EXPLORATION FOR URANIUM UTILIZING

THE TRACK ETCH TECHNIQUE

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ABSTRACT

The Track Etch‡ method for radon detection is discussed as it relates to uranium exploration. Particular emphasis is placed on the use of the Track Etch technique in detecting non-outcropping deposits of uranium and the advantages of this method over the previously used radon emanometer techniques.

Sub-surface gas transport mechanisms as they may be related to uranium exploration are reviewed. The results from several uranium exploration programs which have used the Track Etch method are presented with specific illustrations of applications of this technique to a wide variety of environments in Australia, Canada and the United States.

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‡ The Track Etch system is covered by U.S. and foreign patents.

Introduction

The detection of near surface soil gas radon anomalies has been used for a number of years as an exploration tool in exploring for buried uranium mineralization.[1,2] Radon anomalies can often be detected at the surface over hidden uranium ore bodies when other surface radiometric techniques (using scintillometer or geiger counters) are ineffective because of the short range (1 ft. or less) penetration of the associated gamma radiation. Radon emanating from deeply buried uranium can penetrate through hundreds of feet of over-burden to the earth's surface where it can be detected by proper alpha radiation detection methods.

Several techniques have been developed by measuring radon in the surface soil. The older "emanometer" methods have used either an alpha-sensitive phosphor-coated chamber coupled to a photo-multiplier or an alpha-sensitive ionization chamber. The gas sampling period with the emanometer method is usually in the order of a few seconds or a few minutes. Emanometer equipment is relatively complex, both electrically and mechanically, and the phosphor coated sample chamber is subject to surface contamination from radon daughter products, particularly when high radon levels are measured. The most significant problem in using emanometers, however, is that they measure only a short term soil gas sample which is usually not indicative of the average radon concentration in the immediate area. The latter point is a particularly important limitation since radon concentrations in given locations can vary by as much as a factor of 100 in a 24 hour period due to variations in temperature, barometric pressure, wind, moisture and other conditions.[3] (See Figure 1.) Consequently, individual readings taken with emanometers are often not repeatable, even when measured only a few hours apart, and emanometers are considered particularly unreliable in surveys involving a large number of readings taken over an extended period of time. In order to obtain more meaningful radon measurements it is necessary to obtain integrated average readings over a period of time and this is readily accomplished with the Track Etch method.

The Track Etch Method

The Track Etch method for radon detection has been previously described in detail in several technical papers.[4,5] Essentially it uses special alpha radiation sensitive detectors enclosed in small sampling cups to detect the radon content of the soil gas. (Figure 2.) These Track Etch cups are placed in shallow holes in the earth (about 75 cm. deep) and left undisturbed for several weeks. By leaving the detectors for a period of time they continuously accumulate the readings produced by the varying radon soil concentrations and thus they produce readings indicative of the long term average radon concentrations in the areas being sampled.

One of the significant advantages of the Track Etch method is its extreme simplicity and the fact that the sampling cups can be easily deployed by unskilled personnel. The detectors and cups are simple pieces of rugged plastic material and they have no complicated mechanical or electrical parts to cause problems.

In the field the Track Etch cups are normally used in a grid pattern with spacings ranging between 30 and 1000 meters depending on the size of the area being explored, the dimensions of the expected mineralized area, the local structural trends and other factors. (Figure 3.) The method can be used in both dry and wet climates and it has been successfully used to measure radon under the surface snow in cold environments.

The Track Etch technique, like most other geophysical and geochemical methods, requires an accurate determination of the background (radon) level of the area being surveyed. Thus a minimum of one hundred sampling stations are normally used to statistically determine the general background mean value with the desired accuracy. Experience with nearly 400 exploration programs using the Track Etch method has shown that the background levels can vary by as much as an order of magnitude in different exploration areas around the world. These variations are primarily due to differences in surface and near surface uranium mineralization and to the differences in rock types in the exploration areas.

Sub-Surface Radon Transport

Experience with Track Etch and other radon detection methods has indicated that anomalous uranium mineralization can be detected at depths of up to 300 meters in favorable environments.[6] Several different mechanisms to explain the movement of radon from deep uranium mineralization to the surface have been postulated. They include: (1) gas movement across geothermal gradients to cooler areas, this is predominately an upward movement; (2) seismic and earth tidal pumping effects, the opening and closing of fractures and pore spaces; (3) deep effects of barometric pressure changes; (4) diffusion and transport of more concentrated soil gases (O_2, N_2, CO_2, Ar He and other gases); (5) upward aqueous transport vectors; (6) soil and air temperature differentials; and (7) wind speed, direction and turbulence effects on the soil gas. At the present time little is known about the detailed influences of these primary transport mechanisms.

It is known that open fault zones can act as collectors of anomalous concentrations of radon gas from background uranium values. These zones also act as a direct gas funnel to the surface producing linear anomalies. Since economic mineral deposits often are found in conjunction with fault zones this phenomenon can sometimes be used to advantage in uranium exploration.

Radon does not seem to travel preferentially through highly permeable sandstones rather than low permeability shales unless the primary transport mechanism is due to aqueous movement which is often not the case. Since radon travels as discrete separate atoms through crystal defects, grain boundaries, rock pores and fracture systems, differences in permeability to water have a very small effect on the transport vectors of radon gas.

Ground water movements may also have some effect in producing a detectable halo around an orebody. Periodic rises in the general level of a water table in a district may displace slight concentrations of uranium to a point higher than the deposit. These mineralized zones can act as radon sources and may produce enhanced zones of radon concentration over the orebody. In very alkaline waters, such as active karst areas, radium-226 can also be transported (radium-226 is the immediate parent of radon-222). Since radium is a group 2a element and is geochemically similar to calcium, barium and strontium it can sometimes be moved under the same conditions that cause these elements to be transported.

In all theories of radon soil gas transport mechanisms, it must be remembered that radon is an extremely small concentration component of soil gas. Therefore it must travel as a very minor constituent of the other more concentrated soil gases such as oxygen, nitrogen, carbon dioxide, argon, helium, water vapor, etc. These gases may move upward at velocities of several meters per day transporting the radon to the surface from very deeply buried uranium mineralization.

The Track Etch tehcnique measures only near-surface radon which may have migrated from uranium at several sub-surface locations. Thus it cannot directly distinguish between low-grade uranium mineralization at shallow depths and deeply buried high grade uranium since both can produce the same radon concentrations in the near-surface soil. In some cases a very high anomaly (in relation to the background average) will be detected when there is only low grade uranium at or near the surface. In areas where there are several target horizons at different depths this may be particularly troublesome since shallow mineralization can produce high anomalies which can "mask" deeper targets that may have better mineralization. Similarily, faults and joints with higher radon permeability rates may show higher Track Etch readings than areas with lower permeability but the difference in sub-surface uranium mineralization may be small. Thus radon exploration surveys that are conducted in very homogeneous areas are much easier to interprete than those conducted in areas of complex structures and varied rock types.

The Track Etch detectors, like other radon detection methods, will indicate the presence of all radon isotopes; Rn-222, Rn-220 and Rn-219. Both Rn-222 and Rn-219 are decay products from uranium but Rn-220 (thoron) is a decay product of thorium. Since Rn-220 has a very short half-life (55 seconds) thorium will be detected only if it is present within a short distance of the sampling cup, but it may cause an interference problem when attempting to find more deeply buried uranium. This potential interference can be avoided by measuring each sample location with a spectral- type scintillometer to detect near surface thorium. In actual field experience, the presence of thorium has been a minor problem because it has either been present in very small amounts or it has been closely associated with the desired uranium mineralization such as uranothorite.

Field Experience Using The Track Etch Method

The Track Etch technique for uranium exploration has been used in nearly 400 exploration programs in a large diversity of geologic environments. It was used initially to explore for uranium in continental epigenitic sandstone deposits of the western United States and in the metamorphic terrane of northern Australia. It has been subsequently used in a number of different environments on five continents encompassing most of the uranium deposit types currently under active exploration. These have included pegmatite deposits, plutonic intrusives, vein-type accumulations, caliche accumulations, and syngenetic conglomerates. Results from a few of the exploration programs that have used the Track Etch method are discussed in the following examples.

Australian Experience

One of the first exploration programs using the Track Etch technique was carried out in the East Alligator River district in the Northern Territory. This is an area of vein deposits in metamorphic quartz and chlorite schists. The Track Etch detectors were located on a 30 by 150 meter grid in an area where there was no surficial radiometric anomaly. A 40 Times background Track Etch anomaly was produced over a known orebody which was 75 meters deep. The water table in the area was within 10 meters of the surface indicative of minimal attentuation of the radon signal by thick water cover.

Another test program in Australia was conducted in the Fromme Lake Embayment in South Australia. The target sandstone was a Lower Tertiary paleochannel incised into Cretaceous marine clays and silts. The channel sediments consisted of interbedded quartzose sands and clays and they occurred at depths from 10 to 120 meters. The whole area was overlain by a blanket of relatively impermeable Upper Tertiary lacustrine clays and the uranium deposit occurred in sand at the base of the channel section. The ore averaged 4 meters in thickness at an average grade of 0.25% U_3O_8. A Track Etch anomaly of 2 to 3 times background was detected in the immediate area about 100 meters displaced from the center of the orebody. The low order of the anomaly was probably due to the relatively impermeable nature of the clays overlaying the deposit but the reason for the offset observed on other Track Etch surveys in similar environments.

A large regional Track Etch survey was undertaken in Central Australia to determine the effectiveness of the technique using wide sample spacings in a sedimentary environment. Track Etch cups were placed on one Km centers in order to determine regional geochemical patterns. In this particular case very large areas were removed from consideration as having no geochemical enrichment indicative of potential for uranium mineralization. Conversely a quite extensive area was outlined with heightened Track Etch response. This area was determined to be underlain by a redox geochemical cell front with anomalous uranium accumulations located along it. Exploratory drilling discovered ore grade mineralization at a depth of 25 meters where significant Track Etch anomalies had been detected. (Figure 4.)

Track Etch has also been used effectively to explore for vein uranium deposits in Western Queensland for deposits in metamorphic suites. The technique quite effectively outlined areas of significant uranium mineralization down to depths of 60 meters but in this specific instance no ore grade deposits were found.

Vein uranium deposits also were the targets in an exploration program in Western Australia. The Track Etch survey was undertaken to check out low order airborne anomalies and it produced narrow and elongated anomalies indicating shear zones containing uranium mineralization.

Canadian Experience

A test of the Track Etch technique was undertaken over the Cluff Lake "N" deposit located in Northern Canada in the province of Saskatchewan.[7] The deposits there are in Precambrian metasediments and are covered by 5 to 20 meters of glacial debris. A very high Track Etch anomaly occurred over the main orebody (50 times local background) and lesser anomalies occurred over ore grade mineralization at depths of up to 120 meters. (Figure 5.) A second program was undertaken in the same location during the wintertime by placing the cups under a snow cover. The winter survey showed a similar radon concentration pattern although the absolute values were lower, possibly due to lessened gas mobility or ice crystal accumulation on the Track Etch detectors.

A test Track Etch program was also conducted over potentially mineralized ground in the Beaverlodge uranium district in Canada along a promising structural trend. Several anomalies were encountered with readings of 4 to 5 times background and drilling has located high grade pitchblende directly beneath one of these anomalies.

United States Experience

A uranium exploration program using the Track Etch method was undertaken along the southwest flank of the Gypsum Valley anticline in San Miguel County, Colorado, in the Uravan Mineral Belt of the Colorado Plateau. Gypsum Valley is a northeast-southwest trending salt collapse graben-anticline and uranium deposits are found in the Salt Wash Sandstone member of the Morrison Formation which is partially exposed along the graben walls. Ore deposits previously found in this area range from a number containing only a few tons to several containing several thousand tons. The deposits occur where host sandstones thicken to over 10 meters and where extensive carbonaceous debris and grey mudstones and clay layers are present. The Track Etch program used 100 meter center sample spacings and it produced 15 to 20 significant anomalies. (Figure 6.) One large multi-point anomaly and several small anomalies were found in areas of very intense fracturing and they were probably due to graben margin faulting. Of all of the exploratory holes drilled on the major Track Etch anomalies, 25 out of 35 have encountered signs of mineralization. Eleven have intersected abnormal radioactivity indicative of the passage of mineralizing solutions through the area, twelve have encountered greater than 0.01% U_3O_8 and two have intersected ore grade material at a depth of approximately 150 meters. Geologic differences in the rock types can be seen along the upper edge of the contour map in Figure 6 by noting differences in Track Etch readings. Additional drilling on this program is now being planned.

Track Etch radon prospecting was also successfully applied in an exploration program in the Grants Mineral Belt of New Mexico. The prospect was along a general trend of known mineralization but in an area where no exploratory drilling had been performed. Track Etch cups were placed in a regular square grid pattern on 50 meter centers in an area approximately 1600 meters long and 500 meters wide. Three significant anomalies were detected on the property with a number of Track Etch detectors reading more than three times background. Exploratory drilling was conducted in the area of the largest anomaly and the third drill hole produced the first signs of mineralization. The fourth drill hole intersected a uranium orebody at a depth of 100 meters with an initial ore thickness intersection of 3 meters and an ore grade of 0.34% U_3O_8. Subsequently, the complete orebody was outlined and was found to contain several million pounds of uranium. At the present time it is being prepared for mining. The uranium orebody is located in the Westwater Canyon sandstone member of the Morrison Formation and it is covered by more than 100 meters of other sandstone sequences with shale stringers and thin layers of coal in the intervening beds. The water table in the area is at a depth of 110 meters.

A test of the usefulness of the Track Etch technique was carried out over a known epigenetic geochemical cell accumulation type uranium deposit in a uranium district of southeast Texas. The deposits occurred in marginal marine, littoral, and near shore continental sediments of Tertiary age. Hydrogen sulfide or other reductants that percolated along fault zones acted as the reagent to deposit the uranium in the sediments. The deposit tested was at a depth of 185 meters with the water table at 30 meters. The deposit was covered by thick sequences of sandstone and siltstone. The Track Etch technique produced anomalies of approximately 2.5 to 3 times background but were of sufficient intensity to have directed the drilling that would have located the orebody.

A test of the applicability of the Track Etch technique and a determination of its usefulness compared to traditional uranium prospecting techniques was undertaken in the uranium district of the Front Range of Colorado.[8] The mineralization there is fracture filling uraninite coating breccia fragments, along narrow fault and fracture zones. The rocks of the district are moderately to well metamorphosed Precambrian sediments and some possible volcanics. All sampling was carried out on a 150 meter square grid and several techniques were tested at the same locations along this grid. Intense surficial leaching and thick colluvial cover render traditional airborne and ground radioactivity reconnaissance prospecting useless. Radon gas emanometry and sulfur gas emanometry were slightly more effective but the long and short term variations in soil gas emanation rates made it extremely difficult to gain useful information from these systems. The technique judged most useful was Track Etch. It produced well defined anomalies, up to 88 times background in one case, and several anomalies over 10 times background. The best anomaly produced by radon gas emanometry was 3 times background. (Figure 1.) The excellent definition of the technique, as well as its repeatability, indicated that Track Etch was the best tool for narrow vein-type deposits similar to those of the Front Range in Colorado.

Conclusions

Uranium exploration using the Track Etch method for radon detection has proven to be very effective in a variety of geologic environments. Results have shown that it can detect the presence of non-outcropping uranium mineralization where other surface and airborne radiation detection methods have not been able to detect anomalies. Part of the effectiveness of this method is believed to be related to the fact that the Track Etch detectors provide integrated measurements of the radon concentrations in the near-surface soil. The sensitivity of the Track Etch detectors also makes it possible to detect radon at extremely low concentrations thus making it possible under favorable conditions to detect radon emitted from very deeply buried sources. Under some conditions, anomalies are detected which are related to sub-surface faults and joints. Differences in lithologic units in the survey areas, are also detected where there are significant differences in the uranium content of the rocks.

Field experience has shown that the Track Etch method is easy to employ in remote areas and in areas of difficult accessibility. Only simple field tools and a minimum training of personnel are needed to effectively conduct a Track Etch survey. By using the results from Track Etch surveys, initial exploratory drilling to detect hidden uranium mineralization has been reduced by up to 90% in several instances.

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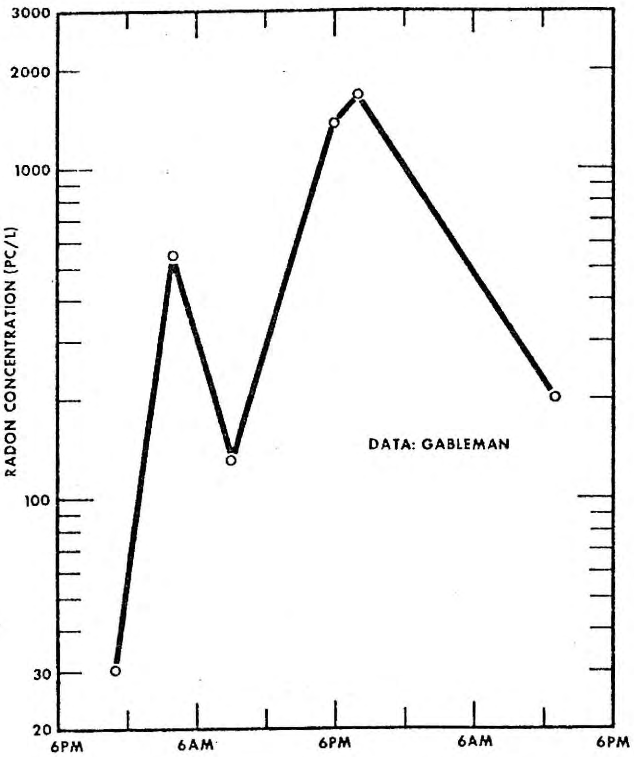

Figure 1. Short Term Variations of Radon in the Soil (Reference 3)

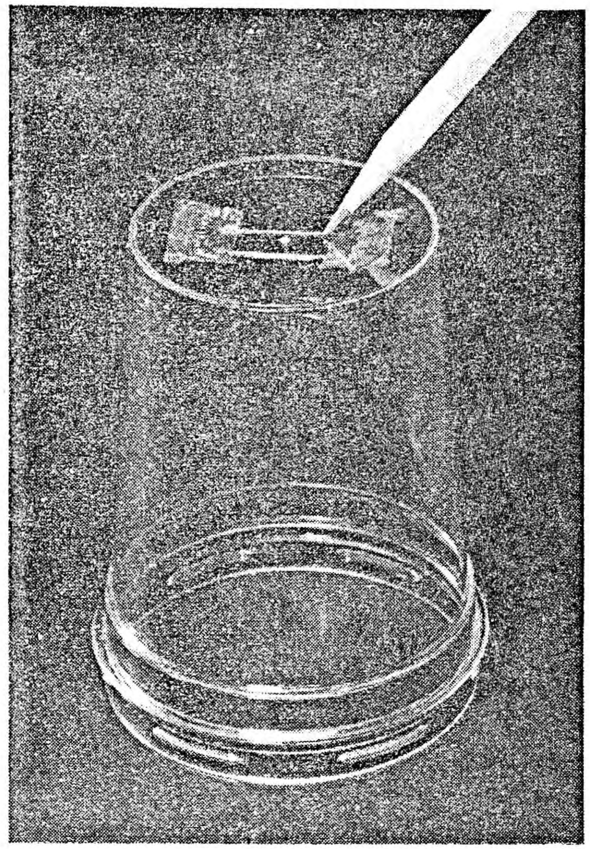

Figure 2. Track Etch Sampling Cup

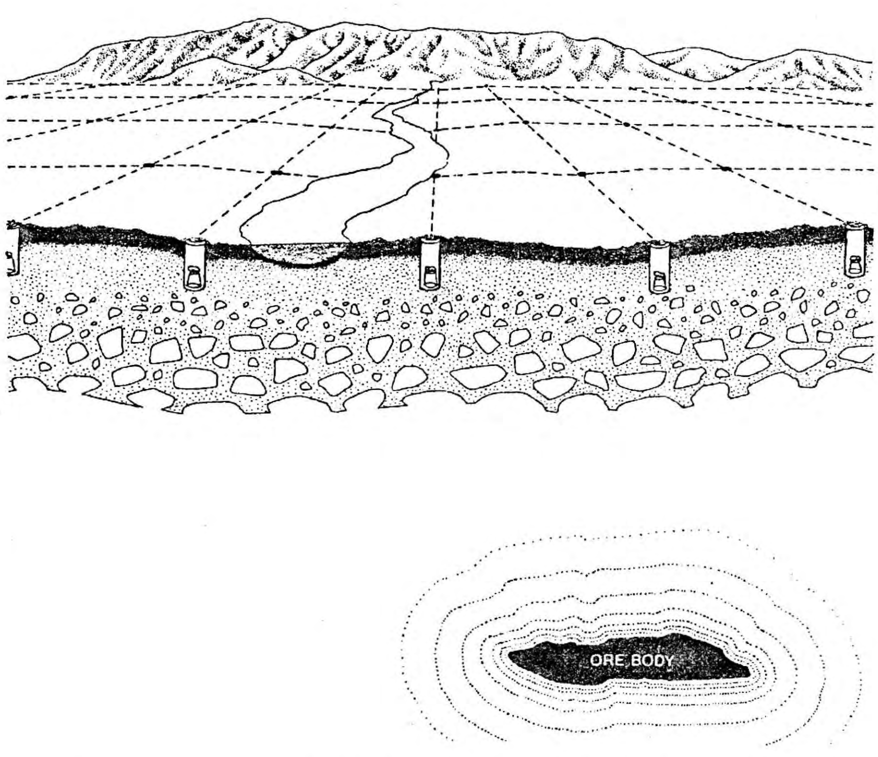

Figure 3. Field Deployment of Track Etch Cups (Typical Grid 30 to 1000 Meter Centers)

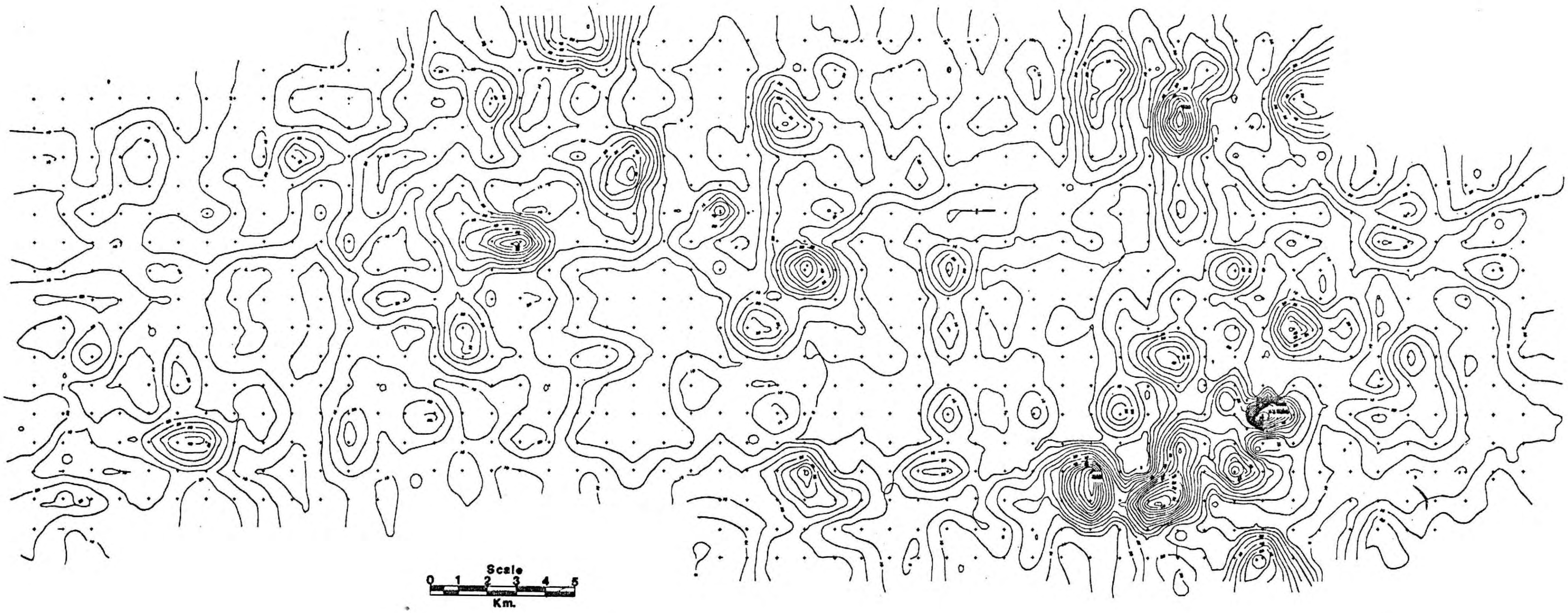

Figure 4. Regional Track Etch Exploration Program - Central Australia

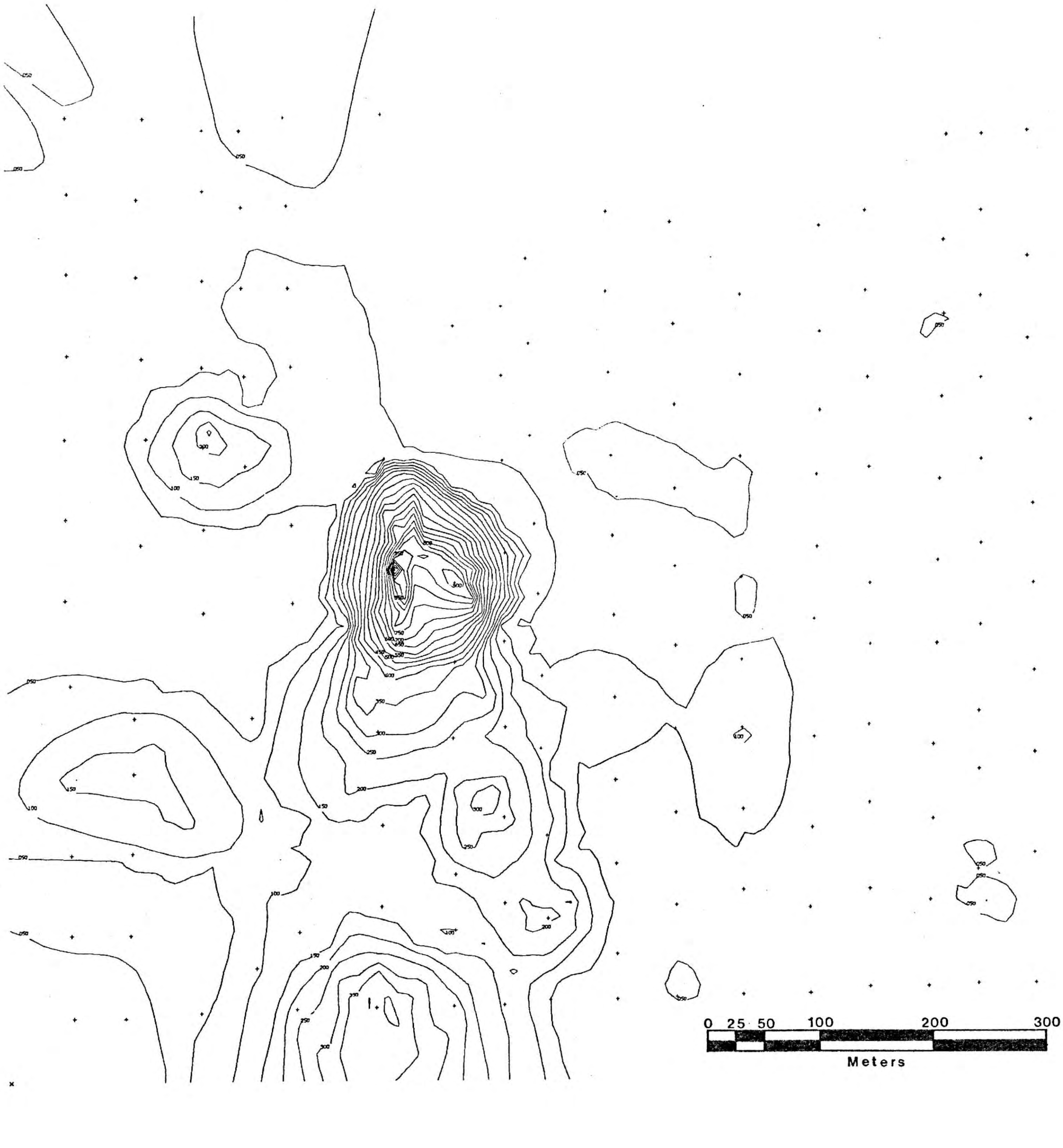

Figure 5. Track Etch Map of Canadian Cluff Lake "N" Deposit

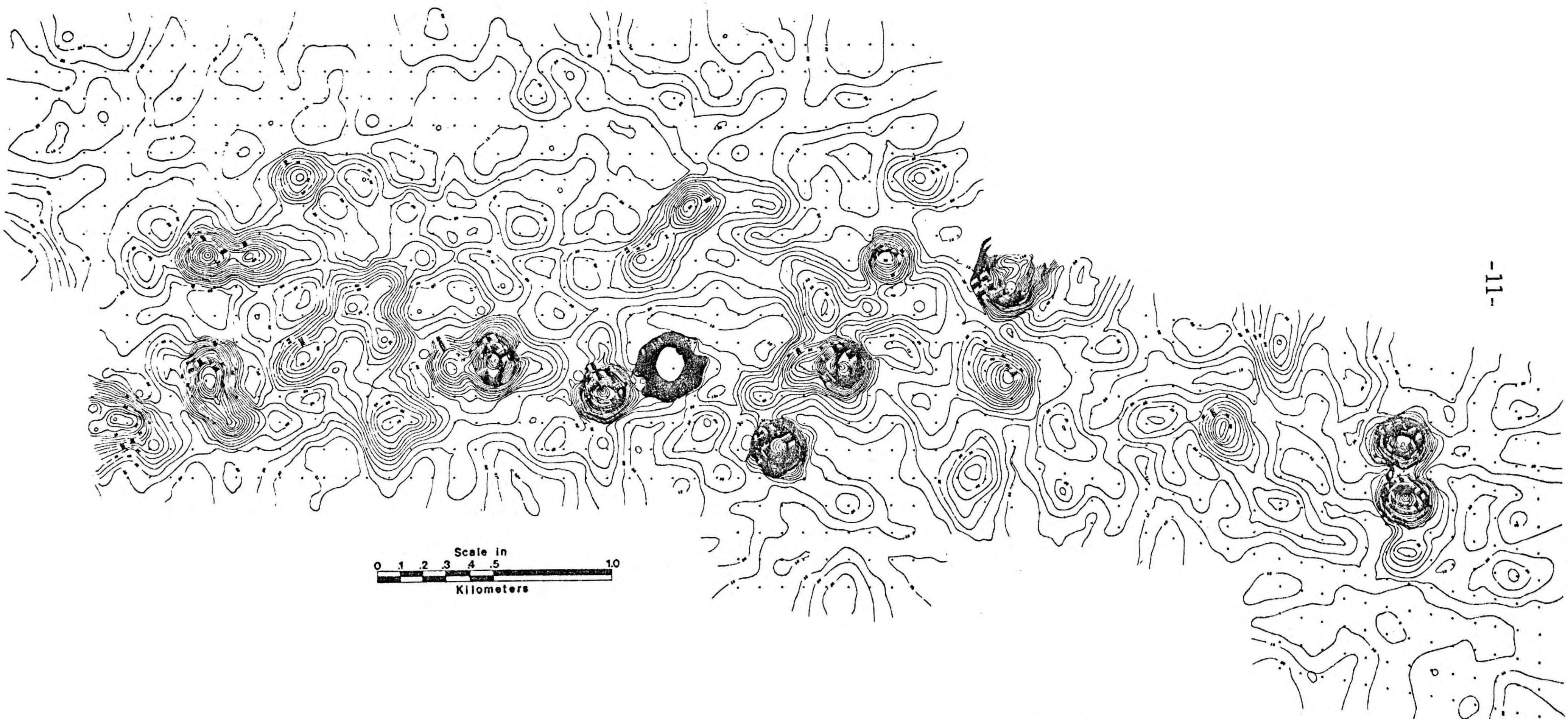

Figure 6. Track Etch Survey - Colorado Area Plateau

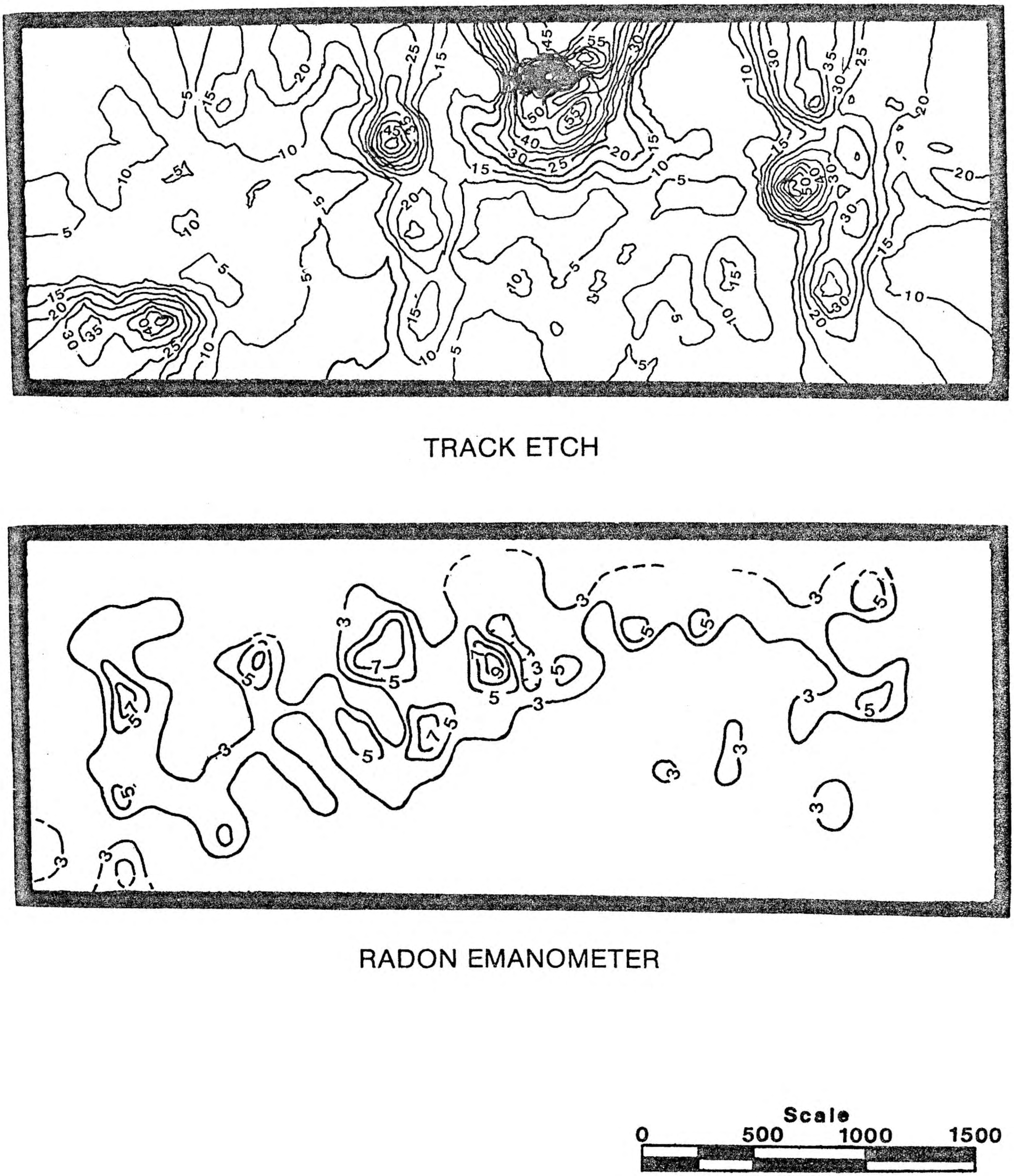

Figure 7. Track Etch and Radon Emanometer Comparison Surveys