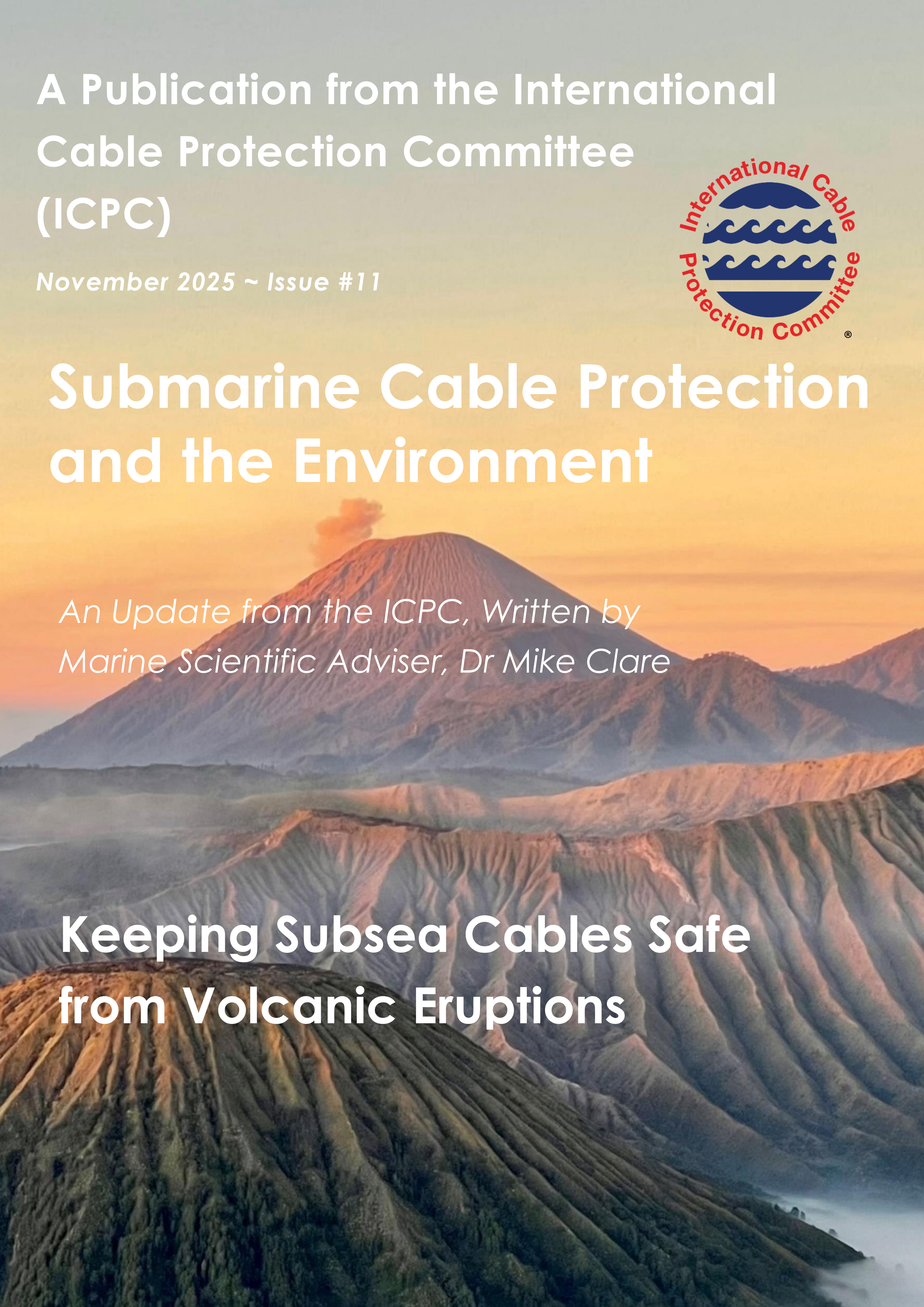

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Submarine Cable Protection and the Environment

An Update from the ICPC, Written by Marine Scientific Adviser, Dr Mike Clare

Keeping Subsea Cables Safe from Volcanic Eruptions

SUBMARINE CABLE PROTECTION AND THE ENVIRONMENT

An Update from the ICPC, Written by the Marine Scientific Adviser

PUBLISHER

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EDITOR’S CORNER

As a society, we are used to things working, or at the very least we have the desire for things to work. I’m used to always having a WiFi connection, turning on Netflix, and I expect power to be delivered to my house so I can keep the lights on. I find I don’t tolerate disruptions to those utility services very well, primarily because so much of my daily life depends on them and, quite frankly, I’m used to them working. But what is often overlooked or forgotten is simply the fact that the infrastructure delivering those services sit right outside in the physical and natural environment. And once in the natural environment, things happen.

Once infrastructure is placed in the natural environment, it is at some risk of damage. If infrastructure is damaged, it can be easy for someone to ask, ‘why was this placed next to a slope susceptible to landslides, or near a submarine canyon susceptible to turbidity currents, or in a region known for seismicity, or next to a volcano?’ The answer is usually, ‘because it had to be.’

A great example of this is submarine cable infrastructure placed near and on volcanic islands. Inhabitants of such islands require the same utility services as the rest of society, particularly noting that broadband connectivity can be considered a human right. But one cannot easily move a volcano to mitigate the risk to physical infrastructure. Instead, one has to acknowledge the environment in which infrastructure has to be placed to provide critical services to people, and then that infrastructure needs to be protected and maintained in a way feasible and suitable for the environment it’s placed in. Generally speaking, volcanic eruptions are rare, but extreme. It’s possible they may never occur in the design life of digital infrastructure, but they do happen. And as a result, it is important to understand these rare but extreme events, how to plan for them, and what maintaining or repairing infrastructure may look like in these environments.

As new and diverse submarine cable routes and landings open up, particularly in the South Pacific—and in geologically hazardous regions, it is important to learn from the past to design resilient routes and maintenance strategies in the future. Digital infrastructure will never avoid the physical and natural environment. But we can study the environment, learn from its processes, and adapt to this in our planning, implementation and maintenance of infrastructure that the world depends on.

Sincerely,

Ryan Wopschall
ICPC General Manager
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OVERVIEW

Volcanoes play a vital role in shaping our planet. They build new land, form fertile soils, and release gases that help regulate Earth's atmosphere and climate over geological timescales. Many of the world's islands, including those in Hawaii and much of the Pacific, owe their existence to volcanic activity. Volcanoes also provide valuable natural resources—such as geothermal energy, minerals, and fertile agricultural land—that sustain communities and economies. Studying volcanoes deepens our understanding of how Earth's interior works, offering insight into plate tectonics and the planet's evolution.

However, volcanoes can also create powerful natural hazards. Their eruptions can trigger devastating events such as ash falls, lava flows, pyroclastic density currents, gas emissions and mudflows known as lahars. These can resculpt landscapes, displace populations, damage infrastructure and disrupt global air travel. On land, volcanic activity can destroy roads, power networks, water supplies, and communications systems, making disaster response more difficult. Increasingly, scientists are recognising that volcanic hazards also extend beneath the sea. Submarine eruptions, flank collapses and

volcanic flows that enter the ocean can damage or sever subsea telecommunications cables, cutting off nations from the global internet—as seen in Tonga in 2022. While damage to subsea cables caused by volcanoes is relatively rare, when it does occur, such damage can occur over unusually long distances, damage multiple cables, and can affect remote island communities that are especially reliant on cables for digital communications. Understanding volcanoes is not only essential for appreciating Earth's dynamic nature but also for protecting the critical infrastructure that modern society depends upon.

FOOD FOR THOUGHT

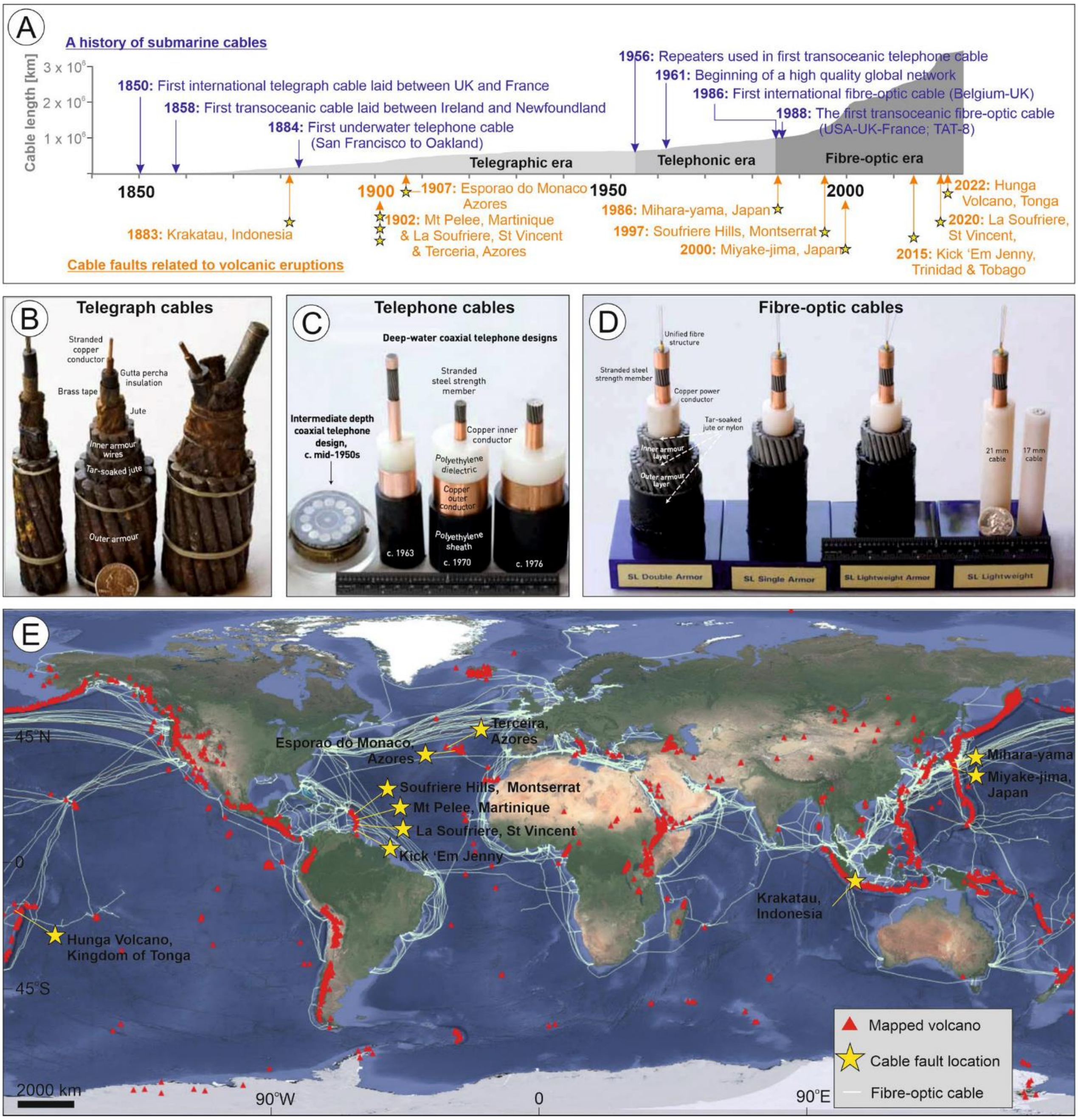
- Around 75% of all volcanic activity on Earth happens underwater—much more than on land. It is estimated that there are over one million submarine volcanoes.
- Most submarine volcanoes are located at divergent plate boundaries, where tectonic plates move apart and magma rises to form new oceanic crust.
- Some submarine eruptions can create new islands, like Surtsey (Iceland, 1963), and others like Kick 'em Jenny (near Grenada), can be hazardous to ships because of sudden gas releases.

INTRODUCTION

More than 1.8 million kilometres of fibre-optic cables lie across the seafloor worldwide, carrying over 99 percent of international digital data—everything from emails and video calls to trillions of dollars in daily financial transactions. These slender cables, usually no wider than a garden hose, form the invisible arteries of the modern economy, and play a particularly important role in connecting small island nations. Natural hazards account for only a relatively small proportion of damage to subsea cables (most is due to accidental human damage such as by fishing or anchor drags), but when such events occur, their spatial footprint can be very large (Bricheno et al., 2024). This is particularly the case for volcanic eruptions and their secondary effects. Recent research has shown that hazards associated volcanic activity at several volcanoes worldwide have damaged undersea cables all the way back to the earliest telegraph cables in the 19th Century through to today’s fibre-optic era (Clare and Yeo et al., 2025). Lessons can be learned from these past instances of damage to improve our understanding of volcanoes, the hazards they pose, and to enhance the resilience of the network that connects remote locations.

▼ **Drone view of a fish farm.**

INTRODUCTION



▲ **Figure 1:** Overview of cable damage relating to volcanic eruptions and the expansion of the subsea cable network. (A) Timeline illustrating the history of subsea cables (blue) and cable damage associated with volcanic eruptions (orange). Instances of cable damage are annotated by yellow stars. Photographs show examples of cables from the telegraph (B), telephonic (C), and fibre-optic (D) era. (E) Geographic distribution of in-service fibre-optic subsea cables, cable faults (stars), and volcanoes (red triangles) based on GVP (2024). Background relief is from Google Earth. Reproduced under a Creative Commons Licence from Clare and Yeo et al. (2025).

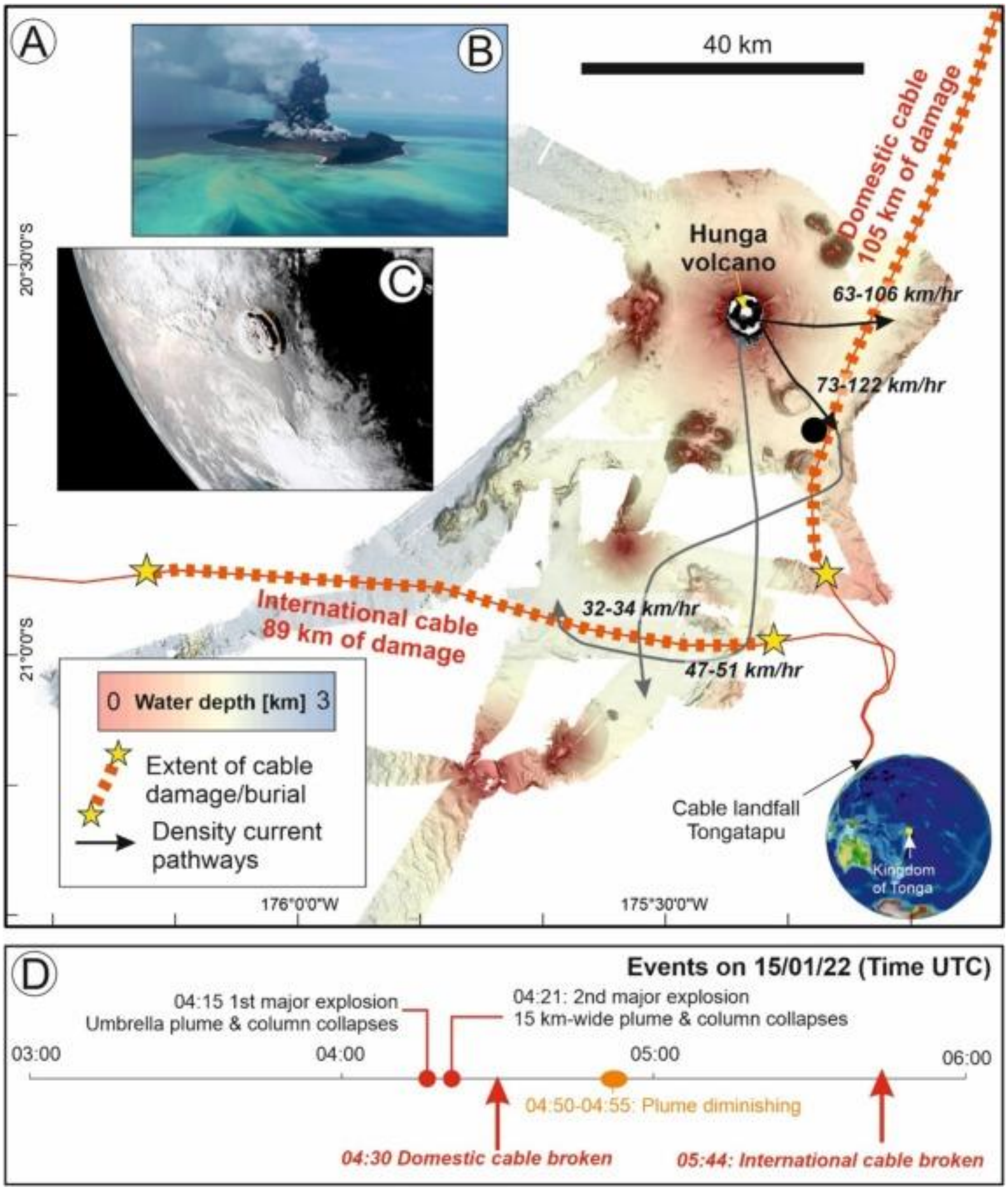
When the Internet Went Dark in Tonga

The 2022 eruption of Hunga volcano (formerly known as Hunga Tonga-Hunga Ha'apai) in the Kingdom of Tonga exposed this vulnerability in a dramatic fashion. When the volcano, which lay almost entirely underwater, exploded — one of the most powerful eruptions in more than a century — it sent towering ash plumes 57 kilometres into the sky and unleashed tsunami waves across the Pacific Ocean. But the most consequential effects were hidden below the surface. The collapse of the eruption column triggered dense, fast-moving flows of volcanic ash and debris that raced along the seafloor at speeds of up to 120 km/hour (Clare and Yeo et al., 2023). These flows severed both of Tonga's subsea cables: its only domestic line which connected island groups, and its only international link to Fiji. Overnight, an entire nation of 100,000 people was cut off from the global internet and phone networks during a major disaster.

It took weeks to restore full connectivity, highlighting how dependent many island nations are on single, fragile cables. For Tonga, the outage halted online banking, e-commerce, and remittance transfers—vital sources of income—and isolated communities when communication was most critical.

▼ **Pacific Ocean and Tsunami evacuation map, Tongatapu island, Tonga.**

When the Internet Went Dark in Tonga



▲ **Figure 2:** Subsea cable damage caused by the January 2022 eruption of Hunga volcano, Kingdom of Tonga. (A) Seafloor relief in the area around Hunga Volcano after the 2022 eruption, showing the locations of the subsea cables. The dashed lines show the lengths of cable buried beyond recovery during the eruption. (B) Image taken of the eruption before the major 15th January 2021 climax (Tonga Geological Services). (C) The January 15th event as viewed from space [NASA]. (D) A simplified timeline of the eruption and cable interruptions on 15th January 2021. Reproduced under a Creative Commons Licence from Bricheno et al. (2024) after Clare and Yeo et al. (2023).

Lessons from History:

150 Years of Cable-Damaging Eruptions

Hunga was not an isolated case. At least eleven eruptions since the 1850s that have damaged one or more subsea cables. The first recorded instance occurred during the 1883 eruption of Krakatau in Indonesia, when a tsunami damaged a telegraph cable in the Sunda Strait. That event was also the first volcanic disaster reported globally in real time—ironically made possible by the same telegraph network that the volcano disrupted.

In 1902, eruptions in the Caribbean at Mount Pelée (Martinique) and La Soufrière (St Vincent) damaged several subsea telegraph cables. On Martinique, lahars (fast-moving volcanic mudflows), and ocean-entering pyroclastic density currents buried and broke at least five cables that connected the island to neighbouring colonies. Offshore St Vincent, six cables were damaged when volcanic flows reached the sea, collapsing parts of the coastline and triggering underwater landslides. At that time, these failures disrupted colonial communications across the region.

Subsequent decades have brought other examples. A pyroclastic density current from Montserrat's Soufrière Hills volcano in 1997 destroyed the island's cable landing station, cutting it off from the Eastern Caribbean Fibre System, with a new cable only laid more than twenty years later. Submarine debris flows at Kick 'em Jenny volcano near Grenada in 2015 damaged two modern fibre-optic cables, while the 2021 eruption of La Soufrière again broke cables off St Vincent through slope collapses and underwater sediment flows.

Even where eruptions were small, indirect impacts can be important. In Japan, eruptions at Miyake-jima (2000) and O-shima (1986) did not destroy cables directly but caused power outages that shut down telecommunications for years. Together, these cases show that volcanic threats to subsea infrastructure can be widespread and diverse.

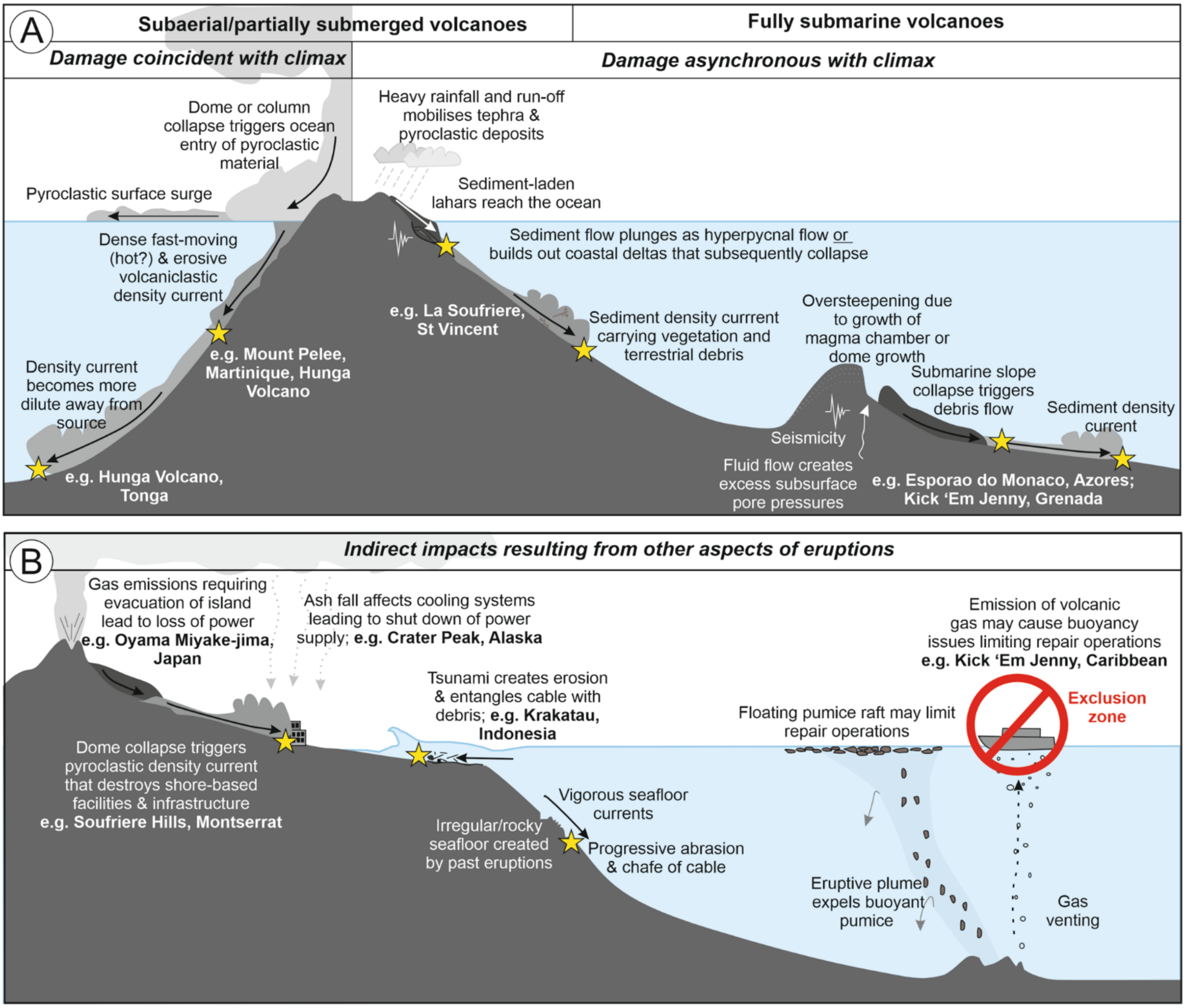
How Volcanic Hazards Break Cables

It is not the erupting lava or ash itself that breaks cables. Instead, secondary hazards—such as tsunamis, underwater landslides, lahars, and pyroclastic density currents—are usually to blame. These processes can travel tens to hundreds of kilometres across the seabed, sometimes damaging cables at depths of more than two kilometres.

For example, the seafloor sediment flows from Hunga travelled more than 100 km from the volcano, burying long stretches of cable under metres of sediment. At Kick 'em Jenny volcano, slope collapses generated slow-moving but powerful underwater flows that abraded and snapped cables within submarine channels. Even months after eruptions end, remobilised volcanic sediments can continue to threaten repaired infrastructure where they are flushed offshore.

There does not appear to be a clear threshold of eruption size or explosivity that determines whether subsea cables are damaged by volcanic hazards. Instead, risk depends on the local setting—the volcano's proximity to coastlines, slope steepness, and the pathways through which volcanic material can enter the sea. Submarine or partly submerged volcanoes pose the greatest hazard because their activity directly disturbs the seabed.

How Volcanic Hazards Break Cables



▲ **Figure 3:** Schematic diagram showing different aspects of volcanic eruptions and associated hazards that can damage subsea cables. (A) Direct impacts associated with volcanic eruptions, including those that coincide with an eruption climax and those that occur asynchronously. (B) Indirect effects of volcanic eruptions that can impact subsea telecommunications connections. Reproduced under a Creative Commons Licence from Clare and Yeo et al. (2025).

Rare but Significant Impacts of Volcanic Activity

Every year, around 150–200 subsea cable faults occur worldwide, mostly from accidental human activity like fishing or anchoring. Natural hazards make up only about 10–20 percent of cases but can be far more consequential, sometimes disabling multiple systems simultaneously. As a result, the eleven examples identified represent a very small percentage of damage globally, but the impacts can be widespread, may create disconnections at a critical time for disaster response, and in remote regions where repairs are challenging. The event itself may also delay repairs, as volcanic eruptions often last for weeks or months, during which time vessel exclusion areas often operate around them. Repairing a deep-sea cable can cost tens to hundreds of millions of dollars, but the indirect losses from interrupted trade and communication are far higher. For small island states that rely on a single international connection, even a temporary outage can freeze their economies.

Many active volcanoes lie close to existing cable routes—especially across the Pacific "Ring of Fire" and the Caribbean arc. As the global cable network expands, the overlap between critical infrastructure and geohazard zones will likely increase, meaning that understanding the risk posed is increasingly important.

Building a More Resilient Network. Many lessons can be learned from past instances of damage to make subsea telecommunications cables more resilient:

1. **Diversify routes.** Avoid concentrating multiple cables within the same route corridors or along steep submarine slopes. Redundant or looped routes may allow data traffic to be rerouted if one cable fails.

2. **Invest in back-up systems to enhance resilience.** The business case for additional cable connections can be hard to justify for connecting small islands with small dispersed populations; hence, back-up solutions are important in hazardous regions. Low-level satellites do not have the bandwidth capacity of subsea cables but may play an important role in bridging communication gaps if cables are damaged. Ensuring there is sufficient supply of spare cable for repairs and ready access to repair vessels will enable more effective repairs.

3. **Improve hazard assessment.** Volcanic and tsunami risk assessment is now routinely integrated into cable-route planning, but there remain many parts of the ocean where there is sparse data coverage of seafloor mapping and where characterisation of volcanic hazards and their eruption recurrence can be improved (e.g. parts of the South Pacific where there are many hazardous submarine volcanoes).

4. **Monitor the seafloor.** Paradoxically, the cables themselves can serve as sensors. Advances in fibre-optic sensing means that the optical fibres at the core of telecommunications cables can detect subtle vibrations and pressure changes, offering a new way to monitor underwater eruptions, earthquakes, and landslides in real time. Using subsea cables in this way could provide early warnings for geological hazards. Indeed, a recent eruption onshore Iceland was forewarned using such technology, informing an effective evacuation (Li et al., 2025). This approach may be particularly important in regions where there is limited to no direct monitoring of submarine volcanoes, filling critical gaps for disaster management.

Bridging Science and Connectivity

Our dependence on high-speed connectivity is growing - from cloud computing to telemedicine and remote work. For communities living in volcanically-active regions, understanding risks posed to their subsea connections is not an abstract concern. Enhancing the resilience of subsea networks against natural and other hazards requires close collaboration between scientists, engineers, policymakers, and telecommunications organisations. The goal is not just to protect cables but to safeguard the global conversations, economies, and emergency responses that flow through them, which is key to the mission of the International Cable Protection Committee.

From the first telegraph laid in 1850 to the fibre-optic networks of today, we have strived to stay connected across oceans. The same forces that built those oceans—volcanoes and tectonic processes—still have the power to locally disrupt them. Recognising and mitigating that risk therefore remains essential, while observations for instances of damage continues to provide new otherwise undocumented insights into some of the most important natural processes on our planet.

Please visit www.iscpc.org for further information.

Sharing seabed and oceans in harmony

The International Cable Protection Committee (ICPC) was formed in 1958 and its primary goal is to promote the safeguarding of international submarine cables against human made and natural hazards. The organisation provides a forum for the exchange of technical, legal and environmental information about submarine cables and, with more than **235 MEMBERS** from over **70 NATIONS,** including cable operators, owners, manufacturers, industry service providers, and governments, it is the world's premier submarine cable organisation. The ICPC comprises of an 18 Member Executive Committee (EC)-led organisation voted in by its Full Members. In addition to the Marine Environmental Adviser (MEA), General Manager (GM) and Secretariat team, the ICPC also has an appointed International Cable Law Adviser (ICLA) as well as a United Nations Observer Representative (UNOR).

Prime Activities of the ICPC:

- Promote awareness of submarine cables as critical infrastructure to governments and other users of the seabed.
- Establish internationally agreed recommendations for cable installation, protection, and maintenance.
- Monitor the evolution of international treaties and national legislation and help to ensure that submarine cable interests are fully protected.
- Liaison with UN Bodies.

Recommendations:

- Taking into account the marine environment, the ICPC authors Recommendations which provides guidance to all seabed users ensuring best practices are in place.
- Educating the undersea community as well as defining the minimum recommendations for cable route planning, installation, operation, maintenance and protection as well as survey operations.
- Facilitating access to new cable technologies.

Advancing Regulatory Guidance:

- Promoting United Nations Convention for the Law of the Sea (UNCLOS) compliance.
- Championing uniform and practical local legislation and permitting
- Protecting cable systems and ships.
- Aiding education of government regulators and diplomats.

Working with Science:

- Supporting independent research into cables.
- Publishing reviews for governments and policy makers.
- Working with environmental organisations.
- Effective public education via various media.

To learn how to become of Member organisation of the ICPC, please click on join here.

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Mike is the Marine Scientific Adviser for the International Cable Protection Committee (ICPC) and Strategic Research Lead at the National Oceanography Centre, UK, where he works as part of the Ocean BioGeoscience Research Group. His research focuses on better understanding the dynamic seafloor, the implications of past and future climate change, impacts of human activities, and quantifying risks to critical infrastructure. Prior to his research role at NOC, he worked for ten years as a geohazard consultant to a range of offshore industries.

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