U.S. DEPARTMENT OF THE INTERIOR
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URANIUM-SERIES DATES ON SEDIMENTS OF THE
HIGH SHORELINE OF PANAMINT VALLEY, CALIFORNIA

by

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INTRODUCTION

The Owens River system consisted of a chain of pluvial lakes occupying a succession of closed basins in southeastern California (Fig. 1). The lakes were supplied primarily by the Owens River which drains the eastern side of the Sierra Nevada, and during historic times Owens Lake has been the terminus of the system. During wetter climates of the past, Owens Lake overflowed to progressively fill a succession of lower basins, China Lake, Searles Lake, Panamint Lake (Lake Gale), and finally, Death Valley Lake (Lake Manly). For most of the past million years Searles Lake was the terminus of the system in which accumulated a 1000 m thickness of sediments and residual salts of the Owens River drainage (G. I. Smith 1984), during which time Panamint and Death Valley remained dry. During climatic extrema Searles Lake overflowed to supply Panamint Lake, and even more rarely, Panamint overflowed to Death Valley. Such events in Panamint Valley are recorded by patchy remnants of shorelines and lake sediments which have been described and documented in the Ph.D. dissertation of R.S. Smith (1976).

At its overflow level the depth of Panamint Lake exceeded 950 feet, its area was about 300 square miles and its volume was about 92 million acre feet (Smith, 1976). The elevation of the high stand was controlled by overflow into Death Valley through Wingate Pass which today is at 1977±1 feet. Patchy shorelines with remnant tufa traceable to this level are found locally throughout Panamint Valley today, and range from 1640 to 2050 feet, apparently modified by late Quaternay tectonism.

Because this shoreline represents an unusually wet period, its exact chronology is of great importance in the reconstruction of the climatic history of the Owens River system. Earlier U-series dating of salts from a drill hole in Searles Lake (Bischoff et al., 1985) indicated that Searles must have been full and perhaps overflowing during what should have been the dry period of the last interglacial according to the Milankovitch theory. At nearby Devils Hole, high-resolution dating of spring deposits (Winograd et al.,1992) revealed a similar discrepancy in which the last interglacial appeared to have begun a full 18 ka earlier than predicted by Milankovitch theory. The present study was an attempt to determine the age of the overflow of Panamint Lake by applying uranium-series dating to remnant sediments, primarily tufa, of the high shoreline. Results indicate that the Panamint tufa and marls have been open-systems for uranium and that neither nominal nor isochron give unequivocal results. Isochrons giving the least scatter suggest an age for the last occupation of the high shoreline in the range of 55 to 95 ka bp.

FIELD RELATIONS

Sampling was carried out at nine different localities throughout Panamint Valley during April of 1988, November of 1990, and February of 1991 at localities described in the following section. The primary remnant sediment is tufa which occurs in isolated patches where bedrock is

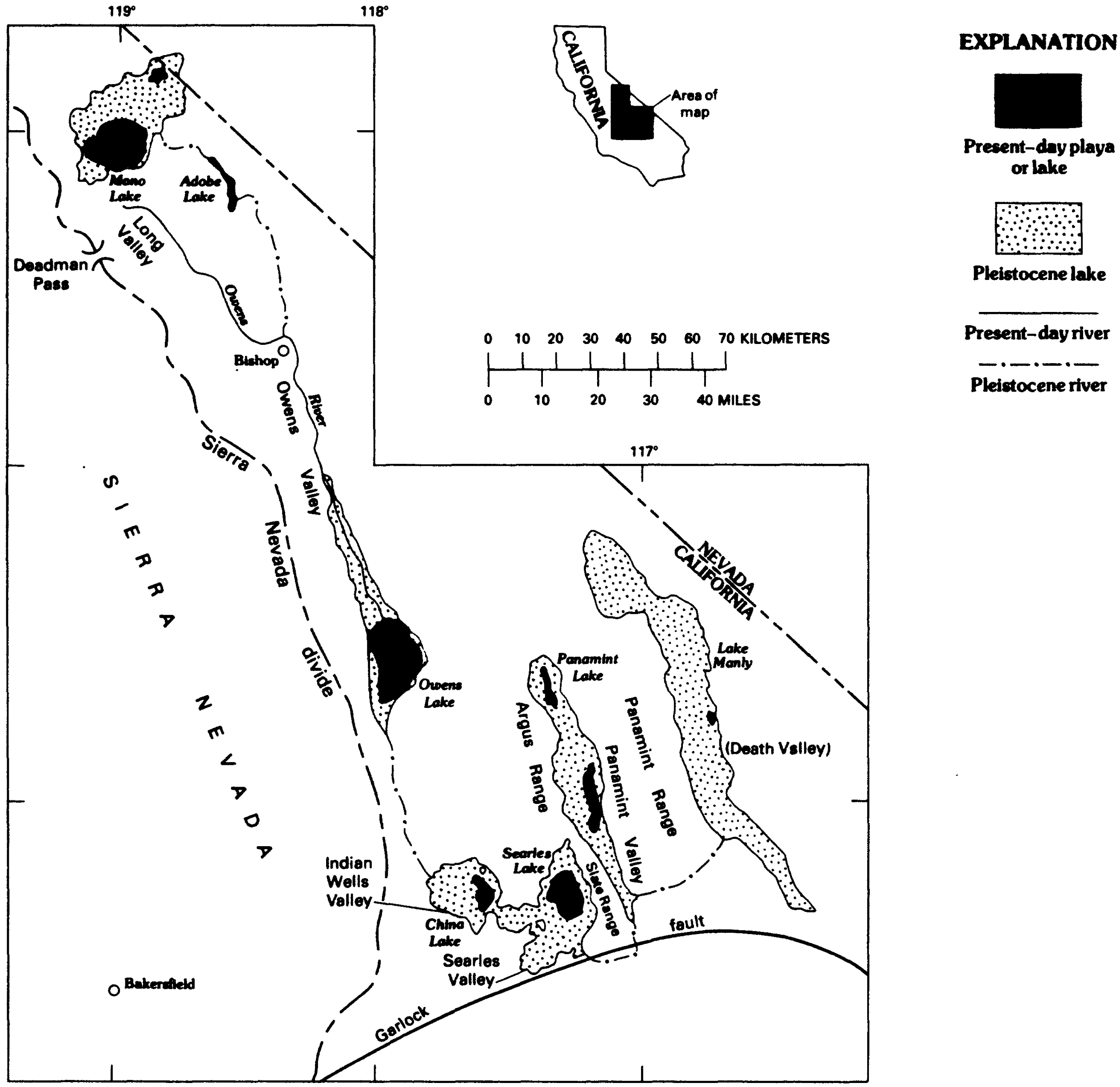


Figure 1

Owens River System and chain of Pleistocene Lakes

FIELD RELATIONS

Sampling was carried out at nine different localities throughout Panamint Valley during April of 1988, November of 1990, and February of 1991 at localities described in the following section. The primary remnant deposit is tufa which occurs in isolated patches where bedrock or older sediments are exposed. The tufa typically contains some fresh-water snail shells and forms rinds or small ridges up to a foot thick around boulders or on sediments. Some encased boulders have pedogenically disintegrated from within these tufa rinds. The occurrence of tufa is isolated, rare, and spotty, appears deeply weathered throughout, and contains an infilling of eolian aluminosilicate debris. In contrast, the most recent tufas in Searles Valley (e.g. 12 ka) are abundant throughout the basin (as are tufas of earlier generations) and have a fresh crystalline appearance when the surface is broken away. The Panamint tufa gives the impression of much greater antiquity. Moreover, there is no evidence at any of the outcrops we visited in Panamint Valley of more than a single generation of tufa, which suggests to us that they all represent a single episode or cycle of a high lake. We conclude that the cycle interval between periodic complete fillings of Panamint Valley was long enough for complete removal of previous shoreline tufa via erosion.

SAMPLE LOCALITIES

1. <u>Ash Hill</u> (Panamint Springs quadrangle 1:24,000, T19S R42E Section 3, SW 1/4 of the SW 1/4). Tufa occurs as mounds and coatings on volcanic rock from 1640 to 2040 feet elevation along the NE flank of Ash Hill. At the lower elevations, tufa mounds ranging up to 10 feet in height are prominent and represent the most striking and best preserved examples in the basin. Samples from this locality are lithoid tufas from various mounds: *PV-7(A-D)* collected in 1988, and *90-1* through *90-4* taken in 1990 (see Smith, 1976, p. 128-132).

2. <u>Lake Hill</u> (The Dunes quadrangle 1:24,000, T18S R42E section 10 NE corner of SW 1/4.) Sample *LHT* is a lithoid tufa collected by Robert Anderson (University of California, Santa Cruz) in 1989 at 1880 feet elevation.

3. <u>High Wildrose Canyon</u> (Maturango Peak NE Quadrangle 1:24,000, T19S R43E Section12 center of NE 1/4.) Sample *HWT* is a lithoid tufa collected by Robert Anderson in 1989 at 2070 feet elevation.

4. <u>Revenue Canyon West</u> (Revenue Canyon Quadrangle 1:24,000 T21S R42E Section1 NE 1/4 of NE 1/4) A patch of tufa is found clinging to an outlier of marble bedrock at 1950 feet elevation. The locality is described by Smith (1976, p. 112). Sample *Pan-91-5* (tufa) was collected here in 1991.

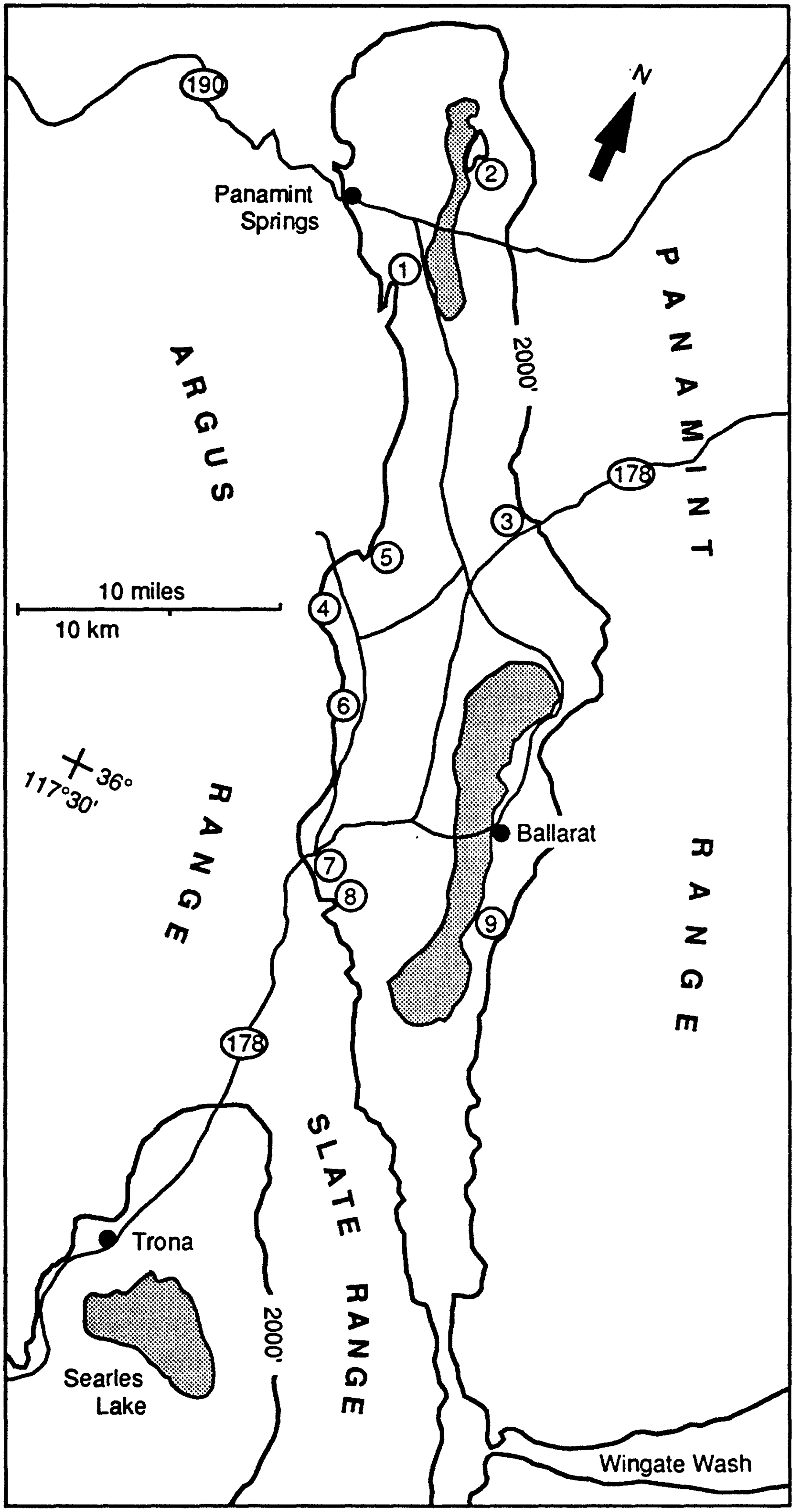


Figure 2
Sketch map of Panamint Valley showing approximate sample localities of high-shoreline tufas and lake sediments

5. Revenue Canyon East (Revenue Canyon Quadrangle 1:24,000 T20S R42E Section 25 NE 1/4 of NE 1/4) A north-south trending prominent shoreline is well defined across the alluvial fan and is marked by extensive deposits of tufa ranging from about 1980 to 2030 feet elevation. The site is described by Smith (1976 , p. 113). Samples collected from this locality in 1991 are: *Pan-91-6A* (tufa at 1980 feet), *Pan-91-6B* (tufa at 2030 feet elevation), and *Pan-91-6C* (tufa at 2030 feet elevation, 30 feet along strike from 6B).

6. Bendire Canyon (Maturango Peak SE quadrangle 1:24,000 T21S R43E Section 20) Gastropod-bearing marl underlies tufa heads and beach rock at this locality at elevations of 1900 to 2010 feet. The locality is described by Smith (1976, p. 112). Samples taken in 1991: *Pan-91-2A* (marl with gastropods), *Pan-91-2B* (tufa head).

7. Camp wash (Maturango Peak SE, 1:24,000, T22S R43E Section 22) Tufa mounds occur along a 3000 feet trend on the SW flank of NW trending ridge at 1840-2010 feet elevation. Samples of tufa from this site: Sample *CWT* was collected at 1840 feet in 1989 by Robert Anderson and *Pan-91-3A* and *Pan-91B* at 1890 and 1840 feet elevation by the authors in 1991.

8. Water Wash (Slate Range Crossing (1:24,000 T22S R43E NE 1/4 Section 34) An embayment of lake deposits consisting of about ten feet of marl and thinly bedded silt are exposed from about 1900 to 1980 feet elevation, dipping about 8-10° to the SW. The marl is overlain by about 2-3 feet of gastropod coquina which, in turn, is capped by carbonate-cemented sand which grades upward into loose beach-gravel. Smith (1976) refers to this locality as "Water Canyon" (p. 103). Samples taken during 1991 are: *Pan-91-1A* (soft marl), *Pan-91-1B* (indurated marl), *Pan-91-1C* (coquina), *Pan-91-1D* (tufa like sediment), and *Pan-91-1E* (indurated marl).

9. South Park Canyon (Manly Falls Quadrangle 1:24,000 T22S R44E Section 26 NE 1/4) Wave cut bench at 2150 feet elevation in overlain by tufa-encrusted lag boulders. The locality is described by Smith (1976, p. 96). Sample *Pan-91-4* (tufa) was collected in 1991.

PROCEDURES

All samples were lightly ground, dissolved in HNO_3, and U and Th isotopes were isolated by ion-exchange chromatography using the procedures described in Bischoff et al. (1988), and analyzed by alpha spectrometry. Multiple analyses were performed on splits of 5 samples in order to construct isochrons (Bischoff and Fitzpatrick, 1991). These were subdivided by grain size into several arbitrary screen sizes (>30 mesh, 30-100 mesh, 100-200 mesh, and <200 mesh) and most were totally dissolved (TD) in a HNO_3-HF mixture in order to dissolve both authigenic carbonate and detrital silicate phases.

RESULTS

Results are shown in Table 1. Samples from the Ash Hill, Lake Hill, and South Park Canyon localities have unusually high uranium contents (12 to 89 ppm U) and are relatively free of detrital contamination ($^{230}Th/^{232}Th$ ratios of 34 to >1000). Samples of soft marl from the Water Wash locality have high uranium contents (12-22 ppm), but also have high levels of detrital contamination ($^{230}Th/^{232}Th$ ratios of 2.5-7.3). Samples from all other localities are broadly similar to each other in that they have uranium contents of 1.4 to 9.6 ppm and much higher levels of detrital contamination ($^{230}Th/^{232}Th$ ratios of 1.8 to 23). Two exceptions are a single tufa sample from the Camp Wash locality (Pan 91-3B) with 13.8 ppm U and $^{230}Th/^{232}Th$ >1000, and a coquina sample from Water Wash (Pan-91-1C) with 3.2 ppm U and $^{230}T/h^{232}Th$ of 61). For all samples $^{234}U/^{238}U$ ratios range between 1.08 to1.38.

Nominal dates on samples of highest integrity (i.e., $^{230}Th/^{232}Th$ >20) show almost no uniformity even among coeval samples from the same outcrop, ranging from 82 to >300 ka. Two samples in this group, 7D, and Pan-91-3A, display excess ^{230}Th ($^{232}Th/^{234}U$ > 1.0) which suggests that some uranium has been lost from the system The eight samples from the Ash Hill locality show the same span in dates, yet all have $^{234}U/^{238}U$ in the same narrow range of 1.11 to 1.20. The two samples showing dates of >300 ka have $^{234}U/^{238}U$ ratios of 1.20 and 1.11, respectively, also indicative of possible uranium loss. This is because samples >300 ka in age are typically greatly in excess of 300 ka and will usually have $^{234}U/^{238}U$ ratios of essentially 1.0 (Gascoyne, 1992).

ISOCHRONS

The 5-point isochron plot of the uranium-rich tufa from the Ash Hills locality (Pan-90-3, Fig. 3) shows considerable scatter (R^2 = 0.85) and yields a date 68±25 ka bp which probably has little meaning. Such scatter is probably due to uranium movement within the samples with loss in some parts and gains in others. The isochron plot of the marl from Bendire Canyon (Pan-91-2A, Fig. 5) is a hopeless scatter plot (R^2 = 0.43), while those for the two marl samples at Water Wash (Pan 91-1A, Fig. 6; and Pan-91-1E, Fig 7) show moderate linearity (R^2 = 0.96 and 0.97, respectively). The latter two yield dates of 66.9±9 and 54.8±8 ka bp respectively. The 4-point isochron for the tufa from Revenue Canyon East (Pan-91-6B, Fig. 4) shows considerably less scatter (R^2 = 0.997) and yields a date of 91±5 ka bp which might be meaningful.

DISCUSSION

It is clear that the scatter in dates of the Ash Hills tufa is not due to detrital contamination, considering the very high $^{230}/Th^{232}Th$ ratios. Scatter is due likely to uranium migration or mobilization, which is not an unreasonable conseqence for these aerialy exposed tufas. In such a process uranium is either lost from all samples to varying degree, or it is lost from one part of a sample and redeposited in another. In the former case, all the samples will appear too old,

Table 1

Uranium and thorium isotopic analyses and derived dates from tufa, marl, and coquina at or near the high shoreline in Panamint Valley, California

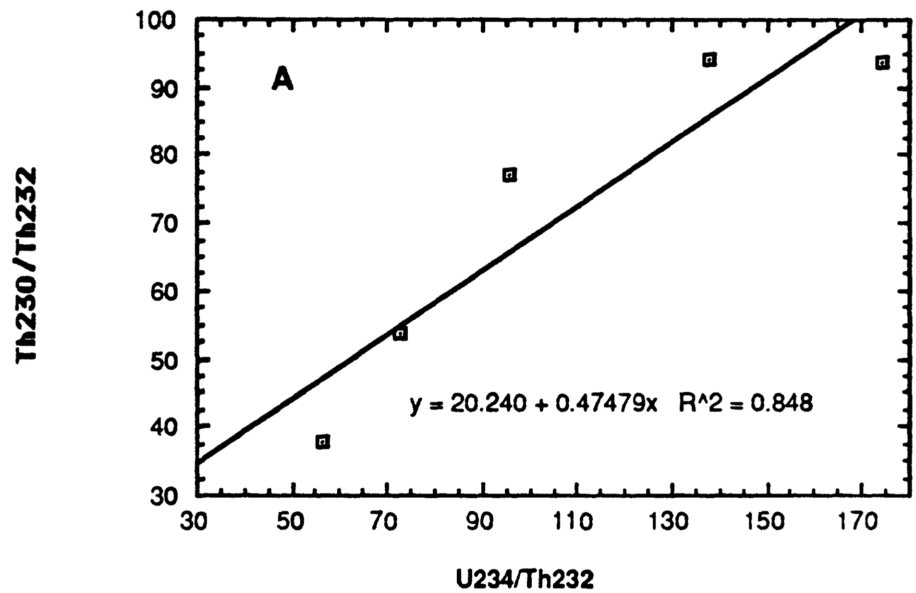
SAMPLE	lab no.	Uppm	$^{234}U/^{238}U$	$^{230}Th/^{232}Th$	Nominal date ka	Notes
			Ash Hill (tufa)			
7A	82-24	51.1±0.06	1.18±0.01	>1000	175^{+7}_{-6}	1650' - 1750'
7B	88-25	45.9±0.06	1.20±0.02	>1000	266^{+18}_{-16}	"
7C	88-26	89.3±0.09	1.17+0.01	>1000	136±5	"
7D	88-29	61.8±0.04	1.16±0.01	>1000	-	" excess ^{230}Th
90-1	90-95	8.3±0.02	1.20±0.02	34±2	>300	2040' highest shoreline
90-2	90-96	51.1±2.0	1.11±0.01	670±2	>300	1760' lowest shoreline
90-2	90-113	62.7±0.7	1.11±0.01	470±2	240^{+15}_{-13}	" "
90-3	90-97	19.2±1.3	1.14±0.02	54±1	140^{+21}_{-18}	1760' bulk
"	90-124	15.2±0.4	1.19±0.03	38±1	115±6	bulk
"	90-140	35.8±0.6	1.18±0.02	36±1	82±3	TD >30 mesh
"	90-141	33.6±0.5	1.19±0.01	119±2	124±4	TD 100-200 mesh
"	90-142	33.5±0.5	1.19±0.01	76±1	160^{+11}_{-7}	TD <200 mesh
						Isochron = 68±25
90-4	90-123	57.8±0.9	1.15±0.1	175±2	125±5	1760'
			Lake Hill (tufa)			
LHT	90-98	11.5±0.2	1.19±0.02	>1000	119±4	1880'
			High Wildrose Canyon (tufa)			
HWT	90-99	2.0±0.06	1.14±0.04	6.2±0.4	135±10	2070'
			Revenue Canyon West (tufa)			
Pan-91-5	91-52	1.4±0.03	1.20±0.03	11.4±0.6	123±6	1950'
			Revenue Canyon East (tufa)			
Pan-91-6A	91-160	1.9±0.03	1.16±0.02	3.9±0.07	117±4	1980'
Pan-91-6B	91-47	1.5±0.03	1.20±0.03	4.0±0.2	110±6	2030' leachate
"	91-48	1.5±0.02	1.23±0.02	4.3±0.2	104±5	TD>30 mesh
"	91-49	2.0±0.04	1.08±0.03	1.8±0.06	136±8	TD<200 mesh

"	91-50	1.7±0.04	1.17±0.03	1.8+0.07	129±8	TD 100-200 mesh
"	91-51	1.6±0.04	1.14±0.04	3.4±0.1	104±6	TD 30-100 mesh
						Isochron = 91±5
Pan-91-6C	92-112	1.4±0.03	1.22±0.03	2.8±0.07	115±5	2030'
			Bendire Canyon (marl/tufa)			
Pan-91-2A						1900' marl
"	91-23	4.3±0.08	1.27±0.02	4.2±0.1	99±4	leachate
"	91-30	7.9±0.01	1.26±0.01	5.4±0.1	82±2	TD<200 mesh
"	91-31	8.5±0.01	1.22+0.02	3.8±0.1	73±2	TD 100-200 mesh
"	91-32	9.6±0.01	1.26±0.01	4.9±0.1	61±2	TD 30-100 mesh
"	91-38	7.2±0.09	1.23±0.02	4.2±0.1	85±2	TD bulk
"	91-39	6.5±0.09	1.26±0.02	4.8±0.1	94±3	TD > 30 mesh
"	91-53	5.9±0.01	1.22+0.02	4.4±0.1	122±5	TD bulk
"	91-54	6.0±0.1	1.25±0.02	4.6±0.1	123±5	TD > 30 mesh
"	91-55	8.3±0.01	1.23±0.02	4.1±0.1	85±3	TD 30-100 mesh
						Isochron = 24±12
Pan-91-2B	92-10	1.7±0.03	1.23±0.02	3.0±0.06	174^{+9}_{-8}	tufa, 2000'
			Camp Wash (tufa)			
CWT	90-100	7.5±0.2	1.29±0.03	16.2±1.0	164^{+11}_{-10}	1840'
Pan-91-3A	91-159	9.0±0.2	1.19±0.02	23±1	-	1890' (excess ^{230}Th)
Pan-91-3B	92-11	13.8±0.4	1.14±0.02	>1000	192^{+18}_{-15}	1840'
			Water Wash (various sediments)			
Pan-91-1A						1980', soft marl
"	91-21	2.9±0.05	1.26±0.02	2.5±0.03	>300	leachate
"	91-24	16.3±0.05	1.10±0.02	4.1±0.1	187^{+23}_{-19}	TD < 200 mesh
"	91-25	11.5±0.03	1.25±0.02	4.7±0.1	134^{+10}_{-9}	TD 100-200 '
"	91-26	22.4±0.07	1.21±0.02	7.3±0.2	87±5	TD >100 "
"	91-27	12.0=0.02	1.20±0.02	3.3±0.06	147±6	TD bulk
"	91-28	12.6±0.02	1.19±0.02	2.9±0.05	114±5	TD >30 mesh
						Isochron date = 66±9
Pan-91-1B	91-84	4.5±0.07	1.11±0.02	1.7±0.2	296^{+32}_{-25}	1980', hard marl
Pan-91-1C	91-66	3.2±0.06	1.38±0.03	61±6	166^{+9}_{-8}	1980' coquina
"	91-40	2.6±0.05	1.35±0.03	6.4±0.2	169±8	"
Pan-91-1D	91-85	2.7±0.05	1.17±0.02	2.70±0.05	274^{+28}_{-23}	tufa-like sediment
Pan-91-1E						1980', indurated marl

"	91-22	1.4±0.03	1.25±0.03	3.2±0.06	--	bulk leachate, excess ^{230}Th
"	91-29	7.5±0.01	1.20±0.02	4.4±0.1	86±3	TD bulk
"	91-41	4.1±0.07	1.12±0.02	3.3±0.09	162^{+9}_{-8}	TD < 200 mesh
"	91-42	4.2±0.08	1.14+0.02	3.9±0.1	136±7	TD 100-200 "
"	91-43	7.3±0.01	1.17±0.02	5.3±0.1	101±4	TD 30-100 "
"	91-44	8.0±0.02	1.10±0.02	5.6±0.3	101±7	TD>30"
"	91-45	3.6±0.01	1.16±0.04	3.0±0.2	146^{+15}_{-13}	TD bulk
"	91-46	3.5±0.01	1.14±0.04	3.2±0.2	187^{+25}_{-21}	TD bulk
						Isochron date = 54±8
			South Park Canyon (tufa)			
Pan-91-4	92-6	16.0±0.4	1.19+0.02	97±10	117±5	2150'

Figure 3

Isochron diagram of tufa sample Pan-90-3 From 1760' elevation at Ash Hill locality. Age error (1s) is based on scatter about the least-squares fit (Schwarcz and Latham, 1989). A: $^{230}Th/^{232}Th$, $^{234}U/^{232}Th$ diagram, the slope of which yields the $^{230}Th/^{234}U$ activity ratio of pure authigenic end-member. B: $^{234}U/^{232}Th$, $^{238}U/^{232}Th$, the slope of which yields the $^{234}U/^{238}U$ activity ratio of pure authigenic end-member.



Date (ka)
68±25

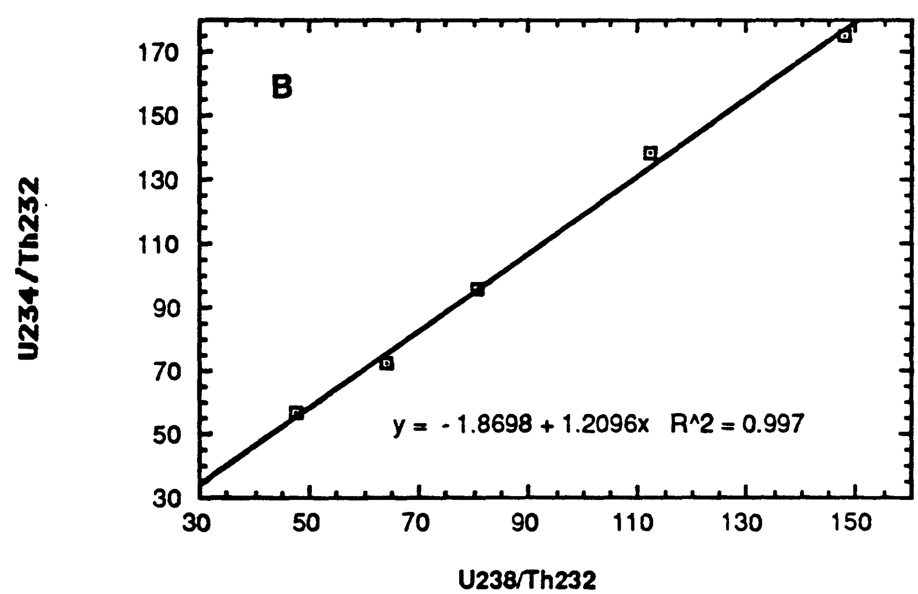


Figure 4

Isochron diagram of tufa sample Pan-91-6B From 2030' elevation at Revenue Canyon East locality. Age error (1s) is based on scatter about the least-squares fit (Schwarcz and Latham, 1989). A: $^{230}Th/^{232}Th$, $^{234}U/^{232}Th$ diagram, the slope of which yields the $^{230}Th/^{234}U$ activity ratio of pure authigenic end-member. B: $^{234}U/^{232}Th$, $^{238}U/^{232}Th$, the slope of which yields the $^{234}U/^{238}U$ activity ratio of pure authigenic end-member.

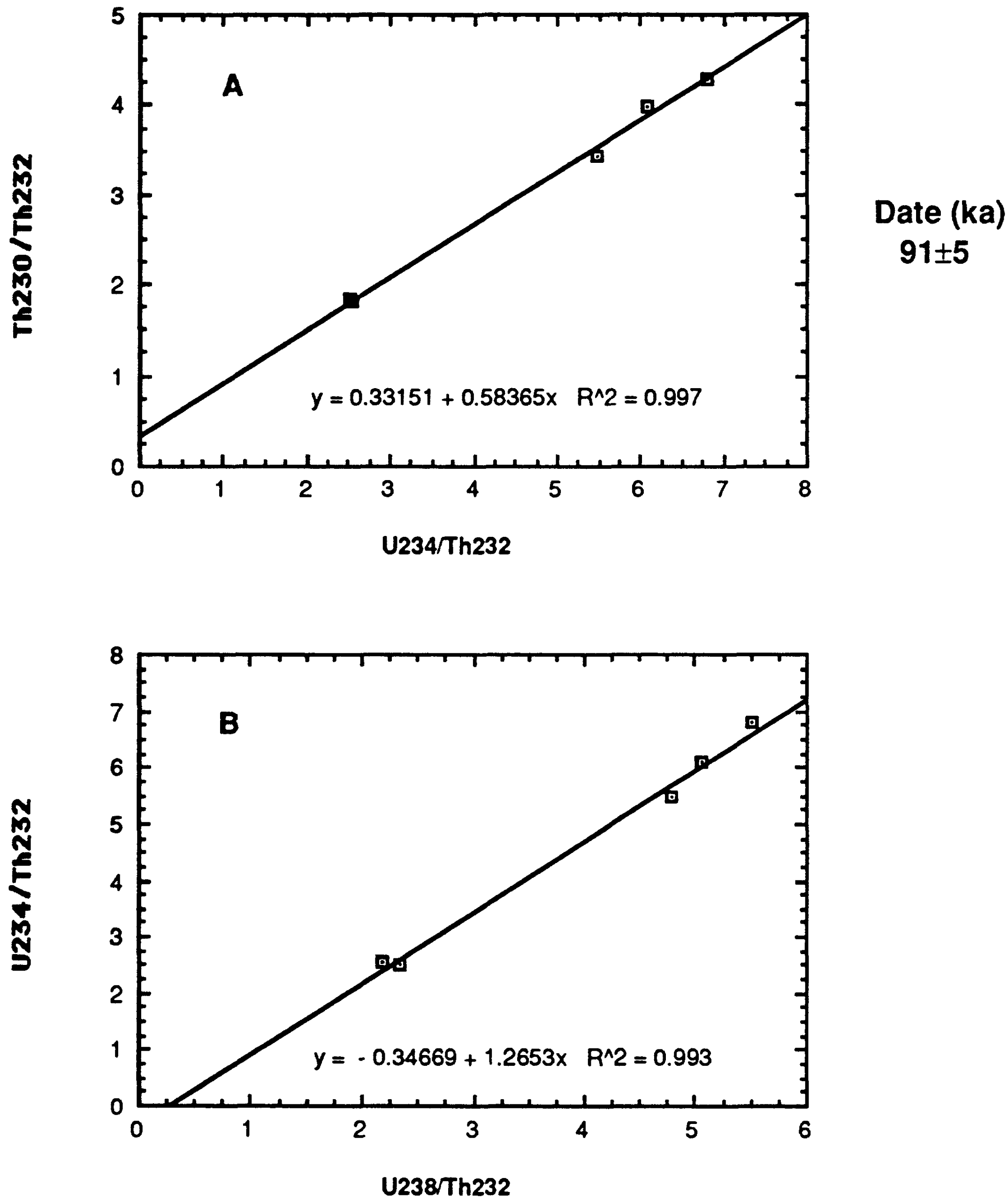
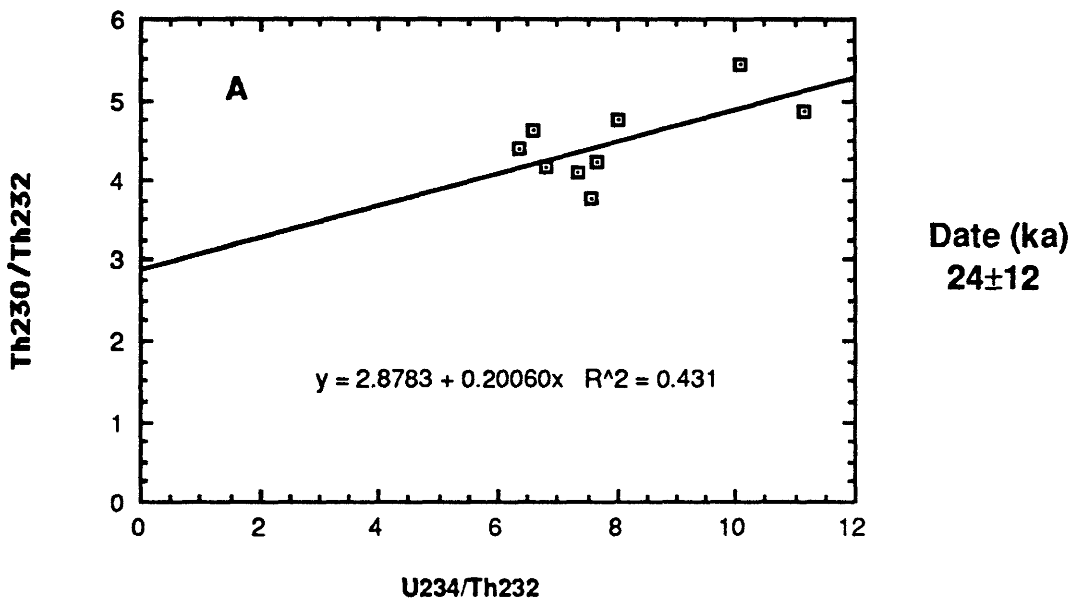


Figure 5

Isochron diagram of marl sample Pan-91-2A From 1900' elevation at Bendire Canyon locality. Age error (1s) is based on scatter about the least-squares fit (Schwarcz and Latham, 1989). A: $^{230}Th/^{232}Th$, $^{234}U/^{232}Th$ diagram, the slope of which yields the $^{230}Th/^{234}U$ activity ratio of pure authigenic end-member. B: $^{234}U/^{232}Th$, $^{238}U/^{232}Th$, the slope of which yields the $^{234}U/^{238}U$ activity ratio of pure authigenic end-member.



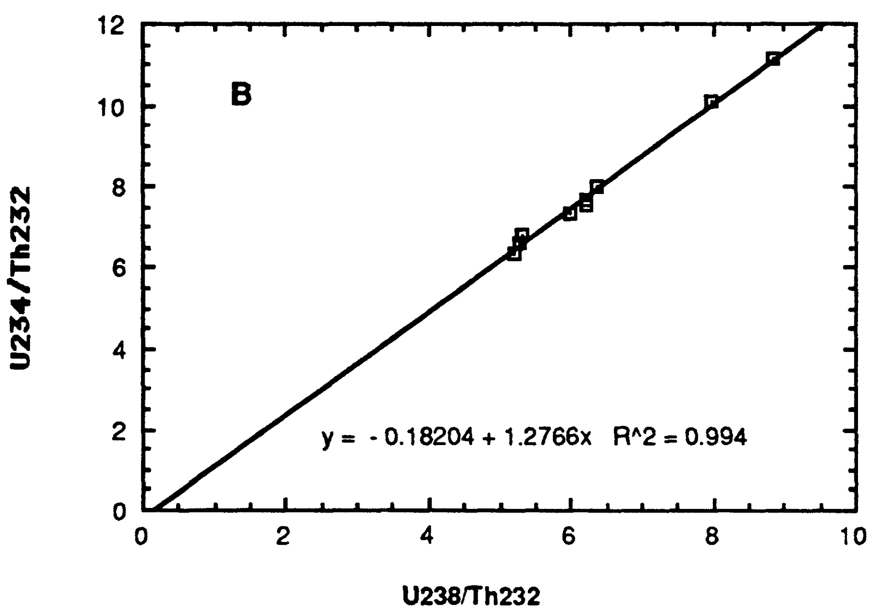
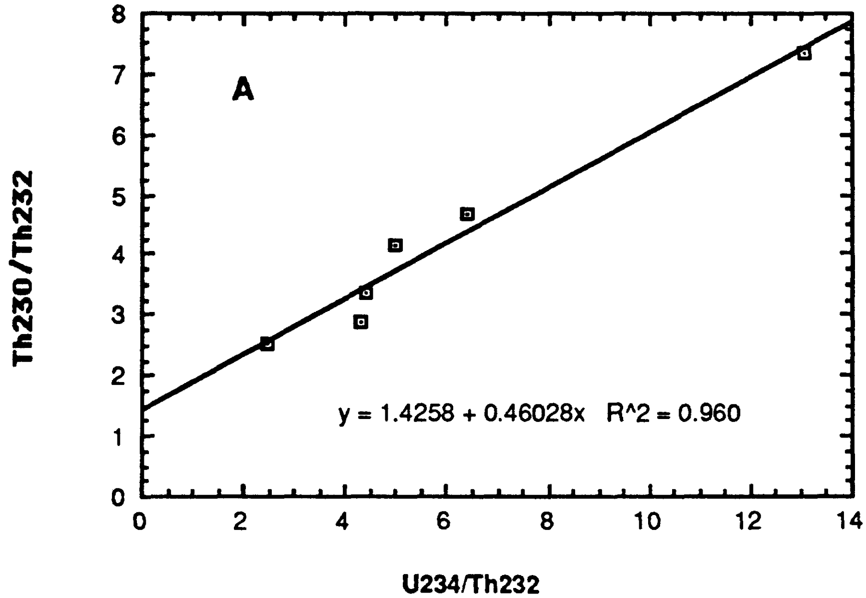


Figure 6

Isochron diagram of marl sample Pan-91-1A From 1980' elevation at Water Wash locality. Age error (1s) is based on scatter about the least-squares fit (Schwarcz and Latham, 1989). A: $^{230}Th/^{232}Th$, $^{234}U/^{232}Th$ diagram, the slope of which yields the $^{230}Th/^{234}U$ activity ratio of pure authigenic end-member. B: $^{234}U/^{232}Th$, $^{238}U/^{232}Th$, the slope of which yields the $^{234}U/^{238}U$ activity ratio of pure authigenic end-member.



Date (ka)
66±9

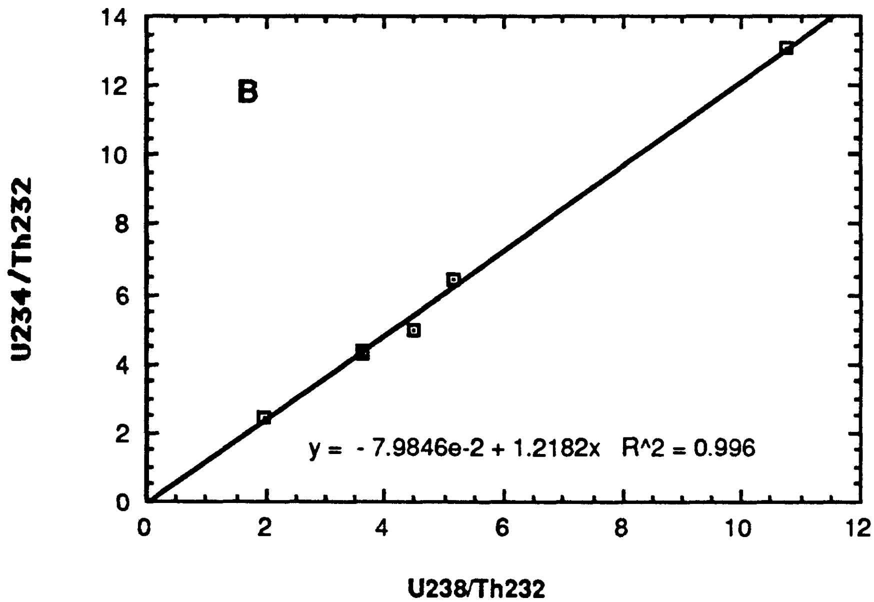
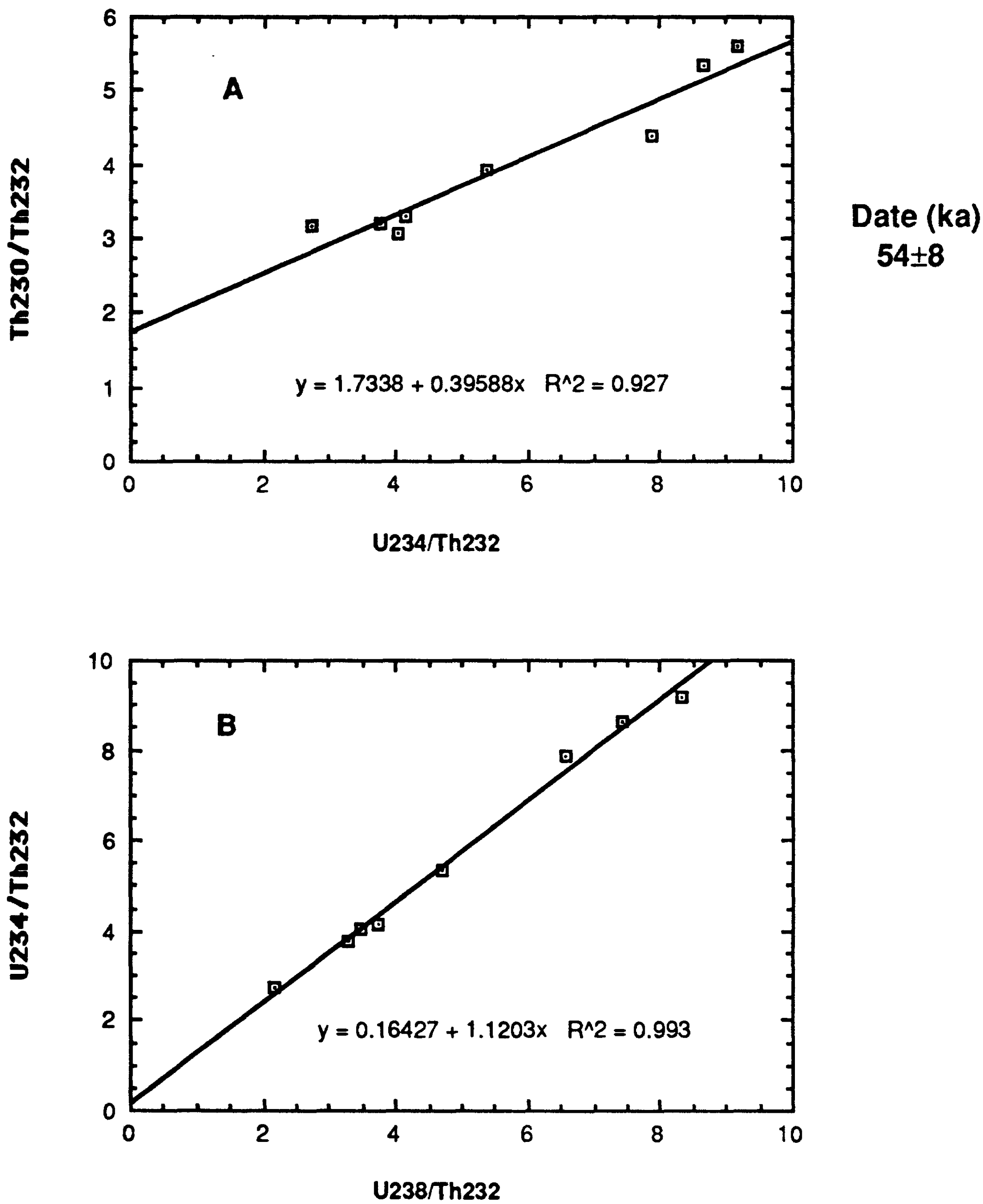


Figure 7

Isochron diagram of marl sample Pan-91-1E From 1980' elevation at Water Wash locality. Age error (1s) is based on scatter about the least-squares fit (Schwarcz and Latham, 1989). A: ^{230}Th/^{232}Th, ^{234}U/^{232}Th diagram, the slope of which yields the ^{230}Th/^{234}U activity ratio of pure authigenic end-member. B: ^{234}U/^{232}Th, ^{238}U/^{232}Th, the slope of which yields the ^{234}U/^{238}U activity ratio of pure authigenic end-member.



whereas in the latter some will appear too old and others too young. The overwhelming majority of the samples analyzed yielded finite dates (<300 ka). If the sediments of the high shoreline were older than the limit of U-series method, about 300 ka, then for the first scenario, all the samples would either show full isotopic equilibrium or excess ^{230}Th, whereas for the second, a large proportion will show equilibrium or excess ^{230}Th and the rest finite dates. That the majority of samples yield finite dates argues that the shoreline is less than about 300 ka. The contrasts with the terminal Pleistocene tufas of nearby Searles Lake suggests that the Panamint shoreline is somewhere between 30 and 300 ka bp. The isochron plots indicate an age in the range of 55 to 95 ka bp.

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BIBLIOGRAPHY

Bischoff, J.L., R.J. Rosenbauer, and G.I. Smith, 1985, Uranium-Series dating of sediments from Searles Lake, California: differences between continental and marine climate records.*Science* **227** 1222-1221.

Bischoff, J.L. and Fitzpatrick, J. A. (1991) U-series dating of impure carbonates: An isochron technique using total-sample dissolution. *Geochimica et Cosmochimica Acta* **55** 543-554.

Bischoff, J.L., Rosenbauer, R.J., de Lumley, H., and Tavoso, A. (1988) A test of Uranium-series dating of fossil tooth enamal: results from Tournal Cave, France. *Applied Geochemistry* 3 145-151.

Gascoyne M. (1992) Palaeoclimate determination from cave calcite deposits. *Quat. Sci. Rev.* **11** 609-632.

Schwarcz H.P. and Lathan A.G. (1989) Dirty calcites 1. Uranium-series dating of contaminated calcite using leachates alone. *Chem. Geol.* **80** 35-43.

Smith G.I. (1984) Paleohydrologic regimes in the Southwestern Great Basin, 0-3.2 my ago, compared with other long records of "Global" climate. *Quat. Res.* **22** 1-17.

Smith R.S. (1976) *Late-Quaternary pluvial and tectonic history of Panamint Valley, Inyo and San Bernardino Counties, California.* Ph.D. dissertation, California Institute of Technology 295p.

Winograd I.J. Coplen T.B. Landwehr J.M. Riggs A.C. Ludwig K.R. Szabo B.J. Kolesar P.T. and Revesz K.M. (1992) Continuous 500,000-year climate record from vein calcite in Devils Hole, Nevada. *Science* **258** 255-260.