LECTURE #10: Volcanoes: Monitoring & Mitigation

Date: 23 February 2021

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

- different types (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 earthquakes under an active volcano

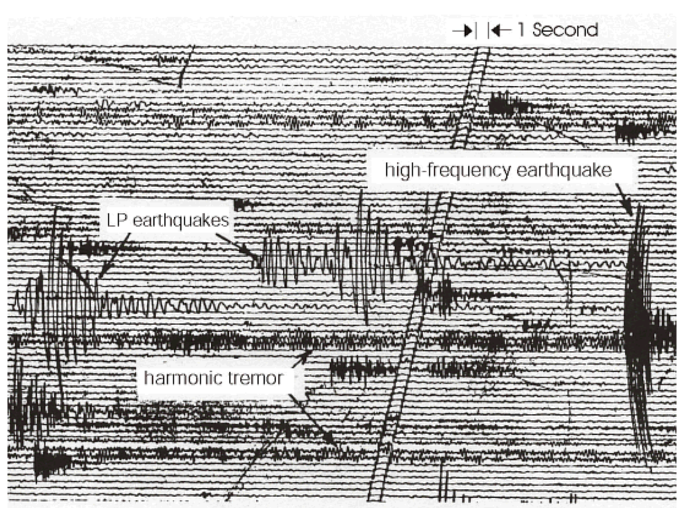
    - high-frequency EQ's
      - caused by rock fracture above a magma body
      - brittle fractures, therefore these occur at shallow depths (0-3 km)
      - generally small M and high F

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

    - A-seismic zone
      - region of no EQ's
      - could define a larger magma storage area

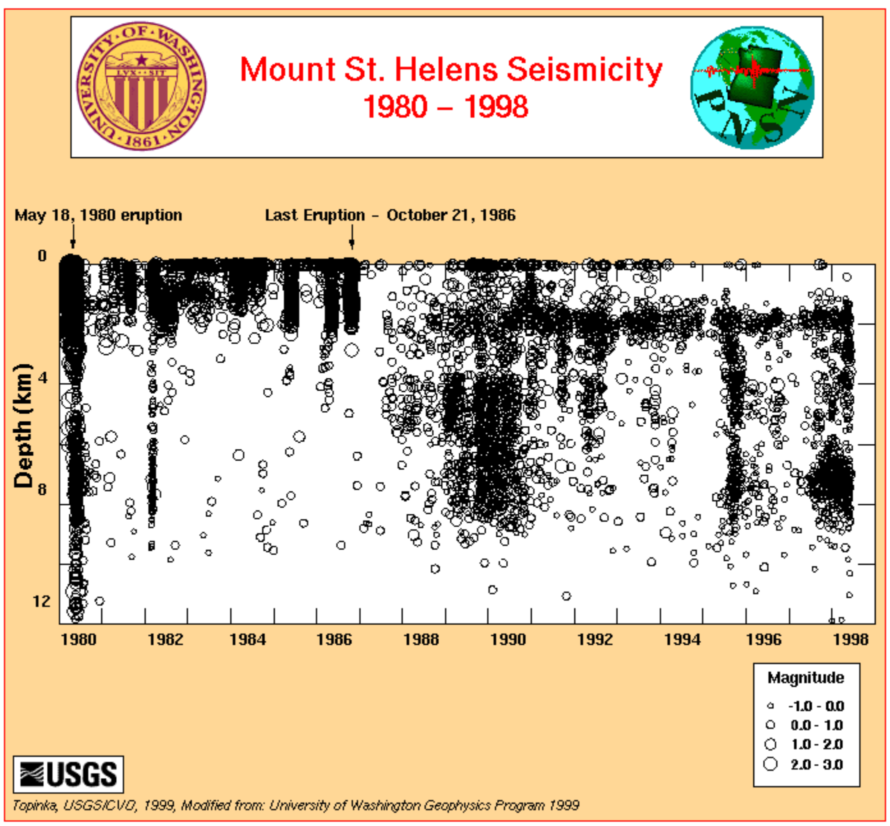
    - changes in the patterns are important
      - example: if a volcanic tremor started to increase and move toward the surface, and then shallow, high frequency EQ's increased, what could that tell you?

      - *it could signal magma rise and an impending eruption*



II. Example: Mt. St. Helens, Washington

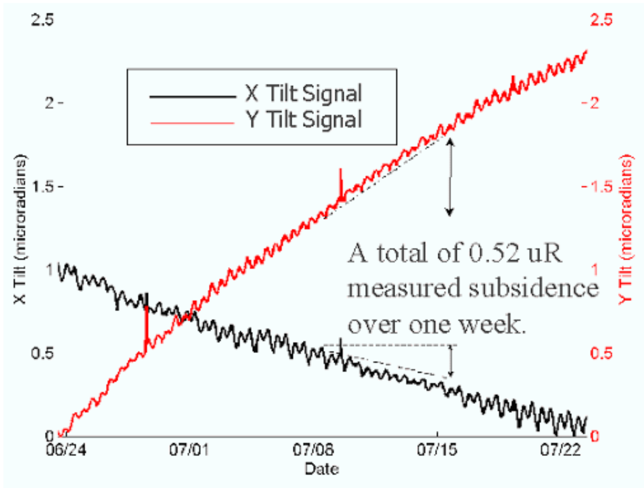
October 1, 2004 eruption



III. Volcanic Monitoring (con't)

- 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 techniques
    - not used as often on stratovolcanoes



  - 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 weeks to days 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 device 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

    - can be direct sampling or indirect measurements

    - 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 cameras (newer) can be mounted on a plane, helicopter or 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. 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 new 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 effect sometimes and then only on a small scale
    - large, fast flows will quickly overtop any man-made structure

    - used 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 blockage
    - 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 third world countries where the population is high and the information dissemination is low
  - needed also in first world countries where the recurrence interval is large and therefore there is no perceived threat from volcanoes

  - 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