LECTURE #11: Volcanoes: Monitoring & Mitigation

Date: 19 February 2025

I. What is volcanic monitoring?

- the continuous collection of one or more data sources for the purpose of assessing a volcano's activity state and any precursors to an eruption

- unlike EQs, volcanoes commonly have warning signs *(precursory activity)*

- different types of monitoring *(several of which are interrelated):*
  - seismic
  - deformation
  - heat discharge
  - gas discharge
  - water flows

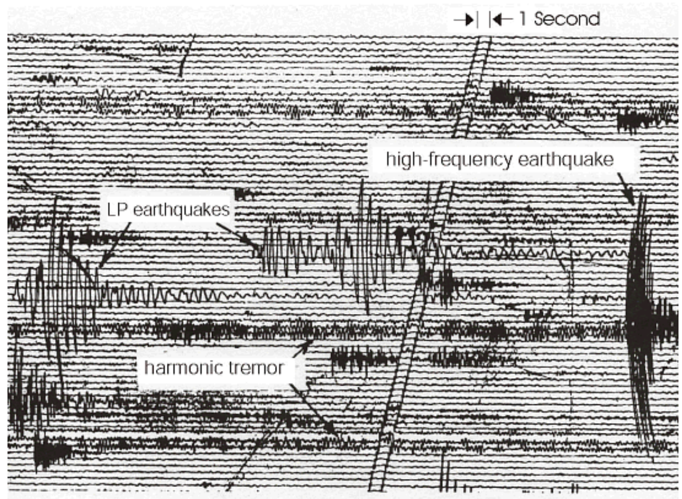
  - seismic monitoring
    - network of seismometers to measure the magnitude (M), frequency (F) and distribution (position) of earthquake types under an active volcano:

    - types:
      - high-frequency EQs
        - caused by rock fracture above a magma body as it rises
        - these occur at shallow depths (0-3 km)
        - generally small M and high F

      - volcanic tremor
        - caused by magma movement in the conduit as well as the formation of gas bubbles in the magma
        - causes long-period EQs
        - lower depth than high-frequency EQs

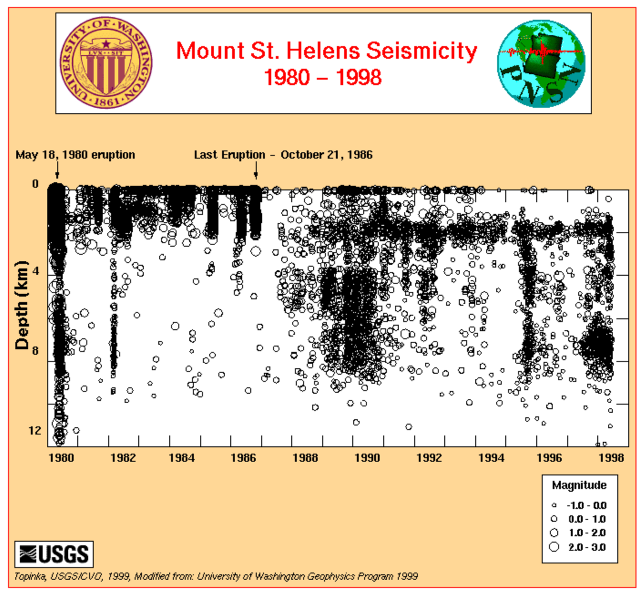
      - A-seismic zone
        - region of no EQs
        - could define a larger magma storage area *(no brittle rocks to fracture, no earthquakes)*

- *changes in the patterns are important*
  - example: if a volcanic tremor started to increase and move toward the surface, and then shallow, high frequency EQs increased, what could that tell you?



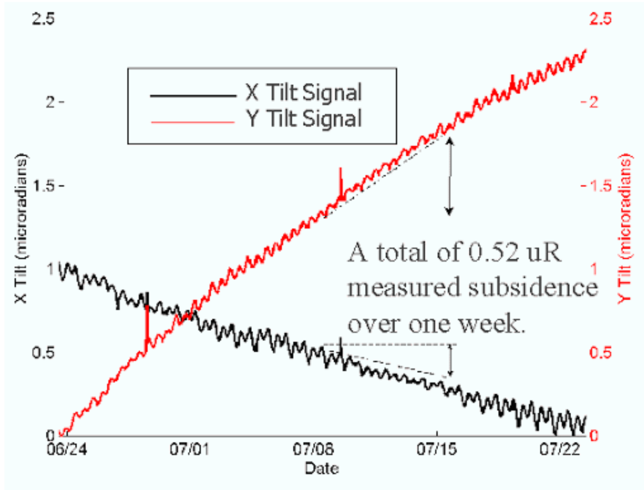
II. Example: Mt. St. Helens, Washington

October 1, 2004 eruption



III. Volcanic Monitoring *(continued)*

- deformation
  - measurement of changes in the volcano's shape due to increasing pressures and/or the presence of new magma
  - how?
    - tilt meters:
      - highly sensitive liquid-filled tubes many meters long (old tech) and electronic systems (newer tech)
      - can detect changes in slope as small as 1mm over 1km distance
      - one of the oldest monitoring techniques
      - not used as often on stratovolcanoes *(more common in Hawaii)*



- laser sighting:
  - precise measurements of the distance between a laser base station and a reflective target
  - targets are placed on the volcano and observations are made from a safe distance
  - if distance gets shorter with time, the volcano is inflating

- global positioning system (GPS):
  - technique that uses satellite broadcasts to precisely locate the receiver's location and elevation
  - a series of GPS receivers on a volcano can record very small changes in inflation and lateral movement (similar to laser sighting)

- heat flow
  - volcanoes can begin to heat up days to months before an eruption
  - soil and water (groundwater and surface water) temperatures can be monitored
  - how??
    - direct measurement
      - using probes
      - can be dangerous for the volcanologist

    - indirect measurements
      - radiant heat can be measured from a distance
      - using a hand-held camera for short distances (< 5km)
      - using a more sensitive device flown in an aircraft or a satellite

- volcanic gas monitoring
  - chemistry of the volcanic gas can be used to determine the composition of the magma and the likelihood of an eruption
  - for example, certain gases exsolve (are released) from the magma at different depths
  - the percentage of these and their chemistry can change with time before an eruption

- how??
  - direct measurement
    - volcanologists capture gases emitted from:
    - vents
    - fumaroles
    - lakes
    - soil
    - can be very dangerous


direct measurements

  - indirect measurements
    - satellite, plane, and ground measurements
    - certain gases are easily detectable (SO_2, H_2, HF)
    - others are not (H_2O, CO_2, CO)
    - example: correlation spectrometer (COSPEC) is used to detect SO_2 by looking at UV light passing through the plume


direct measurements (COSPEC)

    - COSPEC (older) and UV or thermal IR cameras (newer) can be mounted on a plane, helicopter, vehicle, or positioned on the ground

- hydrologic monitoring
  - lahar hazards (immediately after an eruption)
  - long-term threat of sediment transport/erosion and increased flooding (months to years after an eruption)
  - how??
    - direct measurements
      - stream gauges
      - mapping
    - indirect measurements
      - acoustic-flow monitor (AFM) stations
      - rainfall meters

IV. Volcano Hazard Mitigation

- <u>mitigation:</u>
  - activities, processes, or procedures designed to reduce and/or eliminate the threats of volcanic hazards
    - important to remember that mitigation is different than monitoring
    - however, monitoring is necessary for eventual mitigation

- different categories:
  - physical structures/effort
  - public education
  - use of modern technologies

- physical structures:
  - lava diversion
    - use of permanent or temporary structures to keep the lava from advancing into a town or structure
    - works because of the slow moving nature of most lava flows
    - only is effective sometimes and then only on a small scale
    - large, fast flows will quickly overtop any man-made structure

    - used semi-successfully in the 1983 eruption of Mt. Etna
    - within a month the flow was 6.5 km long threatening 3 towns
    - rubble barrier about 10 m high, 30 m wide & 400 m long
    - total cost = $3 million (potentially saved ~ $5-25 million)
    - eventually worked, *except that the lava got diverted into another town and destroyed it!*

  - water cooling
    - rapid cooling of the flow front using cold water in order to strengthen the lava and form a natural barrier
    - used in Iceland in 1973 to try to possibly stop a flow from closing off and important harbor
    - used north Atlantic seawater for days
    - some were convinced that the flow was stopping anyway and that the water did very little

  - lahar diversion
    - use of Sabo dams
    - common in Japan and Indonesia
    - structures designed to divert lahars from populated areas
    - or to strain out large boulders which would be the most damaging

- public education:
  - can be critical in reduction of the risks
  - needed in poorer countries where the population is high, and the information dissemination is low
  - needed also in wealthier countries where the recurrence interval is large and therefore the perceived threat from volcanoes is not understood

  - how ??
    - begin training early *(Japan does this for grade school kids living in hazard-prone areas)*
    - continue public education/drills/training in those areas *(especially before and during a hazard)*
    - increase funding for monitoring at hazardous volcanoes
    - eventually produce a geologic and hazards map for the volcano and the surrounding areas
    - have the local towns integrate those reports into their operating plan