[PS]The Genesis and Controlling Factors of Large Mesozoic Granite Weathering Crust Reservoir in Penglai 9-1 Oil Field, Bohai Bay Basin*

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Abstract

The Penglai9-1 buried-hill oil field is located on the Miao Xi Uplift, and has proven reserves of more than 2×10^8 m^3. It is so far the single largest and the only Mesozoic granite oil field in the Bohai Bay Basin. The high-quality reserve stratum is located in the upper middle part of the weathered crust of granite, with a distribution area of more than 80 km^2 and a maximum reservoir thickness of more than 200 meters. The reservoir space is mainly pore type and fissure-pore type, and secondary pore-fissure type including intercrystalline pores, dissolution pores in the lithic fragments and hornblende and micro fissures. Reservoir shows as loose sand in core and resulted in sand production during testing. Based on the petrology and outcrop analysis, we propose that weathering is the major factor responsible for the formation of the high-quality reservoir, and the dissolved feldspar is the main genetic mechanism. Leaching resulted in the apparent decrease of mechanical strength of granite. Tectonic stress, gravitational force, and heat-expansion and cold-contraction of crystals may be important factors for the formation of intercrystalline pores and micro fissures. High-quality reservoir lateral variation is governed by the following factors. First, shallow burial and low thermal evolution is a key factor to keep the reservoir in a condition close to the initial weathering crust. Rock joints, fault zones and palaeotopography have important roles in controlling the high-quality reservoir's lateral variation. Joint and fault fissures form an efficient channel for permeating atmospheric water resulting in a thick weathered crust. This effect in the Penglai9-1oil field shows as a high-quality reservoir with a thick, joint-shaped reflection. On the contrary, reservoirs with joint shaped reflections, the underdeveloped area is thin. In fault belts, the thickness of reservoirs is obviously thicker. Palaeotopography controlled the preservation of the strongly or moderately weathered belt for which is always loose and easily removed. This effect in the Penglai9-1 oil field shows as thick high-quality reservoir mainly distributed at flat belts around the higher center of the granite. The reservoirs away from the high center, the slope, toe and the platform at the top of slope in micro-palaeotopography, are always thicker than those at upper-middle part of the steep slope.

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ABSTRACT

Penglai9-1 buried-hill oil field locates at Miao Xi Uplift, and has proved reserves of more than 2×10^8 m³. It is so far the single largest and the only Mesozoic granite oil field in Bohai Bay Basin. The high-quality reserve stratum locates at the middle-upper part of the weathering crust of granite, with the distribution area of more than 80 km² and the maximum reservoir thickness of more than 200 meters.

The reservoir space are mainly pore and fissure-pore and secondly pore-fissure type includes inter-crystalline pores, dissolving pores in the lithic fragments and hornblende and micro fissures. Reservoir shows as loose sand in core, resulted in sand production during testing. Based on the analysis of petrology and outcrop, we proposed that weathering is the major factor responsible for the forming of the high-quality reservoir, and the dissolving of feldspar is the main genetic mechanism. Leaching result in the apparent decrease of mechanical strength of granite, then the tectonic stress, the force of gravity, and heat expansion and cold-contraction of crystals may be the important factors for the formation of inter-crystalline pores and micro fissures. High quality reservoir lateral variation is governed by the followed factors. The most important of all, shallow bury and low thermal evolution degree are the key factors to keep reservoir in a similar appearance to the initial weathering crust.

Rock joints, faults zone and palaeotopography have important roles in controlling the high-quality reservoir lateral variation. Joint fissures and fault fissures form an efficient channel for atmospheric water permeating, as a result, thick weathering crust developed. This effect in Penglai9-1oil field showing as high quality reservoir at joint shaped reflection developed area is thick, and on the contrary, reservoir at joint shaped reflection underdeveloped area is thin. In concentrating belt of faults, the thickness of reservoir is obviously thicker. Palaeotopography controls the preservation of the strongly or moderately weathered belt for which is always loose and will be easily removed. This effect in Penglai9-1 oil field presents as thick high-quality reservoir mainly distributed at flat belt around high center of the granite. The reservoirs at the flat ground, the foot of the slope and the platform at the top of slope in micro-palaeotopography are always thicker than those at upper-middle part of the steep slope.

1. Geological background

Penglai9-1 buried-hill oil field locates at Miao Xi Uplift, Bozhong depression, Bohai Bay Basin, which is the single largest and the only Mesozoic granite oil field with a large oil-bearing area over 80 km² and a large oil column height (maximum height over 200 m)

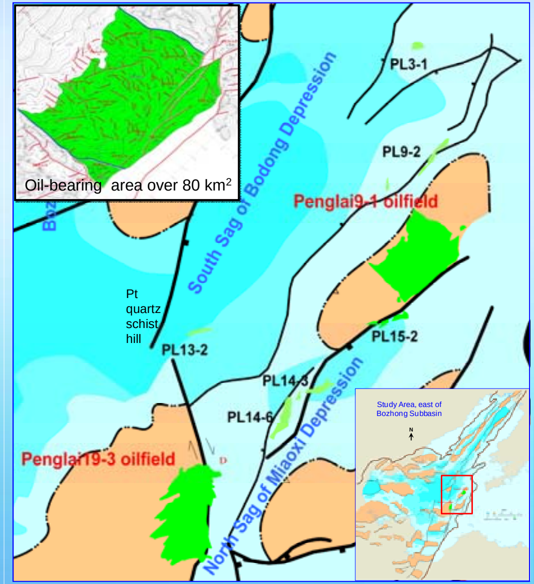

Fig.1.1 geological location of the interest region

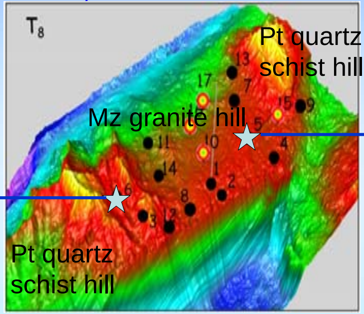

Fig.1.3 3D visible palaeogeomorphology and lithology distribution of the penglai9-1

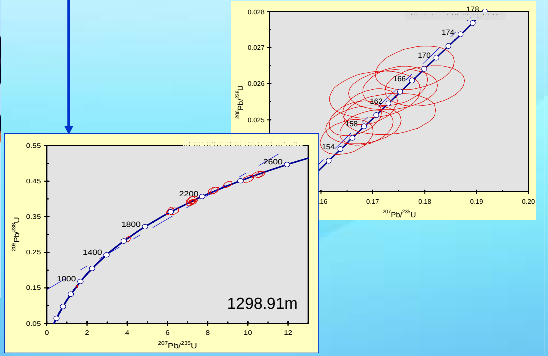

Fig.1.4 age of different part of PL9-1 buried hill (single grain zircon U-Pb dating by LA-ICP-MS)

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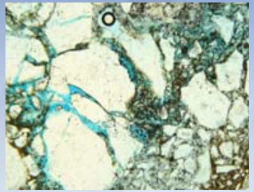
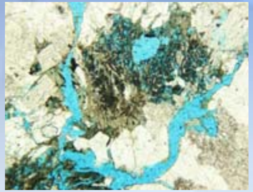
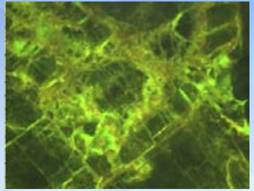
2. The reservoir characteristics and space



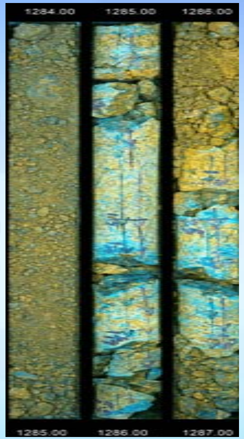
Well 2,1285.0 m, inter-crystalline pores and fissures (casting)



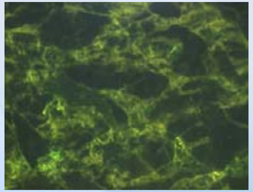
Well 11,1605.0m, dissolving pores of hornblende and fissures (casting)



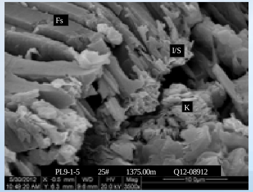
Well 11, 1605.79m, oil filling the dissolving pores and fissures of feldspar (fluorescence)



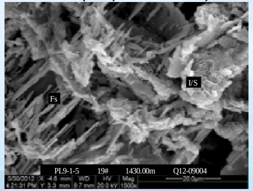
Well 2, core photograph of strong weathered layer



Well 14, 1460.0m, oil filling the dissolving pores and fissures of feldspar (fluorescence)



Well 5, 1375.0m, dissolving pores of feldspar (SEM)



Well 5, 1430.0m, dissolving pores of feldspar (SEM)

Fig.2.1 reservoir spaces in granite buried hill

3. The diagenetic physical simulation result and conclusion

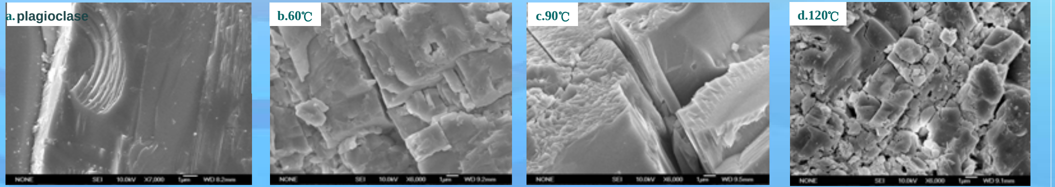


Fig.3.1 dissolution simulation result of atmospheric water on plagioclase

The dissolution simulation of atmospheric water on plagioclase reflects the obvious dissolving phenomenon in plagioclase with the temperature increasing. The weathering mechanism of feldspar may be the major cause for pore increasing and mechanical strength decreasing of granite.

4. The evidence of petrology and outcrop

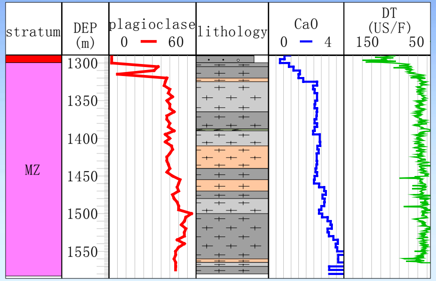


Fig.4.1 The mineral vertical variation in the interest area, Well 5

Fig.4.2 Outcrop of thick weathering crust at Huangshan

Mineral analysis indicates that plagioclase has a remarkable reduction at the upper layers of the weathering crust. On one of the weathering crust outcrop of Huangshan granite, which shows as easy breaking granite shape, indicates that it is the local weathering crust.

5. The bend oil-water interface and stratiform-like reservoir model

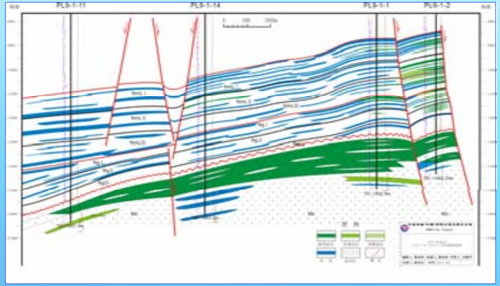


Fig.5.1 Reservoir model showing lateral distribution of the bend oil-water interface of the interest region

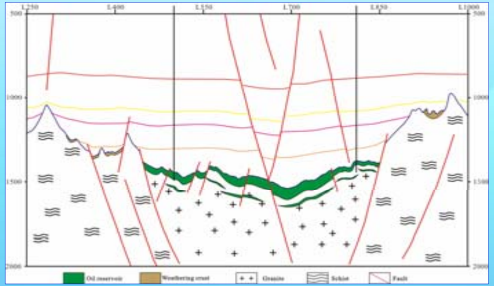


Fig.5.2 Reservoir distribute as stratiform-like model covering the granite hill

Restrict by the development of weathering crust, the oil-water interface is bend, and the reservoir presents stratiform-like model.

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6. The controlling factors of reservoir development

6.1 The preservation condition of weathering crust

Shallow burial depth and low thermal evolution degree are the key factors to keep reservoir in a similar appearance to the initial weathering crust.

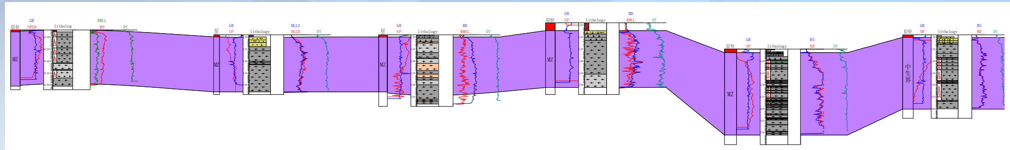

Fig.6.1 the burial depth of the granite (top depth 1200-1500m)

6.2 The joint role in controlling the reservoir lateral variation

Fig.6.2 profile observation of joint in controlling the weathering on granite (Huangshan)
a. Along the joint, weathering is strong b. Thick sand-like weathering crust preserves clear joints which means it is sathrolite. c. At the concentrated joint band, the granite is heavily broken

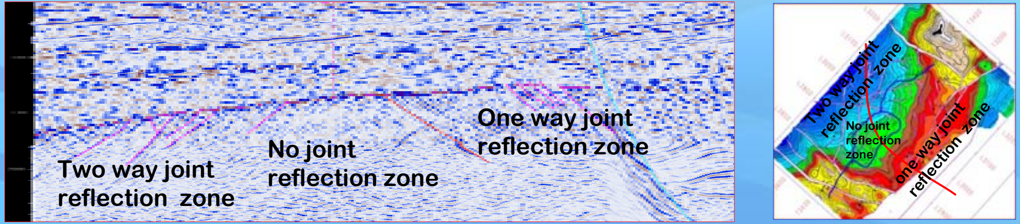

Fig.6.3 the relation between joint-shaped reflection and reservoir thickness
The reservoir thickness of different zones: Well 17: 69 m; Well 10:13.5m; Well 2: 221m

6.3 The relationship of faults with reservoir thickness

Fig6.4 the fault-fracture zone in field profile (Jiguan hill Qinhuangdao)

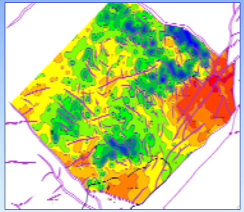

Fig6.5 faults distribution & Diagram of reservoir thickness of 100m below the top of the interest granite

Fault and tectonic movement will result in a wide fault-fracture zone, which is an effective pathway for the atmospheric water infiltrating.
In Penglai9-1, the larger fault-concentrated zone, the thicker sediments deposited.

6.4 The palaeotopography influence on weathering crust preservation

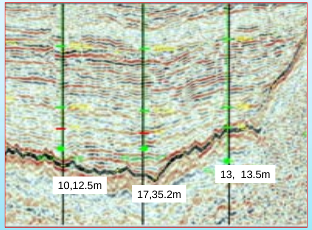

Fig6.6 the reservoir thickness at different landforms

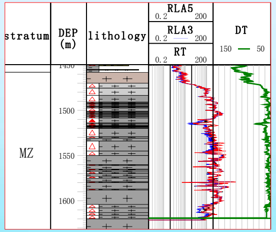

Fig6.7 the thin reservoir thickness at Well 13

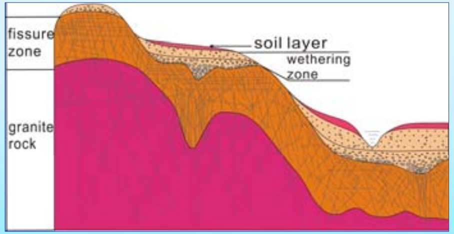

Fig6.8 reservoir distribution model

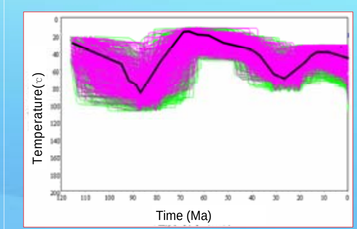

Fig.6.9 the apatite fission track simulation result

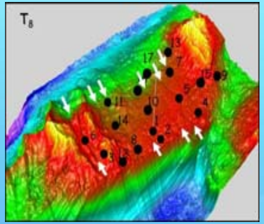

Fig.6.10 the valley on the 3d visible palaeotopography map

Palaeotopography controls the preservation of the strongly or moderately weathered zone for which is loose and can be easily removed. Based on the apatite fission track simulation, we found that the interest granite may be uplifted at 27Ma, which could probably be the important denudation stage. And from the 3D visible palaeogeomorphology, we can even identify the clear denudation valley!