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Slow strain waves in the Earth: observational evidence and models

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Recent remarkable progress in theoretical studies of the solitary strain waves, that have contributed greatly to the solution of the fundamental problem of strain waves in the Earth, is overviewed.
The concept of strain waves generated in the Earth is based on the results of the study of earthquake distribution and slow tectonic deformation processes and the transfer of geophysical field anomalies.
Propagation of strain waves is represented quantitatively by the rates of earthquake migration and geophysical responses to active faulting. These processes, and possibly the related strain waves, are either of global (global tectonic waves) or local (strain waves in faults) scales (Bykov, 2005). Global tectonic waves propagating at velocities from 10 to 100 km/yr are detected from migration of large earthquakes (Stein et al., 1997), seismic velocity anomalies (Nevsky et al., 1987), offsets of water level in wells along faults (Barabanov et al. 1988), or from transient displacement of seismic reflectors (Bazavluk and Yudakhin, 1993). Strain waves along crustal faults at velocities of 1-10 km/day are inferred from radon, electrokinetic and hydrogeodynamic signals, such as solitary waves (Nikolaevskiy, 1998). Migration of episodic tremor and slow slip events along plate boundaries in subduction zones and transform fault zones at a rate of 10 km/day, on an average (Schwartz and Rokosky, 2007), may be new evidence and indication of strain waves in the Earth.
The detected mechanisms of strain wave exciting are caused by the block and microplate rotation, relative block displacement in crustal fault zones, transform faults, zones of the lithospheric plate collision and subduction and irregularity of the Earth's rotation (Bykov, 2005).
These waves in the shape of kinks or solitons moving at velocities a great number of orders less than those of the ordinary seismic waves provide the possibility to explain slow stress redistribution in the crust.
During a recent decade the sine-Gordon equation has been successfully applied for mathematical modeling of mechanisms of rotation and slippage of the crustal blocks generating slow solitary strain waves (Nikolaevskiy, 1995, 1996; Garagash, 1996; Mikhailov and Nikolaevskiy, 2000; Bykov, 2001, 2008; Gershenzon et al., 2009, 2011). Development of these models was motivated, in the first place, by an intention to obtain equation solutions in the shape of slow solitary inertial strain waves. The elasticity, or viscoelasticity, or elastoplasticity models (without account of blocks rotation) do not produce such results.
The principal goals of an overview are: (i) to give observational data of seismic migration and strain waves; (ii) to demonstrate mathematical models of fault-block geological media, leading to the classical or perturbed sine-Gordon equations; (iii) to show the application of mathematical models for explanation of the observed effects in geological media.