Data acquisition in oil and gas drilling

ICDP Training Course 2019 – Downhole Measurements

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Introduction – E&P Project lifecycle overview

G&G work and hydrocarbon potential assessment on an area of interest

Block Award

- Contractual agreement with Country / Award owner
- Definition of work commitments and phase lengths
- Economical terms
- Joint venture terms

Exploration Phase

- G&G work for prospect maturation
- Fulfill work commitments
- DoD decision (Drill or Drop)
- Exploration well(s)

Appraisal Phase

- G&G work for field definition (in place and recoverable resources)
- Fulfill work commitments
- Appraisal well(s)
- BoK (Concretization)
- PDO Submission (Plan for Development and operations)

Development / Production Phase

- G&G work for field production optimization
- Fulfill work commitments
- Development well(s)
- Producers, injectors, disposal, etc.
- Field Production

Abandonment / Relinquishment phase

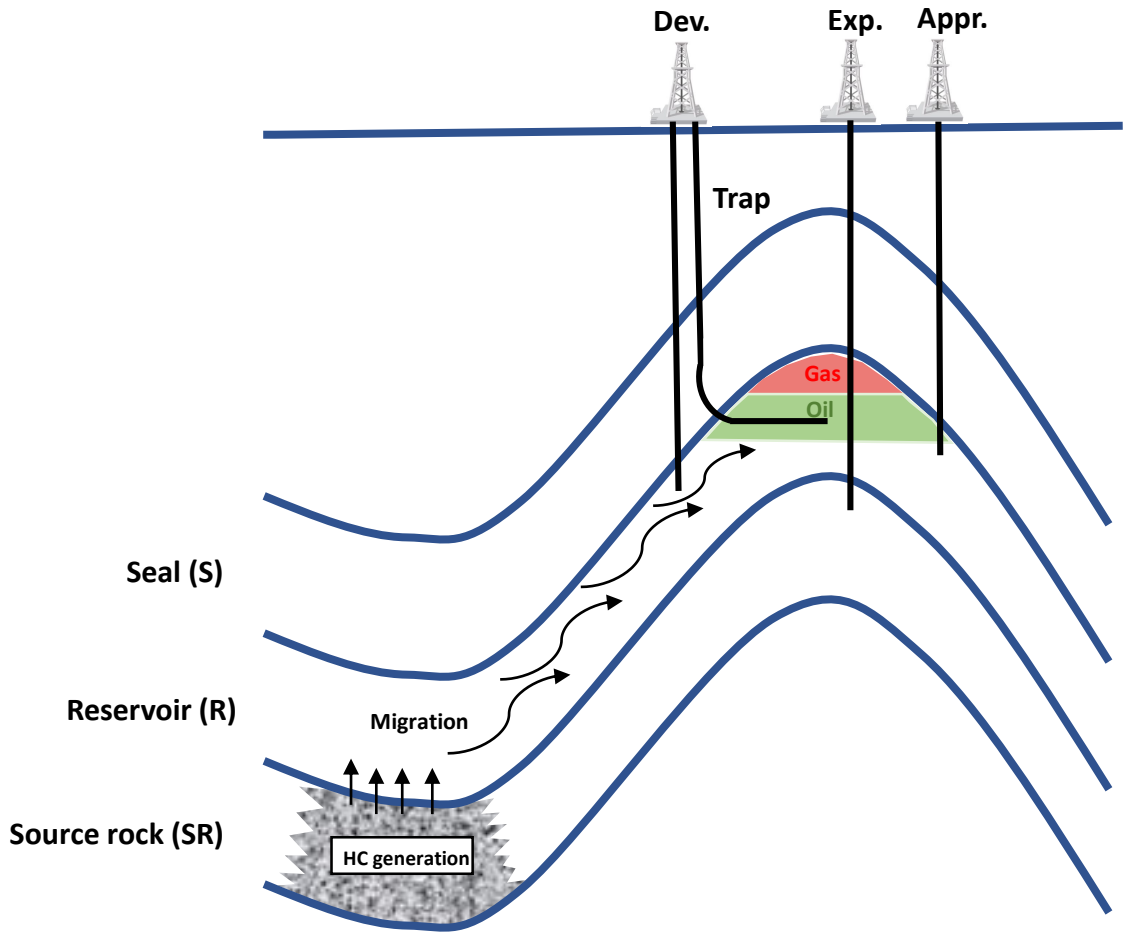
- Field abandonment
- Fulfill work commitments

Drilling

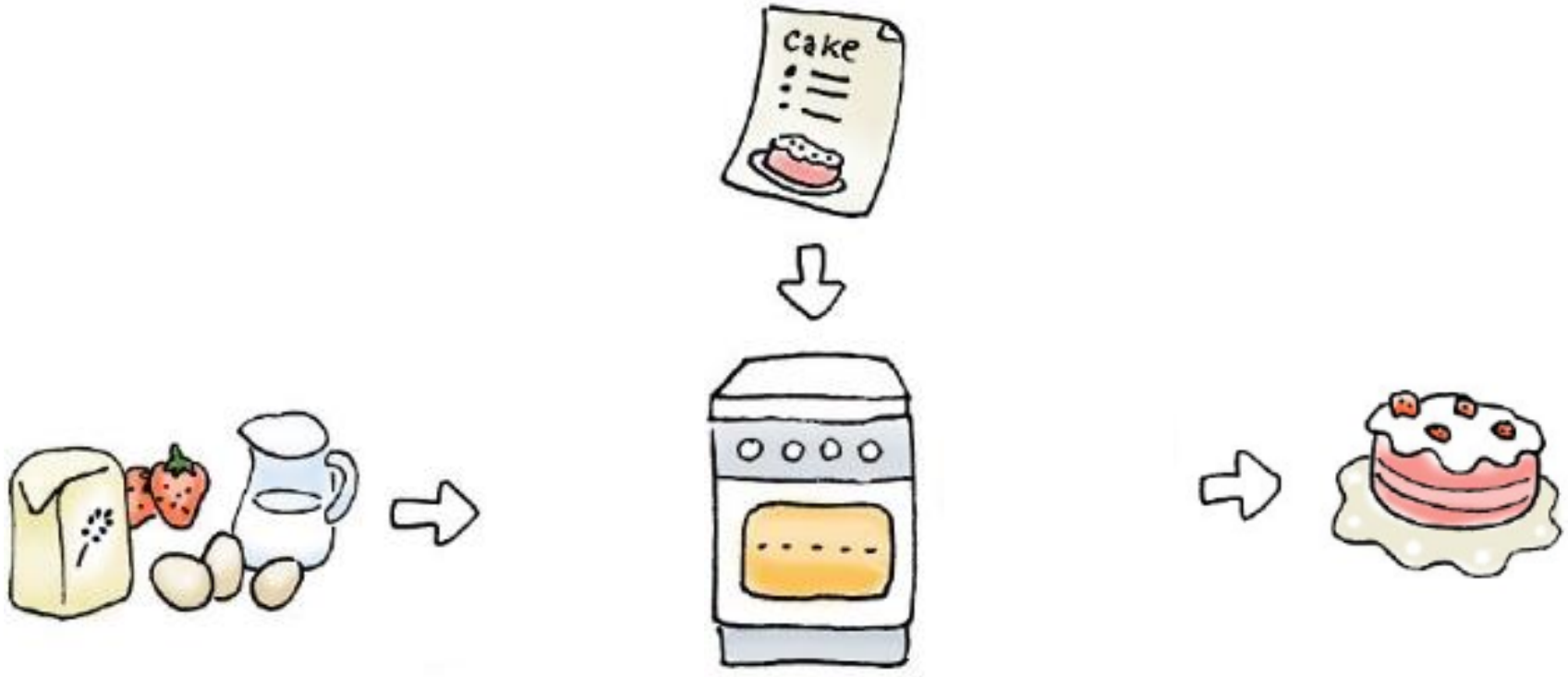
Introduction – Petroleum System Elements

- Generation (SR)
- Migration
- Reservoir
- Seal
- Trap
- Preservation / Accumulation

Geological chance of success = Pg
≠ Economical chance of success = Pe



Oil & Gas drilling Geological Operations



Prospect definition and geological concept → Drilling planning and execution → Results analysis and integration

- ICDP / OSG
- Operational geologist
- Wellsite geologist (WSG)

Data acquisition plan design – Well objectives

- ICDP Project well objectives?

- Oil & Gas well geological objectives:
  - Dependent on the project phase: exploration vs appraisal vs development
  - Can be summarized as three main objectives:
    1. Defining the presence and potential of hydrocarbon accumulations
       - ✓ Reservoir presence and trap outline
       - ✓ Fluid content & properties
       - ✓ Potential in place volumes
    2. Reservoir quality and dynamic behavior
    3. Production and its optimization

Formation boundaries

Lithology

Bedding & structure

Porosity

Fracture network

Saturations

Permeability

Pressures & pressure support

Fluid properties

Fluid samples

Connectivity

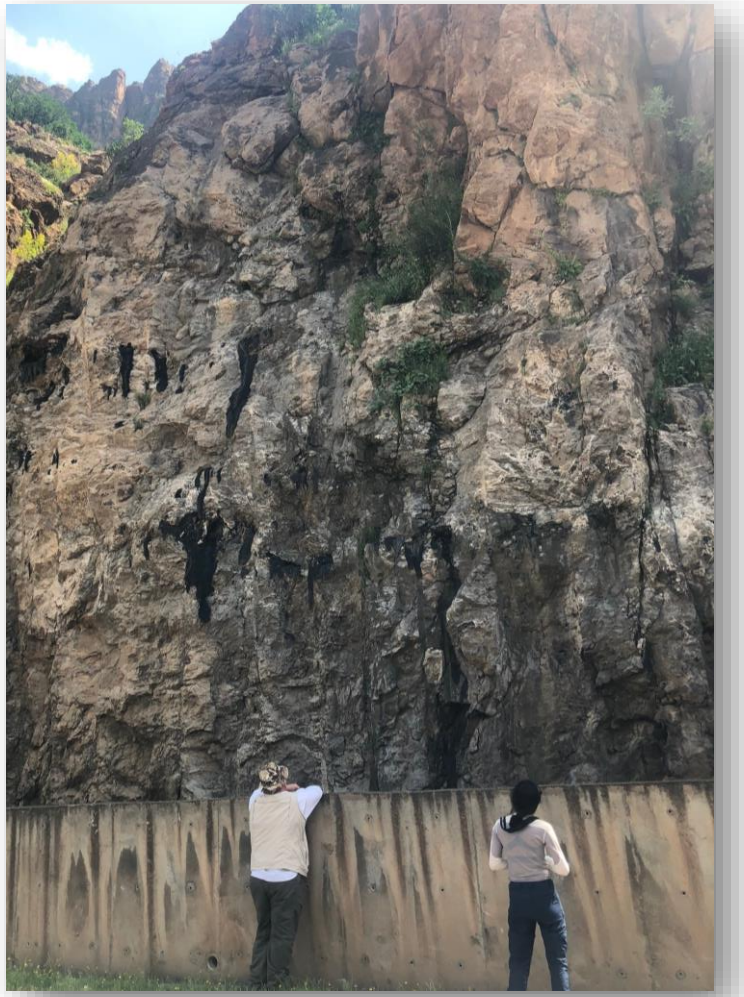
Productivity

Data acquisition plan design – Geological and operational factors

- Onshore / offshore
- Overburden lithology
- Reservoir geology
  - Siliciclastic
  - Carbonates
- Reservoir depth, pressure and temperature
- Discovery?
- Well design
  - Hole size
  - Vertical, deviated, horizontal
- Drilling fluids
- HSE and contractual commitments
  - H2S
  - Pressure regimes
  - Needs for while drilling decision making?
- Tool availability
- Budget

Oil & Gas drilling - Formation evaluation data

- While drilling data
  - Gas content
  - Cuttings
  - MWD/LWD
- Conventional coring
- Wireline (or equivalent) logging
- Testing and long term testing



Pre-Logging data: while drilling data

Qualitative / Semi quantitative

- Mud logging: refers to data based on the monitoring of drilling fluid
  - Main functions of drilling fluid:
    - Provide hydrostatic pressure in the borehole
    - Keep the drill bit cool and cleaned
    - Carry drill cuttings out (or avoid them falling to TD while no circulation)
  - Main data inputs:
    - Gas measurement
    - Drill cuttings
  - Lag time

Pre-Logging data: while drilling data

Qualitative / Semi quantitative

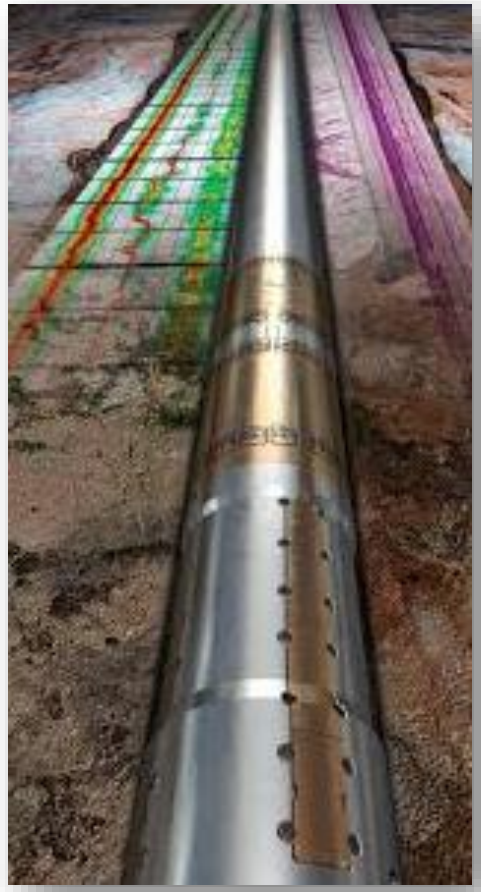
- Gas content: background gas, hydrocarbon indicator, pressure indicator, drilling operation indicator
- Cuttings analysis: lithology, hydrocarbon direct indications, biostrat analysis (while/post drill)
- Additional drilling data:
  - ROP: can be an indicator on lithology and/or porosity – drilling break

Pre-Logging data: while drilling data

Quantitative

- MWD / LWD: equivalent to wireline logging measurements
  - Secures data in case logging cannot be performed
  - Saves rig time if no additional logs are required
  - Provides RT data for while drilling decisions
  - Measurements with minimal drilling mud invasion

- Usual measurements included in Oil&Gas:
  - GR and/or Near bit GR
  - Resistivity and/ or Near bit resistivity
  - Neutron & Density
  - Borehole images (resistivity)
  - Sonic
  - Formation tester



Coring

- Conventional coring is the exception rather than the rule
  - Ex. NCS regulations

- SWC

Tool animation by SLB at:
https://www.slb.com/services/characterization/reservoir/wireline/xl_rock.aspx

Logging: Tools and data

- Geophysicist:
  - Where are my tops?
  - Does seismic interpretation agree with the log data?
  - How is the synthetic looking?

- Geologist:
  - Where are my tops?
  - Do I have reservoir? How good is it?
  - Are there HC in the well? Which type?
  - Reserves?
  - How is it tie with my offset wells?

- Drilling engineer:
  - How much cement do I need?
  - What's the dogleg severity?
  - Where is my casing depth?
  - Where should I place the packers?

- Production engineer:
  - Where and how should I complete the well?
  - What are the expected production rates?
  - Is there gas or water break though expected?
  - Do I need to stimulate the formation?

- Usual logs:
  - **Formation evaluation** (FE) logs
  - Seismic logs
  - Well integrity logs
  - Production logs

- Logging method dependent on well condition and inclination:
  - Wireline
  - Alternative methods (i.e. TLC =Tough logging conditions)

Logging: Tools and data

- **Gamma ray logs**

Measurements: Gamma ray, spectral gamma ray (U, Th, K))

Principle: Measurement of natural radioactivity around the wellbore (counts). Detector (scintillator crystal converting gamma ray energy into visible light flash) + photomultiplier (converts individual light flashes into electrons which are amplified to generate detectable electric pulse) + amplifier-discriminator circuit (differentiates between pulses generated by gamma ray from the formation and those from background electrons).

Application(s):
- Reservoir delineation
- Well-well correlation
- Lithology indicator
- Recognition of radioactive minerals
- Clay content and types - Vsh
- Sedimentary environmental studies (depositional sequence)
- CSG vs OH

- **Caliper logs**

Measurements: borehole size and eccentricity,

Principle: Direct measurement of various borehole radiuses by mechanically opened arms following the borehole wall. Acoustic tool also available.

Application(s):
- Borehole condition identification
- Bad hole flag for log analysis
- Stress field indicator
- Hole volume (cement volume)
- Presence of mudcake

Logging: Tools and data

- **Sonic log**

Measurements: Formation velocities / slowness / travel time. Vp, Vs, Vst.

Principle: Measurement of traveltime of the sonic pulse through the formation from transmitter (emitting sonic pulse) to receiver on a known tool arrangement.

Application(s):
- Porosity estimation
- Fracture detection
- Mechanical property determination
- Evaluation of fluid type
- Seismic exploration and calibration
- Geophysical interpretation (synthetic seismograms)
- Permeability indicator

- **Resistivity logs**

Measurements: Resistivity / conductivity measurements at different depth of penetrations

Principle: Dependent on drilling fluid, either measuring resistivities by injecting current with electrodes (laterolog) or measuring conductivity by coil induced current (induction).

Application(s):
- Presence of permeable zones
- Bed boundaries
- Detailed sand count
- Caliper
- Indication of mudcake thickness
- Hydrocarbon indicator
- Input for saturation estimations

- **Image logs**

Measurements: Up to 360 degree acoustic or resistivity image of the wellbore.

Principle: Through high resolution rotating transducer incorporating transmitter and receiver for acoustic measurements. Microresistivity measurements along wellbore wall through pads for resistivity images

Application(s):
- Borehole shape and condition
- Structural analysis
- Stratigraphic analysis
- Depositional environment studies
- Fracture network modelling
- Depth matching and core orientation

Logging: Tools and data

- **Neutron**

Measurements: Hydrogen index. As H is mostly in HC and H2O, estimation of porosity.

Principle: Includes a chemical source producing high energy neutrons, which slow down due to collision with H atoms present in the rock matrix and fluid. Arriving thermal neutrons are then measured and hydrogen index calculated accordingly.

Application(s):
- Porosity estimation
- Lithology
- Clay analysis
- Gas detection

- **Density**

Measurements: Bulk density ('Electronic density')

Principle: Includes a chemical source sending high energy gamma rays into the formation. Gamma ray will collide with electrons and undergo Compton scattering. The number of gamma rays which are back-scattered to the detector is inversely related to the electron density of the formation, which is almost identical to the mass density. Measuring the gamma ray energy loss the density can be estimated.

Application(s):
- Porosity estimation
- Lithology
- Caliper
- Mechanical properties
- Seismic impedance calculations

- **Magnetic resonance logs**

Measurements: Hydrogen relaxation time. Porosity & related pore size

Principle: Strong magnetic field is applied so hydrogen's polarity will change. The time needed for the H to return to original alignment through a precession movement can be measured. Total porosity (and related pore size) can then be derived.

Application(s):
- Porosity estimation
- Total porosity independent of lithology and without radioactive sources
- Porosity class: micro, meso , macro
- Gas identification
- Free fluid and bound fluid volumes
- HC verification
- Permeability

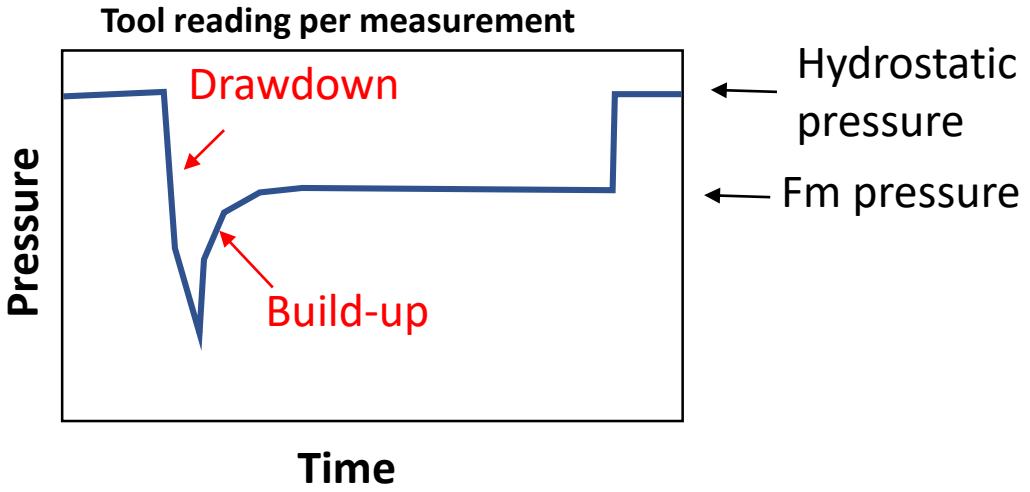
Logging: Tools and data

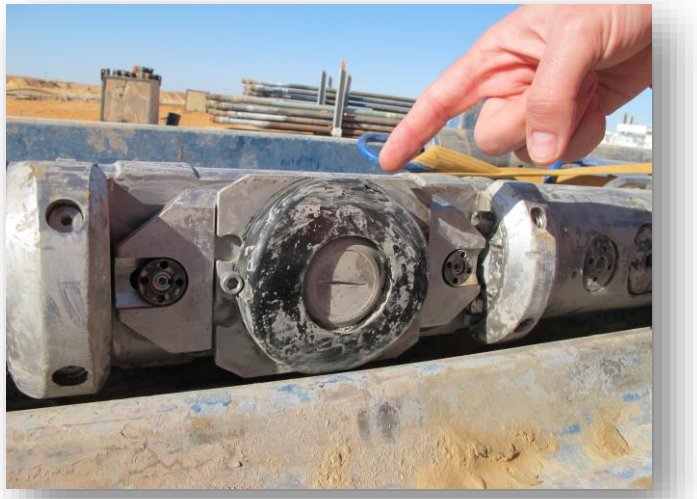
- **Formation tester**

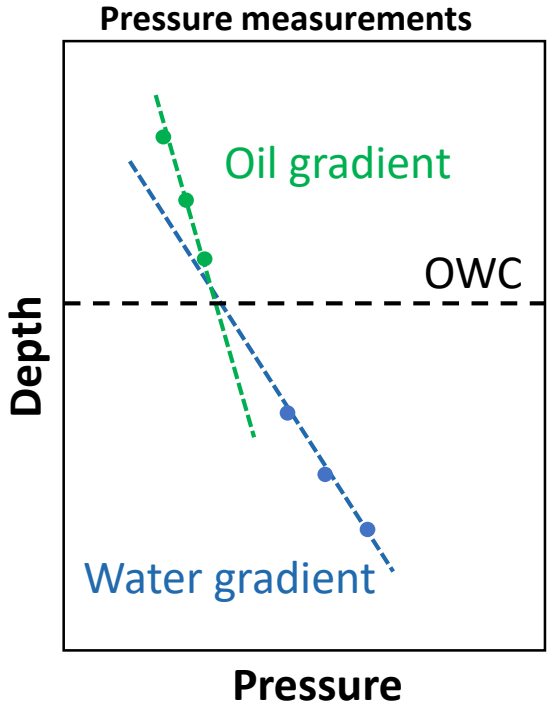
Measurements: Pore pressure and mobility, fluid samples

Principle: Packer / probe with telescopic back-up pistons provide a fluid path from the formation to the tool flow-line with pressure gauges and drawdown is applied so formation fluid is circulated. Resistivity and temperature sensors to evaluate the fluid type. Fluid sampling possible.

Application(s):
- Determination of reservoir initial pressure
- Defining in-situ fluid properties
- Estimation of fluid contacts
- Permeability profiling
- Fluid determination

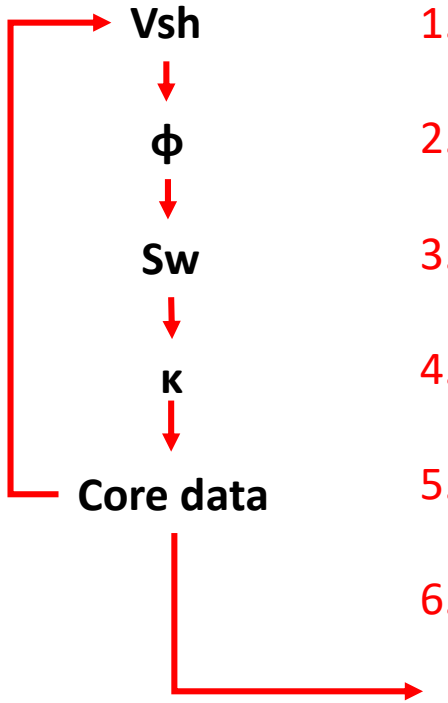






Logging: Tools and data

- Quick log evaluation workflow – Shale/Sand system



1. Identify Reservoir and estimate Vsh: GR & Neutron/density cross plots
2. Estimate Porosity: Bulk density, Neutron Log, Sonic log, NMR log, combination cross plots
3. Estimate Saturation: resistivity and picket plot
4. Estimate Permeability: when / if available, empirical approach
5. Calibrate with core data, re assess when/if necessary
6. Set cut-offs and analyse results
   - Net reservoir
   - Net pay
   - Main reservoir properties (ϕ, Saturation, Permeability)

Case example

Key learnings

- Data acquisition program is based on specific well objectives.
- Current technology has been developed to fulfill E&P needs and provides good coverage and tool alternatives for the main geological challenges in the industry.
- New tools and data analysis techniques are continuously developing
- Industry – Science collaboration underexploited

	Oil & Gas		Science
Well objectives	-	≤	+
Economical resources	+	>	-
Time resources	-	<	+