PERMEABILITY INCREASE BY SEISMIC WAVES:
EFFICIENCY OF UNCLOGGING OF FRACTURE PROCESS

Mai-Linh Doan*
Laboratoire de Géophysique Interne et Tectonophysique, Université Joseph Fourier,
GRENOBLE Cedex 9 38000, FRANCE
Tel: +33-04-76-63-52-09, Fax: +33-04-76-63-52-52, E-mail: Mai-Linh.Doan@obs.ujf-grenoble.fr

Emily E. Brodsky
Earth & Marine Sciences Department, University of California Santa Cruz,
SANTA CRUZ CA 38000, USA

Keywords: *Permeability, Earth Tides, Poroelasticity, Dynamic triggering*

ABSTRACT

Seismic waves increase permeability. A striking example is given by the Piñon Flat Observatory. There, the water levels of four wells have been permanently monitored for more than 20 years. Two boreholes exhibited systematic changes in their response to Earth tides due to close and distant earthquakes. This disturbance tames after a few month.

A possible mechanism to explain this phenomenon is the unclogging of the fractures. This mechanism may also apply in a fractured medium like the LSBB observatory.

INTRODUCTION

Seismic waves increase permeability [1]. Beresnev and Johnson [2] report the numerous attempts by Russian scientists to increase oil production by seismic vibrations; they recorded some success, sometimes, but the process was still poorly understood. Failures to increase permeability were also frequent.

Another illustration is provided by the Piñon Flat Observatory (PFO), where major Californian earthquakes induced systematic changes in the tidal response of two wells [1]. These observations are exceptional by the length of the time series, exceeding 20-year long. They document permanent change in the tidal response of the wells to both local and regional earthquakes.

EFFECT OF PERMEABILITY ON THE TIDAL RESPONSE OF THE WELL

To understand the tidal changes, we need to understand how comes a borehole can record tides.

The Sun and the Moon apply gravity forces on the Earth. Because of the large size of the Earth, these gravity forces are heterogeneous within the Earth, resulting in tidal strain. This strain is quite predictable; hence the tidal response of a poroelastic medium provides information on its poroelastic behavior.

The response of a well to earth tides is complex [4]. It is also controlled by the hydraulic properties of the medium that control the fluid diffusion to the well [5]. If the medium is very permeable, the water level reflects instantly the pore pressure, whereas if the medium is too impermeable, the well is insensitive to change in water pressure. In between, there is a time lag dependent on the permeability of the borehole. At PFO, this time lag varies with time.

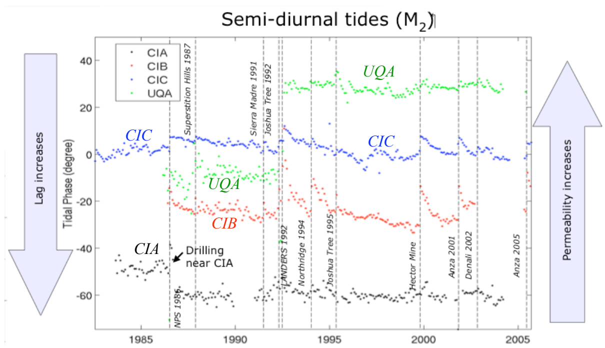

Fig. 1 Temporal evolution of the tidal response of the four wells of the Piñon Flat Observatory (CIA, CIB, CIC and UQA), computed with a modified version of BAYTAP-G. There are in tidal response consecutive to the major earthquakes within California and farther.

We have refined the tidal processing (Fig. 1). For instance, we prove that the Denali earthquake that happened in 2002 in Alaska affected the well. Elkhoury et al. [1] showed that the change in permeability is proportional to the amplitude of the seismic wave.

We used the new dataset of tidal response to test some possible processes to that may explain the changes in permeability.

EFFECT OF SHAKING ON A FRACTURED MEDIUM

Shaking can affect a medium in two ways: (1) by moving the fracture walls or (2) by inducing fluid flow within the medium.

It is difficult to guess how moved walls can induce a disturbance lasting a few months before coming back to the initial state. On the other hand, unclogging of fracture by fluid flow [6] can be a viable mechanism to explain transient change in permeability.

*To whom all correspondence should be addressed.

We first compute the flow induced by shaking, using a theoretical impulse response and the seismic data recorded near PFO. We then suppose a step in permeability is induced when fluid flow exceeds a threshold limit. After the shaking, we compute the expected Earth tides response within the disturbed area.

Figure 2 shows the best match for hole CIB. The threshold in the volumetric flow rate per unit area is about 10^{-9}m/s, and the permeability within the affected zone is multiplied by 6. These values give a good estimate of the permeability change.

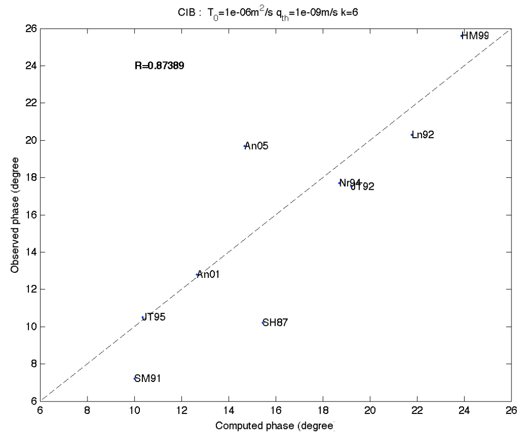

Fig. 1 Comparison of the M2 observed delay in tidal response compared to the delay modeled after an unclogging process.

CONCLUSION

The Piñon Flat Observatory provides more than 20 years of water level data. They display change in tidal response that reflect change in permeability. A possible process for the change is the unclogging of fractures. Yet, we have only a black box model, without further data to test the proposed explanation. Therefore a long term, multi-disciplinary low noise observatory like the LSBB may be a good site to test such phenomenon.

REFERENCES

[1] J. Elkhoury, E. E. Brodsky & D. C. Agnew: *Nature*, **441** (2006) 1135-1138.

[2] I. A. Beresnev & P. A. Johnson: *Geophysics*, **59** (1994) 1000-1017.

[3] E.E. Brodsky & S. Préjean: *J. Geophys. Res.* **110** (2005)

[4] S. Rojstaczer & D. C. Agnew: *J. Geophys. Res.* **94** (1989) 12403-12411

[5] P. Hsieh, J. Bredehoeft & J. Farr: *Water Res. Res.* **23** (1987) 1824-1832

[6] E. E. Brodsky, E. Roeloffs, D. Woodcock & I. Gall: *J. Geophys. Res.* **108** (2003)