Geohazards

Report by
Juergen Mienert
ESONET geohazard working group
Barcelona

Introduction and working group objectives

The ESONET geohazard working group discussed European continental margins and oceanic islands where ocean geohazards occur. We focused on: (1) What do we wish to achieve studying geohazards? (2) What are potential target areas? (3) What has to be monitored using ocean observatories?

The importance for improving our understanding of geohazards is evident from global events. Globally, disasters affected 146 million people and inflicted an estimated damage of US$ 100-145 billion over a few years as documented by various reports. One of the major natural catastrophic events was dramatically shown by the Sumatra earthquake and associated tsunami of late 2004. It became very clear to the public that the oceans are the source of some of the most severe geologic hazards. Tsunamigenic earthquakes and/or submarine slides tend to occur several times per century in some areas, commonly destroying coastal areas, with devastating impact on communities and coastlines both near to and far from the source. Such events are also evident at European continental margins as for example by the 1755 Lisbon earthquake in the E-Atlantic and to a minor degree by the 2003 Algerian earthquake in the W-Mediterranean.

"Geohazards" are events caused by geological processes that change dramatically environmental conditions and present severe threats to coastal populations, offshore and onshore properties and offshore built infrastructures. Earthquakes, submarine landslides, volcanic eruptions, and tsunamis are typical examples of such natural events and their consequences. Offshore, geological processes and human activities, for instance in connection with offshore petroleum exploration and production, can contribute causing man-made geohazards. Earthquakes are often considered the most important geohazards but much of the damage may be caused by the submarine slides and large mass flows triggered by them.

There is an urgent need to improve our basic technology to determine better the development of geohazards and inherent risks, and our ability to deal with them. Consequently, the monitoring of potential geohazard locations using long term observatories led to a request from our society towards new research and technology development. The need is also accentuated by increased concern for geohazards in offshore hydrocarbon exploration areas. Increased vulnerability of more coastal areas to earthquakes because of rapid growth of urban centres exists as well. Furthermore, climate research indicates that one may expect more geohazards in the future due to ocean warming, increased ocean current strength, melting of ice on land, melting of gas hydrate in the seabed and permafrost thaw.

Results of the Working group discussions

What do we wish to achieve studying geohazards?

The mechanisms and controls on in-situ deformations leading to geohazards are still incompletely understood, as are their distribution in time and space. Due to their oceanic setting, resulting submarine slope failure and/or tsunamigenic events are often preserved in the marine sedimentary record. Thus, we need first to read this past geologic record including source and impact areas, and second to monitor recent physical and chemical processes and changes in material properties associated with geohazard development. Developing a scientific understanding of the geological and physical processes underlying these hazards is crucial for our efforts to evaluate their frequency and distributions, to produce predictive models, and to mitigate their risks. The characterization and understanding of the causes and consequences of oceanic geologic hazards is an important element for basic ocean science and urban and offshore planning.

An European observatory network involving potential geohazard fields in Mediterranean and NE Atlantic regions needs to be supported by:

- ✓ Geohazard Seabed Mapping and Geological Site Characterization
- ✓ Fault Offsets and Fault Activity Analysis
- ✓ Pore Pressure Analysis
- ✓ Gas Hydrate Quantification and Stability Modeling
- ✓ Tsunamigenic Geohazard evaluations
- ✓ Hazard Impact Assessment

What are potential target areas?

Oceanic hazards can be generated in many geological settings encompassing shelf areas with man made or natural made gas blow outs (North Sea, Barents Sea) and continental slope regions. These include passive margins and their slopes in which rapid sedimentation, fluid overpressure, or gas hydrate dissociation can cause slope failures. Explosive eruptions of volcanoes at active margins of the Mediterranean and sudden flank deformations on coastal or island volcanoes such as the Canaries can induce large scale collapse and catastrophic landslides having the potential for devastating tsunamis. Earthquakes along major faults systems of the E-Mediterranean or the W-Mediterranean are frequently active with a potential for causing damage onshore and offshore. Clearly, the seismically active plate boundaries of the Mediterranean are potential target areas but also the areas of the North where the largest oceanic gas hydrate provinces of Europe occur. Other target areas are large submarine canyons at the Iberian Peninsula such as the Nazare canyon or the Rhone canyon in the E-Mediterranean. Active and frequent downslope transport by turbidity currents may inhibit building underwater infrastructures or destroy existing underwater cable systems. Examples of offshore geohazard target areas are therefore regions within:

- ➢ Active fault systems and Seismicity
- ➢ Slope systems with slope instabilities and/or active submarine channels
- ➢ Canyon systems with active turbidity currents
- ➢ Volcanic systems and Oceanic islands
- ➢ Shallow (pressurised) gas systems and gas hydrates
- ➢ Exploration sites for assessing the environmental impact

What has to be monitored using ocean observatories?

The main monitoring goal for ocean geohazards should be to improve our pre-warning and hazard assessment capability. It is essential to develop and verify methodologies and techniques to understand the risk associated with offshore geohazards.

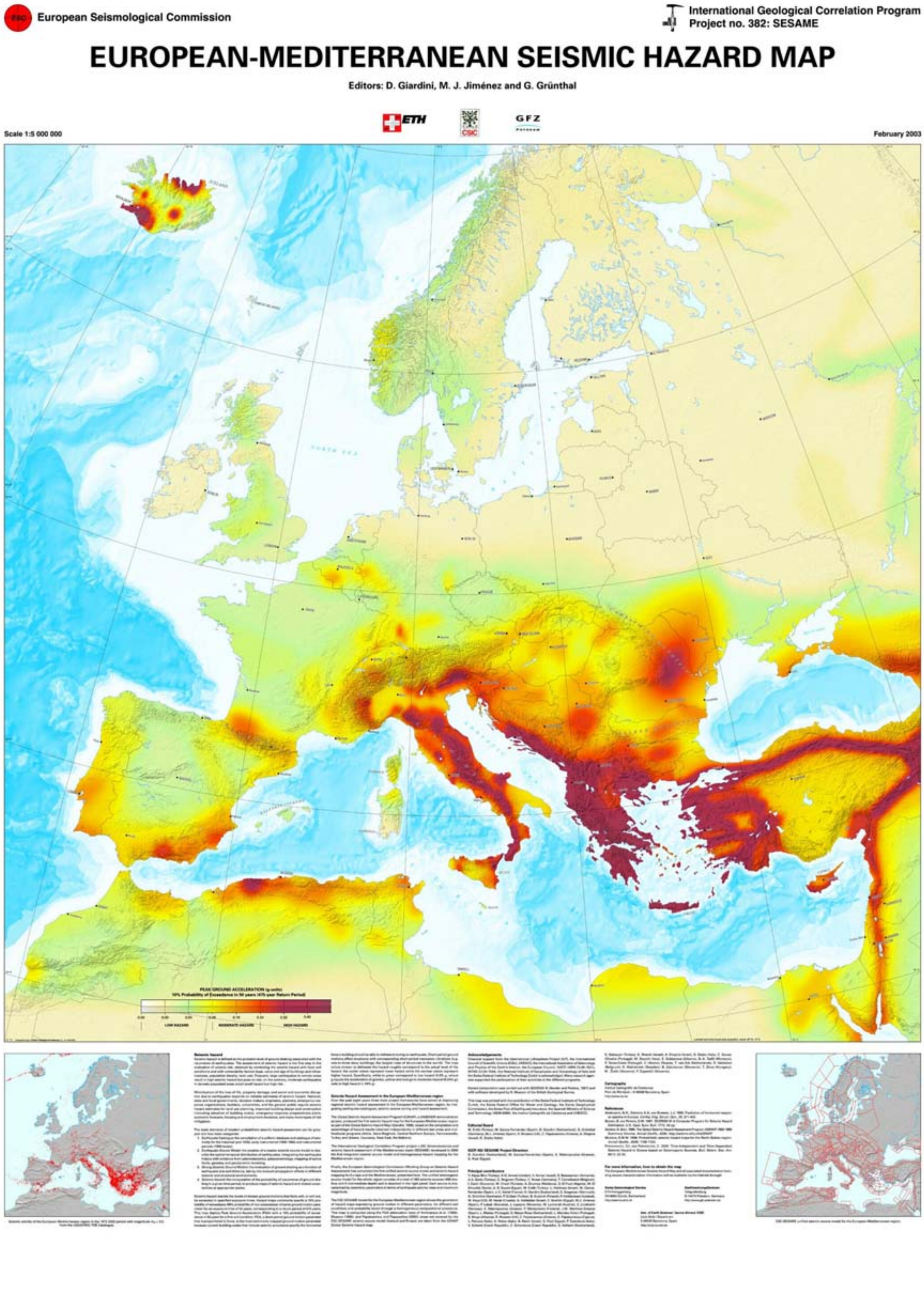
Today's and future scenarios of human activity will neither stop at deepwater slopes (> 1000m water depths) nor at tectonically active areas. Seabed deformations and instability, mass movements, excess pore pressure build up generated by natural processes or human activity, may cause damage to and loss of humans and infrastructures. Thus a careful measurement and monitoring of each geological setting is important to understand seabed instability mechanism.

Monitoring rapid deposition of sediments and tectonic compression where a high excess pore pressure is generated is needed. The excess pore pressure can cause reduced soil strength and thus an increased likelihood of seabed instability both at a large and small scale. A geohazard needs to be monitored starting at the precursor. One of the keys is also to determine geohazards from the deep to the shallow geosphere, and to monitor both the biosphere and hydrosphere (pore water) response before, during and after an event. In particular the influence of the hydrosphere on generating a geohazard is so to speak unknown. **In summary, we need to better understand the precursors of geohazards!** For example, two-dimensional modeling of the New Jersey margin suggests that lateral fluid flow in permeable beds under differential overburden stress produces fluid pressures that approach the lithostatic stress where overburden is thin, i.e. at the base of the slope. This transfer of pressure may cause slope failure initiation at the base of the continental slope (Dugan and Flemings, 2000) leading to catastrophic retrogressive slope failures as documented on the passive Norwegian margin. The timing of the processes is more or less unknown.

If new knowledge can be achieved it will enable a more rational assessment of geohazards including their risks, and it will give valuable assistance for future ocean infrastructure and coastal developments. Each geologic setting in the European seas will have different requirements, depending on tectonic activity, slope morphologies, and other forcing mechanisms (Cochonat et al., 2007). The availability and further development of observatory technologies with participation of offshore industries will play a key role in defining the types of *in-situ* and long-term measurements that can be made at reasonable costs. Real time observatories are requested to transmit and report very important precursor measurements.

Certainly, we may question whether the precursory phenomena for geohazards do exist. Clearly, we never will be able to increase our predictive capability if we do not determine, which transient signs might indicate imminent geohazards.

Thus, real-time sea-floor observations and long-term monitoring of regions, where a geohazard might occur in a relatively short term are necessary. Transients in physical parameters that are deemed important are mainly seismic moments, fluid flow and pore pressure, gas hydrates and pore pressure, temperature, rate of sediment deformation, rapid and high sedimentation rates, weakened sediment layers (Mienert, in press). Transients in the geochemistry of pore fluids may as well be important. Supporting the request for observatories, it becomes clear that the real time observations cover not only a range of physical and geochemical sensors but also a range in depth from the seabed to the deep geosphere, which requires a careful selection of sites and the involvement of drilling operations to deploy borehole observatories.



Seismic Hazard Map of the European-Mediterranean region, in terms of peak ground acceleration at a 10% probability of exceedance in 50 years for stiff soil conditions, has been published in 2003 under the auspices of the European Seismological Commission (ESC).

References

Cochonat, P., Dürr, S., Herzig, P., Mevel, C., Mienert, J., Schneider, R., Weaver, PPE, Winkler, A. 2007. The deep-sea frontier- Science challenges for a sustainable future, ISBN 92-79-05266-8, European Communities, printed in Belgium, pp.52.

Dugan, B., Flemings, P. B. 2002. Fluid flow and stability of the US continental slope offshore New Jersey from the Pleistocene to the present Geofluids 2 (2) , 137–146 doi:10.1046/j.1468-8123.2002.00032.x

Mienert, J., in press. Methane hydrates and submarine slides, Encyclopedia of Ocean Sciences, Elsevier-Oxford, UK.