GEOCHRONOLOGICAL STUDIES OF MALANI VOLCANICS AND ASSOCIATED IGNEOUS ROCKS OF SOUTHWEST RAJASTHAN, INDIA: IMPLICATIONS TO CRUSTAL EVOLUTION

SHAKTI SINGH RATHORE

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Physical Research Laboratory

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Dedicated to
my parents and
fond memories
of my late
grand father

CERTIFICATE

This is to certify that the thesis incorporates the results of independent investigations carried out by the candidate himself and have at no time been submitted for any other degree or diploma.

(Shakti Singh Rathore)

Candidate

(Dr. T. R. Venkatesan)

Guide

(Prof. S. J. Desai)

Co-Guide

Prof. S. J. Desai

Head, Deptt. of Geology

M. S. University of Baroda

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BRIEF OUTLINE OF THE THESIS

The geology of Rajasthan illustrates a classical example of rocks ranging in ages from the earliest crustal component (ca. 3300 Ma) to the recent one. The Precambrian rocks of Rajasthan evolved through three major orogenic cycles namely the Banded Gneissic Complex, the Aravalli Supergroup and the Delhi Supergroup. The Malani igneous province (*MIP*), representing the youngest Proterozoic tectonomagmatic event in southwest Rajasthan, has been suspected in recent times to represent a single magmatic cycle based on their geochemical characteristics.

This thesis describes detailed geochronological studies, of different rock units from *MIP* of southwest Rajasthan, India, using K-Ar, ^{40}Ar-^{39}Ar and Rb-Sr dating techniques. About 20 whole rock samples were analyzed for ^{40}Ar-^{39}Ar studies and 30 samples for Rb-Sr studies. Additionally about 10 samples were analyzed for K-Ar and 15 samples for their Sr isotopic studies.

The geochronological findings provide a new interpretation and an insight into the evolution of *MIP* of southwest Rajasthan. The description of various rock types, their geological set up, and the geochronological studies of these rocks of the *MIP* are elaborated in five chapters of the thesis. A brief summary of each chapter is given below:

Chapter 1 describes the regional framework of Precambrian geology of Rajasthan with specific reference to *the MIP* and objective of the thesis. The province covers an area of about 50,000 sq. km in southwest Rajasthan. The important rock types of the province are rhyolites and granites with minor occurrences of basic, intermediate, acidic and alkaline volcanics and their plutonic equivalents. The concept of *MIP* representing a single late Proterozoic tectonomagmatic event has been belied by the detailed geochemical studies carried out from different parts of the province during the last one decade by various workers. However, no chronological informations were available. The present study, therefore, was undertaken to provide precise time constraints to the various geochemically distinct associations, using K-Ar, ^{40}Ar-^{39}Ar and Rb-Sr systematics, in order to construct an evolutionary model for the *MIP* of southwest Rajasthan.

Chapter 2 has description of different associations which were emerged out after detailed petrographic and geochemical work carried out from different parts of the ***MIP*** by various workers.

Chapter 3 deals with the experimental techniques employed during the course of present work. The chapter is divided into three parts. In the first two parts K-Ar and ^{40}Ar-^{39}Ar dating techniques and their experimental details have been discussed. The third part outlines briefly the Rb-Sr dating method and the procedures for sample crushing, chemical processes for separation of Rb and Sr, mass spectrometric work for Rb and Sr isotopic analysis and XRF analysis. The XRF studies, of only a few samples, were carried out at Wadia Institute of Himalayan Geology (WIHG), Dehradun and the Rb and Sr isotopic studies were carried out at KDMIPE, ONGC, Dehradun in addition to the analyses done at PRL, Ahmedabad. The scheme of using different dating techniques was as follows:

(i) K-Ar dating technique employed during the initial course of this work for preliminary screening of the samples.

(ii) ^{40}Ar-^{39}Ar dating technique for dating of younger magmatic events of mildly alkaline rocks of Tavidar and the alkaline and hyperalkaline rocks of Mundwara alkali igneous complex. The technique was also applied for dating of older rhyolites and granites from Pali and Jalore, respectively.

The samples for ^{40}Ar-^{39}Ar studies were irradiated, for 2-3 weeks, in APSARA reactor of Bhabha Atomic Research Center (BARC), Bombay. The horizontal fluence variation, as measured by ^{50}CO activity relative to the monitor sample, was not more than 5.5%. ^{40}Ar system blanks are comparable with blanks in similar extraction systems used in other laboratories.

(iii) Finally Rb-Sr method for dating of (a) Malani volcanics, including ultrapotassic rhyolites from Diri, Gurapratap Singh and Manihari, (b) Peraluminous (normal) and peralkaline granites from Jalore and Siwana, respectively and, (c) Associated normal and peralkaline rhyolites from Siwana ring complex.

Based on replicate analyses of calibration mixtures and a few rock samples, the errors in the mass spectrometric determinations of ^{87}Rb and ^{86}Sr are estimated to be within ±0.5% leading to a random error of not more than ±1% for their ratios and

in general 0.008% for $^{87}Sr/^{86}Sr$. ^{87}Rb and ^{86}Sr concentrations are calculated by isotope dilution technique. The $^{87}Sr/^{86}Sr$ ratios are corrected for mass fractionation assuming $^{86}Sr/^{88}Sr = 0.1194$ in the sample. The blank contribution was negligible compared to the Rb and Sr concentrations of the samples studied. The analysis of the NBS 987 standard, made during the course of this study at KDMIPE, Dehradun, gave a mean value of 0.710219 ± 0.000058. The errors quoted in this thesis are at 2σ level.

Chapter 4 includes the Results and Discussion. The samples analyzed by Rb-Sr method have been plotted on Sr evolution diagrams to calculate the age of isotopic equilibration of a given set of related samples and the Sr isotopic composition at equilibration using the two-error least-square regression method. The samples analyzed by ^{40}Ar-^{39}Ar method have been plotted on age spectrum diagrams as well as correlation or isochron diagrams to appraise their formation ages as well as post thermal disturbances, if any. The whole rock Rb-Sr ages illustrate distinct magmatic events at about 780, 730, 700, and 670 Ma ago. Additionally the older rocks have suffered a thermal disturbance between 500-550 Ma ago as revealed by ^{40}Ar-^{39}Ar spectra. The region has since then, remained tectonically undisturbed until younger magmatic events which took place between 70 to 64 Ma ago as indicated by ^{40}Ar-^{39}Ar studies of Tavidar volcanics and Mundwara igneous complex.

The data discussed provides a framework for the establishment of a reliable geochronology of the area. The major new findings are:

(i) *The Malani igneous province of southwest Rajasthan does not represent a single magmatic event as hitherto believed and instead represents a polyphase igneous activity.*

(ii) *Basalt-andesite-dacite-rhyolite association of Pali district are the oldest in the Malani province. These rocks were formed about 780 Ma ago from the magma generated in lower crust (excluding basalts). The basalts, though contemporary to the other associated felsic volcanics, have different source and presumably have come from much deeper level in the mantle.*

(iii) *The Jalore and Siwana granites represent two different magmatic events and were emplaced at about 730 and 700 Ma ago, respectively. The initial Sr ratios are indistinguishable but indicate derivation of the magma from the lower crust. Further, the Siwana granites and associated peralkaline rhyolites*

(pantellerites) are coeval and cogenetic.

(iv) *The outer rhyolites exposed south of the Siwana ring structure represent the youngest activity at Siwana about 670 Ma ago. These rocks have a very high initial $^{87}Sr/^{86}Sr$ ratio of 0.7110 due to incorporation of radiogenic ^{87}Sr in the residual magma.*

(v) *The ultrapotassic rhyolites exposed at Manihari of Pali district have similarity in the age and initial Sr ratio with those of the outer rhyolites of Siwana, suggesting possible derivation of these rocks from the same residual magma.*

(vi) *^{40}Ar-^{39}Ar studies of basalt, dacite and rhyolite from Diri and Gurapratap Singh as well as of Jalore granites have indicated the existence of a thermal event around 500-550 Ma ago.*

(vii) *^{40}Ar-^{39}Ar studies of mildly alkaline rocks of Tavidar have indicated a span of 2 Ma from 66 to 64 Ma for the differentiated rocks, ranging in composition from andesite to potassic rhyolites. Less voluminous basic rocks (hawaiites) are contemporary to the mildly alkaline rocks but have low initial Sr ratio of 0.70441 as compared to an average of 0.70525 for the latter and indicate derivation of the magmas at different levels in the mantle.*

(viii) *At Mundwara, the igneous activity started around 70 Ma and culminated about 64 Ma ago. The average initial Sr ratio of the complex is 0.70457, suggesting an upper mantle origin of the magma.*

Chapter 5 presents the conclusions arrived at based on the present studies and scope for future work.

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