भारतीय प्रौद्योगिकी संस्थान
(भारतीय खनि विद्यापीठ)
धनबाद

IIT ISM

INDIAN INSTITUTE OF TECHNOLOGY
(INDIAN SCHOOL OF MINES)
DHANBAD

GPC510 - Well logging

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TEACHING OUTLINE

Week 2

Tutorial 4 – Borehole effects, environmental impacts

Tutorial 5 – Tool geometry, resolution, rock composition

Tutorial 6 – depth of investigation, resolution, resistivity, salinity

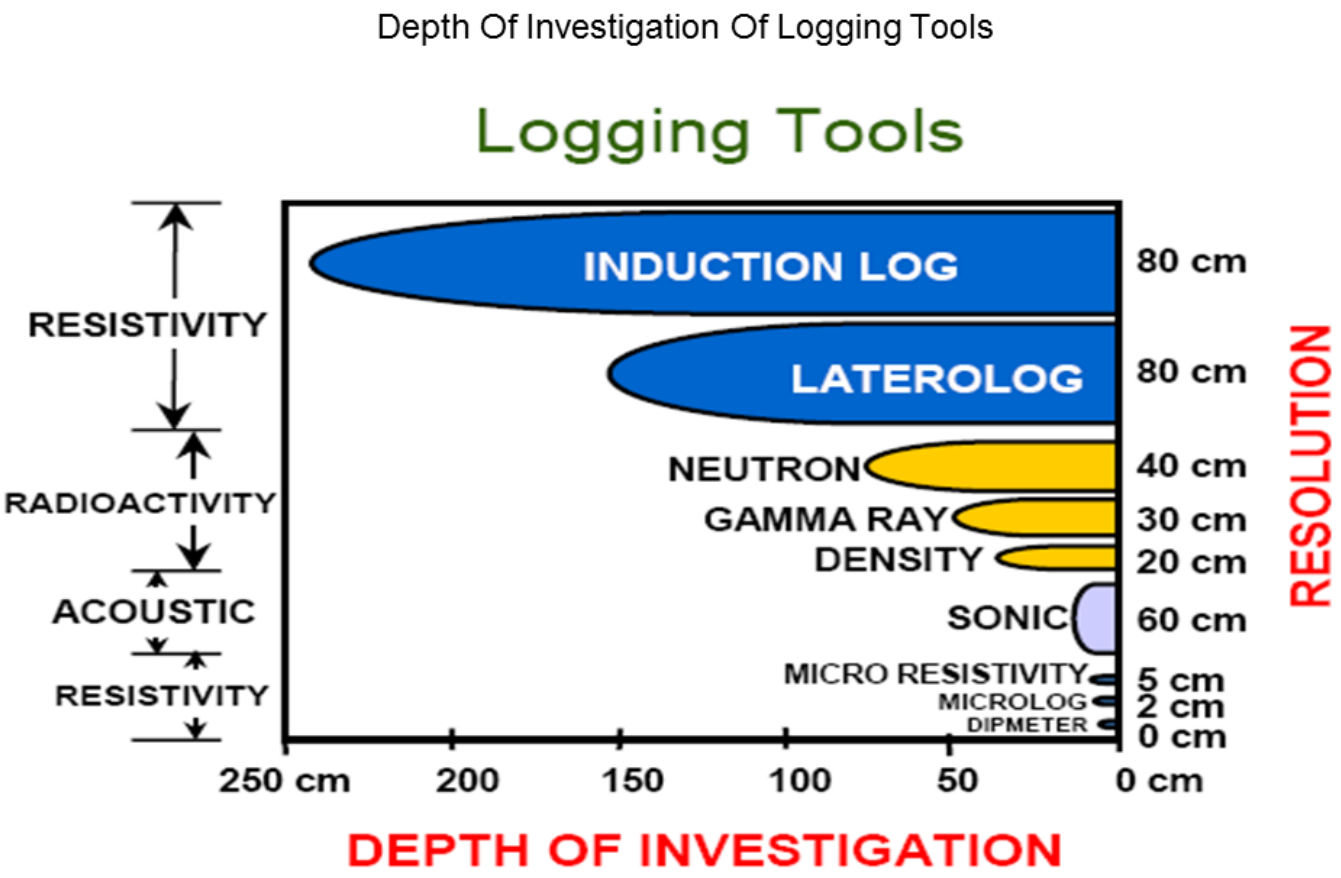
Week 3

Tutorial 7 – Clay definition, porosity

AGENDA

- Resistivity & Salinity
- Clay definition
- Porosity

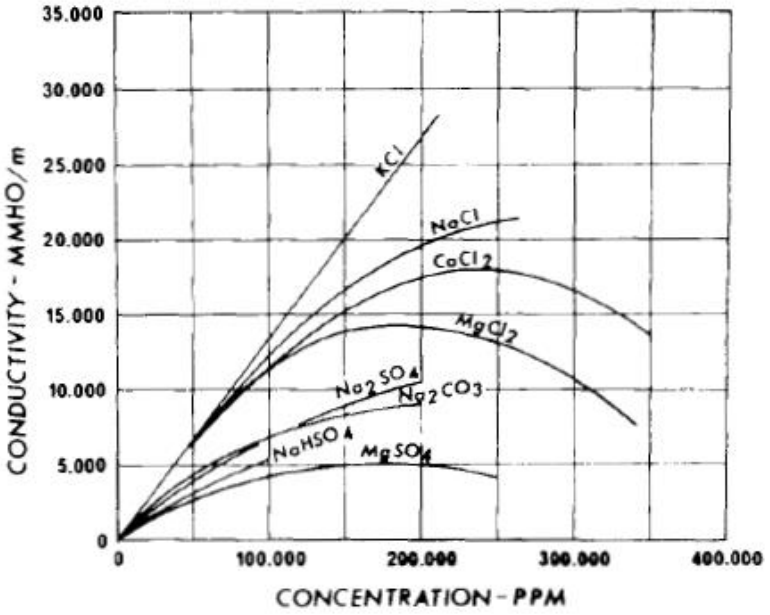
DEPTH OF INVESTIGATION & RESOLUTION



Ref: Bond, 2009

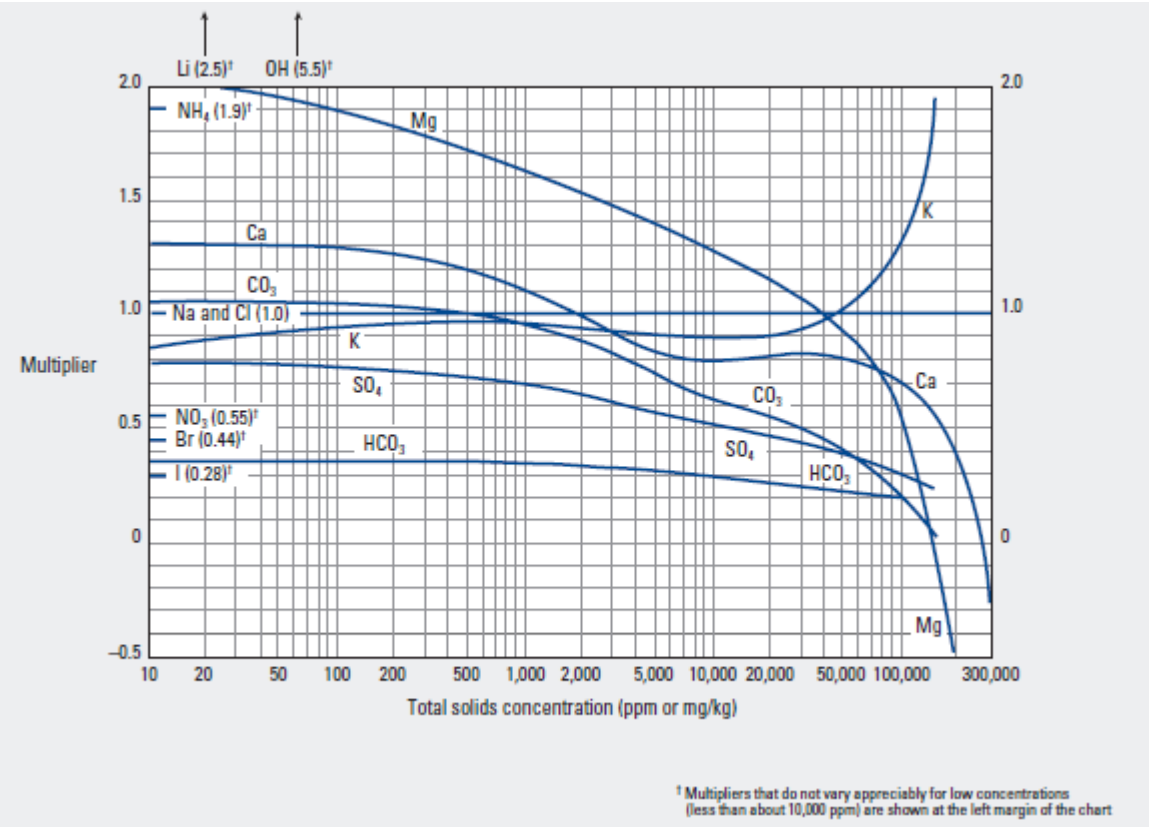
RESISTIVITY AND SALINITY

- Salinity is a measure of the concentration of dissolved salts
- Expressed in ppm [mg solute/ L solution]
- Salt water has salinity of 35000 ppm
- Resistivity of an electrolyte depends upon concentration and type of dissolved salts



RESISTIVITY AND SALINITY

- Charts to convert other dissolved salts in terms of equivalent NaCl
- NaCl is the most salt contained in formation waters and in the drilling muds



Ref: Schlumberger

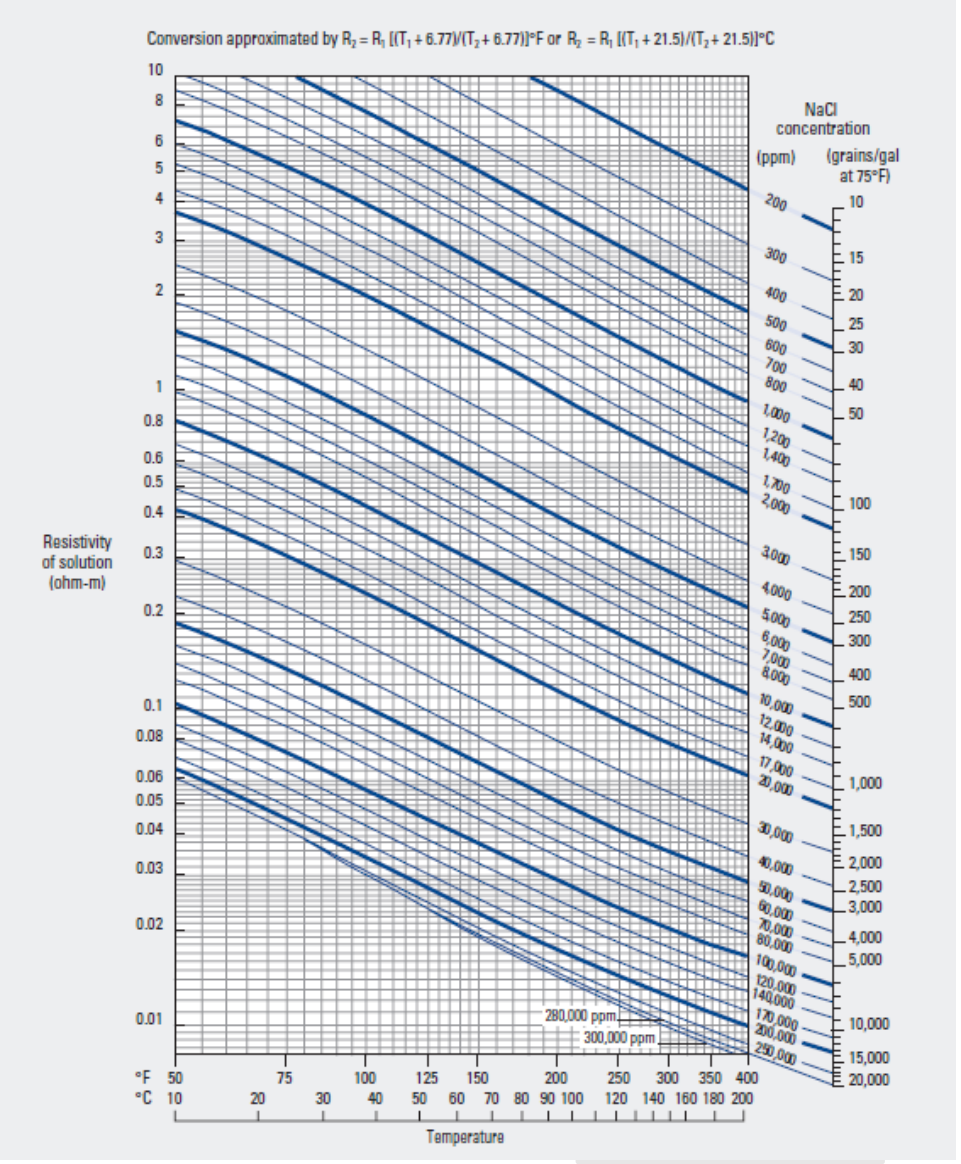
RESISTIVITY& TEMPERATURE

- Resistivity of a solution decreases with increasing temperature
- According to Arp's formula -

$$R_{wT2} = R_{wT1}\left[\frac{T_1+6.77}{T_2+6.77}\right] \text{ in } (^0\text{F})$$

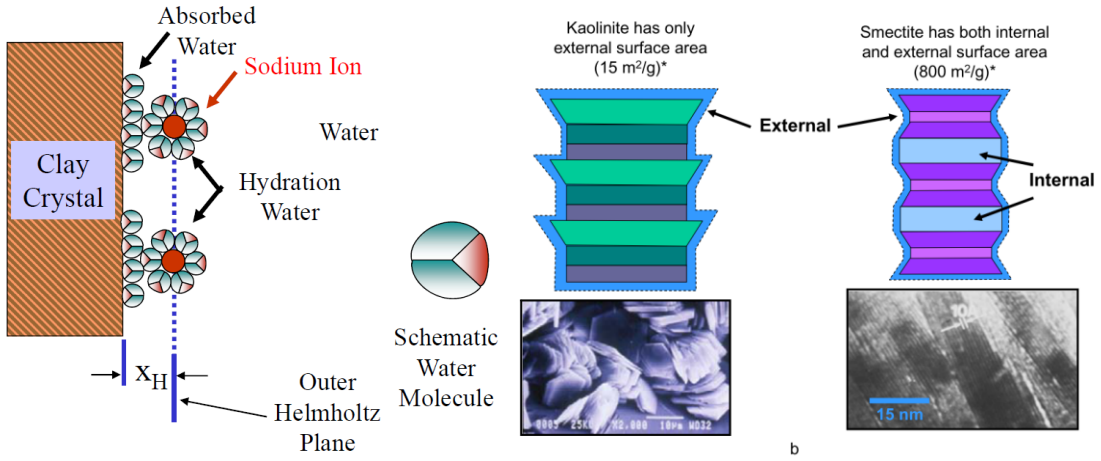
$$R_{wT2} = R_{wT1}\left[\frac{T_1+21.5}{T_2+21.5}\right] \text{ in } (^0\text{C})$$

- Chart presented here can be used to convert resistivity at a given temperature to that at any other temperature



PHYSICAL PROPERTIES OF CLAYS

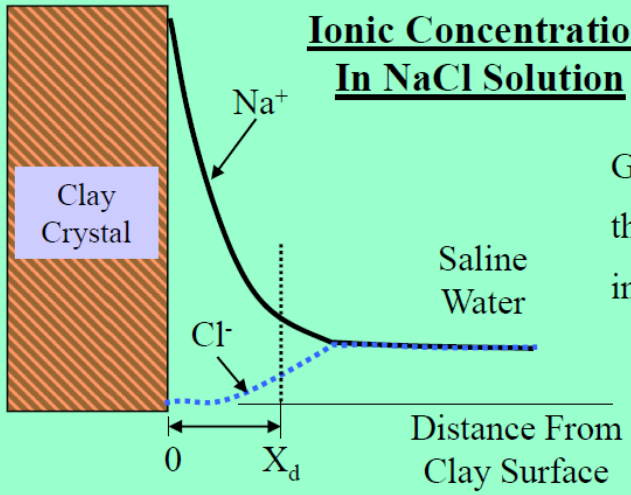
- Clays are sheet-like particles , very thin (a few angstroms = 10^{-7} mm) but large specific surface area (SSA), creating a strong negative electric fields perpendicular to the clay surfaces
- It attracts positive ions (Na+, K+, Ca2+) and repels negative ions (Cl-) present in the water, lead to the concept of Cation Exchange Capacity (CEC)
- SSA and CEC are expressed in m2/gram



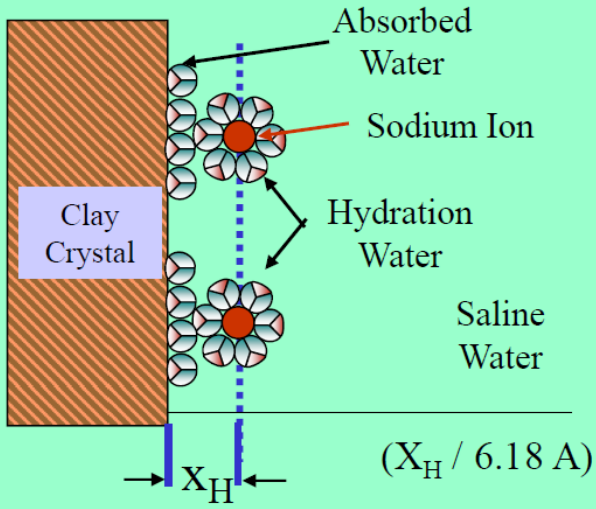
Sample	CEC (meq/100gr)	SSA-N2 (m^2/gr)	TSSA-EGME (m^2/gr)
Smectite[a]	76.1–150[b–f]	31.13[i], 75.9[j]	400–850[h,m]
Illite	9–40[b–d,f,g]	25[k], 67.2[j]	57–118[h,m]
Chlorite	1[c]	15[k]	9–62[h,m]
Kaolinite	0.9–15[a–e,h]	11.5[i]–21[j]	9–62[h,m]
Kerogen	<0.5[h]	5.5–300[l]	860–921[h]

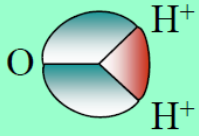
Ref: Passey et al, 2010; Saidian et al., 2016; Pete, 2016

DIFFERENT MODEL OF DIFFUSE LAYER



Gouy profile of diffuse layer, thickness $X_d = 3.06\sqrt{\frac{1}{(n)}}$ increases as salinity decreases.



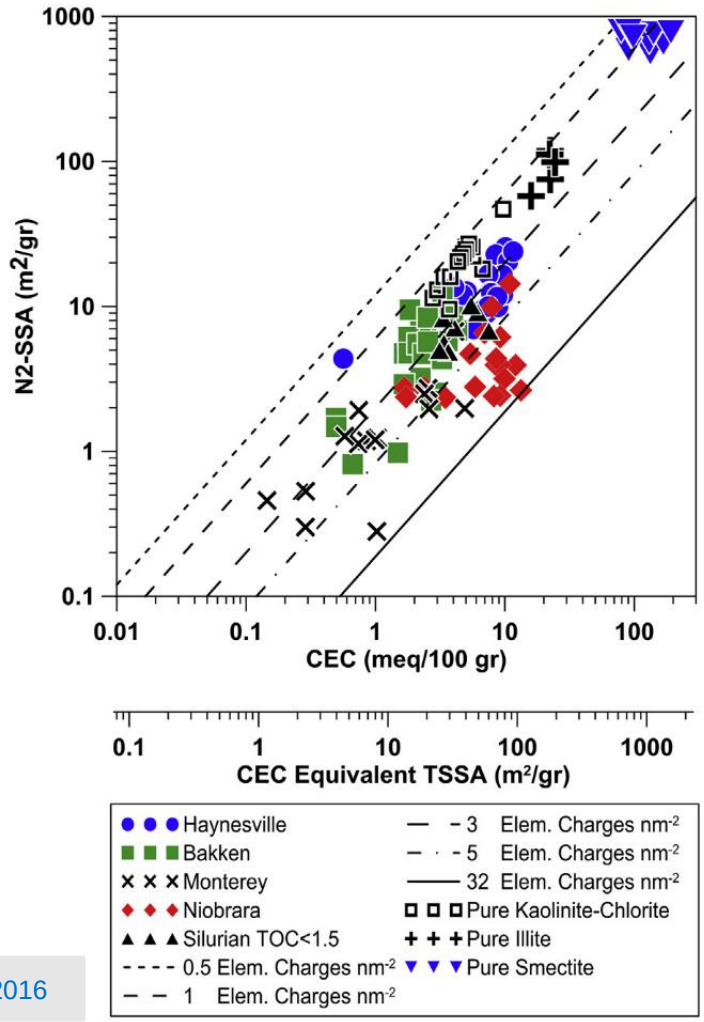


Model of exclusion layer (Helmholtz Plane)sodium ions excluded from surface layer by dielectric properties of water

n – concentration of ions (number of ions/m^3)
A – thickness in Angstrom (1 A = 10^{-10} m)

RESISTIVITY OF CLAYS

- Excess of conductivity in clays is due to additional cations held loosely captive in a diffuse layer surrounding to clay particles
- Conductivity of a clay dominated sedimentary rock (inverse of resistivity) depends upon (i) free water/ water filled pore space (ii) CEC
- Dealing with formation containing clay can not be considered to be non-conductive for solid matrix
- CEC and SSA indirectly influence subsurface rock's mechanical and elastic properties



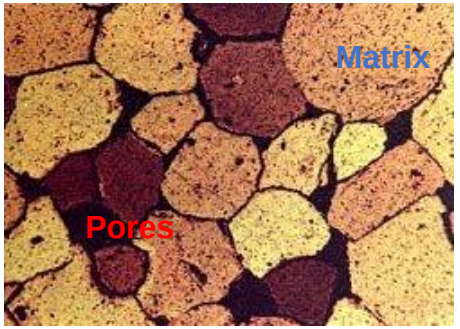
Ref: Saidian et al., 2016; Pete, 2016

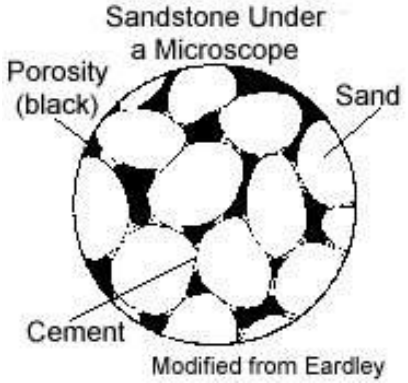
POROSITY

- Porosity is defined as the ratio of the pore volume to the bulk volume (V_b) of the rock
- The pore volume is the available space which holds pore fluids (water, hydrocarbon)

$$\emptyset = \frac{pore\ volume}{bulk\ volume} = \frac{V_b - V_g}{V_b}$$

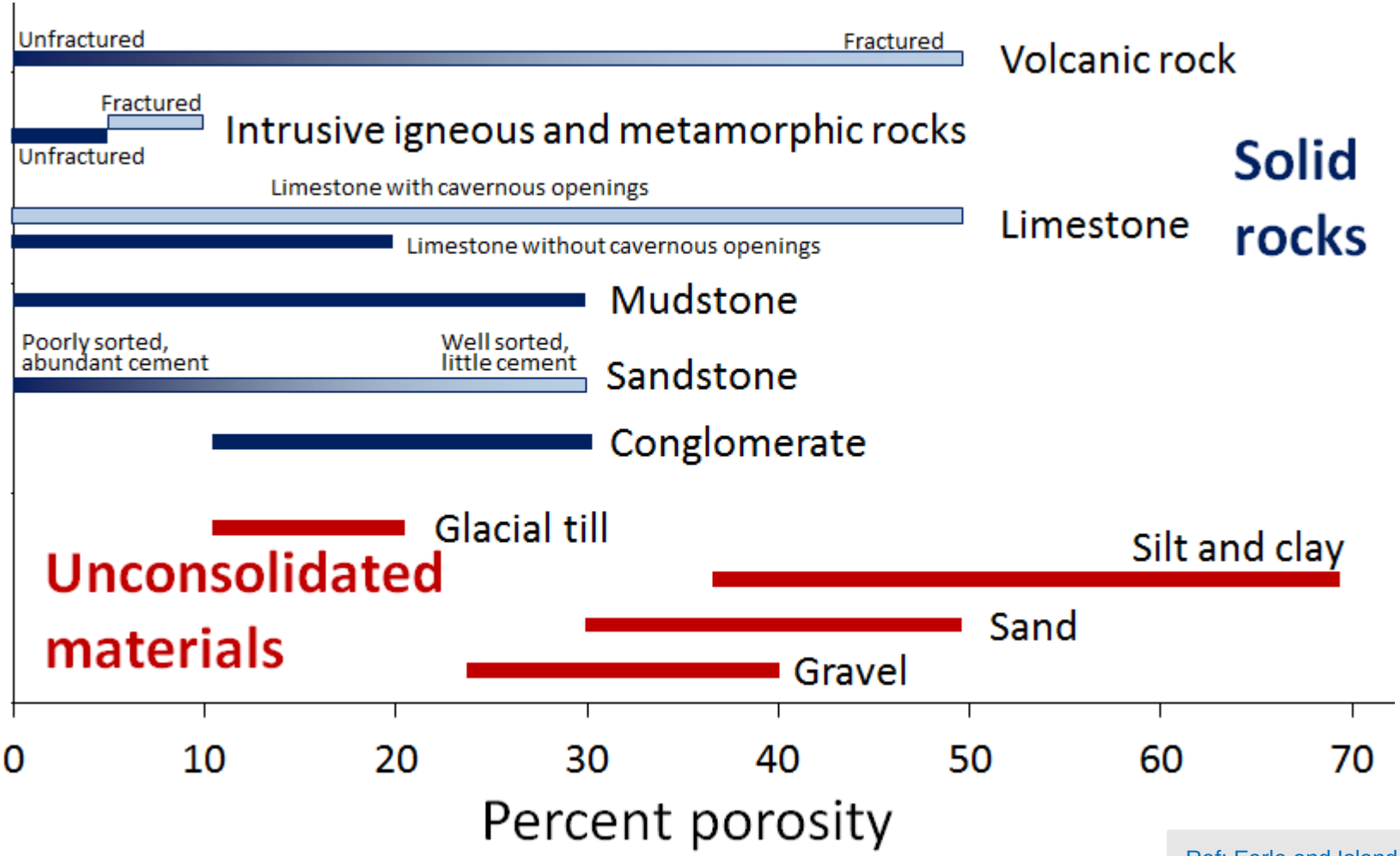
- Total porosity (ϕ_t) is the total pore volume relative to the bulk rock volume
- Total porosity is a combination of intergranular and secondary
- Effective porosity (ϕ_e) is the ratio of interconnected pore volume and the bulk volume of the rock





Ref: Geomore.com

POROSITY CHART OF ROCKS



Ref: Earle and Island, 2015

POROSITY TOOLS

- Porosity can be calculated from several wireline logging tools (Sonic, Density, Neutron) and can be estimated from Resistivity log
- Some a prior knowledges are necessary (depositional environment, log type) before going into porosity calculation
- Necessary action should be taken to tackle poor hole conditions, presence of hydrocarbons and shale within the reservoirs
- All reliable logs can be used to compute porosity

END OF LECTURE