Origin of Overpressure and Pore Pressure Prediction in Carbonate Reservoirs of the Abadan Plain Basin

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This thesis is submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in the Australian School of Petroleum, Faculty of Engineering, Computer & Mathematical Sciences, The University of Adelaide

November 2016

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Abstract

This thesis analyses overpressure throughout the Abadan Plain Basin and evaluates pore pressure in this basin using conventional petroleum industry methods, as well as two new proposed pore pressure prediction methods. Overpressures in the Abadan Plain Basin are primarily exist within carbonates, whereas most previously published overpressure analysis has been undertaken in shale-dominated clastic rocks. Overpressure in this basin is encountered in two main zones, primarily the Gachsaran and Gadvan/Fahliyan formations. South-west to north-east oriented thickening and shortening, as result of Arabia-Eurasia collision, has affected the pressure regime within the Gachsaran Formation, but seemed ineffectual to the Gadvan and Fahliyan overpressures.

In order to analyse overpressure origins and test conventional pore pressure prediction methods, a discrimination scheme was applied to remove the impact of lithology on the log recordings, resulting in isolating the minor shale interbeds within, and as a representative of, the carbonate sequences. Disequilibrium compaction was identified as the primary origin of overpressure in the Abadan Plain Basin. Eaton's (1972) pore pressure prediction method was applied on the filtered shale data with an exponent of 1.0 for sonic velocity, 0.1 for resistivity, and 5 for density data. Bowers' (1995) method was also tested and, while it accurately predicted pore pressure in the Gadvan and Fahliyan formations, it underestimates pore pressure in shallower formations.

This thesis also introduces a new 'compressibility method' for pore pressure prediction, developed by the author, that uses porosity-compressibility correlations. This new 'compressibility method' provided reliable pore pressure prediction results in the studied wells. Alternatively, overpressure as a result of sediment compaction is also estimated using Biot's (1941) general theory of three-dimensional consolidation. A generalised compaction model was constructed, and the resulting modelled pore pressure provides a reasonable estimate of observed pore pressure.

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28/11, 2016

Acknowledgments

I'd like to express my great thanks to my principal supervisor, Dr. Mark Tingay, for his support and genuine advices on the concepts and techniques for identifying overpressure origin and employing pore pressure prediction methods. I also thank my co-supervisor, Dr. Khalid Amrouch, and my former co-supervisor, Dr. Rosalind King, for their consultation and collaborations on the geological principles.

I also express great thanks to Dr. Saeid Jamshidi for his help in advancing my skills in MatLab software and Mr. Hossein Khoshdel for his generous assistance in helping me to work with Petrel modelling package.

Finally, my sincere thanks to my wife, mum, dad and two brothers for their continuous support and kind understanding all throughout my degree. I wouldn't have succeeded without their support and encouragement.

List of Symbols

P_h: hydrostatic pressure

σ: stress

σ': effective stress

σ_v: lithostatic pressure

σ_{max}: effective stress at the onset of unloading

ρ: density

ρ_b: bulk density

ρ_f: fluid density

ρ_{ma}: matrix density

ρ_{shale}: shale density

ρ_{normal}: density of normally compacted shale

g: gravitational acceleration

z: depth

ϕ: porosity

P: pressure

GR: Gamma ray

Δt: measured interval transit time

Δt_{ma}: matrix interval transit time

Δt_f: pore fluid interval transit time

Δt_{normal}: interval transit time of normally compacted shale

R_{shale}: shale resistivity

R_{normal}: resistivity of normally compacted shale

V: sonic velocity

V_{normal}: sonic velocity of normally compacted shale

V_0: sonic velocity at the surface

V_{max}: sonic velocity at the onset of unloading

V_b: bulk volume

V_p: pore volume

P_p: pore pressure

A: Bowers' regional parameters

B: Bowers' regional parameters

cs: an empirical regional correction factor for unconsolidated sediments

P_h: hydrostatic pressure

σ_v: lithostatic pressure

σ_{max}: effective stress at the onset of unloading

γ: exponent

η: empirically derived constant in Gardner's equation

B: empirically derived constant in Gardner's equation

α': a coefficient that measures the ratio of the liquid volume squeezed out to the volume change of the soil in an unconfined loading

α: Biot's poroelastic parameter

ν: Poisson's ratio

G: shear modulus

C: compressibility

C_b: bulk compressibility

C_r: rock compressibility

C_{bc}: bulk compressibility versus confining pressure

C_{bp}: bulk compressibility versus pore pressure

C_{pc}: pore compressibility versus confining pressure

C_{pp}: pore compressibility versus pore pressure

Cr: matrix compressibility

Q: a coefficient that measures the amount of liquid that can be forced into the sample under pressure while the volume of the sample is kept constant

1/H: a measure of the sample compressibility for a change in fluid pressure

1/R: measures the change in liquid phase content for a given change in fluid pressure

θ: the increment of liquid phase volume per unit volume of soil

q: flow rate

A: area

k: permeability

h: thickness

μ: viscosity

U: unloading parameter

x: Eaton exponent