Mapping Earth's Volcano Types

Which volcano types are common near tectonic plates and boundaries and what spatial patterns emerge from them?

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Abstract

As we move across the Earth's surface, it becomes overwhelmingly evident to us humans that our planet is alive with forces far beneath our feet. Mountains risen in jagged silhouettes, oceans plunging into the abyss and valleys split ajar like deep wounds etched into the land's surface, but few features capture the raw power of Earth's interior like volcanoes. From the broad, gentle domes of Hawaii's shield volcanoes to the towering strata-volcanoes of the Pacific Ring of Fire, each type of volcano stands as a testament to the forces that forged it. This story map invites you on a journey across this dynamic terrain - not by descending into these enigmatic craters, but by exploring the spatial patterns of volcanoes around the world. By combining techniques of spatial analysis, this map aims at identifying what types of volcanoes are

most frequent near tectonic plates and plate edges, and what spatial patterns they give birth to.

Aerial View of Icelandic Geothermal Landscape

Process of Analysis

Defining the research question

This provided a central focal point for collection of data, analysis and mapping.

Identifying a reliable set of data

This constitutes locating a trustworthy dataset with comprehensive volcano information. ArcGIS's Global Volcanoes Map and Tectonic Plate Boundaries Map based on the Smithsonian Volcano Database were used for this study.

Importing data into ArcGIS

Began analysis by opening the Global Volcanoes Map on ArcGIS and overlaying the layer of tectonic plates and boundaries to it.

Selecting the analysis method

The statistical analysis tool in ArcGIS, 'Summarize Nearby' was deemed apt for the research question chosen.

Performing the spatial analysis procedure

The summarize-nearby tool was used to add a buffer of 300km from the tectonic plate boundaries and to calculate the number of volcanoes located within the area, by each type.

Identifying clustering patterns

Observed whether a certain type of volcano appeared clustered within the used buffer. Projected this data onto a bar chart for better data visualization.

Interpreting spatial patterns

Explained patterns observed by relating geological processes to map observations.

Data

Raster Spatial Data

- Imagery with labels basemap - A tiled raster layer providing high-resolution satellite and aerial imagery worldwide was used as the basemap to provide visualization context.

Vector spatial data

- point layer - depicting the locations of the volcanoes.
- line layer - depicting the tectonic plate boundaries.
- polygon layer - depicting tectonic plates.

Attribute Data

- Volcano Type - Nominal Variable containing a string of the type of volcano. eg: Caldera, Compound, shield etc.
- Dominant Rock Type - Nominal Variable describing the main lava or rock composition. eg: Foidite, Basalt, Trachybasalt.
- Tectonic Setting - Nominal Variable identifying the tectonic environment where the volcanoes are located. eg: Rift zone, Intraplate.
- Elevation - Ratio variable depicting the heights of the volcanoes.

Spatial Analysis Procedure

To investigate the spatial distribution of volcanoes, ***overlay analysis and summarize nearby analysis*** were used. First, the global volcanoes map (Point) was overlayed on the Tectonic Boundaries map (Line), performing a Point-on-Line Overlay.

Then, a 300km buffer was applied around tectonic plate boundaries to identify volcanoes located closest to these active regions. Then, these volcanoes were grouped by their type using the summarize by tool, calculating the statistics for most frequent type of volcanoes near the edge plates.

Additionally, volcano attributes such as tectonic setting and dominant rock type were analyzed in relation to the volcanic location. ***Overlaying*** volcano points with tectonic settings allowed identification of correlations between volcano type and tectonic environment. Similarly, analyzing dominant rock type in conjunction with tectonic environment was carried out, using the ***summarize nearby tool***.

To visualize findings, each set of data were configured into a bar chart, displaying clearly which type of volcano, rock/lava type are more frequent near tectonic boundaries and different types of plates themselves.

Ethical Considerations

This project makes use of publicly available geological data on GIS, which do not generally consist of personal or sensitive data. As a result, the concerns related to privacy or confidentiality were minimal. Citations of the spatial data used can be found in the references section.

The analysis does not directly involve indigenous communities or their data, but it is important to acknowledge broader principles of Indigenous Data Sovereignty (IDS), when considering last-based data, specially volcanic and tectonic environments, as these

regions overlap with locations that hold cultural or spiritual meaning to these communities.

Recognizing this, any current or future work that involves collection of volcanic data, land use planning or volcanic risk/hazard communication should follow the principles of CARE.

Indigenous women engaged in mountaineering

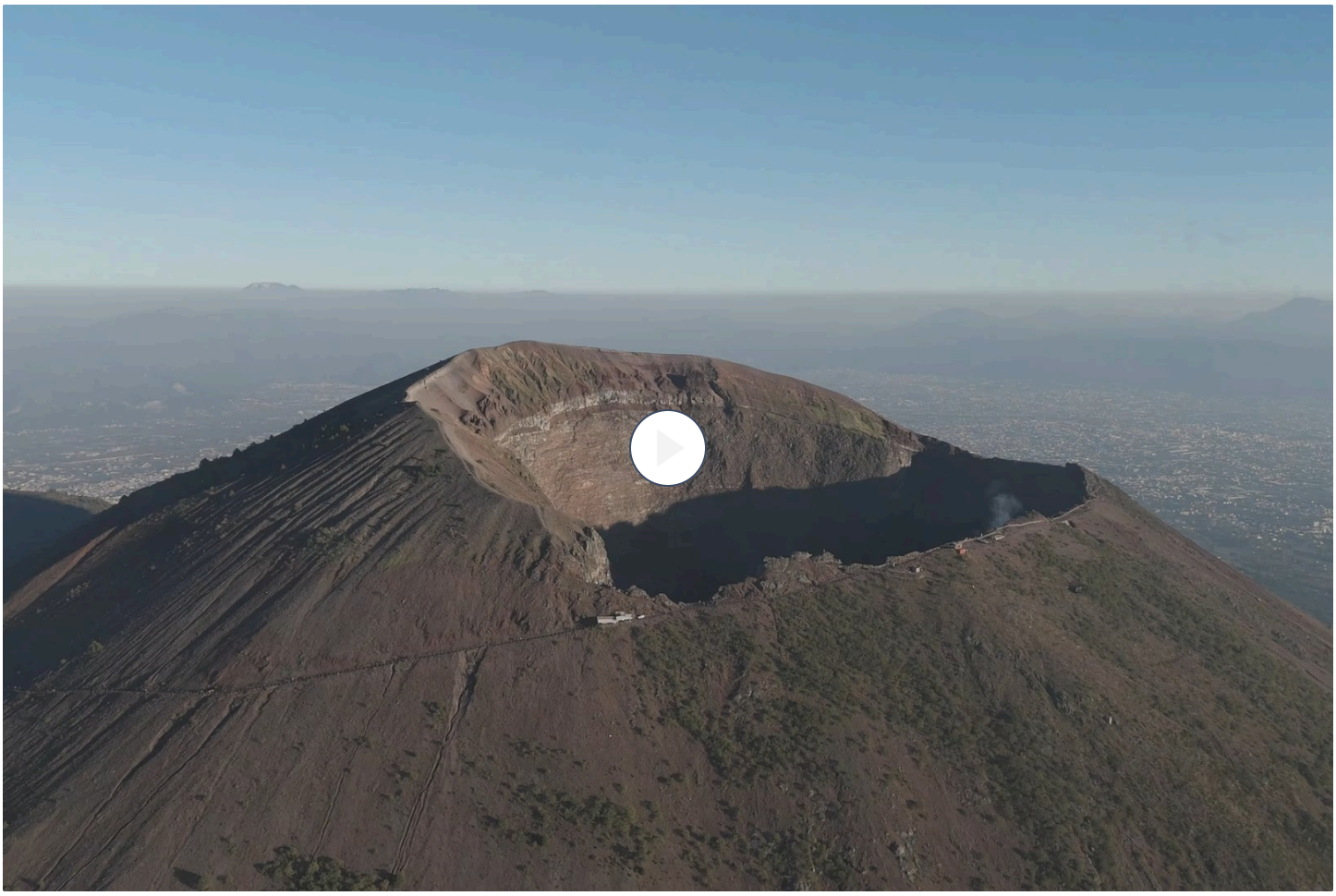
- *C - Collective Benefit*
- *A - Authority to Control*
- *R - Responsibility*
- *E - Ethics*

Using the above principles, indigenous people should be situated as owners of their data and incorporated into the process of collecting, owning, storing and releasing of data, as stewards rather than subjects of their backdrop.

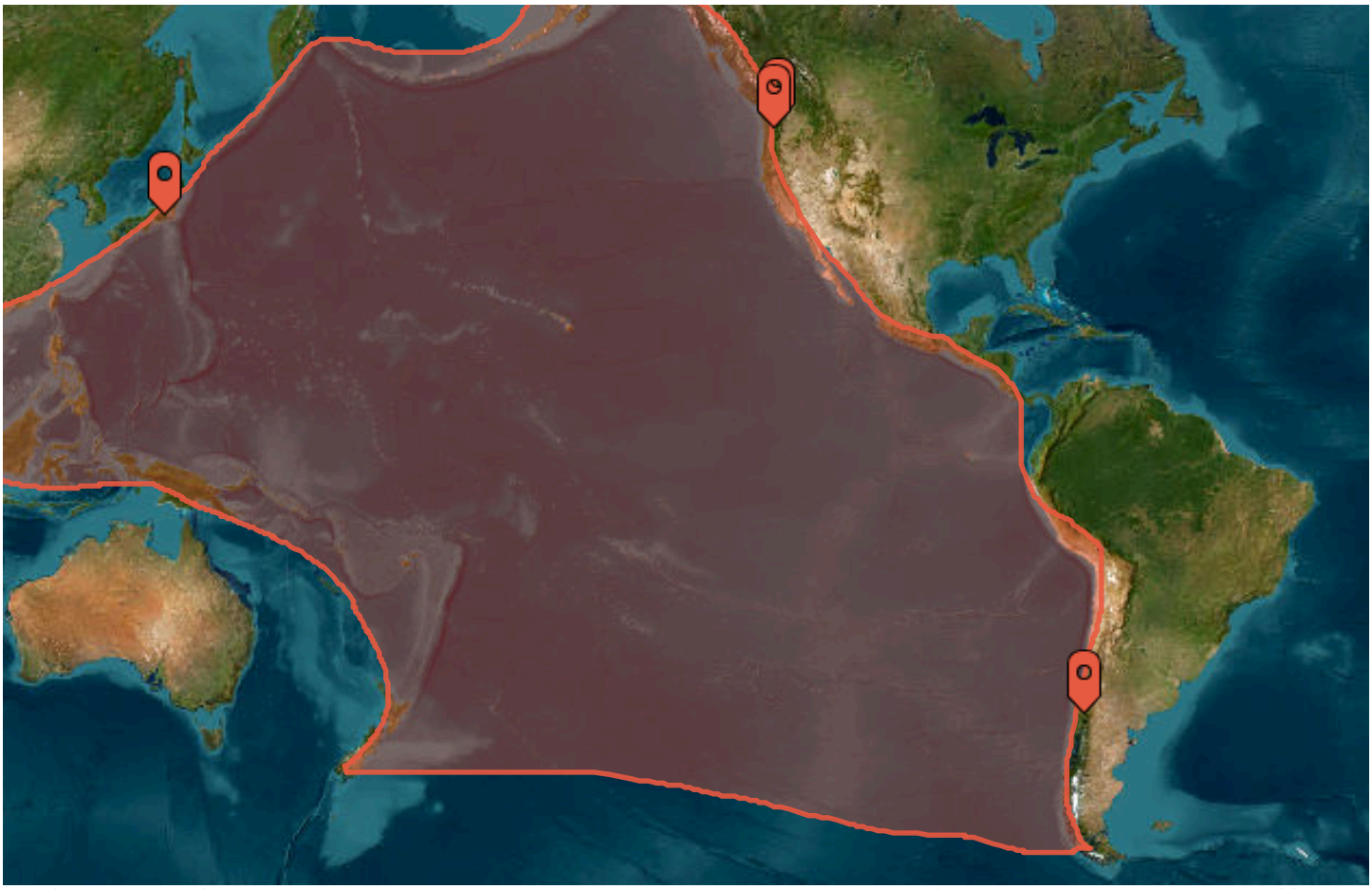
Findings of the study

Stratovolcanoes are more frequent near convergent tectonic boundaries

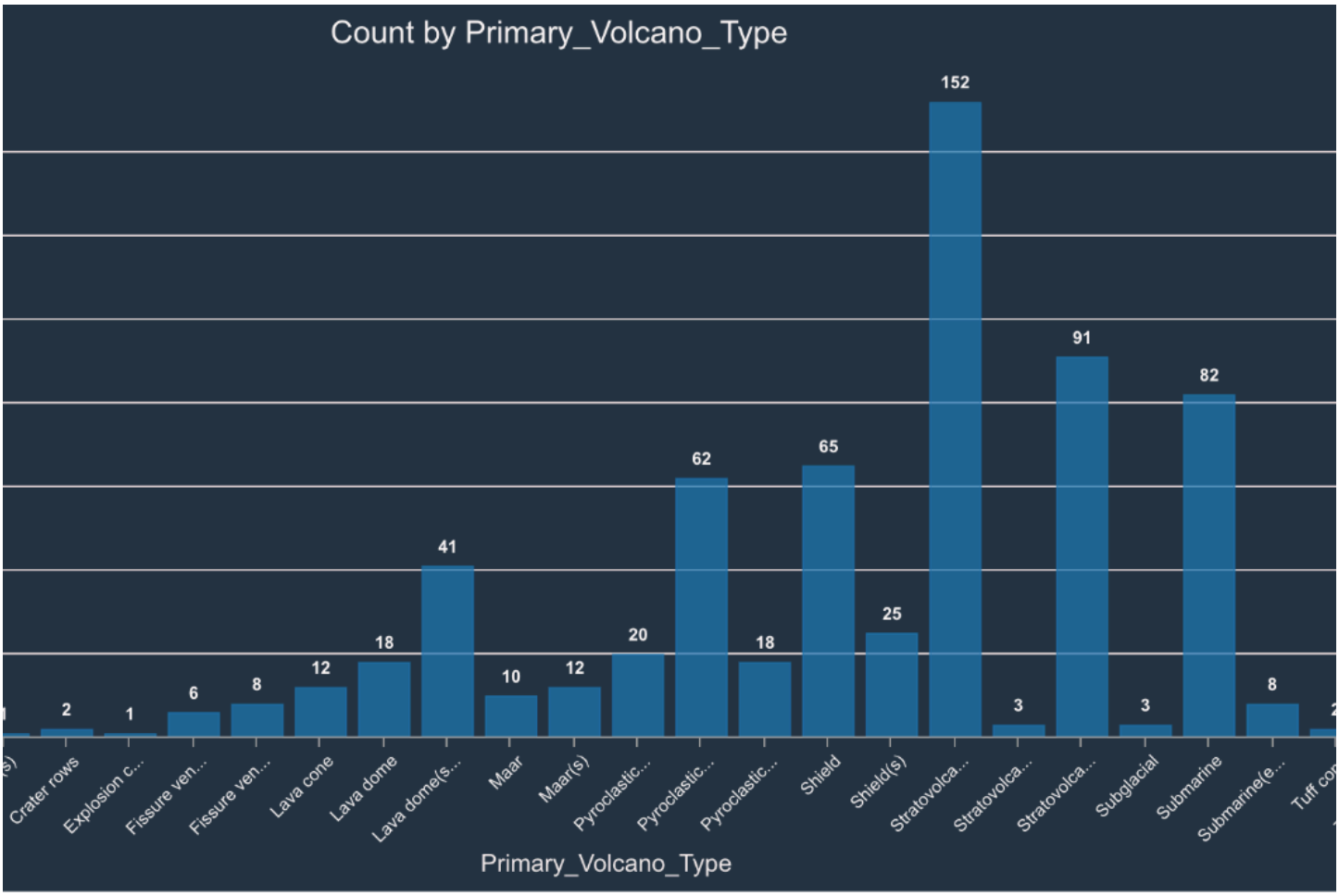
- When volcanoes near a buffer of 300km from tectonic boundaries were analyzed, ***Stratovolcanoes*** emerged to be the most dominant type. These volcanoes tend to form around the subduction zones and were found to be the most common in the Pacific Ring of Fire. (Eldridge, 2025)



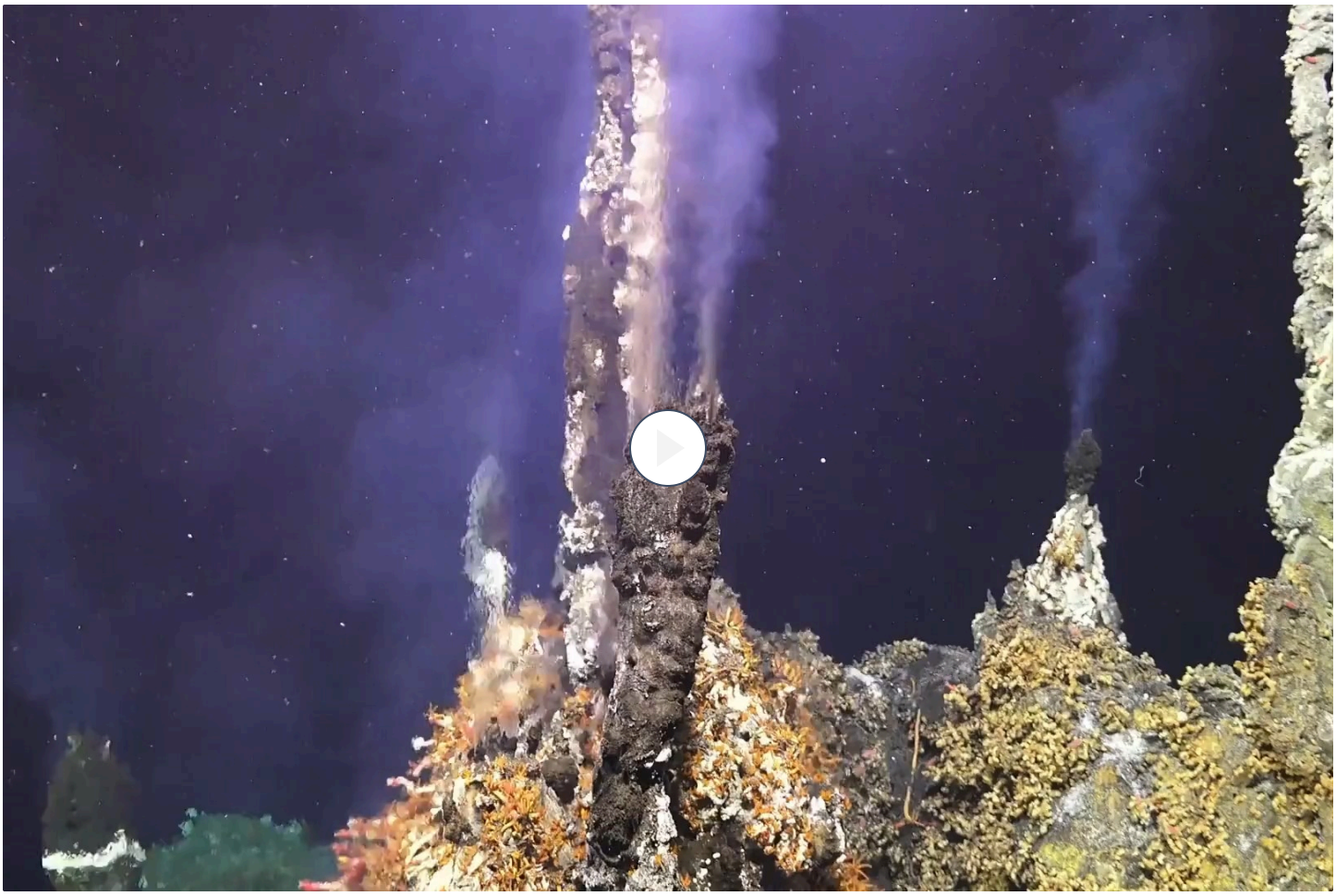
- Stratovolcanoes tend to be dominant and violent close to plate boundaries due to the process of subduction where a heavier tectonic plate dives beneath a second plate in these zones.
- Mount Vesuvius in Campania, Italy whose eruption infamously led to the fall of the Pompeii City, is a stratovolcano formed by the collision of African and Eurasian Tectonic Plate Boundaries. (Gasparini, 1998)



- The boundaries of the below polygon depict the pacific ring of fire and some of its its infamous stratovolcanoes.



- 243 Stratovolcanoes were found within close proximity to tectonic boundaries as per the graph. ***Submarine volcanoes (82)*** were the second most prominent while ***Caldera (78)*** volcanoes came in third.



Submarine volcanoes are the second abundant volcanoes around tectonic boundaries, given that 80% of all volcanic activity happens under the ocean. *(Smithsonian National Museum of Natural History) At mid-ocean ridges, plates diverge and erupt into passive lava flows, that ultimately cool into forming a* continuous mountainous structure.

> *"Submarine volcanic activity accounts for roughly 75 percent of the average annual volume of magma that reaches Earth's crust."*
>
> ***(Turgeon, 2025)***

- ***Calderas*** ranked as the third most frequent volcano type, indicates the role of boundary related magmatic systems in producing the large, explosive sunken formation. Intense tectonic activity is required for the release of a high volume of magma, during an eruption, which empties the underground chamber. With nothing to support the ground above the chamber, it collapses and forms a cauldron-like shape.

Most common type of volcanic rock was identified to be *Basaltic Andesite*, which is found more frequently near convergent plate boundaries.

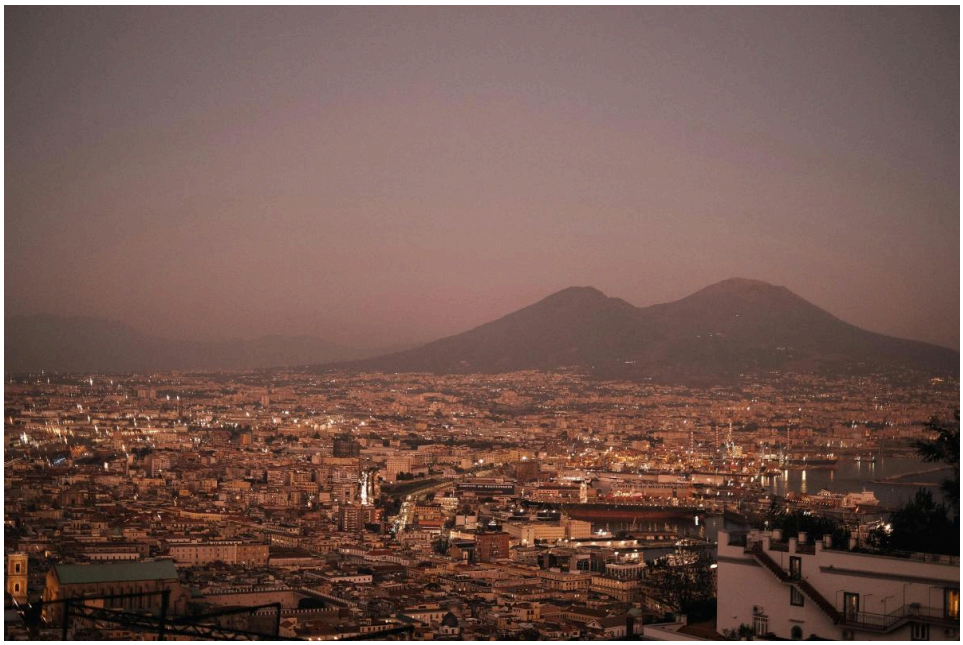
- Volcanic Terrains of Stratovolcanoes are mostly composed of Basaltic Andesite, contributing to their classic steeps and conical shape.
- These are a popular source of geothermal energy used for electricity generation.

Decision-Making Applicability

Understanding which volcano types are most prominent in different tectonic regions is important for a wide range of research, planning and stewardship. By analyzing and visualizing volcanoes by their types and constituents, this story map offers a clear blueprint of where volcanic activity is most likely to concentrate globally.

For hazard assessment and management, identifying clusters of the dangerous and explosive stratovolcanoes within 300km of tectonic boundaries provides the stepping stone for monitoring and preparedness. Regions where dense populations overlap with volcanic arcs can be made a priority with regard to evacuation

planning and early warning systems. Allocating more resources towards these areas of vulnerability would be an efficient initiative that governments and environmental organizations can take.



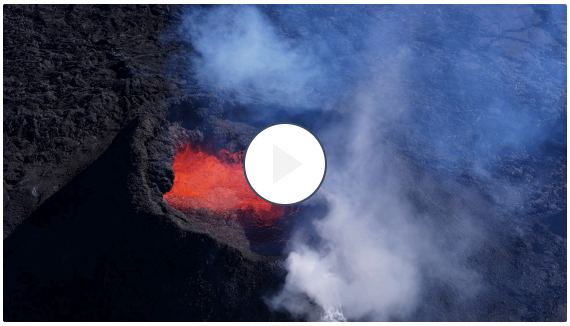
Naples, Italy

The tectonic context and volcanic rock type analysis can be used as a means of identifying sources of geothermal energy production, contributing to sustainable energy production during a time of rapid climate change. This analysis can further support climate change research, by identifying the volcanoes that have the highest potential to influence the atmosphere and the Ozone Layer. Stratovolcanoes near subduction zones for example, are capable of emitting large amounts of Sulfer Dioxide, which can lead to global cooling. However, volcanic Carbon Dioxide can propagate global warming.

Emissions from volcanic activity

Conclusion and Summary

Exploring the global distribution of volcanoes to understand how their characteristics relate to tectonic boundaries revealed clear patterns in volcano type, dominant rock composition and tectonic setting. The spatial overlay and and summarize nearby procedures revealed that most volcanoes located close to plate boundaries are stratovolcanoes, which commonly form in convergent settings due to the process of subduction. Intermediate Magma or Basaltic Andesite and Andesite remain the topmost volcanic rocks found in areas of volcanic activity. Their composition influences eruption style and magma viscosity, shaping the topography of volcanic regions.



Active volcano eruption

These patterns have practical value to multiple fields: identifying volcano clusters and where they are most common in helps guide hazard preparedness, infrastructure planning, geo-engineering, land use and climate readiness decisions. Understanding where different tectonic plates and boundaries intersect with development zones is crucial for decision making around zoning, community development and infrastructure placement. The tectonic context and the dominant rock types can also be useful in

recognizing geothermal hotspots, which humanity is in dire need of at the moment. These findings support a deeper understanding of the dynamic processes that converge beneath our feet.

References

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