MOR eruptions

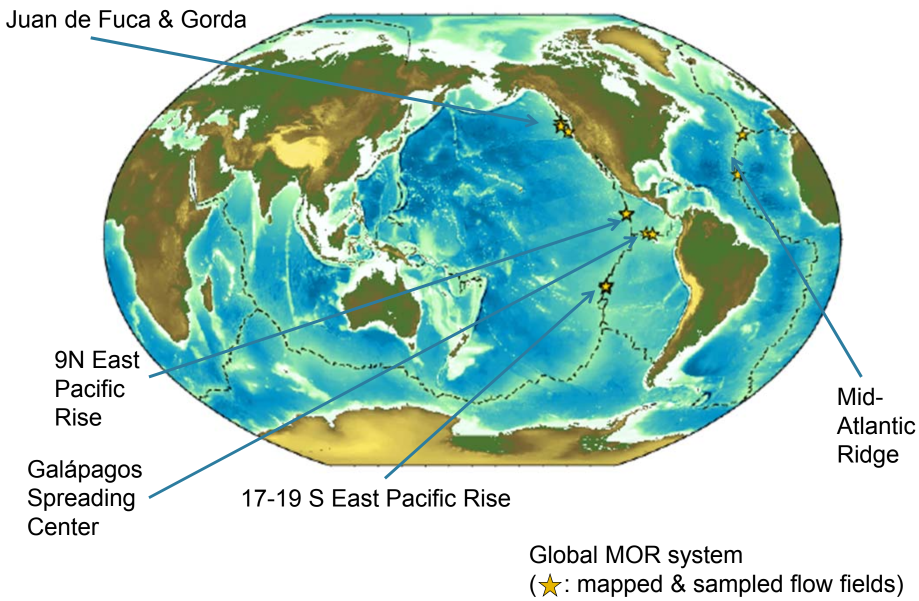
geologic mapping & petrologic variation

GG711 • Oct 25, 2011

Why map MOR eruptions?

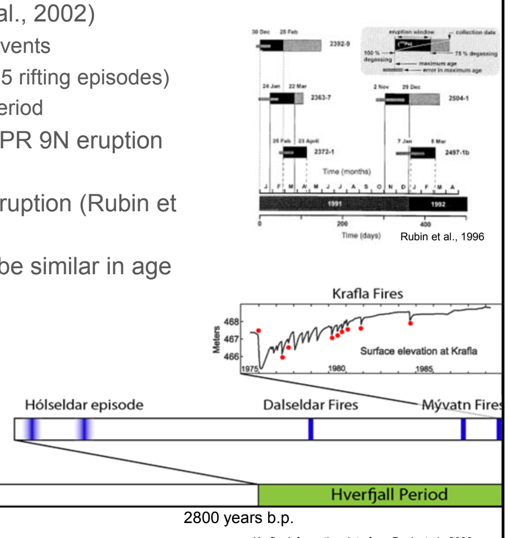
- Eliminate some uncertainty about temporal and spatial variability
- Lengths of eruptive fissures → magmatic transport processes; stress regime in upper crust
- Petrologic variability → spatial variations in temperature; compositional heterogeneity of magma reservoir
- Eruptive volume → magma reservoir size; eruption recurrence intervals
- Lava morphology → local flow velocities; effusion rates

Mapped & Sampled MOR eruptions



How to define a MOR eruptive unit?

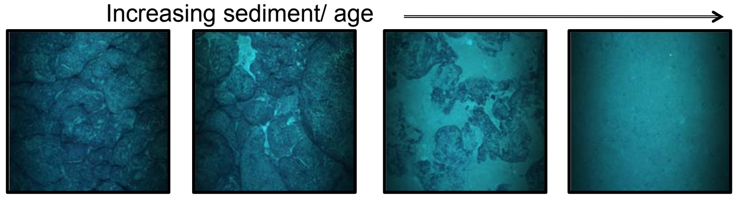
- Episodicity of MOR eruptions: Events → Episodes → Periods?
  - Krafla fires (summary: Sinton et al., 2002)
    - 1975-1984: 20 rifting/ magmatic events
    - Last 2800 years: Hverfjall period (5 rifting episodes)
    - Ending 7500 years ago: Lúdent period
  - At least two “events” in 1991-2 EPR 9N eruption (Rubin et al., 1994)
  - 4 (?) events in 2005-6 EPR 9N eruption (Rubin et al., in prep)
- Lavas from a given eruption should be similar in age and composition



MOR flow mapping methods: visual observations

- Sediment cover, superposition, cross-cutting relationships
- Effectiveness of sediment cover as proxy for age depends on sedimentation rate, eruption recurrence intervals, relief/ slope, currents at seafloor, hydrothermal venting
- Used in reconaissance-type studies to identify eruptive units
- Used to confirm eruption; define boundaries even where other evidence (e.g. seismic, bathymetric) exists

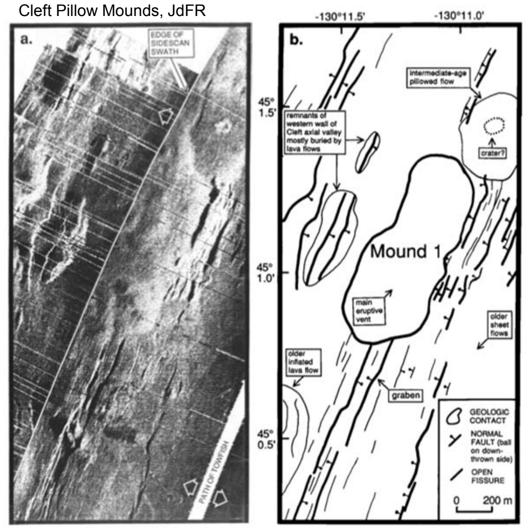
Increasing sediment/ age →



MOR flow mapping methods: side-scan sonar

- Shows seafloor texture, morphology, structures
- Contrasts in backscatter can be caused by sediment cover (also lava morphology)
- Faults easily identified

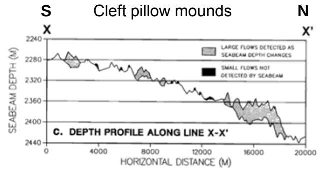
Cleft Pillow Mounds, JdFR



Chadwick & Embley, 1994

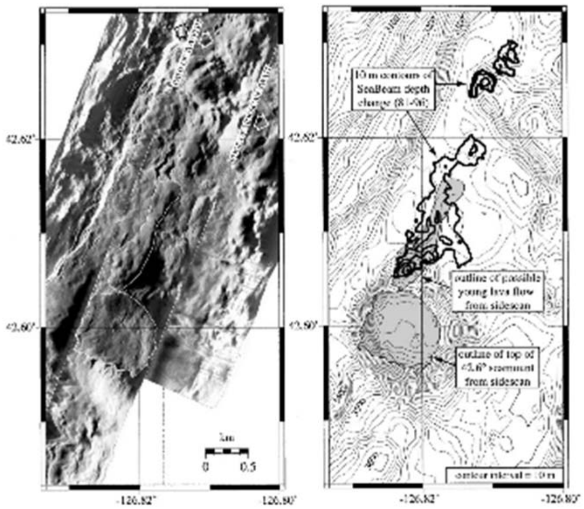
MOR flow mapping methods: repeat bathymetry

- Used successfully: 1996 N. Gorda (Chadwick et al., 1998); Cleft pillow mounds (Embley & Chadwick, 1996)
- Requires repeat bathymetric surveys (need baseline data)
- Dependent on accuracy of navigation during surveys
- Can't detect thin flows (e.g. EPR 9N eruptions: Haymon et al., 1993)



Embley & Chadwick, 1994

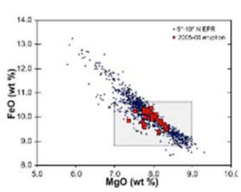
1996 N. Gorda eruption

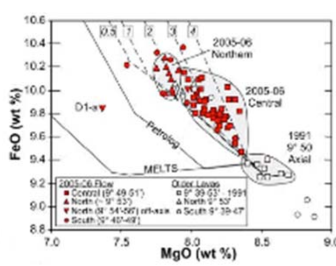

Chadwick et al., 1998

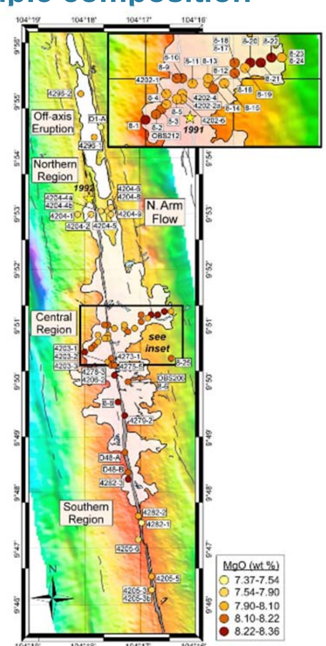
MOR flow mapping methods: sample composition

- Limited compositional range erupted in each eruption (Rubin et al., 2001)
- Can be bi-modal (e.g. South Hump, SEPR) or vary along axis (e.g. Aldo Kihi, SEPR) (Sinton et al., 2002)
- Ridge segment can repeatedly erupt similar compositon lavas over 1000's of yrs (Sinton et al., 2002)
- Useful as mapping tool in conjunction with other methods

9N EPR, 2005-6 eruption



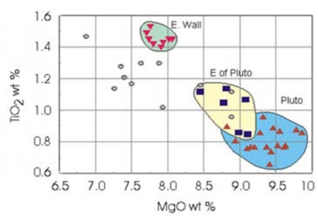




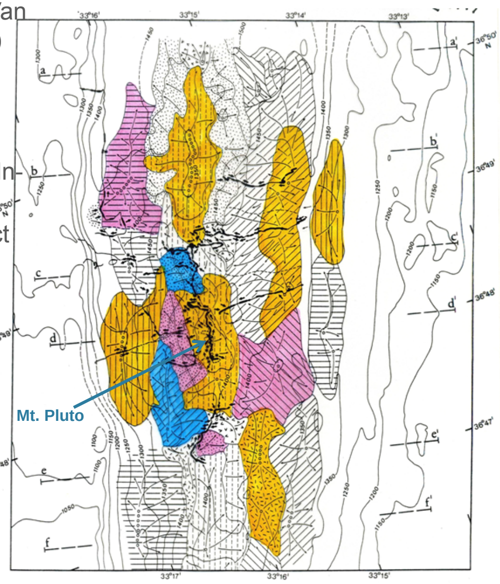
Goss et al., 2010

MOR Mapping: Slow Spreading

- MAR: FAMOUS region (Ballard & Van Andel, 1977; Bryan & Moore, 1977)
- Episodicity unclear
- Eruptive volume: 65-800 x10^6 m^3
- Use diver observations: sediment cover, flow direction, bathymetry; Mn-coating on samples
- Estimate ~10,000 years to construct axial volcanoes



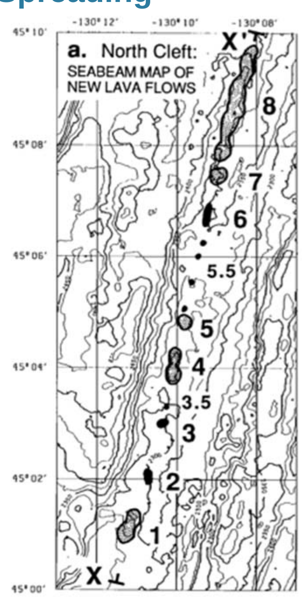
Compositional data compiled by J. Sinton from Bryan & Moore, 1977



Ballard & Van Andel, 1977; coloring by John Sinton?

MOR Mapping: Intermediate Spreading

- JdF, N. Gorda eruptions
- Event-response programs following T-waves/ event plumes
- Eruptive volumes: 2-55 x 10^6 m^3
- Mapped eruptions apparently short-lived events (episodes up to ~2 yr?)
- Range of eruptive morphologies: sheets; chains of pillow mounds (N. Gorda, Chadwick et al., 1998; JdFR, Chadwick & Embley, 1994; CoAxial, Embley et al., 1995)

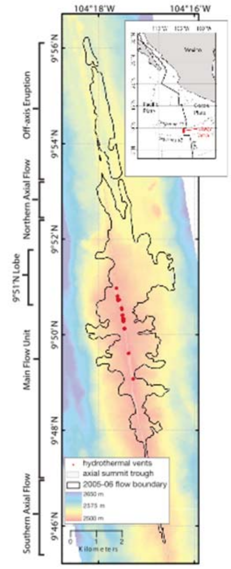


Chadwick & Embley, 1994

MOR Mapping: Fast Spreading

- Repeat eruptions at 9N, EPR: 13 year interval
- High-effusion rate fissure eruptions
- Eruptive volumes: ~5-22 x 10^6 m^3
- Importance of lava channels in transporting lava off-axis (Soule et al., 2005; 2007)
- Evidence for multiple "events" in each eruption (Rubin et al., in prep.)

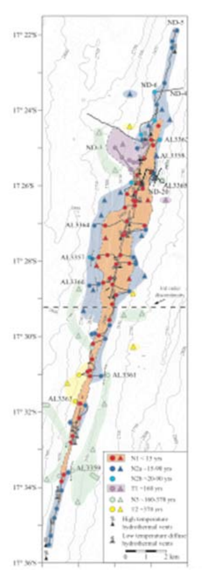
9N EPR 2005-6



Fundis et al., 2010

MOR Mapping: Super-Fast Spreading

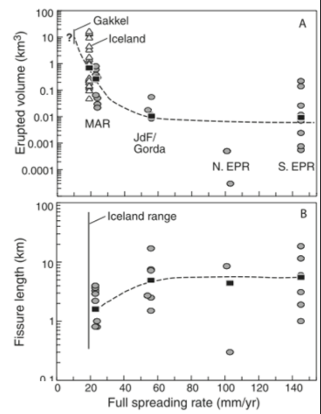
- 17-19 SEPR (Auzende et al., 1996; Sinton et al., 2002; Bergmanis et al., 2007)
- Range of eruptive morphologies: mostly high effusion rate eruptions along extensive fissure systems
- Range in eruptive volume: < 1 – 220 x10^6 m^3
- Tectonism-dominated vs. volcanism-dominated regions
- Progression of post-volcanism hydrothermal activity (shimmering water; venting from fissures and black smoker chineys; hydrothermal vents along faults w/ well-developed fauna; young black smokers and diffuse venting along graben-bounding faults) (Auzende et al., 1996)



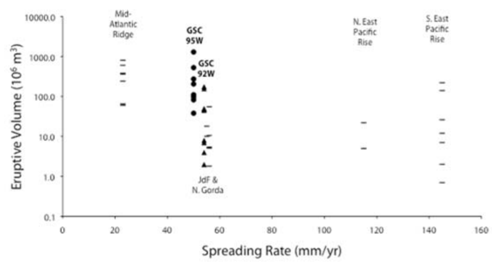
Bergmanis et al., 2007

Lessons from mapped MOR eruptions

- Spreading rate - eruptive volume inverse correlation
  - Presence of quasi-steady-state magma chamber at fast spreading rates
- Spreading rate - fissure length direct correlation
  - Strongly tensional stress state in crust at fast spreading rates

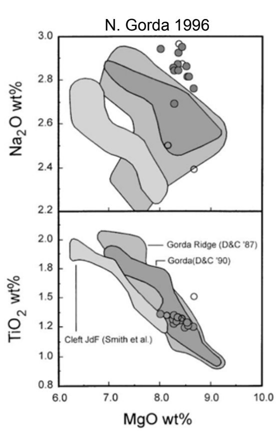


Sinton et al., 2002

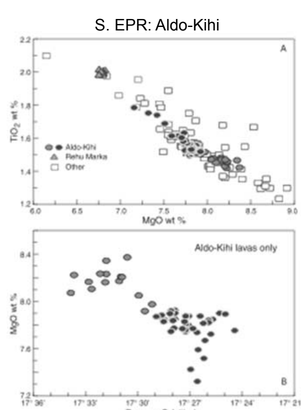


Petrologic Variation within Individual Eruptions

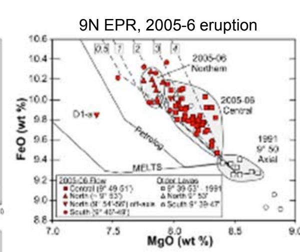
- Spatial variability (along-axis): indicative of magma chamber variability?
- Temporal variability within eruption?



Rubin et al., 1998



Sinton et al., 2002



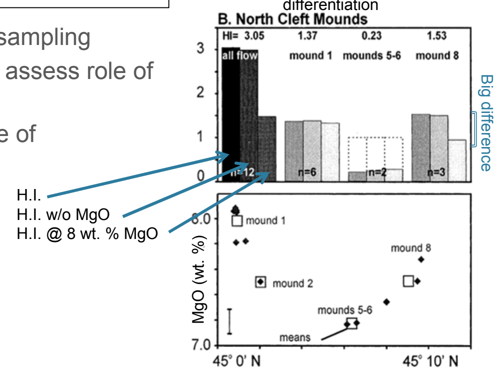
Goss et al., 2010

Heterogeneity Index

H.I. =Σ(Si/Pi)/n, where:
Si: 2σ dev. from mean of data for element i
Pi: Analytical precision for element i
n: number of elements considered
(see Rubin et al., 2001

- Can adjust by T-factor to assess sampling
- Can use range instead of sdev to assess role of outliers/ comp. extremes
- Can adjust for MgO to assess role of differentiation in H.I

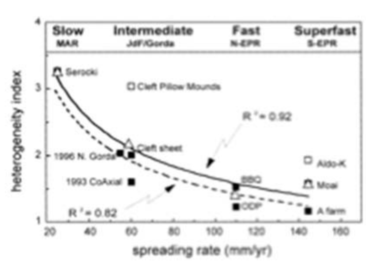
Adjusting for variable degrees of differentiation

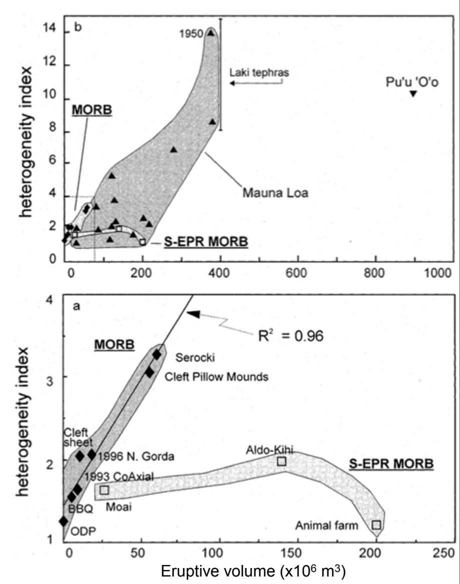


Rubin et al., 2001

Heterogeneity Index

- Excluding super-fast spreading ridges, H.I. correlates directly with eruptive volume and inversely with spreading rate
- More heterogeneity at slow-spreading ridges & lg eruptions
- Steady-state amc at fast-spreading rates homogenizes magmas (Sinton & Detrick, 1992)





Rubin et al., 2001