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Influence of Oil Reservoir on Earthquake (IORE Theory)

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Abstract: The effect of oil reservoirs on intensity of earthquake has been discussed in this paper. The data for this research have been obtained from IRIS Earthquake Browser which has given earthquake data for South West of Iran, where there are high pressure oil fields. In this article, attempt has been made to show seismicity of oil fields that has been changing with time. Some simple simulation experiments were also performed to get a relation between mechanical vibration through some compact soil in a box and absorption of these vibrations by a water bag which was placed underneath the soil, inside the box. The results were used to explain absorption of an earthquake impact by an oil reservoir and oil reservoirs work as dampers.

Keywords: Earthquake, earthquake and oil reservoir relation, oil reservoir, oil reservoir absorbs seismic waves, oil reservoirs damping seismic waves

INTRODUCTION

The relation between quakes and the rate of oil production was observed in Florida, US for the first time in the 1950's. The earthquake in the south of California on July 21, 1952 also led to the change in oil producing rate in Kern County. Of two neighboring oil producers, one had 14 bbl/d increases in the oil production rate, the other had 48bbl/d reduction and the two wells in the same oil field had different effects due to the natural earthquake. This reflects the complexity of these responses and in another earthquake in Tajikistan on May 14, 1970 led to the change in the oil producing rates of many gushers, which lasted for several months. Moreover, the oil producing wells near the faults had a maximum production rate change. The earthquake in Tangshan, China in 1976 also led to the change in production rates of 29 oil producing wells, which were far away from the earthquake center (Zhang *et al*., 1999).In Quebec Reservoir Induced Seismicity (RIS) was observed on the two reservoirs (Ding, 1992). In 1998 observations over the last 30 years by Russian and U.S. investigators demonstrate that elastic wave stimulation can influence fluid flow through saturated porous media. A surface Vibroseis source or down hole seismic source tool to stimulate fluid flow in underground oil reservoirs (Johnson, 1998). In the year 2003, in co-operation with the department of Geophysical Techniques, Information technologies and Systems (GTIS) at Ukhta state technical university (Russia) and Ultrasonic World LLC, Switzerland, the company has developed and produced lot of powerful ultrasonic systems for oil production stimulation. Progress Ultrasonic Group LLC (2012). Ultrasonic waves demonstrate motion in oil reservoirs.

This paper is concerned with the study of some observations and data collected from the South-West of Iran, near Ahvaz, where oil was discovered in 1908 (Australian Dictionary of Biography, 2010). The averages of oil reservoirs depth are in the range of 4.5 to 6 km (Research Institute of Petroleum, 2011).The main geological structures in Ahvaz (a city in the South -West of Iran) are influenced by the rocky formation of the area. The faults in Ahvaz are named F1 to F13 (Ahvaz Academic Team, 2010). The average depth of earthquake in this region is less than 70 km (IRIS Earthquake Browser, 2010).The observation has been done in a region located on the fault and also oil reservoirs. All oil and gas reservoirs in this area have high pressure. Masjed - Soleyman is another oil rich city in the South-West of Iran where the first oil well was found in 1908 (Abbasi, 1995). Unfortunately, after the decline of oil resources there in the late 1960's, and the final shutting of its remaining oil wells in 1980-81, the city has been faced with a chronic decline in oil production (Research Institute of Petroleum, 2011). In the present research , it has been attempted to show that the reduction in oil reserves in this area has led to more earthquakes and seismicity of oil fields that has been changing with time. To confirm this postulation, two methods are presented. The first method was experimental and used simulated earthquake waves and the second method utilized some recorded seismicity data from Masjed-Soleyman earthquakes.

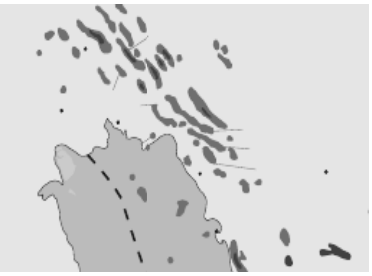

Fig. 1: Khoozestan Oil Zone (Pars Times, 2011)

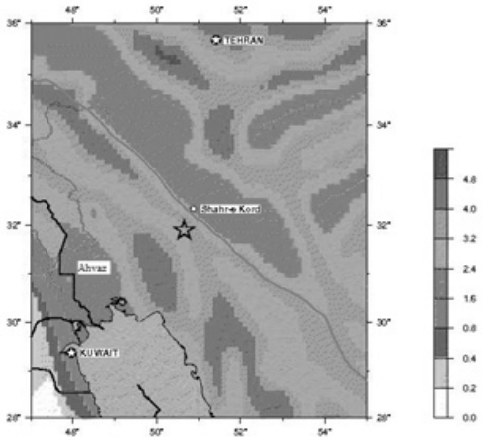

Fig. 2: Seismic Hazard Map southern west of Iran (Building and Housing Research Center, 2005)

MATERIALS AND METHODS

Experimental: A simple simulated reservoir was built from a flexible flat bag about 20x30x4 cm. This bag was filled with water and air. The water acted as the oil in a reservoir. It was placed in large box (95x95x90cm). The spaces around the bag in the box were filled with soil in two steps. The bag was in the center of the box, surrounded with compressed soil. Since the bag's wall was flexible, the compressed soil imposed hydrostatic pressure in all direction on it. Care should be taken to prevent any rupture damage to the bag. The bottom of the box was hit lightly with a hammer and the intensity of the sound vibration on the soil surface was checked with a medical stethoscope. The experiment was repeated without the bag in the soil. A large box was used in order to minimize the sound transmitted by the box walls. Consequently, the vibration sound was transmitted solely by the soil which was in the box. The stethoscope was inserted in the soil surface, about 3cm inside the soil, above the bag.

Masjed-Soleyman seismicity: Masjed-Soleyman was selected because the first operational gusher was exploited in 1908 and it was closed in 1980-81.According to the plate tectonic map, there is a fault in the South-West of Iran where there are oil and gas reservoirs (Fig. 1). As Fig. 2 shows, Ahvaz has low seismicity.

The geographical region for this research was chosen around Masjed-Soleyman (Latitude Range: 31.67 to 32.25 - Longitude Range: 48.96 to 49.64) and the research was performed on the seismicity during the last 45 years. This period of seismicity was divided in three categories with 15 years in each category.

The first category: 15 years period before the first gusher was closed (Australian Dictionary of Biography, 2010) (Fig. 3 and Table 1).

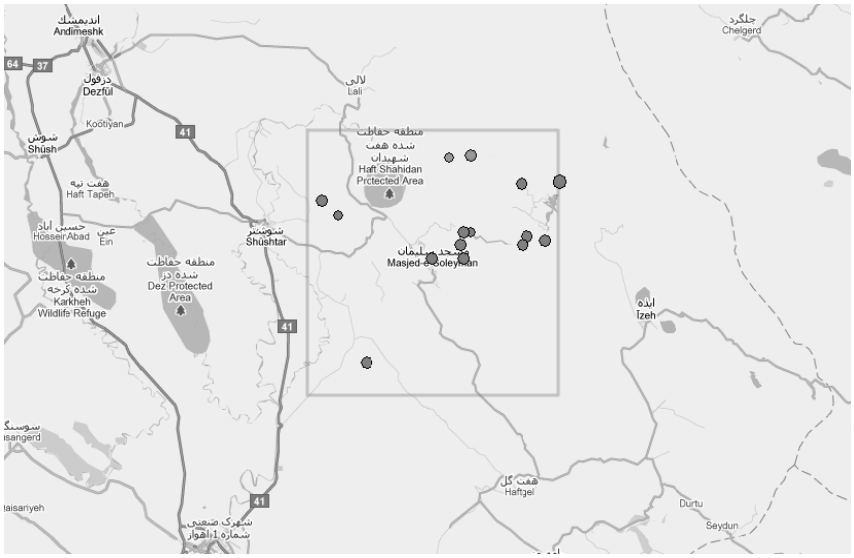

Fig. 3: 15 Gusher was closed before 15 years period

Table 1: Geographical region before 15 years period

Magnitude	Depth (km)	Time	Lat	Lon
4.7	38.7	1978/12/15	32.002	49.5407
4.7	46.0	1978/12/14	32.1363	49.5384
5.1	46.3	1978/12/14	32.0188	49.5503
5.6	40.4	1978/12/14	32.1399	49.6389
4.4	33.0	1978/09/14	32.1943	49.3436
4.1	43.0	1978/07/28	32.0291	49.3997
4.3	37.3	1976/02/15	32.0652	49.0419
4.6	72.5	1973/03/14	31.9705	49.3801
4.8	85.6	1973/03/13	32.0291	49.3806
4.9	61.8	1973/03/12	32.002	49.3728
5.1	63.9	1973/02/07	31.9703	49.2959
4.7	37.0	1970/03/15	32.1	49.0
4.8	52.0	1969/10/20	32.01	49.6
4.6	70.0	1967/02/21	31.74	49.12
4.5	26.0	1965/06/26	32.2	49.4

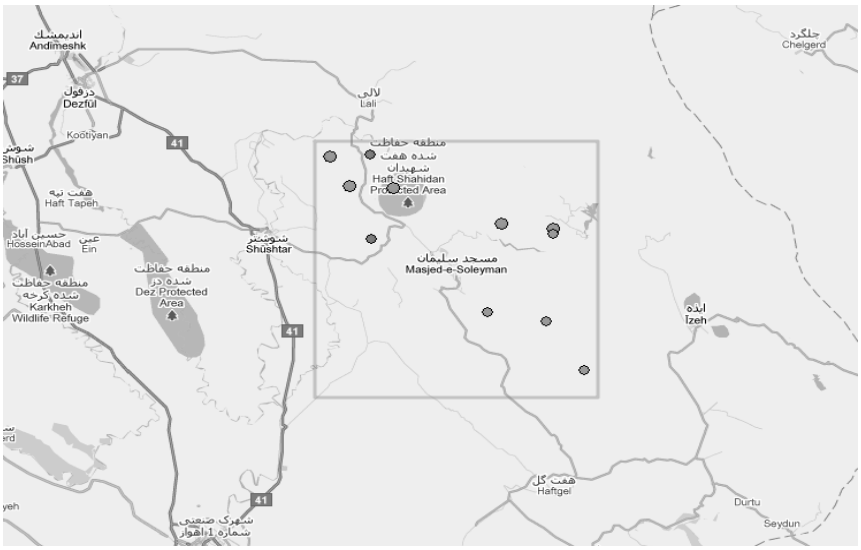

Fig. 4: Gusher was closed after first period of 15 years

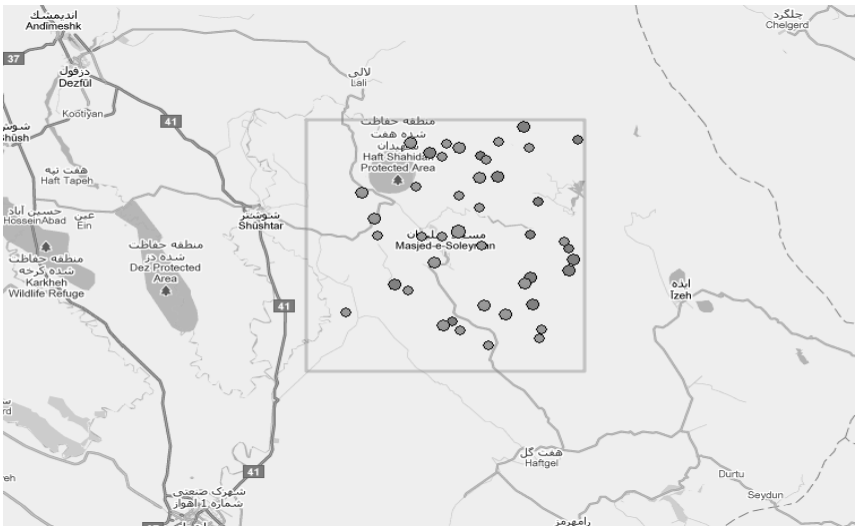

Fig. 5: First gusher finished after second period of 15 years

Table 2: Geographical region after first period of 15 years

Magnitude	Depth (km)	Time	Lat	Lon
4.2	33.0	1994/07/3	31.8637	49.3723
4.1	70.5	1993/12/2	32.0316	49.0961
4.4	33.0	1993/06/0	32.0439	49.5295
4.1	33.0	1993/03/2	31.842	49.514
4.1	33.0	1992/05/1	31.7295	49.603
4.6	33.0	1991/09/2	32.1526	49.0436
4.4	79.1	1990/12/3	32.2234	49.0918
4.5	29.0	1988/04/1	32.1466	49.1477
4.7	0.0	1985/03/1	32.0537	49.5293
4.6	33.0	1983/10/0	32.2191	48.9966
4.6	33.0	1982/11/1	32.0663	49.4055

Table 3: Geographical region after second period of 15 years

Magnitude	Depth (km)	Time	Lat	Lon
5.1	9.4	2009/10/04	31.874	49.492
4.25	10.0	2008/10/02	31.9612	49.3865
4.01	22.7	2007/04/15	32.2031	49.4283
4.07	10.0	2006/11/07	31.9849	49.1348
5.1	33.0	2005/12/26	32.0239	49.1264
4.4	15.0	2005/12/10	32.1891	49.5027
4.2	10.0	2005/02/27	32.199	49.3
4.5	50.0	2004/05/30	32.178	49.259
4.6	10.0	2004/05/30	32.201	49.214
4.6	42.9	2004/03/01	31.824	49.509
4.44	10.0	2004/03/01	31.7661	49.5324
4.5	59.7	2004/01/09	32.239	49.487
4.07	34.2	2004/01/09	31.9537	49.5972
4.16	33.0	2004/01/07	32.0498	49.3821
4.7	49.4	2004/01/07	31.929	49.609
4.1	50.0	2004/01/06	32.207	49.621
4.46	33.0	2004/01/06	31.9706	49.5855
4.7	61.3	2004/01/06	31.904	49.597
4.11	15.0	2004/01/06	31.7453	49.5273
4.6	34.6	2004/01/06	31.888	49.505
4.12	15.2	2003/12/26	31.7627	49.334
4.94	34.1	2003/12/11	31.8714	49.175
4.01	31.1	2003/02/27	32.0997	49.2266
4.7	33.0	2003/01/30	32.084	49.094
4.7	33.0	2003/01/01	31.801	49.445
4.3	22.2	2002/12/31	31.7287	49.4029
4.5	10.0	2002/09/26	32.12	49.381
4.4	10.0	2002/09/26	32.077	49.33
5.5	10.0	2002/09/25	31.995	49.329
4.1	33.0	2002/07/30	32.162	49.397
4.4	33.0	2001/12/24	31.856	49.207
4.7	33.0	2001/12/23	31.776	49.293
4.2	63.8	2001/12/23	31.784	49.315
4.3	33.0	2001/12/23	31.982	49.29
4.6	33.0	2001/12/23	31.921	49.272
4.3	33.0	2000/04/15	32.168	49.289
4.3	48.9	1996/03/31	31.9878	49.5033
4.7	53.7	1996/01/04	32.1228	49.4241
4.2	0.0	1995/08/09	31.8055	49.0571
4.0	78.3	1995/08/05	32.0643	49.5228
4.5	33.0	1995/06/08	32.1884	49.3315
4.1	33.0	1995/06/07	31.9828	49.2417
4.2	124.6	1995/06/04	32.1699	49.3823
4.5	18.4	1995/04/18	31.822	49.3914

Earthquakes occurring: 15
Date Range: 1965/01/01 to 1980/01/02

The Second Category: The first period of 15 years after the first gusher was closed in 1980-1981. Bozorgnia and Bertero (2004) (Fig. 4 and Table 2).
Events Shown: 11
Date Range: 1980/01/01 to 1995/01/02

The Third Category: The second period of 15 years (30 years after the first gusher had been finished) – (Charles *et al*., 1992) (Fig. 5 and Table 3).
Events Shown: 44
Date Range: 1995/01/01 to 2010/01/02

RESULTS AND DISCUSSION

According to the categories, shown in Tables 1-3, which illustrate the Masjed-Soleyman earthquakes and also the exploitation history of oil reservoirs in that area, their initial pressure has been diminished with time due to prolong exploitation while the seismicity of the region has increased. The experimental results also showed that the intensity of vibration sound from the box with the water bag was lower than the intensity of vibration when the water bag was absent. In other experiments, the position of the stethoscope was changed. The stethoscope was inserted in the soil and closer to the water bag. The distance between the stethoscope and the water bag was reduced in consecutive tests. As the stethoscope was moved towards the bag in each experiment the sound was weaker. In another group of tests, the stethoscope was fixed above the bag and bag's content was changed. The water pressure inside the bag was increased in each test. When the water pressure was increased the intensity of vibration was decreased and vice versa. These tests showed that there was an inverse relation between the water pressure inside the bag and transmission of vibration from the bottom of the box upward through the compacted soil and the bag containing pressurized water. Consequently, the hammer hits produced mechanical waves and the sound vibration was absorbed by the bag during its transmission through the soil and the bag. In these simulation experiments, the water bag was resembled to a reservoir and mechanical vibrations due to the hammer hits were resembled to earthquakes. Thus, it may be concluded that oil reservoirs absorb seismic waves, similar to the water bag in these simulation experiments which absorbed the mechanical vibrations of hammer hits.

CONCLUSION

In conclusion, oil reservoirs can damping the earthquake and the Influence of Oil Reservoir on Earthquake (IORE) happens in the regions that have high pressure oil reservoirs and are on geological faults and are Earthquake-prone. This can be a warning to the oil-rich regions where previously had low seismicity, but with increasing oil exploitation the rate of seismicity has increased.

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