FRAC MONITORING METHODS YESTERDAY, TODAY AND TOMORROW

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RESUMEN

El advenimiento de la perforación horizontal y la fracturación en los shale plays no convencionales revolucionaron el negocio del gas y el petróleo en Norte América. La tecnología de la microsísmica ha provisto de una herramienta en tiempo real que permite a los ingenieros de terminación conocer que es lo que está sucediendo cuando intervienen los pozos antes que bombear a ciegas. El monitoreo con microsísmica es a la fracturación como el perfilaje es a la perforación. La tecnología aplicada no es nueva pero ha sido ampliamente usada en los últimos 5 a 10 años. Se han logrado avances en adquisición e imagen pero los desarrollos más importantes son en el entendimiento de lo que nos quieren decir los datos según la manera en que las rocas responden al tratamiento de fracturación hidráulico y como un pozo va a producir. Los datos obtenidos nos dicen que las rocas son sumamente variables; que las respuestas al tratamiento varían de etapa en etapa, de pozo a pozo y a lo largo del tiempo haciendo necesario más monitoreos de los pozos intervenidos.

INTRODUCTION

The advent of horizontal drilling and frac'ing in unconventional shale plays has revolutionized the oil and gas business in North America. Microseismic technology has provided a real world, real time tool that allows the completion engineers to know what is happening when they treat the wells rather than pumping blindly. Microseismic monitoring is to frac'ing as logging is to drilling. The technology is not new but has largely come into play in the hydraulic fracturing world over the last 5 to 10 years. Advances in acquisition and imaging have been made but the most important developments are in the understanding of what the data are telling us about the way the rocks respond to the hydraulic fracturing treatment and how a well will produce. The data tells us that the rocks are highly variable; that treatment responses vary from stage-to-stage, well–to-well and over time driving the need to monitor more of the wells being treated.

YESTERDAY

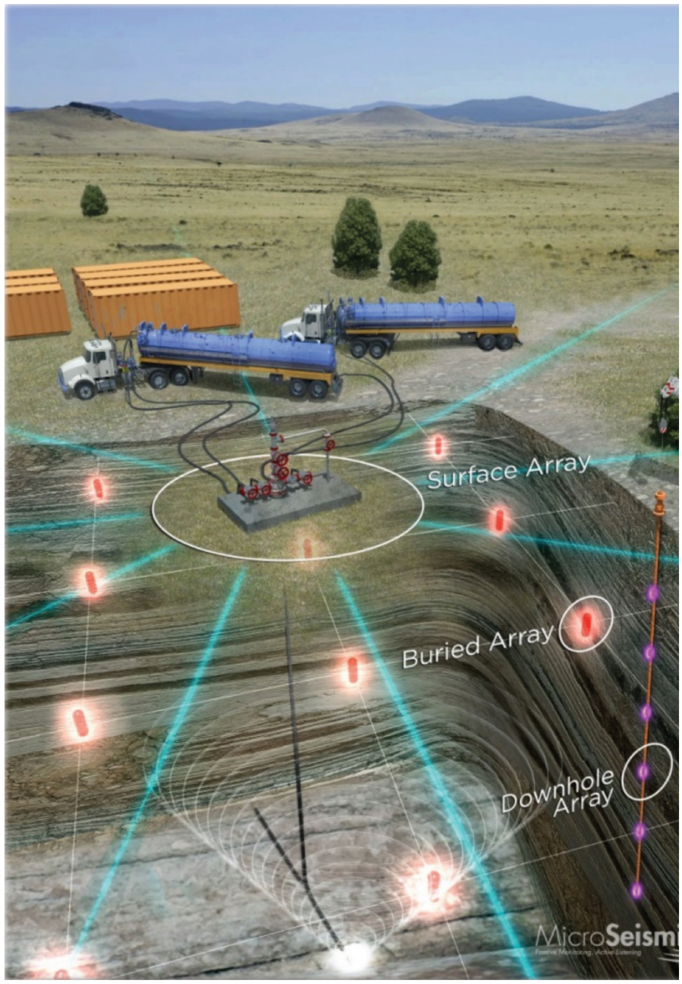
In the mid 1960's a cause-and-effect relationship was observed between an increase in the seismicity occurring near Denver, Colorado and the injection of waste liquid in a nearby disposal well at a US government facility. The observation lead to a series of experiments that gave birth to the idea that one could track pressure changes in a reservoir as a result of fluid injection by mapping the location of the small microseismic events that are triggered by the injection. In principle this was no different than mapping the location of globally occurring earthquakes as was being done on a routine basis. In practice, the fact that these events were typically 4 or 5 orders of magnitude smaller in amplitude than the tectonic events of interest required some changes in the detection methodology. In order to pick the arrival time of these microseismic events with sufficient accuracy, it was necessary to place the receivers at near reservoir depths. Ideally the monitor wells with the sensors should be placed surrounding the likely event positions in order to use a trilateration/triangulation location procedure. Typically, more than one observation wellbore was too expensive for any widespread use of the technology, so a single wellbore solution using a multi-level string of geophones became the norm to provide an "80% solution". Microseismic monitoring of this sort probably was employed in less than 1% of the wells frac'ed up until the shale revolution in North America. The challenge of understanding how to treat these new shale reservoirs led to a significant uptick in monitoring.

TODAY

As shale exploration and development began to dominate North American exploration and production activity, several factors drove the development of alternatives to the legacy downhole approach to microseismic monitoring. In new basins, the lack of wellbores that could be employed as monitor wells was a problem. Few players were willing to drill wells solely for monitoring purposes. Some plays, the Haynesville of Louisiana for example, were found to have temperatures that exceeded the operating specs of the downhole equipment. As lateral lengths of the horizontal wells began to exceed 4000 feet, it became increasingly difficult to monitor the entire length of a well with a single monitor well. Having more than one monitor well is usually deemed too expensive. Lastly, as interpretation techniques have advanced, the determination of event focal mechanism has become a standard analysis tool. Such determination is not readily available with a single, vertical monitor well.

The alternative to downhole monitoring is to deploy surface arrays and to use a full waveform processing approach to event location (sometimes called beam steering or migration). Location accuracy requirements drive the aperture of such a surface or near surface array to be large. Typical arrays have diameters that are twice the reservoir depth. To overcome the low signal size at the surface, a relatively high fold is required, typically 1000 fold or more on the actual surface or at least 100 fold if the geophones are set in shallow (100m) holes. Since a surface array can be arbitrarily sized, it is easy to monitor laterals of several kilometers length with such arrays, and even to monitor all the wells in an entire field.

Today about 40% of treatment monitoring is performed with surface or near surface arrays. Of the remaining 60%, about half are monitored with single downhole arrays, and about half are monitored with multiple downhole arrays, often with one of the arrays being "tractored" into the lateral part of a nearby well and moved along the wellbore in tandem with the treatment stage along the stimulated well. In total, about 5% of the wells treated are monitored.



TOMORROW

Microseismic monitoring has shown itself to be the only way for completion engineers to "see" what their treatment has achieved without waiting 2 or more years to evaluate performance, and yet only a very small percentage of wells is monitored. This is likely because the extraction of knowledge about the reservoir and how it will produce from the microseismic data has lagged behind the development of field acquisition and processing techniques. It is in the areas of data interpretation and integration with other data types that the most valuable development work is taking place. The results of a monitoring job are no longer being presented as simply "dots in the box" *i.e.* event hypocenters pictured in relation to pumping parameters over time. Rather the event focal mechanism for each event is being estimated and from that estimates of the strike, dip and area of the failure plane of each event are made. The body of connected failure planes is turned into an estimate of the discreet fracture network that was created by the treatment, representing the drainage system to the well.

We are now able to estimate reliably what part of that fracture network has received proppant such that it will stay open longer during production. We are working towards making a reasonable estimate of what that treated well is likely to produce. This, of course has to be delivered to the operator in near real time such that he can make on the fly decisions about treatment parameters, stage length and well spacing. All this will go toward making sure that the operator harvests the maximum reserves at a minimum cost. In the future, monitoring will not just be used at the pilot stage of a field development, but will be used on most if not all wells to ensure that each is treated in a way to achieve optimal production.

ABOUT AUTHOR

Peter M. Duncan is Founder, President and CEO of MicroSeismic, Inc. a Houston based oil field service company. He holds a Ph.D. in Geophysics from the University of Toronto. He began his career as an exploration geophysicist with Shell Canada before joining Digicon Geophysical, first in Calgary then in Houston. In 1987 he helped Digicon found ExploiTech Inc, an exploration and production consultancy. In 1992 he was one of 3 founders of 3DX Technologies Inc., an independent oil and gas exploration company where he served as Vice President and Chief Geophysicist. Duncan was 2003-04 President of the Society of Exploration Geophysicists (SEG). Duncan was the Fall 2008 SEG/AAPG Distinguished Lecturer speaking on the subject of Passive Seismic at 45 venues around the world. He is an Honorary Member of SEG, the Canadian Society of Exploration Geophysicists (CSEG), the Geophysical Society of Houston (GSH) and the European Association of Geoscientists and Engineers (EAGE). He received the Enterprise Champion Award from the Houston Business Journal in 2010, the World Oil Innovative Thinker Award in 2011, the Ernst and Young Gulf Coast Technology Entrepreneur of the Year for 2013 and the EY National Energy, Cleantech and Natural Resources Entrepreneur of the Year Award for 2013.