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Troyee Dasgupta
Soumyajit Mukherjee

Sediment Compaction and Applications in Petroleum Geoscience

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Troyee Dasgupta
Department of Earth Sciences
Indian Institute of Technology Bombay
Mumbai, Maharashtra, India

Soumyajit Mukherjee
Department of Earth Sciences
Indian Institute of Technology Bombay
Mumbai, Maharashtra, India

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Troyee Dasgupta *dedicates this book to her daughter "Rahini Dasgupta, born on 31-Jan-2017"*.

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Contents

Symbols

Φ	Porosity
Φ_0	Average surface porosity of the surface clays
c	A constant
z	Burial depth
ρ_h	Hydrostatic pressure
γ_w	Specific weight of water
h	Height of column of water
G_h	Hydrostatic pressure gradient
P	Pore pressure
σ_v	Overburden stress
σ_e	Effective stress
α	Biot's effective stress coefficient
Rn	Resistivity normal trend
R	Resistivity log
X	Normal compaction trend
Δt	Interval transit time
Δt_n	Interval transit time normal trend
Y	Pore pressure gradient
P_f	Formation fluid pressure
α_v	Normal overburden stress gradient
β	Normal fluid pressure gradient
Z	Depth
Δt	Sonic transit time
A, B	Parameters
P_B	Pore pressure
σ_A	Effective stress at A
P_{NA}	Hydrostatic normal pore pressure at point A
OB_B	Overburden pressure at point B
OB_A	Overburden pressure at point A
σ_M	Mean effective stress
σ	Vertical effective stress

σ_h	Minimum horizontal stress
σ_H	Maximum horizontal effective stress
V	Sonic velocity
V_{min}	Minimum sonic velocity of the rock matrix
V_{max}	Maximum sonic velocity of the rock matrix
Σ	Vertical effective stress
P	Pore pressure
ρ_{max}	Maximum matrix density
ρ_f	Fluid density
Δt_f	Interval transit time of fluid
Δt_n	Interval transit time for the normal pressure in shales
Δt	Transit time of shale
V_p	Compressional wave velocity
V_{ml}	Mudline velocity
U	Parameter representing uplift of the sediments
σ_{max}	Effective stress
v	Velocity
V_m	Sonic interval velocity with the shale matrix
a_m	Ratio of the loading and unloading velocities in the effective stress curves
V_{max}	Velocity at the start of unloading
P_{ulo}	Pore pressure due to unloading
$Ø_{RHOB}$	Porosity from density log
ρ_{ma}	Matrix density
ρ_b	Bulk density measured by log
ρ_{fl}	Fluid density
Δt_{ma}	Interval transit time of the matrix
Δt_{fl}	Fluid transit time
Δt	Average interval transit time from log
$Ø_{DT}$	Porosity from sonic log
$Ø_{RILD}$	Porosity from resistivity log
R_w	Formation water resistivity
n	Saturation exponent
m	Cementation exponent
Rt	True resistivity of the formation
t_{ma}	Sonic transit time of the rock matrix
ϕz	Porosity at depth z
ϕ_0	Porosity at the surface
b	A constant
Δt	Transit time measured by the sonic log

Δt_o	Transit time at the present sedimentary surface
c	Compaction coefficient
z	Burial depth
Δt_o	Transit time near to the transit time of water

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Compaction of Sediments and Different Compaction Models

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Abstract

Various simple and advanced models exist for mechanisms of uniform and non-uniform sediment compaction that increases density and reduces porosity. While the classical Athy's relation on depth-wise exponential reduction of porosity is not divided into any distinct stages, the Hedberg's model involves four stages. Weller's model utilized Athy's and Hedberg's relations to deduce a sediment compaction model. Power's compaction model additionally considers clay mineralogy. Several other porosity/compaction models exist, e.g., those by Teodorovich and Chernov, Burst, Beall, and Overton and Zanier. The geometry of the depth-wise porosity profile depends on the sedimentation rate, compaction mechanism and pressure solution model. This chapter reviews porosity variation with depth for the following rock types: shales, shaly sandstones, sandstones and carbonates.

1.1 Introduction

The chemical and the physical properties of sediments and sedimentary rocks alter as the overburden pressure increases. These changes relate to burial depth, temperature and time. Experiments by Warner (1964) suggested that acceleration of the rate of compaction of sediments seem to be the only change at <200 °F. Compaction of sediments reduces porosity and increases density (Bjørlykke et al. 2009). The reduction of porosity is a convenient way of measuring the amount of sediments compacted since deposition took place, for practical purposes. Empirical compaction curves are the plots of porosity versus depth up to ~6 km. Mechanical compaction being the primary mechanism of compaction, clay minerals are often utilized in many models to visualise how grains rearrange with depth. The composition varies from proximal to distal part of the basin and the compaction pattern of each sediment type differs (Bjørlykke et al. 2009). Compaction models explain the major processes for the sediment compaction. This helps the interpreters to visualise the relationship of porosity loss with depth and the probable reason for anomalous zones. The evolution of compaction models and porosity reduction with depth from different parts of the world are presented in Fig. 1.1.

1.2 Porosity Models

Sediment porosities undergo changes with burial. In the consecutive sections the different models are explained.

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