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PRELIMINARY GEOLOGICAL INTERPRETATION OF WELL WATER URANIUM ANOMALIES, CARBONIFEROUS BASIN, MARITIME PROVINCES

by

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INTRODUCTION

This report which supplements Open File Report 340 (Dyck et al., 1976a) presents a preliminary geological interpretation of the uranium anomalies detected during an orientation survey of water wells in parts of New Brunswick, Nova Scotia and all of Prince Edward Island. Particular attention is given to northern Nova Scotia where many anomalies are located. The well water data are compared with data of stream sediment surveys in northern Nova Scotia (Little and Durham, 1971) and southeastern New Brunswick (Smith, 1968) and with the results of an airborne gamma-ray spectrometer survey on Prince Edward Island (Richardson and Holman, 1975). The compilation of this report is based on published data only, and it is hoped that the conclusions will aid in further exploration work.

Brief summaries on geologic and physiographic aspects of the Maritime Provinces are given in Open File Report 340. The major features of the Carboniferous to Triassic stratigraphy are given in Table I. A recent publication (Dyck et al., 1976b) summarizes the data of Open File Report 340.

PROCEDURE OF EVALUATION

The well water uranium values exceeding 1 ppb uranium were computer-contoured (Dyck et al., 1976a) and indicate a number of anomalies with varying intensities (Fig. 1). The generally higher uranium values in northern Nova Scotia form a large regional high. Areas with no samples or with low uranium values within this regional high are represented by several geochemical depressions which can easily be mistaken by the unaware reader for uranium highs, e.g. two areas along the coast northeast of Pugwash.

Table III lists all anomalies with at least two values exceeding 4 ppb uranium except for two occurrences, west of New Glasgow (location no. 2) and west of Kentville (location no. 14), which are based on a single high uranium value with a low uranium background in the surrounding area. The significance of these two "anomalies" is questionable.

The anomalies of Table III were evaluated with respect to

a) location,

b) intensity,

c) host rock,

d) rock unit underlying the host rock,

e) associated minerals.

TABLE I CARBONIFEROUS TO TRIASSIC STRATIGRAPHY IN THE MARITIME PROVINCES (modified after Kelley, 1970 and Little and Durham, 1971)

AGE	GROUP	LITHOLOGY
Triassic	Fundy	basalt in upper part; red conglomerate, sandstone, siltstone, and shale in lower part
Stephanian to Early Permian	Upper Pictou	predominantly red sandstone, conglomerate and shale
Westphalian C and D	Lower Pictou	brown and grey sandstone, mudstone and conglomerate; grey and red wacke; carbonaceous shale; coal
Westphalian A and B	Cumberland	brown, red, green and grey sandstone, shale and conglomerate; coal
Late Namurian and Westphalian A	Riversdale	grey to black, locally red, shale, sandstone, siltstone, and, locally, conglomerate
Late Viséan to Late Namurian	Canso	red, green, and grey mudstone, sandstone, shale, siltstone, and argillite
Viséan to Early Namurian	Windsor	red and grey shale and limestone, gypsum, anhydrite, salt; minor limestone conglomerate
Late Devonian, Tournaisian, and Early Viséan	Horton	red and grey sandstone, shale, mudstone, siltstone; grit, conglomerate, arkose; locally volcanic tuff, breccia and flows in lower part

EVALUATION

a) LOCATION

It is quite evident from Figure 1 that most uranium anomalies occur in northern Nova Scotia. On Table III Column I all significant anomalies are listed and are arranged approximately from east to west.

b) INTENSITY OF URANIUM ANOMALY

The highest uranium values, up to 52 ppb U, occur in northern Nova Scotia in a belt of densely packed anomalies (locations 1 through 11). Another area occurs in the Tormentine region of southeastern New Brunswick where four values exceed 10 ppb uranium. Beyond these two regions the intensities of the uranium anomalies drop off considerably, and the anomalies are widely scattered.

c) HOST ROCK

It is appropriate to emphasize at this point that most of the tested wells were sunk into glacial sediments that cover most of the Maritimes. It is not known, however, how many of the wells penetrate the glacial sediments into the underlying bedrock. In the low-lying areas of Cumberland and Pictou Counties the glacial sediments have an average thickness of 4.5 to 7.5 m and 1 to 4.5 m respectively (Nowland and MacDougall, 1973; Cann and Wicklund, 1950), but are considerably thicker along the slopes of upland areas (D.R. Grant, pers. comm. 1977). As the thin till cover is a poor aquifer (Brown, 1970), it is likely that most wells were drilled through the glacial sediments. This is supported by the fact that most wells in the lowland regions are deeper than 10 metres (Dyck et al., 1976a, Map no. 3).

The close relationship of most uranium anomalies with a particular bedrock unit probably justifies the assumption that the well water properties are largely derived from the bedrock which is here referred to as the host rock.

The majority of anomalies appear to be related to rocks of the Pictou Group, and they are particularly concentrated in the lower Pictou of Westphalian C and D age. In the Tormentine region of New Brunswick the host rock appears to be the sandstone member of cycle III of the Pictou Group (Van de Poll, 1973). On Prince Edward Island the anomalies probably occur in stratigraphically higher strata of the upper Pictou Group that are known to contain spores of Stephanian and Early Permian age (Barss et al., 1963; Hacquebard, 1972).

Table II illustrates which rock units appear to give rise to the uranium anomalies observed in the well water.

TABLE II RELATIONSHIP OF ROCK UNITS TO WELL WATER URANIUM ANOMALIES

ROCK UNIT	LOCATION NO.	NO. OF ANOMALIES
Pictou: lower	5,6,7,8,10,12,16, part of 1 and 3,	8
upper	15,18,19, part of 1 and 3	4
Lower Pictou and Riversdale	4,9	2
Lower Pictou and Moncton	17	1
Triassic Sediments	14	1
Triassic and Horton	13	1
New Glasgow Conglomerate	2	1
Windsor	11	1
		19

Only 4 of the 19 anomalies are restricted to non-Pictou rocks and two of these are based on single high values.

The Riversdale anomaly in the southern part of the River John area (location no. 4) occurs in rocks that were originally mapped by Fletcher (1893) as Middle and Upper Permian and were later called the Pictou Group by Bell (1925, 1944). Bell reassigned some of the Middle and Upper Permian of Fletcher to the Riversdale. Belt (1965) re-examined the Canso and Riversdale and, in some areas such as near Tatamagouche, River John and along the northern shore of the Malagash Peninsula remapped some of the Riversdale rocks as part of the Pictou Group. The mapping history shows that a convincing assignment to the lower Pictou or to the upper Riversdale appears to be difficult. Therefore, the uranium anomaly in the Riversdale at location 4 may actually occur in the lower Pictou.

The New Glasgow Conglomerate west of New Glasgow (location no. 2) had originally been mapped by Fletcher (1893) as a basal "Pictou" conglomerate but was later reassigned by Bell (1925) to a stratigraphic position now regarded as equivalent to the lower Cumberland Group.

It is interesting to note that the coal-bearing sequence of the Cumberland Group is virtually devoid of uranium anomalies. The red Triassic sediments host only minor anomalies despite their superficial resemblance with some of the Pictou sediments.

The high proportion of anomalies in lower Pictou rocks could be due to a larger percentage of tested wells being drilled into the lower Pictou. However, of 1721 well sites sampled only 335 or 19.4% are underlain by lower Pictou bedrock. A more detailed breakdown according to map-areas is shown below. The four 1:500,000 map-areas approximately quarter the sampled area:

Map Sheet 1:500,000	Number of wells underlain by lower Pictou bedrock	Percentage of total wells (1721 sites)
Moncton	35	2.0
Amherst	69	4.0
Truro	231	13.4
Charlottetown	-	-
	335	19.4

d) UNDERLYING ROCK UNITS

Table III illustrates that the host rocks giving rise to the uranium anomalies are in most cases separated from underlying rock units by an unconformity which does not necessarily imply an angular contact relationship, but it does imply a hiatal period preceding the deposition of the overlying unit. This is particularly true for the lower Pictou Group which appears to be the source of the most promising anomalies. The rocks underlying the Pictou in northern Nova Scotia belong mostly to the Riversdale Group east of the Malagash Peninsula and to the Windsor Group west of it (Ells, 1885, p.41E; Bell, 1944, p.31-54). The implications of this relationship are discussed later.

e) ASSOCIATED MINERALS

There is an association of uranium anomalies with copper sulfides and pyrite (Gross, 1957; Brummer, 1958). This relationship is indicated as well by superimposing the uranium anomalies on the geological maps prepared by Fletcher (see map references for more information). Both Fletcher (1893) and Ells (1885) drew attention to the copper occurrences which were sporadically mined around the turn of the century. Fletcher in particular was apparently a keen recorder of mineral occurrences and, on the basis of regional copper showings, proposed two copper zones in the lower part of his unit G4b (Middle and Upper Permian) which is now largely assigned to the Pictou Group. The two copper zones are shown on Figures 1 and 2. Many of the uranium anomalies are on or near these two copper zones of Fletcher, and such a spatial association is referred to in Table III Column V as "north Cu-zone" or "south Cu-zone". At two localities barite has been recorded by Fletcher close to present-day uranium anomalies.

Unfortunately Fletcher's mineral showings have not been transferred onto later geological maps. However, the copper potential of the Upper Carboniferous in the Maritime Provinces has been repeatedly investigated (Papenfus, 1931; Wiese, 1957 and Brummer, 1958).

COMPARISON OF WELL WATER ANOMALIES WITH STREAM SEDIMENT AND AIRBORNE GAMMA-RAY SPECTROMETER DATA

The well water anomalies were compared with stream sediment anomalies in southwestern New Brunswick (Smith, 1968) and in northern Nova Scotia (Little and Durham, 1971). No comparable stream sediment values are published for the Tormentine area of New Brunswick and for Prince Edward Island. Anomalies equal to and exceeding 1 ppm uranium are shown on Figure 2.

There is a considerable similarity between the anomaly pattern established by the well water and stream sediment surveys. The area of northern Nova Scotia shows the same dense pattern of anomalies for stream sediments as was obtained from the well water data. Elsewhere the anomalies are scattered.

Almost all stream sediment anomalies in northern Nova Scotia are close to or overlap with well water anomalies. In the Tatamagouche and River John regions (areas 4 and 5) four stream sediment anomalies appear to occur upstream from high well water values.

A number of rather localized stream sediment anomalies appear to follow the fault zone on the south side of the Cobequid Mountains, Nova Scotia, a pattern not reflected by the well water data.

Table III Major characteristics used in the evaluation of uranium anomalies

LOCATION	NUMBER	RANGE OF ANOMALY (in ppb U)	HOSTROCK RELATED TO URANIUM ANOMALY UNDERLYING ROCK Unconformity / Normal contact	REMARKS
NOVA SCOTIA				
PICTOU area:				
north & northwest	(1)	1-16	LOWER AND UPPER PICTOU RIVERSDALE	north copper zone
south	(2)	<1-12	NEW GLASGOW Cgl. RIVERSDALE, CANSO	only one anomalous value
RIVER JOHN area:				
northeast & central	(3)	2-52	LOWER AND UPPER PICTOU RIVERSDALE	with copper & barite
south	(4)	6-20	Lower PICTOU RIVERSDALE	north copper zone, barite
"	(4)	1-22	RIVERSDALE RIVER JOHN	south copper zone
TATAMAGOUCHE area:	(5)	1-30	Lower & basal PICTOU RIVERSDALE	near north copper zone
MALAGASH PENINSULA	(6)	1-8	basal PICTOU WINDSOR	with copper
WENTWORTH CENTRE area:				
north & central	(7)	1-31	Lower PICTOU basal PICTOU Cgl.	north copper zone
southwest	(7)	2-5	Lower PICTOU basal PICTOU Cgl.	south copper zone
PUGWASH area:	(8)	1-26	Lower PICTOU WINDSOR	with copper
OXFORD area:	(9)	18 to	basal PICTOU WINDSOR, RIVERSDALE	
	(9)	20	RIVERSDALE CANSO	
SHINIMIKAS RIVER area				
north & northeast	(10)	2-22	Lower PICTOU WINDSOR?, RIVERSDALE?	with copper
south	(11)	1-6	WINDSOR ?	
AMHERST area:	(12)	1-5	Lower PICTOU WINDSOR	
TRURO area:				
north	(13)	1-6	TRIASSIC SED. WINDSOR, HORTON	
south	(13)	1-5	HORTON ?	
KENTVILLE area	(14)	<1-14	TRIASSIC SED. pre-Carb. basement	only one anomalous value
NEW BRUNSWICK				
TORMENTINE area	(15)	1-20	Upper PICTOU, cycle III SS Lower PICTOU, cycle II fines	
MONCTON area:	(16)	1-8	Lower PICTOU, cycle II fines Lower PICTOU, cycle II SS	
SALISBURY area:	(17)	1-18	MONCTON ?	
	(17)	1-9	Lower PICTOU, cycle II SS Lower PICTOU, cycle I fines	
PRINCE EDWARD ISLAND				
central	(18)	1-7	Upper PICTOU, unit A3 SS Upper PICTOU, unit A2	
northwest	(19)	1-5	Upper PICTOU Upper PICTOU	

The well water anomalies on Prince Edward Island are not reflected by data of a recent airborne gamma-ray spectrometer survey (Richardson and Holman, 1975). The uranium values of the spectrometer survey show a rather random pattern broken only by a fairly strong easterly trending anomaly east of Summerside in the drainage area of the Dunk and Trout rivers in west-central Prince Edward Island. The moderately high uranium anomaly (1.2 to 1.6 ppm) follows approximately the eastnortheasterly trend of broad folds mapped by Frankel and Crowl (1970). This particular area is quite negative with regard to well water data.

A drill hole near Kelly Cross, P.E.I., showed uranium concentrations (0.029% U_3O_8) at a depth of 219 m (718 feet) (Prest et al., 1969). The drill site is only 10 km south of the centre of the airborne spectrometer uranium high, and it is possible, on the basis of fairly steep dip readings of up to 70° nearby, that the uranium-bearing strata at depth outcrop to the north. Clearly, more field work needs to be done in this area.

Airborne gamma-ray spectrometer data for the River John-Tatamagouche area of northern Nova Scotia will be released by the Geological Survey of Canada in 1977.

DISCUSSION

The depositional environment of the Pictou Group in the Maritime Provinces was such that it could have led to the formation of uranium-vanadium-copper deposits of the Colorado Plateau type. Most of the criteria required by Stanton (1972) and Grutt (1972) for the formation of such deposits are met. The following is a list of criteria which according to Grutt (1972) indicate optimum conditions for a rock unit to be a potential host of uranium mineralization:

1) medium to coarse, poorly sorted sandstones,

2) grey, green or tan sandstones with interbedded grey and/or green mudstones,

3) finely divided pyrite in unoxidized sandstones,

4) limonite- and/or hematite-stained outcrops,

5) ratios of sandstone to shale of 1:1 to 4:1,

6) sandstones dipping less than 5°,

7) sandstones containing anomalous vanadium, molybdenum, and selenium,

8) detrital sediments containing vegetal carbonaceous material or other reducing agents,

9) radioactivity anomalies greater than 5 times background,

10) U_3O_8 geochemical stream sediment anomalies greater than 5 ppm,

11) U_3O_8 in groundwater greater than 10 ppb and

12) oxidized uranium minerals in outcrops.

Additional criteria mentioned by Grutt (1972) in the same context are:

a) fluvial sandstones,

b) derived from provenance of granitic and metamorphic rocks or clastic rocks,

c) near an unconformity,

d) stratigraphically lower than tuffaceous measures,

e) feldspathic, arkosic or quartzose sandstones, and

f) in intracratonic basins.

The mineralized horizons in the Pictou Group described by Papenfus (1931), Brummer (1958) and Gross (1957) meet the textural and mineralogical requirements. Brummer (1958, p. 312) describes the sulfide-bearing Pictou as follows: "Sulfides occur only in the light-grey sandstone, arkose, and shale layers, which are thin, lenticular, and occur interbedded with red mudstones or red-brown argillaceous sandstones at four or five different horizons in the sequence. The minerals are erratically distributed throughout the gray sediments and are invariably associated with carbonized plant-fragments". Gross (1957, p. 19) describes the Pictou as "grey sandy beds which contain copper minerals and limonitic specks associated with uraniferous carbonaceous material". The mineralized clastics are generally described as coarse, gritty and conglomeratic (Brummer, 1958).

The Pictou sediments are mostly fluvial in origin (van de Poll, 1973); their arkosic nature suggests a granitic or metamorphic provenance; they overlie an unconformity (Bell, 1944; Kelley, 1970; van de Poll, 1972) and were deposited in an intracratonic basin. The Pictou Group generally displays fairly shallow dips.

Criterion 10 states that stream sediment anomalies should exceed 5 ppm U_3O_8 or 4.25 ppm U. Little and Durham (1971) show several uranium highs with up to 3 ppm U and report values exceeding 3 ppm U that were not indicated on their map. Smith's (1968) report on southeastern New Brunswick shows many values exceeding 5 ppm U. Criteria 11 requires that groundwater anomalies should exceed 10 ppb U_3O_8 or 8.5 ppb U. Table III illustrates that most well water uranium anomalies in the lower Pictou Group reach much higher values than 8.5 ppb U.

Criteria 10 and 11 are based on data collected in regions with generally drier climates than the humid-temperate climate of the Maritime Region. Therefore, the values of 5 ppm U and 10 ppb U which Grutt (1972) proposed as guide figures for uranium exploration by the stream sediment and groundwater method respectively, may be considerably lower in areas with a high rainfall and more intense weathering.

Unfortunately no information is available with respect to conditions 5 (sandstone-shale ratio), 7 (values for Mo, V and Se) and 9 (background radioactivity).

Oxidized uranium minerals in outcrop (condition 12) have not yet been recognized in northern Nova Scotia. The apparent lack of such minerals may also be related to climatic conditions.

So far there is only one criterion (condition d - stratigraphically below tuffaceous measures) that does not satisfy the requirements for the formation of uranium mineralization.

The above comparison of required and existing criteria certainly suggests that uranium deposits of the roll front or blanket type could have developed in the lower Pictou of northern Nova Scotia. Crossbed measurements by van de Poll (1973) indicate a fairly uniform easterly current direction for the Pictou Group in New Brunswick. This current trend can be assumed to continue into northern Nova Scotia but should be verified. Replacement of plant cell structures by copper sulfides and pyrite (Papenfus, 1931; Brummer, 1958) suggests an early period of mineralization, probably during early Pictou time while there was still a regional easterly groundwater gradient. Uranium roll fronts would have progressed in the same general easterly direction.

THOUGHTS ON THE ORIGIN

The unconformable relationship of the Pictou Group with earlier strata (Bell, 1944; Kelley, 1970; van de Poll, 1972) suggests a period of erosion and nondeposition prior to renewed subsidence and deposition of Pictou sediments. During the late stage of the pre-Pictou hiatus, weathering rather than erosion was probably the dominant process and areas underlain by incompetent rocks such as the evaporite-bearing Windsor Group, were likely to become the site of wide, shallow topographic depressions. Prolonged weathering could have led to a first stage concentration of uranium and base metals in such low-lying areas.

Predominantly coarse clastics of the lower Pictou Group spread eastward, across a large section of the Maritimes. Oxidizing groundwater flowing through these initial sediments west of the Malagash Peninsula in northern Nova Scotia probably collected a large amount of solubles from the underlying, evaporite-bearing Windsor Group. As a consequence the groundwater

became alkaline making it an excellent potential carrier for base metals and uranium. Changes in alkalinity and in the redox potential occurred when the groundwater encountered near-stagnant conditions or flowed through buried swamps, meander cut-offs, etc. Any large amount of buried organic matter would have acidified the groundwater, creating reducing conditions and leading to the precipitation of sulfides and uranium minerals.

Such an interpretation could explain the dense pattern of well-water uranium anomalies in northern Nova Scotia. West of the Malagash Peninsula Pictou sediments rest in many places directly on Windsor sediments (Ells, 1885, p. 41E; Bell, 1944, p. 31-54) and may have become the site of second-stage concentration of uranium remobilized by alkaline groundwater from first-stage concentration pockets below. Groundwater could have continued to mineralize favourable Pictou strata in an easterly, down-drainage direction (Tatamagouche and River John areas) where the Pictou Group rests on Cumberland and Riversdale sediments.

The lack of anomalies in the easternmost-Pictou outcrops northeast of New Glasgow could be due to a number of factors each of which is highly speculative since the geochemical survey was discontinued east of New Glasgow.

It has been assumed above that the lower Pictou Group of New Brunswick continues into northern Nova Scotia. Maps by Gussow (1953, fig. 6) and van de Poll (1973, fig. 2) indicate such a trend. It is equally possible that the lower units of the Pictou Group thin to the east and that some of the Pictou sediments in northern Nova Scotia are represented by cycle III (van de Poll, pers. comm. 1977) or the Richibucto Formation of the Pictou Group (Gussow, 1953). Such an interpretation would explain the continuation of uranium anomalies into the Tormentine Peninsula of New Brunswick. However, biostratigraphic evidence (Bell, 1944, p. 29, fig. 11; Barss et al., 1963; Barss and Hacquebard, 1967; Hacquebard, 1972, p. 80-82) indicates that nearly all Pictou strata in northern Nova Scotia are of Westphalian C and D age. Spores of Stephanian age have been found only in part of the River John - Toney River area (Hacquebard, 1972, fig. 7).

Additional biostratigraphic and, particularly, lithostratigraphic data are needed to refine the correlation of the Pictou Group in the Maritime Provinces and to determine possible differences in paleocurrent directions. If uranium and copper mineralization in northern Nova Scotia is an early epigenetic event accurate knowledge of the direction of transport during early Pictou time is vital both for the interpretation of the source as well as for the discovery of deposits in the down-current direction.

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LITERATURE REFERENCES

BARSS, M.S. and HACQUEBARD, P.A.
1967: Age and the stratigraphy of the Pictou Group in the Maritime Provinces as revealed by fossil spores; Geol. Assoc. Can., Spec. Paper No. 4, p. 267-282.

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.

BELL, W.A.
1925: Carboniferous formations of Northumberland Strait, Nova Scotia; Summary Rept., 1924, Part A, Geol. Surv. Can., p. 142c-180c.

BELL, W.A.
1944: Carboniferous rocks and fossils floras of northern Nova Scotia; Geol. Surv. Can., Memoir 238, p. 1-54.

BELT, E.S. Stratigraphy and paleogeography of Mabou Group and related Middle Carboniferous facies, Nova Scotia, Canada; Geol. Soc. Am. Bull., vol. 76, p. 777-802.

BROWN, I.C.
1970: Groundwater geology, Geology and Economic Minerals of Canada; Geol. Surv. Can., Economic Geology Report No. 1, p. 766-791.

BRUMMER, J.J.
1958: Supergene copper-uranium deposits in northern Nova Scotia; Economic Geology, vol. 53, p. 309-324.

CANN, D.B. and WICKLUND, R.E.
1950: Soil survey of Pictou County, Nova Scotia; Can. Dept. Agr., Nova Scotia Soil Survey, Report No. 4, 66 p.

DYCK, W., GARRISON, E.W., GODOI, H.O., and WELLS, G.S.
1976a: Minor and trace element contents of well waters, Carboniferous Basin, eastern Canada, Federal-Provincial Uranium Reconnaissance Program; Geol. Surv. Can., Open File Report 340, 36 p.

DYCK, W., CHATTERJEE, A.K., GEMMELL, D.E., and MURRICANE, K.
1976b: Well water trace element reconnaissance, eastern Maritime Canada; J. Geochem. Explor., vol. 6, p. 139-162.

ELLS, R.W.
1885: On the geological formations of eastern Albert and Westmoreland counties, New Brunswick, and of portions of Cumberland and Colchester counties, Nova Scotia; Geol. Surv. Can., Annual Report, vol. 1, Report E, 71 p.

FLETCHER, H.
1893: On geological surveys and explorations in the counties of Pictou and Colechester, Nova Scotia; Geol. Surv. Can., Annual Rept. 1890-91, vol. V, Part II, Rept. A, 193 p.

RANKEL, L. and CROWL, G.H.
1970: Permo-Carboniferous stratigraphy and structure of central Prince Edward Island; Geol. Sur. Can., Paper 69-17, 26 p.

GROSS, G.A.
1957: Uranium deposits in Gaspé, New Brunswick, and Nova Scotia; Geol. Surv. Can., Paper 57-2, 27 p.

GRUTT, E.W., Jr.
1972: Prospecting criteria for sandstone-type uranium deposits in Uranium prospecting handbook, Howie, S.H.U., Davis, M. and Ostle, D. (editors); Nato Adv. Study Inst., London, 1971, p. 47-8.

GUSSOW, W.C.
1953: Carboniferous stratigraphy and structural geology of New Brunswick, Canada; Bull. Am. Assoc. Petrol. Geol., vol. 37, p. 1713-1816.

HACQUEBARD, P.A.
1972: The Carboniferous of eastern Canada; 7 ème Congr. Intern. du Carbonif., Krefeld, 1971, p. 69-90.

HOWIE, R.D. and CUMMING, L.M.
1963: Basement features of the Canadian Appalachians; Geol. Surv. Can., Bull. 89.

KELLEY, D.G.
1970: "Carboniferous and Permian" in southeastern Canada in Geology and Economic Minerals of Canada; Geol. Surv. Can., Econ. Geol. Rept. No. 1, p. 284-296.

LITTLE, H.W. and DURHAM, A.A.
1971: Uranium in stream sediments in Carboniferous rocks of Nova Scotia; Geol. Surv. Can., Paper 70-54, 17 p.

NOWLAND, J.L. and MacDOUGALL, J.I.
1973: Soils of Cumberland County; Nova Scotia; Can. Dept. Agr., Nova Scotia Soil Survey, Report No. 17, 133 p.

PAPENFUS, E.B.
1931: "Red Bed" copper deposits in Nova Scotia and New Brunswick; Economic Geology, vol. 26, p. 314-330.

POLL, H.W., van de
1972: Stratigraphy and economic geology of Carboniferous basins in the Maritime Provinces; 24th Intern. Geol. Congr., Field Excursion A60, guidebook, 96 p.

POLL, H.W., van de
1973: Stratigraphy, sediment dispersal and facies analysis of the Pennsylvanian Pictou Group in New Brunswick; Maritime Sediments, vol. 9, p. 72-77.

PREST, V.K., STEACY, H.R. and BOTTRILL, T.J.
1969: Occurrences of uranium and vanadium in Prince Edward Island; Geol. Surv. Can., Paper 68-74, 14 p.

RICHARDSON, K.A. and HOLMAN, P.B.
1975: Airborne radioactivity map, Prince Edward Island; Geol. Surv. Can., Open File 269.

SMITH, A.Y.
1968: Uranium in stream sediments in southeastern New Brunswick; New Brunswick Dept. Nat. Res., Min. Res. Branch, Inf. Circ. 68-3, 4 p.

STANTON, R.L.
1972: Ore Petrology; McGraw Hill Book Co., 713 p.

WIESE, R.G., Jr.
1957: An occurrence of mineralized organic material in Nova Scotia; Economic Geology, vol. 52, p. 76-82.

GEOLOGICAL SURVEY OF CANADA MAP REFERENCES

NOVA SCOTIA (from east to west)

Antigonish Town Sheet, 1893, Map 388, Nova Scotia Sheet No. 34, geology by H. Fletcher *et al.*

New Glasgow Sheet, 1902, Map 600 Nova Scotia Sheet No. 44, geology by H. Fletcher *et al.*

Stellarton Sheet, 1902, Map 598, Nova Scotia Sheet No 43, geology by H. Fletcher *et al.*

New Glasgow, 1940, Map 616A; geology by W.A. Bell.

Toney River Sheet, 1902, Map 608, Nova Scotia Sheet No. 45, geology by H. Fletcher.

Pictou Sheet, 1903, Map 609, Nova Scotia Sheet No. 46, geology by H. Fletcher *et al.* (this map shows the eastern termination of Fletcher's copper zones).

Westville Sheet, 1902, Map 610, Nova Scotia Sheet No. 47, geology by H. Fletcher *et al.*

Malagash Sheet, 1905, Map 794, Nova Scotia Sheet No. 60, geology by H. Fletcher *et al.*

Malagash Peninsula, 1920, Publication No. 1796, geology by A.O. Hayes.

Tatamagouche Sheet, 1905, Map 793, Nova Scotia Sheet No. 59, geology by H. Fletcher *et al.* (this map shows the central part of Fletcher's copper zones).

Earltown Sheet, 1902, Map 637, Nova Scotia Sheet No. 58, geology by H. Fletcher.

Truro, 1958, Map 1058A, geology by I.M. Stevenson.

Pugwash Sheet, 1905, Map 795, Nova Scotia Sheet No. 61, geology by H. Fletcher *et al.*

Wentworth Sheet, 1905, Map 796, Nova Scotia Sheet No. 62, geology by H. Fletcher *et al.* (this map shows the western termination of Fletcher's copper zones).

Noel Sheet, 1905, Map 837, Nova Scotia Sheet No. 64, geology by H. Fletcher.

Londonberry, 1946, Map 874A, geology by L.J. Weeks.

Shinimikas, 1945, Map 842A, geology by W.A. Bell.

Oxford Sheet (West Half), 1938, Map 410A, geology by G.W.H. Norman and W.A. Bell.

Bass River, 1946, Map 867A, geology by L.J. Weeks.

NEW BRUNSWICK

Moncton, 1941, Map 646A, geology by G.W.H. Norman.

Salisbury, 1941, Map 604A, geology by J.S. Stewart.

Petitcodiac (East Half), 1941, Map 642A, geology by J.S. Stewart.

Petitcodiac (West Half), 1941, Map 643A, geology by J.S. Stewart.

PRINCE EDWARD ISLAND

Central and eastern Prince Edward Island, 1970, Fig. 2 of G.S.C. Paper 69-17, geology by L. Frankel and G.H. Crowl.