# Monogenetic Volcanic Fields

## Introduction

- Volcanic activity
  - Volcanic fields (monogenetic volcanoes)
    - Monogenetic: formed during single episodes with no subsequent eruptions, single magma
  - Large volcanic edifices (paccommodate)
    - Polygenetic: erupts repeatedly, different magmas

## Origins

- Central volcanoes develop when magma supply is sufficient to maintain a thermal anomaly about a central conduit
  - Conduit provides low-energy pathway as long as thermal anomaly persists
- In volcanic fields magma supply rate is low so conduits are not maintained between volcanic eruptions

## Arrangement of Volcanoes

- Volcanoes commonly clustered within volcanic fields
- Constitute linear chains that follow tectonic structures (faults)
- May also form on flanks of composite volcanoes and large shields and within calderas, distributed along rift zones
- Monogenetic activity can result in areally extensive volcanic fields over periods of hundreds of thousands to millions of years

# Monogenetic Volcanic Fields

- Introduction
- Characteristics
- Geologic structure
- Petrogenesis
- Origins
- Field example (Chichinautzin Volcanic Field)

## Introduction

- Volcanic fields
  - Small volcanoes (monogenetic) <1km³
    - Cinder cones
    - Maars
    - Tuff cones
    - Tuff rings
    - Small shield volcanoes
    - Lava domes
  - Composition: basaltic (mainly)
## Magma Supply Rate

- New magma find own pathways to surface, no accumulation in shallow crustal magma chambers
- Low rates of heat transfer due to low rates of magma production
- Extension and subduction play a role
- Distributed volcanoes are more likely to occur in areas of high strain rate due to decreased opportunity for dike interaction and coalescence of magmas in crustal magma chambers
- Volcanism can develop in volcanic fields in response to changes in rate of magma production and/or extension
- Low rates of magma production and high rates of extension result in the formation of volcanic fields

## Physical Characteristics

- Number of volcanic vents
- Timing and recurrence rates of eruptions (age)
- Distribution of vents and relationship to tectonic features

## Probability of Future Eruptions

### Table 1

- Wide range of areas, volumes and longevities
  - Small: <50 vents over 1000 km²
  - Large: >100 vents over >1000 km²
- No apparent correlation between # of vents and longevity
- Rates of volcanism typically wax and wane over long time periods

## Age Determination

- Age for individual events
- Relative dating
  - Stratigraphy
  - Paleomagnetic
  - Cinder cone geomorphology
- Radiometric
  - $^{14}$C
  - K-Ar
  - Ar-Ar
- Linked to geologic mapping to delineate chronology

## Age of Volcanism

- Ideally: volcanic event = volcanic eruption
  - Subsequent eruptions may obliterate or obscure previous volcanic activity
- Morphology
  - Event = individual edifice
  - Mappable eruptive units (assemblage of volcanic products with cogenetic origin from common vent)
  - Formation of multiple volcanic vents during single event

## Recurrence Rate

Average recurrence rate

$$\lambda = \frac{(N-1)}{(t_0 - t_1)}$$

N= # volcanic events, $t_0$= age oldest event, $t_1$=age youngest event

Typical long term recurrence rates: $10^{-4}$ – $10^{-5}$ v/yr, low compared to eruptive frequencies of composite cones
<table>
<thead>
<tr>
<th><strong>Age Variation</strong></th>
<th><strong>Distribution (Spatial Patterns)</strong></th>
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<tbody>
<tr>
<td>• Long term averages smooth variations in recurrence rates that may span comparatively short time</td>
<td>• Shifts in location of cinder cones volcanism is common</td>
</tr>
<tr>
<td>• Episodic behavior can produce orders of magnitude variation in eruption recurrence rates</td>
<td>• Shifts in volcanism <em>may</em> be related to regional tectonic processes</td>
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<tr>
<td>• Simple measure of volcanic activity</td>
<td>• Vent alignments are common (short local alignments and regional alignments)</td>
</tr>
<tr>
<td>• Episodic recurrence rates</td>
<td>• Spatial patterns exist because recurrence rate is not uniform across the volcanic field</td>
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<td>• Time trend relating eruption volumes and rates of activity</td>
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<tr>
<th><strong>Cinder Cone Clustering</strong></th>
<th><strong>Probability of Future Eruptions</strong></th>
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<tbody>
<tr>
<td>• Occurs at different scales</td>
<td>• Spatial patterns + recurrence rate</td>
</tr>
<tr>
<td>• Volcanic activity within clusters may wax and wane on short time-scales compared to the whole volcanic field, or recurrent volcanism occurs within individual clusters over the entire history of the volcanic field</td>
<td>• Probability of future eruption in volcanic field within a small area in some time interval: $P(\text{volc. er. Within small } \Delta A, \Delta T) = 1 - e^{-\lambda \Delta t \Delta y \gamma}$</td>
</tr>
<tr>
<td>• Clustering: magma supply varies across the volcanic field</td>
<td>$\lambda =$ Temporal recurrence rate, $\gamma =$ spatial weighting factor</td>
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<td>• Reflects the scale of geochemical, temperature, and pressure variations in the mantle source of the region</td>
<td>Both estimated from past patterns of volcanic activity</td>
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<td></td>
<td>Can be integrated over some larger area or over some longer period of time</td>
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<tr>
<th><strong>Geologic Structure</strong></th>
<th><strong>Vent Alignment</strong></th>
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<tr>
<td>• Alignments are common</td>
<td>• Alignments typically parallel regional and local structures</td>
</tr>
<tr>
<td>– Infer presence and orientation of subsurface dikes and dike sets</td>
<td>• Ascending magmas exploit preexisting structures repeatedly during separate episodes</td>
</tr>
<tr>
<td>– Indicators of crustal stress orientation</td>
<td>• Preexisting faults and joints are more energy-efficient paths</td>
</tr>
<tr>
<td>– Infer mechanisms of shallow dike injections</td>
<td>• Vent alignments may form in response to a variety of fault geometries</td>
</tr>
<tr>
<td>– Assess long-term volcanic hazards</td>
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<tr>
<td>– Problematic to distinguish in basaltic volcanic fields with hundreds of vents because they are often interspersed among a greater number of unaligned cones</td>
<td></td>
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</tbody>
</table>
### Faults and Dikes
- Injection accommodate crustal stress
- Faults: slip
- Dikes: increased total crustal volume
- Topography related to faults may be suppressed near volcanic fields
- Stress is accommodated by dilation of the crust during dike injection rather than by slip

### Types of Fields
- Low-volume, low density volcanic fields
- Large volume volcanic fields
  - Cinder cone alignments are common

### Low-volume Fields
- Rate of dike injection does not accommodate crustal stress
- Fault systems continue to experience slip
- Dikes tend to parallel or inject into these fault systems

### Large Volume Fields
- Mapped faults are rare, cinder cone alignments are less common
- Rate of dike injection accommodates regional tectonic stress equalizing the magnitudes of principal horizontal stresses
- Orientations vary substantially across the volcanic field and over time

### Geologic Structure
- Nearly linear behavior of total eruptive volume through time
- Direct relationship between crustal strain rate and volume eruption rate

### Effects of Strain Rate Change
- Uniform crustal strain rates over a long period of time and melts are produced by decompression in response to extension
- Changes in strain rate may result in changes in the rate of volcanic activity
**Petrogenesis**

- Volumetrically dominated by basalts (≤52 wt% silica) and basaltic andesites (52-56 wt% silica)
- Compositional variability
  - Variable degrees of partial melting
  - Magma mixing
  - Fractional crystallization
  - Assimilation of crustal material (contamination)

**Consequences**

- Short-lived nature of monogenetic cinder cones precludes involvement of long-lived shallow basaltic magma reservoirs
- Field-wide geochemical trends may exist (changing source conditions)

**Springerville volcanic field. 400 vents. mapped vents formed between 2.1 and 0.3 Ma during volumetrically steady state volcanism. Studies of vent distribution and timing of volcanism show that rates of activity varied from cluster to cluster suggesting that individual source regions for magma were localized and short lived compared to the entire volcanic field. Vents by symbol indicate clusters, thick shading indicates alignments, thin lines indicate faults.**

**Cinder cone alignments can form along faults in a variety of geometries.**

a) Cones can be aligned along the fault trace or at an intersection of two faults.

b) Cones can be offset laterally from the fault as a function of fault dip, which controls the distance from the fault trace at which the ascending dike will break out of the fault zone.

c) Cones can form an en-echelon array along the fault trace.