UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

# Uranium in Holocene valley-fill sediments, and uranium, radon, and helium in waters, Lake Tahoe-Carson Range area, Nevada and California

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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## Introduction

In the Sierra Nevada and in other granitic terranes in the United States and Canada, significant accumulations of uranium occur in surficial, organic-rich sediments of late Pleistocene to Holocene age that fill stream valleys. Such occurrences were first noted in a few localities in the Sierras during early uranium exploration in the western United States (Bowes and others, 1957; Swanson and Vine, 1958). More recently however, such occurrences have been found to be widespread in many areas of the United States and Canada (Radiation Control Section, 1983; Otton, 1984; Culbert, Boyle and Levinson, 1984). Uranium appears to be largely associated with organic matter entrained in the sediment and is commonly so recently accumulated that radioactivity, which is produced mostly by the daughter isotopes of uranium decay, is very low. Detection of these accumulations by conventional radiometric techniques is generally not possible (Levinson and others, 1984) and this may explain why most of these deposits have been overlooked during earlier work. Mechanisms of entrapment of the uranium may include adsorption, ion exchange, and reduction (Szalay, 1964; Nakashima and others, 1984).

Reconnaissance sampling by R.R. Culbert during the spring of 1981 (written commun., 1982) identified accumulations of uranium in several drainages along the west side of the Carson Range near the edge of Lake Tahoe, and also at a few localities in valley-fill sediments in the bottom of Carson Valley east of the Carson Range (Fig. 1).

We sampled valley-fill sediments, surface waters, near-surface waters, and spring waters in the Carson Range and adjacent parts of Carson Valley (Fig. 1) and analyzed them variously for uranium, radon, and helium. This sampling was designed to determine the extent and distribution of the surficial uranium accumulations identified by Culbert, the nature of the surficial sedimentary hosts, the uranium content of waters associated with the accumulations, and the presence of radiogenic gases known to occur with uranium deposits. Culbert's work and the early findings of this study were reported by Otton and Culbert (1984).

## Geographic and geologic setting

The Carson Range (Fig. 1) lies between Carson Valley on the west and the Lake Tahoe basin on the east. Its crest ranges in elevation from approximately 2300 to 3000 m. The range is underlain mostly by Mesozoic granodiorites which intrude metamorphosed Mesozoic sedimentary and volcanic rocks (Moore, 1961; Armin and others, 1981). Locally, Tertiary volcanic and hypabyssal plutonic rocks unconformably overly or intrude these older units. The range is bounded on both flanks by high-angle normal faults which separate the Carson Range block from adjacent downdropped blocks that underlie Carson Valley and the Lake Tahoe basin. Valleys within the range contain deposits of late Pleistocene to Holocene alluvium and, locally in the higher

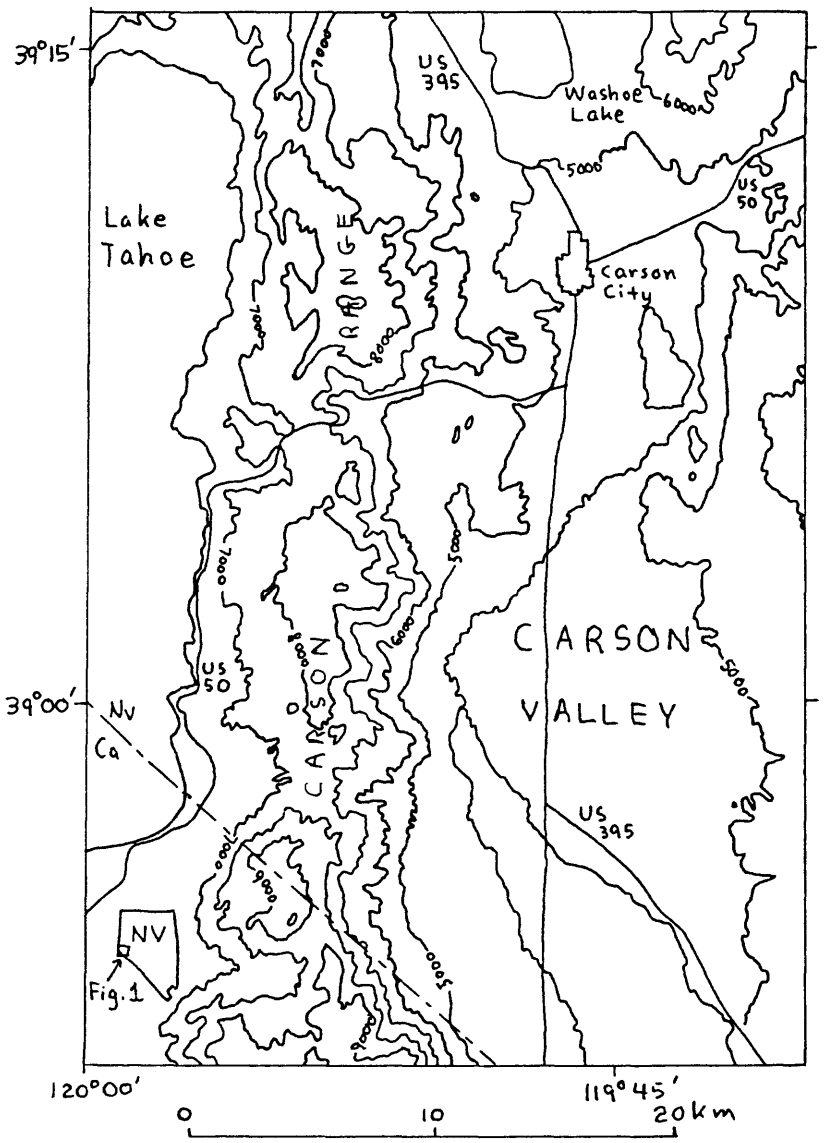


Fig. 1- Location map for the Carson Range, Lake Tahoe, and Carson Valley, Nevada and California. Base from Walker Lake and Reno NTMS 2° sheets. Elevations in feet.

valleys, deposits of glacial moraines.

Most stream drainages in the range contain deeply weathered bedrock. In the areas underlain by plutonic rocks, a thick mantle of grus covers most slopes, and bedrock exposures occur only on steep slopes. The valleys are generally flat-bottomed to broadly U-shaped and vegetated. Because of rapid infiltration of runoff into the granitic grus, no channelized stream flow occurs in the upper reaches of most stream valleys, even during periods of rapid snow melt. Farther down the valleys streams are fed from intermittent and permanent springs along the valley floor. Where the streams are fed largely by meltwater from snows, the point of inception of surface flow in the channels migrates downstream as the dry season progresses and the water table lowers. Where contributary springs are fed by fault or fractures, they are more permanent and stream flow occurs all year round. Areas of permanent water are marked by stands of riparian vegetation such as willow, alder, and aspen. Accumulations of fine-grained valley-fill sediments rich in organic matter are common in these areas. Locally the streams are ponded and peat has accumulated.

The bottom of Carson Valley lies at an approximate average elevation of 1400 m. Carson Valley is filled with late Tertiary to Holocene basin-fill sediments. Numerous fault-line springs emerge along the east side of the Carson Range adjacent to Carson Valley and feed into slow-moving, swampy streams, locally termed sloughs, that are important tributaries to the Carson River.

The surface of Lake Tahoe lies at an elevation of 1899 m although the bottom of the lake is several hundred meters depper. Along the west side of the Carson Range near the shores of Lake Tahoe, beach and delta deposits stand at various elevations above and below the present lake level. Sediments of the small valleys within the Carson Range merge with these delta and beach deposits upstream from the lake's edge.

## Sampling and analytical methods

Widely spaced auger samples of valley-fill sediment were taken (Fig. 2) along the length of the Carson Range from the High Meadows area in the south (sample sites 1 to 5) to the upper Franktown Creek area in the north (sample site 23) and in adjacent parts of Carson Valley (sample sites 24 to 27). More closely spaced samples were collected in the west-central part of the Carson Range (Fig. 3). Samples of valley-fill sediments were obtained using two types of hand augers; (1) a 10 cm diameter bucket auger and (2) an auger bit constructed by welding together two 4 cm by 46 cm ship's auger bits. Coupling with light-weight drill rod permits sampling with this fabricated bit to depths of 12 m. In addition to auger sampling, some holes were cored using a modified Livingston stationary piston corer (overall length 145 cm; barrel length 122 cm; barrel O.D. 5 cm). Samples were collected during each of three field seasons (1982-1984). Auger samples were collected in 0.3 m intervals and placed in cloth sample sacks. Continuous core samples were split into

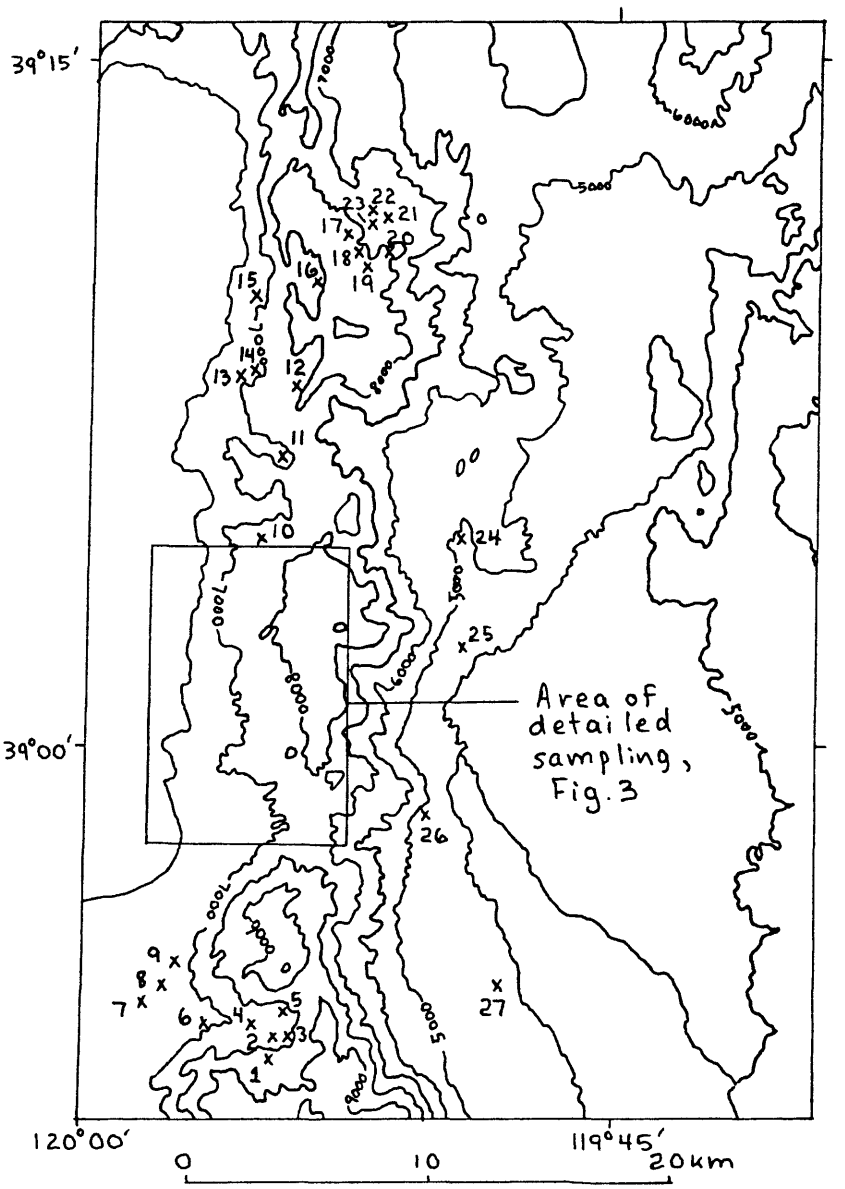


Fig. 2- Location of reconnaissance auger sample sites in the Carson Range and Carson Valley. Uranium values for numbered localities are found in Table 1.

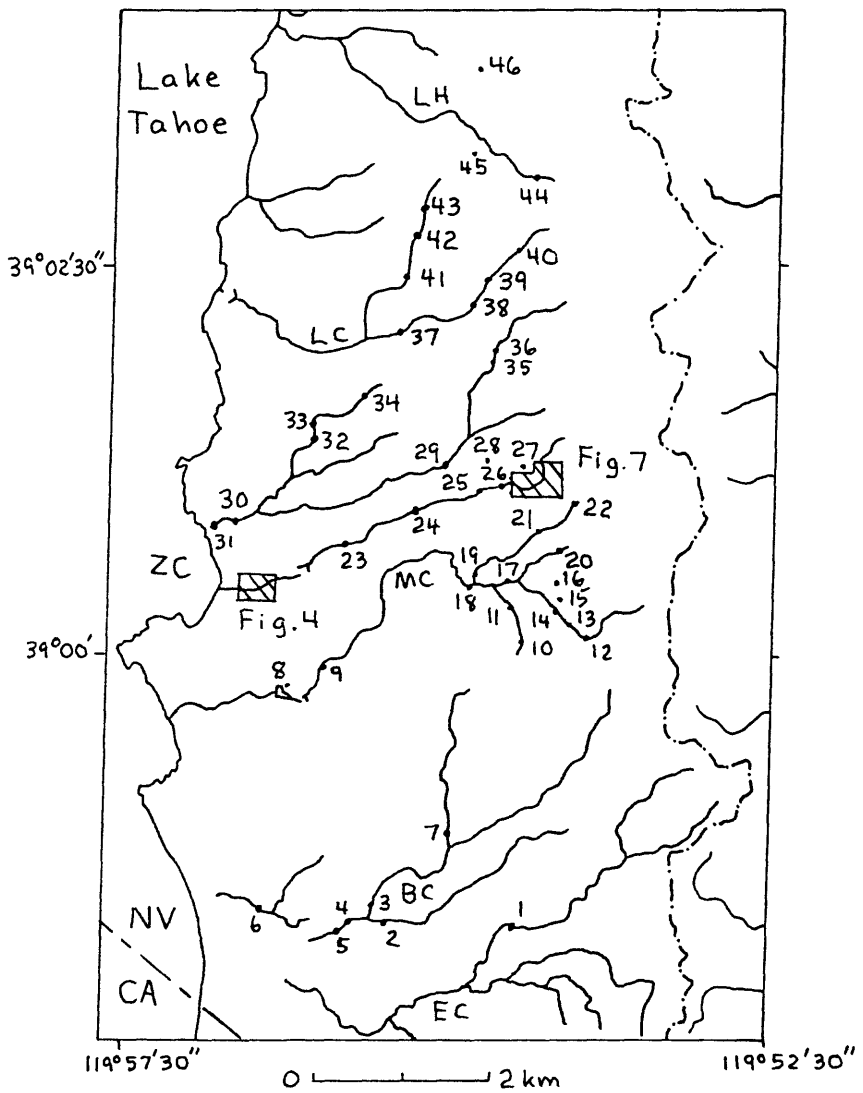


Fig. 3- Auger sample location sites, west-central part of the Carson Range. See Fig. 2 for location, Table 1 for uranium analyses. EC- Edgewood Creek; BC- Burke Creek; MC- McFaul Creek; ZC- Zephyr Cove; LC- Lincoln Creek; LH- Logan House Creek. Cross-hatch- areas of detailed sampling, Figs. 4 and 7. Dash-dot line- crest of the range.

lithologically distinct intervals during later examination of the core in the lab. All samples were dried at 105° C for 24 hours and crushed in a ceramic mill. Splits were analyzed for uranium content by a delayed neutron activation technique (Millard and Keaten, 1982). All analytical data for uranium in solids is reported on a dry weight basis.

Water samples included spring, flowing stream, near-surface, well, and tap waters. The near-surface samples were collected from 0.3 m deep holes augered in water-saturated ground.

Water samples for radon and helium analyses were collected April 12, 1984. Sampling was restricted to springs and streams in the area along or near U.S. 50 on the west side of the Carson Range (Fig. 1). Radon analyses were made immediately, helium measurements were made in the lab May 25, 1984. Each water sample was collected in a 1 liter, high density, polyethylene bottle, sealed with a septum cap. The bottle was filled to 850 ml, leaving a 150 cc air space above the water. The bottle was shaken for 1 minute and then allowed to stand for 3 minutes to permit equilibration of air in the headspace of the bottle with gases dissolved in the water. Samples of the air above the water were withdrawn for radon analyses through the septum with a 50 cc hypodermic syringe and injected into the evacuated chamber of an alpha-sensitive scintillation cell through fittings attached to the cell. The volume of the cell and fittings is 160 cc. Readings were taken on a commercially available counter (EDA Electronics, Ottawa). Background readings were taken before each sample reading and correction factors applied to sample readings. The cell was flushed and reevacuated after each reading using a hand pump attached to the cell with fittings.

Samples of the air above the water were also withdrawn from the same sample bottle with a 20 cc syringe for helium analyses. The 20 cc sample were injected into an evacuated stainless steel cylinder of 8 cc volume, thus the cylinder was deliberately overpressurized. In the lab, a 10 cc syringe was used to extract a sample from the overpressurized cylinder and the sample was then injected into a modified mass spectrometer tuned for helium 4. The helium content of a sample is reported as ppb in excess of the helium content of the atmosphere (5240 ppb). The sensitivity of the technique is about 10 ppb.

Water samples for uranium analyses were collected in July 1984. Samples were filtered through 0.45 micron millipore filters , acidified to pH<2 with $HNO_3$, and stored in acid-washed polyethylene bottles. Approximately 0.5 ml of filtered, acidified water was placed in a 2/5 dram, acid-washed, polyethylene vial containing a fission-track detector (a 0.5 $cm^2$ platelet of highly polished, acid-washed, pure silica glass). The samples, and similarly processed standard solutions and blanks, were then irradiated at a neutron flux of $2.5 \times 10^{12}$ neutrons/$cm^2$/sec for 4 hours in the research reactor facility of the U. S. Geological Survey in Denver, Colorado to induce fission of $U^{235}$. After about 1 week, the glass was recovered and etched for 2 min with 48% reagent-grade hydrofluoric acid to enlarge areas of damage produced by fission fragments of $U^{235}$. Resultant fission tracks were viewed with a microscope at 400x. The track

density was compared to the density produced by submersion of glass in a 100 ppb U standard solution. The blank averaged approximately 0.6 ppb U. This technique is specific for $U^{235}$ which, in nature, has a constant ratio to $U^{238}$, the principal isotope of uranium. Occasional dense clusters of fission tracks on the silica detectors indicated that, in some samples, a small fraction of uranium was associated with particulate material that passed through the 0.45 micron filter. Data reported here are for dissolved uranium only. Seven samples were also analyzed by a more conventional fluorometric technique and results are within ±15 percent of the fission track values.

## Results and discussion

### Uranium in Recent sediments

In the northern part of the study area (sample sites 10 to 23, Fig. 2), stream valley sediments have generally low uranium values (<100 ppm) with occasional moderate (100 to 1000 ppm) to high values (>1000 ppm, Table 1). Two exceptional values were found, however. One of 1600 ppm uranium (Location 22, Fig. 2, Table 1) was found in a 0.3 m depth interval in a bog at the southeast edge of the Hobart Reservoir and one of 2270 ppm uranium (Location 15, Fig. 2, Table 1) was found in a 0.3 m depth interval at a spring seep along a tributary to Marlette Creek below Marlette Reservoir (Site 15A). Sediments in the bottom of Spooner Lake (near our site 11), sampled by Culbert in 1981 (written commun., 1982) but not accessible to us because of higher water, contain up to 2250 ppm uranium over a 0.5 m interval. In the southern part of the study area (sample sites 1 to 9, Fig. 2) values found were generally less then 100 ppm (Table 1). Similar values were found in the auger holes along the bottom of Carson Valley adjacent to the east side of the Carson Range (sample sites 24 to 27, Fig. 2), although Culbert (written commun., 1982) had found some values as much as 200 ppm.

In the west-central part of the Carson Range (Fig. 3 and Table 2), however, moderate to high uranium values are common in the valley-fill of most of the stream drainages where stream gradients are low, riparian vegetation is present, and significant quantities of organic matter have accumulated in the sediment along the valley bottom. Local high concentrations of uranium occur in sediment from the upper reaches of Logan House Creek and other streams as far south as Burke Creek (Fig. 3). Although most of the anomalous values are in the range of 100 to 500 ppm over 0.3 m intervals, values of as great as 5760 ppm were found (see discussion of the upper Zephyr fen below).

The stream valley that empties into the southern part of Zephyr Cove (Fig. 3) was chosen for more detailed study because early sampling had showed persistent high values for uranium in the drainage. Along this valley are two areas of water-saturated ground, referred to here as the lower Zephyr marsh and the upper Zephyr fen. The lower Zephyr marsh lies along the stream valley where it crosses U.S. 50 at approximately a right angle (Fig. 4). The principal surface drainage enters the marsh at its

Table 1- Uranium content (ppm on a dry weight basis) of auger samples from the Carson Range and Carson Valley (Fig. 2)

| Depth (m) \ Hole # | 1 | 2A | 2B | 3A | 3B | 4 | 5 | 6 | 7A |
|---|---|---|---|---|---|---|---|---|---|
| 0-0.3 | 6.51 | 7.13 | 4.67 | 4.96 | 3.67 | 12.6 | 30.3 | 163 | 93.2 |
| 0.3-0.6 | 1.14 | | 10.7 | | 5.29 | | 15.0 | 68.9 | |
| 0.6-0.9 | 0.66 | | 22.8 | | | | | | |
| 0.9-1.2 | 65.0 | | | | | | | | |
| 1.2-1.5 | 74.1 | | | | | | | | |

| Depth (m) \ Hole # | 7B | 7C | 7D | 8A | 8B | 8C | 9A | 9B | 9C |
|---|---|---|---|---|---|---|---|---|---|
| 0-0.3 | 122 | 33.5 | 67.1 | 40.2 | 87.9 | 67.7 | 25.2 | 12.9 | 10.3 |
| 0.3-0.6 | | | | 33.0 | | | | | |

| Depth (m) \ Hole # | 10 | 11A | 11B | 11C | 12 | 13 | 14 | 15A |
|---|---|---|---|---|---|---|---|---|
| 0-0.3 | 10.2 | 3.05 | 53.7 | 3.06 | 64.3 | 16.0 | 386 | 2270 |
| 0.3-0.6 | | 3.25 | 36.3 | | 329 | | 29.5 | |
| 0.6.-0.9 | | 2.98 | | | | | | |
| 0.9-1.2 | | 3.98 | | | | | | |

| Depth (m) \ Hole # | 15B | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|
| 0-0.3 | 182 | 6.35 | 6.96 | 5.82 | 37.4 | 54.0 | 22.8 | 241 | 7.67 |
| 0.3-0.6 | | | | | 12.7 | 69.0 | 7.90 | 1600 | 8.40 |
| 0.6-0.9 | | | | | | 17.1 | 37.9 | 866 | |
| 0.9-1.2 | | | | | | | | 19.8 | |
| 1.2-1.5 | | | | | | | | 56.7 | |

| Depth (m) \ Hole # | 24 | 25 | 26 | 27 |
|---|---|---|---|---|
| 0-0.3 | 8.66 | 9.81 | 53.4 | 23.8 |
| 0.3-0.6 | 5.05 | 9.93 | 40.7 | 8.77 |
| 0.6-0.9 | | 12.0 | 36.2 | |
| 0.9-1.2 | | 7.68 | | |

Table 2- Uranium content (ppm on a dry weight basis) of auger samples from the west-central part of the Carson Range (Fig. 3)

| Depth (m) | Hole # 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0-0.3 | 9.84 | 184 | 351 | 431 | 297 | 146 | 106 | 31.1 | 353 | 106 |
| 0.3-0.6 | | 319 | 290 | 332 | 417 | 286 | 27.1 | 16.8 | 304 | 66.0 |
| 0.6-0.9 | | 241 | | | 375 | 119 | 31.1 | 7.94 | 292 | 45.8 |
| 0.9-1.2 | | | | | 190 | | 30.8 | | | 31.8 |
| 1.2-1.5 | | | | | | | 19.6 | | | |
| 1.5-1.6 | | | | | | | 18.2 | | | |

| Depth (m) | Hole # 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0-0.3 | 611 | 13.0 | 11.5 | 150 | 73.7 | 546 | 2520 | 261 | 228 | 47.3 |
| 0.3-0.6 | 1630 | 9.89 | | 145 | 49.2 | 177 | 1270 | 684 | 461 | 30.8 |
| 0.6-0.9 | 1520 | 9.22 | | | | | 612 | 236 | | |
| 0.9-1.2 | 232 | | | | | | | | | |

| Depth (m) | Hole # 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0-0.3 | 214 | 39.8 | 79.7 | 252 | 956 | 1640 | 175 | 1240 | 609 | 220 |
| 0.3-0.6 | 335 | 34.6 | 120 | 139 | 1090 | 1210 | 88.7 | 2450 | 333 | 104 |
| 0.6-0.9 | 167 | | | | 325 | 922 | | 1850 | 145 | 90.9 |
| 0.9-1.2 | 71.3 | | | | 678 | 1030 | | 1220 | | |
| 1.2-1.5 | | | | | | | | 472 | | |
| 1.5-1.8 | | | | | | | | 93.5 | | |

| Depth (m) | Hole # 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0-0.3 | 65.1 | 528 | 146 | 145 | 194 | 146 | 158 | 20.6 | 7.30 | 8.16 |
| 0.3-0.6 | 218 | 66.3 | 286 | | 214 | 112 | 75.5 | 19.4 | 5.53 | 5.83 |
| 0.6-0.9 | 227 | | 119 | | 586 | 87.1 | 28.6 | | | |
| 0.9-1.2 | 153 | | | | 93.6 | 85.6 | | | | |
| 1.2-1.5 | 24.8 | | | | 38.5 | | | | | |
| 1.5-1.8 | 276 | | | | | | | | | |
| 1.8-2.1 | 1360 | | | | | | | | | |
| 2.1-2.4 | 357 | | | | | | | | | |

| Depth (m) | Hole # 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|
| 0-0.3 | 118 | 681 | 51.6 | 3.67 | 892 | 89.7 |
| 0.3-0.6 | 59.3 | 386 | 36.4 | | 414 | |
| 0.6-0.9 | | 104 | | | | |

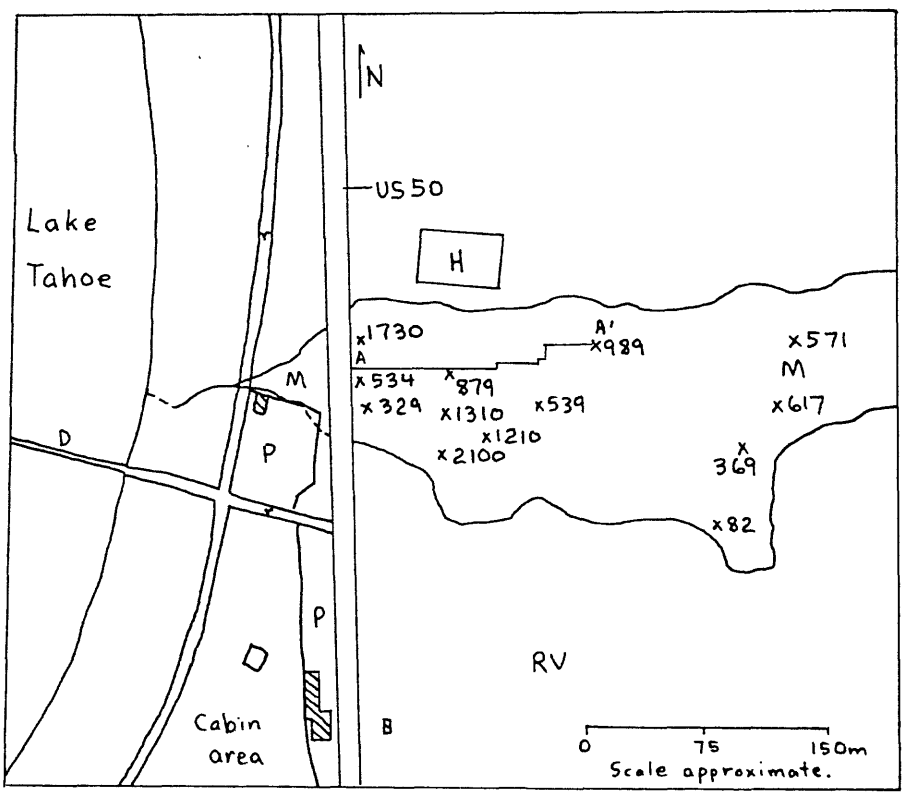


Fig. 4- Plan map for the lower Zephyr marsh. M- marsh; H- riding stable complex; RV- recreational vehicle park; D- dock; r- secondary roads. Cross-hatch- principal buildings. Base from air photo supplied by the Nevada Department of Transportation. Map is distorted. Marsh covered by willow, alder, reed and sedge. A-A'- Auger hole cross-section, Fig. 5. x- bucket auger samples sites with uranium in ppm, dry weight basis.

northeast corner. The surface flow from this principal tributary branches out from a single channelized stream to multiple, poorly defined channels and unchannelized flow. A second tributary valley with no surface drainage enters at the southeast corner of the marsh.

Sampling was limited to the area upstream from U.S. 50. Bucket auger samples of the surface sediment in the marsh show uranium values ranging from 82 to 2100 ppm on a dry weight basis (Fig. 4). In this limited sample set higher values tend to occur in the lower part of the marsh where the sediment is more uniformly water-saturated. Higher values also tend to occur in the northeast corner of the marsh near the principal inflow of water. A cross-section along the axis of the marsh (Fig. 5A) shows that the valley-fill sediment is characterized by organic muck at the surface, succeeded downward by clay and silt commonly with abundant fine plant debris and sand. The sand locally contains coarse fragments of plants. The sand content of the section increases progressively upstream at the expense of finer-grained materials. These units seem best interpreted as sand channel, sand sheet, overbank, and pond deposits based on comparison with the present surface environment. The uranium content of auger samples along the cross-section is as much as 2000 ppm (Fig. 5B). As in the surface samples, the uranium in the cross-section appears to be concentrated in the downstream portion of the bog, however, sands and silts at the upstream edge of the profile also contain significant uranium values. The lower Zephyr marsh is estimated to contain about 24,000 kg of uranium (Table 3).

The upper Zephyr fen (Fig. 6) occurs about 3 to 4 km upstream from the lower Zephyr marsh. In this area the stream valley splits and goes around a small hill. The fen occurs at the downstream confluence of the two valleys. It is covered by reed and sedge whereas upstream and downstream extensions are covered variously by willow, alder, and scattered pines. A large number of springs and seeps issue from a steeply pitched, willow- and alder-covered slope along the east edge of the fen (Samples W3, W4, W5, Fig. 6). More modest inflow occurs from stream channels, springs, and seeps in two areas; (1) the north end of the fen where one principal tributary valley and a lesser tributary valley enters (W6, W13); and (2) the northwest part of the fen where the other principal tributary valley enters (W7, W8,). The outflow is to the southwest across a manmade dam of cut timbers about 1 m high. This dam artificially deepened the bog and formed a pond which has since been filled with organic-rich sediment.

Two cross-sections along fences of core and auger holes (Fig. 7A and 8A) show that the fen is dominated by reed-sedge peat which locally reaches thicknesses of 4.6 m. Logs, abundant woody debris, thin lenses of silt and clay, and at least one thin layer of volcanic ash occur within the peat. The organic matter content of the sediment (estimated by loss on ignition) is as much as 92%. At depth, and at the upstream edge of the fen, the peat intertongues with silt, clay, sand, and granular sand. Auger holes in the valley-fill sediment downstream (sites 25 and

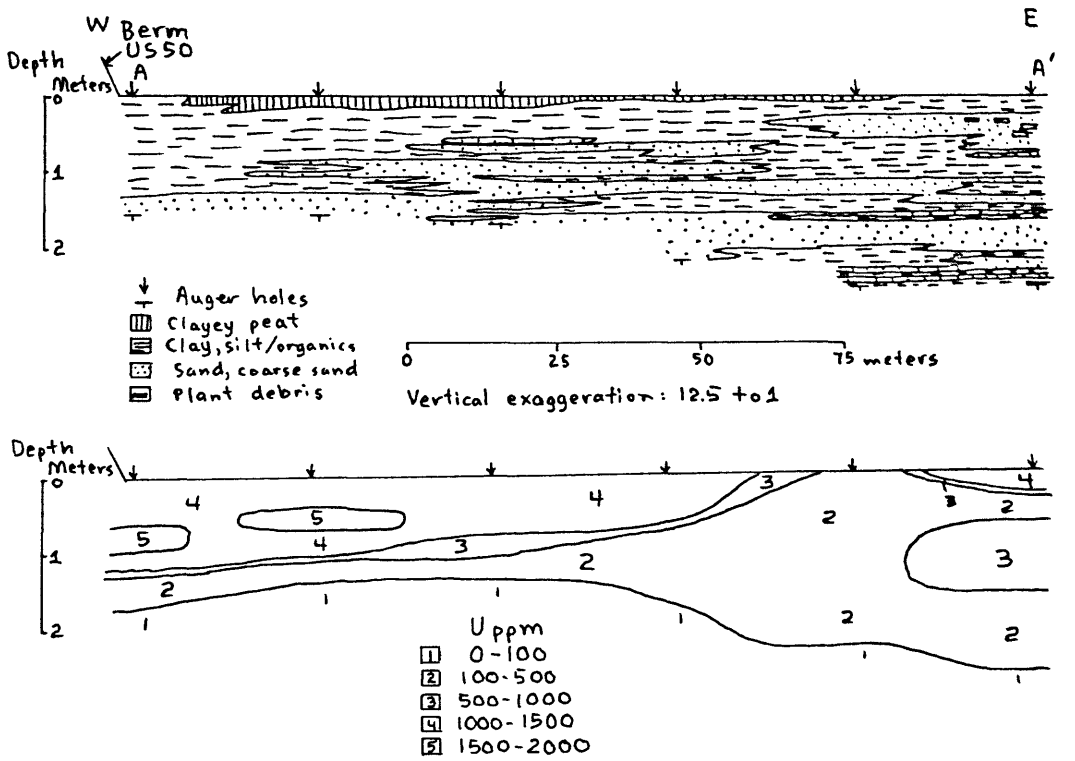


Fig. 5- A- Stratigraphic cross-section up the lower Zephyr marsh. See Fig. 4 for location.
B- Contour map of uranium values along cross-section.

Table 3- Calculation of uranium
in the lower Zephyr marsh

Dimensions of the deposit- 1.5 m thick (T) by 250 m long (L) by 100 m wide (W), from Figs. 4 and 5, using a cutoff of 200 ppm for thickness determination.

Average dry bulk density of host (d)- 0.8 g/cc (800kg/$m^3$). Estimated from Fig. 5, using 0.7 g/cc for clay and 1.3 g/cc for unconsolidated sand (Sowers and Sowers, 1961; Terzaghi and Peck, 1948). Note that the estimated average dry bulk density is biased towards the lighter material because it tends to have the higher uranium concentrations.

Average grade of uranium (g)- 800 ppm (0.08 weight percent or 0.0008 weight fraction). Estimated from average of surface samples (Fig. 4) and samples in profile (Fig. 6) above a cutoff of 200 ppm.

Volume of sediment (V)= TLW
= 1.5 m x 250 m x 100 m
= $3.75 \times 10^4$ $m^3$

Weight of sediment (w)= dV
= 800 kg/$m^3$ x $3.75 \times 10^4$ $m^3$
= $3.0 \times 10^7$ kg

Weight of contained uranium= wg
= $3.0 \times 10^7$ kg x 0.0008
=24,000 kg

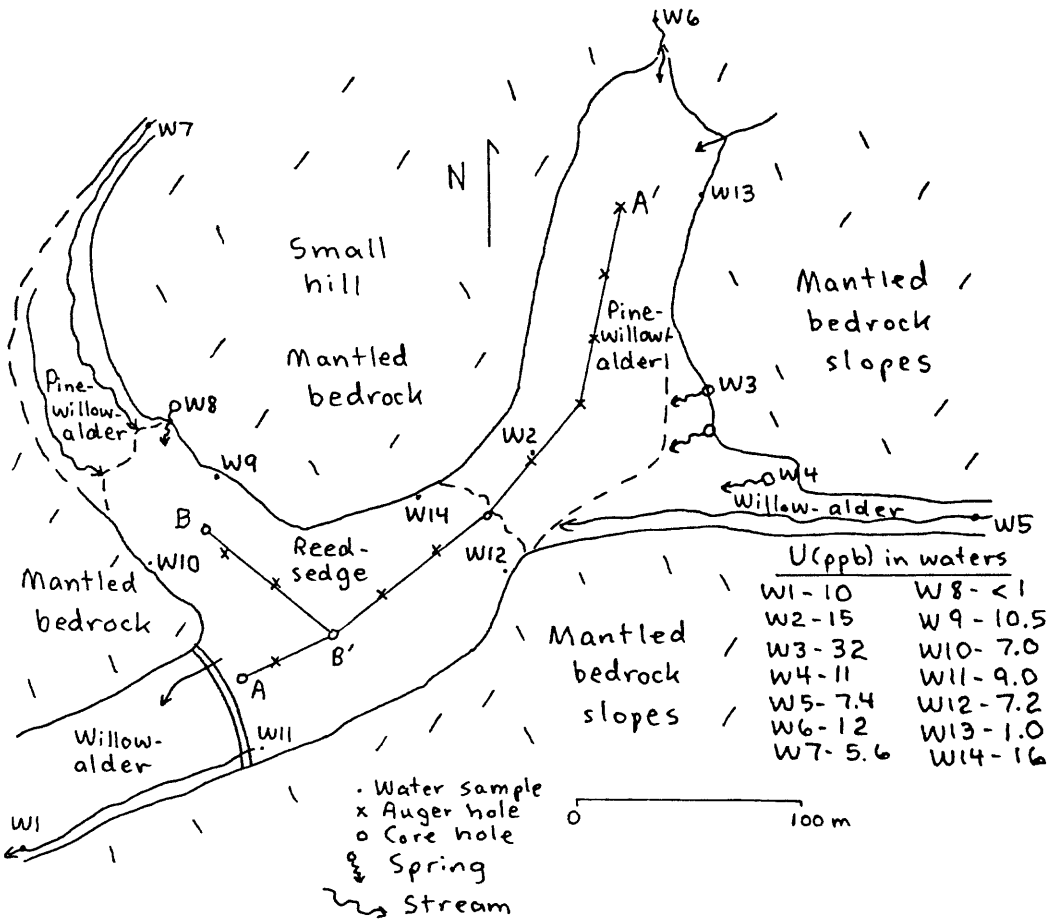


Fig. 6- Plan map for the upper Zephyr fen with water sample locations and data. Principal vegetative cover zones separated by short dash line. A-A', B-B'- lines of stratigraphic and uranium contour cross-sections (Figs. 7A,B and 8A,B). Water samples W10, W11, W12 and W14 are near-surface samples taken from shallow auger holes.

26, Fig. 3 and Table 2) suggest that the bog extends downstream from the dam about 0.6 km.

The 1 to 5 cm ash layer is tentatively identified as Mazama ash on the basis of chemical similarities to Mazama ash reported in Osgood Swamp just south of Lake Tahoe (Dave Adam, 1967; Robert Zielinski, unpub. data, 1984). If this identification is correct, much of the sediment in the upper Zephyr fen is post-6700 years B.P.

Uranium concentrations in the fen (Fig. 7B and 8B) include the highest seen in this study (3000 to 5760 ppm), and average about 1500 ppm on a dry weight basis (Table 4). The highest values generally occur on the east side of the small hill and in the lower half of both cross-sections. The highest values in the cross-section A-A' occur adjacent to water sample W3, which carries the highest uranium concentration (32 ppb). Uranium values in the upper 1 meter of sediment near the dam locally exceed 1000 ppm (Fig. 7B). Such concentrations must have formed during last 100 years, the maximum probable age of the dam.

These observations suggest that the springs along the east edge of the fen are a major source for the uranium in the fen and that uranium can accumulate rapidly in such environments. The upper Zephyr fen and its downstream extensions are estimated to contain about 15,000 kg of uranium (Table 4).

## Uranium in waters

The presence of anomalous accumulations of uranium in surficial sediments suggests that the associated ground and surface waters are enriched in uranium. Therefore, during the summer of 1984 we sampled waters in the Carson Range and adjacent areas. Seven reconnaissance samples were taken from streams and springs in the Carson Range and in the adjacent Carson Valley (Fig. 9). The stream and spring samples ranged from <1 ppb uranium at Walley's Hot Spring and at a spring 5 km west of the intersection of U.S. 395 and U.S. 50 to 14 ppb uranium at a spring along the Kingsbury Grade on the east side of the Carson Range. Water taken from a residence in the Gardiner Mountain area of the city of South Lake Tahoe (west of the area of Fig. 9) contained 3.7 ppb uranium.

Waters were also sampled in the area of detailed auger and core sampling in the west-central part of the Carson Range (Fig. 6 and 10). These waters range from <1 ppb uranium along Lincoln Creek to 177 ppb uranium in near-surface water taken from an auger hole in the lower Zephyr marsh adjacent to U.S. 50. In general, the drainages that are known to host anomalously uraniferous sediments in the west-central part of the Carson Range also contain springs and streams with anomalously high (>10 ppb) uranium concentrations.

Ground waters reported for the state of Nevada (Drury and others, 1981) range from 0.01 ppb to 179 ppb uranium, average 4.9 ppb; surface waters range from 0.01 ppb to 13.5 ppb, average 2.6

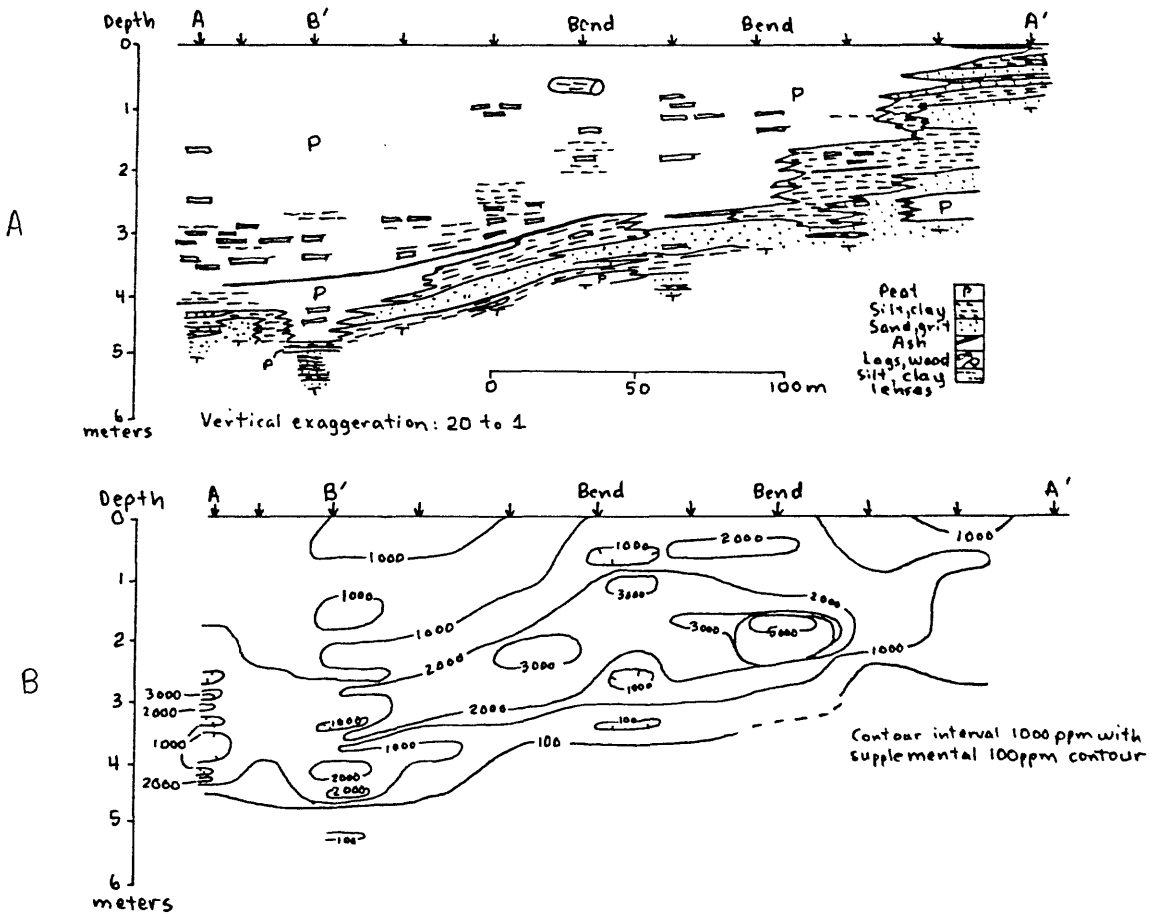


Fig. 7A- Stratigraphic cross-section A-A' in the upper Zephyr fen. See Fig. 6 for location.

7B- Contour map of uranium values along A-A'. Highest value is 5760 ppm U over a 0.3 m depth interval.

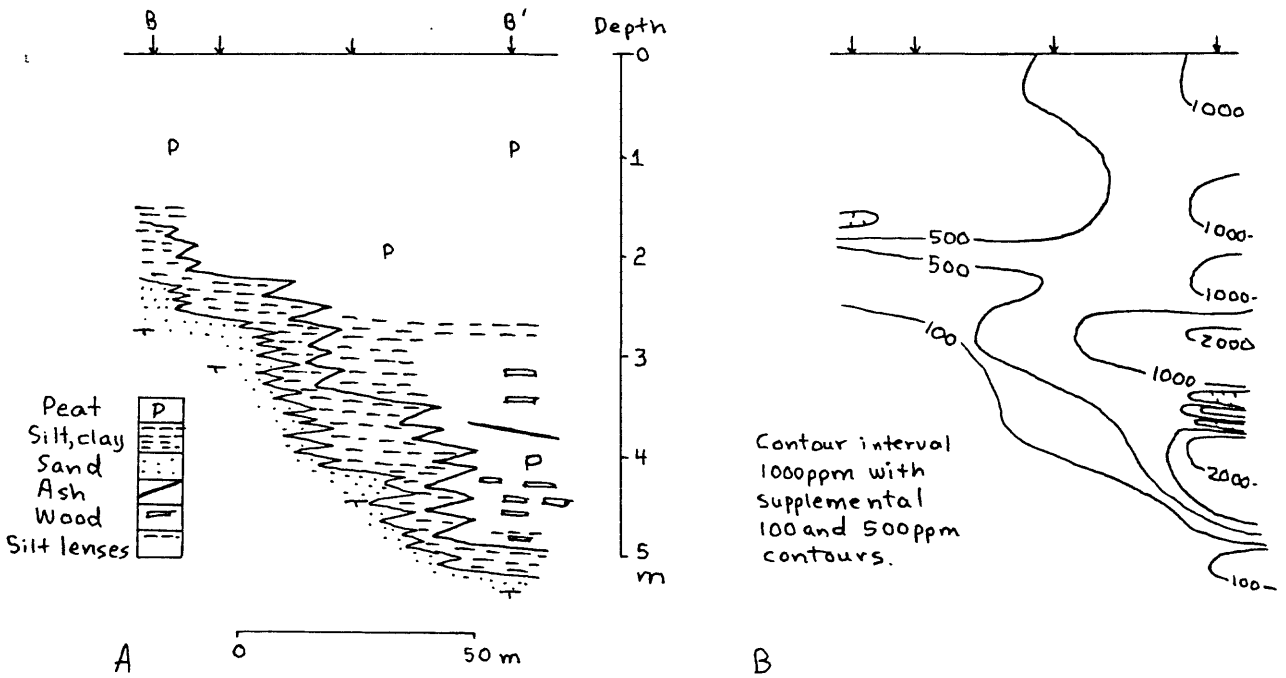


Fig. 8A- Stratigraphic cross-section B-B' in the upper Zephyr fen. See Fig. 6 for location.
8B- Contour map of uranium values along B-B'.

Table 4- Calculation of uranium
in the upper Zephyr fen

Calculation of the uranium content of sediment that is composed predominately of peat is very sensitive to the dry bulk density of the peat. Measurements of the dry bulk density of peat range from 0.04 g/cc to about 0.6 g/cc (Marachi and others, 1983; Clymo, 1983). Because of this variability, dry bulk densities used here were determined for the upper Zephyr fen using core material from the fen itself.

Data for the fen

| | T (m) | L(m) | W (m) | Average density ($kg/m^3$) | Average grade (weight frac) |
|---|---|---|---|---|---|
| Block A | | | | | |
| 1 | 2.4 | 130 | 60 | 80 | 0.001 |
| 2 | 1.8 | 130 | 60 | 200 | 0.0015 |
| Block B | | | | | |
| 1 | 2.7 | 90 | 60 | 140 | 0.002 |
| Block C | | | | | |
| 1 | 1.8 | 90 | 60 | 400 | 0.00075 |
| Block D | | | | | |
| 1 | 1.2 | 75 | 45 | 140 | 0.0004 |
| 2 | 0.8 | 75 | 45 | 350 | 0.0004 |
| Block E | | | | | |
| 1 | 2.4 | 300 | 30 | 200 | 0.001 |

Uranium calculation (See Appendix 1 for details)

$$\text{Uranium}_{(\text{total})} = 2.4 \times 130 \times 60 \times 80 \times .001 + 1.8 \times 130 \times 60 \times 200 \times .0015 + 2.7 \times 90 \times 60 \times 140 \times .002 + 1.8 \times 90 \times 60 \times 40 \times .00075 + 1.2 \times 75 \times 45 \times 140 \times .0004 + 0.8 \times 75 \times 45 \times 350 \times .0004 + 2.4 \times 300 \times 30 \times 200 \times .001$$

$$= 1500 + 4200 + 4100 + 300 + 200 + 400 + 4300$$

$$\text{Uranium}_{(\text{total})} = 15{,}000 \text{ kg}$$

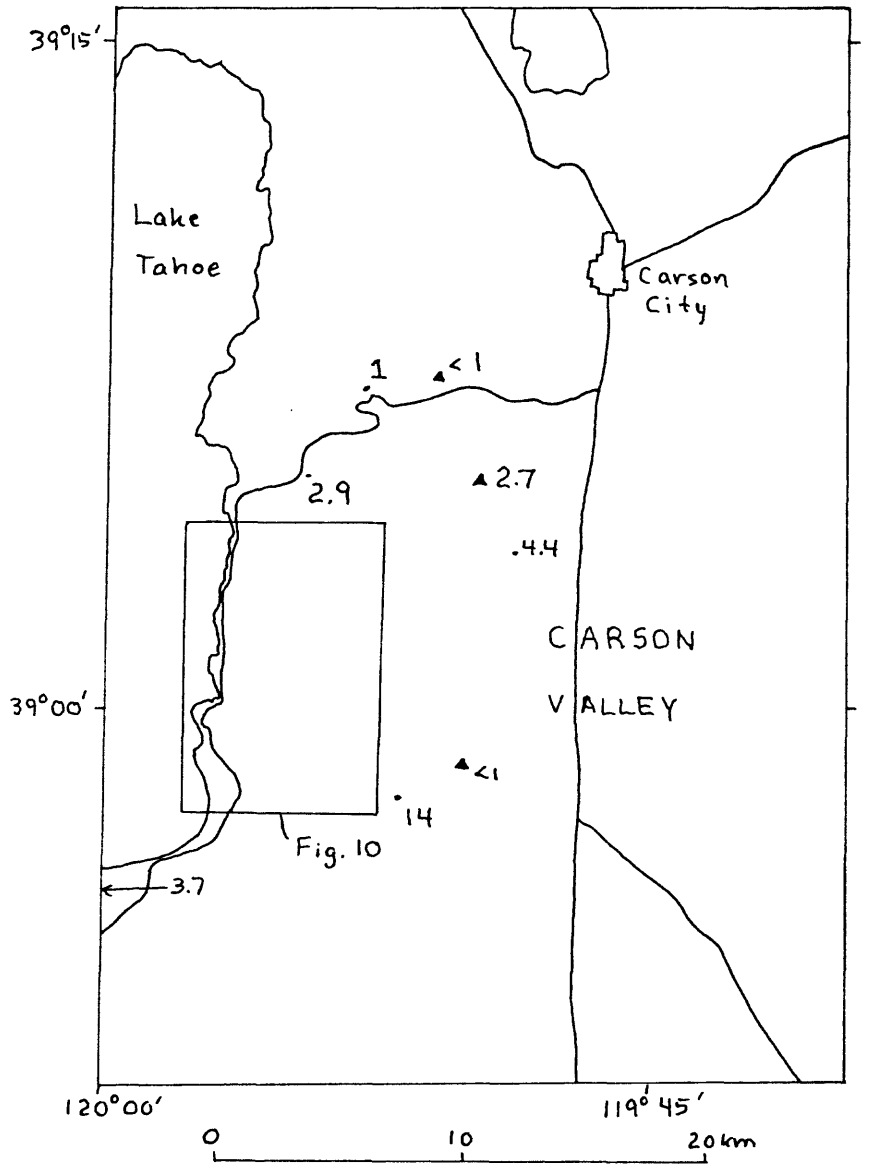


Fig. 9- Uranium in waters of the Carson Range and adjacent areas. Values in ppb. Dots- stream waters; triangles- spring waters. Sample containing 3.7 ppb U from tap water at private residence in the Gardner Mt. area of the city of South Lake Tahoe.

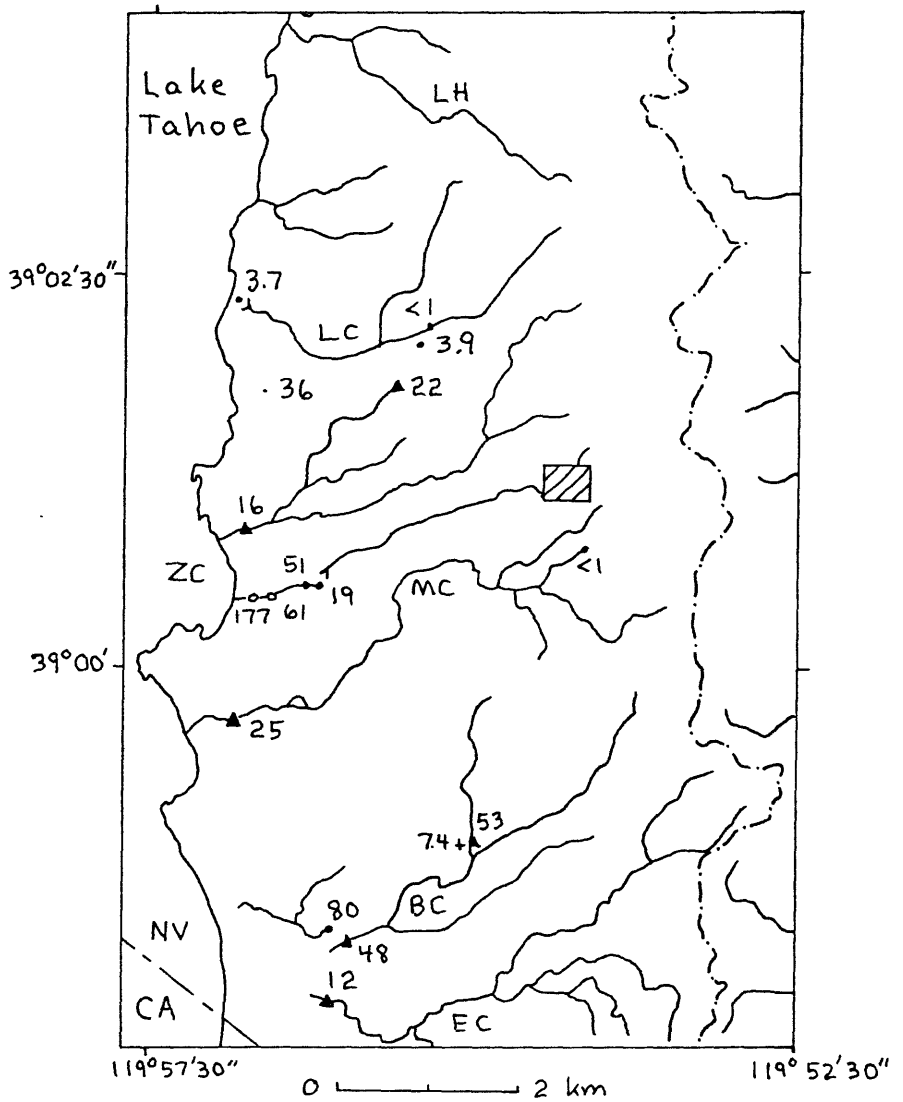


Fig. 10- Uranium in waters in the west-central part of the Carson Range. Values in ppb. For stream names, check Fig. 3. Triangles- stream waters; dots- spring waters; circles- near-surface waters; plus- well water. Cross-hatched area- detailed water sampling, see Fig. 6.

ppb; and domestic waters range from 0.05 ppb to 20 ppb, average 3.7 ppb. The spring and near-surface waters sampled in this study lie within the range of previously reported ground water values, however, many values for streams, especially those in the west-central part of the Carson Range (Fig. 10), exceed the previously reported values for surface waters. Although no national standard for uranium in drinking water (Maximum Contaminant Level) has yet been established by the Office of Drinking Water of the Environmental Protection Agency, a health effects guidance level of 10 pCi/l (15 ppb) uranium has been published (Cothern and others, 1983). This value, published for review and comment, is based on health effects (radiation carcinogenesis and kidney damage) and is not an official regulation. Many of the waters sampled in this study exceed this health effects guidance level.

## Radon and helium in waters

Because radon and helium are the products of radioactive decay of uranium, they commonly are found in anomalous concentrations in water and soil gas associated with uranium deposits in the United States and elsewhere (Smith and others, 1976; Rose and Korner, 1979; Reimer and others, 1979). High levels of radon also occur in ground waters in areas underlain by granitic or high-grade metamorphic bedrock that contain uranium but no indications of economic uranium deposits (Brutsaert and others, 1981; Asikainen and Kahlos, 1979). Sampling for radon and helium has not been undertaken in areas similar geologically and geomorphically to the Carson Range (A. B. Tanner and G. M. Reimer, oral commun., 1984). In order to establish baseline values and possible anomalous values in this region, radon and helium measurements were made for spring and surface waters at several sites near U.S. 50 immediately east of Lake Tahoe extending from Trout Creek north to the northern part of Zephyr Cove (Fig. 11).

Radon values range from 0 to 345 pCi/l. All but two samples were 8 pCi/l or less. The values are again lower in the small, turbulent streams and higher in the deeper slow-moving streams. The highest value (345 pCi/l) was found in Folsom Spring which also has high helium and uranium values. The spring at the head of the lower Zephyr marsh yielded no detectable radon but its helium level was similar to that of Folsom Spring. The spring along Burke Creek yielded 42 pCi/l. Radon levels in the limited number of ground waters sampled during this study do not exceed the interim suggested safe limit for radon of 500 pCi/l (United States Environmental Protection Agency, 1976), although one value (345 pCi/l) approaches the limit. A more recent study of radon in domestic water supplies in Maine recommends a higher limit in water (10,000 pCi/l; Hess and others, 1979).

The value for radon in Folsom Spring implies a nearby concentration of radium, the immediate precursor of radon. $Rn^{222}$ has a 3.825 day half-life, and the other principal Rn isotope, $Rn^{220}$, has a 55.6 second half-life. Thus, radon does not migrate very far in most natural ground water environments. Folsom

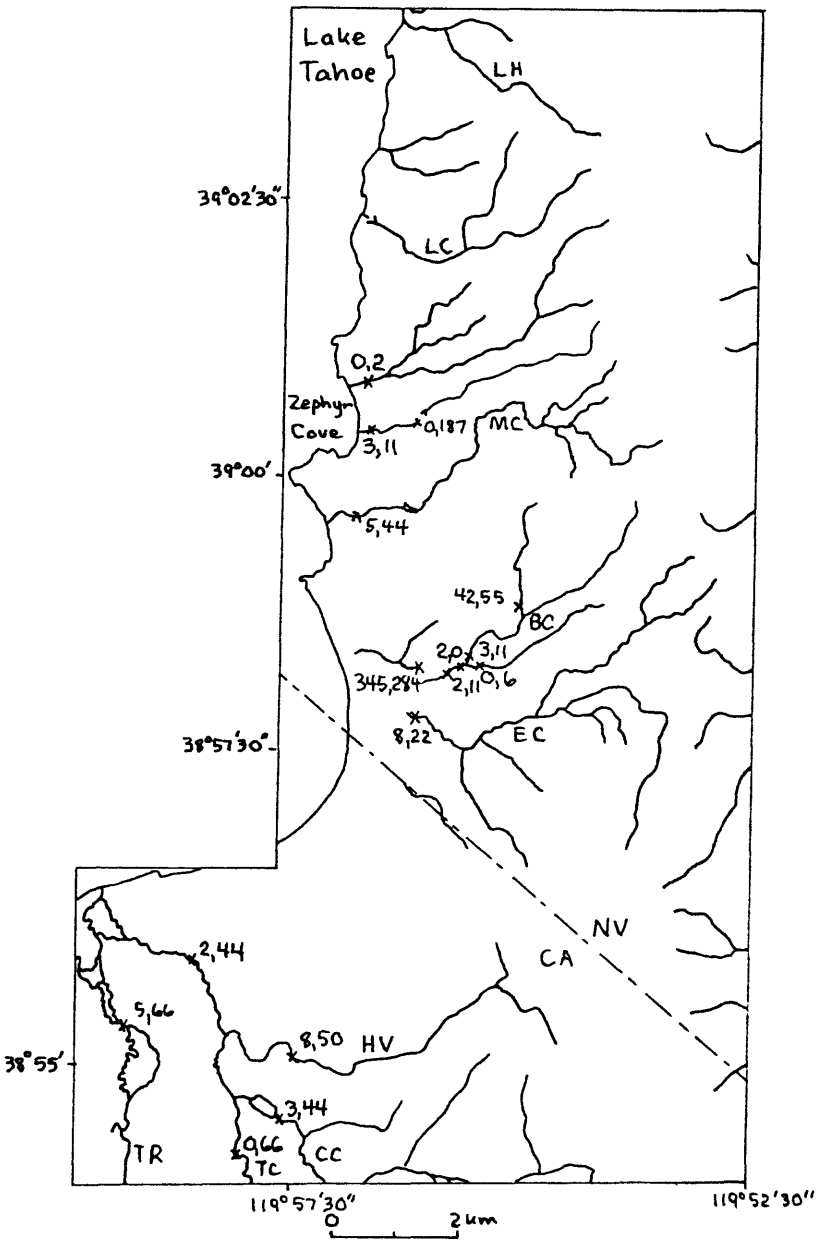


Fig. 11- Radon and helium in waters in the west-central part of the Carson Range. First number- radon in pCi/l; second number- helium in ppb above air (5240 ppb). LH- Logan House Creek; LC- Lincoln Creek; MC- McFaul Creek; BC- Burke Creek; EC- Englewood Creek; HV- Heavenly Valley Creek; CC- Cold Creek; TR- Upper Truckee River.

Spring has a very limited drainage basin (approximately 28,000 $m^2$), no accumulations of organic matter other that associated with a thin soil horizon are known and thus no accumulations of uraniferous surficial sediment occur. It seems likely that the radon, as well as helium and uranium come from some nearby bedrock source where uranium has previously been concentrated, such as a fault or fracture zone within the granodiorite.

Helium values in the waters range from 0 to 284 ppb above the atmospheric value (5240 ppb). The highest values for helium occur in two springs, Folsom Spring (284 ppb) and the spring at the upper end of the lower Zephyr marsh (187 ppb). A third spring along Burke Creek contained 55 ppb. Small, turbulent streams carry little helium (0 to 44 ppb), whereas deeper, slow-moving streams carry moderate levels of helium (44 to 66 ppb). Differences in the helium content of the streams probably results from greater mixing with air in the smaller, more turbulent streams. These helium levels do not constitute any potential environmental hazard.

Source for uranium

Based on local hydrologic flow regimes, the abundance and distribution of uranium in waters and near-surface sediment, and locally elevated radon values in springs, uranium almost certainly is derived from the granitoid rocks of the Carson Range. However, the presence of surficial uranium deposits in the Carson Range is surprising, because granodiorites, the dominant rock type in the study area, are not usually considered a good source for uranium and the plutonic rocks of the Carson Range are not geochemically similar to plutonic rocks that are known to be uranium sources. Granodiorites and granites from the Carson Range south of latitude 39° were sampled as part of the National Uranium Resource Evaluation of the Walker Lake 2° NTMS sheet (Durham and Felmlee, 1982). Eleven samples from within the study area ranged from 2.90 to 10.10 ppm U and averaged 5.41 ppm U. The thorium content of these rocks ranged from 9.91 to 37.10 ppm and averaged 17.42 ppm. The thorium to uranium ratio ranged from 2.02 to 4.28 and averaged 3.27. Armin and others (1983) also examined the mineralogy and determined the major element geochemistry of the granodiorites and granites in the southern part of this study area. The rocks are not unusual in their gross geochemistry or mineralogy nor are they unusual in their uranium or thorium content and the thorium to uranium ratio when compared to other granitic rocks in the western United States (Marjaniemi and Basler, 1972). The thorium to uranium ratio does not suggest a major loss of uranium from the bedrock. They do not fit the mineralogic and geochemical criteria of a good uranium donor granite such as the Archean granites of the Granite Mountains in Wyoming (Stuckless and Pires Ferreira, 1976).

In addition, no significant differences in the uranium geochemistry or other rock geochemical characteristics can be discerned between the southern part of the study area where little uranium appears to be moving in the surficial environment and the west-central part of the study area where there is

abundant uranium moving in the surficial environment. The west-central part of the Carson Range is underlain by the granodiorite of Daggett Pass and the granodiorite of East Peak and their probable northward extensions (Armin and others, 1983, T. Grose, written commun., 1984). Two samples of the granodiorite of East Peak yielded 4.56 and 4.09 ppm uranium, slightly below the average uranium content for rocks in the area. Three samples of the granodiorite of Bryan Meadow which underlies sediment sample locations in the south part of the area yielded 5.12, 4.90 and 10.10 ppm uranium.

We have noted deep weathering of the bedrock in the range even in roadcuts several meters high. It may be that, locally, due to variations in large ion partitioning during crystallization of the magmas, some uranium is sited in very labile positions within the rock, such as biotites or intergranular surfaces, and thus a part of the uranium present is readily leached during movement of water through the rock. If so, subtle petrologic differences in the bedrock within the study area may be more significant than gross geochemical differences. Implied in this is that the surface samples collected during the NURE study may not adequately reflect the original uranium content of the rocks nor the variability in uranium content within the study area.

The pathways of movement of uranium from bedrock sources into surficial sediments are not well known, however there are two possibilities: (1) near-surface leaching of exposed bedrock in the drainage basin, or (2) leaching of uranium from bedrock fractures by deeply circulating ground water. The first case implies a direct path from near-surface bedrock to surficial sediment and relatively recent movement. The second case implies an earlier dominantly downward movement of uranium along fracture zones possibly under different climatic conditions and a relatively recent remobilization of uranium from the fractures under current geomorphic and climatic conditions. Evidence from this study does not exclude either possibility and both may be operating.

Mass balance calculations suggest that very modest losses of uranium through weathering of near-surface rocks could provide sufficient uranium. For example, the drainage basin of the upper Zephyr fen has an area of about 1.75 $km^2$. Geologic reconnaissance and augering has established that no significant accumulations of organic matter and uranium occur upstream from the fen. If the upper 1 meter of granodiorite and grus within the drainage basin supplied all of the uranium to the fen, it would only need to have lost 0.34 ppm uranium to account for all the uranium present. From the uranium concentration in outflow water, it is obvious that the fen is not a highly efficient trap, however the deep weathering noted above may allow uranium to be leached from a larger body of rock than the upper 1 meter.

The granodiorites of the west-central Carson Range are deeply weathered, yet X-ray mineralogy of the clastic sediments in a few of the drainages show that feldspar, quartz and mica dominate, essentially no clay is present. It may be that during cold, glacial and periglacial conditions during the late

Pleistocene, deep physical weathering but little chemical weathering of the rocks occurred. Since the last glaciation more temperate conditions may have permitted chemical weathering to begin, and ground waters are now flushing uranium from previously physically weathered rock. The higher uranium content in the basal sediments of the upper Zephyr fen may reflect initial flushing of labile uranium from weathered rocks shortly after deglaciation.

The radon content at Folsom Spring, as noted above, may reflect a local uranium concentration in a fracture system. Although concentrations of uranium in bedrock fractures cannot be demonstrated in this study area because subsurface data are not available, other areas of surficial uranium deposits such as Stevens County, Washington are known to have uranium concentrations in bedrock fractures. In the drainage basin of the Flodelle Creek deposit in eastern Stevens County, uranium concentrations of as much as 500 ppm occur in facture zones encountered in drill holes (Robert E. Miller, Joy Mining Co., Spokane, Washington, written commun., 1983). The distribution of surficial uranium accumulations in the Carson Range may thus, in part, be related to zones of fracturing and shearing in the bedrock.

## Conclusions

Anomalous accumulations of uranium (more than 100 ppm) occur in sediment rich in organic matter at spring seeps, along valley bottoms, and in fens and marshes in the Carson Range. Uranium accumulations in the Carson Range are locally of high grade (as much as 0.6% on a dry weight basis) and accumulations exceeding 100 ppm have been documented in the area extending from the upper reaches of Franktown Creek on the north to Cold Creek on the south. The area of possible additional accumulations is open to the north, south, and west. Within the area of detailed sampling in the west-central Carson Range, uranium accumulations along the stream drainages from Logan House Creek south to Burke Creek commonly exceed 1000 ppm over 0.3 m intervals. Uranium accumulations in this area are distributed as shown in Figure 12. These accumulations are of a grade similar to uranium deposits under development in northeast Washington State, but the calculated tonnages of uranium are lower (Radiation Control Section, 1983; Robert E. Miller, Joy Mining Company, Spokane, Washington, written commun., 1983).

Reconnaissance sampling conducted during this study showed that slightly anomalous accumulations of uranium (20-100 ppm) also occur in the valley-fill sediments on the bottom of Carson Valley adjacent to the Carson Range.

The uranium content of waters in the study area range from <1 ppb to 177 ppb. Waters in the west-central part of the Carson Range are generally uniformly enriched in uranium. Elsewhere in the area where uraniferous sediment was found but no water samples have been collected, similar elevated levels of uranium are expected in the surface and ground waters. These uraniferous waters are clearly entering the private and public water supply

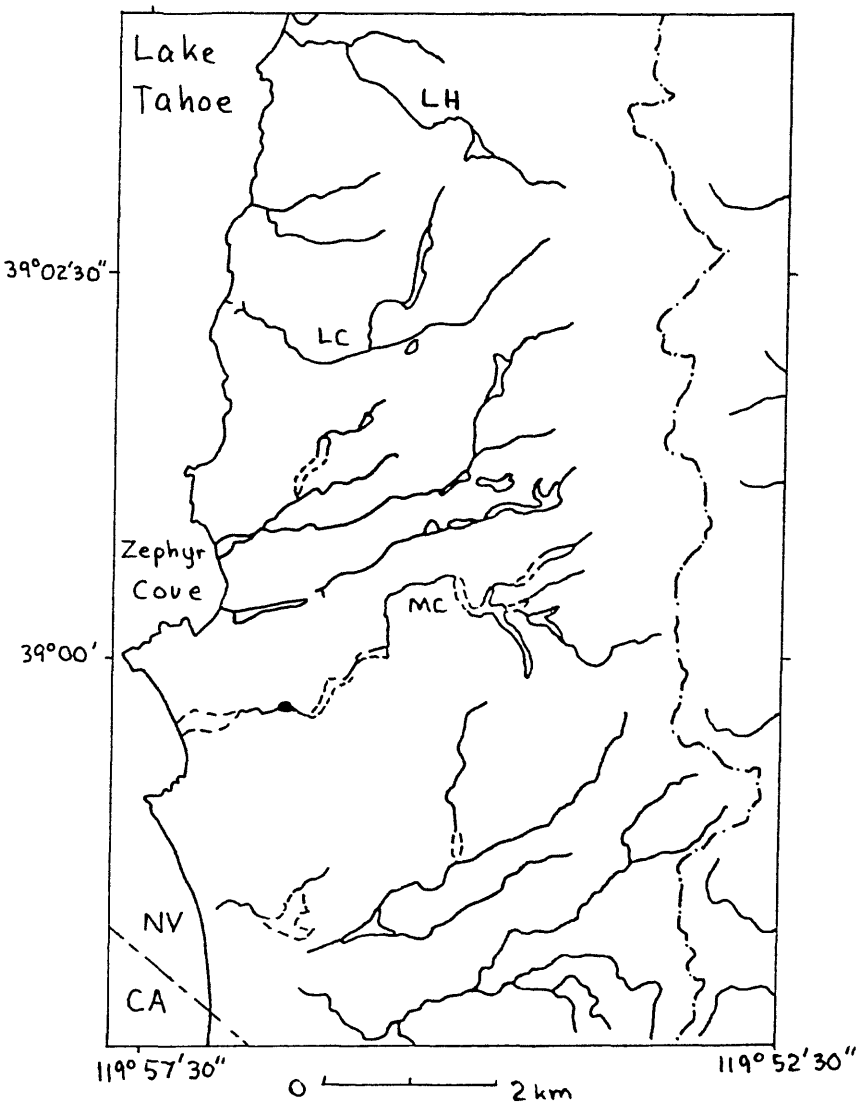


Fig. 12- Suggested areas of significant accumulations of uranium in Holocene valley fill, west-central Carson Range (at least 0.3 m of 100 ppm). Solid line- accumulations indicated by data (Figs. 3-7, Table 2). Dashed line- inferred accumulations.

systems in some parts of the study area, however it is not known how much uranium is reaching users of the water supply.

Geologic and geomorphic environments similar to the Lake Tahoe-Carson Range area are common in the Sierra Nevada. These studies thus suggest that other areas in the Sierra Nevada, in addition to those already identified, are likely to have uranium moving in the surficial environment although the data in this study do not allow us to predict what areas are most likely. Two springs immediately west and southwest of Lake Tahoe and others in the central Sierras are known to contain anomalous values of uranium (Glen Alpine spring, 54.7 ppb, and Rubicon Soda Spring, 12.7 ppb, and others; Tables 3 and 4, Barnes and others, 1981). Sediments associated with these springs have not yet been sampled.

Helium values in spring waters (284 ppb, 187 ppb) are clearly higher than those of surface waters (0-66 ppb) and turbulent streams contain less than non-turbulent ones. This relative order was expected and probably indicates loss of helium from surface waters during turbulent mixing with the atmosphere. No basis exists for comparison of these helium values to similar areas elsewhere.

Similar to helium, radon levels in springs thought to represent ground waters (345 pci/l, 42 pci/l) are higher than in samples from surface water sources. Turbulent streams contain less than non-turbulent ones. Atmospheric mixing seems to be the most reasonable explanation for these variations.

The presence of significant accumulations of a potentially hazardous, naturally-occurring substance in the near-surface environment of a populated area raises some questions regarding the effect of man-induced environmental changes, such as acid rain, on uranium trapped in the sediment. Laboratory studies of uraniferous sediment rich in organic matter may allow us to evaluate the potential of liberating uranium from such sediments and creating transient increases in the level of uranium moving in water in the natural environment.

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