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Study on Adaptability of Suizhong 36-1 Oilfield Acidizing Fluid System

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Abstract

This article took CNOOC Suizhong 36-1 reservoir cores as the research object, carried out short core acidification flow simulation test and ESEM microanalysis of four kinds of acid fluid system. By comparing several kinds of acid fluid system, we found the deep-penetration and low-damage acidizing fluid can not only effectively dissolve inorganic impurities, but also remove the emulsified oil pollution, meanwhile it could greatly reduce the secondary damage caused by acidification. The result of the acidification is most accorded with the requirements of Suizhong 36-1 oilfield.

Key words: Aciding fluid; Acidification flow simulation test; ESEM micro-analysis

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INTRODUCTION

The Determination of Acidizing Fluid System

According to Suizhong 36-1 oilfield sandstone reservoirs with properties of high porosity and high permeability, and analysis of water injection damage factors. The deep-penetration and low-damage acidizing fluid was chosen by screening the main acid and acid additives. This acid system can keep its activity for a long time, delay acid/rock reaction rate and keep a low PH value of the residual acid.

The deep-penetration and low-damage acidizing fluid is mainly composed of: 5% ~ 7% DH + 2% ~ 5% FS + 3% YES + 3% ~ 6% HCl + 1% corrosion inhibitor + 1.5% inhibitor ferric ion stabilizer QS - 2 + 1.5%anti-swelling agent + 1% demulsifier + 1% cleanup additive + 0.1% anti acid slagging agent FK - 1.

The Characteristics of Acid System

Aiming at various plugging types of injection wells, through analyzing the characteristic of the SZ36-1 oil reservoir and contrast effects of various sandstone acid system[1]. The acid system and acid additives are optimized and chosen, and the optimum use of their concentration is also determined. Finally, the formulation of low damage acid system is proposed so that the damage caused by sewage can be controlled.

(a) The moderate total acid concentration of main acid in acid system will be conduce to improve the effect of plug removal and reduce the content of precipitate generated by fluorosilicate, fluorine aluminate and hydrated silicon. It also can remove the acidification secondary damage to protect rock matrix.

(b) The acid system with specific surface active agent can reduce damage which caused by corrosion inhibitor and remove of the emulsified oil pollution.

(c) The depth and low damage acid system not only can delay acid/rock reaction rate to achieve the goal of deep penetrating, but also keep a low PH value of the residual acid to reduce secondary damage caused by reaction products.

(d) The acid system has high operability and low damage.

(e) Compared with the conventional mud acid acid system, the depth and low damage acid system is easy to remove plugs.

1. SHORT CORE ACIDIFICATION FLOW SIMULATION TEST

A short core simulation test with similar reservoir natural cores and simulation cores which combined Suizhong 36-1reservoir cuttings and clay minerals was carried out on the basis of indoor conditions. The specific scheme was shown in Table 1.

Table 1
Laboratory Short Core Acidification Flow Simulation Test Scheme

No.	Core No.	Temperature (℃)	Injected fluid procedure and formula			
			Prepad fluid	Prepad acid	Main acid	Subsequent fluid
1	PQ1211	65	Clean and sewage injection+2%KCl	12%HCl+ additive	12%HCL+3%HF+ additive	2%KCl
2	PQ1212	65			6%HCL+8%HBF_4+ additive	
3	PQ1213	65			Multi-hydrogen acid system	
4	PQ1214	65			depth and low damage acid system	

1.1 Experimental Procedures

(a) Injected the test liquid sequential on core flow test instrument, measured the change of core permeability before and after acid injection. The core permeability was calculated according to Darcy's formula[2].

(b) Polluted for 15 PV with the Suizhong 36-1 injected water. Determined the core permeability which was polluted.

(c) Injected the ahead fluid (20 PV), main acid (30 PV), subsequent fluid and displacement fluid (15 PV).

(d) Measured the core permeability with 2%KCl.

1.2 Experiment Results

The results were discussed as follows:

Table 2
Short Core Acidification Flow Simulation Test Results

Core No.	Core permeability K ($\times10^{-3}$ μm^2)					Permeability ratio
	Original	Polluted prepad fluid K_1	Prepad acid	Main acid	Subsequent fluid K4	K_4/K_1
PQ1211	768	552	356	489	698	1.26
PQ1212	636	421	292	508	689	1.64
PQ1213	689	386	252	398	435	1.13
PQ1214	725	538	416	958	966	1.79

(a) After injected 12% ahead fluid HCl, the permeability of 1~4 core decreased, and there were a lot of CO_2 bubbles concentrated at the export. With the decrease of bubble, the permeability of the core rose slowly. In the later period of injected ahead acid, there was nearly no bubble which showed that the 12% HCl had basically dissolved carbonate cements in the core.

(b) No.1 test's result was based on the influence of conventional mud acid (12%HCl+3%HF) on the core acidification effect. Results were shown in Figure 1.

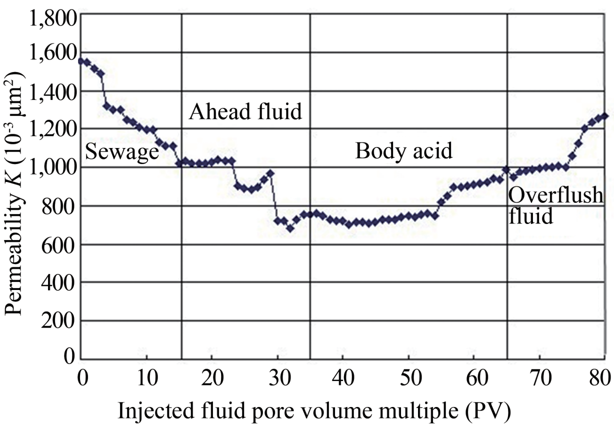

Figure 1
The Acidification Experiment Results of Simulation Core and 12%HCl+3%HF Under 65 ℃

As can be seen from Figure 1, the core permeability K stabilized at 1,022×10^{-3} μm^2 after injected the clean and sewage mixed water for 15 PV, after injected 12%HCl for 5 PV, K decreased to 812 ×10^{-3} μm^2. When the injection rate of 12%HCl arrived at 15 PV , K continued to decline to 753 ×10^{-3} μm^2. After injected 8 PV 12%HCl+3%HF, K rose rapidly to 869×10^{-3} μm^2, injected for another 8 PV, K stabilized at about 910×10^{-3} μm^2, and then decreased gradually. After injected 12%HCl+3%HF for 25 PV, K increased to 935×10^{-3} μm^2. And then injected the main acid, K basically stabilized at 980×10^{-3} μm^2. After injected the displacement fluid 2%KCl, K recovered to 1,200×10^{-3} μm^2, and eventually stabilized at 1,265×10^{-3} μm^2. Finally, K had increased 1.24 times.

At the same time, there is a great degree of damage on the core entrance after acidification test, which showed that the conventional mud acid reacted with rock quickly on the condition of 65 ℃, resulting in a large number of active acid consumed in the core entrance. It undermined the core framework, and the particles caused by erosion entered into deep core, when noted the displacing liquid, the permeability reduction would cause secondary damage to reservoir.

(c) Test 2 used 6%HCl+8%HBF4 acid system, this is one of the most common acidizing fluid system in Suizhong 36-1 oilfield. The test results were shown in Figure 2.

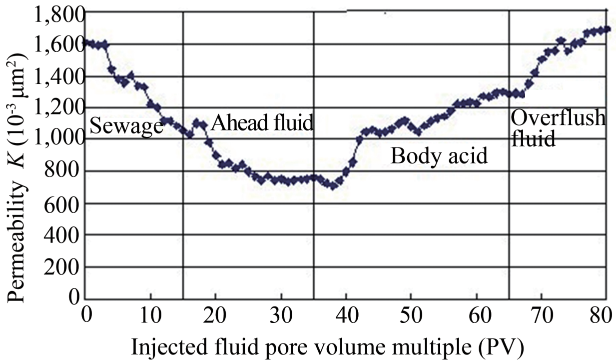

Figure 2
The Acidification Experiment Results of Simulation Core and 6%HCl+8%HBF4 Under 65 ℃

As can be seen from Figure 2, the core permeability *K* was stabilized at 1,057×10^{-3} μm^2. After injecting mixed injection sewage 15 PV, *K* is 763×10^{-3} μm^2. After injecting 12%HCl; *K* increased to 1,283×10^{-3} μm^2 gradually. After injecting 6%HCl+8%HBF4; *K* was stabilized at 1,689×10^{-3} μm^2. Then, injected replacement fluid 2%KCl. Finally, *K* increased 1.60 times. Compared with the test one, the ratio of core permeability has a more substantial increase before and after acidification, the permeability improved largely after injecting 2% KCl displacement fluid.

At the same time the extent of damage of the core in test 2 is significantly less than in the test 1, the extent of damage of the core skeleton caused by acid skeleton is small, particle migration is less, but there is still a slight acid dissolution hole at Inlet end, the result indicates that acid only acts on the inlet end of the core, if we use fluoroborate instead of hydrofluoric acid, the HF formed deeply helps to protect the formation rock skeleton[3].

(d) In test 3, we used a multi-hydrogen acid system to react with laboratory simulation core. The test result is shown in Figure 3.

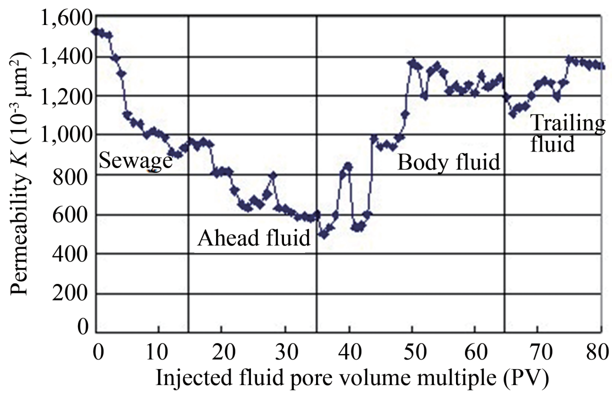

Figure 3
The Acidification Flow Experiment Result of Multi-Hydrogen Acid System and Laboratory Simulation Core

As can be seen from Figure 3, the core permeability *K* was stabilized at 967×10^{-3} μm^2 after injecting mixed injection sewage 15 PV, the value of *K* keep at 763×10^{-3} μm^2 after injecting 12%HCl; *K* increased to 1,286×10^{-3} μm^2 gradually after injecting MH acid; *K* was stabilized at 1,347×10^{-3} μm^2 after injecting 2%KCl replacement fluid. Finally, *K* had increased 1.4 times.

At the same time the removed core end is intact, that indicated multi-hydrogen acid system response is slow and it is a good retarded acid which won't corrode core surface overly. From the point of view on the improvement of core permeability, this acid system can remove plugs of deep reservoir, but the increase rate isn't high[4].

(e) We used depth and low damage acid in test 4, the test result is shown in Figure 4.

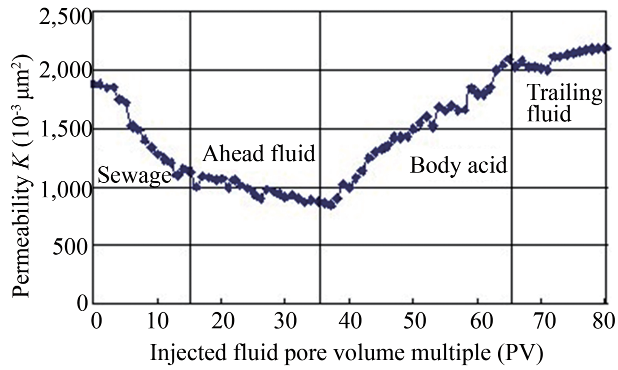

Figure 4
The Acidification Flow Experiment Result of Depth Low Damage Composite Acid and Laboratory Simulation Core

As can be seen from Figure 4, the core permeability *K* dropped from 1,876×10^{-3} to 1,207×10^{-3} μm^2 after injected mixed injection sewage 15 PV, and after injected 12%HCl K dropped to 878×10^{-3} μm^2 ; *K* increased to 2,096×10^{-3} μm^2 gradually after injected depth and low damage composite acid; *K* was stabilized at 2,186×10^{-3} μm^2 after injected replacement fluid 2%KCl. Finally, *K* had increased 1.81 times.

In the whole process of injecting acid, *K* rises steadily, which shows acid-rock reaction is gradual and the acid system can delay reaction rate, core permeability gradually improves with the consumption of acid, but the reaction rate isn't as quickly as conventional mud acid reaction. The removed core end is intact, won't corrode core surface overly, from the point of view on the improvement of core permeability, this acid system can remove plugs of deep reservoirs, which is more suitable for the demand of Suizhong 36-1 oilfield acidizing.

2. CORE ENVIRONMENTAL SCANNING ELECTRON MICROSCOPE MICROANALYSIS

Core scanning electron microscope can observe changes of the core internal structure, analyze and compare acidification and non-acidification core porosity and permeability structure, compare dissolution conditions of rock matrix as well as clay minerals caused by different acid system, which is helpful to understand the action of acid in the formation. Laboratory used Suizhong 36 reservoir cuttings combined clay minerals as analog core and made five SEM experiments in order to compare before and after acidification, and a variety of acid dissolution conditions, such as the changes of no acidification core poroperm structure, after conventional mud acid core poroperm structure, fluoroborate system core poroperm structure after acidification, multi-hydrogen acid system after acidification core poroperm structure and depth acid acidified low damage composite core poroperm structure.

2.1 The Core Poroperm Structure After No Acidification

As can be seen from the figure, unacidified previous core surface is roughness, the cementation of clay minerals and sand particles is dense, no large pores no particle shedding and transport phenomena. Poroperm structure is simple, development is balanced.

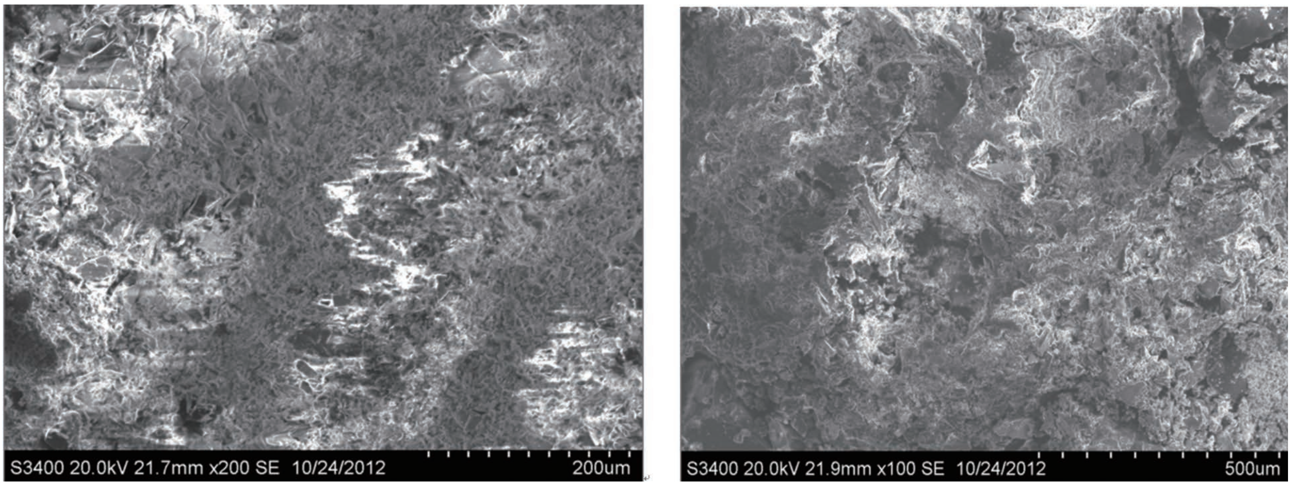

Figure 5
No Acidification Core Poroperm Structure

2.2 The Core Poroperm Structure After Mud Acid Acidification

As can be seen from the figure, core acid-rock reaction is more severe, the cementation of core end some particles after acidification, there are obvious particle shedding phenomenon, the cement was completely corroded, connectivity between pores significantly changed for the better. There is the produce of cave, feldspar dissolution hole shown in figure, and you can see particles crisp shedding and migration, the cement between sand has been almost corroded.

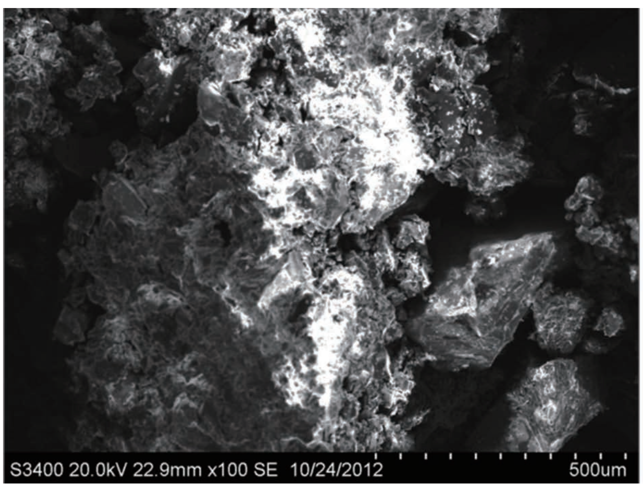

Figure 6
Etching Cave Caused by Mud Acid

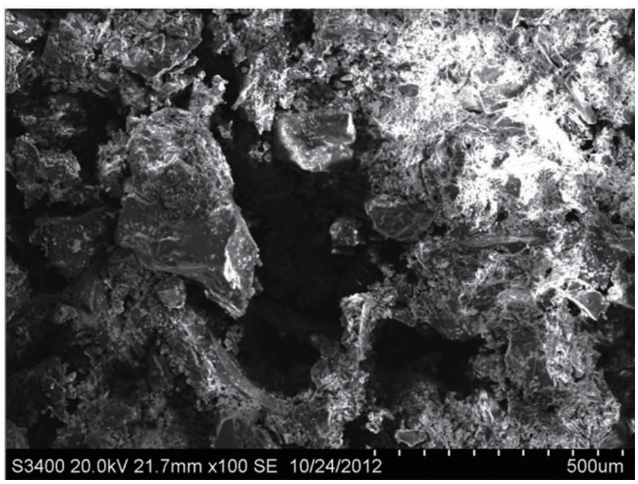

Figure 7
Particle Transport After Acidification by Mud Acid

2.3 The Core Poroperm Structure After Fluoroborate Acidification

As can be seen from the figure, core poroperm condition has improved after acidification by fluoroborate, there are no phenomenon of cave and dissolved pores corroded by HF[5]. You can clearly see from the image above that there are the generation and adsorption of secondary sediment and the migration of fine particles, but it isn't as obvious as using HF, the size and number of particles significantly improved, clay cement is corroded partly but the relatively strong is cemented with quartz grains.

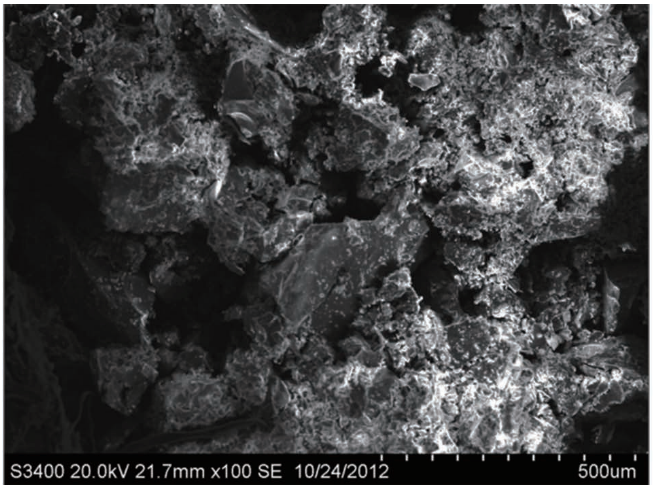

Figure 8
Corrosion Phenomena Exist (But Not Obvious)

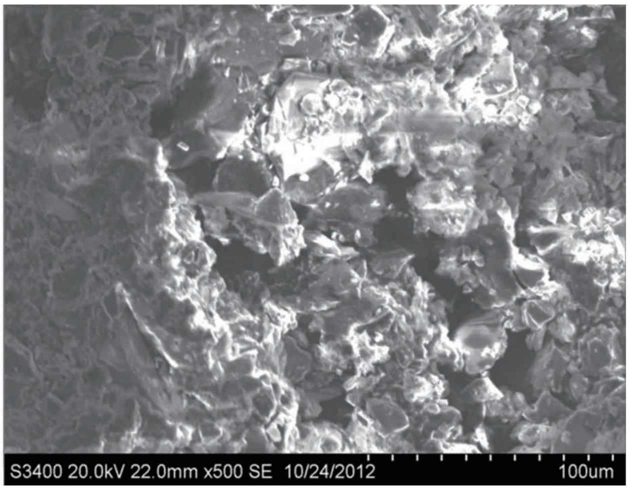

Figure 9
Migration of Small Particles

2.4 The Core Poroperm Structure After MH Acid Acidification

As can be seen from the figure, core poroperm condition has improved after acidification by MH acid, but the improvement condition isn't obvious, there are no phenomenon of cave and dissolved pores corroded by HF[6]. You can clearly see from the image above that clay minerals are still cemented densely, there is no phenomenon of particles falling off. But from the perspective of improving the permeability, acidifying effect isn't obvious.

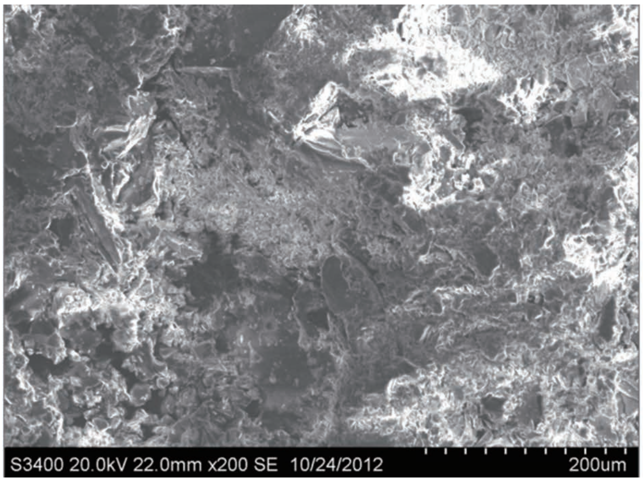

Figure 10
Clay Minerals Is Still Cemented Densely

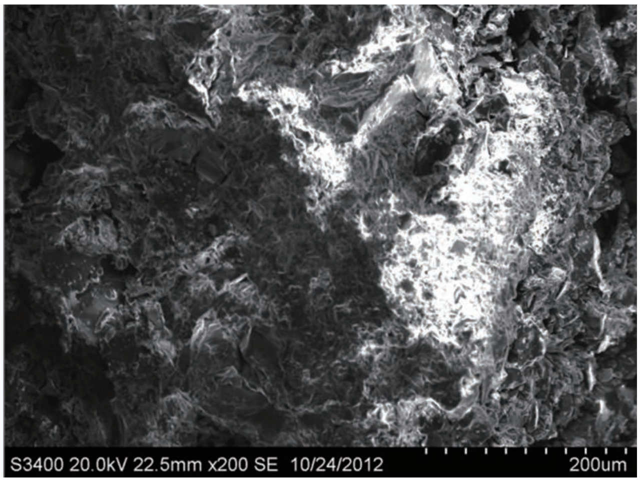

Figure 11
Poroperm Structure Improved Partly After Acidification

2.5 The Core Poroperm Structure After Depth Low Damage Composite Acid Acid System

As can be seen from the figure, core poroperm condition has improved after acidification by composite acid, there are no phenomenon of cave and dissolved pores corroded by HF. You can't clearly see from the image above that there are the generation and adsorption of secondary sediment and the migration of fine particles. The dissolution amount of clay cement is low and the it is cemented with quartz grains densely, which is suitable for the request of Suizhong 36-1 oilfield acidizing[7].

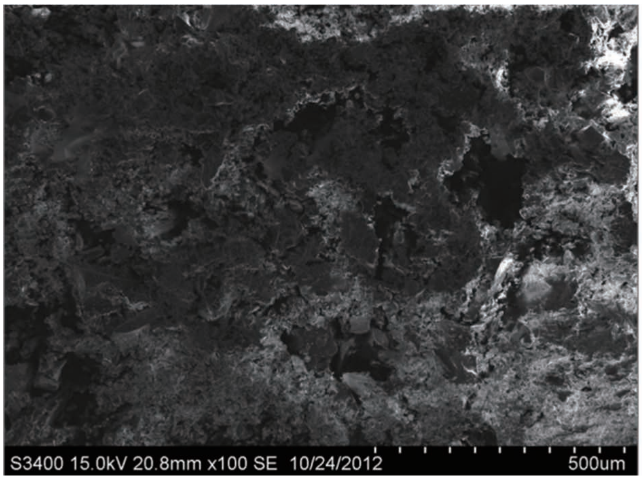

Figure 12
Poroperm Structure Improved After Acidification

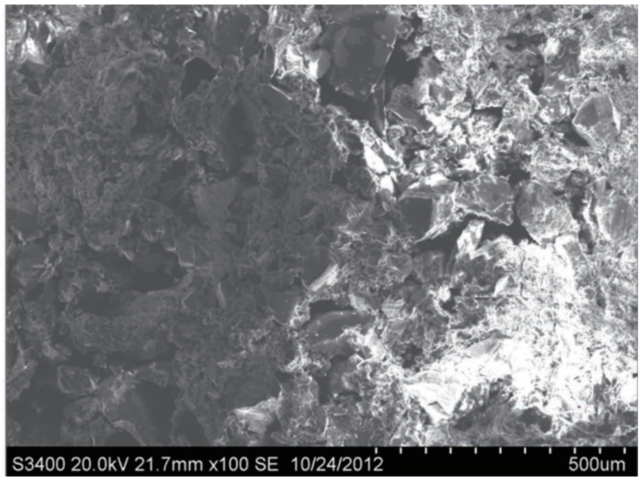

Figure 13
Clay Is Cemented Densely, No Particle Migration

CONCLUSION

(a) During the short core acidification flow simulation experiment, the rate of improvement of core permeability after acidification is as following: Depth and low damage acid > 6%HCl + 8%HBF4 > MH acid > conventional mud acid.

(b) If the concentration of depth and low damage acid system is moderate, it will be conduced to improve the effect of plug removal and reduce the content of precipitate generated by fluorosilicate, fluorine aluminate and hydrated silicon. It also can delay acid-rock reaction rate in order to achieve the goal of depth acidification, maintain a low PH value of the residual acid , reduce the acidification secondary damage to protect rock matrix, which is suitable for Suizhong 36-1 oilfield.

REFERENCES

[1] Li, L., Nasr-El-Din, H. A., Chang, F. F., & Lindvig, T. (2009). *Reaction of simple organic acids and chelating agents with calcite*. Paper presented at International Petroleum Technology Conference, 3-5 December, Kuala Lumpur, Malaysia.

[2] Taylor, K. C., Nasr-EI-Din, H. A., & Mehta, S. (2006). Anomalous acid reaction rates in carbonate reservoir rocks. *SPE Journal*, *11*(4), 488-496.

[3] Mumallah, N. A. (1991, February). *Factors influencing the reaction rate of hydrochloric acid and carbonate rock*. Paper presented at SPE International Symposium on Oilfield Chemistry, Anaheim, California.

[4] Kntizier, T., Yaseen, M., Dutta, B. K., & Chacon, E. (2002, February). *A systematic approach to improve the performance acid-fracturing treatments in low-pressure, low-temperature wells*. Paper presented at International Symposium and Exhibition on Formation Damage Control, Lafayette, Louisiana

[5] AL-Dahlan, M. N., & Nasr-EL-Din, H. A. (2001, February). *Evaluation of retarded HF acid systems*. Paper presented at SPE International Symposium on Oilfield Chemistry, Houston, Texas.

[6] Mumallah, N. A. (1996). Hydrochric acid diffusion coefficients at acid-fracturing conditions. *JPTE*, *15*(2-4), 361-374.

[7] Rabie, A. I., & Nasr-El-Din, H. A. (2011, September). *Measuring the reaction rate of lactic acid with calcite using the rotating disk apparatus*. Paper presented at SPE Middle East Oil and Gas Show and Conference, Manama, Bahrain.

