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L'âge maximal d'une concrétion à Green Creek, Ontario

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Résumé de l'article

Un morceau de bois (? *Salix* sp.), prélevé dans une concrétion calcaire provenant de la terrasse de - 43 m au site de Green Creek, en Ontario, a fourni un âge radiocarbone de 9 960 ± 820 BP (GSC-2498). Les carbonates de la concrétion ont fourni un âge apparent de 14 400 ± 250 BP (GSC-2530). L’âge du bois est un âge maximal pour la mise en place des sédiments qui entourent le bois ainsi que pour la formation de la concrétion. Le résultat de la datation sur les carbonates semble anormal. L’âge maximal du bois, en se basant sur la limite d’erreur, est de 10 789 BP. À ce moment, la mer de Champlain recouvrait la région jusqu’à au moins 100 m d’altitude. L’âge réel du bois se rapproche probablement plus de celui des moules d'eau douce prélevées à - 53 m à Bourget (10 200± 90; GSC-1968) ou du bois découvert à ~ 61 m à Hawkesbury (9 860 ± 230; BGS-257). Les sédiments de la terrasse de ~ 43 m ont probablement été mis en place en eau douce. La présence d’une flore et d’une faune terrestre et d’eau douce, dans diverses concrétions provenant du site de Green Creek, suggère d’ailleurs une mise en place des sédiments dans un milieu estuarien ou d’eau douce. La présence anormale, semble-t-il, d’organismes marins, comme les squelettes de poissons, dans les concrétions est reliée à un processus chimique de la précipitation d’un ciment calcaire provoqué par la putréfaction de la chair des organismes. Ce phénomène pourrait contribuer à la conservation de fossiles fragiles au cours d’un ou même de plusieurs cycles d’érosion. Certains fossiles retrouvés dans les concrétions du site de Green Creek sont probablement allochthones aux sédiments dans lesquels ils se retrouvent.

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Notes

MAXIMUM AGE FOR A CONCRETION AT GREEN CREEK, ONTARIO

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ABSTRACT Wood (? *Salix* sp.) from a concretionary nodule found at ~ 43 m a.s.l. at the Green Creek, Ontario, site was dated at 9 960 ± 820 BP (GSC-2498). The carbonate concretion has an apparent age of 14 400 ± 250 BP (GSC-2530). The wood date is a maximum age for the enclosing sediment and for its cementation; the carbonate date appears anomalous.

At the time of the upper limit of error for the wood date (10 780 BP) Champlain Sea stood at or above 100 m a.s.l. The true age of the wood probably is compatible with that of freswhater shells at ~ 53 m a.s.l. at Bourget, Ontario (10 200 ± 90; GSC-1968), and of wood at ~ 61 m a.s.l. at Hawkesbury, Ontario (9 860 ± 330; BGS-257). Terrace sediments at ~ 43 m a.s.l. probably are of freshwater origin. Terrestrial and freshwater flora and fauna in earlier collections of concretions from Green Creek also suggest an estuarine to freswhater environment for the enclosing sediments.

Occurrence of complete skeletons of fish and other vertebrates in concretions is related to chemically induced carbonate cementation during early stages of putrefaction of soft-bodied animals. This could preserve skeletal remains through several cycles of erosion. Therefore some concretions carry fossil remains that may be allochtonous to the sediment in which they now occur.

RÉSUMÉ *L'âge maximal d'une concrétion à Green Creek, Ontario*. Un morceau de bois (? *Salix* sp.), prélevé dans une concrétion calcaire provenant de la terrasse de ~ 43 m au site de Green Creek, en Ontario, a fourni un âge radiocarbone de 9 960 ± 820 BP (GSC-2498). Les carbonates de la concrétion ont fourni un âge apparent de 14 400 ± 250 BP (GSC-2530). L'âge du bois est un âge maximal pour la mise en place des sédiments qui entourent le bois ainsi que pour la formation de la concrétion. Le résultat de la datation sur les carbonates semble anormal.

L'âge maximal du bois, en se basant sur la limite d'erreur, est de 10 789 BP. À ce moment, la mer de Champlain recouvrait la région jusqu'à au moins 100 m d'altitude. L'âge réel du bois se rapproche probablement plus de celui des moules d'eau douce prélevées à ~ 53 m à Bourget (10 200± 90; GSC-1968) ou du bois découvert à ~ 61 m à Hawkesbury (9 860 ± 230; BGS-257). Les sédiments de la terrasse de ~ 43 m ont probablement été mis en place en eau douce. La présence d'une flore et d'une faune terrestre et d'eau douce, dans diverses concrétions provenant du site de Green Creek, suggère d'ailleurs une mise en place des sédiments dans un milieu estuarien ou d'eau douce.

La présence anormale, semble-t-il, d'organismes marins, comme les squelettes de poissons, dans les concrétions est reliée à un processus chimique de la précipitation d'un ciment calcaire provoqué par la putréfaction de la chair des organismes. Ce phénomène pourrait contribuer à la conservation de fossiles fragiles au cours d'un ou même de plusieurs cycles d'érosion. Certains fossiles retrouvés dans les concrétions du site de Green Creek sont probablement allochthones aux sédiments dans lesquels ils se retrouvent.

HISTORICAL BACKGROUND OF GREEN CREEK CONCRETIONS

Concretionary nodules of laminated sediment have been collected for more than a century at a site about 10 km east of the Parliament Buildings of Ottawa, Ontario, on the south bank of the Ottawa River and in the valley of a small tributary, Green Creek (Green's Creek, in earlier literature) (Fig. 1). Hiawatha Park, at the same place, was the terminus of a now long-defunct Ottawa River ferry boat where, it is said, the ferry pilot made a small commerce from collecting and selling concretions, getting his best prices for those containing skeletal remains of fish and other organic remains. These popular curios were also the subject of numerous scientific comments and studies that have

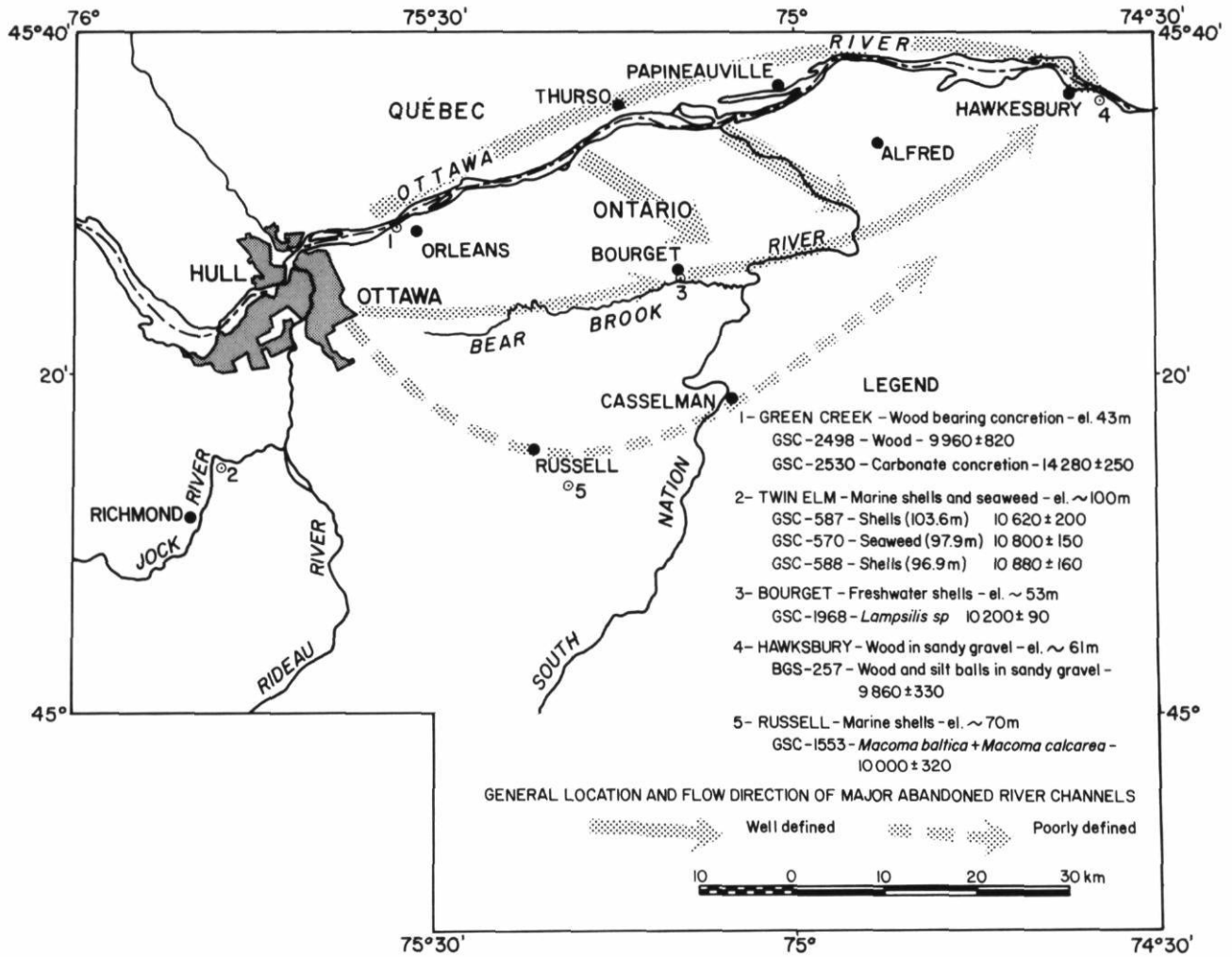

FIGURE 1. Location map. Sites of radiocarbon dates referenced in text and pattern of major abandoned river channels.

Cartes de localisation des datations au radiocarbone cités dans le texte et schéma des principaux chenaux fluviatiles délaissés.

appeared in the literature. The age and significance of the concretions and of their contained fossils have been the subjects of varied interpretation.

In a summary report, LOGAN (1863, p. 916-917) reported: "About the mouth of Green's Creek in Gloucester, a bed in the clay, near highwater mark, abounds in nodular masses, which are strewn along the shore of the Ottawa for two miles to the eastward. These seem to have been formed by a process of concretion around various organic remains." Among these remains he noted *Mallotus villosus*, or capeling of the lower St. Lawrence" and other species of fish and molluscs of the marine environment. Emphasis of marine fossil content of concretions by numerous studies and references gives rise to the general concept that the clay deposits that enclose the fossils, are, therefore, of marine origin.

It should be noted, however, that after his notation of marine species present in the clay, LOGAN (1863, p. 917) added: "besides which are a species of freshwater shell, and various land-plants. Among the latter, Dr. Dawson has recognized the following species: *Drosera rotundifolia, Trifolium repens, Potentilla Norvegica, P. tridentata, P. Canadensis, Arctostaphylos uva-ursi, Populus balsamifera, Potamogeton perfoliata, and P. natans;* besides grasses, carices, mosses, and algae."

HARINGTON (1971, 1972, 1977, 1978 and references therein) summarized the history and environment of Champlain Sea and reviewed the vertebrate fossils

found, including fish. Many of the reference specimens were enclosed in concretions from the Green Creek site. CHAMPAGNE *et al.* (1979) reported the occurrence of a deepwater sculpin, *Myoxocephalus thompsoni* (Girard), in a Green Creek concretion. The discussion of the significance of this vertebrate "only recoded from freshwater" in association with other species, some clearly freshwater and some clearly marine, from other concretions led the authors to indicate some choice as to interpretation of the environment that is represented. Their suggestions range from catastrophic drainage of freshwater lakes into the sea, to the alternative that "the "sea" itself may have been fresh during the final phase...". Further evidence of a freshwater environment was presented by GRUCHY (1968) who identified a lake trout *Christivomer namayacush*, that is not anadromous (*i.e.*, does not travel between the sea and freshwater).

DAWSON (1893) noted "upper" (= non-marine?) and "lower" (= marine) clays in the St. Lawrence Lowland and apparently used marine fossil content (in preference to freshwater and terrestrial forms he also identified) in the concretions to classify the Green Creek sediments as "lower" clay. JOHNSTON (1917), however, classified the younger clay at Green Creek and other similar sediment of the Ottawa region as lacustrine, but ANTEVS (1925, 1939) recognized two clay bodies at Green Creek, and elsewhere in Ottawa Valley, and used the presence of marine species in the concretions of the "upper" clay to support his concept of two separate invasions of the valley by the sea; first Champlain Sea, then "Ottawa Sea". Indeed ANTEVS (1925) introduced the name "Lake Ottawa" for the environment of deposition of sediment identified by Johnston, and only later (ANTEVS, 1939) changed it in favour of "Ottawa Sea". The present writer (GADD, 1961, 1963, 1971) has challenged the Ottawa Sea concept, and has supported an interpretation closer to that of JOHNSTON (1917). Commenting on previous "unsatisfactory" reports of sandy beds between two clay beds in Ottawa Valley, ANTEVS (1962, p. 197) brought his conclusions almost full cricle with the statement that his "new interpretation implies that Champlain Sea had only one deep-water stage".

The nature and origin of the concretions themselves were investigated in a classic paper by KINDLE (1923) in which he made this significant statement (p. 624): "The general absence of concretions from the clays cut by ditches leads to the inference that their development is limited to a superficial zone of clay which has been exposed for a considerable period in the streambank sections of the district." JOHNSTON (1917, p. 29), speaking of the Ottawa Valley concretions, made these similar notes: "calcereous concretions... are not known to occur in the clays exposed in excavations as in the brickyards away from the stream valleys", and further: "Where seen in place in the clays the concretions lie with their longer axis in the direction of the planes of bedding. The beds show no evidence of bulging or unevenness around the concretions... It is generally held that calcareous clay concretions..., are found only in the zone of cementation, above the general permanent level of the ground water... Hence it is probable that the concretions were formed after the complete withdrawal of the marine waters and largely during the time since the establishment of the present drainage."

OTHER NOTES ON THE ORIGIN OF CONCRETIONS

Observations on the nature of concretions in St. Lawrence Valley varved clay led the present author (GADD, 1971, p. 47-48) to the conclusion that groundwater moved horizontally most freely along the coarse-grained (summer) layers of the varves and that the sediments probably were cemented as a result of evaporation of groundwater at the exposure face. More recently CARTER *et al.* (1977), working in Ireland, compared the chemistry and mineralogy of concretions in varves with those of natural, or uncemented, varves. Their findings allowed the conclusion that "slow percolation of groundwater may have assisted the process" of the formation of nodular concretions. In addition, they determined that the carbonate content of concretions was about 15% higher than that of uncemented varves of the same formation.

BERNER (1969) revealed another aspect of the origin of concretions by observing fish sealed in jars containing sea water and other solutions over periods of only to 205 days. From his study of the chemical reactions activated by bacterial decomposition of the fish, he suggested "that some ancient $CaCO_3$ concretions, especially those enclosing fossils of soft-bodied organisms, may have been formed rapidly after death in the form of natural Ca soap (adipocere) which was later converted to $CaCO_3$". The experiments showed that chemical conditions present were adequate "to precipitate calcium as $CaCO_3$ during the early stages of decay".

It is not surprising that various authors, dealing with one or more of the varied characteristics of concretions found at Green Creek, Ontario, should have had a number of different interpretations of their findings. New information, presented here, may provide a control over the use of some types of data for the interpration of the environment of deposition of the sediments themselves and of the cementation of concretions at Green Creek.

SETTING AND AGE OF THE WOOD-BEARING CONCRETION

The Hiawatha Park collecting ground for the Green Creek concretions is located on the shore of Ottawa River about 10 km east of Ottawa and about 1.5 km north of Highway 17, near the village of Orleans, Ontario (Fig. 1). On the 5000 metre UTM grid of Map 1425A (RICHARD *et al.*, 1977) the coordinates of the locality are 455350353. At that place the south bank of Ottawa River (water level el. *ca.* 43 m) is a near-vertical scarp approximately 3 m high. The sediment in the bank is identified by RICHARD *et al.* (1977) as silt and silty clay with some sand in abandoned river channel deposits. All of the sediment exposed is rhythmically laminated in alternately coarse and fine grained strata whose colours are correspondingly light and dark. On first observation the sediment appears varved, but closer examination of individual strata reveals channeled erosional features, miniature crossbedding, mixtures of graded and ungraded beds, and abrupt changed in grain size of strata, suggesting a fluvial or upper delta environment of deposition rather than glaciolacustrine (see, for example, GADD, 1977). A boring made by the writer in 1961 showed that a sharp contact exists between the non-calcareous, rust-mottled sediment of this exposure and the underlying unoxidized and calcareous blue-grey sediment typical of the Champlain Sea. The contact is approximately 10 m below the present water level of the Ottawa River at this place.

Calcareous concretions found in place here occur in, or at least are centred in, the coarser-grained layers, but may include one or more finer grained strata within the cemented nodule. Other than in the concretions, however, the sediment has no visual reaction to field acid test and therefore appears to contain little free carbonate.

Not clearly stated in other literature is the fact that the majority of concretions found at the Green Creek site are not found *in situ* within the clay strata, but lie exposed on the present shore of Ottawa River and in the stream bed of Green Creek. Because the number of concretions visible in the exposed beds during any visit is relatively small compared to the numbers on the shore, it is assumed that the bulk of concretions that have been collected in large numbers over the years have been found lying exposed on the modern shore and stream bed. It is further assumed that the great majority of these concretions formed, or were at one time present, in the exposed strata and have been removed and concentrated by erosion of the river bank.

In 1961, the present writer made a collection of all concretions from a strip of shore measuring 3 × 30 m lying between low water level of Ottawa River and the base of the river bank scarp; their total number was approximately seven hundred. All were split so as to expose the core of the concretion. By far the largest number of concretions consisted solely of cemented sediment. Fewer than sixty concretions (<10%) had nuclei. Among the nuclei such things as pebbles and mudballs, including till, sand lenses, etc. were common, leaving only about thirty of the concretions that contained organic remains as nuclei. These remains included single marine mollusc shells and groups of typical Champlain Sea shells such as *Hiatella arctica*, *Macoma balthica*, and *Portlandia arctica*; five or six concretions had fish remains (only two with fairly complete skeletons) (*e.g.*, NMC 36088, Fig. 2). Some others contained other disseminated organic matter in very small quantities; one contained the cast of a feather (NMC-36089, Fig. 3) (specimen currently on display in the collections at the National Museum of Natural Sciences, Ottawa). Only one concretion from this collection contained a piece of wood large enough for radiocarbon dating. This latter concretion is the subject of principal interest of this paper.

The concretion containing wood (Fig. 4) originally was a complete ellipsoid. The wood fragment was entirely enclosed when found. The piece of wood, destroyed for radiocarbon analysis, was 4.7 cm long, 0.5 cm maximum diameter and had bark, some of which adhered to the enclosing carbonate walls. Because of shrinkage of the wood during fossilization it was smaller than the cavity, up to 1 cm diameter, in which it laid. The piece of wood was eroded at its ends and therefore appears to have been transported. In his internal GSC Wood Identification Report No. 77-14, R. J. Mott commented as follows: "Wood fragment has dried completely and cells have shrunk making accurate identification impossible. Wood is angiosperm and has some characteristics similar to willow (Salix sp.)."

The collector (NRG) preserved the wood in its concretion, but because it weighed only 0.6 gm in its air-dried state, radiocarbon dating was not attempted in the hope that additional material would come to light. Since no other suitable material had been discovered in several collections made during the succeeding 16 years, the wood and the enclosing carbonate-rich concretion were submitted for dating in 1977. The age of the wood, corrected for isotopic fractionation, is 9960 ± 820 years (GSC-2498); the large error term reflects the small size of the sample. The corrected age

FIGURE 2. Green Creek concretion containing *Mallotus villosus* (ident. by C. R. Harington; National Museum specimen, NMC 36088). Dimensions of concretion: 14 cm long, 3.5 cm wide.
Mallotus villosus *dans une concrétion du site de Green Creek (identifiée par C. R. Harington, échantillon du Musée national du Canada n° NMC 36088). Dimensions de la concrétion : 14 cm de longueur sur 3,5 cm de largeur.*

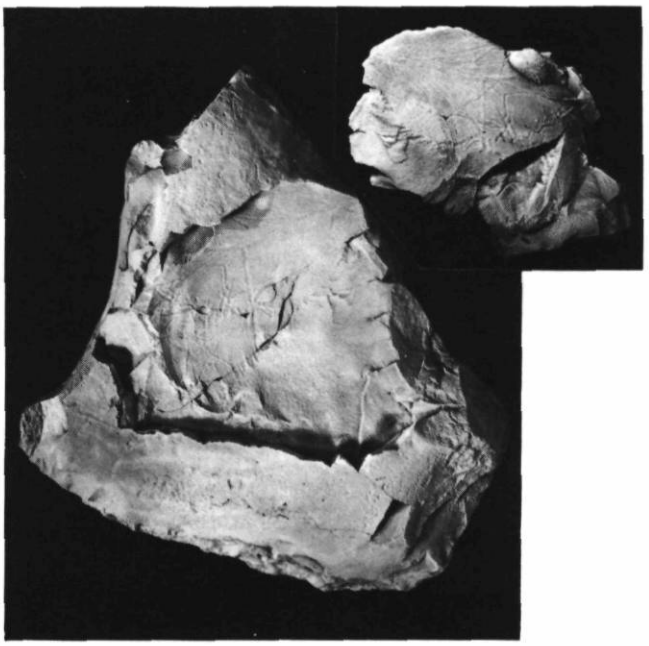

FIGURE 3. Green Creek concretion containing imprint of a feather (unindent.), National Museum specimen, NMC 36089. Dimensions of concretion: 10 × 12 cm (larger part).
Impression de plume (non identifiée) dans une concrétion du site de Green Creek (échantillon du Musée national du Canada n° NMC 36089). Dimensions 10 × 12 cm (dans sa plus grande partie).

of the concretion is 14 400 ± 250 years (GSC-2530; see also Table I)[1].

DISCUSSION

Choice of wood sample to represent age of the sediment: There is no doubt that in Ottawa Valley there has been marine submergence followed by emergence and dissection of marine sediments, with the end member of the series being the present freshwater fluvial system. It follows that, regardless of when or where the fluvial system originated, any sediment of the fluvial system may contain reworked products of earlier times. In the Green Creek concretions there are materials that are Precambrian and Paleozoic (pebbles in Fig. 5), Pleistocene glacial and marine (varved mudballs, till balls, fossils), and Pleistocene-Holocene freshwater and terrestrial materials (e.g., those listed by Dawson, *in* LOGAN, 1863, *op. cit.*). In short, there is a kaleidoscopic representation of all the environments involved in the production of the total sediment and fossil assemblage.

Clearly the Precambrian and Paleozoic pebbles cannot represent the environment of deposition of the post-Champlain Sea fluvial sediments in which the concretions are found. Champlain Sea Molluscan fossils whose shells are found most commonly as single valves with their long axes parallel to the bedding plane (*cf.* Fig. 5) must also be considered as transported and therefore not likely to represent specifically the environment of deposition of the surrounding sediment; in that regard, their presence is perhaps no more significant than that of the Precambrian pebbles.

1. Critical reader C. Hillaire-Marcel suggests that this paper should discuss and explain the >14 000 ^{14}C dating of the carbonate concretion. He indicates that geochemical models may be employed to rationalize the figures, but that some questions remain. The author's observations reported in this note present a minimum of factual data against which criteria, assumptions and models of this kind may be tested; much more corroborative data would be necessary for a valid analysis. This note describes the first instance in which two different materials have been dated from a single concretion, yet the new data may indicate the true geological environments, sequences and ages that may apply in such analysis. The author believes that the problem is best served at present by the descriptive approach and that discussion and analysis of geochemical models would be premature and beyond the scope of this paper.

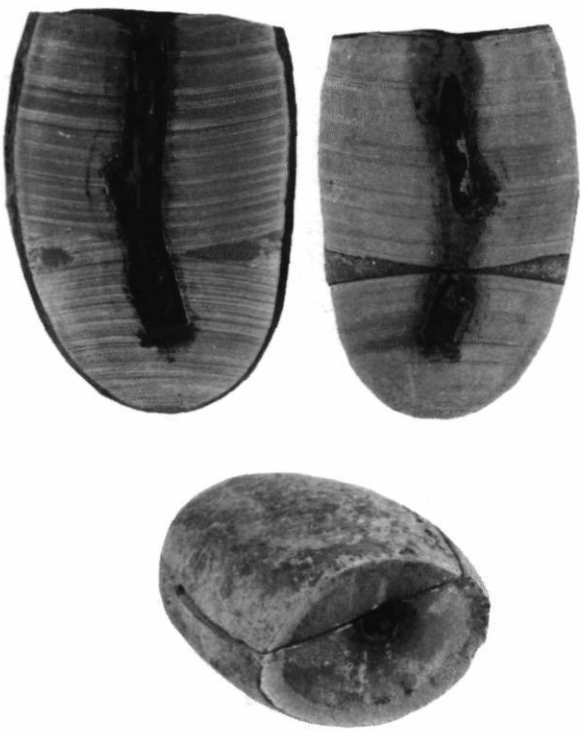

FIGURE 4. Green Creek concretion containing piece of Willow (ident.? *Salix* sp. by R. J. Mott): a) concretion split to show wood (now destroyed) in place; b) concretion reassembled to show discovery aspect. Dimensions of concretion, max. width 5 cm, max. length 7.5 cm (original concretion approx. 9 cm).
Morceau de bois (? Salix *sp. identifié par R. J. Mott): a) concrétion sectionnée afin de montrer le morceau de bois (détruit depuis) dans sa position originelle; b) assemblage des deux sections afin d'en montrer l'aspect au moment de la découverte: Dimensions: 5 cm de largeur maximale, 7,5 cm de longueur maximale (9 cm environ pour la concrétion originelle).*

One might believe that skeletal remains of vertebrate fish and land animals would represent the environment of deposition, simply because it is difficult to conceive of animal skeletal remains being transported intact through even one cycle of erosion. However, rapid cementation during decay of soft-bodied organisms, as indicated by BERNER (1968, *op. cit.*) may provide the necessary resistance to erosion. Even though Harington (personal communication) indicates that numerous concretionary specimens show marine molluscs in an apparent living relationship with fish skeletons and that, therefore these animals in life were of the same age; the entire concretion may have been transported intact and may be allochthonous to the particular sedimentary layer in which it now rests.

If we extend our thinking to the deposits on the shore of the modern Ottawa River, we can see very easily that concretions of all types and probably of several ages, are being buried in present-day sediments. I assume that none of those concretions has formed *in situ* in the modern sediment and that none can represent the modern environment of the sediment in which they are being incorporated. Modern driftwood, *e.g.*, logs that have espaced from log booms of the local paper mills, other materials such as mill and city effluents, and clams living in the river mud, are the type of fossil that could be considered as representative of the modern environment of sedimentation and of its age; but not the concretions.

In the same way, possibly only the piece of willow(?) wood from the Green Creek concretion (Fig. 4) may be representative of the environment and age of the sediment exposed in the river bank. However, even that piece of wood may have been recycled a number of times and cannot necessarily be considered specifically representative. It provides only a maximum age for the sediment. Until a younger piece of wood, or other younger fossil in living position, is found, this one wood fragment must serve as a reference point.

Wood vs. carbonate date: Other publications (*e.g.*, HILLAIRE-MARCEL, 1977) have used radiocarbon age of carbonate concretions to represent the age of the sediment in which they are found, but this requires a selective measurement on chemical rather than mechanical deposits. Total carbonate analyses may be exptected to reflect the age of local bedrock. HILLAIRE-MARCEL (1979, *e.g.*, p. 220-221) states that carbonate granules in both glaciolacustrine and marine sediments in the St. Lawrence Lowland are derived from local bedrock sources: "*les fractions carbonatées des sédiments paraissent indubitablement héritées des socles locaux.*" This is reflected in the similarity between the $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios of the sediments and of the local Paleozoic or Precambrian rocks.

The dates obtained on wood and carbonate material of the concretion shown in Figure 4 are widely divergent. That the carbonate (GSC-2530) was older than the wood (GSC-2498) was in some degree predictable. Carbonate material in the sediment probably includes granules of both Paleozoic and Precambrian carbonate rocks (*cf.* HILLAIRE-MARCEL, 1979, *op. cit.*); these contaminate any contemporaneously precipitated carbonate. Groundwater that percolated through the sediment and that probably added as much as 15% of the datable carbonate of the concretion (*cf.* CARTER *et al.*, 1977) would be the only other source of carbonate contemporaneous with the deposition of the sediment

TABLE I

Ottawa Valley Dates Compared with Green Creek Concretion

Sample Elevation (m a.s.l.)	Material Dated	Laboratory Dating Number	Uncorrected ^{14}C Age	$\delta^{13}C$ (‰)	Corrected ^{14}C Age	Sample Weight (g)	Counter (I)	Pressure (atm.)	Counting Time (days)	Comments
Twin Elm ~104 m	Shells *Macoma balthica*	GSC-587	10 620 ± 200	—	—	61.0	2	2	2	30% leach; sample mixed with dead gas for counting (some gas lost)
~ 98 m	Seaweed mainly *Laminaria*	GSC-570	10 800 ± 150	—	—	44.3 burned	5	1	3	NaOH treatment omitted
~ 97 m	Shells *Macoma balthica*	GSC-588	10 880 ± 160	—	—	68.5	5	1	2	20% leach
Russell ~ 70 m	Shells *Macoma balthica* & *Macoma calcarea*	GSC-1553	10 000± 320	—	—	11.5	2	2	3	10% leach; sample mixed with dead gas for counting
Hawkesbury ~ 60 m	Wood (unident.)	BGS-257	9 860 ± 330	—	—	4.3				No pretreatment
Bourget ~ 53 m	Shells *Lampsilis* sp.	GSC-1968	10 200 ± 90	—	—	46.1	5	1	3	20% leach
Green Creek ~ 43 m	Wood (? *Salix* sp.)	GSC-2498	9 980 ± 820	−26.3	9,960 ± 820	0.6	2	2	3	HC1 and distilled water; NaOH omitted; sample mixed with dead gas for counting
~ 43 m	Carbonate concretion	GSC-2530	14 300 ± 250	−20.1	14,400 ± 250	14.1	2	2	2	No pretreatment; sample mixed with dead gas for counting

or with its cementation. It would seem possible, then, that the groundwater, too, was contamined by old carbonate.

Radiocarbon laboratory procedure included acid treatment of the wood sample (See Table I). It is unlikely that the wood as dated could have been contaminated by older carbonate. The wood is therefore the preferred dating material.

Sedimentary granules and the wood fragment in Green Creek sediment both are of greater age than the fluvial sediment they combine to form. Lacking fossils that are in living position, the closest approximation of the time of sedimentation is the age of the younger transported material, which in this case is presumed to be the small piece of willow(?) wood. Because of the small size of the wood sample there is a wide margin of error (±820 yr.) in the calculated age that gives a hypothetical range of ages for the wood between 10 780 and 9140 years BP.

Age comparison with other dated deposits : Radiocarbon ages of marine shells and seaweed (ident. as mainly *Laminaria* by ILLMAN *et al.* (1970)), at Twin Elm, Ontario (MOTT, 1968) (GSC-570, -587, -588, Table I) establish that regional sea level (Champlain Sea) was at or above 100 m a.s.l. in the potential time range of 11 040 to 10 420 yr. BP. RICHARD (1973) (GSC- 1553, Table I) records a marine shell date from Russell, Ontario, indicating that sea level may have been at about 70 m a.s.l. in the time range 10 320 to 9680 yr. BP. If we assume the wood grew near the freshwater fluvial system in which it is found there is little possibility that the Green Creek wood sample, collected at about 43 m a.s.l., could have a true radiocarbon age in excess of 10 000 years. The age of the Green Creek sediment, logically, is less than that.

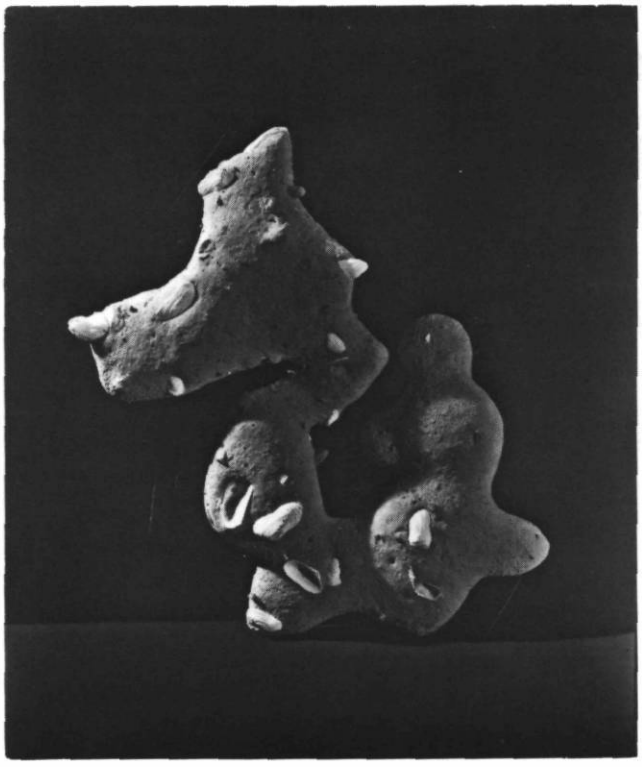

FIGURE 5. Large Green Creek concretions containing fossils and pebbles: 5a) *Hiatella arctica* and numerous granules of both Paleozoic and Precambrian rocks (max. dimensions of concretion: 12 cm wide, 18, 5 cm high; b) *Hiatella arctica* and numerous granules and pebbles. Large pebble of Precambrian granite gneiss, lower right, is approximately 3 cm in long diameter; maximum dimension of concretion: 22 cm wide, 18 cm high. Note: in figure 5a and 5b, the bedding plane of the concretion is parallel to the plane of the paper, therefore fossils shown lie with long axes parallel to the bedding plane.

Grosses concrétions provenant du site de Green Creek contenant des fossiles et des cailloux: 5a) Hiatella arctica *et plusieurs granules de roches paléozoïques et précambriennes. Dimensions maximales de la concrétion: 12 cm de largeur et 18,5 cm de hauteur; 5b)* Hiatella arctica, *plusieurs granules et cailloux. À remarquer un gros caillou de gneiss granitique précambrien, dans la partie inférieure droite, dont la largeur maximale est de 3 cm. Dimensions maximales: 22 cm de largeur, 18 cm de hauteur. À noter que dans ces figures le plan de sédimentation concorde avec celui du papier; les fossiles visibles ne sont pas en position de vie, l'axe le plus long étant parallèle au plan de sédimentation.*

The undisturbed marine sediments of Ottawa Valley have been extensively eroded by a river channel system at least 16 km wide at Ottawa (RICHARD *et al.*, 1977) from which at least 50 m of sediment has been removed in areas adjacent to Ottawa River and its tributaries. Secondary fluvial deposits within this now largely abandoned fluvial system at elevation *ca.* 53 m have yielded freshwater shells (*Lampsilis* sp.) at Bourget, Ontario, whose radiocarbon age is 10 200 ± 90 years (GSC-1968) (GADD, 1976; Table I). (Possible contamination of the freshwater shell carbonate of this sample would allow for the sediment to be considerably younger than 10 200 years.) SHARPE (1979, and oral communication, December 1979) reports wood from fluvial sandy gravel at elevation 61 m near Hawkesbury, Ontario, whose age is 9860 ± 330 years (BGS-257). The concretionary sediments at Green Creek occur in a younger sector of the same channel system at an elevation of *ca.* 43 m a.s.l. The Green Creek sediments, being deposited at the lower elevation and incised more deeply into the underlying marine sediment, are younger than those at Bourget (~53 m) and possibly also younger than those at Hawkesbury (~61 m). Therefore, if the presence of *Lampsilis* sp. at Bourget (Table I) indicates a freshwater environment in the channel system, a younger, lower sector of the same system also should have been related to freshwater.

CONCLUSIONS

1. The radiocarbon age of a piece of willow(?) wood enclosed in a calcareous concretion at Green Creek, Ontario, establishes the maximum age of the enclosing sediment and of its cementation at 10 780 to 9 140 years BP (9 960 ± 820; GSC-2 498). Comparison with other dates in the area precludes the possibility that the true age could exceed 10 000 yrs. BP.

2. The anomalous age of 14 400 ± 250 years (GSC- 2530) for the concretionary nodule around the

piece of wood is related to the presence of carbonate granules of Precambrian and Paleozoic age in the sediment, and to dissolved material of the same age in the percolating groundwater that presumably provided the cement.

3. It is possible that the majority of fossil forms in the Green Creek concretions contained in freshwater sediment are in fact allochthonous, having been accumulated in fluvial sediments by erosion of earlier marine and freshwater sediments. Such a possibility would help to explain the association of marine, freshwater and terrestrial life forms in a single sediment whose identification and origin has proven enigmatic to several authors.

4. Topographic position with respect to dated freshwater shells indicates contemporaneous or subsequent deposition of the sediments at Green Creek; this infers freshwater conditions at the time of burial and cementation of the wood-bearing concretion.

5. The preferred interpretation of the Green Creek sediment as being of freshwater fluvial origin precludes the existence as live animals, during deposition of that sediment, of only the strictly marine species. All other materials found in the concretion, representing birds, land animals, land and water plants, lake trout, deep water sculpin, capelin in spring spawning conditions, may be accommodated in a fluvial environment draining to a nearby estuary. The burden of proof lies with establishing comptability of the ages of these various materials with that of the wood sample reported in this paper.

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