Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS28-P19 会場:コンベンションホール 時間:5 月 23 日 18:15-19:30

中国四川盆地南西部炭酸塩岩貯留層における注水誘発地震の発生過程
A detailed view of the injection-induced seismicity in a carbonate gas reservoir in Southwestern Sichuan Basin, China

雷 興林[1*], 馬　勝利[2], 陳　文康[3], Chunmei Pang[3], Jie Zeng[3], Bing Jiang[3]
Xinglin Lei[1*], Shengli Ma[2], Wenkang[3], Chunmei Pang[3], Jie Zeng[3], Bing Jiang[3]

[1] 産業技術総合研究所, [2] 中国地震局地質研究所, [3] 自貢地震局
[1]Geological Survey of Japan, AIST, Japan, [2]Institute of Geology, China Earthquake Administration, [3]Zigong Earthquake Administration

Seismicity at a gas reservoir located in the relatively stable Sichuan Basin, China, mirrors the injection pressure of unwanted water, suggesting that the seismicity is injection induced. Injection under high pressure on a routine basis began on 9 Jan. 2009, and continued to July 2011. During the injection period, over 120,000 m^3 of water was pumped under a wellhead pressure of up to 6.2 MPa into the limestone formation of Permian 2.45 to 2.55 km beneath the surface. The injection induced more than 7,000 surface recorded earthquakes, including 2 M4+ (the largest one was ML4.4), 20 M3+, and more than 100 M2+ events. Data observed by a nearby local seismic network and five temporal stations provide a detailed view of the spatio-temporal distribution of the induced earthquakes. Most events were limited to depths ranging from 2.5 to 3.5 km, which is consistent with the limestone formation of Permian. In a map view, hypocenters are concentrated in a NNW extended ellipsoidal zone approximately 6 km long and approximately 2 km wide centered approximately 1 km northwest of the injection well.

The spatio-temporal distribution and other statistical results indicate that the triggered seismicity is characterized by four typical phases, which reflect the patterns of the injection rate and wellhead pressure. The largest ML4.4 events occurred when the wellhead pressure reached 0.9 MPa at the very beginning of injection. Various factors, such as the shear mechanism, the pattern of hypocenter distribution, and the fractal dimensions, indicate that the induced seismicity in the region resulted from the reactivation of pre-existing faults. Injected fluids diffuse outward along pre-existing faults, which were originally stressed, weakening the faults and leading to their reactivation. The intersections of a set of conjugate fractures are particularly suitable for fluid flowing. Some relatively large dipped faults likely bound the outward fluid flow and provide paths for upward leakage and downward flow.

The overall migration front follows a typical pore-pressure diffusion curve with a hydraulic diffusivity of 0.1 m^2/s. There are also some fast responses of seismicity on pressure change reflecting pore-pressure diffusion along the surface of pre-existing faults with a hydraulic diffusivity on the order of 1 to 10 m^2/s. Multi sources of evidence, such as the shear mechanism, pattern of hypocenter distribution, and small elevated pore pressure as compared with the least principal stress in the region show that the induced earthquakes occurred as a result of lowering of the effective normal stress on known or unknown pre-existing blind faults.

キーワード: 注水誘発地震, ガス田, 炭酸塩岩貯留層, ETAS モデル, 間隙圧
Keywords: Injection-induced seismicity, Gas field, Carbonate Reservoir, ETAS model, Pore-pressure