RECEIVED MAY 0 1 1991

Interpretation of Slip-Induced Water Well Level Changes at Parkfield

14-08-0001-G1691

J. W. Rudnicki
Department of Civil Engineering
Northwestern University
Evanston, IL 60208
(708)-491-3411

(For period October 1, 1990 to March 31, 1991)

Objective

Properly calibrated water wells can function as inexpensive and sensitive strainmeters. Solutions predicting water well level changes due to slip are needed to infer fault slip history and distribution from observed water well level changes. Recent solutions for pore pressure changes induced by fault slip have demonstrated that the coupling between deformation and pore fluid diffusion can strongly affect the response of the well to slip, particularly if the well is close to the fault, and, consequently, the inference of fault slip from water well level changes. The objective of this study is to assess effects of coupling between deformation and diffusion on the inference of fault slip from observed water well level changes and to include these effects in the analysis of observed water well level changes at Parkfield.

Results

We have examined coupled deformation-diffusion effects on the recovery of five creep induced water level changes recorded in the deep interval of the Middle Mountain well from January 1989 to July 1990. The observed water level changes are characterized by a sharp drop and a slow recovery with magnitudes of the change ranging from 11 to 15 cm.

In work reported in the abstract by Yin et al. [1990], we used the following function suggested by Wesson [1988] to describe the slip history of the creep events:

$$u(t)=u_0\{1-[C(b-1)u_0^{b-1}t+1]^{-\frac{1}{b-1}}\}$$

The values of u_0, the final displacement, and the constants b and C were obtained from data at two creepmeters near the well. In more recent work, we have found that the recovery of the water level can be modelled adequately by using a simple step function for the slip history. In other words, the time scale of water level recovery is so slow that the detailed form of the slip increase is not important. The induced pore pressure response is obtained from Rudnicki's [1987] solution for the instantaneous slip on an impermeable plane in a fluid-saturated porous medium. We calculated the pore pressure responses for y = 460 m (the distance of the well from the fault trace), a diffusivity of c = 0.15 m²/s (a value consistent with those inferred from tidal analysis of the well) and various values x or, equivalently, $\theta = \tan^{-1}(y/x)$. Comparison of the results with the five observed water level changes indicates that the values of x range from 0 ($\theta = 90°$) to 322 m ($\theta = 55°$). This suggests that the main portion of the creep events may have stopped at different distances from the well. Replotting the water level changes (divided by the maximum change) against $4ct/r^2$ ($r^2 = x^2 + y^2$) with the value of x appropriate for each event diminishes the spread of the data (Figure 1). The calculated results for $\theta = 55°$ and $\theta = 90°$ are also shown.

In order to examine the effect of the permeability of the fault plane on the water level decay, we have also calculated the pore pressure induced by a sudden introduction of slip on a permeable plane. Because fluid diffusion across the fault is possible for this case, the pore pressure change for the permeable fault decays much faster than that for the impermeable fault. Although the results for the permeable fault can be made to fit the data by choosing the diffusivity to be very small, the results for the impermeable fault appear to give a better fit.

References

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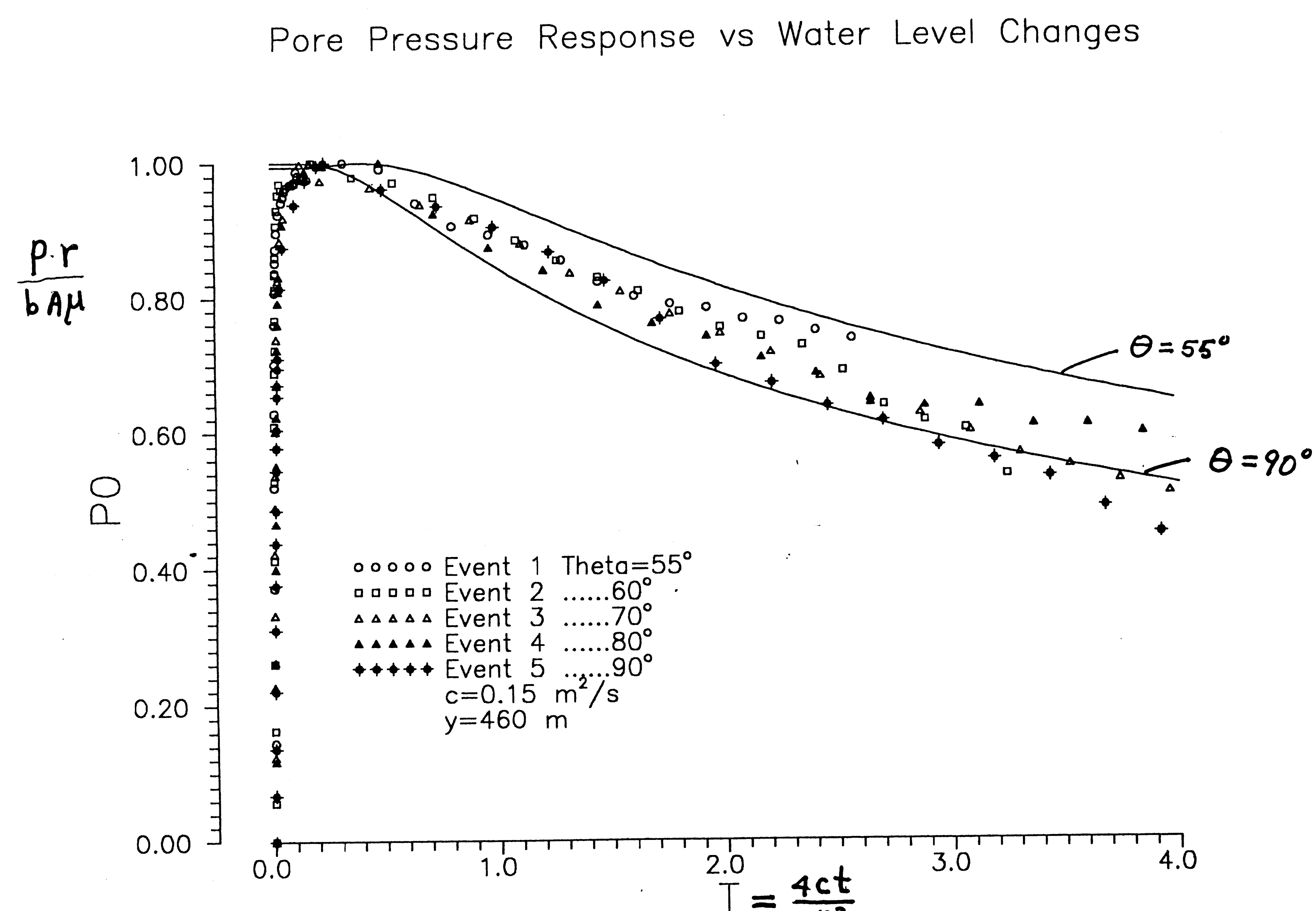
Publication

Yin, J., E. A. Roeloffs, and J. W. Rudnicki, Coupled deformation diffusion effects on water level changes induced by fault creep at Parkfield, California (Abstract), **EOS, Transactions of the AGU, 43,** p. 1474, 1990.



Pore Pressure Response vs Water Level Changes
1.00
0.80
0.60
0.40
0.20
0.00
PO
p·r / bAμ
0.0
1.0
2.0
3.0
4.0
T = 4ct / r²
θ = 55°
θ = 90°
Event 1 Theta=55°
Event 2 ......60°
Event 3 ......70°
Event 4 ......80°
Event 5 ......90°
c=0.15 m²/s
y=460 m

Figure 1