OREGON PROJECT NOTIFICATION AND REVIEW SYSTEM

STATE CLEARINGHOUSE

Intergovernmental Relations Division
240 Cottage Street S.E., Salem, Oregon 97310
Leslie Lehmann, Coordinator Ph: 378-3732

STATE A-95 REVIEW CONCLUSIONS

APPLICANT: Ore. Dept. of Geology & Mineral Industries

PROJECT TITLE: Exploration for Uranium & Geology of the Bear Creek Valley-Sams Valley Areas of S.W. Ore.

DATE: January 19,1977

The state has reviewed your project and reached the following conclusions:

- [x] No significant conflict with the plans, policies or programs of state government have been identified and your proposal is endorsed as presented.
- [ ] Relevant comments of state agencies are attached and should be considered in the final design of your proposal.
- [ ] Potential conflicts with the plans and programs of the state agency(s) have been satisfactorily resolved. No significant issues remain.
- [ ] Significant conflicts with the plans, policies or programs of state government have been identified and remain unresolved. The final proposal has been reviewed and the final comments and recommendations of the state are attached.

NOTICE TO FEDERAL AGENCY

The following is the officially assigned State Identifier Number:

7612 2 /50

This number should be used on all correspondence and particularly on SF 240 as required by OMB A-98.

A copy of this notification and attachments, if any, must accompany your application to the federal agency as required by OMB A-95. Comments of the appropriate local reviewing agencies must also be included.

OREGON PROJECT NOTIFICATION AND REVIEW SYSTEM

STATE CLEARINGHOUSE

Intergovernmental Relations Division
240 Cottage Street S.E., Salem, Oregon 97310
Leslie Lehmann, Coordinator Ph: 378-3732

PNRS STATE REVIEW

Project #: 7612 2 750 Due Date: JAN 14

To Agency Addressed: If you intend to comment but cannot respond by the return date, please notify us immediately. If no response is received by the due date, it will be assumed that you have no comment and the fil will be closed.

PROGRAM REVIEW AND COMMENT

To State Clearinghouse: We have reviewed the subject Notice and have reached the following conclusions on its relationship to our plans and programs:

(X) It has no adverse effect.

( ) We have no comment.

( ) Effects, although measurable, would be acceptable.

( ) It has adverse effects.

( ) We are interested but require more information to evaluate the proposal.

( ) Please coordinate the implementation of the proposal with us.

( ) We request review of the final application.

( ) State agency permits are required to implement this project. (list below)

( ) Additional comments for project improvement. (Attach if necessary

- - - - - - - - - - -

REMARKS (Please type or print legibly)

RECONNAISSANCE EXPLORATION FOR URANIUM AND GEOLOGY IN THE BEAR CREEK AND SAMS VALLEY AREAS OF JACKSON COUNTY.

Agency HISTORIC PRESERVATION OFFICE
STATE PARKS & RECREATION BRANCH
525 TRADE STREET SE
SALEM, OREGON 97310

By [signature]

UNSOLICITED URANIUM EXPLORATION PROPOSAL

Submitted to

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

by

State of Oregon Department of Geology and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

for

Exploration for Uranium and Geology of the
Bear Creek Valley - Sams Valley areas of Southwest Oregon

The proposed study will consist of a reconnaissance exploration of about 150 square miles in the Bear Creek Valley and Sams Valley in Jackson County, Oregon, (see index map), to determine the potential for uranium mineralization. Bear Creek Valley and Sams Valley are underlain by a thick sequence (8,000 feet to 9,000 feet) of early Tertiary continental sediments including shales, sandstones, and conglomerates. Cross-bedding, cut and fill structure, and the lenticular nature of the sediments indicates a low relief, fluvial environment, and the abundant carbonaceous material (sub tropical flora) indicate a moist- humid-climatic environment. The lowermost sediments tend to be arkosic with a change to tuffaceous sandstones and shales in the upper part of the section. The Ashland granite pluton and early Western Cascade Volcanics (Little Butte) are presumed to be the source rocks for the sediments.

A survey of the literature about sandstone type uranium deposits in general (Craig, Brooks, and Patton, 1975) shows that the Bear Creek Valley - Sams Valley sedimentary rocks have many of the characteristics that are indicative of uranium deposits in other areas.

We have no reports of radioactive mineralization at the surface in the Bear Creek or Sams Valleys and there are no records to indicate whether any exploration has ever been done.

Fischer (1975) in a paper at the 1975 Uranium and Thorium Research and Resources Conference at Golden, Colorado summarized the "exploration guides to new uranium districts and belts" as follows:

"The principal U. S. source of uranium is deposits in continental, lenticular sandstone beds. Beds of this type are probably the best hunting ground for groups of significant new deposits--in reality, new districts and belts--that will be needed to satisfy future requirements for uranium. A model, evolved from the major productive districts and belts, presents geologic relations that may be useful as guides in selecting the beds and areas most likely to contain significant deposits.

"Host rocks favorable for large uranium deposits are sandstone lenses interbedded with mudstone; these mudstone beds or some overlying beds commonly contain volcanic ash. Sedimentation on a low-lying terrane with a high water table, yielding nonoxidizing conditions of water-saturated beds, is indicated by the preservation of coalified fossil plants, which are present in almost all host beds. During ore formation the host beds dipped gently, owing to initial stream gradient or slight tectonic tilting. The ore-forming solutions were ground waters that moved downward by gravity. The ore formed slowly under stable conditions, at shallow to moderate depths, in zones a few miles to a few tens of miles from the depositional or erosional edges of the host beds, at places where adequate reducing conditions were encountered. The reducing agents are obscure and perhaps varied. Roll-type deposits seem to have formed relatively late after accumulation of the host beds, whereas tabular-type deposits may have formed relatively soon after sedimentation.

"Sandstone units having some or all of the lithologic characteristics favorable for uranium deposits are numerous and widespread in the United States and they occur in areas of different geologic setting and history. If new districts are to be found at tolerable costs, geologic guides will have to be used to select for exploration the sandstone units and areas most likely to contain groups of significant deposits."

The Bear Creek Valley and Sams Valley sedimentary rocks have many of the physical properties and geologic relations listed above that would indicate a favorable environment for uranium deposits and is deemed worthy of a preliminary evaluation. There are no records to indicate that any exploration for radioactivity has ever been done.

Two radioactive occurrences are reported in the presumed source rocks, one a short distance to the northeast in rhyolite tuffs of the Little Butte volcanic rocks, and the other in pegmatite dikes of the Ashland granite pluton.

There are two reported radioactive occurrences in the presumed source rocks; one just northwest of Trail in a rhyolite tuff, and the other in pegmatite dikes of the Ashland granite.

Previous Work:

Wells (1956) mapped the sedimentary rocks as Umpqua Formation of Eocene age. He suggested that the lower part were of marine origin, grading upward into continental deposits, water-transported, and air-transported clastic rocks of volcanic origin. The stratigraphy of the sediments in the Bear Creek Valley has been described in a Ph.D. thesis by McKnight (1971) however, the continuation of the sediments northwestward into Sams Valley has not been described in any detail.

Work Proposed:

The proposed study will consist of the following:

1. A ground (foot and vehicle) radiometric reconnaissance of all accessible outcrop areas in Bear Creek Valley and Sams Valley using a sensitive detection device (Gamma Ray Scintillometer or portable Gamma Ray Spectrometer). The readings will be used to make an isorad map of the area.

2. Make a grid survey for radon gas using the Track etch, Terradex method. This technique involves placing a small radiation sensitive plastic detector housed in a small sampling cup in shallow holes (2½ feet deep) in the ground. These detectors measure the concentration of radon gas and when measured can be used to indicate the presence of anomalous uranium mineralization. A detailed description of the track etch technique is attached. The materials, analysis of the exposed detectors as well as contour maps showing radon gas concentrations will be furnished by the Terradex Corporation.

3. Collect and analyze 10 water and stream sediment samples from strategic locations to determine uranium content.

4. In conjunction with 1, 2, and 3, above, we will do a geologic reconnaissance to correlate the little known stratigraphy in Sams Valley with the already described Payne Cliffs Formation in the Bear Creek Valley. The information from this part of the study will be incorporated in a preliminary report and geologic map.

Organization and Facilities:

The State of Oregon Department of Geology and Mineral Industries has complete office, accounting, editing, drafting, analytical facilities and staff to carry out the proposed work, except as noted in (2) above. The material, readout, and interpretation of the radon gas grid survey will be contracted to the Terradex Corp. All parts of the proposed work will be carried out concurrently and the project would begin May 1, 1977, and be completed by December 31, 1977.

Principal investigators will be Norman V. Peterson, District Geologist, State of Oregon Department of Geology and Mineral Industries, Grants Pass Field Office, P. O. Box 417, Grants Pass, Oregon 97526, and Monty Elliott, Assistant Professor, Southern Oregon State College, Ashland, Oregon 97520. A resume' for each is attached.

Selected References:

Boberg, W. W., 1975, Exploration for uranium in Wyoming, in Craig, L. C., Brooks, R. A., and Patton, P. C. (eds.), Abstracts of the 1975 Uranium and Thorium Research and Resources Conference: U. S. Geol. Survey Open-File Report 75-595. 54 p.

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McKnight, B. K., 1971, Petrology and sedimentation of Cretaceous and Eocene rocks in the Medford-Ashland region, Southwest Oregon, Oregon State Univ. Ph.D. Thesis. 177 p.

Peterson, N. V., 1959, Preliminary geology of the Lakeview uranium area, Oregon: The Ore Bin vol. 21, no. 2, p. 11-16.

Wells, F. G., 1956, Geologic map of the Medford quadrangle, Oregon - California: U. S. Geol. Survey Map GQ-89.

UNSOLICITED URANIUM EXPLORATION PROPOSAL

Submitted to

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

by

STATE OF OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
1069 State Office Building
Portland, Oregon 97201

TITLE OF PROPOSED PROJECT:

EXPLORATION FOR URANIUM AND GEOLOGY
OF THE BEAR CREEK VALLEY - SAMS VALLEY AREAS OF SOUTHWEST OREGON

Principal Investigator: Norman V. Peterson, Economic Geologist
Department of Geology and Mineral Industries
P.O. Box 417
Grants Pass, Oregon 97526

PROPOSED STARTING DATE: May 1, 1977

PROPOSED COMPLETION DATE: December 31, 1977

AMOUNT REQUESTED FROM ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION	$ 22,400
OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES.	2,060
TOTAL PROJECT COST.	$ 24,460

E N D O R S E M E N T S

Principal Investigator:	Approving Administrative Official:
Name: Norman V. Peterson	Raymond E. Corcoran
Signature: Norman V. Peterson	R. E. Corcoran
Title: Economic Geologist, State of Oregon Department of Geology and Mineral Industries	State Geologist, State of Oregon Department of Geology and Mineral Industries
Date: December 9, 1976	December 9, 1976

EXPLORATION FOR URANIUM AND GEOLOGY OF THE BEAR CREEK VALLEY - SAMS VALLEY AREAS OF SOUTHWEST OREGON

The proposed study will consist of a reconnaissance exploration of about 150 square miles in the Bear Creek Valley and Sams Valley in Jackson County, Oregon (see index map) to determine the potential for uranium mineralization. Bear Creek Valley and Sams Valley are underlain by a thick sequence (8,000 feet to 9,000 feet) of early Tertiary continental sediments including shales, sandstones, and conglomerates. Cross-bedding, cut and fill structure, and the lenticular nature of the sediments indicate a low relief, fluvial environment, and the abundant carbonaceous material (sub tropical flora) indicate a moist- humid-climatic environment. The lowermost sediments tend to be arkosic with a change to tuffaceous sandstones and shales in the upper part of the section. The Ashland granite pluton and early Western Cascade Volcanics (Little Butte) are presumed to be the source rocks for the sediments.

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housed in a small sampling cup in shallow holes ($2\frac{1}{2}$ feet deep) in the ground. These detectors measure the concentration of radon gas and where measured can be used to indicate the presence of anomalous uranium mineralization. A detailed description of the track etch technique is attached. The materials, analysis of the exposed detectors as well as contour maps showing radon gas concentrations will be furnished by the Terradex Corporation.

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Boberg, W. W., 1975, Exploration for uranium in Wyoming, in Craig, L. C., Brooks, R. A., and Patton, P. C. (eds.), Abstracts of the 1975 Uranium and Thorium Research and Resources Conference: U. S. Geol. Survey Open-File Report 75-595. 54 p.

Fischer, R. P., 1975, Exploration guides to new uranium districts and belts, in Craig, L. C., Brooks, R. A., and Patton, P. C. (eds.), Abstracts of the 1975 Uranium and Thorium Research and Resources Conference: U. S. Geol. Survey Open-File Report 75-595. 54 p.

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Peterson, N. V., 1959, Preliminary geology of the Lakeview uranium area, Oregon: The Ore Bin vol. 21, no. 2, p. 11-16.

Wells, F. G., 1956, Geologic map of the Medford quadrangle, Oregon - California: U. S. Geol. Survey Map GQ-89.

ESTIMATED PROJECT COSTS

Field supplies: maps, sample bags, bottles, etc.	$ 250
Analytical work for 10 water and soil sediment samples.	200
Material, interpretation, reports, and maps for radon gas survey (500 cups).	8,900
Rental of scintillation counter or gamma ray spectrometer (Geometrics 408-734-4616 6R 101A) - 2 months	500
Salaries:	
Principal Investigator, N.V. Peterson - 4 mos.	6,400
Principal Investigator, M.A. Elliott - 1½ mos.	2,100
Field Assistant - 3 mos.	1,800
Field expenses - per diem	850
Transportation (5,000 miles).	750
Drafting - base maps, geologic map.	650
Administrative costs (20 percent of Salaries & Wages).	2,060
TOTAL.	$ 24,460

DATA SHEET

Monty Arthur Elliott

Basic Facts

Age	32	Military	1-Y
Height.	5-8	Handicaps.	Eye glasses
Weight.	190	Police Record. . . .	None
Race.	Caucasian	Credit Rating. . . .	Excellent
Family.	Wife & daughter	Political Party. . .	Republican

Education

Degrees Held

1971 Doctor of Philosophy (Geology), Oregon State University

1966 Bachelor of Arts (Geology), Oregon State University

1962 High School Diploma, Willamina Union High School (Oregon)

Experience

1972-77 Assistant Professor of Geology, Southern Oregon State College; Dr. W. B. Purdom, Chairman, Department of Geology, Ashland, Oregon 97520

1970-73 Visiting Assistant Professor of Geology, Portland State University, Summer Sessions. Dr. Marvin Beeson, Chairman, Department of Earth Science, Portland, Oregon 97207

1970-72 Visiting Assistant Professor of Geology, World Campus Afloat. Dr. Richard J. Sneed, Chairman, Division of International Studies, Chapman College Orange, California 92666

1970 Research Assistant, Oregon State University, conducting X-ray fluorescent chemical analyses of lavas with Dr. E. M. Taylor, Department of Geology, Corvallis, Oregon 97207

1969 Field Geologist, summer of structural reconnaissance and formation sampling in Brooks Range, Alaska for J. P. Chauvel, Union Oil Co. of Calif., 628 East 5th Avenue, Anchorage, Alaska 99501

1966 Field Geologist, summer of base metal exploration in Yukon Territory for J. P. B. Sawyer, Mastodon-Highland Bell Mines, Ltd., #502-1200 West Pender St., Vancouver 1, B. C., Canada

Professional Societies and Acitvities

Member, The Geological Society of America

Active Member, American Association of Petroleum Geologists

Associate Member, The Society of Econômic Paleontologists and Mineralogists

Publication and Papers

Elliott, M. A., 1975 "Geology-City of Ashland" in Natural Resources - City of Ashland Planning Unit: Special Report, Soil Conservation Service, Medford, Oregon, pp 37-45, map.

Elliott, M. A., 1974, Late Cretaceous Sublittoral and Fluvial Sedimentation, Klamath Mountains, Oregon: Geol. Soc. America Abs. with Programs, V. 6, No. 3, p. 172-173.

Elliott, M. A. and Bostwick, D. A., 1973, Occurence of Yabeina on the Klamath Mountains, Siskiyou County, California: Geol. Soc. America Abs. with Programs, V. 5, No. 1, p. 38.

In preparation:

Late Cretaceous Superjacent Sedimentation- Klamath Mountains

References

Dr. John Eliot Allen, emeritus, Department of Earth Science, Portland State University, Portland, Oregon 97207

Dr. Harold E. Enlows, emeritus, Department of Geology, Oregon State University, Corvallis, Oregon 97331

Dr. William B. Purdom, Chairman, Department of Geology, Southern
Oregon State College, Ashland, Oregon 97520

URANIUM EXPLORATION WITH THE TRACK ETCH TECHNIQUE

H. W. Alter
J. E. Gingrich

Terradex Corporation
1900 Olympic Blvd.
Walnut Creek, California 94596

Presented at the
45th Annual International Meeting
Society of Exploration Geophysicists
Denver, Colorado
October 12-16, 1975

URANIUM EXPLORATION WITH THE TRACK ETCH TECHNIQUE

H, W, ALTER, TERRADEX CORP.

J. E. GINGRICH, TERRADEX CORP.

ABSTRACT

The Track Etch* technique for uranium exploration has been used on a large number of uranium exploration programs representing a wide spectrum of geological environments. Initial results have been promising in most of these surveys and new uranium ore bodies have been found by using this relatively new technique.

The Track Etch method utilizes small solid state alpha track detectors to measure the radon gas emitted by uranium ore bodies and it can thus detect uranium mineralization buried at depths too great to be measured with surface or airborne scintillometer techniques. The method is also simpler, more reliable and more sensitive than the emanometer methods previously used for radon detection.

The environments in which the Track Etch technique has been employed have included sedimentary deposits in New Mexico and Wyoming, vein-type deposits in Colorado and Australia, and deposits covered with glacial till in Canada. This paper will discuss the basics of the Track Etch technique, how it is being applied in the field, and will review some case histories from several field surveys.

* Track Etch is covered by U.S. and Foreign Patents of Terradex Corporation, Walnut Creek, California.

Introduction

The natural radioactivity associated with uranium makes it possible to prospect for uranium ore bodies using radiometric measurement methods. The instruments usually employed (scintillometers or Gieger counters) do not measure the uranium radioactivity directly but are sensitive to the gamma radiation in the natural radioactive decay products (primarily Bismuth-214) which are present in all rocks and soils containing uranium mineralization. Because these instruments are sensitive to gamma rays they must be used relatively close to the source of radiation or the radiation becomes so attenuated by the intervening materials that it cannot be measured accurately. Airborne gamma-ray surveys are normally conducted at altitudes of a few hundred feet and they detect only surface or near-surface mineralization buried less than one foot. Portable hand-held gamma detectors must also be used within a foot of buried uranium mineralization to adequately detect its presence. When prospecting for deeply buried uranium with gamma sensitive instrumentation it is necessary to first drill an exploratory hole to the desired depth and then probe the hole with a gamma detector to determine the presence of uranium mineralization. Because of the gamma attenuation characteristics of soil and rock the drill hole must be in, or very close to, the uranium mineralization in order for it to be detected. Thus sub-surface mineralization becomes much more expensive to locate using gamma ray detection techniques.

Uranium also produces several alpha emitting radioactive decay products which are not directly detected by gamma-sensitive instrumentation. (Figure 1) One of these alpha emitting decay products is radon gas. A small amount of radon is continuously released from all uranium mineralization and this radon can move from significant depths through the covering rock and soil to the surface where it can be detected with the proper equipment. The mechanisms which cause radon movement to the surface are not well understood but its transport is related to meteorological "pumping action" that occurs due to variations in barometric pressure and air temperature changes which cause sub-surface gases to move considerable vertical distances. These mechanisms however also cause wide variations in the radon concentrations at the surface and some researchers have found changes of as much as a factor of 100 in a twenty-four hour period at a single location. It is this variation in radon concentrations at the surface that makes it difficult to use radon concentration measurements as a guide to buried uranium mineralization.

The possibility of using radon as a uranium prospecting tool was first suggested nearly 50 years ago but it has only been in the last 20 years that it has been used to any appreciable extent. This is partly due to the fact that earlier exploration efforts were concentrating on the more easily found surface or near surface deposits where gamma sensitive instrumentation is effective. As the discovery of new ore bodies at greater and greater depths has become increasingly expensive using gamma sensitive instrumentation, new and improved methods including those utilizing radon measurements have been increasingly used.

During the last few years several types of radon measuring instruments (sometimes called emanometers or "sniffers") have been developed. They usually consist of a small gas chamber covered with an alpha-sensitive phosphor which is optically coupled to a photomultiplier. The chamber is filled with soil gas pumped from a shallow hole in the surface soil. Each scintillator pulse from the phosphor is counted for a short period of time. The equipment thus measures the total alpha radioactivity from the radon in the soil gas sample.

These instruments are relatively complex both electrically and mechanically and the phosphor coated sample chamber is subject to surface contamination from radon daughter products. The biggest problem with the radon emanometer however is that it measures only a short-term soil gas sample which is usually not indicative of the average radon concentration in the immediate area. Because of these factors and others many users of radon emanometers have achieved only limited success in locating new uranium ore bodies on the basis of the instantaneous radon measurements.

The Track Etch System

A new technique called Track Etch for radon measurement has recently been developed which eliminates the major problems of the emanometers. It is also very simple and easy to use in the field. The Track Etch technique is based on the utilization of a newly discovered radiation sensitive plastic detector. These detectors are placed in small sampling cups that are placed in shallow holes in the ground where they measure the soil gas radon concentrations. (Figure 2) The detectors are sensitive to the alpha particles emitted by radon and they are processed in an etching solution to provide visible track-like images of the alpha particles, hence the name Track Etch. The detectors are unique in that they are not sensitive to light or to the gamma or beta radiation produced by the various elements in the soil and in the way they are used in the sampling cups they are only sensitive to the alpha emitting radon isotopes within the sampling cup.

In a typical uranium exploration program, sampling cups containing Track Etch detectors are placed in holes, about 2½ feet (70 cm) deep over the area being explored. (Figure 3) The sample holes are located in a grid pattern between 30 and 1000 meters apart depending on the size of the area being explored, and the dimensions of the expected ore bodies. After the cups are in place, the holes are covered and the cups are left undisturbed for several weeks. By leaving the sample cups undisturbed for this period of time, a meaningful average radon concentration can be measured. At the end of the sample measuring period, the cups are recovered and the detectors are processed and read to determine the number of alpha tracks recorded and hence the average radon level at the sample location. To obtain the maximum amount of information from the Track Etch readings, the data are usually presented in the form of radon contour maps or graphs.

The Track Etch system like other radon detection methods can also indicate the presence of near-surface thorium mineralization since thorium produces the alpha emitting thoron gas (Radon-222). (Track images in the detectors are essentially the same for any gaseous emitter.) Since thoron gas is a very short lived isotope (55 seconds) thorium will be detected only if it is present a few feet from the sampling cup. This potential interference problem can be avoided by measurement of each sampling point with a spectral-type scintillometer which detects the presence of thorium.

The Track Etch system like many geophysical and geochemical methods requires the accurate determination of the background (radon) level for the area being surveyed. Thus a minimum of about one hundred sampling stations should be used to statistically determine the general background value with the desired accuracy. Experience with a large number of exploration programs 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 due to differences in surface and near surface uranium mineralization and in differences in general rock types in the exploration areas.

Field Test Results

The Track Etch methods for uranium exploration have been employed in nearly 200 exploration programs in a variety of geological environments. Some of the initial work was carried out in the sedimentary deposit areas of western United States and the vein-type deposits of Australia. Most recently several successful programs have been carried out in Canada. The following results are typical examples from some of these programs and while they do not discuss details from the full range of Track Etch experience they illustrate a few of the results from varied types of exploration programs.

Sedimentary Basins - Western United States

In one sandstone area of the Western U.S. the usual method for uranium exploration required the drilling of 500 foot exploratory holes on a planned pattern and radiometrically logging the holes with scintillometer probes. There were no surface gamma radiometric anomalies to assist the exploration efforts in this area. The specific area selected for exploration was along a general trend of known mineralization but where no exploratory drilling had been completed on the property of interest. Track Etch sampling cups were placed in a regular square grid pattern on 150 foot centers in an area approximately one mile long and one third of a mile wide. The resulting radon contour map is shown in figure 4. Three anomalies were detected on the property with a number of detectors reading more than three times background. In the follow-up exploratory drilling program over the highest anomaly the third exploratory drill hole produced the first signs of mineralization and the fourth hole which was drilled in the down-dip direction from the anomaly intersected a uranium ore body at a depth of

330 feet. The initial intersection showed 9 feet of ore with a grade of 0.34% U_3O_8. Subsequently more than 40 holes were drilled in the area with most intersecting ore grade material. The ore body has now been delineated to the point that it is known to contain several million pounds of uranium and it is expected to be mined in the near future.

The most significant factor in finding this ore body using the Track Etch radon technique is the fact that it is at depths ranging up to 360 feet and that it is covered by several sandstone sequences with some shale stringers and thin layers (2 - 3 feet) of coal in the intervening beds. The water table in this area is about 350 feet so it can be assumed that the radon is penetrating through essentially dry cover. In addition to the drilling around the primary anomaly some exploratory drilling was done in areas with low radon values and no significant uranium mineralization was found. One test hole drilled into a second anomaly has shown some mineralization but its full extent has not yet been fully evaluated.

Vein-type Deposits - Western United States

Several Track Etch programs have been completed in the hard-rock environments of the Rocky Mountains where the usual targets are vein-type deposits. The Track Etch technique is particularly attractive for these areas because of the rugged terrain usually encountered which makes it difficult or impossible to survey using airborne radiometric techniques and where exploratory drilling is very expensive.

One Track Etch test survey was undertaken in an area of known uranium mineralization surrounding several mines and prospects in the major uranium producing district of the Front Range of Colorado. This is an area of intense surface leaching and associated thick colluvial cover which renders conventional airborne or surface radiometric prospecting techniques inadequate. In addition the terrain relief is extreme and the targets are small, averaging 3 to 5 feet wide by 100 to 200 feet long making it difficult to use conventional exploratory drilling methods to locate the mineralization. The test survey using a random grid on 500 foot centers produced excellent Track Etch anomalies over all of the known significant mineralization in the district. An anomaly over the Schwartzwalder Mine was more than eleven times background where the mineralization was at a depth of approximately 150 feet. Three different surveys conducted in one small area over a span of 18 months identified one large anomaly each time the measurements were made and demonstrated the repeatability of the technique in this environment.

Meta sedimentary Deposits - Northern Canada

An orientation study using Track Etch was conducted in Northern Canada over a known metasedimentary ore body which was covered by glacial till. This program was the first conducted in this environment and it was done for the purpose of determining the applicability of the technique in such glaciated environment. The uranium deposit consists of several pitchblende-bearing lenses associated with gently dipping fracture zones in paragneisses and granites of Archean or Aphebian age. Mineralized zones were outlined by drilling and they occur at depths ranging from 10 to 60 feet in thickness. Approximately 160 Track Etch sample cups were placed in shallow holes, averaging 2½ feet in depth along grid lines at approximately 200 foot centers. Sampling extended well beyond the boundaries of the known ore zone.

The survey results were plotted on a radon contour map as shown in figure 5. A number of high readings from the Track Etch detectors were found over the ore body with a peak value of more than 50 times the background value measured for the surrounding area. The highest value was obtained where there is known ore grade material in mineralized lenses at several depths ranging from 60 to 260 feet. Other anomalous readings were obtained over ore grade mineralization at depths ranging up to 350 feet.

Recent experience from two other test programs in Northern Canada is worthy of note. Tests were conducted over known ore bodies covered by perma-frost and in both instances significant anomalies were detected. These results tend to confirm the porous nature of the perma-frost cover and suggest the usefullness of the Track Etch technique in this environment.

Australian Experience

A number of exploration programs have been conducted in Australia using the Track Etch method. The environments explored have included several surveys in the Alligator Rivers area of the Northern Territory, the Frome Lake Embayment of South Australia and several sedimentary areas in other parts of the country. One of the earliest test programs was conducted over a known ore body in the East Alligator River uranium district. There was no indication of the presence of this ore body from normal aerial or ground radiometric surveys although the presence of anomalously high radon concentrations in the area was known. Track Etch detectors placed on a 100 by 500 foot grid clearly located an anomaly over the known ore body with the highest reading more than 40 times background. The ore body was at a depth of 250 feet covered pri- by sediments and the water table in the area was relatively near the surface (10 to 80 feet) clearly indicating from the results that the signal was not substantially attenuated by the thick water cover. (Preliminary results from other programs seem to indicate that there may even be an enhancement of the signal in areas with a high water table.)

In another Australian test program in the Frome Lake area of South Australia a survey was made over an ore deposit in a Lower Tertiary paleochannel sand which was at a depth of 330 feet. The ore averaged 12 feet in thickness at an average grade of 0.25% U_3O_8. The whole area was overlain by a sequence of relatively impermeable Upper Tertiary lacustrine clays. The Track Etch radon map of this area identified several low order (2 to 3 times background) anomalies over the known ore body. The anomalies were displaced about 300 feet from the center of the ore body for reasons not yet clear. The low order of the anomalies probably reflects the thickness of the overburden and the impermeable nature of the clay cover.

Regional Surveys

During the last year and a half the Track Etch technique has been used on several regional exploration surveys in the U.S. and Australia by placing the sampling cups on very wide centers (up to 5000 feet between points). These surveys have usually been performed in new exploration areas where there may have been some weak airborne or surface anomalies but where no major mineralized areas had been discovered. In these situations the Track Etch results are expected to be especially valuable since the results can be used to guide the initial exploration drilling which often is done very blindly since little is usually known about the sub-surface geology. Results to date indicate that in the areas tested there are broad anomalies that are due to known increases in mineralization and the variations in readings have been attributed to changes in sub-surface geological units or geological structure. Follow-up surveys using closely spaced sample points around the regional anomalies have further defined the detailed variation in local mineralization and these results are being used to guide detailed exploratory drilling. The promising results from these regional surveys already completed has proven the value of the Track Etch method in this mode of use.

Conclusions

The Track Etch technique for uranium has proven to be a valuable tool for uranium exploration in areas where the more conventional surface radiometric techniques are not effective. The method of sampling eliminates the probelms of variability in radon measurements encountered with other techniques and the simplicity makes it both highly reliable and easy to use in the field. It is particularly attractive for preliminary surveys and for exploring in remote areas where there is usually a limited amount of field support available.

Experience with the Track Etch system has indicated that its use can result in significant savings in exploration drilling costs. Exploration drilling can be reduced by up to 90% by utilizing the Track Etch radon contour maps to guide the initial drilling phases. In addition, valuable information about the sub-surface geology can be obtained which can be very useful not only in uranium exploration but also in exploration for other minerals. Experience has shown that the Track Etch radon technique can operate effectively in most any terrain from tropical areas of Australia to the perma-frost covered arctic regions of Canada.

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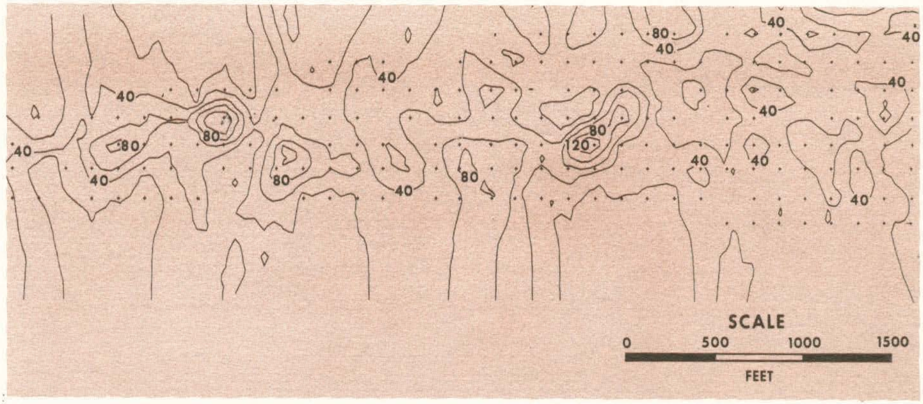
Gingrich, J. E., "Results from a New Uranium Exploration Method", Transactions of the Society of Mining Engineers, pp 61-64, Vol. 258, March, 1975.

Beck, L.S. and J.E. Gingrich, "Track Etch Orientation Survey-Cluff Lake Area Northern Saskatchewan", presented at the Canadian Institute of Mining Annual General Meeting, Toronto, May 6, 1975.

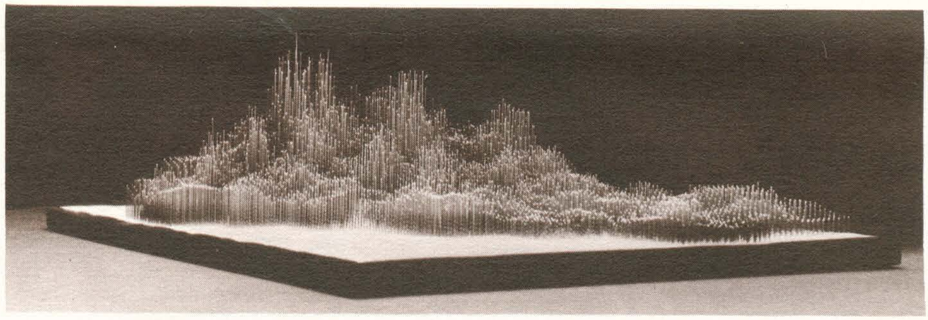
Data displays

To help get the most out of the Track Etch film data, the information is normally shown in the form of radon contour maps. One such map for an actual exploration carried out recently can be seen at right.



Radon contour maps from Track Etch surveys . . . such as this one for a new uranium find in New Mexico . . . help to locate deeply buried ore bodies.

An even more graphic . . . and therefore useful . . . display of the data can be had in the form of a three-dimensional pin plot (see photograph). In this type of display, each pin represents a field sampling point, the height of the pin indicating the normalized radon concentration at that point.



Three-dimensional pin plots of radon concentrations measured with Track Etch film are very valuable in visualizing surveyed areas.

An outstanding track record

The Track Etch service has proved its effectiveness in over 30 survey programs carried out to date in several major uranium exploration areas throughout the world. It has led to the discovery of new uranium resources, and in no case has it failed to detect known uranium deposits buried up to 500 feet deep.

To cite just a few examples:

A Track Etch survey was recently conducted in an area of New Mexico where no previous test drilling had been done and where surface radiometric readings had shown no signs of uranium. With the help of the Track Etch data, the exploration company was able to locate a new uranium ore body buried at a depth of 330 ft. Most significant is the fact that the ore body is covered by more than 300 feet of sandstone with shale and coal stringers. The water table in this area lies at a depth of 300 to 400 feet.

Thus far, over a million pounds of uranium have been found here, and the full extent of the ore body has not yet been determined.

A recent test of Track Etch over a known ore body in the Northern Territory of Australia provides another example of the technique's efficacy. Normal groundbased or aerial radiometric surveys did not indicate the presence of this ore body.

With film readings running to more than 40 times background, the Track Etch survey clearly located the ore body, which lay 250 feet deep in an area where the water table is 10 to 30 feet below the surface.

Finally, in another test carried out in a sedimentary exploration area of South Australia, Track Etch detected ore bodies at depths of 360 to 430 feet. The uranium ore in this area was covered mainly by unconsolidated Quaternary clayey sands and gravels and the water table was at a level of 200 feet. No surface or airborne radiometric anomalies could be detected from these ore bodies with standard scintillometer techniques.

There's more

These are just the highlights of the Track Etch story. For more information and specifics, contact:

TERRADEX CORPORATION
1900 Olympic Boulevard
Walnut Creek, California 94596
Phone: (415) 938-2545
Telex: 337-793

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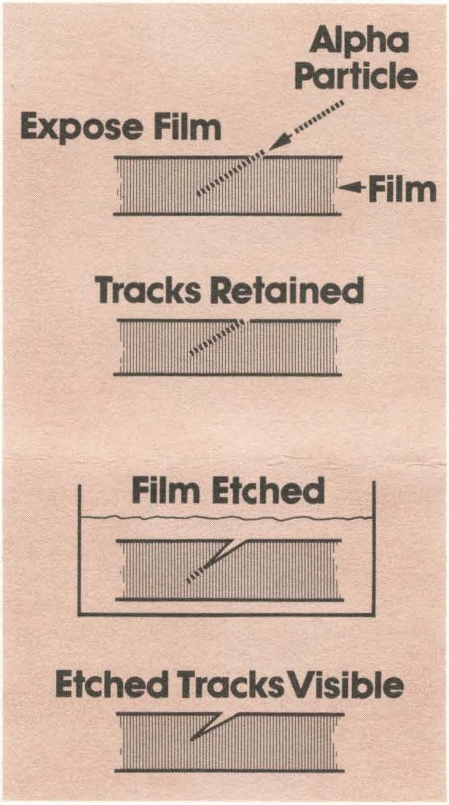
Track Etch at work

Typically, small pieces of Track Etch film attached to the insides of small cups are placed in shallow (2½ foot) holes over the area being explored. The sampling holes are spaced in a regular grid pattern on 50 to 1500 foot centers, depending on how large an area is to be covered, the size and depth of the suspected ore bodies, and other factors.

When the sampling cups are in place, the holes are covered and left undisturbed for several weeks to attain equilibrium conditions. At the end of that time, the Track Etch film samples are retrieved and returned to Terradex for processing and analysis. The films are processed by etching to make the recorded alpha tracks visible so they can be counted (see diagram). The density of tracks on the film samples . . . normalized to a standard field exposure time . . . is directly related to the radon concentration at the corresponding field sampling points.

The processed film data, along with sample location data, are used to prepare radon contour maps which are used to guide exploratory drilling in the anomalous areas.

Track Etch film cups are placed upside down in shallow holes over the survey areas.



The Track Etch process reveals film tracks left by alpha particles from radon gas.

That, simply put, is how Track Etch works. Now let's see what makes it the unique and valuable tool it is.

Selectivity and equilibrium are the keys

To begin with, the Track Etch method provides a reliable and sensitive measure of the radon concentration in the soil gas at the sampling point. Track Etch film is *not* sensitive to light, gamma, or beta radiation, and the sampling cup ensures that the film will not record alpha particles from the minerals in the surrounding soil.

But mainly, leaving the films in the ground for several weeks results in a true equilibrium measurement of soil radon concentration. In other words, by "washing out" the short-term variations due to temperature and barometric effects . . . radon readings can vary by more than 10 times in any 24 hour period at a single location . . . Track Etch avoids the drawbacks of "sniffers" and other such instantaneous grab-sample methods.

A shovel will do it

Emplacing the Track Etch films takes little in the way of field equipment and practically no training. An unskilled person using a shovel to dig the sampling holes and small pieces of plywood to cover them can do the job after just a few minutes instruction. Where accessibility permits, of course, the holes can be drilled more quickly with a portable or truck-mounted post-hole auger.

Field operations with Track Etch thus remain unencumbered by electronic devices or other complex equipment . . . which is important in rugged terrain and in areas with difficult accessibility.

Easy on the environment

One very attractive feature of the Track Etch field survey is its minimal impact on the environment. The small (4-in. diameter) shallow sampling holes are easily backfilled after sampling is finished, and all traces of the survey can be erased with little additional effort.

Also, since the holes remain covered during sampling, there is practically no interference with other surface activities such as farming or grazing while the survey goes on.

Deep hole surveys

In addition to the surface grid sampling technique, Track Etch films can also be used to analyze the gas present in exploratory drill holes. To do this, the films are attached to thin wires and lowered into the holes.

This method is particularly useful in deep-ore areas, or those with tight overlying structures, where the radon gas may not work its way up to the surface. The technique can also be used to measure radon from ore bodies at significant horizontal distances from the drill holes.

Data protection

Track Etch uranium exploration results are treated with the strictest confidence by Terradex. Map input coordinates and other data may be coded to further preserve proprietary information.

TRACK ETCH*
a new way to find Uranium

With the hunt for more uranium ore now taking on new urgency, there is a greater-than-ever need for an effective and economic means of locating deeply buried ore bodies. Track Etch*, a unique service now offered by Terradex, is just such a method.

Track Etch is a new surface exploration technique that can assist in pinpointing hard-to-find uranium deposits. At the same time, it is extremely simple to use, has minimal impact on the environment and is capable of bringing about large savings in exploratory drilling costs.

The Track Etch method uses a special dielectric film that is sensitive to alpha radiation given off by radon gas. This film is thus capable of detecting and measuring the anomalously high levels of radon near the earth's surface which indicate the presence of buried uranium ore bodies.

*Track Etch is a service mark of Terradex Corporation

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TRACK ETCH*
Services and Prices

Complete Services Supplied by Terradex
Terradex supplies the Track Etch detector cups and all instructions needed to perform a Track Etch uranium exploration survey. We process the detectors and prepare a report with maps of the results. The only effort required of the client is to place the Track Etch sampling cups in the exploration area and return them to us.

The complete services supplied by us include:

1. **Consultation at Terradex to plan the Track Etch program.**
2. **Pre-numbered Track Etch sampling cups with detectors installed ready for field use.**
3. **Detailed handling instructions.**
4. **Field data sheets for recording pertinent survey data.**
5. **Airfreight to and from any major airport in the world.**
6. **Processing and reading all Track Etch detectors.**
7. **Computer analysis and tabulation of the data.**
8. **A detailed statistical evaluation of the data.**
9. **Terradex† Track Etch contour and grid maps showing results.**
10. **A report summarizing the program findings.**

We can supply a free Track Etch program planning booklet on request. Track Etch cups are shipped with proper protection so that the detectors will not record alpha radiation before they are ready to be used. (The detectors will not detect any other radiation.) We prepay shipment to any major airport with regularly scheduled airline service that will handle airfreight. We also pay for return airfreight shipment. The client provides the field services of placing and removing the cups.

When the Track Etch cups are returned from the field, we process and read the detectors. The resulting data are computer analyzed, tabulated, and ranked after adjustment to an equivalent 30-day exposure for each detector. A statistical evaluation is made of the data, including a determination of the background mean and its standard deviation. The processed data are also used to produce two kinds of maps. One is a Track Etch radon contour map that defines the variations in radon levels in the area explored. The other is a grid map showing Track Etch readings at each sample point, with statistically high points marked. Any grid map supplied by the client will be contoured and/or plotted free of charge, provided we consider the dimensional and statistical specifications adequate to permit useful plotting. A Terradex letter report summarizes the results and identifies the anomalous areas showing most promise for further exploration and drilling.

You are welcome to free consultation at the Terradex offices to plan the field work if you supply maps and other pertinent data on the area to be explored. Free consultation at Terradex is also available to help interpret the results. You can also request field consultation at the consulting rates shown below.

A program for 100 Track Etch cups is the minimum offered, since it has been found that most areas of interest require at least this number to provide good statistical results.

Thoron Filter Kits
Complete discrimination against interference from thoron (Rn-220) gas is provided by Track Etch Thoron Filters. We supply these proprietary filters in kit form with snap-on covers. The use of Thoron Filters is recommended in many Track Etch applications.

Field Work by Customer
The client's field work — cup layout, placement, and recovery — is easy, needing only the simplest equipment. A Terradex booklet telling how to do the field work is included with the cups. During the field work, the client prepares sample location grid maps that we use as base maps for plotting.

Optional Services Supplied by Terradex
Field consultation services on the exploration program are available at a charge of $300 per day plus travel and living costs. Our consultants can help plan the program and instruct field personnel in the most effective way to use Track Etch cups, record the field data, and interpret the results. This service can be particularly useful when applying the Track Etch technique to new or unusual situations.

Limitations of Tests and Data
We keep survey data and all other sensitive information strictly confidential and will not release any data to other parties without specific permission from the client. Since field work is performed by the client, only the client knows where the exploration sites are located. Coded map coordinates can also be used to preserve additional confidentiality. We do not accept responsibility for subsequent action taken by the client or its consultants as a result of Track Etch surveys.

Delivery Schedule
Shipment of Track Etch cups is made within two days after receipt of an order at Terradex in Walnut Creek, California. You can place orders by telephone, but you should confirm by letter or Telex.

After the Track Etch cups are returned, preliminary results identifying major anomalies will usually be ready within five working days. This information is transmitted by telephone or Telex. Completed tabulated data with a written report and maps are airmailed in ten working days or less.

Price Schedule
The price of Track Etch services depends on the number of cups used. Larger programs have substantially lower unit costs. If you plan to survey more than one area, you can save money by ordering a larger number of cups and dividing them between survey areas. The minimum order is 100 cups. Orders for more than 4000 cups will be quoted on request.

Number of Track Etch cups	Service Price Per Cup
100 — 999	U.S. $15.00
1000 — 1999	14.00
2000 — 2999	13.00
3000 — 3999	12.00
4000 and greater	Request quote

Additional Optional Services
A. Thoron Filter Kits: U.S. $1.00 per cup.

B. Heavy duty cups for use underwater and in rugged environments: U.S. $1.00 per cup additional over listed price.

C. Field consulting: U.S. $300 per day plus travel and living expenses. Consulting at Terradex, no charge.

Ordering Information
Place orders for Track Etch services through:

Terradex Corporation
1900 Olympic Boulevard
Walnut Creek, California 94596
Phone: (415) 938-2545
Telex: 337-793

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The process of radon detection using track registration material is covered by U.S. and foreign patents: USA 3,665,194 and 3,303,085; Australia 424,388; Canada 911622; S. Africa 68/3983; other patents issued and pending. Thoron Filters are covered by U.S. patent 4,064,436; other patents pending.

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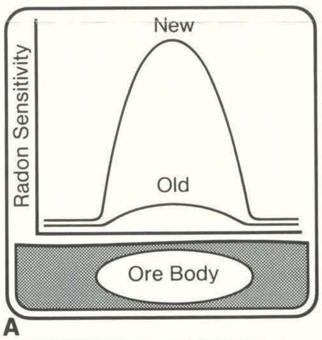
Now–
uranium exploration made even better, easier, cheaper.

Meet the new Improved Type Track Etch* system. All the benefits of the field-proven Track Etch method (800+ surveys by 150+ clients around the world), plus outstanding improvements.



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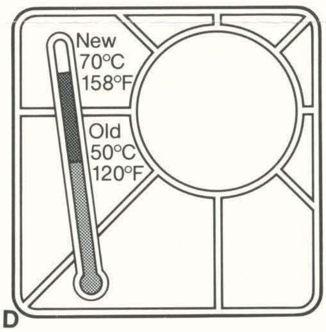

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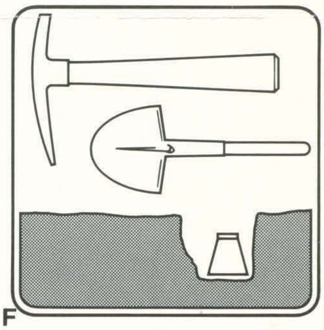

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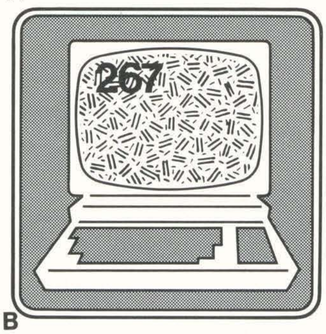

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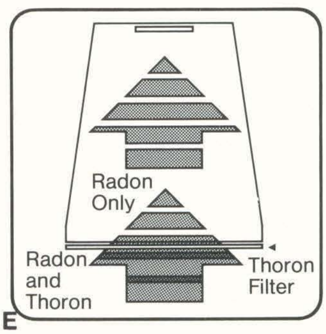

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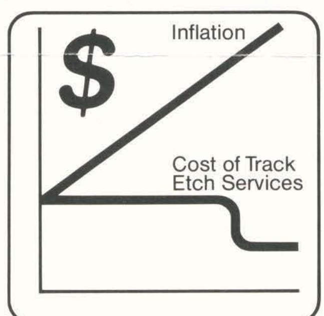

C

A. Higher sensitivity allows detection of weaker radon signals that may come from ore bodies at even greater depths. Track Etch responds **only** to alpha particles from radon gas. Track Etch is not affected by other forms of radiation.

B. Fully automated reading gives higher accuracy, faster turnaround at Terradex, more rapid followup in the field.

C. While the costs of nearly everything else are soaring with inflation, we've cut our charges for Track Etch as much as 35 percent. The minimum order is smaller, too.

D. Greater thermal resistance makes field handling easier in hot environments.

E. Our proprietary Thoron Filters (optional) eliminate interference caused by thoron from near-surface thorium.

F. Fieldwork is still as simple. Make shallow holes (a pick and shovel will do). Plant the cups. Wait a while. Retrieve the cups. Ship them back to us for analysis. That easy.

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Track Etch Orientation Survey in the Cluff Lake Area, Northern Saskatchewan

L. S. Beck, Director,
Saskatchewan Geological Survey,
Regina, Sask., and
J. E. Gingrich, Vice-President,
Terradex Corporation

Abstract

Track Etch is a recently designed method of uranium exploration that uses small pieces of special plastic film to detect the presence of radon gas emitted by buried uranium deposits. By using a sampling time of at least 25 days, the Track Etch technique eliminates the problems of sensitivity and fluctuations in background values normally present with other radon detection methods.

During the summer of 1974, an orientation survey was carried out over the 'N' zone of Amok (Canada) Limited, in the Cluff Lake area of northwestern Saskatchewan. This was the first test of the method in an area of glacial overburden and the results have been encouraging.

The 'N' zone consists of several pitchblende-bearing lenses associated with gently dipping fracture zones in paragneisses and granites of Archean or Aphebian age. The mineralized zones have been outlined by drilling and occur at depths ranging from 10 to 100 metres. The mineralized area is covered by sandy till and outwash ranging from a few metres to 20 metres in thickness.

Approximately 160 Track Etch sample cups were placed in shallow holes at the surface at roughly 70-metre centres. Sampling extended well beyond the boundaries of the known ore zone. High Track Etch values were obtained over the deposit, with a peak anomaly of more than 60 times the background value measured for the surrounding area.

Dr. L. S. Beck was born and educated in England and received his geological training at the University of Leeds. Since joining the Saskatchewan Department of Mineral Resources in 1957, he has held various positions, including that of resident geologist at Uranium City and chief geologist of the Precambrian Division. He is currently director of the Saskatchewan Geological Survey.

James E. Gingrich is the vice-president of Terradex Corporation, a company providing uranium exploration services using Track Etch. He has been involved in a number of uranium exploration programs in the U.S., Canada, Australia and other countries for the last three years. Before joining Terradex, he was with General Electric, where he was involved with uranium development technology and research related to several nuclear power projects.

Mr. Gingrich has published several technical papers on uranium exploration, radon measurements and nuclear power. He holds a degree in chemical engineering from Oregon State University and is a member of the American Institute of Chemical Engineers, the American Nuclear Society and the Atomic Industrial Forum.

Keywords: Exploration, Uranium exploration, Track Etch, Radon gas, Cluff Lake area, Glacial overburden, Pitchblende, Carswell Structure, Athabasca Formation, Sampling.

Introduction

SINCE 1968, several pitchblende deposits have been found in northern Saskatchewan at, or near to, the unconformity between the overlying Athabasca Formation and the older basement. Most of the exploration has been concentrated either around the edge of the sandstone basin or in the vicinity of the Carswell circular structure (Fig. 1), where the sandstone is relatively thin.

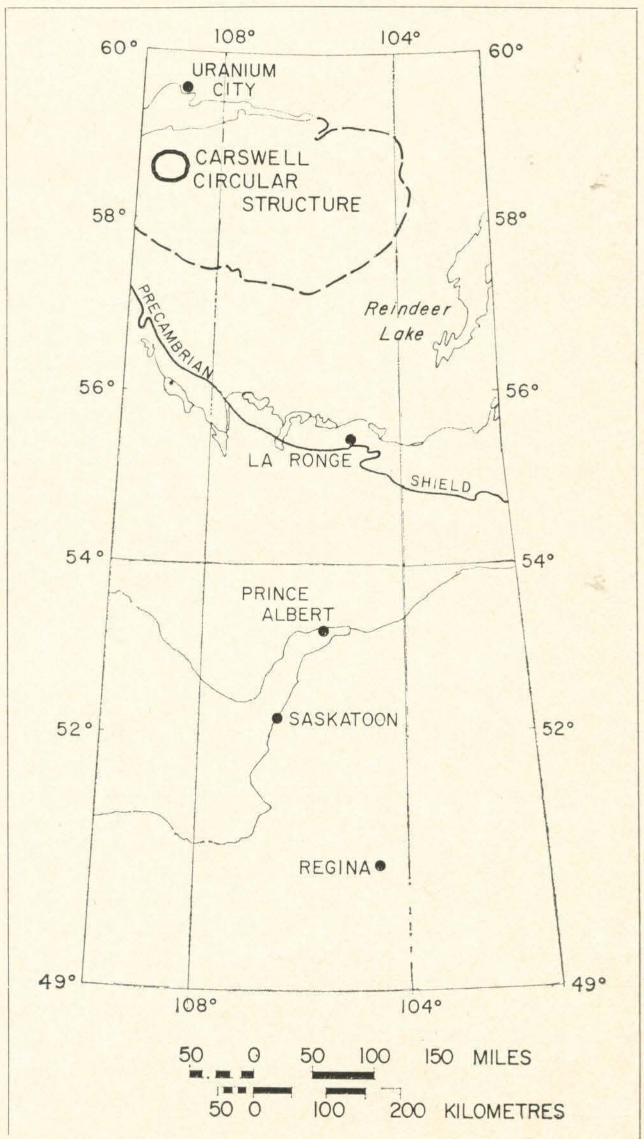

FIGURE 1 — Location Map.

Initial interest in specific areas has been prompted by the discovery of mineralized float, but detailed follow-up has been tedious and expensive due to the extensive glacial cover. No single geological, geochemical or geophysical method appears to have been successful; rather a broad spectrum of techniques has been necessary to provide the confidence and incentive to mount the major drilling programs necessary to define ore zones.

In view of these exploration problems, the recently designed Track Etch* method of uranium exploration appeared to offer promise as a useful exploration tool in the Athabasca sandstone terrain. Hitherto, the technique had been mainly used in non-glaciated, sedimentary environments of Australia, the United States and South Africa, where uranium deposits, not normally disclosed by other surface or airborne techniques, have been detected at depths as great as 160 m (personal communication, Track Etch customer, specific information confidential).

To test the method in the glaciated terrain of the Athabasca sandstone basin, the 'N' zone of Amok Limited, within the Carswell circular structure, was selected as a suitable test area for the method. The deposit is of "conventional" grade, rather than the very high grade of some of the other recently discovered ore zones, and exploration had not yet reached the stage where undue disturbance of the geochemical landscape might be anticipated. Furthermore, the ore zone was virtually entirely covered by glacial deposits.

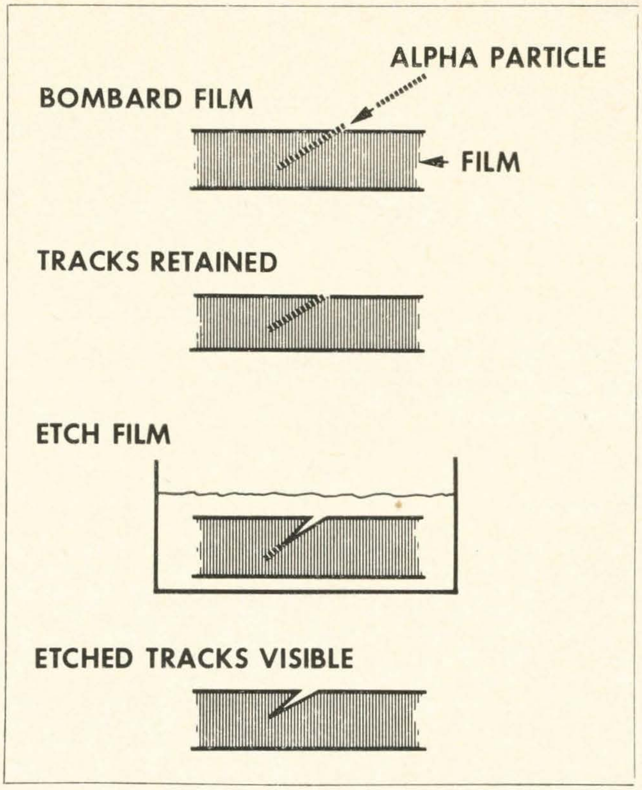

FIGURE 2 — Track Etch process.

The Track Etch Method

Radon surveys have been used in the search for uranium in many exploration districts. Some cases involve radon measurement of surface or sub-surface waters; others involve radon measurement of subsurface soil gas. The typical equipment to measure radon soil gas is the radon emanometer, which is sometimes called the "sniffer". The emanometer measures the alpha activity of the soil gas, over a short period of time, about a minute or so, by means of a phosphor-coated sample container. The emanometer is complex, both mechanically and electronically, when compared to a Track-Etch cup and, moreover, the short sampling period greatly restricts its sensitivity. Radon concentrations in given locations commonly vary by a factor of two to three, but in certain instances they may vary by as much as a factor of 100 in a 24-hour period due to variations in temperature, barometric pressure, wind and moisture (Gabelman, 1974). Because the emanometer measures soil gas radioactivity over a very short period of time, it often detects changes resulting from these other factors and the measurements do not necessarily represent the average radon levels at the sample location. Consequently, individual readings taken with an emanometer are often not repeatable, even when made only a few hours later, and they are considered unreliable in surveys involving a large number of readings over a wide area.

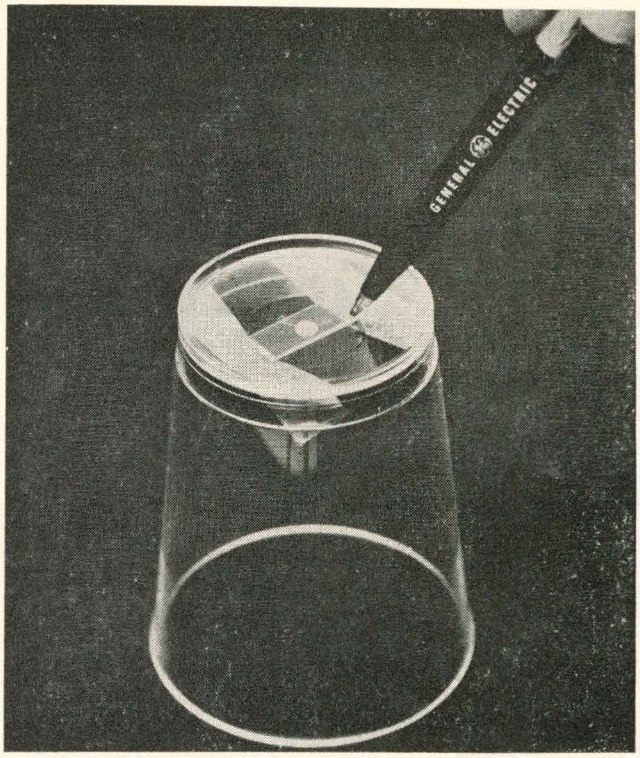

FIGURE 3 — Track Etch sample cups.

The Track Etch technique eliminates these major problems in making radon measurements, because the method is very sensitive, it is simple in construction and use, and it makes true average measurements of radon in a given area by measuring the radon alpha activity continuously for several weeks. The Track Etch method utilizes small pieces of special radiation-sensitive plastic film to detect the alpha particles emitted by radon gas entering the sampling cups. These films are processed in an etching solution to provide visible track-like images of the alpha particles recorded by the films (Fig. 2); hence the name "Track Etch" (Fleischer *et al.*, 1972). The alpha tracks are counted to determine the average amount of radon present during the exposure period, and by comparing track

*Track Etch is covered by U.S., Canadian and foreign patents.

readings from numerous films placed in a surveyed area it is possible to determine anomalously high radon concentrations, which are strong indicators of nearby uranium mineralization.

The Track Etch method can also indicate the presence of near-surface thorium mineralization, because thorium produces the alpha-emitting thoron gas (track images in the film are essentially the same for any gaseous emitter). As thoron gas is a very short-lived isotope (55 seconds) thorium will be detected only if it is present a few feet from the sampling cup. This potential interference problem can generally be avoided by careful measurement of each sampling point with a spectral type of scintillometer which detects thorium.

In order to make the measurements of radon using the Track Etch method, the sampling cups must be left undisturbed for a period of three weeks or longer. This necessitates visiting the sampling point twice and, of course, results in about one month's time to complete the survey. This period of time is absolutely necessary, however, in order to circumvent the problem of short-term radon fluctuations.

In a typical exploration program, several hundred sample cups (Fig. 3) containing Track Etch films are placed in holes, about 70 cm deep, over the area being explored. The sample holes are located in a grid pattern of between 30 and 1000 metres, depending on the size of the area being explored and the dimensions of the expected orebodies. After the cups are in place, the holes are covered and the cups are left undisturbed for several weeks. By leaving the sample cups undisturbed for this period of time, a meaningful average radon concentration can be measured. At the end of the sample-measuring period, the cups are recovered and the film is processed and read to determine the number of alpha tracks recorded and hence the average radon level at the sample location. The data are usually presented in the form of radon contour maps or profiles.

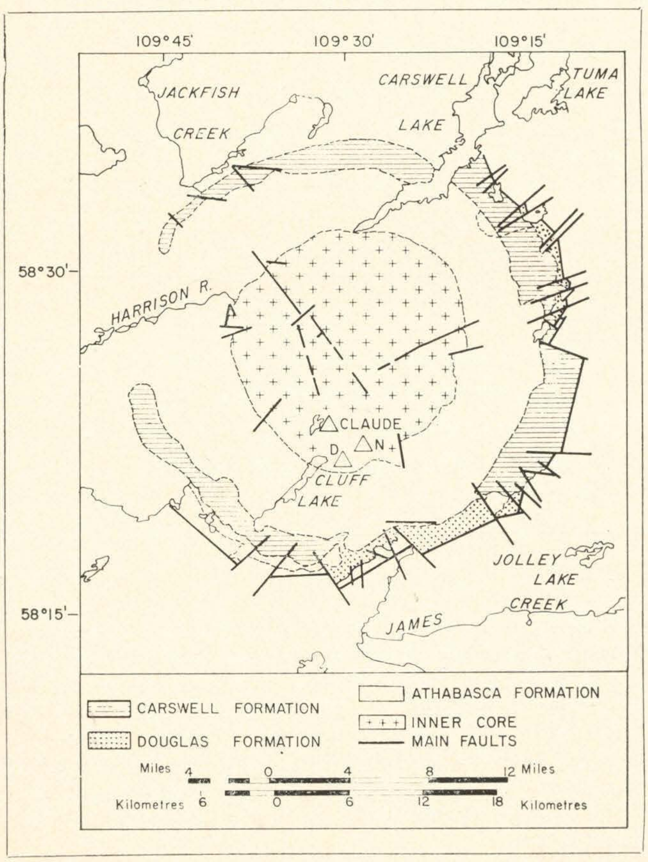

FIGURE 4 — Geological sketch of the Carswell structure (after Meunier).

Carswell Circular Structure

GENERAL GEOLOGY

The structure has a diameter of approximately 40 km and forms a prominent geologic and topographic feature within the generally monotonous Athabasca basin (Fig. 4).

The feature has an inner core, roughly 18 km in diameter, composed of tightly folded, metamorphosed and granitized rocks of the basement complex of Archean or Aphebian age. The core is bounded by an outward-dipping set of ring faults, separating it from a central zone of flat and gently dipping Athabasca sandstone. The central zone of Athabasca Formation is overlain conformably by a complexly folded sequence of dolomite (Carswell Formation) and fine-grained clastic rocks (Douglas Formation) forming the outer ring of the structure. A set of inward-dipping ring faults separate the strata of the Carswell and Douglas formations from the main body of the Athabasca Formation lying outside of the Carswell Dome.

The Carswell Circular Structure has been variously interpreted as a cryptovolcanic structure (Fahrig, 1961), a diapiric feature (Currie, 1969) and an eroded impact phenomenon (Innes, 1964).

HISTORY OF EXPLORATION

Recognising the unconformity between the Athabasca Formation and the basement complex as a favourable target zone for uranium exploration, Mokta Canada Limited (now Amok) carried out a helicopter-borne, total-count scintillometer survey of the entire Carswell Dome at a line spacing of 200 m in 1968-69. The survey revealed a number of broad, weak anomalies. Ground follow-up, utilizing a variety of exploration techniques, has resulted in the discovery of three separate ore deposits, termed the 'D zone', the 'N zone' and the 'Lac Claude deposit'.

The N Zone

Ground prospecting of the broad, weak radiometric anomaly in the vicinity of what is now known as the N Zone was carried out in 1969 and resulted in the discovery of a small occurrence of secondary uranium minerals in glacial overburden. In the following year, stripping of the overburden revealed mineralized bedrock (large E-W trench, near locality C, Fig. 5A).

Further trenching was not feasible, due to the extensive glacial cover, and a variety of geophysical and geochemical surveys were carried out in 1971-72 in order to trace the mineralized zone. This indicated a north-trending zone of brecciation and faulting, within which the discovery trench was roughly central. In 1972, a grid drilling program of the brecciated zone commenced and is continuing at the present time. Only drilling to the end of 1974 is shown in Figure 5.

The drilling has resulted in the discovery of a number of pitchblende lenses, associated with gently to moderately dipping shear zones in granitic and metasedimentary gneisses, at depths ranging from 10 to 100 m and contained within a north-trending zone at least 1800 m long and 500 m wide.

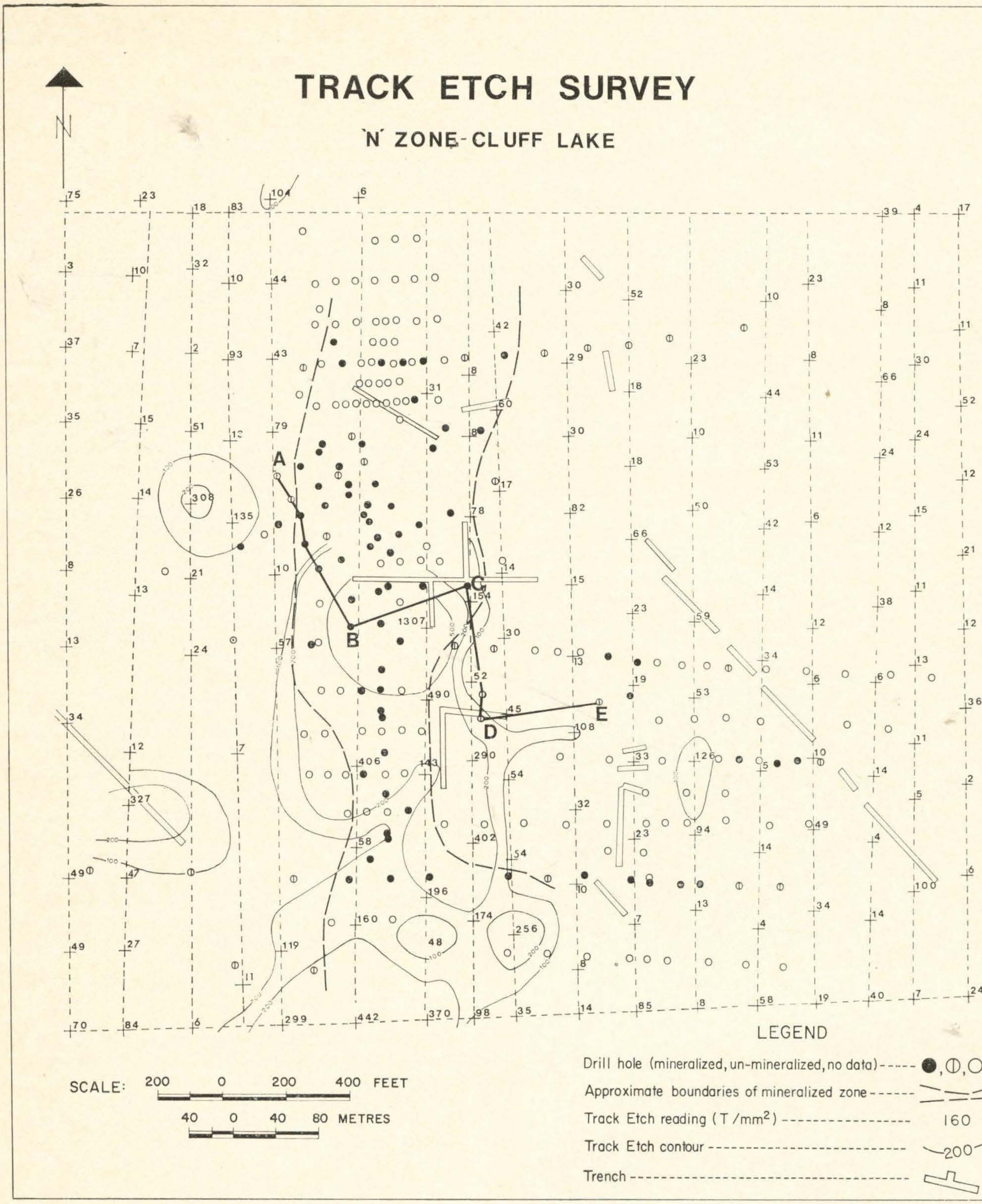

FIGURE 5A — Track Etch survey, "N" zone, Cluff Lake.

Apart from the showing exposed in the trenched area, the mineralized zone is covered by till and sandy outwash ranging from a few metres to 20 metres in thickness (Fig. 5B).

Track Etch Survey of the N Zone

SURVEY PROCEDURE

The existing grid of the deposit was used for survey control (Fig. 5), and cups were placed in shallow holes, averaging 70 cm in depth, along grid lines at approximately 70-m intervals. It was originally planned to dig the holes with a power auger, but this was not operational at the time of the survey and the holes were dug by hand. A manually operated post-hole auger was tried, but it proved unsuccessful because of the bouldery till (this type of auger has proved suitable in areas of sandy till — B. H. Tan, personal communication).

The holes took about 10 man-days to complete and cups were placed on July 1-2, 1974. Several of the holes filled with water and cups were not placed in these. All holes were dug away from possible contamination, such as near trenches and drill-hole locations, and scintillometer readings were taken at each sample location. Apart from a total count of 3-4 times background obtained from near the large trench (same location as the highest Track Etch reading of 1306), no readings greater than 1.5 times background were recorded.

The cups were recovered on July 23-24 and dispatched to Terradex Corporation for processing.

RESULTS

Results for each sample are quoted in terms of the number of tracks recorded for each square mm of film (T/mm^2) and are shown in Figure 5A.

Statistical treatment of the data was carried out by Terradex and is summarized below and in Figure 6.

No. of observations	158
Min. value	2.3
Max. value	1306.5
Median	28.3
Background mean	22.6
Standard deviation from background mean	15.7

Contour intervals used in Figure 5A are based on the following percentile data:

T/mm^2 contour	Approx. percentile equivalent
10	20
20	40
50	65
100	85
200	95
500	99

As can be seen from the contour map of the Track Etch readings (Fig. 5A) and the cross section (Fig. 5B), there is a pronounced positive correlation between the mineralized zone and the high Track Etch readings.

Conclusions and Recommendations

1. Track Etch appears to be capable of outlining buried ore zones in the Athabasca sandstone terrain where overburden thicknesses range up to 20 m.

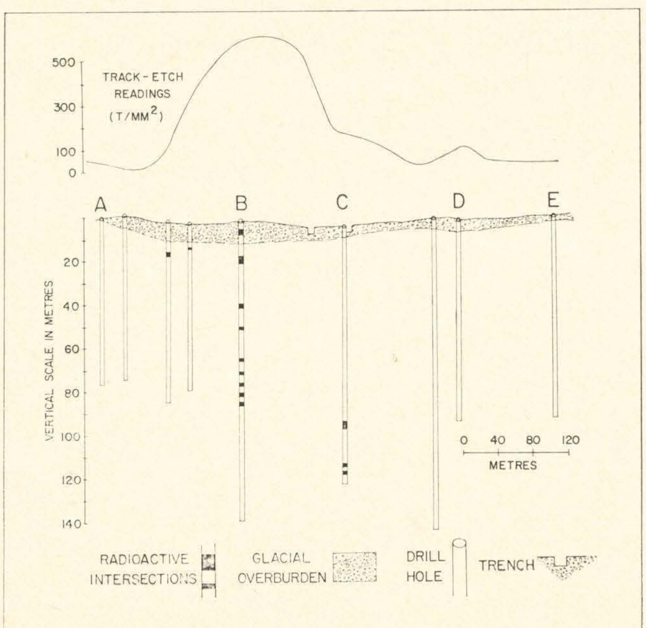

FIGURE 5B — Cross section, "N" zone.

2. In view of the success of the technique at much greater depths (160 m) in other parts of the world, there is reason to believe that much deeper deposits than that of the Amok 'N' zone would be disclosed by Track Etch in the Athabasca sandstone basin.

3. The most favourable terrain for carrying out Track Etch surveys is in well-drained, sandy till.

4. At the time of the survey, it was believed that cups should only be placed in dry holes and, as a result, all waterlogged holes were disregarded. Since then, it has been pointed out that wet holes can, in fact, be used. The air space in the cup protects the film and keeps it dry and, as long as the cup maintains its upright position during the survey, a meaningful alpha count will be obtained. A simple way to keep the cup upright is to wedge and anchor it in the base of the hole with small rocks. Even though a hole may be dry at the start of the survey, it is recommended that the cup be anchored if heavy rains are possible during the duration of the survey.

5. Many swampy areas are either inaccessible in the field season or have such a heavy vegetation cover that the abundance of roots in the soil prevents the digging of suitable holes for the Track Etch cups. In view of these field problems, the advantage of running the survey in winter, when the swamps are frozen, is obvious. Furthermore, it would not be necessary to dig holes, as the cups could be placed after the first heavy snowfall, at the base of the snow directly on top of the ground, and the snow cover would protect the cups for the duration of the winter.

To test the feasibility of using Track Etch in winter, most of the lines across the Amok 'N' zone were re-run. Cups were placed in early January 1975 and were recovered in April before spring melting occurred. The additional sampling time was considered necessary, as the migration of radon will presumably be slower through frozen overburden. The winter survey disclosed a similar anomalous pattern to that of the summer survey, although absolute T/mm^2 values were considerably lower. On recovery of the cups, it was noted that the inner surfaces of most of them were coated with a layer of ice crystals, which probably protected the film and explains the much lower values. Further studies into the use of the Track Etch method in winter are planned.

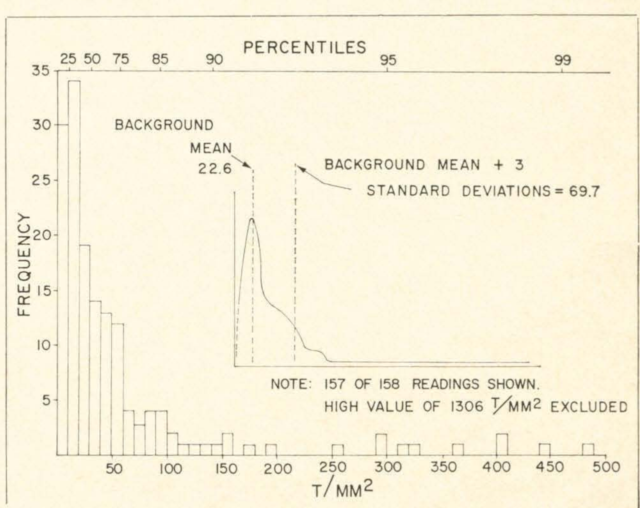

FIGURE 6 — Histogram and frequency curve for 157 Track Etch readings

Acknowledgments

Field work for the summer survey was carried out by T. H. de Zoysa, who also compiled data for Figures 5 and 6. Mr. de Zoysa was capably assisted in the field by Jill Lexier. The winter survey was undertaken by Drs. R. J. C. Munday and J. Hoeve. Percentile data were provided by Tsu Min Fuh using SaskComp program MR09105V.

The surveys would not have been possible without the ready cooperation of the Amok technical staff, and their assistance is gratefully acknowledged.

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A STREAM SEDIMENT ORIENTATION PROGRAMME
FOR URANIUM IN THE
ALLIGATOR RIVER PROVINCE,
N.T., AUSTRALIA

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Presented at the
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Sydney, Australia
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Contents

Introduction

Following the discovery of the Koongarra uranium orebody in 1970, and the recognition of the Alligator River Uranium Province, various attempts were made to apply stream sediment techniques to uranium exploration in the area. None of these orientation surveys yielded results which could be interpreted as defining the Koongarra Orebody or the uranium mineralization at Anomalies A and X. A later survey, in addition to conventional determinations of uranium, copper and lead on various size fractions, also attempted to indicate the relative quantity of uranium daughter products present in the sample. In the Koongarra area, samples were also spaced much more closely than in previous surveys, and the samples for comparison were also collected from the South Alligator Valley, where uranium was known in the drainage system.

General

The geology of the Koongarra area is described by Foy and Pederson 1976 and that of the South Alligator Valley by Foy 1976. Both areas are located approximately 220 km in a south-easterly direction from Darwin. The climate is monsoonal. The Koongarra uranium deposit is situated on gently sloping ground, comprising steep-dipping Lower Proterozoic schists below a rugged, faulted escarpment of unconformable gentle-dipping Middle Proterozoic sandstone rising 200 to 300 m above the plain. Uranium mineralization is confined to the Lower Proterozoic schists. The South Alligator area is a valley, 3 km in width, of steep-dipping Lower Proterozoic siltstone between escarpments of unconformable gentle-dipping Middle Proterozoic sandstone and volcanics. Numerous small uranium mines are elevated up to 150 m above the valley floor. Uranium mineralization occurs both in Lower and Middle Proterozoic rocks.

The Koongarra orebody shows downslope dispersion of oxidized uranium which appears to be limited to approximately 100 m from the primary ore zone. Considerably lower spectrometer readings for this oxidized ore compared with the primary ore, where uranium is in equilibrium with its daughters, indicated leaching of uranium daughter products from this secondary ore zone. Speculation that uranium daughter elements could be concentrated in stream sediments had been raised by the occurrence of the numerous "black swamp" radiometric anomalies in the area. The difficulty of measuring the minute concentrations of uranium daughter elements anticipated in active stream channels was solved by exposing Track Etch cups, Gingrich and Fisher 1976, which gives a relative measure of radon gas to the stream sediment samples.

Sample Treatment

Large samples in excess of 1 kg were collected from the active stream channels. Nineteen samples were collected from the South Alligator Valley and twenty-five from the Koongarra area. After drying, mixing and splitting a 100 g sample was placed in an evaporating dish and a Track Etch*

* The Track Etch system is covered by U.S. and Foreign patents.

cup placed over the evaporating dish, the size of which was selected to be a tight fit for the cups (Figures 1 and 2). A sixty day exposure period was used to obtain maximum effect on the Track Etch detectors and four blank samples were used to monitor contamination from atmospheric radon. Such contamination was found to be very low, the four blanks returning a mean of 0.4 T/sq.mm.

From the remainder of the sample an assay split was prepared, and after sizing, assay splits were taken of the +10 mesh, the -10+40 mesh, the -40+80 mesh, the -80+200 mesh and the -200 mesh fractions. Determinations were carried out on the above assay splits for copper and lead by A.A.S. and for uranium oxide by fluorometric analysis at Geochemical and Mineralogical Laboratories, Darwin.

Results

Base Metals

The results of the determinations for copper are shown in Table 1 and lead in Table 2.

TABLE 1

BACKGROUND VALUES AND RANGES OF VALUES FOR COPPER

(ALL RESULTS IN PPM)

Mesh Size Fraction	Koongarra Area			South Alligator Valley		
	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range
+10	9.3	7.2	2-28	25.2	10.2	8-44
-10+40	5.0	3.6	2-16	15.7	9.7	4-36
-40+80	3.7	2.5	2-10	16.8	9.2	4-36
-80+200	7.0	4.2	4-18	25.3	11.9	10-46
-200	10.4	6.4	2-26	28.2	12.5	14-56
Total Sample	5.4	3.8	2-18	19.6	8.9	8-34

TABLE 2

BACKGROUND VALUES AND RANGES OF VALUES FOR LEAD

(ALL RESULTS IN PPM)

Mesh size Fraction	Koongarra Area Mean	Standard Deviation	Range	South Alligator Valley Mean	Standard Deviation	Range
+10	11.4	9.1	4-36	20.1	5.6	12-30
-10+40	3.4	2.6	2-12	12.3	6.3	4-30
-40+80	3.7	2.6	2-10	13.7	7.3	4-36
-80+200	6.1	5.1	2-24	17.7	7.8	6-44
-200	17.4	4.5	8-28	25.2	8.5	14-56
Total Sample	6.8	3.5	4-16	17.9	4.2	10-26

Only a few of the determinations could be regarded as weakly anomalous and these are not regarded as being sufficiently definitive. Generally the backgrounds and absolute values are enhanced in the +10 and -200 mesh fractions. The background values of copper and lead in the South Alligator Valley for all fractions are also much higher by a factor of 3 to 4 than those of the Koongarra Area (Figures 3 and 4).

Uranium

The results of determinations for uranium are shown in Table 3.

TABLE 3

BACKGROUND VALUES AND RANGES OF VALUES FOR URANIUM OXIDE

(ALL RESULTS IN PPM, X INDICATES LESS THAN 0.5 PPM)

Mesh size Fraction	Koongarra Area Mean	Standard Deviation	Range	South Alligator Valley Mean	Standard Deviation	Range
+10	2.2	2.4	X-95	8.9	5.8	3-100
-10+40	1.0	1.4	X-12	4.8	3.7	1- 90
-40+80	0.9	1.0	X-17	5.9	4.5	1-100
-80+200	2.0	1.8	X-36	8.5	4.2	3-130
-200	8.3	5.1	4-70	11.2	4.4	6-190
Total Sample	1.7	1.3	1-21	6.6	3.4	2- 66

The background values of uranium in the South Alligator Valley are much higher than those of the Koongarra Area (Figure 5).

Four anomalous uranium samples were found at Koongarra, in very close proximity to the orebody (Figure 6). In reconnaissance stream sediment sampling it is doubtful if samples in these positions would be taken. As expected several anomalous samples were found in the South Alligator Valley (Figure 7). Generally the contrasts between anomalies and background appeared best in either the +10 mesh or the -200 mesh fraction and were noticeably depressed in the -10 to +80 fractions.

Radon

The detectors contained in the Track Etch cups detect radon gas and the relative radon concentrations are expressed in tracks per square millimeter (T/sq.mm). In the Koongarra Area the mean was 11.2 T/sq.mm with a standard deviation of 13.4 and a range of 3 to 72 T/sq.mm while in the South Alligator Valley the mean was 12.5 T/sq.mm with a standard deviation of 12 and a range of 3-52 T/sq.mm. While these results appear very similar the radon concentration also depends on the quantity of uranium present and its state of equilibrium. Complete determination of the quantity and state of daughter products present in each sample was beyond the scope of this survey, but it was found some approximation could be made by dividing the relative radon value from the Track Etch reading by the quantity of uranium oxide in the original sample and arriving at a ratio.

When these derived ratios were examined Koongarra was found to have a ratio background mean of 4.1 with a standard deviation of 1.9 and a range from 0.7 to 18.0 while the South Alligator Area had a ratio background mean of 1.6 with a standard deviation of 1.1 and a range from 0.3 to 4.5. Only one of the South Alligator samples could be considered as weakly anomalous (Figure 6) while 8 of the Koongarra samples could be considered strongly anomalous and 6 weakly anomalous (Figure 7).

These anomalous samples in the Koongarra area defined a zone around and down drainage from the orebody, showing a train in the major drainage of sufficient size to be recognizable in a reconnaissance programme. The known uranium mineralization at Anomalies A and X was also defined by these anomalous ratios.

Conclusions

Copper and lead were found to be poor indicators for uranium in the area. Uranium oxide both in the +10 and -200 mesh was found to be a useful indicator but only showed a very short train. The derived ratio of radon to uranium oxide was found to be the best indicator of an orebody similar to Koongarra. While this method of stream sediment geochemistry appears to show some promise it requires testing over a much wider area.

Acknowledgements

The authors thank the management of Noranda Australia Limited for permission to publish this paper and Terradex Corporation for supplying the Track Etch cups used.

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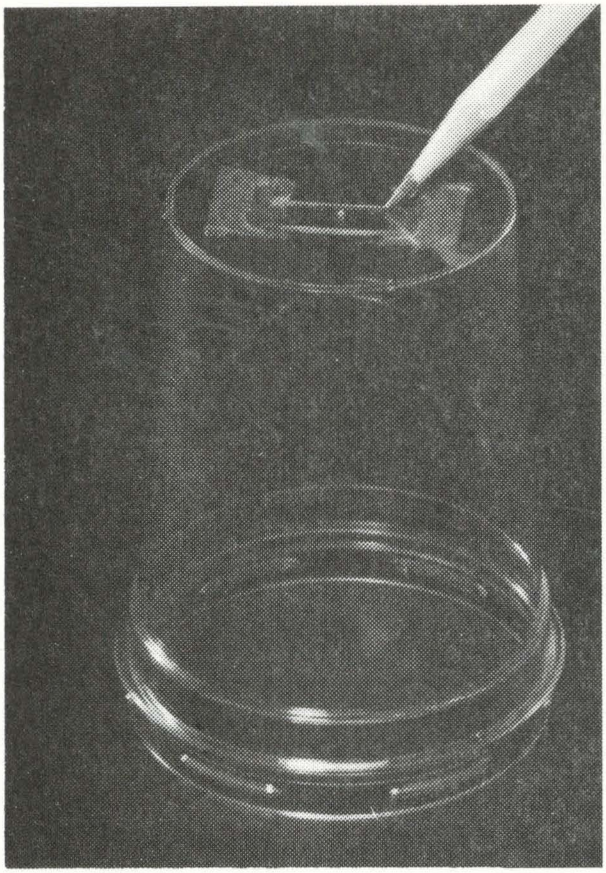

Figure 1. Track Etch Cup

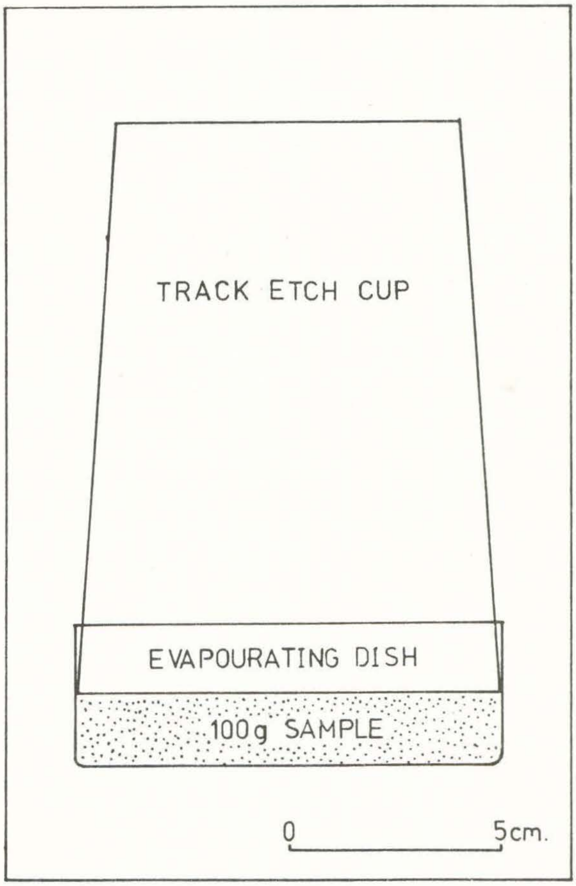

Figure 2. Track Etch Cup in Position Over Stream Sediment Sample

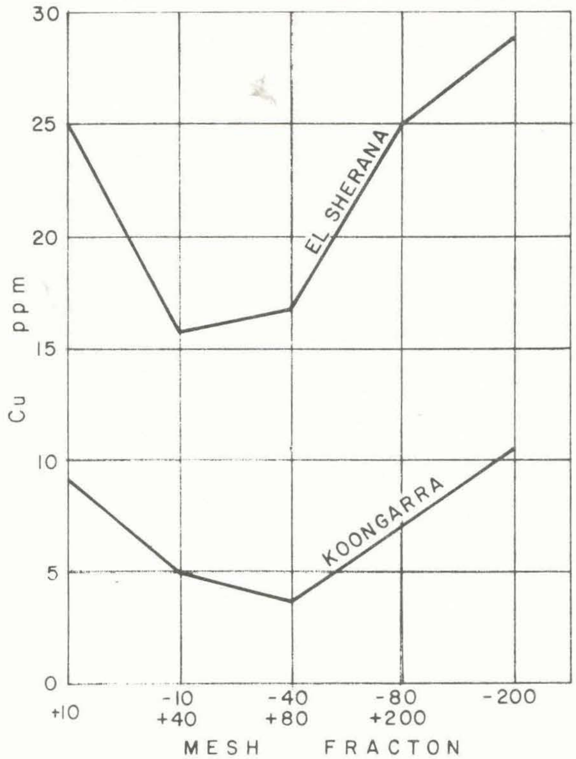

Figure 3. Copper Concentrations (Background Means) in Various Mesh Fractions

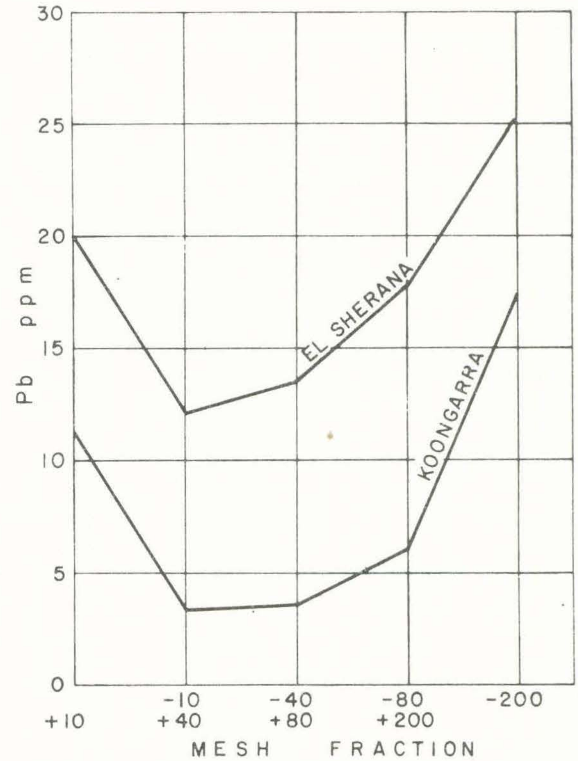

Figure 4. Lead Concentrations (Background Means) in Various Mesh Fractions

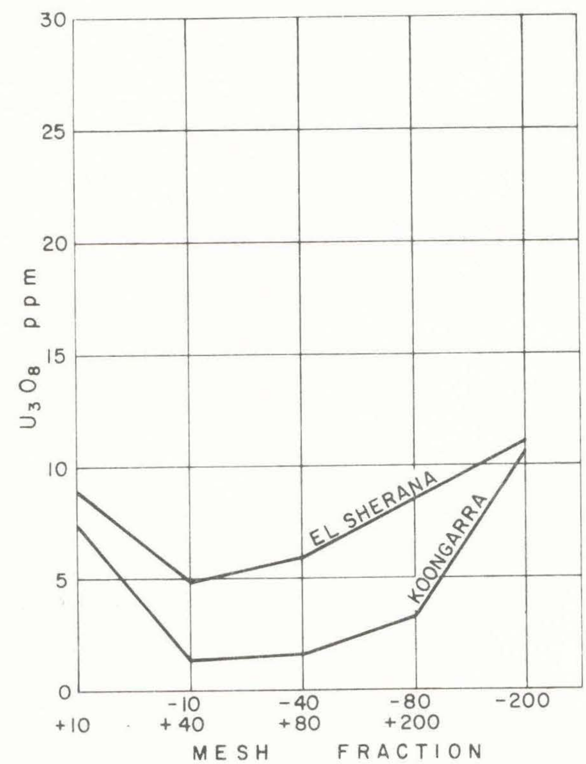

Figure 5. Uranium Concentrations (Background Means) in Various Mesh Fractions

EXPLORATION FOR URANIUM UTILIZING
THE TRACK ETCH TECHNIQUE

James E. Gingrich*
James C. Fisher*

Presented at the
25th International Geological Congress
Sydney, Australia
16 - 25 August 1976

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 ore-body 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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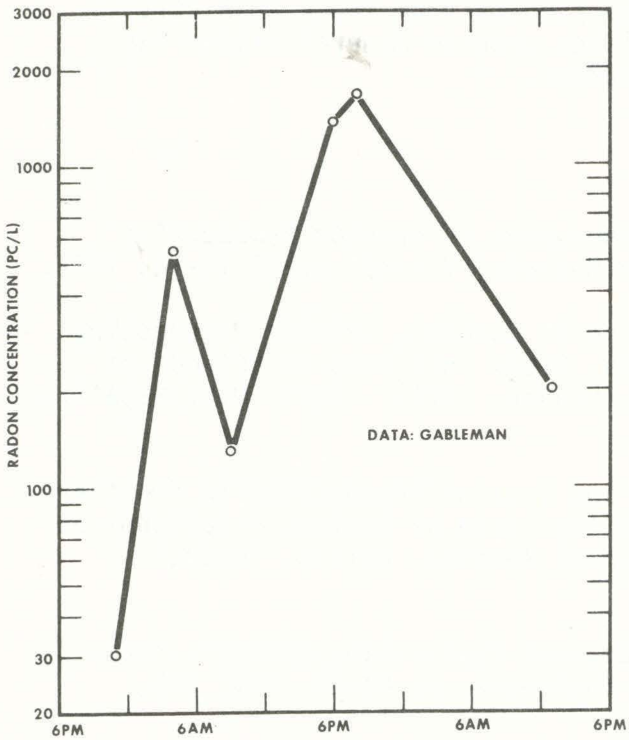

Figure 1. Short Term Variations of Radon in the Soil (Reference 3)

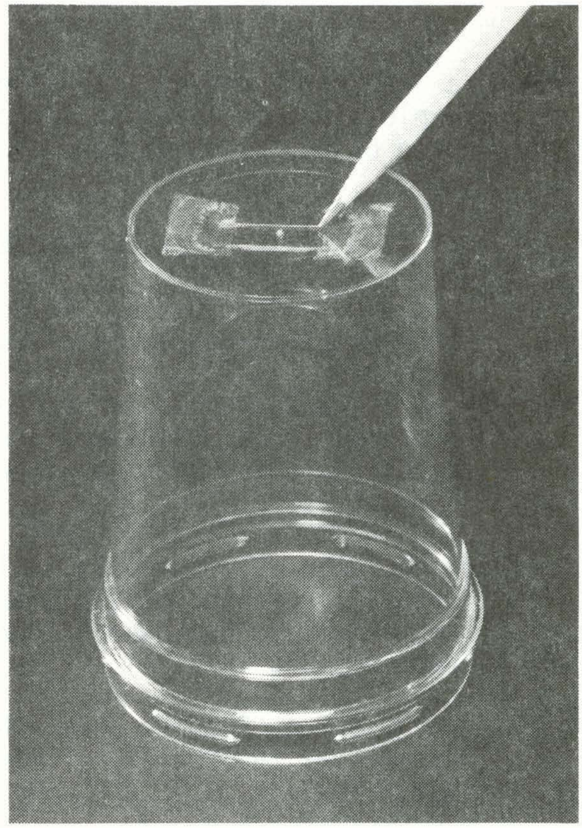

Figure 2. Track Etch Sampling Cup

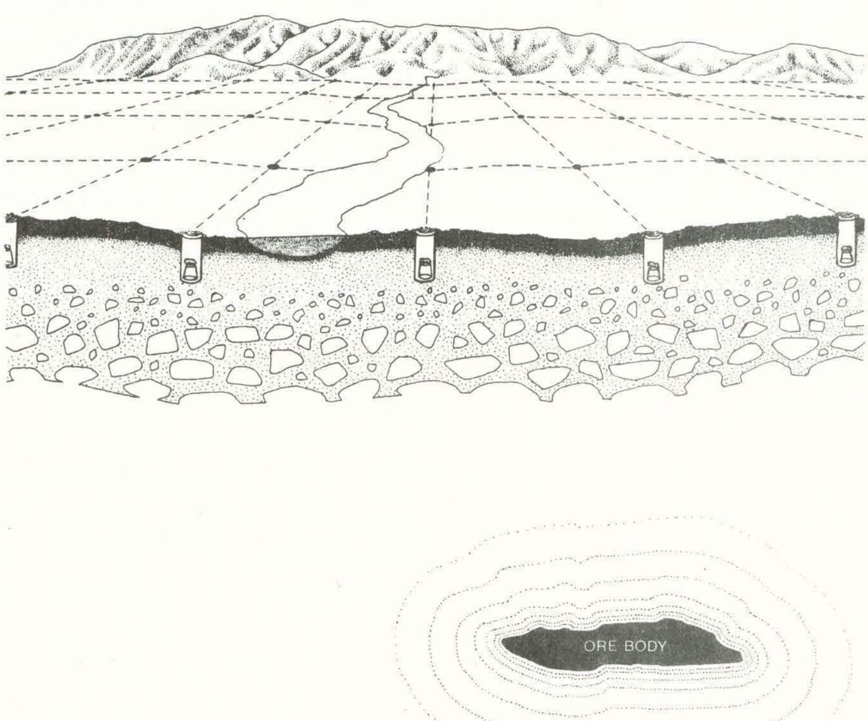

Figure 3. Field Deployment of Track Etch Cups (Typical Grid 30 to 1000 Meter Centers)

IAEA/SM/208-19

URANIUM EXPLORATION USING THE TRACK ETCH METHOD

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ABSTRACT

The Track Etch* system is a relatively new technique for uranium exploration that is based on the detection of radon gas anomalies. The Track Etch method utilizes small solid-state alpha track detectors to measure radon in the near surface soil gas. Because the Track Etch technique measures a long term sample of soil gas, it eliminates the major problems usually encountered in using radon measurements as guides to subsurface uranium mineralization. The Track Etch method described is also simpler, more reliable, and can achieve greater sensitivity than the emanometer methods previously used for radon detection.

This paper discusses the basic Track Etch radon detection system and how the method is used in uranium exploration. It also reviews the results from several exploration programs that have successfully utilized the Track Etch system and discusses the possible radon transport mechanisms.

* The Track Etch process is covered by U.S. and foreign patents.

Introduction

The detection of radon anomalies that may be associated with uranium ore bodies has been used with some success in uranium exploration for a number of years. Miller and Ostle[1] refer to some of the earliest work in radon detection around the uranium deposits found at Joachimsthal, Czechoslovakia and they also refer to some of the earliest development of radon detection instrumentation in the Soviet Union. Later work in the 1960's on the development of more sophisticated radon detection equipment along with a discussion of the several factors affecting the use of the radon method in the search for uranium were discussed by Peacock and Williamson.[2] More recently additional development of other radon detection equipment has been undertaken.[3][4] This research has been carried out to develop radon instrumentation and techniques that can detect uranium ore bodies that are buried too deeply to be detected with conventional surface or airborne gamma-sensitive scintillometer techniques. These gamma sensitive techniques are only effective where the uranium mineralization is at, or very near, the surface and in many uranium exploration areas of the world surface scintillometer techniques are not effective because all geological targets of interest are deeply buried. In these areas the only effective method of exploring has been to use expensive pattern drilling techniques along with thorough interpretation of the subsurface geology coupled with a variety of geophysical and geochemical tools.

The effective use of radon detecting techniques at the surface offers the potential opportunity of inexpensively detecting uranium mineralization buried several hundred feet deep. In the past the normal way of sampling radon with emanometers (or "sniffers") has been to measure the alpha radiation emitted by a small sample of soil gas pumped from the near surface soil. The usual detection methods use either an alpha-sensitive phosphor coated chamber coupled to a photo-multiplier or an alpha-sensitive ionization chamber. The gas sampling period is usually in the order of a few seconds or a few minutes.

These emanometers are 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 an emanometer, however, is that it measures only a short term soil gas sample which is usually not indicative of the average radon concentration in the immediate area. The latter 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.[5] Consequently, individual readings taken with an emanometer are often not repeatable, even when measured only a few hours apart, and emanometers are considered unreliable in surveys involving a large number of readings over a wide area. Because of these factors and many others, the users of radon emanometers have achieved only limited success in locating new uranium ore bodies on the basis of the instantaneous radon measurements. In order to obtain more meaningful radon data it is necessary to obtain integrated readings over a period of time and this is readily accomplished with the Track Etch system.

The Track Etch System

The Track Etch method is based on the utilization of small alpha radiation sensitive solid-state plastic detectors. These detectors are attached to the inside bottom surfaces of small sampling cups that are placed in shallow holes in the ground where they measure the soil gas radon concentrations.(Figure 1) The Track Etch detectors are subsequently processed in a special etching solution where they produce visible track-like images of the alpha particles that have impinged on the detectors; hence the name "Track Etch". The Track Etch detectors are unique in that they are not sensitive to light or to the gamma or beta radiation that might be produced by the various elements in the soil and, in the way they are utilized in the sampling cups, they are sensitive only to the alpha emitting radon isotopes within the cups.

In a typical uranium exploration program, sampling cups containing Track Etch detectors are placed in holes, about 75 cm. deep over the area being explored.(Figure 2) The sample holes are normally located in a grid pattern between 30 and 1000 meters apart depending on the size of the area being explored, the dimensions of the expected ore bodies, the local structural trends, and other factors. After the cups are in place, the holes are covered and the cups are left undisturbed for several weeks. By leaving the sample cups undisturbed for this period of time the Track Etch detectors continuously accumulate the readings produced by the varying radon soil gas concentrations and thus produce a reading indicative of the long term average. Under most conditions the sampling period is 3 to 4 weeks or longer since research has indicated that shorter term measurements (one week and less) have a very significant variability. At the end of the sample measuring period, the cups are recovered and the detectors are processed and read to determine the number of alpha tracks recorded and hence the average radon level at the sample location. To obtain the maximum amount of information from the Track Etch readings, the data are usually presented in the form of radon contour maps or graphs.

One of the significant advantages of the Track Etch method is its extreme simplicity and the fact that the sampling cups can be deployed by unskilled labor. The cups have no mechanical or electrical parts to cause problems and emplacing them takes only the simplest field equipment such as a hand operated auger or shovel. These factors are also very important in surveying rugged terrain and in less developed areas where technical support facilities are limited.

The Track Etch system can also be used for measuring radon levels in very wet surface conditions and under the snow. Where surface water is encountered the sampling cups are placed in the water in the inverted position with a small weight holding the cup in place. In this manner the cup acts like a diving bell and maintains a gas space between the water and the detector. Radon thus measured in the gas space is in equilibrium with radon in the water below the cup. A similar Track Etch technique is currently being developed for measuring radon at the bottom of deep lakes. In the wintertime the Track Etch cups can be placed under the snow on the soil surface to measure local radon levels. Wintertime surveys conducted in this manner are often more easily accomplished than by using the standard sampling method during other times of the year particularly in very swampy areas.

A special application of the Track Etch system has also been developed for measuring the radon in deep drill holes. Sample cups containing the detectors are attached to thin cables and lowered into the holes. This method is expected to be quite useful in exploring areas already partially drilled or in areas with tight overlying structures where radon may not penetrate to the surface. The deep hole technique may also make it possible to measure radon that has moved significant horizontal distances under the less permeable overlying structures.

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 only 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 problem 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 as in uranothorite.

The Track Etch technique, like many geophysical and geochemical methods, requires an accurate determination of the background (radon) level for the area being surveyed. Thus a minimum of one hundred sampling stations should normally be used to statistically determine the general background mean value with the desired accuracy. Experience with a large number of exploration programs, using Track Etch 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 apparently due to differences in surface and near surface uranium mineralization and to the differences in rock types in the exploration areas.

Radon Transport From Deep Ore Deposits

Various authors have quoted very shallow limits on the maximum penetration of radon for uranium ore body detection.[7,8,9] Successful experiences of the Track Etch technique as well as reported work from other radon surveying programs indicates that anomalous mineralization may be detectable to depths much greater than previously indicated; up to 200 meters in some cases.[10] Several different mechanisms to explain the movement of radon from deep uranium mineralization to the near surface have been postulated. They include: (1) Gas movement across geothermal gradients to cooler and hence lower pressure areas, this is predominately an upward movement; (2) earth tidal pumping effects, the opening and closing of fractures and pore spaces; (3) pore pressure changes due to seismic stresses; (4) deep effects of barometric pressure changes; (5) diffusion pressures of more concentrated soil gases (O_2, N_2, CO_2, Ar, He and other gases); (6) upward aqueous transport vectors; (7) soil and air temperature differentials; and (8) wind speed, direction and turbulence effects on the soil gas. At the present time little is known about any of these primary transport mechanisms and this is an area where further experimental research may be very fruitful.

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.

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. In fact, some evidence suggests that shale sections may be more transparent to radon gas than sandstone sections.[11]

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 is sometimes 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 component of soil gas (1pCi/1 = 0.66 x 10^{-18} liters Rn/liter). Therefore, radon 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. To explain the deep penetration depths observed only slightly higher transport velocities than indicated previously(7,9,12), from 4 to 6 x 10^{-3}cm/sec or approximately 3 to 5 meters per day are proposed. Using the lower figure of 3 meters per day and a 1 ppm soil overlying 2000 ppm ore body, an anomaly three times background should be produced over the ore body if it were buried 120 meters deep. Using a transport velocity of 5 meters per day and the same conditions, a 3 times background anomaly should be produced over an orebody 200 meters deep.

Field Experience With Track Etch

The Track Etch system for uranium exploration has been employed in over 300 exploration programs in a wide variety of geologic environments. Most of the initial surveys were carried out in the sedimentary deposit areas of western United States and the vein-type deposits of Australia. More recently several successful programs have been carried out in Canada and various parts of Africa. The following results are typical examples from some of these programs. While they do not discuss details of the full range of Track Etch experience they illustrate a few of the results from varied types of exploration programs.

Western Unisted States Sedimentary Basins

In many of the sedimentary basin areas currently being exploted for uranium in the western United States there are no surface or air scintillometer anomalies to use as exploratory guides and pattern drilling techniques are normally used along with other guides in uranium exploration. One of these areas in the Grants Mineral Belt of New Mexico was selected for exploration with the Track Etch method. The specific prospect was along a general trend of known mineralization but no exploratory drilling had been performed on the property. 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. The resulting Track Etch radon contour map is shown in figure 3. 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 so it can be assumed that the radon at the surface is penetrating through essentially dry cover. In addition to the drilling around the primary anomaly some exploratory drilling was done in areas with low radon values and no significant uranium mineralization was found. One test hole drilled into a second anomaly has shown some mineralization but its full extent has not yet been fully evaluated.

Front Range Colorado - Vein-Type Deposits

Uranium deposits in the Front Range of the Rocky Mountains in Colorado occur as high grade vein deposits of fracture breccia fillings of uraninite. The Schwartzwalder Mine, the most productive of the district, has produced approximately 9 million pounds of U_3O_8 since 1956 with an average shipping grade approximately 0.7%. Traditional prospecting techniques are generally ineffective in locating uranium deposits in this area because of the intense leaching of the soil and rock horizons and because of the colluvial cover.

In order to test several exploration techniques simultaneously in the Front Range, an extensive comparison study was made using airborne and ground radioactivity measurements, soil geochemistry, geobotany, biogeochemistry, SO_2 gas geochemistry, radon emanometry and Track Etch techniques.[13] Each technique was tested utilizing a 150 meter square grid with samples taken at the same locations so that evaluative comparisons could be made. Most of these techniques were found to be largely unproductive for several reasons.

The highly leached condition of the soil derived from vein exposure weathering and the vein outcrop itself, where seen, produced very slight radiometric responses. In several instances a vein outcrop, productive at depth, analyzed lower in uranium content than the total rock background of the district. The highest gamma ray response was twice background and was associated with an exposure of bare granitic gneiss rather than a potential ore horizon.

Extreme variability was noted in the radon soil gas signal using a radon emanometer. A variability of 10 to 15 times local background was sometimes observed due to the effects of barometric pressure changes, soil temperature variations, and other factors. Perhaps most disturbing were the topographic/wind direction effects on the emanometer reading. Wind impinging against a steep hillside seemed to produce a localized high pressure zone causing atmospheric air dilution to some depth below the 40 cm. penetration length of the sampling probe. Conversely, on the leeward sides of hills, localized low pressure zones seemed to provide increased soil radon emanation rates. These topographic differentials varied daily or hourly with respect to wind direction and velocity. When all the variability was removed from the signal using a series of base calibration stations, the highest radon emanometer anomaly was 3 times background. This anomaly occurred in an area of uranium mineralization but other areas, as well mineralized, showed practically no anomalous responses. (Figure 4)

The Track Etch radon technique was the most effective method tested in this comparison study. All the major uranium deposits and most of the minor prospects were outlined with this technique with anomaly to background ratios in the ranges of 4 to 10 times background. (Figure 4) One vein system of the Schwartzwalder mine produced an anomaly 17 times background. In addition, one very intense and extensive anomaly, 88 times background, was indicated in an area of previously indicated minor potential utilizing all of the more conventional techniques. The greater sensitivity of the Track Etch technique compared with that of the emanometer can be seen by comparing the two contour maps shown in Figure 4.

Metasedimentary Deposits - Northern Canada

An orientation study using Track Etch was conducted over the Cluff Lake "N" deposit located in Northern Canada. The "N" deposit is in metasedimentary rocks which are covered by glacial till. The Track Etch program was the first conducted in this environment and it was done for the purpose of determining the applicability of the technique in a glaciated terrain. The uranium deposit consisted of several pitchblende-bearing lenses associated with gently dipping fracture zones in paragneisses and granites of Archean or Aphebian age. Mineralized zones had been outlined by drilling and they were found to occur at depths ranging from 10 to 120 meters. Approximately 160 Track Etch sample cups were placed in shallow holes, averaging 70 cm. in depth along grid lines at approximately 70 meter centers. Sampling extended well beyond the boundaries of the known ore zone.

The survey results were plotted on a radon contour map as shown in figure 5. A number of high readings from the Track Etch detectors were found over the main ore body with a peak reading of more than 50 times the background value measured for the surrounding area. The highest reading was obtained where there is known ore grade material in mineralized lenses at several depths ranging from 10 to 90 meters. Other anomalous readings were obtained over ore grade mineralization at depths up to 120 meters.

This area was resurveyed with Track Etch cups during the winter by placing the cups at the base of the snow cover. The winter survey disclosed a similar pattern to the summer survey although the absolute readings were considerably lower. It is believed that the lower values were due to a combination of lower radon migration rates and the fact that the detectors were found covered with a layer of ice crystals when they were recovered. Further studies into the use of Track Etch technique in the wintertime are in progress.

Recent experience from two other test programs in Northern Canada is worthy of note. Tests were conducted over known uranium mineralization covered by permafrost and in both instances significant anomalies were detected. These results tend to confirm the porous nature of the permafrost cover and suggest the usefulness of the Track Etch technique in this environment.

Australian Experience

A number of exploration programs have been conducted in Australia using the Track Etch method. The environments explored have included several surveys in the Alligator Rivers area of the Northern Territory, the Fromme Lake Embayment of South Australia and several sedimentary areas in other parts of the country. One of the earliest test programs was conducted over a known orebody in the East Alligator River uranium district. There was no indication of the presence of this orebody from aerial or ground radiometric surveys although anomalously high radon concentrations in the general area were known to occur. Track Etch detectors placed on a 30 by 150 meter grid clearly located an anomaly over the orebody with the highest reading more than 40 times background. The orebody was a depth of 75 meters. The water table in the area was relatively near the surface (3 to 10 meters) clearly indicating from the results that the signal was not substantially attentuated by the thick water cover. (Preliminary results from other programs seem to indicate that there may even by an enhancement of the signal in areas with a high water table).

In another Australian test program in the Fromme Lake area of South Australia a survey was made over an ore deposit in a Lower Tertiary paleochannel sand which was at a depth of 110 meters. The ore averaged 4 meters in thickness at an average grade of 0.25% U_3O_8. The whole area was overlain by a sequence of relatively impermeable Upper Tertiary lacustrine clays. The Track Etch radon map of this area identified several low order (2 to 3 times background) anomalies over a known ore body. The anomalies were displaced about 100 meters from the center of the ore body for reasons not yet fully understood. The low order of the anomalies probably reflects the thickness of the overburden and the low permeability nature of the clay cover.

Regional Surveys

During the last year and a half the Track Etch technique has been used on several regional exploration surveys in the U.S. and Australia by placing the sampling cups on very wide centers (up to 1500 meters between points). These surveys have usually been performed in new exploration areas where there may be encouraging geologic conditions or good geochemical and geophysical indications but where no major mineralized areas had been discovered. In these situations the Track Etch results are expected to be especially valuable since the results can be used to guide a more extensive exploration effort preceding the initial exploration drilling; often done very blindly since little is usually known about the subsurface geology. Results to date indicate that in the areas tested, there are broad anomalies that are due to known increases in uranium mineralization and we have found that variations in readings in some cases have been attributed to changes in sub-surface lithologies or structures. Follow-up surveys using closely spaced sample points around the regional anomalies have further defined the detailed variation in local mineralization and these results are being used to guide detailed exploration drilling. The initial results from these regional surveys has shown that the Track Etch method may be a valuable tool in regional uranium surveys.

Conclusions

The Track Etch technique for uranium has proven to be a valuable tool for uranium exploration in areas where more conventional surface radiometric techniques are not effective. The method of sampling eliminates a major portion of the variability problem in radon measurement encountered with other techniques and the simplicity makes it both highly reliable and easy to use in the field. It was found to be particularly attractive for preliminary surveys and for exploring in remote areas where there is usually a limited amount of field support available.

Experience with the Track Etch system has indicated that its use can result in significant savings in exploration drilling costs. Exploration drilling has been reduced by up to 90% by utilizing the Track Etch radon contour maps to guide the initial drilling phases. In addition, valuable information about the sub-surface geology can be obtained which may be very useful not only in uranium exploration but also in exploration for other minerals. Experience has shown that the Track Etch radon technique can operate effectively in most any terrain from the tropical areas of Australia to the permafrost covered artic regions of Canada.

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Figure 1. Track Etch Detector in Sampling Cup

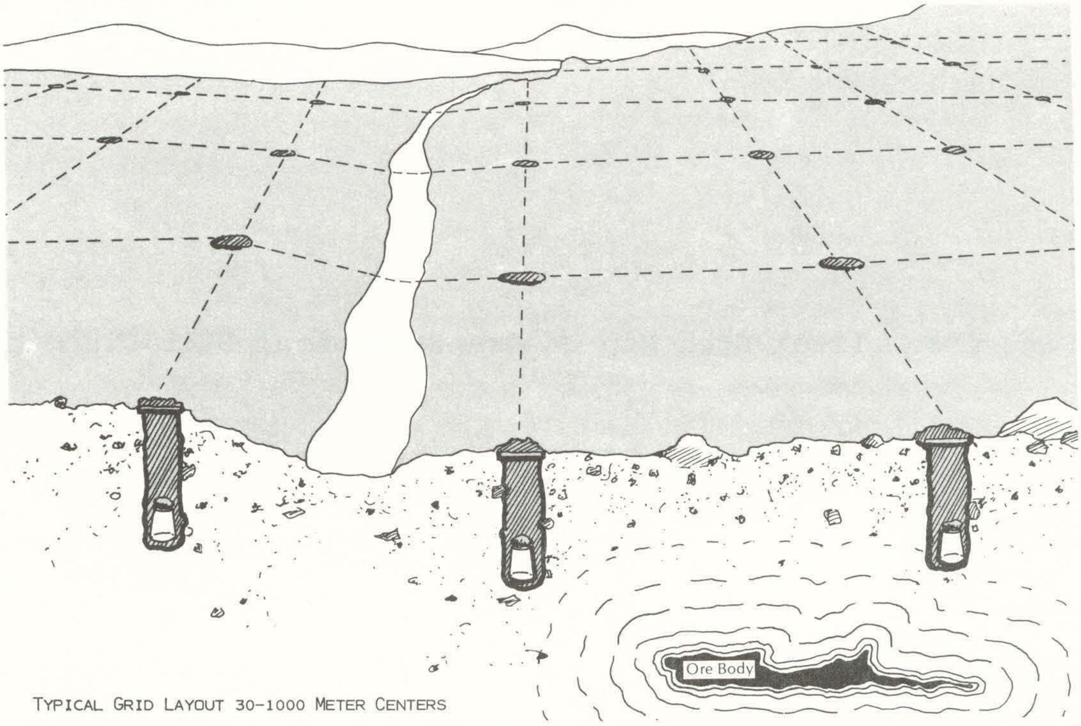

Figure 2. Typical Track Etch Cup Sampling Arrangement.

APPLICATION OF TRACK ETCH RADON PROSPECTING TO

URANIUM DEPOSITS, FRONT RANGE, COLORADO

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ABSTRACT

Traditional uranium exploration techniques were utilized and comparatively evaluated in the Front Range, Colorado uranium province. 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 make it extremely difficult to gain useful information from these systems. The technique judged most useful was Track Etch radon prospecting. The excellent definition of the technique, as well as its repeatability, indicate that it is an ideal prospecting tool for narrow vein-type deposits similar to those of the Front Range, Colorado.

INTRODUCTION

Traditional uranium prospecting techniques have been used with very limited success for uranium exploration in the Front Range of Colorado. (Figure 1) For this reason a small test area that includes known uranium deposits, occurances and prospects was chosen to be used in an evaluation of these traditional methods. In addition, several newly developed exploration techniques were evaluated as to their usefulness in uranium exploration.

In the summer of 1974 an area of vein uranium mineralization in the Front Range of Colorado (Figure 1) was explored for uranium ore potential utilizing the Track Etch cup radon sensing technique along with various other types of surveys including radon emanometry, airborne and ground scintillometer surveying, soil sampling, sulfur gas sampling and several other experimental techniques. The 3½ square mile area chosen to test the technique is shown in Figure 2. The area is called Target Area A and it includes several historically active uranium deposits in addition to the currently operating Schwartzwalder Mine.

Each technique was utilized on a randomly placed 500 foot square sampling grid so that no bias, due to variations in sample density, soil conditions or surficial indications, could influence the results of the test.

At the end of the test program each technique was evaluated on the basis of several criteria, these include: how well the technique indicated known deposits, prospects and occurances; how highly expressed were the anomalies; how many new zones of potential mineralization were outlined; and the ease and convenience of each technique.

FRONT RANGE, COLORADO URANIUM DISTRICT

High grade uranium ore occurs in the Front Range of Colorado. The main districts are the Golden Gate Canyon-Ralston Creek areas both within the Ralston Buttes 7½ minute quadrangle. This area is located approximately 20 miles west-northwest of downtown Denver, Colorado (See Figure 1). The Schwartzwalder Mine, the most productive of the district, has produced approximately nine million pounds of U_3O_8 since 1956 with an average shipping grade approximately 0.7%.

The rocks of the district are composed of moderately to well metamorphosed Precambrian sediments and possible volcanics with limited exposures of granodiorite and hornblende diorite intrusive igneous rocks. Rock types grade from muscovite-biotite schists, through calc-silicate gneisses to granitic gneisses and hornblende gneisses. The area is extensively fractured which was probably initiated in the Precambrian but which saw renewed movement during the Laramide Orogeny.[1]

Mineralization, mostly in the form of fracture filling uraninite, is localized in two major areas, along Golden Gate Canyon and along Ralsston Creek. Control of ore localization seems to be based on four factors; 1) the occurance of north-northwest trending, possibly deep rooted fracture zones, 2) intense branching and bifurcation of the fracture zones with associated brecciation, 3) fracturing at some angle to metamorphic foliation rather than nearly parallel with it so that fault dialation causes zones of open spaces for mineralization, and 4) the preparation of the breccia/fracture zones by the deposition of reduced sulfide minerals that later act as the reductant in a redox reaction that promotes the precipitation of the uranium minerals.[2] Also indicative of potentially mineralized areas are zones of intense soil yellow ochre to orange ochre coloration, a possible manifestation of alteration by mineralizing solutions.

Of the above mentioned five features, all but number four were able to be recognized on remotely sensed aerial and satellite photography and imagery. This data was plotted on maps and, based on only the relative occurrence of all but number four, four target areas of potential mineralization were chosen.

An area with the highest coincidence of these factors indicative of potential mineralization was then chosen to test the applicability of various types of ground uranium exploration techniques, this area is called Target Area A (See Figure 2). A square grid on 500 foot centers was overlain on the primary test area and sampling program was performed on that grid.

RALSTON BUTTES - TARGET AREA A TEST

An investigation of the major uranium exploration techniques was undertaken to evaluate the usefulness of each method in prospecting for vein uranium deposits. Each of the techniques will be discussed as to their merits and disadvantages in applying them in a Front Range vein-type uranium terrain.

When a hole was driven to take a soil gas sample for the radon emanometer the soil sample was taken in exactly the same location. The scintillometer was then put into the hole made and the total gamma radioactivity was measured. This was done to determine if there were any gamma emitter concentrations in the B soil horizon which was sampled. A series of other readings were also taken to be used to explain any variations in soil gas emanation rates. These readings included; soil type (silty, sandy, loamy, gravelly), soil thickness(depth to bedrock), soil cover (bushes, grasses, bare, etc.), air temperature, soil temperature relative humidity, wind speed and direction, degree of slope, topographic class (ridge, slope, valley, etc.), associated rock type, mineralization seen, cloud cover, morning and evening barometric pressure, and several other factors. Many of these factors may have an effect on the concentration and migration of radon in soil and bedrock.

Gamma-ray Scintillometer Surveying

This technique was not especially useful in this area because of the extensive leaching of the surface and remobilization of the uranium minerals deeper into the soil and rock horizons. Extreme variations in soil thickness, surface geometry, and soil types also cause many of the scintillometer readings to be suspect.

The major deposit in this area, the Schwartzwalder Mine, was discovered on the basis of a radiometric surface anomaly very limited in areal extent (less than 20 square feet). Even this very small radiometric anomaly would have been even less extensive if the surface had not been disturbed by earlier prospecting for copper.[3] In other words the largest deposit was found by surface radiometric prospecting but its discovery was mostly luck.

In no instances were any significant radioactive anomalies located in uncontaminated soils or bedrock exposures. Anomalies indicated in

Figure 3 were probably due to surficial contamination in areas of intense mining and prospecting or due to concentrations of potassium or thorium, rather than uranium, minerals in the soils or outcrops of pegmatitic or granitic rock.

Very slight radioactivity increases were often detected over vein structures but in a cursory exploration would not have been detected since the author traced veins exposed in trenches and prospects to undisturbed areas to test the usefulness of the radioactivity prospecting technique.

Radon Emanometry

Radon emanometry involves withdrawing a small sample of gas from the soil using a sample probe and circulating the gas through a phosphor coated sample chamber. Alpha particles produce scintillations on this sample chamber which are sensed by a photo-multiplier tube with the total alpha/light signal converted to an electronic meter reading. The main problem with emanometer radon surveying is that it only measures a short term sample which is affected by interfering factors which causes the signal to not be indicative of the average radon concentration in the area tested.

In Target Area A interfering factors such as changes in wind speed, direction and turbulence, atmospheric pressure changes, soil and air temperature differentials, and a host of other effects cause even the most carefully carried out radon emanometry survey to be suspect. In an effort to cancel out these effects several calibration stations were read a number of times during each sampling period. In several instances variations at the base station were on the order of 10 to 15 times local background. These values were used to bring readings obtained during that period back to a base so that effective comparisons could be made. Additional factors within the test area compounded the potential for error. Such things as extreme variations in soil permeability, soil moisture, and sampling technique may all have adversely affected the survey. Figure 4 is a contour map of the radon emanometry value of Target Area A. Only one anomaly presents a peak three times background and with less rigid control on the above mentioned factors, this anomaly would have not appeared at all. This anomaly is located over a zone of minor mineralization but in other mineralized areas, such as the Schwartzwalder Mine, practically no increase in radon signal is evident.

Soil Sampling

An analysis of the soil samples indicates areas of slight uranium and thorium anomalies. This is very encouraging until one realizes that the highest anomalies occur where the soil is poorly developed with bedrock very shallow and where the relief is not extreme so that the residual concentrations of the two radioelements are not disturbed by down slope leaching. Areas of thick pine tree covered ground seem to lack anomalies also and this may be due to the leaching actions of humic material generated in the soil by the decay of the forest mull. Figure 5 is a contour map of 124 spectrometric uranium analysis out of 226 samples taken. Only in the case of one sample was the analysis greater than three times background and that was in an area of probable contamination. Natural variability of the soil mineralogy, based on the parent rock material, seemed to play a greater role in determining uranium content than did anomalous mineralization. In some instances the copper content of the soil was helpful in the quest to locate mineralized structures but only in areas of thin residual soils and never where thick colluvial cover predominated.

Other elements, such as selenium, molybdenum, nickel, zinc, arsenic and iron, are even less effective indicators of mineralization. The same factors that control the concentrations of uranium and thorium may also affect these elements.

Sulfur Gas Sampling

This technique relys upon the measurement of the SO_2 gas produced by the oxidizing of metallic sulfide mineral concentrations.[(4)] Areas in Target Area A that have high concentrations of uranium mineralization and that lie below a surficial zone of intense oxidation have associated pyrite and chalcopyrite and are probably producing sulfur gas in low concentrations. Low order sulfur gas anomalies were detected in areas of probable mineralization and the second highest anomaly fairly well outlines the area north of the Schwartzwalder Mine that contains several of the major prospects or non-economic mines of the district. (Figure 6)

Since the Schwartzwalder Mine is now well tunneled and ventilated, this may promote increased sulfide oxidation and SO_2 gas formation producing an anomaly at the surface which is probably greater than would have been found if the survey had been run previous to the mining. In other words the slight anomaly to the north is possibly as indicative of sulfide mineralization at depth as is the one over the Schwartzwalder Mine.

The same factors that affect the emanations of radon gas in the soil also adversely affect the reliability of sulfur gas measurement. Meteorologic factors as well as soil permeability and moisture variations cause this technique of soil gas sampling over a very short period to be difficult to interpret. Concentrations of organic material such as swampy vegetation and organic accumulations also give off sulfur gas which may interfere with a correct interpretation of the readings.

Track Etch Radon Prospecting

One of the most useful techniques of uranium exploration is a method developed by researchers at General Electric Company and now currently available from the Terradex Corporation in California.[(5)] This technique involves the placing of a series of plastic cups in shallow holes in the ground on a grid pattern. The cups are implanted upside down so that upward migrating radon gas enters the cup which measures the gas concentration. The cup also protects the sensor material inside from mud, water, dirt and other natural substances. (See Figure 7)

Inside the cup and taped to the bottom of the cup is a small strip of dielectric Track Etch material with a section of its surface exposed to the flux of alpha particles produced by the radioactive decay of the gaseous radon. When an atom of radon decays it emitts a low energy alpha particle which travels 2.8 to 6 cm at a high velocity in air, propelled by the energy given off by the decay. A certain percentage of the total radon/alpha decays in the cup, within 6 cm of the dielectric material, are oriented so that when an alpha is emitted it strikes the track registration strip leaving a very small damage track.

After a certain length of time (3 weeks - 6 weeks) the cups are retrieved, the track registration strip removed and the tracks counted. The material is etched thereby making the damage tracks visible under moderate magnification. The track density values are then reported and a contour map is produced on the original grid map showing radon concentration contours. This contour map is then interpreted to indicate areas of potentially promising uranium concentration.

Some of the advantages of Track Etch technique are:

1. This technique averages diurnal and longer meteorological and geological variations which cause changes in radon emanation rates, sometimes up to two orders of magnitude.

2. This technique seems to present significant radon anomalies providing the geologist with obvious points of further exploration. This aspect is doubly important when one considers that the amount of radon produced by uranium in equilibrium with its daughter products is extremely small. As an example, if we take into account radon production, mineral emanating power, and decay, one billion grams of uranium in a rock (approximately 650,000 tons of .2% ore) has the ability to continuously provide approximately 1.2×10^{-5} grams of radon to the soil above it, not a large amount by any means.

3. The cups are lightweight and can be carried and used in areas of rough terrain or poor access.

4. There are no electronic circuits to break down in the field and there are no batteries to wear out.

5. No special skills are required to implant the cups and retrieve them.

Some of the disadvantages of the Track Etch radon prospecting technique are:

1. Need to go to location twice, once to bury cups and once to retrieve them. Because of this there is a moderate time lapse to the return of results after cup implantation, up to six weeks depending on how long they are left in the ground. The time lapse is required, though, because variations in the radon signal make it impossible to sample for less than several weeks and get an accurate value for the average radon concentration at a particular location. Therefore, Track Etch prospecting may not be applicable in areas where the uranium potential must be appraised within a couple of weeks, but then other radon techniques probably would not provide adequate results either.

2. The Track Etch cup technique cannot distinguish between radon-222 (radon) and radon-220 (thoron), a daughter product of thorium. In areas with large amounts of thorium in the rocks false anomalies might be generated. Since the half life of radon-220 is so short (54.5 seconds) compared to that of radon 222 (3.8 days) its migration distance is, therefore, much shorter before decaying to undetectable limits. Using the half lives as a ratio, thoron can migrate 1/6000th as far as an equal amount of radon before decaying to a daughter product. For this reason the thoron contribution from deeply buried ore bodies is considered negligible. Thoron contributions from shallow sources can be discerned with a spectral scintillometer by determining the thorium content of the soil in the vicinity of the cup.

3. The Track Etch material is heat sensitive so it must be used with caution in very hot areas. In most cases a 2 to 2½ foot hole allows the cups to be implanted below the extreme temperature soil zone.

4. This method can sometimes indicate anomalies in areas where there exists only soil radium (Ra) concentrations. The chance that any radium soil concentrations are unrelated to the parent uranium concentrations is probably fairly poor. Also soil radioactivity readings are taken during the placing of the cups and any anomalous soil radium concentrations should be defined and accounted for during Track Etch data interpretation. It may take a good knowledge of the local structure, stratigraphy, hydrology, and general geologic history to unravel the source of the radon anomaly but a geologist must know these things to undertake a successful uranium exploration program in any case.

5. The technique cannot differentiate between deeply buried high grade deposits and shallow, low grade deposits but it rarely creates a false anomaly indicating anomalous radon concentrations where no source for the gas exists. It is a valuable guide to but not a substitute for exploratory drilling and logging.

Front Range Example

In this area of narrow vein concentrations of uranium mineralization a program of Track Etch radon sampling on 500 foot centers would seem to be impractical. Uranium mineralization in these zones may seldom reach 10 feet in thickness and the author believes that zones thicker than 3 feet are rare. It would seem that on such a wide spaced survey that the chance of locating a single cup over a mineralized vein is remote. The success of the Track Etch cup program may be explained by the occurrence of extensive rock fracturing, even to depths of 100 feet or more.

The entire upper few feet of the bedrock is extensively fractured and frost brecciated, and tectonic or load relief fracturing on a large scale may reach depth up to tens of feet. Tectonic fracturing of the rocks to a moderate extent may reach depths up to 500 feet. (See Figure 8) Therefore, the radon gas produced even deep in the rock may have adequate channelways to the surface. The intensification of fracturing as one approaches the ground surface may then redistribute the upward migrating radon gas along minor fracture zones so the gas moves to the soil-bedrock interface along many microfractures. Then as the radon gas transports through the thin soil layer the gas is even more widely dispersed. If this model is true a cup planted anywhere on the broader anomaly will indicate the presence of uranium at depth but only one coincident with the highest peaks will indicate the major fault migration channelways so that a program of resampling on a smaller grid is usually a good second step. Figure 9 is a contour map of the Track Etch survey locations in Target Area A. The Schwartzwalder Mine is very evident on the survey. The second largest anomaly (approximately 17 times background) is situated nearly over one of the auxiliary vein structures associated with the main productive veins of the mine. Since two Track Etch locations directly over the mine were not used because of probable contamination this anomaly is quite encouraging. Two other second order anomalies were found to amply indicate two known zones of mineralization while the anomaly in the northwest corner of the map seems to be situated over the extension of a major fault.

The very large anomaly (approximately 88 times background) northwest of the Schwartzwalder Mine is over an area of slightly prospected terrain and seems to indicate an area of great potential mineralization. A resurvey of this area with 26 cups on 250 foot spacings indicates this anomaly is quite extensive with 20 out of the 26 cups being anomalous.

Other Techniques

Techniques such as geobotany, biogeochemistry stream sediment and stream water sampling were investigated but all but the biogeochemistry were found to be totally useless in the test area. The biogeochemistry may find some moderate usefulness in areas of extensive conifer coverage, but Target Area A had limited forest cover with mostly low grass and bush vegetation, so proved to be only slightly useful.

Several other techniques of exploring for vein-type uranium deposits of the Colorado Front Range were examined and two techniques of vein system exploration were examined by R. Stahl of the U.S. Bureau of Mines (currently with M.E.S.A., Denver, Colorado).[6] His work seems to indicate a high usefulness of horizontal resistivity survey in locating vein produced resitivity contrasts.

SUMMARY

In the target area the surveys were conducted over several known uranium deposits from the highly productive veins at the Schwartzwalder Mine to small unproductive prospects. In some cases the ground scintillometer survey indicated several areas of known mineralization, and did not indicate other zones. The same thing happened with the radon emanometry, sulfur gas geochemistry and several other of the techniques.

In the case of the Track Etch program all areas of known mineralization were located to some extent or another. Additionally one new area of extremely intense radon production, far exceeding that over the highly ventilated Schwartzwalder Mine, was located.

A second cup survey was undertaken in the area of anomalous radon production, located on the first survey by two cups. Twenty six cups were located on a grid of 250 feet in this second survey, 13 of them read greater than 10 times background and 7 of them greater than 5 times background. This seems to indicate there exists a fairly large area of high potential for good uranium mineralization about .9 miles north-northwest of the Schwartzwalder Mine.

CONCLUSIONS

Of all of the ground uranium exploration techniques tested in this area of narrow vein uranium deposits possibly the most effective method seems to be radon Track Etch prospecting with horizontal resistivity, also very effective. (Figure 10) The Track Etch is useful in locating zones of anomalous mineralization, the horizontal resistivity is useful in locating potentially mineralized structures. Based on this study soil sampling and ground scintillometer radioactivity surveying was intermediate in effectiveness. The least effective technique was radon emanometry but measurement of many of the factors that tend to cause inaccuracies in an emanometry survey could upgrade the usefulness of this technique.

Concluded to be totally ineffective in this area was geobotany. This is because so many other factors control the localization of plant communities besides the selective occurrence of trace elements in this mountainous terrain. Partially investigated was the technique of biogeochemistry and some results indicate this technique may be moderately useful in areas of continuous conifer tree cover.[7]

A ground survey in a vein-type uranium area might, therefore, be carried out in the following manner:

Step 1. A Track Etch exploration program undertaken in areas of intense soil red ochre to yellow ochre coloration, indicative of alteration by mineralizing solutions, or across zones of possible fault brecciation. A program of no more than 500 foot locations may be very useful. The spacing should be determined individually for each program. In addition soil and/or bedrock scintillometer surveying along with Track Etch prospecting is advised. Associated soil samples taken with Track Etch survey for possible analysis of copper or other elemental composition is also recommended.

Step 2. A horizontal resistivity survey over Track Etch radon anomalies. This should locate the narrow fault/breccia zones that are producing intense radon flow.

Step 3. A close spaced Track Etch survey along the veins delineated with the horizontal resistivity survey to locate the zone of greatest radon production along the fault, 50 to 100 foot spacings may be advantageous under some conditions.

Step 4. Drilling to locate the source of the radon and to determine the grade and depth of the mineralization.

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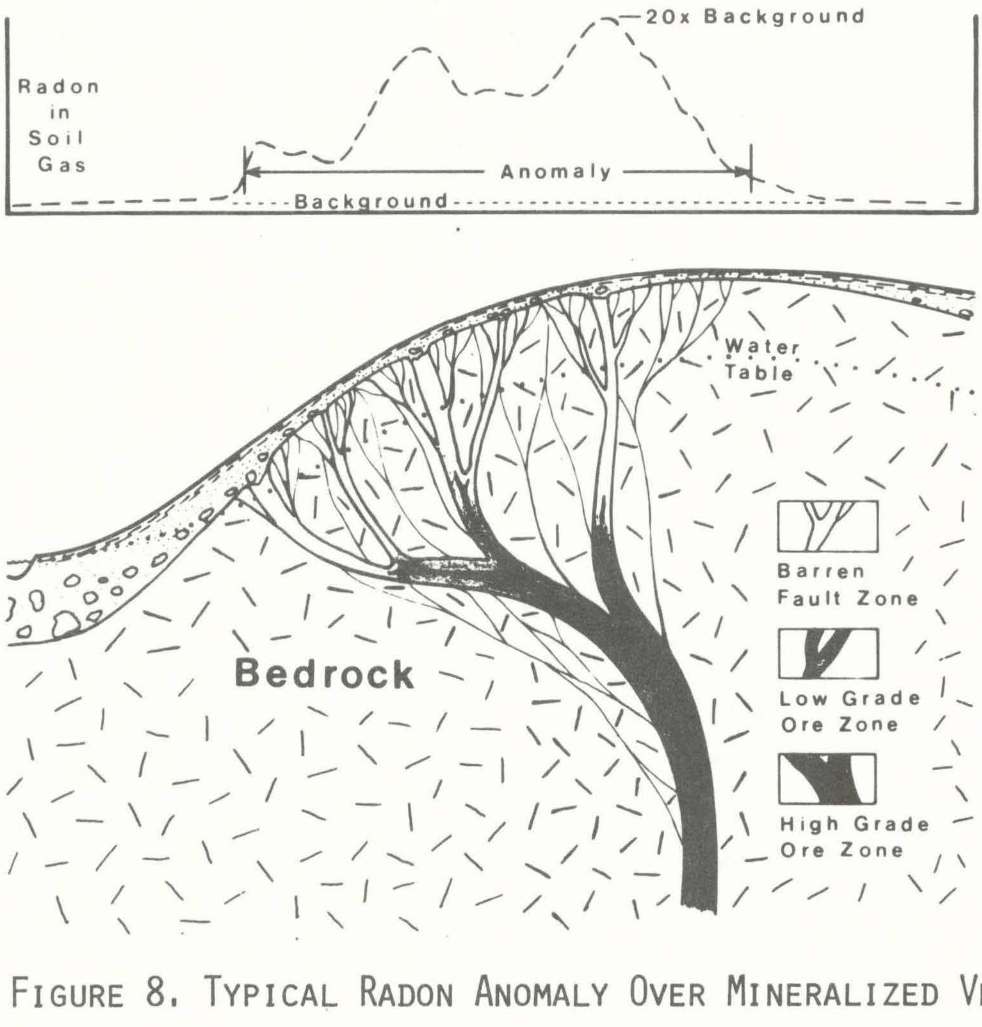


FIGURE 8. TYPICAL RADON ANOMALY OVER MINERALIZED VEIN

FIGURE 10

Relative Usefulness of Ore Guides and Prospecting Techniques for Uranium Exploration

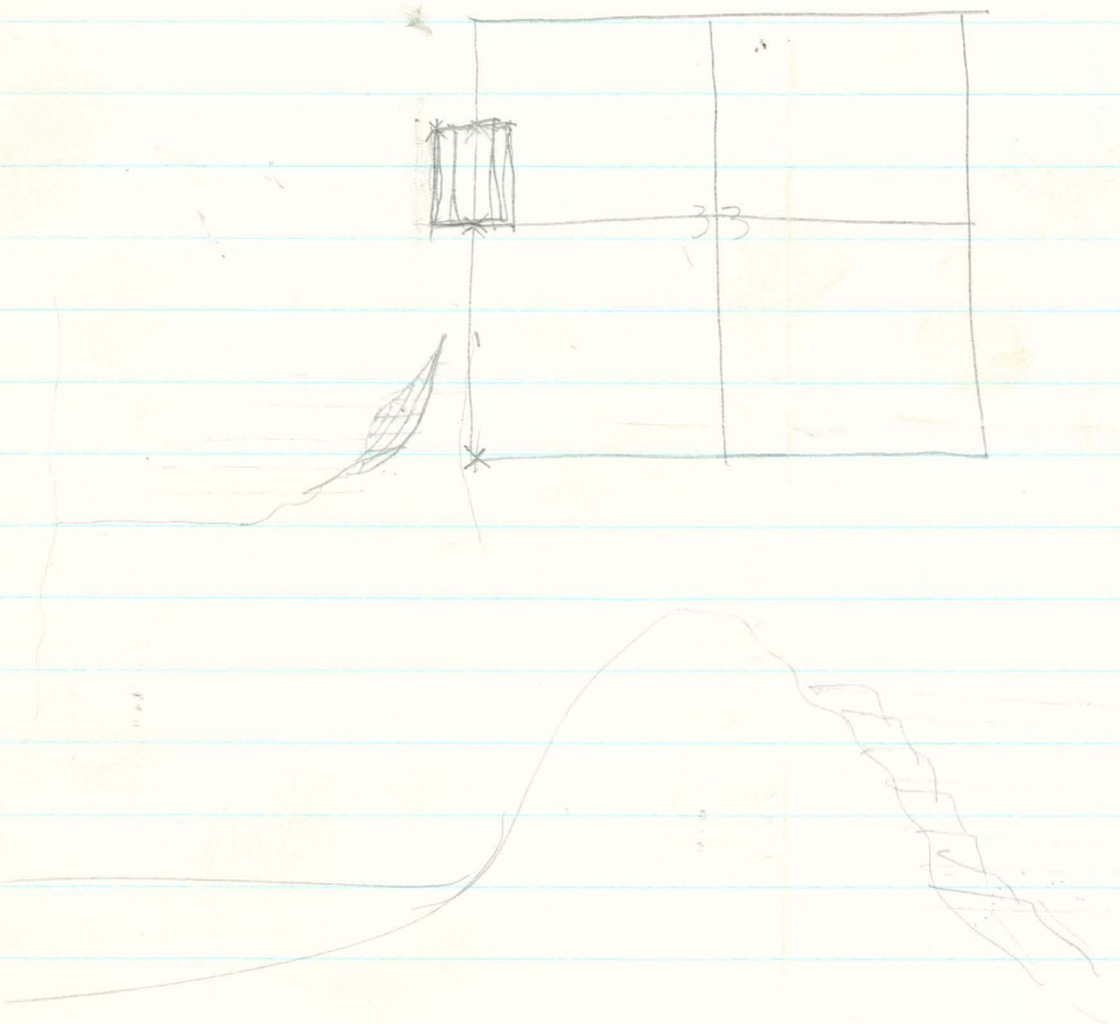
(n)–Techniques not investigated by author		Highly Useful	Moderately Useful	Marginally Useful	Not Useful
Ore Guides	Hematitic and Limonitic Stain	*	*		
Ore Guides	Surficial Radioact.			*	
Ore Guides	Breccia 'Reef' Zones			*	
Ore Guides	Copper Stain	*			
Ore Guides	Rock Chemistry			*	*
Ore Guides	Rock Brittleness		*		
Ore Guides	Intense Fault Branching	*			
Prospecting Techniques	Airborne Gamma-Ray Spectrometer Surv.			*	*
Prospecting Techniques	Ground Radioactivity Surv.		*		
Prospecting Techniques	Radon Emanometry			*	
Prospecting Techniques	Radon Track Etch Prospecting	*			
Prospecting Techniques	Sulfur Gas Sampling		*		
Prospecting Techniques	Geobotany				*
Prospecting Techniques	Biogeochemistry		*		
Prospecting Techniques	Horizontal Resistivity (n)	*			
Prospecting Techniques	Ground (n) Magnetometer Sur.				*
Prospecting Techniques — Soil Sampling	U			*	
Prospecting Techniques — Soil Sampling	Th				*
Prospecting Techniques — Soil Sampling	Cu		*		
Prospecting Techniques — Soil Sampling	Mo				*
Prospecting Techniques — Soil Sampling	Se				*
Prospecting Techniques — Soil Sampling	Zn			*	
Prospecting Techniques — Soil Sampling	Ni			*	
Prospecting Techniques — Soil Sampling	As			*	
Prospecting Techniques — Soil Sampling	Fe			*	

Water samples – } 10
Streamsediment
~~soil~~ samples – } 10

Water Samples –

Emigrant Creek
Gaerky Creek
Myer Creek
Kenucken Creek
Sams Creek
Rock Creek
Little Butte Creek
Snider Creek
Dry Creek
Long Branch

} 10



Notes + Comments on Uranium Deposits

Colorado Plateau U Deposits -

Most deposits occur in stream-laid sandstone lenses of sandstone in the Chinle + Morrison Formations.

Ore minerals partly replace fossil wood but mainly impregnate sandstone, forming tabular ore-bodies.

Deposits are epigenetic, but the source of the ore-metal, the nature of the ore bearing solution, ~~as~~ and the time of ore emplacement are uncertain.

Age - Uncertain but probably Cretaceous.

Mineralization - low intensity - only mild alteration - virtually without gangue minerals

Uranium near Grants, N. Mexico -

U occurs predominantly in continental sandstones of the upper Jurassic Morrison Formation. (some in limestones. Todilto) - Ore is mainly uraninite, uraniferous carbonaceous material coffinite, and oxidized minerals (tyuyamunite, carnotite, uranophane) or localized by mudstone, interstitial carbonaceous material.

Origin not simple - some ore bodies have been modified by Quaternary oxidation, solution, and enrichment.

Origin -

(1) Syngenetic - sandstone, mudstone, tuff, carbonaceous shale

(2)

Sedimentary syngenetic or penecsyngenetic processes.

Morrison sediments are distinctly tuffaceous and clearly indicate a volcanic provenance (lava flows, pyroclastics, geyser, hot spring deposits)

Methods of prospecting –
Traversing with radiation detectors – ground + air borne radiometric reco
& radiometric traverses; geobotanical sampling, test pitting, trenching, rim [illegible]
drilling (percussion, diamond core, rotary, non-core, all types of logging.

Lisbon Valley – Utah

Monument Valley – Utah   Shinarump (Congl. + Carb. shale) of Chinle Fm. of Triassic Age.
Carbonaceous plant remains and their decay products provided a reducing envi
to ppt uranium. soluble uranyl ion to insoluble uranous
*(1) leaching + erosion of large masses of granitic rocks, arkose, and tuffaceous sedim
or (2) from hypogene fluids generated by magmatic activity. * most plaus

Uravan mineral belt –
Ore occurs in the Salt Wash Member of the Morrison Fm. (Uranium – Vanadium)
large alluvial fan formed by an aggrading system of braided streams diverging to the
and east from an apex in south central Utah. 250' thick – interbedded [illegible]
sandstone + mudstone.
Sedimentary structures.
Current lineation, festoons, ripple marks, and scour + fill.
The association of ore deposits with coalified plant remains is not fully under
stood. The reason for localization of ore deposits is unknown.

Deposits of Wyoming + South Dakota   Wind River + Wasat
Host Rocks are medium to Coarse-grained sandstones deposited in conti
or brackish water environments and were derived in large part from th
granitic cores of the uplift and the sedimentary rocks that flank the cor
Age of the host rocks range from Cretaceous to Miocene, but mor
95% of the known reserves are in rocks of early Eocene age.
Unoxidized ore contains pyrite uraninite and/or coffinite, marcasite, hem
Jordisite – Deposits are in the form of ore rolls that contain from a few 100
a few 1000 tons range in grade from 0.1 to 1% U_3O_8