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Structure of elastic presage of earthquake

I.L. Boltenhagen

- In 1960 H.G.Hopkins solved a problem about dynamical expansion of spherical cavity in elastic medium [1]. This solution is used to analyse an elastic presage of earthquake or rock burst [2].
- An approximation of Hopkins's solution, in which stresses and displacements are inversely proportional to a distance from earthquake centre, was applied. For large distance from centre the front of spherical wave of radial displacement is a hump. Its wide depends on Poisson's ratio and is equal to 3-4 of cavity's radius (size of earthquake centre). This hump is an elastic presage and it propagates with velocity of longitudinal wave in solid. A value of maximum radial displacement near the front of wave estimated. Analogous estimations of stresses and mass velocities were carried out.
- Also Hopkins's solution was used to describe a seismic wave near an epicenter of earthquake. For it the image method was applied. Values of horizontal and vertical displacements, velocities and accelerations of earth surface were obtained for various distances from epicenter. For example at the distance, which is equal to the depth of earthquake centre, inside the elastic presage the maximum horizontal displacement is the largest on earth surface.
- *References*

- **1. Timoshenko S.P., Gudier J.** Theory of elasticity. – Moscow: Science, 1975 (last paragraph) [in Russian].
- **2. Boltenhagen I.L., Popov S.N.** Energy analysis of rock burst along tectonic failure // Geodynamic and stress state of the Earth's Bowels. –Novosibirsk: Institute of Mining, 2004. P.433-439 (also look at Internet-site - http://www.boltengagen.narod.ru/artic.html) [in Russian].

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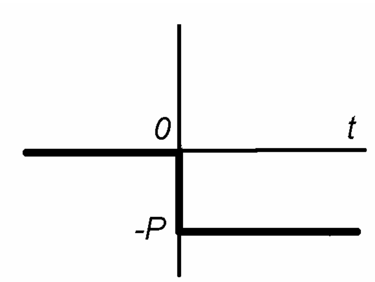
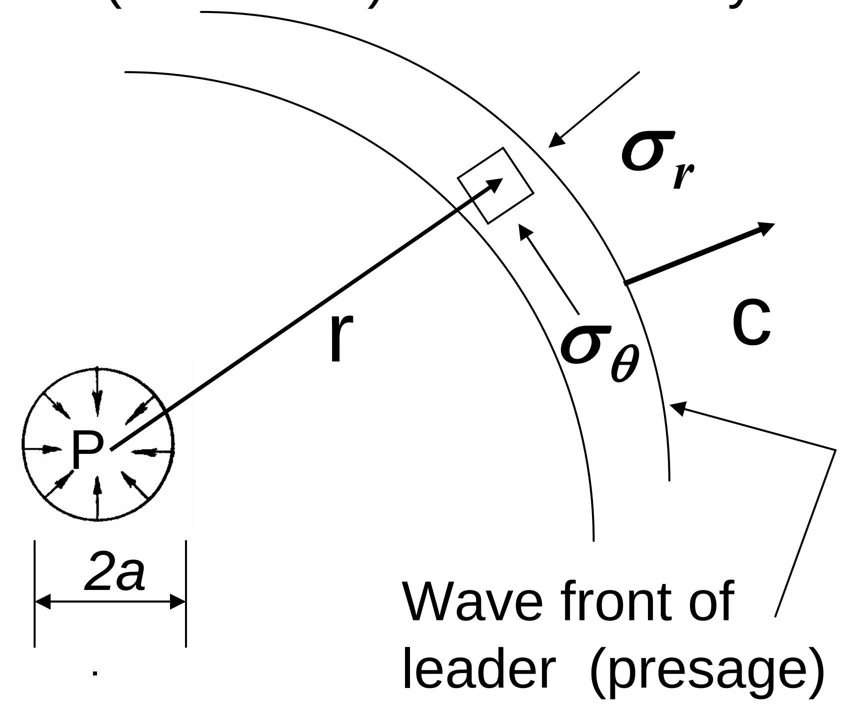
Stresses are **smaller** after earthquake (rock burst)

Simple model of earthquake centre
(without transverse waves):

spherical cavity with sharp diminishing pressure
at time **t=0** of earthquake (rock burst) in elastic body





Solution for sphere (r>>a)

$$\frac{u_r}{a}\,\frac{E}{p(1+\nu)} = \frac{a}{r}\,\frac{1}{s}\,e^{-\gamma\tau}\,\sin(\gamma s\tau)$$

$$\frac{\sigma_r}{p} = -\frac{a}{r}\,e^{-\gamma\tau}\left[\cos(\gamma s\tau) - \frac{1}{s}\sin(\gamma s\tau)\right]$$

$$\frac{\sigma_\theta}{p} = -\frac{\nu}{1-\nu}\,\frac{a}{r}\,e^{-\gamma\tau}\left[\cos(\gamma s\tau) - \frac{1}{s}\sin(\gamma s\tau)\right]$$

$$\tau = t - (r-a)/c$$

time after coming of wave front

$$c = \sqrt{\frac{(1-\nu)}{(1-2\nu)(1+\nu)}\,\frac{E}{\rho}}$$

velocity of wave front

$$s = \frac{1}{\sqrt{1-2\nu}}$$

$$\gamma = \frac{1-2\nu}{1-\nu}\,\frac{c}{a}$$

parameters

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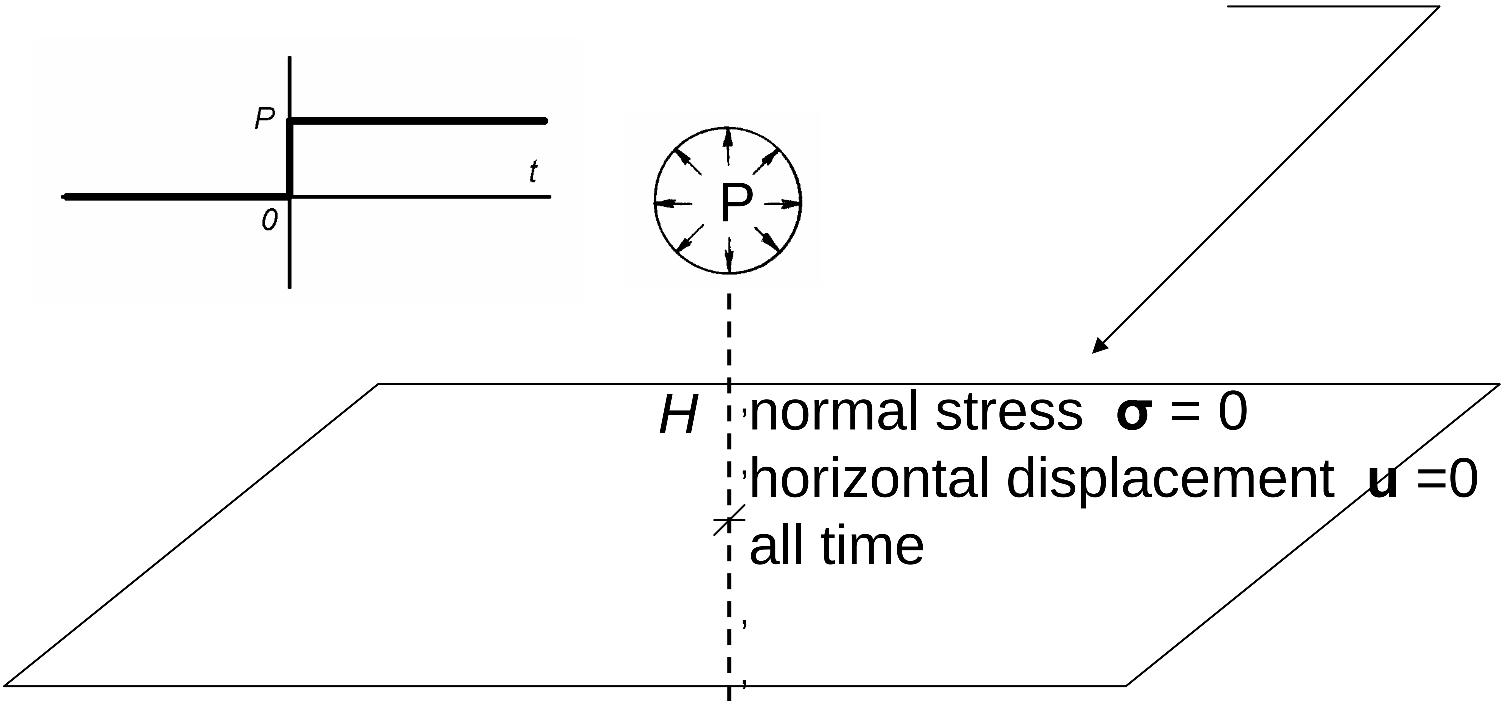
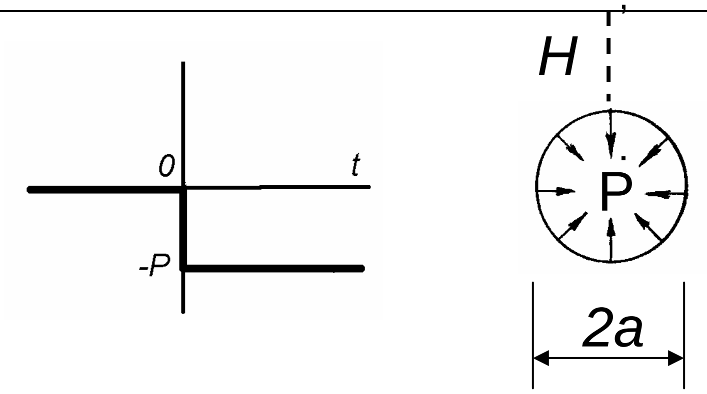
The simplest model of earthquake centre on the depth :

Superposition of two spheres, loaded with positive and negative pressure **p** at time **t**=0 in elastic body. As a result on middle surface between spheres





$$\tau = t - (r - a)/c$$

time after coming of wave front

Solution for two spheres (r>>a) on middle surface

$$D = 2u_r \frac{H}{r}$$

$$D = \frac{p2(1+\nu)}{E}\frac{Ha^2}{r^2}\frac{1}{s}e^{-\gamma\tau}\sin(\gamma s\tau)$$

$$D = \frac{p}{\mu}\frac{a^2H}{H^2+x^2}\sqrt{1-2\nu}\,e^{-\frac{1-2\nu}{1-\nu}\frac{c}{a}\tau}\sin\left(\frac{\sqrt{1-2\nu}}{1-\nu}\frac{c}{a}\tau\right)$$

$$c = \sqrt{\frac{(1-\nu)}{(1-2\nu)(1+\nu)}\frac{E}{\rho}}$$

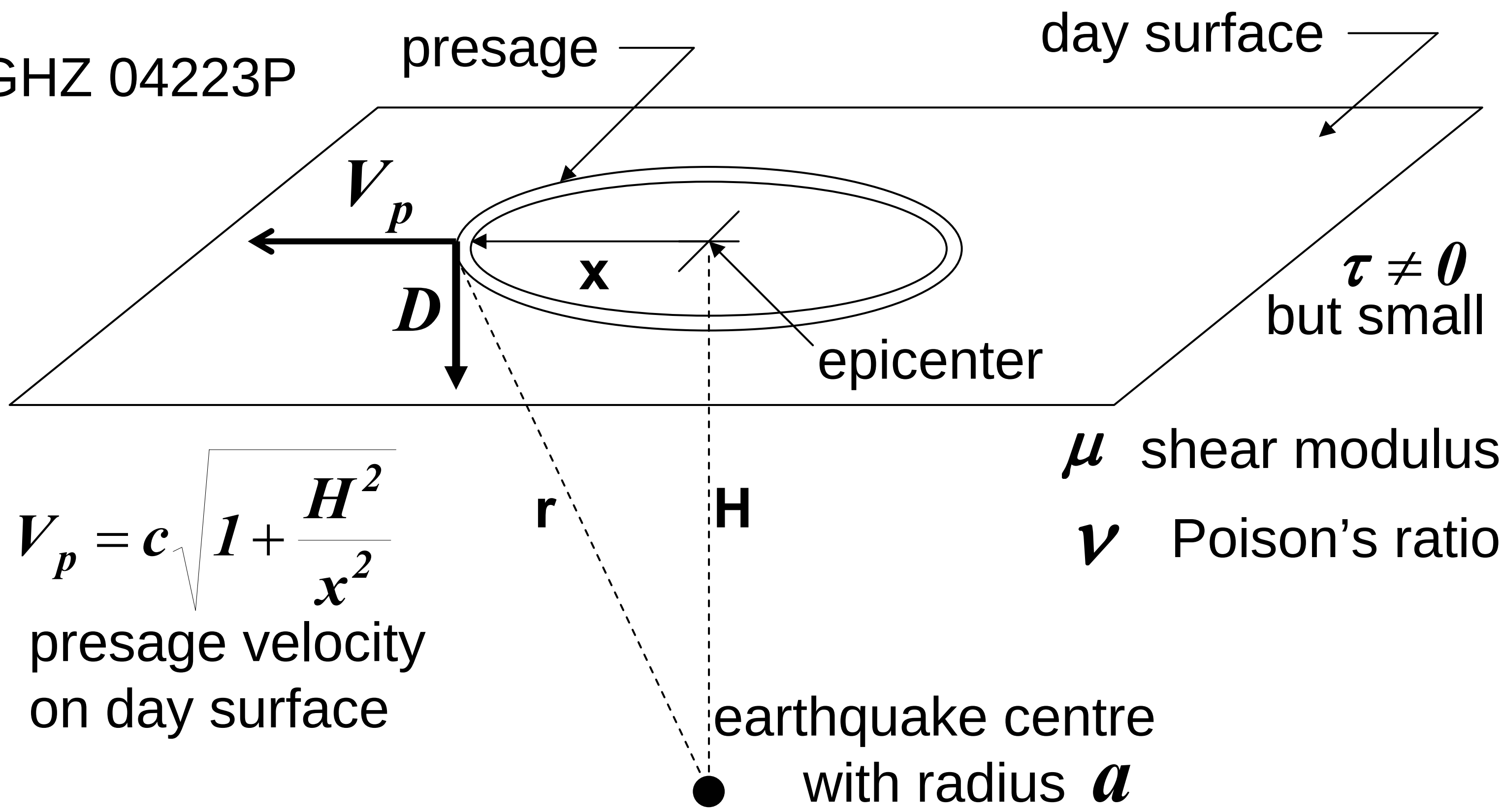
velocity of wave front

$$s = \frac{1}{\sqrt{1-2\nu}}$$

$$\gamma = \frac{1-2\nu}{1-\nu}\frac{c}{a}$$

parameters

Result of superposition of two pressure sources



μ shear modulus

ν Poison's ratio

$$V_p = c\sqrt{1 + \frac{H^2}{x^2}}$$

presage velocity on day surface

vertical displacement

$$D = \frac{p}{\mu}\frac{a^2 H}{H^2 + x^2}\sqrt{1-2\nu}\, e^{-\frac{1-2\nu}{1-\nu}\frac{c}{a}\tau} \sin\left(\frac{\sqrt{1-2\nu}}{1-\nu}\frac{c}{a}\tau\right)$$

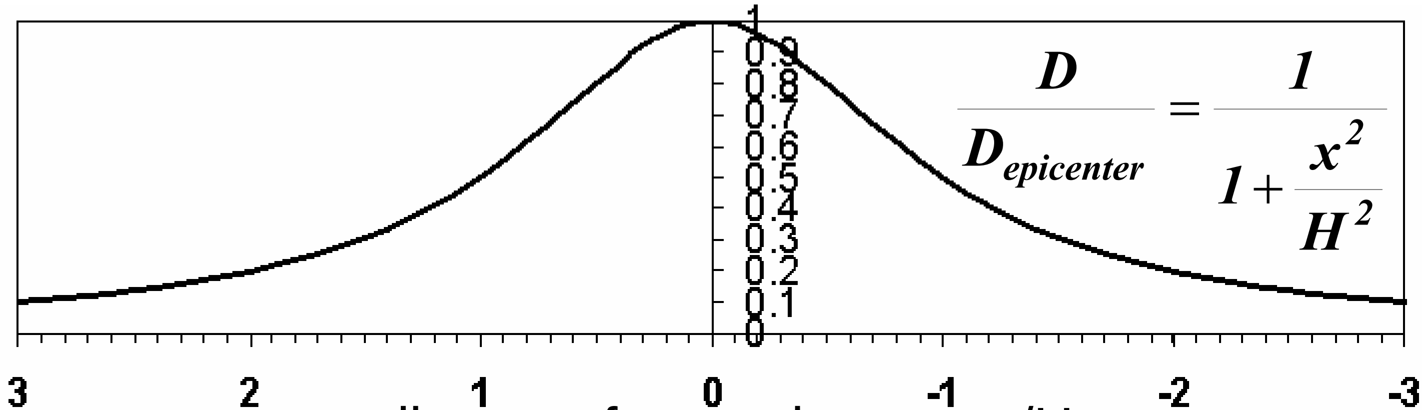
velocity

$$V = c\frac{p}{\mu}\frac{Ha}{H^2 + x^2}\frac{1-2\nu}{1-\nu} e^{-\frac{1-2\nu}{1-\nu}\frac{c}{a}\tau}\left[-\sqrt{1-2\nu}\sin\left(\frac{\sqrt{1-2\nu}}{1-\nu}\frac{c}{a}\tau\right) + \cos\left(\frac{\sqrt{1-2\nu}}{1-\nu}\frac{c}{a}\tau\right)\right]$$

acceleration

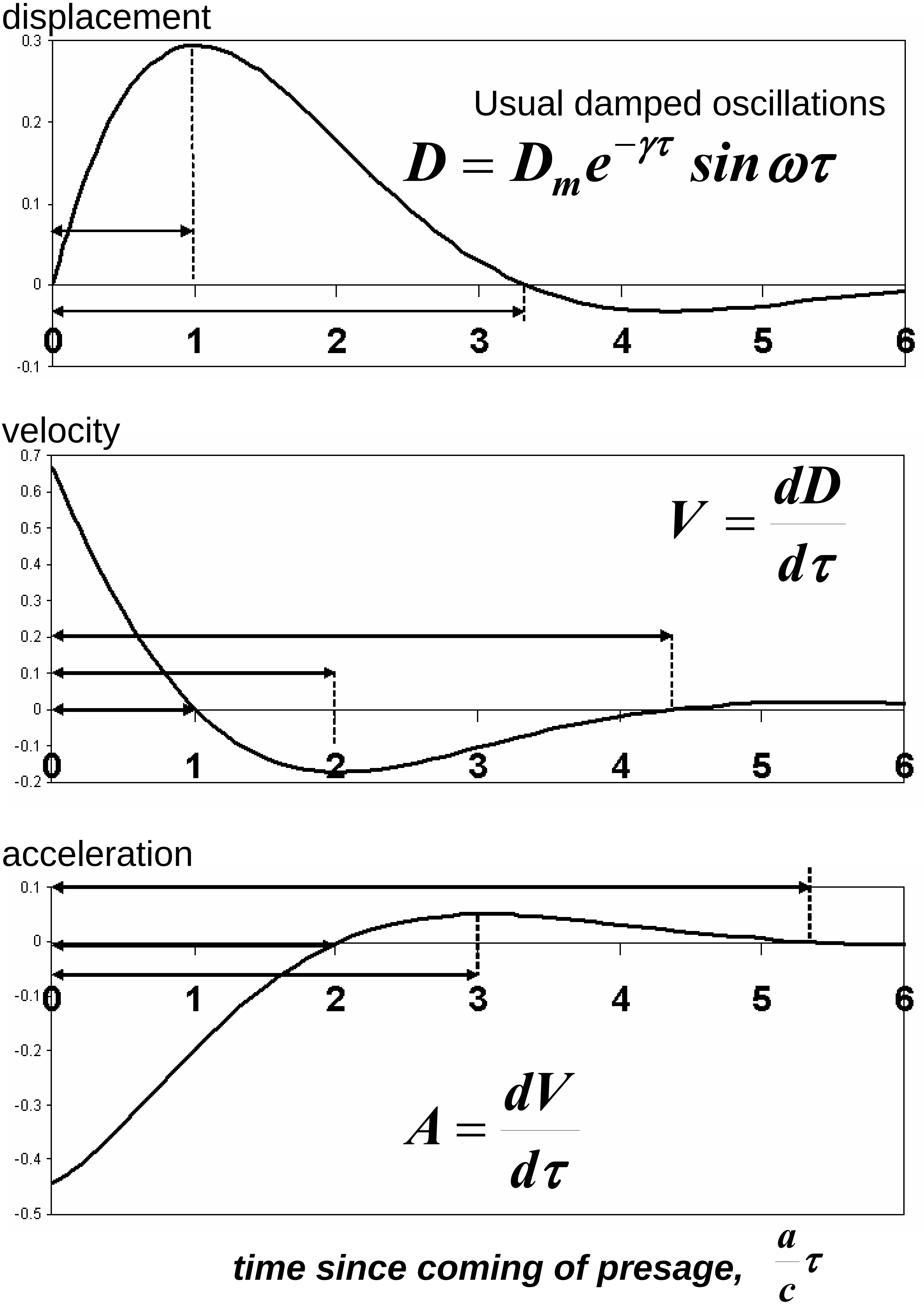
$$A = -\frac{p}{\mu}\frac{2c^2 H}{H^2 + x^2}\frac{(1-2\nu)^{3/2}}{(1-\nu)^2} e^{-\frac{1-2\nu}{1-\nu}\frac{c}{a}\tau}\left[\sqrt{1-2\nu}\cos\left(\frac{\sqrt{1-2\nu}}{1-\nu}\frac{c}{a}\tau\right) + \nu\sin\left(\frac{\sqrt{1-2\nu}}{1-\nu}\frac{c}{a}\tau\right)\right]$$

τ time since coming of presage



distance from epicenter, x/H

Structure of presage on day surface



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To the first traffic lights of city Novosibirsk

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Arch elements in the first buildings of city Novosibirsk