COURSE: GEO-INFORMATICS IN EARTH SCIENCE, TECTONIC HAZARD AND INFRASTRUCTURE MANAGEMENT

LECTURE 8 – Science of Volcanic

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What is Volcanoes

Pyroclastic flows from the 1984 explosive eruption of Mayon, Philippines

Source: Loughlin, S.C., et al, 2015., C. Newhall

What is Volcanoes

Frequent mild-to-moderate explosive eruptions, sometimes accompanied by lava flows, have been recorded since the 19th century from the three active craters at the summit of Langila, WNB, PNG

Source: Wally Johnson, 1970 (Australia Bureau of Mineral Resources

What is Volcanoes

Eruption of Mt. Tavurvur, the active stratovolcano of Rabaul caldera, on 29 August 2014. The ash plume rose to 18 km altitude and dispersed ash to the W and NW of the volcano.

Source: OLIVER BLUETT/AFP/Getty Images, printed in The Washington Post.

Eruption of Tavurvur volcano (Rabaul, PNG) (photo by Ulla Lohmann).

https://www.volcanoadventures.com/expeditions/papua.html

What is Volcanoes

Tavurvur (ENB, PNG) is a strato volcano built up of many layers of hardened lava, tephra, pumice and volcanic ash and is of similar form to the historical Mt Vesuvius in Pompeii that erupted in 79 AD. It is a sub-vent of the Rabaul Caldera which was formed over 1,600 years ago from a massive explosion of gas, ash and lava

Source: https://www.pagahill.com/2016/08/19/mt-tavurvur-and-rabaul/

What is Volcanoes

CITY OF RABAUL AFTER 1994 ERUPTION

Southeastern Rabaul, ENB, PNG

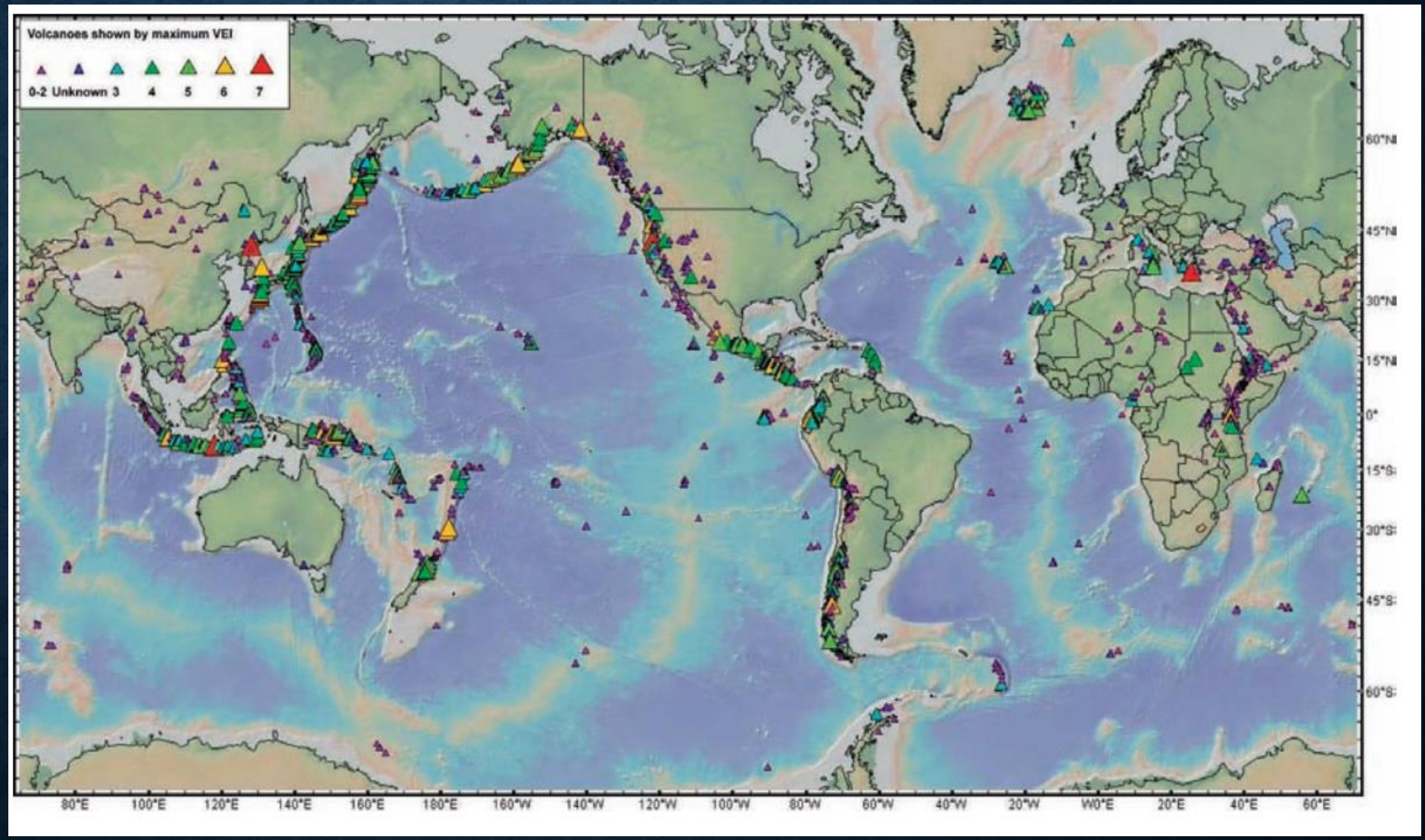
Photo Credit: USGS/Cascades Volcano Observatory, Vancouver, Washington

Volcanic Activities sources

- Most active volcanoes occur at the boundaries between tectonic plates where the Earth's crust is either created in rift zones:

- Tectonic plates move slowly apart

- plates collide and one is pushed below the other.

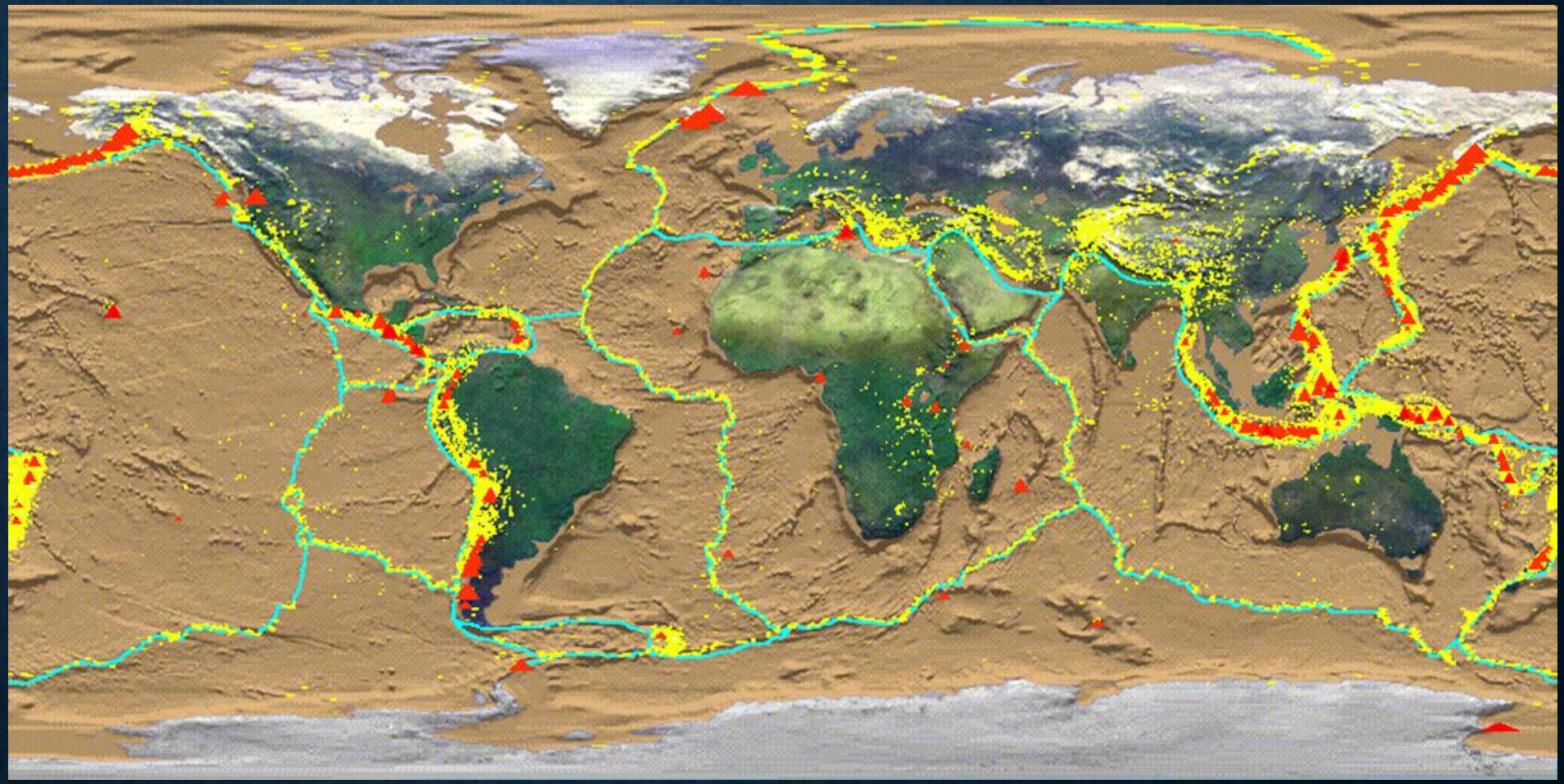


Source: Loughlin, S.C., et al, 2015., Schmincke, 2004, Cottrell, 2014

Volcanic Activities Sources

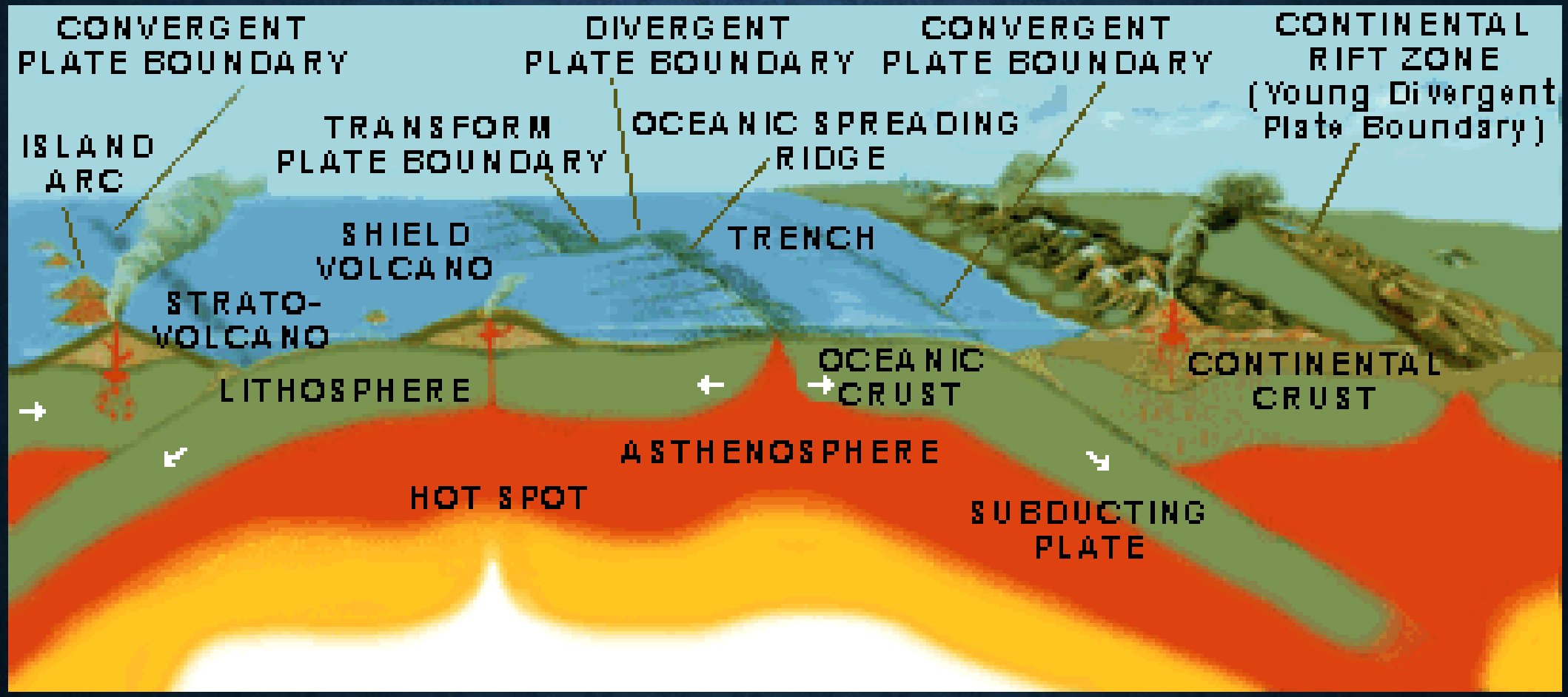
World map showing;

- ✓ plate boundaries - blue lines,
- ✓ the distribution of recent earthquakes- yellow dots
- ✓ active volcanoes - red triangles.



Source: Courtesy of NASA

Volcanic Activities Sources



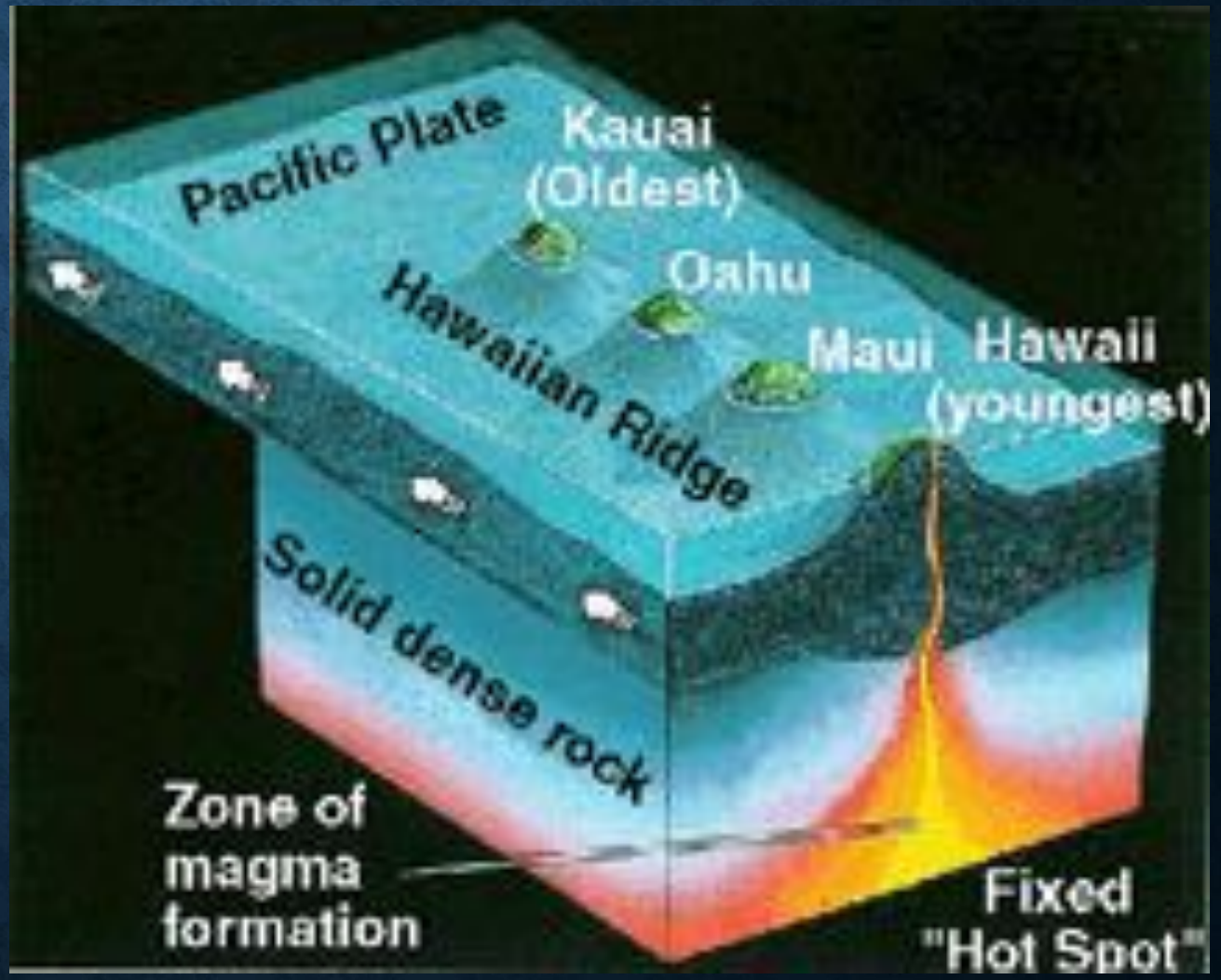
Source: Courtesy of USGS.

Volcanism at divergent and convergent plate margins.

Volcanic Activities Sources

INTRAPLATE VOLCANISM

- Model demonstrating how these chains form above the stationary mantle plume, becoming progressively older to the northwest.



Source: Courtesy of USGS.

How and why do volcanoes erupt?

- Hot, molten rock (magma) is buoyant (has a lower density than the surrounding rocks) and will rise up through the crust to erupt on the surface.
- Same principle as hot air rising, e.g. how a hot air balloon works
- When magma reaches the surface it depends on how easily it flows (viscosity) and the amount of gas (H_2O, CO_2, S) it has in it as to how it erupts.

How and why do volcanoes erupt?

- Large amounts of gas and a high viscosity (sticky) magma will form an explosive eruption;

- Think about shaking a carbonated drink and then releasing the cap.

- Small amounts of gas and (or) low viscosity (runny) magma will form an effusive eruption;

- Where the magma just trickles out of the volcano (lava flow).

How and why do volcanoes erupt?

Non-explosive Eruptions:

- Non explosive eruptions are favored by low gas content and low viscosity magmas (basaltic to andesitic magmas).
- If the viscosity is low, non-explosive eruptions usually begin with fire fountains due to release of dissolved gases.
- Lava flows are produced on the surface, and these run like liquids down slope, along the lowest areas they can find.
- If the viscosity is high, but the gas content is low, then the lava will pile up over the vent to produce a **lava dome** or **volcanic dome.**

source: Chris Johns; Online: https://education.nationalgeographic.org/resource/volcanoes/

How and why do volcanoes erupt?

Explosive Eruptions:

- Explosive eruptions are favored by high gas content and high viscosity (andesitic to rhyolitic magmas).
- Explosive bursting of bubbles will fragment the magma into clots of liquid that will cool as they fall through the air.
- Clouds of gas and tephra that rise above a volcano produce an eruption column that can rise up to 45 km into the atmosphere.

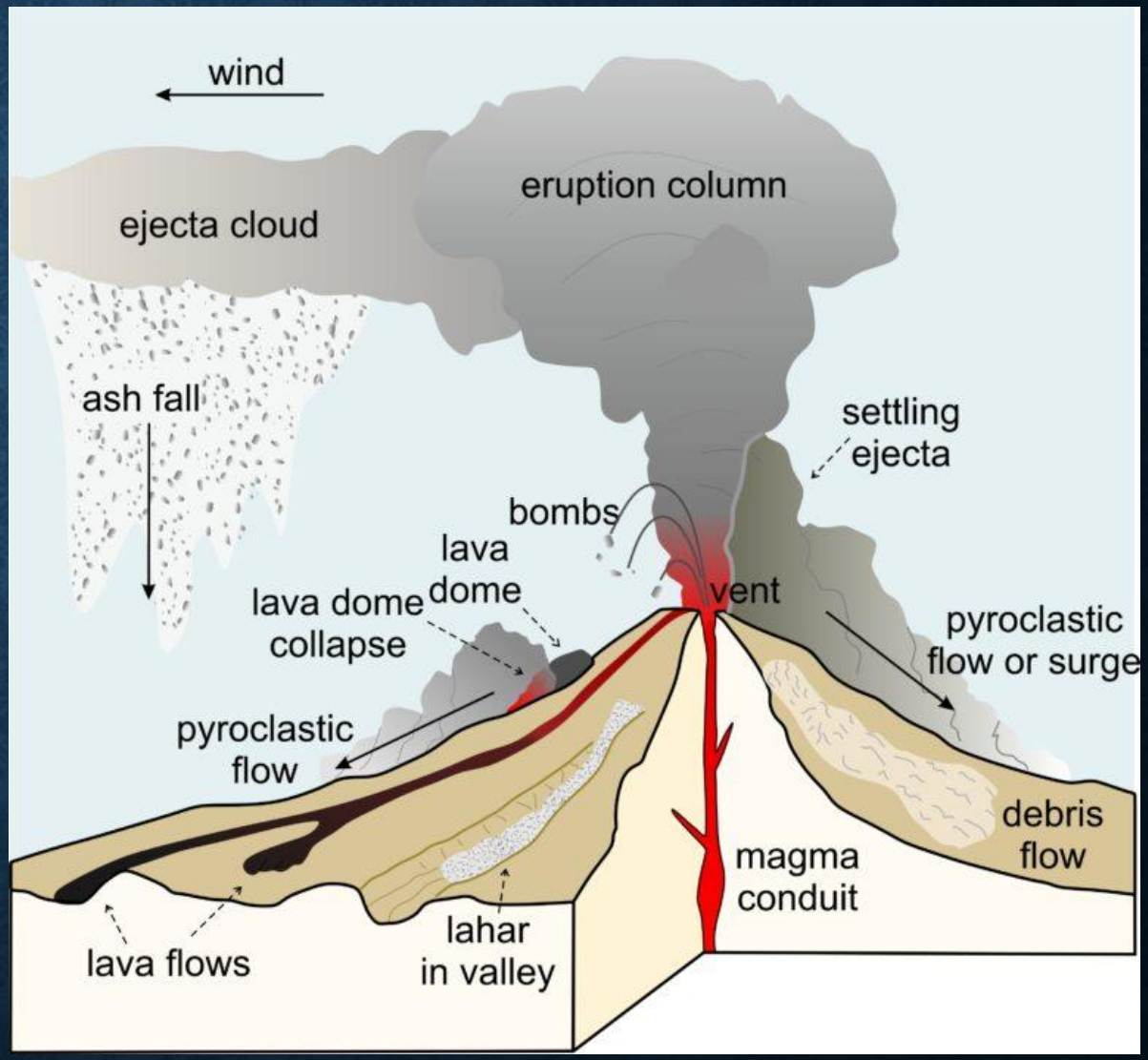
The Santiaguito volcanic Eruption, Source: Martin Rietze/Getty image Online: https://www.wired.com/2017/04/worlds-10-dangerous-volcanoes-ranked/

How and why do volcanoes erupt?

Explosive Eruptions:

- Eventually the tephra in the eruption column will be picked up by the wind, carried for some distance, and then fall back to the surface as a tephra fall or ash fall.

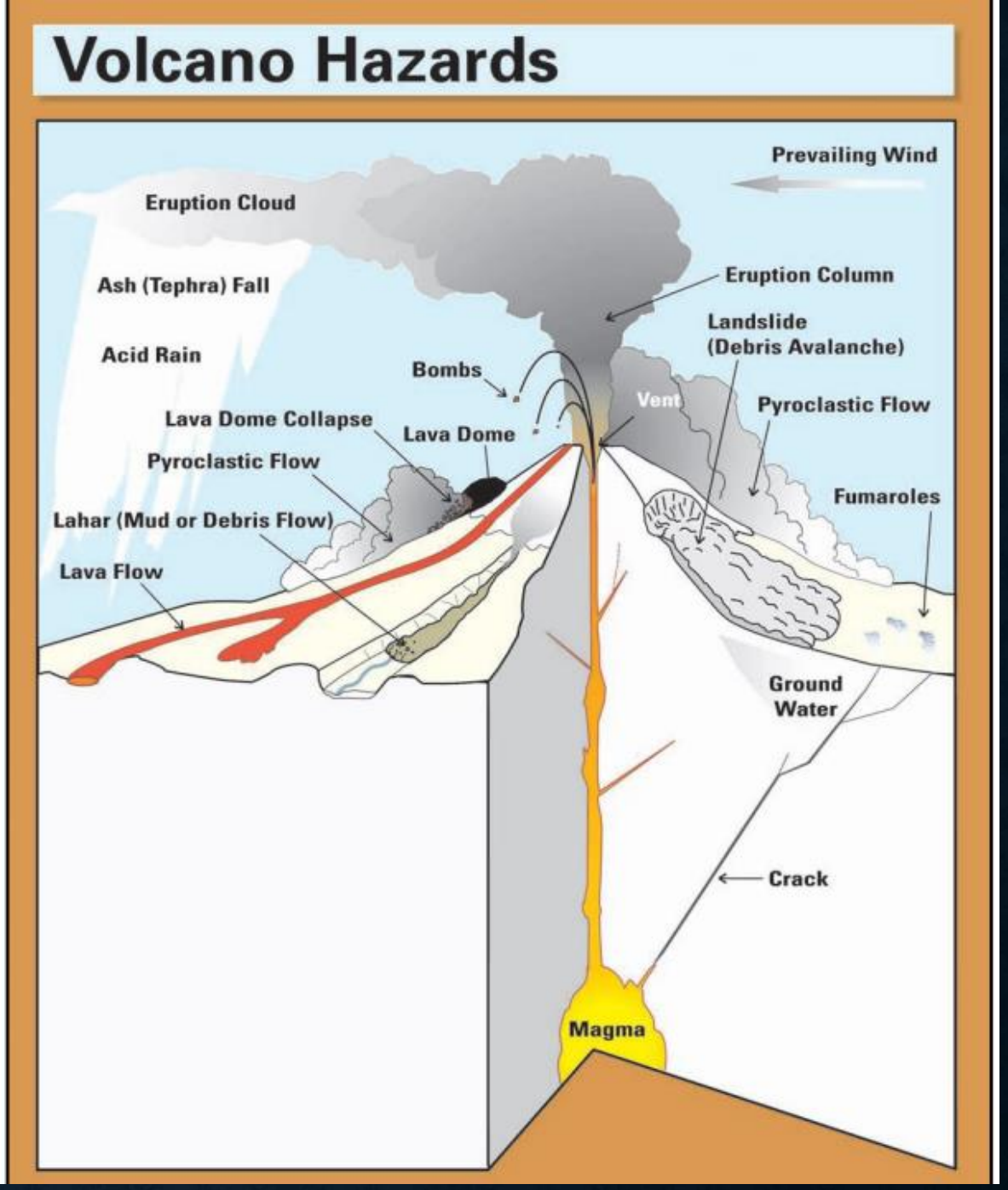
- If the eruption column collapses a pyroclastic flow will occur, wherein gas and tephra rush down the flanks of the volcano at high speed. This is the most dangerous type of volcanic eruption.



Source: Online; https://opengeology.org/petrology/5-explosive-volcanic-eruptions/

Volcano Hazard

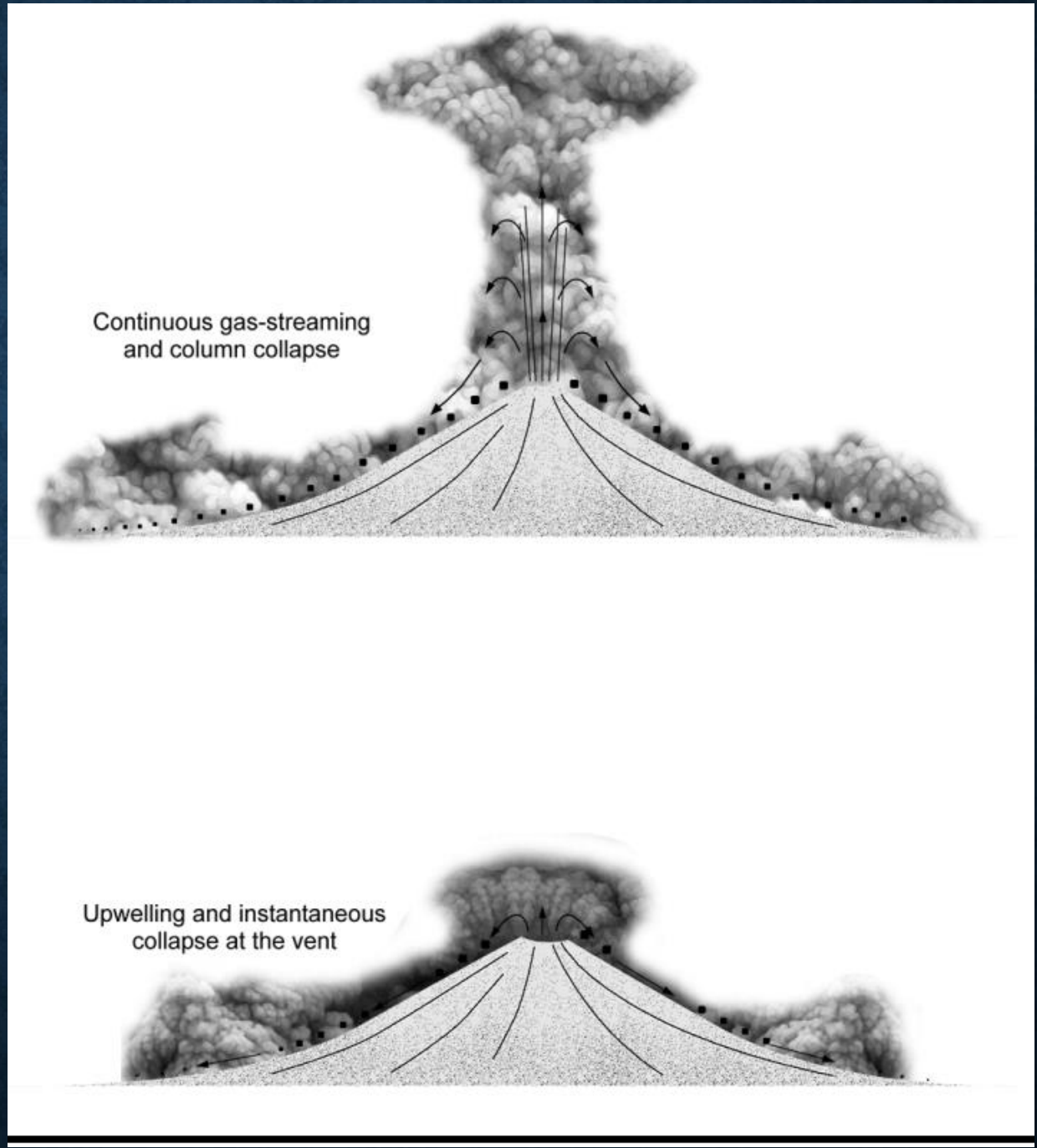
- Pyroclastic flow
- Lahars/Mud flows
- Pyroclastic fall
- Lava flow
- Noxious Gas
- Earthquakes



Source: U.S Geological Survey, Online: https://pubs.usgs.gov/gip/19/downloads/Chapter_2/Activities/Volcanic%20Processes.pdf

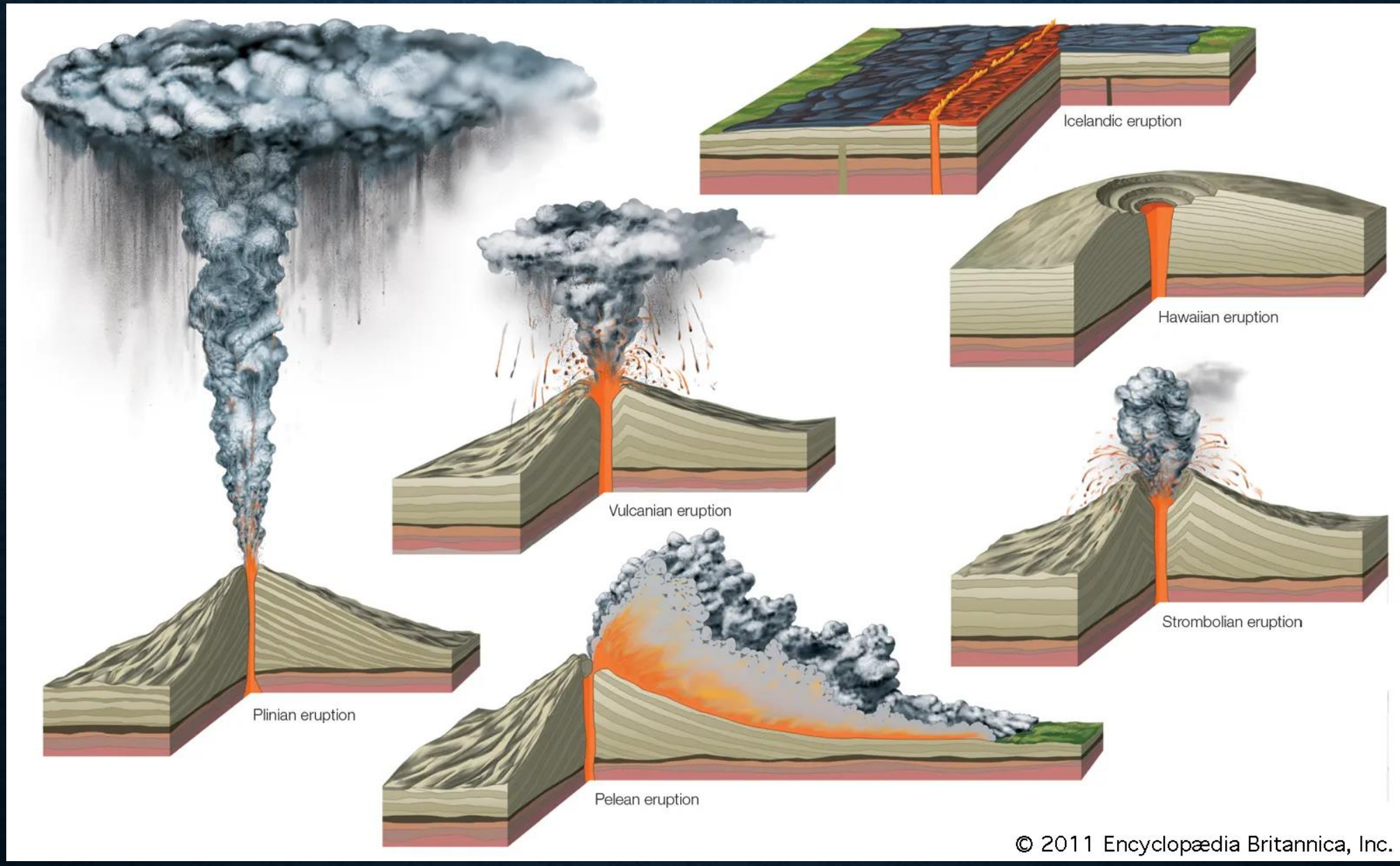
Volcano Hazard

- Pyroclastic fall



Source: Loughlin, S.C., et al, 2015, online: https://nora.nerc.ac.uk/id/eprint/509938/1/WC00020.pdf

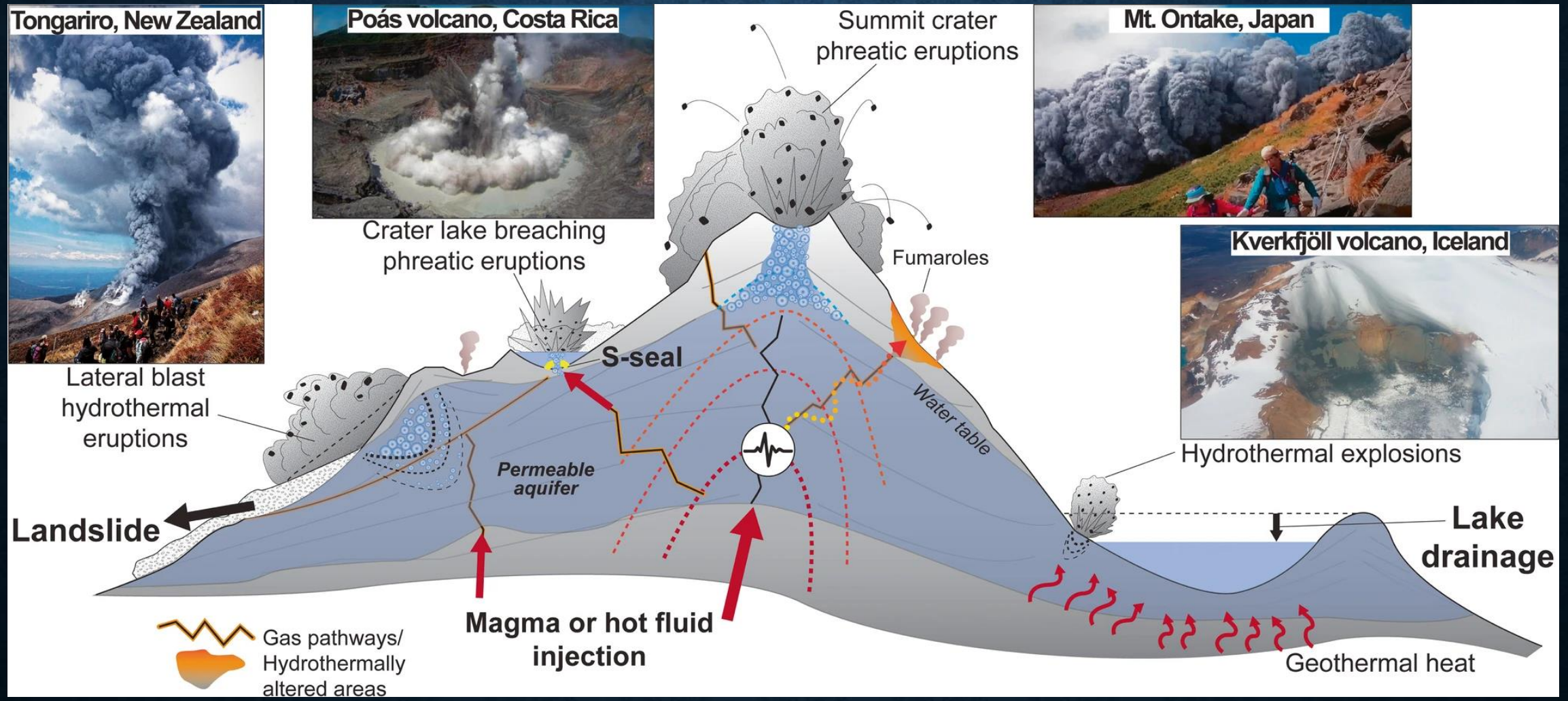
Types of Volcanic Eruption



Source: 2011 Encyclopedia Britannica, Inc. Online: https://www.britannica.com/science/volcano/Six-types-of-eruptions

Types of Volcanic Eruption

Phreatic and Hydrothermal Eruptions: From Overlooked to Looking Over



Source: Montanaro, C., Mick, E., Salas-Navarro, J. et al. 2022

Volcanic Hazard Assessment and Mapping

Volcanic Hazard Assessment

Evaluation of volcanic Hazard:

Two main complementary approaches may lead to their prediction:

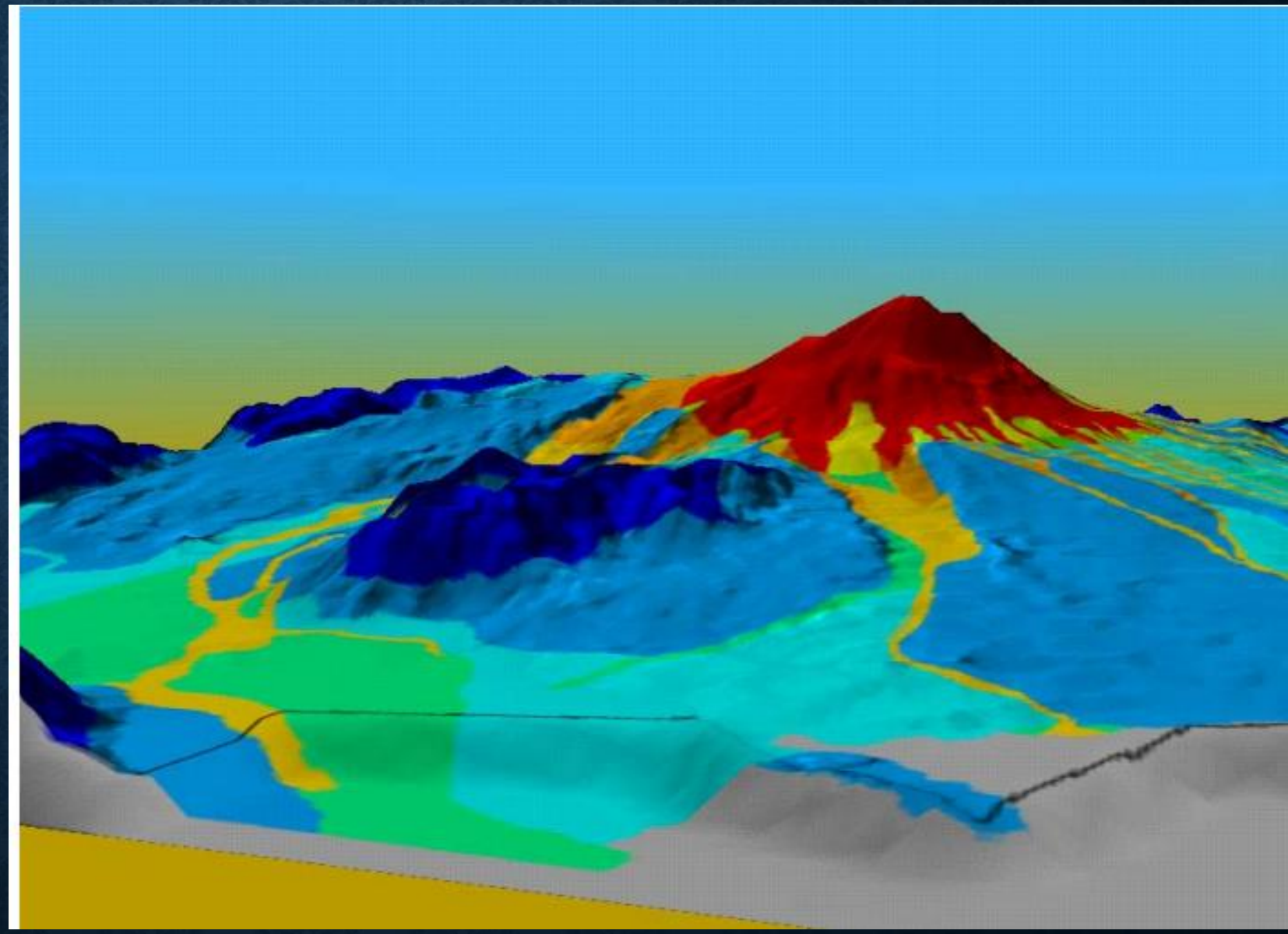
1. Medium – to long-term analysis:

- Study of the eruption history of the volcano
- Volcano hazard mapping and modeling

2. Short term: humans surveillance and instrumental monitoring of the volcano (precursory phenomena)

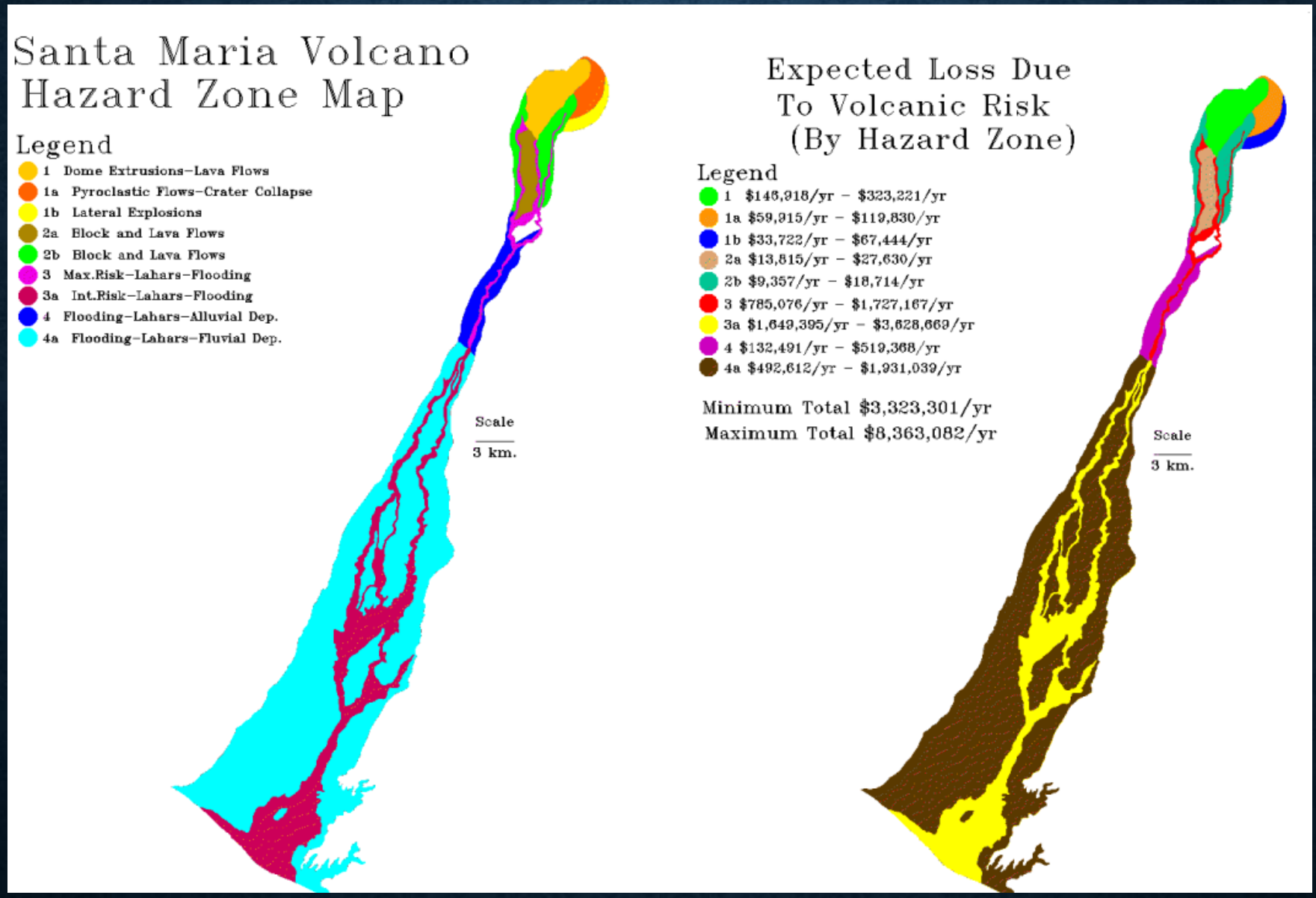
Volcanic Hazard Assessment and Mapping

- Example of a digital terrain model of volcán Villarrica draped with hazard zones.
- The terrain model may be viewed from any perspective and provides a very powerful method of presenting hazard map information in a more easily visualized form.



Source: Dunkley, P N and Young, S R. (2000), Online: https://nora.nerc.ac.uk/id/eprint/509938/1/WC00020.pdf

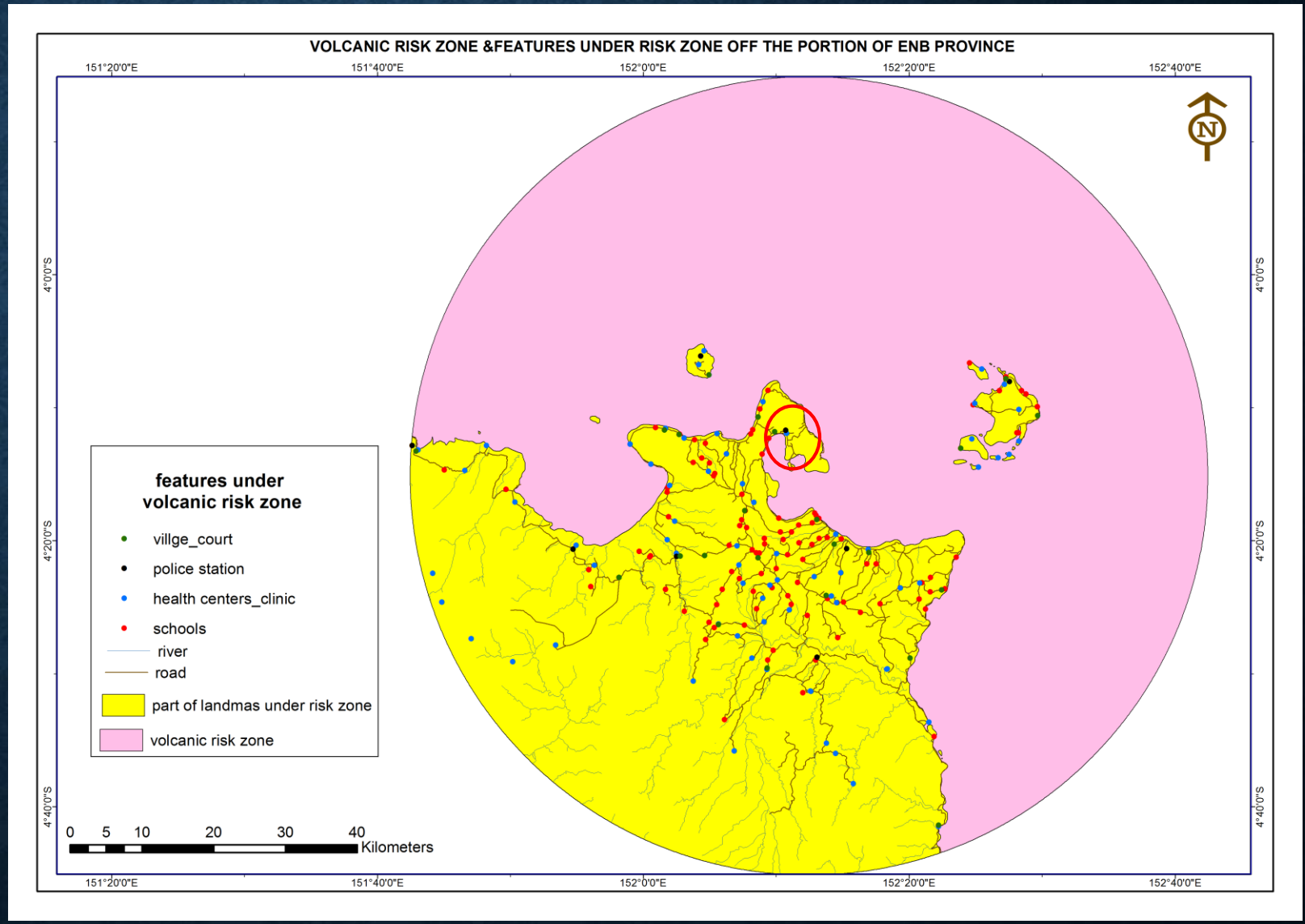
Volcanic Hazard Assessment and Mapping



Source: Dunkley, P N and Young, S R. (2000)., Green and Rose, (1998), Online: https://nora.nerc.ac.uk/id/eprint/509938/1/WC00020.pdf

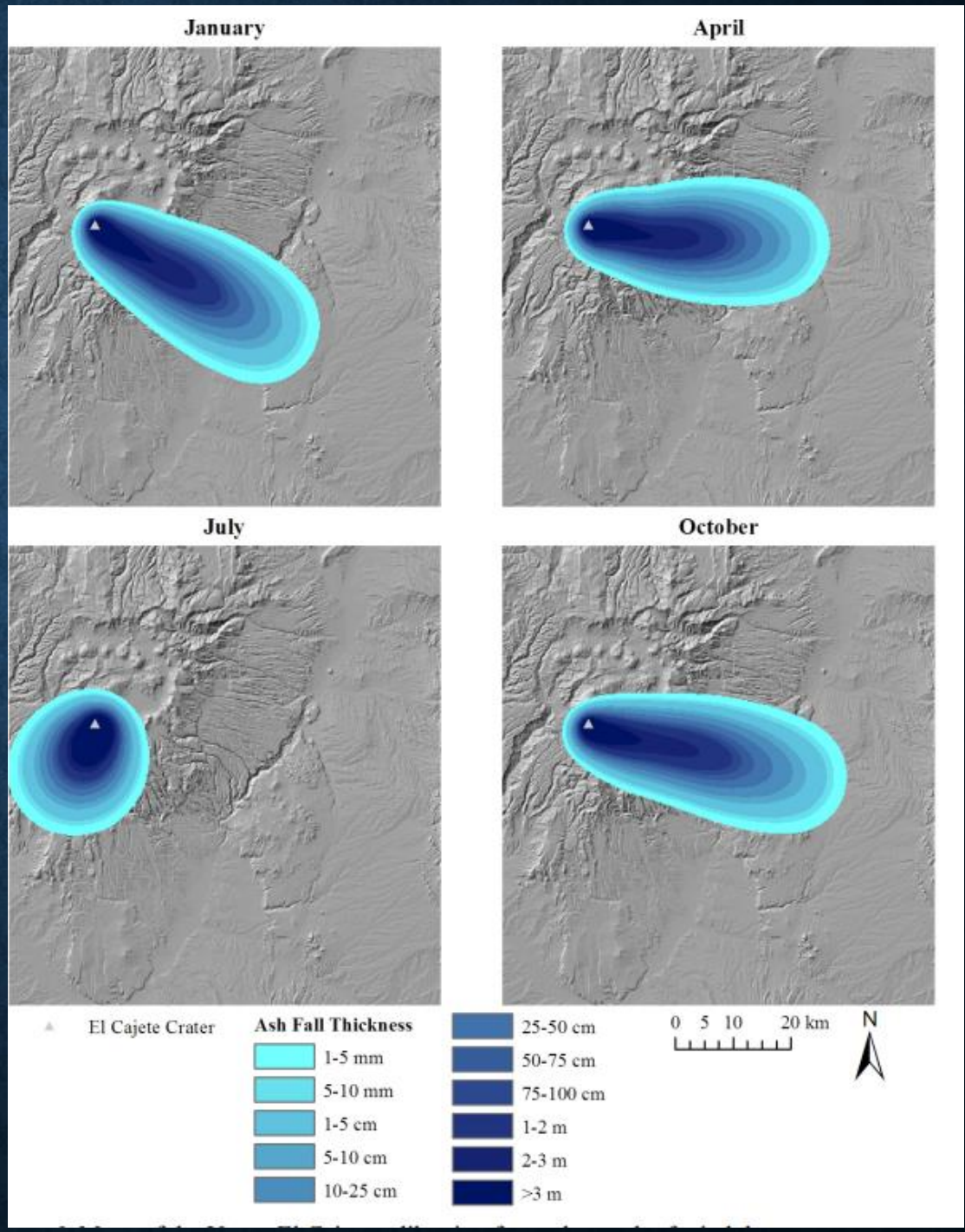
Volcanic Hazard Assessment and Mapping

- Volcanic Risk Zone Mapping of Rabaul-ENP, PNG



Volcanic Hazard Assessment and Mapping

- Volcanic ass fall thickness Based on each month wind direction.



Source: Alcorn. R., 2013: Online; https://geogis.bgsu.edu/theses/RJAlcorn%20Thesis.pdf

Volcanic Hazard Assessment and Mapping

Volcanic Risk

- Standard of living (adjusted to GDP per capita)
- Population Density (persons/hectare)
- Infrastructure (kilometers of highway and power lines)
- Land use - economic activity contributing to GDP

From the four layers of economic data the value was computed in terms of dollars per hectare:

Value = (Standard of living × Population Density) + Infrastructure + Land use

Volcanic Risk was then calculated using the standard formula:

Volcanic Risk = Value × Vulnerability × Hazard

Source: Dunkley, P N and Young, S R. (2000)., Online: https://nora.nerc.ac.uk/id/eprint/509938/1/WC00020.pdf

Volcanic Hazard Assessment and Mapping

Volcanic Risk Map

- Volcanic risk maps allow for the calculation of the economic impact of an active volcano in dollar terms

- These maps are useful for disaster preparedness, and planning because the real cost of the impact of a volcanic eruption can be compared with the cost of mitigation and monitoring effects.

Volcanic Hazard Assessment and Mapping

Volcanic Risk Monitoring and Forecasting

- Most volcanic eruptions are preceded by a variety of environmental changes (precursory signs) which accompany the rise of magma towards the surface:

1. Seismic activity
2. Ground deformation
3. Hydro-thermal phenomena
4. Chemical changes

Volcanic Hazard Assessment and Mapping

Volcanic Risk Monitoring and Forecasting

Short term predictions

Human surveillance and instrumental monitoring of volcanoes.
- using ground based and space base systems.

Techniques:

- Visual Observations
- Use of tiltmeters and GPS (Ground defoemation)
- Use of seismographs (tremors/volcanic earthquakes)
- Measuring Gas emission (chemical composition + temperature
- Remote Sensing.

Volcanic Hazard Assessment and Mapping

Use of Remote Sensing and GIS

Example:

- Mapping Volcanic Terrain
- Hazard and Risk Zonation
- Monitoring Volcanic activity
- Monitoring volcanic eruption
- Part of the early warning system
- Damage assessment after eruption
- Land use Planning

References:

Loughlin, S.C., Vye-Brown, C., Sparks, R.S.J., Brown, S.K., Barclay, J., Calder, E., Cottrell, E., Jolly, G., Komorowski, J-C., Mandeville, C., Newhall, C., Palma, J., Potter, S., Valentine, G. (2015) An introduction to global volcanic hazard and risk. In: S.C. Loughlin, R.S.J. Sparks, S.K. Brown, S.F. Jenkins & C. Vye-Brown (eds) Global Volcanic Hazards and Risk, Cambridge: Cambridge University Press.

Schmincke, H. U. 2004. Volcanism, Berlin Heidelberg, Springer-Verlag, pp. 324

Cottrell, E. 2014. Global Distribution of Active Volcanoes. In: Papale, P. (ed.)Volcanic Hazards, Risks and Disasters. Academic Press.

Montanaro, C., Mick, E., Salas-Navarro, J. et al. Phreatic and Hydrothermal Eruptions: From Overlooked to Looking Over. Bull Volcanol 84, 64 (2022). https://doi.org/10.1007/s00445-022-01571-7

Dunkley, P N and Young, S R. (2000). Volcanic hazard mapping for development planning. BGS Technical Report WC/00/20