

THE APPLICATION OF MICROANALYTICAL TECHNIQUES IN ISOTOPE
GEOCHEMISTRY: 1. SINGLE CRYSTAL $^{40}\text{Ar}/^{39}\text{Ar}$ DATING OF RHYOLITES IN
THE JEMEZ VOLCANIC FIELD, NEW MEXICO, WITH IMPLICATIONS FOR
EVOLUTION OF THE MAGMA SYSTEM. 2. TOWARDS DEVELOPMENT OF A
LASER MICROPROBE FOURIER TRANSFORM MASS SPECTROMETER FOR
ISOTOPIC ANALYSIS OF GEOLOGIC SAMPLES

by

Terry L. Spell

A Dissertation

Submitted to the State University of New York at Albany

in Partial Fulfillment of

the Requirements for the Degree of

Doctor of Philosophy

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ABSTRACT

Dating of single crystals from rhyolites in the Jemez Mountains volcanic field (JMVF) by the laser fusion $^{40}\text{Ar}/^{39}\text{Ar}$ technique reveals phenocryst populations dominated by juvenile crystals, but often containing xenocrystic and altered crystals. Isochron plots of single crystal analyses allow identification of the eruptive age and trapped Ar in the sample. Explosive caldera forming events commenced in the JMVF at 1.78 Ma with eruption of the San Diego Canyon ignimbrites. Xenocrystic material in these units was apparently responsible for the anomalously old K-Ar ages (2.84-3.64 Ma) previously obtained. Further caldera collapse events occurred with eruption of the lower Bandelier Tuff at 1.51 Ma (Toledo Caldera) and the upper Bandelier Tuff at 1.14 Ma (Valles Caldera). These eruptions record the chemical evolution of a large, open system, upper crustal, silicic magma chamber. Postcollapse rhyolites of the Valles Caldera were erupted over an ~1 Ma interval from immediately following caldera formation until ~200 ka. Volcanism was periodic with eruptive activity at ~1.133 Ma, 973-915 ka, 800-787 ka, 557-521 ka, and ~300-170 ka. Most samples contain trapped atmospheric Ar, however several have apparent $^{40}\text{Ar}/^{36}\text{Ar}$ ranging from 282 to 325. Approximately 30% of the postcollapse rhyolites yield $^{40}\text{Ar}/^{39}\text{Ar}$ dates significantly older than previous K-Ar dates. This is most likely due to incomplete extraction of $^{40}\text{Ar}^*$ from high-temperature alkali feldspars. Variations in petrographic, geochemical, and isotopic characteristics indicate that the discrete intervals of volcanic activity are related to the emplacement of shallow upper crustal magma chambers. Magmas erupted at 973-787 ka and 557-521 ka record differentiation sequences controlled by crystal-liquid fraction and minor assimilation, whereas those vented at 1.133 Ma and ~300-170 ka were distinct compositionally but show no differentiation. Nd isotopic compositions ($\epsilon_{\text{Nd}} = -2.7$ to -4.6) indicate that ~20-65% of these rhyolitic magmas was of mantle-derived origin. Sr isotopic values as low as 0.70464 and calculated magmatic $\delta^{18}\text{O}$ of $+6.6$ - 7.0 ‰ suggest that granulitic lower crust of igneous origin was assimilated by basaltic magmas.

Work on the development of a Fourier transform ion cyclotron resonance (FT-ICR) mass spectrometer has established a performance baseline for the initial goal of *in situ* isotopic analysis. The levels of precision for isotope ratio measurements of Kr gas using electron beam ionization provide a measure of the capabilities of FT-ICR under ideal conditions. Ratios of major isotopes are measured to better than $\pm 0.1\%$, whereas those involving minor isotopes are reproducible to $\pm 0.4\%$. Laser ionization (LI) experiments yield significantly lower levels of precision due to variations in ion number from shot to shot, mass fractionation at the sample surface, and a larger spread in ion kinetic energy. LI experiments involving isotope ratios of abundant elements (metallic Ti) give precisions on the order of 1-4%, whereas those involving trace elements (Pb in zircon or monazite) are measured at 9-12%. The application of the SWIFT excitation technique to eject more abundant ions should allow measurement of trace element isotope ratios with precision approaching that seen for abundant elements.

ACKNOWLEDGMENTS

A dissertation such as this is a product of the combined efforts of many people. Most of the work can obviously be attributed to myself, however, no single person could likely undertake such a project and complete it on their own. I suspect that many who look at a dissertation do not fully appreciate the importance of the scientific, financial, and emotional encouragement and support from others unless they have experienced it for themselves.

First I thank Mark Harrison and Steve DeLong, who have served as my advisors during the time I have spent at SUNY-Albany. They have both praised, criticized, questioned, and developed my work as well as my approach to it. I feel especially fortunate that they have also become friends along the way. Mark has been a generous provider of financial backing for summer support and travel to meetings, field work, and lab work. These are all things which have made my time much more productive and enjoyable. Mark and Steve, along with the other members of my committee, John Delano and Chris Roddick, undertook the task of reading and commenting on this dissertation. I thank all of them for their time and efforts.

There are several individuals with whom I have collaborated over the years that deserve mention here. Philip Kyle, my former advisor at New Mexico Tech, has continued to draw me into interesting projects (one of which became chapter 5) and encourage me in my work long after my departure from Socorro. Beyond this, Philip has been, and continues to be, a valued friend. John Wolff and Steve Self have also shown a long standing interest in my work in the Jemez volcanic field and have, through invitations for collaboration on two papers, expanded by research there significantly.

Many fellow graduate students (and recent graduate students) have made their contributions through discussions, arguments, and in some cases, seriously depraved humor (you know who you are) which made the difficult times easier to live through. Thanks go to Pete Copeland, Dave Foster, and Matt Heizler for numerous discussions

about $^{40}\text{Ar}/^{39}\text{Ar}$ dating and igneous petrogenesis. Matt put me up at his house in Los Angeles and made me sandwiches and carrots for lunch more times than I could count. The $^{40}\text{Ar}/^{39}\text{Ar}$ dating in this dissertation benefited greatly from his expertise in running the lab. Bryan Hearn and Dale Mitchell exhibited great patience in helping me understand some of the finer points about the secrets of the FTMS. Ben Hanson introduced me to something I knew little about, experimental petrology, and helped me maintain my sanity during a difficult time in my life. Glenn Gaetani, Rob Alexander, Ben, Dave, Pete, and Matt are thanked for many enjoyable evenings at Sutters and elsewhere. If I have forgotten anyone - forgive me.

These acknowledgements would not be complete if they did not include my wife, Pauline. She has suffered through many years of my graduate studies - sometimes patiently - sometimes not. But above all, the good times are not forgotten.

In many ways the two persons who have contributed the most to making this dissertation possible are my parents. They have always supported me and encouraged me and believed that I could accomplish what I set out to do. You probably would not be reading this if it were not for them.

This work was supported by DOE grants DE-FG02-87ER137222, and DE-FG03-89ER14049, NSF grants EAR-8518396 and EAR-8618588, and a teaching assistantship at SUNY-Albany.

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