Changing our ideas about the evolution of magmatic systems with improved temporal resolution: do we get it right?

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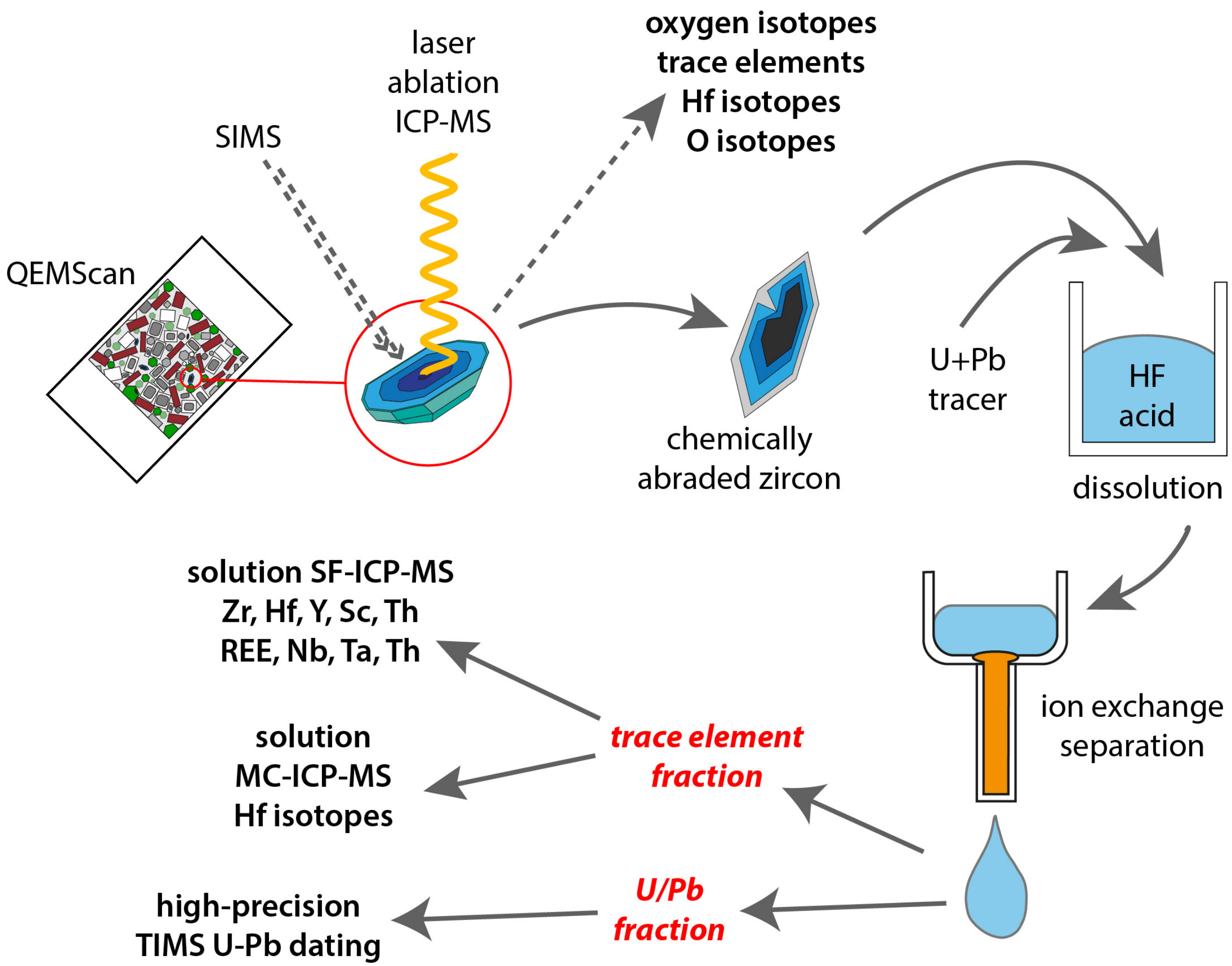
Zircon petrochronology

CA-ID-TIMS U/Pb dating

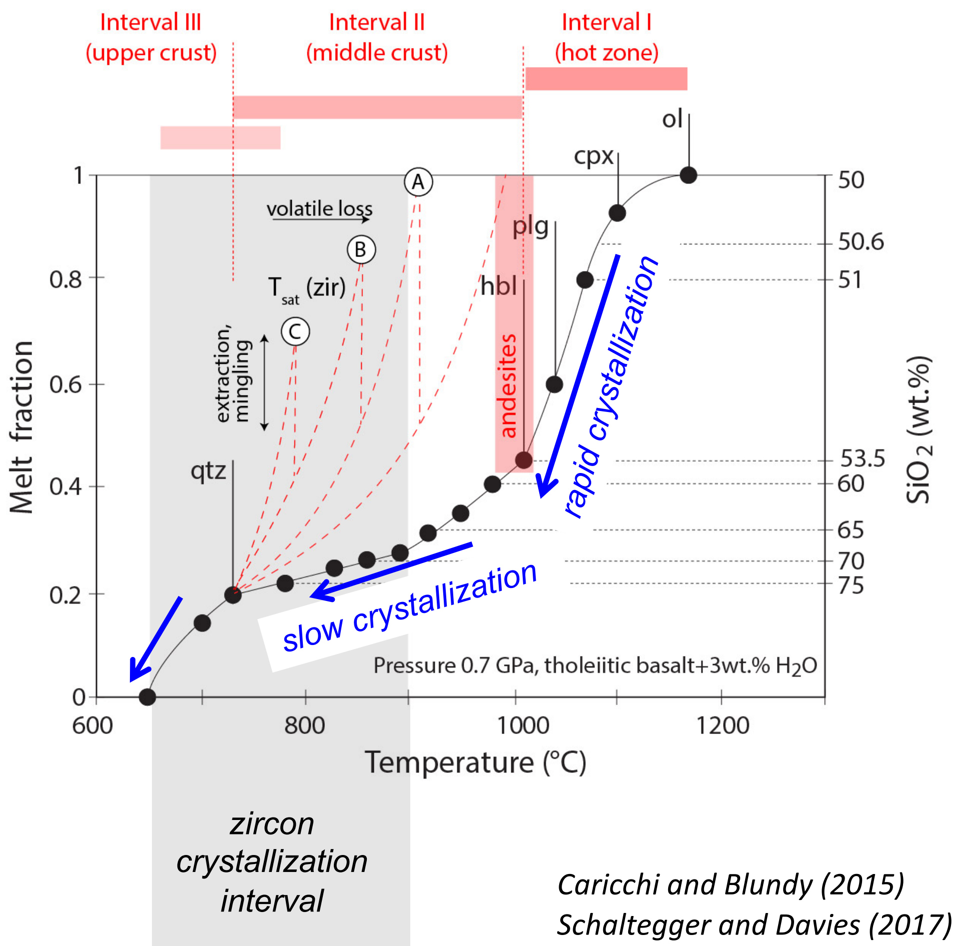


Workflow:

- Imaging
- In-situ chemical and isotopic analysis
- Chemical abrasion
- High-precision dating
- Solution chemical and isotopic analysis

Residence in magma and recycling processes in magmatic systems

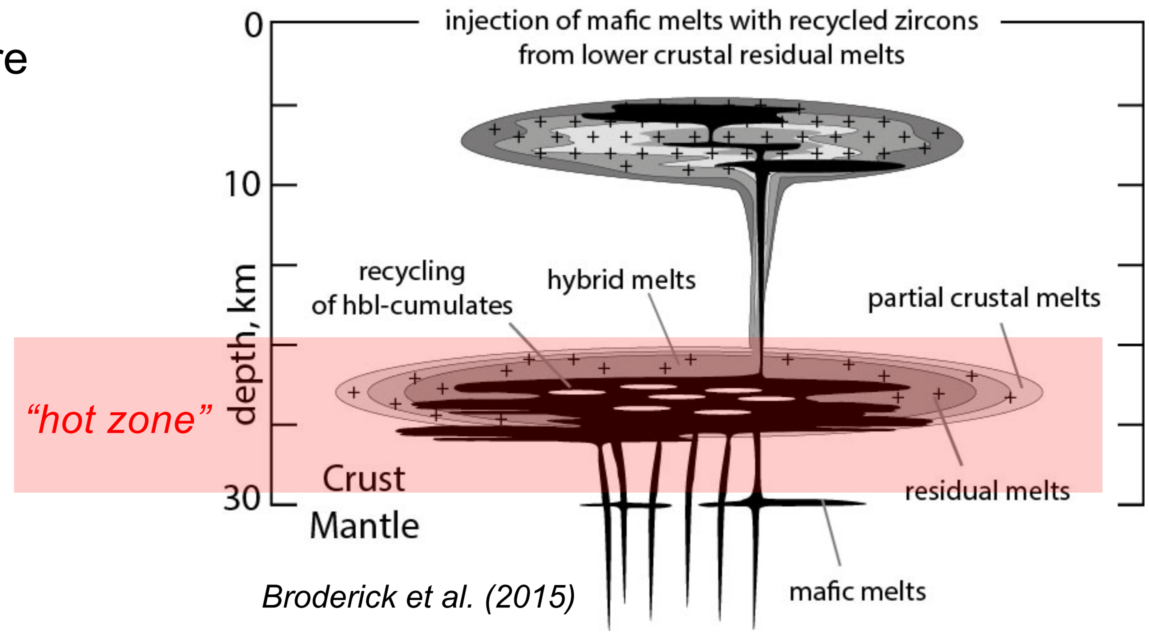
- Arrival at T_{sat}[zirc] as $f_{(Na,\ K,\ Ca,\ Al,\ Si,\ Zr;\ T)}$
- Rapid crystallization at 50-65% SiO_2 (few zircons in marginal portions of a pluton)
- Slow crystallization at 65-75% SiO_2 (many zircons forming between T_{sat} and solidus)
- Rapid crystallization at the solidus (few zircons)
- Sigmoidal age distribution – which grains to select?
- Rejuvenation (partial remelting) of crystal mushes ("cannibalization") during recharge events
- Open system: mixing of liquids, mixing of mushes, transfer of crystals



Caricchi and Blundy (2015)
Schaltegger and Davies (2017)

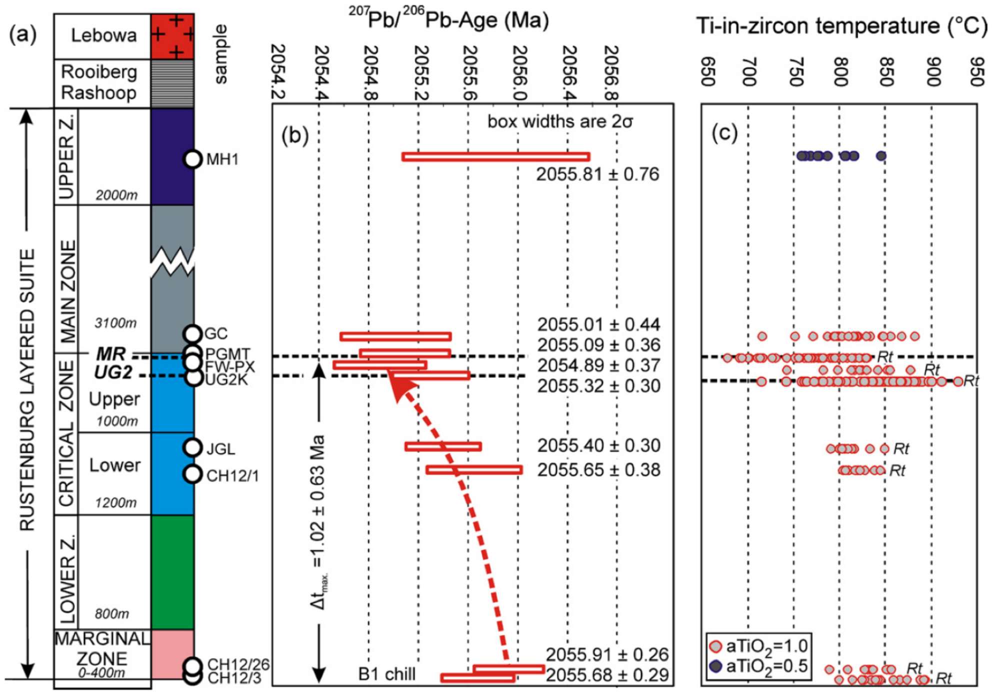
A conceptual model for arc systems

- Much (most?) of the zircon grows at a lower to middle crustal level
- Magma storage is “cold”: crystal mushes, which episodically get rejuvenated during recharge events
- Mixing of melt batches from different origin and their crystals
- Incremental accretion in the upper crust
- relative temporal relationships in the field are younger than zircon crystallization



Broderick et al. (2015)

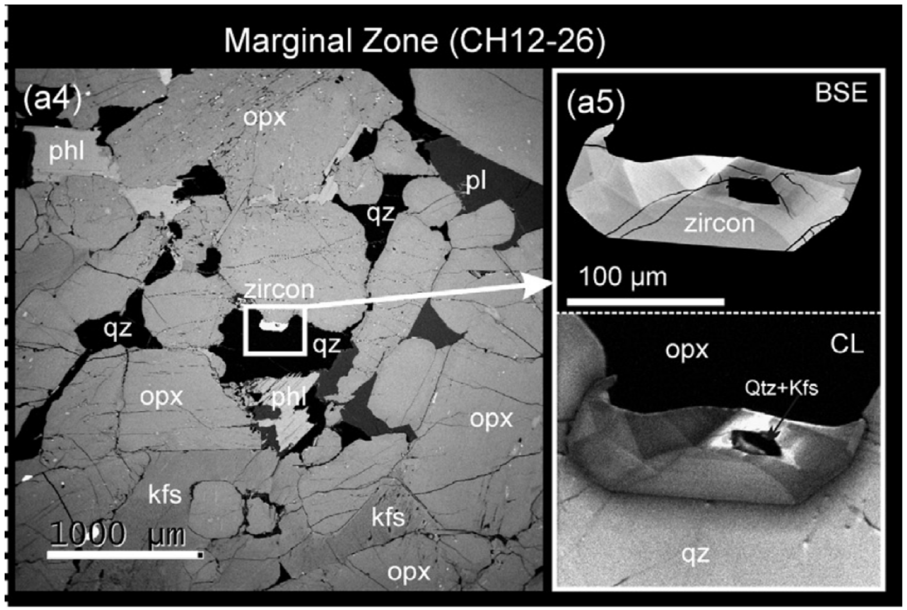
Zircon growth in mafic magmatic systems



Zircon is surprisingly common in tholeiitic MOR gabbros and plagiogranites, sills and dykes of Large Igneous Provinces

Example: interstitial zircon in Bushveld magmas

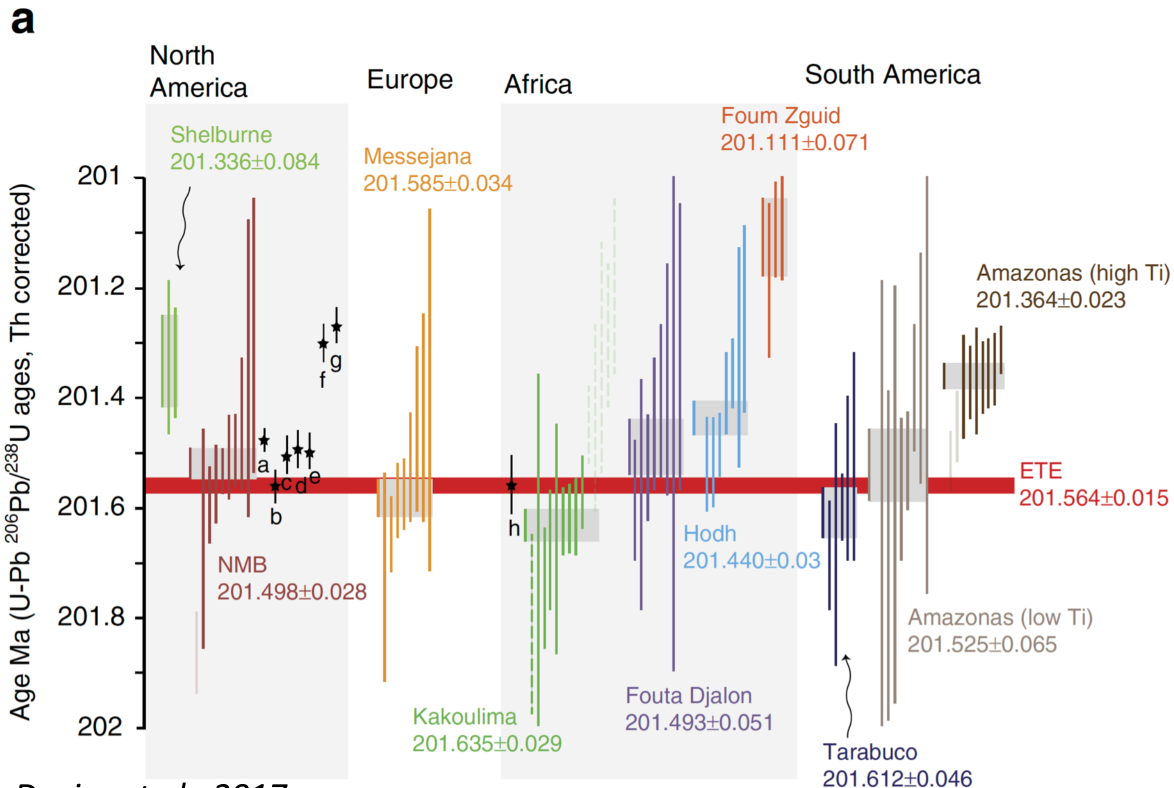
Zeh et al. (2015)



- Zircon is not crystallizing directly from tholeiitic melt but from evolved residual melt
- T estimates for zircon crystallization are at ~900-700°C
- zircon is thus forming after >90 vol% crystallization of major minerals

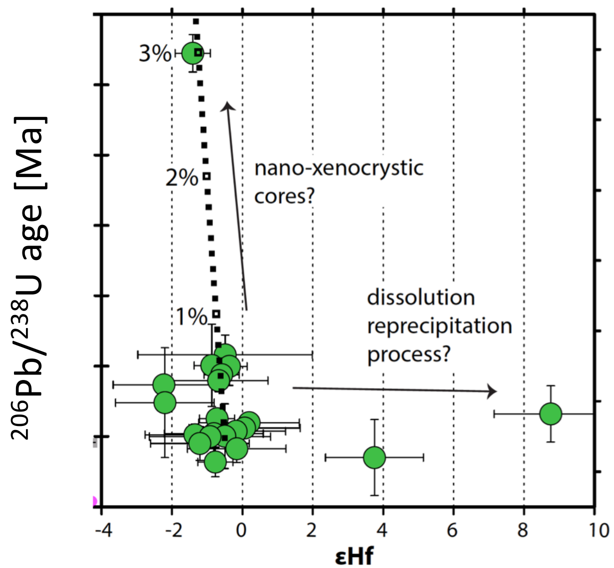
Zircon growth in mafic magmatic systems

Zircon can date emplacement of the dyke/sill complex of a LIP at highest temporal resolution
Example: North Atlantic Magmatic Province



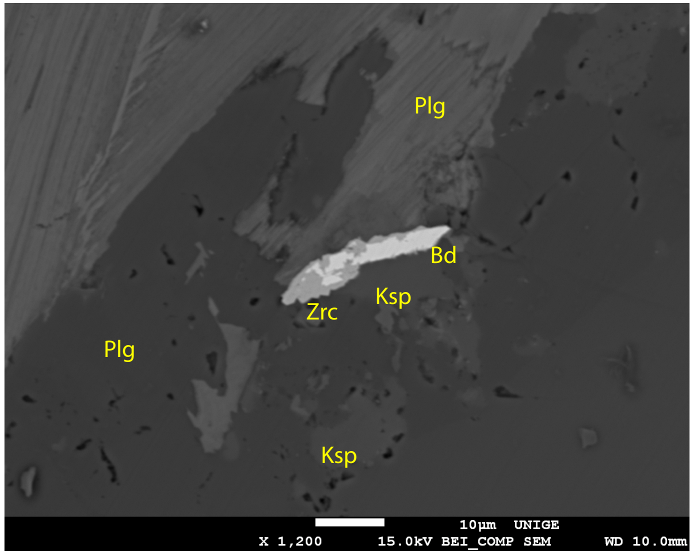
Davies et al., 2017

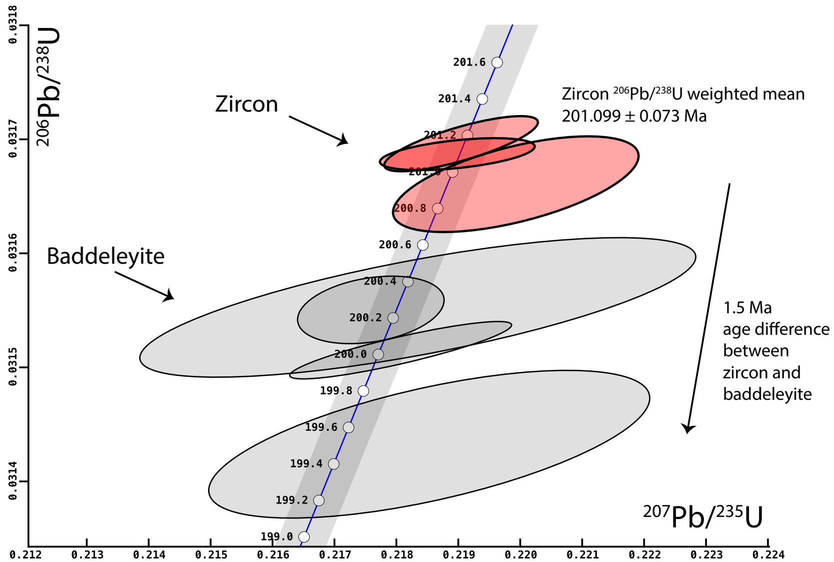
Their age variation, however, indicates participation of an inherited component



Davies et al., in prep.

Alternative if there is no zircon in the rock: Baddeleyite (ZrO_2)





Example from a CAMP basaltic dyke; *Schaltegger and Davies (2017); Davies et al. (in prep.)*

- baddeleyite U-Pb ages are younger than chemically abraded zircon ages
- Main problem with baddeleyite petrochronology is that reliable age information can not be obtained at present due to unresolved Pb loss

Conclusions

- Arc plutons grow through incremental addition of small (- to bigger) melt batches
- The melts were saturated in zircon at intermediate crustal levels, zircon was transported in the melt to upper crustal level
- Zircon crystals were also recycled from previous crystal mushes that were remobilized through incoming hot magma
- Therefore few zircons are in chemical and isotopic equilibrium with the present-day host rock
- Zircon in residual melts of mafic (tholeiitic) systems only saturates after >90% fractional crystallization
- Excess age variation concurrent with Hf isotopes indicates that zircon in residual melts of mafic systems may at least partly nucleate around tiny relics of inherited zircon