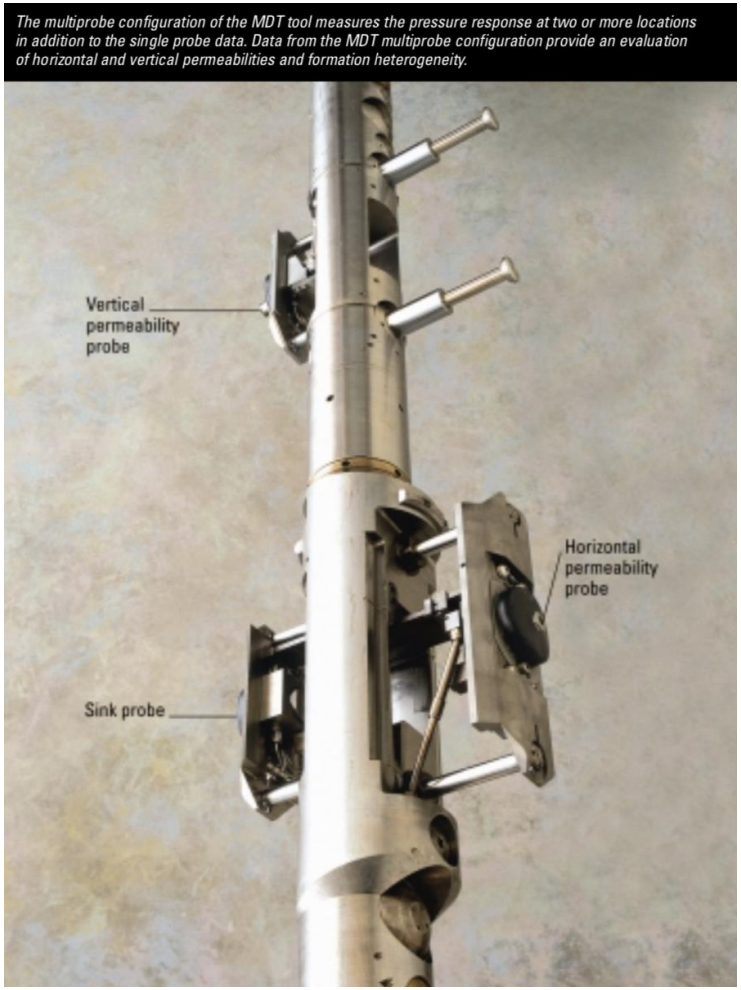
MR Applications

- Porosity
- Pore size
- Permeability
- Fluid type & quantification
- Unconventionals

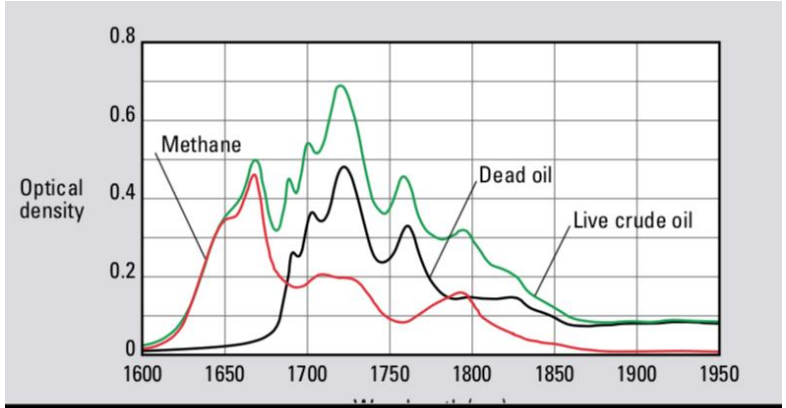




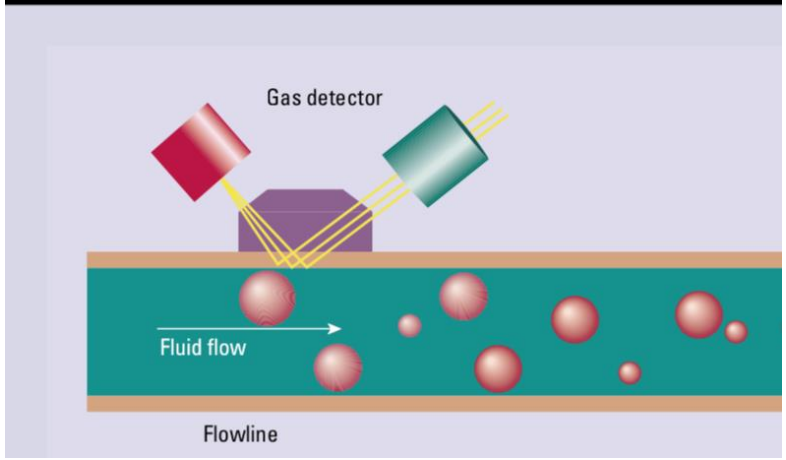
Fluid sampling and analysis



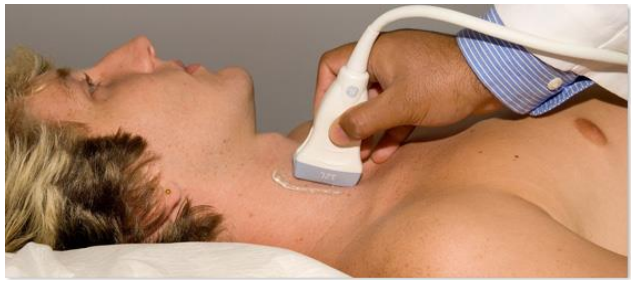
The multiprobe configuration of the MDT tool measures the pressure response at two or more locations in addition to the single probe data. Data from the MDT multiprobe configuration provide an evaluation of horizontal and vertical permeabilities and formation heterogeneity.



dule provides real-time downhole fluid analysis by measuring multiple optical properties o quantify the amount of reservoir and drilling fluids in the flowline.

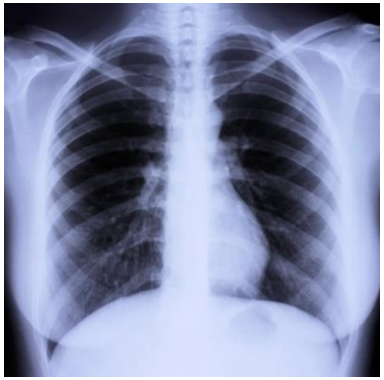


Analogy to Medicine

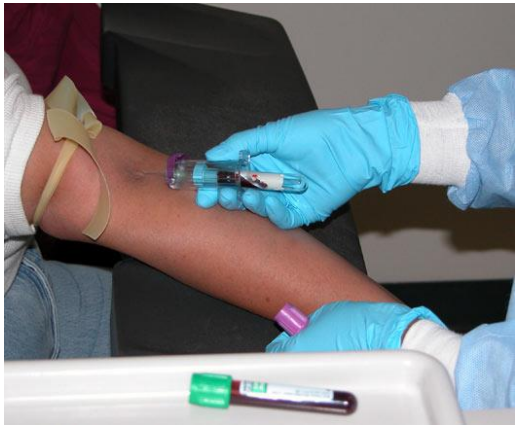


Acoustics

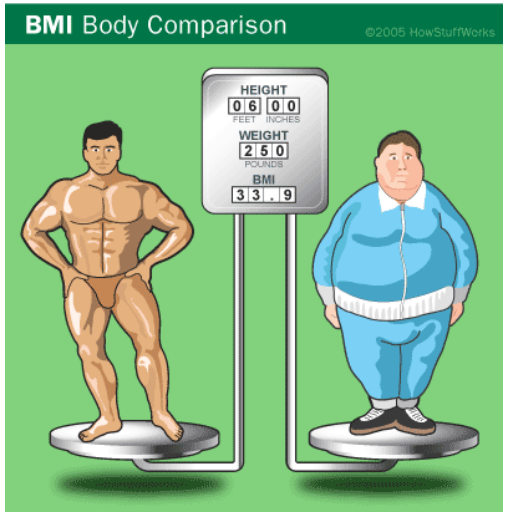
Nuclear



NMR



Fluid sampling & analysis



Resistivity (BMI)

HTHP Technologies
Oilfield Review 2008

Service Domains				Maximum temperature	10 kpsi	12.5 kpsi	15 kpsi	17.5 kpsi	20 kpsi	22.5 kpsi	25 kpsi	27.5 kpsi	30 kpsi	32.5 kpsi	35 kpsi
Drilling and Evaluation	Drilling	RSS		150° C											
		Formate drilling fluids		155° C											
		MWD		175° C											
	Evaluation	Petrophysics	LWD	175° C											
			Wireline (SlimXtreme platform)	260° C											
		Reservoir	LWD	150° C											
			Wireline	260° C											
		Geology	LWD	150° C											
			Wireline	175° C											
		Geophysics	LWD	150° C											
			Wireline (SlimXtreme platform)	260° C											
		Testing	**DST**	215° C											
			Tubing conveyed perforating	200° C											
			Quicksilver Probe tool	260° C											
Development	Cementing	Additives	Retarder	249° C											
			Fluid loss	249° C											
		Test		316° C											
		Evaluation		260° C											
		FlexSTONE HT cement		250° C											
	Stimulation	Fluids		230° C											
		Hydraulic-fracturing monitoring		175° C											
		HEDTA acidizing fluid		205° C											
		ThermaFRAC fluid		190° C											
	Completions	Upper	Subsurface safety and isolation valves	200° C											
			Packers	218° C											
			Flow control	175° C											
		Lower	Screens	175° C											
			Fluids	150° C											
			Tools	175° C											
			Thermal liner hanger	340° C											
Production		**Perforating**		260° C											
		Monitoring	Permanent	175° C											
			WellWatcher Ultra system	300° C											
			Production logging	200° C											
	Artificial lift	ESP	**REDA Hotline550 ESP**	218° C											

HPHT >150°C or 10 kpsi

Ultra-HPHT >205°C or 20 kpsi

HPHT-hc >260°C or 35 kpsi

180921 YQS

HTHP Technology needs ?

- Drilling: LWD
- Formation evaluation
  - nuclear, resistivity, FMI, acoustic, porosity
- Production logging
  - Wellbore flow, pressure & temp
- Permanent/continuous monitoring
  - Downhole temp and pressure, surface flow meter for enthalpy

- included suggestions from Ann Robertson-Tait, GeothermEx

Svartsengi Power Station, Iceland
Thank You!