Chapter 5

The effect of Coulomb stress change on clock advance

5.3 Modeling the effect of Coulomb stress change

5.3.2 Heterogeneous fault

We performed numerical experiments on clock advance on a model of heterogeneous fault with a random distribution of D_C that produces Gutenberg-Richter seismicity with $b = 1$ in a range of about 2 magnitudes. This is the fault whose seismicity was shown in figure 3.3 in chapter 3. The fault has dimensions of $35 \times 35\ km^2$ discretized into 128×128 cells and it has zero dip (it is a strike-slip fault). The bottom edge of the fault is in the depth of 35 km, so the top edge lies on the free surface. The distribution of parameters a and $a - b$ in this model is shown in figures 5.18 and 5.19. The depth dependence prescribed in the interval of 3.5 km to 31.5 km along the fault strike is a standardly used distribution taken after Blanpied et al. (1991)[1], linearly scaled to the depth of 35km. We plot this dependence (in terms of parameters a and $a - b$) in figure 5.20. There are velocity strengthening regions at the top and bottom of the fault, and a velocity-weakening (seismogenig) zone at the center. Near the verticals edges, there's a linear transition from this distribution $a_{Blanpied}$ to $a = 1.5 \times a_{Blanpied}$ and $b = 0$. This transition is used to stabilize the fault near the vertical edges. The distribution of D_C is in figure 5.21. The bottom 5 km have a constant value of $D_C = 0.3$ km (but this value is not important, because $b = 0$ in this depth range). The distribution on the rest of the fault was obtained by using a uniform initial distribution of parameters and using the filters described in subsection 3.0.3 with $N = 0$, $c = 0.82$ km and $a_G = 0$. The mean value of D_C is 0.03 m, and it ranges from 0.01 m to 0.05 m. The value of other parameters

[1](1991) Blanpied, M. L., D. A. Lockner, and J. D. Byedee, Fault stability inferred from granite sliding experiments at hydrothermal conditions, Geophys. Res. Lett., 18(4), 609-612, 1991.

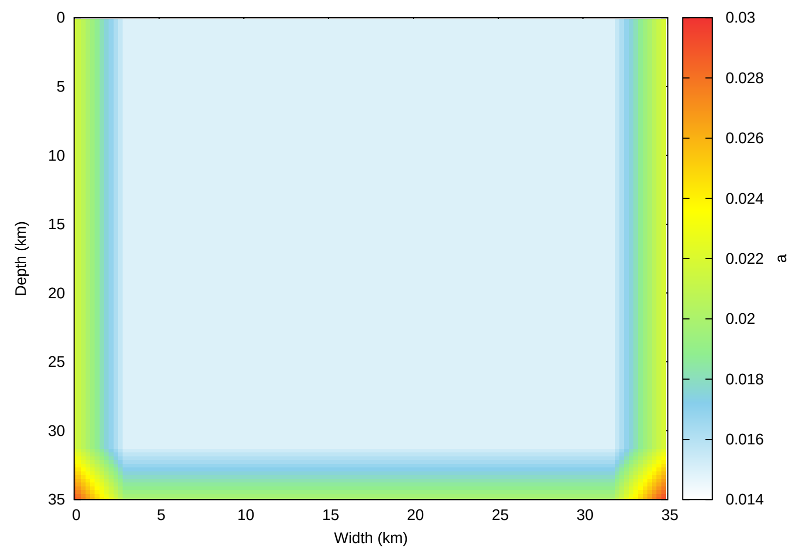

Figure 5.18: Spatial distribution of the frictional parameter a.

is the same as for the homogeneous fault: $\mu_* = 0.6$, $\alpha = \mu_*/3 = 0.2$, $V_* = 10^{-6}$ m, $\sigma_0 = 75$ MPa, $\lambda = 20$ GPa, the shear modulus $\mu = 30$ GPa, $\beta = 3$ km/s and $V_{pl} = 3.5$ cm/year.

For numerical experiments with clock advance, we chose the cycle from figure 3.3 which starts at 518.7 years and, when unperturbed by Coulomb stress, has events occurring at 587.7 years. The inter-seismic time for this cycle is thus 69.0 years. We performed a small number of experiments similar to the case of homogeneous fault - we tested the response to Coulomb stress change of different magnitudes and compared the absolute values of CA for positive and negative Coulomb stress changes. The results are presented below.

5.3.2.1 Results

The graph of CA vs t_0 for several amplitudes of ΔCS applied to the whole fault can be seen in figure 5.22. As we can see, the response of the model is qualitatively the same as that of the homogeneous fault - the dependence of clock advance on time can still be separated in the static, oscillating and the instantaneous triggering phases. In figure 5.23 we show the dependence of the amplitude of the static phase CA_0 on amplitude of Coulomb stress change for three areas of ΔCS application - the whole fault, one half and one quarter of the fault area. Like in the case of the homogeneous fault, CA_0 depends linearly on the ΔCS amplitude and the slope of the dependence is steeper for

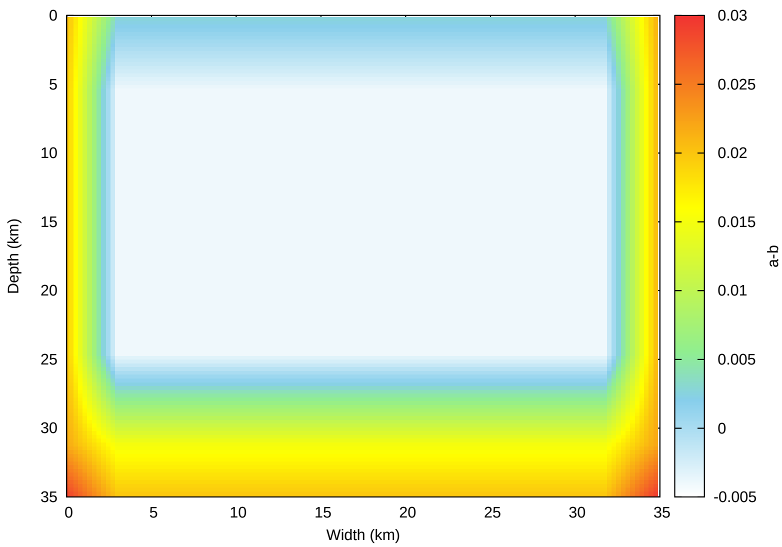

Figure 5.19: Spatial distribution of $a - b$.

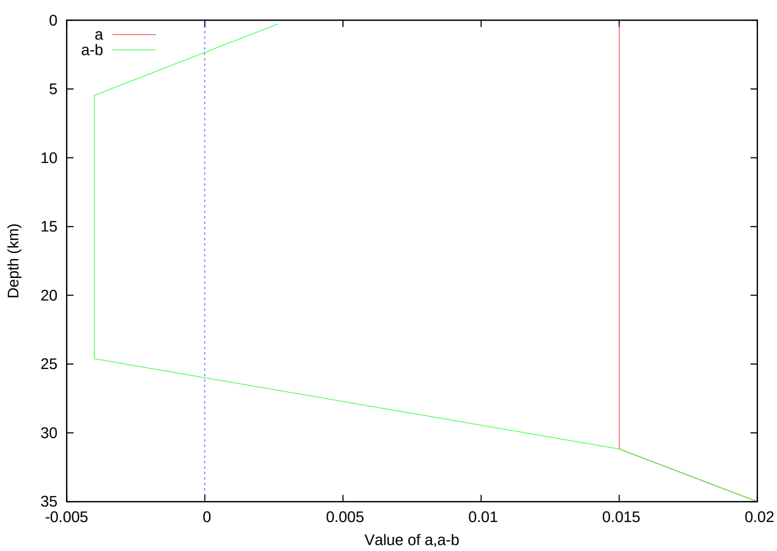

Figure 5.20: Depth dependence of parameters a and $a - b$ at width 12.5 km.

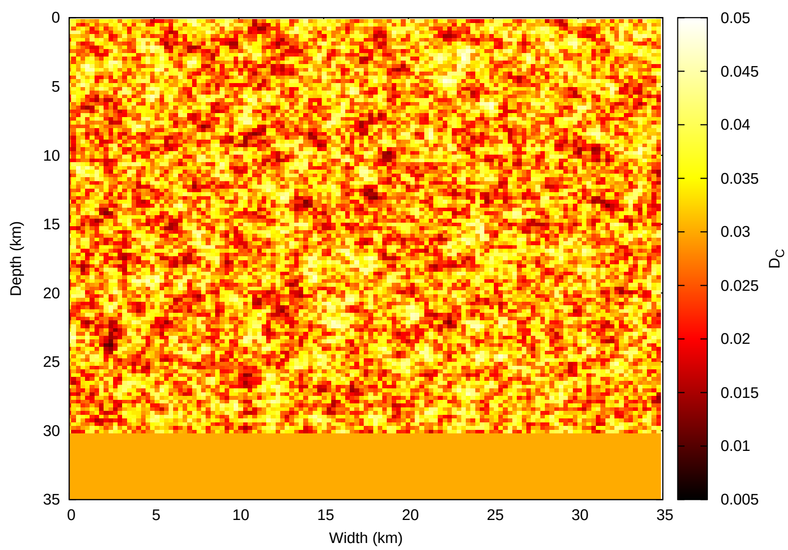

Figure 5.21: Spatial distribution of the parameter D_C.

larger application areas. We also calculated CA for negative values of ΔCS and found that they produce clock delay (negative values of clock advance). The absolute values of CA in the static phase for applications of ΔCS with the same absolute value but opposite signs are the same, although they differ in the later phases - as was the case for the homogeneous fault. This is shown in figure 5.24. Overall, based on the results of these numerical experiments, we didn't find any significant qualitative differences between clock advance behavior of the two models.

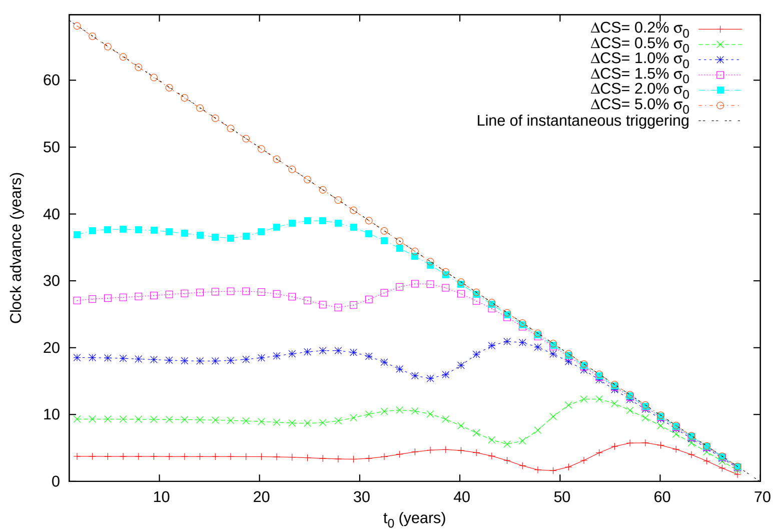

Figure 5.22: CA vs t_0 for increasingly large amplitudes of ΔCS to the area of whole fault.

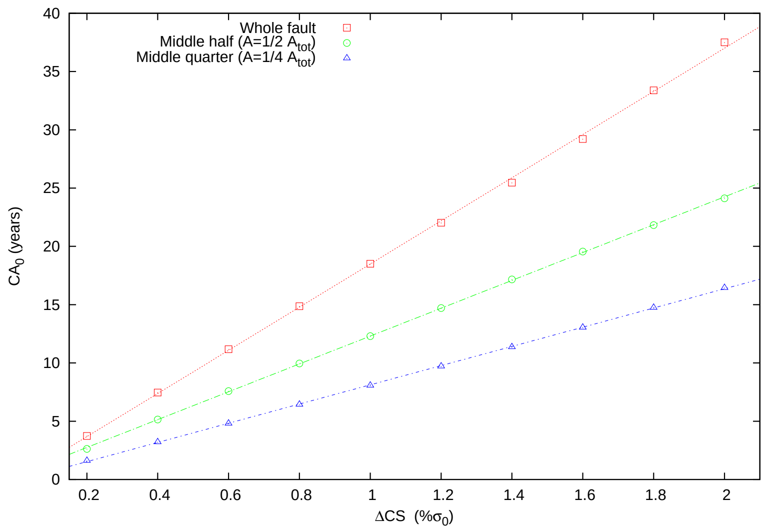

Figure 5.23: CA_0vs ΔCS for application of Coulomb stress to the whole fault (red), to its center half (green) and center quarter (blue). Linear fits are drawn with dashed lines.

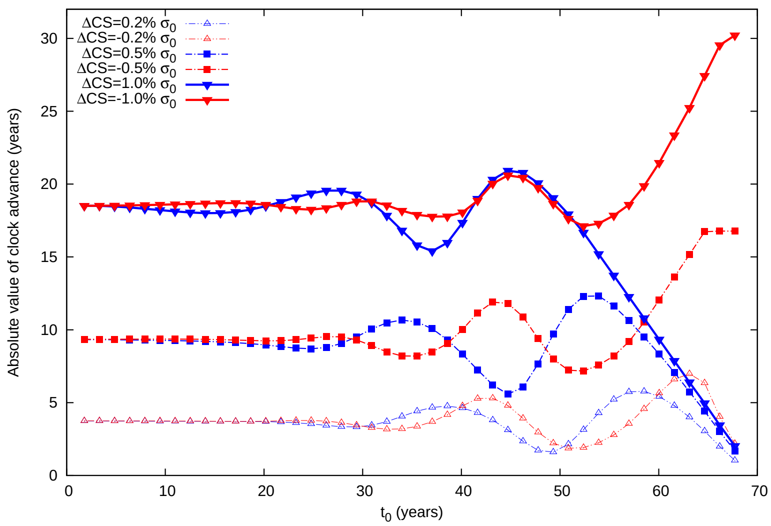

Figure 5.24: Comparison of absolute values of CA for applications of ΔCS with same absolute values, but opposing signs. Three values of $|\Delta CS|$ ($0.002\sigma_0$, $0.005\sigma_0$ and $0.01\sigma_0$) are used. The blue lines represent positive CS application, while the red lines represent negative applications.