Lithofacies and Depositional Environments

Review of Ch 2-4~ 2-10
Rock Physics Seminar, Mar.6th
Chingwen Chen
Outlines

- Introduction
- Facies and depositional environments
- Rock Physics analysis of seismic lithofacies
- Compaction of sands and shales
- Modeling velocity-depth trends
- Rock physics model constrained by local geology
- Conclusion & Discussion
Introduction

- Facies is defined as a rock unit with distinctive lithologic features. (i.e. compaction, grain size, bedding and so on.)
- Establish a link between rock physics and sedimentology
- Facies have a major control on depositional geometries and porosity distributions and can be linked to pattern sedimentary process.
- Facies helps us to link physical properties to data acquisition
Walther’s Law of facies

- When a depositional environment "migrates" laterally, sediments of one depositional environment come to lie on top of another.

- No break in the sedimentary sequence
- Sedimentary sequence continues
- The concept of vertical deposition environment
- Shows the figure in the book

[Sam Boggs, Jr.]
Facies and depositional system

- North Sea turbidite system at seismic scale
- Facies I and VI vary their sand-shale ratio

| Table 2.3 Geological description of seismic lithofacies in North Sea deep-water clastic systems |
|---|---|---|
| Facies | Geological description of facies and subfacies | Gamma-ray log note |
| I | Granules, conglomerates, and pebbly sand. Sand rich in mud and silt. Low sedimentation rate. |
| IIa | Consolidated clean sand |
| IIb | Unconsolidated clean sands |
| IIc | Plane-laminated sand |
| IId | Shaly sand |
| III | Interbedded sandstone |
| III | Interbedded sandstone and shale |
| IV | Silty shales |
| V | Pure shales |
| VI | Chaotic deposits |

IIa: Consolidated clean sand
IIb: Unconsolidated clean sands
IIc: Plane-laminated sand
IId: Shaly sand
Clay content (Sand-Shale relations)

Figure 2.33  Rock physics diagnostics of two sandstone intervals in the type-well, indicating an unconsolidated zone (Facies IIb, open circles) and a cemented zone (Facies IIa, filled squares). The unconsolidated sands have been confirmed by core observations (Figure 2.32). Presence of cemented Heimdal Formation sands has been confirmed in Section 2.3.
Sand-Shale plotting

IIa: Consolidated clean sand
IIb: Unconsolidated clean sands
IIc: Plane-laminated sand
IID: Shaly sand
III : Interbedded sand-stone
IV: Silty shales
V: Pure shales

**Figure 2.34** P-wave velocity versus gamma ray (left) and density versus gamma ray (right), for different seismic lithofacies in training data (i.e. Well 2). Note the ambiguity in P-wave velocity between Facies IIb and IV/V.

**Figure 2.35** Acoustic impedance versus gamma ray (left) and $V_p/V_s$ ratio versus gamma ray (right) in type-well.
Rock physics depth trend

- Study velocity depth trend can be a tool to identify the anomalies which can indicate over-pressure zone/over-compaction and different fluid saturation.
Compaction of Shales and Sands

- In the North Sea, mechanical compaction of sand dominated the diagenetic reduction of porosity for upper 3km
- Pure shale tend to obtain a nearly constant porosity trend vs. depth

\[ \phi = \phi_0 e^{-cZ} \]

Mechanical compaction of sands & shales

\[ \phi = \phi_0 e^{-(\alpha + \beta C_1)Z} \hspace{1cm} C_1 = \frac{V_{cl}}{V_{qz}} \]

Solidity vs. depth for shale

\[ Z=6.02 \ \text{N}^{6.35} \]

\[ Z=15 \ \text{N}^{8} \]

Mechanical compaction of sands

\[ \phi = \phi_D - k(Z - Z_D) \]

Solidity vs. depth Tertiary shales of GOM

\[ Z=3.7\ln[0.49/(1-N)] \]

Chemical compaction (clean sandstone)

North Sea sandstone curve (rather mature)
Compaction of Shales and Sands

**Figure 2.37** Sand and shale porosity models (equations (2.43) and (2.45)) with depth. During shallow burial, porosity change is mainly due to mechanical compaction (curved lines, equation (2.43)), and the porosity decreases with increasing clay content (i.e., increasing ductility). At a certain depth level, clean sands lose porosity mainly via pressure solution and quartz cementation (straight line, equation (2.45)). (Modified from Ramm and Bjørlykke, 1994.) Depth is in meters relative to sea floor (mRSF).
Temperature, pressure, fluid reference density (Environmental control)

Vp, Vs, density model

Distinguish frame properties from fluid properties

Pitfall: maybe over simplified for instance, calcite cement and shallow overpressure and so on
Shale A and Shale B have different porosity.
Conclusions & Discussions

- For sands, there are ambiguities between clay content and sorting (S-wave info will help)
- Potential resolution different between well-log and seismic
- Separate depth-related changes (rock frame compaction) and constant-depth variations (fluid)
- Deviation from expected velocity–depth trends can be related to overpressure, gas, diagenesis, lithology, uplift, etc.