Uranium Distribution and Geology in the Fish Lake Surficial Uranium Deposit, Esmeralda County, Nevada

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Uranium Distribution and Geology in the Fish Lake Surficial Uranium Deposit, Esmeralda County, Nevada

By DAVID L. MACKE, R. RANDALL SCHUMANN, and JAMES K. OTTON

Uranium-enriched lacustrine and marsh sediments in the Fish Lake Valley

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Uranium Distribution and Geology in the Fish Lake Surficial Uranium Deposit, Esmeralda County, Nevada

By David L. Macke, R. Randall Schumann, *and* James K. Otton

Abstract

Fish Lake Valley, in southern Nevada and California, contains about 675 acres of uranium-enriched lacustrine and marsh sediments in an arid alluvial-fan environment. A change in the trend of the Silver Peak Range, which forms the valley's eastern margin, and bedrock spurs that divert clastic sediments away from the marsh have allowed a large deposit of lacustrine and marsh sediment to accumulate. Section lines across the deposit were sampled at 0.3-m intervals to a maximum depth of 6.5 m. All samples were dried and analyzed for uranium and organic matter content. Uranium concentrations in the sediments ranged from 6 to 800 ppm and averaged 64.3 ppm (253 samples). Uranium values correlate with organic content of the samples.

The marsh is fed by ground water and surface runoff derived from the Silver Peak Range. Tertiary volcanic rocks of the Silver Peak Range supply uranium to the base of the deposit in upwelling ground water. The uranium is concentrated in organic-rich layers in the marsh sediments. Water migrating laterally through the marsh sediments at the edge of the permanent pond in the southern part of the area may also contribute uranium to the sediments.

Reconnaissance sampling in the surrounding valley and mountain areas showed minor enrichment of uranium (as much as 150 ppm) in wetland areas and localized accumulations of organic-rich sediments.

INTRODUCTION

Surficial uranium deposits have been broadly defined as "uraniferous sediments or soils, commonly of Tertiary to Holocene age, that have not been subjected to deep burial and may or may not have been cemented to some degree" (Toens and Hambleton-Jones, 1984, p. 9). Surficial uranium deposits occur in wetland, arid-land, and tropical settings (Otton, 1984a). Uranium-fixation mechanisms vary according to the geological setting. The initial fixation of uranium in wetland surficial uranium deposits is probably by adsorption of U(VI) from ground or surface water onto organic matter. Organic-rich sediments are so efficient in trapping uranium that surficial uranium deposits (defined as having uranium concentrations greater than 100 ppm; Otton, 1984a) can form from water containing as little as 5–10 ppb uranium (Otton, 1984a). Modern surficial uranium deposits typically contain very low concentrations of uranium daughter products. Radiometrically equivalent uranium values (uranium calculated from the radioactivity of its decay products) are commonly only 5 to 10 percent of chemical uranium (R. R. Culbert, written commun., 1982). The relative paucity of uranium decay products limits the amount of high-energy gamma rays produced by these deposits and, therefore, their detection by conventional radiometric techniques (Otton, 1984b; Culbert and Leighton, 1981).

Surficial uranium deposits pose an environmental hazard because the uranium can be remobilized in unconsolidated sediments. Ingested from drinking water, uranium is chemically toxic to the kidneys and may also have a finite radiation toxicity (Cothern and others, 1983). Many surficial deposits may exist, and more information on the geologic setting and geochemistry of surficial uranium deposits is needed to assess their potential impact on public health.

The surficial uranium deposit in Fish Lake Valley (fig. 1) was first identified in 1982 during reconnaissance sampling of the Great Basin area (R.R. Culbert, written commun., 1982). Culbert reported values exceeding 1,500 ppm (analysis by low-energy gamma-ray spectrometry). The Fish Lake uranium deposit is significant because it is an organic-rich surficial uranium deposit of the type normally associated with humid climates (Otton,

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1984a) and is in a geologic and climatic setting where silcrete, calcrete, or pedogenic uranium accumulations are expected to occur (Toens and Hambleton-Jones, 1984).

Acknowledgments.—The authors acknowledge the help of Charles T. Pierson with the statistical analysis of the data. Richard Wanty provided modal analyses of the water-chemistry data, and the interpretation of the water chemistry is based primarily on an analysis of the data by Robert A. Zielinski.

PHYSIOGRAPHY AND CLIMATE

Fish Lake Valley is an area of approximately 2,600 km^2 (square kilometers) bounded by the White Mountains to the west, the Candelaria Hills and the Volcanic Hills to the north, the Silver Peak Range to the east, and the Palmetto Mountains, Sylvania Mountains, and the Last Chance Range to the south (fig. 1). The valley floor ranges in elevation from about 1,585 m near its southern end to about 1,430 m at the playa in the northeast (Rush and Katzer, 1973). The Volcanic Hills separate the northern end of the valley into two parts.

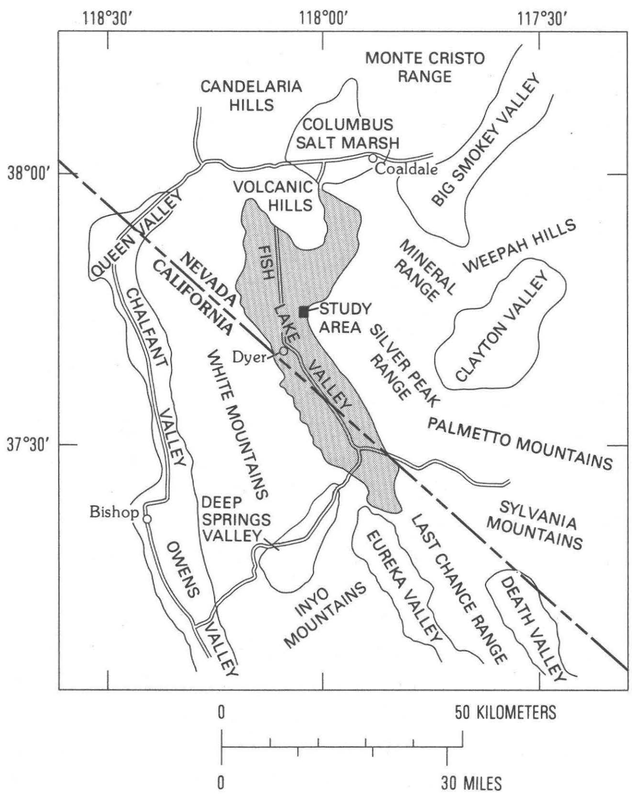


Figure 1. Location map of Fish Lake Valley, Nevada and California, showing adjacent valleys and mountain ranges.

The surface drainages from the northwestern part of the valley skirt the Volcanic Hills and terminate in the playa lake in the northeastern part.

The climate of the region is arid, but at higher elevations topographic effects increase rainfall. Precipitation averages 100 to 150 mm on the valley floor and fan apron, and approximately 610 mm in the White Mountains at elevations above 3,570 m, where it falls principally as snow (Rush and Katzer, 1973).

REGIONAL GEOLOGY

Sedimentary rocks of Precambrian to Ordovician age are exposed in the ranges surrounding the valley. Jurassic and Cretaceous intrusive rocks occur at Mineral Ridge and in the White and Palmetto Mountains (Krauskopf, 1971; McKee and Nash, 1967). The White Mountains are an outlier of the Inyo batholith, a composite granitic batholith that is exposed throughout an area of 1,300 km^2 in east-central California.

Tertiary rock units exposed in the Silver Peak Range are thick sequences of tuffaceous volcanic sandstone and siltstone and interbedded air-fall tuff. Tertiary basalt flows and cinder beds in the Volcanic Hills are locally as much as 240 m in thickness and are approximately contemporaneous with andesite flows and their intrusive equivalents in the White Mountains (Robinson and Crowder, 1973; Crowder and others, 1972). Deposits of late Pleistocene and Holocene age include glacial moraines above 2,590 m in the White Mountains (Krauskopf, 1971), alluvium (which may in part be glacial outwash), bedded clay and silt, landslide deposits, desert wash, colluvium, playa deposits, and freshwater limestone (Albers and Stewart, 1972).

The most abundant Quaternary deposits in the area are alluvial-fan deposits, including desert wash, colluvium, and alluvium, together with playa-lake deposits. Quaternary deposits may be several hundreds of meters in thickness. A large area in the northeastern part of the valley is covered by playa-lake and mud-flat deposits, which are generally crusted by a thin layer of salt (Albers and Stewart, 1972).

The Fish Lake surficial uranium deposit is a post-glacial(?) freshwater marsh within Fish Lake Valley at a bend in the Silver Peak Range where the fault zone bounding the northwestern part of the range apparently ends beneath Fish Lake Valley (figs. 1, 2). North of the bend, the bounding fault is downthrown to the west; south of the bend, the west flank of the range dips under the valley, apparently without a bounding fault (Albers and Stewart, 1965). Fault scarps on the eastern and western sides of the valley displace alluvial fans by several meters and indicate Quaternary faulting.

GROUND WATER AND SPRINGS

The principal source of ground water in Fish Lake Valley is the valley-fill alluvium, and four of the five major spring complexes in the valley flow from the alluvium. The spring at Fish Lake (figs. 2, 3; sample FLW85–1, appendix 1), however, apparently flows from carbonate rock, based on field observations (Garside and Schilling, 1979; Robinson and others, 1976; Rush and Katzer, 1973), and is the largest of a line of springs in the spring complex that begins at Fish Lake and trends northeastward along the flank of the Silver Peak Range, following the fault zone that forms the northeastern edge of the valley. The Fish Lake spring (figs. 2, 3) has an estimated discharge of 0.085 m^3/s (cubic meter per second), which is more than half of the approximately 0.156 m^3/s discharge of the spring complex. The temperature of the Fish Lake spring is 24 °C (Garside and Schilling, 1979). The spring has total dissolved solids of 246 mg/L (milligrams per liter; calculated from data by R.A. Zielinski, written commun., 1985), compared to an earlier reported value of 363 mg/L (Garside and Schilling, 1979). Water samples from the springs at Fish Lake and Dyer cemetery (figs. 2, 3; sample FLW85–2, appendix 1) contained 9 ppb (parts per billion) and 2 ppb uranium, respectively.

In addition to the springs at Fish Lake and Dyer Cemetery, six other springs were sampled for chemical analysis (appendix 1): three within the valley in the valley-fill alluvium, one in carbonate rock in the Silver Peak Range, and two in valley-fill alluvium in the White Mountains. The higher calcium content of the samples from Fish Lake and Dyer cemetery springs (samples FLW85–1 and 2, appendix 1), relative to other water samples (fig. 3), may reflect the influence of local carbonate rock. The higher total dissolved solids of samples FLW85–4 and 5 may indicate interaction of the water with evaporitic salts in the playa sediments, or evaporative concentration.

The three springs sampled in the valley, away from the marsh area, are the Pinto Hill spring, the Lower McNet Ranch spring, and a spring at the southern end of the playa lake (fig. 2). The Pinto Hill spring (sample FLW85–3, appendix 1) is at an elevation of 1,658 m, and the sample was taken from a seep on the south side of the hill. The Lower McNet Ranch spring (sample FLW85–4, appendix 1) is at an elevation of 1,445 m and flows approximately 0.012 m^3/s (Rush and Katzer, 1973) at a temperature of 25 °C (Garside and Schilling, 1979) from a well drilled into a natural spring. There are two springs at this locality, and they seem to flow at about the same rate. These springs drain into a boggy area covered by grasses and reeds that begins about 60 m downslope from the springs and extends northeast, almost to the playa lake. The playa-lake spring (sample FLW85–5, appendix 1) is at an elevation of 1,435 m, near the southern end of the playa. At the spring is a shallow pool 2–3 m in diameter that is surrounded by grasses and reeds.

The McAfee Canyon spring (sample SPW85–1, appendix 1) is at an elevation of 2,270 m, along the thrust fault separating overlying Cambrian shale, quartzite, and limestone from underlying Ordovician shale, chert, and limestone (Stewart and others, 1974). When we sampled the spring, it was little more than a trickle, but diversion structures for livestock use imply that it has had larger discharge.

The two springs sampled in the White Mountains are in the Indian Creek and Trail Canyon drainages. The Indian Creek and Trail Canyon springs flow from Quaternary alluvium that fills valleys cut into the granitic Inyo batholith. The Indian Creek spring (sample WMW85–1, appendix 1) is just below Post Meadow at an elevation of 2,240 m. The spring is on the northern side of the valley near the southern end of an area of small springs. The Trail Canyon spring (sample WMW85–2, appendix 1) is just upstream from a small livestock pond at an elevation of 2,455 m. A boggy meadow is just below the spring.

Water from all five springs (samples FLW85–1 through 5, appendix 1) in the valley has similar major-element chemistry (fig. 4*A–E*), dominated by sodium, potassium, and bicarbonate (HCO_3). Water from the springs in the Silver Peak and White Mountains, however, has major-element chemistry dominated by calcium and bicarbonate (HCO_3; figs. 4*F–H*). Garside and Schilling (1979) and Trexler and others (1983) suggested that the water of the Fish Lake and the Lower McNet Ranch springs is related to hydrothermal systems associated with the Silver Peak caldera complex or the Volcanic Hills extrusive rocks, or both. Edmiston and Benoit (1984) investigated the thermal water of Fish Lake Valley in subsurface wells.

The composition of water samples in this study suggests that there are two types of springs in the valley: feeder springs, and springs affected by evaporative concentration or interaction with evaporite beds, or both.

Sample FLW85–4, in particular, appears to have major-element and chlorine abundances consistent with a three- to four-fold concentration of water similar to FLW85–3. Other trace elements are less concentrated (boron, potassium, strontium, lithium, and uranium) and may be enriched by selective desorption and dissolution of these highly soluble elements from the host sediments. Still other trace elements (organic carbon, zinc, barium, vanadium, and nickel) appear to be precipitating during evaporation.

The spring-water samples from the White Mountains are typical of water in granitic rocks; silica contents are low and in equilibrium with quartz, and calcite is undersaturated. The water sample from the

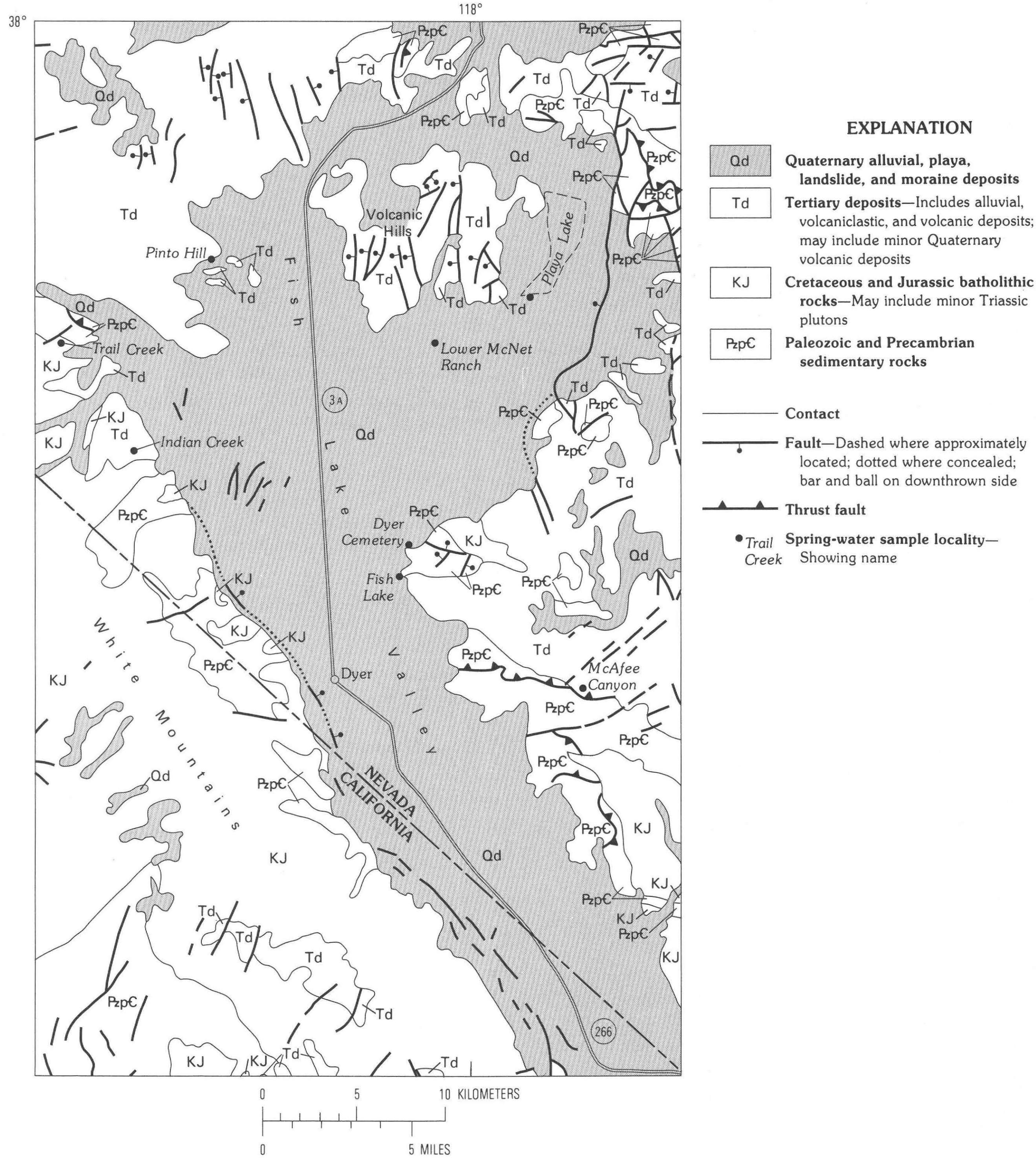


Figure 2. Generalized geologic map of the Fish Lake Valley showing localities of spring water and sediment samples. Geology of California from Jennings (1977). Geology of Nevada from Stewart and Carlson (1978).

Silver Peak Range, however, is higher in silica content, approaching saturation with amorphous silica, possibly indicating equilibrium with volcanic glass. Calcite is oversaturated in the Silver Peak Range water sample, and the concentration is consistent with the presence of calcite-rich sediments in the section. The Fish Lake Valley spring-water samples (FLW85-1 to -5) are also silica rich, and their silica concentrations appear to be limited by the solubility of amorphous silica. Authigenic silica gels may ultimately precipitate from this water.

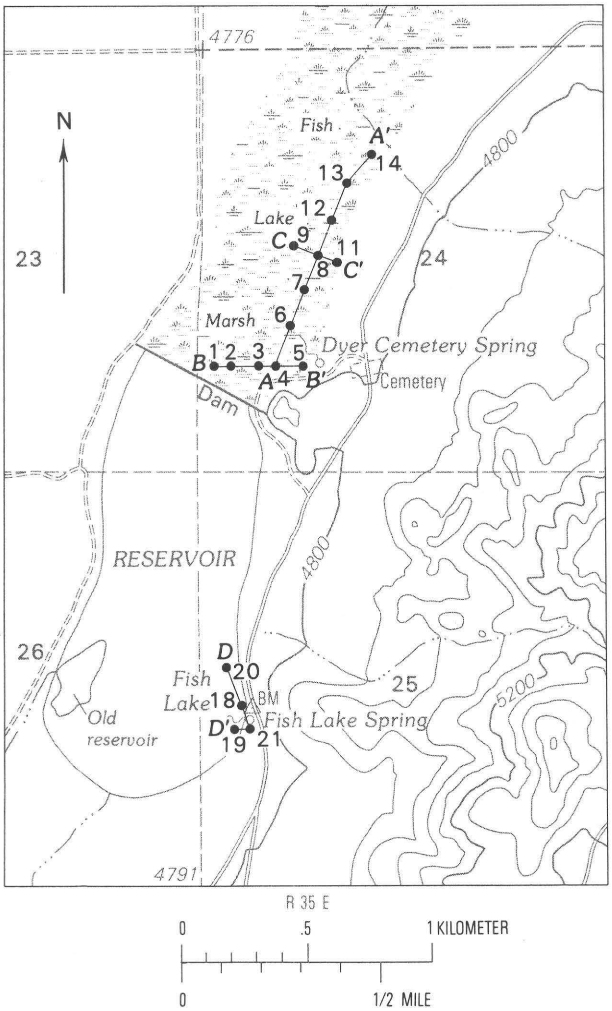


Figure 3. Map of the Fish Lake area showing auger-hole locations in the Fish Lake marsh and lines of cross sections shown in figure 5 (base from Rhyolite Ridge, Piper Peak, Davis Mountain (1963), and Mt. Barcroft (1962) 15-minute topographic quadrangle maps, scale 1:62,500). The original Fish Lake is directly east of auger hole 18. The old reservoir to the west of Fish Lake is manmade. The new dam (see text) floods the entire marsh area to a point approximately 300 m south of holes 19 and 21.

Calcite saturation varies, perhaps indicating slow kinetics of calcite precipitation as water becomes saline in composition (see, for example, the compositions of samples FLW85–3 and FLW85–4, appendix 1).

Based on molar rates of (total alkalinity)/2 $(Ca^{+2}+Mg^{+2})$, this dilute water would evolve upon evaporation to a saline-alkaline brine by precipitation of calcite and dolomite, possibly with the precipitation of magnesium-rich clays. Gypsum is greatly undersaturated in all the water samples, and gypsum precipitation is not predicted during the evaporative concentration of these water compositions.

Uranium is introduced as uranyl carbonate species and should be stabilized and enriched in carbonate-rich formation water as long as the water is sufficiently oxidizing to keep uranium in a U(VI) oxidation state. Carbonate-rich water is less likely to give up uranium to coexisting organic matter (Zielinski and Meier, 1988). An Eh of approximately zero should be sufficient to reduce uranium, and adsorbed uranium may ultimately be fixed in this way. The relatively high concentration of both iron and uranium in some sampled feeder springs (Lower McNet Ranch, samples SPW85–1 and WMW85–1, appendix 1) suggest a rather restricted Eh range of approximately 0–0.2 volts (mildly oxidizing). At lower Eh values, uranium should precipitate as U(IV) minerals (minerals with low uranium solubility). At higher Eh values, iron precipitates as $Fe(OH)^3$. Other water types generally have a more oxidizing chemical signature (high uranium, high V, high NO_3, high As, and low iron and manganese).

Arsenic concentrations are high and rather constant in all of the Fish Lake Valley water samples, and perhaps are controlled by sorption on $Fe(OH)_3$.

THE FISH LAKE SURFICIAL URANIUM DEPOSIT

Fish Lake and Fish Lake marsh are on the eastern margin of Fish Lake Valley and on the western flank of the central Silver Peak Range (figs. 1, 2). Fish Lake is the only permanent natural body of water within the extremely arid valley and is maintained by discharge from the Fish Lake spring. Fish Lake marsh extends about 2,740 m along the axis of the valley and is generally less than 800 m wide. On U.S. Bureau of Land Management aerial photographs taken in 1980, the marsh consists of roughly 2.7 km^2. Fish Lake spring is near the southern end of the marsh, and the Dyer cemetery spring is near the center of the marsh.

Field work for this study was conducted in the fall of 1985. During the previous winter, an irrigation-storage dam was built near the center of the marsh (fig. 3), just south of the Dyer cemetery spring, flooding the southern part of the marsh area. As a result, access to the southern part of the marsh was limited. Therefore, the area was divided into northern and southern sampling areas, and the northern part of the marsh was sampled more extensively than the southern part.

The marsh deposits were sampled using a 25-mm-diameter soil auger, and sample localities were less than 60 m to 150 m apart. Samples were collected at 30-cm intervals within each hole, air dried, and analyzed for uranium by delayed-neutron technique and for organic matter content by weight loss on ignition at 550 °C (appendix 2). Uranium and loss-on-ignition analyses

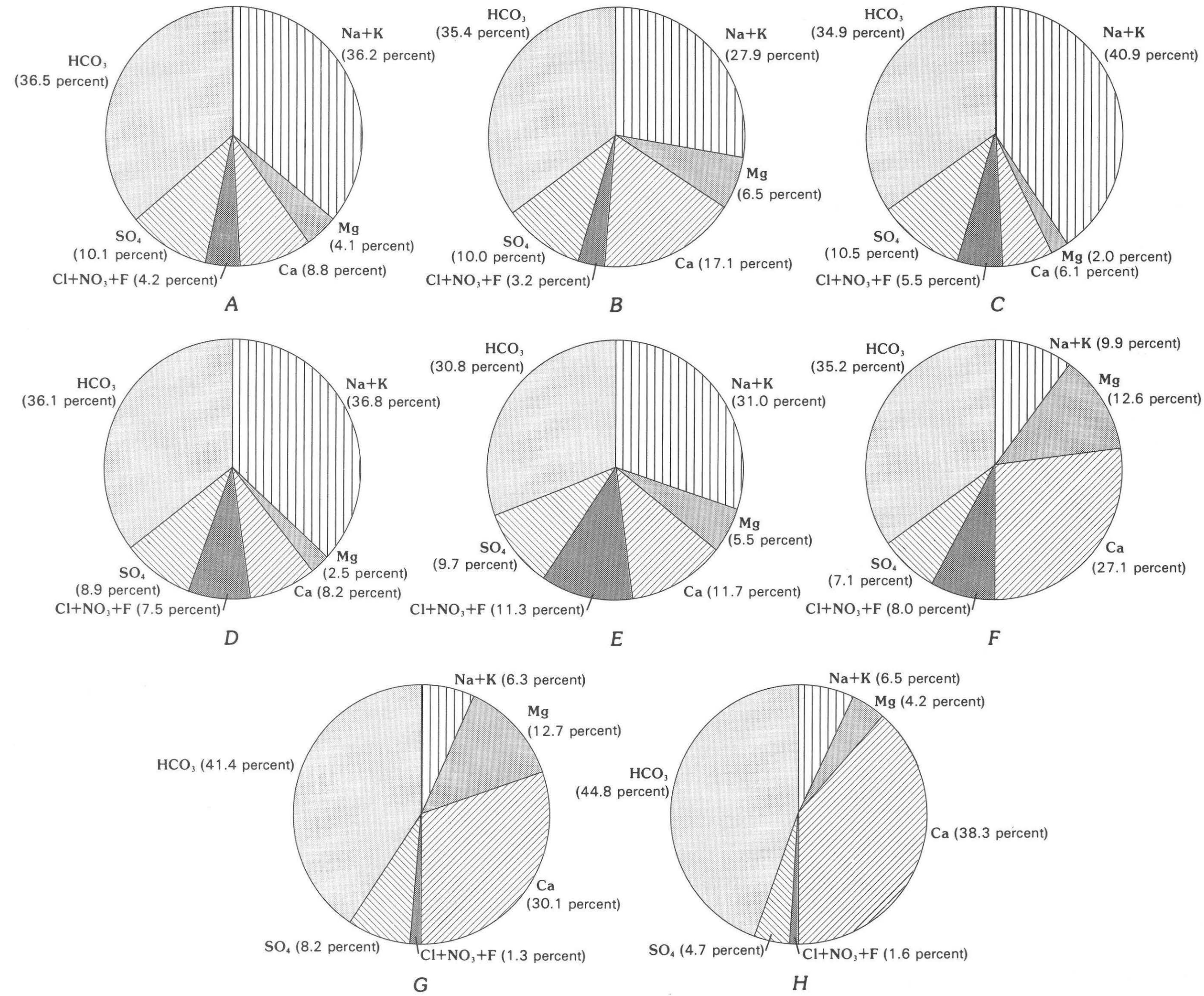


Figure 4. Major-element composition of spring water from Fish Lake Valley and vicinity, Nevada and California. The total cations and the total anions of the major elements balance within approximately 5 percent; the difference is due to minor elements (appendix 1). Location of springs shown on figure 2. *A*, the spring at Fish Lake, sample FLW85–1; *B*, the spring at the Dyer cemetery, sample FLW85–2; *C*, the spring at Pinto Hill, sample FLW85–3; *D*, the spring at Lower McNet Ranch, sample FLW85–4; *E*, the spring at the south end of the playa lake, sample FLW85–5; *F*, the spring in McAfee Canyon, Silver Peak Range, sample SPW85–1; *G*, the spring in Indian Creek canyon, White Mountains, sample WMW85–1; and *H*, the spring in Trail Canyon, White Mountains, sample WMW85–2.

were performed by U.S. Geological Survey laboratories at Denver, Colo. Cross sections of the northern marsh (figs. 5*A*, *B*, *C*, and *D*) were prepared based on field descriptions of the auger samples.

The extent of the marsh deposits is primarily controlled by the discharge from the Fish Lake and Dyer cemetery springs (fig. 3). Although a relatively large marsh extends north of the Dyer cemetery spring, it has been drained and is covered by meadow grasses.

The topography of the Silver Peak Range and the asymmetry of the Fish Lake Valley are secondary controls on the extent of the Fish Lake marsh deposits. Both the Fish Lake and Dyer cemetery springs are at the base of bedrock spurs that have shielded the immediate vicinity of the springs from clastic sediments. Also, a local change in the trend of the Silver Peak Range from northwest to northeast determined the orientation of the nearby Icehouse Canyon (northwest) and Piper Canyon (southeast) drainages, sheltering the marsh from easterly derived clastic sediments. Larger drainage areas, higher relief, and greater precipitation in the White Mountains have produced larger alluvial fans than those of the Silver Peak Range, and the valley axis shifted to the east. The White Mountain front is approximately 3.7 km west of the marsh, and the alluvial-fan sediments that reach the marsh are fine-grained distal silt and clay. Only distal fan sediments reach the marsh area from the alluvial fans of the Silver Peak Range as well, because the bend in the range directed the drainages north and south of the marsh to the northeast and the southeast, away from the marsh area. The result might be called a "clastic shadow zone" in the marsh area, which, together with the bedrock spurs and the small drainage basin immediately to the east of the springs, have allowed organic sediments to accumulate in quiet water conditions with relatively little contamination by clastic material.

The original size of Fish Lake was about 25 m wide by 100 m long. During our field work, the outline of the original pond could still be seen as a ring of vegetation within the reservoir. We estimated the original depth of the pond to be between 3 and 4 m, and it had a nearly vertical wall on the western side (near auger hole 18, fig. 5*D*). The quiet water conditions within the Fish Lake marsh and the low local input of detritus maintained the size of the pond and the position of its western edge, as the sides of the pond were built nearly vertically by accumulation of marsh-plant and diatomaceous sediments, with a minor amount of fine-grained clastic sediments (fig. 5*D*).

At the Dyer cemetery spring, there is no pond comparable to Fish Lake, probably due to the smaller discharge of the spring or to an increase in clastic sediments from the Silver Peak Range at the northern end of the marsh, or both. The spring at the Dyer cemetery is on the northwest flank of a small bedrock spur in an area that has received a larger amount of clastic sediments from adjacent alluvial fans than did the area at the Fish Lake spring. Several small, discontinuous layers of organic-rich material within the northern marsh area (fig. 5*C*, for example, auger hole 8) are analogous to accumulations in and around channels seen on the 1980 aerial photographs. Aerial photographs show that the densest vegetation around the Dyer cemetery spring occurs within the lowest channels of the axial drainage.

Stratigraphy and Uranium Distribution of the Marsh

The stratigraphy of the areas sampled is very persistent (fig. 5*A*, *B*, *C*, and *D*). Many of the beds within either the northern or the southern marsh areas can be traced across the entire sampled area. The units consist of clastic sequences that become finer grained upward and can be traced laterally into correlative organic-rich layers. An idealized unit in the marsh is composed of fine-grained clastic sediments at the base that grade upward to marsh sediments consisting of either a thin peat or a siliceous, diatom-rich organic muck.

Sedimentary unit I in the cross sections (fig. 5*A*, *B*, *C*, and *D*) is made up of two groups of organic sediments, based on field descriptions. The first group generally contains greater than 20 percent organic matter, and the second group generally contains 15 to 20 percent organic matter. Unit II consists of dark clay and silt containing less than 15 percent organic matter. Units III to V are light-colored clastic sediments ranging from clay to coarse sand that generally contain less than 5 percent organic matter but commonly include layers of finely fragmented (less than 3 mm in length), unoxidized plant fragments.

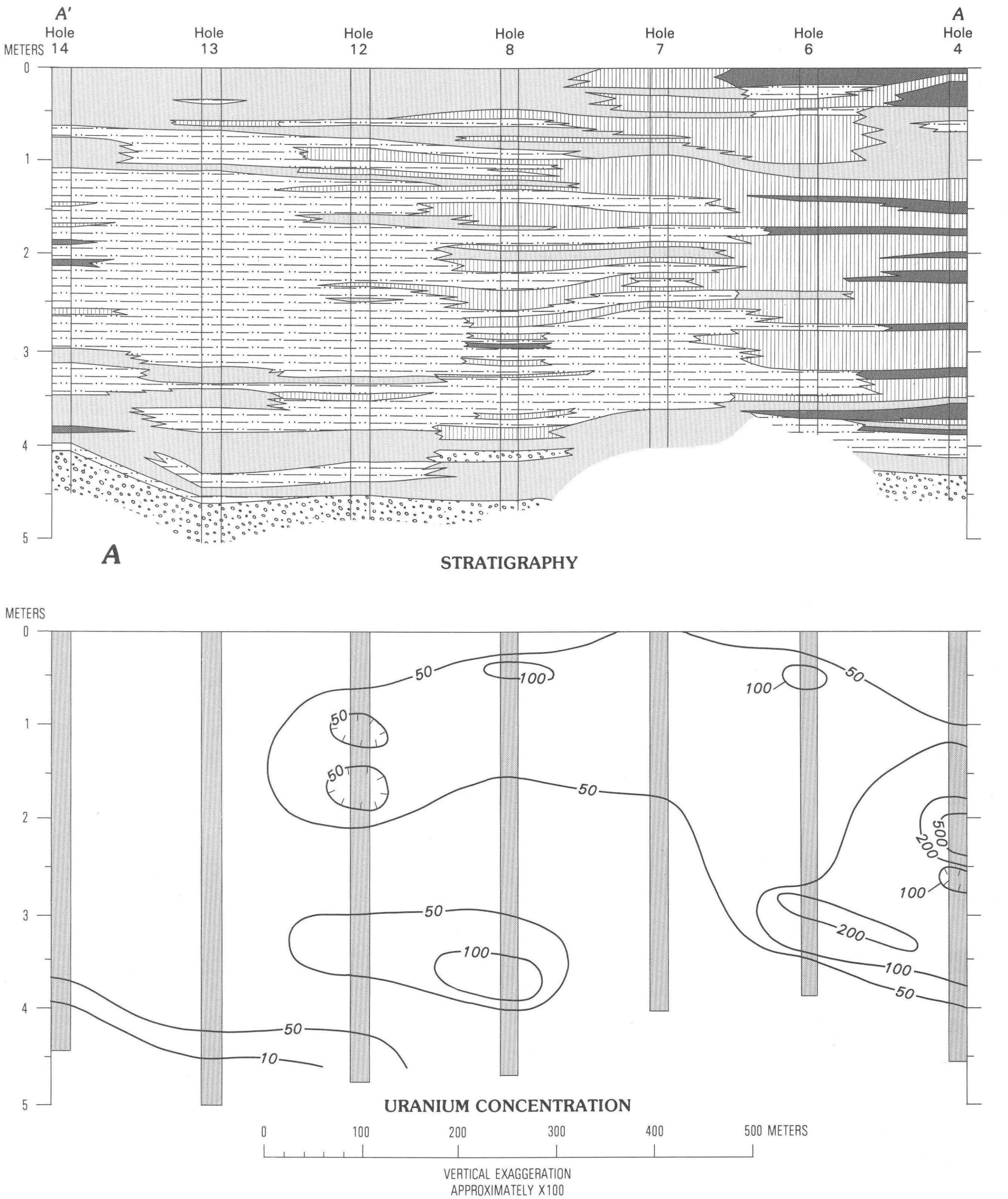
The coarse-grained pebbly sand at the base of the cross sections probably represents alluvial-fan deposits over which the marsh sediments were deposited. At Fish Lake, the base of the organic-rich deposits slopes downward to the northwest and is deepest in auger hole 20 (fig. 5*D*), northwest of the modern pond. There is a steep break in slope on the basal alluvial-fan deposits between holes 21 and 18 (section *C–C′*, fig. 5*D*). A similar break in slope was observed between holes 4 and 3 (section *B–B′*, fig. 5*B*) and may represent a fault scarp on the buried alluvial-fan surface, analogous to modern fault scarps within the valley. Displacement on the possible fault is approximately 1 m in both locations.

Uranium concentrations in 253 samples from the marsh averaged 64.31 ppm. In the northern area, uranium concentrations in 176 samples ranged from 6.63 to 591 ppm and averaged 52.8 ppm. In the southern area, uranium concentrations in 69 samples ranged from 6.07 to 798 ppm and averaged 90.6 ppm.

Surficial uranium deposits associated with organic matter have been studied extensively in both the United States and Europe (Otton, 1984b; Wilson, 1984), where it is assumed that the uranium is fixed by the organic material. Models for fixation of uranium on organic matter have been proposed by Zielinski and Otton (1986) and Zielinski and Meier (1988). Statistical analysis of the uranium distribution and organic matter content (as measured by loss on ignition) for the Fish Lake Valley samples shows that uranium in the Fish Lake marsh is associated with the organic matter (significant correlation at the 99-percent level, $R^2=0.969$). Data was analyzed using the three-parameter log-normal transformation of Miesch (1981) to reduce the skewness of the data (fig. 6).

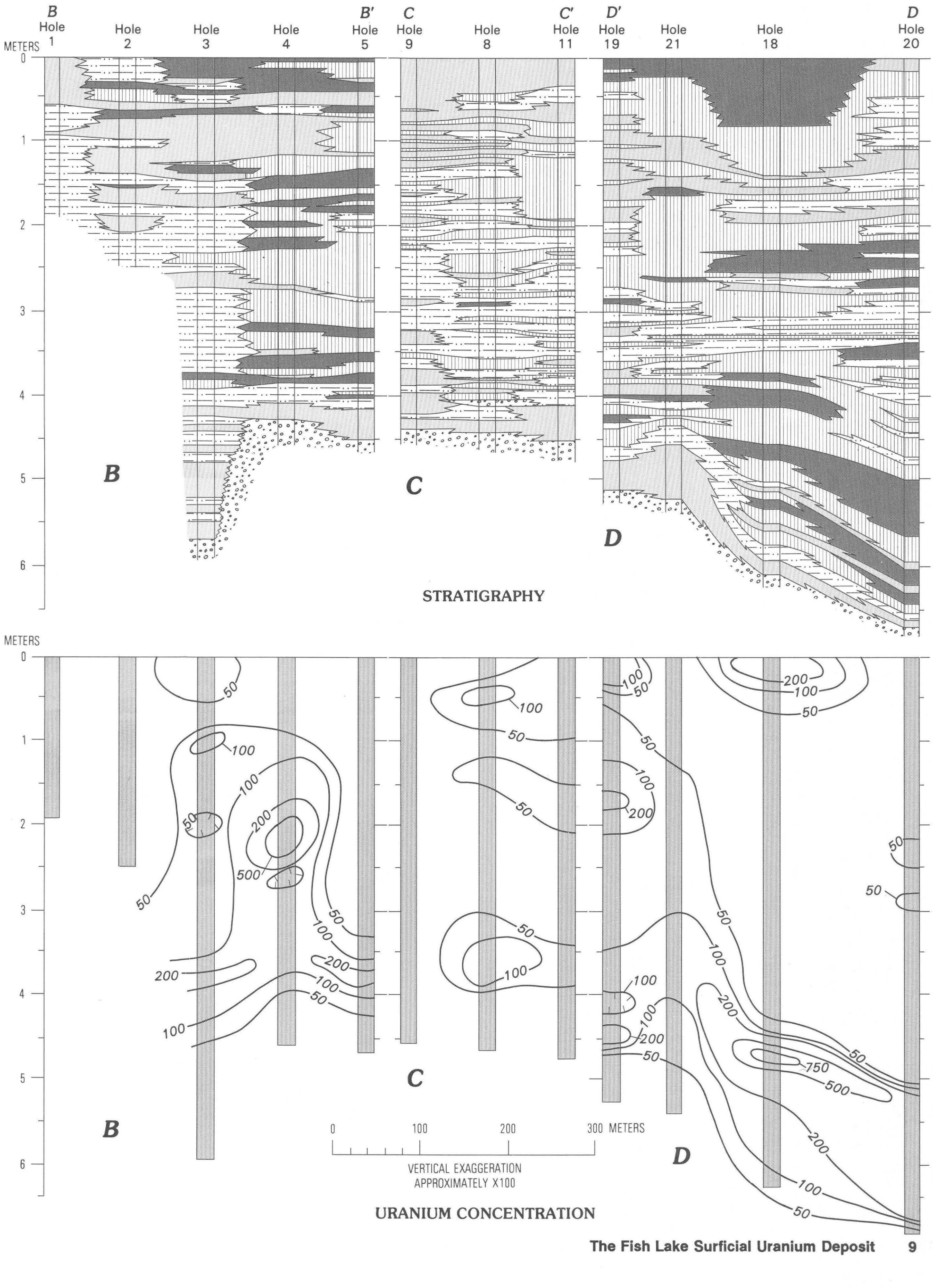
The highest concentration of uranium in the northern part of the marsh is in auger hole 4 (section *B–B′*, figs. 3, 5*A*, *B*). The interval from 1.8- to 2.4-m depth

Figure 5 (following 2 pages). Cross sections showing stratigraphy and uranium concentrations of the Fish Lake area, Fish Lake Valley, Nevada and California. Section locations are shown on figure 3. Samples were collected at 0.3-m intervals in each hole. *A*, North-south cross section *A–A′*. *B*, East-west cross section *B–B′*. *C*, East-west cross section *C–C′*. *D*, North-south cross section *D–D′*.



EXPLANATION

- Silty and clayey mucks and peats with more than 15 percent organic material (determined by loss on ignition)
- Dark silts and clays containing as much as 15 percent organic material
- Clays and silty clays
- Silts, clayey silts, and sandy silts
- Coarse sand and silty and clayey coarse sands
- —50— **Uranium isopleth**—Values in parts per million. Hachures show closed areas of lower uranium values



B
Hole 1
Hole 2
Hole 3
Hole 4
B′
Hole 5
C
Hole 9
Hole 8
C′
Hole 11
D′
Hole 19
Hole 21
Hole 18
D
Hole 20
METERS
0
1
2
3
4
5
6
B
C
D
STRATIGRAPHY
METERS
0
1
2
3
4
5
6
50
100
200
500
750
B
C
D
0
100
200
300 METERS
VERTICAL EXAGGERATION APPROXIMATELY X100
URANIUM CONCENTRATION

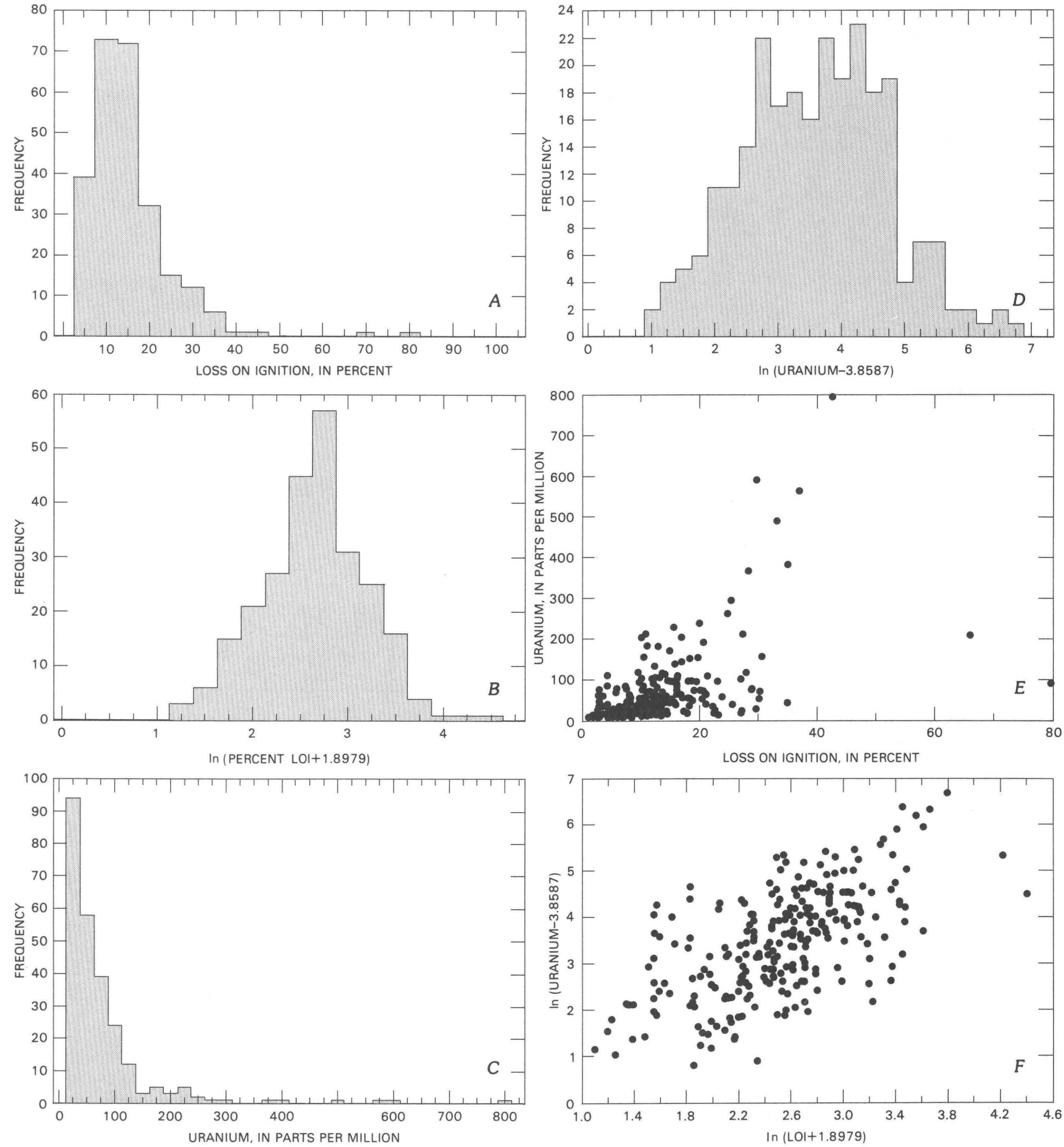


Figure 6. Histograms and scatterplots of uranium content and loss-on-ignition values for sediment samples from the Fish Lake marsh, Fish Lake Valley, Nevada and California. Data for northern and southern areas are combined. Data transformed using gap-test transformations. *A*, histogram of loss-on-ignition values (LOI); *B*, histogram of ln(LOI + 1.8979); *C*, histogram of uranium concentration; *D*, histogram of ln(uranium-3.8587); *E*, scatterplot of uranium versus loss-on-ignition (R^2 = 0.72061); *F*, scatterplot of ln(uranium-3.8587) versus ln(LOI + 1.8979) (R^2 = 0.96924).

(figs. 5*A*, *B*) contains as much as 591 ppm uranium. High uranium values (>100 ppm) also occur in a band at approximately 3.4- to 4.0-m depth that extends from hole 5 on the east to hole 3 on the west (fig. 5*B*). Uranium values exceeded 200 ppm in holes 3 and 5. In the northernmost transverse cross section (*C–C′*, figs. 3, 5*C*), the highest concentrations of uranium (>200 ppm) are near the top and at the base of the section.

The zone of uranium concentration defined by the 100-ppm isopleth at the base of the southern end of cross section *A–A′* (fig. 5*A*) is tabular and extends from hole 4 northward to hole 6. The 50-ppm isopleth delimits an upper and a lower zone of high uranium concentration, both of which extend down the valley as far as hole 12. The 50-ppm isopleth at the base of hole 8 appears to be separate from the upper zone of concentration but does extend to the north as far as hole 12 (fig. 5*A*) and to the east as far as hole 11 (fig. 5*C*).

The highest uranium concentrations in the marsh were found in the area adjacent to Fish Lake (fig. 5*D*) at a depth of 4.3 to 5.2 m in hole 18. These high values apparently correlate with higher concentrations (>200 ppm) at 4.9 to 5.2 m in hole 20 and lower, but elevated, concentrations at approximately the same depth in holes 19 and 21. A second horizon of elevated uranium concentrations occurs in the upper 0.6 m of holes 18 and 19.

RECONNAISSANCE SAMPLING

Six localities in the White Mountains and two in Fish Lake Valley, outside of the Fish Lake marsh, were sampled to locate other areas of uranium concentration associated with organic material within an arid environment (fig. 3): (1) WMA85–1, a boggy area near a spring in the Indian Creek drainage (near water sample WMW85–1, appendix 1); (2) WMA85–2, on the terrace surface of a small tributary, 3 to 4 m above the main valley floor in the Indian Creek drainage; (3) WMA85–3, on the bank of a small stream (near water sample WMW85–2, appendix 1); (4) WMA85–4, Trail Canyon; (5) WMA85–5, Davis Creek; (6) WMA85–6, Chiatovitch Creek; (7) FLA85–15, 16, and 17, near the old reservoir west of Fish Lake spring; and (8) FLA85–22, the boggy area below the spring at the Lower McNet Ranch (near water sample FLW85–4, appendix 1).

The results of the reconnaissance sampling are summarized in table 1, and the data are included in appendix 2. The results suggest that uranium has been concentrated in organic-rich sediments outside of the Fish Lake marsh, but concentrations are generally lower than within the marsh area for similar values from loss-on-ignition analysis.

Table 1. Summary of results of reconnaissance sediment sampling, Fish Lake surficial uranium deposit, southern Nevada.

[See fig. 2 for sample localities. ppm, parts per million; m, meter; mm, millimeter; LOI, loss on ingition]

Sample No.	Sample elevation (meters)	Maximum depth sampled	Average LOI (percent)[1]	Average U (ppm)[2]
		White Mountains		
WMA85-1	2,215	1.5 m	4.9	151
WMA85-2	2,245	150 mm	9.0	9.05
WMA85-3	2,700	1.2 m	3.8	26.78
WMA85-4	2,460	900 mm	11.4	32.4
WMA85-5	2,230	600 mm	4.2	12.8
WMA85-6	2,140	300 mm	5.9	9.78
		Old reservoir		
FLA85-15	1,395	1.1 m	([3])	([4])
FLA85-16	1,395	1.8 m	[3]5.0	[4]11.5
FLA85-17	1,395	1.4 m	([3])	([4])
		Lower McNet Ranch		
FLA85-22	2,265	3.0 m	8.3	14.0

[1] Analyses performed by S. Roof, U.S. Geological Survey, Denver, Colo.
[2] Analyses performed by R.B. Vaughan and D.M. McKown, U.S. Geological Survey, Denver, Colo.
[3] 5.0 is the average LOI of all samples at the old reservoir.
[4] 11.5 is the average uranium content of all samples at the old reservoir.

RESULTS OF STUDY

Fish Lake Marsh

The primary factors controlling the uranium distribution in the Fish Lake marsh are the distribution of organic-rich sediments, the locations of springs, and the structural setting of the valley, all of which are related. The fine-grained organic-bearing sediments interstratified with clastic sediments which commonly include fragmental plant materials suggests that the marsh was frequently covered by silt and clay or that the vegetation was drowned by ponding. Near the springs, the sedimentology of the auger samples shows that individual depositional units commonly become finer grained upward into siliceous diatom-rich lacustrine sediments. The marsh area apparently alternated between lacustrine, marsh, and distal alluvial-fan environments. The organic-rich layers represent marsh environments, and lacustrine clays represent periods when the area near the springs was flooded, forming a shallow lake. The coarser grained clastic layers represent fluvial sediments deposited during flash floods in the valley, during large-volume flows on the adjacent alluvial fans, or during drier periods when the dense vegetation did not exist at the upstream edge of the marsh to trap sediments.

According to Otton (1984b), the highest uranium enrichments associated with uraniferous springs occur closest to the springs, where uranium-rich spring water initially contacts surficial organic material. Localized minor surface enrichment has taken place in the Fish Lake marsh (auger holes 7, 3, 11, 18, and 19 on figs. 5*A*, *B*, *C*, and *D*, respectively), where surface waters soaked into the organic-rich surface sediments. Adjacent to Fish Lake spring, uranium introduction (for example, hole 18, fig. 5*D*) probably is occurring by a combination of surface flow and subsurface lateral flow through at least the uppermost part of the sediment column and possibly at depth. In the remainder of the marsh area more distant from spring sources, the enrichment at the surface is minor, and high uranium concentrations found at depth suggest a somewhat different source.

Upwelling ground water from fracture systems has been suggested as a primary mechanism for several known surficial uranium deposits; uranium is concentrated in organic-rich layers as the ground water moves upward through valley-fill sediments (Culbert and others, 1984; Levinson and others, 1984; Zielinski and others, 1986). The uranium isopleth pattern in cross section *B–B′* (fig. 5*B*) strongly suggests that organic-rich channel-filling sediments have concentrated uranium from an upwelling plume of ground water migrating along fractures in the sediments underlying the marsh. A similar zone of enrichment at the base of cross section *D–D′* (fig. 5*D*) is over a break in slope that suggests fault displacement on the buried fan surface (fig. 5*D*). We suggest that ground water from the fault zone moved upward until it reached relatively impermeable clay-rich sediments (fig. 5*D*), and then it flowed laterally, giving the uranium-enriched zone a tabular shape.

Springs that emerge at the edge of the marsh and deeper ground-water plumes flowing through the coarse sediments at the base of the marsh deposits probably have the same source—the Paleozoic and Tertiary sedimentary rocks of the Silver Peak Range. The relatively elevated concentrations of uranium (50–200 ppm) at the base of cross sections *B–B′* (fig. 5*B*) and *D–D′* (fig. 5*D*) suggest that ground water moving through the marsh sediments from below has a higher uranium content than water that emerges at the springs.

The sedimentary record indicates that Fish Lake Valley alternated between wetter (lacustrine) and drier (marsh-meadow) conditions, probably in response to climatic variations. As climatic conditions in the marsh changed, some uranium may have been redistributed within the sediments, due to changes in the salinity and alkalinity of pore water. Leaching studies conducted by Zielinski and Meier (1988) documented the effects of changes in pore-water composition on the stability of uranium carbonate complexes, especially in water with high carbonate concentrations, as in the Fish Lake marsh. Regardless of the timing of uranium fixation in any particular stratum, organic matter is the primary uranium host, and any pattern of uranium distribution is strongly influenced by the abundance and type of organic matter (Zielinski and Otton, 1986).

Our only estimates for the age of the sediments are, at present, indirect. R.R. Culbert (D.G. Leighton and Associates, Vancouver, B.C., written commun., 1982) noted a volcanic-ash layer, which he assumed to be the Mazama tephra (dated at 6,900 years B.P. (before present); Davis, 1979), at a depth of 2 m within the marsh deposit at one sample locality. We did not identify this tephra layer during our sampling, but if the layer identified by Culbert is the Mazama tephra, its position suggests a rate of sedimentation of approximately 0.3 mm per year for the last 6,900 years. This rate agrees well with sedimentation rates of 0.4 mm per year for the same time interval and a similar climatic and depositional setting, in the Potato Canyon bog of Grass Valley, approximately 240 km to the northeast (Madsen, 1985). Assuming a sedimentation rate of 0.3 mm per year, we estimate that deposition of the marsh sediments began approximately 23,000 years B.P., which agrees reasonably with an estimate by Atwater and others (1986) of 26,000 years B.P. for the start of the last major Sierra Nevada glaciation, corresponding to a period of higher precipitation in the area. We also believe that sedimentation in the marsh area could not have begun significantly earlier than this date, because higher sedimentation rates associated with wetter climatic regimes would have overwhelmed the marsh area with clastic sediments.

Reconnaissance Samples

Minor enrichment of uranium has occurred in other wetlands in the Fish Lake Valley and in wetlands of the surrounding mountains.

Uranium concentrations in sediment samples collected in the White Mountains can be compared to uranium concentrations measured in bedrock samples collected in the White Mountains (F.A. Hills, unpub. data, 1988). A suite of 34 analyses of monzonite, granodiorite, and their saprolite have an average uranium content of 2.79 ppm, ranging from 1.15 to 5.60 ppm, and an average thorium content of 11.04 ppm, ranging from 6.79 to 16.80 ppm. The average uranium:thorium of this suite of samples is 0.252, ranging from 0.116 to 0.458, which is in agreement with a uranium:thorium of 0.3 for average crustal abundance of these elements (Mason and Berry, 1968). Because the analyses of the sediment samples were made using delayed neutron activation analysis, most of the thorium values are qualified, less than a variable detection limit that is dependent upon the amount of uranium present in the sample. Uranium-to-thorium ratios calculated for the sediments using the qualified values therefore represent a minimum value for the ratio. The 17 sediment samples from the White Mountains area have an average uranium:thorium of 2.951, ranging from 0.644 to 4.871, indicating that nearly all of the samples have been enriched in uranium (Adams and Weaver, 1958).

Samples from the areas of the old reservoir (fig. 3) and the Lower McNet Ranch wetland show similar enrichment in uranium. The average uranium:thorium for 15 samples from the area of the old reservoir is 1.056, ranging from 0.434 to 2.346, and the average uranium: thorium for 9 samples from the Lower McNet Ranch wetland is 1.543, with a range from 0.716 to 2.347.

Although there is no statistical correlation between uranium and organic-material content for the 31 samples collected outside of the Fish Lake marsh area ($R^2 = 0.1724$, not significant at the 90-percent confidence level; Fisher, 1954), we assume that organic matter is responsible for the uranium enrichment relative to the source rock.

SUMMARY AND CONCLUSIONS

Tectonic setting, organic content of the sediments, and ground-water hydrology and chemistry are the key factors responsible for the formation of the Fish Lake surficial uranium deposit.

The Fish Lake marsh is at a bend in the Silver Peak Range (fig. 2) where sediment-laden runoff from the range is largely diverted away from the marsh area, so that a lacustrine-marsh environment is maintained.

The fault zone defining the eastern edge of the valley provides an avenue of migration for ground water from the adjacent Silver Peak Range. The water moves upward along faults to the base of the marsh deposit, where uranium is fixed by organic matter in the marsh sediments. Some of the water wells up through the marsh sediments forming springs at the marsh's edge. The springs sustain the marsh vegetation and add uranium to the marsh sediments.

Climatic fluctuations, tectonic movements, or both, during the past 23,000 years have produced periodic flooding of the marsh, creating an intermittent shallow lake and permitting deposition of lacustrine clays. Marsh vegetation was reestablished during drier periods, and it formed organic-rich layers in the deposit. Because uranium enrichment occurs preferentially in organic sediments, the zones of uranium enrichment commonly have a tabular shape that follows the trend of the organic sediments. The zones of maximum enrichment are organic-rich layers closest to the ground-water source, in this area, those layers lying directly above the fault zone.

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APPENDIXES

Appendix 1. Chemical analyses of water from springs in the Fish Lake Valley, the Silver Peak Range, and the White Mountains, Nevada and California

[ppm, parts per million; ppb, parts per billion; <, less than]

Field No.	FLW85-1	FLW85-2	FLW85-3	FLW85-4	FLW85-5	SPW85-1	WMW85-1	WMW85-2
As (ppm)[1]	0.022	0.042	0.043	0.037	0.044	<0.001	<0.001	<0.001
Br (ppm)[2]	<.1	<.1	<.1	<.1	<.1	.10	<.1	<.1
Sc (ppm)[1]	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
NO_3 (ppm)[2]	.87	<.01	<.01	.1	<.01	.25	<.01	.23
PO_4 (ppm)[2]	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Cl^- (ppm)[2]	7.6	5.7	14	60	92	35	.1	2.1
Fl^- (ppm)[2]	1.4	1.8	.65	3.0	1.8	<.02	.55	.4
SO_4 (ppm)[2]	35	38	39	105	110	42	16	12
Al (ppm)[3]	<.1	<.1	<.1	<.1	.1	<.1	<.1	<.1
B (ppb)[3]	240	120	230	1,630	3,200	160	20	20
Ba (ppb)[3]	15	19	25	8	24	5	70	28
Be (ppb)[3]	<1	<1	<1	<1	<1	<1	<1	<1
Bi (ppb)[3]	<10	<10	<10	<10	<10	<10	<10	<10
Ca (ppm)[3]	12.7	27.1	9.54	40.5	55.7	67.0	24.6	40.8
Cd (ppm)[3]	<1	<1	<1	<1	<1	<1	<1	<1
Ag (ppb)[3]	<2	<2	<2	<2	<2	<2	<2	<2
Co (ppb)[3]	<3	<3	<3	<3	<3	<3	<3	<3
Cr (ppb)[3]	<1	<1	<1	<1	<1	<1	<1	<1
Cu (ppb)[3]	<10	<10	<10	<10	<10	<10	<10	<10
Fe (ppm)[3]	<.003	<.003	.03	.14	.32	.11	.10	<.003
Ga (ppb)[3]	<5	<5	<5	<5	<5	<5	<5	<5
K (ppm)[3]	8	8	4	25	15	5	2	2
Li (ppb)[3]	49	30	34	1,070	711	11	7	6
Mn (ppb)[3]	<1	2	6	129	306	9	8	1
Mo (ppb)[3]	20	30	10	20	30	<10	10	<10
Na (ppm)[3]	55.0	46.1	70.5	193	160	25.2	4.7	6.7
Ni (ppb)[3]	<5	8	22	11	11	20	<5	25
Pb (ppb)[3]	<10	<10	<10	<10	<10	<10	<10	<10
Si (ppm)[3]	26	15.1	23.4	49.8	28.1	24.4	1.3	11.2
Sn (ppb)[3]	<6	<6	<6	<6	<6	<6	<6	<6
Mg (ppm)[3]	3.60	6.26	1.86	7.50	15.8	18.9	6.27	2.68
Ti (ppb)[3]	3	<1	<1	<1	<1	<1	6	<1
V (ppb)[3]	13	<6	35	8	<6	<6	<6	<6
Zn (ppb)[3]	8	8	34	7	8	7	7	12
Zr (ppb)[3]	<1	<1	<1	<1	<1	<1	<1	<1
Sr (ppb)[3]	144	474	67.0	620	534	400	78.5	150
Conductivity[4,5]	410	430	440	1,400	1,350	670	225	280
pH[4,6]	8.15	8.05	7.50	7.12	7.75	7.60	7.60	7.70
Acid[4,7]	7.97	8.56	8.27	27.05	22.30	13.25	5.15	7.25
HCO_3[4,8]	160	171	165	541	446	265	103	145
U (ppb)[4]	9	2	2	13	7	17	17	4
Organic C[9]	3.4	4.4	14	3.2	4.0	3.6	3.8	3.6

[1] Analyses performed by hydride generation atomic absorption; analyses performed by D.B. Hatfield and S.A. Wilson, U.S. Geological Survey, Denver, Colo.

[2] Analyses performed by ion chromatography; analyses performed by D.B. Hatfield and S.A. Wilson, U.S. Geological Survey, Denver, Colo.

[3] Analysis performed by ion coupled plasma (ICP) analysis; analyses performed by P.H. Briggs, U.S. Geological Survey, Denver, Colo.

[4] Analyses performed by R.A Zielinski, U.S. Geological Survey, Denver, Colo.

[5] moh/cm^2

[6] Laboratory pH: probably 0.5 of field pH, based on past comparisons (R.A. Zielinski, written commun., 1985).

[7] mL (milliliter) standard acid to pH 4.5, 50-mL sample.

[8] mg/L.

[9] Dissolved organic carbon in mg/L; analyses performed by P.K. Roscio, U.S. Geological Survey, Denver, Colo.

Appendix 2. Data from marsh samples, Fish Lake marsh, Fish Lake Valley and White Mountains, Nevada and California

[See text for sample localities. <, less than; ppm, parts per million]

Sample No.	Depth (m)	Ash[1]	LOI[2]	Th (ppm)[3]	U (ppm)[3]
FL85-1A	0.15	87.9	12.1	<6.6	16.4
FL85-1B	.46	94.8	5.2	22.2	8.21
FL85-1C	.76	95.6	4.4	21.2	12.6
FL85-1D	.61	95.0	5.0	<6.7	21.7
FL85-1E	1.07	95.7	4.3	14.3	12
FL85-1F	1.37	95.6	4.4	30.3	18.5
FL85-2A	.15	81.7	18.3	<11	36.5
FL85-2B	.46	90.5	9.5	6.5	17
FL85-2C	.76	92.1	7.9	<5.6	14.1
FL85-2D	.61	92.2	7.8	<6.2	16.3
FL85-2E	1.07	90.8	9.2	18.9	17.7
FL85-2F	1.37	90.1	9.9	<7.1	18.8
FL85-2G	1.68	90.2	9.8	23.7	21.7
FL85-2H	1.98	92.6	7.4	23.5	19.3
FL85-3A	.15	76.2	23.8	<14	58
FL85-3B	.46	84.9	15.1	<11	53.1
FL85-3C	.76	88.3	11.7	<21	40.5
FL85-3D	.61	88.1	11.9	<16	103
FL85-3E	1.07	88.6	11.4	<15	60.3
FL85-3F	1.37	83.9	16.1	<14	63.1
FL85-3G	1.68	85.5	14.5	<11	42.8
FL85-3H	1.98	83.9	16.1	<21	86.4
FL85-3I	2.28	83.9	16.1	<16	77
FL85-3J	2.59	83.9	16.1	<20	89.4
FL85-3K	2.90	88.1	11.9	<15	69.3
FL85-3L	3.20	85.4	14.6	<20	98.4
FL85-3M	3.50	72.7	27.3	<36	212
FL85-3N	3.81	85.1	14.9	<29	171
FL85-3O	4.11	92.7	7.3	<16	83
FL85-3P	4.42	96.4	3.6	<8.7	34.6
FL85-3Q	4.72	97.4	2.6	<6.4	22.6
FL85-3R	5.03	97.2	2.8	13.7	13.4
FL85-3S	5.33	96.6	3.4	<5.1	14.4
FL85-4A	.15	72.8	27.2	<8.4	22.8
FL85-4B	.46	88.0	12.0	<6.6	11.7
FL85-4C	.76	89.0	11.0	<8.9	22.6
FL85-4D	.61	82.9	17.1	<14	55.2
FL85-4E	1.07	80.3	19.7	<28	154
FL85-4F	1.37	69.4	30.6	<30	157
FL85-4G	1.68	63.1	36.9	<90	565
FL85-4H	1.98	70.4	29.6	<90	591
FL85-4I	2.28	87.3	12.7	<15	80.3
FL85-4J	2.59	84.2	15.8	<24	139
FL85-4K	2.90	78.7	21.3	<20	109
FL85-4L	3.20	79.4	20.6	<31	192
FL85-4M	3.50	87.9	12.1	<17	90.8
FL85-4N	3.81	95.8	4.2	<7.3	32.1
FL85-5A	.15	82.1	17.9	<6.1	17.6
FL85-5B	.46	89.1	10.9	<4.6	10.4
FL85-5C	.76	87.0	13.0	<7.7	24.5

Appendix 2. Data from marsh samples, Fish Lake marsh, Fish Lake Valley and White Mountains, Nevada and California—Continued

Sample No.	Depth (m)	Ash[1]	LOI[2]	Th (ppm)[3]	U (ppm)[3]
FL85-5D-------	.61	85.5	14.5	<5.6	15.3
FL85-5E-------	1.07	77.6	22.4	<6.2	17
FL85-5F-------	1.37	74.4	25.6	<11	39.1
FL85-5G-------	1.68	76.9	23.1	<6.0	12.7
FL85-5H-------	1.98	87.0	13.0	<5.7	12.7
FL85-5I--------	2.28	86.6	13.4	<5.3	11
FL85-5J--------	2.59	85.7	14.3	<7.2	21.6
FL85-5K-------	2.90	77.8	22.2	<9.8	34.6
FL85-5L-------	3.20	69.8	30.2	<16	71.5
FL85-5M------	3.50	83.1	16.9	<33	204
FL85-5N-------	3.81	94.1	5.9	<16	78.1
FL85-5O-------	4.11	97.2	2.8	<7.2	26.5
FL85-6A-------	.15	84.3	15.7	<13	42.8
FL85-6B-------	.46	83.8	16.2	<24	109
FL85-6C-------	.76	79.4	20.6	<18	72.2
FL85-6D-------	.61	84.9	15.1	<14	50.1
FL85-6E-------	1.07	77.0	23.0	<21	95.7
FL85-6F-------	1.37	71.2	28.8	<18	76.1
FL85-6G-------	1.68	71.1	28.9	<19	79.2
FL85-6H-------	1.98	81.9	18.1	<21	96.4
FL85-6I--------	2.28	88.2	11.8	<13	53.2
FL85-6J--------	2.59	84.4	15.6	<39	229
FL85-6K-------	2.90	89.0	11.0	<33	183
FL85-6L-------	3.20	97.0	3.0	<9.9	40.1
FL85-7A-------	.15	79.6	20.4	<14	52.9
FL85-7B-------	.46	79.9	20.1	<17	73.6
FL85-7C-------	.76	86.4	13.6	<13	52.4
FL85-7D-------	.61	81.4	18.6	<21	97
FL85-7E-------	1.07	79.0	21.0	<15	64.1
FL85-7F-------	1.37	85.7	14.3	<14	59.3
FL85-7G-------	1.68	88.2	11.8	<10	32.5
FL85-7H-------	1.98	90.9	9.1	<8.4	22.1
FL85-7I--------	2.28	92.9	7.1	28.3	15
FL85-7J--------	2.59	93.8	6.2	24.6	13.4
FL85-7K-------	2.90	94.6	5.4	22.6	16.8
FL85-7L-------	3.20	95.2	4.8	19.6	19.3
FL85-7M------	3.50	97.0	3.0	16.5	15
FL85-8A-------	.15	85.7	14.3	<8.5	20
FL85-8B-------	.46	83.1	16.9	<28	144
FL85-8C-------	.76	86.3	13.7	<15	59.4
FL85-8D-------	.61	90.7	9.3	<10	32.8
FL85-8E-------	1.07	87.5	12.5	<14	60.6
FL85-8F-------	1.37	88.3	11.7	<11	42.2
FL85-8G-------	1.68	89.1	10.9	<11	41.6
FL85-8H-------	1.98	90.2	9.8	<8.8	30.4
FL85-8I--------	2.28	91.4	8.6	<8.3	26.8
FL85-8J--------	2.59	91.6	8.4	30.2	26.8
FL85-8K-------	2.90	89.8	10.2	<16	75.6
FL85-8L-------	3.20	86.0	14.0	<23	144
FL85-8M------	3.50	87.7	12.3	<24	133

Appendix 2. Data from marsh samples, Fish Lake marsh, Fish Lake Valley and White Mountains, Nevada and California—Continued

Sample No.	Depth (m)	Ash[1]	LOI[2]	Th (ppm)[3]	U (ppm)[3]
FL85-8N	3.81	96.8	3.2	<6.5	17.1
FL85-8O	4.11	98.9	1.1	<3.8	7.03
FL85-9A	.15	79.0	21.0	<13	39.7
FL85-9B	.46	86.0	14.0	<14	44.6
FL85-9C	.76	88.4	11.6	<11	33.1
FL85-9D	.61	90.1	9.9	<8.9	24.8
FL85-9E	1.07	88.4	11.6	<14	42.3
FL85-9F	1.37	86.9	13.1	<12	36.1
FL85-9G	1.68	86.6	13.4	<12	37.7
FL85-9H	1.98	91.0	9.0	19.6	18.7
FL85-9I	2.28	92.9	7.1	16.8	10.2
FL85-9J	2.59	95.2	4.8	16.1	7.28
FL85-9K	2.90	94.6	5.4	16.1	9.65
FL85-9L	3.20	93.8	6.2	17.7	8.67
FL85-9M	3.50	95.1	4.9	11.6	8.37
FL85-9N	3.81	95.3	4.7	<5.1	9.01
FL85-11A	.15	79.2	20.8	<19	66.2
FL85-11B	.46	83.2	16.8	<19	64.2
FL85-11C	.76	81.0	19.0	<22	75.1
FL85-11D	.61	84.1	15.9	<14	38.7
FL85-11E	1.07	84.5	15.5	<12	46.5
FL85-11F	1.37	81.8	18.2	<14	54.4
FL85-11G	1.68	81.7	18.3	<14	56
FL85-11H	1.98	86.9	13.1	<9.6	32.9
FL85-11I	2.28	92.7	7.3	<16.9	10.3
FL85-11J	2.59	93.7	6.3	24.1	13.8
FL85-11K	2.90	92.8	7.2	<9.7	33.7
FL85-11L	3.20	91.8	8.2	<13	54.3
FL85-11M	3.50	94.2	5.8	<14	68.4
FL85-11N	3.81	97.9	2.1	17.9	7.79
FL85-11O	4.11	98.4	1.6	9.8	6.63
FL85-12A	.15	90.3	9.7	<13	48.9
FL85-12B	.46	94.7	5.3	<9.2	27.4
FL85-12C	.76	92.0	8.0	<15	62.2
FL85-12D	.61	93.2	6.8	<8.8	7.79
FL85-12E	1.07	92.1	7.9	<14	50.3
FL85-12F	1.37	91.8	8.2	<11	36.7
FL85-12G	1.68	89.0	11.0	<14	55.8
FL85-12H	1.98	90.5	9.5	<10	35.5
FL85-12I	2.28	91.8	8.2	<11	40.2
FL85-12J	2.59	91.8	8.2	<13	43.9
FL85-12K	2.90	92.5	7.5	<20	77.8
FL85-12L	3.20	89.6	10.4	<15	54.7
FL85-12M	3.50	94.7	5.3	<7.1	19.8
FL85-12N	3.81	93.6	6.4	<8.9	28.5
FL85-12O	4.11	95.7	4.3	<19	84.4
FL85-13A	.15	89.3	10.7	<7.8	17.7
FL85-13B	.46	95.5	4.5	13.2	11.8
FL85-13C	.76	92.4	7.6	<11	35.3
FL85-13D	.61	93.8	6.2	<10	32.5

Appendix 2. Data from marsh samples, Fish Lake marsh, Fish Lake Valley and White Mountains, Nevada and California—Continued

Sample No.	Depth (m)	Ash[1]	LOI[2]	Th (ppm)[3]	U (ppm)[3]
FL85-13E------	1.07	93.7	6.3	<9.9	27.5
FL85-13F------	1.37	93.6	6.4	30.9	13.5
FL85-13G -----	1.68	92.4	7.6	<10	28.6
FL85-13H -----	1.98	92.4	7.6	<8.9	21
FL85-13I-------	2.28	94.4	5.6	16.5	15.9
FL85-13J ------	2.59	95.5	4.5	15	14
FL85-13K------	2.90	97.5	2.5	15.5	8.05
FL85-13L------	3.20	97.2	2.8	13.4	11
FL85-13M-----	3.50	97.1	2.9	17.6	10.5
FL85-13N------	3.81	97.2	2.8	<12	42.7
FL85-13O -----	4.11	97.1	2.9	<42	75.2
FL85-13P------	4.42	98.5	1.5	<7.1	9.91
FL85-14A------	.15	89.8	10.2	<7.5	10.5
FL85-14B------	.46	94.6	5.4	7.5	7.08
FL85-14C------	.76	94.3	5.7	<6.8	9.08
FL85-14D -----	.61	92.3	7.7	<9.2	13.3
FL85-14E------	1.07	90.6	9.4	<17	28.2
FL85-14F------	1.37	90.5	9.5	<14	21.7
FL85-14G -----	1.68	90.0	10.0	<22	26.1
FL85-14H -----	1.98	89.8	10.2	<34	27.3
FL85-14I-------	2.28	91.4	8.6	<17	28.8
FL85-14J ------	2.59	92.9	7.1	<16	26
FL85-14K------	2.90	92.6	7.4	<14	23
FL85-14L------	3.20	95.7	4.3	<22	38.8
FL85-14M-----	3.50	97.2	2.8	<34	61.7
FL85-14N------	3.81	98.6	1.4	<5.9	8.52
FL85-15A------	.15	94.3	5.7	8.7	6.67
FL85-15B------	.46	94.6	5.4	9.3	6.87
FL85-15C------	.76	94.7	5.3	8.6	8.09
FL85-15D -----	.61	94.8	5.2	<7.1	9.9
FL85-16A------	.15	93.8	6.2	<19.6	8.51
FL85-16B------	.46	93.6	6.4	14.2	13.5
FL85-16C------	.76	96.4	3.6	<6.9	14.3
FL85-16D -----	.61	97.1	2.9	<6.2	12.2
FL85-16E------	1.07	97.5	2.5	19.9	9.63
FL85-16F------	1.37	97.6	2.4	16.4	8.36
FL85-17A------	.15	94.0	6.0	17.7	15.5
FL85-17B------	.46	94.8	5.2	15.7	12.7
FL85-17C------	.76	94.5	5.5	18.1	12.5
FL85-17D -----	.61	93.7	6.3	18.3	15.7
FL85-17E------	1.07	93.8	6.2	<7.8	18.3
FL85-18A------	.15	34.1	65.9	<56	210
FL85-18B------	.46	20.3	79.7	<34	92.6
FL85-18C------	.76	70.4	29.6	<12	28.3
FL85-18D -----	.61	89.5	10.5	<10	20.1
FL85-18E------	1.07	92.7	7.3	<11	18.8
FL85-18F------	1.37	92.3	7.7	<17	44.2
FL85-18G -----	1.68	87.1	12.9	<11	17.6
FL85-18H -----	1.98	81.2	18.8	<19	49.4
FL85-18I-------	2.28	87.0	13.0	<11	22.5

Appendix 2. Data from marsh samples, Fish Lake marsh Fish Lake Valley and White Mountains, Nevada and California—Continued

Sample No.	Depth (m)	Ash[1]	LOI[2]	Th (ppm)[3]	U (ppm)[3]
FL85-18J ------	2.59	88.8	11.2	<6.4	14.4
FL85-18K------	2.90	87.2	12.8	<8.3	26.2
FL85-18L------	3.20	89.0	11.0	12	11.2
FL85-18M-----	3.50	82.7	17.3	<8.2	22.3
FL85-18N------	3.81	65.0	35.0	<13	44.1
FL85-18O -----	4.11	69.9	30.1	<15	53.2
FL85-18P------	4.42	57.5	42.5	<140	797
FL85-18Q -----	4.72	71.8	28.2	<68	367
FL85-18R------	5.03	72.1	27.9	<27	118
FL85-18S ------	5.33	81.8	18.2	<30	152
FL85-18T------	5.64	95.7	4.3	<21	109
FL85-19A------	.15	73.0	27.0	<23	102
FL85-19B------	.46	87.4	12.6	<12	38.1
FL85-19C------	.76	91.9	8.1	<15	62.2
FL85-19D -----	.61	90.3	9.7	<23	93.8
FL85-19E------	1.07	86.4	13.6	<29	117
FL85-19F------	1.37	89.9	10.1	<43	203
FL85-19G -----	1.68	89.9	10.1	<24	103
FL85-19H -----	1.98	86.7	13.3	<17	62.2
FL85-19I-------	2.28	89.6	10.4	<13	35.1
FL85-19J ------	2.59	88.5	11.5	<18	70.4
FL85-19K------	2.90	88.2	11.8	<14	45.3
FL85-19L------	3.20	87.3	12.7	<27	105
FL85-19M-----	3.50	90.5	9.5	<28	118
FL85-19N------	3.81	86.4	13.6	<18	70.3
FL85-19O -----	4.11	80.1	19.9	<51	239
FL85-19P------	4.42	97.2	2.8	<6.4	17.3
FL85-19Q -----	4.72	97.9	2.1	<5.3	12.2
FL85-20A------	.15	92.8	7.2	<7.5	17.3
FL85-20B------	.46	93.5	6.5	<5.7	10.1
FL85-20C------	.76	91.5	8.5	9.83	6.3
FL85-20D -----	.61	95.5	4.5	11.8	6.07
FL85-20E------	1.07	93.1	6.9	<4.7	7.94
FL85-20F------	1.37	91.7	8.3	<6.1	11.7
FL85-20G -----	1.68	88.3	11.7	<9.1	23.4
FL85-20H -----	1.98	89.6	10.4	<23	84
FL85-20I-------	2.28	85.7	14.3	<16	44.1
FL85-20J ------	2.59	90.2	9.8	<16	54.3
FL85-20K------	2.90	93.4	6.6	15.9	9.56
FL85-20L------	3.20	92.4	7.6	21.2	17.5
FL85-20M-----	3.50	90.1	9.9	<8.3	27.8
FL85-20N------	3.81	89.4	10.6	<6.2	14.9
FL85-20O -----	4.11	87.5	12.5	<11	41.6
FL85-20P------	4.42	88.3	11.7	<7.3	21.4
FL85-20Q -----	4.72	73.0	27.0	<7.6	17.8
FL85-20R------	5.03	66.9	33.1	<83	491
FL85-20S ------	5.33	65.0	35.0	<66	383
FL85-20T------	5.64	74.7	25.3	<53	295
FL85-20U -----	5.94	75.3	24.7	<46	263
FL85-20V------	6.25	89.2	10.8	<37	213

Appendix 2. Data from marsh samples, Fish Lake marsh, Fish Lake Valley and White Mountains, Nevada and California—Continued

Sample No.	Depth (m)	Ash[1]	LOI[2]	Th (ppm)[3]	U (ppm)[3]
FL85-20W	6.55	98.1	1.9	<4.4	12.4
FL85-21A	.15	77.4	22.6	<8.8	26.1
FL85-21B	.46	87.3	12.7	<6.9	17.6
FL85-21C	.76	90.2	9.8	<7.4	19.2
FL85-21D	.61	93.4	6.6	<6.3	13.6
FL85-21E	1.07	89.0	11.0	<15	62.3
FL85-21F	1.37	86.8	13.2	<16	70.7
FL85-21G	1.68	83.8	16.2	<21	96.5
FL85-21H	1.98	80.6	19.4	<21	95.2
FL85-21I	2.28	81.1	18.9	<20	74.3
FL85-21J	2.59	84.8	15.2	<24	96.2
FL85-21K	2.90	86.8	13.2	<26	106
FL85-21L	3.20	87.1	12.9	<42	181
FL85-21M	3.50	89.5	10.5	<37	155
FL85-21N	3.81	88.8	11.2	<20	62.7
FL85-21O	4.11	90.3	9.7	<16	46.5
FL85-21P	4.42	96.5	3.5	<14	59
FL85-21Q	4.72	98.0	2.0	<5.4	12.2
FL85-22A	.15	80.4	19.6	<9.4	19.9
FL85-22B	.46	88.0	12.0	<7.3	10.7
FL85-22C	.76	91.7	8.3	<7.9	13.3
FL85-22D	.61	94.0	6.0	<9.7	16.4
FL85-22E	1.07	93.1	6.9	<8.7	13.3
FL85-22F	1.37	93.5	6.5	<9.5	22.3
FL85-22G	1.68	93.3	6.7	<7.1	10.3
FL85-22H	1.98	95.3	4.7	11	7.88
FL85-22I	2.28	96.1	3.9	13.6	12
WMA85-1A	.15	86.4	13.6	<31	151
WMA85-1B	.46	96.2	3.8	<13	58.1
WMA85-1C	.76	98.2	1.8	<7.1	25.3
WMA85-1D	.61	97.4	2.6	<10	41.4
WMA85-1E	1.07	97.4	2.6	<12	47.7
WMA85-2	.15	91.0	9.0	9.3	9.05
WMA85-3A	.15	94.5	5.5	<6.1	17.8
WMA85-3B	.46	95.9	4.1	<8.2	29.2
WMA85-3C	.76	96.9	3.1	<11	43.6
WMA85-3D	.61	97.7	2.3	<5.5	16.5
WMA85-4A	.15	88.9	11.1	<5.8	13.5
WMA85-4B	.46	83.2	16.8	<15	61.2
WMA85-4C	.76	93.3	6.7	<7.2	22.4
WMA85-5A	.15	95.1	4.9	19.1	12.3
WMA85-5B	.46	96.6	3.4	15.2	13.3
WMA85-6	.15	94.1	5.9	13.2	9.78
WMA85-7	.15	76.6	23.4	10.2	5.32

[1] In percent of sample.

[2] Loss on ignition at 550 °C, in percent of sample. Analyses performed by S. Roof, U.S. Geological Survey, Denver, Colo.

[3] Analyses performed by R.B. Vaughan and D.M McKown, U.S. Geological Survey, Denver, Colo.

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Maps

Geologic Quadrangle Maps are multicolor geologic maps on topographic bases in 7 1/2- or 15-minute quadrangle formats (scales mainly 1:24,000 or 1:62,500) showing bedrock, surficial, or engineering geology. Maps generally include brief texts; some maps include structure and columnar sections only.

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Miscellaneous Investigations Series Maps are on planimetric or topographic bases of regular and irregular areas at various scales; they present a wide variety of format and subject matter. The series also includes 7 1/2-minute quadrangle photogeologic maps on planimetric bases which show geology as interpreted from aerial photographs. Series also includes maps of Mars and the Moon.

Coal Investigations Maps are geologic maps on topographic or planimetric bases at various scales showing bedrock or surficial geology, stratigraphy, and structural relations in certain coal-resource areas.

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