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PETROLOGICAL AND GEOCHEMICAL INSIGHTS INTO QUATERNARY BASALTIC VOLCANISM AT THE KULA VOLCANIC PROVINCE, WESTERN TÜRKIYE

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Background and Rationale

Türkiye is a tectonically and volcanically active region situated on the boundary between the Eurasian Plate, the African Plate, and the Arabian Plate (Tokçaer et al., 2005). The Kula Volcanic Province (KVP) is a prominent volcanic area and represents the westernmost and youngest volcanism in the country. This area is a monogenetic volcanic field (MVF) and hosts a range of diverse geomorphological features from three eruptive periods, referred to as the first stage (Burgaz), second stage (Elikiçitepe), and third stage (DivlitTepe), representing three different active volcanic phases in the Quaternary Period.

The QRA New Researchers Award facilitated key geochemical analysis as part of a PhD project. The work involved the application of laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) in the elemental analysis of lava flows from the three periods of volcanic activity. This high-resolution technique is widely used for studying and understanding volcanic rocks, able to better assess magma chamber processes from the source origin, during residency in the crustal plumbing system, until finally cooling at the Earth's surface (Oggier et al., 2023). This has been achieved through the analysis of trace element concentrations in different mineral phases including clinopyroxene (CPX), olivine (Ol), amphibole (Amph), and plagioclase (Pl). This approach can help determine magma sources, understand magma evolution and differentiation, determine eruption conditions, and contribute to long-term volcanic monitoring and prediction.

Method

Trace element analyses of the mineral phases CPX, Amph, Ol and Pl were performed at the Department of Earth Sciences "A. Desio" of the University of Milan using an Analyte excite 193 nm ArF excimer laser coupled with a Thermo Fisher Scientific iCAP-RQ mass spectrometer. The operating conditions were the following: 6 J/cm^2 fluence, 40 µm (CPX, Amph and Ol), 65 µm (Pl) spot size, and 10 Hz repetition rate. The acquisition time was 60 seconds on the sample and 40 seconds on the background. Data reduction was carried out with the software package GLITTER (Griffin, 2008) using SiO_2 wt% (Amph, Ol and Pl) and CaO wt% (CPX) concentrations from microprobe analyses as internal standard. The international reference material BCR-2G (Jochum et al., 2005) was used as a calibration standard and reference glasses (NIST612, Pearce et al., 1997; ARM-3, Wu et al., 2019; GSD-2G and ATHO-G, Jochum et al., 2005) were used to monitor accuracy. This study has used spot analysis at the core, intermediate, and rim points of individual mineral grains, providing high-precision elemental concentrations at different locations within a crystal. This approach can provide insights into mineral zoning, and the chemical evolution of individual mineral grains. The core represents the earliest part of the mineral to crystallise therefore its composition can reflect the initial conditions of the melt during the early stages of mineral formation. The intermediate zone reflects the transition between the core and the rim and often shows gradual and/or abrupt changes in composition due to changes in magma composition, temperature, or pressure, reflecting magma mixing, or the introduction of new material. The rim is the last to form and often reflects the final stages of crystallisation or later alteration occurrences. This can provide information about the conditions at the end of the crystal's growth such as cooling and magma solidification.

Results

Preliminary data shows the three episodes of volcanism have characteristic features of mid-ocean ridge basalt (MORB) normalised patterns for within plate alkaline basalts. This is characterised by the enrichment of highly incompatible elements such as rubidium (Rb), barium (Ba), and thorium (Th) relative to moderately incompatible elements such as zirconium (Zf), hafnium (Hf), and samarium (Sm). The ocean-island basalt (OIB) pattern is almost the same as that of the Kula lavas, except all three episodes are enriched in highly incompatible elements compared to OIB.

The rare earth element (REE) data has been normalised to chondritic REE abundances, as proposed by Sun and McDonough (1989). The chondrite-normalised REE patterns for the three periods exhibit characteristic alkaline basalt patterns with enrichment in light-REE (LREE) abundances from lanthanum (La) to europium (Eu) compared to chondritic values. The chondrite-normalised REE patterns for the first stage have the lowest REE abundances, with the first and third stages more depleted, and geochemically similar to one another. Overall, the three periods are greatly enriched compared to chondritic abundances. Since we do not observe an Eu anomaly, it suggests that Pl was not a major fractionating phase, the magma might have crystallised at pressures where Pl was not stable, or primitive or undifferentiated sources, meaning Pl had not yet fractionated from the melt.

Significance

MVFs are found where small batches of magma can erupt effusively and/or explosively for weeks to decades, with monogenetic volcanism producing small-volume volcanoes, typically <1km^3. As the term suggests, monogenetic volcanoes consist of singular eruptions, which means if an eruption stops, volcanism will not occur at the same eruptive centre again. Volcanism in the area may still be active, however, and may occur as newly developed eruptive centres within its monogenetic field. The hazard risks associated with these features are high, with intense urbanisation and population growth a risk to individuals and infrastructure. Using trace element data obtained from LA-ICP-MS, we can begin to develop geological interactions that influence volcanic behaviour and gain knowledge about the geodynamic environment over time. This is incredibly important for MVFs due to the unpredictable eruptive nature,

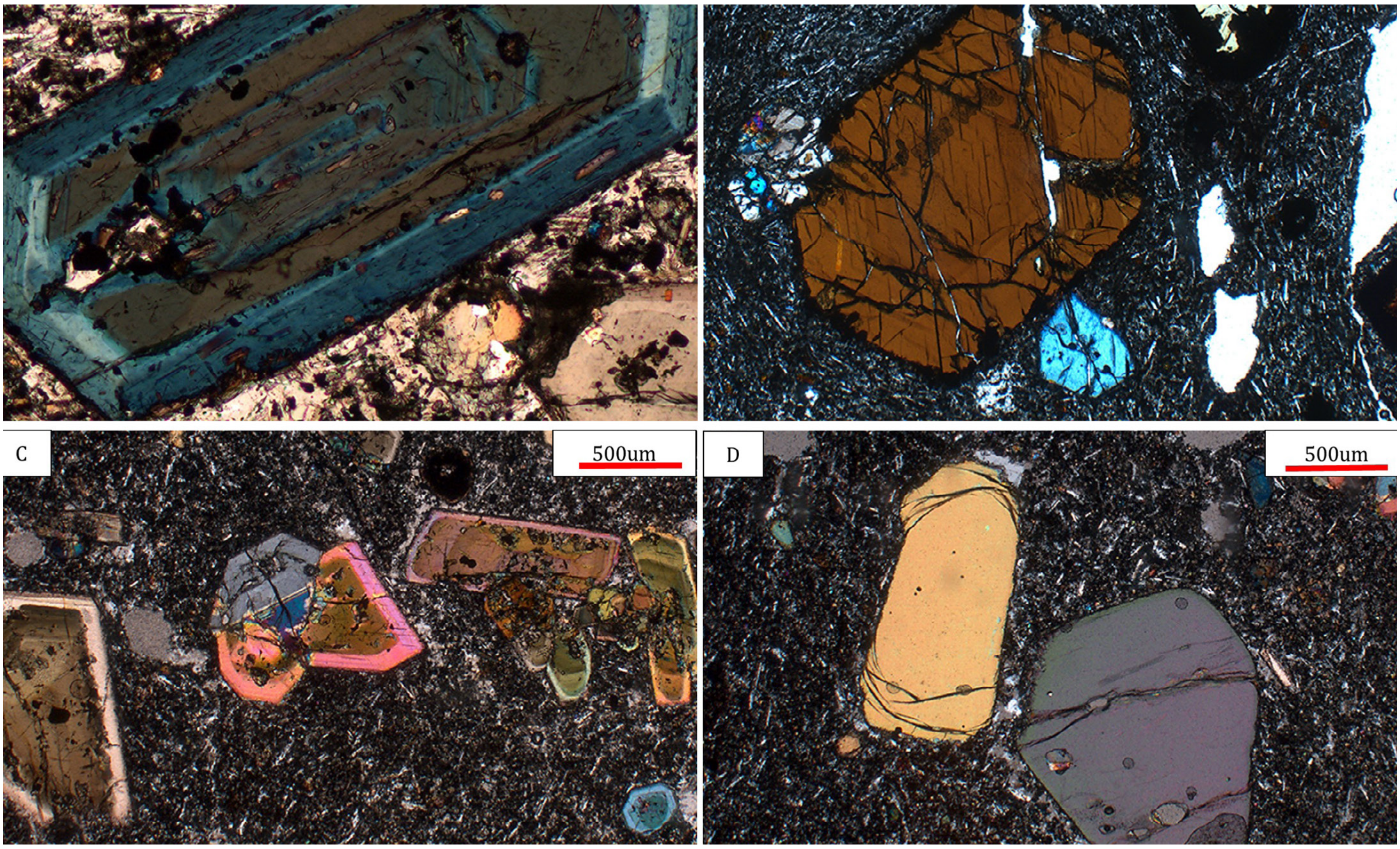

Figure 1: Thin section photographs of mineral phases analysed in cross-polarised light (XPL). A: first stage CPX showing concentric zoning B: first stage Amph with a prominent reaction rim C: multiple second stage CPX crystals with concentric zoning D: euhedral second stage Ol. Spot analysis at the core, intermediate, and rim points of each crystal was carried out to provide insights into any mineral zoning and chemical compositional changes that would have been recorded as the crystals grew.

and uncertainties on origin, longevity, and temporal-spatial distribution of eruptive centres (Jaimes-Viera et al., 2018). The data acquired from this work will be integrated into a detailed geochemical analysis of the temporal and spatial relationships from the volcano and help develop insights into the mechanics driving volcanic activity in the area.

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References

Griffin, W. L. (2008). GLITTER: data reduction software for laser ablation ICP-MS. *Laser Ablation ICP-MS in the Earth Sciences: Current practices and outstanding issues*, 308-311

Jaimes-Viera, M. D. C., Del Pozzo, A. M., Layer, P. W., Benowitz, J. A., & Nieto-Torres, A. (2018). Timing the evolution of a monogenetic volcanic field: Sierra Chichinautzin, Central Mexico. *Journal of Volcanology and Geothermal Research*, 356, 225-242

Jochum, K. P., Willbold, M., Raczek, I., Stoll, B., & Herwig, K. (2005). Chemical Characterisation of the USGS Reference Glasses GSA-1G, GSC-1G, GSD-1G, GSE-1G, BCR-2G, BHVO-2G and BIR-1G Using EPMA, ID-TIMS, ID-ICP-MS and LA-ICP-MS. *Geostandards and Geoanalytical Research*, 29(3), 285-302

Oggier, F., Widiwijayanti, C., & Costa, F. (2023). Integrating global geochemical volcano rock composition with eruption history datasets. *Frontiers in Earth Science*, 11, 1108056

Pearce, N. J., Perkins, W. T., Westgate, J. A., Gorton, M. P., Jackson, S. E., Neal, C. R., & Chenery, S. P. (1997). A compilation of new and published major and trace element data for NIST SRM 610 and NIST SRM 612 glass reference materials. *Geostandards newsletter*, 21(1), 115-144

Sun, S. S., & McDonough, W. F. (1989). Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. *Geological Society, London, Special Publications*, 42(1), 313-345

Tokçaer, M., Agostini, S., & Savaşçin, M. Y. (2005). Geotectonic setting and origin of the youngest Kula volcanics (western Anatolia), with a new emplacement model. *Turkish Journal of Earth Sciences,* 14(2), 143-166

Wu, S., Wörner, G., Jochum, K. P., Stoll, B., Simon, K., & Kronz, A. (2019). The preparation and preliminary characterisation of three synthetic andesite reference glass materials (ARM-1, ARM-2, ARM-3) for in situ microanalysis. *Geostandards and Geoanalytical Research*, 43(4), 567-584