INTRODUCTION TO VOLCANOES: MAGMA, ERUPTIONS, AND LANDFORMS

- Journey of magma from deep underground to surface eruptions and landforms
- Matters for hazards, aviation, resources, and Earth's interior insight
- Activity ranges from gentle lava flows to explosive blasts
- Global distribution with familiarity to earthquakes and mountains

WHAT IS MAGMA AND WHERE DOES IT COME FROM?

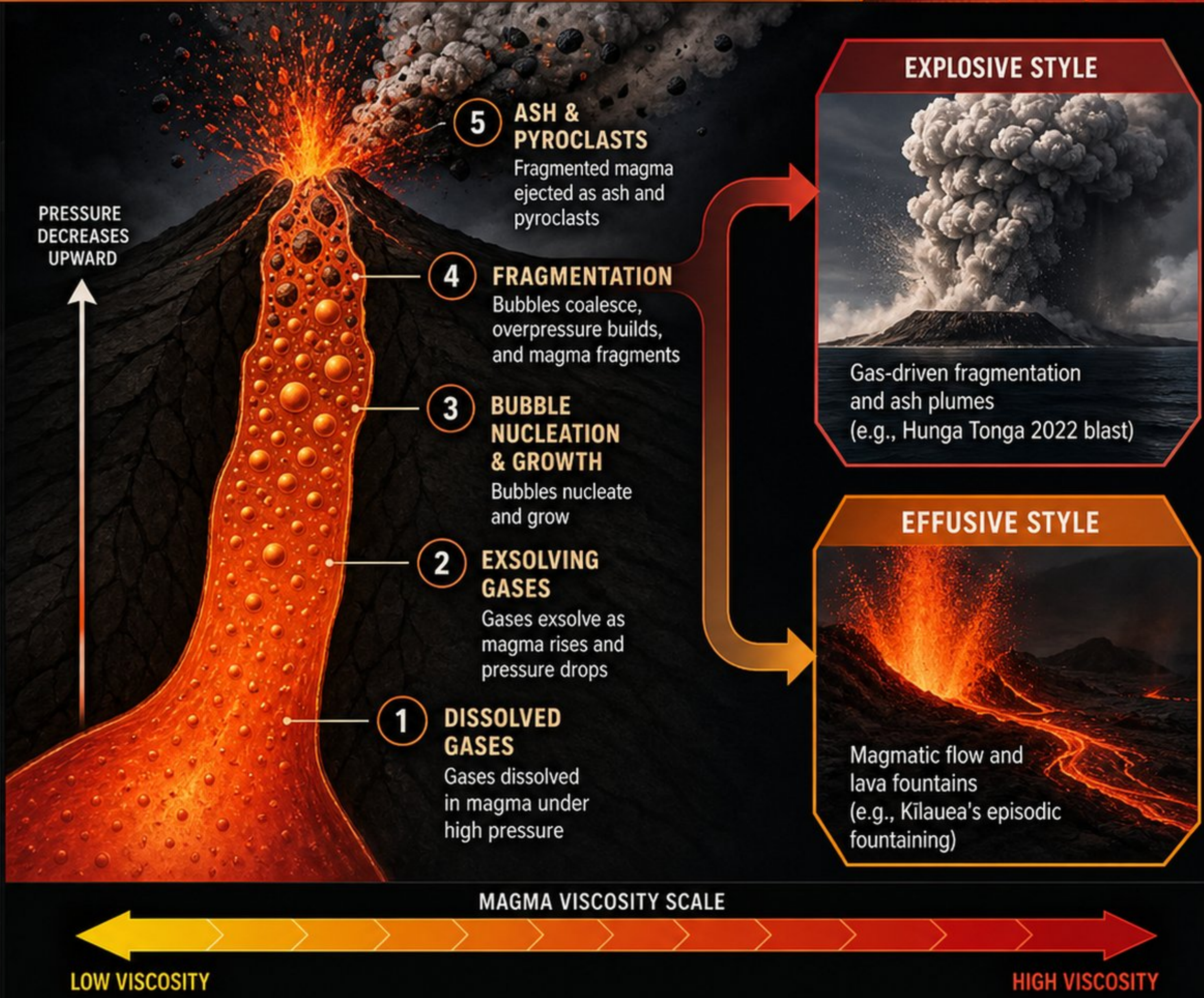
- Molten rock underground is magma; when it reaches the surface it is called lava
- Magma forms by partial melting of mantle rocks through heat, pressure drop, or added volatiles
- Silica content, temperature, and gas content determine magma's viscosity and explosivity
- Three main types: basaltic (low silica, hot, runny), andesitic (medium), rhyolitic (high silica, cool, thick)
- Plate tectonics and hotspots drive magma generation at divergent, convergent, and intraplate settings

MAGMA CHAMBERS
AND THE VOLCANIC PLUMBING SYSTEM

- Subsurface structure: source region, conduits, magma chambers, and vents.
- Magma evolves via fractional crystallization and assimilation of surrounding rock.
- Ascent triggers: buoyancy, volatile exsolution pressure, and tectonic shifts.
- Warning signs: increased seismicity, ground inflation, and gas emissions.
- Real-time satellite InSAR tracks deformation, as seen at Fentale-Dofen, Ethiopia.

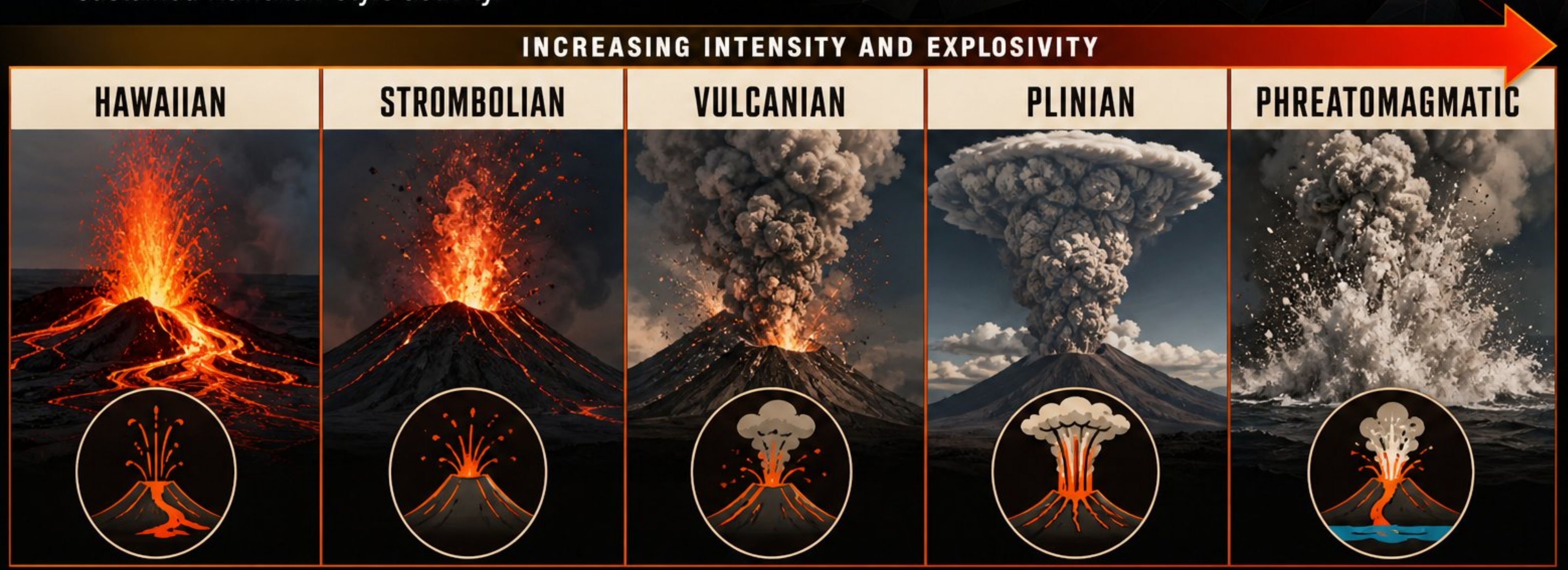
HOW ERUPTIONS HAPPEN: FROM GAS TO EXPLOSION

- Dissolved H_2O, CO_2, SO_2 exsolve as magma rises and pressure drops
- Bubble nucleation, growth, and fragmentation transform magma into ash and pyroclasts
- Effusive style: magmatic flow and lava fountains (e.g., Kīlauea's episodic fountaining)
- Explosive style: gas-driven fragmentation and ash plumes (e.g., Hunga Tonga 2022 blast)
- Viscosity, gas escape efficiency, and ascent rate control eruption style



TYPES OF VOLCANIC ERUPTIONS

- Classification by intensity and style: Hawaiian, Strombolian, Vulcanian, Plinian, and Phreatomagmatic.
- Key factors include magma composition, gas content, and interaction with external water.
- Eruption type can shift within a single event sequence.
- Kīlauea's 2024–2025 episodic fountaining exemplifies sustained Hawaiian-style activity.



VOLCANIC LANDFORMS: SHIELD VOLCANOES, STRATOVOLCANOES, AND CINDER CONES

- **Shield volcanoes** (e.g., Kīlauea) are broad with gentle slopes from basaltic lava flows
- **Stratovolcanoes** (e.g., Lewotobi, Klyuchevskaya) are steep, layered cones from alternating eruptions
- **Cinder cones:** small, steep hills of scoria; lava domes: viscous mounds
- Slope angle and size reveal magma type—low-silica basalt spreads wide, high-silica builds steep
- Landform shape records a volcano's eruption history and future hazard potential

LANDFORMS FROM EFFUSIVE AND EXPLOSIVE ACTIVITY

- Effusive: lava plateaus, pāhoehoe/ʻaʻā flows, lava tubes
- Explosive: calderas, tuff rings, maars, ignimbrite deposits
- Calderas form by collapse after large-volume eruptions
- Kīlauea's crater floor rose 68 m from 2024–2025 lava fountaining
- 2022 Hunga Tonga blast created a massive submarine caldera

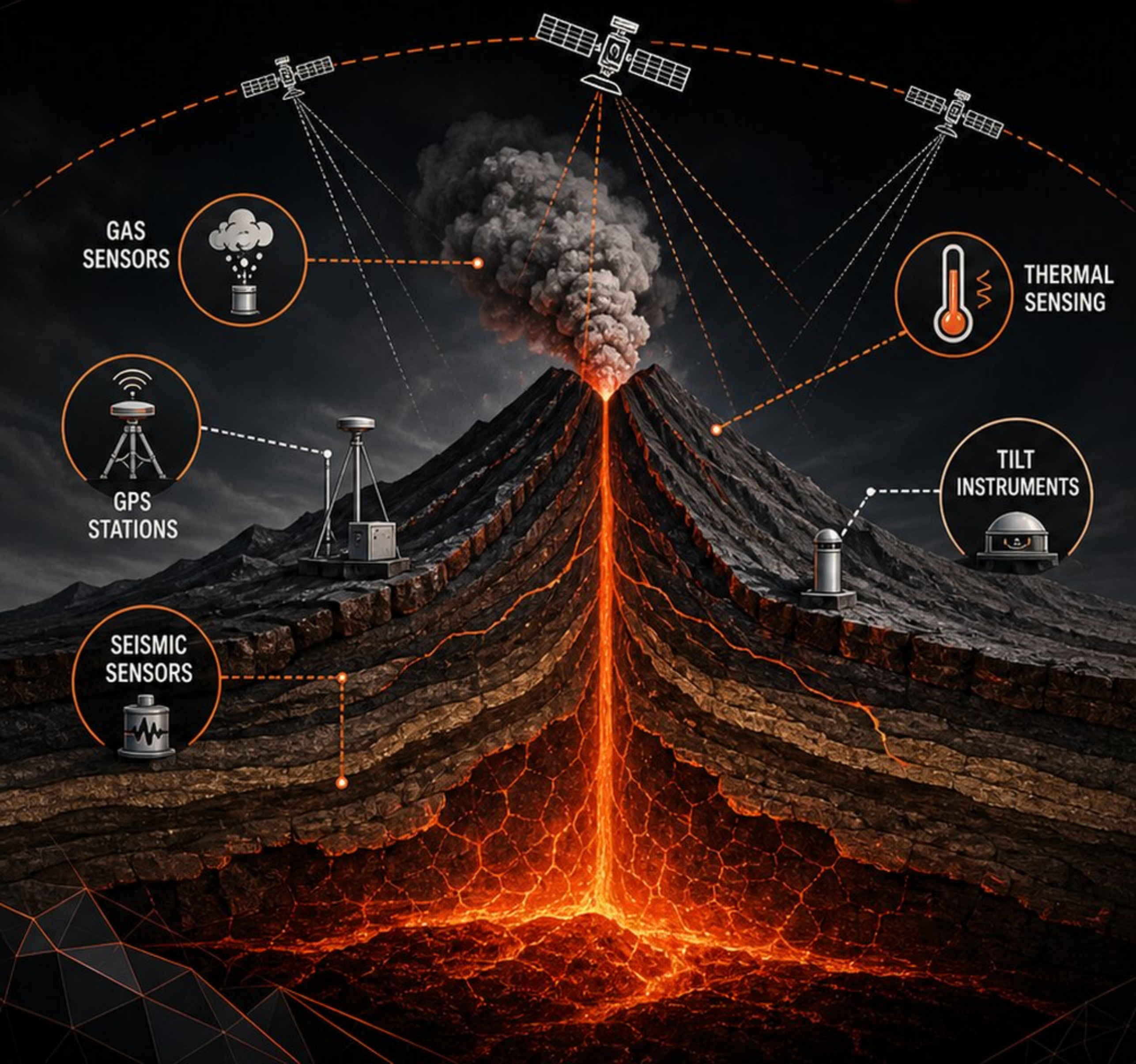
VOLCANIC HAZARDS AND THEIR DIRECT IMPACTS

- **Lava flows:** slow-moving molten streams, typical of effusive eruptions
- **Pyroclastic flows:** deadly, fast-moving avalanches of hot gas and rock
- **Tephra:** volcanic ash and ballistic projectiles blanketing landscapes
- **Volcanic gases:** SO_2 creates vog, causing respiratory health issues
- **Lahars:** volcanic mudflows triggered by eruptions and heavy rain

INDIRECT HAZARDS AND GLOBAL IMPACT OF VOLCANIC ERUPTIONS

- Ash clouds damage engines and disrupt flights globally
- Plumes above 10,000 m pose severe aviation threats
- Ruang (2024) closed Sam Ratulangi Airport, grounding 147 flights
- Lewotobi (2025) forced flight diversions and cancellations
- Sulfate aerosols from Ruang and Hunga reflect sunlight, cooling the surface

Monitoring Volcanoes: Observation Networks and Techniques



- Seismic, GPS, InSAR, tilt, gas, and thermal sensors track unrest
- Satellites like Sentinel-1, MODIS, and EarthCARE detect critical changes
- Data integration drives alert levels: Watch/Orange to Red for explosions
- Forecasting focuses on probabilistic assessments, not exact predictions

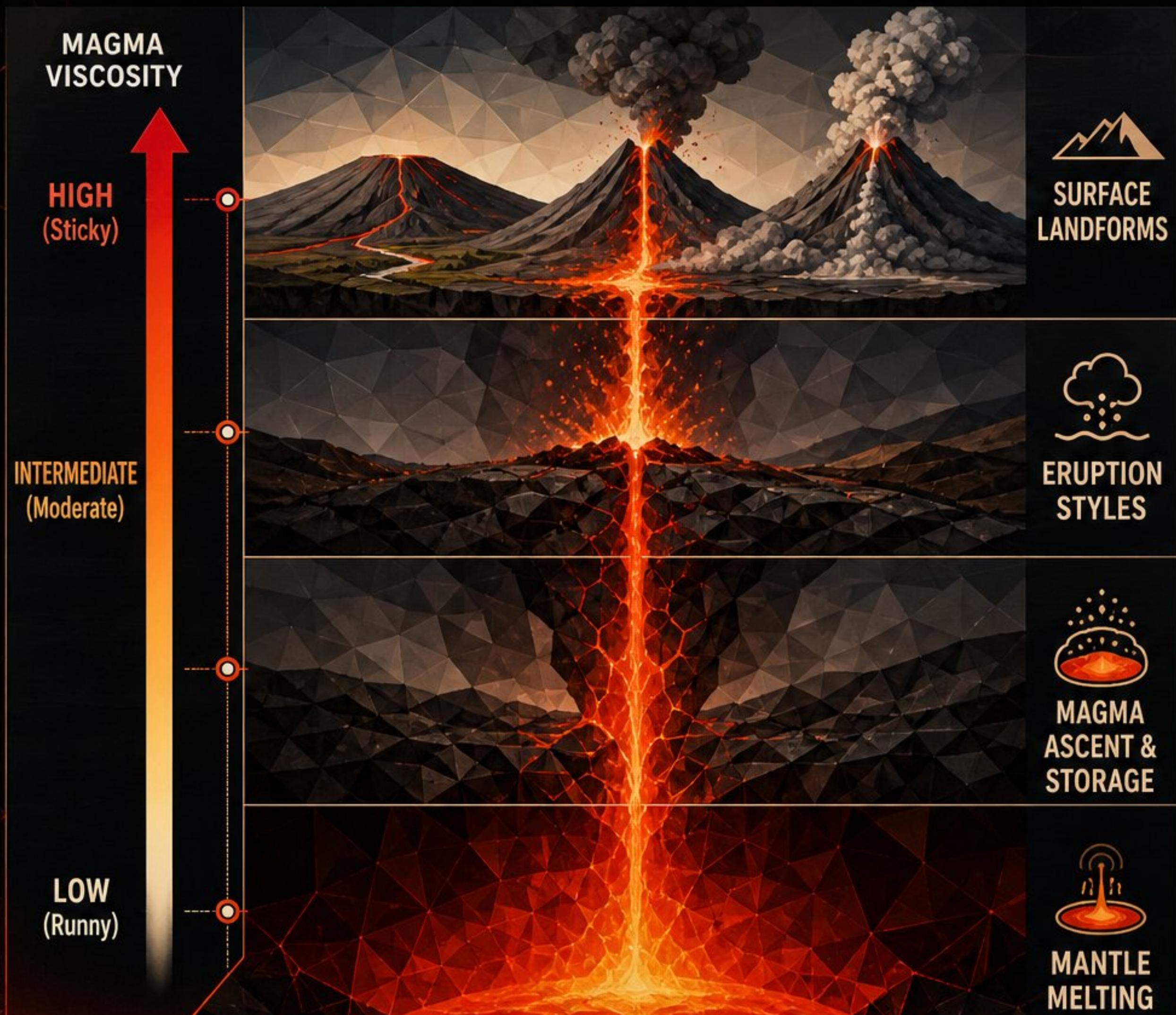
SUCCESS STORIES IN VOLCANIC EARLY WARNING

VOLCANOES

AS GEOLOGICAL RESOURCES

- Geothermal energy: volcanic heat drives power generation, e.g., Iceland's Svartsengi system
- Metal ores like copper, gold, and silver form in ancient volcanic systems
- Weathered volcanic ash creates fertile soils for agriculture
- Volcanic landscapes support tourism and cultural heritage, e.g., Hawaiʻi Volcanoes National Park
- Resource use requires balancing benefits with hazard awareness and risk management

SYNTHESIS: CONNECTING MAGMA, ERUPTIONS, AND LANDFORMS



- Magma's silica content controls viscosity, eruption style, and landform shape
- Basaltic magma creates shield volcanoes; andesitic/rhyolitic builds stratovolcanoes
- Integrated monitoring combines seismicity, deformation, gas, and satellite data
- Recent events show why volcanoes remain both fascinating and dangerous
- Continue learning through USGS observatories, open data, and citizen science