

Case Study

CASES STUDY ON OILFIELD EARTHQUAKE INDUCED BY FLUID INJECTION

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Abstract: In order to improve the production of oil and gas, hydraulic fracturing is adopted in the process of drilling for oil and gas by a growing number of oil companies, or use the deep well to deal with waste liquid in the process of oil production. These activities are likely to induce earthquake. According to records, the earliest oilfield induced earthquake case by water injection date back to the 1950 s, in the United States of California LanFan Dietz. In the late 1970 s, the first oil field induced earthquake by water injection were found at Renqiu oilfield. It reviews some induced earthquake cases occurred at Renqiu oilfield, Shengli oilfield, Rongchang region and Zigong-Longchang region. At the same time, some seismic activities which happened at the Rangely field, Colorado in the United States, the Wilzetta field, Oklahoma in the United States and the Horn river basin, British Columbia are also summarized. **Keywords:** induced earthquake; fluid injection; Liquid waste disposal; Characteristics of induced earthquake.

1 Introduction

Oil and gas development is a dynamic process of a multi-phase fluid flow and reservoir rock matrix deformation coupling, a large number of field engineering practice shows that the high-pressure injection, high pressure fracturing pressure fluid injection measures easily induced Fault Closure Evolution or fault activation, not only resulting in the actual production of injection patterns inadequate, seriously affecting the oil field development results; and may well result in flooding of the storm, cut into a piece of casing damage induced geological disasters such as earthquakes. Oilfield water injection is the main secondary oil recovery method is the use of water injection wells into the formation to supplement conservation measures and reservoir pressure. In the oil and gas development process, often due to liquid injection induced micro-earthquakes or lead to the formation slide and seriously affect the field of normal production, these small earthquakes to oil or water injection wells cause a greater or lesser harm, magnitude high to a certain extent also on the ground facilities causing direct damage; some are due to the formation creep leads to a lot of tubing, causing damage, and even lead to the collapse of buildings and other surface geological disasters.

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2 Cases of earthquake induced by water injection in oilfields

Existing literature and extensive field data indicate that the high-pressure injection of the liquid may cause fault activation, and bring induced geological disasters earthquake and casing damage, flooding and other sexual violence, and cases are mainly:

Oilfield water injection-induced activation of the fault and cause earthquakes. In order to maintain high and stable yield oil field, generally take the high-pressure water injection measures, China's Daqing Oilfield, Renqiu, Jilin Oilfield, Southwest and other oil companies have been a fault reactivation induced seismic phenomena. For example: Renqiu 1975-- period in 1979, due to a large number of water injection to induce a series of earthquakes, the largest magnitude earthquake reached ML3.9; Sichuan Rongchang also due to the natural gas reinjection wells sewage led to five (or more) three times, 4 or above nearly 20 times. Follow-up studies have shown that these earthquakes were injected into the liquid result in the activation of the fault caused. In other countries, the United States in 1952 began to oilfield water injection induced California Portland where Dietz 5.4 earthquake research, after the Denver area field test fluid injection wells in the fault zone further confirmed that the liquid injection and is directly related to the occurrence of earthquakes. 2013, American Journal of Science, continuously published three papers, Nicholas, Ellsworth and Emily and other studies have shown that injection of liquid oil and gas fields, geothermal fields and other activities, triggering earthquakes of American incentives. The vast majority of these earthquakes are smaller, but there are also some more than 5.0, for example 5.7 earthquake November 6, 2011 United States Oklahoma occurred. Their research shows that, in the area of high pressure water injection fault, high pressure fracturing fluid injection will bring significant seismic risk.

3 Research review on the induced earthquake

In recent years, more and more water-induced earthquake in the United States, Canada and other places, foreign scholars they also did a series of studies.

Texas oil fields of Gosse Creek, from 1917-1925, the oil resulting in a rate of 1m ground sinking, sinking in the north and south zones and earthquake fault appeared linked to the earthquake caused the house shake, utensils displacement, overflow basin of water, it is widely felt. United States Wilmington California oil fields, oil production from 1936 to 1966, cumulative ground subsidence amounted to 9m, horizontal radial displacement has reached 3.7 m. The field is in use as early as before the water has emerged earthquake. Yerkes and Castle believes that the two oilfields earthquake occurred entirely caused by the oil. Segall theoretical analysis, pointed out faults and tectonic movement is irrelevant, they are caused by the oil. Once as supplemental

measures to increase production, the role of the fault may still be induced earthquake. But this can not be confused with seismic and tectonic earthquake, in order to avoid making the wrong estimate. Began in April 1962, it did not occur 80 years felt the Colorado Rockies Denver, a series of 3-4 earthquake. After investigation, the military and seismic activity near the plant to more than 3600 meters deep underground waste injection wells related. In order to verify the relationship between hydraulic and earthquakes seek control method and seismic induced earthquake prevention measures, the United States Rangely oil field seismic do controlled experiments confirmed the relationship between water and earthquakes. Japan Matsushiro deep water experiments also confirmed a close relationship between the two.

Wilzetta oilfield Oklahoma occurred near Prague MW4.1 earthquake in 2010, attracting attention, in November 2011 occurred three times $MW \geq 5.0$ earthquake. The water activity Wilzetta oilfield from 1993 has already begun, Kerenan et al factor binding water, the geological conditions and other fields of the earthquake there has been "delayed" phenomenon of speculation. In February 2012, near Youngstown, Ohio occurred MW0.4-3.9 level of the swarm. After investigation, the occurrence of deep earthquakes related to water, and the earthquake epicenter is located below the surface 3.5-5km Precambrian basement below. Kim believes that seismic activity is due to the formation pressure buildup caused.

Yisuo Si and Tatoonie two regions in Canada, British Columbia Horn River basin, 2009 - 2011, several earthquakes occurred in the region. According to the Canadian National Seismograph Network and Resources Canada seismic analysis, seismic and oilfield water injection in the region's mining activities. BC Oilfield Company of Canada for seismic activity was investigated and found that earthquakes always occur during and after hydraulic fracturing or hydraulic fracturing. Water injection and seismic activity are closely linked. And the proposed increase in seismic array layout to get more detailed information.

Mechanism for inducing earthquakes, Evasn proposed after the earthquake due to water pore pressure increases, reducing the friction surface fault rupture, thus causing the fault slip. However, some scholars believe that the water pressure is not sufficient to cause earthquakes. Davis and Frohlich had proposed some specific determination of seismic water standards, according to the actual situation to determine whether it is due to the earthquake caused water. Statistically, water and earthquakes are not connected, that water is not necessarily induced earthquake. For example, the United States has thousands of water points, the test, there are really only a few earthquakes with a direct link.

2013, Ellsworth North America and other places of impoundment, surface and underground

mining activities, groundwater flow and gas extraction and injection of fluids to the subterranean formation induced seismicity are summarized, explained the mechanism of induced earthquakes, and deep water induced earthquakes typical case study, scientific assessment should be pointed out that water-induced earthquake, and discussed the key scientific challenge to assess hazard faced.

In summary, the different regions, pouring oil induced earthquakes for different reasons, with a variety of factors.

4 Conclusions

At present, the oilfield fluid injection induced earthquake of evidence, there is not a detailed collation and sort out, study its mechanism still has a complete theoretical system for liquid injection induced earthquake deformation monitoring and process engineering problems yet mature , the treatment system. Therefore an urgent need for the domestic and international oilfield fluid injection induced earthquake examples are analyzed and the liquid injection induced causes of earthquakes to explore, analyze the main factors influencing the formation of instability, namely the mechanism of this phenomenon generated by research, from meso, dynamic mechanical angle reveal the mechanism of high-pressure liquid injection induced earthquake, for guiding oil efficient development, prevention of geological disasters has important significance.

References

- [1] Segall P. Earthquakes triggered by fluid extraction. *Geology*, 1989, 17(10):942- 946.
- [2] Liu Jianjun, Zhang Linzhi, Zhao Jinzhou. Numerical Simulation on Open Wellbore Shrinkage and Casing Equivalent Stress in Bedded Salt Rock Stratum. *Scientific World Journal*, 2013, Article ID:718196
- [3] Xie Jun, Zhu Zheming, Hu Rong, Liu Jianjun. A calculation method of optimal water injection pressures in natural fractured reservoirs. *Journal of Petroleum Science and Engineering*, 2015, Vol.133:705-7121
- [4] Yerkes RF, Castle R O. Seismicity and faulting attributable to fluid extraction. *Engineering Geology*, 1976, 10(2, 4):151-167.
- [5] J.H. Healy, W.W. Rubey, D.T. Griggs, C.B. Raleigh, The Denver earthquakes. *Science*. 161, 1968:1301–1310.
- [6] Liu Jianjun, Song Rui, Zhao Jinzhou. Numerical Simulation Research on Seepage Mechanism in Pore-scale Deformable Porous Media. *Disaster Advances*, 2013, 6(S1): 49-58
- [7] R. B. Herrmann, S.-K. Park, The Denver earthquakes of 1967-1968. *Bull. Seismol. Soc.*

Am.1981, 71:731–745.

[8] Liu Jianjun, Song Rui, Cui Mengmeng. Improvement of predictions of petrophysical transport behavior using three-dimensional finite volume element model with micro-CT images. *Journal of Hydrodynamics*. 2015,27(2):234-241

[9] P.A. Hsieh, J.S. Bredehoeft, A reservoir analysis of the Denver earthquakes: A case of induced seismicity. *J. Geophys. Res.* 1981, 86: 903–920.

[10] C.B. Raleigh, J.H. Healy, J.D. Bredehoeft, An experiment in earthquake control at Rangely, Colorado. *Science*.1976, 191 (4233):1230–1237.

[11] K. M. Kerenan, H.M. Savage, G.A. Abers, E.S. Cochran, Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake sequence. *Geology*.2013, 41:699–702.

[12] Jianjun Liu, Rui Song. Investigation of water and CO₂ flooding using pore-scale reconstructed model based on micro-CT images of Berea sandstone core. *Progress in Computational Fluid Dynamics, An International Journal*. 2015,15(5):317-326

[13]W.-Y. Kim, Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio. *J. Geophys. Res.*2013, 118(7):3506-3518.

[14]Scott D. Davis, Cliff Frohlich. Did (or will) fluid injection cause earthquakes? Criteria for a rational assessment. *Seismological Research Letters*.1993, 64 (3-4): 207-224.

[15]Scott D Davis, Cliff Frohlich. New objective criteria to determine if fluid injection has induced earthquake .*Eos*, 1987, 68(44):1369.

[16]William L. Ellsworth. Injection-Induced Earthquakes. *Science*.2013, 341: 2259421-7.

[17]Zengli Du, Jianjun Liu, Wenge Liu and Chunhong Li. Frequency-space domain acoustic wave simulation with the BiCGstab (ℓ) iterative method. *Journal of Geophysics and Engineering*, 13(2016): 70-77

[18]Jianjun Liu, Guang Li, Yue Zhang. Numerical Simulation of CO₂ Flooding of Coalbed Methane Considering the Fluid-Solid Coupling Effect. *PLoS ONE*, 2016, 11(3): e0152066

[19]Dai Xiaojun, Liu Jianjun, Zhang Huaying. Application of AR Model in the Analysis of Preearthquake Ionospheric Anomalies. *Mathematical Problems in Engineering*, 2015, Article ID: 157184

[20]Song Rui, Liu Jianjun. Study on Porosity and Permeability of Rock Core based on 3D CT Images and Structured Pore-Network Model. *Journal of Southwest Petroleum University(Natural Science Edition)*, 2015, 37(3):138-145

[21]Quanshu Li; Huilin Xing, Jianjun Liu, Xiangchun Liu. A Review on Hydraulic

Fracturing of Unconventional Reservoir. *Petroleum*, 2015, 1(1):8-15

[22]Leyong Chen, Jianjun Liu. Numerical analysis on the crack propagation and failure characteristics of rocks with double fissures under the uniaxial compression. *Petroleum*, 2015,1(4):373-381

[23]FAN Kaixiang, LIU Jianjun. The Analysis of Effects of Stress and Deformation on Surrounding Rock of the Well During Groundwater Extraction. *Physical and Numerical Simulation of Geotechnical Engineering*, 2015, (20):101-113

[24]Jianjun Liu, Rui Song. Numerical Simulation on Hydromechanical Coupling in Porous Media Adopting Three-Dimensional Pore-Scale Model. *Scientific World Journal*, 2014,Vol.2014, ID:140206

[25]Jianjun Liu, Zheming Zhu, Bo Wang. The Fracture Characteristic of Three Collinear Cracks under True Triaxial Compression. *Scientific World Journal*, 2014,Vol.2014, ID:459025

[26]Liu, Jianjun; Zhang, Huijuan. Experimental Study for Dynamic Mechanical Properties of Shale using Split Hopkinson Pressure Bar. *Disaster Advances*, 2013, 6(11):38-42

[27]Jian-Jun Liu, Xian-Bin Yu, Jin-Zhou Zhao. Numerical simulation of geostress and pore pressure evolution around oil or water well under different injection-production ratio. *Mathematical Problems in Engineering*, Vol.2013, Article number:604748

[28]Zhang BH, Deng JH, Wu WD, Liu JJ. Mode I crack in an elasto-perfectly plastic material under pore water pressure of a finite medium. *Theoretical and Applied Fracture Mechanics*, 2012, Vol.57(1): 31-35

[29]Liu Jianjun, Li Quanshu. Numerical Simulation of Injection Water Flow through Mudstone Interlayer in Low Permeability Oil Reservoir Development. *Disaster Advances*, 2012, 5(4): 1639-1645

[30]Ji YJ; Cheng LS, Liu JJ, Ye LY, Liu D. A simulation of casing damage considering THM coupling. *Petroleum Science and Technology*, 2010, 29(10): 977-987