Gila River channel between lava flows of the Sentinel Volcanic Field and Oatman Mountain (top) of south-central Arizona.
A review of late Cenozoic volcanic activity in the Gila Bend – Buckeye area of western Maricopa County, Arizona

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Arizona Geological Survey

Jon E. Spencer
Senior Geologist
Arizona Geological Survey
416 W. Congress St., #100
Tucson, Arizona 85701
Introduction

The Arlington and Gillespie volcanoes west of Buckeye in western Maricopa County, Arizona, form the northeastern part of a string of basaltic volcanoes that include the extensive Sentinel volcanic field west of Gila Bend (Fig. 1). Potassium-argon geochronologic age determinations indicate that basaltic volcanic activity occurred between about 1 and 4 Ma, with significant variation between different eruptive centers. This review is intended to provide basic information regarding geologically recent volcanic activity near the Palo Verde Nuclear Generating Station, and is intended to contribute to a re-evaluation of geologic hazards in the general area.

The Sentinel – Arlington volcanic field

The Sentinel – Arlington volcanic field extends over about 80 km from Sentinel volcanic field west of Gila Bend northeastward to Arlington volcano west of Buckeye (Richard et al., 2000; Cave and Greeley, 2004). Volcanic rocks in the field are olivine-clinopyroxene basalts that form low relief lava flows and low shield volcanoes, with little evidence of pyroclastic activity (Lynch, 1989; Nealey and Sheridan, 1989; Cave and Greeley, 2007). SiO$_2$ content is ~45-52% (Leeman, 1970; Cave et al., 2007), and $^{87}$Sr/$^{86}$Sr of one sample is 0.7035 (Leeman, 1970). It does not appear that any intermediate or felsic volcanic rocks were erupted in the field.

Age of the Sentinel – Arlington volcanic field

Arlington volcano, a small, basaltic, low shield volcano at the northeastern end of the Sentinel – Arlington volcanic field, is located approximately 10 km southeast of the Palo Verde Nuclear Generating Station (Fig. 1; Cave and Greeley, 2004). Six potassium-argon radiometric dates of basalt rock samples from Arlington volcano range from 1.28±0.25 to 3.28±0.27 Ma (Fig. 1; Appendix 1; “Ma” = “mega-annum” or, equivalently, age in millions of years; uncertainty is one standard deviation), and one $^{40}$Ar/$^{39}$Ar incremental release date yielded a plateau age of 2.37±0.02 Ma (Table 1; Shelby Cave, written commun., 2013). The volcano is geologically simple, consisting of a single, small, low-relief volcano with no soil horizons between flows (Cave and Greeley, 2004). Most likely it was erupted in a single volcanic episode of short geologic duration (<10,000 years), and was not erupted over a 1-2 million year period as suggested by the range of radiometric dates (Cave and Greeley, 2004). Four of the six potassium-argon dates from the volcano range from 1.92±0.42 to 2.28±0.21 Ma (Fig. 1), and suggest that age of the volcano is about 2.1 Ma. The 2.37±0.02 Ma $^{40}$Ar/$^{39}$Ar date suggests that the volcano is slightly older.
Gillespie volcano, located approximately 20 km south of the Palo Verde Nuclear Generating Station, is a morphologically similar low shield volcano without soil horizons or multiple eruptive centers (Cave and Greeley, 2004). Four of five potassium-argon dates range from 2.67±0.2 to 3.6±0.4 Ma, suggesting that the age of the volcano is approximately 3 Ma. Lee and Bell (1975, reproduced here as Appendix 2) and Cave (2007) infer that the Gila River was temporarily dammed by basalt eruption (see also Figure 1 in Greeley and Cave, 2011).

Woolsey volcano, located approximately 35 km south of the Palo Verde Nuclear Generating Station, consists of a significant area of basalt lava flows around and south of a probable volcanic vent referred to as “Woolsey cone” (Peterson et al., 1989). Three potassium-argon dates from the “Basalt of Woolsey cone” of Peterson et al. (1989), 2.58±0.9 Ma, 4.5±0.9 Ma, and 6.7±1.1 Ma, are spread over such a wide range of ages that the age of this volcano remains uncertain. Similarity to other 1-3 Ma basaltic rock in the Sentinel – Arlington volcanic field suggest a similar age, and suggest that the older potassium-argon dates from the Basalt of Woolsey cone are erroneous.

The Sentinel volcanic field and its outliers west of Gila Bend, including Warford Ranch and Theba low shield volcanoes (Cave and Greeley, 2004; Greeley and Cave, 2011), cover perhaps 500 square kilometers (Fig. 1). Significantly more of this field appears to be buried by younger deposits, possibly because of greater age or greater influx of fluvial or eolian sediments. Five 40Ar/39Ar dates from the field range in age from 1.08±0.15 Ma to 2.3±0.035 Ma (Table 1; Cave et al., 2007; Table 1 data provided by Shelby Cave, 2013). Three potassium-argon dates from the Sentinel volcanic field range from 3.1±0.9 to 3.44±0.4 Ma, with one date at 1.72±0.46 Ma (Shoustra et al., 1976; Eberly and Stanley, 1978; Shafiqullah et al., 1980). These dates indicate that the volcanic field records multiple eruptive events over more than two million years, or that the older potassium-argon dating yielded erroneously old dates and the field was erupted between ~1.1 and 2.3 Ma.

Because the Sentinel volcanic field is large and has multiple eruptive centers, it is possible that the duration of its eruptive history was 2-3 million years, but it is also possible that the field is ~1.0 – 2.5 Ma or even younger, and the older potassium-argon dates are erroneously biased toward older ages. Such systematic bias has been identified recently in studies of Quaternary basalts in the western Grand Canyon region, and has been attributed to excess argon trapped in clays that can be removed with sufficient mineral processing and detected by 40Ar/39Ar incremental-release dating (Karlstrom et al., 2007; Crow et al., 2008; compare 40Ar/39Ar dates in Karlstrom et al. [2007, Table 1] with K-Ar dates in Hamblin [1994, Table 1] for basalt units “Gray Ledge”, “Whitmore”, “Layered Diabase”, “Toroweap”, and “Prospect”). The discrepancy between older K-Ar and younger 40Ar/39Ar dates in the Sentinel volcanic field will not be resolved without additional geochronologic study.
Conclusion

The Sentinel – Arlington volcanic field produced extensive, low relief basalt lava flows and small, gently sloping basalt shield volcanoes. Available geochronologic data suggest that the Sentinel – Arlington volcanic field has erupted intermittently over the past 1.1-3.5 Ma, with no clear migration of volcanic activity within the field. Although there is no geochronologic evidence for eruptions during the past one million years, the large range of geochronologic dates from the Sentinel volcanic field, the uncertainties inherent in many of the older potassium-argon dates, and the large number of eruptive centers, allow for the possibility of more recent activity that is as yet undocumented.

References Cited

Crow, R., Karlstrom, K.E., McIntosh, W., Peters, L, Dunbar, N., 2008, History of Quaternary volcanism and lava dams in western Grand Canyon based on LIDAR analysis, $^{40}$Ar/$^{39}$Ar dating, and field studies: Implications for flow stratigraphy, timing of volcanic events, and lava dams: Geosphere, v. 4, no. 1, doi 10.1130/geo00133.1.


<table>
<thead>
<tr>
<th>$^{40}$Ar/$^{39}$Ar date</th>
<th>magnetopolarity</th>
<th>vent</th>
<th>UTME NAD27</th>
<th>UTMN NAD27</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.08±0.15 Ma</td>
<td>R</td>
<td>Malpais</td>
<td>290630</td>
<td>3639792</td>
</tr>
<tr>
<td>1.25±0.024 Ma</td>
<td>R</td>
<td>Wildhorse</td>
<td>300869</td>
<td>3648907</td>
</tr>
<tr>
<td>1.71±0.054 Ma</td>
<td>R</td>
<td>Theba</td>
<td>317303</td>
<td>3641590</td>
</tr>
<tr>
<td>2.30±0.035 Ma</td>
<td>R</td>
<td>Oatman</td>
<td>297002</td>
<td>3654101</td>
</tr>
<tr>
<td>1.91±0.59 Ma</td>
<td>N</td>
<td>Painted Rock</td>
<td>304925</td>
<td>3651830</td>
</tr>
<tr>
<td>2.37±0.02 Ma</td>
<td></td>
<td>Arlington*</td>
<td>337526</td>
<td>3690897</td>
</tr>
</tbody>
</table>

*Sample S-06-166 with no reported magnetopolarity
Figure 1. Geologic map of the Gila Bend – Buckeye area showing major rock units (from Richard et al., 2000) and potassium-argon radiometric dates (in millions of years, with analytical uncertainty at one standard deviation). K-Ar dates from late Cenozoic volcanic rocks (<10 Ma) are from Reynolds et al. (1986). Sample locations are shown as indicated by coordinates reported by Reynolds et al. (1986), but many of these are probably slightly mislocated because coordinates were not provided with sufficient accuracy. Six samples were dated by the $^{40}$Ar/$^{39}$Ar method (Cave et al., 2007; Table 1; data from S. Cave and D. Champion, written comm., 2013). Late Cenozoic K-Ar dates were originally reported by Shoustra et al. (1976, included here as Appendix 1), Eberly and Stanley (1978), and Shafiqullah et al. (1980). Also shown are dates from middle Tertiary igneous rocks (15-30 Ma), as originally reported by the sources listed above and by Spencer et al. (1995).
Appendix 1

Geochronology of the Sentinel Volcanic Field

Originally Published as

Appendix 2Q
Radiometric Age Dating
Dr. Paul Damon (Univ. of Arizona)
Tucson, Arizona
And
Geochron Laboratories Division
Krueger Enterprises, Inc.
Cambridge, Massachusetts

In: Shoustra, J.J., Smith, J.L., Scott, J.D., Strand, R.L. and Duff, D., 1976, Geology and seismicity, site lithologic conditions and Appendix 2Q (radiometric dating in Palo Verde Nuclear Generating Station 1, 2, and 3, Preliminary safety analysis report: Arizona Public Service Commission, v. 2, p. 2.5-60, 2.5-76 and v. 8, Appendix 2Q.
Locations of samples taken for age dating are shown on Figure 2.5-17. Dual sample numbers (FUGRO's and the laboratory) are indicated on sample data sheets from the University of Arizona.
## K-Ar Data on "Arlington Flow" Basalts, Southeast of Palo Verde Hills, Maricopa County, Arizona, Submitted by Fugro, Inc.

<table>
<thead>
<tr>
<th>UAKA Sample No.</th>
<th>FUGRO No.</th>
<th>Description</th>
<th>Percent K</th>
<th>Radiogenic argon-40 in $x10^{-12}$ m/g</th>
<th>Percent atmospheric argon-40</th>
<th>Age in m.y.</th>
</tr>
</thead>
<tbody>
<tr>
<td>73-149</td>
<td>AR-1-73</td>
<td>Whole rock, olivine basalt southeast of Palo Verde Hills. Arlington flow of FUGRO. Lat. 33° 20' 58&quot; N, Long. 112° 46' 41&quot; W.</td>
<td>0.5345</td>
<td>1.88</td>
<td>85.3</td>
<td>1.79 ± 0.19</td>
</tr>
<tr>
<td>73-150</td>
<td>AR-11-73</td>
<td>Whole rock, basalt southeast of Palo Verde Hills area. Lat. 33° 20' 46&quot; N, Long. 112° 46' 08&quot; W.</td>
<td>0.739</td>
<td>1.62</td>
<td>94.0</td>
<td>1.24 ± 0.24</td>
</tr>
<tr>
<td>73-151</td>
<td>AR-17-73</td>
<td>Whole rock basalt. Lat. 33° 21' 05&quot; N, Long. 112° 46' 22&quot; W.</td>
<td>0.531</td>
<td>2.14</td>
<td>86.4</td>
<td>2.22 ± 0.20</td>
</tr>
<tr>
<td>73-152</td>
<td>AR-111-73</td>
<td>Whole rock basalt. Lat. 33° 19' 44&quot; N, Long. 112° 44' 05&quot; W.</td>
<td>0.612</td>
<td>2.31</td>
<td>88.6</td>
<td>2.10 ± 0.23</td>
</tr>
</tbody>
</table>
### K-Ar Ages on Fugro Samples

**Phoenix Quadrangle, Maricopa County**

<table>
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<tr>
<th>UAKA Sample No.</th>
<th>Description</th>
<th>Percent K</th>
<th>Radiogenic argon-40 in x10^-12/mg</th>
<th>Percent atmospheric argon-40</th>
<th>Age in m.y.</th>
</tr>
</thead>
<tbody>
<tr>
<td>73-11</td>
<td>Andesitic basalt, &quot;Wishbone&quot; Hill of Charles Druitt (FUGRO). It overlies volcanoclastic conglomerate with 20° SE dip. It has reversed polarity. (T5N, R5W, SW corner Sec. 2).</td>
<td>2.20</td>
<td>54.8</td>
<td>25.1</td>
<td>14.2 ± 0.2</td>
</tr>
<tr>
<td>73-10</td>
<td>Basal basalt overlying gravel, Hot Rock Hill of Garry Guacci (FUGRO). The gravel surface dips about 10-25° SE. It shows reversed polarity. (T3N, R6W, W central sec. 16).</td>
<td>0.574</td>
<td>15.0</td>
<td>47.2</td>
<td>14.6 ± 0.4</td>
</tr>
<tr>
<td>73-7</td>
<td>Basalt, presumably represents the top of the Gillespie Dam flow. The basal part of the flow (UAKA-73-4) has an age of 2.62 ± 0.45 m.y. The magnetic orientation is at 90° in both the hand specimens collected. (T2S, R5N, NE corner sec. 31).</td>
<td>0.779</td>
<td>1.63</td>
<td>97.0</td>
<td>1.31 ± 0.43</td>
</tr>
<tr>
<td>73-8(G-2)</td>
<td>Basalt near Gillespie Dam site on top of the small hill. It is tilted 35-40° W and has normal polarity. (T2S, R5W, W central sec. 28).</td>
<td>1.24</td>
<td>44.1</td>
<td>35.2</td>
<td>19.9 ± 0.5</td>
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### K-Ar Ages on Fugro Samples from Arlington and Gillespie Dam Areas, Maricopa County

<table>
<thead>
<tr>
<th>UAKA Sample No.</th>
<th>Description</th>
<th>Percent K</th>
<th>Radiogenic argon-40 in $\times 10^{-12}$ m/g</th>
<th>Percent atmospheric argon-40</th>
<th>Age in m.y.</th>
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<tbody>
<tr>
<td>73-25</td>
<td>Biotite, reddish brown tuff, sec. 4, R5W, T3S, Woolsey Peak Quadrangle, Maricopa County (FUGRO No. GD-2).</td>
<td>6.73</td>
<td>347.5</td>
<td>10.1</td>
<td>28.8 ± 0.5</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>345.4</td>
<td>12.7</td>
<td></td>
</tr>
<tr>
<td>73-26</td>
<td>Basaltic andesite, porphyritic, underlies fan materials and basaltic flows. Sec. 6, R5W, T3S, Woolsey Peak Quadrangle, Maricopa County (FUGRO No. G-4).</td>
<td>1.73</td>
<td>82.8</td>
<td>13.1</td>
<td>26.7 ± 0.4</td>
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<td></td>
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<td>82.6</td>
<td>13.1</td>
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<tr>
<td>73-94</td>
<td>Basaltic andesite, drill core 324-325' depth, elevation at drill site is 912', SW corner of sec. 3, R6W, T1S, Arlington Quadrangle, Maricopa County (FUGRO No. PV-33).</td>
<td>1.54</td>
<td>45.3</td>
<td>28.3</td>
<td>16.7 ± 0.3</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>46.3</td>
<td>28.2</td>
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<tr>
<td>UAKA Sample No.</td>
<td>Description</td>
<td>Percent $^3$K</td>
<td>Radiogenic argon-40 in $10^{-12}$m$^3$/g</td>
<td>Percent atmospheric argon-40</td>
<td>Age in m.y.</td>
</tr>
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<td>------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>73-29</td>
<td>Andesitic basalt, grey, aphanitic, slightly vesicular. The basalt overlies a</td>
<td>1.92</td>
<td>67.4</td>
<td>55.9</td>
<td>19.8 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>reworked tuff and is faulted. From Palo Verde Hills, Arlington Quad., Maricopa Co., Ariz. Sec. 25, R7W, T1N (Fugro 2-1).</td>
<td></td>
<td>68.9</td>
<td>55.3</td>
<td></td>
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<tr>
<td>73-30</td>
<td>Intrusive andesitic basalt from Palo Verde Hills, Arlington Quad., Maricopa Co., Az. Sec. 16, R6W, T1N (Fugro 2-2).</td>
<td>2.08</td>
<td>72.5</td>
<td>72.5</td>
<td>19.1 ± 0.7</td>
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<td></td>
<td></td>
<td>70.1</td>
<td>73.6</td>
<td></td>
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<td>73-31</td>
<td>Andesitic basalt dike, 4 ft. thick, from Palo Verde Hills, Arlington Quad., Maricopa Co., Az. Sec. 30, R6W, T1N (Fugro 2-3).</td>
<td>3.26</td>
<td>116.2</td>
<td>34.7</td>
<td>19.9 ± 0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>115.2</td>
<td>35.3</td>
<td></td>
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<td>73-32</td>
<td>Andesitic basalt with partly altered phenocrysts, top of the extrusive volcanic sequence in the Palo Verde Hills. Sec. 10, R6W, T1S, Maricopa Co., Arlington Quad, Az. (Fugro 2-4).</td>
<td>1.34</td>
<td>41.9</td>
<td>70.4</td>
<td>17.7 ± 0.6</td>
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<td></td>
<td>42.9</td>
<td>68.4</td>
<td></td>
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<tr>
<td>73-33</td>
<td>Olivine basalt, well bedded volcanic sequence of the Palo Verde Hills. Sec. 36, R6W, T1N, Arlington Quad., Maricopa Co., Az. (Fugro 2-5).</td>
<td>0.575</td>
<td>20.8</td>
<td>63.1</td>
<td>20.3 ± 0.7</td>
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<tr>
<td>73-27</td>
<td>Andesitic basalt, porphyritic, Gillespie Dam area. Sec. 6, R5W, T3S, Woolsey Peak Quad., Maricopa Co., Az. (Fugro G5).</td>
<td>1.58</td>
<td>55.2</td>
<td>24.8</td>
<td>19.6 ± 0.4</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>55.4</td>
<td>24.9</td>
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### K-Ar Ages on Fugro Samples,
Maricopa County, Arizona

<table>
<thead>
<tr>
<th>UAKA Sample No.</th>
<th>Description</th>
<th>Percent K</th>
<th>Radiogenic argon-40 in x10^-12 m/g</th>
<th>Percent atmospheric argon-40</th>
<th>Age in m.y.</th>
</tr>
</thead>
<tbody>
<tr>
<td>73-21</td>
<td>Palo Verde Hills andesite, tilted 50-70° at sample locality. NW1/4 of section 14, T1N, R7W, Arlington Quadrangle, Maricopa County, Arizona.</td>
<td>2.25</td>
<td>77.04</td>
<td>49.1</td>
<td>19.1 ± 0.4</td>
</tr>
<tr>
<td>73-22</td>
<td>Palo Verde Hills, dark-grey porphyritic basalt or andesite. NW1/4 of SW1/4 of section 17, T1S, R5W, Arlington Quadrangle, Maricopa County, Arizona.</td>
<td>1.31</td>
<td>45.96</td>
<td>51.0</td>
<td>19.4 ± 0.4</td>
</tr>
<tr>
<td>73-9</td>
<td>Arlington basalt flow, the top of the series for which UAKA-73-3 (3.19 ± 0.19 m.y.) is the base. NE corner of section 15, T1S, R5W, Arlington Quadrangle, Maricopa County, Arizona.</td>
<td>0.887</td>
<td>4.145</td>
<td>92.3</td>
<td>2.25 ± 0.36</td>
</tr>
<tr>
<td>Sample No.</td>
<td>Description</td>
<td>Percent K</td>
<td>Radiogenic argon-40 in x10^-12m/g</td>
<td>Percent atmospheric argon-40</td>
<td>Age in m.y.</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------------------------------------------------------------------</td>
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<tr>
<td>73-3</td>
<td>Olivine basalt, 0.2 miles north of Arlington store on old Arizona Route 80, SW1/4 of NW1/4, sec. 22, T2S, R5W, Lat. 33° 19' 40&quot; N, Long. 112° 45' 36&quot; W, Maricopa Co., Arizona</td>
<td>0.648</td>
<td>3.73</td>
<td>85.5</td>
<td>3.19 ± 0.19</td>
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# K-Ar Ages on Basalt Samples Collected by Paul E. Damon of U.A. and John Scott and Gayland Lee of Fugro

<table>
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<th>UAKA Sample No.</th>
<th>Description</th>
<th>Percent K</th>
<th>Radiogenic argon-40 in x10-12m/g</th>
<th>Percent atmospheric argon-40</th>
<th>Age in m.y.</th>
</tr>
</thead>
<tbody>
<tr>
<td>73-4</td>
<td>Basal Gillespie Dam basalt, 1.5 miles past Arlington Cattle Co., 500' west of Highway 80 in the east-central portion of the SE 1/4 of the SE 1/4 of sec. 20, R5W, T2S, Maricopa County, Arizona.</td>
<td>0.538</td>
<td>2.54</td>
<td>78.9</td>
<td>2.62 ± 0.45</td>
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<tr>
<td>73-5</td>
<td>Basalt from roadcut, 8.7 miles east of Sentinel turn-off on Highway 80, Maricopa County, Arizona.</td>
<td>0.900</td>
<td>2.77</td>
<td>92.6</td>
<td>1.71 ± 0.25</td>
</tr>
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**K-Ar DATA ON UAKA-73-149, FUGRO'S INTERCOMPARISON SAMPLE AR-1-73,**
Whole Rock, Olivine Basalt from Arlington Flow, Maricopa County, Arizona

<table>
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<tr>
<th>Sample No.</th>
<th>Percent K</th>
<th>Radiogenic argon-40 in x10^-12 m/g</th>
<th>Percent atmospheric argon-40</th>
<th>Age in m.y.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data submitted to FUGRO on 10 January 1974 (The numbers in parentheses were not given)</td>
<td>0.5345</td>
<td>1.88</td>
<td>85.3</td>
<td>(1.97 ± 0.19)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.54</td>
<td></td>
<td>(1.61 ± 0.19)</td>
</tr>
<tr>
<td>Reanalysis of the hand specimen we saved. It was treated as a separate and discrete sample.</td>
<td>0.558</td>
<td>1.96</td>
<td>83.0</td>
<td>(1.97 ± 0.16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.95</td>
<td></td>
<td>(1.96 ± 0.16)</td>
</tr>
</tbody>
</table>
POTASSIUM–ARGON AGE DETERMINATION

Our Sample No. R-2639
Your Reference: GFAD-8-73
Submitted by: Charles E. Druitt
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality: Olivine basalt
Gillespie Dam flow
Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to-40/+60 mesh.

\[ \frac{\text{Ar}^{40*}}{\text{K}^{40}} = 0.001150 \]

\[ \text{AGE} = 19.6 \pm 1.0 \text{ M.Y.} \]

<table>
<thead>
<tr>
<th>Ar(^{40*}), ppm.</th>
<th>Ar(^{40*})/ Total Ar(^{40})</th>
<th>Ave. Ar(^{40*}), ppm.</th>
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<tr>
<td>0.001976</td>
<td>0.233</td>
<td>0.002106</td>
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<tr>
<td>0.002235</td>
<td>0.182</td>
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<thead>
<tr>
<th>% K</th>
<th>Ave. %K</th>
<th>K(^{40}), ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.505</td>
<td>1.501</td>
<td>1.831</td>
</tr>
<tr>
<td>1.497</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constants Used:
\[ \lambda_\beta = 4.72 \times 10^{-10} / \text{year} \]
\[ \lambda_e = 0.585 \times 10^{-10} / \text{year} \]
\[ K^{40}/K = 1.22 \times 10^{-4} \text{ g/g.} \]

Note: Ar\(^{40*}\) refers to radiogenic Ar\(^{40}\).
M.Y. refers to millions of years.
# Potassium-Argon Age Determination

**Sample Information**

- **Sample No.:** R-2640
- **Your Reference:** GFAD-9-73
- **Submitted by:** Charles E. Druttit
  - FUGRO
  - Arizona Project Office
  - P.O. Box 755
  - Goodyear, AZ 85338
- **Sample Description & Locality:** Olivine basalt
  - Gillespie Dam flow
  - Maricopa Co., AZ
- **Material Analyzed:** Whole rock, crushed to -40/+60 mesh.

**Analytical Results**

\[
\frac{\text{Ar}^{40*}}{\text{K}^{40}} = 0.001122
\]

\[
\text{AGE} = 19.1 \pm 0.9 \text{ M.Y.}
\]

### Argon Analyses:

<table>
<thead>
<tr>
<th>Ar(^{40*}), ppm.</th>
<th>Ar(^{46*})/ Total Ar(^{40})</th>
<th>Ave. Ar(^{40*}), ppm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002349</td>
<td>0.282</td>
<td>0.002419</td>
</tr>
<tr>
<td>0.002633</td>
<td>0.305</td>
<td></td>
</tr>
</tbody>
</table>

### Potassium Analyses:

<table>
<thead>
<tr>
<th>% K</th>
<th>Ave. %K</th>
<th>K(^{40}), ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.820</td>
<td>1.819</td>
<td>2.219</td>
</tr>
<tr>
<td>1.818</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Constants Used:

\[
\lambda_g = 4.72 \times 10^{-10} \text{ / year}
\]

\[
\lambda_e = 0.585 \times 10^{-10} \text{ / year}
\]

\[
K^{40}/K = 1.22 \times 10^{-6} \text{ g/g.}
\]

**Note:** Ar\(^{40*}\) refers to radiogenic Ar\(^{40}\).

M.Y. refers to millions of years.
POTASSIUM-ARGON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.  R-2638
Your Reference:  GFAD-7-73
Date Received:  16 October 1973
Date Reported:  14 December 1973

Submitted by:  Charles E. Druitt
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality:  Olivine basalt
Gillespie Dam Flow
Maricopa Co., AZ

Material Analyzed:  Whole rock, crushed to -40/+60 mesh.

\[ \text{Ar}^{40*}/\text{K}^{40} = 0.001134 \]

\[ \text{AGE} = 19.3 \pm 1.0 \text{ M.Y.} \]

---

Argon Analyses:

<table>
<thead>
<tr>
<th>Ar(^{40*}), ppm.</th>
<th>Ar(^{40*}), Total Ar(^{40})</th>
<th>Ave. Ar(^{40*}), ppm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002252</td>
<td>0.310</td>
<td>0.002422</td>
</tr>
<tr>
<td>0.002592</td>
<td>0.331</td>
<td></td>
</tr>
</tbody>
</table>

Potassium Analyses:

<table>
<thead>
<tr>
<th>% K</th>
<th>Ave. %K</th>
<th>K(^{40}), ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.751</td>
<td>1.751</td>
<td>2.136</td>
</tr>
<tr>
<td>1.751</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constants Used:

\[ \lambda_d = 4.72 \times 10^{-10} / \text{year} \]
\[ \lambda_e = 0.586 \times 10^{-9} / \text{year} \]
\[ K^{40}/K = 1.22 \times 10^{-4} \text{ g/g} \]

---

Note:  Ar\(^{40*}\) refers to radiogenic Ar\(^{40}\).
M.Y. refers to millions of years.
POTASSIUM-ARGON AGE DETERMINATION

Potassium-Argon Age Determination

REPORT OF ANALYTICAL WORK

Our Sample No.  R-2583
Your Reference:  G11a - South
Submitted by:  Charles E. Druitt
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality:  Basalt
Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to -40/+60 mesh

\[ \frac{Ar^{40}_*}{K^{40}} = 0.000381 \]

\[ AGE = 6.5 \pm 1.1 \text{ M.Y.} \]

Argon Analyses:

<table>
<thead>
<tr>
<th>Ar(^{40})*, ppm</th>
<th>(Ar^{40})/Total Ar(^{40})</th>
<th>Ave. Ar(^{40})*, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000352</td>
<td>0.146</td>
<td>0.000347</td>
</tr>
<tr>
<td>0.000342</td>
<td>0.093</td>
<td></td>
</tr>
</tbody>
</table>

Potassium Analyses:

<table>
<thead>
<tr>
<th>% K</th>
<th>Ave. %K</th>
<th>K(^{40}), ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.746</td>
<td>0.747</td>
<td>0.911</td>
</tr>
<tr>
<td>0.748</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constants Used:

\[ \lambda_p = 4.72 \times 10^{-10} / \text{year} \]
\[ \lambda_e = 0.585 \times 10^{-10} / \text{year} \]
\[ K^{40}/K = 1.22 \times 10^{-4} \text{ g/g.} \]

\[ AGE = \frac{1}{\frac{\lambda_e}{\lambda_p} + \frac{\lambda_e}{\lambda_p} \times \frac{Ar^{40}\_*}{K^{40}} + 1} \]

Note: Ar\(^{40}\)* refers to radiogenic Ar\(^{40}\).
M.Y. refers to millions of years.
POTASSIUM-ARGON AGE DETERMINATION

Our Sample No. R-2585

Your Reference: Gila - North

Submitted by: Charles E. Druitt
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality: Basalt
Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to -40/+60 mesh.

\[ \frac{\text{Ar}^{40*}}{\text{K}^{40}} = 0.000146 \]

\[ \text{AGE} = 2.5 \pm 0.9 \text{ M.Y.} \]

### Argon Analyses:

<table>
<thead>
<tr>
<th>\text{Ar}^{40*}, \text{ppm.}</th>
<th>\text{Ar}^{40*}/ \text{Total Ar}^{40}</th>
<th>\text{Ave. Ar}^{40*}, \text{ppm.}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000237</td>
<td>0.209</td>
<td>0.000215</td>
</tr>
<tr>
<td>0.000193</td>
<td>0.221</td>
<td></td>
</tr>
</tbody>
</table>

### Potassium Analyses:

<table>
<thead>
<tr>
<th>% K</th>
<th>Ave. % K</th>
<th>K^{40}, \text{ppm}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.208</td>
<td>1.204</td>
<td>1.469</td>
</tr>
<tr>
<td>1.201</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Constants Used:

\[ \lambda_\beta = 4.72 \times 10^{-10} / \text{year} \]
\[ \lambda_e = 0.585 \times 10^{-10} / \text{year} \]
\[ K^{40}/K = 1.22 \times 10^{-4} \text{ g/g.} \]

\[ \text{AGE} = \frac{1}{\lambda_e + \lambda_\beta} \ln \left[ \frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{\text{Ar}^{40*}}{K^{40}} + 1 \right] \]

**Note:** \text{Ar}^{40*} refers to radiogenic \text{Ar}^{40}.

M.Y. refers to millions of years.
Potassium-Argon Age Determination

Our Sample No. R-2633
Your Reference: GFAD-2-73
Submitted by: Charles E. Druitt
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality: Olivine basalt
Gillespie Dam flow
Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to -40/+60 mesh

\[ \frac{\text{Ar}^{40}}{\text{K}^{40}} = 0.00249 \]

\[ \text{AGE} = 4.2 \pm 0.4 \text{ M.Y.} \]

Argon Analyses:

<table>
<thead>
<tr>
<th>\text{Ar}^{40}, \text{ppm.}</th>
<th>\text{Ar}^{40}/ \text{Total Ar}^{40}</th>
<th>\text{Ave. Ar}^{40}, \text{ppm.}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000273</td>
<td>0.139</td>
<td>0.000251</td>
</tr>
<tr>
<td>0.00229</td>
<td>0.136</td>
<td></td>
</tr>
</tbody>
</table>

Potassium Analyses:

<table>
<thead>
<tr>
<th>% K</th>
<th>Ave. %K</th>
<th>K^{40}, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.835</td>
<td>0.827</td>
<td>1.008</td>
</tr>
<tr>
<td>0.819</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constants Used:

\[ \lambda_d = 4.72 \times 10^{-10} / \text{year} \]
\[ \lambda_e = 0.585 \times 10^{-9} / \text{year} \]
\[ K^{40}/K = 1.22 \times 10^{-4} \text{ g/g.} \]

Note: \text{Ar}^{40} \text{ refers to radiogenic Ar}^{40}.
M.Y. refers to millions of years.
### POTASSIUM-ARGON AGE DETERMINATION

**Our Sample No.** R-2635

**Your Reference:** GFAD-4-73

Submitted by: Charles E. Druitt  
FUGRO  
Arizona Project Office  
P.O. Box 755  
Goodyear, AZ 85338

**Sample Description & Locality:** Olivine basalt  
Gillespie Dam flow  
Maricopa Co., AZ

**Material Analyzed:** Whole rock, crushed to 40/60 mesh.

\[
\frac{\text{Ar}^{40*}}{\text{K}^{40}} = 0.000225  
\text{AGE} = 3.8 \pm 0.4 \text{ M.Y.}
\]

#### Argon Analyses:

<table>
<thead>
<tr>
<th>\text{Ar}^{40*}, \text{ppm.}</th>
<th>\text{Ar}^{40*}/\text{Total Ar}^{40}</th>
<th>\text{Ave. \text{Ar}^{40*}}, \text{ppm.}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000231</td>
<td>0.071</td>
<td>0.000242</td>
</tr>
<tr>
<td>0.000252</td>
<td>0.078</td>
<td></td>
</tr>
</tbody>
</table>

#### Potassium Analyses:

<table>
<thead>
<tr>
<th>% K</th>
<th>Ave. %K</th>
<th>\text{K}^{40}, \text{ppm}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.873</td>
<td>0.879</td>
<td>1.072</td>
</tr>
<tr>
<td>0.885</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Constants Used:

\[
\lambda_\beta = 4.72 \times 10^{-10}/ \text{year}  
\lambda_e = 0.585 \times 10^{-9}/ \text{year}  
\text{K}^{40}/\text{K} = 1.22 \times 10^{-4} \text{ g/g.}
\]

**Note:** \text{Ar}^{40*} refers to radiogenic \text{Ar}^{40}.  
M.Y. refers to millions of years.
POTASSIUM-ARGON AGE DETERMINATION

Our Sample No.  R-2637
Your Reference:  GFAD-6-73
Submitted by:  Charles E. Druitt
   FUGRO
   Arizona Project Office
   P.O. Box 755
   Goodyear, AZ 85338

Sample Description & Locality:  Olivine basalt
   Gillespie Dam flow
   Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to -40/+60 mesh.

\[ \frac{\text{Ar}^{40*}}{\text{K}^{40}} = 0.000192 \]

\[ \text{AGE} = 3.3 \pm 0.4 \text{ M.Y.} \]

**Argon Analyses:**

<table>
<thead>
<tr>
<th>Ar$^{40*}$, ppm.</th>
<th>Ar$^{40*}/$ Total Ar$^{40}$</th>
<th>Ave. Ar$^{40*}$, ppm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.000233</td>
<td>.111</td>
<td>.000200</td>
</tr>
<tr>
<td>.000167</td>
<td>.035</td>
<td></td>
</tr>
</tbody>
</table>

**Potassium Analyses:**

<table>
<thead>
<tr>
<th>% K</th>
<th>Ave. %K</th>
<th>K$^{40}$, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>.852</td>
<td>.855</td>
<td>1.043</td>
</tr>
<tr>
<td>.858</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Constants Used:**

\[ \lambda_\beta = 4.72 \times 10^{-10} / \text{year} \]
\[ \lambda_e = 0.585 \times 10^{-10} / \text{year} \]
\[ K^{40}/K = 1.22 \times 10^{-4} \text{ g./g.} \]

\[ \text{AGE} = \frac{1}{\lambda_e + \lambda_\beta} \ln \left( \frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{\text{Ar}^{40*}}{K^{40}} + 1 \right) \]

**Note:** Ar$^{40*}$ refers to radiogenic Ar$^{40}$.
M.Y. refers to millions of years.
**Potassium-Argon Age Determination**

**Report of Analytical Work**

Our Sample No. R-2641

Your Reference: GFAD-10-73

Submitted by: Charles E. Druitt

FUGRO

Arizona Project Office

P.O. Box 755

Goodyear, AZ 85338

Sample Description & Locality: Olivine basalt

Gillespie Dam flow

Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to -40/+60 mesh.

\[
\text{Ar}^{40*}/\text{K}^{40} = 0.000177 \\
\text{AGE} = 3.0 \pm 0.4 \text{ M.Y.}
\]

**Argon Analyses:**

<table>
<thead>
<tr>
<th>(\text{Ar}^{40*}), ppm.</th>
<th>(\text{Ar}^{40*}/\text{Total Ar}^{40})</th>
<th>Ave. (\text{Ar}^{40*}), ppm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000115</td>
<td>0.082</td>
<td>0.000106</td>
</tr>
<tr>
<td>0.000096</td>
<td>0.088</td>
<td></td>
</tr>
</tbody>
</table>

**Potassium Analyses:**

<table>
<thead>
<tr>
<th>% K</th>
<th>Ave. %K</th>
<th>(K^{40}), ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.491</td>
<td>0.487</td>
<td>0.594</td>
</tr>
<tr>
<td>0.484</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Constants Used:**

\[
\lambda_\beta = 4.72 \times 10^{-10} \text{ year} \\
\lambda_e = 0.585 \times 10^{-10} \text{ year} \\
K^{40}/K = 1.22 \times 10^{-4} \text{ g/g.}
\]

**Note:** \(\text{Ar}^{40*}\) refers to radiogenic \(\text{Ar}^{40}\).

M.Y. refers to millions of years.
POTASSIUM-ARGON AGE DETERMINATION

Our Sample No. R-2661
Your Reference: AR-1-73
Submitted by: Charles E. Drufft
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality: Basalt
Base of Arlington Flow

Material Analyzed: Whole rock, crushed to -60/+100 mesh.

Ar\(^{40}\)*/K\(^{40}\) = 0.000330

AGE = 5.6 ± 7.4 M.Y.

Argon Analyses:

Ar\(^{40}\)*, ppm. Ar\(^{40}\)*/ Total Ar\(^{39}\) Ave. Ar\(^{40}\)*, ppm.

.000279 .117 .000241
.000202 .117

Potassium Analyses:

% K Ave. %K K\(^{40}\), ppm

.595 .596 .727
.598

Constants Used:

\[ \lambda_{\beta} = 4.72 \times 10^{-10}/\text{year} \]
\[ \lambda_{e} = 0.585 \times 10^{-10}/\text{year} \]
\[ K^{40}/K = 1.22 \times 10^{-4} \text{g/g.} \]

Note: Ar\(^{40}\)* refers to radiogenic Ar\(^{40}\).
M.Y. refers to millions of years.
POTASSIUM-ARGON AGE DETERMINATION

Our Sample No. R-2642
Your Reference: GB-4
Submitted by: Charles E. Druitt
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality: Vesicular basalt
Gila Bend Area
Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to -40/+60 mesh.

\[ \frac{\text{Ar}^{40\ast}}{\text{K}^{40}} = 0.000196 \]

\[ \text{AGE} = 3.3 \pm 0.4 \text{ M.Y.} \]

Argon Analyses:

<table>
<thead>
<tr>
<th>Argon 40\ast ppm.</th>
<th>Ar 40\ast/Total Ar 40</th>
<th>Ave. Ar 40\ast ppm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000156</td>
<td>0.076</td>
<td>0.000157</td>
</tr>
<tr>
<td>0.000158</td>
<td>0.073</td>
<td></td>
</tr>
</tbody>
</table>

Potassium Analyses:

<table>
<thead>
<tr>
<th>%K</th>
<th>Ave. %K</th>
<th>K 40 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>.650</td>
<td>.658</td>
<td>.802</td>
</tr>
<tr>
<td>.666</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constants Used:

\[ \lambda_{\beta} = 4.72 \times 10^{-10} / \text{year} \]
\[ \lambda_{e} = 0.585 \times 10^{-10} / \text{year} \]
\[ K^{40}/K = 1.22 \times 10^{-4} \text{ g./g.} \]

\[ \text{AGE} = \frac{1}{\lambda_{e} + \lambda_{\beta}} \ln \left[ \frac{\lambda_{\beta} + \lambda_{e}}{\lambda_{e}} \cdot \frac{\text{Ar}^{40\ast}}{K^{40}} + 1 \right] \]

Note: Ar 40\ast refers to radiogenic Ar 40.
M.Y. refers to millions of years.
POTASSIUM-ARGON AGE DETERMINATION

Our Sample No. R-2634
Your Reference: GFAD-3-73
Submitted by: Charles E. Drütt
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality: Olivine basalt
Gilespie Dam flow
Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to -40/+60 mesh.

\[ \frac{\text{Ar}^{40}}{\text{K}^{40}} = 0.000201 \]

\[ \text{AGE} = 3.4 \pm 0.4 \text{ M.Y.} \]

Argon Analyses:

\[ \text{Ar}^{40*}, \text{ppm.} \]

\[ \begin{array}{ccc}
0.00199 & 0.096 \\
0.00203 & 0.073 \\
\end{array} \]

\[ \text{Ar}^{40*}/ \text{Total Ar}^{40} \]

\[ \begin{array}{ccc}
0.000201 \\
\end{array} \]

\[ \text{Ave. Ar}^{40*}, \text{ppm.} \]

Potassium Analyses:

\[ \text{% K} \]

\[ \begin{array}{ccc}
0.812 \\
0.824 \\
\end{array} \]

\[ \text{Ave. %K} \]

\[ \begin{array}{ccc}
0.818 \\
\end{array} \]

\[ \text{K}^{40}, \text{ppm} \]

\[ \begin{array}{ccc}
0.997 \\
\end{array} \]

Constants Used:

\[ \lambda_\beta = 4.72 \times 10^{-10} / \text{year} \]
\[ \lambda_\alpha = 0.585 \times 10^{-10} / \text{year} \]
\[ \text{K}^{40}/\text{K} = 1.22 \times 10^{-4} \text{ g/g.} \]

\[ \text{AGE} = \frac{1}{\lambda_\alpha + \lambda_\beta} \ln \left[ \frac{\lambda_\beta + \lambda_\alpha}{\lambda_\alpha} \times \frac{\text{Ar}^{40*}}{\text{K}^{40}} + 1 \right] \]

Note: \( \text{Ar}^{40*} \) refers to radiogenic \( \text{Ar}^{40} \).
M.Y. refers to millions of years.
POTASSIUM-ARGON AGE DETERMINATION

Our Sample No. R-2632
Your Reference: GFAD-1-73

Submitted by: Charles E. Druitt
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality: Olivine basalt
Gillespie Dam Flow
Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to -40/+60 mesh.

\[ \frac{\text{Ar}^{40}}{\text{K}^{40}} = 0.000200 \]

\[ \text{AGE} = 3.4 \pm 0.4 \text{ M.Y.} \]

Argon Analyses:

\[
\begin{array}{ccc}
\text{Ar}^{40} & \text{ppm.} & \text{Ar}^{40}/ \text{Total Ar}^{40} & \text{Ave. Ar}^{40}, \text{ppm.} \\
0.000237 & 0.126 & & \\
0.000212 & 0.125 & 0.000225 & \\
\end{array}
\]

Potassium Analyses:

\[
\begin{array}{ccc}
\% \text{K} & \text{Ave.} \% \text{K} & \text{K}^{40}, \text{ppm} \\
0.916 & 0.918 & 7.119 \\
0.920 & & \\
\end{array}
\]

Constants Used:

\[
\begin{align*}
\lambda_0 &= 4.72 \times 10^{-10} / \text{year} \\
\lambda_e &= 0.585 \times 10^{-10} / \text{year} \\
K^{40}/K &= 1.22 \times 10^{-4} \text{g/g.}
\end{align*}
\]

\[ \text{AGE} = \frac{1}{\lambda_e + \lambda_0} \ln \left[ \frac{\lambda_0 + \lambda_e}{\lambda_e} \times \frac{\text{Ar}^{40}}{\text{K}^{40}} + 1 \right] \]

Note: \( \text{Ar}^{40} \) refers to radiogenic \( \text{Ar}^{40} \).
M.Y. refers to millions of years.
POTASSIUM-ARGON AGE DETERMINATION

Our Sample No.  R-2584
Your Reference: Gila - Central
Submitted by:  Charles E. Druitt
FUGRO
Arizona Project Office
P.O. Box 755
Goodyear, AZ 85338

Sample Description & Locality: Basalt
Maricopa Co., AZ

Material Analyzed: Whole rock, crushed to -40/+60 mesh

\[
\frac{\text{Ar}^{40*}}{\text{K}^{40}} = 0.000263
\]

\[
\text{AGE} = 4.5 \pm 0.9 \quad \text{M.Y.}
\]

Argon Analyses:

\[
\begin{array}{ccc}
\text{Ar}^{40*} \text{, ppm.} & \text{Ar}^{40*} / \text{Total Ar}^{40} & \text{Ave. Ar}^{40*} \text{, ppm.} \\
0.000244 & 0.112 & 0.000250 \\
0.000257 & 0.131 & \\
\end{array}
\]

Potassium Analyses:

\[
\begin{array}{ccc}
\text{\% K} & \text{Ave. \% K} & \text{K}^{40} \text{, ppm} \\
0.767 & 0.779 & 0.950 \\
0.790 & & \\
\end{array}
\]

Constants Used:

\[
\lambda_\beta = 4.72 \times 10^{-10} / \text{year} \\
\lambda_e = 0.585 \times 10^{-10} / \text{year} \\
K^{40} / K = 1.22 \times 10^{-4} \quad \text{g/g.}
\]

\[
\text{AGE} = \frac{1}{\lambda_e + \lambda_\beta} \ln \left[ \frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{\text{Ar}^{40*}}{K^{40}} + 1 \right]
\]

Note:  \text{Ar}^{40*} \text{ refers to radiogenic Ar}^{40}.
M.Y. refers to millions of years.
Appendix 2.

*LATE CENOZOIC GEOLOGY ALONG THE GILA RIVER NEAR GILLESPIE DAM, CENTRAL ARIZONA
Lee, Gaylon K., Fugro, Inc., 3777 Long Beach Boulevard, Long Beach, California 90807; Bell, John, Fugro, Inc., 3777 Long Beach Boulevard, Long Beach, California 90807

Detailed geomorphic and age dating studies on remnants of three paired terraces along the Gila River near Gillespie Dam, Arizona (43 miles west-southwest of Phoenix) indicate that (1) the Gila River has incised at least 3 times since its integration between the Phoenix and Gila Bend Basins, and (2) the two higher terraces are at least late Pliocene in age, somewhat older than previously thought. The three terrace levees are 80, 40 and 20 feet above the present Gila River channel. Old pediments and alluvial fan deposits from the adjacent Gila Bend Mountains were graded to and interfingered with deposits of the 80 foot terrace, the highest level of deposition by the Gila River. The 40 foot terrace is relatively well preserved and locally covered by basalt flows near Gillespie Dam and Arlington, Arizona (potassium-argon dated at 3.3 million years and about 2 million years, respectively). The Gillespie Basalt Flow dammed the Gila River at the west end of the Buckeye Hills forcing the river to cut a narrow gorge through Miocene volcanic rocks ~ few thousand feet east of its former channel. Alluvial fans, local pediments, and tributary stream terraces were graded to the 40 foot terrace after extrusion of the Gillespie Basalt. Young alluvial fans at the border of the old river flood plain were graded to the 20 foot silty terrace level. Potsherds of the Hohokam Indian culture contained within deposits of the 20 foot terrace are about 1,100 years old.

*Permission to include this abstract in its entirety requested of the Geological Society of America.