Open Access Library Journal
2023, Volume 10, e9861
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Distribution and Genesis Analysis of Overpressure in X Area of Pearl River Estuary Basin

Zhan Shi

School of Earth Science and Engineering, Xi'an Shiyou University, Xi'an, China
Email: 360450094@qq.com

How to cite this paper: Shi, Z. (2023) Distribution and Genesis Analysis of Overpressure in X Area of Pearl River Estuary Basin. *Open Access Library Journal*, **10**: e9861.
https://doi.org/10.4236/oalib.1109861

Received: February 10, 2023
Accepted: March 11, 2023
Published: March 14, 2023

Abstract

Based on the comprehensive use of logging, pressure measurement, testing and other data, the abnormal pressure was identified, the pressure distribution characteristics and mudstone compaction mode were studied, and the causes of overpressure were analyzed. The results show that there is overpressure in the deep area of the study area, and the plane gradually changes from the north to the central area to overpressure, the pressure coefficient in the main depression area is 1.0 - 1.6, and the pressure coefficient in the eastern area is 1.0 - 1.2; the mudstone index compaction mode is the most common compaction mode, the mudstone in the eastern part of the study area is the common exponential compaction mode, the mudstone in the main depression area is different from the common exponential compaction mode, showing two-stage characteristics, which is a linear two-stage compaction mode; the eastern and main depression areas of the study area are fluid expansion/Pressure conduction causes overpressure.

Subject Areas

Environmental Sciences, Geography

Keywords

Distribution, Overpressure, Compaction Modes, X Area of Pearl River Estuary Basin

1. Introduction

Abnormal high pressure or overpressure is a topic that has attracted much attention in the field of oil and gas in recent years, especially in the field of oil and gas geological exploration, and abnormal pressure or overpressure is often found in oil and gas basins, which is closely related to oil and gas accumulation, and has important safety and indication significance for all aspects of drilling. In addition, the cause of overpressure is also the basis for oil and gas accumulation research, which has important indicative significance for guiding oil and gas field exploration. Only by understanding the cause of overpressure can it be helpful to study the relationship between overpressure and hydrocarbon accumulation. Therefore, this paper aims to study the distribution of overpressure in this area and analyze the causes of overpressure, in order to guide the deepwater area to break through the bottleneck of oil and gas exploration.

2. Geological Overview

The Pearl River Estuary Basin is located in the northern part of the South China Sea and belongs to the southern edge of the South China Continent, and together with the Qiongdongnan Basin, it forms a large oil-bearing basin on the two continental margins of the northern South China Sea, and belongs to the deep-water sedimentary basin that gradually developed from the Mesozoic to the Cenozoic era. 3. Overpressure distribution characteristics [1].

3. Overpressure Distribution Characteristics

The current drilling in X area shows that there is overpressure in the deep area. Vertically, overpressure is mainly developed in strata below 3800 m, mainly including Oligocene Zhuhai Formation and Eocene-Oligocene Enping Formation. On the plane, the pressure coefficient in the main depression of X area is mainly 1.0 - 1.6, and that in the east of X area is mainly 1 - 1.2, with the highest pressure coefficient of 1.5 in X area.

4. Identification of the Causes of Overpressure

For the determination of the cause of over compaction in a certain area, it is first necessary to clarify the normal compaction trend and compaction mode in the study area, and then select the cause identification standard of over compaction in the corresponding compaction mode according to different compaction modes.

4.1. Determination of Normal Compaction Mode of Mudstone in Area X

This paper analyzes the logging curve characteristics of multiple wells in the X area of the Pearl River Estuary Basin and shows that the normal compaction characteristics of mudstone are different in different regions, and at least two normal compaction modes can be identified.

4.1.1. X Exponential Compaction Mode for the Eastern Region

Previous studies have shown that the mudstone index compaction mode is the most common compaction mode. That is, under normal compaction, the porosity of mudstone decreases exponentially with increasing depth [2] [3] [4].

In the eastern part of X Area, usually from the surface to the burial depth of about 3800 m, the porosity of the mudstone and the time difference of sound wave decreased exponentially with the increase of burial depth, the density increased slightly, and the resistivity also increased. With the increase of burial depth, the acoustic time difference, resistivity and density logging curves of the lower part of the Zhuhai Formation and the Shixin-Zhuhai Formation with a buried depth of about 3800 m increased and were accompanied by the development of overpressure.

4.1.2. Linear Two-Stage Compaction Mode in the Main Depression Area of Area X

However, unlike the eastern part of X Area, the mudstone compaction characteristics of the main depression area of X Area are different from the common exponential compaction mode, showing two-stage characteristics. The first stage of linear two-stage compaction was mainly distributed in the lower strata above the Pearl River Formation of the Middle and Miocene with a buried depth of less than 4000 m, which showed that with the increase of burial depth, the porosity of mudstone and the time difference of sound wave decreased linearly, the resistivity increased linearly, and the density increased normally. The second stage of linear two-stage compaction is mainly distributed in the lower part of the Pearl River Formation of the Miocene and the Zhuhai Formation of the Miocene with a burial depth of more than 4000 m, which shows that with the continuous increase of the burial depth, the porosity, acoustic time difference and density of the shale are basically unchanged and remain constant, and the resistivity continues to increase. Overpressure mostly develops in the middle and lower strata of the Oligocene Zhuhai Formation below 4400 m. The developmental level of overpressure is not consistent with the second compaction stage of shale, and the overpressure top interface is usually about 400 m lower than the second stage top interface of shale. Obviously, the second compaction stage of shale cannot be simply identified as an uneven compaction stage.

In fact, in addition to the common exponential compaction mode, the linear two-stage compaction mode is also an important mode of normal compaction of mudstone in sedimentary basins. The linear two-stage compaction pattern of mud shale was discovered in the 2030s, and the linear two-stage compaction mode of mud shale in the US Gulf Coast region was discussed in detail in the 90s of the 20th century [3] [4]. Hunt *et al*. [4] showed that the normal compaction of shale in some wells in the Gulf Coast area of the United States can even be manifested as a three-stage type, and when the porosity is greater than 30%, it conforms to the exponential decline mode, and when the porosity is less than 30%, it first decreases linearly with the increase of depth, and then changes to constant with the increase of depth.

The compaction characteristics of shale in the main depression area of X Area reflect that it conforms to the linear two-stage compaction mode, and the lower part of the Pearl River Formation of the Middle and New Ocene from the surface to a buried depth of 4000 m is the first stage of linear decline of porosity, and below 4000 m is the second stage of constant porosity.

4.2. Logging Curve Combination Analysis Method

This method is the most basic and convincing method for determining the cause of overpressure. The logging curve of the overpressure section usually deviates from the normal compaction trend and has a reversal feature, and the different inversion combination characteristics of different logging curves shown by different causes of overpressure are the main basis for the determination of the cause of overpressure. When using logging data to determine the cause of overpressure, we especially need to pay attention to comprehensive judgment and analysis according to a variety of logging parameters, rather than arbitrarily relying on a single logging data to directly judge, which is likely to lead to incorrect identification of the cause of overpressure [1].

4.2.1. Causes of Overpressure in the Eastern Part of the X Area

The normal compaction mode of mudstone in the eastern part of X Area was consistent with the compacting mode of mudstone index. The previously established overpressure genesis logging curve combination analysis method is mainly based on this normal compaction mode. When applying the combination of logging curves to analyze the causes of overpressure, at least the combined characteristics of three curves of acoustic wave, resistivity and density logging must be applied [5] [6] [7] [8].

The logging curve of the overpressure section in the eastern part of region X showed obvious inversion characteristics, which seemed to have uneven compaction characteristics. However, careful observation and analysis show that although the acoustic time difference, resistivity and density logging curves of the overpressure section are all reversed, the inversion depth of the three is obviously inconsistent, and the inversion depth of the density curve is obviously lagging behind the inversion depth of the logging curve such as acoustic time difference and resistivity.

Therefore, the inversion of the logging curve in the eastern part of the X region indicates that the overpressure should be conductive or overpressure caused by fluid expansion.

4.2.2. Causes of Overpressure in the Main Depression Area of the X Area

Unlike the eastern part of X Area, the shale in the main depression area of X Area conforms to the linear two-stage compaction mode. As mentioned above, the combined analysis method of overpressure genesis logging curve established in the past is mainly based on the shale index compaction model. In view of this, it is necessary to first understand the combination characteristics of logging curves with different genesis overpressure in the linear two-stage compaction mode of shale and its identification methods.

1) Combination characteristics of overpressure logging curves of different causes of linear two-stage compaction mode

For the combined characteristics of logging curves with different genesis overpressure in the linear two-stage compaction mode of shale, there are not many studies involved in domestic or international studies. According to the mechanism of overpressure formation of different genesis and the superpiezoelectric response characteristics of linear two-stage compaction mode of global shale, combined with the combined characteristics and identification methods of overpressure logging curves of different genesis in shale index compaction mode [5] [6] [7] [8], the combination and identification plate of logging curves of different genesis abnormal pressures in the linear two-stage compaction mode of shale are established, so as to improve the method system for identifying the origin of abnormal pressure. The cause of overpressure in the study area was also guided.

a) For the causes of unbalanced compaction, according to the typical characteristics of the development of unbalanced compaction—a large number of porosity is preserved, that is, the porosity of the overpressure section should be significantly greater than that of the normal compaction section, and the overpressure section should be manifested as a large increase in the time difference of the sound wave or a decrease in the velocity of the sound wave, a large decrease in resistivity, and a large decrease in density;

b) For non-unbalanced compaction causes, since fluid expansion/pressure conduction causes overpressure mainly changes the pore connectivity properties of the rock (e.g., the laryngeal channel becomes wider) with little or no effect on the volume properties, it may lead to an increase in acoustic jet lag and resistivity, while the density is slightly reduced or substantially unchanged, or its depth of reduction lags significantly behind the depth of acoustic jet lag and resistivity increase (*i.e.*, the three are inverted and out of synchronization); When structural extrusion occurs, the compaction has stopped, and the compaction effect caused by lateral loading becomes weak or absent, so the induced overpressure of structural extrusion is manifested as acoustic time difference, resistivity and density curves in line with normal compaction trend or slightly stronger compaction trend than normal compaction; The montmorillonite-illite conversion is caused by overpressure, which affects the compressibility of the rock, and during its transformation, with the decrease (unloading) of the effective stress, it will be manifested as a decrease in the velocity of the sound wave and an increase in density [9].

2) Combination characteristics of logging curves in the main depression area of X Area and identification of the cause of overpressure.

The overpressure in the main depression area of X Area mainly develops in the lower part of the second normal compaction stage, such as the Eocene Zhuhai Formation, which has a buried depth of less than 4400 m.

The in-depth analysis of the combined characteristics of the logging curve in the overpressure section shows that except for a slight increase in the resistivity curve, the acoustic time difference and density logging curves remain basically unchanged or slightly deviate from the normal compaction trend. Therefore, in terms of the combined characteristics of logging curves, the comprehensive analysis of this paper concludes that the overpressure in the main depression area of the X region is mainly fluid expansion/conduction overpressure.

5. Conclusions

1) Deep development overpressure in X Area, mostly developed in the Zhuhai Formation of the Ocene and the Enping Formation of the Ceocene and the Enping Formation of the Cenozoic below 3800 m, the pressure coefficient in the eastern part of the X area was mainly distributed as 1.0 - 1.2, and the pressure coefficient in the main depression area was mainly distributed between 1.0 - 1.5, and the maximum could reach 1.55.

2) The logging curve inversion phenomenon occurred in the formation below about 3800 m in the eastern area of X Area, and the density inversion depth was about 200 m lagged compared with the time difference of sound wave and resistivity reversal, and the overpressure caused by fluid expansion/pressure conduction in the eastern area of X Area was comprehensively analyzed.

3) In addition to a slight increase in resistivity curves in the main depression area below about 4400 m, the acoustic time difference and density logging curves remained basically unchanged or slightly deviated from the normal compaction trend, and the main depression area of X area was comprehensively analyzed as the cause of fluid expansion/pressure conduction overpressure.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Wang, J.H., Liu, L.H., Chen, S.H. and Shang, Y.L. (2011) Tectonic-Sedimentary Response and Regional Tectonic Significance of the Second Act of the Zhuqiong Movement in the Enping Depression of the Pearl River Estuary Basin. *Acta Petrolei Sinica*, **32**, 588-595.

[2] Powley, D.E. (1993) Shale Compaction and Its Relationship to Fluid Seals. Section III, Quarterly Report, Jan.-Apr. 1993, Oklahoma City.

[3] Hunt, J.M., Whelan, J.K., Eglinton, L.B., *et al.* (1998) Relation of Shale Porosities, Gas Generation, and Compaction to Deep Overpressures in the U.S. Gulf Coast. In: Law, B.E., Ulmishek, G.F. and Slavin, V.I., Eds. *Abnormal Pressures in Hydrocarbon Environments*. AAPG, Tulsa, 87-104. https://doi.org/10.1306/M70615C5

[4] Hunt, J.M. (1996) Petroleum Geology and Geochemistry. 2nd Edition. Freeman Company, San Francisco.

[5] Fertl, W.H. and Timko, D.H. (1972) How Down Hole Temperature, Pressure Affect Drilling, Part 3: Overpressure Detection from Wireline Methods. *World Oil*, **8**, 36-66.

[6] Fertl, W.H. (1976) Abnormal Formation Pressure, Implication to Exploration, Drilling, and Production of Oil and Gas Reservoirs. Elsevier, Amsterdam.

[7] Hermanrud, C., Wensass, L., Teige, G.M.G., *et al.* (1998) Shale Porosities from Well Logs on Haltenbanken (Offshore Mid-Norway) Show no Influence of Overpressuring. In Law, B.E., Ulmishek, G.F. and Slaving, V.I., Eds., *Abnormal pressures in Hydrocarbon Environments*. AAPG, Tulsa, 65-85. https://doi.org/10.1306/M70615C4

[8] Bowers, G.L. (2002) Detecting High Overpressure. *Leading Edge*, **21**, 174-177. https://doi.org/10.1190/1.1452608

[9] Li, J., Tang, Y., Wu, T., Zhao, J.Z., Wu, H.Y., *et al.* (2020) Genesis of Overpressure and Hydrocarbon Accumulation Effect in Large Oil Area of Conglomerate Conglomerate in Mahu Sag in Junggar Basin. *Petroleum Exploration and Development*, **47**, 679-690.