**Department:** Earth and Environment

**Topic title:** “Magmatic processes and time scales at monogenetic and polygenetic volcanoes of Mexico”

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**Details on the topic and organization:**

*1. Background.*

Volcanism has accompanied society since the beginning, nevertheless, our ability to forecast volcanic eruptions and evaluate their hazards is still limited. In the recent decades there has been a major improvement of the knowledge about the magmatic plumbing systems and the time of magma transfer from the source to the surface. These data are fundamental for improved volcano monitoring and forecasting. Progress has been achieved through geochemical and petrological studies using whole rock composition, major and trace elements and isotopic compositions of minerals (Costa et al., 2020; Chakraborty, 2022). Crystals from mafic volcanoes record timescales of days to years between magma intrusion and eruption, which broadly match those recorded by monitoring data. Whereas the timescales recorded in felsic crystals spanning decades to millennia (Figure 1) (Costa et al., 2021).

The diffusion chronometry studies have been carried out worldwide in various tectonic environments as New Zealand (Brenna et al.,2018), Antarctica (Li et al., 2023), India (Ray et al., 2016), Italy (Iovine et al., 2017; Ubide et al., 2019), Alaska (Reagan et al., 2017), among other. In Latin America, few works in plumbing systems have been done, e.g. México (Johnson et al., 2008; Albert et al., 2020; Larrea et al., 2021), Chile (Ruth et al., 2018), Costa Rica (Oeser et al., 2018) and Colombia (Murcia et al., 2019). The timescales also have been studied in meteorites (Chakraborty and Dohmen, 2022). The diffusion chronometry combined with other monitoring techniques such as geophysical, geodetic and geochemical can estimate a very accurate volcanic hazard estimation (Costa et al., 2020).

*Figure 1. Schematic framework of magmatic plumbing systems for monogenetic volcanic fields. LAB:*

*Lithosphere-Asthenosphere Boundary. Not to scale. Taken from Murcia et al., 2019.*

In this PhD we propose to study the plumbing system, time scales of magma transfer and geological relations of monogenetic volcanoes and their relationship to larger polygenetic volcanoes. Monogenetic volcanism is the most abundant type of subaerial volcanism on Earth and commonly are grouped in clusters or volcanic fields. Those are characterized by small volume vents of mafic magma (~1 km3) emitted during a few days to several years (Nemeth, 2010; Cañón-Tapia, 2016). Commonly, monogenetic centers are perceived as low risk due to their relatively small size and low frequency of eruptions compared with polygenetic volcanoes.

Due to the fact that monogenetic volcanism does not reflect patterns in time and space, and geophysical warning systems typically lack sufficient empirical record with which to compare real time signals, it is crucial to decipher source to surface magmatic pathways (Smith and Németh, 2017; Larrea et al., 2021). Therefore, understanding the plumbing system in volcanic regions becomes a critical factor to effectively assess the volcanic hazard.

**2. Study zone.**

One of the most interesting and varied volcanic arc in the world is the Transmexican Volcanic Belt (Gómez-Tuena et al., 2005, 2018; Ferrari et al., 2012), which include monogenetic volcanism (Figure 1; e.g. Michoacán-Guanajuato, Chichinautzin, Los Tuxtlas field) and highest concentration of stratovolcanoes in the country (e.g. Colima, Popocatépetl, Pico de Orizaba, Chichón). The largest volcanic field of México is the Michoacán-Guanajuato states (MGVF, Hasenaka & Carmichael, 1985a; Valentine & Connor, 2015). This field include more than 2000 volcanic vents of different types, such as: scoria and spatter cones, maars, tuff ring, domes, tuff cones, small shield volcanoes, stratovolcanoes and calderas, each one with particular volcanic hazards associated (Figure 2 and 3) (Hasenaka & Carmichael, 1985a; Connor, 1987; Gómez-Calderón et al., 2023).

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*Figure 2. A. Tectonic setting of the Transmexican volcanic Belt (CVTM) and location of the Michoacán-Guanajuato volcanic field (CVMG) (A and B). Taken from Gómez-Vasconcelos, 2018.*

Although small volume volcanism is distributed in large areas, its product volumes are similar or higher than polygenetic volcanism. For example, the MGVF is an active volcanic zone and has over 700 km3 of volcanic products emplaced in the last 3 Ma (Hasenaka & Carmichael, 1985a). This volume equates to 72 times the Colima volcano (Gómez-Calderón, 2018). Besides Parícutin volcano “born” 80 years ago, the last 20 years the Parícutin region has presented seismic swarms which remind us of the activity of the volcanic system (Legrand et al., 2023). Nowadays, a similar eruption to the Jorullo or Parícutin volcanoes could generate enormous social, economic and environmental impacts, considering that the population has increased exponentially.

**3. Problem statement and research question**

Even though high volcanic density and abundant Holocene volcanism are present in México (over 30 vents; Macias & Arce, 2019), the knowledge about the plumbing system dynamics and associated hazards of monogenetic volcanism is scarce in comparison with polygenetic volcanoes such as Popocatepetl or Colima (Larrea et al., 2021). For this reason, the MGVF is an excellent study area for understanding magmatic plumbing systems (Hasenaka y Carmichael, 1985a; Connor, 1987; Mazzarinni et al., 2010; Pérez-López et al., 2011; Guilbaud et al., 2011; Di Traglia et al., 2014; Cañón-Tapía, 2016; Larrea et al., 2021; Torres-Sánchez et al., 2022). This research proposes a chronometry diffusion analysis of different zoned mineral of diverse volcanoes typology and magmatic series (mafic, shoshonitic, alkaline) within the MGVF. This with the intention to contribute to the understanding of the complexity of the magmatic plumbing systems in volcanic fields and to the volcanic hazard assessment. Additionally, the chronometry diffusion models can help to improve land planning, response and mitigation plans. The principal questions that guide this research are: ¿What is the magma dynamics from source to surface of different volcano typology? ¿Are there a relationship between magma batches features and volcano typology and/or volcanic arc zones? ¿Are there diffusivity signatures associated with specific volcano typology or/and magmatic series? ¿How long would it take for the magma to ascend to the surface after the first geophysical signals in the future? ¿Which regions have high probability of emplacement of a new volcanic system?

**4. Methods.**

The general method of doctoral research includes field campaigns, analytical sessions and research work.

*4.1. Field campaigns.*

The first phase will consist of sampling the pyroclastic products of different volcano typology (spatter, cinder cone, maar, shield volcano, stratovolcano). In case pyroclasts are absent, lavas will be sampled.

*4.2. Analytical methods.*

The petrology and geochemical characterization will be done with a polarizing optical microscope, scanning electron microscope (SEM) and electron probe micro-analyzer (EPMA). Major element crystal compositions will be analyzed by EPMA though core-to-rim traverses on olivine, pyroxene, feldspar, quartz, spinel and apatite with a spacing of 2-4 um at (IPGP/USorbonne). Electron backscattered diffraction (EBSD) obtained from the SEM will be used to determine the orientation of the crystallographic axes. Multi-element compositional maps will be obtained via laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS).

*4.3. Diffusion chronometry*

The diffusion chronometry is based on mineral zonation and gradients in the composition of crystals. The formation of chemical gradients in crystals and/or melts drives the diffusion of molecules or elements during magma storage at high temperatures as the system attempts to return to equilibrium. Through the diffusivities of different elements, we can calculate the timescale of diffusive re-equilibration using the Fick’s second law of diffusion or more sophisticated models (Costa et al., 2008; Costa, 2021). The wide range of elemental diffusivities means that multiple elements can be exploited simultaneously to obtain a more accurate picture of the variety of processes and timescales that can be recorded in a single mineral (Costa et al., 2020).

**5. Expected research outcomes.**

In general, the goals of the research are: i) generate a geochemical-petrological data base from different volcano typology, ii) generate diffusion chronometry and thermobarometry models, and iii) contribute to the assessment of volcanic hazards. Those will be exposed in three research articles.

1. Unraveling the magmatic plumbing system of Michoacán Guanajuato volcanic field, México: diffusion chronometry and thermobarometry of subalkaline, shoshonitic and alkaline lavas.
2. Mafic cumulates in small-scale volcanism, a window for complexity of magmatic plumbing systems.
3. Volcanic hazards of central Transmexican Belt: a diffusion chronometry approach.

**6. PhD Timeline**

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| Activity | Year |
| 1 | 2 | 3 |
| Trimester |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |  |
| Literature review |   |   |   |   |   |   |   |   |   |   |   |   |  |
| Write “State of the Art” chapter |   |   |   |   |   |   |   |   |   |   |   |   |  |
| Field work  |   |  |  |   |   |   |   |   |   |   |   |   |  |
| Sample preparation |   |   |   |   |   |   |   |   |   |   |   |   |  |
| Acquisition of mineral chemical data  |   |   |   |   |   |   |   |   |   |   |   |   |  |
| Writing of 1st article |   |   |   |   |   |   |   |   |   |   |   |   |  |
| Writing of 2nd article |   |   |   |   |   |   |   |   |   |   |   |   |  |
| Writing of 3rd article |   |   |   |   |   |   |   |   |   |   |   |   |  |
| Conclusion |   |   |   |   |   |   |   |   |   |   |   |   |  |

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