DILATANCY-DIFFUSION MODEL

According to the model the earthquake generation process consist of following stages:

Stage 1 - increase of elastic strain.

Stage 2 - elastic strain eventually causes rocks to dilate (increase in volume) when stress on rocks = 50% of the rock strength. Open fractures develop with minor seismicity.

Stage 3 - influx of water into open fractures increase fluid pressure. This lowers the rock strength and facilitates rupture.

Stage 4 - Rupture occurs and fluid pressure and stress on rocks is released.

Stage 5 - Aftershocks activity.

The crustal earthquake dilatants - diffusion model is based on incontestable physical phenomena: dilatancy and diffusion. At first glance there are not serious problems in DD-scenario. But it is not agree with real condition. Let us investigate effects of dilatancy and diffusion in details.

Dilatancy: The dilatancy is the inelastic increase in volume associated with the opening of small cracks in the material by shear deformation.

The excellent example of dilatancy process can be seen if to put a leg on wet sand on a sea coast. The sand around the leg for some time becomes unsaturated - pressure on the sand surface has broken a dense packing of sand grain, and as a sequence led to under saturation by water as a result of the porosity local increase.

This example is resulted here to pay attention on some circumstances.

1. Obviously, the dilatancy is an essentially non-equilibrium phenomenon. In this connection there appears a problem about assumptions that should be accepted to describe a non-equilibrium system. It is important that in the “sand water” system or in any other dilatants medium hydrostatic (lithostatic) pressure **is not** the same function of state variables, as in equilibrium. Equally the thermodynamic potentials cannot be a function only on equilibrium state variables. The full of system dynamics must include **time** dependence of thermodynamic variables (in particular, energy and entropy).

Thus, the description of dilatation process should be based on dynamic equations. The above obvious example indicates definitely the object of research. This is reservoir-induced earthquakes.

Kiyoo Mogi has paid attention to the fact that in focal areas of strong earthquakes the seismic activity decreases in the same way, and the same time seismic activity increases in neighbouring regions (so-called ring-type form of seismicity). But such form of seismicity is characteristic for reservoir-induced earthquakes.

The essential condition of development of earthquake preparation process in DD-scheme is faster formation of dilatants zone at stage II in comparison with filling of newly formed cracks by water from neighbouring areas. Due to pressure growth before earthquake cracks open in the crust, pressure of pore fluids, filling these cracks, drops, so the crust strength temporarily increases (dilatancy hardening), and therefore seismic activity in heart areas decreases.

The dilatancy hardening is determined by Coulomb-Mohr law:

$$\tau = c + f(\sigma - p),$$

Where τ is shearing stress; c is the cohesion shear stress; f is friction coefficient; σ normal stress, equal to geostatic pressure; p is pressure of pore water.

However this law is static and does not take into account the process dynamics. Laboratory experiments prove that effect of dilatancy hardening for such rocks as granite and basalt may be essential only if deformation rate is more that 10^{-7} sec^{-1}, that significantly higher than the deformation rate typical for natural condition(10^{-10} /$^{10-14}$ sec^{-1} [5]) .

Diffusion. In DD-scenario the underground fluids diffuse to a dilatants zone at stage III. Water inflow from neighbouring areas will lead to increase of pore pressure and, hence, will reduce rocks effective strength. Increasing of fluid pressure in DD-scenario is considered as one of the factors predetermining rocks fracture. The catastrophic destruction occurs within a short time interval after water inflow. During this interval foreshocks occur.

At first glance diffusive filling of newly formed dilatant cracks by water from neighbouring areas seems to be quite logical.

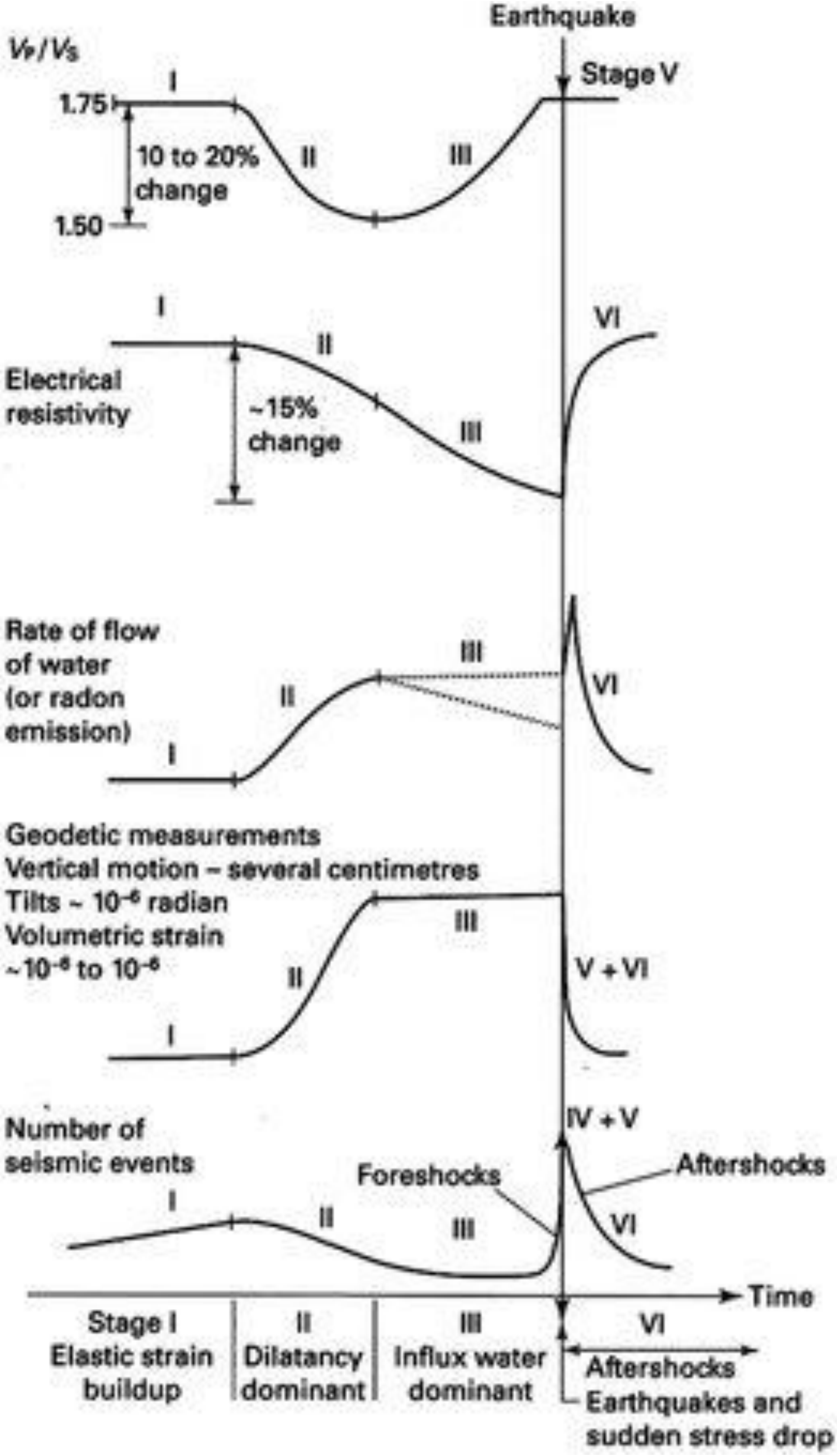
But there are a number of **serious problem** in this connection:

- The microscopic investigations on the samples of the rocks(granite, basalts) show that essential part of dilatants cracks has order of microns, that is, much smaller than the grains size. It is obvious that **water cannot penetrate to micro-cracks.**
- During preparation of earthquakes direct measurements show that deformation magnitude is $\epsilon \sim 10^{-6}$. Obviously, the order of relative changes of underground water levels will be the same $\delta H = \epsilon H$. From this estimation it follows, that for observed variations of underground fluids levels(10-15 cm) during crust earthquakes preparation, thickness of the water-bearing layer should be about 100 km that is more than thickness of the earth crust in several times.

Thus, **the deformation of water-bearing horizons cannot directly cause levels variations.**

The dilatancy is irreducible process. In this connection it is not clear the cause of water levels (surface) restoration after earthquakes.

It is absolutely impossible in context of DD-mechanism to explain the observational increasing of wells debit at the simultaneous drop water level in neighbouring areas.



Earthquake
V_P/V_S
Stage V
I
1.75
10 to 20% change
II
III
1.50
I
VI
II
Electrical resistivity
~15% change
III
Rate of flow of water (or radon emission)
III
II
VI
I
Geodetic measurements
Vertical motion – several centimetres
Tilts ~ 10^{-6} radian
Volumetric strain ~10^{-6} to 10^{-6}
III
II
V + VI
I
IV + V
Number of seismic events
Foreshocks
Aftershocks
I
II
III
VI
Time
Stage I Elastic strain buildup
II Dilatancy dominant
III Influx water dominant
VI
Aftershocks
Earthquakes and sudden stress drop