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URANIUM MINERALIZATION IN NEWFOUNDLAND: AN OVERVIEW OF GEOLOGICAL CHARACTERISTICS AND METALLOGENIC AFFINITIES

G.W. Sparkes
Mineral Deposits Section

ABSTRACT

Exploration in the 1970s and 1980s and more recently (post-2005), has identified uranium mineralization in various locations across insular Newfoundland, in host rocks ranging from Proterozoic to Carboniferous. The style of mineralization varies widely, but known prospects and showings fall into two main groups, namely: i) vein-hosted volcanic- and intrusion-related and ii) sandstone-hosted.

Epigenetic, locally vein-hosted, mineralization is generally associated with, or hosted by, evolved igneous rocks of granitic composition, some of which are peralkaline. Some occurrences in volcanic rocks may be broadly syngenetic with respect to formation of their host sequences, but due to limited geochronological data, timing of mineralization remains largely unconstrained. In some cases, magmatic fluids may be the source, but the possibility that uranium was mobilized and redeposited by lower temperature groundwater cannot be excluded, particularly where mineralization is associated with late fractures. Peralkaline volcano-plutonic suites represent a newly identified target environment for uranium mineralization on the Island, which on the basis of global comparison, may have significant discovery potential.

The Devonian to Carboniferous sedimentary rocks of the Deer Lake Basin, Bay St. George subbasin, and the Connaigre Peninsula areas contain sandstone-hosted uranium mineralization. The features of these showings suggest that uranium was transported in groundwater within sedimentary formations, and precipitated in a range of settings, including tabular zones and 'roll-fronts'. This style of mineralization resembles that documented in other sandstone-hosted uranium provinces such as the Colorado Plateau. Mineralization of this type is generally low-grade where identified in bedrock, but the presence of high-grade boulders containing over 11% U_3O_8 in the Deer Lake Basin provides a powerful incentive for continued exploration.

INTRODUCTION

The best known and most explored uranium mineralization in this Province is located in Labrador, within the Central Mineral Belt (*e.g.*, Sparkes and Kerr, 2008), but, in the 1970s and 1980s, and since 2005, exploration has also been carried out in various parts of insular Newfoundland. This report provides an overview of the metallogeny of uranium in Newfoundland, based on historical sources and field work completed in 2010.

Uranium mineralization was first discovered in Newfoundland in 1970 on the Burin Peninsula (Figure 1), at the Radex prospect (Pearse, 1971). Subsequent uranium exploration in south-central Newfoundland targeted Carboniferous sedimentary rocks of the Deer Lake Basin, the Bay St. George subbasin, and several areas characterized by anomalous lake-sediment geochemistry. These areas have all experienced renewed exploration since 2005, and recent exploration has also targeted Silurian igneous rocks in central Newfoundland. New discoveries have also been found in older Precambrian igneous rocks.

Carboniferous rocks of the Bay St. George subbasin are correlated with similar rocks that host uranium mineralization in parts of Nova Scotia and New Brunswick (Dunsmore, 1977). In the Deer Lake Basin, the discovery of mineralized float assaying up to 11.5% U_30_8 provided some of the highest grade uranium mineralization anywhere in the Province, and this region continues to attract much attention. As in Labrador, uranium exploration declined as a result of poor market conditions in the 1980s and little work was done for almost 25 years. Consequently, our knowledge of the geological and metallogenic affinities of uranium mineralization in the Province is somewhat dated.

Price increases in the mid-2000s stimulated renewed uranium exploration, most notably in the Hermitage Flexure

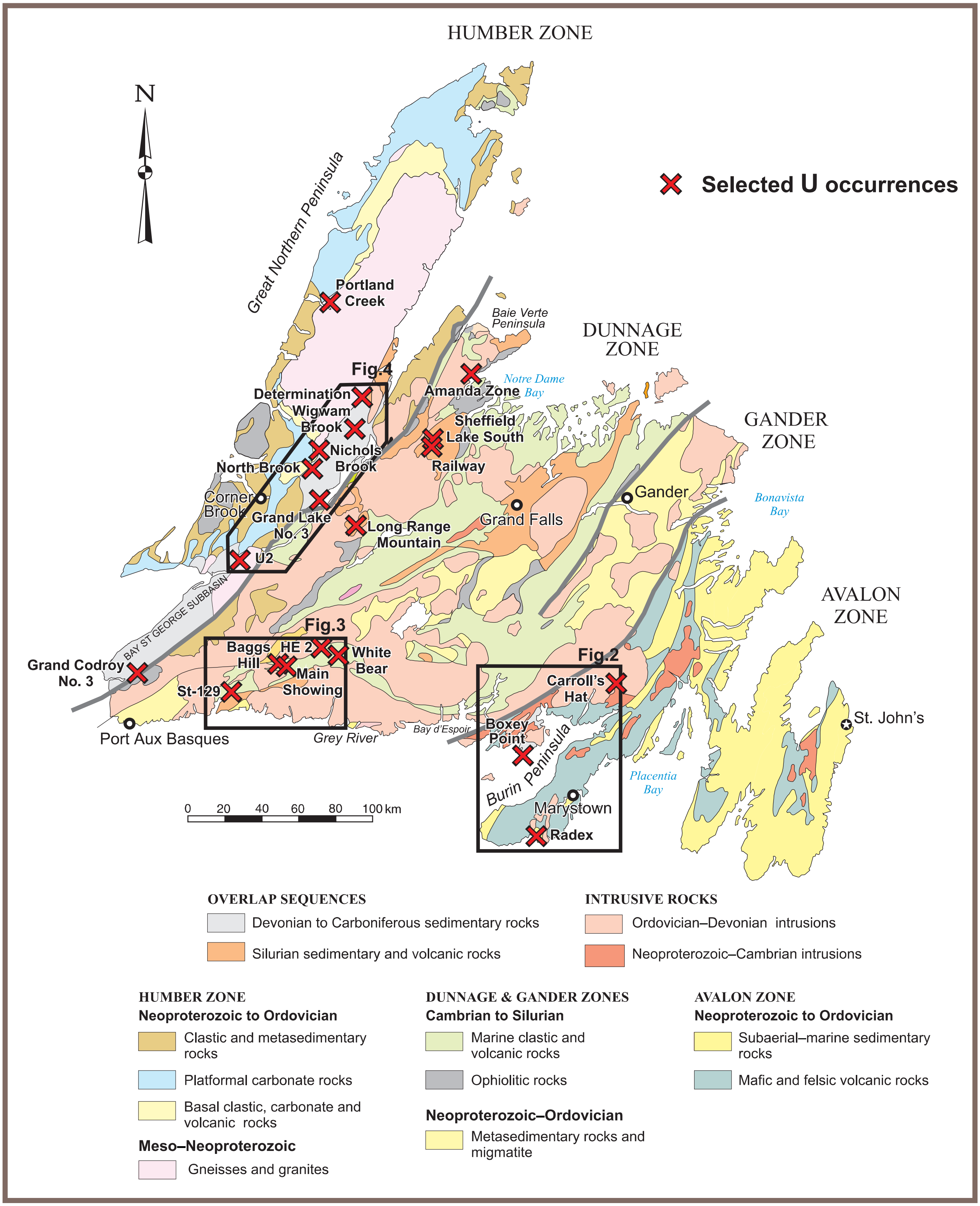

Figure 1. *Simplified geology map of Newfoundland outlining the main districts of uranium mineralization and principle examples discussed in text.*

Table 1. Summary of select uranium occurrences mentioned in text including, maximum uranium assay results, style of mineralization and associated reference

Prospect	Maximum Grade of Mineralization (% U_3O_8)	Style of Mineralization	Reference
Amanda Zone	0.89	Vein-hosted; volcanic	Bayswater Uranium Corporation, Press Release, December 5, 2007
Baggs Hill	0.49	Vein-hosted; plutonic	Commander Resources, Press Release, Novmeber 14, 2005
Boxey Point	0.037	Sandstone-hosted	Greene, 1977
Carroll's Hat	0.32	-	Skopik, 1986
Chan	0.20	Vein-hosted; volcanic	Commander Resources, Press Release, July 12, 2005
Determination	0.27	Vein-hosted; volcanic	Spruce Ridge Resources, Press Release, January 9, 2007
Doucette	1.32	Vein-hosted; volcanic	Commander Resources, Press Release, November 1, 2005
Grand Beach	0.005	Vein-hosted; plutonic	Evans and Vatcher, 2009
Grand Codroy No 3	2.2	Sandstone-hosted	Sherwin, 1981
Grand Lake No. 3	0.10	Sandstone-hosted	Parker and Rizzuto, 1979
HE 2	2.79	Vein-hosted; volcanic	Commander Resources, Press Release, July 18, 2006
Junction Brook	0.028	Sandstone-hosted	Sparkes, unpublished data
Little Lawn River	0.54	Vein-hosted; plutonic	Golden Dory, Press Release, January 14, 2009
Long Range Mountain	0.023	-	JNR, Press Release, December 18, 2009
Main	2.06	Vein-hosted; volcanic	Commander Resources, Press Release, August 18, 2005
Muise	0.32	Vein-hosted; volcanic	Commander Resources, Press Release, July 12, 2005
North Brook	3.73	Sandstone-hosted	Spruce Ridge Resources, Press Release, November 1, 2006
Portland Creek	0.22	Vein-hosted; plutonic	Clarke, 1977
Radex	0.33	Vein-hosted; plutonic	Pearse, 1971
Railway	0.62	-	JNR, Press Release, December 18, 2009
Rocky Brook	0.008	Sandstone-hosted	Sparkes, unpublished data
Sheffield Lake South	0.009	-	JNR, Press Release, December 18, 2009
ST-129	0.80	Vein-hosted; volcanic	Commander Resources, Press Release, September 18, 2005
Troy's Pond	0.22	Vein-hosted; volcanic	Commander Resources, Press Release, August 8, 2006
U2	0.70	Vein-hosted; volcanic	Ucore Uranium, Press Release, October 2, 2007
White Bear #1 & #2	0.108	Vein-hosted; volcanic	Commander Resources, Press Release, August 18, 2005
White Bear #3	0.754	Vein-hosted; volcanic	Commander Resources, Press Release, August 18, 2005
Wigwam Brook	11.5	Sandstone-hosted	Byrne, 1979a

area and in western Newfoundland. This activity resulted in new discoveries, and also improved knowledge of defined environments such as the Deer Lake Basin. Ongoing exploration and drilling continues to outline anomalous radioactivity; however the source(s) for the high-grade material have yet to be identified.

From a classification and metallogenic perspective, uranium in Newfoundland falls into two groups (Table 1), namely vein-hosted volcanic- and intrusion-related (syngenetic to epigenetic), and sandstone-hosted (epigenetic but variably stratiform). The absolute ages of uranium mineralization within these various settings remains unknown, as the majority of occurrences are epigenetic.

REGIONAL GEOLOGY

The Island of Newfoundland represents the northeastern extent of the Appalachian Orogenic Belt, and is divided into four main tectonostratigraphic zones (Williams, 1979; Figure 1). It developed between late Neoproterozoic and Carboniferous times, in several stages (*e.g.*, van Staal, 2007). The Humber Zone represents the Laurentian margin and includes Precambrian crystalline basement (~1600 to ~1000 Ma) overlain by platformal Cambrian–Ordovician sedimentary rocks. The Avalon Zone contains late Precambrian sedimentary, volcanic and intrusive rocks (~760 to ~540 Ma) overlain by a Cambrian–Ordovician sequence with different faunal affinities compared to those of the

Humber Zone. It forms one of several peri-Gondwanan terranes accreted to Laurentia during the early Paleozoic. The region between these two platformal blocks (Dunnage and Gander zones) consists of the tectonized remnants of arcs and marginal basins formed within the Iapetus Ocean and (in the east) as a reworked peri-Gondwanan block termed 'Ganderia', which has an unclear original relationship to the Avalon Zone. In the next section, the geological framework for these individual areas is briefly summarized; the mineralization is described and discussed in a subsequent section.

AVALON ZONE AND BURIN PENINSULA REGION

The southern Burin Peninsula is part of the Avalon Zone of Williams (1979) and is dominated by Neoproterozoic igneous and sedimentary rocks, overlain by Eocambrian to Middle Cambrian, and lesser Devonian to Carboniferous sedimentary rocks. Several Devonian intrusions occur throughout the region, including the peralkaline St. Lawrence Granite, which has a U–Pb age of 374 ± 2 Ma (Kerr *et al*., 1993). The compositionally similar Grand Beach Porphyry has a slightly older, tentative U–Pb zircon age, of 394 +6/-4 Ma (Krogh *et al*., 1988). Previous designation of these igneous rocks as Carboniferous (Bell and Blenkinsop, 1975) was based on Rb–Sr and Ar–Ar data that are now thought to reflect a later disturbance.

The St. Lawrence Granite and similar rocks have high uranium content (a mean value of 8.4 ppm U; locally up to 79 ppm) compared to other granitoid rocks of eastern Newfoundland (Davenport, 1978). These units spatially correlate with uranium anomalies in lake sediments and Quaternary cover, providing an incentive for exploration over the years (Davenport *et al*., 1976; Batterson and Taylor, 2009). The St. Lawrence Granite is well known for its fluorite deposits (Collins, 1984), but both the granite and its country rock (the Eocambrian Inlet Group) also locally host uranium mineralization.

In the Fortune Bay area, north of the Burin Peninsula, felsic volcanic flows, associated ash-flow tuff and overlying siliciclastic sedimentary rocks of the late Precambrian Long Harbour Group are preserved as roof pendants within the Devonian Ackley Granite and host epigenetic vein-hosted uranium mineralization (O'Brien *et al*., 1984; Skopik, 1988). The Ackley Granite lacks the peralkaline traits of the St. Lawrence Granite, but is of similar age (378 ± 2 Ma) based on Re–Os dating of contained molybdenite prospects (Lynch *et al*., 2009). The granite is described by Dickson (1983) and Tuach *et al*. (1986). The Devonian–Carboniferous sedimentary rocks occur in the western Avalon Zone in the Fortune Bay area, southwest of the Ackley Granite. These are of minor extent (Greene, 1975), but do host some uranium occurrences in the region of Boxey Point (Figure 1).

HERMITAGE FLEXURE REGION

The Hermitage Flexure region occupies parts of south-central Newfoundland and the south coast region (Figure 1). It is a structurally complex region that includes Neoproterozoic basement rocks, Ordovician and Silurian volcano-sedimentary sequences and abundant Silurian and Devonian granitoid rocks. In its central and western portions, uranium mineralization is hosted by mid-Ordovician volcanic and sedimentary rocks of the Bay Du Nord Group (O'Brien and Tomlin, 1985; and references therein). This consists of poly-deformed, amphibolite-facies metasedimentary and metavolcanic rocks derived from mainly felsic submarine flows and associated volcaniclastic rocks, intercalated with, and overlain by, pelitic and psammitic metasedimentary rocks (O'Brien *et al*., 1986). The Bay Du Nord Group is intruded by the Iron Bound monzonite, Peter Snout granite and the Baggs Hill Granite. The former two intrusions are postkinematic, and are anomalously radioactive (Chorlton, 1980; Dunsworth, 1981; O'Brien *et al*., 1986; Tuach, 1986). The Baggs Hill Granite, dated at 478 ± 2 Ma (Tucker *et al*., 1994) was interpreted by Chorlton (1980) as a synvolcanic intrusion with respect to volcanic rocks of the Bay Du Nord Group. The Baggs Hill Granite also hosts uranium mineralization. The La Poile Group represents a sequence of Silurian subaerial felsic volcanic and associated epiclastic rocks along with quartz-rich sedimentary rocks of fluvial and alluvial origin (O'Brien *et al*., 1991; and references therein); the youngest rocks in this area are represented by the *ca*. 390 Ma posttectonic Chetwynd Granite (*op. cit.*).

The eastern portion of the Hermitage Flexure region is dominated by Silurian and Devonian granitoid plutonic rocks. The largest expanse is formed by the Burgeo Intrusive Suite, which includes a wide range of compositions from diorite to muscovite granite (Dickson *et al*., 1996). The youngest unit in this area is the Devonian François granite, dated at 378 ± 2 Ma (Kerr *et al*., 1993). The François granite is highlighted by regional lake-sediment surveys, which indicate anomalous Pb, U, F and Mo (Butler and Davenport, 1978, 1980), and also by airborne radiometric data (Broome *et al*., 1987). It forms two overlapping ring complexes of biotite-bearing granite, enriched in Rb, U and Th (Dickson, *et al*., 1996). No mineralization is known in the François granite, but it has been implicated in the genesis of Mo–Cu–W mineralization in the Grey River area (Higgins and Smyth, 1980; Kerr *et al*., 2009).

SILURIAN IGNEOUS SUITES OF CENTRAL NEWFOUNDLAND

In central Newfoundland, uranium mineralization is associated with Silurian peralkaline volcanic rocks, pyroclastic rocks and related high-level intrusions (*e.g.,* Railway prospect; Amanda Zone prospect; (Figure 1). The most extensive of these volcanic sequences is the Springdale Group, which was interpreted as a large subaerial caldera complex by Coyle and Strong (1987). The Topsails Intrusive Suite, a large plutonic complex extending for almost 100 km to the southwest, is interpreted to be comagmatic with the Springdale Group (Whalen and Currie, 1983; Chandler *et al.*, 1987). The Topsails Intrusive Suite is dominated by massive potassic to locally peralkaline granite and related quartz–feldspar-porphyry. The U–Pb ages from the Topsails granites and the Springdale Group are similar at ~429 and 432–427 Ma, respectively (Whalen *et al*., 1987; Chandler *et al*., 1987; Coyle, 1990). On the Baie Verte Peninsula, metaluminous to peralkaline subaerial volcanic rocks and associated subvolcanic intrusions of similar composition are assigned to the King's Point Complex (Innes *et al*., 1960; Hibbard, 1983; Miller and Abdel-Rahman, 1995). The U–Pb age of 427 Ma (Coyle, 1990) suggests that these also correlate with the Springdale Group. Silurian volcanic rocks of similar age also occur in the Cape St. John Group of the Baie Verte Peninsula (Skulski *et al*., 2010).

The Sops Arm Group in southwestern White Bay also contains subaerial volcanic rocks of Silurian age (Smyth and Schillereff, 1982; Kerr, 2006), but these have not been dated precisely, and there is little published information on their geochemistry.

PROTEROZOIC BASEMENT ROCKS OF WESTERN NEWFOUNDLAND

In western Newfoundland, uranium mineralization has been identified within Proterozoic basement rocks of the Long Range Inlier and nearby areas (Figure 1). The Long Range Inlier (Owen, 1991) is a complex region coeval with parts of the Grenville Province of the Canadian Shield. In addition to orthogneiss and metasedimentary gneiss, it includes several large plutonic suites, including the Lake Michel intrusive suite. In the southern part of the Long Range Mountains, east of Stephenville, the Precambrian rocks include a large mafic–anorthositic body (Steel Mountain anorthosite) and some smaller granitoid plutons. The medium- to coarse-grained peralkaline Hare Hill granite, dated at 608 ± 4 Ma, along with adjacent granitic gneisses of the Tulks Pond Complex host uranium mineralization in this region (Currie *et al*., 1986, 1991; Reid and Penney, 2009). These granites are believed to be related to magmatism during Iapetian rifting and/or its marginal seaway (*e.g.*, Cocks *et al*., 1997).

CARBONIFEROUS BASINS OF WESTERN NEWFOUNDLAND

The Carboniferous rocks of western Newfoundland host the most concentration of uranium occurrences on the Island. These rocks occur in two main basins, namely the Deer Lake Basin and the Bay St. George subbasin; the latter is part of the larger Maritimes Basin extending through Nova Scotia, New Brunswick and Prince Edward Island. The Deer Lake Basin developed as an intermontane rift or pull-apart basin and is linked to major strike-slip faulting within the region (Hyde, 1984; Hyde *et al*., 1988). It contains two main groups. The older sequence (Anguille Group) is composed of well-cemented grey sandstone, siltstone and mudstone; this is overlain by the Deer Lake Group, which is composed of conglomerate, coarse-grained sandstone, finer grained siliciclastic sedimentary rocks, limestone and oil shale (Hyde, 1979a).

Most of the uranium occurrences are hosted within the Deer Lake Group, additional stratigraphic details are provided. This group is subdivided into four formations; in ascending order they are: the North Brook, Rocky Brook, Humber Falls, and Little Pond Brook formations (Hyde, 1982, 1984). The North Brook Formation is dominated by red to grey arkosic sandstone and pebble to boulder conglomerate and lesser red siltstone and pink to grey micritic limestone. The Rocky Brook Formation, which consists of red to grey siltstone along with grey, green and black mudstone, minor oil shale, red fine-grained sandstone and rare chert and gypsum. The overlying Humber Falls Formation consists of light grey, light green, pink, red and orange, fine- to very coarse-grained arkosic sandstone and mudstone. The Little Pond Brook Formation is interpreted to be coeval with the Humber Falls Formation and is confined to the southeastern portion of the basin (Hyde, 1982, 1984). This unit consists of red, grey, green and tan sandstone, pebble to boulder conglomerate and siltstone (Hyde, 1982). The North Brook and the Rocky Brook formations are interpreted to represent a fining-upward megasequence, and the overlying Humber Falls Formation forms the lower portion of another fining-upward megasequence (Hyde, 1979a). The North Brook and Humber Falls formations are interpreted to have formed within fluvial to alluvial fan deposits, whereas the Rocky Brook Formation is interpreted as forming as a mixed lacustrine–fluvial deposit (Belt, 1968, 1969; Hyde, 1979a, 1985).

Like the Deer Lake Basin, the Bay St. George subbasin is also closely associated with the development of major transcurrent fault systems (Knight, 1983). The Carboniferous sequence is divisible into three groups, namely the Anguille, Codroy and Barachois (Knight, 1983; and references therein); these units are briefly summarized below. A more detailed lithological description is given by Knight (1983). The Anguille Group consists of nonmarine siliciclastic sedimentary rocks comprising green to grey and red sandstone and siltstone, black shale and mudstone, conglomerate and minor limestone. These are broadly similar to the equivalent succession in the Deer Lake Basin. The Codroy Group consists of a mixed sequence of both marine and nonmarine units including siliciclastic, evaporitic and calcareous sedimentary rocks (Knight, 1983); this group is composed of limestone, red, green and grey siltstone and mudstone, red, green and grey sandstone, muddy, pebbly sandstone and conglomerate, arkosic grit and shale. It contains gypsum, and thick salt (halite) deposits containing minor potash. The contact between the Codroy Group and the overlying Barachois Group is poorly exposed but is assumed to be both gradational and diachronous (Knight, 1982). The Barachois Group consists of green, grey and red sandstone, red siltstone, green to grey mudstone and siltstone, black shale and rare coal beds. Most of the known uranium occurrences are associated with the Mollichignick and Overfall Brook members of the Codroy Group that occur along the southeastern margin of the basin (Knight, 1984).

GEOLOGICAL CHARACTERISTICS, SETTING AND CLASSIFICATION OF URANIUM MINERALIZATION IN NEWFOUNDLAND

This section summarizes the key features of uranium prospects and showings with respect to their host rocks and style of uranium mineralization, in the context of current classifications. This information is drawn from published papers and reports, unpublished industry data (press releases and assessment files) and field observations by the author. The classification is based on recent schemes (Cuney and Kyser, 2009; and references therein), and is, of course, subject to modification as more geochemical and petrographic data become available. This section uses several autoradiographs to show the distribution of radioactive minerals and the textural context of mineralization. These were obtained using a radio-sensitive polymer known as CR-39 resulting in much higher resolution images than obtained using traditional autoradiographs employing photographic or X-ray film. For details on the method, *see* Sparkes *et al*. (2010).

SYNGENETIC AND EPIGENETIC VEIN-HOSTED MINERALIZATION RELATED TO IGNEOUS ROCKS

All uranium occurrences not hosted within Devonian–Carboniferous sedimentary rocks are hosted by, or associated with, plutonic and volcanic rocks of various ages, although there is generally some superimposed structural control. These deposits are found in compositionally evolved rock types, which include peraluminous two-mica leucogranite, high-K calc-alkaline granite, and peralkaline felsic volcanic and plutonic rocks (*cf*. Cuney and Kyser, 2009). In Newfoundland, most of the uranium mineralization of this type occurs either within veins or as fine-grained disseminations within permeable zones marginal to such features.

Burin Peninsula and Adjacent Areas

Exploration History

The first discovery of uranium mineralization on the Island (1970) was a narrow Pb–Zn–U–Ag vein in the region of Little Lawn Harbour, now known as the Radex prospect (Strong *et al*., 1978). The prospect was generated as a result of follow-up steam-sediment sampling of geochemically anomalous regions outlined in a 1969 hydrogeochemical survey (Radex Minerals Limited, 1969), which was carried out as part of a joint venture between Radex Minerals Limited and Newfoundland and Labrador Corporation Limited (NALCO). However, no further significant uranium mineralization was discovered. Golden Dory Resources completed an airborne radiometric survey over the southern Burin Peninsula in 2007, and discovered several new showings near the original Radex prospect. Grab samples, locally assaying up to 1.9% U_3O_8, have been collected from the area (Golden Dory Resources, Press Release, September 26, 2008).

In the Fortune Bay area, the Carroll's Hat prospect was discovered by CEGB Exploration Limited in 1985. Assays of up to 0.32% U_3O_8 were obtained from quartz veins within a quartz–feldspar-porphyry dyke that crosscuts the Ackley Granite (Skopik, 1986). Renewed exploration by Ucore Uranium Incorporated in 2006 provided grab samples containing up to 0.23% U_3O_8 as well as 2.0 g/t Au and up to 5% Cu (Ucore Uranium Incorporated, Press Release, November 20, 2006).

Geology and Mineralization

All known uranium occurrences on the southern Burin Peninsula are hosted within, or are spatially associated with, the St. Lawrence Granite or units inferred to be correlative. The most significant are the Radex, Little Lawn River and Grand Beach prospects (Figure 2). Uranium mineralization occurs as discrete cm-scale veins developed within anomalously uranium-enriched granite or related porphyry or along the intrusive contacts of these units. Elevated radioactivity, as measured using a scintillometer, is not consistently associated with high assay values for uranium, so there may be uranium disequilibrium, with other radioactive elements contributing. At the Radex prospect, some uranium mineralization remains, and occurs along the structural contact between an altered phase of the St. Lawrence Granite and the adjacent fine-grained sulphidic black shale of the Inlet Group (Plate 1). However, much of the higher grade materi-

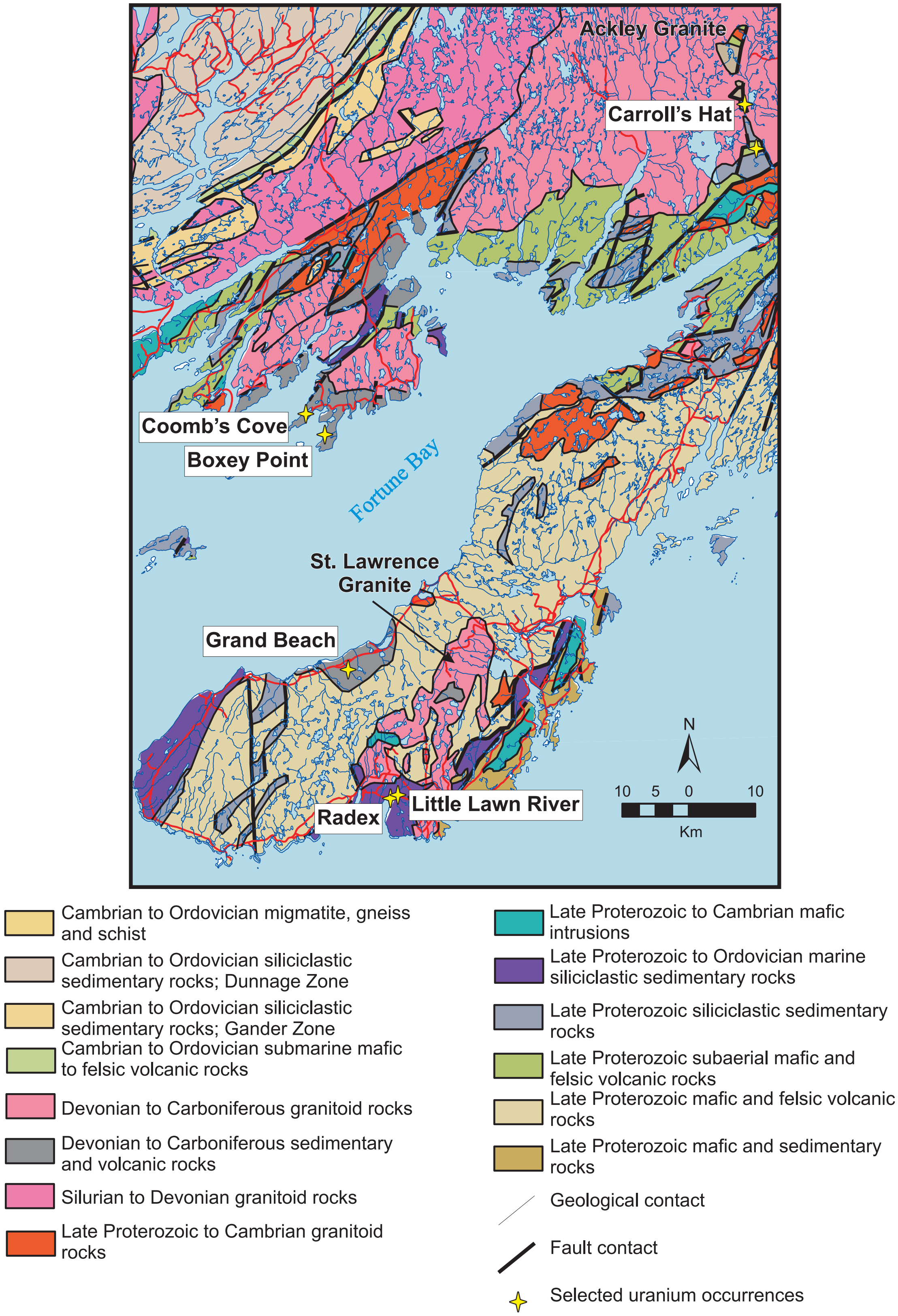

Figure 2. *Simplified geology map of the Burin Peninsula region outlining the location of select uranium occurrences discussed in text.*

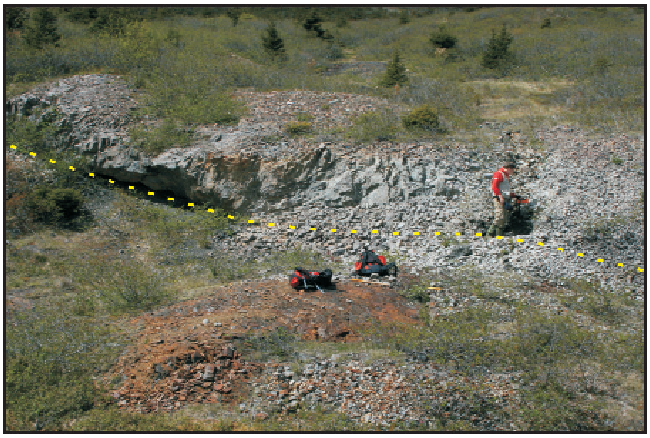

Plate 1. *Photograph of the historical Radex prospect showing the approximated fault contact (yellow dashed line) between the sulphidic black shale of the Inlet Group in the foreground and the pale-grey altered quartz–feldspar-phyric porphyry of the St. Lawrence batholith in the background. The person standing to the right of the photograph marks the actual uranium occurrence.*

al described by Strong *et al*. (1978) seems to have been removed from the site. A CR-39 autoradiograph of mineralized material collected from the prospect demonstrates the vein-hosted nature of the radioactivity having the main concentrations along the margins of a late carbonate–sulphide-bearing vein that crosscuts a cataclastic breccia developed within grey siltstone (Plate 2). Locally, massive 'pitchblende' up to 5 cm thick in association with trace fluorite was historically reported (Strong *et al*., 1978). Re-sampling of the area in 2008 returned assays of up to 0.211% U_3O_8 from the prospect (Golden Dory Resources, Press Release, September 26, 2008), which are much lower than recorded during initial sampling. The Radex vein was also reported to contain galena, sphalerite, chalcopyrite and fluorite (Pearse, 1971). Other base-metal-bearing veins occur in the area around the St. Lawrence Granite, but are not known to be radioactive.

The area around Little Lawn River (Figure 2) was identified by Golden Dory Resources as an area characterized by elevated radioactivity, associated with a discrete quartz-por-

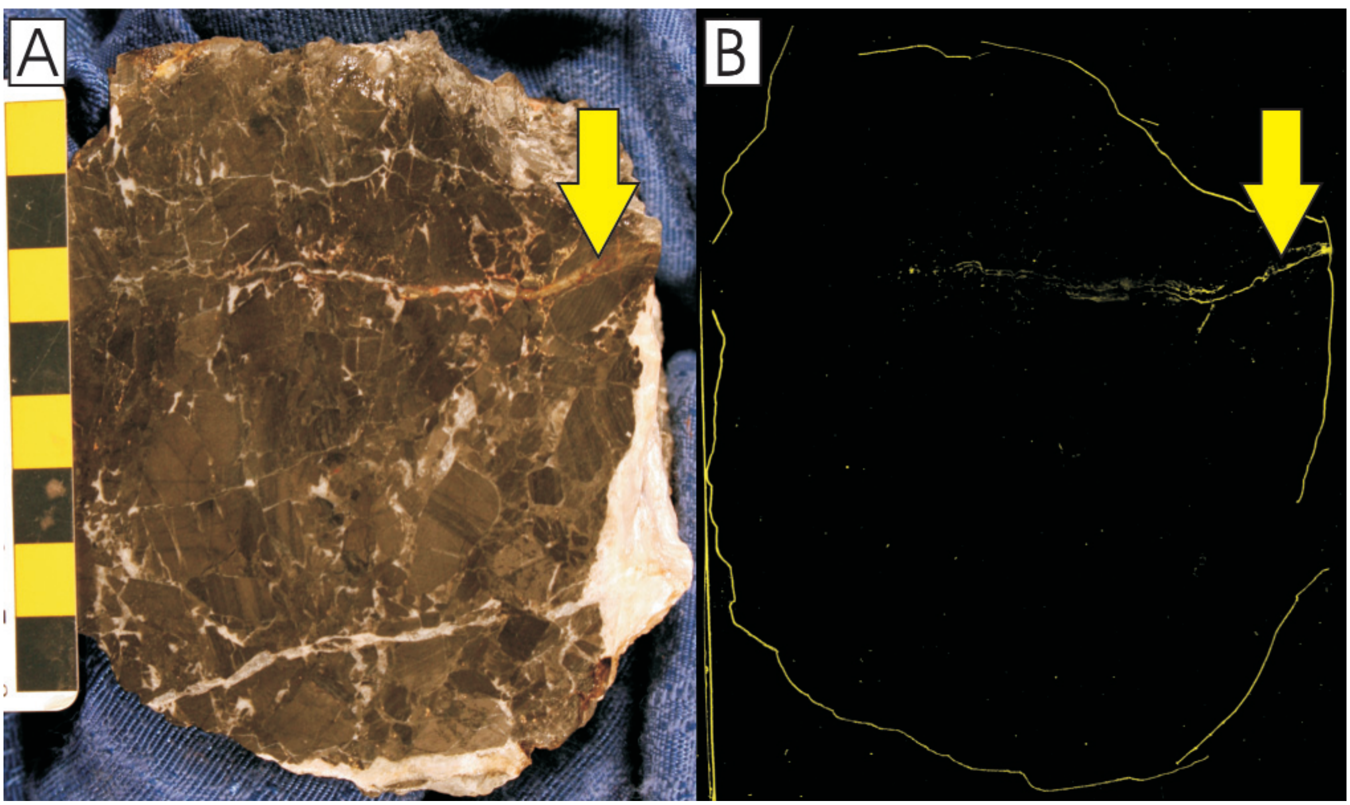

Plate 2. *A) Mineralized hand sample of cataclastic breccia developed within sulphidic black shale at the Radex prospect, which assays 0.016%* U_3O_8 *and 2.7g/t Au; note the rusty weathering sulphide-bearing fracture that crosscuts the brecciation (yellow arrow). B) Autoradiograph of the mineralized sample shown in A outlining the main concentration of the radioactivity within the sample (shown in yellow, minus the outline of the sample) which is primarily hosted along the margins of the late sulphide-bearing fracture.*

Plate 3. *Localized uranium mineralization developed along the intrusive contact between black shale of the Inlet Group and quartz-porphyry of the St. Lawrence batholith at the Little Lawn River prospect.*

Plate 4. *Anomalously radioactive quartz-phyric Grand Beach porphyry containing local cognate xenoliths within a pink, feldspar-rich groundmass.*

phyritic phase of the St. Lawrence Granite, from which assays of up to 0.54% U_3O_8 are locally obtained (Golden Dory Resources, Press Release, January 14, 2009; Figure 2). The quartz-porphyry unit has elevated radioactivity throughout (average of 500 counts per second (cps)), with the highest readings (~3000 cps) occurring along the intrusive contact with black shale of the Inlet Group and/or hematized fractures within the porphyry unit (Plate 3). These zones of mineralization are very localized and most of the contact region displays weaker radioactivity. The localized high-grade zones are interpreted to be a function of later uranium remobilization, and unrelated to the actual intrusion of the porphyry. However, the porphyry unit likely represents the source for the uranium.

In the vicinity of Grand Beach (Figure 2), lake-sediment and till-geochemical surveys demonstrate that the Grand Beach porphyry is anomalous in uranium (Hoffman *et al*., 1978). However, limited drill testing of the area failed to identify any significant uranium mineralization (Pitman, 1978). The Grand Beach intrusion is predominantly a quartz-porphyry, containing mm-scale subhedral quartz phenocrysts within a finer grained pink feldspar-rich groundmass, locally containing cm-scale cognate xenoliths (Plate 4). As seen at Little Lawn River, the porphyry is associated with anomalous radioactivity throughout (average of ~350 cps), but only discrete zones of chlorite-rich fracturing provide a strong response. Recent exploration by Golden Dory Resources has obtained assays of up to 40.9 ppm U from such zones (Evans and Vatcher, 2009). The chlorite-rich fracture zones (Plate 5) are locally exposed within stream beds, as most of the area is covered by Quaternary material. As at Little Lawn River, this style of mineralization is attributed to remobilization of uranium from the surrounding host rocks into more permeable zones; however, the timing of mineralization is unconstrained.

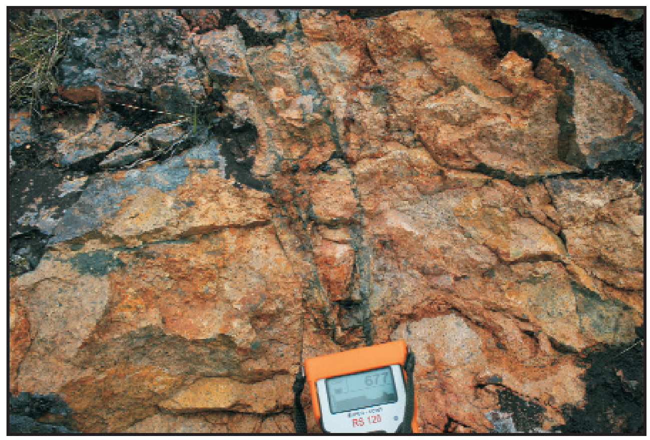

Plate 5. *A rare zone of cm-scale chlorite-rich fracturing and localized brecciation accompanied by anomalous radioactivity developed within the Grand Beach porphyry.*

The Carroll's Hat prospect was not visited by the author. Mineralization is reported to be hosted within Precambrian volcanic and sedimentary rocks of the Long Harbour Group, preserved as roof pendants by the Ackley Granite (Figure 2). Uranium is reported to occur within narrow quartz–magnetite-stockwork zones that are associated with variable hematite alteration (Ucore Uranium Incorporated, Press Release, November 20, 2006). The veins also host anomalous copper and gold (up to 2 g/t Au and 5% Cu) and up to 0.23% U_3O_8 (Landmark Minerals Press Release, October 4, 2006; Stares, 2006; Keyser, 2007). The association with quartz and magnetite, and the polymetallic nature of some veins, suggest that this mineralization is of magmatic–hydrothermal origin, and formed synchronously with the nearby granites.

Hermitage Flexure Region

Exploration History

Mineralization was first discovered by Shell Canada in 1980 around the Peter Snout and Ironbound intrusions, with grab samples assaying >0.23% U_3O_8 (Wells, 1981). Subsequent work delineated several occurrences, namely the Main, Muise and Baggs Hill prospects from which grab samples of up to 3.4% U_3O_8 were obtained (Figure 3; Wells, 1982). However, no advanced exploration work or drilling was carried out.

In 2005, Commander Resources Limited acquired claims that covered known occurrences in the region. Initial results from channel sampling indicated up to 0.11% U_3O_8 over 1.5 m from the Main prospect, and several other chip samples from surrounding prospects assayed >0.1% U_3O_8 (Commander Resources Limited, Press Release, July 12, 2005; Figure 3). Subsequent grab samples contained up to 2.06% U_3O_8 (Commander Resources Limited, Press Release, August 18, 2005). Prospecting revealed the presence of several new areas of anomalous float and outcrop including the Doucette and HE 2 prospects in the White Bear River region, and the Troy's Pond and ST-129 prospects in the western portion of Hermitage Flexure (Figure 3). Channel sampling at the ST-129 prospect produced up to 0.05% U_3O_8 over 6.7 m, including several 1 to 1.5 m intervals containing >0.1% U_3O_8 (Commander Resources Limited, Press Release, November 14, 2006). Commander Resources also carried out the first diamond drilling in the region, testing the Troy's Pond, ST-129, Main, HE 2 and Doucette prospects. Drilling intersected anomalous uranium over limited widths, with the best results in the western region returning 0.045% U_3O_8 over 4.5 m at the Troy's Pond prospect (Commander Resources Limited, Press Release, February 2, 2007). In the White Bear River region, drilling returned values of up to 0.10% U_3O_8 over 0.20 m from the HE 2 prospect, as well as up to 0.11% U_3O_8 over 0.40 m at the Doucette prospect (Commander Resources Limited, Press Release, June 4, 2007).

Geology and Mineralization

Mineralized zones described above are situated within areas of very poor outcrop. Mineralized float is generally interpreted to be of local derivation. This conclusion was supported by follow-up diamond drilling and trenching, which intersected closely similar rocks.

At the White Bear #1 and #2 prospects (Figure 3) uranium is reported to occur within a staurolite-bearing semi-pelitic schist of the Bay Du Nord Group. Radioactive zones, which locally attain 30 cm in width, are stratabound and possibly stratiform within the host metasedimentary rocks (O'Brien and Tomlin, 1985). Assays from the prospects are reported to range from 0.07 to 0.11% U_3O_8 (Commander Resources Limited Website, 2010). Autoradiographs from the region demonstrate the stratiform nature of the radioactivity within the schist and also highlight the preferential concentration of radioactivity within zones enriched in biotite (Plate 6). To the west, at the White Bear #3 and Doucette prospects, higher grade uranium mineralization identified in float consists of fine- to medium-grained quartz-phyric tuff, which is stratigraphically bound by the semi-pelitic schist, and contains up to 0.75% U_3O_8 (O'Brien and Tomlin, 1985; Commander Resources Limited, Press Release, August 18, 2005). The rocks in this region appear much less deformed. Autoradiographs demonstrate that fine-grained radioactive minerals, interpreted to be uraninite, are disseminated throughout the matrix of the sample (Plate 7). The mineralization was interpreted by O'Brien and Tomlin (1985) to be syngenetic with respect to felsic volcanic rocks within the Bay Du Nord Group, with the uranium mineralization locally remobilized into more permeable units such as the quartz-phyric tuff.

In the vicinity of the Baggs Hill prospect, several zones of uraniferous float and sporadic outcrop have been identified both marginal to and within the main intrusion of the Baggs Hill Granite (Figure 3). Within the main body of granite, uranium mineralization infills fractures, and is accompanied by the development of secondary uranium oxide minerals. Grab samples from the mineralized granite have yielded up to 0.49% U_3O_8 along with 0.23% Mo (Commander Resources Limited, Press Release, November 14, 2006). The Main prospect is located east of the Baggs Hill Granite and is hosted within fine-grained, strongly foliated siliceous metavolcanic rocks of the Bay Du Nord Group (Figure 3); the highest radioactivity is associated with localized brittle fracture zones that are marked by a rusty-weathering (Plate 8). Channel sampling of these rusty zones has produced up to 0.11% U_3O_8 over 1.5 m, and grab samples from outcrop in the vicinity return values of up to 2.06% U_3O_8 (Commander Resources Limited, Press Releases, July 12, 2005; August 18, 2005). Limited petrographic work on the felsic metavolcanic host rock indicates the presence of a finely disseminated radioactive mineral, interpreted to be uraninite. This mineral occurs throughout the matrix of the metavolcanic host rock and within crosscutting fractures, and is locally associated with minor chalcopyrite, sphalerite and pyrite (Wells, 1982). Autoradiographs demonstrate the fracture-hosted nature of the mineralization, as well as the preferential concentration of radioactivity within zones of biotite–chlorite alteration (Plate 9). Drilling at the Main prospect intersected brecciated felsic volcanic rocks showing strong silica-sericite alteration. The best result from the seven holes drilled at the prospect was 0.031% U_3O_8 over

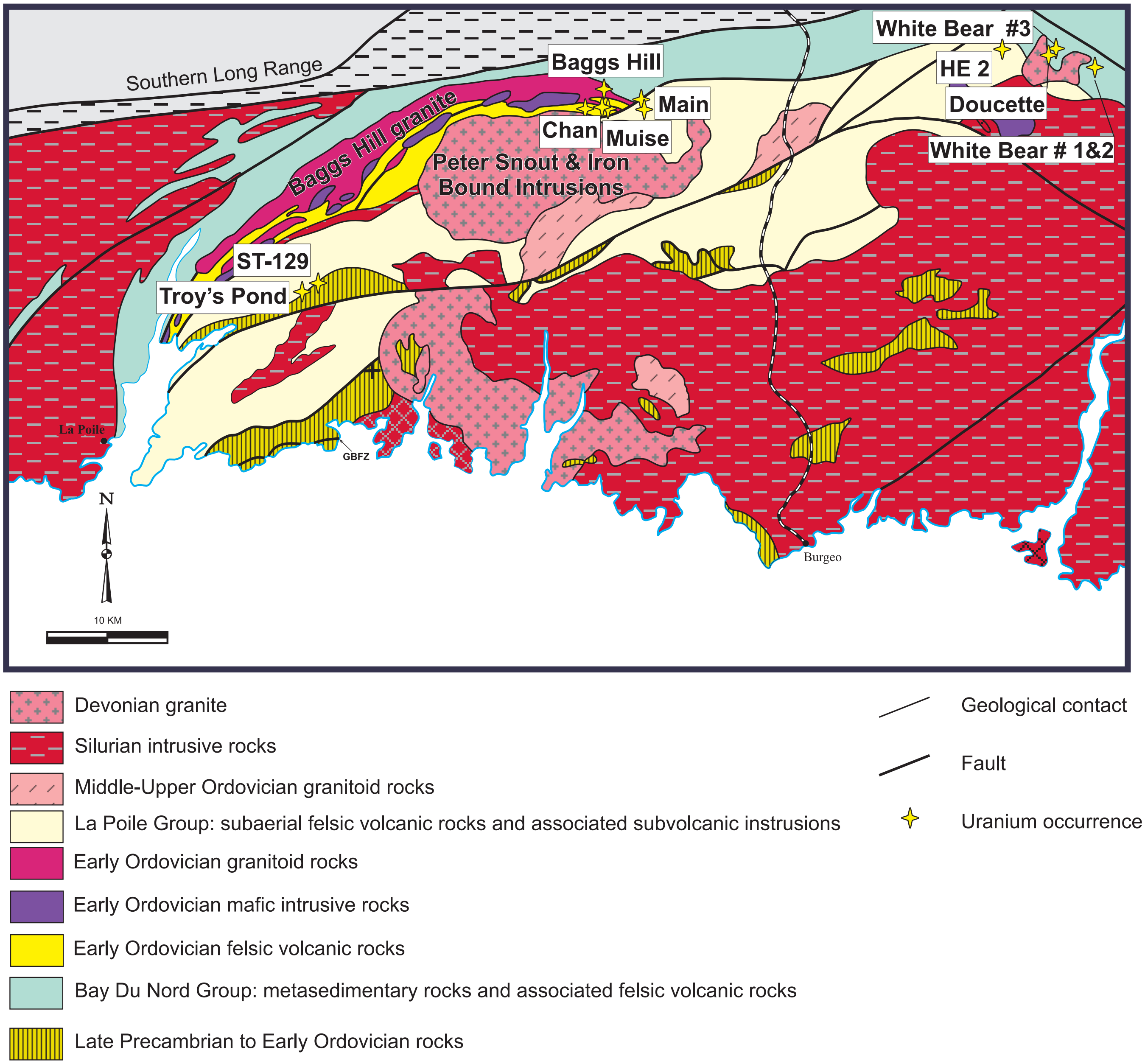

Figure 3. *Western and central portions of the Hermitage Flexure showing distribution of known uranium occurrences. (Simplified regional map compiled from O'Brien* et al.*, 1991; and published and unpublished data.)*

0.5 m (Commander Resources Limited, Press Release, April 9, 2007). Several other occurrences are found marginal to the main body of the Baggs Hill Granite, including the Musie and Chan prospects. Chip sampling of these mineralized zones returned values of 0.32% and 0.2% U_3O_8, respectively (Figure 3; *op. cit.*).

At the extreme western end of the Hermitage Flexure region, mineralization at the Troy's Pond and ST-129 prospects is hosted within tuffaceous metasedimentary rocks of the Bay Du Nord Group similar to those seen elsewhere within the region. At the Troy's Pond prospect, uranium mineralization is associated with mm-scale, rusty-weathering fractures, similar to those seen at the Main prospect (Plate 10). At the Troy's Pond prospect, local grab samples return up to 0.114% U_3O_8 along with up to 0.24% Mo. Channel sampling of the ST-129 prospect returned an average of 0.05% U_3O_8 over 6.7 m, although higher grades of up to 0.12% U_3O_8 over 1.0 m were locally encountered (Commander Resources Limited, Press Release, November 14, 2006). Follow-up drilling at the ST-129 prospect returned up to 0.084% U_3O_8 over 0.5 m. Better results were

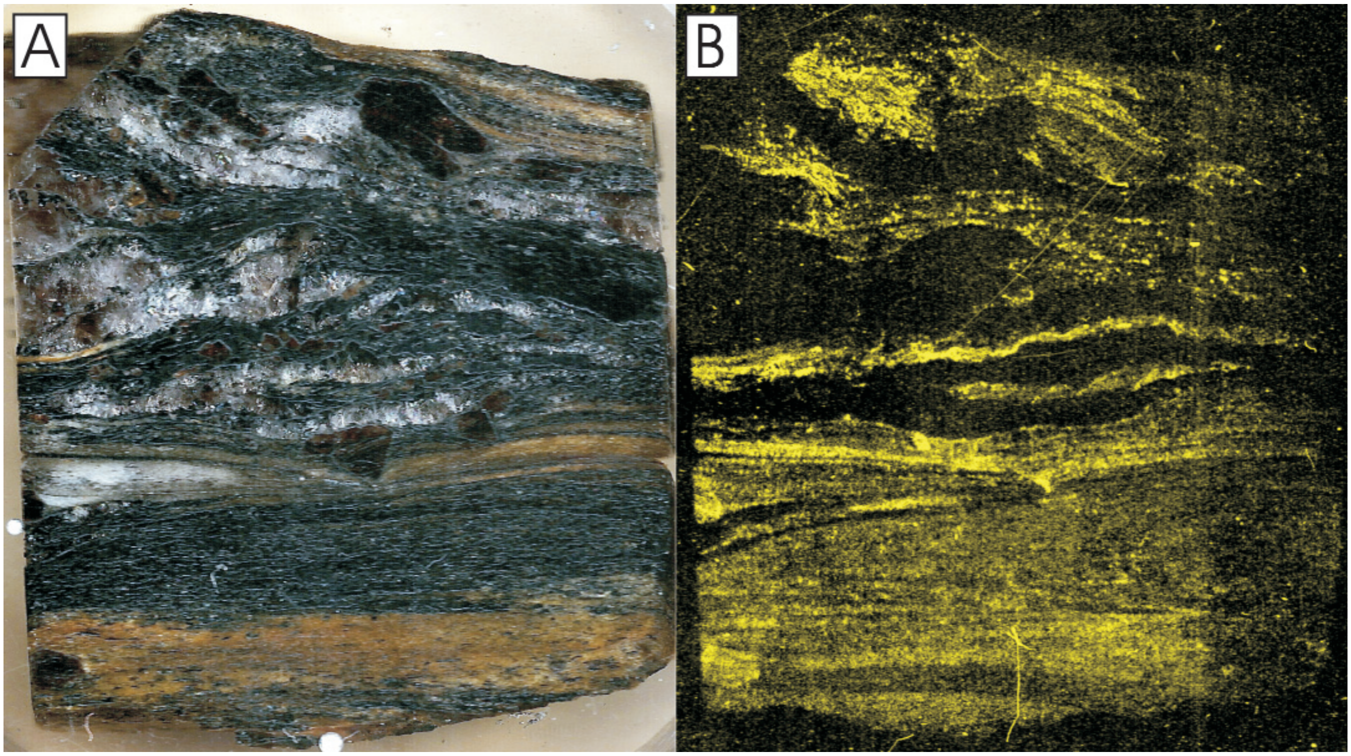

Plate 6. *A) Mineralized polished sample of a staurolitic schist from the White Bear River region; sample is approximately 2.5cm wide***.** *B) Autoradiograph of the mineralized sample shown in A outlining the main concentration of the radioactivity within the sample (shown in yellow), which is primarily concentrated in areas enriched in biotite; note that the development of the radioactivity is interpreted to predate the quartz veining developed within the sample.*

obtained at Troy's Pond, which produced 0.045% U_3O_8 over 4.3 m; including 0.065% over 1.8 m and 0.11% over 0.6 m (Commander Resources Limited, Press Release, February 2, 2007).

Silurian Volcanic and Plutonic Rocks of Central Newfoundland

Exploration History

Silurian peralkaline volcanic and plutonic rocks in central Newfoundland received little attention until late 2007, when the Topsails Igneous Complex and the Kings Point Complex on the Baie Verte Peninsula became the focus of uranium exploration. Bayswater Uranium Corporation optioned the Amanda Zone prospect on the Baie Verte Peninsula, where grab samples yielded up to 0.89% U_3O_8 (Bayswater Uranium Corporation, Press Release, December 5, 2007; Figure 1). Trenching in the area has uncovered well-preserved felsic volcanic and volcaniclastic rocks containing sporadic uranium mineralization. Twelve diamond-drill holes were completed, and intersected similar volcanic units at depth, but failed to intersect any significant uranium mineralization.

In 2007, Altius and JNR Resources agreed to a joint-venture agreement to carry out regional uranium exploration within the Topsails Igneous Complex, using airborne radiometric surveys and detailed lake-sediment sampling. This work covered an area of plutonic and volcanic rocks located in west-central Newfoundland in the region east of the Deer Lake Basin. Several uranium occurrences were discovered, including the Railway, Sheffield Lake South, and the Long Range Mountain prospects (Figure 1). Grab samples from the Railway prospect have returned up to 0.62% U_3O_8, while values of up to 0.009% and 0.023% U_3O_8 were obtained from the Sheffield Lake South and Long Range Mountain prospects, respectively (JNR Resources, Press Release, December 18, 2009).

Spruce Ridge Resources identified several radioactive zones within Silurian volcanic rocks at the northern fringe of the Deer Lake Basin, near southwestern White Bay (Figure 4). Localized mineralization within outcrop assays up to 0.27% U_3O_8 (Spruce Ridge Resources, Press Release, January 9, 2007). Limited drilling has been conducted, but no significant mineralization was reported.

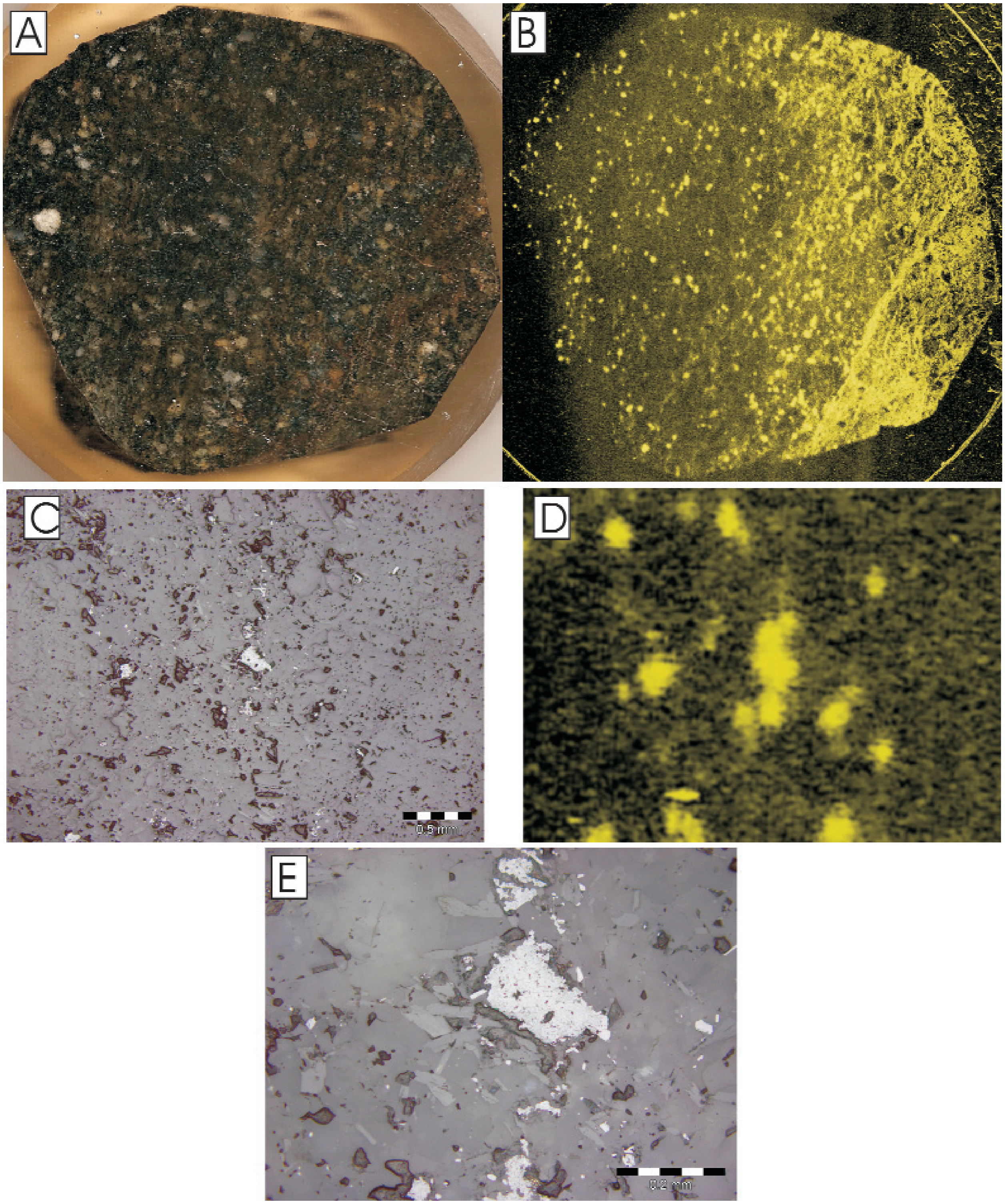

Plate 7. *A) Mineralized polished sample of quartz-phyric tuff from the White Bear #3 prospect; sample is approximately 3 cm wide. B) Autoradiograph of the sample shown in A outlining the main concentration of the radioactivity within the sample (in yellow), which occurs as both fine-grained disseminations throughout the matrix of the tuff as well as within crosscutting fractures. C) Plane-polarized reflected light image from sample shown in A, outlining finely disseminated pale grey radioactive minerals within the matrix of the tuff, which is assumed to be uraninite. D) Portion of an autoradiograph of a polished section outlining the distribution of radioactivity within the reflected light photomicrograph shown in C. E) Magnified view of C showing the ragged finely disseminated radioactive mineral assumed to be uraninite.*

Plate 8. *Pale-weathering felsic metavolcanic rocks of the Bay Du Nord Group crosscut by network-style rusty-weathering uraniferous fractures at the Main prospect.*

Plate 10. *Tuffaceous metasedimentary rocks of the Bay Bu Nord Group crosscut by rusty-weathering uraniferous fractures and joint sets at the Troy's Pond prospect.*

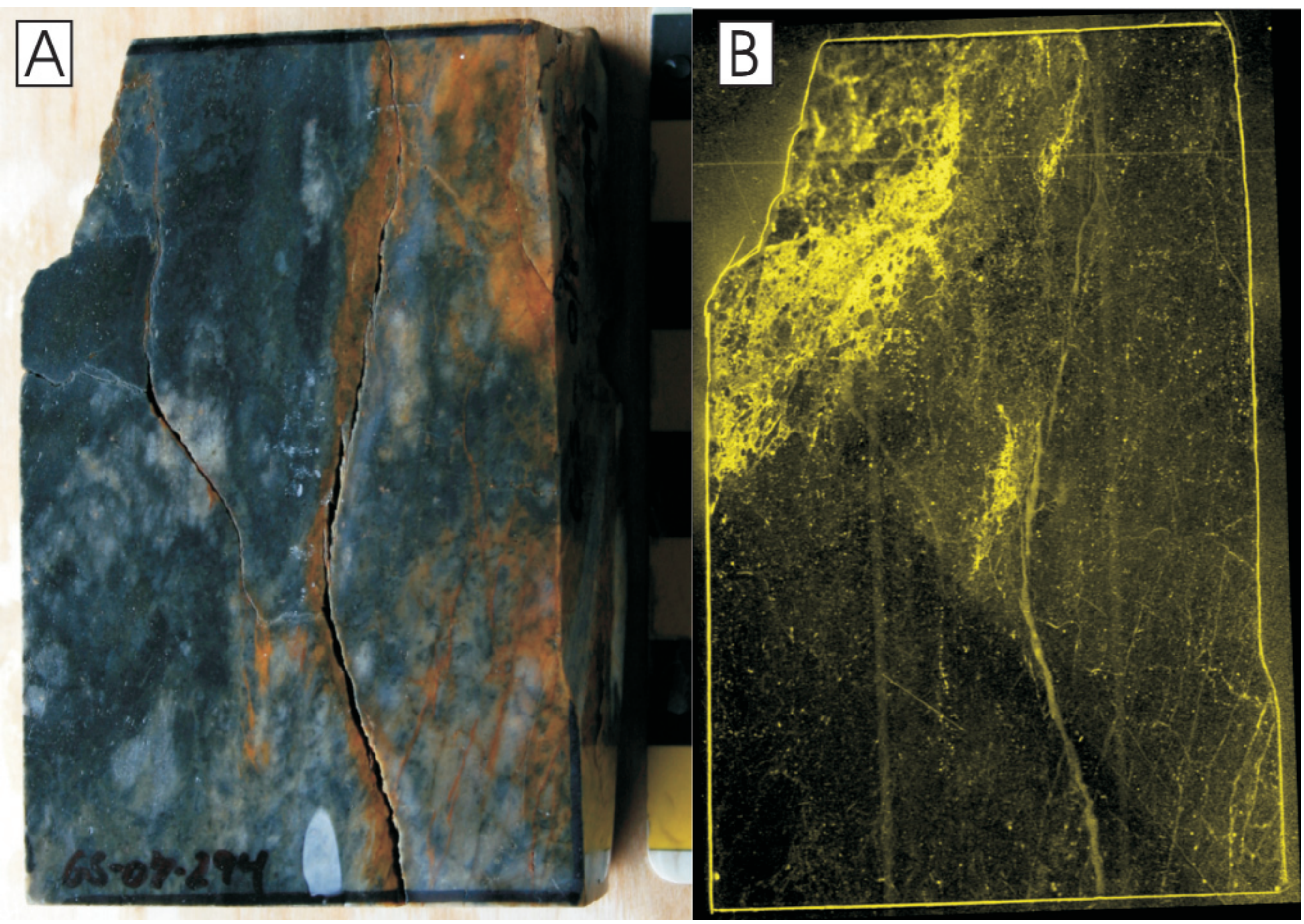

Plate 9. *A) Mineralized grab sample of the felsic metavolcanic host rock at the Main prospect; sample assays 0.12%* U_3O_8*. B)Autoradiograph of sample shown in A, outlining the main concentrations of radioactivity within the sample (shown in yellow, minus the outline of the sample); highest concentrations of radioactivity are associated with regions enriched in biotite (upper left hand corner) and with rusty hairline fractures.*

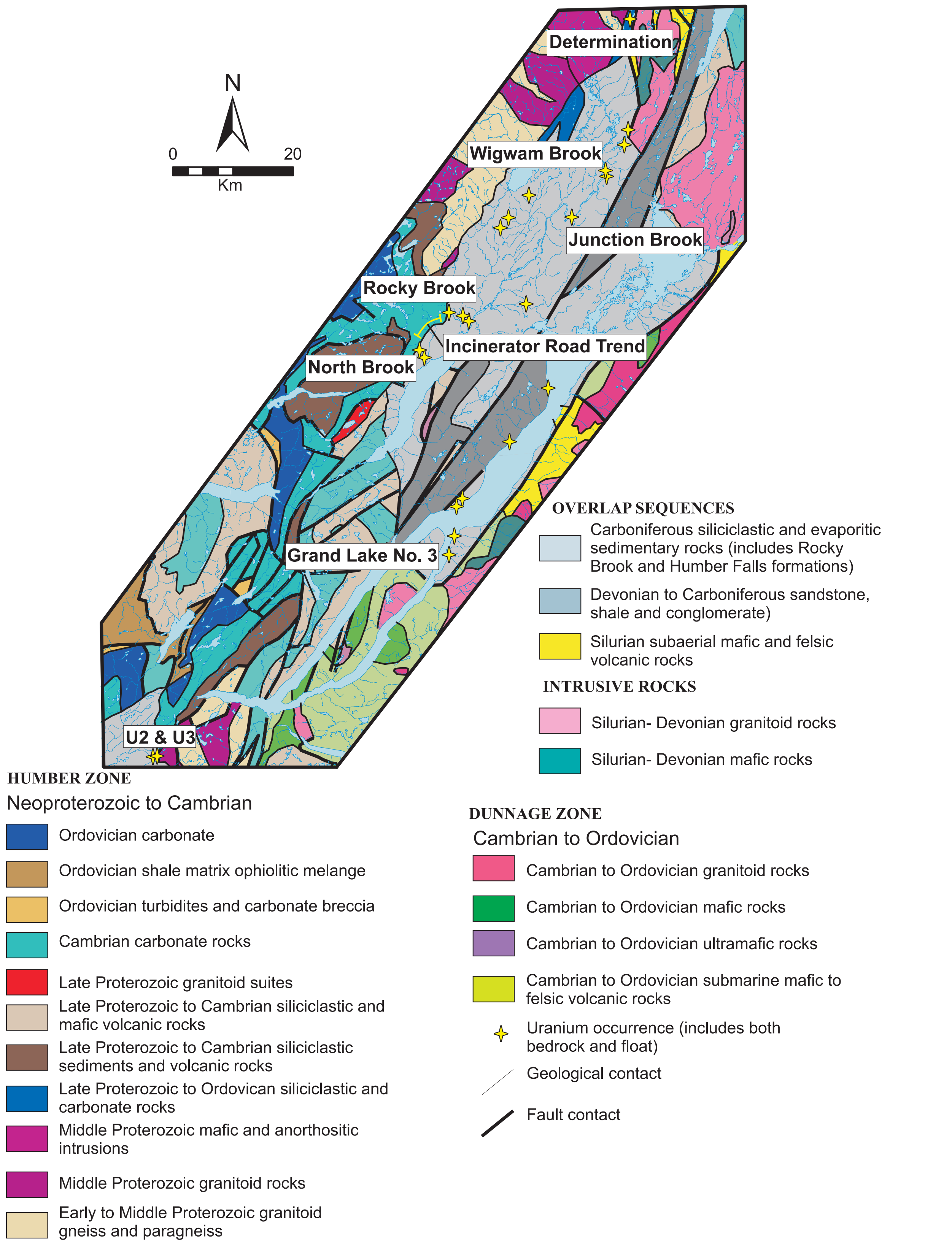

Figure 4. *Distribution of uranium occurrences within the Deer Lake Basin and surrounding region; uranium showings modified from Hyde (1985).*

Geology and Mineralization

Uranium mineralization within the Silurian volcanic rocks of the Kings Point Complex has similarities with that described previously from the Burin Peninsula and Hermitage Flexure regions. However, the host rocks in the Kings Point Complex are much less deformed. At the Amanda Zone, uranium mineralization is concentrated along brittle fractures and joints within chloritic, medium- to thick-bedded, poorly sorted, pebble to cobble breccia and lesser syn-volcanic felsic intrusions (Plate 11). Mineralization within the fracture zones is sporadic and local grab samples assaying up to 0.89% U_3O_8 (Bayswater Uranium Corporation, Press Release, December 5, 2007). Autoradiographs of selected mineralized samples reveal that the radioactivity occurs as finely disseminated material throughout the matrix of the volcaniclastic units. It is typically associated with Fe-oxides developed along hairline fractures, but also occurs as fine-grained disseminations around sulphide-rich and Fe-oxide-rich clasts (Plate 12). Most of the radioactivity is confined to the matrix of the volcaniclastic unit, suggesting that uranium was mobilized from the surrounding felsic volcanic rocks and re-deposited within more permeable zones, possibly *via* reduction involving sulphides.

The Determination prospect, located in the Silurian volcanic rocks of southwestern White Bay (Figure 4), shows several features characteristic of structurally controlled uranium mineralization. Mineralized float, possibly representing subcrop, consists of strongly foliated felsic porphyry that develops a pinkish red colouration due to potassic alteration. Crosscutting fractures are associated with later illite alteration (identified by Visible/Infrared Reflectance Spectroscopy (VIRS) measurements). There is also late-stage quartz veining, which is overprinted by a still-later deformational event (Plate 13). Autoradiographs taken from selected mineralized samples demonstrate that radioactivity is developed marginal to the most intense illite alteration, and is crosscut by the later quartz veining (Plate 14). Uranium-bearing minerals are developed along network-style hairline fractures associated with minor illite alteration marginal to zones of more intense illite alteration; the latter is devoid of any significant radioactivity (Plate14b). Very fine-grained uranium minerals occur in association with finely disseminated Fe-oxide minerals and are locally developed along the ragged margins of fine-grained disseminated pyrite (Plate14d, f). Assay values of up to 0.27% U_3O_8 were obtained from the prospect along with anomalous Ni and Au values (Spruce Ridge Resources, Press Release, January 9, 2007).

Limited information exists within the public domain on the Railway, Sheffield Lake South, and the Long Range Mountain prospects, and due to time constraints these prospects were not visited by the author. Uranium mineralization in association with anomalous Pb and Mo at the Sheffield Lake South prospect is reported to occur predominantly in quartz veins hosted within granite, although the granite is also locally mineralized (JNR Resources, Press Release, December 18, 2009). Mineralization at the Long Range Mountain prospects is associated with rare-earth elements and is hosted by locally derived float consisting of granitic pegmatite and rhyolite (JNR Resources, *op. cit.*).

Plate 11. *Rusty-weathering uraniferous fractures crosscutting chloritic, poorly sorted pebble breccia at the Amanda Zone prospect.*

Grenvillian Basement Rocks in Western Newfoundland

Exploration History

In 1976, Conwest Canadian Uranium Exploration followed up uranium lake-sediment anomalies in the vicinity of Portland Creek (Figure 1). Prospecting identified radioactivity associated with specular/hematite-bearing quartz stockwork zones hosted by granitic basement rocks, assay-

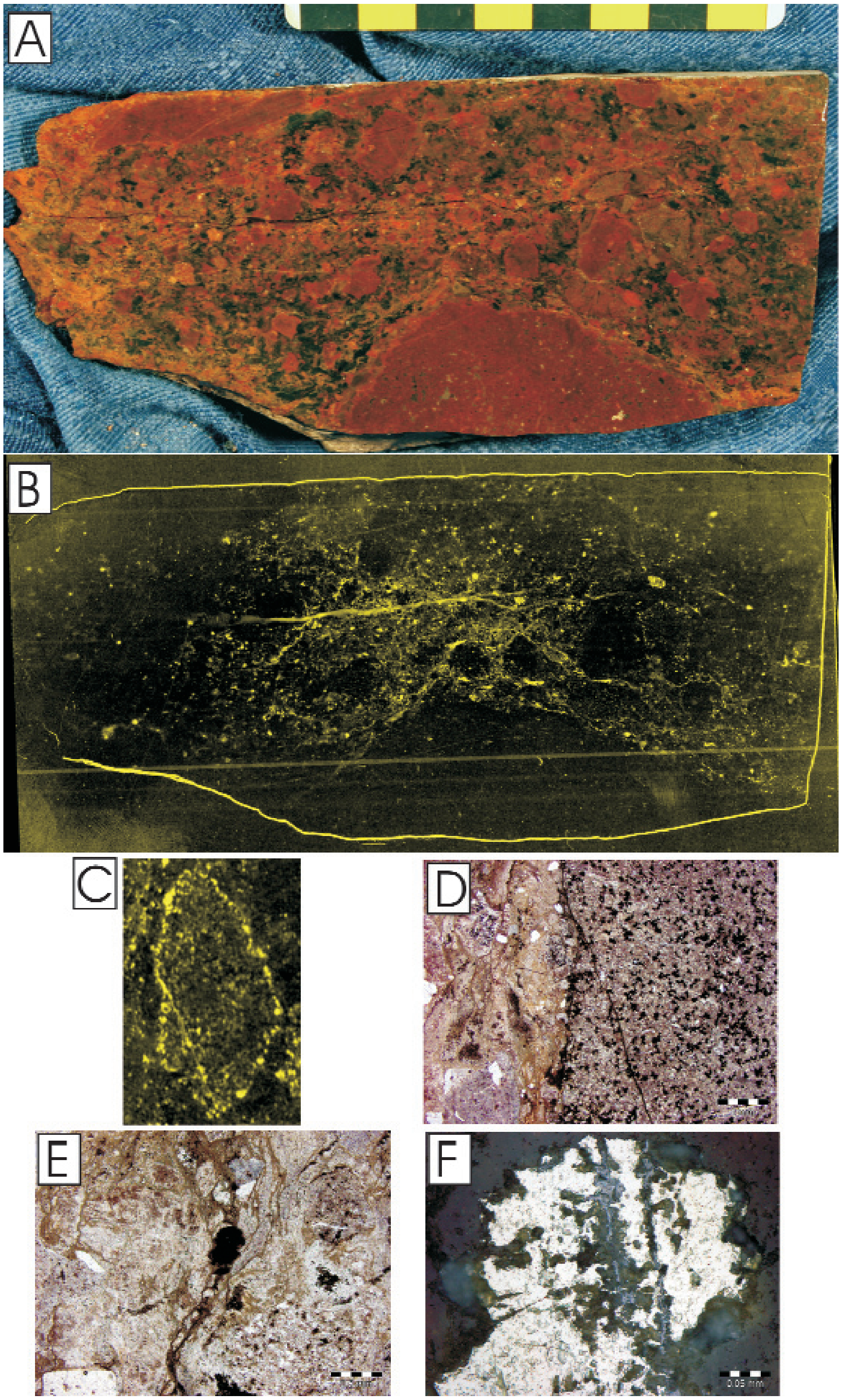

Plate 12. *A) Mineralized hand sample of chloritic poorly sorted pebble breccia from the Amanda Zone prospect. B) Autoradiograph of mineralized sample shown in A outlining the distribution of radioactivity within the sample (shown in yellow, minus the outline of the sample); note the disseminated nature of the mineralization throughout the matrix of the breccia. C) Portion of an autoradiograph from a polished thin section outlining the preferential precipitation of radioactive minerals on select clasts within the breccia. D) Plane-polarized light photomicrograph showing a portion of the clast outlined in C; note the abundant oxides within the clast and the disseminated uraniferous Fe-oxide minerals along the margin of the clast. E) Plane-polarized light photomicrograph showing finely disseminated pyrite occurring along a hairline fracture within the volcanic breccia. F) Reflected-light image of the pyrite crystal shown in E showing the development of a pale-grey radioactive mineral assumed to be uraninite crosscutting the pyrite grain.*

Plate 13. *Strongly radioactive, potassic-altered porphyry affected by illite alteration and later quartz veining at the Determination prospect.*

ing up to 0.22% U_3O_8 (Clarke, 1977). Five drillholes were completed, but no significant mineralization was encountered. In 2007, the property was staked by Ucore Uranium Incorporated, who conducted an airborne radiometric survey of the region. No new mineralization has been reported.

Recent exploration activity has also focused on the Lost Pond region, located along the northeastern portion of the Bay St. Georges subbasin. In this region, the most significant uranium mineralization occurs at the U2 prospect where it is hosted within brecciated and sheared Proterozoic intrusive rocks (Figure 4). This area was first identified in the early 1980s by Shell Canada, through prospecting and boulder tracing, but only limited work was completed at the time (Lewis, 1982). In 2006, Ucore Uranium Incorporated carried out prospecting, trenching and diamond drilling at the U2 and U3 prospects. Trenching at U2 returned values of up to 0.19% U_3O_8 over 3 m and follow-up drilling intersected up to 0.045% U_3O_8 over 12.3 m (Ucore Uranium Incorporated, Press Release, June 8, 2007). In 2008, Ucore optioned the property to Monroe Minerals (now Kirrin Resources Limited), and further drilling ensued. This drilling intersected low-grade uranium mineralization locally assaying up to 0.038% U_3O_8 over 20.1 m, including 0.061% U_3O_8 over 3.0 m (Kirrin Resources Limited, Press Release, April 14, 2009). The area has also attracted attention for rare-earth elements, which are also associated with lesser radioactive zones.

Geology and Mineralization

Only the Lost Pond region was examined by the author, and will be the main focus of this section. At the Portland Creek prospect, minor uranium mineralization has been reported within a quartz–specular hematite-rich breccia developed close to a significant fault structure, but the mineralization appears to be of very limited extent (Clarke, 1977). In the Lost Pond area, at the U2 prospect (Figure 4), mineralization is hosted within fracture zones and associated cataclasite, developed in potassium-feldspar-augen gneiss, orthogneiss, medium-grained granite and quartz syenite. The cataclasite zones are commonly chlorite-rich and also have variably developed hematite alteration. Uranium is associated with the hematization, but not all hematized zones are radioactive. The development of the brittle deformation appears to be relatively late with respect to the formation of the ductile deformation within some of the host rocks, as mineralized fault structures are locally seen crosscutting the regional fabric at right angles.

Uranium mineralization at the U2 prospect is also locally concentrated along the intrusive contact between the orthogneiss and the quartz syenite, where it is associated with hematite alteration as seen in Plate 15. Mineralization also occurs within fractures transecting the quartz syenite, suggesting that the mineralization postdates the intrusion. Autoradiographs from the locality highlight the association of hematite alteration with uranium mineralization (Plate 16). In thin section, the regions of highest radioactivity, as outlined by autoradiographs, are associated with the development of specular hematite and Fe–Ti oxides within the matrix of the cataclasite (Plate 16c and d).

SANDSTONE-HOSTED URANIUM MINERALIZATION

This style of uranium mineralization is confined to Carboniferous sedimentary rocks and includes most of the known uranium occurrences in Newfoundland. Similar styles of mineralization are noted elsewhere in Atlantic Canada, as outlined by Dunsmore (1977). Sandstone-hosted uranium mineralization is best known in the Colorado Plateau and the Gulf Coast Plain in south Texas (*cf.* Cuney and Kyser, 2009). This style of mineralization consists of epigenetic concentrations of uranium minerals predominantly within fluvial, lacustrine, and deltaic sandstone formations (Finch and Davis, 1985). The grade is generally low (0.05–0.4% U) and the primary minerals are uraninite and coffinite (OECD/NEA-IAEA, 2008). Sandstone-hosted deposits are subdivided into four main types: 1) basal, 2) tabular, 3) roll-front, and 4) tectonolithologic. For a more detailed description of these subdivisions, the reader is referred to Cuney and Kyser (2009), and references therein.

Carboniferous Basins of Western Newfoundland

Exploration History

Carboniferous basins in western Newfoundland were explored in the 1970s and 1980s, following the discovery of

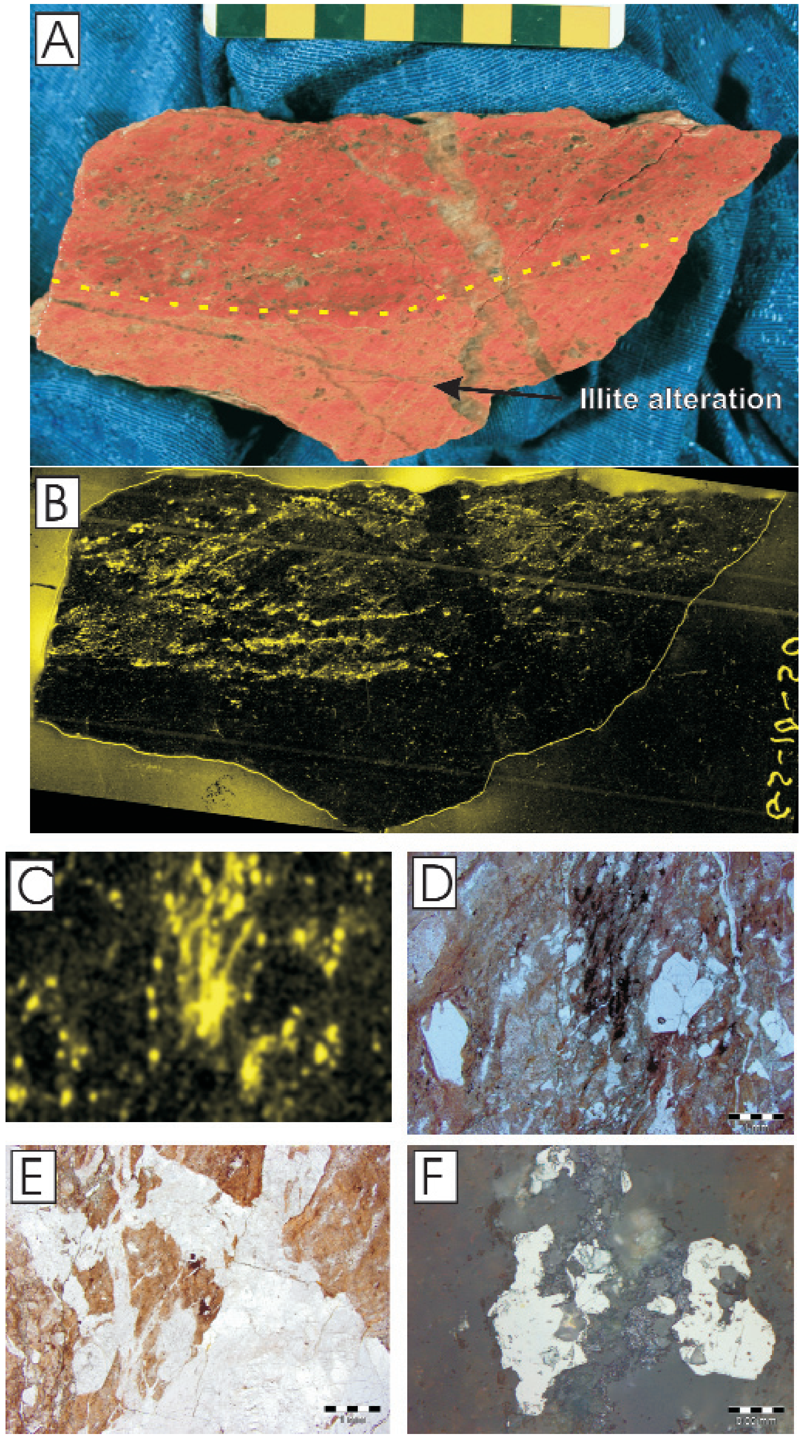

Plate 14. *A) Mineralized hand sample of the potassic-altered porphyry unit crosscut by fracture-hosted illite alteration and later quartz veining (yellow dashed line marks the limit of intense illite alteration). B) Autoradiograph of sample shown in A outlining the distribution of radioactivity within the sample (shown in yellow, minus the outline of the sample); note the radioactivity is developed marginal to the main zone of illite alteration outlined in A. C) Portion of an autoradiograph of a polished thin section outlining the distribution of radioactivity in D. D) Plane-polarized light photomicrograph showing the development of finely disseminated pyrite, uraniferous Fe-oxide minerals and lesser illite along hairline fractures marginal to the most intense illite alteration. E) Plane-polarized light photomicrograph showing the incorporation of mineralized material within a later quartz vein. F) Reflected-light image showing finely disseminated pyrite rimmed by a pale grey radioactive mineral assumed to be uraninite.*

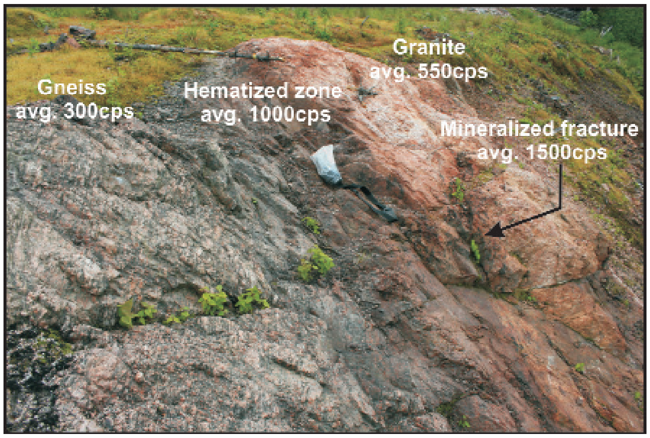

Plate 15. *Zone of hematite alteration and anomalous radioactivity developed along the intrusive contact between the orthogneiss (left) and the quartz syenite (right); note the mineralized fracture crosscutting the intrusive (cps abbreviation denotes counts per second as measured with a RS-120 scintillometer shown near centre of photograph).*

high-grade uranium-bearing float. This float locally contains up to 11.5% U_3O_8 and up to 859 oz/ton of silver. These values prompted extensive trenching and drilling in the vicinity of the Wigwam Brook prospect (Figure 4; Byrne, 1979a), but, comparable grades of mineralization were neither located in outcrop nor during drilling. Anomalous radioactivity was also discovered elsewhere in the Deer Lake Basin, including along the shoreline of Grand Lake, where assays from the Grand Lake No. 3 prospect returned >0.1 % U_3O_8 (Parker and Rizzuto, 1979; Figure 4).

The Bay St. George subbasin in southwestern Newfoundland was also targeted during the 1970s and early 1980s. Westfield Minerals recorded uranium mineralization in 1976, when samples collected from radioactive outcrops within the riverbed of the Codroy River returned assay results of 0.02% U_3O_8 (Byrne, 1979b). High-grade uranium mineralization was discovered locally, such as in a coal-rich sample containing 2.2% U_3O_8 from the Grand Codroy No. 3 prospect. However, most findings were low-grade and exploration was abandoned in the early 1980s (Sherwin, 1981).

Renewed activity in western Newfoundland has mostly targeted the Deer Lake Basin. Since 2004, Altius Minerals, in conjunction with Cameco, and later JNR Resources, have worked steadily to trace the origin of high-grade mineralized sandstone boulders located by previous work. This exploration has included detailed airborne radiometric surveying, ground geophysical investigations, and shallow diamond drilling (O'Reilly *et al*., 2007). Extensive drilling in the region of the high-grade float has intersected low-grade mineralization; including up to 0.014% U_3O_8 over 0.7 m (JNR Resources, Press Release, June 14, 2006). Spruce Ridge Resources has re-evaluated the uranium occurrences in the North Brook region of the Deer Lake Basin (Figure 4), but shallow drilling in the region failed to intersect any significant mineralization. However, they have outlined a zone of anomalous uranium enrichment, known as the 'Incinerator Road Trend', within the basal units of the Rocky Brook Formation, close to its unconformable contact with underlying Cambro-Ordovician siliciclastic basement rocks (Spruce Ridge Resources, Press Release, September 8, 2008). Other regions of anomalous radioactivity within the basin include the Rocky Brook and Junction Brook prospects (Hyde, 1985; Figure 4).

Geology and Mineralization

Uranium mineralization within the Deer Lake Basin was divided into three main groups by Hyde (1985). These are:

1) mineralization associated with the unconformity between the North Brook Formation of the Deer Lake Group and the underlying Cambro-Ordovician carbonate rocks and metasedimentary units along the western margin of the basin;
2) stratiform mineralization occurring in lacustrine siltstone, mudstone and carbonate rocks of the Rocky Brook Formation; and
3) mineralization occurring within sandstone of the Humber Falls Formation of the Deer Lake Group.

The latter includes the high-grade boulders from the Wigwam Brook prospect. Most of these types can be grouped within a single style of mineralization in terms of modern classification schemes, namely sandstone-hosted uranium mineralization (OECD/NEA-IAEA, 2008). Although Hyde (1985) mentions the presence of unconformity related uranium mineralization, no true example of this style of mineralization has yet been identified. However, limited drilling has identified weakly anomalous uranium (up to 175 ppm U_3O_8 over 3.30 m) within basal conglomerate of the Rocky Brook Formation immediately overlying the Cambro-Ordovician carbonate basement rocks (Spruce Ridge Resources, Press Release, September 8, 2008). Thus, mineralization associated with the basal unconformity of the Deer Lake Group may still represent a potential exploration target.

The second and third types of mineralization outlined by Hyde (1985) represent typical sandstone-hosted uranium mineralization. Most occurrences of this style of mineralization are confined to the Rocky Brook Formation, but the high-grade float from the Wigwam Brook prospect is interpreted to originate from the overlying Humber Falls Formation (Hyde, 1979b; 1985). Uranium concentrations rarely exceed 0.1% U_3O_8, and more typically range between 50-

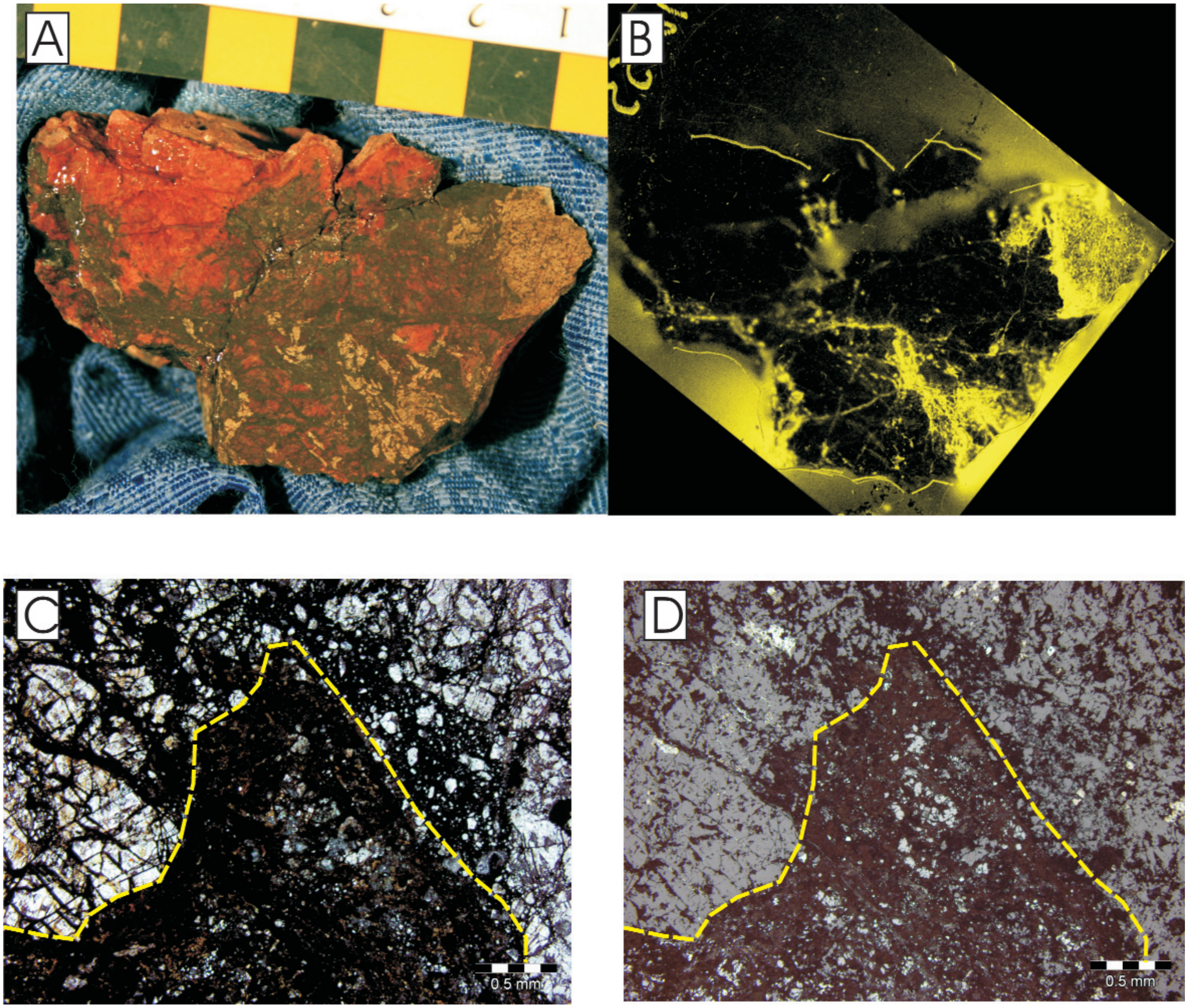

Plate 16. *A) Mineralized hand sample of hematized quartz syenite. B) Autoradiograph of sample shown in A outlining the distribution of radioactivity within the sample (shown in yellow, minus the outline of the sample). C) Plane-polarized light photomicrograph of cataclasite developed within the quartz syenite displaying infiltration of uraniferous oxidizing fluids (radioactivity is restricted to region below the yellow dashed line). D) Reflected-light image of C showing the distribution of specular hematite and accompanying uraniferous finely disseminated Fe–Ti oxide minerals associated with the uranium mineralization.*

200 ppm U. Small discrete zones of high-grade mineralization are also locally developed, such as the 3.73% U_3O_8 sample obtained by Spruce Ridge Resources from the region of the North Brook prospect (Spruce Ridge Resources, Press Release, November 1, 2006), but these are usually associated with hydrocarbon nodules or other such small-scale features within the Rocky Brook Formation. Drilling by Spruce Ridge Resources in the North Brook area intersected the same relatively flat-lying stratigraphy as exposed along North Brook, but only encountered weakly elevated levels of uranium (Spruce Ridge Resources, Press Release, September 18, 2007).

Within the Rocky Brook Formation, uranium mineralization is generally concentrated within reduced beds of thinly bedded to thickly laminated dolomitic siltstone, mudstone and lesser limestone and oil shale. These units are interbedded within a more aerially extensive sequence of oxidized siltstone and sandstone (Plate 17). In areas hosting anomalous uranium mineralization, the stratigraphy is gen-

Plate 17. *Flat-lying zone of anomalous radioactivity primarily concentrated within a dolomitic limestone bed that is interbedded with pale green dolomitic siltstone and mudstone and is in turn overlain by thickly bedded oxidized sandstone; note the average counts per second for the anomalous beds are to the right of the photograph (cps abbreviation denotes counts per second as measured with a RS-120 scintillometer shown in the right of photograph).*

Plate 18. *Thick-bedded, medium- to coarse-grained sandstone scouring underlying thinly bedded grey mudstone and interbedded dolomitic siltstone. Base of sandstone (yellow dashed line) becomes reduced where it lies in contact with the mudstone and both are host to anomalous radioactivity implying that uranium mineralization is not syngenetic with the deposition of the mudstone and is the result of later diagenetic fluid migration.*

erally flat lying to very shallowly dipping. Mineralized beds range from 20 to 75 cm in thickness and rarely exceed 1 m. The uranium mineralization forms tabular bodies and appears stratiform; this mineralization is continuous over several 10s of metres along strike. In local instances, it is evident that the thinly bedded dolomitic mudstone has been scoured, and then infilled by more massive to thickly bedded sandstone, with the sandstone becoming reduced along its base. Both units are associated with anomalous radioactivity (Plate 18). Some of the carbonate rocks that contain uranium show desiccation features as well as delicate laminations of possible algal origin. Hyde (1985) noted that there is no particular facies control on the distribution of uranium and there appears to be no evidence for the enrichment of lower or upper stratigraphic levels within the Rocky Brook Formation. Although the mineralization appears stratiform in many respects, it has yet to be determined if the mineralization is truly syngenetic.

Mineralization within the Humber Falls Formation has been the focus of much exploration and several detailed studies (*e.g.,* Hall *et al*., 1980; Thurlow *et al*., 2003) and is only briefly summarized herein. Mineralized boulders correlate with three separate anomalous zones, the Reid Lot 218–Wigwam Brook, Birchy Brook and Goose anomalies occur in a region of very poor outcrop within the central portion of the Deer Lake Basin (Plate 19). Uranium mineralization is predominantly confined to the matrix of the coarse-grained sandstone (Plate 20) where it displays a close spatial association with finely disseminated hematite and Fe–Ti oxide minerals, as noted by Hall *et al*. (1980). Uranium mineralization occurring within the matrix of the arkosic sandstone is also locally accompanied by anomalous Cu and Ag (*op. cit.*). Mineralization was discovered in outcrop by Westfield Minerals while trenching in the vicinity of the anomalous float. Grab samples yielded values up to 1.28% U_3O_8; however follow-up drilling failed to intersect any significant mineralization (Byrne, 1979a). Current exploration in the area is targeting regional structures that might control stratabound mineralization, and has outlined an anomalous zone of radioactivity elongated parallel to several suspected high-angle reverse faults in the area (O'Reilly *et al*., 2007).

In the Bay St. George subbasin, uranium mineralization displays some similarities with that in the Deer Lake Basin. Mineralization is mainly associated with the upper formations of the Codroy Group along the southeastern margin of the basin (Knight, 1984). In this region, uranium mineralization is commonly associated with malachite. Two main depositional environments have been distinguished by Knight (1984). The first type of mineralization occurs within fine-grained, micaceous, carbonaceous sandstone interbedded with red siltstone and grey mudstone. The highest concentration of mineralization generally occurs along

Plate 19. *Panoramic photo showing the low-lying, poorly exposed region that is host to the high-grade uraniferous float within the central portion of the Deer Lake Basin.*

the basal contact of the sandstone where it lies in direct contact with mudstone (Plate 21). The second type of mineralization is hosted within the basal coarse-grained sandstone facies of fining-upward meandering fluvial sequences in which radioactivity is generally associated with lens of mudstone or carbonaceous plant fossils at the lower most portions of these beds (Plate 22). In both instances, very low levels of uranium mineralization are encountered, ranging from 50 to 150 ppm U. There has been little exploration interest in the Bay St. George subbasin during recent exploration.

Connaigre Peninsula–Fortune Bay area

Exploration History

Anomalous radioactivity was first noted along the southern shore of the Connaigre Peninsula by Greene (1977). The most notable occurrences in the area are the Boxey Point and Coomb's Cove prospects (Figure 2). More recently, the Boxey Point prospect was the subject of exploration carried out by Kirrin Resources Limited (formerly Monroe Minerals). Drilling intersected narrow zones of mineralization that yielded assay results up to 0.164% U_3O_8 over 0.5 m (Kirrin Resources Limited, Press Release, April 5, 2010). However, the drilling failed to intersect similar styles of alteration as exposed along the coastline.

Geology and Mineralization

The host rock to the uranium mineralization on the Connaigre Peninsula is the Great Bay de l'Eau Formation, which consists of red to buff pebble to boulder conglomerate with lesser dark green conglomerate, and red and black shale (Greene, 1975). At the Boxey Point prospect, a yellow rusty-weathering radioactive zone occurs within an otherwise red to pale grey-green sequence of pebble conglomerate and lesser lenses of thin-bedded green sandstone. The main rusty zone associated with the radioactivity is generally developed parallel to bedding but displays a 'roll-front form' in the down-dip direction (Plate 23), Locally, grab samples containing up to 0.037% U_3O_8 have been obtained (Greene, 1977). The mineralization is crosscut by a younger mafic dyke, and the adjacent sediments locally contain the highest grade uranium mineralization. Both the dyke and the mineralization are offset along brittle faults as shown in Plate 23. This mineralization is interpreted to be a slightly different style of sandstone-hosted uranium mineralization, namely a roll-front style akin to that described from areas such as the Colorado Plateau.

SUMMARY AND DISCUSSION

To date, none of the uranium occurrences discovered on the Island of Newfoundland have probable economic significance, but the area has not experienced the extensive exploration activity seen in parts of Labrador.

Uranium mineralization is widely distributed throughout the Island and displays no obvious preferential concentration within any of the four lithotectonic subdivisions. The mineralization can be classified within two main styles, namely, vein-hosted volcanic- and intrusion-related, and sandstone-hosted. Outside the Carboniferous sedimentary basins, uranium occurrences generally display an epigenetic, vein-hosted, style of mineralization that is hosted by or spatially associated with compositionally evolved and locally peralkaline plutonic and volcanic rocks. The ages of these host rocks range from Precambrian (U2 prospect) to Ordovician (Bay du Nord Group) to Silurian (central Newfoundland) and Devonian (southern Burin Peninsula). Some of the uranium occurrences in volcanic settings may be syngenetic with respect to their host rocks, but the timing of most mineralization remains to be determined. In some cases, the fluids may have been late-magmatic hydrothermal solutions, but where mineralization is associated with late crosscutting fracture systems, a relationship to much younger groundwater circulation cannot be ruled out. The potential for granite-hosted styles of uranium mineralization (as seen in Europe) was noted by Strong *et al*. (1978), but there is as yet no indication of any large-scale mineralization of this type in Newfoundland. The peralkaline Silurian volcanic rocks and associated intrusions of central Newfoundland represent a relatively new target for volcanic-hosted uranium deposits. Ana-

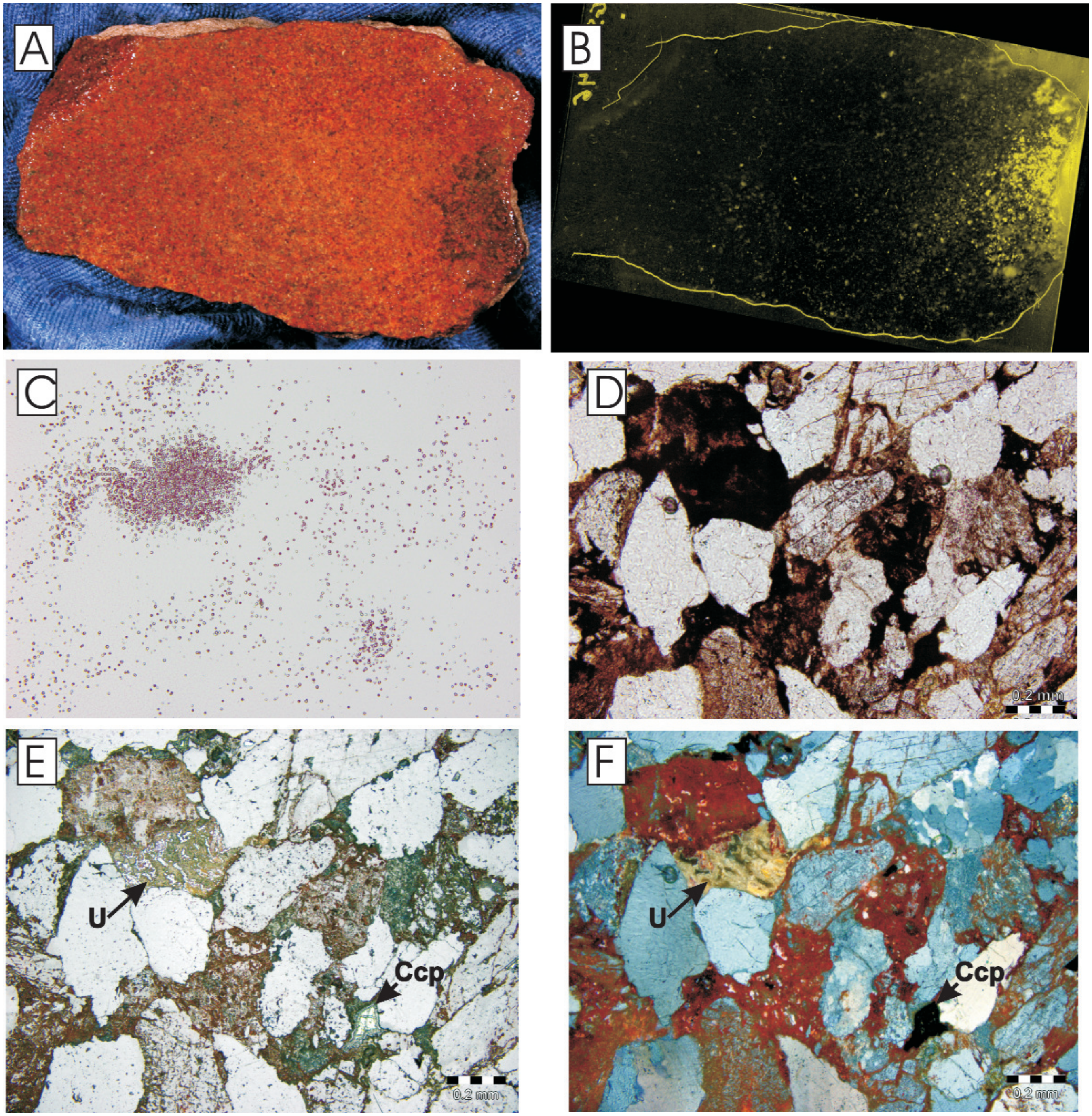

Plate 20. *A) Mineralized float of the Humber Falls Formation from the Wigwam Brook prospect. B) Autoradiograph outlining the distribution of radioactivity (shown in yellow, minus the outline of the sample) within the hand sample. C) Portion of an autoradiograph of a thin section taken from the sample shown in A, which outlines the regions of anomalous radioactivity (cloudy regions). D) Plane-polarized light photomicrograph of the region shown in C, demonstrating the association of radioactivity with the formation of fine-grained Fe-oxide minerals and hematite within the matrix of the sandstone unit. E) Reflected-light image of D showing the presence of an unidentified uraniferous phase (U) along with trace chalcopyrite (Ccp). F) Cross-polarized reflected-light image of E showing the abundance of hematite within the matrix of the sandstone.*

Plate 21. *Thin-bedded red siltstone scoured by pale grey medium-grained sandstone containing rip-up clasts of red mudstone.*

Plate 22. *Carbonaceous plant material associated with anomalous radioactivity within the basal portions of coarse-grained sandstone beds.*

logues for similar styles of mineralization would be the Streltsovskoye-Antei deposit, Russia and the Marysvale volcanic field, United States. Peralkaline igneous suites are relatively abundant in Newfoundland, and have not previously been assessed from this perspective.

Based on the abundance of occurrences, the Carboniferous basins of western Newfoundland offer a high-potential environment to future uranium exploration. The high-grade float discovered 30 years ago in the Deer Lake Basin continues to drive exploration in these areas. Clearly, at grades of >10% U_3O_8, the potential size of an economically important orebody would be very small, and it may not represent an easy target. External detrital sources for uranium in the sedimentary rocks may be present within Proterozoic basement rocks to the north and west, or the peralkaline Silurian volcanic rocks and associated intrusions situated to the east. In the Bay St. George subbasin, mineralization resembles

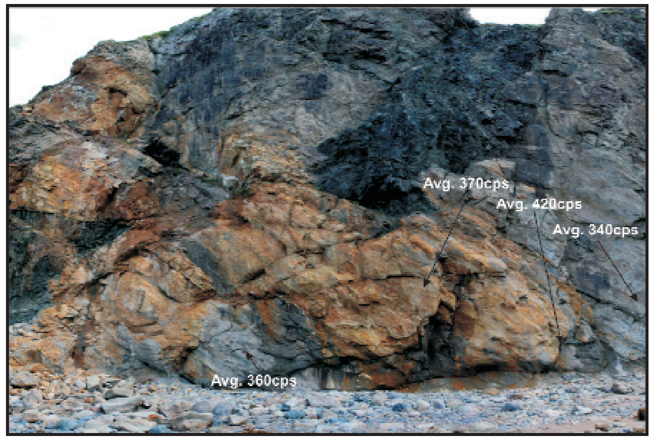

Plate 23. *Possible example of roll-front type uranium mineralization at the Boxey Point prospect (cps abbreviation denotes counts per second as measured with a RS-120 scintillometer); gossan zone to the right of centre in the photograph is approximately 6 m in height.*

that described from rocks of similar age in Nova Scotia (Dunsmore, 1977). In Nova Scotia, highly saline brines derived from underlying evaporate formations were proposed as the potential transport mechanism for uranium (Dunsmore, 1977), and these rocks are also present at depth within the Bay St. George subbasin (Knight, 1983). The mineralization in the Devonian–Carboniferous sedimentary rocks of the Island share many similarities with sandstone-hosted deposits described elsewhere in the world, and this exploration model seems appropriate for future exploration efforts.

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