The puzzle of zoned plutons: Insights from Geochronology, Geochemistry, and Petrogenesis of the Box Springs Plutonic Complex, Peninsular Ranges Batholith, Riverside – California

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AGU23

San Francisco, CA & Online Everywhere

11-15 December 2023

Summary

Granitic plutons often display distinct concentric zoning, identifiable through variations in textures, structures, mineral content and chemical variations from the center toward the edges of the pluton. Plutons can be normally zoned from more mafic margins to more felsic centers or reverse zoned, where mafic cores are surrounded by felsic rims.

The Box Springs Plutonic Complex (BSPC) is a good example of a reverse zoned pluton. A ballooning emplacement model was proposed by Stock (1992). According to this model, the central tonalite expanded upward, displacing the wall rock, developing foliation, and assimilating crust at the edges of the pluton. This study proposes a detailed mapping and structural, geochemical, and geochronological analysis to understand the complex zoning and emplacement of the different units in the BSPC.

Geologic setting

The BSPC presents an elliptical shape and stands out for its discernible textural, reverse compositional, and isotopic zonation. It consists of five major units described from the core as massive high-silica biotite tonalite to foliated tonalite and granodiorite in the edges (Morton et al., 2014). It is situated in the western transition zone of the Peninsular Ranges Batholith (PRB). This zone had intense deformation at 100 Ma and the plutons in the area are characterized by complex emplacement mode, well foliated fabrics, depth of emplacement of 4 to 6 kb, Sri values of 0.7045–0.7050, positive εNdi, and δ18O <9‰.

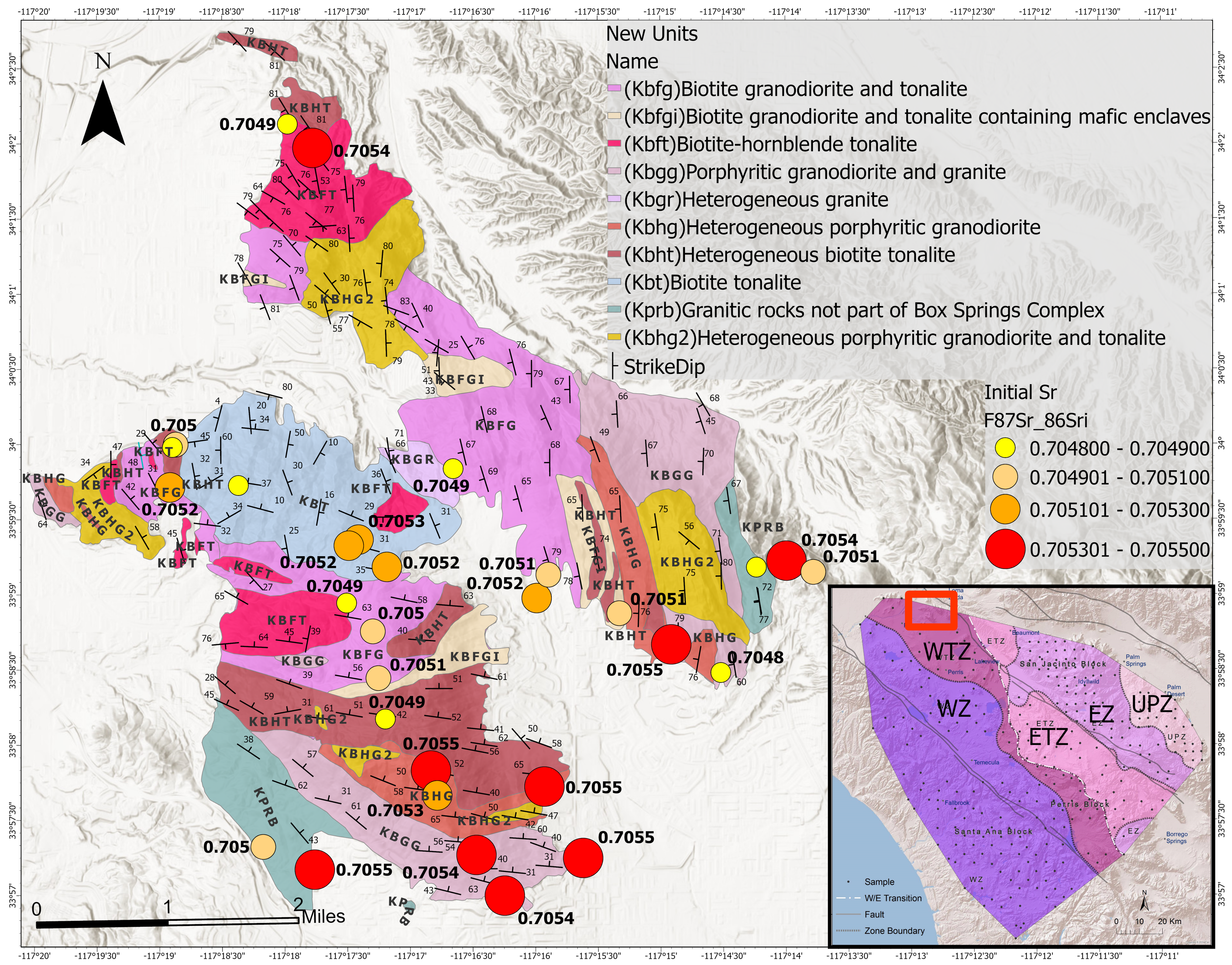

Fig. 1. Initial strontium, structures and location of the Box Springs Plutonic Complex in the northern part of the Peninsular Ranges Batholith and the suggested units. Western zone (WZ), Western transition zone (WTZ), Eastern transition zone (ETZ), Eastern zone (EZ), and Upper-plate zone (UPZ). The geological map has been adapted from Morton et al. (2014), while the inset map has undergone modifications from Pompe (2016).

Mapping techniques

STRABOSPOT ArcGIS Pro

Field relationships and petrography

Units ranged from biotite tonalites, granodiorites, and granites at the center to layered porphyritic granodiorite and tonalites at the margin. The BSPC displayed concentric mineral fabrics, including biotite, feldspar, and hornblende, which plunged towards the center. Fabric intensity was found to be higher at the margins and lesser in the center. The contacts between units were mostly gradational, with evidence of magma mingling, enclaves, cognate inclusions, schlieren, and compositional layering.

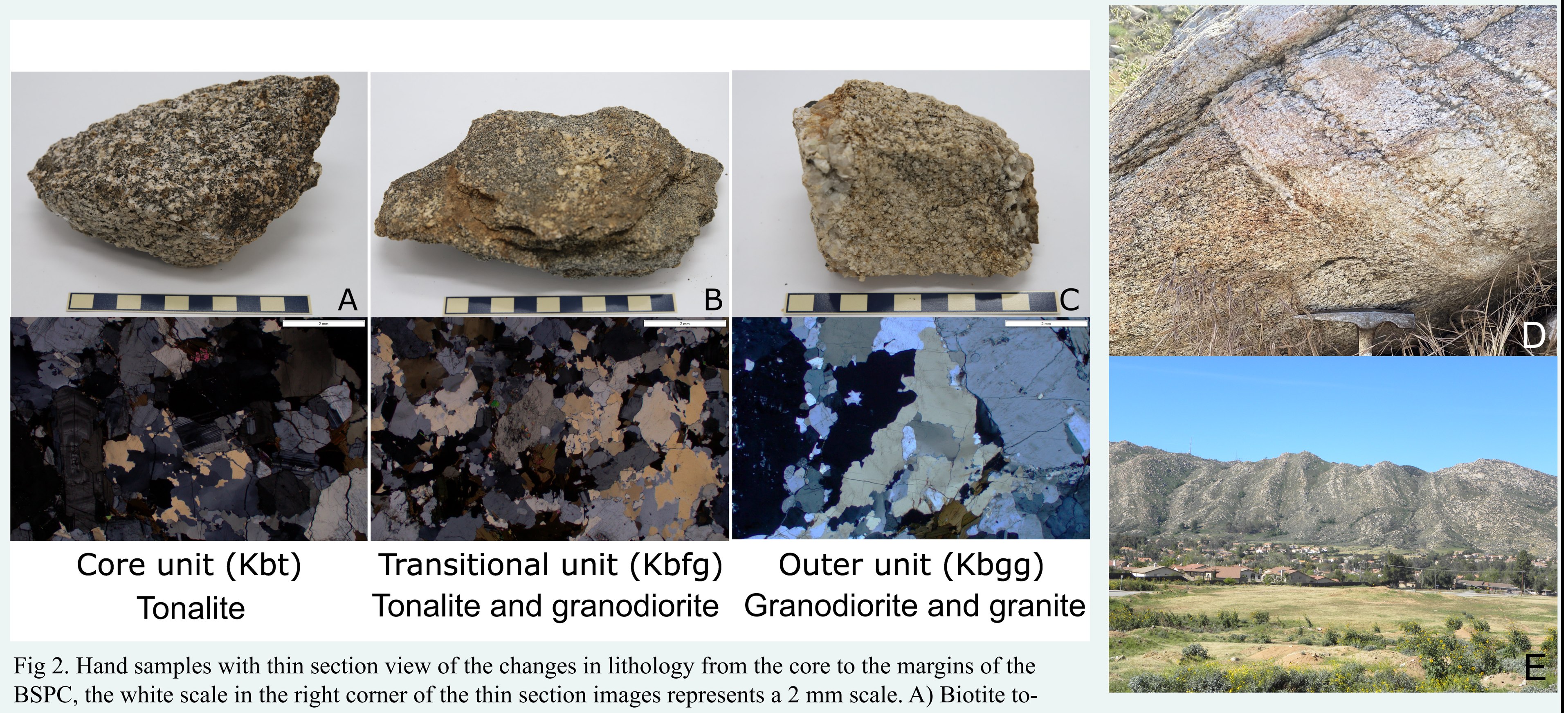

Fig 2. Hand samples with thin section view of the changes in lithology from the core to the margins of the BSPC, the white scale in the right corner of the thin section images represents a 2 mm scale. A) Biotite tonalite. B) Mingling of biotite granodiorite and tonalite. C) Porphyritic granodiorite and granite. D) Schlieren structures in the marginal units (Kbgg). E) Foliation of the marginal units (Kbgg) in the eastern segment of the BSPC.

Geochronology

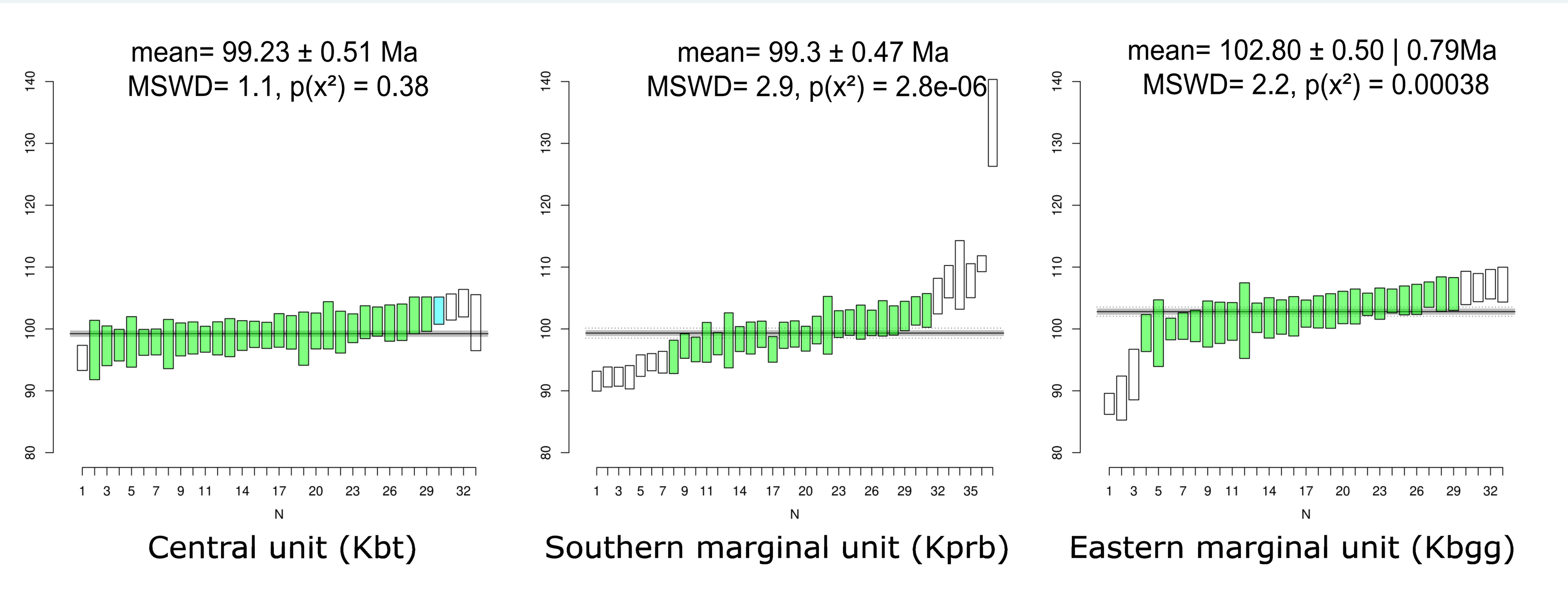

Fig. 3 Zircon U–Pb ages of the central unit (Kbt), compared with the ages of southern marginal unit (Kprb), and the eastern marginal unit (Kbgg). The ages were determined using the weighted mean method with the software IsoplotR Online (see references).

Geochemistry

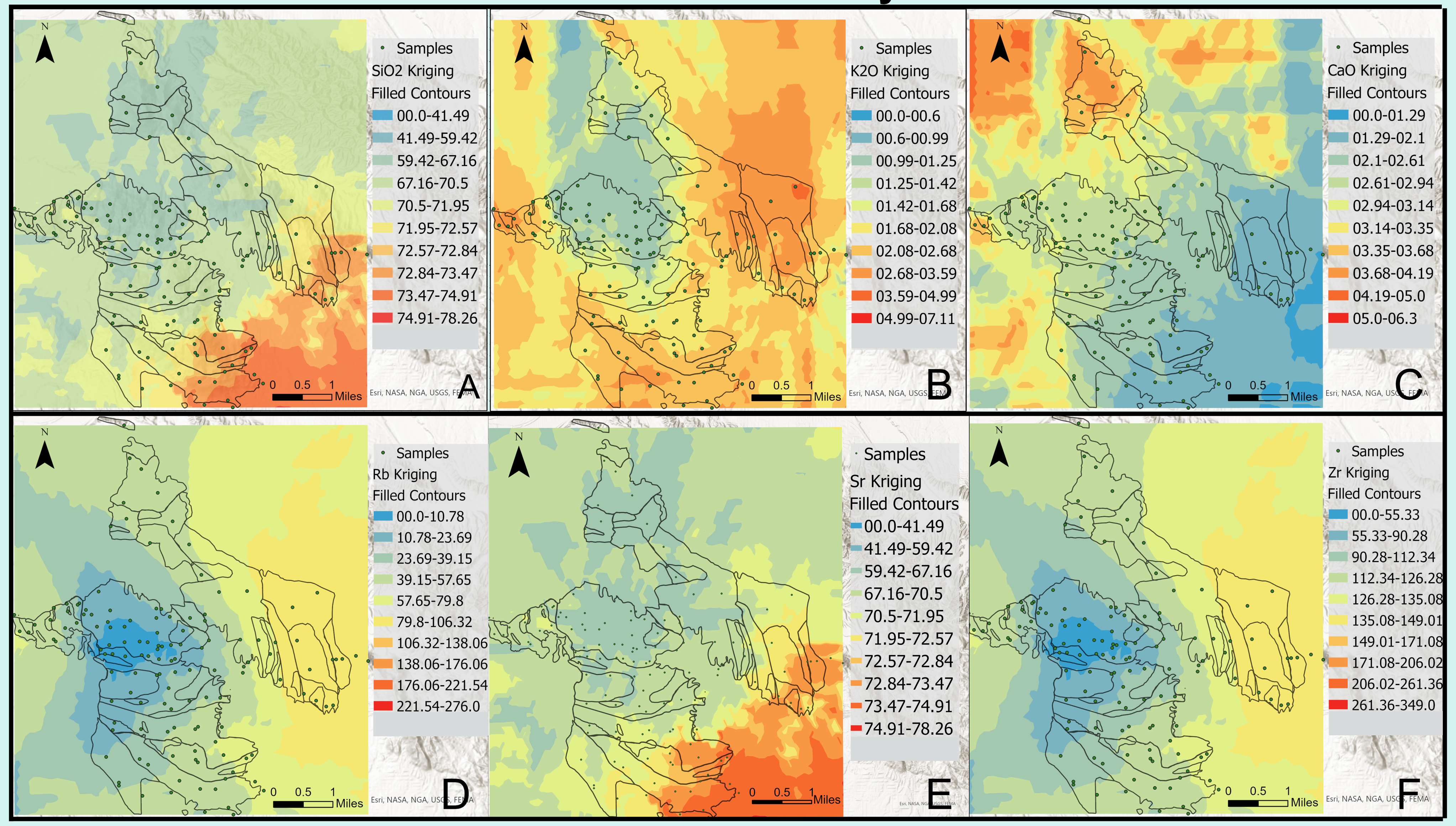

Fig 4. Kriging of the most characteristic major and trace elements with the location of the samples made by ArcGIS Pro with geostatistical wizard. A) SiO2 kriging. B) K2O kriging. C) CaO kriging. D) Rb kriging. E) Sr kriging. F) Zr kriging.

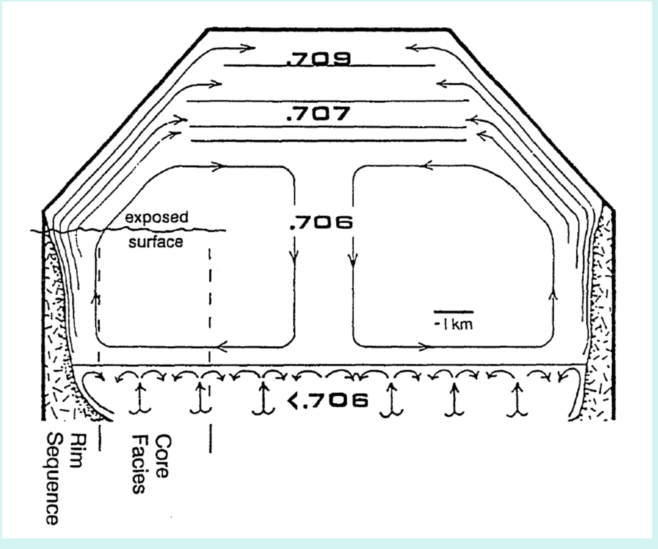

Fig 5. Model of evolution for a steep-walled magma chamber in which crystallization from the walls and roof produces more buoyant fractionated liquids (McBirney and Baker, 1981).

Discussion and conclusions

There is a distinct inverse compositional zoning within the pluton, characterized by a lithological and chemical transition from mafic units at the core to felsic units at the periphery. This zoning is further underscored by a geochronological and structural gradient.

The mechanism proposed for the BSPC is most like one proposed by Bourne and Danis (1987). This model suggests:

- **Emplacement of a large magma reservoir, onset of crystallization and movement of liquid toward the roof.**
- **Failure of the outer crust and escape of evolved liquid to form an "upper reservoir"**
- **Later, magma from the deeper source rose to form diapirs that intruded the core of the upper reservoir having less contact with crustal components.**

Acknowledgements

The authors acknowledge financial support for this study from Loma Linda University, the Colorado Scientific Society and the Geoscience Research Institute GRI2019 - BC01. We thank the lab scientists at the Arizona LaserChron Center and support from NSF grant EAR 1649254.

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