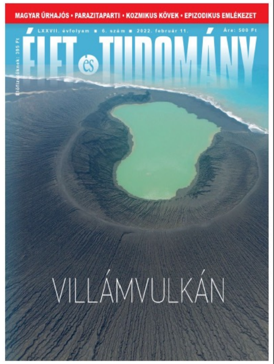
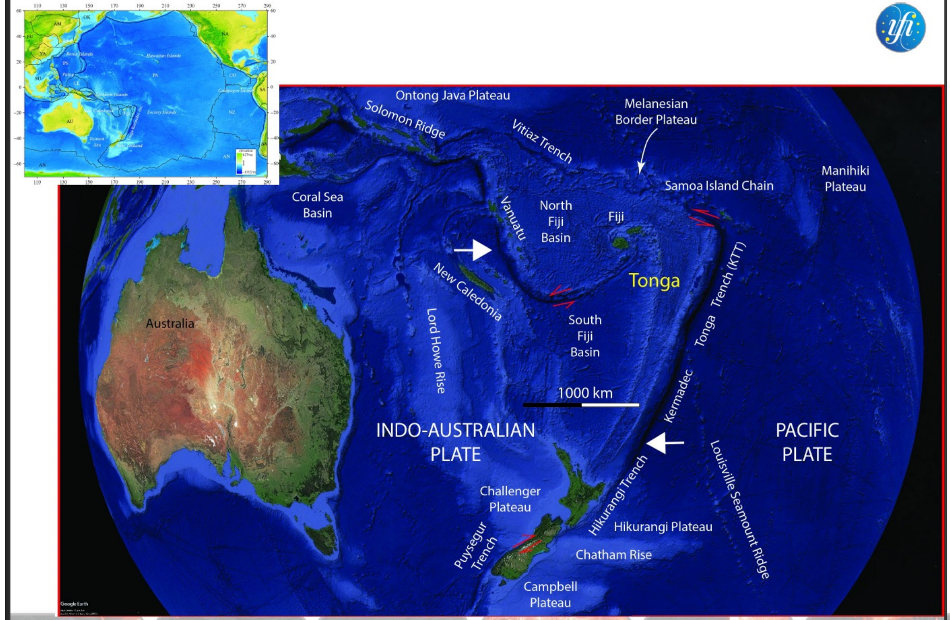


1

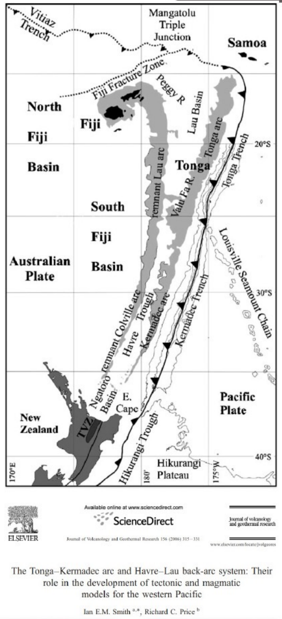
Eruption in Tonga 2022 January 15

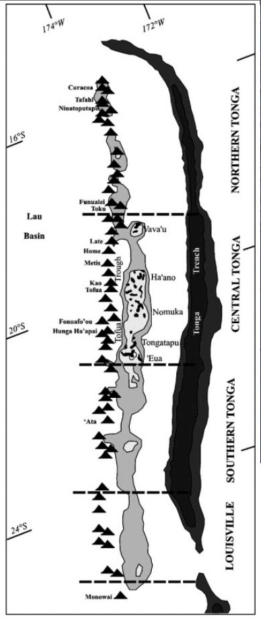
- Why this eruption is Unique?
- Is it unique within the context of volcanism across the Pacific?
- What made the 15 January 2022 event special?
- What are the options to explain the violent volcanic exolosions?
- What can we predict for similar future events? Would they to occur in the same place? Or are we facing some challenges elsewhere?
- What can we learn from this eruption in respect of geoheritage and geodiversity?
- How geoheritage can help to develop efficient programs for resilience toward complex natural hazards?

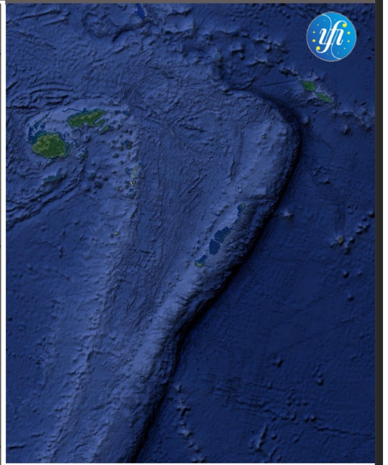
Where is Tonga?



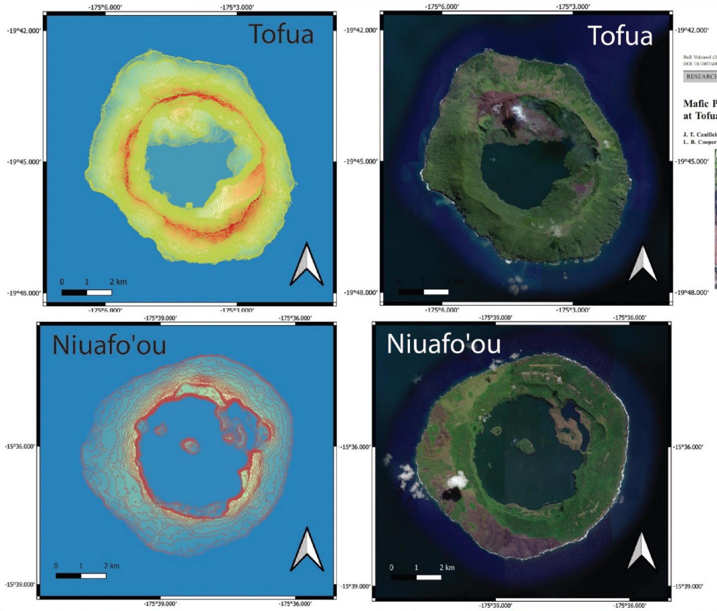
Volcanic History of the Tongan Arc







Type of Volcanism Known from Tonga

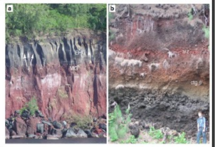


Bull Volcanol (2011) 73:1259–1277
DOI 10.1007/s00445-011-0477-9

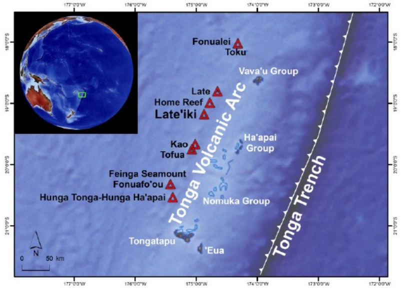
RESEARCH ARTICLE

Mafic Plinian volcanism and ignimbrite emplacement at Tofua volcano, Tonga

J. T. Caulfield · S. J. Cronin · S. P. Turner · L. B. Cooper



Type of Volcanism Known from Tonga



Plank S, Marchese F, Genzano N, Nolde M, Martinis S (2020) The short life of the volcanic island New Late'iki (Tonga) analyzed by multi-sensor remote sensing data. Scientific Reports 10(1):22293

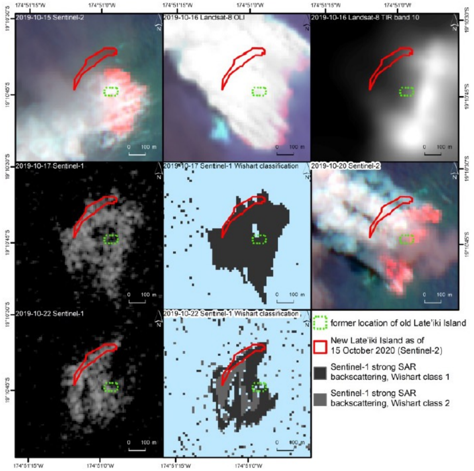
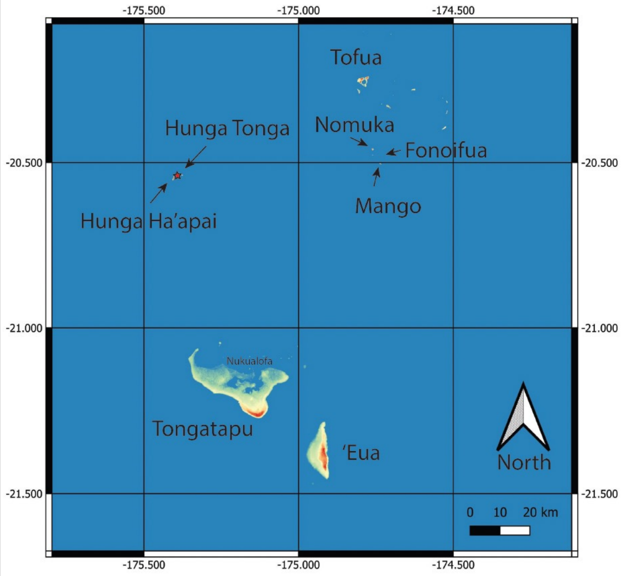
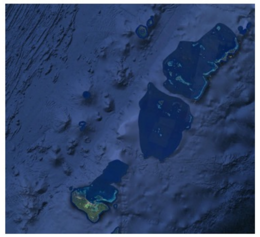


Figure 7. Surtseyan eruption at Late'iki Volcano monitored by Sentinel-2 (15 and 20 October 2019), Landsat-8 (16 October 2019) and Sentinel-1, including result of the polarimetric Wishart classification (17 and 22 October 2019). Background: Sentinel-1 and Sentinel-2 Copernicus data (2019). Landsat-8 image courtesy of the U.S. Geological Survey.

Hunga Tonga – Hunga Ha'apai

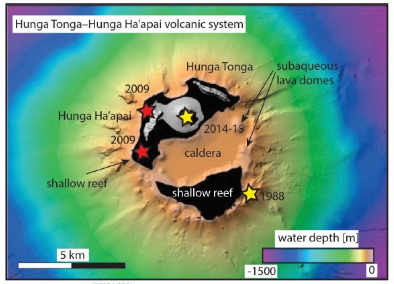


Hunga volcano (Kingdom of Tonga, Southwest Pacific) is a large mainly **submarine edifice** that produced a **series of caldera-forming eruptions ~900 years ago**.



Cronin, S., Brenna, M., Smith, I., Barker, S., Tost, M., Ford, M., Tonga'onevai, S., Kula, T., Vaiomounga, R., 2017. New volcanic island unveils explosive past. Eos, Transactions American Geophysical Union 98, 18–23

Previous Eruptions Known from Hunga



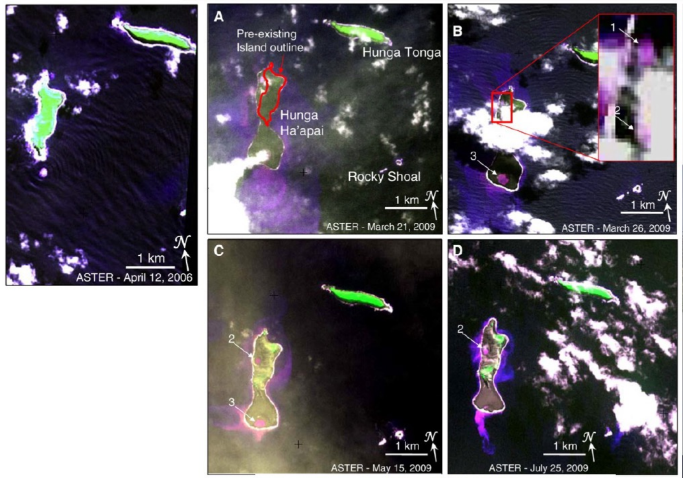
„Geological evidence shows that large eruptions have convulsed Hunga Tonga–Hunga Ha'apai about once every millennium, with huge blasts that occurred in around AD 200 and AD 1100. The past century has brought smaller ones, in 1937 and 1988."

https://www.nature.com/articles/d41586-022-00394-y

These islands represent the remnants of a **cone destroyed by at least two caldera-forming eruptions** (the latest in 1040–1180 CE), and rise from a submerged caldera identified by recent mapping (Cronin et al., 2017)

Cronin, S., Brenna, M., Smith, I., Barker, S., Tost, M., Ford, M., Tonga'onevai, S., Kula, T., Vaiomounga, R., 2017. New volcanic island unveils explosive past. Eos, Transactions American Geophysical Union 98, 18–23

2009 Events



Journal of Volcanology and Geothermal Research 198 (2010) 177–186

Contents lists available at ScienceDirect

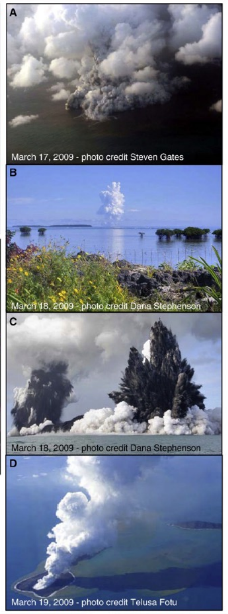
Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

Satellite observations of a surtseyan eruption: Hunga Ha'apai, Tonga

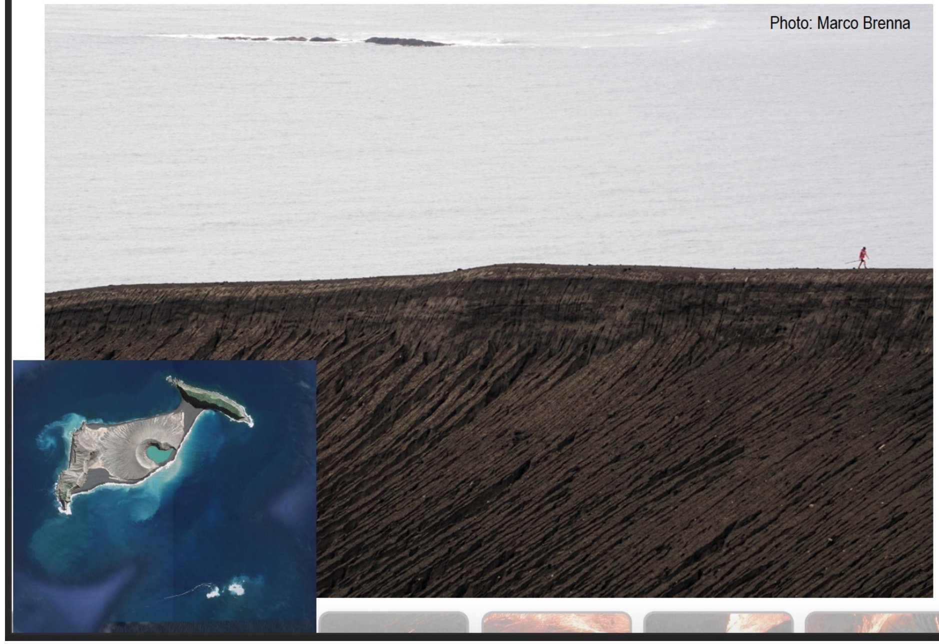
R. Greg Vaughan [a,*], Peter W. Webley [b]

[a] US Geological Survey, Astrogeology Science Center, 2255 N. Gemini Dr, Flagstaff, AZ, USA
[b] Geophysical Institute and Alaska Volcano Observatory, University of Alaska Fairbanks, 903 Koyukuk Drive, Fairbanks, AK, USA



2014-15 Events

2014-15 Events

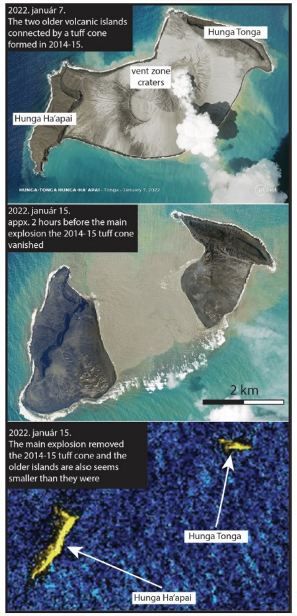


2021 December 31

2021 December Onward

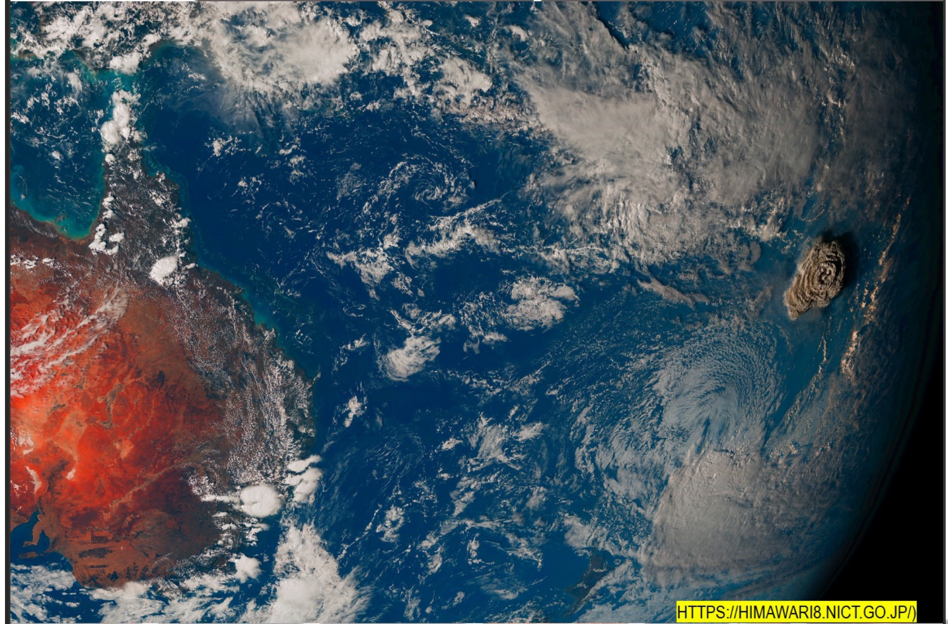
6 January 2022 – Maxar via Getty Images

2022 Main Explosion(s)



COPERNICUS/SENTINELHUB

15 January, 2022



HTTPS://HIMAWARI8.NICT.GO.JP/)

Why Was This Eruption Unique

Volcano eruption in Tonga was a once-in-a-millennium event

https://www.newscientist.com/article/2304822-volcano-eruption-in-tonga-was-a-once-in-a-millennium-event/#ixzz7LDGOsvHp

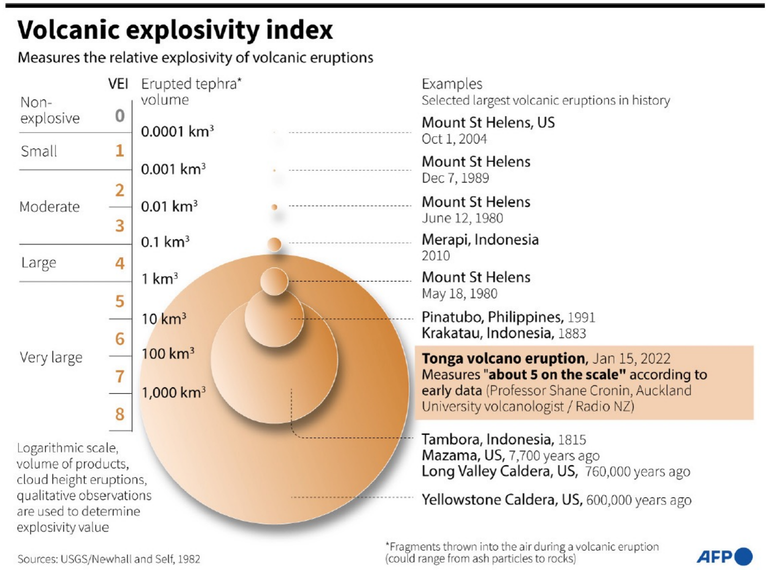
https://eoimages.gsfc.nasa.gov/images/imagerecords/149000/149474/tonga_goeshmw_2022015.mp4

- **An eruption produced an eruption plume that reached 55+ km to the Mesosphere**
- **An eruption that generated shockwaves crossed the Earth numerous times and recorded by various methods like pressure waves, infrasounds etc**
- **An eruption that trigerred tsunami that spread across the Pacific Ocean**
- **An eruption that produced extremelly fine grained ash (few micron across particle size)**
- **An eruption suspected to be in the Volcanic Explosivity Index reaching value of 6 ..**

volcanic explosivity index (VEI) A measure of explosive magnitude of an eruption incorporating both subjective and objective criteria, influenced by factors including volume of ejected pyroclastic material and eruption column height.

volcanic explosivity index (VEI) A scale for the explosive phases of an eruption, mainly based on the column height or on the mass ejected as pyroclasts. It relies on the assumption of a direct proportionality between magnitude and intensity of an eruption, and, as first introduced, varied from 0 to 8. The use of a negative VEI has been proposed to describe small-scale, mainly basaltic, eruptions.

Why Was This Eruption Unique

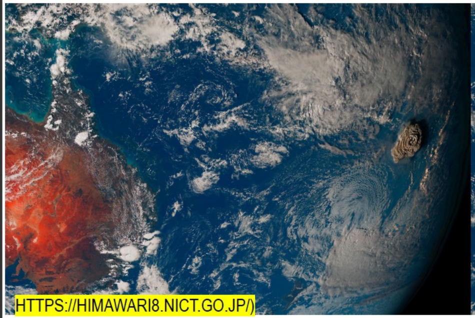


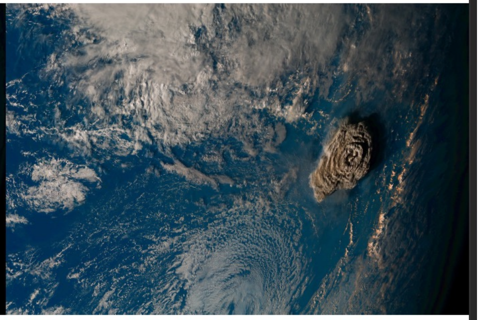
https://www.barrons.com/news/volcanic-explosivity-index-01642671908

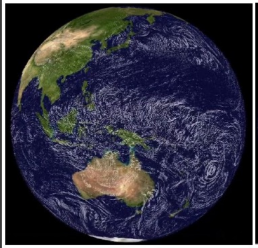
Shockwaves

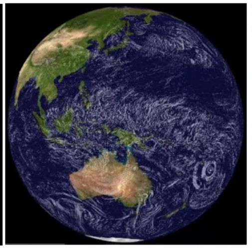
Large Plume – Explosion – 05.16 PM (Tongan Time)

Shockwave – Explosion – 05.25 PM (local)







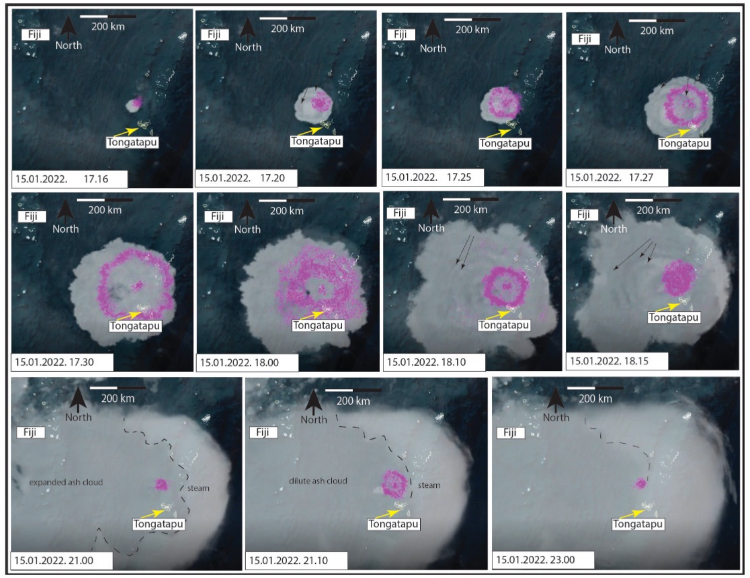


Tsunami

On January 15, 2022 at **4:27 GMT (17.27 Tongan Time)**, a **significant tsunami** was observed across the Pacific basin resulting from the undersea volcanic eruption in the Tonga Islands region. NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) first observed the tsunami wave at its station in Pago Pago, American Samoa, less than an hour later. The height of the wave reached approximately 1.8 feet. Satellite imagery of the Tonga-Hunga Ha'apai volcanic eruption. (CSU/CIRA and JAXA/JMA)

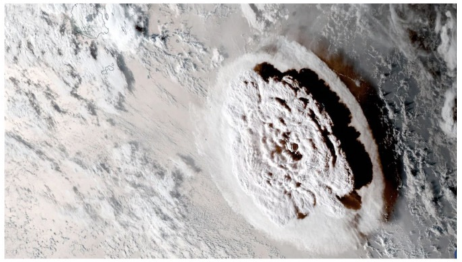
https://www.noaa.gov/news/ripple-effect-what-tonga-eruption-could-mean-for-tsunami-research

Lightning



VAISALA GLOBAL LIGHTNING DETECTION

Ash Fall



Satellite imagery shows the eruption of the Hunga Tonga-Hunga Ha'apai volcano in the Pacific on Jan. 15, 2022. (Rammb/Noaa/Nesdis Handout/EPA-EFE/REX/Shutterstock)

- Very limited direct data yet due to communication disruption
- Ash is very fine grained
- Ash is among the most mafic in composition essentially andesite, basaltic andesite (53-58 vol% SiO_2 (Cronin pers com 2022)
- Pyroclasts are low vesicularity and microlite poor (Cronin pers com 2022)
- Thickness values are controversial, but they are only thin layers and that is visible in the few direct images emerged so far (max dm scale)

Twitter

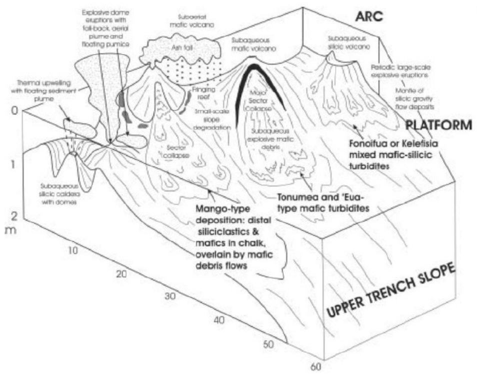
Internet Cable Breakage

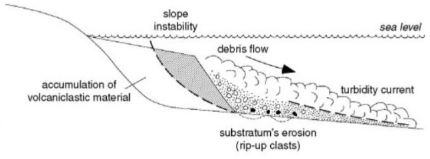
- Internet cable cut off about 40 km from the volcano
- Some sediment cover is apparent but confirmation is needed
- What could have caused this is unknown until safe to be nearby the volcano for survey

Volcano Collapse – Sector Collapse - Landslide

Caldera collapse

Volcanic-induced turbidity current





New Zealand Journal of Geology and Geophysics

Volcaniclastic gravity flow sedimentation on a frontal arc platform: The Miocene of Tonga

Peter F. Ballance , David R. Tappin & Ian P. Wilkinson

Type of Magma-Water Interactions

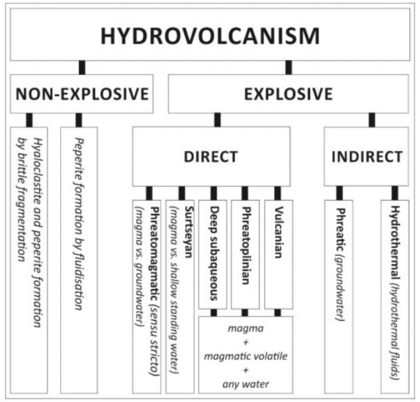
geosciences

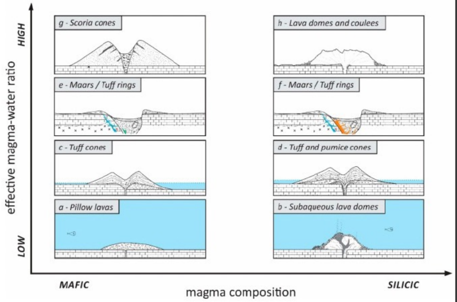
MDPI

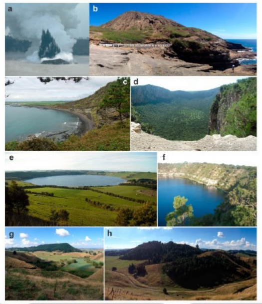
Review

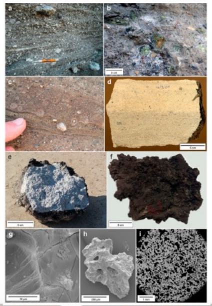
Review of Explosive Hydrovolcanism

Károly Németh * and Szabolcs Kósik





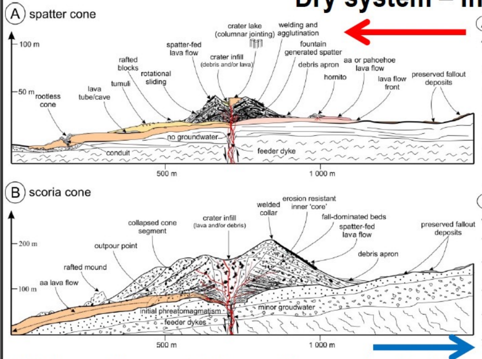


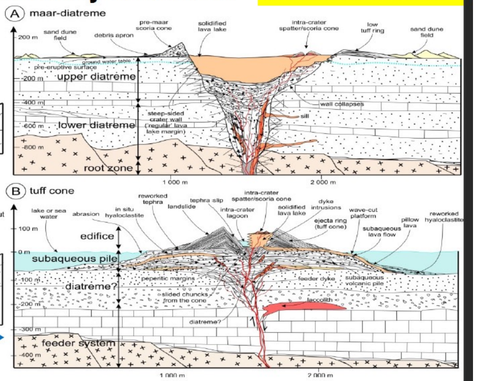


Monogenetic Basaltic Volcanic Systems

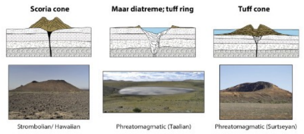
Dry system – Internally controlled

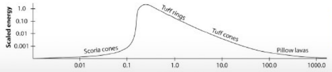
Kereszturi & Nemeth 2012





Wet system – Externally controlled





Wohletz, Valentine, etc. …

Molten-fuel coolant interaction - Phreatomagmatism

Journal of Volcanology and Geothermal Research, 17 (1983) 1—29
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

HYDROVOLCANISM: BASIC CONSIDERATIONS AND REVIEW

MICHAEL F. SHERIDAN[1] and KENNETH H. WOHLETZ[2]

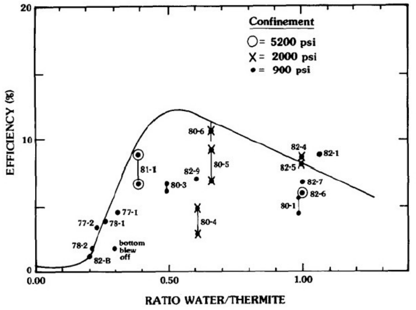
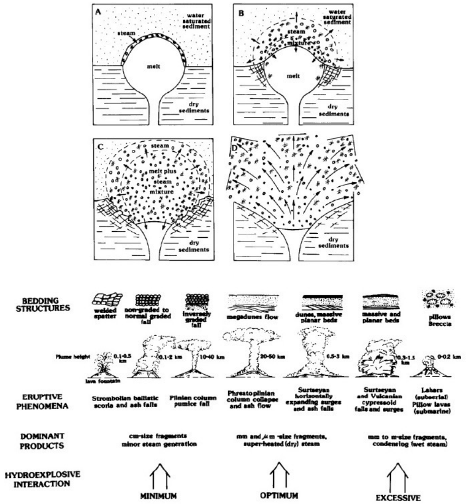
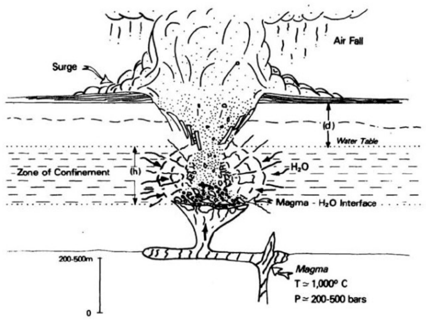


Fig. 2 Efficiency vs. water/melt ratio.

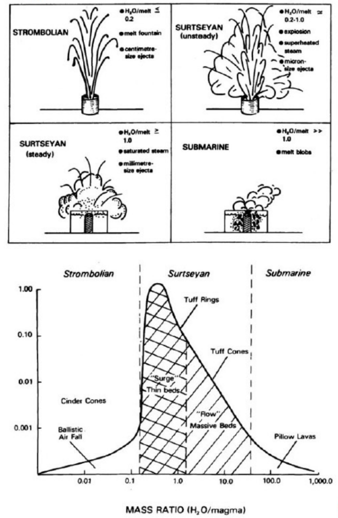


Type of Magma-Water Interactions

Molten-fuel coolant interaction – Phreatomagmatism Causes and Consequences



Wohletz KH and McQueen RG, 1984, Experimental studies of hydromagmatic volcanism. In: Explosive Volcanism: Inception, Evolution, and Hazards, Studies in Geophysics, National Academy Press, Washington, D.C., 158-169



Type of Magma-Water Interactions

Molten-fuel coolant interaction – Phreatomagmatism Causes and Consequences

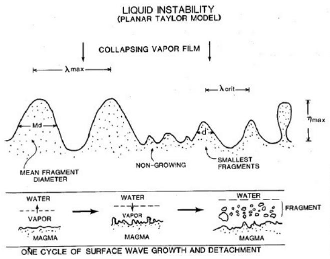


Fig. 4. Illustration of a planar Taylor instability at the interface between magma and a collapsing water-vapor film (*top*). A complete cycle of instability growth is shown at the bottom (see text for description). Oscillation of the film thickness transmits sufficient momentum to the magma so that its surface distorts into waves that can grow until they detach to form small fragments

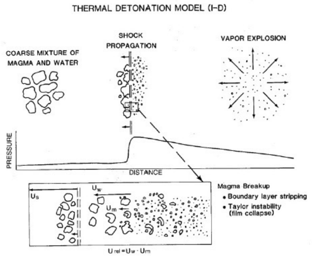
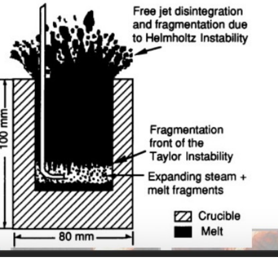


Fig. 5. An alternative model of strong magma–water interaction followed by explosion requires the propagation and sustenance of a shock wave as a *thermal detonation*. The *inset box* shows an expanded view of conditions across the shock wave where u_s is the shock velocity, u_w is the water velocity, and u_m is the magma fragment velocity. Where $u_{rel}=u_w-u_m$ reaches a large enough magnitude, magma breakup by processes such as boundary layer stripping and Taylor instability may result in large heat transfer rates

Wohletz KH, 1986, Explosive magma-water interactions: Thermodynamics, explosion mechanisms, and field studies. Bulletin of Volcanology 48: 245-264

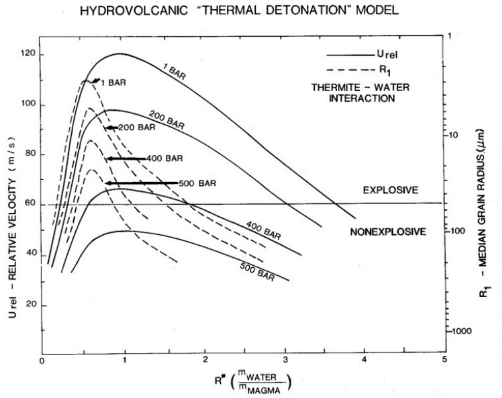
Explosive Thermal Interactions between Molten Lava and Water

G. Fröhlich
IKE, University of Stuttgart, Stuttgart, FRG
B. Zimanowski
V. Lorenz
Institute of Geology, University of Würzburg, Würzburg, FRG



Type of Magma-Water Interactions

Molten-fuel coolant interaction – Phreatomagmatism Causes and Consequences



Wohletz KH, 1986, Explosive magma-water interactions: Thermodynamics, explosion mechanisms, and field studies. Bulletin of Volcanology 48: 245-264

Chapter 26

Magma–Water Interaction and Phreatomagmatic Fragmentation

Bernd Zimanowski and Ralf Büttner
Universität Würzburg, Würzburg, Germany
Pierfrancesco Dellino
Università di Bari, Bari, Italy
James D.L. White
Geology Department, University of Otago, Dunedin, New Zealand
Kenneth H. Wohletz
Los Alamos National Laboratory, Los Alamos, NM, U.S.A.

Fig. 6. Application of the thermal detonation model illustrated in Fig. 5 allows calculation of relative velocity u_{rel} of magma fragments to water in the slurry. If u_{rel} increases beyond about 60 m/s, then magma breakup can occur resulting in high heat transfer rates and subsequent vapor explosion. Note that u_{rel} for the explosive–nonexplosive boundary may vary by plus or minus several tens of meters per second depending upon rheological properties of the melt. *Solid lines* show the dependence of u_{rel} upon R^* for different ambient pressures. The degree of magma breakup determines the resulting tephra grain sizes, r_1, and these are shown as *dashed lines*

Type of Magma-Water Interactions

Hydrovolcanism - Hydromagmatism
Surtseyan-style eruptions

Surtsey erupting - 1 January 1963
NOAA - http://www.ngdc.noaa.gov

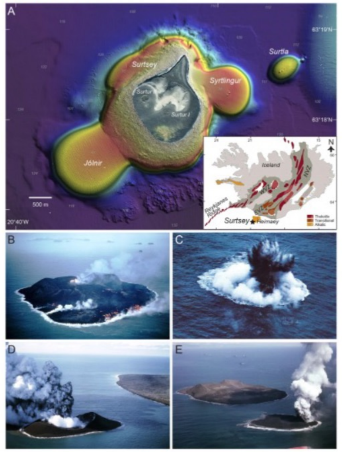


Figure 1. Location and eruptive activity at Surtsey A) Bathymetry of Surtsey as of 2007 multibeam survey, modified with permission from Jakobsson *et al.* [77]. Inset shows outline of Iceland in the North Atlantic with Eastern (EVZ), Western (WVZ), Northern (NVZ), and Snaefellsnes (SnVZ) Volcanic Zones indicated[78]. B) Surtsey during effusive phase of *Surtur II* vent, 16 Oct. 1964. C) Pyroclastic activity at *Surtla*, 29 Dec. 1963; D-E) Pyroclastic activity at *Syrtlingur*, 1 Jul. 1965, and Jólnir, 15 Jul. 1966. Photographs by pilot Sigurjón Einarsson, reprinted with permission.

Schipper C, P Jakobsson S, White J, Palin J, Bush-Marcinowski T (2015) The Surtsey Magma Series. p 11498

Type of Magma-Water Interactions

Hydrovolcanism - Hydromagmatism
Surtseyan-style eruptions

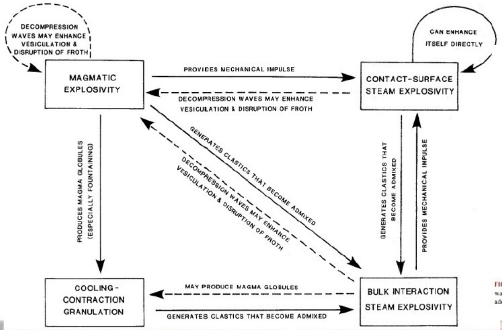
Bull Volcanol (1986) 48: 275-289

Bulletin of Volcanology

© Springer-Verlag 1986

Magma-water interactions in subaqueous and emergent basaltic volcanism

Peter Kokelaar



Chapter 30

Phreatomagmatic and Related Eruption Styles

Bruce Houghton
James D.L. White
Alexa R. Van Eaton

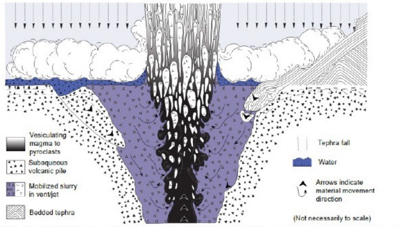
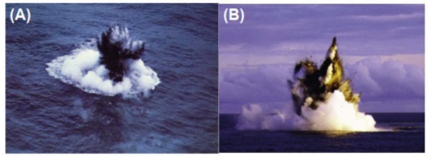


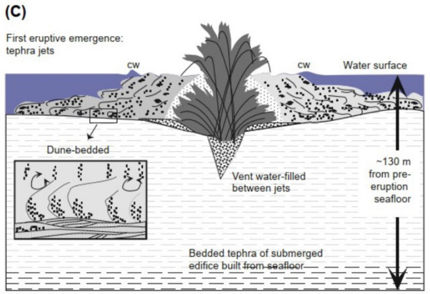
FIGURE 30.6 Conceptual model for processes in the Surtseyan vent in which shear-instability entrainment and mixing of a slurry of recycled tephra and water with rising magma drives discrete or continuous uprush activity. Depending on the setting, the wall rock may be loose to consolidated sediment in addition to buried volcanics. *Modified after Kokelaar (1983).*

Type of Magma-Water Interactions

Hydrovolcanism - Hydromagmatism
Surtseyan-style eruptions

FIGURE 31.2 Surface observations of underwater eruptions, prior to edifice emergence (A) Surtla vent, Surtsey eruption, 29 December 1963 *(Thorarinsson S (1967) Surtsey. The New Island in the North Atlantic. The Viking Press, New York, p 47)*. (B) Tephra jet from Kavachi volcano, Solomon Islands, from vent 2–5 m below water on 14 May 2000; photograph courtesy Pamela Brodie. (C) Inferred processes accompanying tephra jets breaching from slightly submerged vents as at start of Surtsey eruption. Vent occupies one part of broader edifice building to emergence. "cw" = concentric waves; dune-bedded tephra ~10 m underwater results from density currents interacting with surface waves. *(Redrawn after White, J.D.L. (1996) Pre-emergent construction of a lacustrine basaltic volcano, Pahvant Butte, Utah (USA). Bull. Volcanol. 58, 249–262.).*





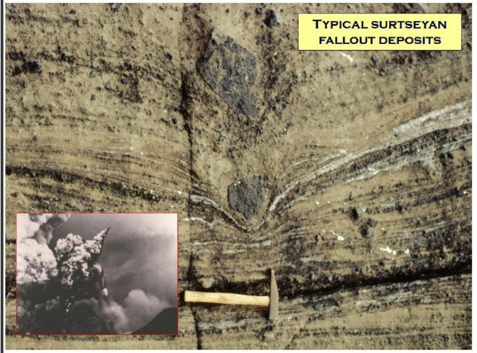
Chapter 31

Submarine Explosive Eruptions

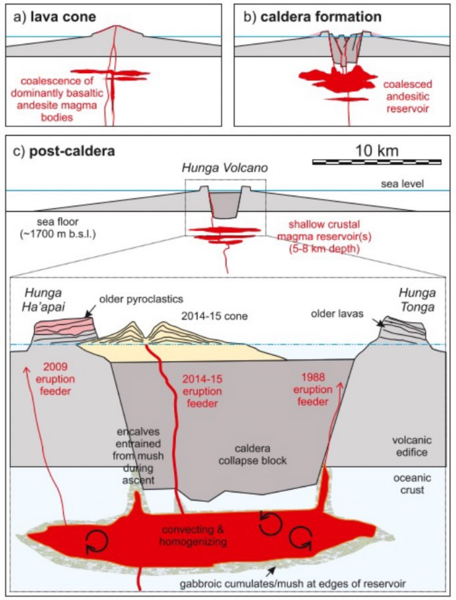
James D.L. White
C. Ian Schipper
Kazuhiko Kano

Type of Magma-Water Interactions

Hydrovolcanism - Hydromagmatism
Surtseyan-style eruptions
Evidences and Eruptive Products



The Role of Hot, New Primary Magma



LITHOS 412–413 (2022) 106614

Contents lists available at ScienceDirect

LITHOS

journal homepage: www.elsevier.com/locate/lithos

Post-caldera volcanism reveals shallow priming of an intra-ocean arc andesitic caldera: Hunga volcano, Tonga, SW Pacific

Marco Brenna[a,*], Shane J. Cronin[b], Ian E.M. Smith[b], Alessio Pontesilli[c], Manuela Tost[d], Simon Barker[e], Sisi Tonga'onevai[f], Taaniela Kula[f], Rennie Vaiomounga[f]

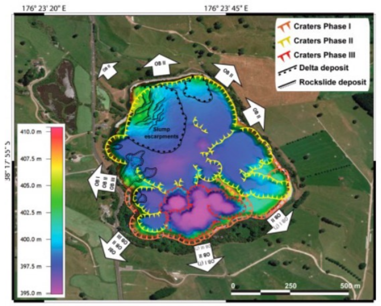
„In all cases of intermediate calderas, the compositional range of post-caldera volcanic products is generally narrower (basaltic andesite/andesite) compared to that of the entire volcano. These compositional relationships suggest that caldera-forming intermediate volcanism in oceanic arc systems is not necessarily caused by sudden arrival of new magma, but follows hundreds to thousands of years of steady supply (and leaking) of magma into a sub-volcanic magmatic reservoir. This is fundamentally different to models generally proposed for continental systems, where tectonics and magma recharge/mixing/buoyancy play a significant role in triggering caldera-forming eruption (Cabaniss et al., 2018; Degruyter et al., 2016; Malfait et al., 2014)."

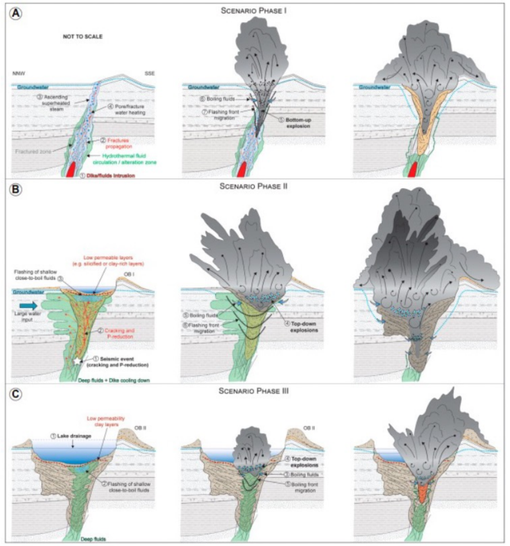
What About Hydrothermal Systems?

THE GEOLOGICAL SOCIETY OF AMERICA®

Complex crater fields formed by steam-driven eruptions: Lake Okaro, New Zealand

Cristian Montanaro[1,2,†], Shane Cronin[2], Bettina Scheu[1], Ben Kennedy[3], and Bradley Scott[4]





Maars vs Hydrothermal Systems

Bull Volcanol (2011) 73:899–915
DOI 10.1007/s00445-011-0466-z

RESEARCH ARTICLE

Deep explosive focal depths during maar forming magmatic-hydrothermal eruption: Baccano Crater, Central Italy

M. Buttinelli · D. De Rita · C. Cremisini · C. Cimarelli

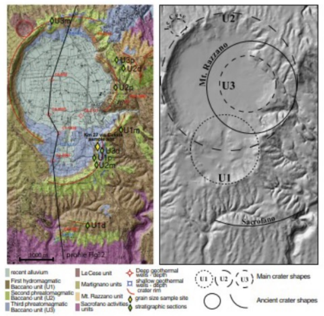
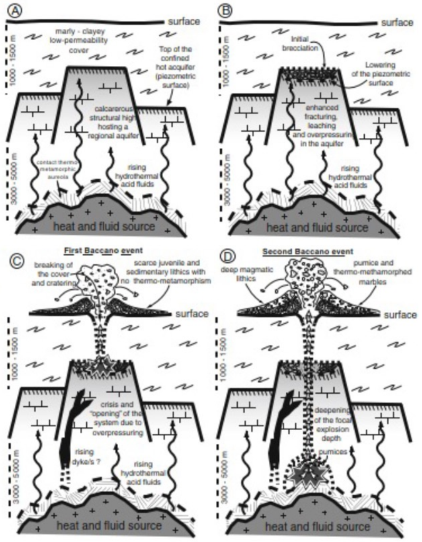


Fig. 9 Schematic representation of the evolution of Baccano maar activity: **a** structural setting of the area in the pre-eruptive stage; **b** initial stage of interaction between the rising hydrothermal acid fluids and the calcareous structural high hosting the regional aquifer; **c** First explosive activity of Baccano maar, characterized by an hydrothermal-phreatic eruption occurred involving the upper part of the confined aquifer on top of the structural high, with a no water–magma interaction. **d** Second explosive activity of Baccano maar, characterized by a more evident phreato-magmatic behaviour of the eruption, showing efficient water–magma interaction, which is accompanied by the deepening of the explosive focal depth (and/or a potential northward shifting of the crater) involving the thermo-metamorphic contact aureole of the magma chamber



Maars vs Hydrothermal Systems

Stix and de Moor *Earth, Planets and Space* (2018) 70:83
https://doi.org/10.1186/s40623-018-0855-z

Earth, Planets and Space

FRONTIER LETTER Open Access

Understanding and forecasting phreatic eruptions driven by magmatic degassing

John Stix[1*†] and J. Maarten de Moor[2†]

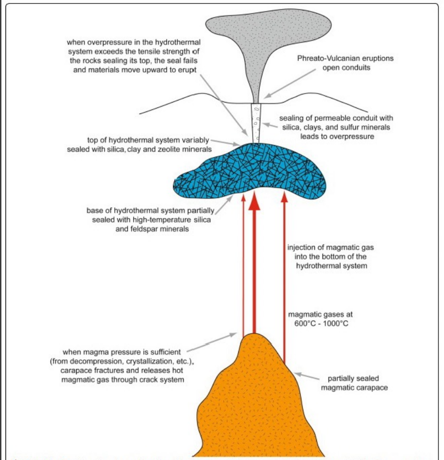


Fig. 4 Model for type 1 phreatic systems and eruptions. A shallow magma body releases gas by intrusion and/or crystallization. The gases are transported upward through a series of cracks, intersecting the hydrothermal system above. If the hydrothermal system is sealed at its top, the system will become pressurized from the addition of hot magmatic gases. Such conditions promote phreatic eruptions

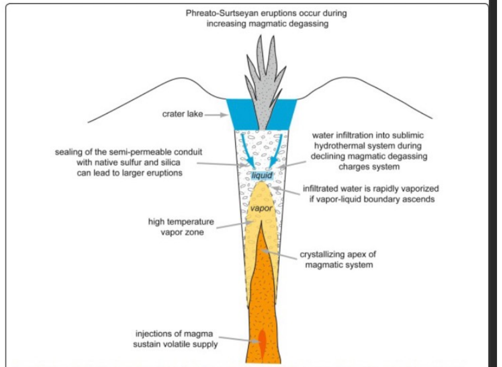
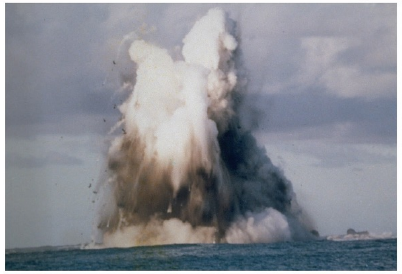


Fig. 5 Model for type 2 phreatic eruptions at Poás. Increasing magmatic gas input into the lake raises the vapor–liquid boundary, resulting in vaporization of confined liquid water, generating volume change, pressurization, and eruption. Compared to type 1 phreatic systems, here the conduit is more open with a shallower magma system. Type 2 phreatic eruptions are also very common at Rincon de la Vieja and other hyperacid crater lake systems. The eruptive style is more akin to surtseyan eruptions than vulcanian eruptions which are more related to type 1 phreatic activity

Similar eruption elsewhere?

A shallow phreatomagmatic, or Surtseyan eruption from Kavachi volcano (Solomon Islands) on 17 or 18 July 1977. Jets of dark ash can be seen emerging from white steam plumes. Numerous individual blocks ejected at high velocity are trailed by steam. Similar activity was observed from boats and airplanes for a period of less than one week. https://volcano.si.edu/gallery/ShowImage.cfm?photo=GVP-00506
Photo by W.G. Muller, 1977 (Barrier Reef Cruises, Queensland, Australia; courtesy of R.W. Johnson).

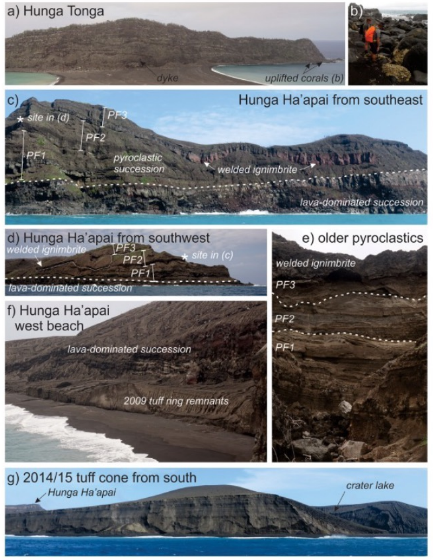


A submarine explosion from Nishinoshima breaches the surface on 9 October 1973. Steam trails behind ejected hot blocks at the margin of the plume. Submarine eruptions began on 12 April 1973 and the new island was first observed on 11 September. Lava flows began in September and three new islands were formed, which joined together during October-November 1973.
Photo courtesy of Japan Meteorological Agency, 1973.

Similar eruption elsewhere?

No eruptive activity was observed during a JMA overflight of Nishinoshima on 5 September 2020, but steam rose from numerous places within the enlarged summit crater (inset). Courtesy of JMA and JCG (Monthly report of activity at Nishinoshima, September 2020)

Geoheritage Legacy of Hunga




LITHOS 412–413 (2022) 106614

Contents lists available at ScienceDirect

LITHOS

journal homepage: www.elsevier.com/locate/lithos

ELSEVIER

Post-caldera volcanism reveals shallow priming of an intra-ocean arc andesitic caldera: Hunga volcano, Tonga, SW Pacific

Marco Brenna[a,*], Shane J. Cronin[b], Ian E.M. Smith[b], Alessio Pontesilli[c], Manuela Tost[d], Simon Barker[e], Sisi Tonga'onevai[f], Taaniela Kula[f], Rennie Vaiomounga[f]

What will be preserved for future?

Can we „rescue" something in-situ?

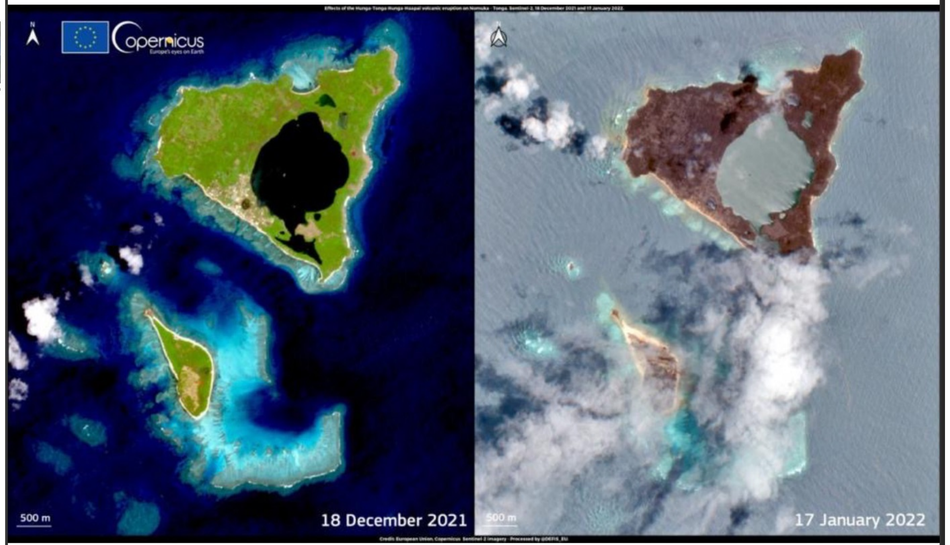
How such event can add value to volcanic geoheritage of a region?

Is exo-situ approach would work?

Do we need to explore advanced technologies and virtual space to „preserve" information for future?

Should we look for analogy?

Geoheritage legacy of Hunga



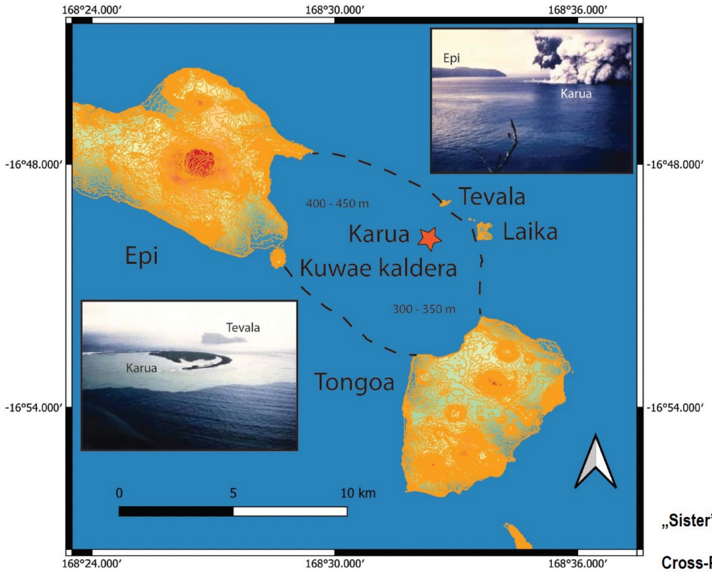
Damage by tsunami and ash fall is apparent days after the event ... but what will remain as messenger of this once in a milenia eruption within decades or human generation lifespan?

What about geodiversity?

Can we see high geodiversity here?

Is the geodiversity changes over time – in short time frame?

Geoheritage for Natural Hazard Resilience



Monzier M, Robin C, Eissen JP (1994) Kuwae (Approximate-to-1425 AD) - The forgotten caldera. Journal of Volcanology and Geothermal Research 59(3):207-218

Gao CC, Robock A, Self S, Witter JB, Steffenson JP, Clausen HB, Siggaard-Andersen ML, Johnsen S, Mayewski PA, Ammann C (2006) The 1452 or 1453 AD Kuwae eruption signal derived from multiple ice core records: Greatest volcanic sulfate event of the past 700 years. Journal of Geophysical Research-Atmospheres 111(D12)

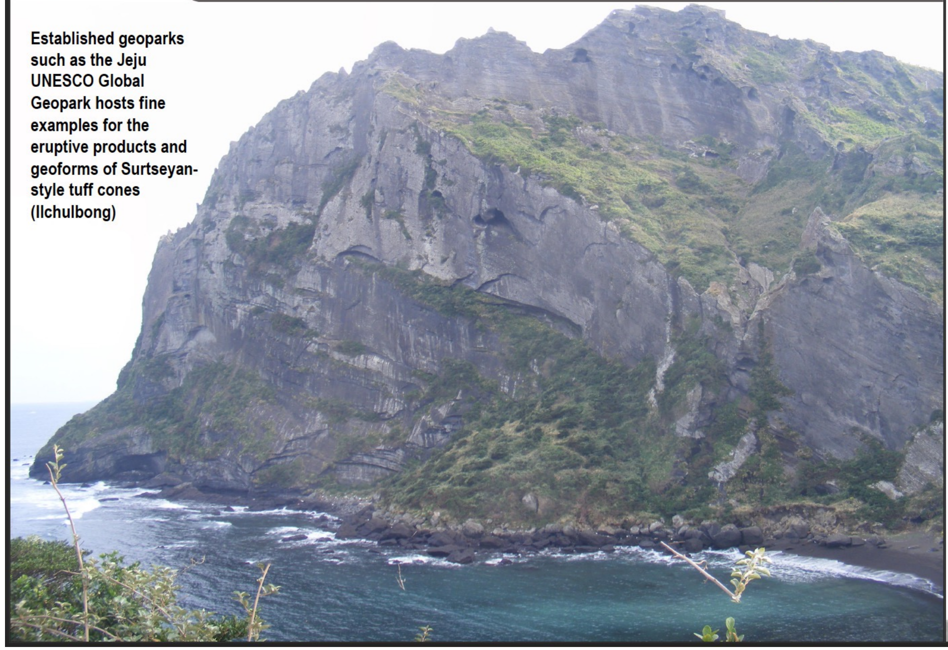
Németh K, Cronin SJ, White JDL (2007) Kuwae caldera and climate confusion. The Open Geology Journal [Bentham Publishing] 1:7-11

„Sister" volcanic system concept?

Cross-Pacific Cooperation?

Surtseyan Geoheritage vs Geopark

Established geoparks such as the Jeju UNESCO Global Geopark hosts fine examples for the eruptive products and geoforms of Surtseyan-style tuff cones (Ilchulbong)



Geocultural Context

First Lapita settlement of Tonga occurred on Fanga'Uta Lagoon on Tongatapu by 2850 calBP, with expansion to the north into Ha'apai, Vava'u and Niuatoputapu beginning two or so generations later (Burley et al. 2015).

Burley, D. V., Edinborough, K., Weisler, M. and Zhao , J. -X. (2015). Bayesian modeling and chronological precision for Polynesian settlement of Tonga. Plos One, 10(3), e0120795

https://www.virtualoceania.net/tonga/photos/towns/ohonua/to0300.shtml

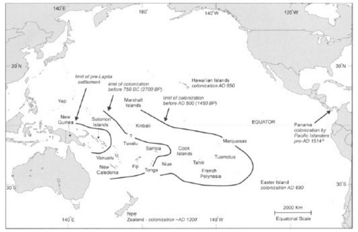
RADIOCARBON, Vol 49, Nr 1, 2007, p 131–136 © 2007 by the Arizona Board of Regents on behalf of the University of Arizona

FIRST LAPITA SETTLEMENT AND ITS CHRONOLOGY IN VAVA'U, KINGDOM OF TONGA

David V Burley[1] • Sean P Connaughton

Department of Archaeology, Simon Fraser University, Burnaby, British Columbia V5A 1S6, Canada.

ABSTRACT. Beginning approximately cal 1400 BC, Austronesian-speaking Lapita peoples began a colonizing migration across Oceania from the Bismarck Archipelago to western Polynesia. The first point of entry into Polynesia occurred on the island of Tongatapu in Tonga with subsequent spread northward to Samoa along a natural sailing corridor. Radiocarbon measurements from recent excavations at 4 sites in the northern Vava'u islands of Tonga provide a chronology for the final stage of this diaspora. These dates indicate that the northern expansion was almost immediate, that a paucity of Lapita sites to the north cannot be explained as a result of lag time in the settlement process, and that decorated Lapita ceramics disappeared rapidly after first landfalls.



~3000 years advanced human occupation history (probably more but information is scaterred).

There must be distant „memories" of similar events in cultural activities, oral traditions and even daily activities … need to be explored.

Nunn PD (2001) On the convergence of myth and reality: examples from the Pacific Islands. Geographical Journal 167:125-138

Geocultural Context

Nunn PD (2003) **Fishing up** or **thrown down**: The geography of Pacific Island origin myths. Annals Of The Association Of American Geographers 93(2):350-364

Table 3. Shallow-Water Volcanoes That Are Known to Have Erupted or May Have Erupted within the Past 3,000 Years

Number	Principal Volcanoes	Known Eruptions	Details and Sources
1	a) Kavachi, Solomon Islands	16 eruptions since December 1950	Data tabulated in Nunn (1994, 86)
2	a) Karua, Vanuatu	10 eruptions since 1897	Data tabulated in Nunn (1994, 87)
	b) Off Efate	Signs of submarine eruption 1881	Located at 18.72°S, 168.37°E (Simkin et al. 1981)
3	a) South of New Caledonia	Eruption report 1963	At 25.78°S, 168.63°E (Simkin et al. 1981)
4	a) Fonuafo'ou, Tonga	11 eruptions since 1781	Data tabulated in Nunn (1994, 87)
	b) Late'iki (Metis Shoal), Tonga	8 eruptions since 1851	Data tabulated in Nunn (1994, 87)
5	a) Manua Islands, American Samoa	Around 1866	Eyewitness account given to Friedländer (1910); located at 14.21°S, 169.60°W (Simkin et al. 1981)
	b) Manua Islands, American Samoa	Signs of submarine eruption 1973	Located at 14.23°S, 169.07°W (Simkin et al. 1981)
6	a) Moua Pihaa, Society Island	An active submarine volcano	Shallow-focus earthquakes at bathymetric high suggest underwater volcano at 18.4°S, 148.6°W (Duncan and McDougall 1976, 201); eruptions in 1969 and 1970 detected (Simkin et al. 1981)
	b) Rocard, Society Island	An active submarine volcano	Eruptions reported in 1966, 1971 and 1972 (Simkin et al. 1981)
7	a) Macdonald Seamount, Austral Island	Occasionally active	Active volcanism reported 500 m below sea level by Johnson and Malahoff (1971); signs visible at ocean surface; eruptions reported in 1928, 1936, 1967 (Simkin et al. 1981)
8	a) Lo'ihi Hawaii Island	Active	Although no eruption has yet been observed, there are numerous indications that this volcano has been active throughout the past 3,000 years; its summit currently lies more than 900 m beneath the ocean surface (Malahoff 1987)
	b) East of Kauai, Hawaii Island	Eruption report 1956	At 21.75°N, 158.75°W (Simkin et al. 1981)
	c) Northeast of Necker, Hawaii Island	Eruption report 1955	At 23.58°N, 163.83°W (Simkin et al. 1981)
9	a) Brimstone Island, Kermadec Island	Erupted 1825	At 30.23°S, 178.92°W (Simkin et al. 1981)
	b) Monowai, Kermadec Island	4 eruptions since 1958	At 25.88°S, 177.19°E (Simkin et al. 1981)
10	a) Rumble III	5 eruptions since 1958	At 35.70°S, 178.48°E (Simkin et al. 1981); summit 140 m below sea level (Volcano World n.d.)

Note: Numbers refer to locations in Figure 3. Not all active submarine volcanoes are listed for New Zealand, Tonga, and Vanuatu. A complete list is given in Simkin et al. (1981), and most are given by *Volcano World* (n.d.).

Taylor, P. W. 1995. Myths, legends, and volcanic activity: An example from northern Tonga. Journal of the Polynesian Society 104:323–46.

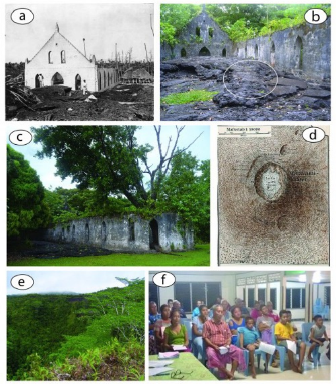
Most throwing-down myths come from islands or island groups that were not fished up. The latter point is clearest in Tonga, where **none of the limestone islands are said to have been thrown down, only the volcanic islands.**

The link between throwing-down myths and erupting volcanoes—which often produce a rain of boulders and ash and sometimes create new land even new islands—**is clear.**

.. the central part of the active volcano Niuafo'ou in Tonga was said to **have been stolen** by imps, who **later dropped it to form the volcanic island Tafahi** (Mahony 1915, 117).

… **these myths have been interpreted as recalling the effects of volcanic eruptions—principally falls of ash and pyroclastics—on nearby islands** (Taylor 1995; Nunn 1999).

Geoeducation Lessons



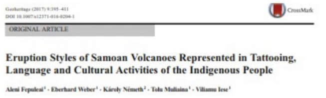
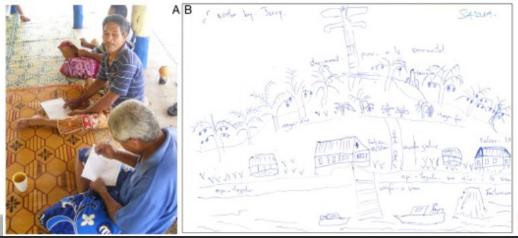


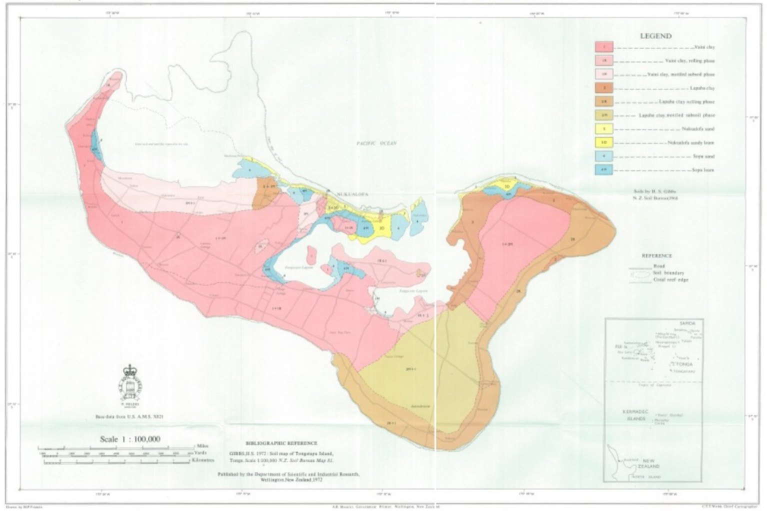
Fig. 10 The 'kusi' stripe wearing by dancers on cheeks, commonly a red for woman and b black for man (source: www.google.com—images for siva samoa)



Geoconservation Lessons

N.Z. Soil Bureau Map 81

SOIL MAP OF TONGATAPU ISLAND, TONGA

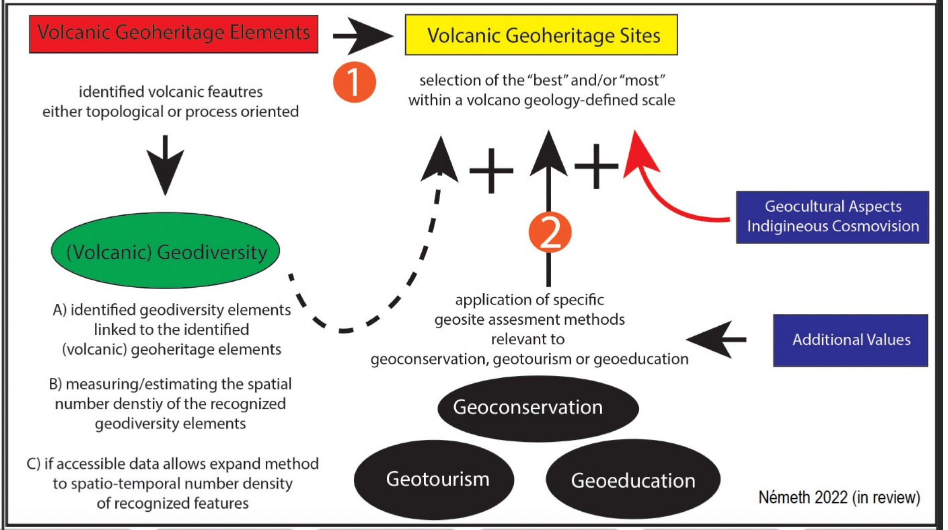


Direct work to establish tephrastratigraphy in Tongatapu

Numerous volcanic event suspected to be recorded in the Pleistocene – Holocene geology of Tongatapu

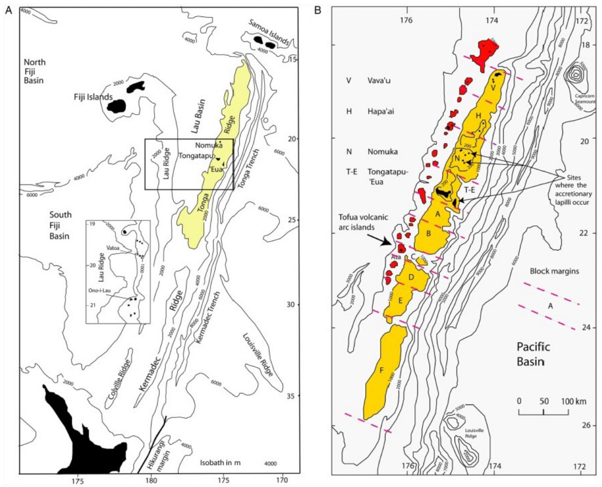
Volcanic Geoheritage

How can we deal with a once a milenia event that likely will leave „nothing" in the geological record …



Looking into the Geological Past

In geological time scale similar events are common in a volcanic arc like the Tonga – Kermadec Arc.



New Zealand Journal of Geology and Geophysics

ISSN: 0028-8306 (Print) 1175-8791 (Online) Journal homepage: https://www.tandfonline.com/loi/tnzg20

Sourcing of Miocene accretionary lapilli on 'Eua, Tonga; atypical dispersal distances and tectonic implications for the central Tonga Ridge

JK Cunningham & AD Beard

To cite this article: JK Cunningham & AD Beard (2016) Sourcing of Miocene accretionary lapilli on 'Eua, Tonga; atypical dispersal distances and tectonic implications for the central Tonga Ridge, New Zealand Journal of Geology and Geophysics, 59:2, 302-312, DOI: 10.1080/00288306.2015.1130728

Summary

- The 15 January 2022 eruption of the Hunga Tonga – Hunga Ha'apai volcano was a once in a millenia event.
- The eruption was dominated by Surtseyan-style explosive eruptions, that culminated to a violent magma-water interaction driven explosive event where new (probably hotter and more mafic – relatively) magma been involved.
- While Surtseyan-style eruptions across the Pacific in arc settings are common, the Hunga eruption had at least one catastrophic explosion due to massive decompression that generated shock waves, triggerred a tsunami and transported very heavily fragmented ash particles to at least 55+ km height.
- While hydrovolcanism – phreatomagmatism is an efficient driving force to produced sustained explosive activity if enough magma available and the external conditions are ideal for maximum thermal to mechanical energy transfer, still it is a disturbing mystery what else needed to generate such energetic decompression (hydrothermal system?)
- The Hunga eruption unlikely will provide direct material to the geological record hindering to use any geosites for volcanic geoheritage purposes, including geoeducation programs for natural hazard resilience.
- Challenging aspects beside the volcanological research is to find a way to communicate and co-develop geoeducation programs within the local community to keep this event as a rare but potential eruption scenario to the Tongan volcanic arc and other similar geotectonic systems across the Pacific.