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The Boulder Barricade at Cap à la Baleine, North Shore of Gaspé Peninsula (Québec): Nature of Boulders, Origin and Significance

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ABSTRACT

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A small (1.5 km long) boulder barricade occurs at Cap à la Baleine on the north shore of Gaspé Peninsula, about 25 km NE of Matane. The boulder barricade is a low ridge at the low tide level formed by a pavement of small to medium size subrounded to rounded clasts of various lithologies. Boulders are closely packed together and compacted into the underlying clay substrate. There are two main groups of boulders. About 40% are Precambrian erratics from the Laurentidian Shield on the north shore of the St. Lawrence estuary, whereas the remaining are from Appalachian lithologies occurring on the south shore of the St. Lawrence, of which 54% are sandstone (graywacke). A few particular indicators are anorthosite, dolostone, quartzite and volcanic erratics. Boulders remaining on the tidal flat surface are a lag from the erosion of a clay diamict, an event which occurred during the Upper Holocene. Originally deposited in the Goldthwait Sea *circa* 13–13.5 ka, the boulders are most likely iceberg drifted erratics from two sources: the Laurentides Ice Sheet still occupying the St. Lawrence valley, and the Appalachian ice, the front of which corresponding to the present shoreline at the time. Today, the Cap à la Baleine boulder barricade forms a natural wave breaker slowing erosion of the tidal flat.

ADDITIONAL INDEX WORDS: *St. Lawrence estuary, shore ice processes, iceberg rafting, boulder pavement, Holocene marine clay.*

INTRODUCTION

Boulder barricades are a coastal feature apparently characteristic of coastlines in cold regions. They have been observed at many localities along Canada's eastern coastline (Dionne, 1994a). Although recognized long ago (Lyell, 1854), they were named by Daly (1902), and adequately described by Tanner (1939). Unfortunately, this important paper written in Finnish was long ignored by the scientific community.

Rosen (1982) defined boulder barricades "as elongate rows of boulders that flank the coastline, separated from the shore by a low gradient nearshore zone. They are the result of ice transport and therefore occur only in Arctic or sub-Arctic regions." In this short paper, as well as in a former paper (Rosen, 1979), little is said about the characteristics of the boulder barricades: *re.* number, size, nature and origin of boulders, size of the rows, tidal environments, nature of the substrate, type of coastline, *etc.*

Boulder barricades are common to the lower north shore of the St. Lawrence where they are called in French *cordons de blocs frangeants* (fringing boulder ridges). They also occur in the upper St. Lawrence estuary upstream Quebec City, where they commonly form two and even three rows (Brochu, 1961; Dionne, 1994a). Typical boulder barricades are rare along the south shore of the middle and lower St. Lawrence estuary, although many rows of boulders occur almost everywhere at various levels in the tidal zone (Dionne, 1972). Those occurring at the low tide level were called by Guilcher (1981) *cordons de blocs de basse mer* (low tide boulder ridges).

This paper reports a remarkable boulder barricade in a coastal area characterized by a straight shoreline and by narrow tidal flats, and provides data on the lithology of the boulders trying to determine their source and the agents which transported and released them in the postglacial sea. There is no emphasis on the processes involved in the formation of the boulder barricade at Cap à la Baleine because this question was discussed in a previous review paper on boulder barricades (Dionne, 1994a).

GEOGRAPHIC AND GEOLOGICAL SETTINGS

Cap à la Baleine is located on the south shore of the Lower St. Lawrence estuary about 25 km downstream from Matane (67° 16′ 30″ W, 48° 55′ 15″ N, Figure 1). Oriented SW-NE the shoreline is relatively straight, but a few small embayments, capes and points can be observed along the coast between Matane and Sainte-Anne-des-Monts. Between Cap à la Baleine and Pointe des Monts on the north shore, the St. Law-

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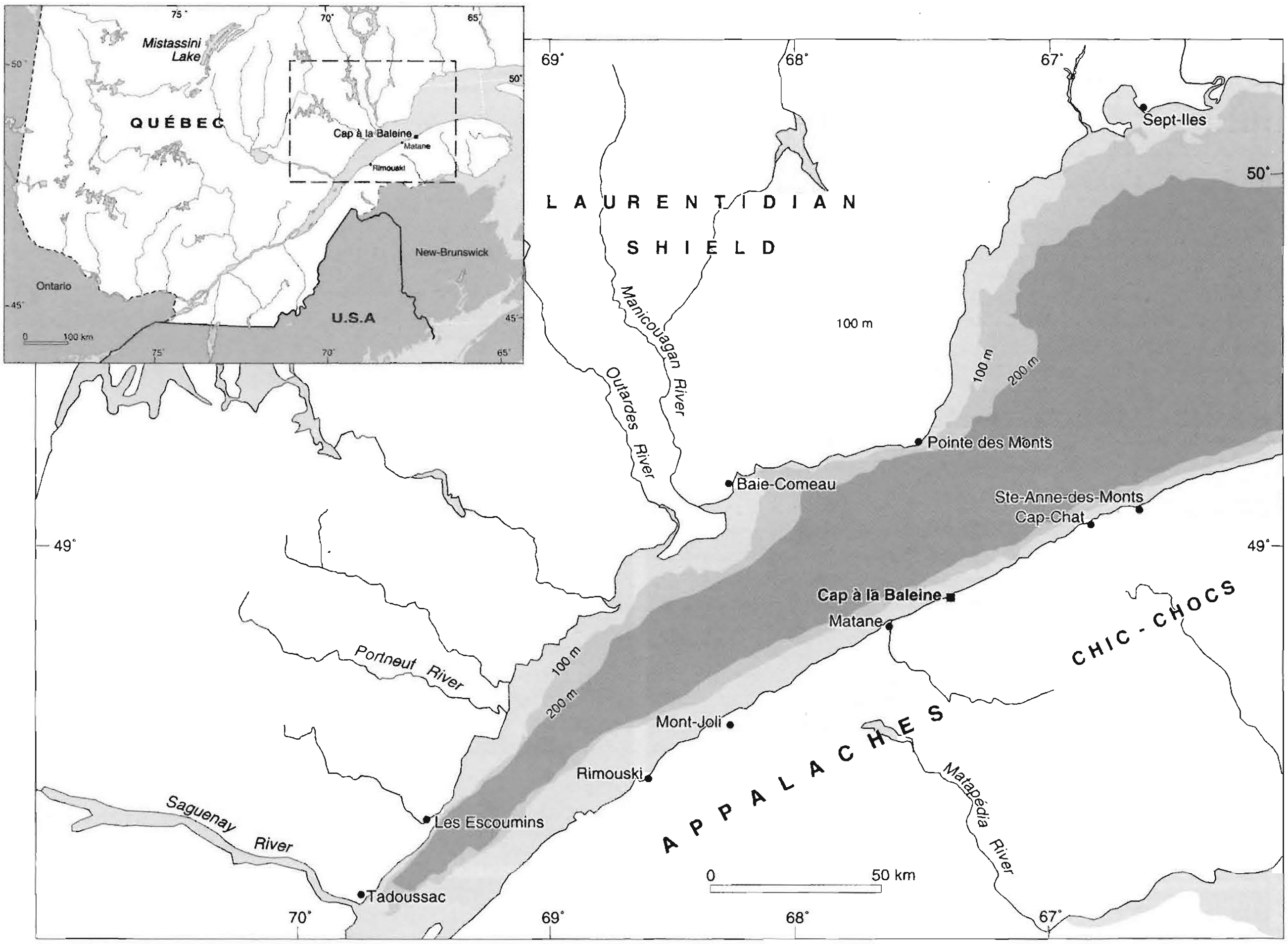


Figure 1. Location map and locality names, Cap à la Baleine area, north shore of Gaspé Peninsula, Québec.

rence estuary is about 40 km wide, but it is much larger eastward, exceeding 100 km between Sept-Iles and Sainte-Anne-des-Monts.

The shore zone is relatively narrow (200–400 m) and is adjacent to a submerged platform about 4 km wide with a water depth up to 100 m (LORING and NOTA, 1973). Seaward is the deep St. Lawrence trough exceeding 300 m (SHEPARD, 1931).

Bordered landward by a narrow cliffed terrace 10 to 15 m high and mainly composed of a glaciomarine stony clay diam-

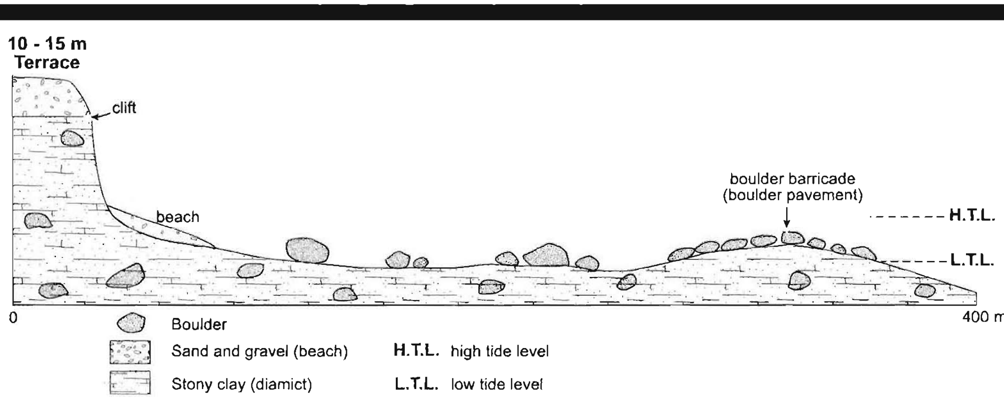
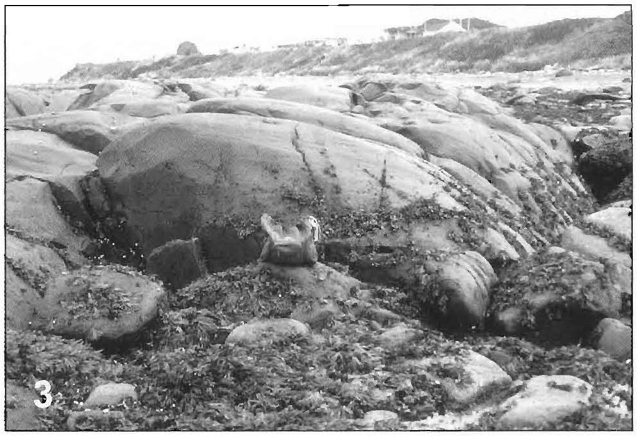
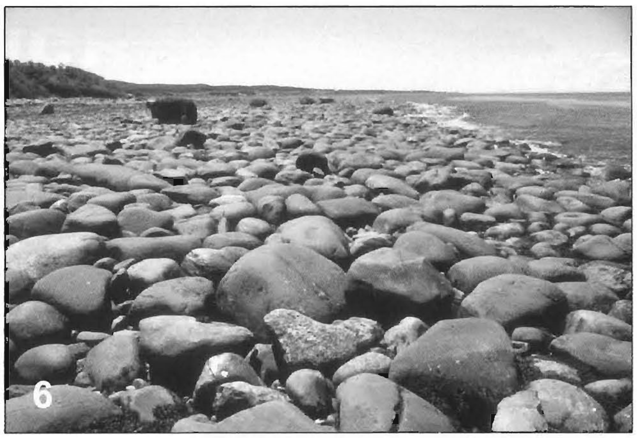
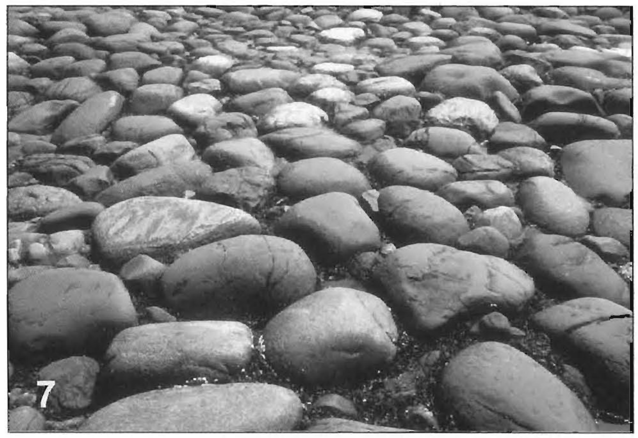


Figure 2. A schematic cross section of the shore zone at Cap à la Baleine.







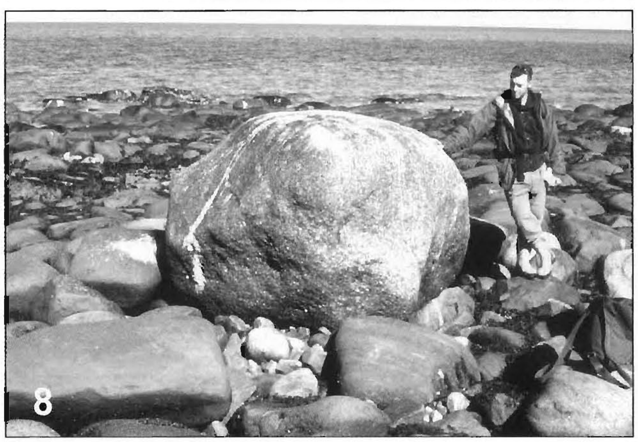


Figure 3. A glacially shaped graywacke outcrop in the intertidal zone at Cap à la Baleine; ice flow direction is from right to left, 01-09-20.

Figure 5. A general view of the boulder barricade at Cap à la Baleine; photo taken from the top of the cliff, note the wide waterfilled section of the tidal flat at mid-tide, and the coarse sandy beach at the foot of the cliff, 01-09-19.

Figure 6. Typical aspect of the boulder barricade at Cap à la Baleine; medium to small size boulders form a pavement about 50 m wide, 97-06-23.

Figure 7. A detail view of the boulder barricade; note that the medium size boulders are tightly packed together and compacted into the underlying clay substrate, 97-06-23.

Figure 8. A mega-boulder of granite (275 × 210 × 160 cm) overlying the boulder pavement; approximate weight is 18 metric tons, 01-09-19.

Figure 9. A gneiss erratic from the Precambrian Shield on the north shore of the St. Lawrence estuary over 50 km away; the boulder is 48 cm long, 01-09-20.

Table 1. *Climatic data of the study area**.

	Station	
	Mont-Joli	Cap-Chat
Mean annual T°	3.5°	3.3°
Mean January T°	−11.1°	−9.5°
Mean July T°	17.2°	16.1°
Extreme minimum T°	33.3°	−30.6°
Degree-day with frost	180	178
Mean annual precipitation	900 mm	1027 mm
Mean annual rainfall	549 mm	689 mm
Mean annual snowfall	367 cm	306 cm
Wind frequency at Mont-Joli Annual prevailing directions:	SSW to WNW = 48% NE to ENE = 13%	
Dominant strong winds	WSW to WNW	
Average wind speed between December and March	24 to 32 km/hr	
Ice season	From December to end of March	

* Data from Canada, (1973).

ict (DIONNE, 1966; LEBUIS, 1973, 1975; LEBUIS and DAVID, 1977), deposited in the Goldthwait Sea (DIONNE, 1977), the shore zone is a relatively flat erosion surface cut into the diamict (Figure 2). The inner tidal zone is, however, slightly lower than the boulder barricade, and is covered by scattered boulders, a few being mega-boulders. The lower tidal zone is entirely covered by subrounded to rounded boulders of small to medium size forming a wide row (25 to 60 m) that can be called boulder barricade or pavement (DAWSON, 1884). A few rock outcrops (graywacke) occur at both ends and in the middle of the study area, where they are glacially shaped and striated indicating a NNW ice flow (Figure 3).

Since there is no meteorological station at Cap à la Baleine, climatic data have been estimated from the two closest meteorological stations: Mont-Joli and Cap-Chat (Table 1). The mean annual air temperature (based on data from 1940 to 1971, CANADA, 1973), is about 3.4°C with a mean January and July temperature respectively −10.2° and 16.6°C. There are 179 degree-day with frost. Mean annual precipitation is approximately 965 mm including 36% of snowfall. The prevailing wind directions (48%) are from the SSW to WNW whereas those from NE to ENE account for 13%. The strongest winds are from WSW to WNW, with an average velocity ranging from 24 to 32 km/hr. Usually, ice is formed along the shore in December and disappears during the last two weeks of March. The tidal flat is normally entirely ice covered from January to March; the thickness of the ice cover ranges from 40 to 80 cm, but commonly the ice cover is broken and chaotic.

Cap à la Baleine is a mesotidal environment with mean tide range averaging 2.7 m, whereas spring tide range is up to 4.1 m, the water level (geodesic zero) is 1.98 m (CANADA, 2001).

Open to offshore and not protected from wind and wave action, the shoreline at Cap à la Baleine is vulnerable and exposed to winds from WSW to WNW which are the dominant directions for frequency and velocity. Although winds from the NW to NE are less common, they also produce waves capable of causing erosion. The main fetch (over 225 km) is from NNE. Consequently, the Cap à la Baleine shoreline can be classified as a moderate to a relatively high wave energy environment (DAVIES, 1972).

BOULDER BARRICADES CHARACTERISTICS

In plan view (Figure 4a), the boulder barricade occurring near the low tide level is arc–shaped seaward. It extends continuously over 1500 m between Anse à la Croix and Cap à la Baleine, forming a low ridge of small to medium size boulders, 20 to 60 mm wide. Seen from the top of the nearby cliff (Figure 5), it looks like a narrow stripe fringing the tidal flat and isolating landward a shallow waterfill depression with scattered boulders and colonies of kelp (*Fucus sp.* and *Ascophyllum sp.*); this basin is only partly drained at low tide. At distance, the resemblance with the classical boulder barricade (DALY, 1902; TANNER, 1939) is quite convincing.

The boulder barricade is formed by closely packed boulders (Figures 6–7) partly rooted into the underlying clayed substrate. This feature is rather typical of boulder pavement (DIONNE, 1972, 1979; HANSOM, 1983; EYLES, 1988; DIONNE and POITRAS, 1998a). Except where a clast has been recently dropped by shore ice, there is only one layer of boulders. The surface of the pavement is slightly higher than the section of the tidal flat occurring shoreward; consequently, the boulder barricade is visible or exposed from mid to low tide level (Figure 4b).

The boulders have a relatively high degree of roundness, 75 to 80% being subrounded to rounded. The size varies from 20–25 to 60–65 cm (axis-a) with a large percentage (50–55%) in the category of 30–45 cm. Only a few mega-boulders (Figure 8) are overlying the boulder pavement. Large erratics are more common in the inner tidal flat section. Scars indicating recent boulder removal are rare, although a few boulders, recently deposited, were observed. In general the boulder pavement is quite stable.

Lithology of Boulders

In most recent papers reporting boulder barricades (ROSEN, 1979; MCLAREN, 1980; GILBERT and AITKEN, 1981; MCCANN *et al.*, 1981; KRAWETZ and MCCANN, 1986), the lithology of boulders forming the barricades at the low tide level has not been considered because it was not significant. At Cap à la Baleine, however, it is an important characteristic since there are two categories of erratics of which one is from a far distance region.

Table 2 summarizes the lithology of boulders forming the barricade. Of the 13 302 boulders counted in 18 plots, 40.6% are Precambrian lithologies (various gneiss, granite (Figures 9–10), anorthosite, *etc.*) from the Laurentidian Shield on the north shore of the St. Lawrence estuary. The most common lithology (56.6%) is a Cambro-Ordovician sandstone (graywacke) of the Tourelle Formation, a lithology outcroping locally in the shore zone and in the coastal area (SLIVITSKY *et al.*, 1991). The percentage of sandstone is greater in the eastern area (Table 2) because it is closer to rock outcrop. Quartzite boulders account for 3% of all lithologies; most quartzite clasts are white quartzite from the Val Brillant Formation (BÉLAND, 1960); there are also a few clasts from the Ka-

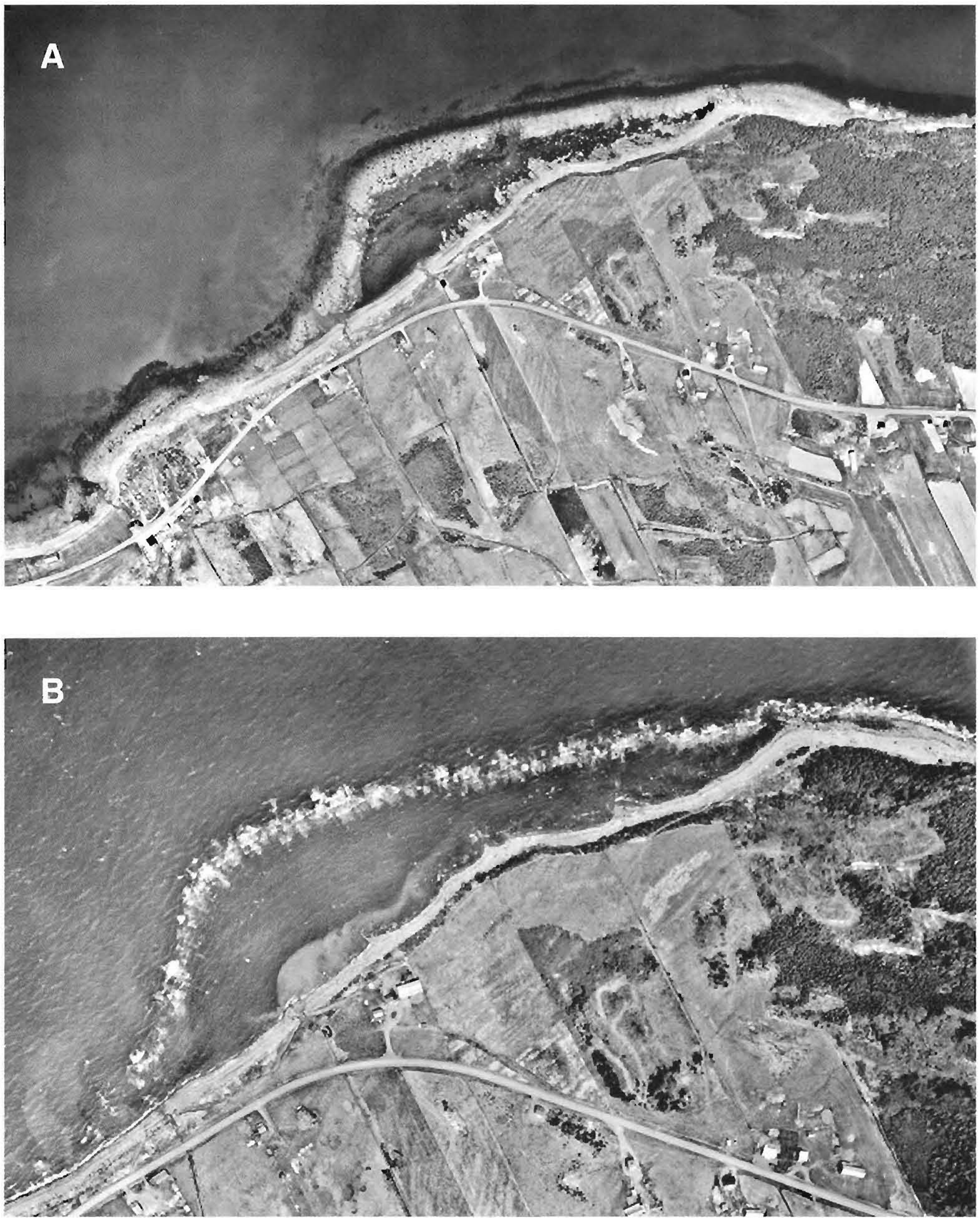


Figure 4. Air photos of the boulder barricade at Cap à la Baleine, Gaspé Peninsula, Québec, at low tide (A), and at high tide (B). Photos nos Q64105-191 and Q64102-24, at scale 800'/1" and 500'/1'; Québec Air Photo Library, Department of Natural Resources.

mouraska Formation. Conglomerates accounting only for 0.7% include two types; one is composed of very small clasts of quartz (0.5 to 1 cm); the other is a coarse grained limestone conglomerate. Mudshales, which account for 0.65% include clasts of local origin (*e.g.* red mudshale of the Tourelle Formation) outcroping in the eastern part of the study area, and brownish calcareous shales from Ordovician and Silurian formations occurring inland. Limestone and volcanic clasts are found occasional. Of interest however, are several dolostone erratics, a lithology not common in the Precambrian and in the Appalachian Formations.

Dolostone Erratics

A separate survey of dolostone clasts was made in 1996 and 1997. A total of 230 clasts of dolostone of various types (Figures 11–15) were observed. Tables 3 and 4 summarize their characteristics and color. About 34% are pink, pinkish or reddish while most (60%) are gray. Dolostone clasts range from one to 490 kg with a mediane of 11 kg (Table 5). Small to medium size clasts (1 to 50 kg), however, are most common accounting for 83.7%, whereas those exceeding 100 kg account only for 6%. Table 6 gives the sizes and weight of the ten largest dolostone boulders observed.

Table 2. *Lithology of erratics of the boulder barrier (in percentage).*

	Precambrian	Sandstone
Entire area		
Number of counts 18		
Number of boulders 13302		
Minimum	25.2	47.3
Maximum	48.2	71.7
Median	40.8	52.9
Average	40.6	54.6
Area A (West)		
Number of counts 9		
Number of boulders 5747		
Minimum	36.0	47.3
Maximum	46.4	63.3
Median	41.5	52.9
Average	41.8	52.6
Area B (East)		
Number of counts 9		
Number of boulders 7455		
Minimum	25.2	47.4
Maximum	48.2	71.7
Median	35.1	59.4
Average	38.8	56.5

One interesting characteristic of the dolostone erratics is that 43.8% were striated. Glacial and glaciel[1] striations account for about 50% each. The degree of roundness (weiring) is relatively high, approximately 70% of clasts being in the categories between subrounded and well rounded (Table 7).

ORIGIN OF THE TIDAL FLAT AND BOULDER BARRICADE

The wide tidal flat at Cap à la Baleine is not an exceptional feature along the St. Lawrence estuary but it is rather rare along the north shore of Gaspé Peninsula because the highlands are close to the present shoreline and the depth of the estuary is increasing rapidly offshore.

As mentioned, the tidal flat is bordered by a cliff-terrace 10–15 m high composed of stony clay (diamict) deposited in the Goldthwait Sea during the early phase of the postglacial transgression *circa* 13–13.5 ka (DIONNE, 1977; DAVID and LEBUIS, 1985). The clay is gray, very sticky and contains a relatively large amount of coarse debris including clasts of boulder size. In the area of Cap à la Baleine, the Goldthwait Sea reached a maximum level of 75 m a.s.l. (DIONNE, 1976, p. 43; LEBUIS and DAVID, 1977). The coastal area, however, rebounded isostatically quite rapidly, and the sea level dropped to about the present day level *circa* 8 ka; the low stand remained for about two millennia before a few meters rise (DIONNE, 1988; DIONNE and COLL, 1995) and a new coastal emerge.

The tidal flat was cut mainly into the diamict deposit during the low stand and during the mid-Holocene Laurentian transgression (DIONNE, 1988a); the coarser debris was mostly left behind as an erosion lag. Subsequently, an unknown quantity of boulders was removed by shore ice under various mechanisms (DRAKE and MCCANN, 1982; DIONNE, 1988b, 1994a), and concentrated near the low tide. Vertical pressures exerted by the ice cover drove down the medium-size boulders into the underlying clay substrate giving to the boulder barricade the appearance of a boulder pavement. At Cap à la Baleine, shore ice was involved in the process, whereas in other geologic settings, this morpho-sedimentary feature may result from other mechanisms.

Today, the cliff is not actively eroded, the escarpment being temporarily stabilized by vegetation; consequently there are no new boulders available except those originating from the local bedrock outcrops. Highly fissured and broken, the graywacke formations regularly release regularly many blocks. These angular clasts are removed and displaced by ice floes mainly into the inner section of the tidal flat; a few blocks were also observed in the lower section, but they are rarely incorporated into the boulder pavement.

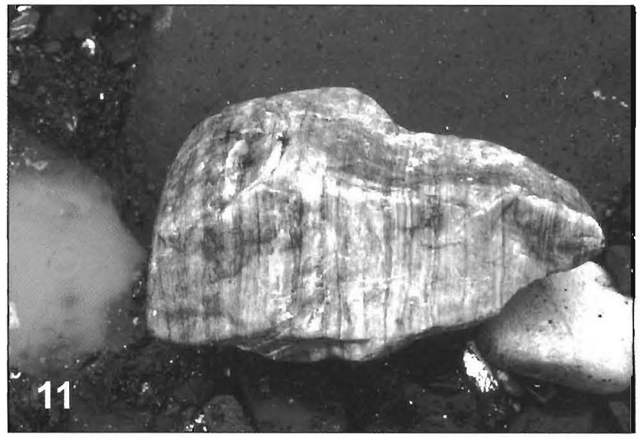
Field observations made at Cap à la Baleine suggest that erosion of the tidal flat is not very active presently. The section covered by the boulder pavement is remarkably stable although there are occasional boulder removals leaving a scar (DIONNE and POITRAS, 1998b, Figure 17). Where the clay is exposed in the zone behind the boulder barricade, erosion by ice, waves and currents is common. This may explain why the surface of the tidal flat is lower than in the inner tidal zone covered by boulders.

ORIGIN OF ERRATICS

The source of most igneous and metamorphic erratics, which are mainly composed of various kinds of gneiss, granitoid and ferromagnesian rocks, and anorthosite, are from the Precambrian Shield to the north of the St. Lawrence estuary (AVRAMTCHEV, 1985). The sandstone graywacke erratics are from nearby Appalachian sources (SLIVITSKY *et al.,* 1991; TREMBLAY and BOURQUE, 1991). No igneous and metamorphic lithologies from younger metavolcanic and metasediametary rocks of the Chic-Chocs formations to the southeast have been observed. The Val Brillant quartzite (BÉLAND, 1960) is, however, a significant Appalachian indicator of a northeast ice flow over a 50 km distance. This remark also applies to the few volcanic erratics observed at Cap à la Baleine; they most likely originated from a small area southwest of St. Adelme, about 15 km to the southwest of Cap à la Baleine (BÉLAND, 1957).

In fact, one (Precambrian) of the two main lithologic components of the boulders suggests a transport over a relatively long distance across the St. Lawrence estuary; the other (graywacke) implies a shorter displacement from the Appalachian uplands and the coastal area. The erratics being in a clayed diamict deposited in the Goldthwait Sea suggest that two different masses of ice were in the surrounding area: the Laurentides Ice Sheet to the north and the Appalachian ice to the south. At that time the St. Lawrence estuary was occupied by an ice shelf calving icebergs into the Goldthwait Sea (THOMAS, 1977), whereas the front of the Appalachian ice was most likely near the present shoreline and in contact with the early postglacial sea. Presently, there is no convinc-

[1] Drift ice action: see the Encyclopedia of Beaches and Coastal Environments, p. 447–448 (SCHWARTZ, 1982).



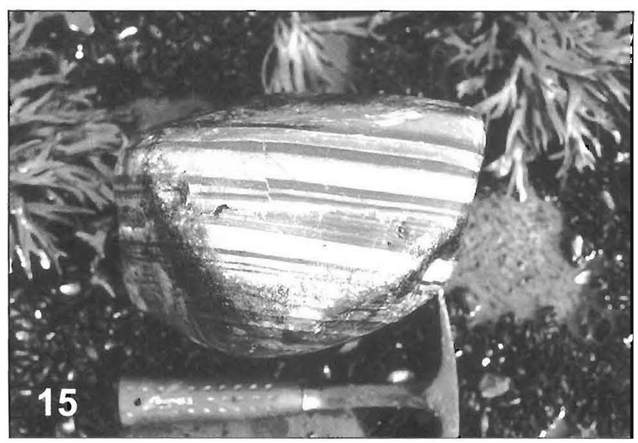


Figure 10. A well rounded granite erratic from the Precambrian Shield, 01-09-19.

Figure 11. A pink lamitated dolostone erratic (45 × 29 × 20 cm), about 49 kg; this lithology is also found on the north shore of the St. Lawrence estuary east of the Saguenay fjord, 96-07-19.

Figure 12. A pink dolostone erratic with gray spots (35 × 18 × 12 cm), weighing about 14 kg; the boulder is striated. This kind of dolostone is common along the south shore of the estuary and has been also found on the north shore, 97-06-21.

Figure 13. A brecchiated gray dolostone erratic (32 × 17 × 16 cm), weighing about 17 kg, 97-06-22.

Figure 14. A marble-like gray dolostone erratic (46 × 32 × 10 cm), weighing about 33 kg, 97-06-21.

Figure 15. A stratified light and dark gray dolostone erratic (24 × 19 × 18 cm), weighing about 18 kg; this variety of dolostone has also been observed in Les Escoumins area, on the north shore of the estuary, 01-09-21.

Table 3. *Characteristics of dolostone erratics (in percentage).*

Marble-like	23.5
Laminated	8.3
Stratified	8.3
Brecchiated	2.6
Arenaceous	3.5
Silty	0.5
Clayey	1.5
With quartz	2.2
Proterozoic type	2.2
Granite type	1.3
Stylolites	0.9
Plications	2.9
Stromatolites	0.4
Micro-faults	0.4
Corrosion	3.9
Striations	41.3

ing evidence that the boulders were released directly by the ice shelf rather than by icebergs. In comparison with other localities along the north and south shores of the St. Lawrence estuary (DIONNE, 1994b; DIONNE and BERNATCHEZ, 2000), we favor the hypothesis of iceberg deposition from nearby ice masses.

Origin of Dolostone Erratics

The source of the dolostone erratics is more complex and difficult to determine because of a lack of knowledge of this lithology in the Shield and in the Appalachian formations (DIONNE, 2002). Of the varieties of dolostone erratics observed at Cap à la Baleine, only a few are known in the Appalachians. The other varieties most likely originated from the Laurentidian Shield. The only area of dolomite formations in the Shield that could have produced the erratics is the Mistassini sedimentary basin of Proterozoic age (NEILSON, 1953; WAHL, 1953), located in central Quebec, over 500 km to the NW of Cap à la Baleine. We did not observe any stromatolitic dolomite erratics at Cap à la Baleine, a typical lithology of the sedimentary formations of the Mistassini area, although many boulders of this lithology occur on the north shore (DIONNE, 1994b; DIONNE and BERNATCHEZ, 2000) and have been observed on the south shore of the St. Lawrence estuary between Le Portage and Rivière-Blanche (DIONNE, 2002).

The percentage of dolostone erratics, which is similar to the percentage of anorthosite erratics, seems to suggest that it is likely that most dolostone erratics originated from the Precambrian Shield rather than from the Appalachian formations. Additional field work and detail geologic mapping are needed to clarify this question. Nevertheless, the dolostone erratics of the boulder barricade at Cap à la Baleine reveal, at least, the existence of this lithology, somewhere in the Shield and/or in the Appalachians.

Table 4. *Color of dolostone erratics (in percentage).*

Pink	19.6
Pink and grey	8.7
Pink and red	2.2
Red	1.7
Pinkish grey	2.6
Grey and pink	0.9
Light grey	21.3
Medium grey	24.3
Dark grey	10.4
Brownish grey	1.7
Greenish grey	0.9
White/whithish	5.6

Table 5. *Weight of dolostone erratics (in percentage by categories in kg).*

1 to 5	27.1
5 to 10	17.7
10 to 20	23.1
20 to 50	15.8
50 to 70	4.9
70 to 100	5.4
100 to 200	3.0
>200	3.0

CONCLUSION

The boulder barricade at Cap à la Baleine is one of the rare occurrences of this cold region feature along the Gaspé shoreline. It resulted from erosion during the Holocene of a stoney clay deposit, which was cut back 300 to 400 m. The ice drifted boulders remained behind on the erosion surface and were subsequently concentrated by shore ice near the low tide level where they have been compacted together into the underlying clay substrate to form a wide elongated row of boulders. The lithology of the erratics is mixed with about 40% of clasts from the Laurentidian Shield on the north shore of the St. Lawrence estuary. Deposition of boulders occurred at the beginning of the Goldthwait Sea in the lower St. Lawrence estuary *circa* 13–13.5 ka, when the Laurentidian ice was still occupying a large portion of the valley, and the Appalachian ice margin was near the present shoreline. The boulders were deposited in the Goldthwait Sea most likely by icebergs rather than directly by a floating ice shelf. Today, the boulder barricade is relatively stable and forms an obstacle at low tide level dispersing wave energy and consequently reducing considerably the potential of erosion by waves of the tidal flat and the cliff at the high tide level.

ACKNOWLEDGEMENTS

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Table 6. *The ten largest dolostone erratics (size in cm; weight in kg).*

82 × 76 × > 35	490	Striated
70 × 58 × 40	304	—
60 × 45 × 50	253	Striated
68 × 48 × > 30	220	Striated
72 × 50 × 32	216	Striated
85 × 40 × > 25	214	Striated
60 × 50 × 35	197	—
58 × 53 × 30	173	Appalachian
55 × 40 × > 30	149	—
50 × 40 × 35	131	Striated

Table 7. *Roundness of dolostone erratics (in percentage).*

Angular	0.4
Angular-subangular	0.4
Subangular	8.3
Subangular-subrounded	23.0
Subrounded	43.5
Subrounded-rounded	19.6
Rounded	4.8

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□ RÉSUMÉ □

Il existe un cordon de blocs frangeant au Cap à la Baleine, sur la côte nord de la péninsule gaspésienne (Québec), à environ 25 km au NE de Matane. Il s'agit d'une crête basse (±1 m) située au niveau inférieur de la marée et formée par un dallage de cailloux subarrondis à arrondis, de taille moyenne (30–50 cm), et de nature lithologique variée. Les blocs sont disposés les uns contre les autres et sont légèrement enfoncés dans le substrat argileux. Le cordon comprend deux catégories de blocs. Environ 40% sont des erratiques précambriens provenant du Bouclier canadien sur la rive nord de l'estuaire du Saint-Laurent, alors que les autres sont des cailloux appalachiens comprenant 54% de grès (grauwacke). Parmi les indicateurs particuliers, on trouve des blocs d'anorthosite, de dolomie et de roches volcaniques. Les blocs à la surface de l'estran argileux constituent un résidu grossier provenant de l'érosion d'un diamicton limono-argileux, un événement survenu durant l'Holocène. Les blocs furent originellement mis en place dans la Mer de Goldthwait *circa* 13,5–13 ka, vraisemblablement par des icebergs issus de l'Inlandsis Laurentidien qui occupait encore une partie de la vallée du Saint-Laurent, et de la calotte appalachienne dont le front coïncidait alors avec le rivage actuel. De nos jours, le cordon de blocs frangeant au Cap à la Baleine forme un brise-lames naturel ralentissant l'érosion du rivage.