EMB Policy Brief

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Uncovering the hidden threat of Marine Geohazards in Europe

European Marine Board
Advancing Seas & Ocean Science

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UKRI Natural Environment Research Council
National Oceanography Centre

This Policy Brief is based on Position Paper 26[1] of the European Marine Board, drafted by an interdisciplinary working group (WG Marine Geohazards, February 2020 – November 2021) consisting of 12 experts, nominated by the European Marine Board member organizations.

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[1] Kopp, H., Chiocci, F. L., Berndt, C., Çağatay, M. N., Ferreira, T., Fortes, C. J. E. M., Gràcia, E., González Vega, A., Kopf, A. J., Sørensen, M. B., Sultan, N., Yeo, I. A. (2021) Marine geohazards: Safeguarding society and the Blue Economy from a hidden threat. Muñiz Piniella, A., Kellett, P., van den Brand, R., Alexander, B., Rodríguez Perez, A., Van Elslander, J., Heymans, J. J., [Eds.] Position Paper 26 of the European Marine Board, Ostend, Belgium. 100 pages. ISSN: 2593-5232. ISBN: 9789464206111 DOI: 10.5281/zenodo.5591938 https://www.marineboard.eu/publications/marine-geohazards-safeguarding-society-and-blue-economy-hidden-threat

A hidden threat to Europe

Europe is looking to the Ocean for opportunities to achieve the ambitious objectives of the European Green Deal[2] and to enable a sustainable Blue Economy[3]. Today, our society depends on critical coastal and marine infrastructure such as ports, telecommunication cables and renewable energy installations. With increasing human activities conducted in the marine environment and an increasing human population living at the coast, society is becoming more exposed and vulnerable to the impacts of marine geological hazards (or geohazards).

Widely-known marine geohazards are earthquakes, submarine landslides, volcanic eruptions, and the tsunamis associated with all of these. Lesser known marine geohazards include rapid changes on the seafloor such as migrating underwater sand waves, and fluid release from the seafloor that can lead to underwater landslides (Figure 1) and can damage infrastructure and operations at sea. In addition, engineering projects such as port expansions and CO_2 injection for carbon capture and storage (or CCS) may destabilize the seabed, thus generating human-induced geohazards such as earthquakes and submarine landslides.

Currently there are no standardized estimations of the impact of marine geohazards in European seas. This is because volcanic eruptions, earthquakes and earthquake-generated tsunamis are considered as "natural disasters", and other marine geohazards such as submarine landslides, underwater sand waves and fluid release from the seafloor are not mapped in a standardized way.

Cascading or cumulative events may often worsen the impact of a single event, for example where earthquakes trigger landslides that in turn trigger tsunamis. The increasing number of infrastructures at sea may also produce so-called Natech accidents[4]: technological accidents triggered by natural disasters. Examples of Natech accidents include the release of hazardous substances or failure of critical energy infrastructure after an earthquake or tsunami, such as the 2011 Tohoku-Oki earthquake and tsunami that affected the Fukushima-Daiichi power plant in Japan. Marine geohazards therefore need to be assessed using a multi-hazard and impact-based approach.

During the last two decades, there has been an increase in awareness of the dangers associated with large-scale disasters caused by geohazards, and that these are not 'a thing of the past'. Although geological events have accounted for only 9% of total global disasters in the past 20 years, they have accounted for 59% of all disaster-related deaths, making them by far the deadliest type of disaster (Mizutori & Guha-Sapi, 2020). In addition, with the interconnectedness of European coastal and marine infrastructure and considering Europe's social fabric and shared seas, a natural disaster on the coast of one European country, would mean that all the European Union Member States would be responsible for disaster relief and financing reconstruction. This makes a better understanding of marine geohazards in Europe financially prudent.

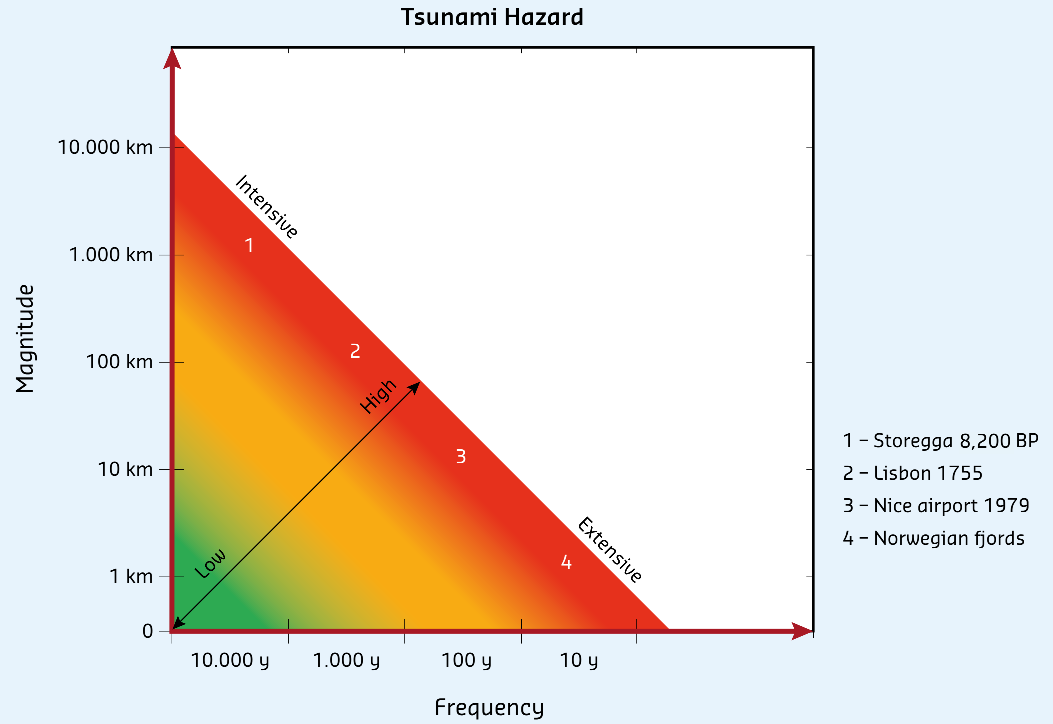

Figure 1. Four European landslide-generated tsunamis are compared in terms of magnitude and frequency, showing how the hazard level depends on the magnitude of the event and the recurrence time (or probability of occurrence). Fluid release from the seafloor has been hypothesized as driving factor for the 1979 Nice landslide and the 8,200 BP Storegga slide.

[2] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[3] https://ec.europa.eu/oceans-and-fisheries/ocean/blue-economy/sustainable-blue-economy_en

[4] https://unece.org/industrial-accidents-convention-and-natural-disasters-natech

Managing the risk

Geohazards are intimately linked to disaster risk. For most risks related to geological processes, prevention or reduction of the hazard is not an option as it is impossible to avoid natural phenomena. Risk mitigation should therefore focus on the reduction of exposure and vulnerability to hazards through the assessment of:

1. **the likelihood of a geohazard occurring;**
2. **the determination of its location, size and character; and**
3. **the primary and secondary impacts it will have (e.g. earthquakes that trigger tsunamis).**

Consequently, accurate disaster risk assessment and mapping for individual processes and regions is critically important for national and local risk governance and mitigation. Disaster risk information is critical for risk reduction strategies and policies to minimize the potential damage to people, infrastructures and economies that ensue from a natural or a human-induced geohazard. Regulatory agencies need this information to plan for the safe development of marine and coastal infrastructure and resources, and to understand the risk to existing infrastructure and prepare contingency planning, capacity assessment and business continuity planning in case a geological event occurs.

Risk assessment processes are a national responsibility and the assessment of marine geohazards is not currently considered in European marine-related directives and initiatives such as the Maritime Spatial Planning (MSP) Directive, Integrated Coastal Zone Management (ICZM), the Marine Strategy Framework Directive (MSFD) or the Blue Economy Strategy. This hampers the development of a general overview of where and why marine geohazards occur in Europe, needed to provide the basic knowledge required to forecast and assess these hazards. The only marine geohazards currently included in national risk assessment, mitigation and emergency plans are earthquakes and volcanic eruptions. Smaller but more frequent events that produce localized, though severe, disasters with great impacts on society and economy, should also be included in risk assessment and mitigation plans for marine and coastal areas. This is especially critical in regions with high coastal population densities, regions hosting substantial coastal and offshore infrastructure, and regions that serve as tourist destinations. Such an assessment of extensive risks (higher probability, lower impact) would lead to better informed decisions regarding the location of settlements and key infrastructure. It would also facilitate the use of early-warning systems to alert authorities and the population to an incoming event, and would promote procedures and prevention measures that would reduce damage.

Large but (luckily) infrequent events (such as tsunamis and volcanic eruptions) attract the most public and media attention, and prompt changes in policies for reducing future risks. However, most Europeans still do not understand that a destructive event such as the Minoan eruption that happened in Santorini during the Bronze Age (Figure 2) could occur again. These geohazards are perceived by many to mostly occur outside of Europe. Hence, increased awareness on the future impacts that marine geohazards could have on Europe is needed.

Geological hazards are unavoidable and will certainly continue to occur in the future. However, risk reduction and mitigation measures should be based on scientific knowledge of events that have occurred in the past, their trigger mechanisms and the propagation of their consequences. This can only be achieved by increasing our knowledge of marine geohazards to inform measures to reduce our exposure and vulnerability to these events.

Credit: Dimitris Sakellariou

Figure 2. The highly touristic slopes of Santorini Island are at the rim of what is left of a former volcano destroyed after the gigantic 'Minoan' super-eruption in the Bronze Age. A new volcano, Nea Kameni (in the foreground), is forming a few kilometers away.

Current scientific studies on marine geohazards focus on:

1. **identifying past geohazard events and evaluating their frequency; as well as,**
2. **identification of structures and monitoring current active processes that may evolve into a marine geohazard.**

Additionally, the development of mathematical models for hazard definition, geotechnical measurements, data collection in the field and laboratories (e.g. mechanical behavior of sediments), and event dating have gradually increased in recent years. These tools should be applied to understand the formation and mechanisms of marine geohazards and their consequences, but also to develop warning systems.

What science is needed to transform marine geohazard assessment in Europe?

Marine geohazards are usually poorly known, ill-characterized, and difficult to monitor with present-day technology (Figure 3). This means that detailed and complete maps of marine geohazards do not exist for most European seas.

To gather crucial data for the probabilistic risk assessment needed by insurance companies and other stakeholders, this requires a census of geohazard features and manifestations in European seas. This census should include a thorough characterization of past geohazard events and an assessment of their frequency.

Monitoring active geological processes and understanding their underlying mechanisms is expensive. This necessitates the use of all seafloor infrastructure installations (such as telecommunication cables) for geohazard monitoring, and support for national and European integrating research and monitoring efforts. These efforts will enable expansion of submarine observatory arrays to become multi-scale, multi-method surveillance for permanent geophysical monitoring of the seafloor. Understanding geohazards also require designated natural marine geohazard laboratories (i.e. areas where geohazards are studied closely, such as the surroundings of Mount Etna, Italy). This type of transformative multihazard assessment will provide better understanding of current risks such as slope movements, sub-seafloor fluid flow, and other destabilizing factors with tsunami potential, which is important for protecting coastal communities, their infrastructures, and the Blue Economy.

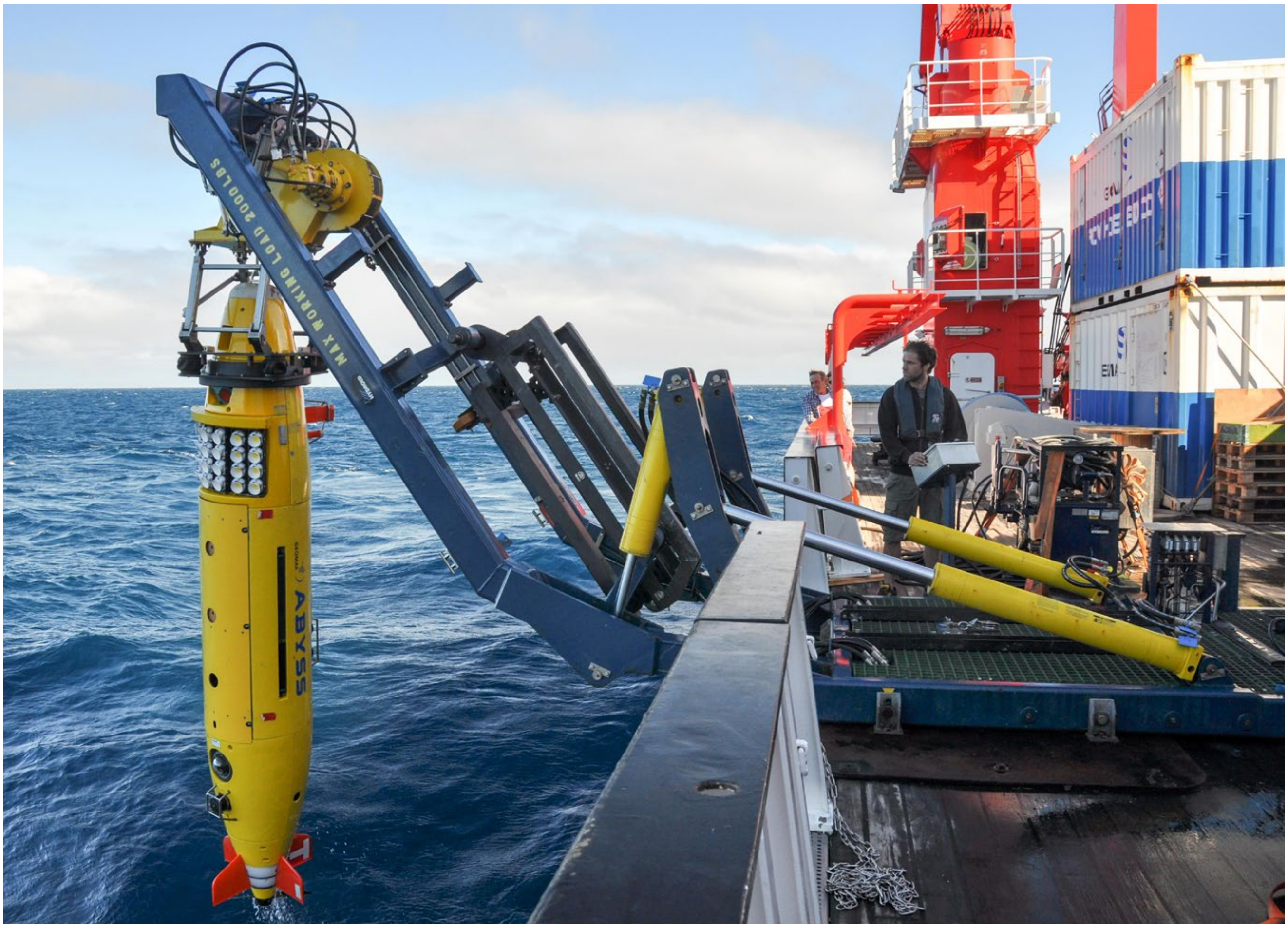

Figure 3. The Autonomous Underwater Vehicle (AUV, a robot capable of underwater missions without constant input from an operator) ABYSS being deployed from the *RV Sonne II* during the SO242/1 expedition.

One key aspect in geohazard research is time, i.e. identifying the stages leading to a certain event or risk. Consequently, innovative technologies (such as artificial intelligence, smart sensors, etc.) are needed to record and recognize precursors to geohazard events. The reliability, integrity and coverage of early warning networks based on seismological, geotechnical and other emerging methods is key. This will increase warning time and improve forecast quality, specifically for tsunamis. The capability to effectively warn and protect coastal communities, their infrastructure, the ecosystems and their services, needs to be ensured.

One key aspect in a changing climate is the potential link to how climate change may trigger geohazards, e.g. by changing Ocean temperature and currents causing more storm events (and associated run-off, sediment remobilization, etc.), groundwater charging, etc. Questions remain on whether a climate-induced increase in natural hazards and geohazards can be identified (and quantified), and whether the probability of their occurrence can be modelled. To model geological processes, larger time-scales (hundreds to thousands of years) are needed for both hindcast and predictive models. Modelling past tsunami wave progagation (Figure 4), wave height and inundation, and landslide reconstruction have been successful. In the future, machine learning approaches using (big) data from these past events and present-day processes will provide knowledge on geohazards, and inform future mitigation measures and resilience.

Recommendations

Considering that marine geological hazards are unavoidable and will certainly occur in the future, risk reduction mitigation measures should focus on decreasing the risk (exposure and vulnerability) and increasing resilience. These measures should be based on scientific knowledge of events that occurred in the past, their trigger mechanisms and the propagation of their consequences.

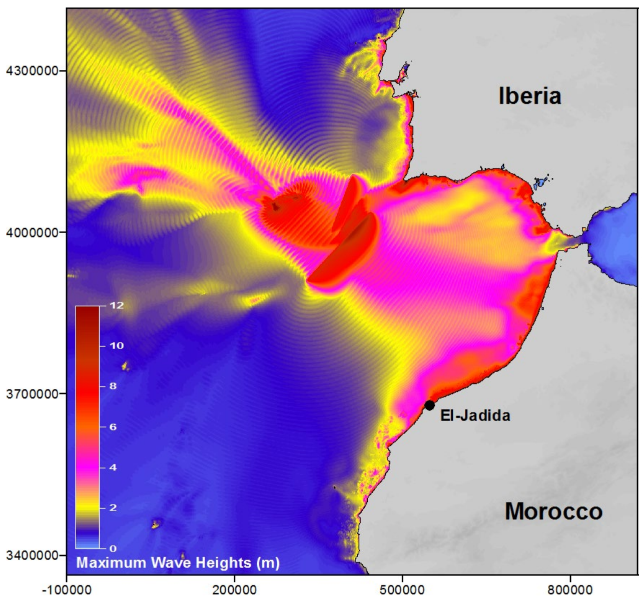

Figure 4. Maximum wave heights modelled for the 1755 Lisbon earthquake. Despite being named after Lisbon, the city that was hit hardest, the earthquake and tsunami occurred roughly 400 km to the south and also affected many towns in the Iberian Peninsula and Morocco.

To achieve this, we recommend to:

- **Include marine geohazards as natural hazards in all policies relating to risk mitigation and land management, at European, regional, national and local levels;**
- **Consider marine geohazards in local, national and EU marine and maritime legislation such as the EU Marine Spatial Planning Directive, legislation pertaining to Integrated Coastal Zone Management, and initiatives that relate to the safe development of the Sustainable Blue Economy;**
- **Require that public authorities use all seafloor infrastructure installations for environmental and geohazards monitoring;**
- **Develop probabilistic scenarios of marine geohazard risks for all major coastal settlements and industrial infrastructures;**
- **Establish stakeholder forums enabling sustained dialogue between the research community and stakeholders to identify knowledge gaps and technological needs. This could be achieved as part of specific EU research programs on marine geohazards;**
- **Set up field laboratories for marine geohazards at focus sites in Europe to concentrate research, facilities and *in situ* modelling;**
- **Promote a common standard for marine geohazard interpretation and mapping to complete a census of geohazard features in European seas, to ensure a pan-European approach for the safe development of the Blue Economy;**
- **Make raw data and homogeneous interpretations available to the scientific community to apply advanced analysis techniques in support of holistic marine geohazard studies;**
- **Combine long-term *in situ* geohazard monitoring with seafloor mapping and geohazard studies to identify long-range signals; and**
- **Support technological advancement to improve the detection capability and availability of sensors.**

References and suggested further reading

Mizutori, M., & Guha-Sapi, D. (2020). Human Cost of Disasters: An overview of the last 20 years 2000-2019. *In Human Cost of Disasters.* https://doi.org/10.18356/79b92774-en

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This Policy Brief and its recommendations support the UN Decade of Ocean Science for Sustainable Development. For more details, please read Position Paper 26 of the European Marine Board.

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EMB policy briefs provide a high-level summary of the key research needs and priorities on topics of strategic and emerging importance in seas and ocean science from a European perspective. Policy briefs are normally (but not always) summary versions of full EMB position papers, produced by EMB expert working groups.

Cover Photo: Plume of discoloured water rising to the surface during the 2011 submarine eruption of the volcano Tagoro, in front of the town La Restinga, El Hierro Island.

Credit: Antonio Márquez - Instituto Volcanológico de Canarias (INVOLCAN)

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