Title
SAMPLING HOT SPRINGS FOR RADIOACTIVE and TRACE ELEMENTS

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DISCLAIMER

SAMPLING HOT SPRINGS FOR RADIOACTIVE AND TRACE ELEMENTS*

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INTRODUCTION

The Lawrence Berkeley Laboratory is conducting a program to define parameters for assessment of geothermal resources, and to develop and evaluate techniques to measure these parameters. Field activities, presently underway, combine interrelating geological, geophysical and geochemical studies, leading eventually to choices of sites for deep test holes. As well as furnishing valuable information on the nature of a potential resource, geochemical data provides a baseline upon which the effects of future geothermal developments may be compared.

To date, most of our studies have been centered in northern Nevada where high regional heat flow, numerous hot springs, and available government land combine to furnish satisfactory field test sites. A regional heat flow map, Fig. 1, shows the Battle Mountain High, an area where heat flow exceeds 2.5 μcal cm^{-2} sec^{-1}. Figure 2 illustrates a cutaway model of a geothermal system considered typical of those associated with basin-and-range fault zones. The fault zone furnishes a pathway for meteoric water to percolate deeply into a region of high geothermal gradient, forming a convecting system which occasionally surfaces as a hot spring.

*Work performed under the auspices of the U. S. Energy Research and Development Administration.

SAMPLING FOR MAJOR AND TRACE ELEMENTS

In our geochemical program, water samples are obtained for laboratory radiometry, x-ray fluorescence analysis for major elements (Si, Na, K, Ca, Al, Mg, and S), and neutron activation analyses for trace elements. Collection methods were devised to retain all solid material, including that which precipitates. Major-element data furnishes chemical geothermometry, based on silica- and alkali-element ratios. Besides establishing natural-background baselines, radio- and trace-element contents of hot and cold spring waters, as well as of country rock, may help illuminate the pathways of meteoric water as it flows from its terrestrial origin into hydrothermal systems, and eventually into springs and wells.

Various types of springs sampled are illustrated on Figs. 3, 4, and 5: a hot pool at Big Sulfur Hot Springs, a warm pool at Leach Hot Springs, and a pool below a cold spring east of Kyle, respectively. (Cold springs are sampled because they may represent the groundwater which enters the fault-zone hydrothermal systems.) To a limited extent we have attempted to directly sample blowing wells, as shown on Fig. 6. Chemical geothermometer temperatures from these samples have compared well with reported measured subsurface temperatures.

Frequently, we sample muddy seeps, where only a small flow of water wells up between the cattle hoofprints. At these springs, a 1/4" diameter tygon tube is inserted directly into the flow, and water is drawn with a hand-operated vacuum pump as shown on Fig. 7. Instead of passing into a bottle, the water can also be drawn directly through a 0.45 micron cellulose acetate filter, whose apparatus is shown on Fig. 8. Therefore, water can be introduced to the filter either directly from the spring, or by pumping from a bottle in the field or laboratory. Normally, 500 ml

Nalgene bottles are used to collect and store the samples. These field sampling techniques, and laboratory analytical methods and results, are described in detail in papers by Bowman et al. (1974, 1975), and Hebert and Bowman (1975).

In the field or laboratory, drops of filtered water are evaporated onto a lexan disc, with a fixing solution, for subsequent x-ray fluorescence analysis. (After the x-ray fluorescence analysis, the lexan can be irradiated, cleaned and etched for determination of the water's uranium content.) Evaporation in the field is shown on Fig. 9, and the resulting disc on Fig. 10.

For H_2S determinations, a silver disc is placed in an unfiltered aliquot of each water sample. The disc is later analyzed for sulfur by x-ray fluorescence. Figure 11 shows the response of x-ray intensity to H_2S by this method.

Filtered samples for neutron activation analysis are obtained by evaporating the water directly from the Nalgene bottles (at 80°C) in the laboratory. The resulting residue is incorporated with a plastic binder into a pellet, and irradiated along with standards in a research reactor at the University of California, Berkeley.

Some results of the neutron activation method are illustrated on Figs. 12 and 13; Fig. 12 illustrates the contrast in uranium contents of hot and cold spring waters, and Fig. 13 the levels of some trace elements in pools of differing temperature at Buffalo Valley Hot Springs.

RADIOACTIVE EFFLUENTS

Prior to sampling, a gamma survey of the spring area is conducted using a portable NaI(Tℓ) detector, shown on Fig. 14. Samples for laboratory radiometry are usually collected by scooping the spring water directly from the pools into Nalgene bottles. This minimizes radon loss which might occur if the water were drawn through the filter system. Bottle lids are immediately taped, and samples transported to the laboratory for gamma-ray pulse-height analyses. The time of sampling is carefully noted, to account for the radioactive decay of ^{222}Rn (3.8-day half-life) between sampling and gamma counting. With a reasonably short interval between sampling and counting, sensitivity of this method is of the order of a few tens of pCi per liter of ^{222}Rn. Along with spring waters, spring wall sinter, tufa, and muck are collected, for subsequent laboratory gamma-ray analyses. This provides comparison of the contents of radium and other radioelements with the ^{222}Rn content of the water.

A sampling system for radon emanating in and around a spring system utilizes alpha-track detectors. This method integrates radon emanation over a long time period, minimizing short-term fluctuations in response to changes in atmospheric conditions. The detectors are inverted plastic cups with specially treated dielectric alpha-sensitive plastic wafers attached inside, as shown on Fig. 15. They are placed, each in an approximately 0.5 meter deep hole, then covered. After several weeks' exposure, the cups are retrieved, detectors removed, etched, tracks counted, and normalized track densities calculated. This service, used primarily by the uranium industry, is provided by Terradex Company in Walnut Creek, California. Resulting track densities in the vicinity of Buffalo Valley Hot Springs, are shown on Fig. 16, and point out the sharp variations in radon emanation at that site. Figure 17 illustrates the contours of radon emanation over a broader area of Buffalo Valley. More detailed descriptions of radiometric methods and results are provided in papers by Wollenberg (1974a and b, 1975).

SUMMARY

The techniques described briefly here have proved successful in obtaining samples of hot and cold spring waters for x-ray fluorescence, neutron activation, and radiometric analyses. These sampling methods require only lightweight, portable field apparatus, and do not involve lengthy collection procedures. Good flexibility in field operations is necessary to accommodate the widely varying conditions of temperature, flow, and accessibility encountered at the different spring sites.

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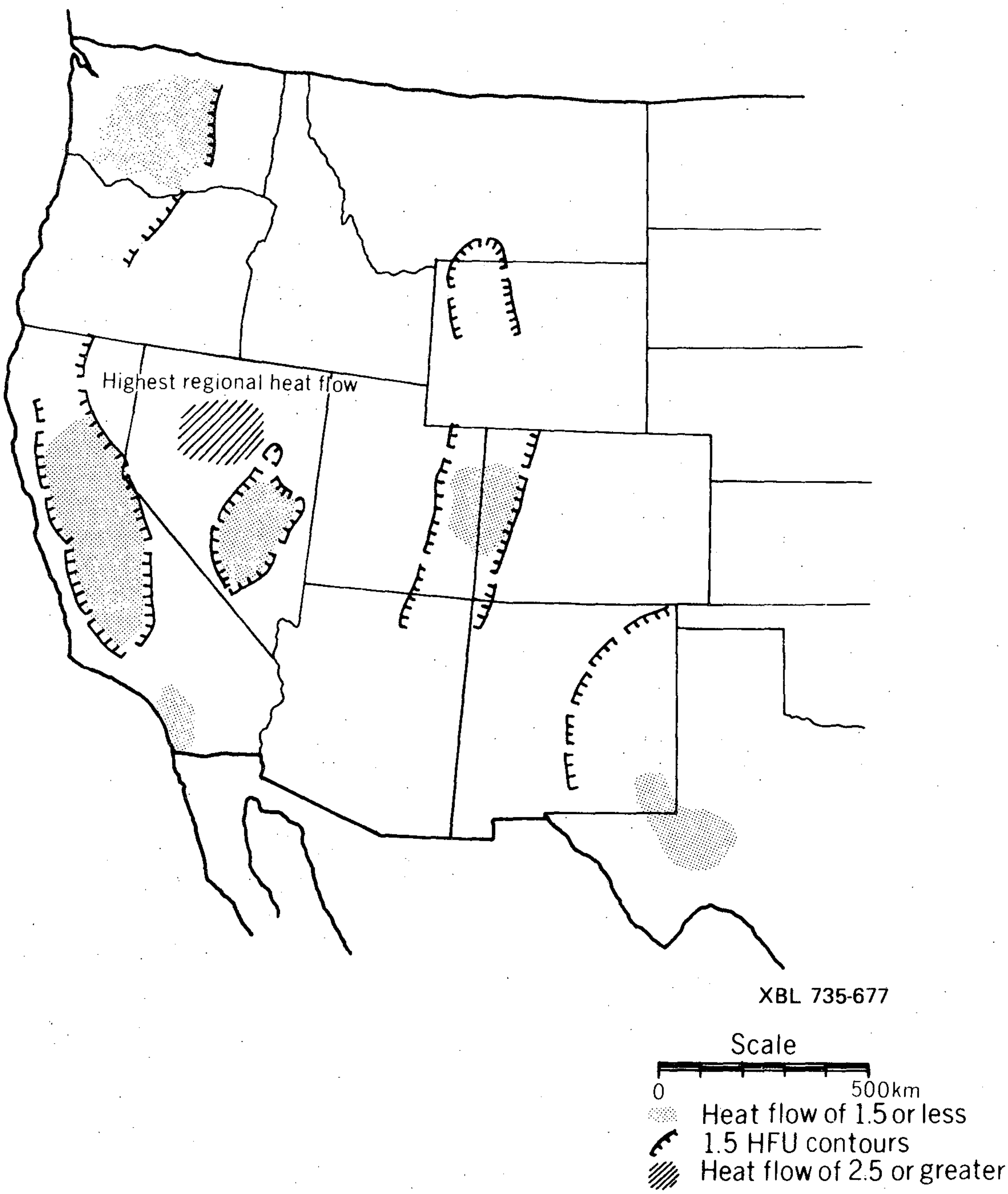

Figure 1 Regional heat flow in the western U.S. (after Sass et al., 1971). The stippled areas have heat flows estimated less than 1.5 μcal cm^{-1}, (hfu) while in the dashed area, the "Battle Mountain High" heat flow probably exceeds 2.5 hfu. Hachured lines indicate the fairly well defined position of the 1.5 hfu contour.

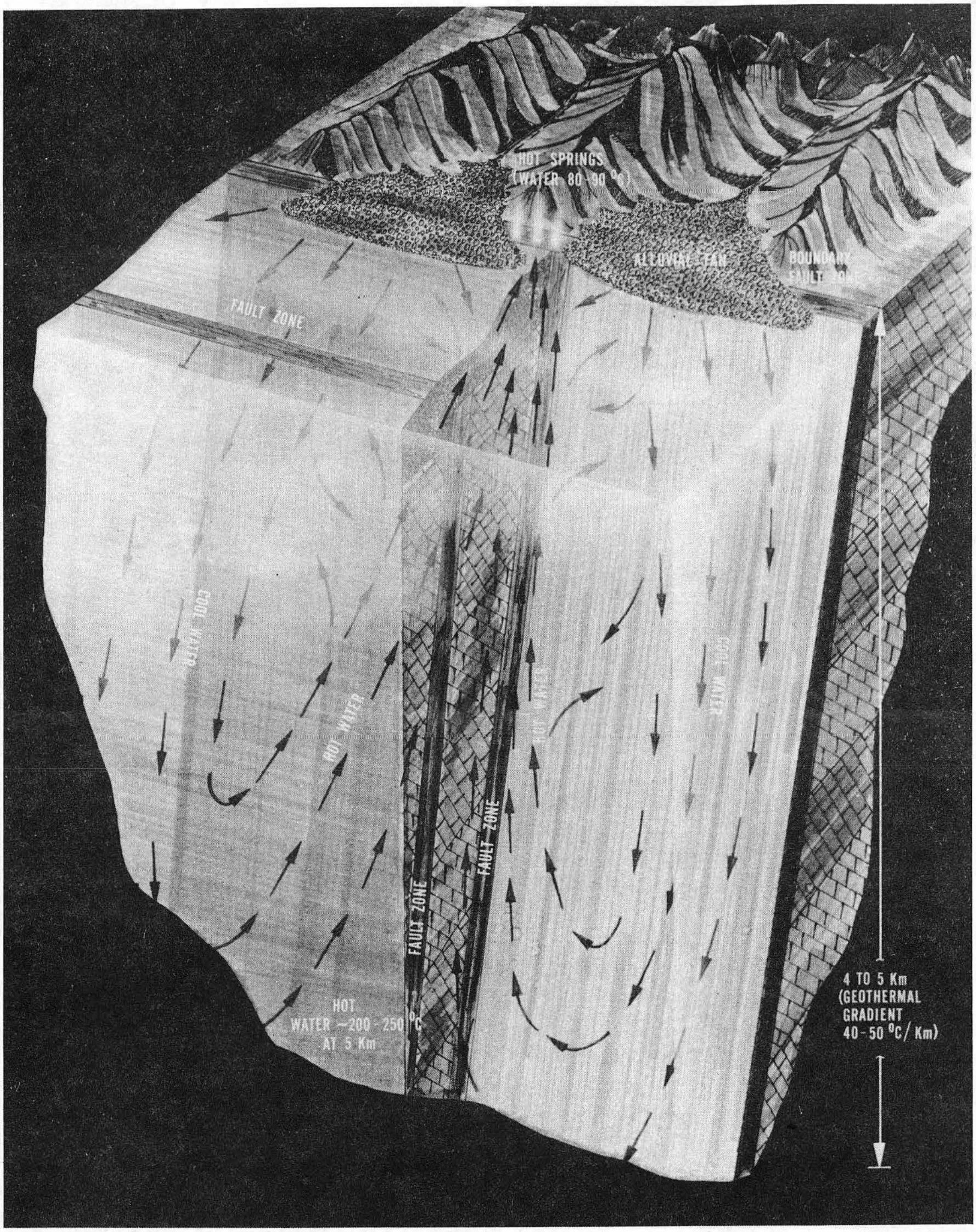

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Figure 2 Schematic cutaway diagram of a geothermal system within a permeable fault zone. Meteoric water enters the fault zone where it intersects near-surface aquifers. Some of the water percolates downward to regions where temperatures reach 150 to 200°C, is heated and rises on the upward limb of a convection cell. Hot springs occur where the cell intersects the surface.

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Figure 3 Water sampling and field radiometry at Big Sulfur Hot Springs, Ruby Valley, Nevada.

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Figure 4 Sampling a warm pool at Leach Hot Springs, Nevada.

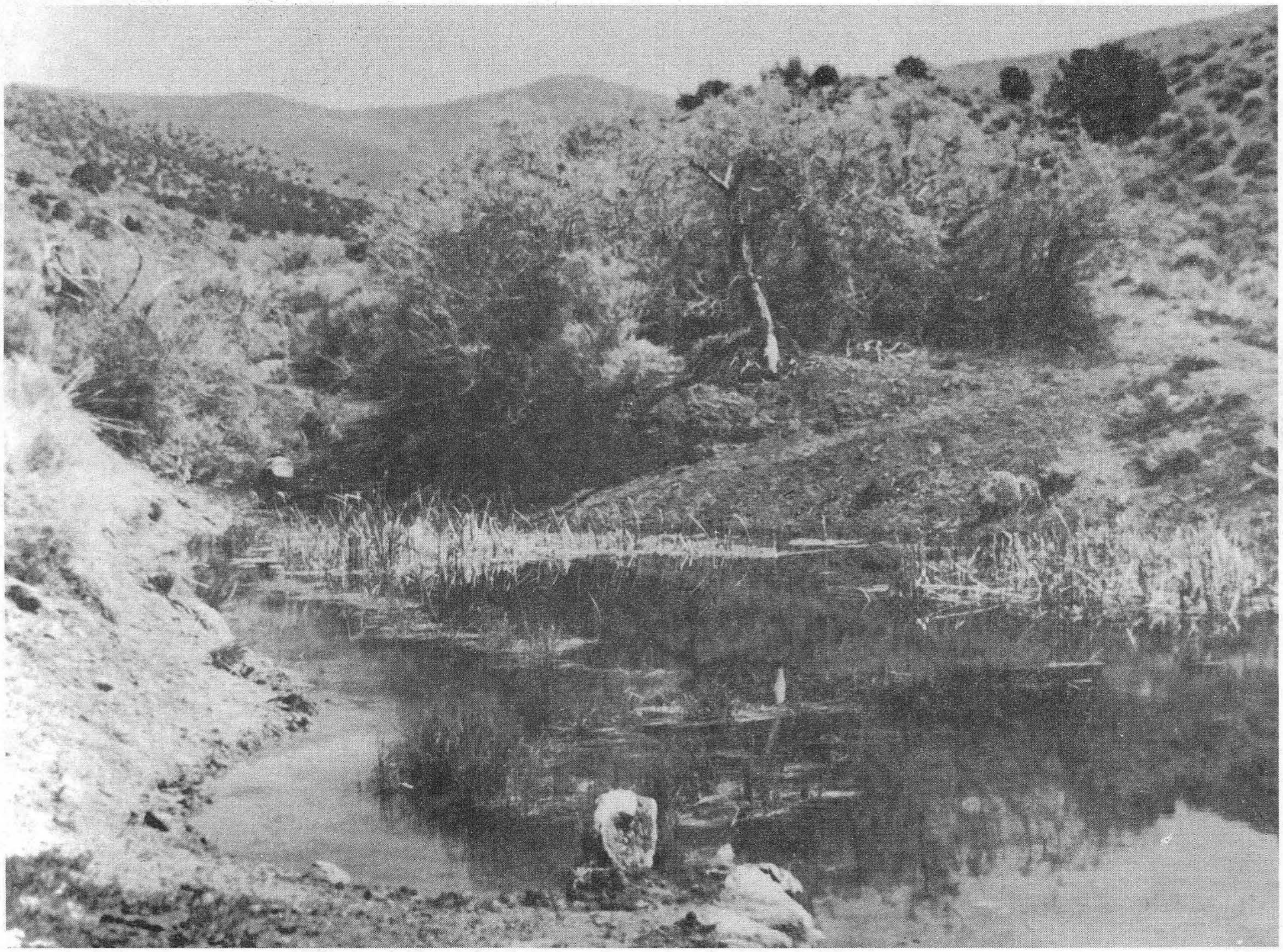

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Figure 5 Outflow from a cold spring east of Kyle Hot Springs, Nevada.

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Figure 6 Sampling a blowing well in northern Nevada.

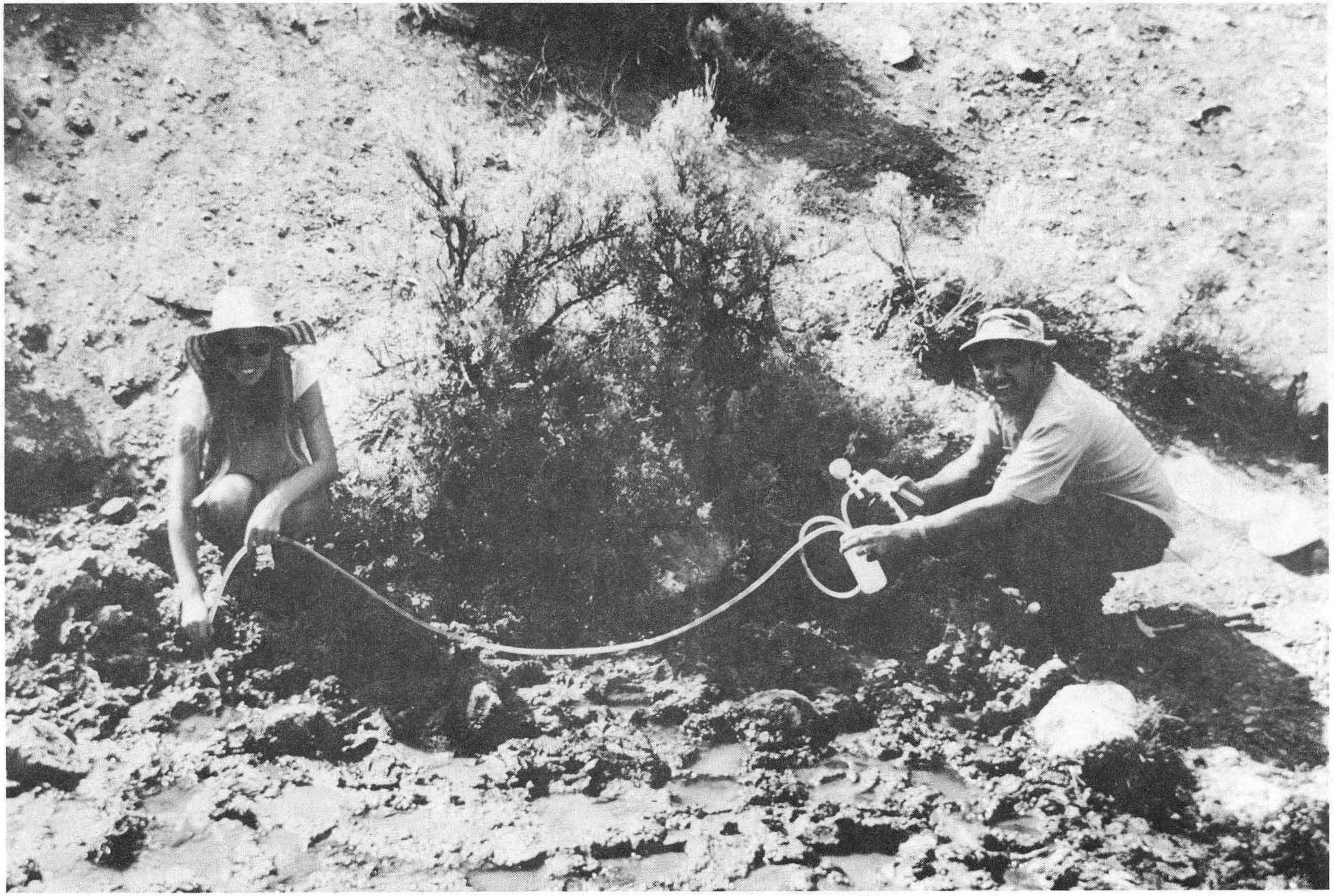

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Figure 7 Sampling a small flow in a muddy seep, using tygon tubing and a small hand-operated vacuum pump.

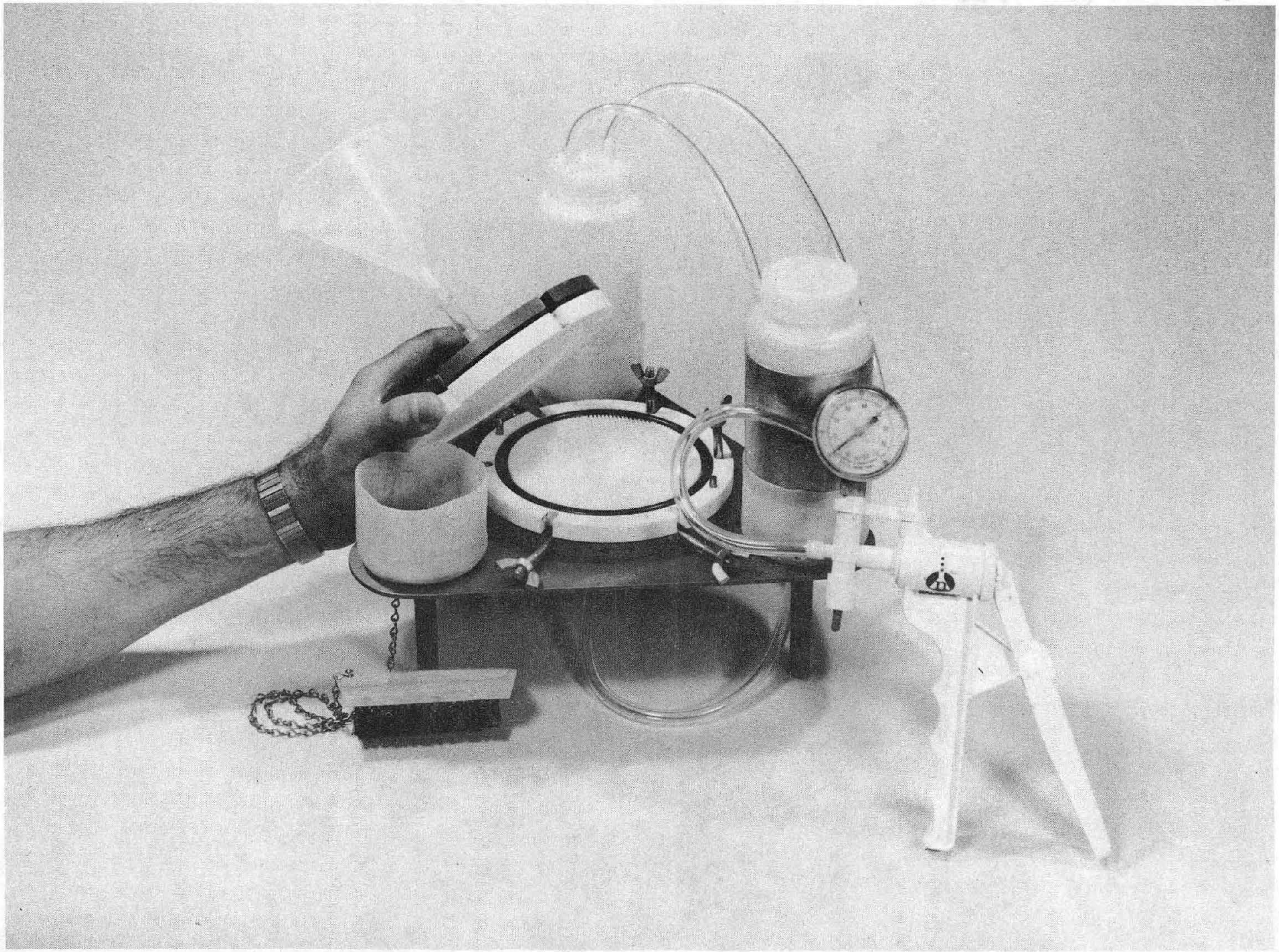

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Figure 8 Portable filtering apparatus with hand-operated vacuum pump.

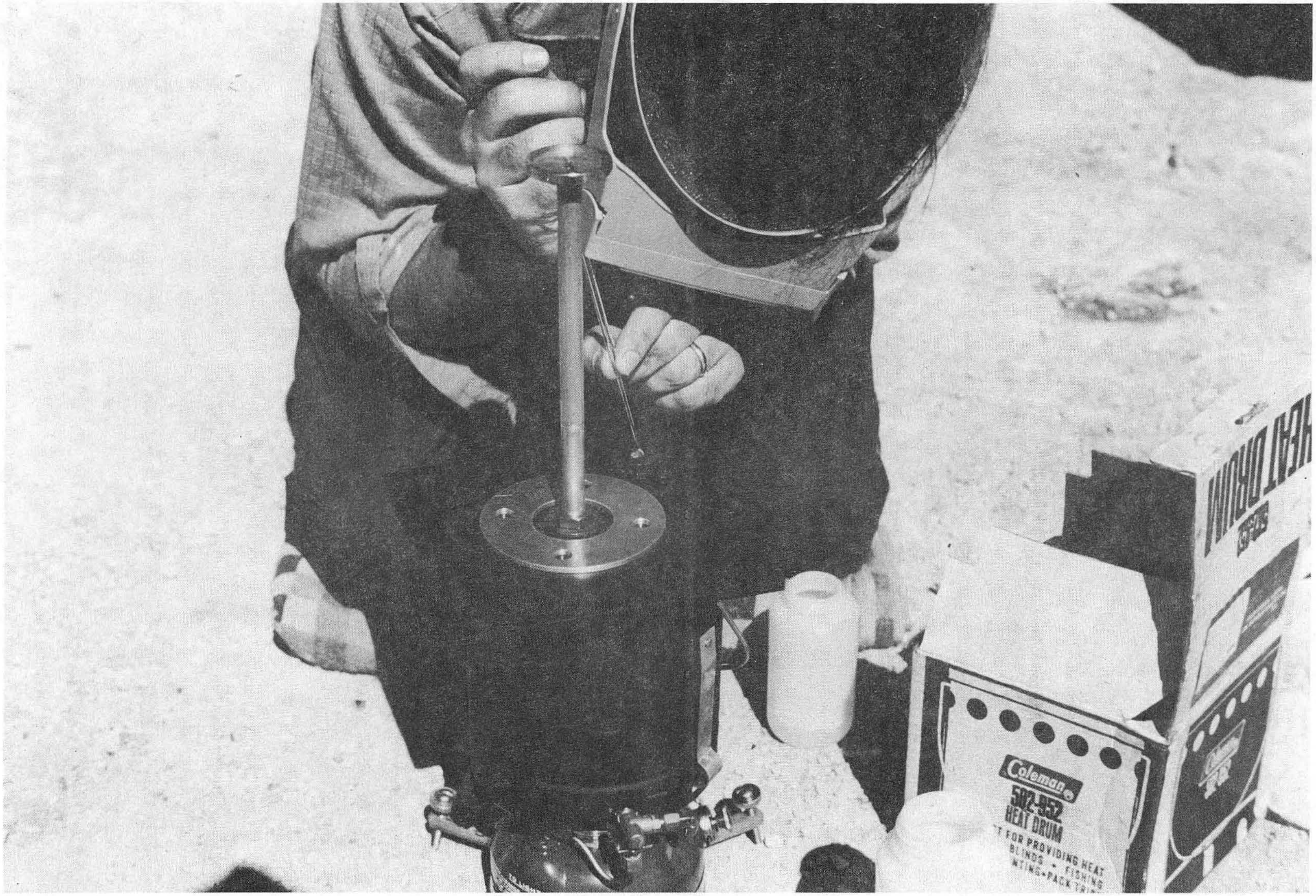

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Figure 9 Evaporating a 50 $\mu\ell$ aliquot of a water sample onto a lexan disc in the field.

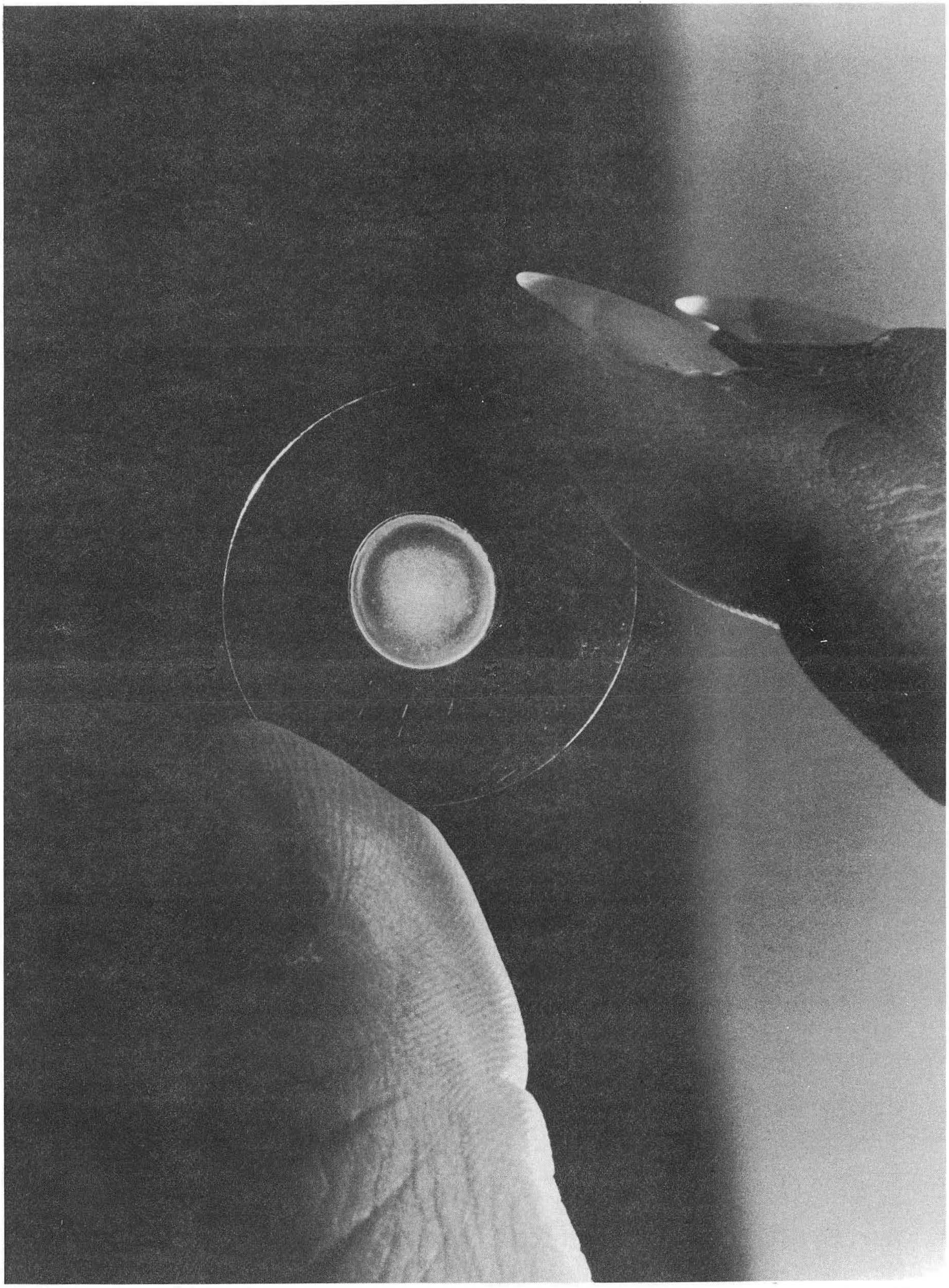

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Figure 10 Lexan disc with evaporated sample affixed. The sample spot is $\sim$ 0.7 cm^2 in area and 2 to 5 microns thick.

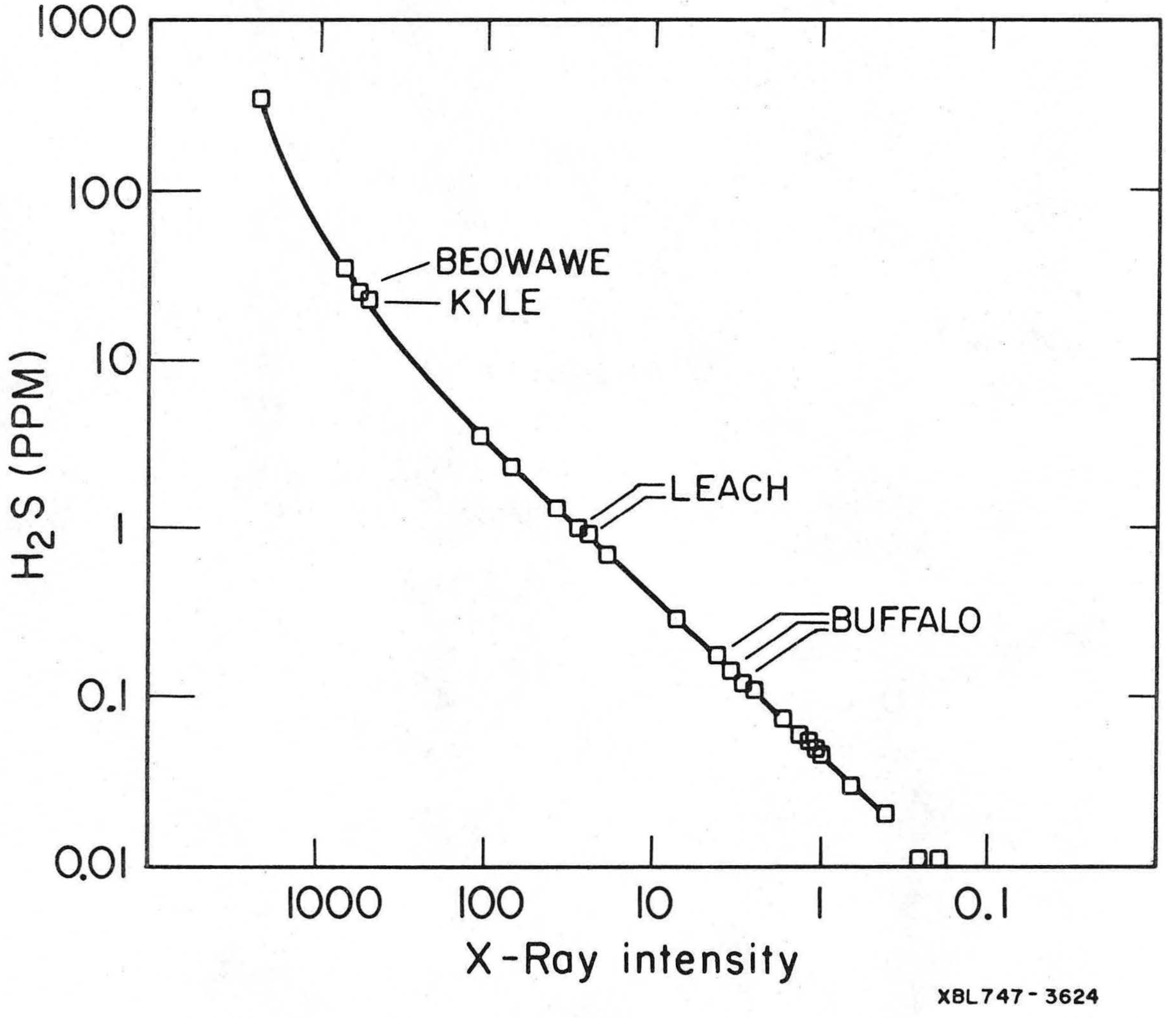

Figure 11 Calibration curve for equivalent H_2S contents of spring waters, using the non-dispersive x-ray fluorescence method.

0 0 0 0 4 4 0 5 1 1 9

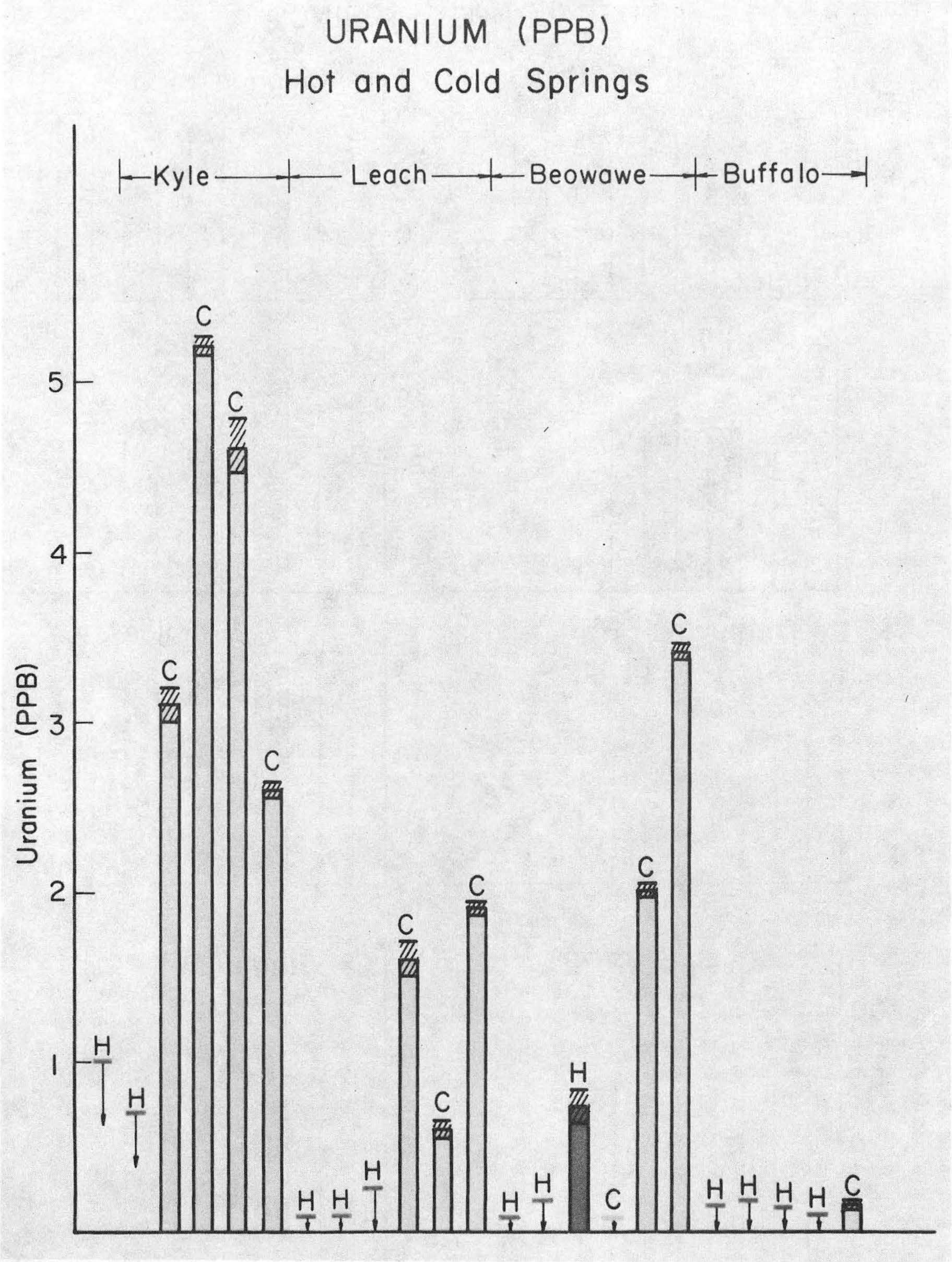

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Figure 12 Uranium abundances (ppb) in hot and cold springs at four geothermal areas in north-central Nevada. C - cold springs, H - hot springs, tails of vertical arrows indicate detection limits.

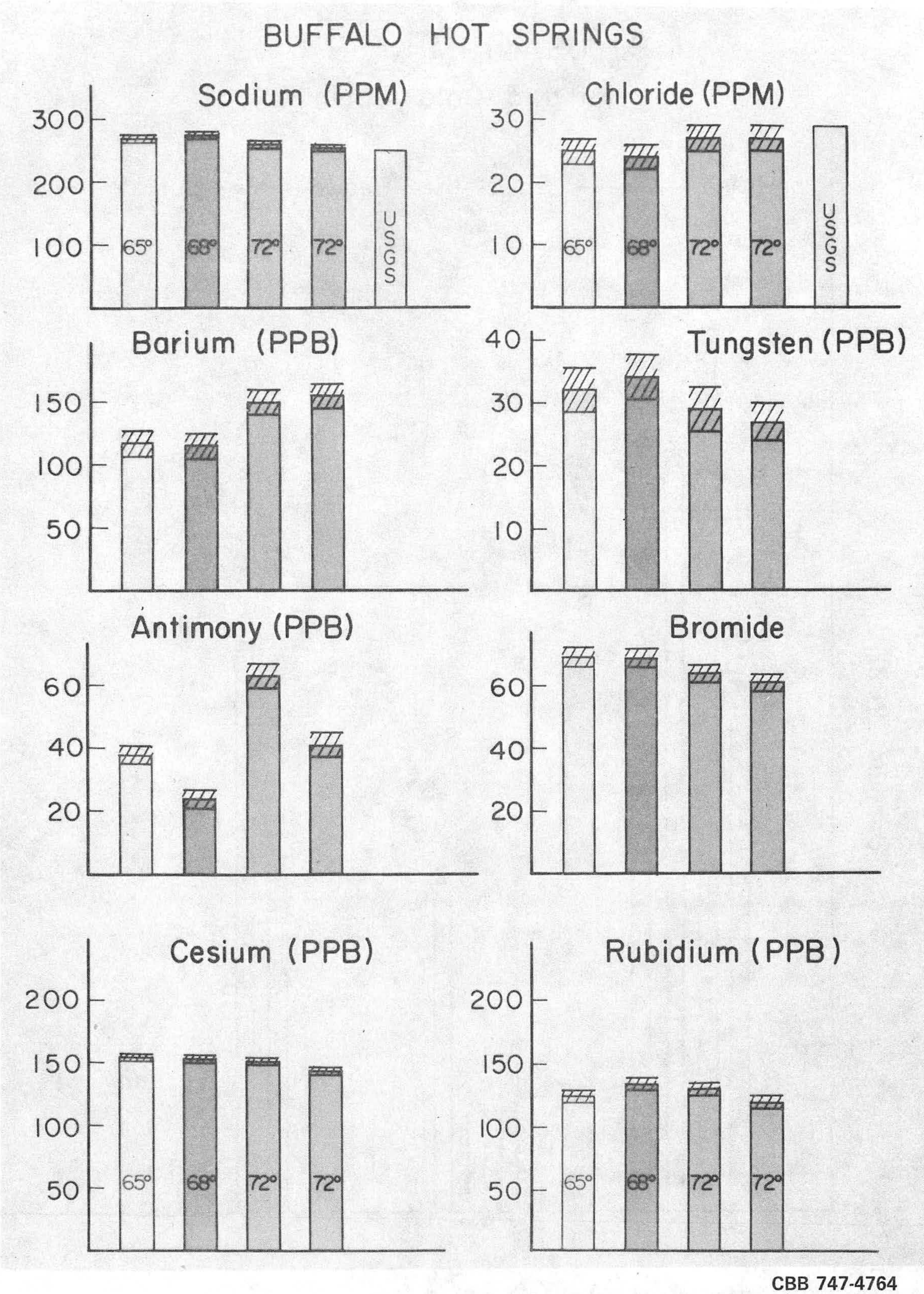

Figure 13 Abundances of the most prominent elements found in four separate hot water pools at Buffalo Valley Hot Springs. Surface water temperature is shown on each bar graph.

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Figure 14 Field gamma counter. The 3-in. by 3-in. NaI(T1) scintillation crystal and photomultiplier tube are encased by the steel cylinder, and are connected to the accompanying count-rate meter.

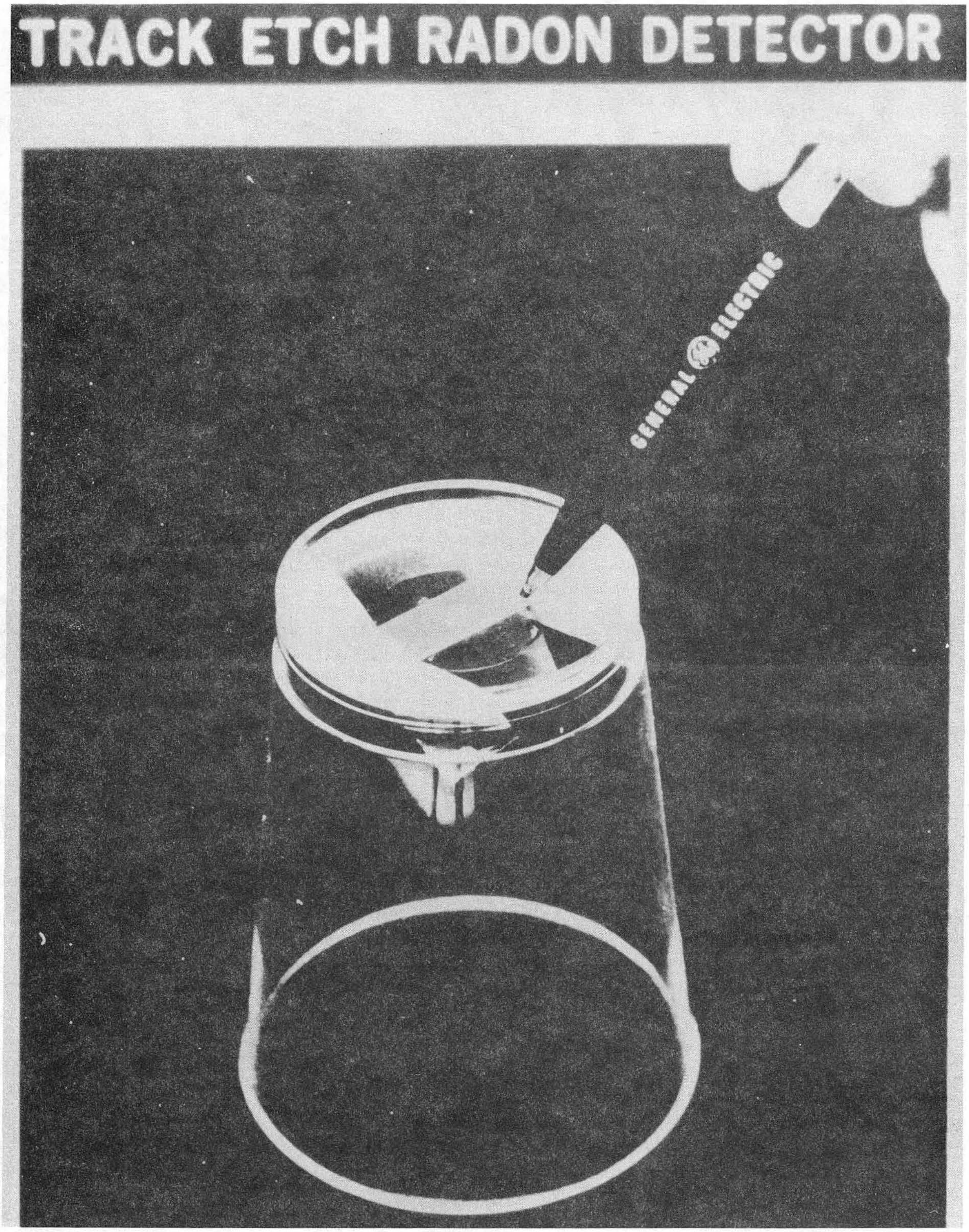

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Figure 15 Alpha track-etch detector mounted on the inside of a plastic cup. (Photo courtesy of Terradex Company)

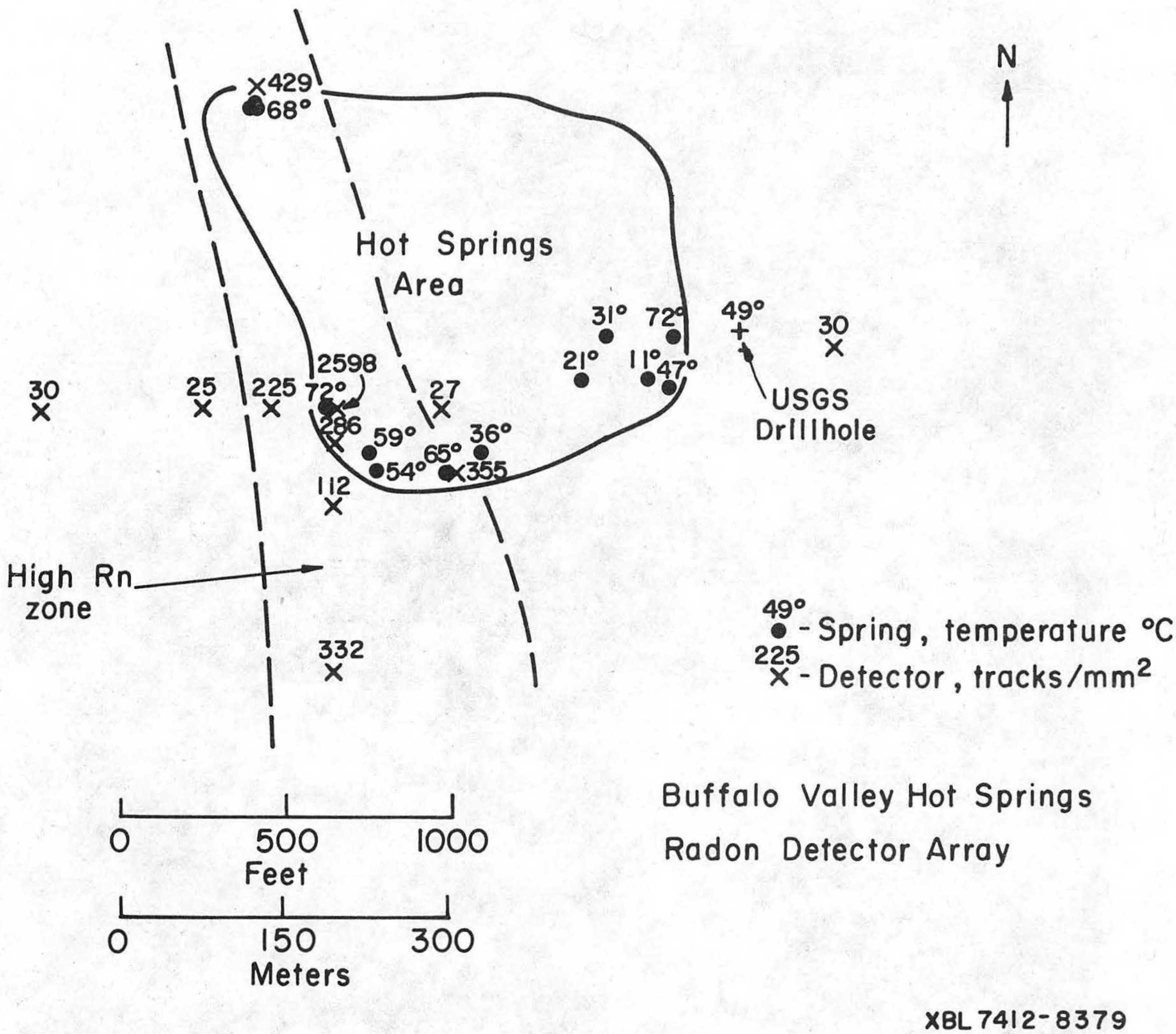

Figure 16 Sketch map of Buffalo Valley Hot Springs ares, showing locations of some of the warm pools, temperatures, and normalized track densities.

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Figure 17 Contours of radon alpha-track density (in tracks mm^{-2}, normalized to a 30-day exposure) in Buffalo Valley. (Dotted numbers are station locations)