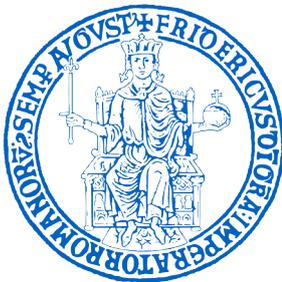


# Pyroxene and olivine chemistry as an indicator of melt evolution. A contribution to the understanding of Somma-Vesuvius eruptive behaviour

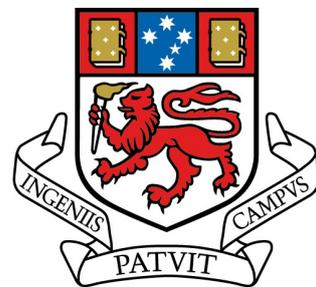
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Doctor of Philosophy

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## Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due acknowledgement is made in the text of the thesis.



Daniele Redi

10<sup>th</sup> March 2014

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# Abstract

Explosive volcanism is commonly related to a process known as fragmentation of magma containing bubbles rich in gas phases. This process is activated by the brittle failure of the melt as its strength is overcome by viscous stresses related to bubble growth and ascending magma flow. Individual volcanoes often produce alternating effusive and explosive eruptions which cyclical dynamics remain unclear and are a subject of ongoing debate.

The Somma-Vesuvius, famous for its explosive Pompeii eruption in AD 79, generated a wide variety of eruptive events during the past 33 Ky, ranging from mild effusive (inter-Plinian) eruptions to highly disruptive (Plinian) phenomena. Over the last 3 decades, a large number of samples have been collected from the Somma-Vesuvius volcanic complex. As a result of this research effort, a large database of chemical analyses of various volcanic products from lavas to pumices and tephra is currently available. This allowed for detailed studies of magma compositions aimed at reconstructing magma differentiation processes and identifying parental and primary magma compositions. Currently there is no general consensus on whether the primary magma precursors to both eruption styles were of a similar composition.

At the same time, the compositions of mineral phases in Somma-Vesuvius volcanic products have received significantly less attention. Phenocryst phases such as olivine and clinopyroxene occur early on the liquid line of descent and dominate fractional crystallization in the primitive magmas. At the later stages of crystallisation they are joined and/or replaced by feldspars, feldspathoids, biotite and oxides. This project aims at characterising minor and trace elements in both olivine and clinopyroxene phenocrysts from representative lava, scoriae and pumice samples from the main Plinian eruptions and a range of inter-Plinian events over the last 33 Ky. The main aim of this work is to present new constraints on the factors leading to the different Somma-Vesuvius eruptive styles.

In order to achieve this goal, 14 pumice samples from Plinian pyroclastic deposits as well as 3 scoriae and 8 lava samples from effusive flows were collected, and a representative number of olivine and clinopyroxene phenocrysts were selected under an optical microscope from each sample and analysed with an electronic microprobe and by a LA-ICP mass-spectrometry, resulting in a large database containing 2127 EMP and 1259 LA-ICP-MS analyses.

The mineral compositions obtained were examined considering the following two factors: 1) eruptive style; and 2) age of the samples. Magmas from Plinian and inter-Plinian eruptions were compared using the results of this study in conjunction with published data on lava chemistry and the compositions of melt and fluid inclusions in phenocrysts. Further, the mineral compositions have been compared with those from other volcanoes of the Roman Comagmatic

Province (RCP) and also from other tectonic settings such as Oceanic Islands, Volcanic Rifts, Mid-ocean Ridges and Supra-subduction Zones, in order to assess the extent of compositional variation among Somma-Vesuvius olivine and pyroxene phenocrysts.

The above approach led to the following main conclusions:

I) olivine and clinopyroxene phenocrysts crystallized simultaneously over a large temperature range from the earliest stages of melt evolution;

II) both olivines and clinopyroxenes display clear bimodal distribution in terms of the proportions between the Mg-rich and Fe-rich end members ( $Mg\# = Mg/(Mg+Fe)$ ): the primitive group has compositions  $Mg\#_{92-82}$ , whereas the evolved group has compositions  $Mg\#_{82-72}$ ;

III) both Plinian and inter-Plinian clinopyroxenes and olivines populations exhibit a narrow trend of major, minor and trace elements contents as a function of their  $Mg\#$ , when compared with mineral compositions from other tectonic settings, including the RCP, indicating a narrow range of melt compositions within the Somma-Vesuvius plumbing system for a given stage of differentiation regardless of the eruption style;

IV) clinopyroxene and olivine phenocrysts compositions in inter-Plinian eruption products display a narrower range compared to the Plinian eruptions;

V) as the result of a narrow compositional range of phenocrysts in inter-Plinian eruptions, there is a larger difference in phenocryst populations composition between individual inter-Plinian eruptions than between Plinian eruptions;

VI) The more evolved ( $Mg\#_{82-72}$ ) Plinian and inter-Plinian clinopyroxene phenocrysts in rocks younger than 2.8 Ky show clear Ca enrichment (23.5-24.5 wt % CaO) in respect to the older rocks. Some of the more primitive olivine phenocrysts ( $Fo\#_{92-82}$ ) from the inter-Plinian eruptions younger than AD 472 (CaO 0.30-0.45 wt %) are also more enriched in Ca than older olivine phenocrysts;

VII) Overall, the compositions of clinopyroxenes from the inter-Plinian eruptions display REE contents which are within the range of the Plinian clinopyroxenes.

The above results suggest:

I) a prevalently magmatic origin of olivine phenocrysts whose presence was previously mainly ascribed to magma reaction with the carbonate basement of the Campania Plain;

II) Persisting multiple sites of crystallisation where magmas of variable extent of fractionation

reside at any given time regardless of the type of eruptive activity;

III) Chemically similar sources of parental magmas feeding the Somma-Vesuvius system, which does not appear to have changed over the last 33 Ky; and

IV) A common composition of parental magmas for the Plinian and inter-Plinian eruptions of the Somma-Vesuvius.

Therefore, this study suggests that the magma residence times and the magma supply rate are the likely main factors controlling eruption style at Somma-Vesuvius. Further insights into these processes may be derived from the study of melt and fluid inclusions within the Somma-Vesuvius olivine and clinopyroxene phenocrysts, which is envisaged as a continuation to this project.

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# Appendices

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1.1 Clinopyroxenes

1.2 Olivines

1.3 Mineral Inclusions

## Appendix 2: LA-ICP-MS data (presented on data disk)

2.1 Clinopyroxenes

2.2 Olivines