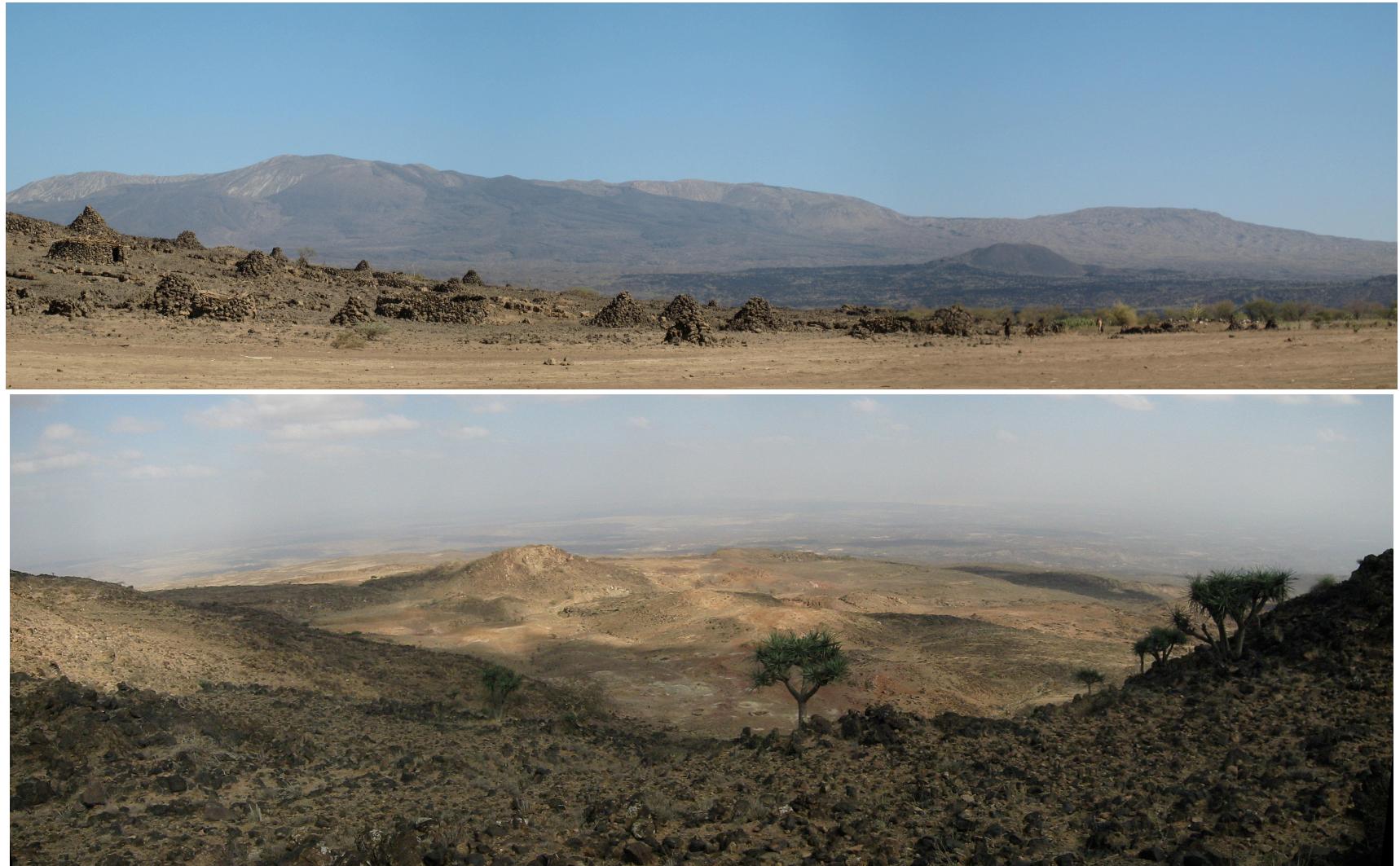


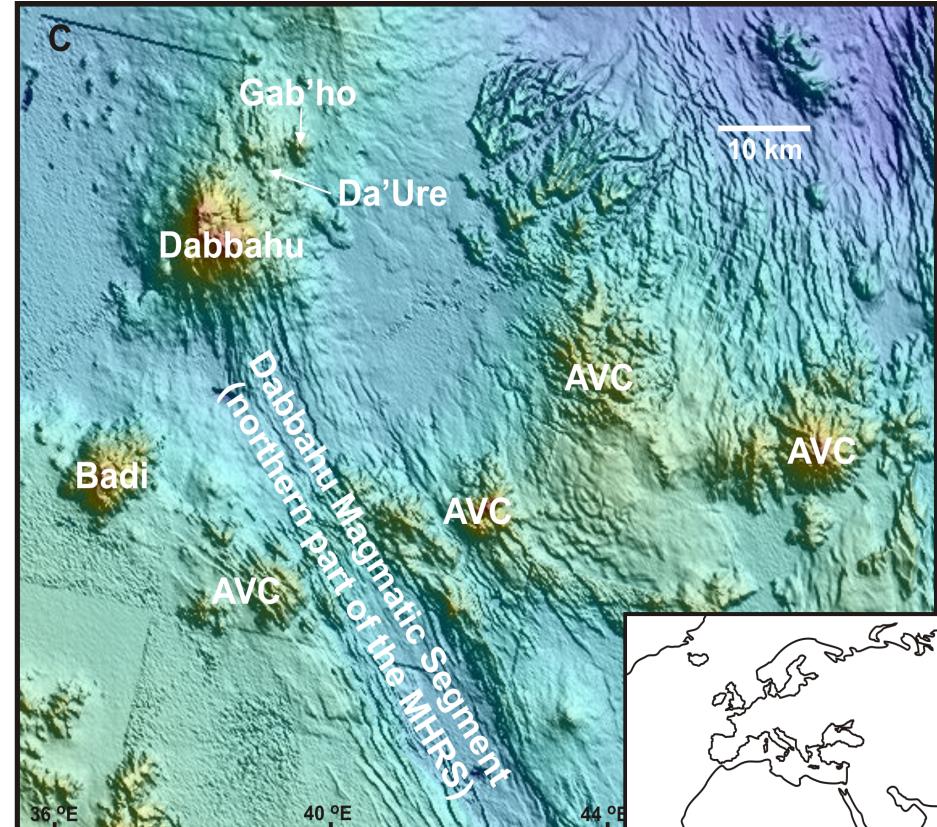
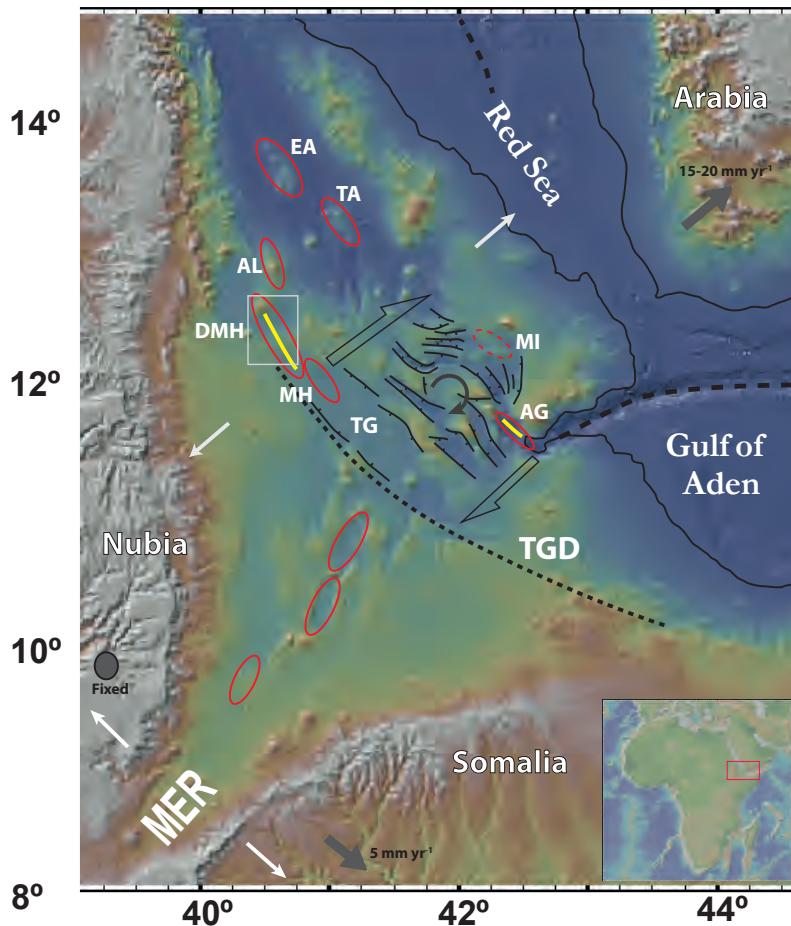
Magmatic Differentiation at Dabbahu Volcano, Afar



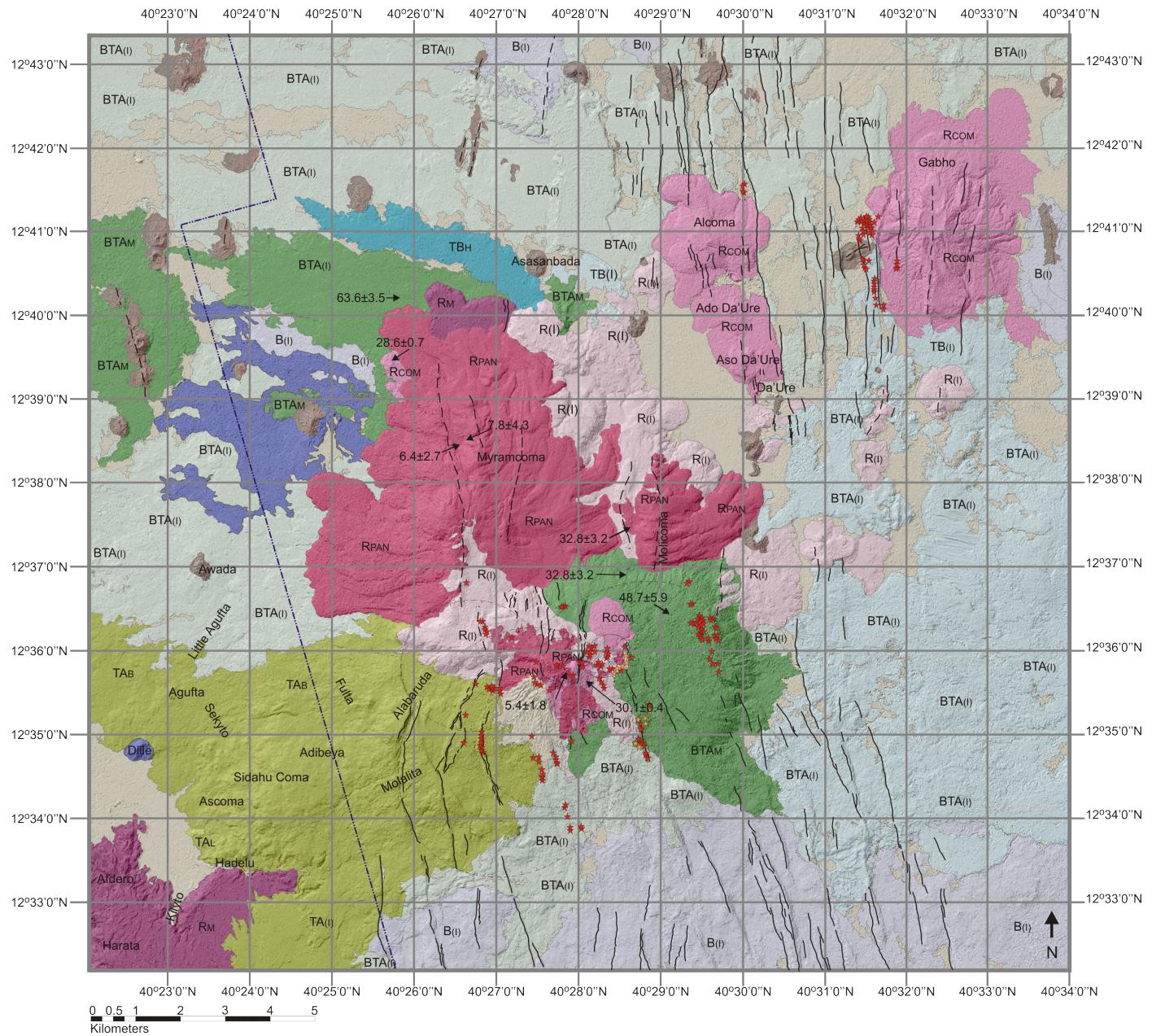
Lorraine Field¹, Jon Blundy¹, Andy Calvert² and Gezahegn Yirgu³

¹University of Bristol, ²USGS Menlo Park, ³Addis Ababa University

Dabbahu Composite Volcano



Northernmost end of active Manda-Hararo Rift Segment
West of 2005 Da'Ure Vent
Small offset from Alayta Rift Segment to North



List of map units

Sampled deposits

RPAN	Pantellerite rhyolites
Rm	Metaluminous rhyolites
Rcom	Comendite rhyolites
Trachyte	
TAB/TAL	Trachyandesite - benmoreites and latites
BTAM	Basaltic trachy andesite - mugearites
TBH	Trachybassalt - hawaiiites
Basalts - mildly alkaline / transitional	

Inferred bedrock

R(I)	Rhyolite
T(A)(I)	Trachyandesite
BTA _n	Basaltic trachy andesite
TB(I)	Trachybassalt
B(I)	Basalts

Superficial deposits

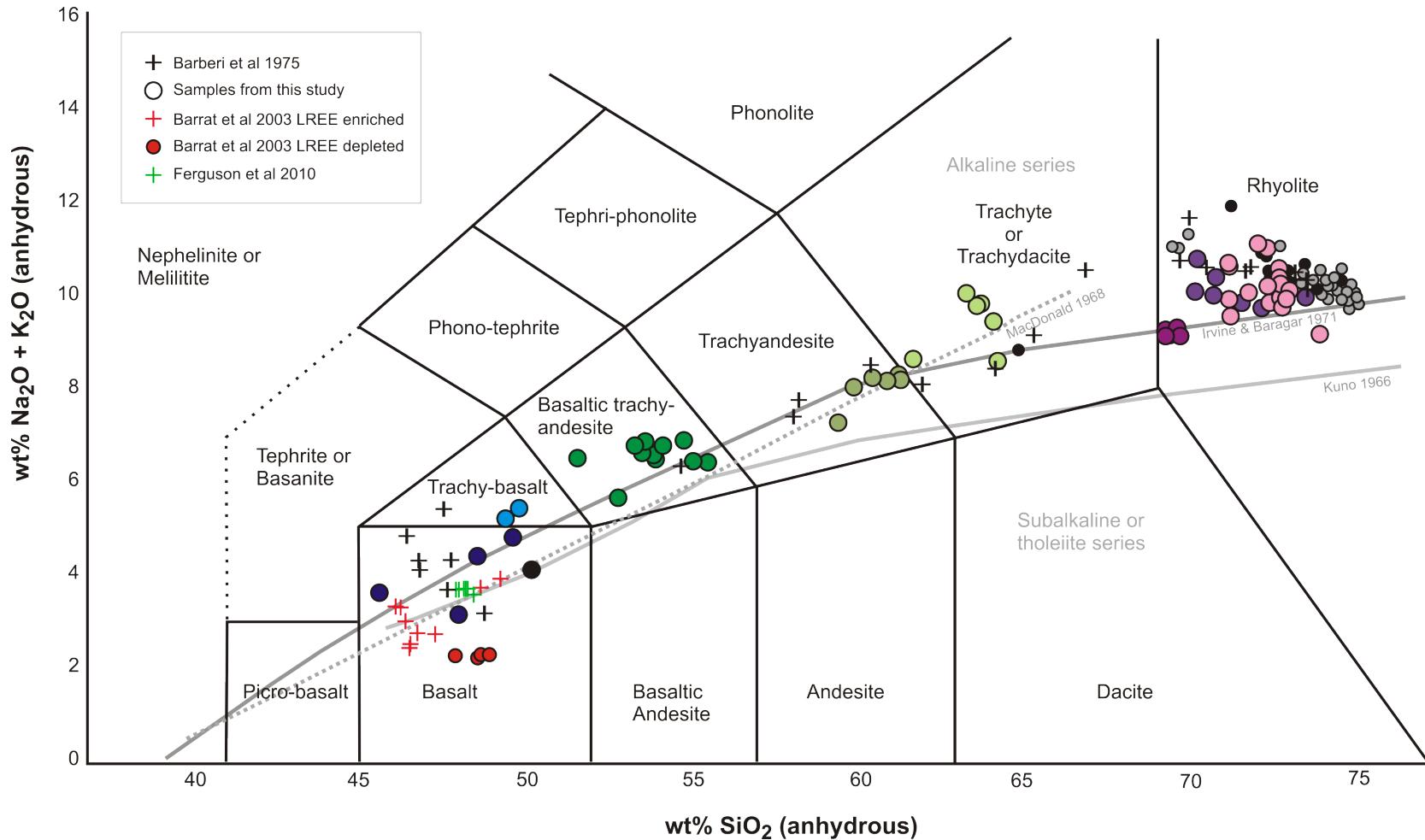
Windblown sand, ash and pumice too thick to determine underlying bedrock
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Symbols

- 33±3: Location and age (ka) of sample determined by $^{40}\text{Ar}/^{39}\text{Ar}$
- Fault
- - - Fissure
- ↔ Caldera (dashed line indicates inferred)
- Scoria cone
- ★ Location of boina (active and non-active)
- ◆ Major hydrothermal alteration
- Western limit of NERC ARSF aerial photographs

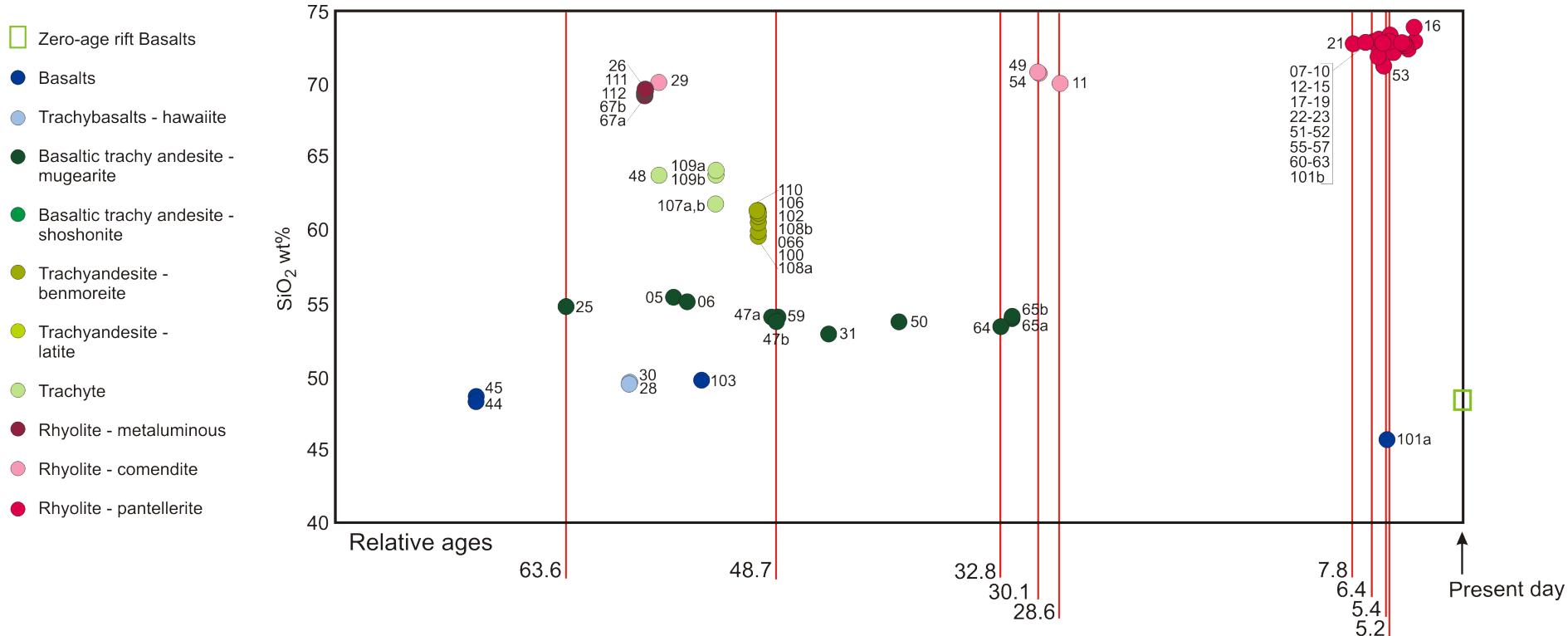
Wide range of magma types erupted from same vent/fissure system

Extreme chemical differentiation



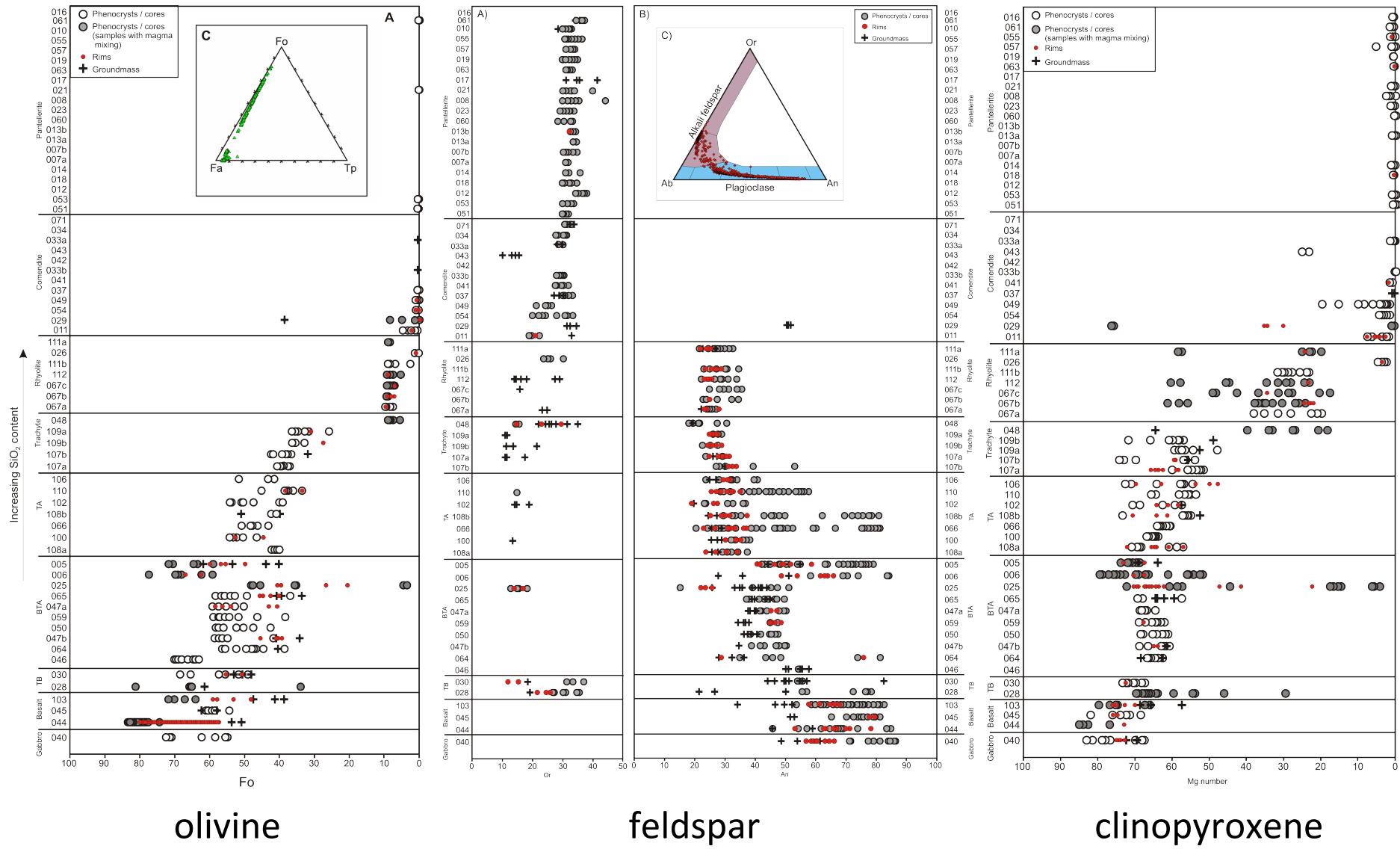
Rocks are phenocryst-poor – close to liquid compositions
 Olivine + plagioclase + cpx stable over entire differentiation trend

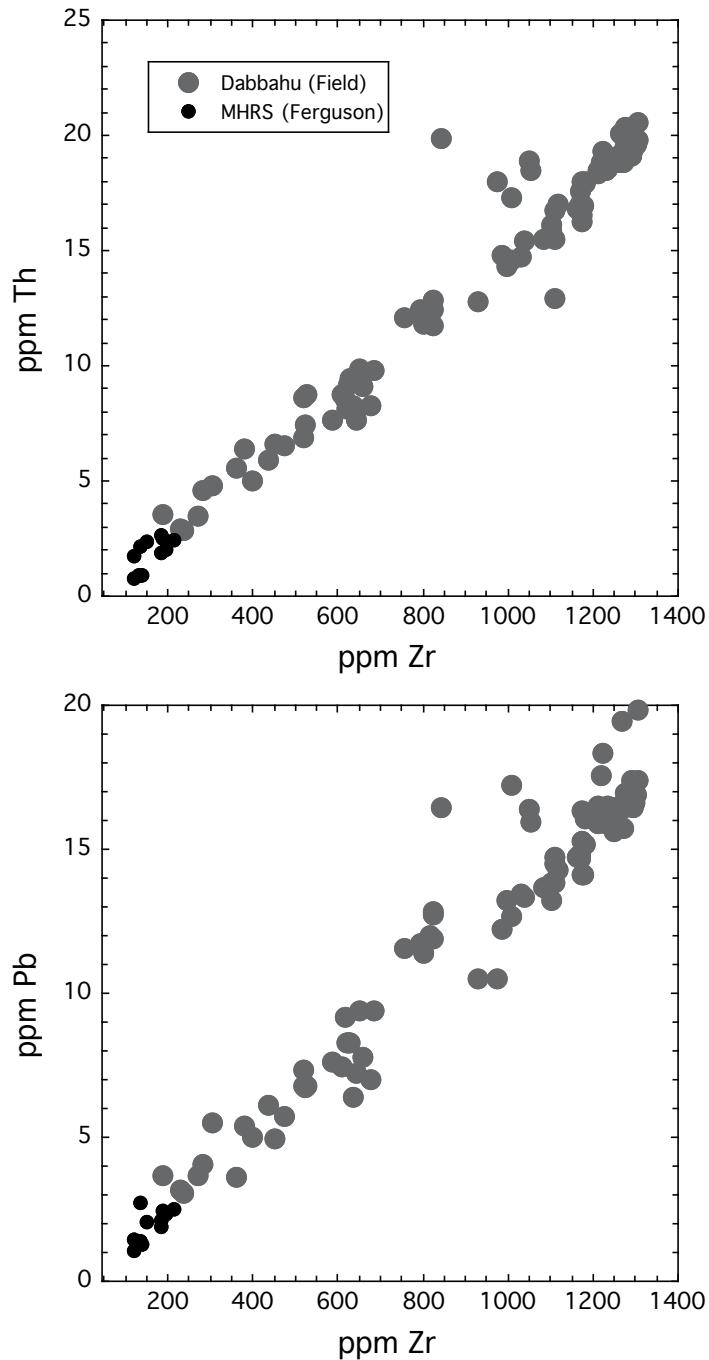
New Ar-Ar dating



- Dabbahu is $\leq 100,000$ years old
- $\sim 35 \text{ km}^3$ erupted volume = $0.01 \text{ m}^3 \text{ s}^{-1}$
- No evidence of temporal chemical evolution

Mineralogical evolution

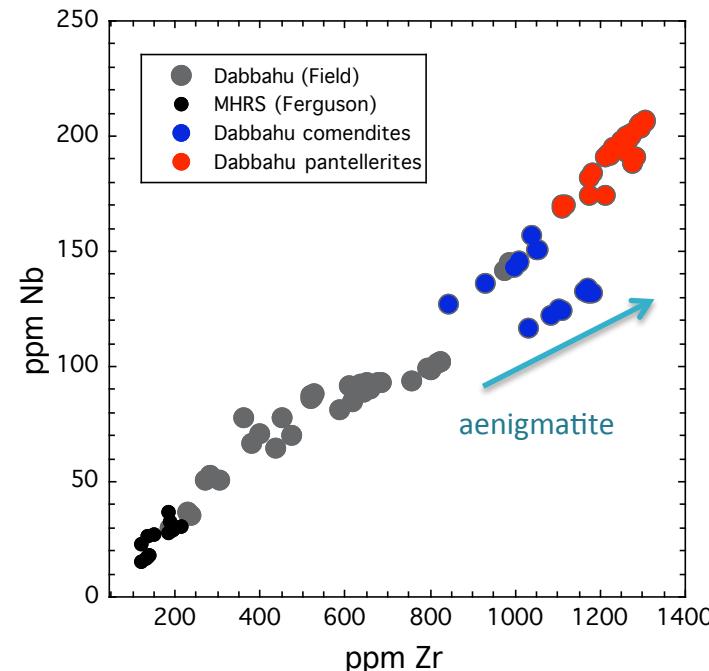


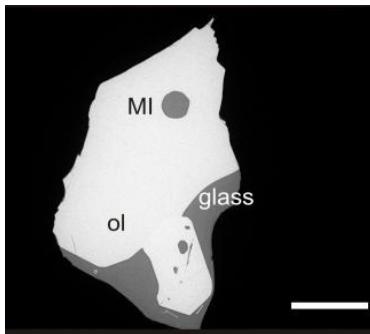


Geochemistry

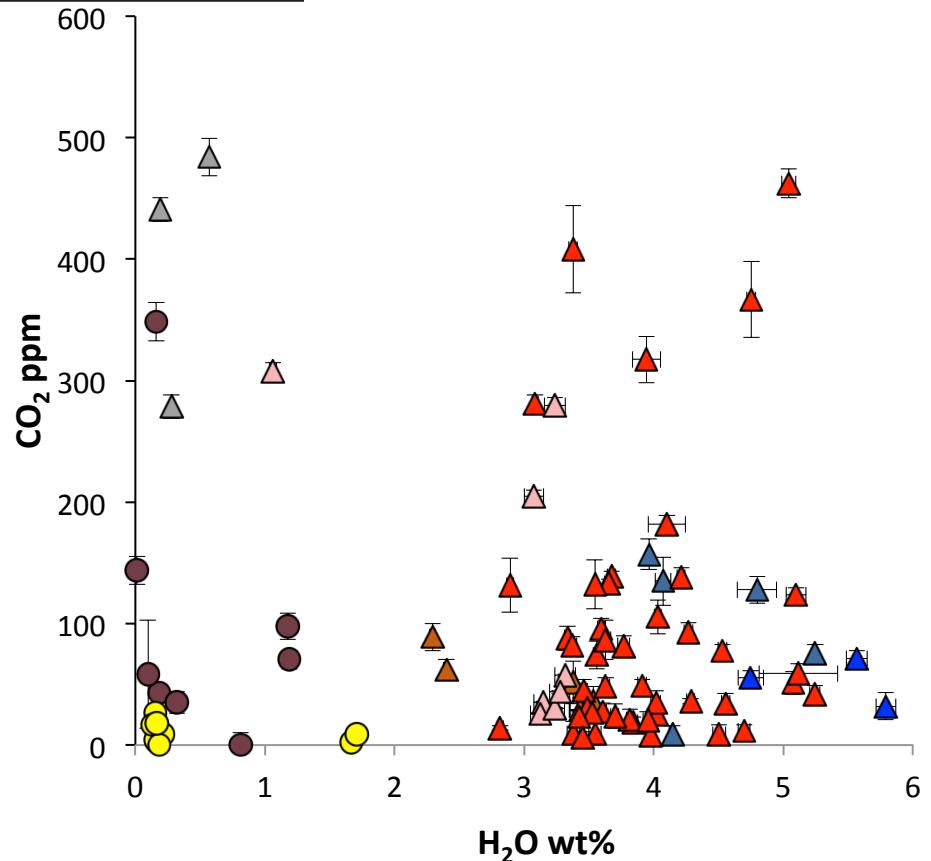
Constant ratios of incompatible elements suggest single magmatic lineage from parental axial basalt

10-fold increase in incompatible trace elements

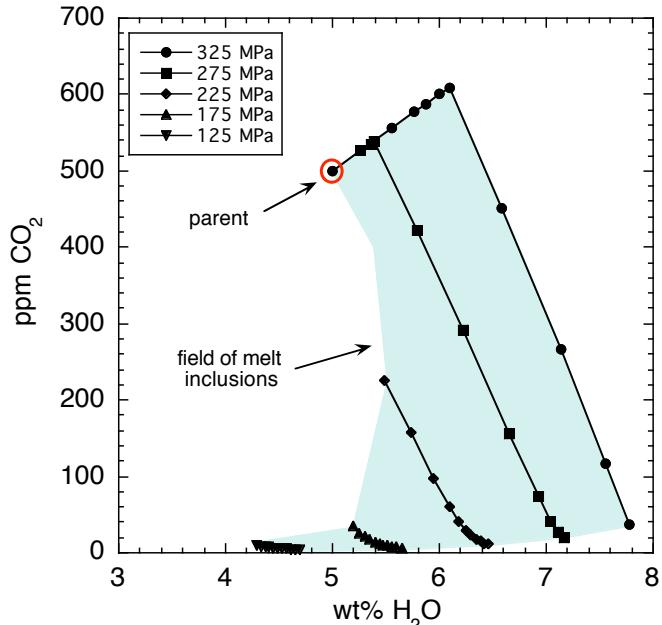
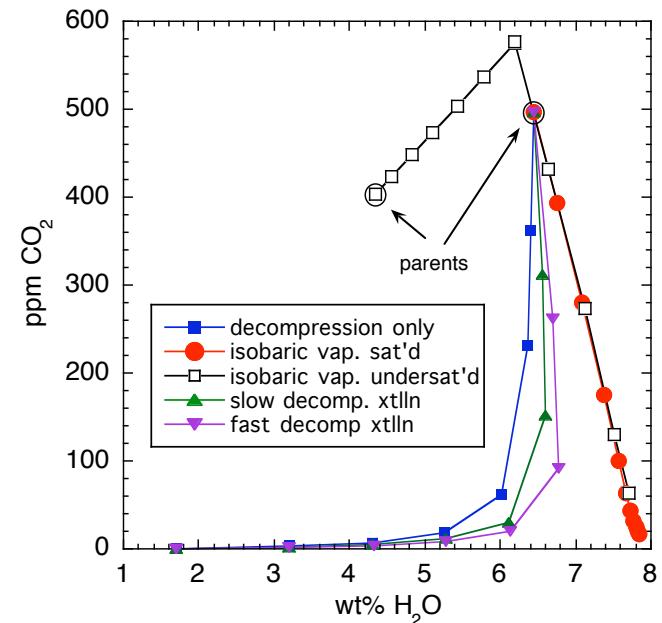




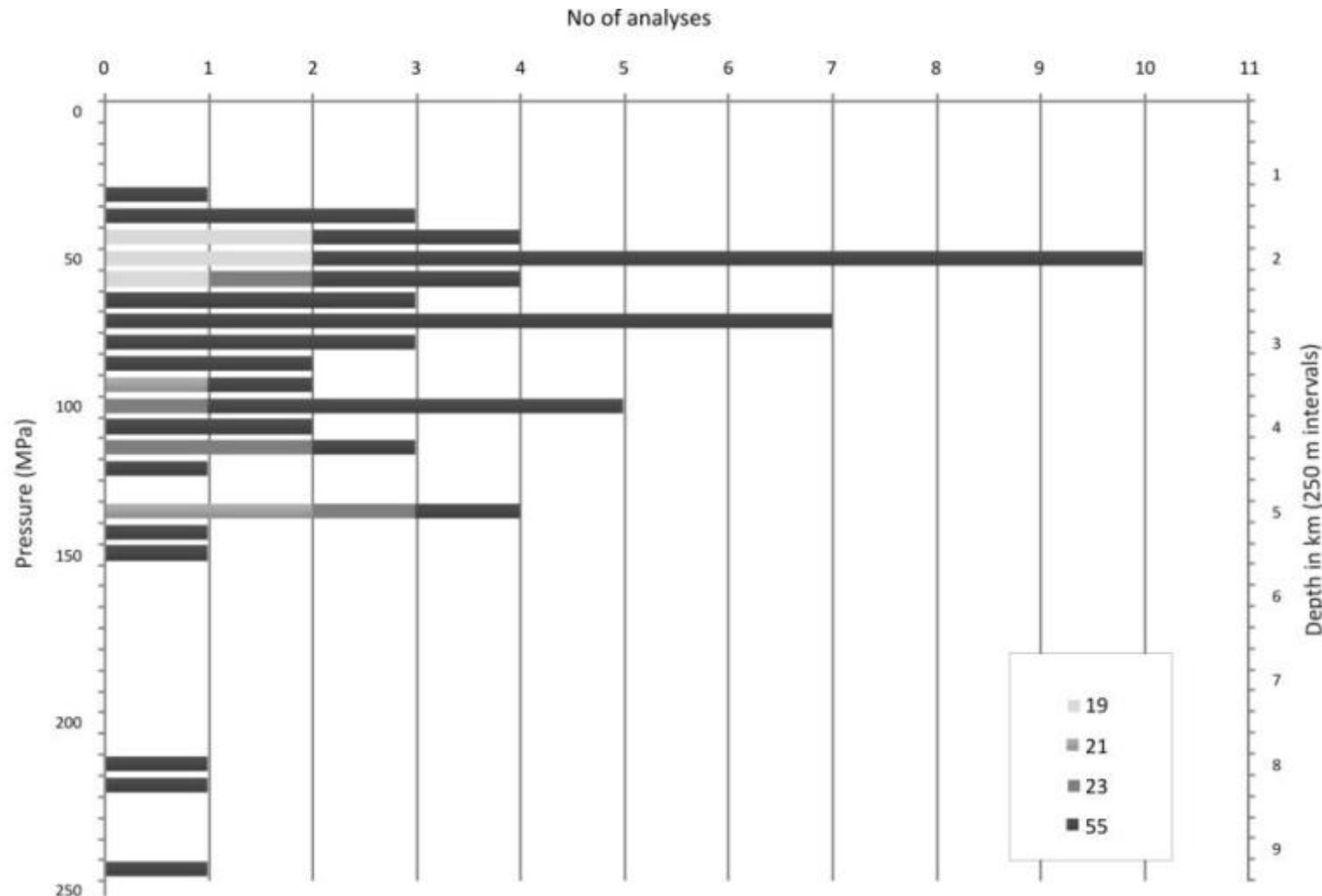
Volatiles in melt inclusions



- Data do not describe simple degassing trends
- Some high CO₂ inclusions – gas fluxing?
- Crystallisation of small magma batches over range of pressures



Depths of entrapment



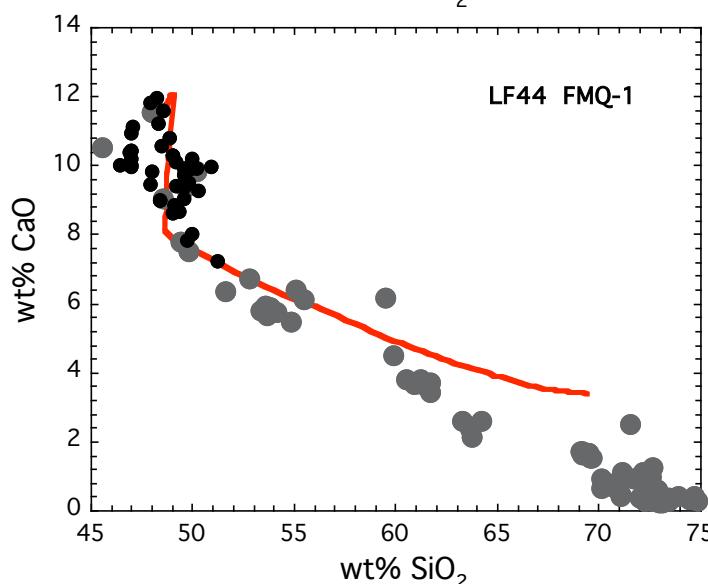
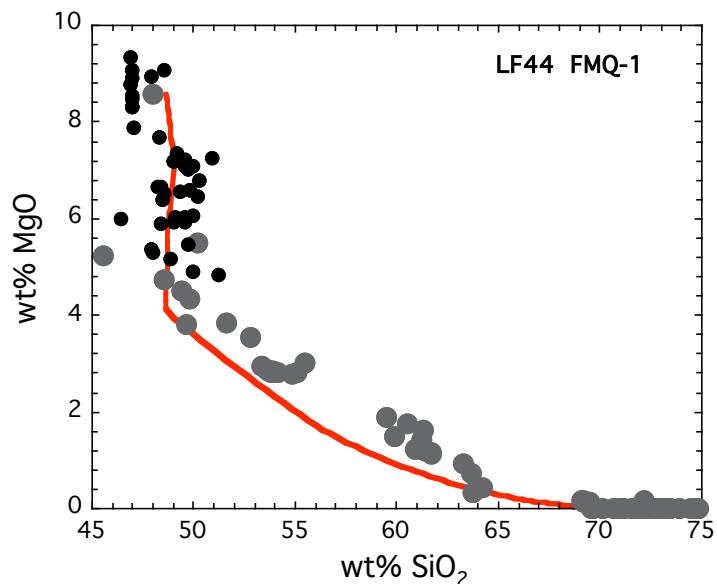
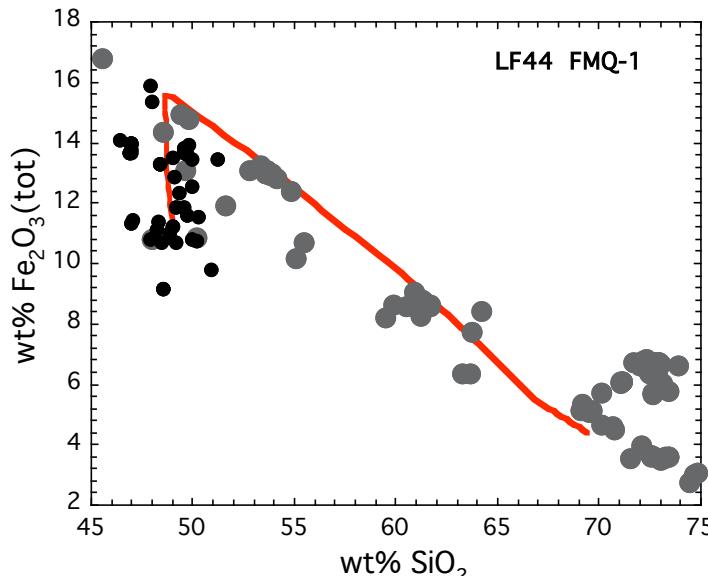
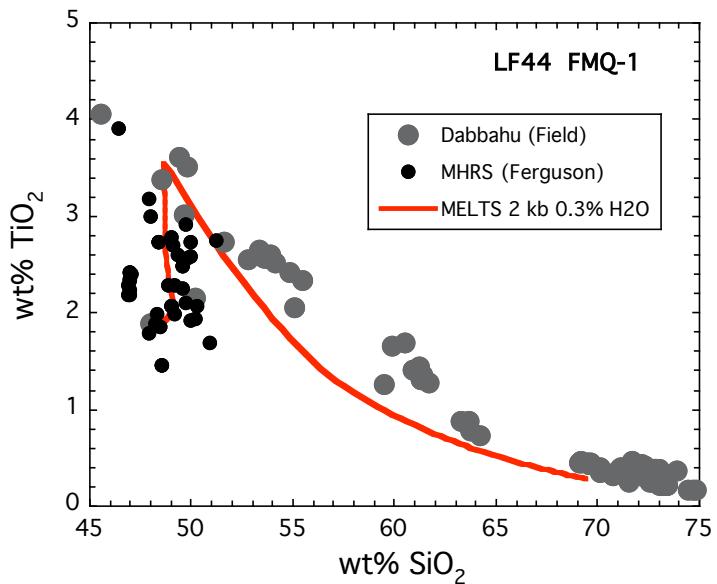
Stacked sills at 2-6 km depth gives good fit to INSAR data

Constraints on crystallisation conditions from MELTS and pMELTS modelling

Observation	Constraint
Basaltic parent has mg# = 0.6	Not in mantle equilibrium
Lack of opx	$f\text{O}_2 < \text{FMQ}$
Ilmenite	$f\text{O}_2 \leq \text{FMQ}-1$
$\text{An}_{80}, \text{Fo}_{80}$	$3 \text{ kb} > P \geq 1 \text{ kb}$
Cotectic OI+Plag+Cpx in basalts	$3 \text{ kb} > P \geq 1 \text{ kb}, \text{H}_2\text{O} \leq 0.3 \text{ wt\%}$
$4 \pm 1 \text{ wt\% H}_2\text{O}$ in rhyolites	$\sim 0.4 \text{ wt\% H}_2\text{O}$ in parent
Liquid line of descent (esp. CaO)	$P \leq 3 \text{ kb}$
Max $\text{Al}_2\text{O}_3 = 17 \text{ wt\%}$	$\leq 0.4 \text{ wt\% H}_2\text{O}$ in parent
Extreme mineral variation	$\leq 90\%$ fractional crystallisation

Run models to obtain best fit to whole-rock chemistry, phenocryst assemblage and mineral compositions

LF44 parent, FC, 2 kb, 0.3 wt% H₂O, FMQ-1



Similar results at 3 kb, 0.1 wt% H₂O

Conclusions

- Shallow differentiation in stacked sills (or dykes) – 2-6 km depth
- Low H₂O content of parent basalt (~0.4 wt%)
- <10% of basaltic input becomes rhyolite
- Shallow, dense cumulates
- Crustal contamination is not *required* by isotope data
- Thermal budget is critical – ~100 ka of silicic magma production
- Differentiation enabled by reduced magma supply at segment end