During late Permian Changxingian, the depositional pattern of Sichuan Basin is notably controlled by Kaijiang-Liangping trough. A series of reef-shoal complexes developed along the carbonate platform margin, with strip-like, oblique-arranged, or bead-like distribution patterns. The reef-shoal complexes have complicated internal structures, and their scale, accretion pattern, and distribution of reservoir rocks are significantly controlled by the ancient landform of the "Kaijiang-Liangping trough". Based on the observation and sedimentary description of outcrops and cores, analysis of drilling profiles, depositional interpretation of geophysical logging data and seismic reflection modes, and information from cast slices and SEM analysis, the ancient landform of the "Kaijiang-Liangping trough" during the Changxingian can be divided into two major categories, fault-controlled steep slope and ramp. In addition, the corresponding internal geologic patterns of reef-shoal development, which are fault-controlled steep slope type and ramp type, are proposed in this article. The former type, fault-controlled steep type, is mainly developed close to present reverse faults or high and steep ancient tectonic breaks. Reefs, mounds, grain shoals, and deposition of inter-shoal marine facies are developed, with organic reefs being the main body. Vertically, multicycle of grain shoal, mound, and organic reef/bioherm developed in the profile, with very thick reefs. Vertical accretion is common, while lateral accretion is normally absent. The shape of the complexes is ridge-like, with great thickness but limited width. The seismic reflection mode is the ridge type, with drapes on the top and onlaps on both sides, and interior chaotic or blank reflections. Favorable reservoirs are mainly reefal dolostones and dolostones of back-reef shallow shoals, which usually appear at the top of each complex cycle. The ramp type is mainly developed in the hinge zone or local highlands of large gentle ancient slopes. Reefs, mounds, grain shoals, and inter-shoal marine facies of deposition are also developed, but the grain shoals are the main body. Multicycle of grain shoal, mound, and organic reef/bioherm are also developed vertically, but the thickness of reefs is much smaller, and there is much more lateral accretion than vertical accretion. The shape is wider and gentler, with relatively a small total thickness. In the seismic reflection modes, its shape is like very gentle and low hills, without any drapes or onlaps on the top or flanks, or internal chaotic reflections, and parallel seismic reflection configuration is common. The best reservoirs are dolostones of grain shoal facies, usually in the mid-upper parts of each complex cycle.
Introduction

The reef-shoal complexes of Lower Permian Changxing Fm. in Sichuan Basin developed along the platform margin on both sides of Kaijiang-Liangping Trough. Scale, accretion type and distribution of reservoirs are controlled by the morphology of platform margin. The internal structural characteristics of reef-shoal complexes are complicated, with intense heterogeneity, which is the most challenging problem to be solved in the exploration of reef-shoal gas pools. Investigation of internal structures of reef-shoal complexes is conducive in understanding distribution of favorable reservoirs, and help to improve economic performance of those types of gas pools.

In this study, using seismic, drilling data and the geological interpreted results of drilling-logs and cores, the tectonics, reef-shoal complexes have been restored and classified into fault-controlled steep slope type and ramp type. Meanwhile, contrasting the different characteristics of reef-shoal complexes by the seismic reflection, the lithologic association, microfacies, diagenesis sequence, reservoir space and reservoir physical property, two main groups of four types of reef-shoal complexes are divided, and the respective geological models of internal structural models of each type is established. Based on the study of reserovirs of reef-shoal complexes, the paper classified the internal structures of reef-shoal complexes into two main types of reef-shoal complexes, which are fault-controlled steep slope type and ramp type, which are quite different, which the former type are more prone to develop better reservoirs with larger scale and better physical properties than the latter type.

Geological Background

The reef-shoal complexes of Lower Permian Changxing Fm. in Sichuan Basin developed along the platform margin on both sides of Kaijiang-Liangping Trough. Scale, accretion type and distribution of reservoirs are controlled by the morphology of platform margin. The internal structural characteristics of reef-shoal complexes are complicated, with intense heterogeneity, which is the most challenging problem to be solved in the exploration of reef-shoal gas pools. Investigation of internal structures of reef-shoal complexes is conducive in understanding distribution of favorable reservoirs, and help to improve economic performance of those types of gas pools.

In this study, using seismic, drilling data and the geological interpreted results of drilling-logs and cores, the tectonics, reef-shoal complexes have been restored and classified into fault-controlled steep slope type and ramp type. Meanwhile, contrasting the different characteristics of reef-shoal complexes by the seismic reflection, the lithologic association, microfacies, diagenesis sequence, reservoir space and reservoir physical property, two main groups of four types of reef-shoal complexes are divided, and the respective geological models of internal structural models of each type is established. Based on the study of reserovirs of reef-shoal complexes, the paper classified the internal structures of reef-shoal complexes into two main types of reef-shoal complexes, which are fault-controlled steep slope type and ramp type, which are quite different, which the former type are more prone to develop better reservoirs with larger scale and better physical properties than the latter type.

Main Methods

Interpretation of seismic response profile by seismic.
Correlation profile of connected wells of formation microfacies.
Using seismic data, to estimate the thickness of Changxing Fm.
Describing the thickness map of Changxing Fm.
Statistical results of thickness from drilling data.
Establishing spatial geological frameworks of reef-shoal complexes for each type.

1. Sichuan Basin, which is part of the Upper Yangtze Plate, is a large superimposed basin with very thick marine carbonates of Sinian–Middle Triassic and continental clastics of Late Triassic–Eocene deposited on the Precambrian basement. (Fig. 1–Fig. 3).
2. The tectonic evolution of the Sichuan Basin can be mainly divided into 3 periods: Cratonic depression and its peripheral foreland basin, intra-orogenic rifting and foreland basin.
3. The Kaijiang-Liangping trough is actually a rifting basin developed in the passive continental margin. It is formed by the uneven syn-depositional rifting activities under regional extensional forces of basement faults during the late stages of Early Permian–Early Triassic (Feixiangian period).
4. The Kaijiang-Liangping trough was firstly proposed by Wang Yongqiang et al in 1989.

Analysis of microfacies of reef-shoal complexes.
Classify the types of reef-shoal complexes.
Classify platform margin types.
Studying the topography and sedimentary of platform margin.
Estimate the angle of the foreslope.

Results

1. The landform of platform margin: fault-controlled steep slope type and ramp type. The landform of platform margin and irregular variation of foreslopes on both sides of Kaijiang-Liangping Trough change vary from north to south, which are classified into fault-controlled steep slope type and ramp type and caused by the uneven syn-depositional rifting activities of basement faults by analyzing typical seismic migration profiles across the both sides of Kaijiang-Liangping trough to summary the internal structures.
2. The scale, accretion pattern, the internal structures and reservoirs of the reef-shoal complexes are controlled by the landform of the platform margin (Fig. 4, Fig. 5).
3. Analyzing the types of reef-shoal complexes reflect on seismic section in different locations of platform margin and making the correlation and microfaciesprofile of connected wells of formation across the both sides of Kaijiang-Liangping trough to summary the internal structures.
4. Thickness of formation are used to restored the palaeogeomorphic landform.

Conclusions

1. Syn-depositional uneven extension and rifting activities of basement faults controlled the ancient topography of platform margin and the scale of reef-shoal complexes.
2. The geomodels of internal structures and characteristics of internal structures of each type are established and summarized.

Important References


*Email: xan@petrochina.com.cn

Geologic Patterns of Internal Architecture in Reef-Shoal Complexes Along Kaijiang-Liangping Trough in Sichuan Basin During Late Permian Changxingian

Anna XU , Zecheng WANG, Xiufen ZHAI, Jifeng YIN
Research Institute of Petroleum Exploration & Development, PetroChina, Beijing 100083, China
The National Oil and Gas Special Project No. 2011ZX05004