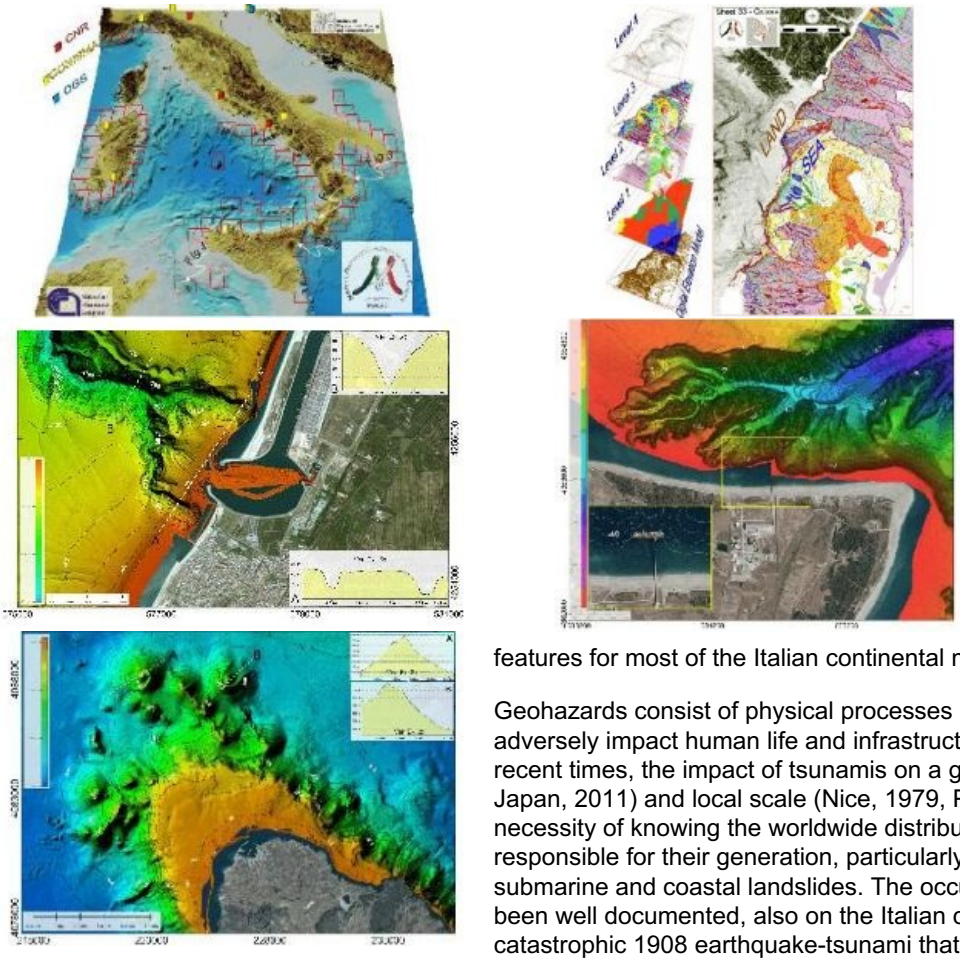
A FIRST-ORDER GEOHAZARD ASSESSMENT BY MEANS OF REGIONAL SEAFLOOR MAPPING

The Italian MaGIC Project



Over the past decades interest for marine geohazard assessment has rapidly grown up, driven by the increasing exploitation of natural resources, the emplacement of bottom-lying structures (cables and pipelines) and by the development of coastal areas, whose infrastructures increasingly protrude to the sea. At the same time, recent advances in seafloor mapping techniques have greatly improved our knowledge of geomorphic features that can be regarded as geohazard indicators, such as volcanic vents, slide scars, canyon headscarps, and fault-related seafloor unevenness. The national Project MaGIC (Marine Geohazards along the Italian Coast) is aimed at depicting potential geohazards based on the acquisition of high-resolution bathymetry and on the production of maps of the geohazard-related geomorphic features for most of the Italian continental margins.

Geohazards consist of physical processes and related effects that have the potential to adversely impact human life and infrastructures, thus leading to a situation of risk. In very recent times, the impact of tsunamis on a global (Indonesia, 2004; Samoa Islands in 2009; Japan, 2011) and local scale (Nice, 1979, Papua New Guinea, 1998) has highlighted the necessity of knowing the worldwide distribution of submarine geological structures responsible for their generation, particularly, seismogenic faults, volcanic activity, submarine and coastal landslides. The occurrence of such catastrophic processes have been well documented, also on the Italian continental margin, as highlighted by the catastrophic 1908 earthquake-tsunami that destroyed Messina and Reggio Calabria, causing over 60,000 casualties or by the more recent landslide-generated tsunamis that occurred at Gioia Tauro in 1977 (Colantoni et al., 1992) and Stromboli in 2002 (Chiocci et al., 2008).

The study of these processes and the assessment of their related hazard has significantly improved from the recent developments in seafloor imaging and mapping techniques, to the extent that many research projects designed for defining marine geohazards are essentially conceived as seafloor mapping projects.

In this view, the Italian Civil Protection Department has funded the 5-year national project MaGIC (December 2007- December 2012), aiming to acquire multi-beam morpho-bathymetry along the most geologically active margins of Italy in order to constitute a reference basis for detecting the most dangerous areas, where future monitoring activities can then be concentrated. This issue is pursued through the production of the ‘Map of geohazard features of the Italian Seas', made up of 72 sheets at scale 1:50,000 (Fig. 1), covering most of the Italian continental margins from 50 to (at least) 1,000m bsl.

The project is co-ordinated by IGAG-CNR (Istituto di Geologia Ambientale e Geoingegneria) and led by Prof. F.L. Chiocci and is supported

by the participation of the whole Italian scientific community currently active in the field of Marine Geology within the four Research Institutes (CNR and OGS) and eight University Departments (Fig 1). More than 70,000 nautical miles of multi-beam data will be analysed and interpreted, of which about 60,000 was specifically acquired during the project. Data acquisition is carried out using the research vessels Urania, Maria Grazia (CNR-National Research Council), Universitatis (CoNISMA Consorzio Interuniversitario per le Scienze del Mare) and Explora (OGS - National Institute of Oceanography and Experimental Geophysics) that were equipped with different multi-beam systems operating at different frequencies according to different bathymetric surveys (Tab. 1). Acquisition standards relative to instrumental calibration and settings, as well as to data processing, have been established in order to assure the highest homogeneity of products despite the very diverse settings along the Italian continental margins.

R/V	Multi-beam systems
Universitatis	Reson SeaBat 125 (455kHz, range 0.5-100m
MariaGrazia	Kongsberg Simrad 3002D (300kHz, range 1-150m)
Explora, MariaGrazia	Reson SeaBat 8111 and 7111 (100kHz, range 5-700m)
Urania	Kongsberg Simrad 710Full (70-10kHz, range 10-1500m)
Universitatis	Reson 8160 (50kHz, max depth 2,700m, range 100-500m)
Explora	Reson SeaBat 8150 (12-24 kHz, range 1,000-6,000m)

Table 1: Multi-baem equipment and the Research vessel used for the MaGIC project

Each sheet is defined by a digital multi-level cartographic file supported by descriptive notes and tables. Specifically, each file is made up by a contour layer, grids at different resolution for the different bathymetric intervals and four specific cartographic levels with increasing detail (Fig. 2):
Level 1 - Physiographic Domains (scale 1:250,000): include regional or sub-regional physiographic features, such as continental shelf, continental slope, intra-slope and bathyal basins, intra-slope relief and seamounts, volcanoes, region-wide erosion areas.
Level 2 - Morphological Units (scale 1:50,000): include the envelope of broad, sub-regional areas defined by a dominant geological process or feature type (e.g. canyon volcanic outcrop, significant landslide, bedform field, etc). Each unit is the object of specific morphometric measurements and classification that allow an association with attributes and tables in GIS environment.
Level 3 - Morpho-bathymetric Elements (scale1:50,000): constitute the basic level of information relative to geohazard features and processes by identifying and tracing all geomorphic features of the seafloor (e.g. lava flow, erosive scarp, slope break, bedform crest, etc) using a lower dimensional limit of about 100m.
Level 4 - Critical Zones (detailed highlights at various scale): because of the civil protection purposes of the project, we include a level aimed at identifying specific situations, defined as Critical Zones (CZ), where geohazard related features deserve special attention due to their close location to human settlements and infrastructures. They are represented by a red rectangle on the cartographic file with a detailed description on specific notes.

Preliminary Results and Conclusions

A total of 60% of the total expected amount of multi-beam data have been acquired in the first three years of the Magic Project. Despite the fact that the multi-beam data were acquired by different research groups in different areas and during different meteo-climatic conditions, the acquisition standards and ad-hoc data processing have guaranteed the precision of the data, as demonstrated by the fact that they fit well in overlapping areas between adjacent sheets.

The acquired data have been used to produce 50 Sheets of the ‘Map of geohazard features of the Italian Seas', where several instability features have been mapped both in volcanic and non-volcanic settings. Most of them occur in shallow-water sectors (first 200m bsl), a few tens to a few hundreds of metres far from the coast. Some of them are located off important coastal infrastructures, such as harbours (e.g. Gioia Tauro Harbour, the busiest and largest container terminal in Italy and the Mediterranean Sea, Fig. 3) and chemical plants (e.g. Punta Alice, Fig. 4).

In addition, several new submarine volcanic and volcano-tectonic features were identified corresponding to the Italian insular volcanoes, such as an amazing field of submarine volcanic cones off Pantelleria (Fig. 5), where a spectacular submarine eruption occurred in 1891 characterised by floating lava bombs on the sea surface. These new data enable us to make new hypotheses on the evolution of these edifices and provide useful insights on their related geohazards.

On a larger scale, the cartographic experience acquired during the first three years of the Magic Project has clearly shown the importance of standardising acquisition principles and interpretative and representative methodologies. For regional scale mapping, the spectrum of geological settings to account for, as well as the variability of a given geomorphic type is extremely broad. The high variability of genetically-equivalent geomorphic features calls for the entire variability range to be accounted for by general definitions and symbols.

The major limiting factor of bathy-morphological data for geohazard assessment is related both to a reliable definition of the frequency of a specific event (a landslide, an eruption) within a given area and to determining the activity state of these events. This information, in fact, cannot be unveiled based solely on multi-beam data, but it requires more detailed studies, i.e. seismic profiles and seafloor sampling. Most importantly, they cannot be accomplished at regional scale, especially in geologically active areas, where the cost of detailed studies

combined with the extremely high number of failures to examine make such hazard assessments prohibitively expensive. Detailed multi-beam mapping and interpretation of geomorphic features thus represent the first, unavoidable step in the identification of marine geohazards, since it remains the only tool for a regional and homogeneous assessment of the occurrence of geohazard feature.

Further Reading

Casalbore, D., Bosman A., Chiocci F.L., 2011. Study of recent small-scale landslides in geologically active marine areas through repeated multi-beam surveys: examples from the Southern Italy. In Submarine Mass Movements and Their Consequences, Series: Advances in Natural and Technological Hazards Research.

Chiocci, F.L., Romagnoli, C., Tommasi, P., Bosman, A., 2008. The Stromboli 2002 tsunamigenic submarine slide: characteristics and possible failure mechanisms. Journal of Geophysical Research, VOL. 113, B10102Colantoni, P., Gennesseaux, M., Vanney, J.R., Ulzeca, A., Melegari G., Trombetta, A., 1992. Processi dinamici del Canyon sottomarino di Gioia Tauro (Mare Tirreno). Giornale di Geologia, ser. 3 Vol. 54/2 pp. 199-213.