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FULL LENGTH ARTICLE

Egyptian diatomite as high fluid loss squeeze slurry in sealing fractures and high permeable formation

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Abstract Lost circulation is the most costly mud related drilling problem, and induced fracture. Water slurry of diatomite is used as the high fluid loss squeeze slurry in the treatment of lost circulation and in decreasing fluid loss. Egypt has diatomite deposits, especially in El-Fayuom Depression. Fourteen samples were collected from Qasr El-Sagha at the northern shore of Birket Qarun. Samples were examined to identify the diatom species then subjected to X-ray fluorescence, XRD and grain size distribution tests. A total of 38 species related to 13 diatom genera were identified. *Cocconeis*, *Epithemia* and *Rhopalodia* were the predominant genera. The diatomaceous earth which acts as a filter aid material was tested with different additives; bentonite, lime, finely divided paper, polymer, barite and different concentrations with different types of lost circulation materials (LCM) to form a high fluid loss squeeze slurry. As a result the required time for collecting the filtrate was decreased to be in the range of 50 s to 1 min and 49 s comparing with the international standard which recommended the filtrate should be collected maximum within 2–3 min.

1. Introduction

Drilling fluid, or mud, may be defined as any fluid that is used in a drilling operation. A drilling fluid is circulated or pumped from the surface, down the drill string, through the bit, and back to the surface via the annulus. It is the single most important part of any earth excavation exercise, especially when drilling for oil and gas. Selection of the best fluid to meet anticipated conditions will minimize well costs and reduce the risk of catastrophes such as stuck drill pipe, loss of circulation, gas kick, etc [1–3].

Lost circulation is the term used to describe the condition characterized by lack of mud returning to the surface after being pumped down a well-bore. It is caused by the loss of some or the whole of the drilling fluid or mud at any depth into the natural fissures or due to high permeability of the formation or by pressure induced fractures [4,5], resulting in fluid loss and there are high costs associated with replacing drilling fluids [6]. Egyptian oil field production is distinguished by loss

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of circulation due to the rocky nature and the high porosity of Egyptian wells [7].

Many lost circulation materials are added to drilling fluids. One of the lost circulation water base mud (WBM) additives that is considered environmentally friendly is silica. Silicates are non-toxic and are multi-functional materials that are being used in drilling mud formulations by causing changes in density, ionic strength, and charge. Silica is needed for critical drilling mud functions such as: drill-bit cooling, bit cleaning, effective cuttings removal to surface, downhole pressure control and Shale stabilization [8].

Diatomite can be combined with other materials such as organic fibbers to be used as a lost circulation control material in water drilling fluids. It is typically used as a rheological modifier or processing aid in a "squeeze" treatment, it has a highly permeable nature which allows it to rapidly form a plug to bridge fractures. Diatoms produce a highly porous mineral which can be used to seal wide fractures, as it will lose fluid very rapidly to provide a solid plug on which an impermeable filter cake may then form. Silica constitutes about 80–90% of the chemical composition of the diatom frustule. Typical high fluid loss slurry contains a mixture of diatomite, bridging agents and barite suspended in either water or oil [9,10].

Almost any type of mud can be used as a carrying fluid for spotting lost circulation materials, but fluids that have extremely high filtration rates are best. Once the initial bridge forms, filtration allows the filtrate to be lost from the slurry depositing a firm filter cake within the fracture itself. This technique should be used against all types of loss zones. There are slight differences in application to these different loss zones, but the main distinction is increasing the size of the bridging agent as the loss zone becomes more severe [11].

The first high solids high fluid loss squeeze was performed with diatomaceous earth in 1956 by Carl Huber, (Phillips Petroleum Company) and John Crocker (Magcobar) on a Phillips Petroleum Company well north of Pampa, Texas. Drilling Specialties Company then a division of Phillips introduced the first commercial product Diaseal M® LCM, in 1964. Today several companies have altered the formula slightly and present it as something new to the industry [12].

This study focused on an environmentally friendly additive diatomite and the efficiency of this slurry. The collected Egyptian diatomite was examined in order to select the highest silicate samples to use in drilling as a high fluid loss squeeze slurry in sealing fractures.

2. Materials and methods

Fourteen sites were chosen to collect fossil diatomite samples from Qasr El-Sagha located at the west of the El-Fayoum depression 90 km southwest of Cairo. Locations of the sites were geographically determined in latitude and longitude by using the global positioning system (GPS).

Samples were prepared by the method described by Jouse et al. [13] and the slides were mounted using the method described by Proschkina–Laverenko et al. [14]. The diatom samples were counted according to the counting method described by Vilbaste [15]. Diatomite samples were prepared for scan electron microscope (SEM) according to Hasle and Fryxell [16].

The material was analyzed using X-ray fluorescence (XRF) by The Ministry of Petroleum, The Egyptian Mineral Resources Authority (EMRA). Centre Laboratory Sector (XRF Lab). The material was analyzed using the XRD test. Particle size distribution of the sample was determined according to API RP 13C [17].

Normal field tests were carried out on water based mud. They cover the properties that are most important to the Mud Engineer at the location. These are primarily performed to keep a record of the basic physical requirements of the mud (filtration, density, viscosity, gel strength, pH), with additional tests to monitor the performance of high-filter-loss-slurry squeeze [17–21].

The hydrostatic pressure that a column of mud exerts upon any point in the hole can be calculated according to [18] as follows:

Hydrostatic pressure (psi) = 0.052 × mud weight (ppg "pounds per gallon") x depth (ft.)

Rheological properties were determined according to:

a – Bingham plastic model

It was estimated according to [18] by the following equations:

$$\text{Plastic Viscosity PV (cP)} = \theta_{600} - \theta_{300}$$

$$\text{Apparent Viscosity AV(cP)} = \frac{\theta_{600}}{2}$$

$$\text{Yield Point Y.P.(lb/100 ft}^2) = \theta_{300} - \text{PV}$$

b – Relation between shear rate, shear stress and effective viscosity

They were estimated by the following equations:

$$\text{Shear Rate } \gamma \text{ (s}^{-1}) = R \times 1.7034$$

$$\text{Shear Stress } \tau \text{ (lb/100 ft}^2) = 1.0678 \times \theta$$

$$\text{Effective Viscosity E.V. (cp)} = \frac{300 \times \theta}{R}$$

c – Power low model

It was estimated by the following equations:

$$\tau = k\gamma^n$$

$$\text{Log}\tau = \log k + n \log \gamma$$

where, θ, viscometer dial reading at Speed R, R, rotary speed, k, consistency, n, flow index.

3. Results and discussion

3.1. Diatom diversity

This study shows that, from the collected 14 sites a total of 13 genera and 38 species were identified belonging to Bacillariophyta. The distribution of different diatomite species varied from one site to another but the six most common species are predominant in most sites (Table 1). It was observed that *Cocconeis placentula* var. *euglypta* is predominant in almost all sites and it frequently presents in only 5 sites. It occupies 17% of the total number of individuals counted at all sites followed by *C. placentula* which represented 16% of the total number of individuals. *C. placentula* is predominant in about 8 sites and frequently presents in 6 sites. *Epithemia sorex*, *Epithemia turgida*, *Rhopalodia vermicularis* and *Rhopalodia gibba* var *ventricosa* are predominant in about 5 sites and

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