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The Overview of Hydraulic Fracturing and the Application in the Process of the Oil-gas Production

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Abstract: Hydraulic fracture is a common geological phenomenon developing in the nature, which plays an important role in the fluid migration, oil and gas preservation and oil-gas safety exploitation. Therefore, this paper, on the basis of in-depth study, defines the generalized concept of hydraulic fracture and points out that the phenomenon of hydraulic fracture is the rock brittleness fracture induced by the increase of pore fluid pressure. Hydraulic fracture includes both tensile rupture caused by the increases of pore fluid pressure and tensile shear and shear fracture also caused by the increases of pore fluid pressure. In this paper, we have used the evaluation method of Retention Press model to acess the risk of hydraulic fracture of the cap rock quantitatively in gas storage of some area.
Keywords: hydraulic fracture, Retention Capacity, caprock.

INTRODUCTION

Narrow hydraulic fracture is also called the natural hydraulic fracture [1], mainly refering to that in the low different stress conditions, there happened tensile rupture because of the increase of pore-fluid pressure, and that leads to form a new hydraulic tensile cracks or the original crack expansion [1-5]. However the general hydraulic fracture is the rock brittle fracture caused by the increase of pore pressure.

Foreign study work of hydraulic fracture began in the late 1960s. In the study of joint development Secor first puts forward the mechanism of natural tensile rupture [1]. After that in the study of formation mechanism of wales mineralization normal fault, Phillips first officially puts forward the concept of hydraulic fracture. He look on the cack expansion process caused by pore fluid pressure increase in the cracks as the hydraulic fracture [2]. Then many geologists began to study hydraulic fracture systematically, expounding the mechanism of hydraulic fracture in detail and the occurred conditions. Many of the world's sedimentary basin, such as Australia Otway basin, the gulf of Mexico basin, the north sea basin and so on, has been carried on the detailed analysis and research, and they pointed out hydraulic fracture is one of the potential risks leading to leakage of oil and gas [6-7]. Mildren studied the sealing capacity of fault trap of Timor Sea, analysed the relationship between the pore fluid pressure within fault and the risk of fault activity, and he pointed out the fault activity caused by hydraulic fracture is the primary reason for oil and gas seepage.

HYDRAULIC FRACTURE PRINCIPLE AND EVALUATION METHOD

Hydraulic fracture, a common geological phenomenon developing in the nature, can develop in tension, strike-slip and even extruding tectonic environment and found in shallow depth in the crust. But it can also develop in the depths of the earth's crust, especially in abnormal high pressure development zone [9]. Many geologists have found evidence of hydraulic fracture in different basin of the world. Anderson studying the fluid flow for Eugene island pointed out that when the pore fluid pressure at the bottom of the cover layer is more than the minimum confining pressure hydraulic rupture occurrs and develop the vertical hydraulic tensile crack [10]. Therefore, it is believed that when the pore fluid pressure is close to 85% of lithostatic pressure, it forms the hydraulic tensile crack in the gulf of Mexico near the top of overpressure mudstone cap rock.

In 1987, Watts expounded the mechanism of hydraulic fracture of the cap rock in detail. Hydraulic fracture pressure of the cap rock is equal to the sum of the minimum horizontal effective principal stress suffered by the caprock and the rock tensile strength [11]. Due to buried depth, the minimum horizontal effective principal stress is often a dozen or even dozens of times higher than the tensile strength of the rock. At the same time, considering distribution of heterogeneity of the shale tensile strength in the plane, often ignore the rock tensile strength and hydraulic fracture pressure of the mudstone estimate for the minimum horizontal principal stress conservatively.

Based on this principle, Gaarenstroom proposed a method to evaluate the hydraulic sealing of the caprock: Retention Capacity (Fig 1, 1-1). It is the difference between the minimum horizontal principal stress and pore fluid pressure[12]. The greater the Retention Capacity suggests that the stronger the caprock sealing ability and if it is less than zero, the cap has a great risk of rupture.

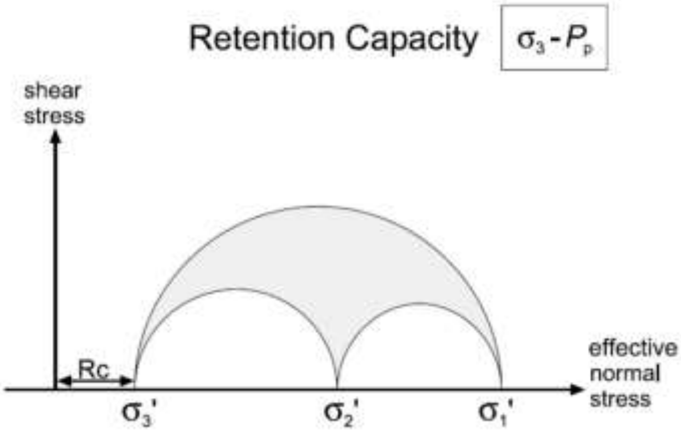

Fig-1: The calculation method of Retention Capacity

$$Rc=\sigma_3-Pp \quad (1\text{-}1)$$

Where R_c is the Retention Capacity/MPa, σ_3 is the minimum horizontal principal stress/MPa, Pp is the pore fluid pressure/MPa.

THE APPLICATION OF HYDRAULIC FRACTURE ASSESSMENT METHOD

Using the in-situ stress logging results of well X-1 of E gas storage, we fit the relationship between the hydraulic fracture pressure and the depth (fig 2). The minimum horizontal principal stress is basically a linear relationship with depth, so we can use an simple equation to express the minimum principal stress with depth (1-2). Statistics of the bottom depth of the caprock of gas storage, we obtained the range of the hydraulic fracture pressure of corresponding caprock (fig 3). The hydraulic fracture pressure of the A, B, C, D, E and F gas storage are 36.1MPa, 26.1 Mpa, 37.6 MPa, 35.8 MPa, 37.3 MPa and 44.8 MPa respectively. The caprock pore pressure of every gas storage must be not exceed above pressure. Or the cap rock will fracture, and result in leakage of oil and gas.

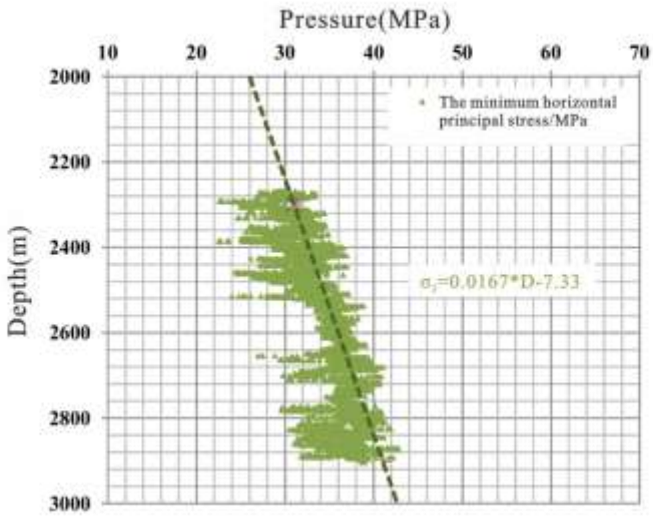

Fig-2: The relationship between the hydraulic fracture pressure and the depth

$$P_c=\sigma_3=0.0167*D-7.33 \quad (1\text{-}2)$$

Where D is the depth/m, Pc is the hydraulic fracture pressure of the caprock/Mpa, σ_3 is the minimum horizontal principal stress/Mpa.

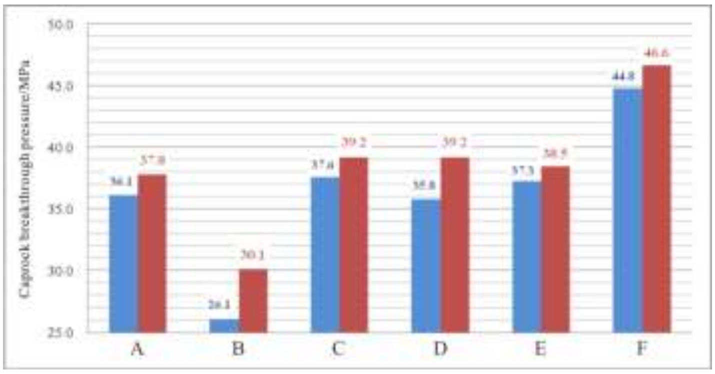

Fig-3: The maximum (red) and minimum (blue) hydraulic fracture pressure of gas storage

CONCLUSIONS

(1) Narrow hydraulic fracture is also called the natural hydraulic fracture, mainly refering to that in the low different stress conditions, there happened tensile rupture because of the increase of pore-fluid pressure, and that leads to form a new hydraulic tensile cracks or the original crack expansion. However the general hydraulic fracture is the rock brittle fracture caused by the increase of pore pressure.

(2) The evaluation of the caprock is processed using the Retention Capacity Model. Due to buried depth, the minimum horizontal principal stress is often a dozen or even dozens of times higher than the tensile strength of the rock. At the same time, considering distribution of heterogeneity of the shale tensile strength in the plane, often ignore the rock tensile strength and hydraulic fracture pressure of the mudstone is approximately equal to the minimum horizontal principal stress.

(3) Applicating of Retention Capacity Model to assess the hydraulic fracture pressure of the A, B, C, D, E and F gas storage respectively, we found that the corresponding minimum hydraulic fracture pressure are 36.1MPa, 26.1 Mpa, 37.6 MPa, 35.8 MPa, 37.3 Mpa and 44.8 Mpa. The caprock pore pressure of every gas storage must be not exceed above pressure. Or the cap rock will fracture, and result in leakage of oil and gas.

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