The Australian Solid Earth Simulator program and advances in understanding the physics of earthquakes

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Summary

The Australian Solid Earth Simulator program aims to develop micro-scale simulation models and software systems and to use the new virtual laboratory capability to probe the physics of complex solids and earthquakes. The ultimate aim of the program is to progress towards the grand scientific challenge of earthquake forecasting and to provide a means to develop improved industrial processes. The program consists of two main components: (1) development of micro-scale simulation models and studies of the underlying mechanisms for earthquakes, fault zone behaviour, localisation phenomena and macroscopic failure; and (2) development of macro-scale simulation models and studies of the physics of interacting fault systems in the Australian intraplate setting and crustal geodynamics. The core research program is multi-institutional involving QUAKES, CSIRO and University of Western Australia, and is collaborative with participants of the ACES visitors program and the Australian Geological Survey Organisation. QUAKES has developed a plug-and-play micro-scale simulation software system – LSMearth – that provides a powerful virtual laboratory and collaborative research environment. Recent numerical simulation studies point to an evolution in the stress correlation function in the lead-up to macroscopic failure suggesting earthquake forecasting is feasible. Observational studies in collaboration with a team from China suggest two recent Australian earthquakes including the deadly Newcastle earthquake could have been forecast. A three-year macro-scale simulation project aiming to simulate centuries of seismicity within a large 3D model representative of the Australian crust is planned.

The micro-models development program

A major focus of the Australian national program is micro-scale numerical simulation models. QUAKES has developed the particle based lattice solid numerical model (LSM). In its present form, the model can simulate fracture, friction, fluid and thermal effects (thermo-porous and thermo-mechanical feedback), granular dynamics, and healing. A plug-and-play software system for the lattice solid model termed LSMearth (Figure 1, left) has been developed (Place and Mora, 2000[2]) to allow easy inclusion of different micro-physics or numerical intergration methods into the model. This enables multiple researchers to develop and use the same software and visualisation system and thus fosters collaborative scientific research. During 2000, the new LSMearth virtual laboratory environment commenced being applied to study of the physics of earthquakes in collaboration with visiting scientists from China, Japan and USA.

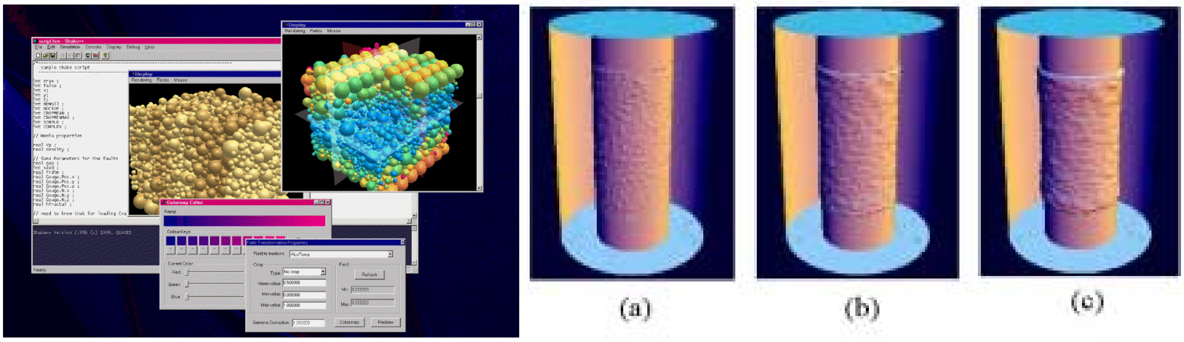

Figure 1: Left: The LSMearth micro-scale modelling software system developed at QUAKES showing a rock structure being subjected to compression[2]. Right: Snapshots of a compression experiment of a cylindrical sample using the discrete element model developed at CISM (courtesy of Hide Sakaguchi[3]).

The Centre for Industrial Solid Mechanics (CSIRO/UWA) independently developed a different particle model based on the discrete element method and is applying the approach to the study of fracture, friction and localisation phenomena in rocks (Figure 1, right). The two different particle based models have different capabilities and numerical approaches, thereby providing a means for validation experiments as well as for development of next generation particle based models combining the best features of each.

Recent advances in earthquake forecasting

Simulation studies using the LSM have been conducted of granular models representing simplified interacting fault systems. These demonstrate the existence of an evolution in the stress-correlation function in the lead-up to large system sized ruptures that point to an underlying mechanism for earthquake forecasting consistent with the Critical Point Hypothesis for earthquakes[1]. Australia-China collaborative research conducted through the ACES visitors program (Australian team: Mora, Place, Weatherley; Chinese team: Yin, Xia, Peng & Wang) yielded the following preliminary outcomes (see Proc. 2-nd ACES Workshop): (1) observations of the critical region for AMR and LURR forecasting approaches are similar suggesting a common physical mechanism (Yin et al), (2) two recent Australian earthquakes exhibited both AMR and LURR and suggesting they could have been forecast (Yin et al), (3) simulations using the lattice solid model exhibit LURR behaviour suggesting its underlying physical mechanism can be studied using the LSM (Wang et al), and (4) CA studies imply multiple behaviours span phase space including SOC, CP and switching suggesting CA studies combined with more realistic physically based models can provide a means to study and identify phase space regimes and advance towards the goal of earthquake forecasting (Weatherley et al).

References

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[3] Sakaguchi, H., Makinouchi, Muhlhaus, H-B., 2000, *Three dimensional particle based modeling of frictional behaviour in shear zones*, in: Proc. 2-nd ACES Workshop.