APPENDIX 4: ^{40}AR/^{39}AR GEOCHRONOLOGY

^{40}Ar/^{39}Ar geochronology was obtained through the New Mexico Geochronological Research Laboratory (NMGRL) at New Mexico Tech, Socorro, New Mexico, (www.ees.nmt.edu/Geol/labs/Argon_Lab/NMGRL_homepage.html). A detailed discussion of the techniques used during this study was compiled by Matthew T. Heizler (NMGRL) and is presented below:

ANALYTICAL METHODS AND RESULTS

One plagioclase and twelve groundmass samples were degassed by the incremental step-heating method using a heating schedule that varied between seven and twelve steps. The five samples irradiated in package NM-172 were heated with a defocused CO_2 laser beam, whereas the seven samples from irradiation package NM-156 were heated within a double vacuum Mo resistance furnace. A synopsis of the analytical methods along with a summary of the age results is provided in Table A4-1 with complete isotopic results given in Table A4-2. More complete information about the general operational procedures of the NMGRL can be found at Internet site http://geoinfo.nmt.edu/publications/openfile/argon/home.html. All of the age spectra and associated isochron diagrams are presented in Figures A4-1 to A4-4. The samples yield apparent ages that range between about 13 and 35 Ma with significantly varying levels of precision that can be linked to age spectrum complexity and K-content. Groundmass age spectra display two basic shapes that are characterized by either overall increasing ages from low to high temperature (Figs. A4-1, A-3a,b) or overall decreasing ages from low to high temperature (Fig. A4-3f,g). Only two samples, MB01-12 and MB01-24, have completely flat spectra with MSWD values that fall within the 95% confidence window for n-1 degrees of freedom (Fig. A4-3d,e). Most age spectra display segments with at least 50% of the total ^{39}Ar released giving acceptable MSWD values, but some samples like MB01-1, MB01-47 and MB00-13 have weighted mean ages that are associated with slightly elevated MSWD values suggestive of scatter than cannot be solely explained by analytical error (Table A4--1). K/Ca spectra are typical of mafic groundmass and have initial steps that begin at about 1 and decrease across the spectra as Ca-bearing phases contribute more to the gas release (Figs. A4-1, A4-3). MB01-12 and MB01-24 have overall lower K/Ca and also much lower K contents compared to the other samples. Radiogenic yields either increase across the entire spectrum or reach a maximum prior to descending at intermediate to high temperatures (Figs. A4-1, A4-3). The plagioclase from MB00-13 has a well-defined (MSWD=1.26) plateau age of 16.45±0.17 Ma for nearly 75% of the total ^{39}Ar released and a fusion step that gives a slightly older apparent age (Fig. A4-3h; Table A4-2). This sample has a flat K/Ca spectrum and a hump-shaped radiogenic yield distribution. All of the samples except MB00-16, MB02-5, and MB01-1 have isochron arrays with acceptable MSWD values for the chosen steps (Figs. A4-2, A4-4; Table A4-1). MB00-16 is characterized by highly scattered isochron data (Fig. A4-2a) and therefore no regression data are provided. MB02-5 displays a slightly elevated MSWD of 2.9 that is likely related to the highly radiogenic nature of this sample that causes the isochron data to cluster near the X-axis (Fig. A4-2c). MB01-1 is essentially a two-point isochron as steps G through H are clustered with step F plotting at only a slightly less radiogenic location (Fig. A4-4a). Most of the isochron ages are indistinguishable from the weighted mean plateau ages except for sample MB00-13 groundmass that has an isochron age (17.25±0.14 Ma) that is older than the plateau age (16.34±0.15 Ma), however this latter sample has an anomalously low ^{40}Ar/^{36}Ar$_i$ value of 272±4 (Fig. A-4g; Table A-2).

DISCUSSION

A preferred eruption age is assigned to each sample except for the highly disturbed sample MB00-16 (Table A4-1). As discussed below, eruption ages are determined from either plateau, isochron or integrated ages depending upon the preferred interpretation of each result. Eruption ages are determined from plateau ages for 8 of the 13 age spectra; however, because overall climbing spectra can be recording the effects of radiogenic argon loss associated with either alteration and/or glass hydration some care should be exercised with some plateau ages. A good example of an age gradient that is probably related to ^{40}Ar* loss is given by MB01-2 (Fig. A4-3b). The substantial age gradient may be indicating that the assigned plateau age is underestimating the true eruption age and perhaps other better-behaved samples can strengthen the interpretation of samples such as these. MB02-43 and

MB02-53 also have climbing spectra but, seem best explained by contamination with excess argon as the isochron arrays for these samples are well-defined and yield $^{40}Ar/^{36}Ar_i$ values that are measurably higher than the atmospheric value of 295.5 (Figs. A4-1d,e, A4-2d,e; Table A4-1). The isochron ages of these two samples are interpreted as eruption ages. The overall decreasing groundmass age spectra (MB01-47, MB00-13; Fig. A4-3f,g) are somewhat difficult to interpret and may be caused by excess argon contamination that is more dominant in the low temperature heating steps and/or ^{39}Ar recoil problems. Typically these spectra types are characterized by highly radiogenic and precise apparent ages and perhaps the best estimate of the eruption age is the integrated age under the assumption that the complexity stems for ^{39}Ar redistribution. This situation would have relative depletion of ^{39}Ar from early gas steps that was implanted into parts of the sample that degas at relatively high temperature steps.

The coexisting plagioclase for groundmass sample MB00-13 provides some insight into the interpretation of the groundmass age spectrum. The plagioclase has a plateau age of 16.45±0.17 Ma that is consistent with the groundmass integrated age and the weighted mean calculated for the final three heating steps (16.64±0.11 Ma; 16.34±0.15 Ma, respectively). The relatively large uncertainty for all of the age assignments for the plagioclase and groundmass do not allow a distinction between the integrated or plateau age of the groundmass; however, the plagioclase does indicate that the isochron age of the groundmass (17.25±0.14 Ma) is not accurate despite the reasonable regression statistics. The isochron for the groundmass is likely affected by ^{39}Ar recoil redistribution because neither the age nor the initial $^{40}Ar/^{36}Ar$ is reliable. Thus, the preferred eruption ages for both of the groundmass samples with steadily decreasing age spectra are the integrated ages (Table A4-1).