Scientia Iranica C (2012) 19 (6), 1601–1607

Sharif University of Technology

Scientia Iranica

Transactions C: Chemistry and Chemical Engineering

www.sciencedirect.com

Positive effect of earthquake waves on well productivity: Case study: Iranian carbonate gas condensate reservoir

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Received 17 May 2011; revised 26 February 2012; accepted 28 May 2012

KEYWORDS

Seismic waves;
Earthquake;
Well production;
Gas condensate;
Porous media;
Skin;
Formation damage;
Condensate dropout.

Abstract Artificially made seismic waves have been used for both tertiary recovery and well stimulation purposes. The idea behind using this method for enhancing recovery came from a number of real examples, in which a kick in oil production has been seen following an earthquake. Most published information has addressed the United States and earlier Soviet Union regions. This paper documents the results of observations regarding the effect of earthquake waves on well production from Khami carbonate gas condensate reservoir in the Marun field, in the northern Persian Gulf. The response of three wells in this reservoir (referred to as wells A, B, and C) to a magnitude $M = 5.7$ earthquake at an approximate distance of 217 km away is discussed. After this earthquake, there was a sharp significant increase in production from well A. The flowing wellhead pressure of this well suddenly increased from 4263 to 5042 psig and went back to its normal condition after five months. The two other wells behaved differently and showed no change in production. Analyses showed the removal of near wellbore formation damage caused by a condensate dropout in well A using natural seismic waves.

1. Introduction

Artificially made seismic waves have been used to enhance recovery from reservoirs [1–4]. The idea behind using this method to enhance oil recovery came from a number of examples in high water cut wells, where a kick in oil production has been seen following an earthquake. The aim of seismic stimulation is to enhance oil production by sending seismic waves across a reservoir to mobilize previously immobile patches of oil. Seismic waves have also been used to remove near wellbore damage caused by condensate dropout [5].

Seismic waves are also generated naturally during earthquake activities. Like the artificial type, natural seismic waves have also been observed to cause changes in oil production rates [6]. Investigating the effect of earthquake waves on well production can provide a better insight into man-made activities and, therefore, provide a valuable piece of information for further experimental and field research.

There have been numerous publications describing the effect of seismic waves generated from earthquakes on oil well production. These publications have evolved into a valuable data base. Most of the published information has addressed the United States and earlier Soviet Union regions. For example, Steinbrugge and Moran [7] describe the effect of the Southern California earthquake of July 1952 on variations in oil well production in Kern County. Simkin and Lopukhov [8] report the positive effect of the earthquake of January 1938 on oil well production in the Starogroznenskoye field, northern Caucasus. Beresnev and Johnson [6] review many observations regarding natural seismic wave influence on oil well production.

In this paper, we document the effect of a magnitude $M = 5.7$ earthquake at an approximate distance of 217 km on 27 August 2008 on the production from three wells in the Khami gas condensate reservoir in the Marun field (referred to as wells A, B and C).

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Peer review under responsibility of Sharif University of Technology.

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doi:10.1016/j.scient.2012.05.009

Figure 1: Geographic location of the Marun field.
Source: The original map is taken from the University of Texas Online Libraries [9].

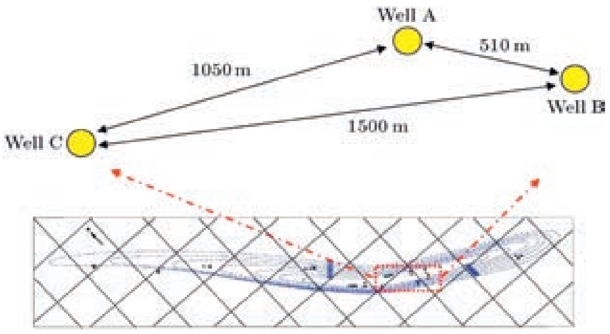

Figure 2: Areal distribution of the studied wells within the reservoir.

Figure 3: Geographic location of epicenter, and stations that recorded the event.
Source: The original picture is taken from the Building and Housing Research Center of Iran [11].

2. Geographic description

Marun is one of the biggest oil fields worldwide located in south western Iran, north of the Persian Gulf and southeast of Ahvaz city. It is 67 km long and 7 km wide. The geographic location of this field is shown in Figure 1. In this figure, the understudy field is colored green to distinguish it from neighboring fields.

During the last decades, Marun has been a major Iranian oil producing field. This field has several carbonate reservoirs, namely, Asmari, Bangestan, and Khami. Asmari and Bangestan are oil reservoirs. The latest information shows that Khami, the deepest Iranian reservoir known yet, is a gas condensate reservoir [10]. The Khami reservoir in this field is 60 km long and 4 km wide, trending towards north west–south east (general trend of Zagros folding) in an asymmetrical anticline structure. This reservoir consists of Cretaceous Dariyan Gadvan and Fahliyan formations. All the wells, *A*, *B* and *C*, have been completed in a Fahliyan formation.

The initial pressure and temperature of the Khami reservoir were 12 556 psig (1 bar = 14.5 psig) and 285 °F (1 °C = 33.8 °F), respectively, at a datum depth of 4805 m. The average depth of this reservoir is around 4500 m. The high pressure and high temperature, along with 4 mD (1 mD = 10^{-15} m^2) permeability tight carbonate lithology, make this reservoir a matchless gas condensate reservoir worldwide.

Wells *A* and *B* are adjacent, the distance between these two wells being 510 m. The third well (i.e. well *C*) is located more than 1 km away from wells *A* and *B*. The Under Ground Contour (UGC) map, the lateral distance between these wells and their approximate location with respect to each other is depicted in Figure 2.

3. The earthquake of 27 August 2008

According to the data provided by the Building and Housing Research Center of Iran [11], this earthquake occurred on August 27th, 2008, at 21:52:40 (UTC) and 01:52:40 (local Iran time), with a magnitude of M5.7 (IGUT), Ml5.6 (IIEES) and M5.7 (NEIC), at the Iran–Iraq border region in the vicinity of the Moosyan border city (Ilam province) of Iran. The epicenter of this event has been located at 32.30N, 47.42E (BHRC), 32.33N, 47.35E (IGUT), 32.36N, 47.35E (IIEES) and 32.44N, 47.41E (NEIC) north of Al-Amarah in Iraq and 28 km south of Dehloran in Iran. The depth of the hypocenter was 10 km.

This event was recorded by 9 sets of digital accelerographs of the Iran Strong Ground Motion Network (ISMN), installed in Moosiyan, Dehloran, Dasht-e-Abbas, Shoosh, Alhaee, Abdolkhan, Ahvaz, Hoveyzeh and Bostan (Figure 3). The seismic movement that we are studying did not have the same force for the same distance in every direction, but was more noticeable to the southeast than in any other direction. As shown in Figure 3, the locations of the stations that recorded the event, those located in Iran, lie inside an irregularly shaped district trending towards north west–south east, which may be attributed to the regional geologic structure. This district lies to the left of the Zagros Mountains. In Figure 3, this district has been separated from the surrounding areas in Iran by a red color

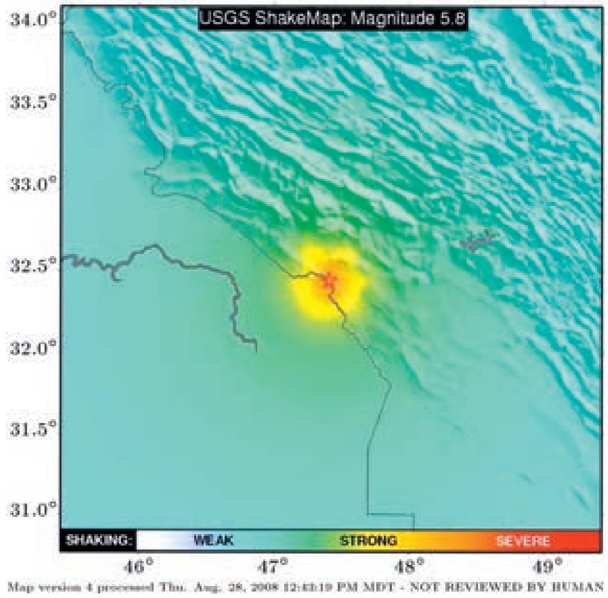

Figure 4: The shake map of the studied earthquake provided by the United States Geological Survey [13].

border. From the shape and dimensions of the district in which the seismic movement was felt, we find that the position of the Zagros Mountains had a remarkable influence on the movement of the seismic waves. They are not an absolute check on the movement, but weaken it remarkably when its direction is perpendicular to the trend of the mountain, this being the reason for the wave travelling a shorter distance to the east and north, while it extended further to the southeast. The district in which the stations recorded the event lies also to the right of the Iran–Iraq border. The author did not find any information about stations recording the event inside Iraq.

Qualitatively speaking, regarding the shaking power of this earthquake in Dehloran and Ilam, as the nearest cities in Iran to the epicenter, there was no loss of life but some buildings were damaged. In these cities, the earthquake consequence was an appearance of cracks in building walls, and broken windows, etc. In Ahvaz city, near where the Marun field is located, the earthquake lasted about 10 s and its intensity was enough to wake and alert many people. This earthquake was strongly felt in Al-Amarah, the nearest city in Iraq to the epicenter. The Los Angeles Times [12] reported on how the people of this city felt regarding the event; "I was sleeping inside my room when I noticed that the lights of the room, the fans and the furniture were moving in different directions. I tried to stand up. I discovered it was not only the ceiling but the floor moving as well", said an Al-Amarah resident. "People, followed by cats, dogs and other animals fled into the streets, shouting to each other and searching for friends and relatives in the dark. After a while, the messages were sent through loudspeakers in the mosques to calm people down.... For hours, the city resembled a doomsday scene. People milled outside, being advised to stay out of their homes by rescue workers in case another temblor struck. By daylight, they had gone home. No casualties were reported, but there were fears another quake could strike".

The United States Geological Survey [13] provides the shake, peak acceleration, peak velocity, and PGA/Sigma maps for this earthquake, shown, respectively, in Figures 4–7.

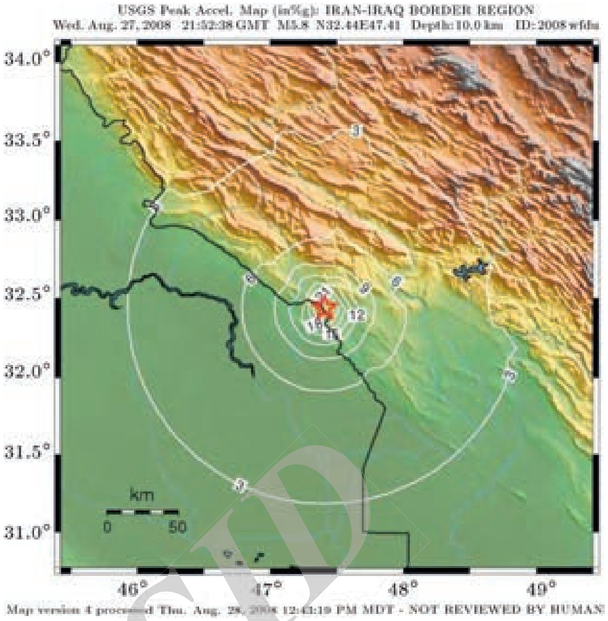

Figure 5: The peak acceleration map of the studied earthquake provided by the United States Geological Survey [13].

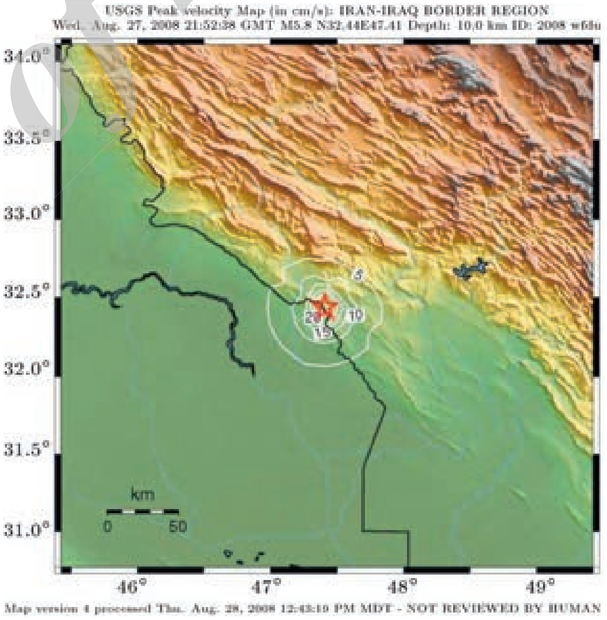

Figure 6: The peak velocity map of the studied earthquake provided by the United States Geological Survey [13].

The geographic location of the epicenter and the Marun field are shown in Figure 8. In this figure, the epicenter and the Marun field have been shown, respectively, as red- and yellow-colored stars. The approximate distance between the epicenter and the Marun field is 217 km, as shown in the figure.

4. Results and discussion

4.1. Well behavior before and after the earthquake

To study the response of the wells both before and after the earthquake, and inferring any change in their production due to the earthquake, we used the flowing wellhead pressure data of the wells. Flowing wellhead pressure is the pressure measured

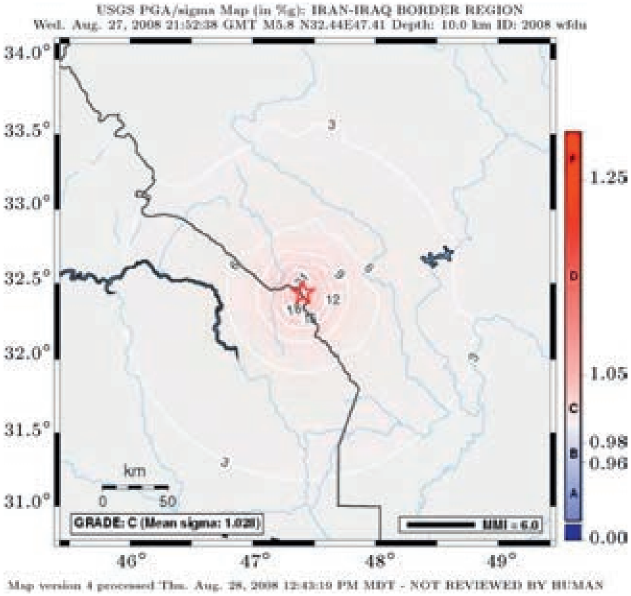

Figure 7: The PGA/Sigma map of the studied earthquake provided by the United States Geological Survey [13].

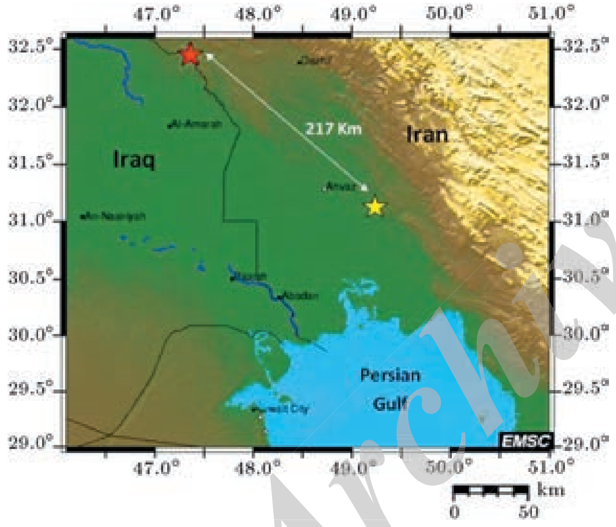

Figure 8: Location of epicenter and Marun field.
Source: The original picture is taken from the European-Mediterranean Seismological Centre [16].

just before the wellhead choke. These data are usually recorded daily or weekly by field production engineers for each well for well production monitoring purposes. Therefore, the history file of the flowing wellhead pressure data is available for each well and can be used once needed. The effect of any event or operation on well production can be traced in this history.

The wellhead flowing pressure as described above is just a qualitative criterion for monitoring the well production. Fluid flow rate is a true quantitative criterion for this purpose. However, direct measurement of fluid production flow rate is not feasible in many fields around the world, including Marun. In the case of the Khami reservoir of the Marun field, an empirical choke correlation obtained from the data of Iranian gas condensate reservoirs, proposed by Mirzaei-Paiaman [14], is used to estimate the production flow rate. Having wellhead flowing pressure, wellhead choke size and gas to liquid ratio data, the production flow rate can be calculated using this empirical correlation.

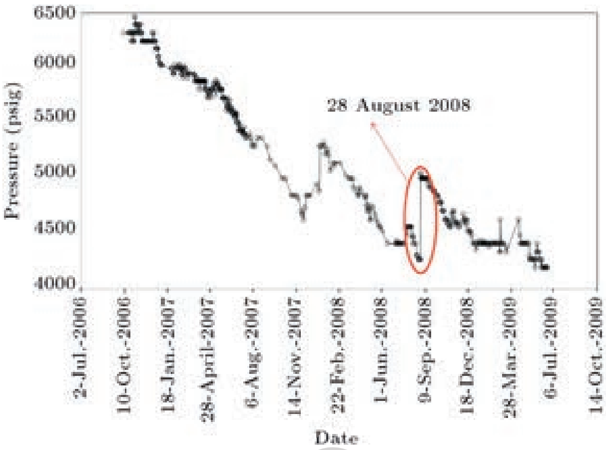

Figure 9: Flowing wellhead pressure history of well *A*.

Also, well flowing bottomhole pressure is measured under some certain conditions during the well production life, for some certain purposes. However, flowing wellhead pressure is measured directly and reported by field production engineers periodically. Therefore, in this study, the flowing wellhead pressure history of wells is used to investigate the effect of earthquake waves on well productivity.

Well *A* had a flowing wellhead pressure of 4263 psig, just a day before the earthquake, producing through a 0.64 in (1 in = 0.0254 m) size wellhead choke. Knowing the gas to liquid ratio of around 6100 SCF/STB (1 SCF/STB $= 0.178\ \mathrm{m}^3/\mathrm{m}^3$) for this reservoir fluid, the gas production flow rate corresponding to this pressure when estimated from the pre-mentioned choke correlation is 23.4×10^6 SCF/day (1 SCF/day $= 0.028\ \mathrm{m}^3/\mathrm{day}$) of gas. The flowing wellhead pressure suddenly increased to 5042 psig just some hours after the earthquake. In this case, the estimated gas production flow rate is 27.7×10^6 SCF/day. This means that an 18.4% increase in production flow rate occurred as a result of the earthquake. The flowing wellhead pressure of 5042 psig went back to its normal condition after five months. The flowing wellhead pressure history of well *A* is shown in Figure 9. Data points at the time of the earthquake, August 27th, 2008, are shown in this figure inside an ellipse. As shown, there was a sudden increase in the flowing wellhead pressure as result of the earthquake on August 27th, 2008.

The flowing wellhead pressure history of well *B* is shown in Figure 10. Both before and after the earthquake, the flowing wellhead pressure was fairly equal, 8350 psig, meaning that the earthquake had no influence on the production of this well. Data points at the time of the earthquake are shown in this figure inside an ellipse.

The flowing wellhead pressure history of well *C* is shown in Figure 11. There was no change in the flowing wellhead pressure after the earthquake. Both before and after the earthquake, the flowing wellhead pressure was fairly equal, 5219 psig.

Except for the sudden increase in the wellhead flowing pressure of well *A* on August 27th, 2008, shown in Figure 9, there are some step-like pressure increases in Figures 9–11 on other dates. These increases in wellhead pressures were not caused by the earthquake and have different origins. These origins are related to operations performed on the wells by production engineers, like reducing wellhead choke size, and starting production after some shut-in period, etc.

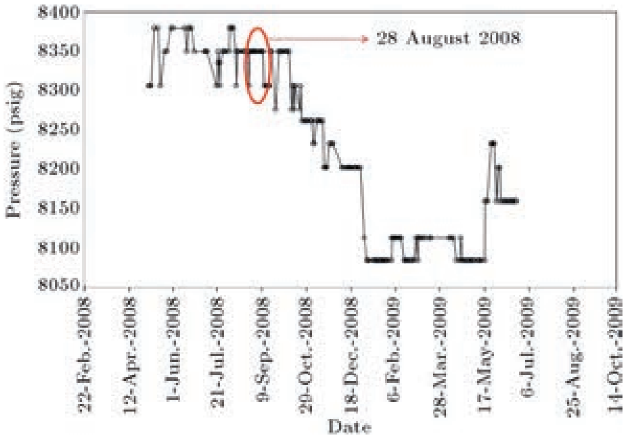

Figure 10: Flowing wellhead pressue history of well *B*.

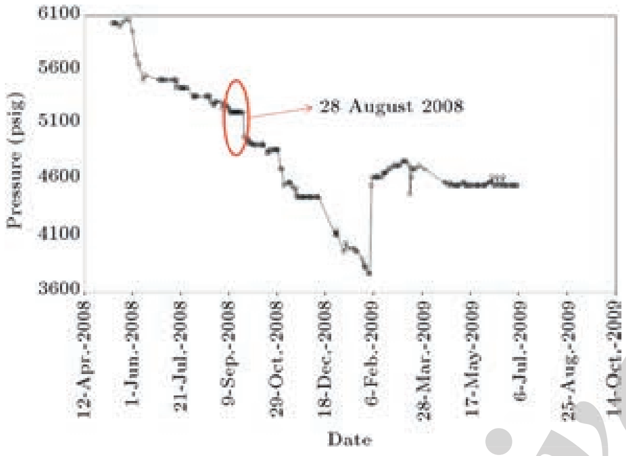

Figure 11: Flowing wellhead pressure history of well *C*.

4.2. Why did the wells behave differently?

Earthquake waves only affected the productivity of well *A* through a sudden increase in wellhead flowing pressure from 4263 to 5042 psig. Wells *B* and *C* behaved differently, and showed no change in their production, indicating the complex nature of the effect.

For wells *A*, *B* and *C*, bottomhole pressure and temperature profile data along with the PVT analysis of the reservoir fluid are available. This profile is a log of pressure and temperature measured at each depth from the bottom to the surface of a flowing well. The bottomhole pressure and temperature profile of well *A* two months after the earthquake is shown in Figure 12. This profile is assumed to be the same as that for two months before, at the time of the earthquake, with minor differences.

In the perforated interval, the fluid entering the wellbore has just left the porous medium and completion. Since a relatively large interval, 387 m, has been perforated, one may ignore the pressure and temperature drop across the perforations, hence, attributing the measured pressure and temperature at each depth in front of the perforations to the near wellbore porous medium. In case of gas wells, the measured temperature in front of perforations may be assumed to be lower than that near the wellbore porous medium, due to gas cooling associated with gas expansion, known as the Joule–Thompson effect.

For well *A*, the measured temperature ranges from a relatively constant 300 °F across the perforated interval to 119 °F at the wellhead. The flowing pressure also varies from 7900 psig at the last perforations to 4337 psig at the wellhead. The perforated interval is from 4638 to 5025 m, inside the 5 in liner. This interval is also shown on the vertical axis of the plot.

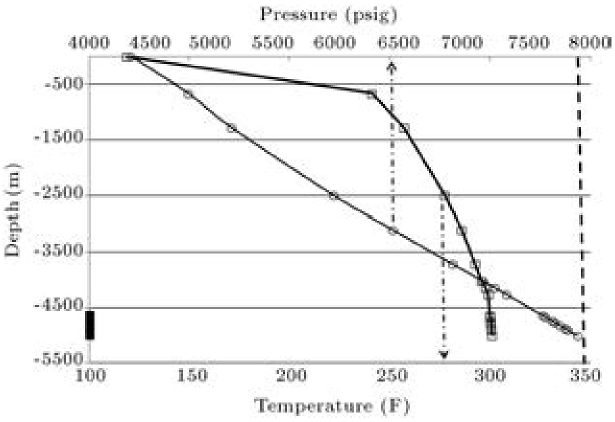

Figure 12: Bottomhole pressure and temperature profiles.

Furthermore, from the PVT experiments, the plot of dew point pressure versus temperature is available for the reservoir fluid. Because of some operational restrictions, downhole fluid sampling was not feasible, therefore, a less reliable but cheap surface sampling method was used to collect representative reservoir fluid for the PVT experiments. Gas and liquid samples were collected from wellhead separators and after recombination in the laboratory, their PVT properties were measured. The fluid samples collected from wellhead separators are less representative of actual reservoir fluid, once compared to the downhole fluid sampling, because they are sampled below the dew point. Therefore, reservoir engineers in charge believe that the true dew point pressure of the reservoir fluid can possibly even be, approximately, 500 psi more than that reported by PVT experiments. Some reasons leading to less reliable PVT analysis results for gas condensate samples collected from surface separators are improper well conditioning, sample contamination, fault flow measuring, liquid carry over and gas carry under, inadequate or poor PVT analysis, etc. [15].

Figure 13 shows the dew point pressures measured experimentally at 4 different temperatures ranging from 280 to 300 °F. A straight line can be drawn through the points showing a linear relationship between the dew point pressure and temperature. Therefore, for temperatures whose dew point pressure has not been measured experimentally, the dew point pressure can be calculated simply using linear regression analysis.

At pressures above dew point pressure, fluid exists as gas, while below it, liquid starts dropping out. At low saturations of the liquid, this phase is immobile in porous medium. But, at higher saturations, where saturation becomes greater than critical saturation, the liquid becomes mobile and flows. Any increase in liquid saturation in the porous medium (either immobile or mobile) around the wellbore is formation damage and causes further pressure drop, increasing the skin coefficient. This is because the dropout of liquid in the porous medium decreases the available flow area to gas, reducing its permeability. Higher skin coefficient means lower production. Therefore, lowering this coefficient by means of stimulation techniques will result in production enhancement.

Plots in Figures 12 and 13 can be used together to investigate the possibility of condensate dropout at the porous medium

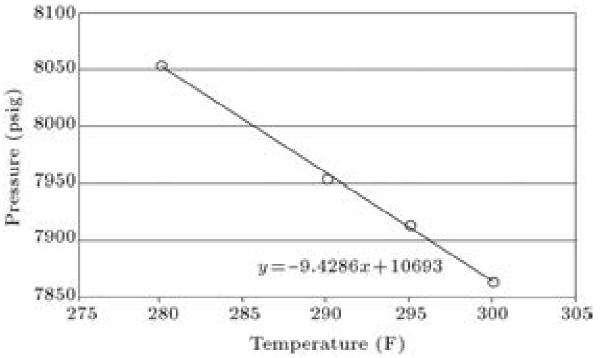

Figure 13: Plot of the experimentally measured dew point pressure versus temperature at temperature range of 280 to 300 °F.

immediately surrounding the wellbore for well *A*. At the perforated interval, the temperature is approximately constant, 300 °F. Flowing pressure at the top and bottom of the perforated interval are, respectively, 7624 and 7900 psig. The dew point pressure is 7864 psig at 300 °F (Figure 13) and has been depicted as a vertical dashed line in Figure 12. Considering the flowing pressure data across the perforation interval, condensate dropout is expected to occur. Furthermore, across the perforated interval, as the interval becomes shallower, the difference between the dew point and flowing pressure increases, implying more dropout in upper intervals. In summary, for well *A*, gas condensation in the porous medium occurs since the flowing bottomhole pressure fell below the dew point pressure of the reservoir gas. Condensation in the porous medium is a formation damage causing an extra skin, and, consequently, leads to loss in well productivity.

Over the years, well *A* has experienced severe loss of productivity. It is confirmed, using well testing analysis of this well, that there is a large skin, due to condensation in the region around the wellbore [10].

On the contrary, for wells *B* and *C*, flowing bottomhole pressure at the production interval, measured during the month of the earthquake, is still above the dew point pressure, showing no condensation in the porous medium and no associated skin. For well *B*, at the top of the perforated interval, flowing pressure is 11 800 psig. Furthermore, the temperature is a nearly constant 285 °F over the perforated interval. From Figure 13, at a temperature of 285 °F, interpolation, using linear regression analysis, gives a dew point pressure of 8006 psig. Since, across the perforated interval, the flowing pressure is greater than the dew point pressure, no condensate dropout occurs in the near wellbore porous medium.

For well *C*, at the top of the production interval, the flowing pressure is 9861 psig. Furthermore, the temperature is a nearly constant 302 °F over the perforated interval. From Figure 13, at a temperature of 302 °F, interpolation, using linear regression analysis, gives a dew point pressure of 7846 psig. Because, across the perforated interval, the flowing pressure is greater than dew point pressure, no condensate dropout occurs in the region immediately surrounding the wellbore.

Mechanisms behind seismic stimulation are not completely recognized, and are a subject of current research. Berensev and Johnson [6] and Jackson et al. [5], however, provide reviews of some possible physical mechanisms, like changes in wettability, viscosity reduction, and surface tension reduction. We believe that the most probable reason for the different responses of the wells being studied under earthquake may be the effect of seismic waves in removing the near wellbore damage/skin, for well *A*. This cannot be the case for wells *B* and *C*, since, in these cases, no liquid condensate is present in the region immediately surrounding the wellbore.

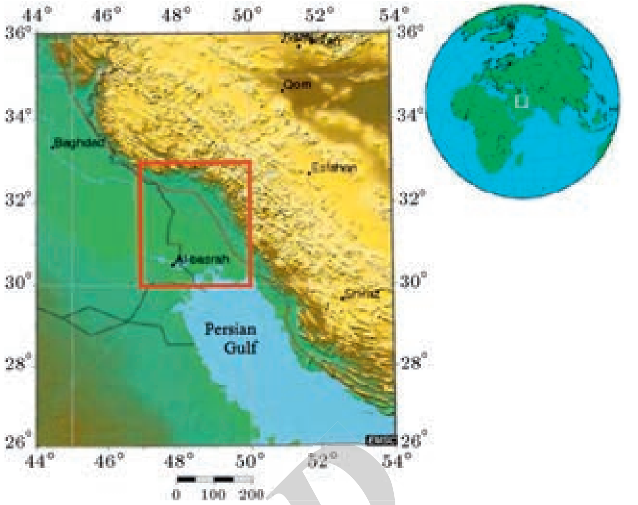

Figure 14: Location of the studied region (located between latitude 30–33 and longitude 47–50).
Source: The original picture is taken from the European-Mediterranean Seismological Centre [16].

In Figure 9, except on August 27th, 2008, there is no sudden strange increase in the wellhead flowing pressure of well *A*, either before that date (starting from the date of condensate dropout initiation, which is not clear) or after it. By strange, we mean those pressure jumps not caused by operations performed on the well. Therefore, one may expect that no other earthquake with a similar impact, in terms of magnitude/distance, has occurred after initiation of condensate dropout in the near wellbore porous medium. The region under study in this paper has been highlighted in the geographic map shown in Figure 14. This region is located between latitude 30–33 and longitude 47–50, surrounding Ahvaz city. Figure 15 shows the history of all the major earthquakes with a magnitude greater than $M = 2.5$, occurring from January 1st, 2007 to July 1st, 2009, and their corresponding magnitudes in this region, based on the data taken from the European-Mediterranean Seismological Centre [16]. In the above time period, in the region under study, the most intense earthquake is that of August 27th, 2008, with magnitude $M = 5.7$; all other earthquakes are all lighter than this.

To compare these findings with observations made in other reservoirs, the authors have listed all reservoirs located between the Marun field and the epicenter. The majority of these are oil reservoirs and a few are gas condensate. Furthermore, these gas condensate reservoirs have pressures above the dew point pressures of their reservoir gas fluids. The flowing wellhead pressure history of the wells in these reservoirs was analyzed and no sudden strange increase in the wellhead pressure was observed during their production lifetime, including August 27th, 2008.

5. Conclusion

The different responses of three wells in a gas condensate reservoir to a magnitude $M = 5.7$ earthquake were studied. One well showed a co-seismic positive increase in production, two wells close by did not respond to the earthquake. The responding well is characterized by condensate dropout in the

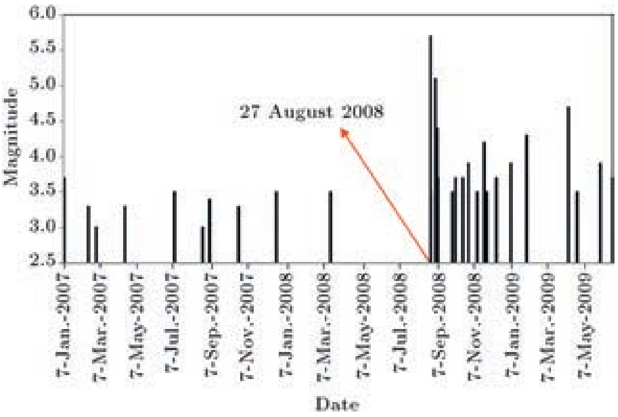

Figure 15: Earthquake magnitudes greater than $M = 2.5$, occurring from January 7th, 2007, to March 7th, 2009.

near wellbore porous medium, whereas, for the two other wells, no condensate accumulation is assumed. The natural seismic waves are believed to be responsible for removal of the near wellbore damage caused by the condensate dropout for the responding well.

Acknowledgments

Abouzar Mirzaei-Paiaman appreciates very much the valuable comments, suggestions and encouragement from Dr. Heiko Woith of the Helmholtz Centre, Potsdam, GFZ, German Research Centre for Geosciences. The authors also thank the anonymous reviewers for their thorough review, and highly appreciate the comments and suggestions which significantly contributed to improving the quality of the publication. The first author thanks the National Iranian Oil Company (NIOC) and the National Iranian South Oil Company (NISOC) for permission to publish this paper. The first author also thanks his colleagues, R. Jeishi, G.A. Safian and M. Farazmand, who provided valuable discussions. We are also thankful to Dr. D. C. Standnes of Statoil, and E. Taymouri of Hamedan Seismic Network, at the Iranian Seismological Center.

References

[1] Nikolaevskiy, V.N. "Mechanism and dominant frequencies of vibrational enhancement of yield of oil pools", *Transactions (Doklady) of the USSR Academy of Sciences: Earth Science Sections*, 307, pp. 570–575 (1989).

[2] Roberts, P.M., Esipov, I.B. and Majer, E.L. "Elastic wave stimulation of oil reservoirs: promising EOR technology?" *The Leading Edge*, 22, p. 448 (2003), http://dx.doi.org/10.1190/1.1579578.

[3] Zhu, T., Xutao, H. and Vajjha, P. "Downhole harmonic vibration oil-displacement system: a new IOR tool", *SPE Western Regional Meeting*, Irvine, California, (March 30–April 1 2005), http://dx.doi.org/10.2118/94001-MS.

[4] Huh, C. "Improved oil recovery by seismic vibration: a preliminary assessment of possible mechanisms", *First International Oil Conference and Exhibition in Mexico*, Cancun, Mexico, (31 August–2 September 2006), http://dx.doi.org/10.2118/103870-MS.

[5] Jackson, S., Roberts, P. and Majer, E. "Advances in seismic stimulation technologies", PTTC Network News, 2nd Quarter. Available Online at: http://www.appliedseismicresearch.com/pdf/stateoftheart.pdf (2001).

[6] Beresnev, I.A. and Johnson, P.A. "Elastic wave stimulation of oil production: a review of methods and results", *Geophysics*, 59, pp. 1000–1017 (1994).

[7] Steinbrugge, K.V. and Moran, D.F. "An engineering study of the southern California earthquake of July 21, 1952, and its aftershocks", *Bulletin of the Seismological Society of America*, 44, pp. 279–283 (1954).

[8] Simkin, E.M. and Lopukhov, G.P. "Vibro-wave and vibro-seismic methods of oil reservoirs stimulation (a review)", *Ser. Oil Industry, No. 15: All-Union Research Institute of Organization, Management and Economics of Oil and Gas Industry* (in Russian) (1989).

[9] University of Texas Libraries, Map No. 503828. Accessed January 2012. Available Online at: http://www.lib.utexas.edu/maps/middle_east_and_asia/iran_oilfield_1978.jpg (1978).

[10] Mirzaei-Paiaman, A. "Severe loss of well productivity in an Iranian gas condensate carbonate reservoir: problem identification and remedy", *Journal of Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, in press (http://dx.doi.org/10.1080/15567036.2010.527913).

[11] Building and Housing Research Center of Iran, Earthquake Data Bank, Accessed January 2012. Available Online at: http://www.bhrc.ac.ir (2008).

[12] Los Angeles Times, Accessed January 2012. Available Online at: http://www.latimes.com/ (2008).

[13] United States Geological Survey, Accessed January 2012. Available Online at: http://www.usgs.gov/ (2008).

[14] Mirzaei-Paiaman, A. "An empirical correlation governing gas-condensate flow through chokes", *Journal of Petroleum Science and Technology*, in press (http://dx.doi.org/10.1080/10916466.2010.529552).

[15] Fontaine, T. Four reasons why your gas condensate fluid model is probably wrong, Fekete Australia Pty. Ltd., Available Online at: http://www.fekete.com/resources/papers/four_reasons_gas_condensate_paper.pdf (1998).

[16] European-Mediterranean Seismological Centre, Earthquake information, Accessed January 2012. Available Online at: http://www.emsc-csem.org/Earthquake/ (2008).

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