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RESEARCH PAPER

Evaluations of oil and gas lateral migration across faults: A case study of Shigezhuang nose structure of Wen'an slope in Baxian sag, Jizhong depression, Bohai Bay Basin, East China

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Abstract: To study the possibility and location of lateral migration of oil and gas across faults, a quantitative evaluation method for lateral migration of oil and gas across faults was established using the Shuangjing Knipe graphic method to identify the juxtaposition site and juxtaposition patterns of sand and sand in the upper and lower walls of the reverse faults and the consequent faults, combined with the oil and gas limit method of fault lateral seal in the test oil area. The quantitative evaluation method was applied to the first and two members of the Paleogene Shahejie strata (referred to as Es1 and Es2) of Shigezhuang nose structure of Wen'an slope in Baxian sag, Jizhong depression, Bohai Bay Basin, to determine the juxtaposition site of sand and sand in the upper and lower walls of the fault, and the shale gouge ratio (SGR) lower values are 26% and 29% respectively in the strata Es1 and Es2. Thus, the location of lateral migration of oil and gas across faults was determined. Based on the oil and gas distribution characteristics of the strata Es1 and Es2, and variation trend of nitrogen compounds in 4 wells in the strata Es1, the results were consistent with the quantitative evaluation of the location of lateral migration of oil and gas across faults, the feasibility of the evaluation method was preliminarily verified.

Key words: Bohai Bay Basin; Jizhong depression; Wen'an slope; hydrocarbon lateral migration; shale gouge ratio; fault lateral seal; oil and gas seal limit; Knipe diagram method

Introduction

In the process of hydrocarbon migration, faults can not only serve as conduits for vertical migration of oil and gas, but also provide pathways for lateral migration of oil and gas. Whether the oil and gas can migrate laterally across faults mainly depends on the lateral sealing ability of the fault[1–8]. As of 2016, fault lateral sealing evaluation methods can be divided into two categories: qualitative and quantitative. The qualitative evaluation methods are mainly based on Allan diagram and Knipe diagram[9–12]. The Knipe diagram methods can quickly judge the juxtaposition of the hanging wall and footwall of the fault, when sand and mudstone are juxtaposed on the hanging wall and footwall of the fault, the fault has the ability to seal oil and gas laterally; when sand and sand are juxtaposed on the hanging wall and footwall of the fault, it is favorable for oil and gas across faults and occur lateral migration. The quantitative evaluation methods mainly include clay smear potential[13], shale smear factor[14] and shale gouge ratio[15] methods etc. Among them, shale gouge ratio (SGR) is the main method for quantitatively evaluating lateral sealing ability of fault; its value is proportional to the cumulative thickness of the mudstone in the faulted formation, and inversely proportional to the fault displacement. The lateral sealing of fault has a dialectical relationship with hydrocarbon migration and accumulation. When the fault is laterally sealed, it can effectively block oil and gas from further migration and trap oil and gas into accumulation. When the fault doesn't seal laterally, it is a favorable pathway for oil and gas lateral mi-

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gration. At present, the qualitative and quantitative evaluation methods are mostly applied to evaluate whether faults can laterally trap oil and gas, but seldom applied to quantitatively evaluating lateral migration of oil and gas. Therefore, in this study, the qualitative and quantitative evaluation methods are combined to analyze the specific positions of oil and gas cross fault lateral migration, which is of theoretical and practical significance to accurately indicate the path of hydrocarbon migration.

1. The evaluation method of lateral migration position of oil and gas across fault

The prerequisite for the lateral migration of oil and gas across fault is the configuration relation between faults and sand bodies, namely whether there is sand and sand juxtaposition on the hanging wall and footwall of the fault. However, it is not enough to just consider whether the sand and sand juxtapose, the lateral opening or sealing of the sand and sand juxtaposition on the fault plane must be considered too. When the fault is sealed laterally, even the sand and sand juxtaposition, oil and gas can not move laterally across the fault; on the contrary, when the fault is open, the sandstone layers on both sides of the fault are connected and the oil and gas can move laterally across the fault. Therefore, it is very important to identify whether there is sand and sand juxtaposition on the hanging wall and footwall of the fault and the lateral sealing ability of the fault at the site of sand and sand juxtaposition.

1.1. Method of identifying the sand and sand juxtaposition at the upper and lower block of the fault

In this paper, the Knipe diagram method is used to judge the sand and sand juxtaposition on the hanging wall and footwall of the fault. The premise of using the method is to assume that the stratigraphic changes on both sides of the fault are identical. However, affected by geological factors such as faulting, sedimentation and denudation, the hanging wall and footwall of the fault are not identical actually (in such as formation thickness, lithology etc). Therefore, in order to reflect the strata on both sides of the fault as closely as possible, one well is chosen respectively from the hanging wall and footwall of the fault which could reflect the thickness and lithology of strata on the two sides of the fault. That is the so-called double-wells-Knipe graphical method. According to the relationship between fault inclination and formation inclination, the faults are divided into two types, reverse fault and consequent fault. When drawing the map of double-wells-Knipe, the observation plate of reverse fault is different from that of the consequent fault, and the juxtaposition relationships between the two sides of the fault are also different. When the hanging wall and footwall of a reverse fault juxtapose, the observation plate is the footwall of the fault. Affected by syn-sedimentation or denudation, the hanging wall strata become thinner and new overlying strata are formed, with the increase of displacement and buried depth, the juxtaposition of footwall strata and the corresponding hanging wall strata becomes smaller, while the juxtaposition of overlying strata becomes larger (Fig. 1a). When the hanging wall and footwall of the consequent fault juxtapose, the observation plate is the hanging wall of the fault. Affected by compaction and denudation, the thickness of the footwall strata is less than that of the corresponding hanging wall strata, with the increase of displacement and buried depth, the juxtaposition of hanging wall strata and the corresponding footwall strata becomes larger, and the juxtaposition of overlying strata becomes smaller (Fig. 1b). In summary, based on the double-wells-Knipe graphical method, combined with the juxtaposition patterns of sand and sand in the upper and lower block of the reverse fault and the consequent fault, according to the quantitative relation between displacement and buried depth, finally the juxtaposition site of sand and sand in the upper and lower block of the fault can be determined.

1.2. Identification method of the lateral sealing ability of the sand-sand juxtaposition site in the hanging wall and footwall of the fault

According to the identification method of sand and sand juxtaposition on the hanging wall and footwall of the fault, the

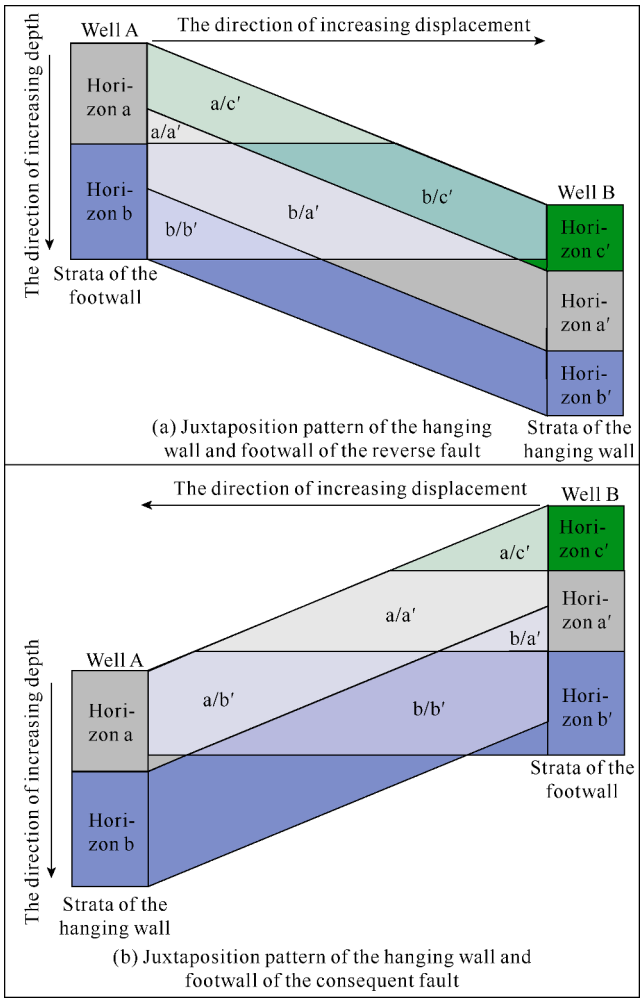

Fig. 1. Stratigraphic juxtaposition pattern of the hanging wall and footwall of the fault.