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Salt Dome Caused Distortion of Seismic Reflection and Approaches to Eliminate Its Effects

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Abstract. The tremendous wave transit velocity difference between salt rock and its surrounding rock causes seismic reflection distortion for formations beneath it on seismic section in time domain, leading to fake structures and fake faults to be interpreted. By the aid of forward modeling, effects caused by the variation of salt thickness, wave transit velocity and existence of low velocity interbeds inside salt dome on seismic reflection under salt dome are analyzed. The case study of Zhanazhol oilfield about how to eliminate effects of seismic reflection distortion caused by salt dome during seismic interpretation are presented, in which these effects are eliminated through proper time-depth conversion with an average velocity field built based on stack velocity replacement with velocity calculated from VSP data and nearby synthetic seismograph.

Introduction

Pre-Caspian Sea basin lies to the north of modern Caspian Sea, mainly in Kazakhstan territory, with an area of 500 thousand sq. kilometers and a maximum sediment thickness of 22 kilometers which dips to the center though a terraced manner(Fig.1). The formation of this basin is divided into three groups, which are, ranking upwards, pre-salt formation, salt formation and post-salt formation[1]. The pre-salt includes formation from Devonian system to the lower part of lower Permian series with a thickness of 3-4km in the margin of the basin and 10-13km in the center, principally composed of clastic rocks and carbonates. The salt formation comprises the uppermost Kungurian stage of lower Permian series with a thickness of 1-6km, mainly composed of halites, minor anhydrites and carbonates, in which more than 1500 salt domes develop across the Pre-Caspian Sea basin. The post-salt formation includes formation from upper Permian series to Quaternary system with a thickness of 5-9km, mainly composed of clastic rocks. Many large carboniferous hydrocarbon reservoirs have been discovered in this basin[2], as one of them, Zhanazhol oil field is comprises two groups of hydrocarbon-bearing carbonate formation KT-I and KT-II. In this article, a case study of

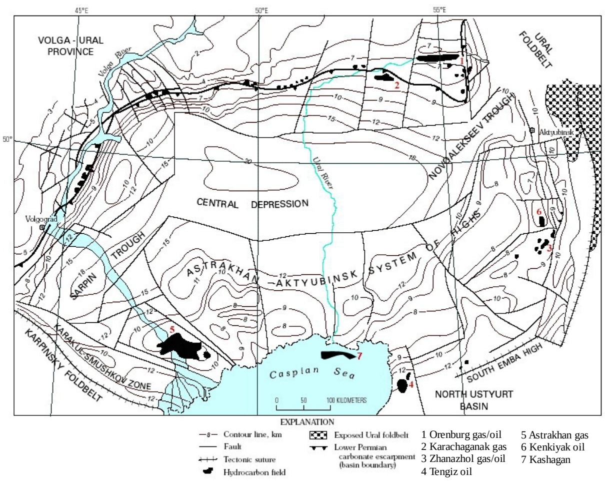

Fig 1 Hydrocarbon distribution map of Pre-Caspian Sea basin

KT-II is presented to show what kind of distortions can be caused by a salt dome on seismic reflection and how to eliminate their effects during seismic interpretation.

Salt Dome Characteristics in Zhanazhol Oilfield

By the aid of time slice, the top and bottom horizons of salt formation are interpreted, and the shapes of salt domes across Zhanazhol projection area are outlined. There are five salt domes in all, numbered as 1 to 5(Fig. 2), with their area from 7.0 to 99.5 sq. kilometers, maximum thickness from 600 to 2000 meters. Four of them are salt pillow typed and one is diapir typed(Table 1) [3].
According to the well log data of well sin-1 which locates in the southeast of salt dome No. 2, the sonic curve of salt formation is of small variation, with the calculated average wave transit velocity being about 4600/s(Fig. 3).

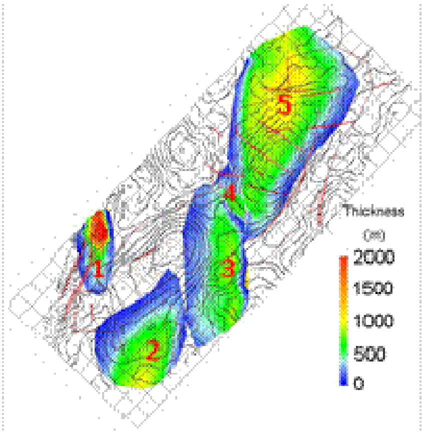

Fig. 2 Salt dome distribution across Zhanazhol

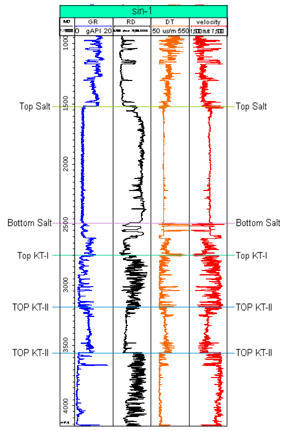

Fig. 3 Well logging curves of well sin-1

Table 1 Statistics of salt dome characteristics of Zhanazhol

No. of salt domes	Area (km^2)	Maximum Thickness (m)	Type
1	16.3	2000	Salt diapir
2	43.1	950	Salt pillow
3	49.3	900	Salt pillow
4	7.0	600	Salt pillow
5	99.5	1000	Salt pillow

Effects Caused by Salt Domes on Pre-salt Reflection

The seismic reflection under salt dome is distorted by the “dragged up” effect because of the prominent increase in wave transit velocity of salt rock to that of its surrounding rocks.

The Effect of Salt Dome Thickness on Pre-salt Seismic Reflection. By the aid of forward modeling, it is concluded that, when the wave transit velocity in salt dome and its surrounding rocks and the thickness of surrounding rocks is fixed, the “dragged up” magnitude of seismic reflection is in normal proportion to the thickness of the salt dome, and somewhat in a linear way[4]. Given the transit velocity in salt dome and its surrounding rocks is 4600 m/s and 3600m/s respectively, the “dragged up” magnitude increases 12ms with each 100 meters increment in salt dome thickness.

The Effect of Wave Transit Velocity in Salt Dome on Pre-salt Seismic Reflection. By the aid of forward modeling, it is concluded that, when the thickness of salt dome and its surrounding rocks, and the wave transit velocity in surrounding rocks is fixed, the “dragged up” magnitude is in normal proportion to the wave transit velocity in the salt dome, and somewhat in a linear way[4]. Given the thickness of a salt dome and its surrounding rocks are both 2000 meters, the "dragged up" magnitude increases 21ms with each 100m/s increment in wave transit velocity in salt dome.

The Effect of Low velocity Interbeds in Salt Dome on Pre-salt Seismic Reflection. Based on the superposition style of salt dome and it surrounding rocks in Zhanazhol oilfield, it is presumed that the surrounding rocks is composed of separate layers with wave transit velocity from 2100 to 3900 m/s, and two separate interbeds exist inside a salt dome with wave transit velocity of 2900 and 3000 m/s respectively. According to forward modeling simulation result, low velocity interbeds can cause breaks or distortion of seismic events beneath a salt dome on calculated seismic sections (Fig. 4).

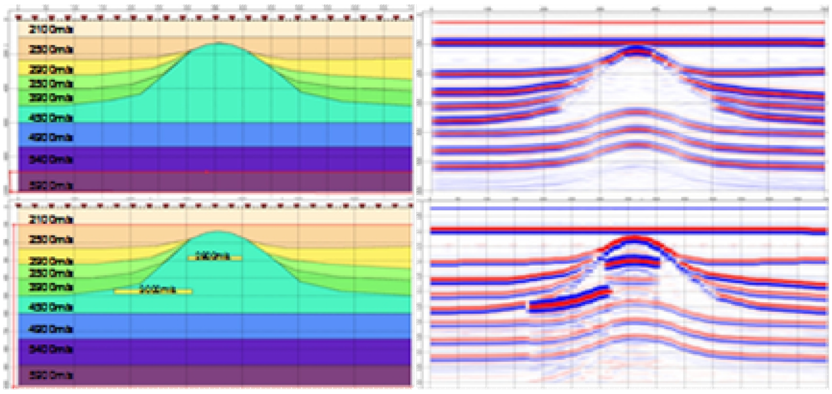

Fig. 4 Effects of low velocity interbeds inside salt dome to seismic reflection

Salt Dome's Effect on Reflection Features of Faults. Beneath salt dome No.5 of Zhanazhol, there is a vertical fault in geological model, and faults exist both on the seismic section calculated by forward modeling and the corresponding real seismic section (Fig. 5), which indicates that a salt dome can't get faults beneath it disappeared on a seismic section.

There isn't salt rock developed between salt dome No.2 and No.3 in Zhanazhol oilfield, leaving a "salt gap" filling with surrounding rocks. Thought no faults exists in geological model, forward modeling results and corresponding real seismic sections indicate that there are two fake faults beneath the salt gap due to the concave shaped events caused by "dragged up" effect of salt domes from two sides(Fig. 6).

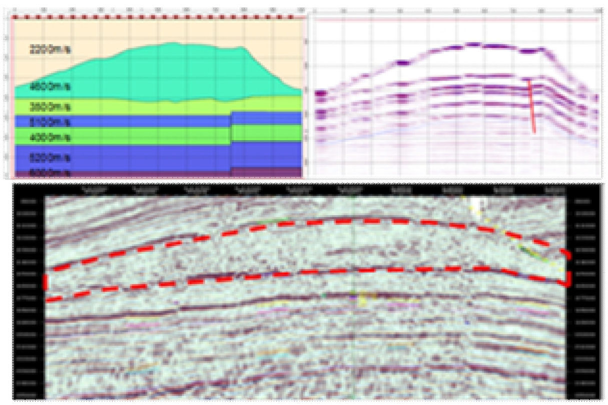

Fig. 5 a Fault beneath a salt Dome showing on calculated and real seisimc section

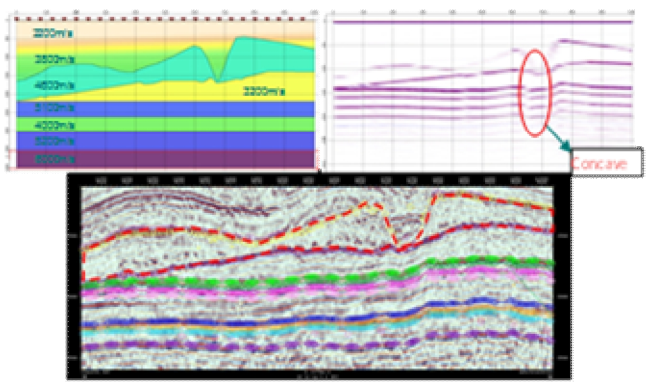

Fig. 6 Salt gap caused fake faults on calculated and real seisimc section

There are three vertical faults beneath salt dome No.1 with their fault planes paralleling to each other in geological mode, however, faults come out in a flower shape on real and calculated seismic sections due to dragged up" effect of salt dome(Fig. 7).

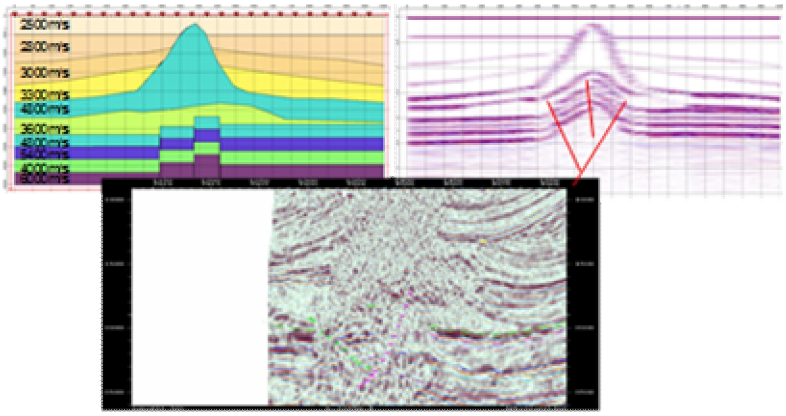

Fig. 7 Salt dome caused change of dip orientation of beneath faults

Approaches to Remove Effects of Salt Domes during Seismic Interpretation

Some efforts are made to remove the effects of salt domes on seismic reflection in Zhanazhol oilfield. Firstly, all the formation is reduced to three groups, then the interval velocity of each group from stack velocity spectrum is replaced with VSP data and synthetic seismograph, finally, an average velocity field is calculated to do time depth conversion.

Formation Reduction. The formation is reduced into three groups which are z1, z2, and z3, with z1 including formation from seismic reference datum to the top of salt rock, z2 from the top of salt rock to the top of KT-II, and z3 from the top to the bottom of KT-II.

Velocity replacement. For group z1, most synthetic seismographs not covering the upper part, under the confinement of interval velocity got from stack velocity spectrum, VSP data and synthetic seismograph are applied to calculate its interval velocity with Co-Kriging Simulation. For group z2 mostly covered by enough synthetic seismographs, the interval velocity is calculated from VSP data and synthetic seismograph with Moving Average Simulation. And for group z3 mostly covered by synthetic seismographs in the center of the field, the interval velocity is calculated from VSP data and synthetic seismograph through Co-Kriging Simulation under the confinement of seismographs with smooth interval velocity.

Building of Average Velocity Field. Average velocity is calculated from interval velocity with Dix equation[5], and the average velocity field is built based on the reduced formation through geological modeling method[6]. After all the correction, velocity got from average velocity filed fits perfect with that from synthetic seismograph(Fig. 8), and an accurate structure map of top KT-II is obtained after time depth conversion with depth errors less than 2‰(Fig. 9).

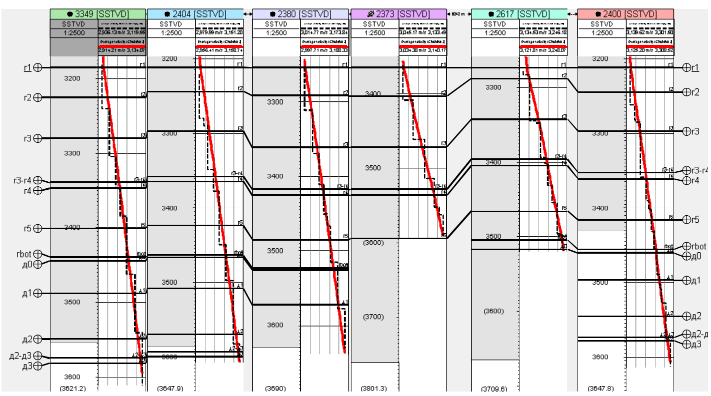

Fig. 8 Comparison of average velocity from velocity field and seismograph

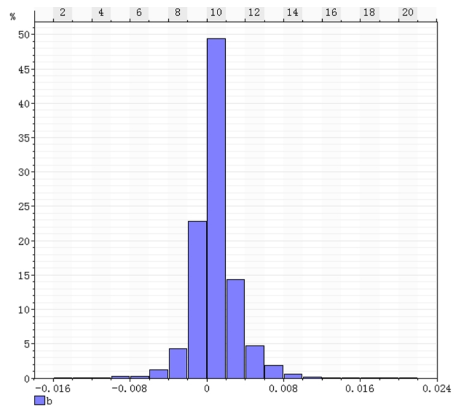

Fig. 9 Histogram of relative depth errors of structrue map

Summary

Salt dome can cause distortion of seismic reflection beneath it in time domain due to the tremendous wave transit velocity difference between salt rock and its surrounding rocks, giving rise to fake structures and fake faults in seismic interpretation. The fake structure can be eliminated through suitable correction of the stack velocity using VSP data or synthetic seismograph to get accurate structure maps after time depth conversion.

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