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## Supplementary tables

Table S1 Amount of  $^3\text{He}$  gas released during each heating step for the plagioclase step-degassing experiments. All measurements are blank-corrected. Hyphen indicates heating steps below blank level and are treated as a zero gas release step in the forward MDD model inversion.

Table S1A. LABCO-Plag-Da – Ferrar Dolerite plagioclase

| Step | Temperature<br>(°C) | time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 24.4                | 60            | -                                | -     | 0.0000                              |
| 2    | 80.0                | 30            | 0.085                            | 0.017 | 0.0013                              |
| 3    | 90.0                | 30            | 0.147                            | 0.021 | 0.0037                              |
| 4    | 100.0               | 30            | 0.237                            | 0.022 | 0.0074                              |
| 5    | 100.0               | 60            | 0.405                            | 0.028 | 0.0139                              |
| 6    | 100.0               | 120           | 0.821                            | 0.036 | 0.0269                              |
| 7    | 69.9                | 80            | 0.076                            | 0.016 | 0.0281                              |
| 8    | 70.0                | 160           | 0.101                            | 0.018 | 0.0297                              |
| 9    | 70.0                | 240           | 0.143                            | 0.020 | 0.0320                              |
| 10   | 90.0                | 120           | 0.299                            | 0.024 | 0.0367                              |
| 11   | 90.0                | 180           | 0.493                            | 0.027 | 0.0445                              |
| 12   | 100.0               | 180           | 1.002                            | 0.038 | 0.0604                              |
| 13   | 120.0               | 60            | 1.030                            | 0.041 | 0.0768                              |
| 14   | 120.0               | 120           | 1.805                            | 0.052 | 0.1054                              |
| 15   | 120.0               | 180           | 2.386                            | 0.062 | 0.1433                              |
| 16   | 140.0               | 60            | 2.203                            | 0.055 | 0.1782                              |
| 17   | 140.0               | 120           | 3.245                            | 0.071 | 0.2297                              |
| 18   | 140.0               | 180           | 3.801                            | 0.072 | 0.2900                              |
| 19   | 160.0               | 60            | 3.229                            | 0.078 | 0.3413                              |
| 20   | 160.0               | 120           | 4.781                            | 0.089 | 0.4171                              |
| 21   | 160.0               | 180           | 4.462                            | 0.088 | 0.4879                              |
| 22   | 180.0               | 60            | 3.316                            | 0.064 | 0.5405                              |
| 23   | 180.0               | 120           | 4.436                            | 0.090 | 0.6109                              |
| 24   | 180.0               | 180           | 3.728                            | 0.083 | 0.6701                              |
| 25   | 200.0               | 60            | 2.410                            | 0.054 | 0.7083                              |
| 26   | 200.0               | 120           | 2.917                            | 0.065 | 0.7546                              |
| 27   | 200.0               | 180           | 2.496                            | 0.055 | 0.7942                              |
| 28   | 249.9               | 30            | 2.123                            | 0.053 | 0.8279                              |
| 29   | 250.0               | 60            | 2.271                            | 0.060 | 0.8639                              |
| 30   | 299.9               | 30            | 3.139                            | 0.063 | 0.9137                              |
| 31   | 300.0               | 60            | 2.046                            | 0.054 | 0.9462                              |
| 32   | 324.9               | 30            | 1.066                            | 0.039 | 0.9631                              |
| 33   | 325.0               | 60            | 0.906                            | 0.036 | 0.9775                              |
| 34   | 349.9               | 30            | 0.523                            | 0.027 | 0.9858                              |
| 35   | 350.0               | 60            | 0.498                            | 0.033 | 0.9937                              |
| 36   | 335.0               | 60            | 0.130                            | 0.018 | 0.9958                              |
| 37   | 310.0               | 60            | 0.022                            | 0.015 | 0.9961                              |
| 38   | 290.0               | 90            | 0.026                            | 0.013 | 0.9965                              |
| 39   | 360.0               | 60            | 0.086                            | 0.017 | 0.9979                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |       |    |       |       |        |
|----|-------|----|-------|-------|--------|
| 40 | 380.0 | 60 | 0.052 | 0.016 | 0.9987 |
| 41 | 399.9 | 30 | 0.005 | 0.013 | 0.9988 |
| 42 | 399.9 | 60 | 0.039 | 0.014 | 0.9994 |
| 43 | 424.9 | 30 | 0.007 | 0.012 | 0.9995 |
| 44 | 424.9 | 60 | 0.007 | 0.011 | 0.9996 |
| 45 | 449.9 | 30 | 0.022 | 0.013 | 1.0000 |

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Table S1B. LABCO-Plag-Db – Ferrar Dolerite plagioclase

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 24.7                | 60            | -                                | -     | 0.0000                              |
| 2    | 100.0               | 30            | 0.416                            | 0.030 | 0.0039                              |
| 3    | 100.0               | 60            | 0.712                            | 0.041 | 0.0105                              |
| 4    | 100.0               | 120           | 1.279                            | 0.048 | 0.0225                              |
| 5    | 69.9                | 80            | 0.152                            | 0.025 | 0.0239                              |
| 6    | 70.0                | 160           | 0.290                            | 0.028 | 0.0266                              |
| 7    | 70.0                | 240           | 0.292                            | 0.030 | 0.0293                              |
| 8    | 90.0                | 120           | 0.482                            | 0.033 | 0.0338                              |
| 9    | 90.0                | 180           | 0.708                            | 0.039 | 0.0404                              |
| 10   | 100.0               | 180           | 1.276                            | 0.051 | 0.0523                              |
| 11   | 120.0               | 60            | 1.291                            | 0.046 | 0.0644                              |
| 12   | 120.0               | 120           | 2.431                            | 0.068 | 0.0871                              |
| 13   | 120.0               | 180           | 2.875                            | 0.068 | 0.1139                              |
| 14   | 140.0               | 60            | 2.639                            | 0.067 | 0.1385                              |
| 15   | 140.0               | 120           | 4.172                            | 0.088 | 0.1775                              |
| 16   | 140.0               | 180           | 4.698                            | 0.092 | 0.2213                              |
| 17   | 160.0               | 60            | 3.721                            | 0.087 | 0.2560                              |
| 18   | 160.0               | 120           | 5.38                             | 0.11  | 0.3062                              |
| 19   | 160.0               | 180           | 5.89                             | 0.12  | 0.3612                              |
| 20   | 180.0               | 60            | 4.112                            | 0.095 | 0.3996                              |
| 21   | 180.0               | 120           | 6.10                             | 0.13  | 0.4565                              |
| 22   | 180.0               | 180           | 6.45                             | 0.12  | 0.5167                              |
| 23   | 200.0               | 60            | 4.044                            | 0.095 | 0.5544                              |
| 24   | 200.0               | 120           | 6.08                             | 0.12  | 0.6112                              |
| 25   | 200.0               | 180           | 6.66                             | 0.13  | 0.6733                              |
| 26   | 249.9               | 30            | 14.52                            | 0.23  | 0.8088                              |
| 27   | 250.0               | 60            | 4.051                            | 0.092 | 0.8466                              |
| 28   | 299.9               | 30            | 6.57                             | 0.12  | 0.9080                              |
| 29   | 300.0               | 60            | 4.193                            | 0.089 | 0.9471                              |
| 30   | 324.9               | 30            | 1.908                            | 0.061 | 0.9649                              |
| 31   | 325.0               | 60            | 1.609                            | 0.053 | 0.9799                              |
| 32   | 349.9               | 30            | 0.639                            | 0.037 | 0.9859                              |
| 33   | 350.0               | 60            | 0.567                            | 0.037 | 0.9912                              |
| 34   | 335.0               | 60            | 0.153                            | 0.027 | 0.9926                              |
| 35   | 310.0               | 60            | 0.051                            | 0.022 | 0.9931                              |
| 36   | 290.0               | 90            | 0.037                            | 0.022 | 0.9934                              |
| 37   | 250.0               | 90            | 0.007                            | 0.022 | 0.9935                              |
| 38   | 250.0               | 120           | 0.016                            | 0.022 | 0.9936                              |
| 39   | 215.0               | 180           | -                                | -     | 0.9936                              |
| 40   | 265.0               | 120           | 0.020                            | 0.021 | 0.9938                              |
| 41   | 285.0               | 90            | 0.028                            | 0.022 | 0.9941                              |
| 42   | 300.0               | 60            | 0.045                            | 0.022 | 0.9945                              |
| 43   | 330.0               | 60            | 0.070                            | 0.023 | 0.9951                              |
| 44   | 360.0               | 60            | 0.149                            | 0.025 | 0.9965                              |
| 45   | 380.0               | 60            | 0.131                            | 0.027 | 0.9977                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |        |    |       |       |        |
|----|--------|----|-------|-------|--------|
| 46 | 399.94 | 60 | 0.145 | 0.026 | 0.9991 |
| 47 | 424.95 | 60 | 0.097 | 0.024 | 1.0000 |

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Table S1C. ROB-Plag-Da – Ferrar Dolerite plagioclase

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 28.1                | 30            | 1.070                            | 0.044 | 0.0039                              |
| 2    | 100.0               | 20            | 63.64                            | 0.82  | 0.2346                              |
| 3    | 100.0               | 30            | 43.98                            | 0.58  | 0.3940                              |
| 4    | 70.0                | 30            | 4.63                             | 0.10  | 0.4108                              |
| 5    | 70.0                | 60            | 7.80                             | 0.14  | 0.4390                              |
| 6    | 70.0                | 90            | 9.72                             | 0.16  | 0.4743                              |
| 7    | 90.0                | 30            | 9.89                             | 0.16  | 0.5101                              |
| 8    | 90.0                | 60            | 15.06                            | 0.24  | 0.5647                              |
| 9    | 100.0               | 30            | 10.08                            | 0.17  | 0.6013                              |
| 10   | 120.0               | 10            | 8.22                             | 0.14  | 0.6311                              |
| 11   | 120.0               | 20            | 11.69                            | 0.19  | 0.6734                              |
| 12   | 120.0               | 30            | 10.95                            | 0.18  | 0.7131                              |
| 13   | 140.0               | 10            | 6.47                             | 0.12  | 0.7366                              |
| 14   | 140.0               | 20            | 8.07                             | 0.14  | 0.7658                              |
| 15   | 140.0               | 30            | 7.42                             | 0.13  | 0.7928                              |
| 16   | 159.9               | 10            | 3.968                            | 0.083 | 0.8071                              |
| 17   | 160.0               | 20            | 5.27                             | 0.10  | 0.8262                              |
| 18   | 160.0               | 30            | 5.372                            | 0.098 | 0.8457                              |
| 19   | 179.8               | 6             | 2.041                            | 0.059 | 0.8531                              |
| 20   | 179.9               | 10            | 2.706                            | 0.065 | 0.8629                              |
| 21   | 179.9               | 20            | 3.954                            | 0.085 | 0.8772                              |
| 22   | 199.9               | 10            | 3.361                            | 0.073 | 0.8894                              |
| 23   | 200.0               | 25            | 5.21                             | 0.10  | 0.9083                              |
| 24   | 249.8               | 10            | 6.03                             | 0.12  | 0.9302                              |
| 25   | 249.9               | 15            | 4.127                            | 0.089 | 0.9451                              |
| 26   | 279.8               | 10            | 4.960                            | 0.096 | 0.9631                              |
| 27   | 279.9               | 20            | 3.120                            | 0.070 | 0.9744                              |
| 28   | 260.0               | 30            | 1.277                            | 0.043 | 0.9790                              |
| 29   | 190.0               | 45            | 0.137                            | 0.017 | 0.9795                              |
| 30   | 170.0               | 60            | 0.089                            | 0.014 | 0.9799                              |
| 31   | 150.0               | 90            | 0.065                            | 0.014 | 0.9801                              |
| 32   | 200.0               | 60            | 0.248                            | 0.018 | 0.9810                              |
| 33   | 240.0               | 60            | 0.672                            | 0.033 | 0.9834                              |
| 34   | 299.9               | 30            | 1.376                            | 0.045 | 0.9884                              |
| 35   | 300.0               | 60            | 1.189                            | 0.041 | 0.9927                              |
| 36   | 324.9               | 30            | 0.590                            | 0.026 | 0.9949                              |
| 37   | 325.0               | 60            | 0.482                            | 0.028 | 0.9966                              |
| 38   | 349.9               | 30            | 0.234                            | 0.020 | 0.9975                              |
| 39   | 350.0               | 60            | 0.167                            | 0.020 | 0.9981                              |
| 40   | 325.0               | 60            | 0.069                            | 0.013 | 0.9983                              |
| 41   | 374.9               | 30            | 0.112                            | 0.015 | 0.9987                              |
| 42   | 375.0               | 60            | 0.120                            | 0.014 | 0.9992                              |
| 43   | 399.9               | 40            | 0.100                            | 0.023 | 0.9995                              |
| 44   | 400.0               | 60            | 0.073                            | 0.013 | 0.9998                              |
| 45   | 424.9               | 30            | -                                | -     | 0.9998                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |       |    |       |       |        |
|----|-------|----|-------|-------|--------|
| 46 | 424.9 | 30 | 0.022 | 0.010 | 0.9999 |
| 47 | 449.9 | 30 | 0.018 | 0.011 | 0.9999 |
| 48 | 499.9 | 30 | 0.017 | 0.012 | 1.0000 |

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Table S1D. ROB-Plag-Db – Ferrar Dolerite plagioclase

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 23.9                | 30            | 0.365                            | 0.024 | 0.0022                              |
| 2    | 59.7                | 30            | 9.65                             | 0.16  | 0.0612                              |
| 3    | 59.8                | 60            | 15.26                            | 0.24  | 0.1545                              |
| 4    | 75.0                | 30            | 20.12                            | 0.31  | 0.2774                              |
| 5    | 75.0                | 60            | 26.42                            | 0.39  | 0.4389                              |
| 6    | 90.0                | 30            | 23.37                            | 0.34  | 0.5817                              |
| 7    | 90.0                | 60            | 23.88                            | 0.35  | 0.7277                              |
| 8    | 24.0                | 30            | 0.064                            | 0.014 | 0.7281                              |
| 9    | 100.0               | 15            | 6.57                             | 0.13  | 0.7682                              |
| 10   | 100.0               | 30            | 7.80                             | 0.13  | 0.8159                              |
| 11   | 120.0               | 10            | 4.88                             | 0.10  | 0.8457                              |
| 12   | 120.0               | 20            | 4.528                            | 0.099 | 0.8734                              |
| 13   | 120.0               | 30            | 3.044                            | 0.068 | 0.8920                              |
| 14   | 140.0               | 10            | 1.778                            | 0.049 | 0.9029                              |
| 15   | 140.0               | 20            | 2.075                            | 0.062 | 0.9155                              |
| 16   | 140.0               | 30            | 2.001                            | 0.054 | 0.9278                              |
| 17   | 160.0               | 10            | 1.095                            | 0.040 | 0.9345                              |
| 18   | 160.0               | 20            | 1.527                            | 0.044 | 0.9438                              |
| 19   | 160.0               | 30            | 1.476                            | 0.049 | 0.9528                              |
| 20   | 179.9               | 6             | 0.508                            | 0.026 | 0.9559                              |
| 21   | 179.9               | 10            | 0.678                            | 0.031 | 0.9601                              |
| 22   | 180.0               | 20            | 0.930                            | 0.044 | 0.9658                              |
| 23   | 199.8               | 10            | 0.644                            | 0.034 | 0.9697                              |
| 24   | 200.0               | 25            | 1.061                            | 0.040 | 0.9762                              |
| 25   | 249.8               | 10            | 1.171                            | 0.041 | 0.9833                              |
| 26   | 249.9               | 15            | 0.664                            | 0.031 | 0.9874                              |
| 27   | 279.8               | 10            | 0.530                            | 0.026 | 0.9906                              |
| 28   | 279.9               | 20            | 0.394                            | 0.022 | 0.9930                              |
| 29   | 259.9               | 30            | 0.160                            | 0.017 | 0.9940                              |
| 30   | 190.0               | 45            | 0.040                            | 0.012 | 0.9943                              |
| 31   | 170.0               | 60            | 0.021                            | 0.011 | 0.9944                              |
| 32   | 150.0               | 90            | 0.025                            | 0.011 | 0.9945                              |
| 33   | 200.0               | 60            | 0.048                            | 0.013 | 0.9948                              |
| 34   | 240.0               | 60            | 0.096                            | 0.015 | 0.9954                              |
| 35   | 299.9               | 30            | 0.132                            | 0.017 | 0.9962                              |
| 36   | 300.0               | 60            | 0.098                            | 0.016 | 0.9968                              |
| 37   | 324.9               | 30            | 0.030                            | 0.012 | 0.9970                              |
| 38   | 325.0               | 60            | 0.036                            | 0.012 | 0.9972                              |
| 39   | 349.9               | 30            | 0.020                            | 0.012 | 0.9973                              |
| 40   | 350.0               | 60            | 0.022                            | 0.012 | 0.9975                              |
| 41   | 325.0               | 60            | 0.021                            | 0.011 | 0.9976                              |
| 42   | 300.0               | 60            | 0.009                            | 0.011 | 0.9977                              |
| 43   | 275.0               | 52            | 0.001                            | 0.010 | 0.9977                              |
| 44   | 250.0               | 90            | 0.013                            | 0.012 | 0.9978                              |
| 45   | 200.0               | 120           | 0.016                            | 0.011 | 0.9978                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |       |    |       |       |        |
|----|-------|----|-------|-------|--------|
| 46 | 269.8 | 60 | 0.005 | 0.011 | 0.9979 |
| 47 | 300.0 | 60 | 0.007 | 0.010 | 0.9979 |
| 48 | 374.9 | 30 | 0.022 | 0.012 | 0.9981 |
| 49 | 375.0 | 60 | 0.034 | 0.011 | 0.9983 |
| 50 | 399.9 | 40 | 0.016 | 0.011 | 0.9984 |
| 51 | 400.0 | 60 | -     | -     | 0.9984 |
| 52 | 424.9 | 30 | 0.013 | 0.010 | 0.9984 |
| 53 | 424.9 | 30 | -     | -     | 0.9984 |
| 54 | 449.9 | 30 | 0.244 | 0.019 | 0.9999 |
| 55 | 499.9 | 30 | 0.012 | 0.012 | 1.0000 |

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Table S1E. FCs-Kspar-Da – Fish Canyon Tuff sanidine

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$  | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|--------|-------------------------------------|
| 1    | 24.7                | 60            | 0.0064                           | 0.0081 | 0.0006                              |
| 2    | 100.0               | 30            | 0.147                            | 0.015  | 0.0140                              |
| 3    | 100.0               | 60            | 0.269                            | 0.021  | 0.0385                              |
| 4    | 100.0               | 120           | 0.414                            | 0.029  | 0.0761                              |
| 5    | 70.0                | 80            | 0.071                            | 0.011  | 0.0826                              |
| 6    | 70.0                | 160           | 0.078                            | 0.016  | 0.0897                              |
| 7    | 70.0                | 240           | 0.135                            | 0.016  | 0.1020                              |
| 8    | 90.0                | 120           | 0.204                            | 0.020  | 0.1205                              |
| 9    | 100.0               | 180           | 0.433                            | 0.050  | 0.1600                              |
| 10   | 120.0               | 60            | 0.67                             | 0.12   | 0.2211                              |
| 11   | 120.0               | 120           | 0.680                            | 0.039  | 0.2829                              |
| 12   | 120.0               | 180           | 0.886                            | 0.044  | 0.3635                              |
| 13   | 139.9               | 60            | 0.756                            | 0.042  | 0.4322                              |
| 14   | 140.0               | 120           | 0.986                            | 0.047  | 0.5219                              |
| 15   | 140.0               | 180           | 1.008                            | 0.047  | 0.6136                              |
| 16   | 160.0               | 60            | 0.442                            | 0.033  | 0.6538                              |
| 17   | 160.0               | 120           | 0.551                            | 0.032  | 0.7039                              |
| 18   | 160.0               | 180           | 0.422                            | 0.029  | 0.7423                              |
| 19   | 180.0               | 60            | 0.211                            | 0.023  | 0.7615                              |
| 20   | 180.0               | 120           | 0.323                            | 0.029  | 0.7908                              |
| 21   | 180.0               | 180           | 0.263                            | 0.023  | 0.8148                              |
| 22   | 199.9               | 60            | 0.195                            | 0.035  | 0.8325                              |
| 23   | 200.0               | 120           | 0.273                            | 0.022  | 0.8573                              |
| 24   | 200.0               | 180           | 0.290                            | 0.024  | 0.8837                              |
| 25   | 249.8               | 30            | 0.223                            | 0.021  | 0.9040                              |
| 26   | 249.9               | 60            | 0.396                            | 0.025  | 0.9400                              |
| 27   | 299.9               | 30            | 0.338                            | 0.024  | 0.9707                              |
| 28   | 300.0               | 60            | 0.230                            | 0.019  | 0.9916                              |
| 29   | 324.9               | 30            | 0.040                            | 0.012  | 0.9953                              |
| 30   | 325.0               | 60            | 0.0068                           | 0.0093 | 0.9959                              |
| 31   | 349.9               | 30            | -                                | -      | 0.9959                              |
| 32   | 350.0               | 60            | -                                | -      | 0.9959                              |
| 33   | 335.0               | 60            | -                                | -      | 0.9959                              |
| 34   | 310.0               | 60            | 0.0027                           | 0.0077 | 0.9961                              |
| 35   | 290.0               | 90            | 0.012                            | 0.012  | 0.9972                              |
| 36   | 250.0               | 90            | 0.0036                           | 0.0077 | 0.9976                              |
| 37   | 250.0               | 120           | 0.0021                           | 0.0085 | 0.9978                              |
| 38   | 215.0               | 180           | 0.025                            | 0.011  | 1.0000                              |
| 39   | 265.0               | 120           | -                                | -      | 1.0000                              |

Table S1F. ML-Plag-Da – Mono Lake oligoclase

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 100.1               | 30            | 5.48                             | 0.32  | 0.0193                              |
| 2    | 100.0               | 60            | 8.66                             | 0.50  | 0.0498                              |
| 3    | 100.0               | 120           | 14.18                            | 0.81  | 0.0998                              |
| 4    | 70.0                | 80            | 1.330                            | 0.086 | 0.1045                              |
| 5    | 70.0                | 160           | 2.56                             | 0.16  | 0.1135                              |
| 6    | 70.0                | 240           | 2.37                             | 0.15  | 0.1218                              |
| 7    | 90.0                | 120           | 6.65                             | 0.38  | 0.1453                              |
| 8    | 90.0                | 180           | 7.99                             | 0.46  | 0.1734                              |
| 9    | 100.0               | 180           | 8.48                             | 0.49  | 0.2033                              |
| 10   | 120.0               | 60            | 12.58                            | 0.72  | 0.2476                              |
| 11   | 120.0               | 120           | 13.53                            | 0.77  | 0.2952                              |
| 12   | 120.0               | 180           | 17.9                             | 1.0   | 0.3583                              |
| 13   | 140.0               | 60            | 14.77                            | 0.84  | 0.4104                              |
| 14   | 140.0               | 120           | 24.0                             | 1.4   | 0.4948                              |
| 15   | 140.0               | 180           | 39.9                             | 2.3   | 0.6353                              |
| 16   | 160.0               | 60            | 22.1                             | 1.3   | 0.7133                              |
| 17   | 160.0               | 120           | 18.2                             | 1.0   | 0.7776                              |
| 18   | 160.0               | 180           | 17.18                            | 0.98  | 0.8381                              |
| 19   | 180.0               | 60            | 7.50                             | 0.43  | 0.8645                              |
| 20   | 180.0               | 120           | 9.85                             | 0.56  | 0.8992                              |
| 21   | 180.0               | 180           | 8.59                             | 0.49  | 0.9295                              |
| 22   | 200.0               | 60            | 4.65                             | 0.30  | 0.9459                              |
| 23   | 199.9               | 120           | 3.83                             | 0.22  | 0.9594                              |
| 24   | 200.0               | 180           | 3.53                             | 0.21  | 0.9718                              |
| 25   | 249.9               | 30            | 1.323                            | 0.086 | 0.9765                              |
| 26   | 250.0               | 60            | 1.87                             | 0.11  | 0.9831                              |
| 27   | 299.9               | 30            | 1.61                             | 0.10  | 0.9887                              |
| 28   | 300.0               | 60            | 1.430                            | 0.088 | 0.9938                              |
| 29   | 324.9               | 30            | 0.786                            | 0.056 | 0.9966                              |
| 30   | 325.0               | 60            | 0.230                            | 0.024 | 0.9974                              |
| 31   | 349.9               | 30            | 0.063                            | 0.016 | 0.9976                              |
| 32   | 350.0               | 60            | 0.027                            | 0.015 | 0.9977                              |
| 33   | 335.0               | 60            | 0.025                            | 0.014 | 0.9978                              |
| 34   | 310.0               | 60            | 0.028                            | 0.014 | 0.9979                              |
| 35   | 290.0               | 90            | 0.037                            | 0.014 | 0.9980                              |
| 36   | 250.0               | 90            | 0.027                            | 0.014 | 0.9981                              |
| 37   | 249.9               | 120           | 0.047                            | 0.015 | 0.9983                              |
| 38   | 215.0               | 180           | 0.237                            | 0.027 | 0.9991                              |
| 39   | 265.0               | 120           | 0.043                            | 0.014 | 0.9992                              |
| 40   | 285.0               | 90            | 0.036                            | 0.016 | 0.9994                              |
| 41   | 300.0               | 60            | 0.022                            | 0.013 | 0.9995                              |
| 42   | 330.0               | 60            | 0.019                            | 0.013 | 0.9995                              |
| 43   | 360.0               | 60            | 0.036                            | 0.015 | 0.9996                              |
| 44   | 380.0               | 60            | 0.036                            | 0.015 | 0.9998                              |
| 45   | 399.7               | 60            | 0.021                            | 0.014 | 0.9998                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |       |    |       |       |        |
|----|-------|----|-------|-------|--------|
| 46 | 425.0 | 60 | 0.033 | 0.014 | 1.0000 |
| 47 | 599.7 | 15 | 0.012 | 0.013 | 1.0000 |

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Table S1G. SURTp-Plag-Da – Surtsey labradorite

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$  | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|--------|-------------------------------------|
| 1    | 24.5                | 60            | 0.067                            | 0.012  | 0.0001                              |
| 2    | 100.2               | 30            | 144.9                            | 1.3    | 0.1140                              |
| 3    | 100.1               | 60            | 179.5                            | 1.6    | 0.2553                              |
| 4    | 100.0               | 120           | 28.07                            | 0.29   | 0.2773                              |
| 5    | 70.0                | 80            | 2.527                            | 0.061  | 0.2793                              |
| 6    | 70.0                | 160           | 9.31                             | 0.14   | 0.2867                              |
| 7    | 70.0                | 240           | 62.94                            | 0.62   | 0.3362                              |
| 8    | 90.0                | 120           | 18.98                            | 0.22   | 0.3511                              |
| 9    | 90.0                | 180           | 169.7                            | 1.5    | 0.4846                              |
| 10   | 120.1               | 60            | 60.12                            | 0.56   | 0.5319                              |
| 11   | 120.0               | 120           | 449.8                            | 3.9    | 0.8858                              |
| 12   | 140.1               | 60            | 73.60                            | 0.68   | 0.9437                              |
| 13   | 140.0               | 120           | 63.33                            | 0.59   | 0.9935                              |
| 14   | 160.0               | 60            | 2.073                            | 0.054  | 0.9951                              |
| 15   | 160.0               | 120           | 3.790                            | 0.081  | 0.9981                              |
| 16   | 180.0               | 60            | 1.704                            | 0.049  | 0.9995                              |
| 17   | 180.0               | 120           | 0.068                            | 0.012  | 0.9995                              |
| 18   | 200.0               | 60            | 0.050                            | 0.013  | 0.9996                              |
| 19   | 200.0               | 120           | 0.040                            | 0.010  | 0.9996                              |
| 20   | 200.0               | 180           | 0.050                            | 0.012  | 0.9996                              |
| 21   | 249.9               | 30            | 0.004                            | 0.010  | 0.9996                              |
| 22   | 249.9               | 60            | 0.0164                           | 0.0092 | 0.9996                              |
| 23   | 299.7               | 30            | 0.008                            | 0.010  | 0.9996                              |
| 24   | 299.9               | 60            | 0.016                            | 0.010  | 0.9997                              |
| 25   | 324.7               | 30            | 0.039                            | 0.012  | 0.9997                              |
| 26   | 324.8               | 60            | 0.0062                           | 0.0088 | 0.9997                              |
| 27   | 349.6               | 30            | -                                | -      | 0.9997                              |
| 28   | 350.0               | 60            | 0.023                            | 0.010  | 0.9997                              |
| 29   | 334.7               | 60            | 0.0035                           | 0.0088 | 0.9997                              |
| 30   | 309.9               | 60            | 0.0039                           | 0.0094 | 0.9997                              |
| 31   | 290.0               | 90            | 0.015                            | 0.010  | 0.9997                              |
| 32   | 250.0               | 90            | 0.023                            | 0.010  | 0.9998                              |
| 33   | 250.0               | 120           | 0.026                            | 0.010  | 0.9998                              |
| 34   | 215.0               | 180           | 0.097                            | 0.014  | 0.9998                              |
| 35   | 265.0               | 120           | 0.054                            | 0.010  | 0.9999                              |
| 36   | 284.9               | 90            | 0.023                            | 0.011  | 0.9999                              |
| 37   | 300.0               | 60            | 0.013                            | 0.010  | 0.9999                              |
| 38   | 330.0               | 60            | 0.019                            | 0.010  | 0.9999                              |
| 39   | 359.8               | 60            | 0.020                            | 0.010  | 1.0000                              |
| 40   | 380.0               | 60            | 0.022                            | 0.010  | 1.0000                              |
| 41   | 399.9               | 60            | 0.0173                           | 0.0084 | 1.0000                              |
| 42   | 425.0               | 60            | 0.022                            | 0.010  | 1.0000                              |

Table S1H. SW-1-Plag-Da – Stillwater Complex bytownite

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 24.6                | 60            | -                                | -     | 0.0000                              |
| 2    | 100.0               | 30            | 0.459                            | 0.037 | 0.0024                              |
| 3    | 100.0               | 60            | 0.874                            | 0.044 | 0.0070                              |
| 4    | 100.0               | 120           | 1.611                            | 0.059 | 0.0154                              |
| 5    | 70.1                | 80            | 0.215                            | 0.034 | 0.0166                              |
| 6    | 70.0                | 160           | 0.281                            | 0.035 | 0.0180                              |
| 7    | 70.0                | 240           | 0.371                            | 0.038 | 0.0200                              |
| 8    | 90.0                | 120           | 0.653                            | 0.042 | 0.0234                              |
| 9    | 90.0                | 180           | 1.083                            | 0.047 | 0.0291                              |
| 10   | 120.0               | 60            | 1.957                            | 0.063 | 0.0394                              |
| 11   | 120.0               | 120           | 3.517                            | 0.083 | 0.0578                              |
| 12   | 140.0               | 60            | 4.44                             | 0.10  | 0.0811                              |
| 13   | 140.0               | 120           | 6.97                             | 0.14  | 0.1177                              |
| 14   | 160.0               | 60            | 6.83                             | 0.14  | 0.1535                              |
| 15   | 160.0               | 120           | 10.11                            | 0.18  | 0.2065                              |
| 16   | 180.0               | 60            | 8.54                             | 0.15  | 0.2514                              |
| 17   | 180.0               | 120           | 12.48                            | 0.22  | 0.3169                              |
| 18   | 200.0               | 60            | 9.41                             | 0.18  | 0.3662                              |
| 19   | 200.0               | 120           | 13.41                            | 0.23  | 0.4366                              |
| 20   | 200.0               | 180           | 14.07                            | 0.24  | 0.5104                              |
| 21   | 249.9               | 30            | 8.85                             | 0.16  | 0.5568                              |
| 22   | 250.0               | 60            | 13.47                            | 0.23  | 0.6275                              |
| 23   | 299.9               | 30            | 17.93                            | 0.29  | 0.7216                              |
| 24   | 299.7               | 60            | 19.50                            | 0.31  | 0.8239                              |
| 25   | 324.9               | 30            | 10.11                            | 0.19  | 0.8769                              |
| 26   | 325.0               | 60            | 10.99                            | 0.21  | 0.9345                              |
| 27   | 349.9               | 30            | 4.92                             | 0.11  | 0.9603                              |
| 28   | 350.0               | 60            | 4.54                             | 0.10  | 0.9841                              |
| 29   | 335.0               | 60            | 1.302                            | 0.057 | 0.9910                              |
| 30   | 310.0               | 60            | 0.430                            | 0.037 | 0.9932                              |
| 31   | 290.0               | 90            | 0.267                            | 0.034 | 0.9946                              |
| 32   | 250.0               | 90            | 0.069                            | 0.030 | 0.9950                              |
| 33   | 250.0               | 120           | 0.089                            | 0.030 | 0.9954                              |
| 34   | 215.0               | 180           | 0.042                            | 0.030 | 0.9957                              |
| 35   | 265.0               | 120           | 0.100                            | 0.030 | 0.9962                              |
| 36   | 285.0               | 90            | 0.120                            | 0.031 | 0.9968                              |
| 37   | 300.0               | 60            | 0.101                            | 0.030 | 0.9973                              |
| 38   | 330.0               | 60            | 0.198                            | 0.031 | 0.9984                              |
| 39   | 360.0               | 60            | 0.175                            | 0.032 | 0.9993                              |
| 40   | 380.0               | 60            | 0.095                            | 0.030 | 0.9998                              |
| 41   | 400.0               | 60            | 0.038                            | 0.029 | 1.0000                              |

Table S2 Amount of  $^3\text{He}$  gas released during each heating step for pyroxene step-degassing experiments. All measurements are blank-corrected. Hyphen indicates heating steps below blank level and are treated as a zero-gas release step in the forward MDD model inversion.

Table S2A. LABCO-Px-Db – Ferrar Dolerite pyroxene

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 24.1                | 20            | 0.017                            | 0.011 | 0.0001                              |
| 2    | 199.9               | 20            | 5.11                             | 0.11  | 0.0181                              |
| 3    | 249.7               | 10            | 2.203                            | 0.067 | 0.0259                              |
| 4    | 249.9               | 30            | 1.626                            | 0.056 | 0.0316                              |
| 5    | 299.7               | 10            | 2.598                            | 0.068 | 0.0408                              |
| 6    | 299.9               | 30            | 4.360                            | 0.098 | 0.0562                              |
| 7    | 349.8               | 15            | 13.17                            | 0.23  | 0.1027                              |
| 8    | 374.8               | 15            | 23.83                            | 0.39  | 0.1869                              |
| 9    | 399.4               | 6             | 17.36                            | 0.29  | 0.2482                              |
| 10   | 399.7               | 10            | 21.51                            | 0.36  | 0.3242                              |
| 11   | 399.8               | 15            | 20.22                            | 0.34  | 0.3956                              |
| 12   | 449.8               | 15            | 48.33                            | 0.76  | 0.5663                              |
| 13   | 474.8               | 15            | 32.08                            | 0.51  | 0.6797                              |
| 14   | 499.4               | 6             | 11.56                            | 0.21  | 0.7205                              |
| 15   | 499.6               | 10            | 11.02                            | 0.20  | 0.7594                              |
| 16   | 524.3               | 6             | 6.85                             | 0.13  | 0.7836                              |
| 17   | 524.6               | 10            | 6.96                             | 0.14  | 0.8082                              |
| 18   | 549.3               | 6             | 4.68                             | 0.10  | 0.8247                              |
| 19   | 574.3               | 6             | 5.07                             | 0.11  | 0.8426                              |
| 20   | 574.6               | 10            | 4.97                             | 0.11  | 0.8602                              |
| 21   | 574.8               | 20            | 5.32                             | 0.12  | 0.8790                              |
| 22   | 624.2               | 6             | 3.089                            | 0.074 | 0.8899                              |
| 23   | 639.2               | 6             | 2.990                            | 0.079 | 0.9005                              |
| 24   | 599.9               | 30            | 3.686                            | 0.083 | 0.9135                              |
| 25   | 599.8               | 30            | 2.325                            | 0.064 | 0.9217                              |
| 26   | 599.9               | 30            | 1.714                            | 0.056 | 0.9277                              |
| 27   | 499.9               | 60            | 0.315                            | 0.025 | 0.9289                              |
| 28   | 400.0               | 120           | 0.099                            | 0.018 | 0.9292                              |
| 29   | 400.0               | 180           | 0.088                            | 0.018 | 0.9295                              |
| 30   | 300.0               | 240           | 0.039                            | 0.013 | 0.9297                              |
| 31   | 649.9               | 60            | 5.74                             | 0.12  | 0.9499                              |
| 32   | 699.7               | 15            | 2.493                            | 0.068 | 0.9587                              |
| 33   | 699.9               | 30            | 2.649                            | 0.075 | 0.9681                              |
| 34   | 749.6               | 15            | 2.060                            | 0.057 | 0.9754                              |
| 35   | 749.6               | 15            | 1.064                            | 0.040 | 0.9791                              |
| 36   | 849.4               | 6             | 1.733                            | 0.050 | 0.9853                              |
| 37   | 874.2               | 6             | 1.000                            | 0.040 | 0.9888                              |
| 38   | 849.1               | 6             | 0.296                            | 0.025 | 0.9898                              |
| 39   | 824.0               | 6             | 0.173                            | 0.018 | 0.9904                              |
| 40   | 774.8               | 30            | 0.185                            | 0.021 | 0.9911                              |
| 41   | 600.0               | 120           | 0.019                            | 0.012 | 0.9912                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |       |     |       |       |        |
|----|-------|-----|-------|-------|--------|
| 42 | 849.6 | 15  | 0.347 | 0.025 | 0.9924 |
| 43 | 899.6 | 15  | 0.532 | 0.030 | 0.9943 |
| 44 | 899.8 | 30  | 0.537 | 0.028 | 0.9962 |
| 45 | 874.0 | 6   | 0.041 | 0.013 | 0.9963 |
| 46 | 874.8 | 30  | 0.169 | 0.018 | 0.9969 |
| 47 | 844.8 | 30  | 0.073 | 0.016 | 0.9972 |
| 48 | 799.6 | 15  | 0.010 | 0.013 | 0.9972 |
| 49 | 749.6 | 15  | -     | -     | 0.9972 |
| 50 | 699.8 | 30  | -     | -     | 0.9972 |
| 51 | 600.0 | 180 | 0.020 | 0.012 | 0.9973 |
| 52 | 699.8 | 30  | -     | -     | 0.9973 |
| 53 | 774.6 | 15  | -     | -     | 0.9973 |
| 54 | 874.7 | 15  | 0.064 | 0.014 | 0.9975 |
| 55 | 899.6 | 15  | 0.090 | 0.015 | 0.9978 |
| 56 | 899.6 | 15  | 0.059 | 0.015 | 0.9980 |
| 57 | 899.6 | 15  | 0.061 | 0.015 | 0.9982 |
| 58 | 949.6 | 15  | 0.158 | 0.017 | 0.9988 |
| 59 | 999.0 | 6   | 0.176 | 0.018 | 0.9994 |
| 60 | 999.6 | 15  | 0.164 | 0.019 | 1.0000 |

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Table S2B. LABCO-Px-Da – Ferrar Dolerite pyroxene

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 24.6                | 60            | 0.036                            | 0.013 | 0.0001                              |
| 2    | 125.0               | 30            | 0.240                            | 0.023 | 0.0004                              |
| 3    | 150.0               | 30            | 0.626                            | 0.030 | 0.0014                              |
| 4    | 175.0               | 30            | 0.829                            | 0.036 | 0.0026                              |
| 5    | 175.0               | 60            | 0.660                            | 0.035 | 0.0036                              |
| 6    | 175.0               | 120           | 0.543                            | 0.032 | 0.0044                              |
| 7    | 199.9               | 30            | 0.509                            | 0.028 | 0.0052                              |
| 8    | 199.9               | 30            | 0.317                            | 0.023 | 0.0057                              |
| 9    | 224.8               | 15            | 0.549                            | 0.029 | 0.0065                              |
| 10   | 224.9               | 30            | 0.646                            | 0.031 | 0.0075                              |
| 11   | 249.8               | 15            | 0.849                            | 0.037 | 0.0087                              |
| 12   | 249.9               | 30            | 0.809                            | 0.037 | 0.0100                              |
| 13   | 249.9               | 30            | 0.472                            | 0.027 | 0.0107                              |
| 14   | 274.9               | 15            | 0.792                            | 0.036 | 0.0119                              |
| 15   | 274.6               | 30            | 0.817                            | 0.039 | 0.0131                              |
| 16   | 299.8               | 15            | 1.027                            | 0.041 | 0.0146                              |
| 17   | 299.9               | 30            | 1.198                            | 0.046 | 0.0164                              |
| 18   | 324.9               | 20            | 2.132                            | 0.057 | 0.0197                              |
| 19   | 349.8               | 15            | 3.661                            | 0.077 | 0.0252                              |
| 20   | 349.9               | 30            | 4.170                            | 0.083 | 0.0315                              |
| 21   | 374.4               | 6             | 2.238                            | 0.065 | 0.0348                              |
| 22   | 374.8               | 15            | 4.424                            | 0.090 | 0.0415                              |
| 23   | 399.5               | 6             | 4.575                            | 0.088 | 0.0484                              |
| 24   | 399.8               | 15            | 8.31                             | 0.14  | 0.0609                              |
| 25   | 424.8               | 15            | 13.71                            | 0.19  | 0.0815                              |
| 26   | 424.9               | 30            | 14.53                            | 0.20  | 0.1034                              |
| 27   | 449.8               | 15            | 12.64                            | 0.19  | 0.1225                              |
| 28   | 449.9               | 30            | 15.87                            | 0.21  | 0.1464                              |
| 29   | 474.8               | 15            | 14.07                            | 0.21  | 0.1675                              |
| 30   | 474.9               | 30            | 18.82                            | 0.24  | 0.1959                              |
| 31   | 499.4               | 6             | 8.32                             | 0.14  | 0.2084                              |
| 32   | 499.6               | 10            | 10.49                            | 0.15  | 0.2242                              |
| 33   | 529.7               | 15            | 29.68                            | 0.53  | 0.2689                              |
| 34   | 559.7               | 15            | 45.79                            | 0.54  | 0.3379                              |
| 35   | 599.7               | 15            | 73.00                            | 0.81  | 0.4478                              |
| 36   | 629.8               | 20            | 82.43                            | 0.93  | 0.5719                              |
| 37   | 669.7               | 20            | 68.90                            | 0.77  | 0.6757                              |
| 38   | 699.8               | 20            | 36.15                            | 0.43  | 0.7302                              |
| 39   | 749.8               | 30            | 30.43                            | 0.38  | 0.7760                              |
| 40   | 774.8               | 30            | 8.60                             | 0.14  | 0.7889                              |
| 41   | 799.5               | 15            | 4.775                            | 0.095 | 0.7961                              |
| 42   | 829.5               | 15            | 7.01                             | 0.13  | 0.8067                              |
| 43   | 869.5               | 15            | 10.10                            | 0.17  | 0.8219                              |
| 44   | 899.4               | 15            | 10.04                            | 0.15  | 0.8370                              |
| 45   | 649.9               | 60            | 0.254                            | 0.023 | 0.8374                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |        |     |       |       |        |
|----|--------|-----|-------|-------|--------|
| 46 | 350.0  | 180 | 0.026 | 0.014 | 0.8374 |
| 47 | 500.0  | 120 | 0.047 | 0.014 | 0.8375 |
| 48 | 600.0  | 120 | 0.049 | 0.013 | 0.8376 |
| 49 | 699.8  | 30  | 0.127 | 0.019 | 0.8378 |
| 50 | 749.6  | 15  | 0.237 | 0.021 | 0.8381 |
| 51 | 849.5  | 15  | 2.244 | 0.059 | 0.8415 |
| 52 | 899.4  | 15  | 5.62  | 0.11  | 0.8500 |
| 53 | 929.4  | 15  | 8.72  | 0.14  | 0.8631 |
| 54 | 959.4  | 15  | 11.67 | 0.17  | 0.8807 |
| 55 | 999.4  | 15  | 21.22 | 0.29  | 0.9126 |
| 56 | 1099.4 | 15  | 27.02 | 0.34  | 0.9533 |
| 57 | 1099.6 | 30  | 17.98 | 0.24  | 0.9804 |
| 58 | 1099.8 | 60  | 9.37  | 0.14  | 0.9945 |
| 59 | 32.8   | 60  | -     | -     | 0.9945 |
| 60 | 1149.5 | 15  | 2.109 | 0.054 | 0.9977 |
| 61 | 1149.8 | 60  | 1.374 | 0.047 | 0.9998 |
| 62 | 1149.3 | 90  | 0.126 | 0.017 | 0.9999 |
| 63 | 1149.7 | 90  | 0.022 | 0.012 | 1.0000 |
| 64 | 1149.8 | 120 | 0.014 | 0.012 | 1.0000 |

Table S2C. ROB-Px-Da – Ferrar Dolerite pyroxene

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 24.2                | 60            | 0.042                            | 0.019 | 0.0001                              |
| 2    | 125.0               | 60            | 3.714                            | 0.081 | 0.0068                              |
| 3    | 150.0               | 30            | 0.459                            | 0.027 | 0.0076                              |
| 4    | 175.0               | 30            | 0.732                            | 0.032 | 0.0089                              |
| 5    | 175.0               | 60            | 0.587                            | 0.031 | 0.0099                              |
| 6    | 175.0               | 120           | 0.635                            | 0.033 | 0.0111                              |
| 7    | 200.0               | 30            | 0.722                            | 0.031 | 0.0124                              |
| 8    | 200.0               | 30            | 0.383                            | 0.023 | 0.0131                              |
| 9    | 224.9               | 15            | 0.768                            | 0.036 | 0.0145                              |
| 10   | 225.0               | 30            | 0.751                            | 0.033 | 0.0158                              |
| 11   | 249.9               | 15            | 1.016                            | 0.039 | 0.0176                              |
| 12   | 250.0               | 30            | 0.888                            | 0.037 | 0.0192                              |
| 13   | 250.0               | 30            | 0.522                            | 0.030 | 0.0202                              |
| 14   | 274.9               | 15            | 0.841                            | 0.036 | 0.0217                              |
| 15   | 275.0               | 30            | 1.014                            | 0.037 | 0.0235                              |
| 16   | 299.9               | 15            | 1.636                            | 0.050 | 0.0264                              |
| 17   | 300.0               | 30            | 2.122                            | 0.058 | 0.0303                              |
| 18   | 324.9               | 20            | 4.237                            | 0.090 | 0.0379                              |
| 19   | 349.9               | 15            | 7.51                             | 0.13  | 0.0514                              |
| 20   | 350.0               | 30            | 7.97                             | 0.15  | 0.0657                              |
| 21   | 373.7               | 6             | 4.340                            | 0.089 | 0.0735                              |
| 22   | 374.9               | 15            | 7.68                             | 0.13  | 0.0873                              |
| 23   | 399.7               | 6             | 7.36                             | 0.13  | 0.1005                              |
| 24   | 399.9               | 15            | 11.24                            | 0.18  | 0.1207                              |
| 25   | 424.9               | 15            | 20.19                            | 0.29  | 0.1570                              |
| 26   | 425.0               | 30            | 19.83                            | 0.30  | 0.1927                              |
| 27   | 449.8               | 15            | 19.19                            | 0.28  | 0.2272                              |
| 28   | 450.0               | 30            | 24.14                            | 0.36  | 0.2706                              |
| 29   | 474.9               | 15            | 22.35                            | 0.33  | 0.3107                              |
| 30   | 475.0               | 30            | 28.66                            | 0.39  | 0.3623                              |
| 31   | 499.5               | 6             | 11.67                            | 0.19  | 0.3832                              |
| 32   | 499.7               | 10            | 15.44                            | 0.24  | 0.4110                              |
| 33   | 529.8               | 15            | 44.19                            | 0.60  | 0.4904                              |
| 34   | 559.8               | 15            | 57.31                            | 0.76  | 0.5934                              |
| 35   | 599.8               | 15            | 68.36                            | 0.89  | 0.7163                              |
| 36   | 629.9               | 20            | 58.82                            | 0.78  | 0.8220                              |
| 37   | 669.8               | 20            | 41.38                            | 0.56  | 0.8964                              |
| 38   | 699.8               | 20            | 17.23                            | 0.26  | 0.9274                              |
| 39   | 749.9               | 30            | 6.41                             | 0.11  | 0.9389                              |
| 40   | 774.8               | 30            | 2.608                            | 0.068 | 0.9436                              |
| 41   | 799.6               | 15            | 1.324                            | 0.047 | 0.9460                              |
| 42   | 829.6               | 15            | 1.958                            | 0.053 | 0.9495                              |
| 43   | 869.6               | 15            | 3.570                            | 0.079 | 0.9559                              |
| 44   | 899.6               | 15            | 4.372                            | 0.097 | 0.9638                              |
| 45   | 649.9               | 60            | 0.230                            | 0.020 | 0.9642                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |        |     |       |       |        |
|----|--------|-----|-------|-------|--------|
| 46 | 350.0  | 180 | 0.032 | 0.012 | 0.9642 |
| 47 | 500.0  | 120 | 0.044 | 0.012 | 0.9643 |
| 48 | 599.7  | 120 | 0.073 | 0.013 | 0.9645 |
| 49 | 699.8  | 30  | 0.021 | 0.013 | 0.9645 |
| 50 | 749.7  | 15  | 0.047 | 0.012 | 0.9646 |
| 51 | 849.6  | 15  | 0.649 | 0.033 | 0.9657 |
| 52 | 899.6  | 15  | 1.740 | 0.052 | 0.9689 |
| 53 | 929.6  | 15  | 2.399 | 0.063 | 0.9732 |
| 54 | 959.5  | 15  | 2.929 | 0.070 | 0.9784 |
| 55 | 999.4  | 15  | 3.343 | 0.073 | 0.9845 |
| 56 | 1099.0 | 15  | 4.602 | 0.099 | 0.9927 |
| 57 | 1100.0 | 3   | 0.471 | 0.026 | 0.9936 |
| 58 | 1099.5 | 30  | 2.717 | 0.066 | 0.9985 |
| 59 | 1149.3 | 15  | 0.600 | 0.030 | 0.9995 |
| 60 | 1150.0 | 26  | 0.205 | 0.020 | 0.9999 |
| 61 | 1150.0 | 33  | 0.052 | 0.014 | 1.0000 |
| 62 | 33.8   | 60  | -     | -     | 1.0000 |

Table S2D. GEM-CPx-Da – Clinopyroxene

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$  | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|--------|-------------------------------------|
| 1    | 24.4                | 30            | -                                | -      | 0.0000                              |
| 2    | 70.1                | 60            | 0.0035                           | 0.0078 | 0.0000                              |
| 3    | 70.1                | 120           | -                                | -      | 0.0000                              |
| 4    | 100.0               | 120           | 0.0064                           | 0.0077 | 0.0000                              |
| 5    | 135.0               | 60            | -                                | -      | 0.0000                              |
| 6    | 175.0               | 60            | 0.0186                           | 0.0077 | 0.0001                              |
| 7    | 200.0               | 60            | 0.0086                           | 0.0079 | 0.0002                              |
| 8    | 225.0               | 30            | -                                | -      | 0.0002                              |
| 9    | 225.0               | 60            | 0.0095                           | 0.0073 | 0.0002                              |
| 10   | 249.9               | 30            | 0.0045                           | 0.0079 | 0.0002                              |
| 11   | 274.9               | 15            | 0.0088                           | 0.0082 | 0.0002                              |
| 12   | 274.9               | 30            | 0.0066                           | 0.0074 | 0.0003                              |
| 13   | 274.9               | 15            | 0.0022                           | 0.0078 | 0.0003                              |
| 14   | 299.9               | 15            | 0.0115                           | 0.0078 | 0.0003                              |
| 15   | 299.9               | 30            | 0.0085                           | 0.0099 | 0.0004                              |
| 16   | 300.0               | 60            | 0.0281                           | 0.0093 | 0.0005                              |
| 17   | 324.9               | 15            | 0.0234                           | 0.0091 | 0.0006                              |
| 18   | 324.9               | 30            | 0.0353                           | 0.0096 | 0.0007                              |
| 19   | 349.9               | 15            | 0.065                            | 0.012  | 0.0010                              |
| 20   | 349.9               | 30            | 0.090                            | 0.013  | 0.0013                              |
| 21   | 374.6               | 6             | 0.0543                           | 0.0098 | 0.0016                              |
| 22   | 374.9               | 15            | 0.102                            | 0.014  | 0.0020                              |
| 23   | 399.7               | 6             | 0.109                            | 0.014  | 0.0024                              |
| 24   | 399.8               | 15            | 0.222                            | 0.016  | 0.0033                              |
| 25   | 424.8               | 15            | 0.484                            | 0.026  | 0.0053                              |
| 26   | 424.9               | 30            | 0.671                            | 0.029  | 0.0081                              |
| 27   | 449.8               | 15            | 0.589                            | 0.027  | 0.0105                              |
| 28   | 449.9               | 30            | 0.860                            | 0.032  | 0.0140                              |
| 29   | 474.8               | 15            | 0.980                            | 0.035  | 0.0180                              |
| 30   | 474.9               | 30            | 1.448                            | 0.048  | 0.0239                              |
| 31   | 499.5               | 6             | 0.631                            | 0.028  | 0.0265                              |
| 32   | 499.7               | 10            | 0.880                            | 0.034  | 0.0300                              |
| 33   | 529.8               | 15            | 3.063                            | 0.075  | 0.0426                              |
| 34   | 559.8               | 15            | 5.92                             | 0.12   | 0.0667                              |
| 35   | 599.7               | 15            | 13.05                            | 0.22   | 0.1200                              |
| 36   | 629.8               | 20            | 23.52                            | 0.37   | 0.2160                              |
| 37   | 669.7               | 20            | 37.68                            | 0.58   | 0.3698                              |
| 38   | 699.7               | 20            | 40.53                            | 0.61   | 0.5352                              |
| 39   | 749.8               | 30            | 51.87                            | 0.77   | 0.7469                              |
| 40   | 774.8               | 30            | 40.45                            | 0.62   | 0.9121                              |
| 41   | 799.5               | 15            | 14.43                            | 0.24   | 0.9709                              |
| 42   | 829.6               | 15            | 4.371                            | 0.090  | 0.9888                              |
| 43   | 868.4               | 15            | 1.235                            | 0.043  | 0.9938                              |
| 44   | 899.4               | 15            | 0.693                            | 0.026  | 0.9967                              |
| 45   | 649.9               | 60            | 0.0096                           | 0.0082 | 0.9967                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |        |     |        |        |        |
|----|--------|-----|--------|--------|--------|
| 46 | 350.0  | 180 | -      | -      | 0.9967 |
| 47 | 500.0  | 120 | -      | -      | 0.9967 |
| 48 | 600.0  | 120 | 0.0215 | 0.0083 | 0.9968 |
| 49 | 699.8  | 30  | 0.0113 | 0.0088 | 0.9968 |
| 50 | 749.6  | 15  | 0.0262 | 0.0091 | 0.9969 |
| 51 | 799.5  | 15  | 0.028  | 0.016  | 0.9971 |
| 52 | 849.5  | 15  | 0.116  | 0.013  | 0.9975 |
| 53 | 899.3  | 15  | 0.152  | 0.015  | 0.9982 |
| 54 | 929.7  | 15  | 0.177  | 0.017  | 0.9989 |
| 55 | 959.7  | 15  | 0.115  | 0.013  | 0.9993 |
| 56 | 999.0  | 15  | 0.038  | 0.010  | 0.9995 |
| 57 | 1099.5 | 15  | 0.0371 | 0.0091 | 0.9996 |
| 58 | 32.7   | 30  | -      | -      | 0.9996 |
| 59 | 1099.6 | 30  | 0.0043 | 0.0091 | 0.9997 |
| 60 | 1099.7 | 60  | 0.0112 | 0.0090 | 0.9997 |
| 61 | 1150.0 | 15  | 0.034  | 0.010  | 0.9999 |
| 62 | 1198.8 | 15  | 0.0237 | 0.0096 | 0.9999 |
| 63 | 1199.2 | 23  | 0.0126 | 0.0084 | 1.0000 |

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Table S2E. GEM-OPx-Da – Orthopyroxene

| Step | Temperature<br>(°C) | Time<br>(min) | $^3\text{He}$<br>( $10^6$ atoms) | $\pm$ | Cumulative<br>fractional<br>release |
|------|---------------------|---------------|----------------------------------|-------|-------------------------------------|
| 1    | 24.1                | 30            | -                                | -     | 0.0000                              |
| 2    | 70.1                | 60            | 0.008                            | 0.011 | 0.0000                              |
| 3    | 70.0                | 120           | -                                | -     | 0.0000                              |
| 4    | 100.0               | 120           | 0.012                            | 0.011 | 0.0000                              |
| 5    | 135.0               | 60            | 0.009                            | 0.011 | 0.0000                              |
| 6    | 175.0               | 60            | 0.030                            | 0.012 | 0.0000                              |
| 7    | 200.0               | 60            | 0.055                            | 0.013 | 0.0000                              |
| 8    | 224.9               | 30            | 0.026                            | 0.012 | 0.0000                              |
| 9    | 224.9               | 60            | 0.016                            | 0.010 | 0.0001                              |
| 10   | 249.8               | 30            | 0.017                            | 0.011 | 0.0001                              |
| 11   | 274.8               | 15            | 0.058                            | 0.012 | 0.0001                              |
| 12   | 274.8               | 30            | 0.091                            | 0.014 | 0.0001                              |
| 13   | 274.7               | 15            | 0.021                            | 0.011 | 0.0001                              |
| 14   | 299.5               | 15            | 0.212                            | 0.021 | 0.0002                              |
| 15   | 299.8               | 30            | 0.097                            | 0.016 | 0.0002                              |
| 16   | 300.0               | 60            | 0.168                            | 0.021 | 0.0003                              |
| 17   | 324.9               | 15            | 0.461                            | 0.036 | 0.0005                              |
| 18   | 324.9               | 30            | 0.347                            | 0.029 | 0.0006                              |
| 19   | 349.8               | 15            | 0.293                            | 0.025 | 0.0007                              |
| 20   | 349.9               | 30            | 0.947                            | 0.063 | 0.0010                              |
| 21   | 374.5               | 6             | 0.625                            | 0.044 | 0.0012                              |
| 22   | 374.8               | 15            | 1.584                            | 0.096 | 0.0018                              |
| 23   | 399.4               | 6             | 1.067                            | 0.067 | 0.0022                              |
| 24   | 399.8               | 15            | 2.59                             | 0.15  | 0.0031                              |
| 25   | 424.8               | 15            | 2.88                             | 0.17  | 0.0041                              |
| 26   | 424.9               | 30            | 8.83                             | 0.49  | 0.0072                              |
| 27   | 449.8               | 15            | 2.09                             | 0.12  | 0.0080                              |
| 28   | 449.9               | 30            | 3.63                             | 0.21  | 0.0092                              |
| 29   | 474.8               | 15            | 9.38                             | 0.52  | 0.0125                              |
| 30   | 474.9               | 30            | 10.03                            | 0.55  | 0.0161                              |
| 31   | 499.4               | 6             | 4.08                             | 0.23  | 0.0175                              |
| 32   | 499.7               | 10            | 6.55                             | 0.37  | 0.0198                              |
| 33   | 529.7               | 15            | 12.79                            | 0.71  | 0.0243                              |
| 34   | 559.7               | 15            | 86.5                             | 4.7   | 0.0549                              |
| 35   | 599.7               | 15            | 87.6                             | 5.4   | 0.0858                              |
| 36   | 629.8               | 20            | 177.7                            | 9.6   | 0.1485                              |
| 37   | 669.7               | 20            | 364                              | 20    | 0.2769                              |
| 38   | 699.7               | 20            | 735                              | 40    | 0.5363                              |
| 39   | 749.8               | 30            | 1018                             | 55    | 0.8957                              |
| 40   | 774.8               | 30            | 194                              | 11    | 0.9640                              |
| 41   | 799.5               | 15            | 24.6                             | 1.7   | 0.9726                              |
| 42   | 829.3               | 15            | 24.7                             | 1.4   | 0.9814                              |
| 43   | 867.8               | 15            | 24.7                             | 1.4   | 0.9901                              |
| 44   | 900.0               | 4.17          | 4.03                             | 0.23  | 0.9915                              |
| 45   | 649.9               | 60            | 1.453                            | 0.088 | 0.9920                              |

Supplement for Bergelin et al., “Diffusion kinetics of  $^3\text{He}$  in pyroxene and plagioclase and applications to cosmogenic exposure dating and paleothermometry in mafic rocks.”

|    |        |     |        |        |        |
|----|--------|-----|--------|--------|--------|
| 46 | 350.0  | 180 | 0.030  | 0.011  | 0.9920 |
| 47 | 500.0  | 120 | 0.066  | 0.013  | 0.9921 |
| 48 | 600.0  | 120 | 0.470  | 0.036  | 0.9922 |
| 49 | 699.8  | 30  | 0.702  | 0.049  | 0.9925 |
| 50 | 749.6  | 15  | 0.743  | 0.051  | 0.9927 |
| 51 | 799.6  | 15  | 1.78   | 0.11   | 0.9934 |
| 52 | 849.6  | 15  | 4.46   | 0.25   | 0.9949 |
| 53 | 899.5  | 15  | 7.14   | 0.40   | 0.9975 |
| 54 | 929.6  | 15  | 4.67   | 0.27   | 0.9991 |
| 55 | 959.7  | 15  | 1.61   | 0.10   | 0.9997 |
| 56 | 999.7  | 15  | 0.352  | 0.029  | 0.9998 |
| 57 | 1099.8 | 15  | 0.029  | 0.012  | 0.9998 |
| 58 | 32.5   | 30  | 0.0026 | 0.0096 | 0.9998 |
| 59 | 1099.8 | 30  | 0.060  | 0.013  | 0.9998 |
| 60 | 1099.9 | 60  | 0.078  | 0.016  | 0.9999 |
| 61 | 1149.4 | 15  | 0.044  | 0.012  | 0.9999 |
| 62 | 1149.9 | 60  | 0.129  | 0.017  | 0.9999 |
| 63 | 1149.9 | 90  | 0.141  | 0.018  | 1.0000 |
| 64 | 1150.0 | 2.5 | 0.060  | 0.014  | 1.0000 |

Table S3 Total measured  $^3\text{He}$  and  $^4\text{He}$  concentrations in Fish Canyon sanidine (FCs) grains

| Sample name | Storage time (yr) | Aliquot | Mass (mg) | Mean radii ( $\mu\text{m}$ ) | Measured $^3\text{He}$ ( $10^9$ atoms $\text{g}^{-1}$ ) | Measured $^4\text{He}$ ( $10^{12}$ atoms $\text{g}^{-1}$ ) |
|-------------|-------------------|---------|-----------|------------------------------|---|--|
| FCs-504     | 1.86              | a       | 1.40      | 471                          | $163.9 \pm 3.4$   | $93.10 \pm 0.60$   |
|             |                   | b       | 1.70      | 502                          | $406.5 \pm 8.6$   | $107.64 \pm 0.61$  |
| FCs-496     | 2.70              | a       | 1.12      | 215                          | $88.0 \pm 2.1$  | $31.37 \pm 0.32$   |
|             |                   | b       | 0.90      | 197                          | $65.8 \pm 1.6$  | $18.88 \pm 0.19$   |
| FCs-492PR   | 3.85              | a       | 0.89      | 225                          | $91.3 \pm 2.2$  | $5.400 \pm 0.056$  |
|             |                   | b       | 1.37      | 260                          | $78.8 \pm 1.9$  | $3.303 \pm 0.034$  |
| FCs-456PR   | 8.40              | a       | 0.64      | 301                          | $75.8 \pm 3.9$  | $2.906 \pm 0.025$  |
|             |                   | b       | 0.34      | 190                          | $79.4 \pm 1.9$  | $3.769 \pm 0.033$  |
| FCs-443PR   | 9.65              | a       | 0.53      | 173                          | $83.2 \pm 2.1$  | $12.89 \pm 0.11$   |
|             |                   | b       | 0.95      | 173                          | $70.1 \pm 1.7$  | $3.863 \pm 0.032$  |
| FCs-400c    | 13.64             | a       | 1.61      | 496                          | $14.17 \pm 0.35$  | $1.2247 \pm 0.0098$  |
|             |                   | b       | 1.23      | 430                          | $9.34 \pm 0.25$   | $2.096 \pm 0.018$  |
| FCs-391     | 14.69             | a       | 1.24      | 335                          | $21.90 \pm 0.54$  | $4.145 \pm 0.044$  |

Table S4 Summary of modeled MDD diffusion kinetics results for  $^3\text{He}$  in proton-irradiated quartz grain sample HU-08-03.

| Sample name | radii<br>( $\mu\text{m}$ ) | modeled initial<br>conditions | misfit | Ea<br>( $\text{kJ mol}^{-1}$ ) | $\ln(D_0/a^2)$<br>$\ln(\text{s}^{-1})$ | Fractional<br>release | irradiation<br>loss | storage<br>loss |
|-------------|----------------------------|-------------------------------|--------|--------------------------------|--|-----------------------|---------------------|-----------------|
| HU-08-03    | 0.0256                     | no loss                       | 9.0    | 100.3                          | 17.8                                   | 0.33                  | -                   | -               |
|             |                            |                               |        |                                | 16.5                                   | 0.17                  |                     |                 |
|             |                            |                               |        |                                | 13.7                                   | 0.18                  |                     |                 |
|             |                            |                               |        |                                | 12.1                                   | 0.14                  |                     |                 |
|             |                            |                               |        |                                | 9.3                                    | 0.075                 |                     |                 |
|             |                            |                               |        |                                | 6.8                                    | 0.11                  |                     |                 |
|             |                            | loss                          | 5.5    | 94.3                           | 16.9                                   | 0.28                  | 0.0126              | 0.1579          |
|             |                            |                               |        |                                | 15.4                                   | 0.29                  |                     |                 |
|             |                            |                               |        |                                | 12.4                                   | 0.14                  |                     |                 |
|             |                            |                               |        |                                | 10.9                                   | 0.13                  |                     |                 |
|             |                            |                               |        |                                | 8.0                                    | 0.072                 |                     |                 |
|             |                            |                               |        |                                | 5.7                                    | 0.080                 |                     |                 |

## Supplementary figures

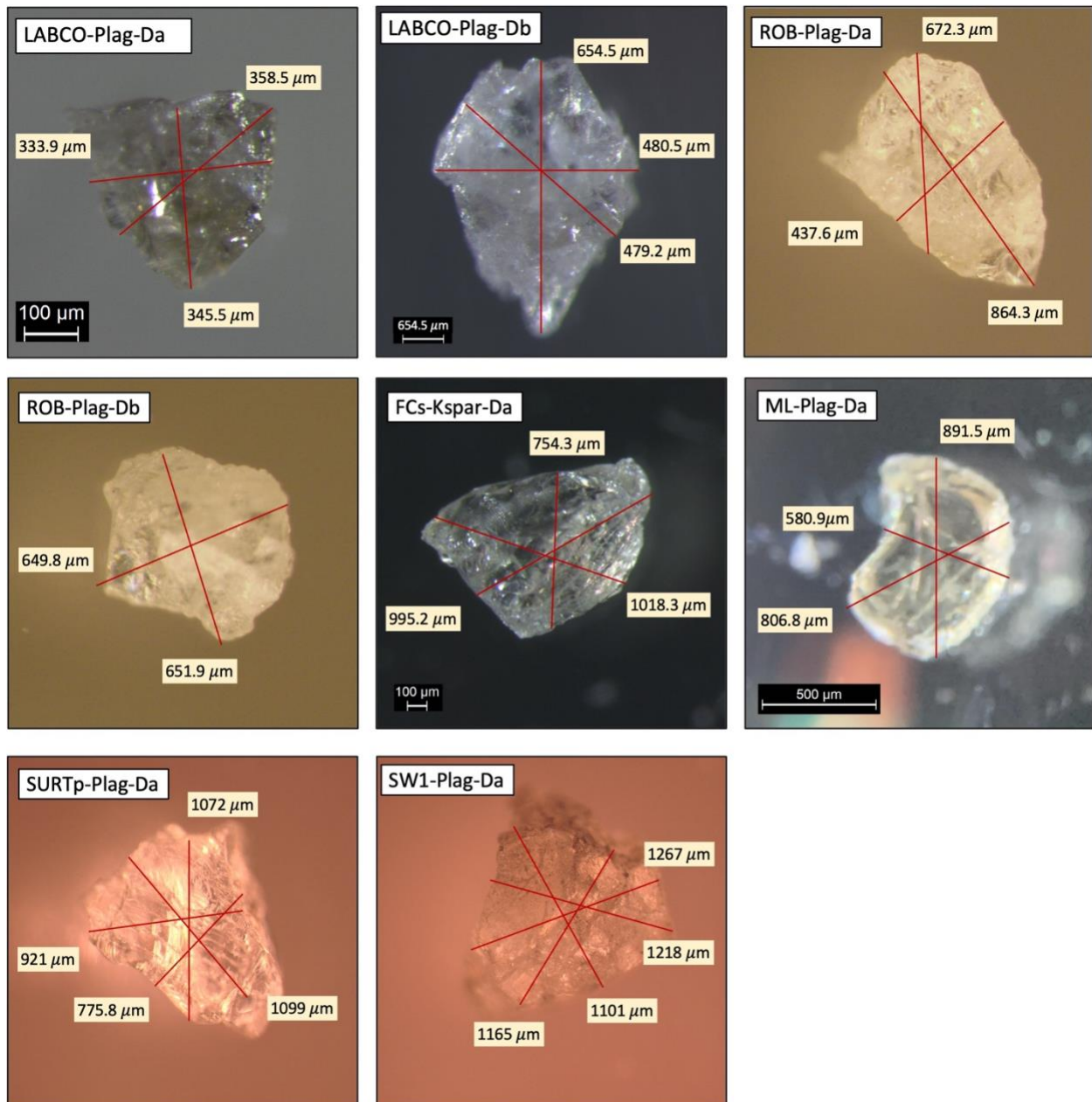


Figure S1 Photographs of irradiated plagioclase grains

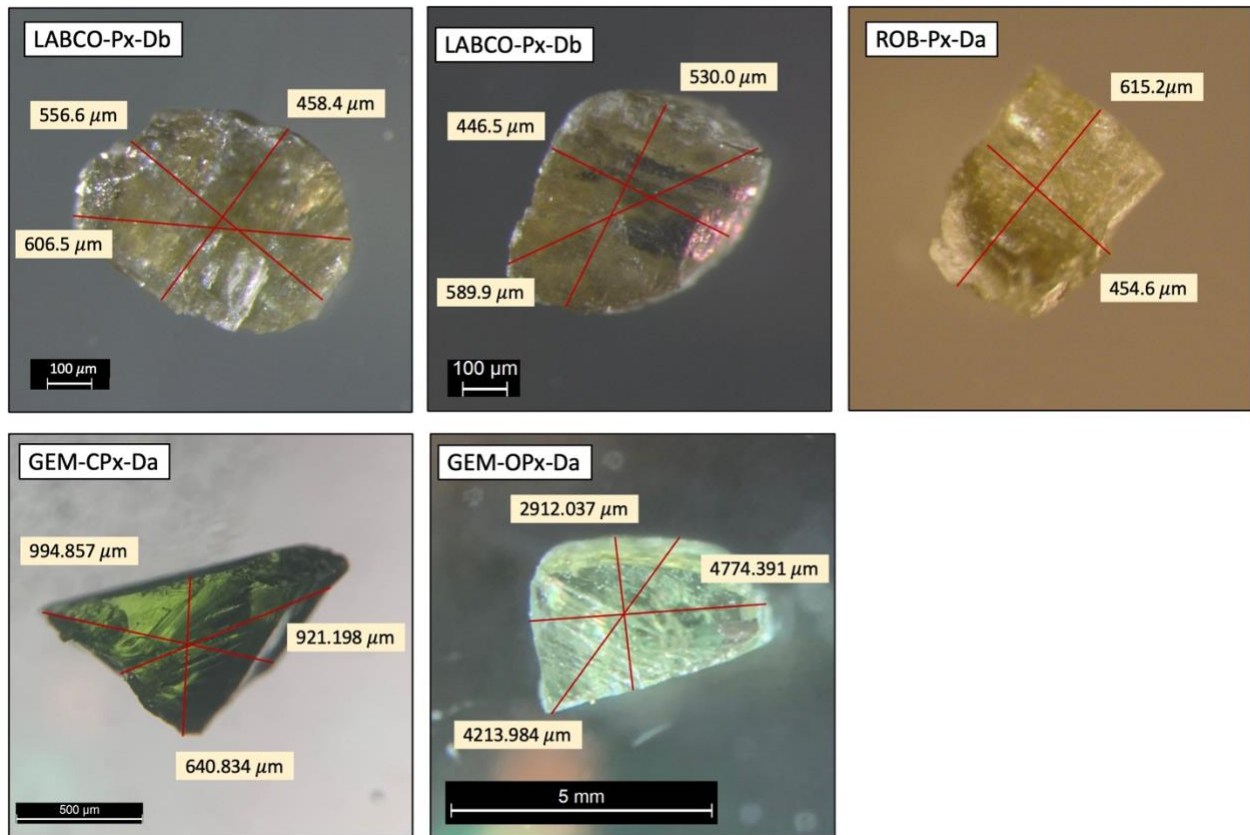


Figure S2 Photographs of irradiated pyroxene grains

Figure S3 Forward-modeled MDD results for the HU-08-03 quartz grains, when (a) excluding and (b) including forward modeled irradiation and storage loss prior to step degassing experiment. Each result is displayed in the Arrhenius, fractional release, and residual plots. Colored circles show the observed apparent  $^3\text{He}$  diffusivity from the step-heating experiment. Vertical lines show the uncertainty in  $\ln(D/a^2)$ . Black dots show the modeled predicted apparent diffusivity from the best reduced misfit, where the grey lines represent the diffusion kinetics of each individual domain modeled, with the line thickness being proportional to the fractional size of the domain. The Fractional release plot compares the measured and predicted fractional gas release from each heating step during the diffusion experiment. The residuals are defined as the difference between the calculated  $\ln(D/a^2)$  from a given heating step and the expected  $\ln(D/a^2)$  from the first MDD model domain at that same temperature and plotted against the cumulative gas release.

