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## Multiphysics dissipative waves as a multiscale precursor phenomenon to geodynamic instabilities

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We present the hypothesis that material instabilities based on multiscale and multiphysics dissipative waves hold the key for understanding the universality of physical phenomena that can be observed over many orders of scale. The approach is based on an extended version of the thermodynamic theory with internal variables (see related abstract by Antoine Jacquey et al. for session EMRP1.4 entitled: "Multiphysics of transient deformation processes leading to macroscopic instabilities in geomaterials"). The internal variables can, in many cases, shown to be related to order parameters in Lev Landau's phase-transition theory. The extension presented in this contribution consists of replacing the jump condition for the symmetry-breaking order parameter at the critical point (e.g., density difference at the liquid-gas transition) through considering a second-order phase transition, where the internal variables change continuously from the critical point due to the propagation of material-damaging dissipative waves. This extension to the first-order theory allows assessing the dynamics of coupling the rates of chemical reactions, failure and fluid-flow as well as thermo-mechanical instabilities of materials. The approach gives physics-based insights into the processes that are commonly described by empirical relationships. Here, we present a first analytical model extended by numerical analyses and laboratory and field observations that show the existence of these precursor phenomena to large-scale instabilities. In the event that the propagating waves lead to a large-scale instability, the dissipation processes are predicted to leave tell-tale multi-scale structures in their wake, which can be used to decipher the dynamic processes underpinning the event.

First analyses from a laboratory analogue experiment are presented, illustrating the slow speed of the waves and their peculiar dispersion relationships and reflection from boundaries. An idealized 1-D (oedometric) compaction experiment of a highly porous (45% porosity) carbonate rock investigates the emergence of localized compaction bands proposed to be formed by long-term

resonant collision of the transient dissipation waves. Complementary numerical models of the phenomenon allow in-depth analysis of the dynamics and illustrate the physics of the formation of dissipative waves.

For field application, we propose that a multiscale analysis - from the grain- over the outcrop- up to the lithospheric scale - can be used to extract quantitative information directly from natural deformation bands, fractures, and fault zones on, for example, the state of stress, the size of the underlying earthquakes, the flow and mechanical properties of the host rock, and the spatiotemporal evolution of fluid and mechanical pressure associated with faulting. The experimental investigation of the fundamental instability has broader applications in the fields of industrial processing of multiphase materials, civil, mechanical, and reservoir engineering and solid mechanics.