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K-AR AGES OF THE FRIANT PUMICE MEMBER OF THE TURLOCK LAKE FORMATION, THE BISHOP TUFF, AND THE TUFF OF REDS MEADOW, CENTRAL CALIFORNIA

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The Bishop Tuff (Gilbert, 1938; Sheridan, 1965; Bateman, 1965; Bailey and others, 1976; Hildreth, 1979) is a voluminous rhyolitic ash flow tuff sheet erupted from Long Valley caldera on the east side of the Sierra Nevada, north of Bishop. The tuff overlies the Sherwin Till (Sharp, 1968), providing evidence of glaciation more than 0.7 m.y. old in the Sierra Nevada. Ash from the eruption of the Bishop Tuff is found over a large area of the western United States, as far east as Nebraska, and serves as a valuable Quaternary stratigraphic marker horizon (Izett and others, 1970; Merriam and Bischoff, 1975). The Bishop Tuff has normal magnetic polarity and was erupted during the earliest part of the Brunhes Normal Epoch (Dalrymple and others, 1965).

The tuff of Reds Meadow (Huber and Rinehart, 1967) is a rhyolitic ash flow tuff, similar to the Bishop Tuff, exposed in scattered erosional remnants in the valley sides of the Middle Fork of the San Joaquin River only a few kilometers from Long Valley. Huber and Rinehart (1967) speculated that the tuff of Reds Meadow may be correlative with the Bishop Tuff, and whole-rock and mineral chemical data (Hildreth, 1979) tend to confirm the correlation. The tuff of Reds Meadow has normal polarity and a paleomagnetic direction that is nearly identical to that of the Bishop Tuff (Allan Cox, quoted in Huber and Rinehart, 1967).

The Friant Pumice Member of the Pleistocene Turlock Lake Formation is an alluvial deposit exposed in the eastern San Joaquin Valley where the San Joaquin River emerges from the Sierra Nevada. Where exposed, the member consists almost entirely of rhyolitic ash and pumice that was probably deposited very shortly after eruption from a source in the San Joaquin River drainage (Janda, 1965). The Friant Pumice Member occurs near the base of the upper unit of the Turlock Lake Formation, an alluvial deposit that probably represents glacial outwash from the Sierra Nevada. In the subsurface the Friant rests conformably on the Corcoran Clay Member of the Turlock Lake, which is a widespread stratigraphic marker in the subsurface of the San Joaquin Valley (Janda, 1965; Marchand, 1976; Marchand and Allwardt, in press). The source of the Friant is unknown, but Huber and Rinehart (1967) speculated that it might be correlative with the tuff of Reds Meadow and the Bishop Tuff. In the subsurface of the southern San Joaquin Valley near Bakersfield, a thin rhyolitic ash layer occurs near the base of the E clay of Croft (1972) and 4 m above the magnetic reversal marking the Brunhes-Matuyama polarity transition (Davis and others, 1977). The E clay has been correlated with the Corcoran Clay Member (Croft, 1972) and the ash with the Bishop Tuff (Davis and others, 1977).

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The ages of the three rhyolitic tuff units are of considerable importance because of the value of the ash of the Bishop Tuff and the Corcoran Clay Member as widespread Quaternary stratigraphic markers, the relation of the Bishop Tuff to the type Sherwin Till, and the occurrence of the Friant Pumice Member in probable glacial outwash. This note provides some previously unpublished K-Ar age data, reconciles all of the existing ages to the new decay constants (Steiger and Jager, 1977), and provides a brief evaluation of the age data.

The currently accepted K-Ar age of the Bishop Tuff is based on the analyses of Dalrymple and others (1965), who also reviewed previous work. Samples from three localities (see below) gave ages ranging from 0.69 to 0.76 m.y. with a weighted mean, where weighting is by the inverse of the variance, of 0.725 ± 0.015. None of the individual sample ages differ from the weighted mean at the 95 percent level of confidence. The K-Ar age of 0.725 m.y. agrees with fission track ages of two samples averaging 0.74 ± 0.05 m.y. (Izett and Naeser, 1976). The K-Ar age is also stratigraphically consistent with K-Ar ages of eight rhyolite domes in Long Valley caldera that postdate the eruption of the Bishop Tuff (Bailey and others, 1976). Seven of these domes have calculated ages that fall between 0.652 ± 0.014 m.y. and 0.694 ± 0.017 m.y. The eighth dome has a calculated age of 0.751 ± 0.016 m.y., which does not differ significantly from the Bishop Tuff age at the 95 percent level of confidence.

The age of the tuff of Reds Meadow is based on two measurements on a sample (2C530) from the basal air-fall unit exposed near Devils Postpile National Monument. The mean of these measurements is 0.675 ± 0.024 m.y., which does not differ significantly from the Bishop Tuff age at the 95 percent confidence level.

The age of the Friant Pumice Member is based on K-Ar measurements in two laboratories on two separate samples collected from the California Industrial Minerals Co. quarry north of Friant. The ages are virtually identical with a weighted mean of 0.615 ± 0.022 m.y. This age does not differ significantly from the age of 0.675 m.y. for the tuff of Reds Meadow but differs significantly from the 0.725 m.y. age of the Bishop Tuff at the 95 percent level of confidence. If the confidence level is lowered to 90 percent, then the difference in age between the Friant and the tuff of Reds Meadow becomes statistically significant.

Contamination by older xenocrystic material is always a potential problem in the accurate K-Ar dating of welded tuffs. This problem is well illustrated by the numerous incorrect (older) ages published for the Bishop Tuff (see summaries in Dalrymple and others, 1965; Izett and Naeser, 1976) and by the older ages obtained for bulk samples of the tuff of Reds Meadow (sample 427f below: Huber and Rinehart, 1967). Recent mineralogical work on pumice from the Bishop Tuff has shown the existence of rare xenocrystic andesine and hornblende (Hildreth, 1979) and other heavy minerals (Sarna-Wojcicki and others, 1980), but xenocrystic potassium feldspar has not been found. Thus, although it is thought that the separation of sanidine from carefully cleaned pumice fragments circumvents the contamination problem (Dalrymple and others, 1965), the possibility that contaminating potassium feldspar remains within the pumice cannot be entirely precluded.

On the basis of existing radiometric age data and the presumption that the sanidine separates were not significantly contaminated by older xenocrystic potassium feldspar, I tentatively conclude that the Friant Pumice Member is younger than the Bishop Tuff and is probably younger than the tuff of Reds Meadow. The Bishop Tuff and the tuff of Reds Meadow are probably correlative. This correlation is strengthened by the identical magnetic polarities and paleomagnetic directions (Allan Cox, quoted in Huber and Rinehart, 1967; Dalrymple and others, 1965) and the chemical similarity (Hildreth, 1979) of the two units.

If these conclusions are correct, then the Friant Pumice Member, which rests conformably on the Corcoran Clay Member, and the (Bishop?) ash, which occurs near the base of the E clay in the southern San Joaquin Valley, may not be correlative but instead may represent two distinct ash eruptions. In addition, the Turlock Lake Formation then represents outwash from a post-Sherwin glaciation (c.a. 0.615 m.y. old) in the Sierra Nevada. If the Friant was not derived from the Bishop Tuff or the tuff of Reds Meadow, then the source of the Friant remains a mystery as no other potential source area has been found (Huber and Rinehart, 1967).

The conclusion that the Friant Pumice Member represents a post-Bishop Tuff eruption differs from the conclusion of Sarna-Wojcicki and others (1980), who have discussed the problem in detail and correlate these two units primarily on the basis of stratigraphic relations in the Borrego Formation of Tarbet and Holman (1944) east of the Salton Sea and the lack of another source for the Friant. I agreee, however, with Sarna-Wojcicki and his colleagues that uncertainty remains as to the exact ages and possible correlation of the Bishop Tuff and the Friant, and the hypothesis that these two units are correlative cannot yet be precluded.

Argon measurements were done by isotope dilution using equipment and techniques described by Dalrymple and Lanphere (1969). Potassium was measured by flame photometry using a lithium internal standard. Constants used in the calculations are $\lambda_\epsilon + \lambda_\epsilon' = 0.581 \times 10^{-10}$ yr^{-1}, $\lambda_\beta = 4.692 \times 10^{-10}$ yr^{-1}, K^{40}/K total $= 1.167 \times 10^{-4}$ mol/mol. Errors are estimates of the standard deviation of precision (Cox and Dalrymple, 1967). I thank N. K. Huber, D. E. Marchand, and A. M. Sarna-Wojcicki for their manuscript reviews and most helpful suggestions.

SAMPLE DESCRIPTIONS

1. *66A069* K-Ar

Friant Pumice Member (37°00'35"N, 119°43'57"W; in quarry of California Industrial Minerals Co.; NE¼ NE¼ S1,T11S,R20E; Millerton Lake West 7½' quad; Madera Co., CA). *Analytical data*: K_2O = 11.02%, 11.02%, $^*Ar^{40} = 9.80 \times 10^{-12}$ mole/gm, $^*Ar^{40}/\Sigma Ar^{40}$ = 64.3%. *Collected by*: R. J. Janda and G. B. Dalrymple, 1966. *Comment*: Sample consisted of pink pumice pebbles hand-picked from the upper part of the pumice alluvium exposed in the quarry and cleaned in the laboratory. 62SJ-1 (below) is from the same locality. U.S.G.S. analysis.

(sanidine) 0.618 ± 0.031 m.y.

2. *62SJ-1* K-Ar

Friant Pumice Member (same locality as 66A069, above). *Analytical data*: K_2O = 10.39%, 10.50%, $^*Ar^{40} = 9.21 \times 10^{-12}$ mole/gm, $^*Ar^{40}/\Sigma Ar^{40}$ = 87.0%. *Collected by*: R. J. Janda, 1962. *Comment*: The sample consisted of pink pumice pebbles hand-picked from the upper part of the pumice alluvium exposed in the quarry and cleaned in the laboratory. Partial analytical data were published by Janda (1965). Berkeley analysis KA1064.

(sanidine) 0.612 ± 0.031 m.y.

3. *2C530* K-Ar

Tuff of Reds Meadow (37°37'50"N, 119°04'10"W; on SE side of stream gully 250 m NE of Sotcher Lake, Devils Postpile 15' quad, Madera Co., CA). *Analytical data*: K_2O = 10.71%, 10.72%, $^*Ar^{40} = 1.008 \times 10^{-11}$ mole/gm, 1.078×10^{-11} mole/gm, $^*Ar^{40}/\Sigma Ar^{40}$ = 55.5%, 62.3%. *Collected by*: Allan Cox, N. K. Huber, and G. B. Dalrymple, 1962. *Comment*: The sample is from the basal air fall pumice and consists of pumice pebbles screened at the outcrop then hand-picked and cleaned in the laboratory. Partial analytical data published by Huber and Rinehart (1967). U.S.G.S. analyses.

(sanidine) 0.675 ± 0.024 m.y.

4. *427f* K-Ar

Tuff of Reds Meadow (37°37'06"N, 119°04'22"W; 100 m E of Reds Meadow Hot Spring, Devils Postpile 15' quad, Madera Co., CA). *Analytical data*: K_2O = 10.57%, 10.63%, $^*Ar^{40} = 1.678 \times 10^{-11}$ mole/gm, $^*Ar^{40}/\Sigma Ar^{40}$ = 7.50%. *Collected by*: R. J. Janda, 1962. *Comment*: The sanidine was separated from a sample of the welded ignimbrite and is almost certainly contaminated with older material. The apparent age is a maximum age for the unit only. The age is cited by

Huber and Rinehart (1967) along with an age of 1.4 m.y. measured on another bulk sample of the loosely welded ignimbrite collected near 427f (R. W. Kistler, personal communication, 1965). Berkeley analysis KA1233.

(sanidine) 1.10 ± 0.05 m.y.

5. *64G001* K-Ar
Bishop Tuff (37°27'33"N, 118°22'02"W; W½ S4, T6S,R33E; in quarry on W side of road, Bishop 15' quad, Inyo Co., CA). *Analytical data*: K_2O = 10.63%, 10.56%, $*Ar^{40}$ = 1.152 x 10^{-11} mole/gm, 1.180 x 10^{-11} mole/gm, $*Ar^{40}/ΣAr^{40}$ = 61.6%, 45.8%. *Collected by*: Allan Cox and G. B. Dalrymple, 1964. *Comment*: Sanidine separated from pumice fragments from unwelded ash flow near base of unit. Data and description from Dalrymple and others (1965).

(sanidine) 0.764 ± 0.027 m.y.

6. *64G002* K-Ar
Bishop Tuff (37°33'28"N, 118°39'22"W; in road cut on NE side U.S. 395, W½ S34,T4S,R30E). *Analytical data*: K_2O = 10.69%, 10.72%, $*Ar^{40}$ = 1.154 x 10^{-11} mole/gm, 1.090 x 10^{-11} mole/gm, $*Ar^{40}/ΣAr^{40}$ = 56.0%, 78.6%. *Collected by*: R. J. Janda, 1964. *Comment*: Sanidine separated from pumice fragments from basal air-fall unit. Data and description from Dalrymple and others (1965).

(sanidine) 0.726 ± 0.025 m.y.

7. *64G003* K-Ar
Bishop Tuff (37°49'29"N, 118°46'34"W; SE¼ SE¼ S28,T1S,R29E; from outcrop SE side of road at 8420 ft. elevation, Cowtrack Mtn. 15' quad, Mono Co., CA). *Analytical data*: K_2O = 10.94%, 10.97%, $*Ar^{40}$ = 1.035 x 10^{-11} mole/gm, 1.160 x 10^{-11} mole/gm, $*Ar^{40}/ΣAr^{40}$ = 42.2%, 60.9%. *Collected by*: C. M. Gilbert, 1964. *Comment*: Sanidine separated from large pumice block from near upper exposed surface of the Bishop Tuff. Data and description from Dalrymple and others (1965).

(sanidine) 0.691 ± 0.025 m.y.

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