ments, were tried in the "eye" of the tool. The best fit of a cylindrical shaft to the tool, as determined by the contact of the shaft with the interior surfaces of the beveled hole, is by a 15-mm-diameter shaft. Such a shaft makes an angle of 40 degrees with the long axis of the tool, regardless of which side of the hole it is inserted through, and the shaft surface snugly fits the beveled surfaces at the top and bottom of the hole. An 18-mm-diameter shaft does not quite fit the rounded trough-like bevels, and makes an angle of about 44 degrees with the long axis of the tool, whereas a shaft as small as 13 mm in diameter is decidedly a misfit, even though it could be easily bent by the tool.

These experiments suggest that as a shaft wrench the tool would be most effective on shafts between 14 and 17 mm in diameter, which are comparable with what one would expect to have been used for hafting the 25 Clovis points now known from San Pedro Valley. The lightness of shafts of these diameters suggests that they may have been used as foreshafts for spears or darts.

To the best of our knowledge this possible Clovis shaft wrench is unique in New World archeology; we would appreciate information regarding similar finds in either the New World or the Old.

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Glaciation in Taylor Valley, Antarctica, Older Than 2.7 Million Years

Abstract. *Potassium-argon dates for three samples of basaltic scoria from Taylor Valley, on the west side of McMurdo Sound, indicate that the basalt, which antedates and postdates major glaciations, is at least 2.7 million years old.*

The extensive ice-free areas in the Transantarctic Mountains, fringing the west coast of McMurdo Sound, are among the largest in Antarctica. Drift left by ancient glaciers is widespread, and thus the region offers an outstanding opportunity for study of the glacial history of the continent. Taylor Valley extends for about 85 km through the mountains, from the Antarctic Ice Sheet on the west to McMurdo Sound on the east. The western 50 km of the valley are occupied by Taylor Glacier, an outlet of the ice sheet; the eastern 35 km are now free of ice except for small alpine glaciers on the valley walls (Fig. 1). The floor of the eastern part of the valley ranges in altitude from sea level to about 100 m, and the flanking peaks attain altitudes exceeding 2000 m.

Taylor Valley has been extensively modified by ice during past glaciations. The cross profile is characterized by a

Fig. 1. Taylor Valley, eastward to McMurdo Sound; sources of the dated basalts are indicated on the upper benches and walls. Circles mark basalts at known and possible vent areas; nearby dark accumulations of basalt are talus, till, gelifluction deposits. The *x*'s mark sources of dated samples (Table 1). The dark strip of basalt debris near Taylor Glacier (lower right) is a moraine derived mainly from volcanic sources, further up the valley, on the valley wall. The flanking mountains stand as high as 2000 m above ice-covered Lake Bonney (center). [U.S. Navy, for U.S. Geological Survey, 7 November 1959]

narrow, inner, U-shaped valley set within an outer valley consisting of broad benches that meet the steep, straight valley walls with an open-U profile (Fig. 1). All spurs on the valley walls are truncated, glacially molded bedrock is common, and hanging valleys are present. Glacial drift mantles the valley to an altitude of at least 1000 m (*1, 2*). Péwé (*1*) assigned drift throughout the McMurdo Sound region, including Taylor Valley, to four glaciations; although bracketing radiometric dates were not available, he attributed great ages to the drift of the older glaciations, on the basis of weathering and erosional features. Angino and others (*2*) mapped moraines and volcanic complexes in part of Taylor Valley and related some of the features to Péwé's sequence.

Fig. 2. View southward across the high-valley surfaces on the south side of Taylor Valley. Basalt in the lower part of the photograph has been eroded and smeared out by an advance of Taylor Glacier; sample 1 (Table 1) is from this complex. Basalt in the upper part of the photograph is overlaid by a moraine deposited by the small glacier in the background. Evidence of post-eruption glaciation of the basalt in the center of the photograph is inconclusive. [U.S. Navy, for U.S. Geological Survey, 22 November 1958]

Numerous small cinder cone–lava flow complexes of basalt have been erupted from short fissures on the broad benches and walls of the outer valley to an altitude of at least 1500 m (*3*). The basalt complexes all rest on surfaces within glacially eroded Taylor Valley (Fig. 1) and thus postdate extensive glaciation of the valley. Below about 800-m altitude the cones and flows have been extensively eroded by advances of Taylor Glacier; basalt now occurs as irregular mounds, and scoria have been smeared out and incorporated in the glacial drift. Above 800 m some volcanic features, fronting alpine glaciers, have been overrun by local advances (*2*); whether all have been affected by glacial advances is a question that must await further field study. The relation of the volcanic features to the glacial sequence proposed (*1*) for the region is still uncertain, although the dated volcanics may antedate all four major glaciations recognized by Péwé. The only firm conclusions warranted at present are that all the volcanics postdate extensive glaciation of the valley, and that many of the volcanics antedate later advances of Taylor Glacier and small glaciers on the valley walls.

The lava flows and cones in upper Taylor Valley are composed of alkaline olivine-augite-labradorite basalt; most of the basalt is vesicular. The average of four similar chemical analyses yields (percentages by weight): SiO_2, 45.0; Al_2O_3, 14.8; iron as FeO, 13.0; MgO, 7.1; CaO, 9.3; Na_2O, 4.3; K_2O, 1.7; TiO_2, 2.9; P_2O_5, 0.65; MnO, 0.22; H_2O, 0.8; and CO_2, 0.16.

Potassium-argon dates were obtained from three whole-rock samples of the basalt (Table 1). Sample 1 is from a basaltic complex that has been modified by an advance of Taylor Glacier (Fig. 2); sample 2 is from an eruption that, according to Angino and others (*2*), antedates and postdates local advances of Solas Glacier, a small alpine glacier on the south wall of the valley; and sample 3 is from a lateral moraine of Taylor Glacier and was derived from a source on the valley wall. The samples, all of which are vesicular and porphyritic, contain up to 30 percent glass; however, no zeolites or other signs of alteration are present.

Table 1. Potassium-argon dates from whole-rock samples of basalt from upper Taylor Valley. Sample 1 (Fig. 1): from basalt complex on a bedrock bench 4 km east of Lake Bonney (Fig. 2); the complex has been overridden by an advance of Taylor Glacier, and scoria have been incorporated into the drift. Sample 2: from scoria pile that antedates and postdates local advances of Solas Glacier (*3*). Sample 3: from lateral moraine near snout of Taylor Glacier; sample derived from volcanic complex further up the valley. Constants used for calculations of dates: $K_{\lambda\beta}$, 4.72 $\times$ 10^{-10} year; $K_{\lambda e}$, 0.584 $\times$ 10^{-10} year; K^{40}/K, 0.0119 atm percent.

Radiogenic Ar^{40} ($\times$ 10^{-6} cm^3)	Air correction (%)	K (%)	Age ($\times 10^6$ yr)
	Sample 1		
0.13	92	1.21	2.8 ± 0.2
.14	90	1.20	
	Sample 2		
.14	98	1.36	2.3 ± .8
.11	98		
(.08)	(99)		
	Sample 3		
.15	93	1.43	2.6 ± .2
.14	80	1.41	

Analyses for argon were done by isotopic dilution. The precision of the total-argon determination and the correction for atmospheric argon were accurate to within 1 percent. Potassium analyses were done by atomic-absorption spectrophotometry. The relatively high potassium contents and the unexpectedly great ages resulted in production of measurable amounts of radiogenic argon, despite the large atmospheric-argon corrections. Within limits of errors, two of the samples give identical ages of about 2.7 million years, and the third, less accurately dated, could be of the same age. The consistent results indicate that argon probably has been retained by the glass in the samples; however, if argon has been lost, the dates provide minimum ages for the samples.

The main conclusion, derived from the two accurately dated basalts and their relation to glacial features, is that glaciations in Taylor Valley antedated and postdated 2.7 million years. Whether the ice sheet in East Antarctica had attained a full-bodied condition, similar to its present configuration, prior to 2.7 million years ago, or whether Taylor Glacier was at that time fed from accumulation in currently ice-covered highlands west of Taylor Valley, remains an open question.

Elsewhere in Antarctica, a potassium-argon date, of basalt resting on a glaciated surface, indicates that Jones Mountains were glaciated more than 22 ± 12 million years ago (*4*). Paleomagnetic stratigraphy and the occurrence of ice-rafted debris in Antarctic deep-sea cores indicate that calving glaciers were present in Antarctica at least 3 million years ago, and that the greatest amount of ice-rafted debris was produced between 2 and 3 million years ago (*5*). From the ranges of sub-Antarctic and Antarctic planktonic Foraminifera in deep-sea cores, Bandy (*6*) concluded that Antarctica was largely covered by ice during the late Miocene and middle Pliocene; thus the potassium-argon dates from Taylor Valley are consistent with these other data in pointing to the great antiquity of major Antarctic glaciation.

Note added in proof: Fieldwork now in progress has confirmed that till deposited by Taylor Glacier underlies the dated volcanics, and that subsequent advances of the glacier have overrun the volcanics at least up to an altitude of approximately 1250 m.

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Cosmic Ray–Produced Radionuclides as Tracers of Atmospheric Precipitation Processes

Abstract. *Through recent developments in instrumental analysis it is now possible to measure with good precision the rainwater concentrations of five short-lived radionuclides which are produced by cosmic ray spallation of atmospheric argon. These measurements provide a method for studying the in-cloud nucleation times and aerosol scavenging efficiencies, and promise to provide information on short-term processes which occur in rain and snow formation.*

Radionuclides are produced continuously in the atmosphere by cosmic rays. Their absolute production rates vary considerably with both altitude and latitude but remain relatively constant with time. Following formation, most of these radionuclides quickly become attached to the normal atmospheric aerosols and thus can serve as tracers of the subsequent behavior of these aerosols. Some of the radionuclides with half-lives of months to years have been used in studying atmospheric mixing processes, while the longer-lived radionuclides have served as tracers of geophysical processes and in dating biological and geological phenomena. It has been recognized that radionuclides with half-lives of minutes to hours would be useful in studying atmospheric precipitation scavenging mechanisms since their half-lives are of the same order of magnitude as the time scale on which precipitation processes occur (*1, 2*).

The main deterrent in the use of these radionuclides as tracers of atmospheric processes has been the fact that they are present in extremely small concentrations and are therefore very difficult to detect and measure. With the development of ultrasensitive counting techniques, it has become possible to measure several of these short-lived radionuclides with high precision (*3, 4*). The five radionuclides, ^{34m}Cl ($T_{1/2}$ = 32 minutes), ^{38}Cl ($T_{1/2}$ = 37.3 minutes), ^{39}Cl ($T_{1/2}$ = 55 minutes), ^{38}S ($T_{1/2}$ = 2.9 hours), and ^{24}Na ($T_{1/2}$ = 15 hours), which are spallation products of atmospheric argon, have been measured in several rains and their relative and absolute concentrations determined. Their absolute concentrations in precipitation are related to the scavenging efficiency and the altitude from which the precipitation occurred, while their relative concentrations provide information on the time spent by the host particles subsequent to collection in the cloud but prior to their deposition at the earth's surface.

In spallation reactions with the atmosphere, high-energy primary cosmic rays produce large numbers of secondary neutrons and protons which in turn are responsible for most of the spallation reactions resulting in radionuclide production in the atmosphere. The production rate of radionuclides in the atmosphere depends on both altitude and latitude, and are discussed in detail by Lal and Peters (*5*). The overall relative production rate per gram of air increases by 2 to 3 orders of magnitude between sea level and the top of the atmosphere. Although the total atmospheric production rate increases by almost an order of magnitude in moving from the geomagnetic equator to the poles, the tropospheric production rate only varies by about twofold. About 30 percent of the radionuclide production takes place in the troposphere and the remainder in the stratosphere.

The radionuclides resulting from cosmic ray spallation reactions in the atmosphere which have been observed to date, with their half-lives, include ^{10}Be (2.7×10^6 years), ^{36}Cl (3×10^5 years), ^{14}C (5730 years), ^{32}Si (~ 700 years), ^{3}H (12.26 years), ^{22}Na (2.60 years), ^{35}S (86.7 days), ^{7}Be (53 days), ^{33}P (25 days), ^{32}P (14.3 days), ^{28}Mg (21.3 hours), ^{24}Na (15.0 hours), ^{38}S (2.9 hours), ^{31}Si (2.62 hours), ^{39}Cl (55 minutes), ^{38}Cl (37.3 minutes), and ^{34m}Cl (32.0 minutes) (*2, 6*). The latter of this group, with half-lives of minutes to hours, can be used as tracers of precipitation-scavenging processes.

Measurements of the absolute production rates of these radionuclides have not been reported; however, estimates which are good to within a factor of 3 or 4 can be made which are based on spallation-yield curves extrapolated to argon (*5*). The absolute atmospheric production rates of these short-lived radionuclides are now being more precisely estimated from measurements of the equilibrium concentration of the radionuclides in the air (*7*).