

PS Overpressures and Their Significance in Offshore Bohai Bay Basin, China*

Xiao Wang¹, Stuart J. Jones³, Sheng He², Qiang Liu⁴, and Chunyang Cheng⁵

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¹China University of Geosciences(Wuhan), Wuhan, Hubei Province, China (yueguanyu@foxmail.com)

²China University of Geosciences(Wuhan), Wuhan, Hubei Province, China

³Durham University, Durham, United Kingdom

⁴CNPC Jidong Petroleum, Tangshan, China

⁵CNPC Liaohe Petroleum, Panjin, China

Abstract

The Bohai Bay Basin is a major continental hydrocarbon basin located in eastern China, of which the offshore part of the basin contains more than one-third of the total reserves. The research focuses on two main depressions in the offshore Bohai Bay Basin: the Bozhong and Liaodongwan Depressions. The stratigraphy in the basin is dominated by thick braided river, lacustrine and fan delta sediments of the Eocene Shahejie (Es) and Oligocene Dongying (Ed) Formations. The distribution of overpressure in the basin was evaluated by integrating direct pressure measurements and drill stem tests (DST) and pressures calculated from wireline logs. In total, 1433 DST from 143 wells has been incorporated into this study from the overpressured Es and Rd Formations. Overpressure tends to be restricted to the Bozhong and Liaodongwan Depressions that encountered the highest sedimentation rates. Compaction disequilibrium is favored as the main mechanism to explain overpressure generation in much of the offshore Bohai Bay Basin, primarily due to the rapid sedimentation rates (~500 m/m.y.) of fine-grained sediments. However, our data indicates that the highest-magnitude overpressures are caused by the addition of hydrocarbon generation from the source rocks within the Es Formation. The depth to the top of the overpressure intervals ranges from 2000 to 2800 m and in several portions of the basin bears a close correlation to source rock depth of the Es Formation. All of the overpressured reservoirs and source rocks have a minimum temperature of ~87°C and overpressured source rocks have a vitrinite reflectance (Ro) values of 0.6% or higher. Many of the overpressured source rocks contain microfractures that may be related to episodic expulsion of hydrocarbons or overpressure dissipation. Overpressure in the sandstone intervals of the Es Formation and to a lesser extent of the younger Ed formation corresponds to anomalously high porosity of up to 38% compared to the regional porosity-depth trend for the basin. In many cases the overpressure reservoir sandstones reflect an undercompacted state of burial and show a close association with tight calcareous mudstones that form an effective pressure seal in the basin. The distribution of overpressure, vertical effective stress, porosity, and general reservoir quality of the reservoir sandstones are investigated as part of this study to more accurately guide the exploration in the offshore Bohai Bay Basin, China.

Overpressures and Their Significance in Offshore Bohai Bay Basin, China

Xiao Wang¹, Sheng He¹, Stuart Jones², Qiang Liu³, Chunyang Cheng⁴ (* xiao.wang@cug.edu.cn)

¹Key Laboratory of Tectonics and Petroleum Resources, MOE, China University of Geosciences, Wuhan, Hubei, China; ²Department of Earth Sciences, Durham University, Durham, UK; ³PetroChina Jidong Oilfield Company, Tangshan, Hebei, China; ⁴PetroChina Liaohe Oilfield Company, Panjin, Liaoning, China

Introduction

Bohai Bay Basin is a major continental hydrocarbon basin located in eastern China. Bozhong and Liaodongwan Depressions are two main depressions of its offshore area. The stratigraphy is dominated by thick sediments of the Eocene Shahejie (Es) and Oligocene Dongying (Ed) Formations (Fig. 1).

The distribution of overpressure in the basin was evaluated by integrating direct pressure measurements and drill stem tests (DST) and pressures calculated from wireline logs. In total, 1433 DST from 143 wells has been incorporated into this study from the overpressured Es and Ed Formations. Overpressure tends to be restricted to the Bozhong and Liaodongwan Depressions that encountered the highest sedimentation rates.

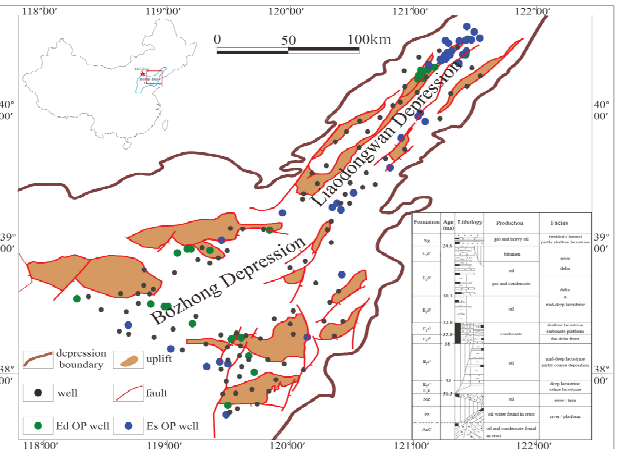


Figure 1. Geological settings of offshore Bohai Bay Basin

Overpressure distribution Characteristics

Overpressure in offshore Bohai Bay Basin are mainly distributed in Bozhong Depression and Liaowangwan Depression (Fig. 1). Vertically, the overpressured interval ranges from (2000 to 3800 m) are found within the Ed and Es Formations. Overpressure in Ed formation can reach to 31 MPa at 3431 m; in Es the maximum overpressure is 24 MPa at 3791 m (Fig. 2).

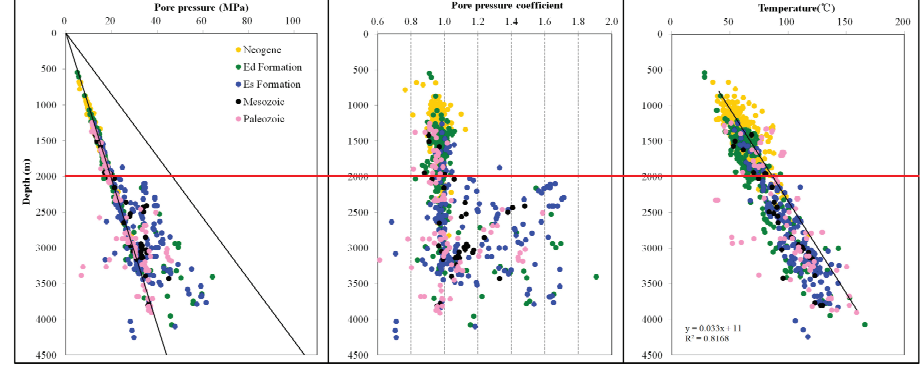


Figure 2. Measured pore pressure and temperature data (DST, RFT).

Generation mechanism of overpressure

Compaction disequilibrium is favoured as the main mechanism to explain overpressure generation in much of the offshore Bohai Bay Basin, primarily due to the rapid sedimentation rates (~500m/m.y) of fine-grained sediments. The calculated high sedimentation rates of over ~450 m/m.y. for the Ed and Es Formations is attributed to be the primary cause of overpressure in the basin (Fig. 3). Sedimentation rates vary slightly for the same horizon in different areas: Es3 in northeast Liaodongwan Depression shows the greatest sedimentation rate while in other depressions the values are lower, and Es1+2 in Bozhong Depression has the greatest sedimentation rate amongst all the depressions; Ed in all the depressions exhibit fast sedimentation and maximizes in Bozhong Depression. The trends of sedimentation rates are consistent with the distribution of overpressures.

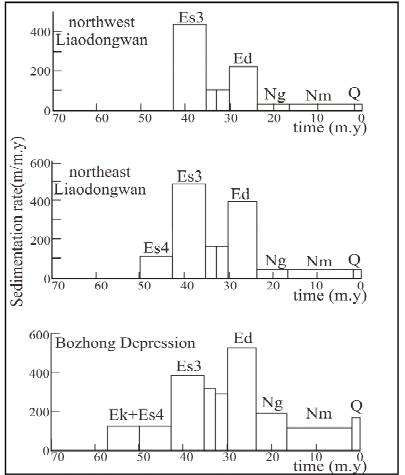


Figure 3. Sedimentation rates in Liaodongwan and Bozhong Depressions

Massive oil generation is another important mechanism in the deeper portion of the offshore Bohai Bay Basin. Temperature and thermal maturity in Es and some parts of Ed Formation indicate significant hydrocarbon generation. All of the overpressured reservoirs and source rocks have a minimum temperature of ~87°C and overpressured source rocks have a vitrinite reflectance (Ro) values of 0.6% or higher. (Fig. 4).

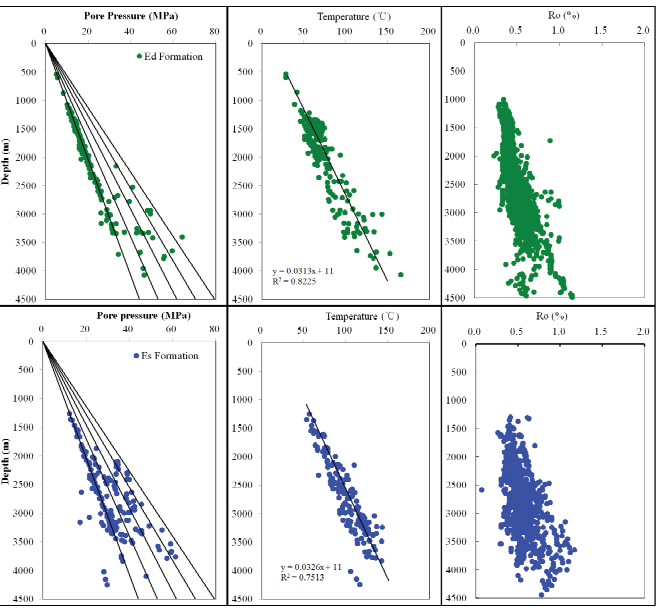


Figure 4. Pressure, temperature and Ro of Ed (in green) and Es (in blue).

Porosity preservation in overpressured sandstones

Sandstone porosities in Es Formation range 10~30% from the depth of 2600 m; in Ed Formation they value 8~35% from the depth of 1700m. Overpressure in the sandstone intervals of the Es Formation and to a lesser extent of the younger Ed formation corresponds to high porosity of up to 38% compared to the regional porosity-depth trend for the basin and trends in basins with similar age and thermal gradient. The off-trend high porosities predominantly fall in the overpressured intervals (Fig. 5). Porosity-vertical effective stress analysis validate the positive effect of overpressure on high porosity preservation.

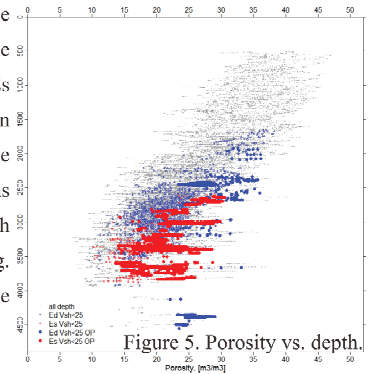


Figure 5. Porosity vs. depth.

Overpressured mudstone as regional cap rock

Overpressure in Ed spread extensively in the north of Liaodongwan Depression. Most of the hydrocarbon layers are underneath the overpressured mudstone in Ed Formation (Fig. 6), indicating it serves as a regional overpressure caprock and this sealing function could connect to that in Liaohe Depression.

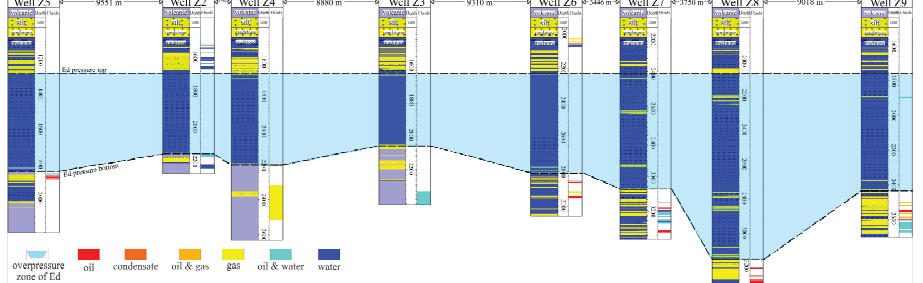


Figure 6. Vertical distribution of hydrocarbon bearing layer in north Liaodongwan.

Conclusions

Overpressure in the offshore Bohai Bay Basin are mainly confined in the Es and Ed Formations within the Bozhong and Liaodongwan Depressions, and can reach up to 30 MPa.

Disequilibrium compaction has been identified as the main mechanism of overpressure generation. However, hydrocarbon generation of the deeper portion of the basin (usually within the Es Formation) has added to the amount of overpressure at the present day.

Reservoir quality of sandstone in the Ed and Es Formations is variable but there are anomalous porosities from the regional trend. The off-trend high porosities predominantly fall in the overpressured intervals. Porosity-vertical effective stress analysis validate the positive effect of overpressure on high porosity preservation. Disequilibrium compaction caused overpressure in Ed Formation spread extensively in north Liaodongwan Depression and the overpressured mudstone serves as a regional caprock.