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Research on fabric characteristics and borehole instability mechanisms of fractured igneous rocks

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Abstract: There are favorable exploration prospects in igneous rock reservoirs. However, problems of borehole instability occur frequently during drilling igneous formations, which is a serious impediment to oil and gas exploration and production. The lack of systematic understanding of the inherent instability mechanisms is an important problem. A series of experiments were conducted on several igneous rock samples taken from the sloughing formations in the Tuha area in an attempt to reveal the inherent mechanisms of wellbore instability when drilling in fractured igneous rocks. Research methods involved slurry chemistry, analysis of micro-geological features (Micro-CT imaging, SEM), and rock mechanics testing. The experimental results indicated that clay minerals were widely distributed in the intergranular space of the diagenetic minerals, crystal defects, and microcracks. Drilling fluid filtrate would invade the rock along the microcracks. The invasion amount gradually increased over time, which constantly intensified the hydration and swelling of clay minerals, leading to changes in the microscopic structure of igneous rocks. Primary and secondary microcracks can propagate and merge into single cracks and thus reducing rock cohesion and the binding force along cleavage planes. Based on this result the authors propose that a key towards solving wellbore instability in igneous formations is that specific micro-geological characteristics of the igneous rocks should be taken into consideration in the design of antisloughing drilling muds.

Key words: Igneous rocks, microcracks, clay minerals, hydration, instability

1 Introduction

Borehole instability caused by clay mineral hydration during drilling is a major problem in the oil industry. This phenomenon usually occurs in the clay-rich mud shale; however, with expansion of exploration, it is also found in the drilling of igneous formations (Mitsuhata et al, 1999; Sahabudin and Darren, 2000). In recent years, borehole collapse, hole enlargement, lost circulation, pipe sticking and other complex problems often emerge in most of oil and gas basins when drilling into igneous rocks (basalt, tuff-based), resulting in the expansion of the drilling cycle and increase in drilling cost. To reduce wellbore instability problems in igneous rock formations, several researchers have investigated the factors influencing borehole instability. Researchers focusing on metasomatic alteration petrology pointed out that the neutral or basic igneous rocks, especially pyroclastic rocks under hydrothermal conditions (contact with the formation fluid under high temperature conditions) would be vulnerable to argillization. Plagioclase is often altered to kaolinite and smectite minerals. Numerous studies show that clay minerals in igneous rock formations tending to suffer from borehole instability consist mainly of smectite, whose physical and chemical properties present strong dispersibility or expansibility (Bhuyan and Passey, 1994; Stjern et al, 2003; Thomson, 2003; Rohrman, 2007). When contacted with incompatible drilling fluid filtrate, these clay minerals would be hydrated (in the forms of dispersion or expansion), thus leading to wellbore instability. In the Jidong Oilfield, the basalt and tuff formations in the Guantao Group where borehole instability occurs contain a large number of clay minerals, up to 36%-78%, with a relative content of smectite of 90%-97%. The high content and wide distribution of opaline silica which also expands easily may also be one of the reasons for borehole instability (Yuan et al, 2007). Tuff is easily to disperse, with a core recovery rate of less than 10%, while basalt and altered basalt have relatively low dispersibility, but still expand easily with an expansion ratio up to 38%-43% (Zhang et al, 2010).

In addition, the particular petrological structure of igneous rocks is also a potential factor of borehole instability (Sato et al, 1999; Kawamoto and Sato, 2000; Jerram et al, 2009; Karakul and Ulusay, 2009; Wang et al, 2010). Weak planes and non-homogeneous structure greatly weakens the strength of formation rock. Moreover, the micro-structures of igneous rocks also have an impact on the deformation mode (Crosta et al, 2010; Hossain and Seshagiri, 2008; Lutz et al, 2010),

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