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The Omar Story: The Role of Omars in Assessing Glacial History of West-Central North America
Le rôle des omars dans l'interprétation de l'évolution glaciaire du centre-ouest de l'Amérique du Nord
Die Rolle der Omars bei der Einschätzung der glazialen Geschichte von West-Zentral-Nordamerika

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Résumé de l'article

Des erratiques de roches protérozoïques du Groupe de Belcher du sud-est de la baie d'Hudson, montrant certaines caractéristiques particulières, ont été transportés vers le nord-ouest, l'ouest et le sud, sur des centaines de kilomètres au cours du Wisconsinien, à travers la baie d'Hudson, le nord de l'Ontario, jusque dans l'Ouest canadien et dans plusieurs états voisins du nord des États-Unis. Le plus abondant de ces erratiques, l'« omar », est un grauwacke silicieux et massif contenant, dans les cas d'altération, des concrétions calcaires de couleur chamois. Ces erratiques proviennent de la Formation d'Omarolluk du Groupe de Belcher, qui affleure dans l'archipel des Belcher et qui occupe probablement une grande partie du fond marin du sud-est de la baie d'Hudson. Des erratiques de jaspe oolitique rouge, beau- coup moins abondants que les omars, mais tout aussi distinctifs, proviennent de la Formation de Kipalu du Groupe de Belcher. Nous proposons donc le terme « kipalus » pour désigner ces jaspes. La répartition de ces deux types d'erratiques, en conjonction avec les indicateurs d'écoulement glaciaire du Wisconsinien, résulte probablement de deux glaciations distinctes qui ont engendré plusieurs lobes glaciaires majeurs. Cet article, qui résume les observations de terrain de nombreux géoscientifiques canadiens et américains, retrace l'évolution de notre interprétation sur la provenance des erratiques et décrit les critères permettant d'isoler les « vrais » omars d'autres erratiques de grauwacke à concrétions provenant d'autres parties du soubassement rocheux.

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THE OMAR STORY: THE ROLE OF OMARS IN ASSESSING GLACIAL HISTORY OF WEST-CENTRAL NORTH AMERICA

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ABSTRACT The direction of Wisconsinan glacial dispersion of distinctive Proterozoic erratics derived from the Belcher Group in southeastern Hudson Bay is shown to have been northwestward, westward and southward for hundreds of kilometres across Hudson Bay, Northern Ontario, western Canada, and several adjoining northern States. The most distinctive of these erratics, termed "omars", are composed of massive siliceous wacke characterized by buff-weathering calcareous concretions; these erratics were derived from the Omarolluk Formation of the Belcher Group, exposed in the Belcher Islands of eastern Hudson Bay, and probably underlying much of the southern part of this inland sea. Far less common but equally distinctive are erratics of red oolitic jasper that were derived from the Kipalu Formation of the Belcher Group. In parallel with the now widely accepted field term "omar", we introduce the term "kipalu" for such erratics of oolitic jasper. A map showing the distribution of the distinctive erratics, in relation to indicators of Wisconsinan glacier movement, provides the basis for inferring at least two discrete glaciations that produced several major ice lobes. This paper summarizes the field observations of numerous Canadian and American earth scientists, traces the evolution of thought on provenance of the distinctive erratics, and outlines the criteria for distinguishing "true" omars from erratics derived from other bedrock sources of concretion-bearing wackes.

RÉSUMÉ *Le rôle des omars dans l'interprétation de l'évolution glaciaire du centre-ouest de l'Amérique du Nord.* Des erratiques de roches protérozoïques du Groupe de Belcher du sud-est de la baie d'Hudson, montrant certaines caractéristiques particulières, ont été transportés vers le nord-ouest, l'ouest et le sud, sur des centaines de kilomètres au cours du Wisconsinien, à travers la baie d'Hudson, le nord de l'Ontario, jusque dans l'Ouest canadien et dans plusieurs états voisins du nord des États-Unis. Le plus abondant de ces erratiques, l'« omar », est un grauwacke silicieux et massif contenant, dans les cas d'altération, des concrétions calcaires de couleur chamois. Ces erratiques proviennent de la Formation d'Omarolluk du Groupe de Belcher, qui affleure dans l'archipel des Belcher et qui occupe probablement une grande partie du fond marin du sud-est de la baie d'Hudson. Des erratiques de jaspe oolitique rouge, beaucoup moins abondants que les omars, mais tout aussi distinctifs, proviennent de la Formation de Kipalu du Groupe de Belcher. Nous proposons donc le terme « kipalus » pour désigner ces jaspes. La répartition de ces deux types d'erratiques, en conjonction avec les indicateurs d'écoulement glaciaire du Wisconsinien, résulte probablement de deux glaciations distinctes qui ont engendré plusieurs lobes glaciaires majeurs. Cet article, qui résume les observations de terrain de nombreux géoscientifiques canadiens et américains, retrace l'évolution de notre interprétation sur la provenance des erratiques et décrit les critères permettant d'isoler les « vrais » omars d'autres erratiques de grauwacke à concrétions provenant d'autres parties du soubassement rocheux.

ZUSAMMENFASSUNG *Die Rolle der Omars bei der Einschätzung der glazialen Geschichte von West-Zentral-Nordamerika.* Erratische Blöcke des Proterozoikums von der Belcher-Gruppe in der Südost-Hudson-Bay , die charakteristische Merkmale aufweisen, sind während der glazialen Dispersion im Wisconsin nordwestwärts, westwärts und südwärts über Hunderte von Kilometern über die Hudson Bay, Nord-Ontario, West-Kanada und verschiedene angrenzende nördliche Staaten zerstreut worden. Die charakteristischsten dieser erratischen Blöcke, die man « Omars » nennt, bestehen aus massiver Kiesel-Grauwacke mit gelbbraunen Kalk-Konkretionen ; diese erratischen Blöcke stammen von der Omarolluk-Formation der Belcher-Gruppe, welche in den Belcher-Inseln der östlichen Hudson Bay ausgesetzt ist und wohl einen großen Teil des Meeresbodens im Süd-Abschnitt dieses Inland-Meeres einnimmt. Sehr viel weniger verbreitet aber genauso charakteristisch sind erratische Blöcke aus rotem Rogenstein-Jaspis, die aus der Kipalu-Formation der Belcher-Gruppe stammen. Entsprechend zu dem nun allgemein akzeptierten Begriff « Omar » führen wir für solche erratischen Blöcke aus Rogenstein-Jaspis den Terminus « Kipalu » ein. Eine Karte, welche die Verteilung dieser unverwechselbaren erratische Blöcke zeigt, liefert in Verbindung mit Hinweisen über die Gletscher-Bewegung im Wisconsin die Grundlage für die Annahme von mindestens zwei verschiedenen Vereisungen, welche mehrere größere Eisloben produziert haben. Dieser Aufsatz fasst die Feldbeobachtungen von zahlreichen kanadischen und amerikanischen Geologen zusammen, zeichnet die Entwicklung der Überlegungen zu der Herkunft der besonderen erratischen Blöcke nach, und definiert Kriterien zur Unterscheidung zwischen « echten » Omars und erratischen Blöcken, die von anderem anstehenden Gestein mit Grau-Wacke-Konkretionen stammen.

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INTRODUCTION[1]

The term "omar" (Prest, 1990) refers specifically to a glacial erratic of massive dark siliceous greywacke that contains light-toned (generally buff-weathering) calcareous concretions which are typically subspherical and weather recessively (Fig. 1). Omars, which commonly occur in and on eskers and outwash, but which also may be found in till and lacustrine deposits, are inferred to have been derived from the Belcher Group in southeastern Hudson Bay. Most of the erratics were dispersed northwestward and westward (Veillette, 1995) across the Hudson Bay Paleozoic Basin by Labrador Sector ice, followed by westward and southwestward movement of ice across the Paleozoic and Archean terrain of Northern Ontario and northern Manitoba (Fig. 2). In Ontario west of James Bay, however, the erratics were redeposited by Cochrane ice flowing southward over mainly Paleozoic strata. In southwestern Manitoba, southern Saskatchewan and southern Alberta, dispersal of the Proterozoic erratics was by dominantly south and southeast-flowing Keewatin Sector ice. The distribution of erratics in these provinces is suggestive of a northern provenance, such as the Proterozoic Athabasca Basin, but this basin lacks concretion-bearing wackes (Ramaekers, 1990). We therefore conclude that the Prairie occurrences of omars must also have been derived from the Belcher Group. Labrador Sector ice probably transported them first northwestward and then westward, perhaps as far as the Foothills. After recession of that ice sheet, many of the omars became incorporated in advancing Keewatin Sector ice, which spread them southward over the Prairies and into the northern United States. This strong flow of ice, which is now referred to as Plains ice (Dyke and Prest, 1987) seems to have radiated from a marginal Keewatin Sector ice dome west of Great Slave Lake (north of which the flow was northward to the Arctic). Thus, most omars on the Prairies have been redeposited.

HISTORY

The occurrence in Northern Ontario of glacial erratics of "dark-coloured granular quartzite" [rocks that now would be classified as greywacke, or wacke][2] was first reported by Robert Bell of the Geological Survey of Canada. In his report on the country between lakes Superior and Winnipeg, he referred to erratics of "dark grey granular quartzite and siliceous banded hematite [as having been] transported a long distance from the northeast, as indicated by their worn character and the direction of glacial striae" (Bell, 1873, p. 111). Later, in his report on the country between James Bay and lakes Superior and Huron, Bell (1879a, p. 325) referred to the abundance of: "Dark grey (sometimes almost black)[rather fine grained quartzite [greywacke] ... often with] rounded and elongated spots which weather into pits. ... Boulders of similar rocks are abundant along the Albany River below Martin Falls" (now Marten Falls, which is within the Paleozoic Lowland).

Bell also studied the bedrock geology of the east coast of Hudson Bay, and referred to the "Huronian [Proterozoic] Manitounuk and Nastapoka groups", but made no mention of overlying drift materials (Bell, 1879a). In a subsequent report on his explorations along the Churchill and Nelson rivers and around Gods and Island lakes in northern Manitoba, Bell (1879b, p. 24CC; 1880), noted that a large portion of the drift materials were derived "from the east coast of Hudson Bay ... among these may be mentioned the very dark grey quartzite [greywacke] with occasional light spots which on weathering out form rounded pits ...". He also mentioned that pebbles of "a peculiar variety of [oolitic] red jasper such as that on Long Island", commonly found in association with the concretionary greywackes, closely resembled rocks with which he was familiar on the east coast of Hudson Bay, including Long Island[3].

Bell summarized his regional observations in Northern Ontario (Bell, 1887, p. 36G): "Along the Attawapishkat, Albany and Kenogami Rivers, as well as on the west coast of James Bay, the most remarkable feature in the composition of the drift is the abundance of pebbles and boulders of dark grey granular siliceous felsite or greywacke. It constitutes the greater number of the boulders and pebbles of the extensive reefs which have been referred to, between Akimiski Island and the west shore, and is abundant among the boulders of the coast between Rupert's House and Moose Factory. Well-rounded fragments of this rock are also found along the Moose and Missinaibi Rivers, and as far west as Lonely Lake [perhaps Missinaibi Lake], and southward to Lake Superior. It is characterized by round spots, from the size of a pea to that of a cricket ball or larger, of a lighter colour than the rest of the rock, which weather out into pits of the same form. ... This rock occurs *in situ* on Long Island, off Cape Jones, on the east main coast, where it strikes southwestward or with the greater length of the island. The same rock, no doubt, continues under the sea for some distance in the direction of its strike."

Another reference to long-distance transport of erratics of both Archean rocks and Proterozoic greywacke was provided by Upham (1896, p. 130-131). In referring to Archean boulders in the drift of northern Montana, which were derived from source rocks in the vicinity of Reindeer Lake and northeast of Lake Winnipeg, he stated as follows: "The least distance from the most western of these [Archean] bowlders (*sic*) to the margin of the Archean belt is about 550 miles. Other bowlders of Archean origin which must have traveled nearly or quite as far occur in Kansas, Missouri, and Illinois, on the southwestern part of the drift-bearing area of the United States. The method of transportation of all these is believed by the writer to have been wholly by the slow current of land ice."

1. Access to the Glacial Map of Canada (Geological Survey of Canada Map 1253A, Prest *et al.*, 1968) and official provincial road maps is recommended for perusal of this account, and evaluation of Figs. 2 and 3.

2. [Explanatory information for quotations is added in this fashion.]

3. The occurrence of outcrops of Omarolluk Formation on Long Island has not yet been confirmed.

FIGURE 1. Representative collection of omars, showing normal size range, subspherical shapes, and different degrees of recessive weathering of calcareous concretions that provide the characteristic signature of wacke clasts derived from the Omarolluk Formation of Hudson Bay.

Collection représentative d'omars montrant une granulométrie normale, une forme sub-sphérique et les différentes phases d'altération des concrétions calcaires, qui ensemble constituent les principales caractéristiques des fragmnents de grauwacke provenant de la Formation d'Omarolluk de la baie d'Hudson.

Upham continued as follow: "Dr. Robert Bell observes that the bowlders and pebbles of the drift on the west coast of Hudson Bay, near the mouth of the Churchill and on the lower part of the Nelson, consist largely of rocks like those of the opposite eastern coast of Hudson Bay, which is 500 miles distant. But the farthest known transportation of rock fragments in the drift recorded in part by Dr.Bell, whose observations are supplemented by my own, is from James Bay southwest to North Dakota and Minnesota. The rock thus recognized is a 'dark gray, granular, siliceous felsite or greywacke, ... characterized by round spots, from the size of a pea to that of a cricket ball or larger, of a lighter color that the rest of the rock, which weather out into pits of the same form' ... Farther to the southwest and south I have observed fragments of it, usually only a few inches but in some instances a foot or more in diameter, occurring very rarely in the drift in the northeastern part of North Dakota, where the largest piece ever found by me was about 30 miles south of the international boundary and 50 miles west of the Red River, and at numerous localities in Minnesota, where it extends at least as far south as Steele County, 75 miles south of St. Paul and 1 000 miles southwest of its outcrop north of James Bay."

For some time after the remarkable journeys and numerous notations of Robert Bell in Northern Ontario and in northern Manitoba, and the observations of Upham in the northern United States, the matter of long-distance transport of Proterozoic greywacke clasts west and southwest from Hudson Bay received but scant attention. While mapping bedrock geology for the Ontario Department of Mines in 1941, one of us (V.K.P., field notes) noted the occurrence of Proterozoic greywacke erratics in the Washi Lake area (where the Albany River jogs northward before crossing onto the Paleozoic strata). He concluded that these cobbles and boulders had been transported across the Paleozoic terrain from the Proterozoic Belcher Islands, some 700 km to the northeast.

MID-CENTURY REVIVAL OF INTEREST IN OMARS

ONTARIO

Interest in the glacial dispersal of Proterozoic greywacke and jasper erratics from the Belcher Group was renewed as a result of the Roads to Resources Program carried out under the joint auspices of the Geological Survey of Canada and the Ontario Department of Mines in 1959-61. The bedrock geology of eight 4-mile map-areas (each 1° latitude by 2° longitude) was studied by officers of the Geological Survey of Canada, and summarized by Duffell *et al*. (1963). The regional surficial geology of the eight map-areas was compiled by Prest (1963), based on field studies in 1960-61 and air photo analysis in 1962. The bedrock geology of two of the 4-mile map-areas (Lake Miminiska and Fort Hope) was studied by Jackson (1961, 1962), who had recently mapped the Belcher Islands (Jackson,1960), and thus was able to confirm that the concretion-bearing greywacke and the oolitic jasper were identical in appearance to parts of the Omarolluk and Kipalu formations, respectively. For descriptions of the Omarolluk and Kipalu formations, see Dimroth *et al*. (1970, p. 106, 110-113).

One of us also mapped two 4-mile map-areas (Red Lake and North Spirit Lake, Donaldson, 1959, 1961), and thereby

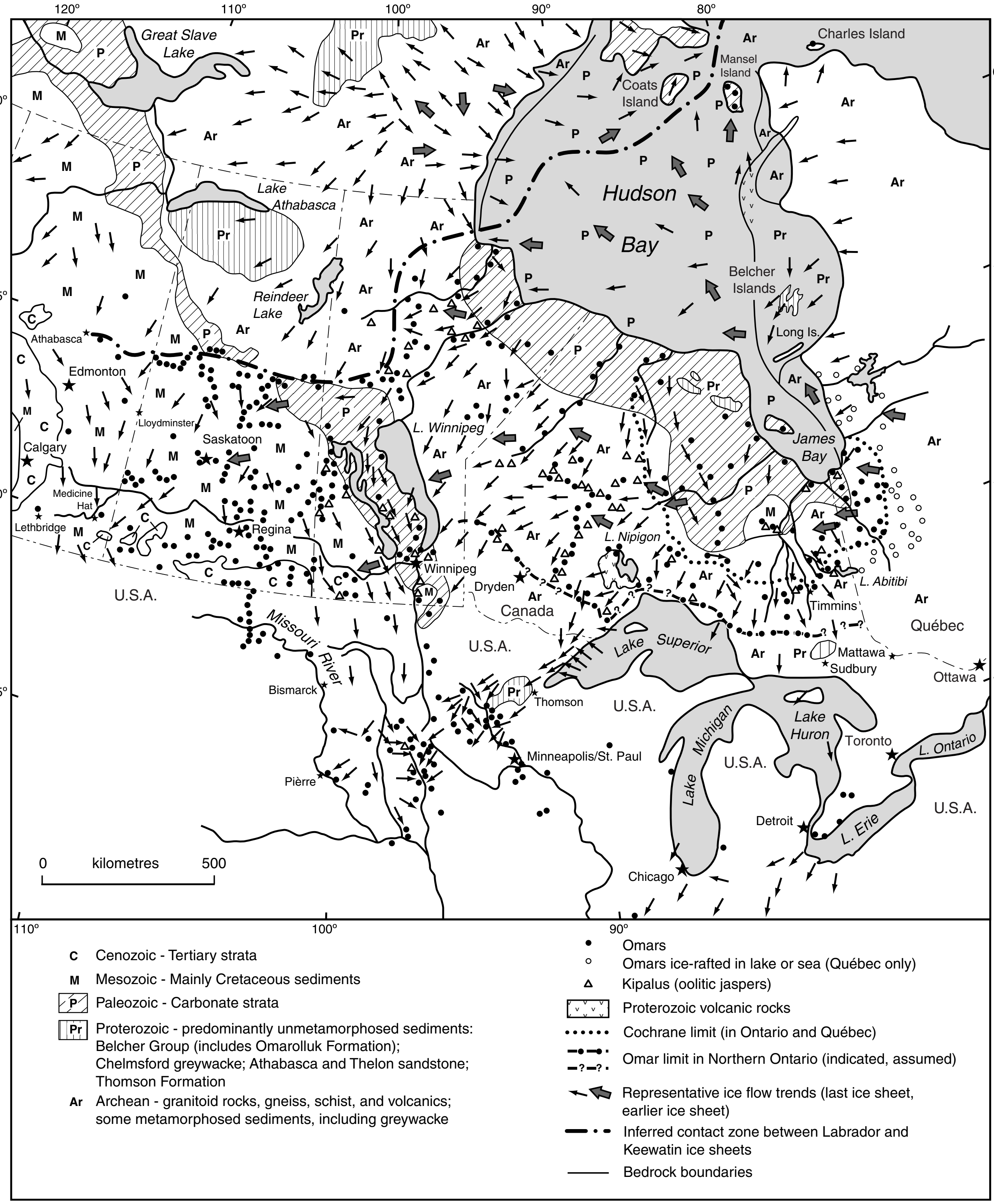

FIGURE 2. Map of west-central North America, showing distribution of omars, occurrences of kipalus (oolitic jasper clasts), generalized bedrock geology, and Pleistocene ice-flow trends.

Carte de la partie occidentale du centre de l'Amérique du Nord montrant la répartition des omars, les sites où des kipalus (fragments de jaspe oolitique) ont été signalés, la géologie du substratum et les axes d'écoulement glaciaire au Pléistocène.

became familiar with the occurrence of Proterozoic erratics overlying the Archean terrain in that part of Northern Ontario. In collaboration with B.D. Ricketts, Donaldson subsequently studied the stratigraphy and sedimentology of the Belcher Islands, including the Omarolluk and Kipalu formations (Ricketts, 1979, 1981; Ricketts and Donaldson, 1981). Of particular significance to the omar story, he supervised a study of concretions in the Omarolluk Formation by J. McEwen (McEwen ,1978; McEwen *et al.*, 1978).

In his report on the surficial geology of the Red Lake-Landsdowne House region (51° - 53° N; 86° - 94° W) Prest (1963) documented the dispersion of Paleozoic and Proterozoic clasts over the Precambrian terrain; an appendix to this report contains 26 compositional analyses of glacial materials, showing the presence of omars at 16 sites, and oolitic jaspers at 14 sites (in parallel with omars, the oolitic jaspers are herein termed “kipalus”, because of their presumed derivation from the Kipalu Formation of the Belcher Group). A pebble count in the northeastern part of the Red Lake-Landsdowne House region, about 80 km west of the Paleozoic contact, gave 56 % Archean rocks, 35 % Proterozoic greywacke (including omars), 8 % Paleozoic limestone, and 0.5 % each of chert and oolitic jasper clasts (kipalus). Other pebble counts farther west, especially those from eskers, yielded greywacke contents as high as 19 %, but most were below 5 %. In the Weagamow Lake and Caribou Lake 4-mile map-areas (within the Red Lake-Landsdowne House region), P.F. Finamore (pers. comm., 1962) examined raised beaches of Glacial Lake Agassiz. He noted omar cobbles at nine sites and oolitic jasper pebbles at four of them. Paleozoic limestone clasts were seen at seven of these sites, and red sandstone at two. The latter were possibly from the Loaf Formation of the Belcher Group.

In her till and geochemical studies southwest of Cochrane (National Topographic Survey Map {NTS} 42A/13,14), M.B. McClennahan of the Geological Survey of Canada (pers. comm., 1995) recorded omar cobbles and boulders at 22 sites and pebbles of oolitic jasper at 10 of these. Red sandstone clasts, possibly from the Loaf Formation of the Belcher Group, were noted at six of the sites. In addition, E. Sado (pers. comm., 1984) carried out stone counts in the eastern part of Northern Ontario while mapping surficial geology for the Ontario Geological Survey. Clasts of Proterozoic wacke and/or jasper were recorded at 20 of 30 sites; these have been incorporated in Figure 2.

While mapping the surficial geology of the Red Lake and Masden map-areas for the Ontario Geological Survey at a scale of 1: 50 000, Prest (1980, 1982) noted only rare occurrences of omars and oolitic jaspers (kipalus). In 1983, Prest and E. Sado (then with the Ontario Geological Survey) carried out an extended search for omars from Ignace on the Trans-Canada Hwy. (Highway 17) north to the Agutua Moraine, and thence west along this moraine to the road terminus at Windigo Lakes (see Official Ontario Road Map and Prest, 1990, Fig. 27). The 1984 sites recorded by J.A. Richard (former Consulting Geologist, Timmins) and Prest throughout the Hearst-Cochrane – Abitibi region, and north to Detour Lake, some 120 km north of Lake Abitibi, are included in Prest (1990, Fig. 27). Richard (Richard and Hilborn, 1984a, b) had earlier completed two 1: 50 000 surficial geology maps in the Cochrane District for the Ontario Geological Survey, and therefore was familiar with the distribution of omars as well as erratics of concretion-free wacke. Farther north, H. Thorleifson (pers. comm., 1989) observed omar clasts scattered along the full lengths of the Severn and Sachigo rivers, and along the lower reaches of Winisk River. These data contributed to his excellent account of the implications of regional ice flow in Northwestern Ontario (Thorleifson *et al.*, 1993a, b). Wacke clasts containing weathered-out calcareous concretions, collected in 1999 along the upper reaches of the Albany River by Marian Flammang of Duluth, have been confirmed by one of us (H.D. M.) to be omars.

The foregoing information provides an overview of omar occurrences in Northern Ontario. We now will present data pertinent to the concept of a “southern omar limit” in the southeastern part of Northern Ontario. The generalized omar distribution map (Fig. 2) includes the 1986 observations of Prest and J. Easton in Northern Ontario (field work supported by the Ontario Geological Survey). They searched for omars both within and beyond the Cochrane Limit (see G.S.C. Map 1253A). From the town of Mattawa in the Ottawa River valley, west to Lake Nipissing, north to the Cobalt area, and southwest to the Sudbury Basin, they did not observe any omars. Thus there is a broad region in the southeastern part of Northern Ontario which appears to be omar-free (*i.e.* there is a “southern omar limit”, as will be discussed below). On Hwy. #144 at the town of Chelmsford within the central part of the Sudbury Basin, however, they did note outcrops of concretion-bearing wacke (Chelmsford Formation). Although most of the concretions were large and irregular, some were small and round, similar to those typical of Belcher-derived omars. A search over a large area up to 15 km to the southwest of the Chelmsford outcrops, however, failed to locate any omar-like erratics, or even clasts of Chelmsford wacke.

Continuing north on Hwy. #144, no omars were observed for some 90 km until the junction with Hwy. #560, west of the town of Westree (see Official Ontario Road Map). Because omars had earlier been noted farther north on Hwy. #144 and along Hwy. #101 to Timmins, they directed their omar search westward along a private access road that is now in part the extension of Hwy. #560. This road passes through the towns of Ramsey, Chapleau and Wawa (Fig. 3). Omars were noted at many places along and just south of this road. They are associated with a calcareous till which ends in a major outwash area (shown on Map 1253A), and also with lake deposits (see Ontario Department Lands and Forests Map S465 by Boissonneau, 1966). At one site, the omars were seen to overlie an older non-calcareous till. A curved line drawn through the small morainal features at the head of the outwash, through the towns of Wawa, Chapleau, Sultan and Ramsey, marks the margin of a pre-Cochrane morainal complex, as well as the southern limit of omars in Northern Ontario. Omars were not observed along the restricted access road between Ramsey and Hwy. #17, nor along Hwy. #129, thus supporting the concept of a southern omar limit.

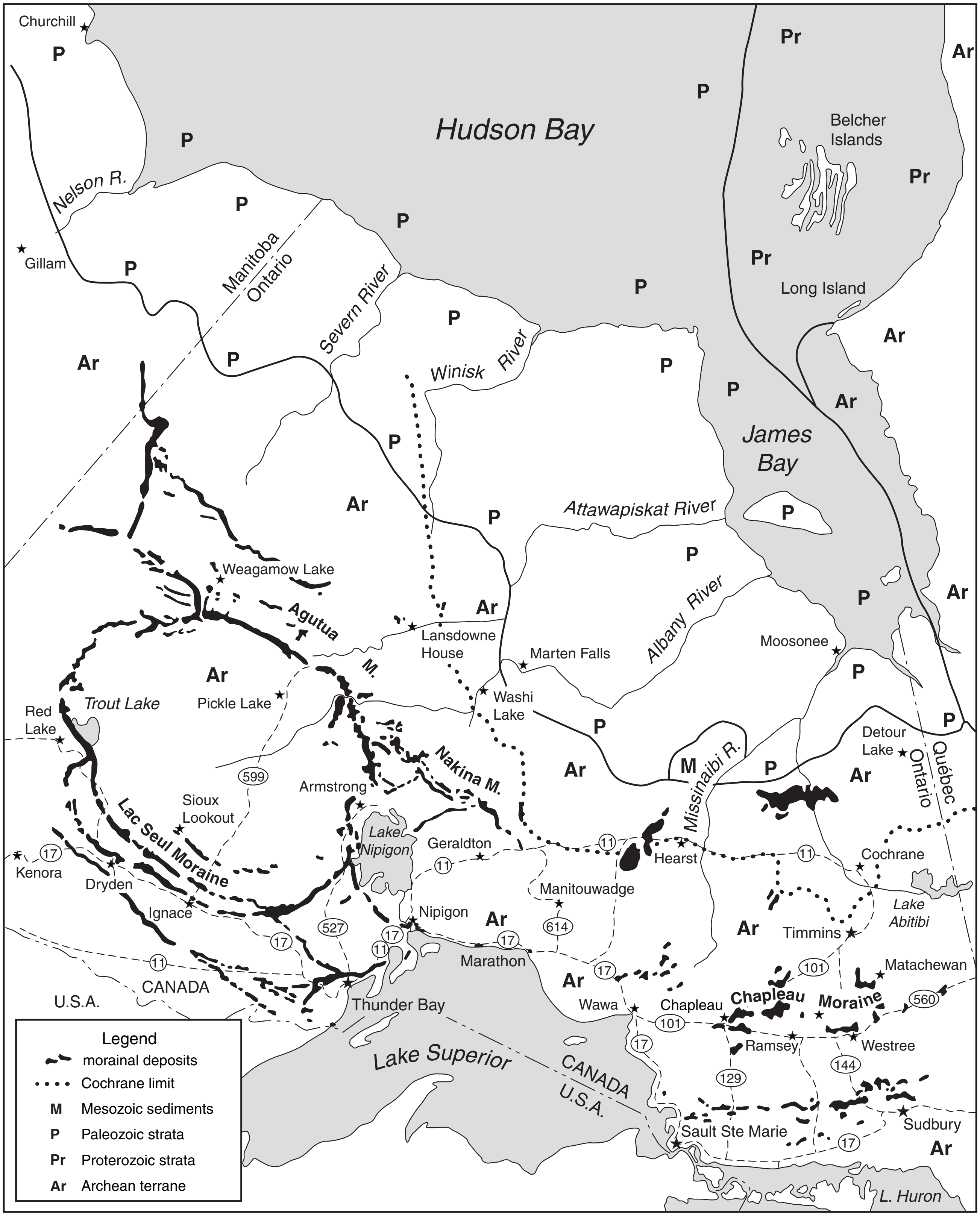

FIGURE 3. Map of Northern Ontario, showing place names and Pleistocene features mentioned in the text.

Carte des quelques grands traits du Pléistocène discutés dans le texte et des noms de lieux du nord de l'Ontario.

In discussing the morainal deposits in the Chapleau area, and their extensions eastward into Québec, Boissonneau (1968; see his Fig. 3) identified three belts of scattered moraines as Chapleau I, II, and III, with the first of these as the oldest and farthest north. He stated that "only the moraines of the Chapleau I belt appear to have been overridden, and only the moraines of the Chapleau II belt appear to have been modified by lake action". However, Boissonneau's Chapleau II belt more likely represents the oldest pre-Cochrane recessional moraine consisting of till that is non-calcareous. Omars along the western part of this morainal belt are inferred to have been introduced during a minor re-advance of a younger rather than an older ice front, and the till of this late advance is calcareous. For additional information on these moraines and others throughout Northern Ontario, see Sado and Carswell (1987).

Highway #560 has not been checked for omars east from Westree through to the Québec border. This route intersects several morainal knobs and outwash deposits (Veillette *et al.*, 1991;G.S.C. Map 1253A), and appears to closely correspond to the continuation of the mapped Chapleau II belt. It may link up with the Roulier Moraine in Québec, which continues eastward for 70 km, and is both non-calcareous and devoid of omars (J. Veillette, pers. comm.,1998).

From the western end of the Chapleau Moraine, the trace of the "omar limit" is speculative. No drift exposures were seen along Hwy. #17 north and west to the junction with Hwy. #614, nor were omars seen in drift sections northward as far as Manitouwadge. From there northward to Hwy. #11 and west to the Geraldton area, and north to the Nakina Moraine, omars are relatively common (Thorleifson and Kristjansson, 1993b). Southwest from Geraldton to Nipigon and Thunder Bay, they are sparse. Thus, a gently curving line north of Lake Superior and Hwy. #17 may be tentatively regarded as denoting the probable southern omar limit in this southeastern part of Northern Ontario.

West from the city of Thunder Bay, the southern omar limit again appears to approximately follow Hwy. #17, which adheres closely to the trend of major outwash and morainal deposits of the Hartman and Lac Seul moraine systems. In spite of a sysematic search by one of us (VKP), omars and kipalus were observed only at the northwest end of Lac Seul and at one site southwest of Red Lake; thus, the omar limit likely is close to this region, rather than farther south as earlier hypothesized on the basis of sparse omar occurrences at Dryden and Kenora (see Prest, 1990, Fig. 27). In either case, the southern omar limit would not extend beyond the Ontario/Manitoba border, because of the southeastward flow of Keewatin Sector ice (see GSC Map 1253A).

Prest and Sado (unpublished field notes) examined drift exposures south from Dryden for about 50 km along Hwy.# 502, without finding a single omar or kipalu. The apparent lack of omars in this part of Northern Ontario suggests that the omar limit swings northward toward the Red Lake area, rather than as previously shown by Prest (1990, Fig. 29). An omar cobble found by E. Nielsen near Kenora may relate to an older advance of Labrador Sector ice in southeastern Manitoba.

Before leaving the matter of omar dispersal in Northern Ontario, mention must be made here of omars noted in southern Ontario by E. Sado. He first observed (pers. comm. 1981) a large wacke boulder, which bears a municipal plaque detailing the history of sand and gravel extraction, in Leamington, in an area of abandoned pits northwest of Leamington (north of Point Pelee). Although this boulder does not display distinct spherical concretions, it does contain calcareous streaks and blotches. In 1984, Neilsen and Prest accompanied Sado to see this boulder, and they agreed that it might be an omar. Just north of Leamington, they observed a concretion-bearing boulder about 1m in diameter, which they assessed to be a typical omar. Several smaller omars were seen in a nearby rock garden. E. Sado (pers. comm., 1986) subsequently observed omars in two areas northeast of Sarnia, some 500 km south of the presumed southern limit of omars in Northern Ontario. In addition, an omar was observed recently near Amherstberg, south of Windsor (T. Morris, Ontario Geological Survey, pers. comm., 1997). All of these omars probably were deposited by the Late Wisconsinan Huron ice lobe.

MANITOBA AND DISTRICT OF KEEWATIN

Evidence for the westward transportation of Belcher Group erratics, including omars, was expanded into Manitoba by E. Nielsen during his surficial geology studies for the Manitoba Department of Mines from 1980 to 1984. He first identified concretion-bearing greywacke and oolitic jasper from several sites on the Churchill, Nelson and Hayes rivers in northeastern Manitoba (thus confirming Robert Bell's observations), and later in the west-central, southwestern, and Interlake parts of the province (see Fig. 4). To quantify the spatial occurrences in Manitoba, Nielsen made stone counts on the 4 to 16 mm size fractions from some 100 sites, differentiating Archean rocks, Proterozoic wacke, and Paleozoic carbonates. In northern Manitoba the stone counts were on 300 clasts, and elsewhere were commonly on over 100 (Nielsen, pers. comm., 1982, 1988). Near Gillam, on the railway to Churchill and close to the western limit of the Paleozoic belt and some 900 km from the Belcher Islands, Proterozoic greywacke ranged from 4 to 24 % and carbonate from 60 to 80 % of the total sample, whereas Archean rocks averaged only 21 % (Fig. 4). To the west and southwest of Gillam, the concentration of greywacke erratics diminishes rapidly. Thus, in the Thomson area, some 200 km southwest of Gillam, Proterozoic greywacke ranged from only 1 to 3 %, and carbonate from 10 to 60 % of the sample. These different values reflect the positions of the sample sites relative to the interplay of Labrador *versus* Keewatin ice flow (see Surficial Geology Map of Manitoba, Map 81-1 for details, and Glacial Map of Canada, 1253A for the broad-scale relationships). In the Interlake region, the high carbonate content reflects proximity to the Manitoba Paleozoic limestone belt. The overall results are summarized in Figure 4. Note that the sample sites in southwestern Manitoba lie within the region of dominant Keewatin ice flow where the greywacke erratics, including omars, have been redistributed.

	Proterozoic wacke	total Archean	Phanerozoic carbonate
Gillam	4 - 24 %	21 %	60-80 %
Thompson	1 - 3 %	65 %	10 - 60 %
northern interlake	1 %	12 %	87 %*
central interlake	< 1 %	15 %	85 %*
southern interlake	1 %	17 %	82 %*
Belair	1 %	32 %	67 %
South Riding Mountain	2 %	37 %	61 %
Turtle Mountain	2 %	38 %	60 %

* abundance influenced by contributions from underlying Manitoba Limestone

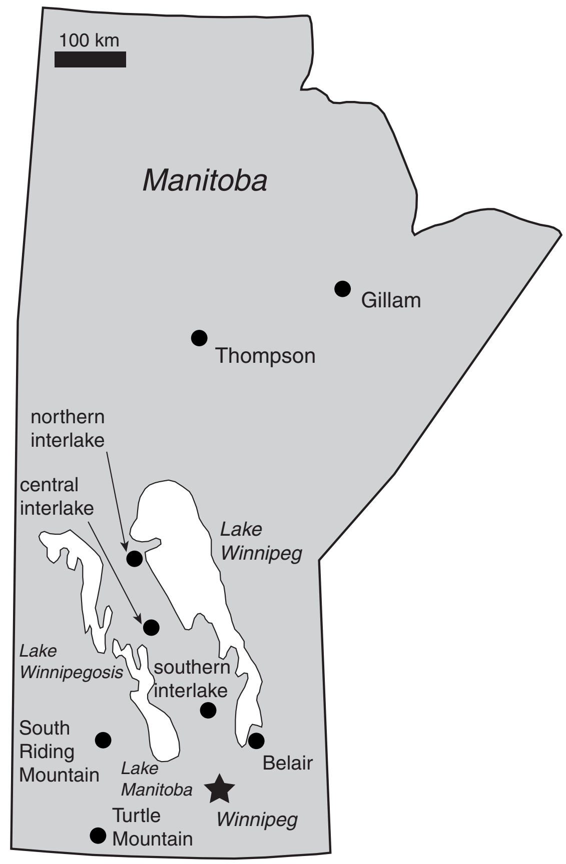

FIGURE 4. Relative abundances of clasts in Manitoba tills, keyed to site locations that are shown on accompanying outline map of the province. Based on data provided by E. Nielsen (pers. comm. to V.K.P., 1984, 1998).

Abondance relative des fragments dans les tills du Manitoba, en association avec la localisation des sites apparaissant sur la carte d'accompagnement. Carte établie à partir de données fournies par E. Neilsen (communication personnelle, 1984).

In northeastern Manitoba, though omars are not specifically mentioned in many surficial geology reports, there is much pertinent information on the composition of the surficial deposits (Klassen, 1983; Dredge *et al.*, 1986; Dredge, 1988; Kaszycki and DiLabio, 1986). No omars were observed north of the lower reaches of the Seal River, which enters Hudson Bay some 50 km northwest of Churchill. Kaszycki's regional studies (including several Geological Survey of Canada Open File Reports) confirm and expand on the observations of Nielsen, and establish a western limit to both omar and carbonate dispersal. The Labrador Sector ice apparently was constrained by the advancing Late Wisconsinan Keewatin Sector ice which occupied most of northwestern Manitoba. The interplay of Keewatin and Labrador Sector ice is marked by a series of major interlobate moraines extending from Seal River southward to the Thomson area, and beyond to a point (Latitude 54° 30' N; Longitude 99° 00' W) on the Canadian National Railway (see Manitoba Map 81-1). The known distribution of omars conforms well to this southward jog, but from this location, the omar sitings extend westward across Saskatchewan, roughly along Latitude 55° (see Fig. 2), and on into Alberta, probably also constrained on the north by the Keewatin ice lobe.

Omars and concretion-free greywacke clasts in northeastern Manitoba were clearly derived from the Omarolluk Formation of the Belcher Group, and were dispersed by Labrador Sector ice. In northwestern Manitoba, however, Keewatin Sector ice prevented incursion of the eastern ice, and thus inhibited dispersion of omars into northwestern Manitoba and the District of Keewatin (now Nunavut). A brief outline of events in the former district of Keewatin is warranted here as part of the omar story. Shilts and his co-workers reported on the extent and duration of the Keewatin Sector ice flow during the Wisconsinan glacial stage (Shilts *et al.*, 1979; Shilts, 1980, 1982). Whereas the Keewatin Ice Divide (Lee, 1959) is regarded as a Late Wisconsinan retreatal dome from which ice flowed eastward into Hudson Bay only during break-up of the continental ice, Shilts showed that the main eastward flow was from a dome well to the west of the Keewatin Ice Divide. This dome is now referred to as the ancestral Keewatin Ice Divide (Dyke and Prest, 1987). This flow was of long duration, and so Keewatin drift was dispersed far offshore in Hudson Bay. Aylsworth and Shilts (1991) have shown that, whereas wacke erratics transported by Keewatin Sector ice are prevalent on Coats Island, the Belcher Group erratics transported by Labrador Sector ice predominate on Mansel Island (see Fig. 2).

SASKATCHEWAN-ALBERTA

Nielsen and Prest, with the support of B. Schreiner (Director of Environment Branch, Saskatchewan Research Council), extended the search for omars into central Saskatchewan and briefly into the Lloydminster-Edmonton-Athabasca region of Alberta. The northern limit of omars, redistributed by the Plains ice of the Keewatin Sector, may be at Lac LaBiche, Alberta (Latitude 54° 45' N; Longitude 111° 57' W). However, the preponderance of omar sitings in Saskatchewan (see Fig. 2), is the result of detailed investigations over many years by W.G.Q. Johnston (Research Geologist, Regina, supported by the Saskatchewan Research Council). Johnston has mapped the distribution of numerous distinctive glacial erratics throughout the central and southern parts of the Province, documenting the occurrence of pebble- to boulder-size clasts of Proterozoic greywacke, including omars on the surface of the till, and in stone piles created during the clearing of fields (W.G.Q. Johnston, pers. comm.,1989, 1996). The erratics were dispersed southward by the Late Wisconsinan Plains ice lobe. Johnston also noted the occurrence of omars in an older till, presumably deposited by earlier, unrestricted, west or southwest ice flow. H. Thorleifson (pers. comm., 1991) collected a striated omar boulder from a borrow pit on the east side of the City of Saskatoon. This omar was part of a striated boulder pavement at the lower contact of the Late Wisconsinan Battleford Till. Several omars were observed by Niesen and Prest within the Saskatoon city limits, but west of there, as far as Lloydminister, omar sitings were sparse.

In southern Alberta, omars and oolitic jasper were first reported by archaeologist E. Grypa, who relayed his findings to E. Nielsen, having earlier worked with Nielsen in Manitoba (E. Nielsen, pers. comm., 1982). Nielsen also noted omars in soil samples (collected by I. Shetsen) from south-central Alberta, and during a field excursion in 1989 he (E. Nielsen, pers. comm., 1984) found an omar cobble at the Kipp Section on the Old Man River west of Lethbridge. Assuming an overall west and southwest flow of Labrador Sector ice from Hudson Bay, followed by southeastward flow of Keewatin/Plains Sector Ice, this cobble must have travelled a minimum of 2400 km from its source. An omar boulder was also found several years earlier at the Golden Valley Bluff on the South Saskatchewan River near Medicine Hat (by the late D. Proudfoot, then with Alberta Research Council). This boulder has since been forwarded to the Geological Survey of Canada, and confirmed by one of us (J.A.D.) to display the sedimentary features and petrographic characteristics of the Omarolluk Formation. An excellent example of geological reasoning has been recently demonstrated by Frank McDougall, a Saskatchewan farmer who, unaware of earlier publications on omars, published a discussion of greywacke field stones "that contain perfectly round holes that occur on the outside surface". He correctly interpreted the holes to be weathered concretions, and recognized the potential of such clasts for tracking glacial transport back to their source (McDougall, 1999).

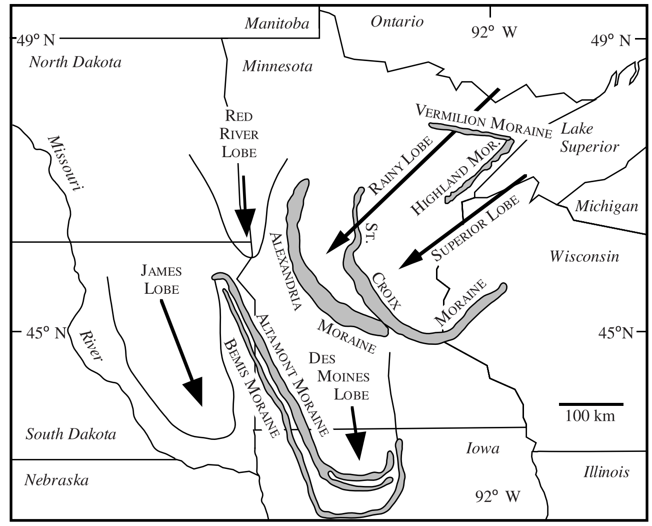

FIGURE 5. Generalized surficial geology and Pleistocene ice-flow trends in Minnesota and parts of adjacent states.

Aperçu de la géologie des formations de surface et des axes d'écoulement glaciaire pléistocène, au Minnesota et dans certaines parties des états voisins.

NORTHERN UNITED STATES

Omars have been noted in at least eight States, but they are sparse except in North Dakota, eastern South Dakota and Minnesota (Fig. 5). Their distribution supports and expands on the earlier observations of concretionary greywacke by Upham (1896). After Upham's initial report, there was little interest in omar distribution in the United States until the mid-1980s, when J.D. Lehr (Minnesota Department of Natural Resources) visited E. Nielsen in Manitoba and perceived the importance of omar distribution in assigning provenance to glacial deposits in Canada. Lehr subsequently began to systematically record and collect concretionary greywacke clasts in Minnesota. This program was subsequently expanded by other workers, including H.D. Mooers and P. Larson of the University of Minnesota at Duluth and J.P. Gilbertson of the South Dakota Geological Survey (now with the East Dakota Water Development District, Brookings, South Dakota). Numerous observations of concretionary greywacke clasts have also been made by H.C. Hobbs, C.J. Patterson and G.N. Meyer of the Minnesota Geological Survey. In addition, Bob Biek (1994) published a short paper on his observations in North Dakota.

Concretionary greywacke clasts have been found in deposits of the Des Moines, James River and Red River lobes of the Keewatin (Plains) Sector ice, and in the Rainy and Superior lobes of the Labrador Sector ice (Fig. 4). Such clasts are relatively common in calcareous deposits of the Rainy lobe in central Minnesota, but decrease in abundance to the northeast, and clasts of both concretionary greywacke and carbonate appear to be absent throughout northeastern Minnesota (and the adjoining parts of Ontario, as previously discussed).

In Minnesota, the Late Wisconsinan episode of glaciation can be subdivided into three major advances that deposited distinctive sedimentary associations (Mooers and Lehr, 1997). The earliest advance of Labrador Sector ice was the Hewitt phase of the Rainy lobe, which terminated at the Alexandria moraine (Fig. 5) *ca*. 23-21 K ^{14}C years BP. Ice-transported sediments associated with the Hewitt phase occur throughout west-central Minnesota, and contain an abundance of both Paleozoic carbonate and omars; however, a quantitative assessment of their relative abundance is lacking.

The next major advance, the St. Croix phase of the Rainy and Superior lobes (Wright and Ruhe, 1965), culminated *ca*. 16-15.5 K ^{14}C years BP (Clayton and Moran, 1982; Mooers and Lehr, 1997), and is marked by the St. Croix Moraine in central Minnesota (Fig. 5). The drift of this moraine is strikingly different from that deposited during the preceding Hewitt phase, even though regional flow directions were similar. Limestone erratics, abundant in the deposits of the Hewitt phase, are rare in the St. Croix-phase deposits, although associated tills throughout the region commonly contain a few percent $CaCO_3$ in the matrix (Mooers, 1988; Gowan, 1993). Omar erratics are less abundant in the sediments of the St. Croix phase, but where seen, their calcareous concretions are deeply pitted or completely removed due to weathering. When the ice retreated eastward from the moraine, the resulting recessional deposits were devoid of both carbonate and omars. The next prominent moraine system is the Vermilion-Highland Moraine (Wright and Ruhe, 1965; Mooers and Lehr, 1997). Drift of the Rainy lobe deposited during this phase is also free of both omars and carbonate.

Numerous geologists contributed to the plot of the omar sites within the United States (Fig. 2). A copy of the Quaternary Geology Map of Minnesota (State Map Series S1) showing the locations of numerous omar sitings was provided by J. D. Lehr (pers. comm., 1998). Each omar siting is lettered according to the character of the associated Late Wisconsinan tills (Wadena, Rainy, Superior and Des Moines/Red River ice lobes). The omar sitings of H.C. Hobbs in Rice and Fillmore Counties (pers. comm.,1998) have also been added to Figure 2; these are north and southeast respectively of Steele County, where Upham (1896) obtained his southernmost siting of greywacke clasts, some 120 km (70 miles) southeast of St. Paul. J.P. Gilbertson (pers. comm., 1996) forwarded information on omar occurrences and glacial trends in South Dakota. He also provided spot occurrences of omars from Wisconsin, Minnesota, Michigan, Ohio and Iowa. In 1986, Thorleifson and Prest found omar pebbles and oolitic jasper granules in the Farm Creek stream bed near Peoria, Illinois (Amqua Field Stop 4: Follmer *et al*., 1986)

In October 1989, Carrie Patterson collected a probable omar, with a weathered-out concretion, from a site about eight miles southeast of the town of Jasper in the southwestern corner of Minnesota, in an area of pre-Wisconsinian drift (*i.e.* beyond the Bemis and Altamont moraines of the Des Moines lobe); this specimen was sent to E. Nielsen, who confirmed that it was indeed an omar. Previously, the source of similar erratics widely dispersed in Late Wisconsinan deposits in the Dakotas and Minnesota had been the subject of lively debate on several field trips. A Belcher Islands source was generally accepted after the publication by Prest (1990), although other sources are still being considered.

Some surficial geologists have questioned long-distance transport of omars, favouring more local sources. Because of this, a source other than the Omarolluk Formation of Hudson Bay must be considered (Meyer *et al*., 1998; Mooers and Lehr, 1997). Strata of several Proterozoic formations of the Animikie Series in northeastern Minnesota contain greywacke, and the Thomson Formation, in particular, locally contains calcareous concretions (Morey and Ojakangas, 1970; Lucente and Morey, 1983). These rocks may have provided omar-like clasts for down-ice transport, thus casting doubt on some omar occurrences in central Minnesota. However, a Thomson source cannot account for omar sites elsewhere in Minnesota and the Dakotas. Furthermore, most of the Animikie Series rocks are deeply buried by pre-Late Wisconsinan glacial sediment. Moreover, studies of the lithology of the Hewitt Till of the Rainy lobe show a paucity of Animikie clasts (Meyer, 1986). In addition, petrographic and geochemical criteria can provide a reliable basis for distinguishing true omars (see subsequent section on Criteria for Recognition of Omars).

QUÉBEC

The omar story would not be complete without mention of the concretion-bearing greywacke erratics at the south end of James Bay and along its east coast (Bell, 1879a). As earlier mentioned, Bell determined the source area to be in southeastern Hudson Bay, and referred to bedrock outcrops on Long Island (north end of James Bay, within the Proterozoic basin). Although the Omarolluk formation is not presently known to crop out on Long Island, the Belcher Islands and their off-shore environs are clearly the source area for both omars and kipalus. These were transported southward in James Bay and then southeast in Québec by the Cochrane surges (Hardy, 1976; Vincent and Hardy, 1979). The ice-flow features are clearly shown on G.S.C. Map 1253A, but the limit of the Cochrane Till has since been more precisely defined by Veillette *et al*. (1991), who reported that omars are dispersed over the Cochrane Till region, as well as in patches of clayey till resting on the surface, beyond the Cochrane Till limit. These omar-bearing till patches were formed by the melting of frozen till clasts that were ice rafted and released through the water column as dropstones. Such patches of ice-rafted till occur as far as 200 km east of the Cochrane limit within glacial Lake Ojibway in the northern part of the District of Abitibi (Veillette *et al*., 1991). Deglacial activity responsible for dispersal of wacke clasts in the James Bay region is discussed in detail in a well-illustrated report by Veillette (1997). In the northern part of the Québec Cochrane Till region, omars were also noted by J. Richard (pers. comm., 1984), both on the surface and in drill samples through the drift mantle, and into the pre-Cochrane Matheson Till.

J.-C. Dionne (Département de géographie and Centre d'études nordiques, Université Laval; pers. comm.,1986) was the first to observe omars in marine beach deposits east of Hudson Bay. Because there were no glacial advances eastward from the Belcher Islands, these omars must have been ice rafted. Since that time, many omars have been observed in both the marine and older lacustrine beaches east of James Bay (J. Veillette, pers. comm., 1999). Because of a late flow of ice from the Belcher Islands northward toward Hudson Strait, omars should also be present on the Ottawa Islands, but are as yet unreported. They are, however, abundant farther north on Mansel Island, and a few were noted on the east coast of Coats Island (but not elsewhere on that island due to the strong outflow of Keewatin Sector ice: W. Shilts, pers. comm., 1986; Aylsworth and Shilts, 1991). Labrador Sector ice passing over Mansel Island must have advanced beyond Hudson Bay, because D. Bruneau (Département de géographie, Université de Montréal; pers. comm., 1991) collected a typical omar cobble from a frost boil on Charles Island in Hudson Strait (northeast corner of Fig. 2). The calcareous concretions in this cobble are partly weathered-out, perhaps reflecting derivation from an older till. Prof. Bruneau reported that this was the only omar seen in three summers of field work on and near Ungava Peninsula.

CRITERIA FOR RECOGNITION OF OMARS

Because siliceous wackes bearing calcareous concretions occur elsewhere in the Canadian Shield, caution is warranted in mapping the distribution of omars. However, a number of distinctive features serve to provide reliable criteria for distinguishing true omars (*i.e.* clasts derived from the Omarolluk Formation of Hudson Bay) from other concretionary wackes. We here summarize the criteria for recognizing tillstones derived from the Omarolluk Formation.

The Omarolluk Formation is a succession of thick-bedded, massive, fine-grained silica-cemented lithic wackes. The wackes form the basal parts of turbidite beds in which calcareous concretions are extremely abundant, and so derived clasts of even pebble size commonly display one or more concretions, most of which are subspherical and weather recessively. Rip-up clasts of black mudstone less than 1 cm are common in the Omarolluk wackes, and most are elongate and well rounded. Also characteristic of the Omarolluk are subtle, wispy dewatering structures, best seen on slabbed surfaces. The Omarolluk wackes have undergone only slight metamorphism (prehnite-pumpellyite to lower greenschist facies), and do not show evidence of significant penetrative deformation.

In thin section, the Omarolluk wacke is seen to contain abundant angular grains of monocrystalline quartz and plagioclase, minor K-spar, volcanic rock fragments (some basaltic grains show quench textures), clastic grains of biotite, muscovite and chlorite, and detrital grains of magnetite, ilmenite, sphene, zircon, tourmaline, epidote and apatite. Warping of the clastic micaceous flakes around framework grains is common. Angular fragments of quartz and chert, in association with well-rounded detrital carbonate grains, provide a characteristic signature. In contrast, clasts derived from virtually all Archean wackes can be recognized in thin section by the generally higher degree of metamorphism, strong penetrative deformation fabrics, and the secondary alignment of micas and chlorite along cleavages.

Among Proterozoic wackes, the "best" Omarolluk simulators are the rocks of the Animikie Series and the Chelmsford Formation, both mentioned previously as possible sources of omar-like clasts. Although these units show more features in common with the Omarolluk Formation than do Archean wackes, a number of features can be used to differentiate them with considerable reliability. Calcareous concretions in the Chelmsford Formation are generally large (> 5 cm) and ovoid, whereas the concretions in the Omarolluk are generally near-spherical and small (< 5 cm). Calcareous concretions in the Animikie Series are also lenticular or ellipsoidal, and many are rimmed by cone-in-cone structures; they are most common in argillites, less common in siltstones, and almost absent in wackes (Lucente and Morey, 1983; R.J. Ojakangas, pers. comm., 1999). Some Omarolluk concretions show successive growth shells, and coalescence is typical. Many of the Omarolluk dewatering structures occur as millimetre-scale sheets normal to bedding; most pass through the concretions, but some are deflected around the concretions, demonstrating their pre-concretion to penecontemporaneous origin. Dewatering structures also occur in the Chelmsford Formation, but they commonly are tubular, have sharp margins, and show a more random pattern relative to bedding (some pollywog-shaped dewatering structures in the Chelmsford Formation were at one time mistaken for fossils).

In thin-section, samples of Chelmsford wackes appear superficially similar to Omarolluk wackes, by also containing abundant of volcanic rock fragments, angular monocrystalline quartz and lesser amounts of fresh to slightly altered plagioclase. Detrital heavy minerals are similar but less abundant. Samples of Chelmsford, unlike the Omarolluk, generally display faint cleavage and are somewhat carbonaceous. Those samples of the Thomson Formation seen in thin section differ from the finer-grained, better sorted, Chelmsford and Omarolluk samples in containing up to 15 % moderately rounded coarse-sand-sized polycrystalline quartz grains and a lower abundance (< 6 %) of plutonic rock fragments.

A more detailed petrographic and geochemical study of omars, focussing on criteria for distinguishing true omars from erratics derived from other bedrock sources of concretion-bearing wackes, is in progress (J.A.D. and H.D.M., with R.W. Ojakangas).

DISCUSSION AND CONCLUSIONS

In view of the large size of the region throughout which omars have been dispersed (Fig. 2), the possibility of other source areas must be evaluated. This concept has long been considered, but the evidence in support of other sources is scant. Furthermore, in view of the known trends of

Late Wisconsinan ice-flow features, together with widespread evidence of older northwestward- and westward-directed glacial striations, a single source area better accounts for the regional dispersal (*i.e.* early predominant northwestward to westward flow of ice from the Belcher Islands, followed by early and late southward dispersal). The common association of oolitic jasper erratics with the omars in Northern Ontario and in Manitoba provides strong supporting evidence for a Belcher Group source, because the jasper clasts are typical of those in the iron-formation beds of the constituent Kipalu Iron Formation. In addition, the very low grade of metamorphism (lower greenschist) and lack of penetrative deformation of the Proterozoic Omarolluk Formation serves to distinguish omars from wacke clasts derived from most Archean greenstone belts. Oolitic jasper clasts (kipalus) found in association with omars across Northern Ontario and Manitoba exhibit the same low-grade metamorphism and lack of penetrative deformation, which has allowed oolitic and granule textures to be perfectly preserved.

Low-grade Proterozoic-age siliciclastic wackes, however, do occur in Northern Ontario, such as in the Gowganda Formation of the Huronian Supergroup, Southern Province, and in the Chelmsford Formation of the Whitewater Group, Sudbury Basin. Both of these units, however, occur in what appear to be omar-free regions, and although the Chelmsford wacke contains some calcareous concretions, it does not appear to have contributed any omar-like clasts to the area immediately south of the Sudbury Basin. However, Chelmsford wacke clasts appear to have been carried southward by the Huron ice lobe, as witnessed by the large plaque-bearing boulder near Leamington.

As mentioned earlier, the omar-free region in eastern Northern Ontario extends west to include the Sudbury Basin and north from there, as seen on Hwy. #144, for some 90 km to the extension of the Chapleau Moraine (Boissonneau, 1966). Other north-south roads were also traversed between the Chapleau Moraine and Lake Huron. Eastward this omar-free zone extends to the Ontario-Québec boundary, in the vicinity of Earlton, which is “on-line” with a narrow end moraine in Québec (Veillette, 1996; see G.S.C. Map 1253A). Many roads remain to be examined along and north of Hwy. #560, to better establish the ‘omar-limit concept’ and to expand the omar coverage.

Note that the ice-frontal position of the Chapleau Moraine Complex mimics that of the Cochrane Surges (the Cochrane Till limit) some 150 km to the north, as shown on G.S.C. Map 1253A. Note also that these ice-frontal positions are lateral to the main northwestward and westward flow over the Belcher Islands, and thus they must account for substantial omar dispersal in Ontario and Québec.

The concept of an omar dispersal “limit” in Northern Ontario is difficult to reconcile with the previously mentioned observations by E. Sado of a few omars in southwestern Ontario, and with the widely scattered southerly sitings in Michigan, Ohio, and Illinois. Regarding the seeming gap in omar dispersal between the Chapleau Moraine in Northern Ontario and the sitings in southwestern Ontario, it is noteworthy that no omars were observed in the Lake Simcoe area nor on Bruce Peninsula in Georgian Bay, despite careful searching over several years by J. Easton (Dixon Hydrogeology Ltd.,Barrie, Ontario; pers. comm., 1997). Explanations involving slow basal ice flow on the one hand, and the more rapid peripheral growth on the other, have been suggested (Prest, 1990, p. 131).

In view of the large omar-free gap between the previously discussed southern omar limit in Northern Ontario and the few localities where omars have been observed at the western end of Lake Erie in southern Ontario, it has long been surmised that an older episode of ice flow carried omars from Hudson Bay before their final emplacement by the Late Wisconsinan Erie ice lobe. This two-fold event is not required if their emplacement was by the Late Wisconsinan Huron ice lobe (see GSC Maps 1253A and 1257A). Lake Huron is on line with southward ice flow from the Belcher Islands, as are exposures of the Chelmsford Formation. Thus, both Proterozoic basins could have supplied wacke clasts to areas south and east of Lake Huron.

Considering other Proterozoic source areas, the Thomson Formation in Minnesota consists in part of massive wacke that locally contains calcareous concretions similar to those characteristic of the Omarolluk Formation. As mentioned earlier, several American geologists familiar with the Thomson Formation are confident that they can differentiate between the Thomson and Omarolluk erratics as seen in Minnesota. Furthermore, given what is currently known about Late Wisconsinan glacier dispersal, clasts of concretionary wackes in northernmost Minnesota and in the Dakotas cannot have come from the Thomson Formation. Instead, dispersal of the concretionary wake clasts can be best attributed to southeast-flowing ice as mapped in adjacent parts of Manitoba and Saskatchewan. This southeastward ice flow across the Canadian Prairies (see G.S.C. Map 1253A), relates to the Plains lobe of the Keewatin Sector, with its Late Wisconsinan divide perhaps centred in northern Alberta (Dyke and Prest, 1987). But without a source to the north, how can the widespread dispersal of concretionary wackes in this region be explained? They must have been derived from the Omarolluk Formation, having been initially introduced by one or more older Labrador Sector ice sheets that flowed westward from the Belcher Islands, before full development of the Late Wisconsinan Keewatin/Plains ice complex which subsequently dispersed the omars southward. The omar erratics appear to thin out northward in Saskatchewan and Alberta, roughly along 55° latitude, and increase southward. Sparse isolated omars north of 55° latitude may be remnants of the earlier Labrador Sector glaciation, left behind rather than redirected southward by the Keewatin/Plains glacial movements.

Only in Saskatchewan have all the roads been adequately examined for omars. Much remains to be done elsewhere, and perhaps this presentation of the “omar story” will spur further investigations in all parts of the region discussed herein, and perhaps beyond.

ACKNOWLEDGEMENTS

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