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CREEP: LONG-TERM TIME-DEPENDENT ROCK DEFORMATION IN THE NEMO DEEP-SEA LABORATORY: A PILOT STUDY.

The time-dependent properties of brittle rock deformation are of first-order importance for understanding the long-term behaviour of the Earth's upper crust, as well as for the temporal evolution of mid-term precursories before earthquakes (Meredith et al., 1990; Main et al., 1992) and eruptions (Vinciguerra, 1999;2002). Water saturated rocks are ubiquitous in the crust, and the chemical influence of water leads to time-dependent deformation and failure through such mechanisms as "stress corrosion cracking" that can allow rocks to fail over extended periods of time at stresses far below their short-term failure strength and at low strain rates (Atkinson & Meredith, 1987).

The traditional way of investigating this has been to carry out laboratory "brittle creep" experiments on rock samples held at constant differential stress, and to measure the resulting strain as a function of time.

Typically, results have been interpreted involving three individual creep phases; primary (decelerating), secondary (constant strain rate or steady state) and tertiary (accelerating or unstable). The deformation may be distributed during the first two, but localizes onto a fault plane during phase three.

Classical models to explain this behaviour (reviewed in Main, 2000) have concentrated on the secondary phase, while those attempting to explain accelerating creep (e.g. Davy et al., 1995) are necessarily more complex, requiring large numbers of degrees of freedom. In practice, these latter are not solvable with the limited data currently available. More recently, mean-field theory damage mechanics approaches have been developed, involving a two-stage failure process representing a transition from distributed microcrack damage up to some critical threshold where crack interaction leads to acceleration to failure on a localized fault plane (Lockner,1998; Main, 2000).

Recent experimental observations (Baud & Meredith, 1997) support this approach. While the applied creep stress has a crucial influence on the creep strain rate and overall time-to-failure (e.g. a 10% reduction in stress produces two orders of magnitude reduction in strain rate and increase in time-to-failure), the level of damage at the onset of the accelerating (localization) phase remains essentially constant.

This is true whatever the measure of damage; creep strain, crack volume or acoustic emission energy. However, Main (2000) points out that model predictions outside the the range of laboratory values are strongly dependent on the precise mathematical form of the equation describing the stress corrosion mechanism (exponential (Lockner) or power law (Main)), and concludes that it will be difficult to distinguish between competing models given the lower limit of strain rates practicably achievable in the laboratory. This project aims to address that problem directly by extending

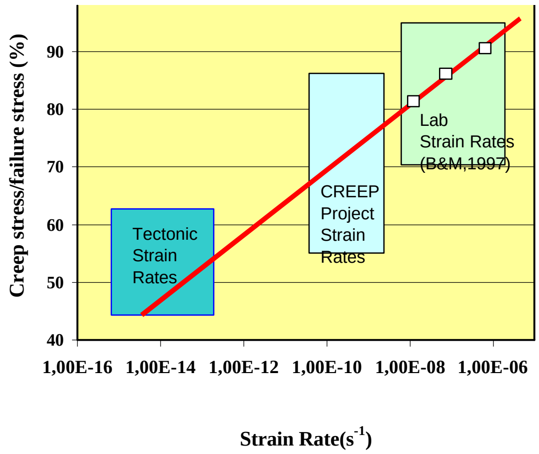
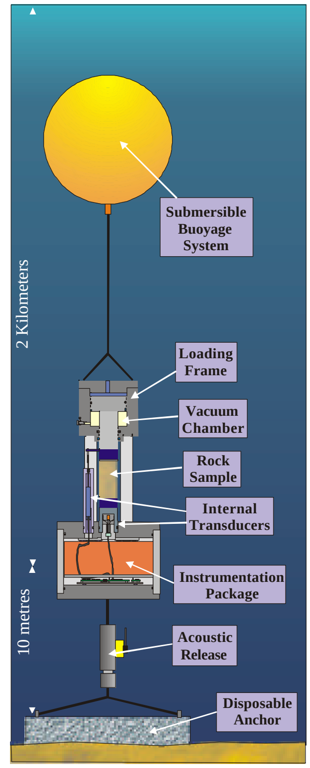


Fig. 1



significantly the range of achievable strain rates through much longer-term experiments conducted in a deep-sea laboratory, as shown in Figure1.

Fig.2

In order to do so we are building a prototype apparatus for long-term constant stress "creep" experiments to be conducted in collaboration to NEMO. NEMO (NEutrino Mediterranean Observatory) is a research and development consortium towards the realization of a submarine laboratory for high-energy neutrino detection and interdisciplinary activities. While studies are developed to search and characterise the suitable site and technologies, research activities are carried out at the interdisciplinary ‘test site’ of Laboratori Nazionali del Sud located 20km offshore of Catania.

The test site is relatively close to the coast, has flat bathymetry at a depth of 2100m, has weak and stable water currents, and low biological activity and sedimentation rate. A building has been purchased on the coast to act as a data reception centre.

Data will be transmitted in real time, by means of an electro-optical cable connection. The experimental arrangement is shown in Figure 2.

The deformation apparatus (with internally sealed measurement transducers) sits above an instrumentation package (battery pack and data acquisition system) in a sealed pressure housing.

Since for the pilot tests no connection with the electro-optical cable is planned, the battery pack has a lifetime of 6 months, and a back-up power source protects data should the battery pack fail.

The apparatus is manufactured from a corrosion resistant alloy for extreme corrosive conditions. The confining pressure around the jacketed, water-saturated rock sample is provided by the ambient water pressure (≈20MPa), and the constant creep stress is provided by an actuator that amplifies the ambient water pressure.

The great advantage of operating at depth is therefore that the system is simple; it is "passive", has few moving parts, and requires no maintenance.

Tests can therefore be run for much longer times than would be feasible in the laboratory, thus accessing strain rates intermediate between laboratory and tectonic rates (Figure 1). The duration of laboratory creep experiments is typically a few hours to a few days. In this pilot study we propose to conduct a minimum of three experiments with durations from a few weeks to up to 6 months (in future phases we envisage creep experiments with durations up to several years). The apparatus will be fixed approximately 10m above the seabed; held in place by a disposable concrete anchor and supported by a deep-sea buoyage system.

At the end of each experiment, the ensemble can be recovered by activating the acoustic release, whereupon it will float to the surface to be recovered by CNR oceanographic vessels.

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