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## Damage by Swelling Clay and Experimental Study of Cyclic Foam Stimulation

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The performances of the formation damage are permeability decreasing, skin factor increasing and productivity index decreasing. Generally, formation damage is not reversible. This phenomenon is known as reverse funnel effect (Porter 1989). People have been trying to find effective ways to remedy the reservoir damage. Stimulation and hydraulic fracture are traditional way to fix formation damage. However, they all have inevitable limitations. The stimulation fluid is acid usually, which will cause equipment/tubing corrosion, second formation damage and environmental pollution. These problems limit the application of them. And they are not suitable for horizontal well as the gravity, especially for stimulation (Xu and Pu 2013).

Bond and Holbrook take foam into the field of oil recovery (Friedmann, Chen, and Gauglitz 1991; Bond and Holbrook 1958; Aarra, Skauge, and Martinsen 2002; Castanier 1989; Zhdanov et al. 1996). Foamed cement plays an important role in preventing and controlling the shallow water flow in deepwater drilling effectively (Zhang et al. 2011). Foam is also important for fracturing and acidizing of low permeability, low pressure or strong water-sensitive reservoirs (Zheng et al. 2011; Xu et al. 2002). These applications all show the important role of foam in oil and gas industry.

Recently, we take foam as a stimulation fluid to remedy the formation damage which is caused by clay swelling. However, nitrogen foam is a complicated system and is a structured fluid. The bubbles with different sizes separated by the lamellae form the foam fluid with special structure. Under the shearing action, the foam could deform, collapse, coalesce, and regenerate, which eventually leads to the complexity of foam transporting and blocking in porous media. Therefore, we choose experiment method to

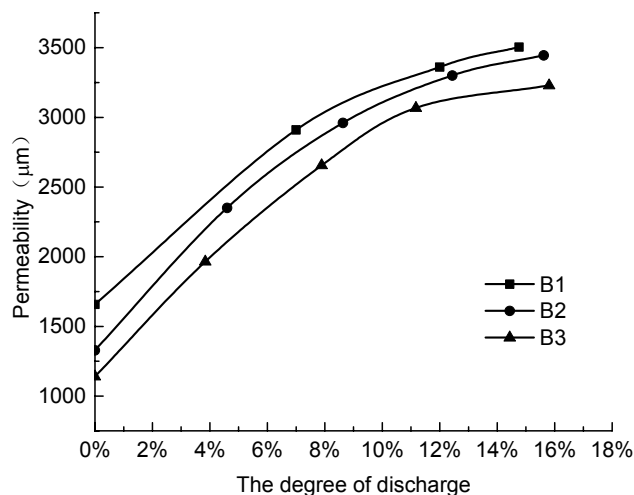


Fig. 1 Permeability vs the degree of discharge

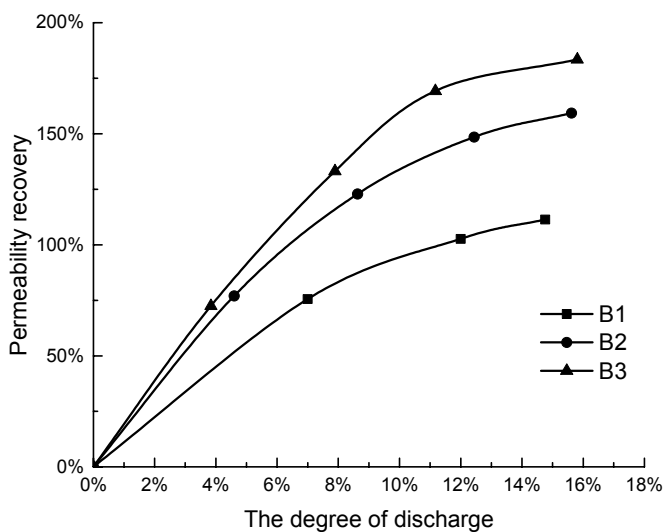


Fig. 2 Permeability recovery vs the degree of discharge

study the stimulation process.

In this paper, reservoir damage caused by clay is due to

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**Table 1 Types of magmatic sulfide deposits in China**

| Core      | Height (cm) | The diameter of drifting sand (μm) | The quality of drifting sand (g) | The quality of bentonite (g) |
|-----------|-------------|------------------------------------|----------------------------------|------------------------------|
| <b>B1</b> | 8.04        | 148                                | 40                               | 0                            |
| <b>B2</b> | 8.35        | 148                                | 40                               | 4                            |
| <b>B3</b> | 8.46        | 148                                | 40                               | 8                            |

clay swelling or transport / deposition, results in porous media blockage, its restorations are summarized. Foam was proposed to discharge blockage and to stimulate porosity and permeability near wellbore, cyclic foam stimulation test designed based on this (fig.1, 2, table 1). In order to simulate formation damage caused by clay in different levels, 3 man-made sand producible cores invent firstly based on PVA film wrapped fine sand and calcium bentonite. Experiments results show that more weight percentage of clay in formation, permeability has a bigger reduction, foam has 'a good discharge effects on sand blockage and clay swelling. Permeability restitution coefficient is defined, permeability get faster recover before the extent of discharge about 11%, clay caused damage severe than the formation damage by fine sand. The scientific guidance can be provided for the application of Cyclic Foam Stimulation by this research.

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