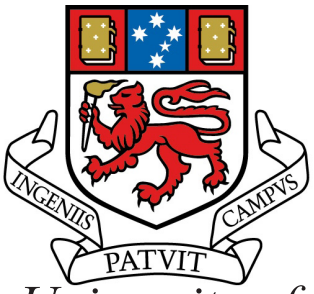
Pyroxene and olivine chemistry as an indicator of melt evolution. A contribution to the understanding of Somma-Vesuvius eruptive behaviour

by

Daniele Redi

B.Sc & Second Level Italian Degree at University of Siena

University of Naples "Federico II"



University of Tasmania

Submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

March, 2014

Declaration

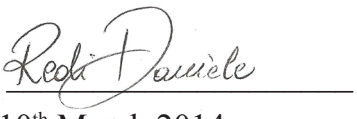
This thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due acknowledgement is made in the text of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

Daniele Redi

10th March 2014

Access Authority

This thesis may be made available for loan and limited copying in accordance with the Copyright Act, 1968.



Daniele Redi

10th March 2014

Acknowledgements

During this long process called “PhD”, I have experienced a long series of “ups” and “downs”. It has not been easy managing the scientific expectations as well as the bureaucracy which two Universities require. At the same time, I found quite hard leaving my beloved Tuscany to live first in a different city in Italy (Naples) and after in a different continent (Australia) for the last four years.

During this roller coaster of experiences, some people within the University had played a key role to motivate me and keep me on “track” and they must be thanked. First of all, I am infinitely thankful to both my Italian supervisors the Professors Annamaria Lima and Benedetto De Vivo with who I started this amazing project on Mt. Somma-Vesuvius in 2010 at the University of Naples. I loved the Professor De Vivo’s energetic attitude and the constructive comments and feedback on the thesis which both of them carefully gave me.

I feel also very lucky that along the path I met and worked with the Professor Leonid Danyushevsky who has been my supervisor at the University of Tasmania for the past three years. I am a big believer that in our life we meet the people from whom we were meant to learn something. You are a brilliant scientist and a good man. I appreciated all the help you gave me, your efforts to improve my scientific skills and to shape my character as well as the patience with which you dealt with me and my “drama queen” personality.

I want also deeply thank all the lab stuff, Dr Sandrin Feig, Dr Karsten Goemann, Ms Sarah Gilbert and Mr Jay Thompson from the University of Tasmania for the massive help they gave me in analysing my samples at the EMP and LA-ICPMS facilities. I especially appreciated the company of Sarah and Jay. Your work attitude and your friendship have been really important and it mean a lot to me.

Many other people among academic and non-academic stuff gave me their attention and precious support during this long journey which I will never forget. These people are: Davide Ianniello, Dr Angela Doherty, Carmela Rezza, Dr. Stefano Albanese, Dr Maja Radivojevic, Tim Williamson, Hannah Johnson, Dr Jeff Steadman, Dr Anita Parbhakar-Fox, Mr JianXiang Guan, Courtney Cocks, Ashley Hanke (all my love is with you), Brielle Mason (and all the Mason family, you are such great people), Amy Dart (and all the Dart family, I love you infinitely), Skye Hamilton (whose creative personality enriched my life), Dr Anthony Brown (one of my best friends and confidant in Australia), Nawin Jinangoen (whose cookery delighted my palate and boost my work), and last but not least Minh Vo (whose infinite patience, support and yummy food kept me warm and fed).

I cannot finish this section without expressing my most deeply gratitude for all the love, time,

logistic support and motivation I received from my family (mamma, babbo e Tiziano). Vi voglio bene con tutto il mio cuore. Sono stato lontano ma ne valeva la pena e vi ringrazio per tutto il supporto che mi avete dato in tutti questi anni e durante questa esperienza.
Lastly, I have to say a big thank to a special person Ms Renée Brémond without whom I could never reached this goal; six years ago when I came to France you simply changed and I believe saved my life forever (tu as changé ma vie pour toujours).

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 overcame 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. Phenocrysts 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.

Table of Contents

Chapter 1: Introduction

Chapter 2: Regional Geology; parentage of the Italian Volcanism

Chapter 3: Somma-Vesuvius

Chapter 4: Sampling & Laboratory

Chapter 5: Clinopyroxenes Mineralogy at Somma-Vesuvius

Chapter 6: Olivines Mineralogy at Somma-Vesuvius

Chapter 7: Summary and conclusions

List of Figures

List of Tables

Appendices

Appendix 1: EMP data (presented on data disk)

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