GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 68-74

OCCURRENCES OF URANIUM AND VANADIUM IN PRINCE EDWARD ISLAND

(Report and figure)

V. K. Prest, H. R. Steacy and T. J. Bottrill

GEOLOGICAL SURVEY

OF CANADA

CANADA

PAPER 68-74

OCCURRENCES OF URANIUM AND VANADIUM IN PRINCE EDWARD ISLAND

V. K. Prest, H. R. Steacy and T. J. Bottrill

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Available by mail from the Queen's Printer, Ottawa,

from Geological Survey of Canada,
601 Booth St., Ottawa,

and at the following Canadian Government bookshops:

HALIFAX
1735 Barrington Street

MONTREAL
Æterna-Vie Building, 1182 St. Catherine St. West

OTTAWA
Daly Building, Corner Mackenzie and Rideau

TORONTO
221 Yonge Street

WINNIPEG
Mall Center Bldg., 499 Portage Avenue

VANCOUVER
657 Granville Street

or through your bookseller

Price $ .75 Catalogue No. M44-68-47

Price subject to change without notice

ROGER DUHAMEL, F.R.S.C.
Queen's Printer and Controller of Stationery
Ottawa, Canada
1969

CONTENTS

ABSTRACT

Minor amounts of uranium associated with vanadium have been recognized in outcrop and at depth in the Permo-Carboniferous sediments of Prince Edward Island. Concentrations occur in greenish grey phases of the normally red sandstone, indicating a reducing environment. The uranium vanadates rauvite and francevillite, have been identified. Source of the uranium is believed to be older rocks to the west. Uranium is believed to have been precipitated under reducing conditions from percolating groundwaters.

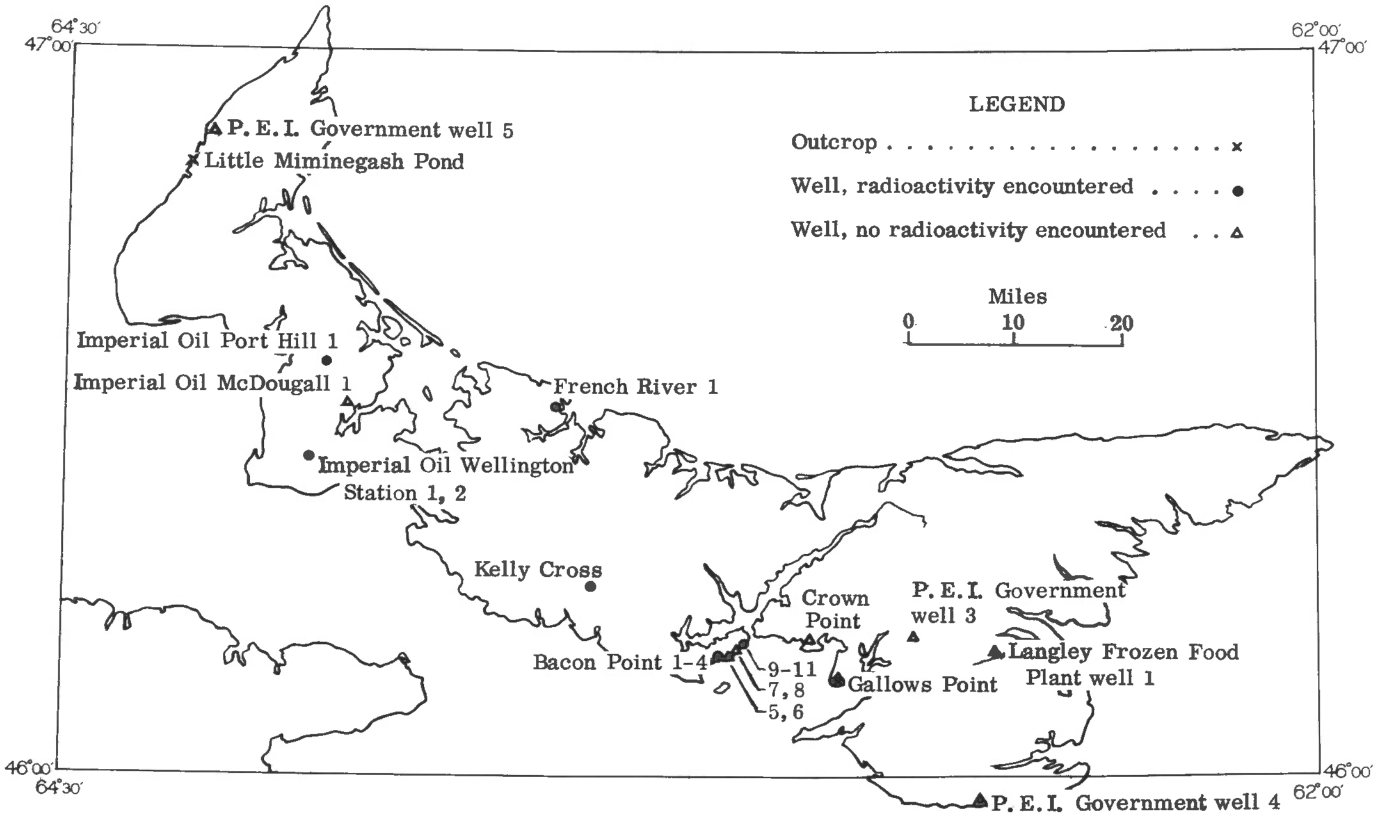

Figure 1. Location of wells monitored for radioactivity and of outcrop north of Little Miminegash Pond, Prince Edward Island.

INTRODUCTION

This report describes the first occurrences of uranium and vanadium in Prince Edward Island. They are unique in extending to Canada uranium-vanadium occurrences in continental sediments similar to those in the Carboniferous to Jurassic of the United States. The occurrences, in sandstone, extend the known geographic and stratigraphic distribution of uranium in the Maritime Provinces. While as yet insufficient data are available to appraise their economic significance the occurrences bear similarities in their geology and geochemistry to uranium deposits in sandstones in the Colorado Plateau (Finch, 1967).

Uranium occurrences elsewhere within the Permo-Carboniferous basin of the Maritime Provinces have been recorded or predicted by Brummer (1958), Gross (1957), Lang et al. (1962), Roscoe (1966), Rose (1967) and Smith (1969). Vanadium has been reported in trace amounts in the province by Rose (1967).

Uranium was first noted in a specimen collected from north of Little Miminegash Pond on the west coast of Prince Edward Island during normal field studies in the province. On November 20, 1968, officers of the Geological Survey of Canada on behalf of the Uranium Programme conducted a scintillometer survey and collected additional samples. Readings with the scintillometer of up to 3.5 times the background count were obtained on the cliff face between Little Miminegash Pond and Cape Gage. The highest readings were obtained on those grey and green phases of the normally red sandstone containing black patches different in appearance from carbonaceous 'trash'.

The availability at the Geological Survey of Canada of samples from wells drilled in the Maritime Provinces by oil companies, well drilling companies and agencies of the provincial and federal governments, presented an opportunity to test drill core and cuttings from 28 wells drilled in Prince Edward Island. Samples from 16 of these wells were tested for radioactivity with a sensitive laboratory Geiger counter. One of these contains five abnormally radioactive sections in greenish-grey sandstones.

The geographic and stratigraphic extension of uranium occurrences to the island, and the uranium-vanadium association, support the concept that concentrations of these metals may occur in the Permo-Carboniferous basin of the Maritime Provinces.

Project Number: 670029.
Manuscript received: 30 December 1968.
Authors' address: 601 Booth Street,
Ottawa 4, Ontario.

Acknowledgment is made to the Chemical Analysis Section, Extraction Metallurgy Division, Mines Branch for assays; and to the Mineralogy and Analytical Chemistry Sections of the Geological Survey of Canada for analytical work and laboratory assistance.

TOPOGRAPHY AND GLACIATION

Prince Edward Island is a rolling lowland generally less than 200 feet above sea level with a maximum elevation of about 470 feet. In the central and southeastern parts of the island the local relief may reach 300 feet, but in general is only a few tens of feet. Part of the western end of the island is noticeably low and flat. There are a few peat bogs, those in the west being the largest, with a diameter of about 1 mile.

During the last or Wisconsin Glaciation, Prince Edward Island was overridden by ice that moved east-southeast. The glacier receded by flowing in diverse directions controlled by topography and a rising sea level. Glaciation resulted in a widespread mantle of till and glaciofluvial deposits up to about 35 feet thick. In many parts of the island, where glacial drift is lacking a soil mantle is developed directly on the bedrock. Bedrock is poorly exposed but can be seen in sea-cliffs, road-cuts and other excavations.

AGE, LITHOLOGY AND STRATIGRAPHY

The strata of Prince Edward Island are part of the larger Carboniferous basin of the Maritime Provinces deposited as a result of the Maritime disturbance of the Appalachian orogeny. The strata in the west of the island are Upper Pennsylvanian (Stephanian) in age (Barss et al., 1963). Those around Hillsborough Bay and in the central area of the island are Lower Permian (Frankel, 1966). The age of the uppermost rock units on the island is not known; they are at least post-Lower Permian and according to Frankel may be as young as Mesozoic.

The predominant characteristic of all the stratigraphic units is their mixed lithology. The Permian and younger rocks of the eastern and central parts of the island, dominated by sandstones, have been divided by Frankel on the basis of their lithological characteristics into three major stratigraphic units. The lowermost unit, of Lower Permian age, consists of 3,500 feet of sandstone, mudstone, mudstone breccia, and minor conglomerate. These are followed by 1,700 feet of sharpstone conglomerate, greywacke and lithic sandstone (collectively 60%), together with arkose and feldspathic sandstone as in the lower unit. The conglomerate contains angular to subangular fragments up to six inches in length of quartz, quartzite, felsitic and porphyritic volcanics and some granitoid rocks of extra-basinal origin. Sorting is usually poor. Overall, this middle unit exhibits rapid and abrupt changes in facies.

The uppermost unit, only 225 feet thick, consists of sandstones similar to those of the lower units, but with 25 per cent of conglomerate and conglomeratic sandstone. The conglomerate consists of well-rounded disc or roller-shaped pebbles and cobbles 1/4-inch to 8 inches long, of quartzite and quartz. This unit is believed to rest with marked disconformity on the older unit.

DEPOSITIONAL ENVIRONMENT AND STRUCTURAL SETTING

The environment of deposition can be determined from the lithology, the sedimentary structure, the geochemistry, and fossil content of the beds. The strata are generally irregular, being commonly lenticular or wedge-shaped with marked crossbedding and scour-fill structures. Disconformities are common but because of the lack of horizon markers they cannot readily be traced for more than a few tens to locally more than a few hundreds of feet. Compaction and slump structure are also common, especially where massive beds of medium-grained sandstone have been deposited over mudstone. Mudstone, therefore, occurs both as very irregular beds and as lenses squeezed into the adjoining siltstone, sandstone or breccia units. Fairly continuous horizons of any of the lithologic units may be suddenly terminated by scour-fill deposits of another type.

The clastic sediments indicate a continental environment with dominantly oxidizing conditions. Additional evidence for this environment comes from the general lack and poor preservation of vegetal and vertebrate remains. The presence of iron in the red ferric state may be considered a strong argument for oxidizing conditions. However the possibility that a large part of the coloration may have been derived from older red sedimentary rocks should not be overlooked, because such rocks form an important part of the rock sequence in the adjoining Maritime Provinces. Also lithic fragments and pebbles of these older rocks have been noted in the island breccia and conglomerate.

The Pennsylvanian to post-Lower Permian strata indicate a gradual change from a deltaic-lacustrine environment to that of a flood plain and alluvial fan environment. Langston (1963) believes that the depositional characteristics together with the fossil content indicate: "... a subaerial, aggrading, and fairly well-drained surface, most probably deltaic, on which large lakes developed only occasionally and for relatively brief periods of time. The repetition of scour-fill features and torrential clastics indicate that subaerial surfaces were subjected to periodic and short-lived flooding from near-by uplands. Drainage was largely confined to a few large channels whose adjacent flood-plains were broad and relatively dry".

The strata are folded along northeast- to east-trending axes that in general appear to plunge gently eastward. Over large areas the strata appear to be flat-lying but where folds are known the beds have dips up to about 12 degrees. Steeper bedding-plane dips, up to about 40 degrees, represent a combination of structural dip and foreset bedding dips. Periods of gentle folding, separated by erosion intervals, took place during sedimentation of the complex island sequence. Though the Maritime disturbance had all but ceased by Permian time (Poole, 1967) it appears that minor post-Lower Permian deformation took place. The youngest rock unit for instance is preserved in down-warped and faulted areas. In the central parts of the island these strata are broken by faults of uncertain displacement that trend slightly north of east.

URANIUM OCCURRENCES

The discovery outcrop is one mile north of Little Miminegash Pond, Tignish map-area (Prest, 1962). Here the exposed red mudstone and sandstone is characterized by greenish grey reduction ellipsoids of which a few are radioactive. These range up to six inches in diameter and collectively appear to occupy about one per cent of the rock. Many ellipsoids have small centres of predominantly carbonaceous material. However those that are radioactive generally contain large, charcoal grey, noncarbonaceous centres. Samples in Table 1 are representative of those ellipsoids on the cliff face having the highest count in a scintillometer survey.

TABLE 1

ANALYSES FOR URANIUM, THORIUM AND VANADIUM OF SAMPLES COLLECTED NORTH OF LITTLE MIMINEGASH POND. (NTS 21 I/10W, 46°50'45"N., 64°15'30"W.)

Sample No.	Analyses in per cent U_3O_8	ThO_2	V_2O_5
1	0.042	0.003	5.00
2	0.075	0.004	3.92

Samples from 16 of the 28 wells drilled in Prince Edward Island (Howie, 1966) were monitored for radioactivity with an end-window Beta counter. These 16 wells represent only a small part of the stratigraphic sequence and are limited in their geographic coverage of the island (Fig. 1). The well samples consist of (a) nearly complete sections of core, (b) sections taken intermittently during the drilling to determine major stratigraphic changes, and (c) chip samples, each representing 10 or 50 feet intervals of core. Core is often missing due to poor recovery. Accordingly, some uranium-bearing strata may be missing.

Kelly Cross Well

The best results were obtained on a well drilled near the village of Kelly Cross. The radioactivity is associated with sections of core up to 2 feet long in which the sandstone is greenish grey, in contrast to the normal red. All of the radioactive sections are in grey sandstone, but not all grey sandstones are radioactive. The highest values are found at or near the bottom of the sandstone sections, at their contacts with compact mudstone. However, some of the less radioactive sections appear at intermittent levels in the sandstone, without any apparent lithological or stratigraphical controls. Where radioactive sandstone occurs directly above a mudstone, the top of the mudstone is grey-green.

Table 3 lists, by depth and length, the core analyzed for uranium, thorium and vanadium. Samples 1-9 inclusive were from beds found to be radioactive during the monitoring of the core. Samples 10-13 inclusive represent the common red bed lithologies selected to give background data. Analysis in Table 3, sample 1 to 9 inclusive, are on lengths of core extending beyond the radioactive sections indicated in the monitoring. The source of the radioactivity often appeared to be concentrated in the coarsest basal sections of the graded sandstones.

Other Wells

Radioactivity above normal background levels, but representing a content of less than 0.01 per cent U_3O_8 was detected in core sections from wells drilled at French River (No. 1), Bacon Point (Nos. 1, 5, 11), Wellington Station (No. 1) and McDougall. Only very limited lengths of the core are available for the Wellington Station No. 1 and McDougall wells. The remaining wells in Table 2 gave no indication of radioactivity during monitoring.

MINERALOGY AND GEOCHEMISTRY

The presentation of a detailed account of the mineralogy and geochemistry is beyond the scope of this paper. The following notes, therefore, are only of an introductory nature.

Two uranium minerals have been identified namely, rauvite, $CaO.2UO_3.5V_2O_5.16H_2O$ and francevillite (Ba, Pb) $(UO_2)_2$ $(VO_4)_2$ $5H_2O$. Both were identified in samples collected from the outcrop north of Little Miminegash Pond, and may represent the first Canadian occurrences of these two minerals. Rauvite occurs as a soft yellowish mass a few mm in diameter in the discovery specimen, and is apparently the source of the radioactivity of this specimen. Francevillite occurs as greenish yellow films along the perimeter of and within the black centre of sample No. 2 (Table 1). Identifications of the two minerals are based on their X-ray diffraction patterns.

TABLE 2

WELLS MONITORED FOR RADIOACTIVITY

Wells as nearly complete core sections

WELL NAME	LOCATION			COMPLETION			SAMPLED DEPTH
	GENERAL DESCRIPTION	CO-ORDS.	ELEV. (feet)	DEPTH (feet)	YEAR	AGE	
Kelly Cross No. 1	Village of Kelly Cross.	Lat: 46° 15'52" Long: 63° 26'45"	170	1501	1964	Permian	4-1501
French River No. 1	North of highway 7A, Lot 20.	Lat: 46° 30'30" Long: 63° 30'34"	90.53	200	1962	Permian	18.200
Bacon Point No. 1	About 350' from road along sixth lot-line west of Church.	Lat: 46° 9'51" Long: 63° 10'51"	102.6	51.5	1961	Permian	12.8-51.5
Gallows Point No. 2	Gallows Point, 10' from Gallows Point No. 1.	Lat: 46° 7'42" Long: 63° 57'28"	18.53	501	1962	Permian	9-501
Crown Point No. 1	On Crown Point Road.	Lat: 46° 11'2" Long: 63° 00'24"	12.49	615	1962	Permian	15-611
Wellington Station No. 2	Lot 16, about 154' south of Wellington Station No. 1.	Lat: 46° 26'10" Long: 64° 01'25"	41	364	1962	Permian Pennsylvanian	10-359
Bacon Point No. 5	About 500' from road along first lot line east of Church.	Lat: 46° 10'4" Long: 63° 10'2"	75.3	205.8	1961	Permian	9-205.8
Bacon Point No. 11	About 775' from road along sixteenth lot-line east of Church.	Lat: 46° 10'45" Long: 63° 8'50"	134.3	101	1961	Permian	7-99

Wells as intermittent core sections

WELL NAME	LOCATION			COMPLETION			SAMPLED DEPTH*
	GENERAL DESCRIPTION	CO-ORDS.	ELEV. (feet)	DEPTH (feet)	YEAR	AGE	
Imperial Oil Ltd. Wellington Station No. 1	Lot 16, about 2 miles southwest of Wellington.	Lat: 46°26'10" Long: 64°01'25"	41.62	9714	1958	M	20-9710
Imperial Oil Ltd. MacDougall No. 1	MacDougall	Lat: 46°30'32" Long: 63°56'29"	35.32	9082	1958	M	10-9082
Imperial Oil Ltd. Port Hill No. 1	South side of road about 1 1/2 miles west of Port Hill Station.	Lat: 46°34'17" Long: 63°48'54"	121.8	4649	1958	Pre-Carboniferous (granite)	10-4640

*No core was available between 0-1,000 feet.

Wells as chip samples

WELL NAME	LOCATION			COMPLETION			SAMPLED DEPTH
	GENERAL DESCRIPTION	CO-ORDS.	ELEV. (feet)	DEPTH (feet)	YEAR	AGE	
Langley Frozen Food Plant No. 1	East of Montague and north of C.N.R. tracks.	App: Lat: 46°10'11" Long: 62°38'36"	25	603	1963	Permian or Pennsylvanian	21-590
P.E.I. Government Well No. 3	About a mile east of Glencoe Station.	Lat: 46°11'26" Long: 62°47'24"	115	2044	1909	Permian or Pennsylvanian	60-2035
P.E.I. Government Well No. 4	1 1/4 miles west of Little Sands, Lot 62	Lat: 45°57'50" Long: 62°40'23"	30	2082	1909	Permian or Pennsylvanian	25-2030
P.E.I. Government Well No. 5	About 1 mile northeast of Miminegash.	App: Lat: 46°53'27" Long: 64°13'20"	20	1670	1910	Permian and Pennsylvanian (Pictou Group)	1670

TABLE 3

ANALYSES FOR URANIUM, THORIUM AND VANADIUM ON SECTIONS OF CORE FROM WELL DRILLED AT KELLY CROSS

Specimen	Depth (feet)	Length (inches)	Colour	Lithology	U_3O_8	ThO_2 as per cent	V_2O_5*
1	99	4	Red/Grey	Sandstone	.001**	.002	.100
2	99	2 1/2	Red/Grey	Mudstone	<.001	.0035	.027
3	712	2 3/4	Red	Sandstone	<.001	.0025	.018
4	712 3/12	3 1/2	Grey	Sandstone/ mudstone	.004	.0045	.068
5	712 6/12	2	Red	Mudstone	<.001	.0025	.014
6	716	6	Grey	Sandstone	.004	.001	.041
7	716 6/12	6	Grey Red	Sandstone Mudstone	.029	.001	.680
8	763	12	Grey	Sandstone	.004	.002	.130
9	911	2	Grey-green	Streaked sandstone	.004	.004	.920
10	768	24	Red	Sandstone	<.001	.003	.092
11	748	24	Red	Laminated mudstone	<.001	.0045	.027
12	890	24	Red	Siltstone	<.001	.004	.045
13	82	24	Red	Intraform-ational breccia	<.001	.002	<.005

* Analyses for $V_2O_5 \pm 15\%$.

**A radiometric count equivalent to 0.015% U_3O_8 was obtained over a limited area at the base of this specimen.

Sample No. 2 is essentially an arenite with an iron-vanadium rich centre. A qualitative spectrographic analyses of the whole specimen showed a content as follows.

MAJOR	MINOR	STRONG TRACE	TRACE
silicon	iron	zircon	nickel
aluminium	titanium	manganese	calcium
	magnesium		strontium
	vanadium		barium
			yttrium
			cobalt
			lead
			uranium

A qualitative X-ray fluorescence analysis of a selected portion of the black centre gave the following content.

MAJOR	MEDIUM	MINOR	TRACE
vanadium	copper	uranium	yttrium
iron	selenium	zinc	strontium
		manganese	rubidium
		titanium	zirconium
			calcium

The same portion contained only 0.04 per cent total carbon, indicating that the centre is chemically distinct from the otherwise carbonaceous centres. Autoradiographs indicate discrete radioactive mineral grains. Doloresite $3V_2O_4.4H_2O$ has been tentatively identified as one of the constituents of the black matrix.

Sparse yellowish grains of vesigniéite $Cu_3Ba(VO_4)_2(OH)_2$ were observed in the sandstone, at and near its contact with mudstone in the core at a depth of 99.5 feet in the Kelly Cross well. Also non-uraniferous vanadium compounds are present as yellow to greenish yellow stains on the discovery specimen. These stains prompted the initial tests for vanadium and uranium.

The minerals are of secondary origin and were probably formed in hydrous oxidizing conditions from both extrinsic and intrinsic elements in the arenites. The extrinsics are probably uranium, vanadium, copper, iron, selenium, nickel, zinc, cobalt and barium. Elements with which uranium would appear to have the strongest geochemical affinity are vanadium, iron and copper.

Fischer and Stewart (1961) report that deposits of uranium, vanadium, and copper in sandstones can be divided on the basis of the geochemical cycles of these elements, and suggest that a selective relationship exists between the metal content and the genetic character of the host rock. Uranium with copper occurs in first generation sandstones, and uranium with vanadium in second generation sandstones. The uranium occurrences known elsewhere in the basin can be distinguished from those on the island by their respective associations with either copper or vanadium. The genetic character of the host rock changes with stratigraphic position so that the island deposits occur in rocks younger than the hosts of other Maritime basin occurrences. There is therefore a possible genetic distinction in the time of formation between island occurrences and those elsewhere in the basin.

ORIGIN

The authors believe these occurrences on Prince Edward Island to be of penesyngenetic origin, the metals having been concentrated by precipitation from percolating pore waters in areas of relatively strong reducing conditions. They were concentrated by the continual evaporation of pore-waters with a normal ionic content of metals, that were trapped in the restricted drainage basin at the time of deposition.

There is an observed relationship of genetic significance, between concentrations of metals and green-grey arenites. This coloration is indicative of a reducing environment, suitable for precipitation of the metals. Suitable reducing conditions could have been created by the presence of sulphides, bacteria, or carbonaceous material, or by a restricted water flow during deposition and diagenesis. That the drainage was restricted, probably to a local basin, is indicated by the presence of coal and saline deposits (Howie, personal communication). The normal content of salts and humic acid would have been trapped in the sediments in a closed drainage system being retained as sedimentary pore-waters, at least until later deformation. Thus suitable conditions for the existence of a reducing environment could have occurred over a long period from the time of the original deposition until the groundwaters migrated, long after diagenesis.

The metals were derived from either the rocks involved in the Appalachian orogeny adjacent to the basin, the Windsor volcanics, or from overlying Triassic volcanics known to occur elsewhere in the Maritime Provinces. The association of the copper with first generation sandstones, and of vanadium with second generation sandstones indicates that each of these metals is associated with the deposition of its individual host rocks. The metals taken into solution in the pore-waters of the source rocks would have been precipitated in those parts of the sediments which were relatively strongly reducing. However, some of the uranium may have been derived from the breakdown of resistates and rock fragments in the sediments and taken into solution by percolating groundwaters.

The occurrences may also represent, in part, metals redissolved in local groundwaters and concentrated by continual percolation through restricted reducing areas suitable for their precipitation. The present minerals were formed in hydrous oxidizing conditions long after this initial precipitation. The minerals have not been identified from depths below the probable zone of recent oxidation.

GUIDES TO EXPLORATION

The foregoing data have emphasized certain characteristics of the uranium occurrences which may be used as guides to exploration. These are:

(1) Sedimentary formations in which sandstones and mudstones are predominant.

(2) Frequent occurrence of lithological interfaces of the two major members, and the presence of channel features.

(3) Greenish-grey phases of the normally red arenites.

(4) Geochemical association of uranium, vanadium, copper and iron.

SELECTED BIBLIOGRAPHY

Bain, F.
1881: Notes on fossils from the red sandstone system of Prince Edward Island; Can. Naturalist, vol. 9, pp. 463-464.

Bain, F., and Dawson, J. W.
1885: Notes of the geology and fossil flora of Prince Edward Island; Can. Record Sci., vol. 1, pp. 154-161.

Barss, M.S., Hacquebard, P.A., and Howie, R.D.
1963: Palynology and stratigraphy of some Upper Pennsylvanian and Permian rocks of the Maritime Provinces; Geol. Surv. Can., Paper 63-3.

Brummer, J.J.
1958: Supergene copper-uranium deposits in Nova Scotia; Econ. Geol., vol. 53, p. 309.

Crowl, G.H.
1960a: Surficial geology, Mount Stewart, Prince Edward Island; Geol. Surv. Can., Map 36-1960.

1960b: Surficial geology, Souris, Prince Edward Island; Geol. Surv. Can., Map 37-1960.

Dawson, J.W.
1854: On fossil coniferous wood from Prince Edward Island; Proc. Acad. Nat. Sci. Philadelphia, vol. 7, pp. 62-64.

1891: The geology of Nova Scotia, New Brunswick and Prince Edward Island or Acadian Geology; Macmillan & Co. Ltd., London, pp. 1-694.

Ells, R.W.
1884: Report on explorations and surveys in the interior of the Gaspé Peninsula and Prince Edward Island; Geol. Surv. Can., Rept. Prog. 1882-83-84, Pt. E, 1883, pp. 11-19.

Finch, W.I.
1967: Geology of epigenetic uranium deposits in sandstone in the United States; U.S. Geol. Surv., Prof. Paper 538.

Fischer, R.P., and Stewart, J.H.
1961: Copper, vanadium and uranium in sandstone - their distribution and geochemical cycles; Econ. Geol., vol. 56, 3, pp. 509-520.

Frankel, L.
1960: Surficial geology, Montague, Prince Edward Island; Geol. Surv. Can., Map 33-1960.

1961: Surficial geology, Rustico (East Half), Prince Edward Island; Geol. Surv. Can., Map 34-1961.

1966: Stratigraphy and structure of southeastern Prince Edward Island; Geol. Surv. Can., Bull. 145, Part I.

Garrells, R.M., and Larsen, E.S., 3d; compilers
1959: Geochemistry and mineralogy of the Colorado Plateau uranium ores; U.S. Geol. Surv., Prof. Paper 320.

Gross, G.A.
1957: Uranium deposits in Gaspé, New Brunswick, and Nova Scotia; Geol. Surv. Can., Paper 57-2.

Gussow, W.C.
1953: Carboniferous stratigraphy and structural geology of New Brunswick, Canada; Am. Assoc. Pet. Geol., vol. 37, No. 7.

Holden, R.
1913: Some fossil plants from Eastern Canada; Ann. Botan., vol. 27, No. 106, pp. 243-255.

Howie, R. D.
1966: Catalogue of well samples from Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland at the Geological Survey of Canada, Ottawa; Geol. Surv. Can., Paper 65-40.

Lang, A. H., Griffith, J. W., and Steacy, H. R.
1962: Canadian deposits of uranium and thorium; Geol. Surv. Can., Econ. Geol. Ser. No. 16.

Langston, W., Jr.
1963: Fossil vertebrates and the Late Palaeozoic red beds of Prince Edward Island; Nat. Mus. Can., Bull. 187.

Leidy, J.
1885: On Bathygnatus borealis, an extinct Saurian of the new red sandstone of Prince Edward Island; Am. Jour. Sci., ser. 2, vol. 19, pp. 444-446.

McKay, E. J.
1955: Criteria for outlining areas favourable for uranium deposits in parts of Colorado, Utah; U.S. Geol. Surv., Bull. 10095-J.

Milligan, G. C.
1949: Geological Survey of Prince Edward Island; Dept. Industry, Nat. Resources, Charlottetown.

Melin, R. E.
1957: Selected annotated bibliography of the geology of sandstone type uranium deposits in the United States; U.S. Geol. Surv., Bull. 1059-C.

Owen, E. B.
1949: Pleistocene deposits of O'Leary map-area, Prince County, Prince Edward Island; Geol. Surv. Can., Paper 49-6.

Poole, W. H.
1967: Tectonic evolution of the Appalachian region of Canada; Geol. Assoc. Can., Spec. Paper No. 4, Geology of Atlantic region.

Prest, V. K.
1962: Geology of Tignish map-area, Prince County, Prince Edward Island; Geol. Surv. Can., Paper 61-28.

1964: Geology of Charlottetown map-area, Prince Edward Island; Geol. Surv. Can., Paper 64-16.

Prest, V.K., and Brady, J.G.
1964: The geology and ceramic properties of shale from Bacon Point, Prince Edward Island; Geol. Surv. Can., Paper 63-35.

Roscoe, S.M.
1966: Unexplored uranium and thorium resources of Canada; Geol. Surv. Can., Paper 66-12.

Rose, E.R.
1967: Vanadium occurrences in Canada; Geol. Surv. Can., Paper 66-57.

Smith, A.Y.
1969: Uranium in stream sediments in southeastern New Brunswick; N.B. Dept. Mines, Information Circular 68-3.

Watson, L.W.
1912: The geological age of Prince Edward Island; Trans. Nova Scotian Inst. Sci., vol. 13, Pt. 2, pp. 145-149.