THE EASTWARD TRANSPORT OF ERRATICS IN JAMES BAY AREA, QUEBEC

La présence de cailloux erratiques à l'est d'affleurements de roches indicatrices sur la côte orientale de la baie de James ne constitue pas une preuve de l'existence d'une calotte glaciaire située quelque part à l'ouest ni d'un écoulement glaciaire de l'ouest vers l'est au cours du Pleistocène. Les indicateurs que l'on trouve dans les dépôts littoraux et à la surface du till remanié des basses terres de la baie de James ont été apportés par les glaces flottantes après le départ des glaciers.

INTRODUCTION

It has been known for many years sedimentary and volcanic (intrusive) erratics of Proterozoic and Paleozoic ages are present at the surface of the crystalline Precambrian (Archean) lowlands east of James Bay and Hudson Sea, Québec. The transport of these erratics is attributed by LEE (1959, 1960) to an early eastward ice flow from a hypothetical ice dome located somewhere in Hudson Sea or west of it. They were first transported inland by the older glaciation onto granitic-metamorphic terrain, and were transported again westward by the last ice flow from inland to Hudson Sea. In addition they may have been redistributed during the Tyrrell Sea episode by marine processes, especially by drift ice : « The earlier glacial transport has been shown to have carried erratics eastward from Hudson Sea and James Bay ; the latter glacial transport carried those erratics westward and so modified the inland extent of their dispersal. Still later marine processes concentrated the erratics into beach ridges in a vertical sequence on the sides of hills. Ice rafting was considered as a mean of transport for placing the erratics in the boulder beach ridges. This, however, seems improbable. Instead of a spotty distribution of erratics expected from ice rafting there is a high proportion of these erratics in all beach ridges » (LEE, 1959, p. 221).

The only four localities of Proterozoic and Paleozoic erratics on the Precambrian crystalline shield reported are close to the present shoreline : two sites are in the Great Whale area, another near Cape Jones, and one near Eastmain. LEE (1959, p. 219) indicates that « the erratics are distinctive enough and sufficiently numerous within a distance of about 6 miles (9,5 km) of their source rocks to be readily noticeable . . . ». No indication of the altitude of sites studied is given nor are any details about countings and percentages of erratics offered in this paper. However, LEE (in a letter, 1973) provided the following information about two sites near Great Whale River : 10 erratics from the Nastapoka Group were found in a boulder beach at 100 m altitude, and 4 erratics in a boulder beach at 160 m ; these sites are located between 3 and 4 km from the present shoreline. LEE mentions « the elevation of possible outcrop-sources for these erratics is much lower than the 325-525 ft. (100-160 m) altitudes at which boulders were found. This does not indicate ice rafting as a method of transport for these erratics... »

The purpose of this note is to discuss LEE's hypothesis in the light of observations made in the Fort George area. Because LEE's paper was published in a world known geological journal and nobody, to the author's knowledge, has discussed the hypothesis suggested. It is significant to note that LEE's hypothesis was never discussed nor rejected by CRAIG (1969).

OBSERVATIONS IN JAMES BAY AREA

LEE's assumption that erratics were first transported by glaciers with an eastward flow was viewed with skepticism by this author when he began studies in the James Bay area. To test theory with facts, field observations were made in the Fort George area during the summer 1973. Numerous sites pre-selected on air photos were visited and examined closely for erratics. Observations were made either on modern and ancient sea shores or sea bed within an area of about 2 000 km², located between long. W.78°15′ and 79°15′, and lat. N.53°30′ and 53°55′, measuring 40 km in a north-south direction and 50 km in a west-east direction (Fig.). In this area, the following sites were examined : 1) modern tidal flats ; 2) modern beaches and spits ; 3) raised beaches built during the Tyrrell Sea episode ; 4) reworked and unreworked till of drumlins.

Erratics occurred in 28 of the 32 sites studied (Table). In most sites the proportion of erratics is very low, less than 0.1%. However, it is higher along the modern shore where proportion of erratics in tidal flats may rise up to 2%.

Two main lithological types of erratics were considered significant : 1) Paleozoic limestones and dolostones outcropping on the west coast, and on most islands in the west half of James Bay and Hudson Sea (DOUGLAS, 1969 ; NORRIS *et al.*, 1967) ; North and

TABLE

Observations on Indicator Erratics, Fort George Area, Quebec
(numbers refer to sites shown on figure)

1. Modern boulder spit, near Goose Bay : a few Paleozoic limestone, and Proterozoic dolomite and basalt erratics.
2. Tidal flat, Goose Bay : numerous Paleozoic limestone erratics (3 to 20 cm), most erratics being perforated by molluscs, and lying on a mud surface ; about 1% limestone erratics.
3. Raised cobble beach, S. of Goose Bay : a few Paleozoic limestone pebbles ; altitude 30 m.
4. Raised cobble beach, about 9 km E. of Goose Bay : a few Paleozoic dolomite and basalt erratics ; altitude 35 m.
5. Boulder lag (wave reworked till) at surface of a drumlin S. of Goose Bay : a few Proterozoic dolomite boulders ; altitude 20 m.
6. Tidal flat, Loon Bay : numerous Paleozoic limestone erratics biologically corroded, (about 1.5%), and a few Proterozoic dolomite and stromatolitic limestone erratics, lying on a mud surface.
7. Till flat over an eroded drumlin, Loon Bay : a few Paleozoic limestone and Proterozoic dolomite erratics.
8. South shore of La Grande Rivière, about 7 km E. of Fort George : numerous Paleozoic limestone erratics.
9. Raised cobble and boulder beach N. of La Grande Rivière, about 10 km E. of Fort George : one Proterozoic stromatolitic limestone boulder ; altitude 30 m.
10. Raised beach (gravel and boulder lags) at surface of a drumlin, S. of Guillaume River, about 20 km E. of Fort George : one Paleozoic limestone cobble ; altitude 35 m.
11. Raised beach (cobble and boulder lags) at surface of a drumlin, S. of Guillaume River, about 35 km E. of Fort George : one Paleozoic coral limestone cobble ; altitude 65 m.
12. Boulder and cobble spit, near Big Island : a few Paleozoic limestone cobbles, and one Proterozoic dolomite boulder.
13. Tidal flat, Tees Bay : numerous Paleozoic limestone erratics and a few Proterozoic dolomite boulders lying on mud and marine clay deposits.
14. Tidal flat, Aquatuc Bay : numerous Paleozoic limestone erratics (about 1.5%) some being biologically corroded, lying on marine clay.
15. Raised beach (gravel and boulder lags) at surface of a drumlin, E. of Tees Bay : a few Proterozoic dolomite erratics ; altitude 20 m.
16. Raised beach (gravel and boulder lags) at surface of a drumlin, S. of La Grande Rivière, about 11 km S.E. of Fort George : a few Proterozoic dolomite erratics ; altitude 35 m.
17. Raised beach, S. of la Grande Rivière, about 17 km S.E. of Fort George : One Paleozoic limestone cobble, one Proterozoic stromatolitic limestone boulder, and a few dolomite erratics ; altitude 35 m.
18. Raised beach (cobble and boulder lags) at surface of a drumlin, about 10 km E. of Tees Bay : a few Proterozoic stromatolitic limestone and dolomite erratics (including 3 boulders) ; altitude 33 m.
19. Raised beach (gravel and boulder lags) at surface of a drumlin, S. of La Grande Rivière, about 35 km S.E. of Fort George : one Proterozoic dolomite boulder ; altitude 66 m.
20. Tidal flat, Aquatuc Bay : numerous Paleozoic limestone erratics lying on a thin silty sand deposit overlying marine clay.
21. Tidal flat, Dead Duck Bay : numerous Paleozoic limestone erratics biologically corroded, and a few Proterozoic dolomite boulders lying on marine clay.
22. Tidal flat, Dead Duck Bay : numerous Paleozoic limestone erratics (about 2%) biologically corroded lying on marine clay.
23. Tidal flat, Dead Duck Bay : numerous Paleozoic limestone erratics (about 2%) lying on marine clay.
24. Raised beach (cobble and boulder lags) at surface of a drumlin, 6 km N.E. of Dead Duck Bay : one Paleozoic limestone erratics ; altitude 20 m.
25. Raised pebble and cobble beach, S.E. of Dead Duck Bay : one Paleozoic limestone erratic ; altitude 25 m.
26. Raised beach at surface of a drumlin, 10 km S.E. of Dead Duck Bay : one Paleozoic limestone boulder, and one Proterozoic dolomite erratic ; altitude 33 m.
27. Gravel and boulder lags at surface of a drumlin, 11 km S.E. of Dead Duck Bay : a few Paleozoic limestone and Proterozoic dolomite erratics ; altitude 33 m.
28. Unreworked till in a drumlin, about 6 km S.E. of Fort George : no Paleozoic nor Proterozoic indicators ; altitude 25 m.
29. Raised beaches over till (drumlin), about 22 km E. of Fort George : one Paleozoic limestone erratic in beach sediments ; no Paleozoic nor Proterozoic indicator in the underlying unreworked till ; altitude 55 m.
30. Unreworked till in a drumlin, about 27 km E. of Fort George : no Paleozoic nor Proterozoic indicators ; altitude 60 m.
31. Raised beach (reworked till) at surface of a drumlin, S. of La Grande Rivière, about 42 km E. of Fort George : no Paleozoic nor Proterozoic erratics ; altitude 67 m.
32. Raised beach (reworked till) at surface of a drumlin, S. of La Grande Rivière, about 47 km E. of Fort George ; altitude 67 m.

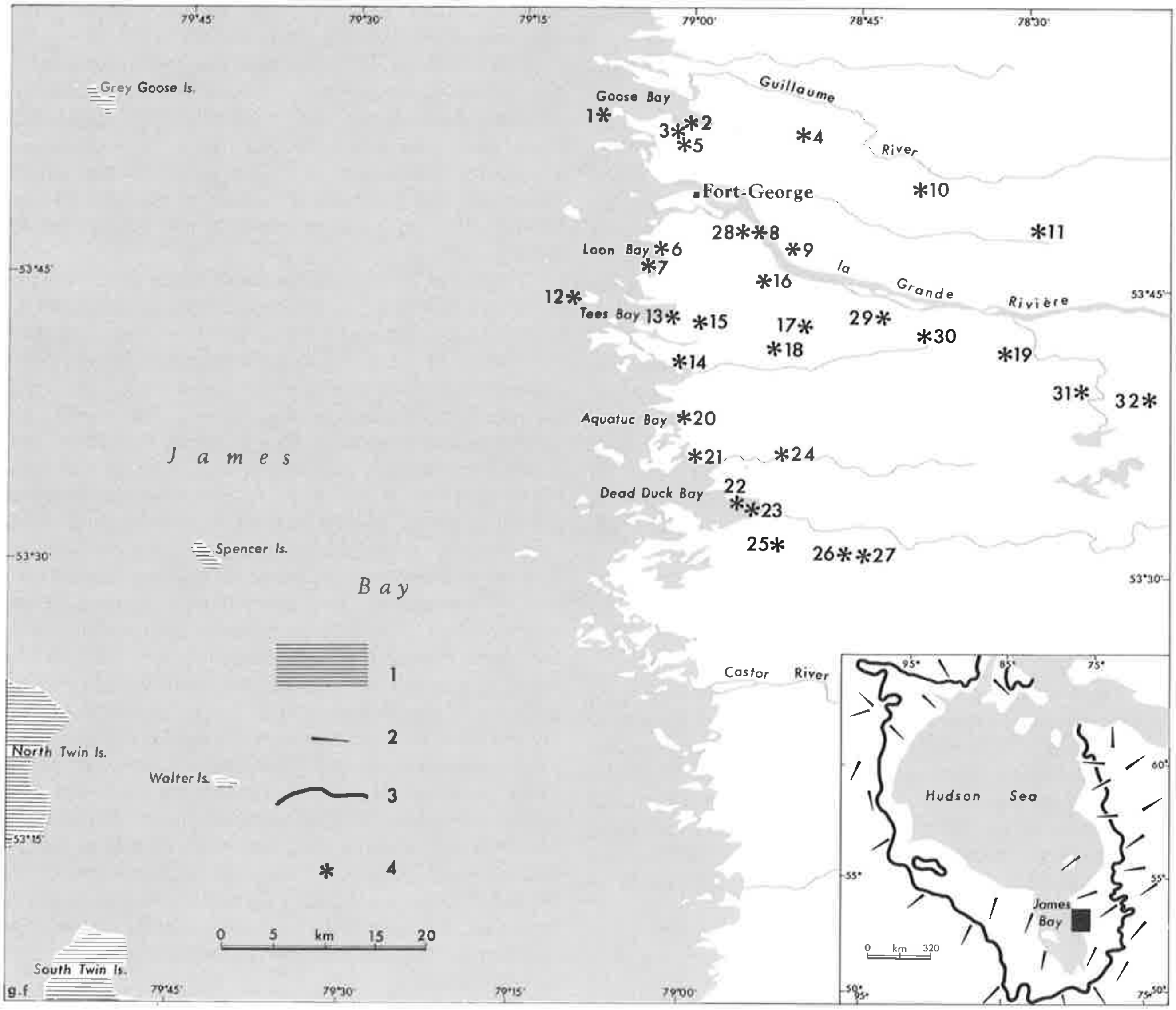

FIGURE. Location map and place-names. Islands are made of Paleozoic rocks. Inset map : continuous line corresponds to maximum level of Tyrell Sea ; arrows indicate direction of glacial flow.

Carte de localisation et noms de lieux. Les îles sont formées de roches paléozoïques. En carton : la ligne continue correspond à la limite maximale atteinte par la mer de Tyrell ; les flèches indiquent le sens de l'écoulement glaciaire.

South Twin, Spencer, Walter, and Grey Goose islands located between 45 and 125 km west and south-west of Fort George ; 2) dolimitic rocks of the Belcher Group and dolomitic and stromatolitic limestones and basalt of Manitounuk Group of Proterozoic age (EADE, 1966), outcropping along the east coast of Hudson Sea and on Belcher Islands, from 110 to 250 km north of Fort George.

These indicators contrasted with those of local bedrock which are mainly composed of granit, gneiss, granodiorite, andesite, and rhyolite of Archaean age. There is also some siltstone, quartzite and arkose in the Manitounuk Group along the east coast of Hudson Sea, and some sandstone and quartzite of Proterozoic age (Sakami Formation) about 150 km inland in the northern part of Lake Sakami. Erratics from these rocks were not considered quantitatively significant.

Because of the very low proportion of erratics in most sites, only a few countings were made ; however, every erratic was noted. Sizes of indicators range from 3 to 60 cm.

Erratics are most abundant along the modern sea shore especially in tidal flats (sites Nos. 2, 6, 13, 20, 21, 22, 23), were they rest on a mud or a marine clay deposit, and are evidently ice-rafted debris (DIONNE, 1974). They are composed mainly of Paleozoic limestone and dolostone, most being highly corroded by molluscs particularly by *Hiatella arctica.* In addition a few erratics of dolomitic and stromatolitic limestones were found (sites Nos. 6, 13, 21). A very low proportion of erratics (Paleozoic limestone and dolostone, Proterozoic dolomitic limestone and basalt) are found on boulder and gravel spits along the shore (sites Nos. 1, 7, 12). A few erratics (Paleozoic limestone and dolostone, Proterozoic dolomitic and stromatolitic limestones, and basalt) are found on raised beaches built during the Tyrrell Sea episode (sites Nos. 3, 4, 9, 17, 25, 29), and at the surface of wave-washed drumlins (sites Nos. 5, 10, 11, 15, 16, 18, 19, 24, 26, 27). No significant indicator was found in the unreworked till of drumlins respectively at 6, 22, and 27 km E. of Fort George (sites Nos. 28, 29, 30). There appears to be no indicators inland at a distance exceeding 50 km east of Fort George (sites Nos. 31, 32).[1]

From observations made in the Fort George area Paleozoic limestone indicators are more abundant in modern tidal flats than in modern beaches or spits, raised beaches and reworked till at surface of drumlins, and no significant indicator is found at a distance exceeding 50 km from the present shoreline. Paleozoic limestone indicators are found in 78% of the 28 sites, dolomitic rocks in 53.6%, stromatolitic limestone in 14.3%, and basalt in 7.2%.

DISCUSSION

LEE's (1959) theory of an eastward ice flow transporting erratics is questionable particularly when he recognized erratics are concentrated into beach ridges. To conclude erratics were first moved eastward by a later ice flow, a different distribution of indicators should be expected, and at least a few erratics should be found in unreworked glacial deposits, and possibly also outside the area covered by the Tyrrell Sea (LEE, 1968).

Field observations made during the summer of 1973 show : 1) that indicators do not occur more than 50 km from the present shoreline even though topography is flat and no major relief could have obstructed inland glacial dispersion of them, and 2) that no indicators are found in unreworked till (in drumlins) at a relatively short distance from the shore [2].

LEE (1959, p. 221) has rejected the hypothesis of ice rafting as the agent of the eastward transport of erratics, because of the relatively high proportion of erratics into beach ridges while he expected a a « spotty distribution ». In his letter to the author, he argues that the lower elevation of possible outcrop sources for the erratics make it impossible for ice rafting.

The Great Whale and the Cape Jones areas referred to by LEE (1959) are located respectively about 150 km and 110 km north of Fort George. The sites of erratics mentioned by LEE are located within 6 km from the present shoreline, where Proterozoic rocks (dolomitic and stromatolitic limestones, basalt, sandstone, and quartzite) outcrop along the east shore of Hudson Sea. It is normal at such a short distance from source rocks the proportion of indicators in beaches and reworked glacial deposits be higher than in the deposits of the Fort George area, located many kilometres from the source of indicators. However, the proportion of erratics in the boulder beaches referred to by LEE are relatively low. Although the possible sources of erratics are lower than the boulder beaches, it is possible for ice rafting to occur because pressured ice forming big underwater ridges and anchor ice can pick up erratics on sea bottom and bring them up to the surface. Then occurrence of erratics in beach ridges does not necessarily prove erratics were transported eastward by a former ice sheet located somewhere in Hudson Sea before being retransported westward by a later glacier. Recent work (CRAIG, 1969), on deglaciation of the Hudson Sea area does not indicate any eastward glacial flow over the crystalline lowlands east of Hudson Sea and James Bay, and LEE's hypothesis is not mentioned nor discussed.

It is thought that in the Fort George area indicators were transported eastward and southwestward by drift ice, and it is believed that data collected in that area are reliable for most of the coastal lowland area east of James Bay [3] and possibly Hudson Sea. Arguments in favor of drift ice action rather than glacier ice are numerous : 1) Occurrence of millions of ice drift boulders lying over Quaternary mud and marine clay deposits on modern tidal flats ; 2) Higher percentage of Paleozoic limestone indicators in modern tidal flats

1. Although only two sites are mentioned in this paper, several other sites located farther east were examined. No significant erratics, e.g, Paleozoic or Proterozoic rocks were found in these sites.

2. It should be mentioned here that only three observations were made in unreworked till of drumlins (sites nos 28, 29 and 30).

3. Observations made in the Eastma'n area during the summer of 1974 corroborate the conclusion reached earlier from data collected in the Fort George area.

when compared to raised beaches and reworked drumlins 50 km from the shore ; 4) Absence of indicators increasing distance landward, and absence of any significant indicators in raised beaches at a distance exceeding 50 km from the shore ; 4) Absence of indicators in unreworked till at relatively short distances from the present shoreline ; 5) Low altitude (less than 70 m) of deposits containing indicators made by ice rafting possible during the last phase of the Tyrrell Sea, indicators being possibly picked-up from Proterozoic rock outcrops along the east shore of Hudson Sea and possibly also from the Belcher Islands, and Paleozoic rock outcrops from the western half of James Bay ; 6) Last glacial ice flow direction which is N.E. 60°-65° S.W., as indicated by striations and drumlins, so that indicators from the east coast of Hudson Sea would never have been distributed in the Fort George area.

LEE's argument against drift ice action is not convincing. It is a misconception of drift ice activity to believe a « spotty distribution of erratics » rather than a concentration will result from this action. There is a major difference in the amount of erratics transported between ice rafting and kelp rafting for example. Detailed studies in the St. Lawrence Estuary (DIONNE, 1971, 1972) provided evidence that drift ice does effectively concentrate erratics. For example, at the surface of marine clay terraces on the south shore of the St. Lawrence Estuary between Rivière-du-Loup and Trois-Pistoles, 80% of erratics are crystalline rocks from the north shore drifted by ice across the St. Lawrence, and along the shore, numerous boulder ridges are composed of crystalline boulders in proportions of 75%. The proportion of ice drifted indicators in the James Bay area is so small that no problem arises in attributing their transport to drift ice rather than to glacier ice. For those who have visited the tidal flats along the east coast of James Bay, it is evident ice rafting is the main process transporting coarse material along the shore, and elsewhere in Hudson Sea (PELLETIER, 1969). However it is possible the glacial history of the area north of Great Whale River may be sligthly different from the area south of it as suggested by LEE (in a letter, 1973).

CONCLUSION

The occurrence of Paleozoic and Proterozoic indicators in the deposits of the crystalline lowland area east of James Bay and possibly also Hudson Sea is in no way reliable evidence of a former eastward glacier flow although it does not negate the possibility of such a movement. However, there is as yet no evidence of such an eastward ice flow : « The earlier ice is known only from the presence of erratics east of the source rocks », (LEE, 1959, p. 219). Erratics are more likely drift ice clasts scattered in shore deposits or in reworked till [4].

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