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Glaciotectonic structures in Eastern and Arctic Canada

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Canada

CONTENTS

GLACIOTECTONIC STRUCTURES IN EASTERN AND ARCTIC CANADA

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GIS infomatics by A.M. Prégent

INTRODUCTION

Prior to the mid-1980s little attention was given by glacial geologists to faulting and deformation structures generated by continental and alpine glaciers. More recently, the identification and interpretation of glaciotectonic structures have become increasingly important to understanding the incorporation and transport of materials within ice sheets, the distribution of large bedrock rafts within till sheets, and the effect of mass loading by continental glaciers on the earth's crust.

This report is the first compilation of information on the nature and distribution of glaciotectonic structures in eastern and Arctic Canada. Its purpose is to provide a starting point for research on glacial deformation by summarizing extant regional information. The information herein is an integral part of the Glaciotectonic Inventory of North America and Europe, a mapping project of the Work Group on Glaciotectonics of the International Association for Quaternary Research (INQUA). Aber *et al.* (1993) have explained the origin and development of the project, and generated continental-scale GIS-linked maps showing glaciotectonic features, glacial landforms and ice limits, bedrock types, and topography. Their report provides a preliminary interpretation of the relationships between distributions of glaciotectonic features across North America, and glacial landforms, ice flow styles, and bedrock. The data that was necessary to establish these relationships for eastern and Arctic Canada is derived from this paper.

The work presented here consists of (1) a table of site data showing the location and types of glaciotectonic features, linked to references. This table was used in the North American Inventory. (2) GIS computer maps showing the distribution of basic categories of glaciotectonic features. These were generated using the linked site data. (3) an annotated bibliography describing the deformation structures at each site shown on the maps. (4) a conventional list of references cited according to author. Following a call for submissions printed in national and international journals, the inventory was assembled from written submissions from geologists reporting structures seen in the field, and from an extensive literature survey. Although some articles dealt directly with glaciotectonic issues, a number of the descriptions were in the form of inadvertent comments on glacial deformation, made while the authors were writing about other topics. I have attemped to place these observations into a relevent context in the annotated bibliography, but in some cases, the descriptions are still fragmentary. The following individuals directly contributed basic data used here: J. Andrews, W. Blake Jr., S. Dallimore, L. Dredge, A. Dreimanis, M. Durand, A. Dyke, P. Egginton, D. Evans, J. Fyles, D. Grant, S. Hicock, D. Hodgson, P. Karrow, R. A. Klassen, M. Parent, V. Prest, M. Rappol, R. Stea, D. St-Onge, J. Veillette, and J-S. Vincent. A. Prégent set up the data files which generated the maps used in this paper. M. Coyle and R. Knight assisted with initial manual plotting of the data.

On the maps shown in this report, glaciotectonic features are grouped into several categories, following the basic classifications of the INQUA Subcommission. They include structures generated primarily by lateral stresses exerted by moving warm-based and cold-based glaciers, and those generated by the vertical stress of glacier loading and unloading of the earth's crust. They give evidence for both brittle and plastic styles of deformation.

Those classed as surface forms (Δ) are deformation structures that have visible topographic expression. They commonly occur as ice thrust blocks and ridges, or as push moraines, ranging from dm to km in length. The ridges are constructed of preglacial and glacial sediments with some intercalated rock slices, or as upthrust slabs of consolidated bedrock.

Large buried features (*) have deformation structures 2-10 m in size. They have no surface expressions but are revealed in excavations or cliff faces. They include folds and faults in glacial and interglacial sediments, and in bedrock.

Small buried features (•) are <2 m in length or amplitude and include structures in natural exposures and roadcuts. The most commonly observed structures are folds, faults, diapirs and brecciated zones in glacial and glaciofluvial sediments, but glacially induced slips along cleavages, and bent or fractured bedrock are also present in slate and sandstone rock. Although individual features are small, groups of features may cover large areas.

The thrust rock (+) symbol refers to large and small buried features consisting mainly of laterally transported slabs of coherent bedrock. The most notable are the thrust limestone slabs underlying parts of Montréal.

Basement faults (▪) are vertical offsets in the bedrock, common in slate and shale. At most sites the cumulative throw is less than 2 m, and offsets commonly appear as parallel sets of faults, each with a movement of mm to cm. Where there has been more movement (dm), the faulting commonly occurs as a reactivation of older faults, or coincides with seismically active zones. Most glaciotectonic structures of this type are believed to be generated by vertical stress release during glacier loading and unloading. Some of the reported basement faults are elongated pop-up structures; these have been included in this bibliography as potential glaciotectonic features, although it is possible that they are related to regional seismic or tectonic stress relief. In a number of cases, particularly those in Ontario, the genesis of these features has been ascribed to different mechanisms by different authors, or by one author at different times.

TABLE 1 SITE DATA

Site	Latitude (°N)	Longitude (° W)	Code	Author reference
YT01	69.60	139.07	Δ	Mackay, 1959; Rampton, 1982
YT02	69.34	138.70	Δ	Mackay, 1959; Rampton, 1982
YT03	69.19	138.23	Δ	Mackay, 1959; Rampton, 1982
NT01	69.50	135.28	Δ	Mackay and Stager, 1966; Rampton, 1982
NT02	69.49	135.71	Δ	Mackay and Stager, 1966
NT03	69.70	134.86	Δ	Mackay, 1971
NT04	69.79	134.35	Δ	Dallimore and Egginton, unpub.
NT05	69.61	134.31	•	Dallimore and Egginton, unpub.
NT06	69.58	133.89	•	Dallimore and Egginton, unpub.
NT07	69.45	133.00	•	Rampton and Mackay, 1971
NT08	69.92	129.01	Δ	Mackay, 1956
NT09	68.35	119.39	Δ	St-Onge and McMartin, 1987
NT10	73.56	115.42	Δ	Vincent, 1983
NT11	73.50	122.80	Δ	Vincent, 1983
NT12	73.11	119.68	Δ	Vincent, 1983
NT13	71.89	123.84	Δ	Vincent, 1983
NT14	72.26	125.65	*	Vincent, 1983
NT15	71.96	125.68	+	Vincent, 1983
NT16	73.33	116.01	•	Vincent, 1983
NT17	73.50	104.61	Δ	Hodgson, unpub
NT18	77.01	118.92	■	Fyles, unpub. Hodgson et al., 1993
NT19	77.97	114.09	Δ	Fyles, 1965
NT20	77.25	105.31	Δ	Hodgson, unpub.
NT21	79.02	104.38	Δ	Fyles, unpub.
NT22	79.42	90.58	Δ	Robitaille and Greffard, 1962; Kalin, 1971
NT23	79.49	91.67	Δ	Kalin, 1971
NT24	80.43	93.68	Δ	Kalin, 1971
NT25	80.15	94.14	Δ	Kalin, 1971
NT26	80.12	94.37	Δ	Kalin, 1971
NT27	79.97	94.26	Δ	Kalin, 1971
NT28	79.79	93.82	Δ	Kalin, 1971
NY29	79.52	93.25	Δ	Kalin, 1971
NT30	79.51	92.81	Δ	Kalin, 1971
NT31	79.47	94.29	Δ	Kalin, 1971
NT32	79.41	91.12	Δ	Kalin, 1971
NT33	78.85	92.92	Δ	Kalin, 1971
NT34	78.54	91.59	Δ	Kalin, 1971
NT35	78.41	90.87	Δ	Kalin, 1971
NT36	78.38	90.44	Δ	Kalin, 1971
NT37	78.45	89.97	Δ	Kalin, 1971
NT38	78.63	90.06	Δ	Kalin, 1971
NT39	78.96	90.10	Δ	Kalin, 1971

TABLE 1 SITE DATA

Site	Latitude (°N)	Longitude (° W)	Code	Author reference
NT40	78.59	88.05	Δ	Kalin, 1971
NT41	79.00	88.38	Δ	Kalin, 1971
NT42	79.25	89.68	Δ	Kalin, 1971
NT43	81.84	86.87	Δ	Evans, 1989
NT44	81.92	86.31	Δ	Evans, 1989
NT45	82.01	84.38	Δ	Evans, 1989
NT46	82.24	85.59	Δ	Evans, 1989
NT47	80.88	83.01	Δ	King, 1983; Hodgson, unpub.
NT48	78.63	74.86	Δ	Blake, unpub.
NT49	78.11	75.95	Δ	Blake, unpub.
NT50	77.03	86.24	Δ	Souchez, 1971
NT51	82.62	69.30	Δ	Kalin, 1971
NT52	82.67	78.30	Δ	Kalin, 1971
NT53	81.94	80.09	Δ	Kalin, 1971
NT54	82.11	83.05	Δ	Kalin, 1971
NT55	82.08	83.28	Δ	Kalin, 1971
NT56	82.05	83.27	Δ	Kalin, 1971
NT57	81.19	81.95	Δ	Kalin, 1971
NT58	81.27	80.45	Δ	Kalin, 1971
NT59	81.27	80.29	Δ	Kalin, 1971
NT60	80.99	85.13	Δ	Kalin, 1971
NT61	81.16	79.45	Δ	Kalin, 1971
NT62	81.01	75.02	Δ	Kalin, 1971
NT63	79.72	78.83	Δ	Kalin, 1971
NT64	79.82	75.39	Δ	Kalin, 1971
NT65	73.47	100.19	Δ	Dyke et al., 1992
NT66	73.54	99.15	Δ	Dyke et al., 1992
NT67	71.21	95.51	•	Dyke and Matthews, 1991
NT68	68.16	85.72	•	Dredge, 1990
NT69	73.47	80.60	Δ	Klassen, 1982
NT70	73.21	79.73	Δ	Klassen, 1982
NT71	73.08	79.34	Δ	Klassen, 1982
NT72	73.00	79.23	Δ	Klassen, 1982
NT73	73.56	78.57	Δ	Klassen, 1982
NT74	73.52	78.49	Δ	Klassen, 1982
NT75	70.26	75.26	•	Terasmae et al., 1966
NT76	71.15	71.42	•	Andrews, unpub.
NT77	69.53	69.55	•	Andrews, unpub.
NT78	69.60	113.57	Δ	Sharpe, 1988
NT79	71.67	96.84	■	Dyke et al., 1991
NT80	69.69	83.24	■	Dredge, in press

TABLE 1 SITE DATA

Site	Latitude (°N)	Longitude (° W)	Code	Author reference
NT81	64.28	81.76	■	Basham et al., 1977; Adams and Basham, 1989; Dredge, 1991
NT82	72.41	96.02	■	Basham et al., 1977; Adams and Basham, 1989; Dyke et al., 1991
NL01	52.91	66.94	•	Gosse, 1989
NL02	47.64	59.26	■	Grant, unpub.
NL03	46.76	53.61	•	Eyles and Slatt, 1977
NS01	47.20	60.15	■	Neale, 1964
NS02	47.00	60.42	■	Neale, 1964; Grant, 1990
NS03	46.89	60.49	■	Neale, 1963a, Grant, 1990
NS04	46.94	60.68	■	Neale, 1963b
NS05	45.58	61.59	■	Stea, unpub.
NS06	45.33	62.57	■	Stea, unpub.
NS07	45.08	61.86	*	Stea and Brown, 1989
NS08	45.27	62.41	■	Goldthwait, 1924
NS09	44.65	63.59	■	Goldthwait, 1924
NS10	44.85	63.36	•	Morner, 1973
NS11	45.12	63.72	■	Prest, unpub.
NS12	45.08	64.49	+	Grant, unpub.
NS13	44.41	65.26	■	Goldthwait, 1924
NS14	43.97	66.16	+	Dredge and Grant, 1987: Grant, 1987
NS15	43.91	66.17	•	Dredge and Grant, 1987; Grant, 1987
NS16	44.08	66.18	•	Dredge and Grant, 1987; Grant, 1987
NS17	44.05	66.15	*	Grant, 1987
NS18	44.03	66.17	■	Grant, 1980; Dredge and Grant, 1987
PE01	46.13	62.91	•	Prest, unpub.
NB01	45.61	65.04	■	Seaman, unpub
NB02	45.28	66.06	■	Matthew, 1984, Broster and Burke, 1990
NB03	45.91	66.24	■	Fyffe, 1983
NB04	45.94	66.91	■	Adams, 1981
NB05	46.96	66.83	+	Fyffe and Pronk, 1985
NB06	47.17	67.93	•	Rappol, 1989
NB07	47.27	68.27	•	Rappol, 1986
NB08	47.38	68.37	■	Dredge, unpub.
NB09	47.43	68.38	■	Rappol, unpub.
NB10	45.87	67.37	•	Broster and Seaman, 1991
NB11	46.64	66.79	■	
QU01	47.61	61.51	•	Dredge and Grant, 1987; Parent, unpub.
QU02	47.57	61.49	•	Dredge and Grant, 1987; Parent, unpub.
QU03	47.53	61.71	•	Dredge and Grant, 1987; Parent, unpub.
QU04	47.42	61.77	+	Dredge and Grant, 1987; Parent, unpub.
QU05	47.40	61.78	+	Dredge and Grant, 1987; Parent, unpub.
QU06	47.41	61.88	+	Dredge and Grant, 1987

TABLE 1 SITE DATA

Site	Latitude (°N)	Longitude (° W)	Code	Author reference
QU07	47.22	61.98	•	Dredge and Grant, 1987
QU08	47.24	61.90	*	Dredge and Grant, 1987
QU09	47.24	61.96	Δ	Dredge and Grant, 1987
QU10	49.10	65.98	+	Veillette, unpub.
QU11	47.50	68.79	+	Rappol, unpub.
QU12	47.79	69.51	•	Lee, 1963; Rappol, in press
QU13	47.85	69.39	•	Lee, 1963; Rappol, in press
QU14	47.91	69.44	•	Lee, 1963; Rappol, in press
QU15	47.77	69.48	•	Lee, 1963; Rappol, in press
QU16	46.74	71.70	+	Schroeder et al., 1990
QU17	46.52	70.93	■	Chalmers, 1897
QU18	46.20	70.70	■	Chalmers, 1897
QU19	46.10	70.61	■	Chalmers, 1897
QU20	45.81	70.41	■	Chalmers, 1897
QU21	45.99	70.79	■	Oliver et al., 1970
QU22	45.94	70.96	■	Chalmers, 1897
QU23	45.80	71.08	■	Oliver et al, 1970
QU24	45.56	71.21	■	Chalmers, 1897
QU25	45.55	71.29	■	Oliver et al., 1970
QU26	45.51	71.83	■	Chalmers, 1897
QU27	45.66	72.14	■	Chalmers, 1897
QU28	45.45	72.03	■	Oliver et al., 1970
QU29	45.32	72.28	■	Chalmers, 1897
QU30	46.44	72.77	•	Occhietti, 1977
QU31	46.66	72.15	Δ	Occhietti, 1977
QU32	46.44	72.92	•	Occhietti, 1977
QU33	46.43	72.59	Δ	Parent and Occhietti, 1988
QU34	45.62	73.59	+	Grice, 1972; Durand and Ballivy, 1974; Ballivy et al., 1977; Schroeder et al, 1986; Prichonnet et al., 1987
QU35	45.59	73.56	+	Grice, 1972; Durand and Ballivy, 1974; Ballivy et al., 1977; Schroeder et al, 1986; Prichonnet et al., 1987
QU36	45.46	73.83	+	Grice, 1972; Durand and Ballivy, 1974; Ballivy et al., 1977; Prichonnet et al., 1987.
QU37	45.51	73.64	+	Schroeder et al., 1986
QU38	45.45	73.67	•	Stansfield, unpub; Schroeder et al., 1986
QU39	45.55	73.59	+	Schroeder et al., 1986
QU40	49.76	77.64	•	Veillette, unpub.
QU41	55.28	77.75	■	Morner, unpub.
MA01	58.57	95.75	•	Dredge and Nixon, 1992
MA02	50.46	97.60	Δ	Dredge and Cowan, 1989; Woodsworth-Lynas, 1990

TABLE 1 SITE DATA

Site	Latitude (°N)	Longitude (° W)	Code	Author reference
MA03	55.50	94.06	Δ	Dredge and Cowan, 1989
ON01	48.73	92.09	■	Oliver et al., 1970
ON02	48.73	91.98	■	Lawson, 1911
ON03	48.82	91.66	•	Leggett and Bartley, 1953
ON04	48.63	90.07	■	Oliver et al., 1970
ON05	49.62	87.96	■	Oliver et al., 1970
ON06	49.70	87.02	•	Hicock, 1987.
ON07	49.78	86.52	■	Oliver et al., 1970
ON08	48.73	85.83	•	Hicock, 1987
ON09	44.60	79.00	■	Liberty, 1969
ON10	44.29	76.04	■	Cushing et al., 1910
ON11	42.61	81.39	•	Dreimanis, unpub.; Dreimanis, 1958; 1982; 1987; Dreimanis and Packer, 1959; Dreimanis and Karrow, 1965; Hicock and Dreimanis, 1985; Dreimanis et al., 1987
ON12	42.73	81.41	•	Dreimanis and Karrow, 1965; Dreimanis, unpub.
ON13	42.67	81.23	•	Dreimanis and Karrow, 1965; Dreimanis, unpub.
ON14	43.15	81.34	•	Dreimanis, unpub.; Dreimanis and Packer, 1959; Dreimanis and Karrow, 1965
ON15	43.04	81.28	•	Dreimanis, unpub.; Dreimanis and Packer, 1959
ON16	43.02	81.28	•	Dreimanis, unpub.; Dreimanis and Packer, 1959
ON17	42.98	81.28	•	Lavrushin, 1976
ON18	42.95	81.29	•	Dreimanis, unpub.; Dreimanis and Packer, 1959
ON19	42.76	81.01	•	Dreimanis, unpub.
ON20	42.78	81.00	•	Dreimanis, 1958; 1982, 1987; Dreimanis and Packer, 1959; Dreimanis and Karrow, 1965; Dreimanis et al., 1987
ON21	42.76	81.03	•	Dreimanis, 1958; 1982; 1987; Dreimanis and Packer, 1959; Dreimanis and Karrow, 1965; Dreimanis et al., 1987
ON22	42.75	81.05	•	Barnett and Kelly, 1987
ON23	42.44	81.71	•	Dreimanis, unpub.
ON24	42.55	81.54	*	Dreimanis, unpub.
ON25	42.59	81.47	•	Dreimanis, unpub.
ON26	43.49	79.71	*	Wilson, 1902
ON27	43.52	79.66	■	Karrow, 1963, 1987
ON28	43.44	79.71	■	Karrow, 1963, 1987
ON29	43.44	79.71	■	Karrow, 1963, 1987
ON30	43.44	79.71	■	Karrow, 1963, 1987
ON31	43.44	79.71	■	Karrow, 1963, 1987

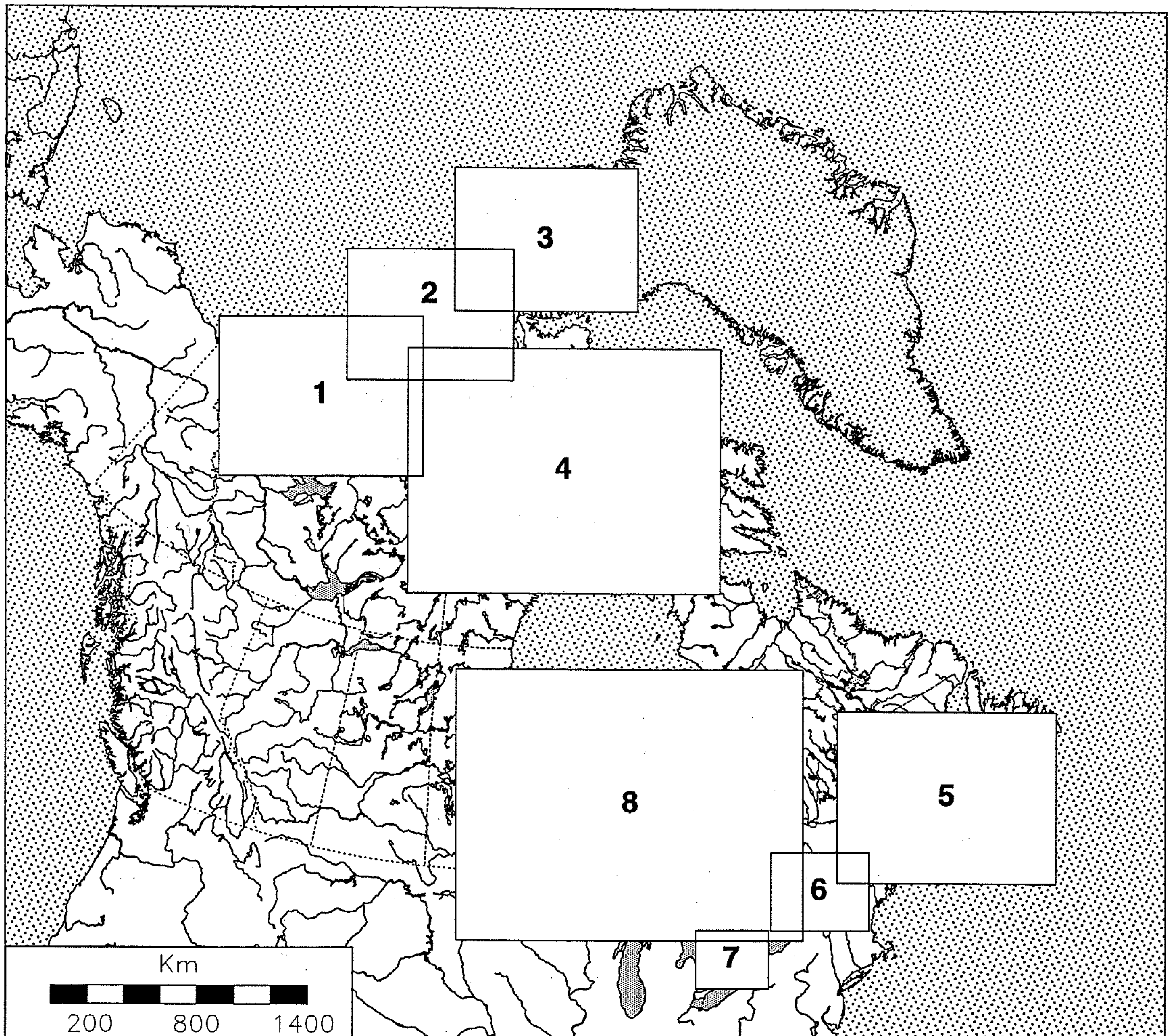
TABLE 1 SITE DATA

Site	Latitude (°N)	Longitude (° W)	Code	Author reference
ON32	43.44	79.71	■	Karrow, 1963, 1987
ON33	43.36	79.78	■	Karrow, 1963, 1987
ON34	43.43	79.82	■	Karrow, 1963, 1987
ON35	43.87	79.67	•	Dreimanis, unpub.; Hicock and Dreimanis, 1985, 1992
ON36	43.82	79.60	•	Dreimanis, unpub.; Hicock and Dreimanis,1992
ON37	43.72	79.63	•	Hicock and Dreimanis, 1985
ON38	43.73	79.28	•	Hicock and Dreimanis, 1989, 1992
ON39	43.81	79.11	•	Dreimanis,unpub.
ON40	43.82	79.18	*	Karrow, 1967; Mohajer et al, 1992
ON41	43.77	79.17	•	Karrow, 1967
ON42	43.41	79.74	+	Karrow, 1963, 1987
ON43	53.01	86.17	Δ	Dredge and Cowan, 1989

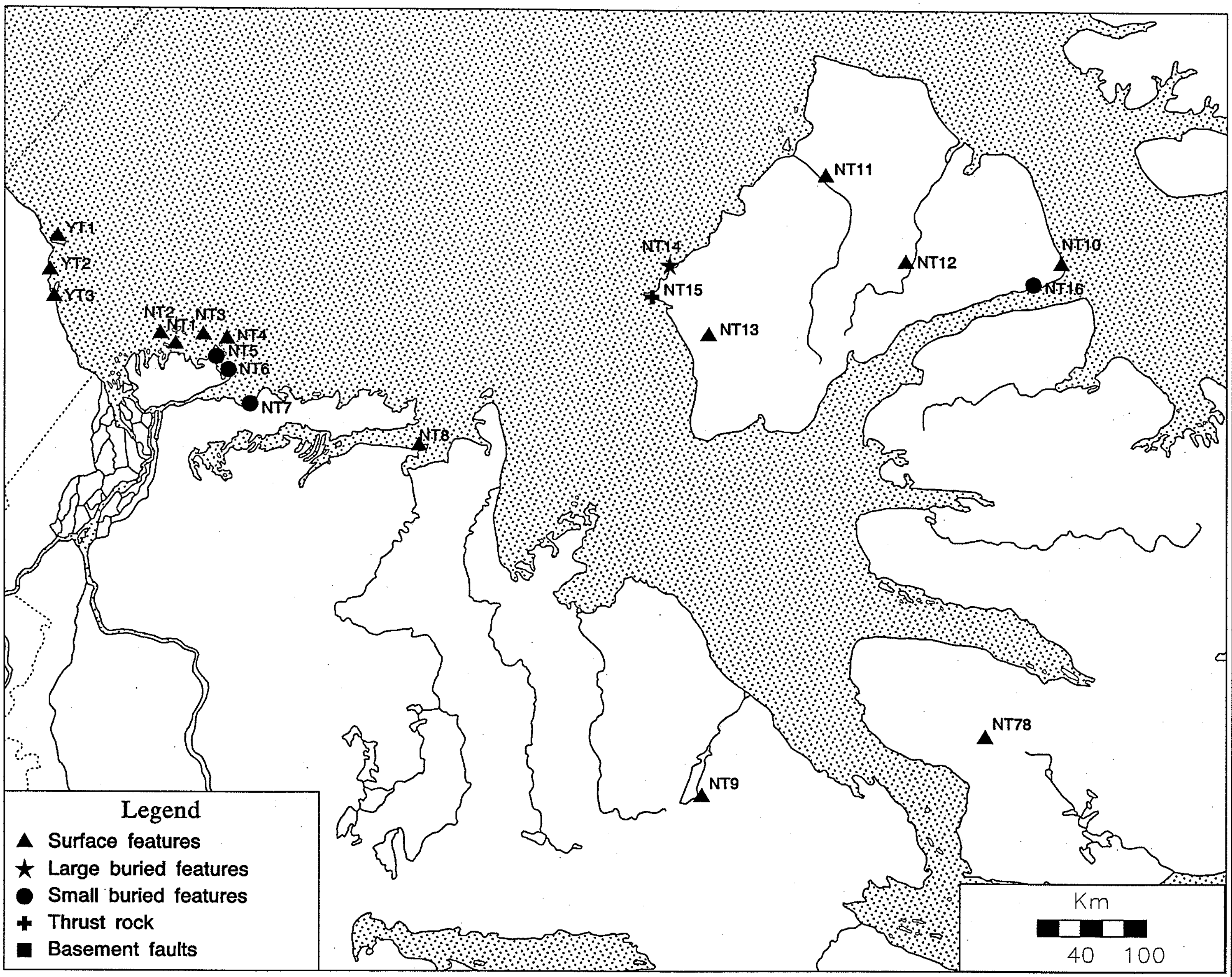
YT = Yukon Territory
NT = Northwest Territories
NL = Newfoundland and Labrador
NS = Nova Scotia
PE = Prince Edward Island
NB = New Brunswick
QU = Québec
MA = Manitoba
ON = Ontario

Δ = Surface features
* = Large buried features
• = Small buried features
+= Thrust rock
■ = Basement faults

Index Map



Sheet 1: Glaciotectonic Features, Yukon & Northwest Territories



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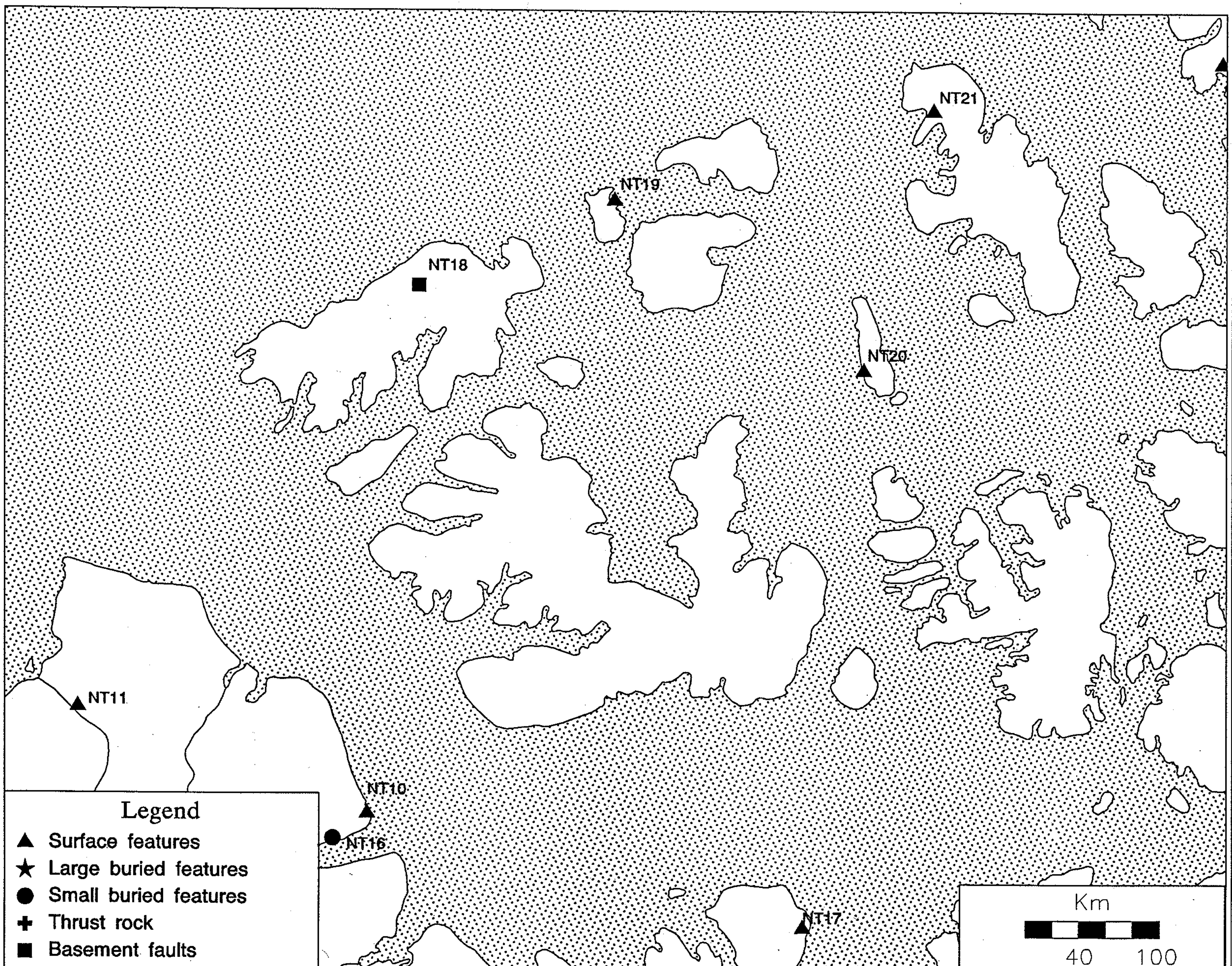
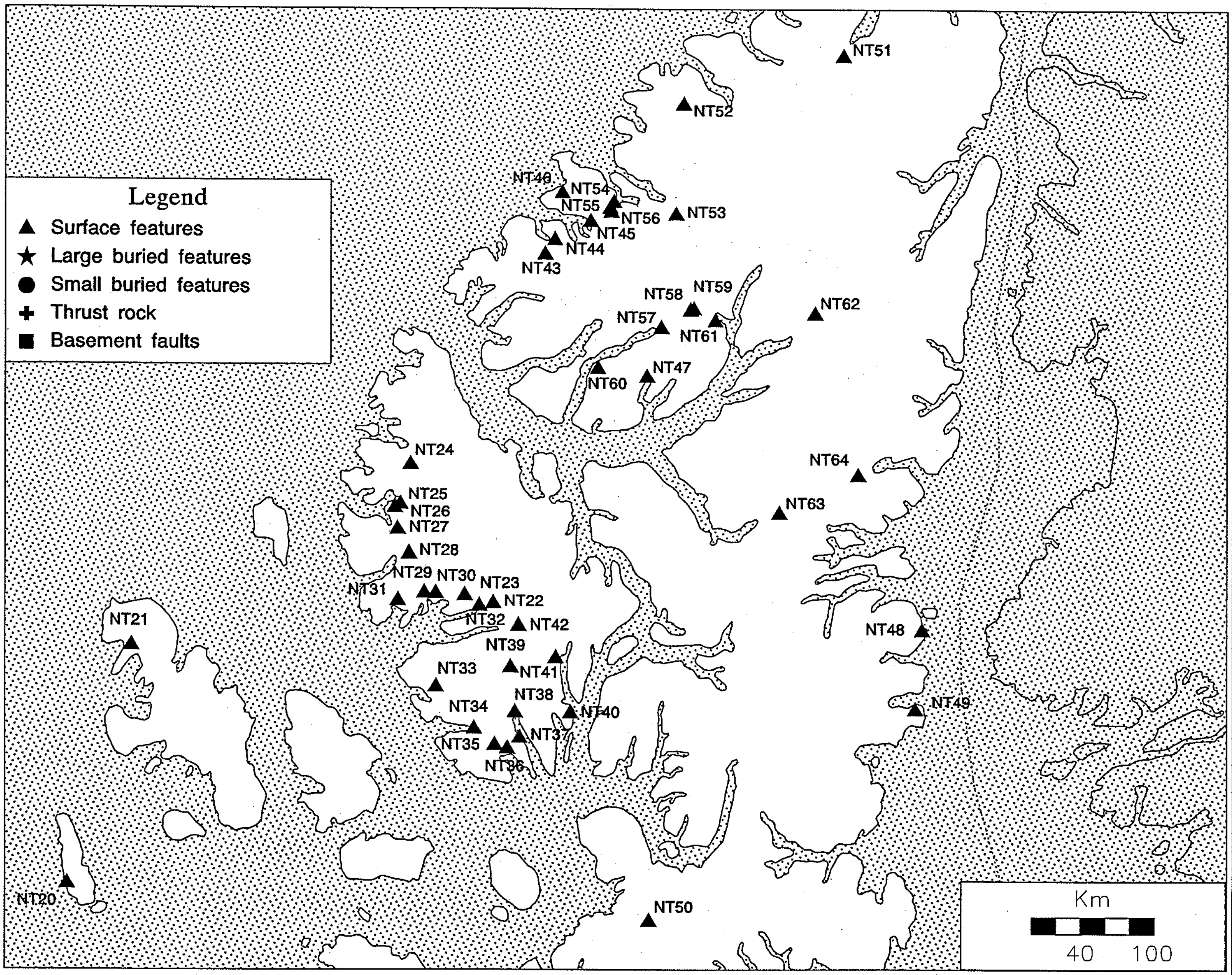
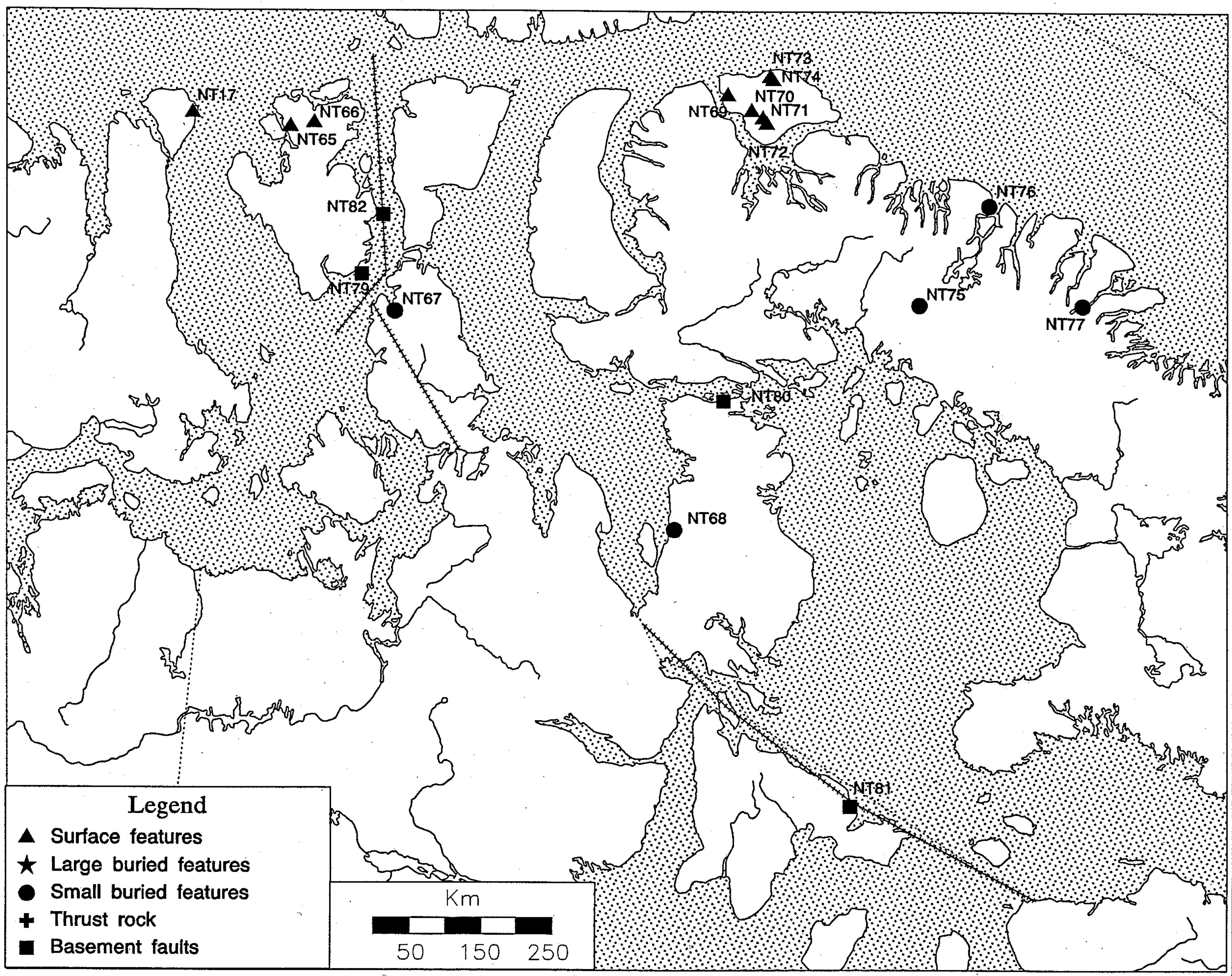


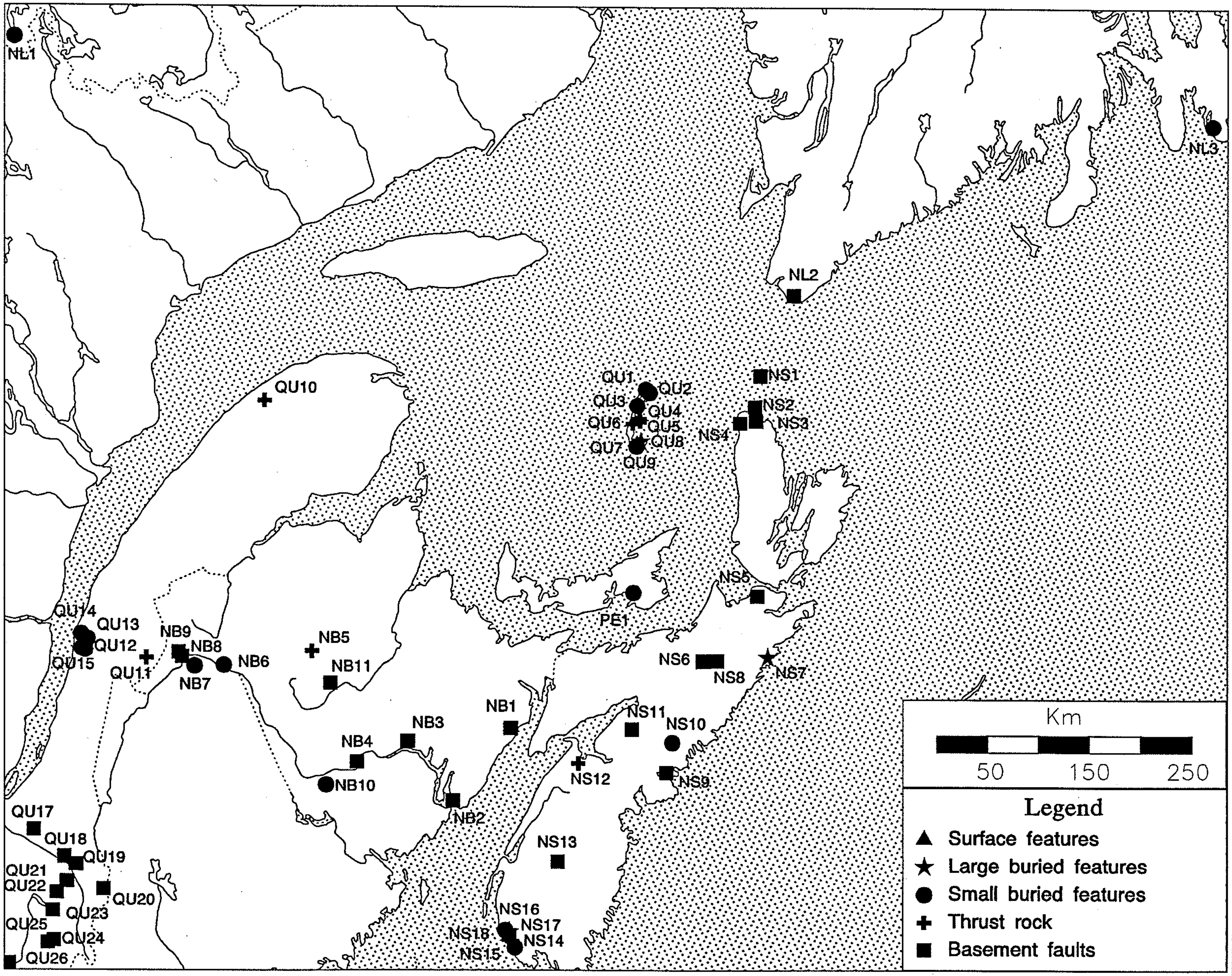
Sheet 3: Glaciotectonic Features, Northwest Territories



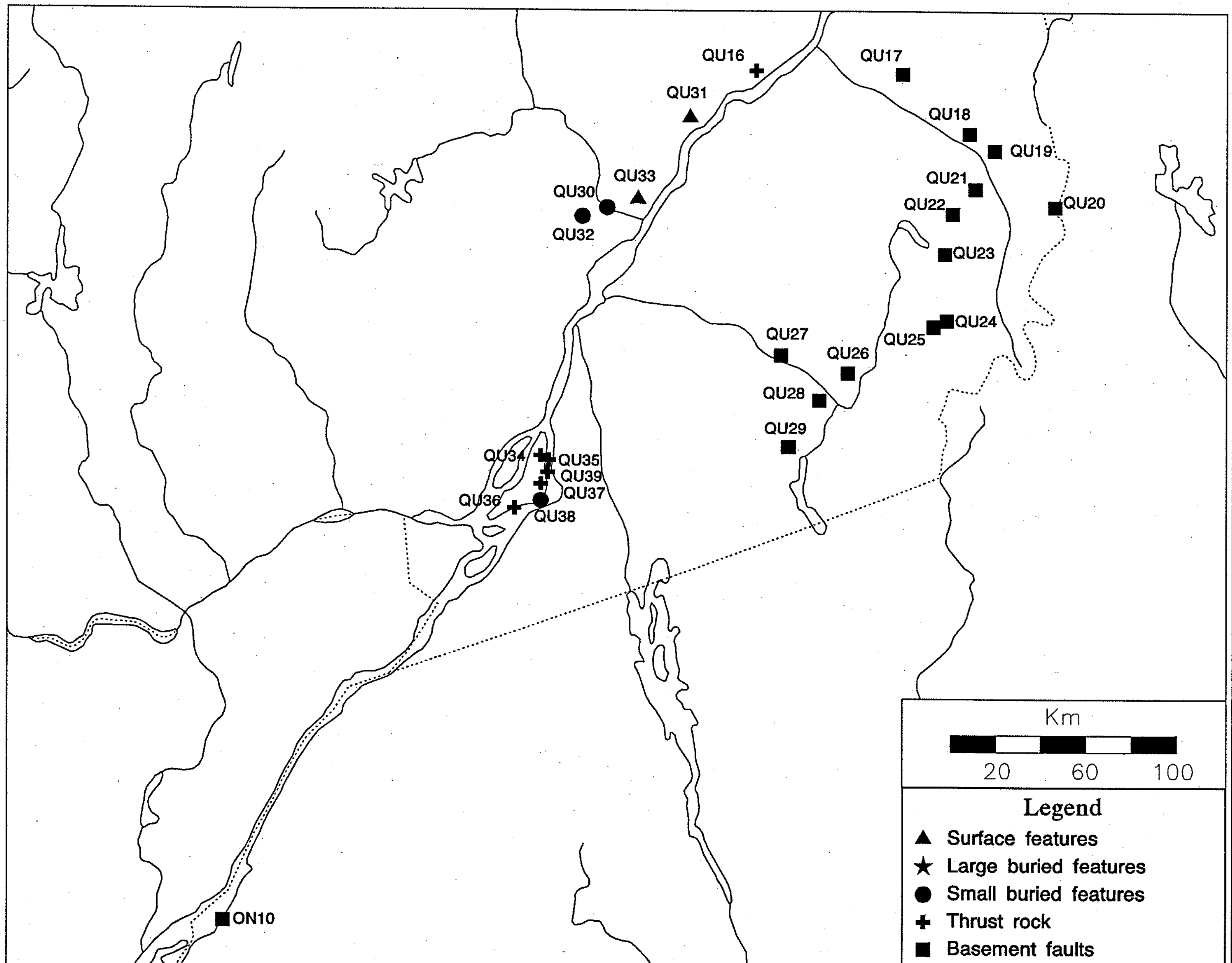
Sheet 4: Glaciotectonic Features, Northwest Territories



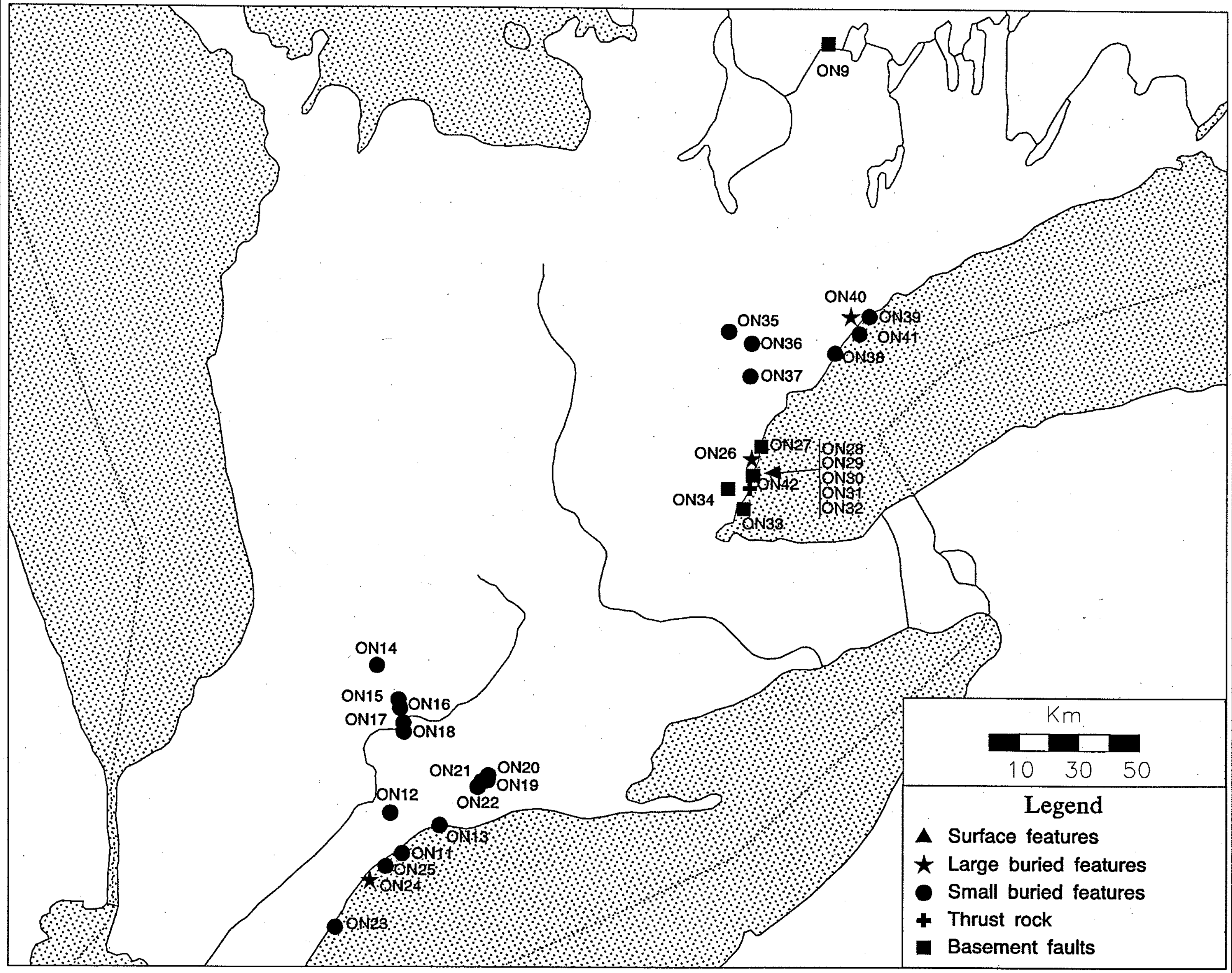
Sheet 5: Glaciotectonic Features, Maritimes & Québec



Sheet 6: Glaciotectonic Features, Ontario & Québec



Sheet 7: Glaciotectonic Features, Ontario



Sheet 8: Glaciotectonic Features, Manitoba, Ontario & Québec

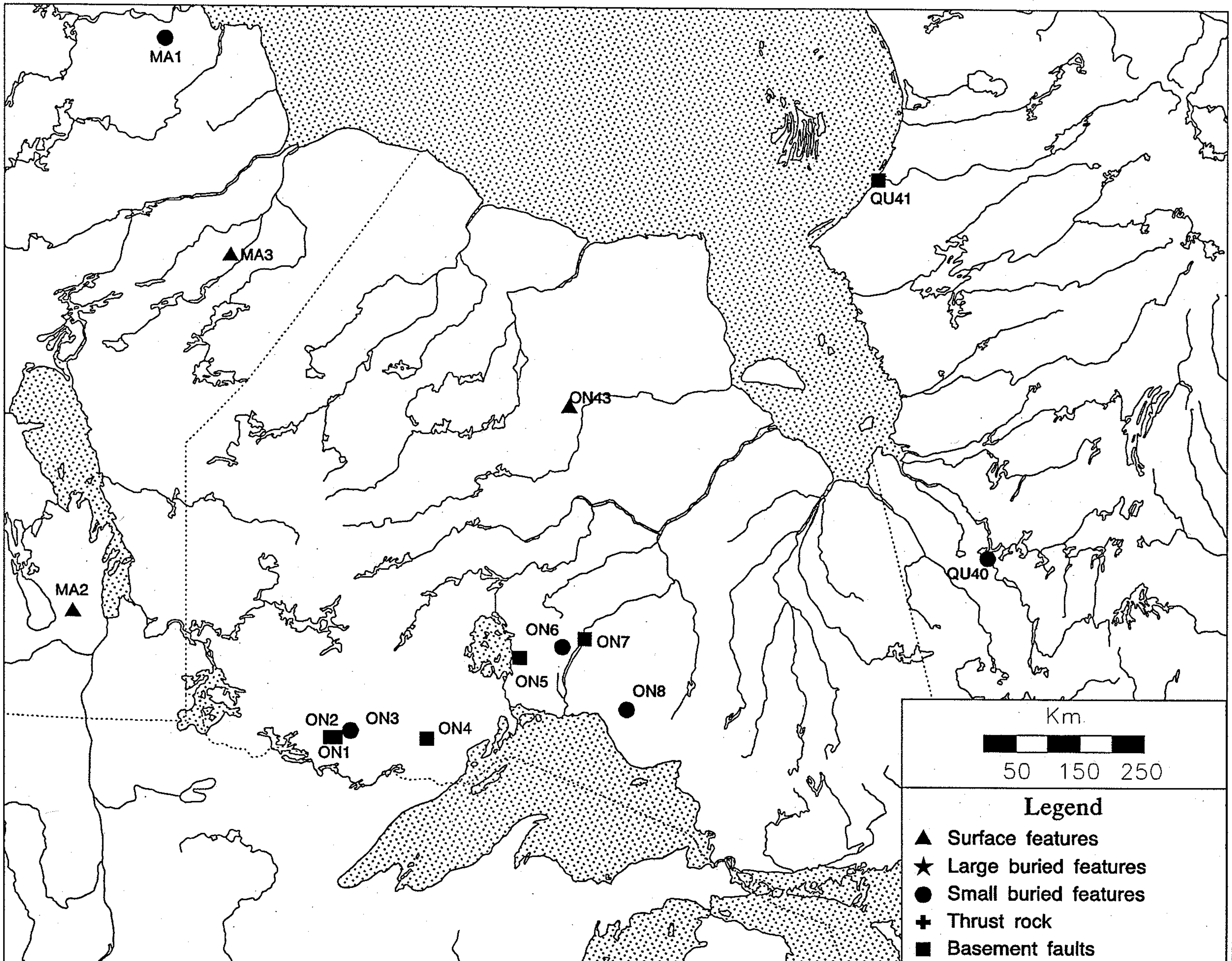


TABLE 2: ANNOTATED BIBLIOGRAPHY

YT01 **MACKAY, J.R. 1959. Glacier ice-thrust features of the Yukon coast. Canada Department of Mines and Technical Surveys, Geographical Bulletin 13: 5-21. RAMPTON, V.N. 1982. Quaternary geology of the Yukon Coastal Plain. Geological Survey of Canada, Bulletin 317, 49 p.** Herschel Island. The island is an ice thrust moraine formed during the Buckland (Early Wisconsinan) Glaciation. There are surface ridges and trenches. The island rises to 200 m and exposures are 30 m high. Some deformed beds extend through the entire section. Middle Pleistocene (or at least pre-Illinoinan) marine sediments were thrust fromHerschel Basin lying to the southeast. There are complexly folded and faulted marine clays and deltaic sands with organic lenses, with repetition of steeply folded and faulted beds. Deformations include folds, inclined beds, fault planes, and shear planes as well as surface ridges. Slickensides are abundant on sheared surfaces in clays. Open anticlines and synclines have dips of 3-5°, and a few beds are overturned to the west. Beds generally dip 15°, but some are vertical. Thrust planes are present. Thrusting is related to high porewater pressure in unfrozen sediments underlying permafrost.

YT02 **MACKAY, J.R. 1959. Glacier ice-thrust features of the Yukon coast. Geographical Bulletin 13: 5-21. RAMPTON, V.N. 1982. Quaternary geology of the Yukon Coastal Plain. Geological Survey of Canada Bulletin 317, 49 p.** Stokes Pt. Yukon coast. Deformation occurred during the Sabine phase of the Buckland glaciation (Early Wisconsinan) forming ridges and cuestas up to 75 m high, with faults and folds in sections. Push was to the southwest, then southeast. Clayey beds have shear planes that are slickensided.

YT03 **MACKAY, J.R. 1959. Glacier ice-thrust features of the Yukon coast. Geographical Bulletin 13: 5-21. RAMPTON, V.N. 1982. Quaternary geology of the Yukon Coastal Plain. Geological Survey of Canada Bulletin 317, 49 p.** King Pt to Kay Pt, Yukon coast. Deformation occurred during the Sabine phase of the Buckland glaciation (Early Wisconsinan) as ridges and cuestas up to 75 m high, with faults and folds in sections. Push was to the southwest, then southeast.

NT01 **MACKAY, J.R. and STAGER, J.K. 1966. Thick tilted beds of segregated ice, Mackenzie delta area, N.W.T. Biuletyn Peryglacjalny 15: 39-43.** Mackenzie delta, NWT. Kendall Island. Pleistocene sediments are glacially thrust into ridges which are internally deformed. Ridges are 6 m high and 30 m wide along 2.5 km of the coast. Thrust is from the northwest. There are slickensided shear planes in clays, tilted beds of sand with ice layers more than 3 m thick, folds cut by shear planes, and contorted beds of sand and slickensided clay, with large sheets dipping 40° SSE. The island ascends to 35 m asl. The sediments are possibly Sangamon, or else pre-Illinoian in age. The glacier thrusting was Early Wisconsinan (Toker Point=Buckland).

NT02 **MACKAY, J.R. and STAGER, J.K. 1966. Thick tilted beds of segregated ice, Mackenzie delta area, N.W.T. Biuletyn Peryglacjalny 15: 39-43.** Garry Island. Bluffs are 10-20 m high, and exposed deformation is along 2 km of the coast. Ice beds are tilted, folded and sheared, and some of the shear planes have slickensides. Optical axes of the ice are normal to original strata.

NT03 **MACKAY, J.R. 1971. The origin of massive icy beds in permafrost, western Arctic coast, Canada. Canadian Journal of Earth Sciences 8: 397-422.** Hooper

Island. Banded ground ice has been glacially folded. The paper contains a good photo of glacially thrust beds (folds with amplitude about 5 m).

NT04 **DALLIMORE, S. and EGGINTON, P. Unpublished data from Mackenzie delta, NWT.** Pullen Island. Small folds and other glaciotectonic structures are exposed in the cliff face on the north side of the island. Structures are similar to those reported by Mackay.

NT05 **DALLIMORE, S. and EGGINTON, P. Unpublished data from Mackenzie delta, NWT.** Richards Island. Small folds and other glaciotectonic structures are exposed in the cliff face on the north side of the island. Structures are similar to those reported by Mackay.

NT06 **DALLIMORE, S. and EGGINTON, P. Unpublished data from Mackenzie delta, NWT.** Summer Island. Small folds and other glaciotectonic structures are exposed in cliff faces. Structures are similar to those reported by Mackay.

NT07 **RAMPTON, V. and MACKAY, J.R. 1971. Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula, Richards Island and nearby areas, District of Mackenzie. Geological Survey of Canada Paper 71-21.** Tuktoyaktuk town site, NWT. Small folds in massive ice are exposed in an ice cellar at Tuk. The icy sands have been bent into horizontal overturned folds as a result of overriding by glacial ice.They probably underlie most of the land area. Photo GSC-158980.

NT08 **MACKAY, J.R. 1956. Deformation by glacier ice at Nicholson Peninsula, NWT. Arctic 9: 218-228.** Nicholson Peninsula, NWT. Ice thrust ridges and internal glacially deformed features are exposed in coastal sections which are 20+ m high. The deformed unit is 8 km long and 6 km wide, and is composed of Quaternary marine sand, silt, clay and ice. Ridges strike parallel to the west coast. Strata dip west at 15°, and are locally deformed and contorted into small folds, overturns, and drag folds of 2-3 m amplitude indicating thrust from west. Closely spaced (2 cm) fault planes in clay beds are horizontal, slightly curved, and slickensided. The beds were unfrozen at the time of deformation.

NT09 **ST-ONGE, D.A. and McMARTIN, I. 1987. Morphosedimentary zones in the Bluenose Lake region, District of Mackenzie. Geological Survey of Canada Paper 87-1A: 89-100.** Bluenose Lake thrust moraine is a steepsided ridge of bouldery sand and gravel 20-30 m high with an east facing slope that is steeper than the west. The ridge was deposited by meltwaters and debris flows which dumped englacial and supraglacial debris in a trench that developed within the ice. The trench is thought to correspond to zones of weakness along thrust planes which marked the margin of active ice. Its age is Late Wisconsinan. A glaciotectonic origin is surmised from the ridge shape and the regional model.

NT10 **VINCENT, J.-S. 1983. La géologie du Quaternaire et la géomorphologie de l'Ile de Banks, Arctique Canadien. Geological Survey of Canada Memoir 405, 118 p and Map 1565A, scale 1:500 000.** The 30 km long thrust moraine formed in Late Wisconsinan time at the margin of the Viscount Melville Sound ice shelf during the Amundsen Glaciation. It is more than 20 m high and is composed of Late Pleistocene marine silts.

NT11 **VINCENT, J.-S. 1983. La géologie du Quaternaire et la géomorphologie de l'Ile de Banks, Arctique Canadien. Geological Survey of Canada Memoir 405, 118 p and Map 1565A, scale 1:500 000.** Bernard River. A 4 km long thrust moraine, greater than 20 m high, is made of Cretaceous, Tertiary and early Pleistocene sediments.

NT12 **VINCENT, J.-S. 1983. La géologie du Quaternaire et la géomorphologie de l'Ile de Banks, Arctique Canadien. Geological Survey of Canada Memoir 405, 118 p and Map 1565A, scale 1:500 000.** Thomsen River. A set of composite ridges/imbricate thrusts 18 km long and 30 - 40 m high was built at the margin of the middle Pleistocene Thomsen Glacier. The ridges are composed of slabs of Cretaceous sediments and till. Air photos show thrust planes.

NT13 **VINCENT, J.-S. 1983. La géologie du Quaternaire et la géomorphologie de l'Ile de Banks, Arctique Canadien. Geological Survey of Canada Memoir 405, 118 p and Map 1565A, scale 1:500 000.** Kellett River. A series of ice thrust moraines 20-30 m high and 10 km long was built at the margin of the middle Pleistocene Thomsen Glacier.

NT14 **VINCENT, J.-S. 1983. La géologie du Quaternaire et la géomorphologie de l'Ile de Banks, Arctique Canadien. Geological Survey of Canada Memoir 405, 118 p and Map 1565A, scale 1:500 000.** Worth Point. The section at Worth point exposes glacially deformed sediments. Structures are less than 10 m in size. Early Pleistocene till of the Banks Glaciation is mixed with Cretaceous bedrock and Tertiary sediments.

NT15 **VINCENT, J.-S. 1983. La géologie du Quaternaire et la géomorphologie de l'Ile de Banks, Arctique Canadien. Geological Survey of Canada Memoir 405, 118 p and Map 1565A, scale 1:500 000.** Duck Hawk Bluffs. A thin, 50 cm thick layer of Cretaceous Kanguk Fm sediment was likely frozen to the base of the Banks Glacier in the early Pleistocene, was carried, and then thrust over sands and gravels of Miocene Beaufort Fm. The bed is traceable for 4-5 km and is wedged between the underlying Beaufort sediment and overlying lodgement till of the Banks Glaciation.

NT16 **VINCENT, J.-S. 1983. La géologie du Quaternaire et la géomorphologie de l'Ile de Banks, Arctique Canadien. Geological Survey of Canada Memoir 405, 118 p and Map 1565A, scale 1:500 000.** Sections expose folded and contorted middle Pleistocene glaciomarine deposits of the Big Sea, which postdates the Thomsen Glaciation. The sediments were deformed during an early Wisconsinan? advance of the Amundsen Glacier. Folds vary in size from centimetres to several metres.

NT17 **HODGSON, D.A. Unpublished data from Stefansson Island.** Marine sediments have been thrust into ridges tens of metres high, in a zone 1 km wide and several km long. The age is about 9 ka.

NT18 **FYLES, J. Unpublished data from Prince Patrick Island. HODGSON, D.A., TAYLOR, R.B., and FYLES, J.G. 1993. Sea level changes during the Holocene and latest Pleistocene on Brock and Prince Patrick Islands, Canadian Arctic Archipelago. Géographie physique et Quaternaire, in press.** Fault scarps in the Tertiary Beaufort Fm, with throws of about 10-15 m are parallel to the bedrock strike. They are post-Tertiary in age and may be of glaciotectonic or seismic origin. Alluvial terraces post-date the faults.

NT19 **FYLES, J.G. 1965. Surficial geology, western Queen Elizabeth Islands. Geological Survey of Canada Paper 65-1, p. 3-5.** An arcuate belt of ice thrust ridges 6-30 m high is composed of thrust Schei Pt sandstone, and overlies sand and pebbles of the Beaufort Fm (Tertiary). The thrust direction indicates that glacier ice flowed westwards through Wilkins Strait. Age unknown.

NT20 HODGSON, D.A. Unpublished data from Lougheed Island. Sites show possible deformation of unconsolidated Cretaceous rock and Quaternary marine sediments into thrust ridges. Age unknown.

NT21 FYLES, J. Unpublished data from Ellef Ringnes and Prince Patrick Islands. Contorted, folded Beaufort (Tertiary) gravels form the upper part of a ridge. Glaciotectonics would explain the position of these beds, but the area is supposed not to have been covered by ice during the last glaciation.

NT22 KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal. ROBITAILLE, B. and GREFFARD, C. 1962. Notes sur les matériaux terminaux du glacier Thompson, Canada arctique. Geographical Bulletin 17: 85-94. A detailed description of the Thompson push moraine. The snout of the Thompson glacier is bulldozing the frozen detritus of a push moraine, and advancing at about 26 m per yr. The main material is frozen outwash cemented by ice. The push moraine is subdivided into ridges running transversely to the glacier. 1/3 of the structural trends are radial; 2/3 are concentric to the tongue. The ridges are a minimum of 10-20 m high. Fissures in front of the moraine are additional glaciotectonic features. Structures include vertical and thrust faults and folds, with thrust surfaces being 5-20 degrees, and deformed and slickensided ice in the faults. There are also large folds in the glacier. Glaciotectonism is active; the maximum age is 5700 ka, based on a wood date of 5690±140 in the moraine. Robitaille describes imbricate thrust ridges and push structures from cross-stratified outwash in front of Thompson Glacier, mixed with lentils of ice. Ridge crests are 30 m high and 60-90 m apart. He also reports overturn folds and bent beds. Giant fissures have been created by glacial pushing (pression), and sliding and rotating of the separated blocks. The ridge is described as a polar push moraine, but its shape and lack of deformation of the strata suggest a thrust mechanism. The area is underlain by permafrost.

NT23 KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal. Finsterwalder glacier push moraine is 2.7 km long, 1/2 km wide, and 25 m high. It consists of stratified outwash and till. Blocks are horizontal or dip slightly towards the glacier. Structural trends are transverse.

NT24 KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal. Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT25 KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal. Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT26 KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal. Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT27 KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal. Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT28 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT29 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT30 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT31 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT32 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

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NT36 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4. McGill University, Montreal.** Push moraines on the west side of the Axel Heiberg ice cap. Most are outlet glaciers in retreat.

NT37 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4. McGill University, Montreal.** Push moraines on the west side of the Axel Heiberg ice cap. Most are outlet glaciers in retreat.

NT38 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4. McGill University, Montreal.** Push moraines on the west side of the Axel Heiberg ice cap. Most are outlet glaciers in retreat.

NT39 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT40 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT41 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT42 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines associated with retreating outlet glaciers on the west side of the Axel Heiberg ice cap.

NT43 **EVANS, D. 1989. The nature of glacitectonic structures and sediments at subpolar glacier margins, northwest Ellesmere Island. Geografiska Annaler 71: 113-123.** Phillips Inlet. Four glaciers are fronted by sets of thrust block moraines. Ridges are 1-2 km long, and 5-20 m high. They are composed of outwash with beds dipping 20° towards the glacier in some places, and of glacimarine silt in others. The glacier rests on frozen material. In many places the original bedding is undisturbed. As well as the thrust blocks, there is internal deformation in some places, including strike-slip displacements, other faults, and contorted and folded mud. Some blocks rest on stagnant glacier ice. The glacier snout was at the thrust blocks in 1959. The maximum age is 5200±60 (TO-472) based on a date within marine sediments.

NT44 **EVANS, D. 1989. The nature of glacitectonic structures and sediments at subpolar glacier margins, northwest Ellesmere Island. Geografiska Annaler 71: 113-123.** Phillips Inlet. Four glaciers are fronted by sets of thrust block moraines. Ridges are 1-2 km long, and 5-20 m high. They are composed of outwash with beds dipping 20° towards the glacier in some places, and of glacimarine silt in others. The glacier rests on frozen material. In many places the original bedding is undisturbed. As well as the thrust blocks, there is internal deformation in some places, including strike-slip displacements, other faults, and contorted and folded mud. Some blocks rest on stagnant glacier ice. The glacier snout was at the thrust blocks in 1959. The maximum age is 5200±60 (TO-472) based on a date within marine sediments.

NT45 **EVANS, D. 1989. The nature of glacitectonic structures and sediments at subpolar glacier margins, northwest Ellesmere Island. Geografiska Annaler 71: 113-123.** Phillips Inlet. Four glaciers are fronted by sets of thrust block moraines. Ridges are 1-2 km long, and 5-20 m high. They are composed of outwash with beds dipping 20° towards the glacier in some places, and of glacimarine silt in others. The glacier rests on frozen material. In many places the original bedding is undisturbed. As well as the thrust blocks, there is internal deformation in some places, including strike-slip displacements, other faults, and contorted and folded mud. Some blocks rest on stagnant glacier ice. The glacier snout was at the thrust blocks in 1959. The maximum age is 5200±60 (TO-472) based on a date within marine sediments.

NT46 **EVANS, D. 1989. The nature of glacitectonic structures and sediments at subpolar glacier margins, northwest Ellesmere Island. Geografiska Annaler 71: 113-123.** Phillips Inlet. Four glaciers are fronted by sets of thrust block moraines. Ridges are 1-2 km long, and 5-20 m high. They are composed of outwash with beds dipping 20° towards the glacier in some places, and of glacimarine silt in others. The glacier rests on frozen material. In many places the original bedding is undisturbed. As well as the thrust blocks, there is internal deformation in some places, including strike-slip displacements, other faults, and contorted and folded mud. Some blocks rest on stagnant glacier ice. The glacier snout was at the thrust blocks in 1959. The maximum age is 5200±60 (TO-72) based on a date within marine sediments.

NT47 **HODGSON, D.A. Unpublished data from Ellesmere Island. KING, L. 1983. Contributions to the glacial history of the Borup Fiord area, northern Ellesmere Island, NWT. In Schroeder-Lanz and Kinzl (eds.), Late- and postglacial oscillations of glaciers: glacial and periglacial forms. Balkema, Rotterdam. p. 305-323.** Borup Fiord. A push moraine is situated 2 km from the head of Oobloyah Bay. The moraine is 50-70 m in front of the Karl Troll Glacier, which is advancing today. Ridges are more than 25 m high. Radial crevasses in the frozen ground and small ramparts with disturbances in the vegetation cover prove that it is still active. King suggests bulldozer-type action. The inner side of the moraine is current. Outer ridges could be as old as 6 ka. King also mentions a push moraine in Hare Fiord.

NT48 **BLAKE, W. JR., Unpublished data from Ellesmere Island.** At Cape Herschel, a thrust ridge of marine sediment, several metres high developed when the Alfred Newell Glacier surged less than 10 years ago. Blake notes that although these are polar glaciers there is water issuing from underneath the snout and as waterspouts farther back on the glacier.

NT49 **BLAKE, W. JR., Unpublished data from Ellesmere Island.** At Cadogan Inlet, a thrust feature lies in front of the present glacier. There are also ridges of marine sediment. The age is less than about 3ka.

NT50 **SOUCHEZ, R.A. 1971. Ice-cored moraines in south-western Ellesmere Island, NWT. Journal of Glaciology 10: 245-254.** There are small ice-cored moraines, whose "formation seems to be more complex than simple upwarping of foliation bands at the margin of the ice cap".

NT51 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines from northern Ellesmere, plotted from air photos.

NT52 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines from northern Ellesmere, plotted from air photos.

NT53 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines from northern Ellesmere, plotted from air photos.

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NT59 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines from northern Ellesmere, plotted from air photos.

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NT64 **KALIN, M. 1971. The active push moraine of the Thompson glacier. Axel Heiberg Island Research Report 4, McGill University, Montreal.** Push moraines from northern Ellesmere, plotted from air photos.

NT65 **DYKE, A.S., MORRIS, T., GREEN, D., and ENGLAND, J. 1992. Quaternary geology of Prince of Wales Island, Arctic Canada. Geological Survey Canada Memoir 433, 142p.** Slabs of thrust dolomite with till form sharp-crested ridges 10-20 m high. The bedrock slabs constitute about 1/4 of the volume of the moraine. Dyke suggests a readvance of the cold-based ice margin with bedrock frozen-on. These moraines have a different morphology from others on the island, which are broader and still contain remnant ice. They were created during the Wisconsin deglaciation.

NT66 **DYKE, A.S., MORRIS, T., GREEN, D., and ENGLAND, J. 1992. Quaternary geology of Prince of Wales Island, Arctic Canada. Geological Survey Canada Memoir 433, 142p.** Slabs of thrust dolomite with till form sharp-crested ridges 10-20 m high. The bedrock slabs constitute about 1/4 of the volume of the moraine. Dyke suggests a readvance of a cold-based ice margin with freezing on of bedrock. These moraines have a different morphology from others on the island, which are broader and still contain remnant ice. They were formed during the Wisconsin glaciation.

NT67 **DYKE, A.S. and MATHEWS, J. 1987. Stratigraphy and paleoecology of Quaternary sediments along Pasley River, Boothia Peninsula. Géographie physique et Quaternaire 41: 323-344.** photo. Sand beds are interfolded with till and overlain by till. Deformation is in the order of several metres and occurred during the Wisconsin advance.

NT68 **DREDGE, L. A. 1990. The Melville moraine: sea level change and response of the Foxe Ice Dome. Canadian Journal of Earth Sciences 27: 1215-1224.** Melville Peninsula, NWT. Shear planes are exposed in the distal side of the Melville End Moraine near Folster Lake. Exposed parts of plates are about 1-2 m thick and cover a distance of 100 m. They are composed of local bouldery basal till thrust into mixed basal and englacial till.

NT69 **KLASSEN, R.A. 1982. Glaciotectonic thrust plates, Bylot Island, District of Franklin. Geological Survey of Canada Paper 82-1A: 369-373.** Imbricate low angle thrust plates composed of valley-floor outwash are found in front of the glacier in a number of places, where they form benches. They are 5-10 m thick, and were formed by faulting and low-angle thrusting of sediments due to glacier movement. One set of benches is not overlain by till and Klassen suggests that the thrusting occurred in front of the ice margin. Others are till covered, and for these he suggests a sub-glacial thrust origin. They indicate permafrost conditions because there is no disturbance of any of the laminae in the outwash sheets. The maximum age is 120±80 years, based on twig dates in the outwash sheets. Glaciers today are thought to be near their maximum neoglacial positions.

NT70 **KLASSEN, R.A. 1982. Glaciotectonic thrust plates, Bylot Island, District of Franklin. Geological Survey of Canada Paper 82-1A: 369-373.** Imbricate low angle thrust plates composed of valley-floor outwash are found in front of the glacier in a number of places, where they form benches. They are 5-10 m thick, and were formed by faulting and low-angle thrusting of sediments due to glacier movement. One set of benches is not overlain by till and Klassen suggests that the thrusting occurred in front of the ice margin. Others are till covered and for these he suggests a sub-glacial thrust origin. They indicate permafrost conditions because there is no disturbance of any of the laminae in the outwash sheets. The maximum age is 120±80 years, based on twig dates in the outwash sheets. Glaciers today are thought to be near their maximum positions.

NT71 **KLASSEN, R.A. 1982. Glaciotectonic thrust plates, Bylot Island, District of Franklin. Geological Survey of Canada Paper 82-1A: 369-373.** Imbricate low angle thrust plates composed of valley-floor outwash are found in front of the glacier in a number of places, where they form benches. They are 5-10 m thick, and were formed by faulting and low-angle thrusting of sediments due to glacier movement. One set of benches is not overlain by till and Klassen suggests that the thrusting occurred in front of the ice margin. Others are till covered and for these he suggests a sub-glacial thrust origin. They indicate permafrost conditions because there is no disturbance of any of the laminae in the outwash sheets. The maximum age is 120±80 years, based on twig dates in the outwash sheets. Glaciers today are thought to be near their maximum positions.

NT72 **KLASSEN, R.A. 1982. Glaciotectonic thrust plates, Bylot Island, District of Franklin. Geological Survey of Canada Paper 82-11A: 369-373.** Imbricate low angle thrust plates composed of valley-floor outwash are found in front of the glacier in a number of places, where they form benches. They are 5-10 m thick, and were formed by faulting and low-angle thrusting of sediments due to glacier movement. One set of benches is not overlain by till and Klassen suggests that the thrusting occurred in front of the ice margin. Others are till covered and for these he suggests a sub-glacial thrust origin. They indicate permafrost conditions because there is no disturbance of any of the laminae in the outwash sheets. The maximum age is 120±80 years, based on twig dates in the outwash sheets. Glaciers today are thought to be near their maximum positions.

NT73 **KLASSEN, R.A. 1982. Glaciotectonic thrust plates, Bylot Island, District of Franklin. Geological Survey of Canada Paper 82-1A: 369-373.** Imbricate low angle thrust plates composed of valley-floor outwash are found in front of the glacier in a number of places, where they form benches. They are 5-10 m thick, and were formed by faulting and low-angle thrusting of sediments due to glacier movement. One set of benches is not overlain by till and Klassen suggests that the thrusting occurred in front of the ice margin. Others are till covered and for these he suggests a sub-glacial thrust origin. They indicate permafrost conditions because there is no disturbance of any of the laminae in the outwash sheets. The maximum age is 120±80 years, based on twig dates in the outwash sheets. Glaciers today are thought to be near their maximum positions.

NT74 **KLASSEN, R.A. 1982. Glaciotectonic thrust plates, Bylot Island, District of Franklin. Geological Survey of Canada Paper 82-1A: 369-373.** Imbricate low angle thrust plates composed of valley-floor outwash are found in front of the glacier in a number of places, where they form benches. They are 5-10 m thick, and were formed by faulting and low-angle thrusting of sediments due to glacier movement. One set of benches is not overlain by till and Klassen suggests that the thrusting occurred in front of the ice margin. Others are till covered and for these he suggests a sub-glacial thrust origin. They indicate permafrost conditions because there is no disturbance of any of the laminae in the outwash sheets. The maximum age is 120±80 years, based on twig dates in the outwash sheets. Glaciers today are thought to be near their maximum positions.

NT75 **TERASMAE, J., WEBBER, P., and ANDREWS, J. 1966. A study of late-Quaternary plant-bearing beds in north-central Baffin Island. Arctic 19: 296-318.** Isortoq River: Peaty beds were deformed by overriding ice moving from east to west during a pre-Foxe glaciation.

NT76 **ANDREWS, J.T. unpublished data from Baffin Island.** McBeth Fiord: "folded marine beds, late Foxe".

NT77 **ANDREWS, J.T. unpublished data from Baffin Island.** Scott Inlet: "faulted beds".

NT78 **SHARPE, D.R. 1988. Late glacial landforms on Wollaston Peninsula, Victoria Island, Northwest Territories: product of ice-marginal retreat, surge, and mass stagnation. Canadian Journal of Earth Sciences 25: 262-279.** The eastern part of the Colville Moraine comprises folded and deformed ridges forming an 8-10 km wide moraine which includes plates of thrust sediments. These are shear moraines.

NT79 **DYKE, A.S., MORRIS, T. and GREEN, D. 1991 Postglacial tectonic and sea level history of the central Canadian Arctic. Geological Survey of Canada Bulletin 397, 56p.** Postglacial tectonic lineaments on Dixon Island cross raised beaches, till, and bedrock. Similar features occur to the north on the Peel Sound coast of Prince of Wales Island. The collective throw is down to the east by several metres.

NT80 **DREDGE, L.A. in press. Surficial geology of northern Melville Peninsula, NT. Geological Survey of Canada Memoir.** Sets of small, parallel bedrock faults along the north coast of Melville Peninsula trend at right angles to the alignment of Fury and Hecla Strait. These features postdate glacial shaping and polishing of the bedrock, and are thought to be produced as a glacial unloading response. Individual vertical movements are in the order of 1-2 m. Emergence curves suggest that faulting along the south coast of Fury and Hecla Strait occurred 6.5-6.8 ka.

NT81 **BASHAM, P.W., FORSYTH, D.A. and WETMILLER, R.J. 1977. The seismicity of northern Canada. Canadian Journal of Earth Sciences 14: 1646-1667. DREDGE, L. A. 1991. Raised marine features, radiocarbon dates**

and sea level changes, Eastern Melville Peninsula, Arctic Canada. Arctic 44: 63-75. Basham et al. report an arcuate band of seismicity along the Boothia Arch. They speculate that the Foxe-Baffin block is responding independently to postglacial uplift, and could be decoupled from the rest of the Shield. Seismic activity and block tilting to the northeast of this part of the crust was proposed as reactivation of old (mid-Paleozoic horst and graben) structures caused by high differential stress during glacial unloading. The activity follows the edge of the Foxe Ice Sheet. Dredge measured the elevation of the 6800 year raised shoreline and suggested that block tilting related to the Bell Arch produced abnormally steep gradients on the postglacial shoreline on eastern Melville Peninsula. This movement is linked to the unloading of glacial ice in Foxe Basin 6800 years ago.

NT82 **ADAMS, J. and BASHAM, P. 1989. The seismicity and seismotectonics of Canada east of the Cordillera. Geoscience Canada 16: 3-16. BASHAM, P.W., FORSYTH, D.A. and WETMILLER, R.J. 1977. The seismicity of northern Canada. Canadian Journal of Earth Sciences 14: 1646-1667. DYKE, A.S., MORRIS, T. and GREEN, D. 1991. Postglacial tectonic and sea level history of the central Canadian Arctic. Geological Survey of Canada Bulletin 397, 56 p.** Basham et al. report a band of seismicity along the Bell Arch. They speculate that the Foxe-Baffin block is responding independently to postglacial uplift, and could be decoupled from the rest of the Shield. Seismic activity and block tilting was proposed as reactivation of old (Cretaceous-Tertiary rifting on Boothia Pen) structures caused by high differential stress during glacial unloading. The activity follows the edge of the Foxe Ice Sheet. Dyke reports 60-120 m warping in part of the central Arctic about 9300 years ago, but little tilting in other area. He proposes that postglacial rebound involved movement of a mosaics of blocks, some tilting, others not.

NL01 **GOSSE, J. 1989. Description and interpretation of the Quaternary deposits at Scully Mine, Wabush, Labrador. B Sc thesis, Memorial University, Nfld. 115 p.** Subglacial fluvial sediments overlain by till have been glaciotectonized. Features include smears, high-angle normal faults in the sediments, overturned beds, and sheared off structures. Most features are about 50 cm in size. A shearing mechanism is proposed: permafrost and foundering are ruled out. There may not have been regional permafrost at the time of the tectonism, but in that case the sediments were frozen by lee-side freezing as the overriding ice passed southwards over a hill north of the pit. Deformation occurred during the Late Wisconsinan glaciation.

NL02 **GRANT, D.R. Unpublished data from southwestern Newfoundland.** Cape Ray. A pre-Wisconsinan wave-cut bench in granite gneiss is offset along the trace of the Long Range Fault. The total offset (up on the northwest) of at least 1 m occurs on 7 small faults. Faulting is the possible reactivation of 130 km of an old fault in glacial times as suggested by the offset across the Aspy Fault Zone on Cape Breton Island and the elevation of correlative benches on St. Paul Island.

NL03 **EYLES, N. and SLATT, R.M. 1977. Ice-marginal sedimentary, glacitectonic, and morphologic features of Pleistocene drift: an example from Newfoundland. Quaternary Research 8: 267-281.** Stacked imbricated melt out tills are considered as products of thrusting along ice marginal shear planes. They were produced when the Wisconsin glaciers were of the cold Arctic type.

NS01 **NEALE, E.R.W. 1964. Geology, Cape North, Nova Scotia. Geological Survey of Canada Map 1150 A with marginal notes.** St. Paul Island, NS. Wave-cut rock benches range in elevation from 1-7 m in the vicinity of Cape North (St. Paul Island), but on the southern end of St. Paul Island, traces of the bench occur at 11 m elevation. Striae and stoss-and-lee forms show that Pleistocene ice movement was east-southeast.

NS02 **GRANT, D.R. 1990. Late Quaternary movement of Aspy Fault, Nova Scotia. Canadian Journal of Earth Sciences 27: 984-987. NEALE, E.R.W. 1964. Geology, Cape North, Nova Scotia. Geological Survey of Canada Map 1150 A with marginal notes.** A wave cut bench extends south for several kms from Cape North at elevation 6±2 m. At the Aspy Fault Zone it appears on the south side at twice its elevation to the north. The movement postdates the Sangamon interglacial bench, and is a possible reactivation of an older fault.

NS03 **GRANT, D.R. 1990. Late Quaternary movement of Aspy Fault, Nova Scotia. Canadian Journal of Earth Sciences 27: 984-987. NEALE, E.R.W. 1963a. Geology, Dingwall, Cape Breton Island, Nova Scotia. Geological Survey of Canada Map 1124 A.** Dingwall, Cape Breton Island, N.S. Tilted wave-cut rock benches overlain by stratified fluviatile deposits, at Sugar Loaf and northeastward along the coast, are up to 11 m above present high tide level. Faulting related to post glacial uplift has caused minor displacements both in the bedrock benches and in the overlying fluviatile deposits. Striae and poorly developed stoss-and-lee forms suggest that Pleistocene ice movement was eastward.

NS04 **NEALE, E.R.W. 1963b. Geology, Pleasant Bay, Nova Scotia. Geological Survey of Canada, Map 1119 A.** Pollett Cove. Faulting related to post glacial uplift has caused minor displacements both in the bedrock benches and in the overlying fluviatile deposits.

NS05 **STEA, R. Unpublished data from central NS.** Stea reports small folds and offset striations with 2-4 cm displacement.

NS06 **STEA, R. Unpublished data from central NS.** Stea reports offset striations with displacement 1-5 cm.

NS07 **STEA, R. and BROWN, Y. 1989. Variation in drumlin orientation, form and stratigraphy relating to successive ice flows in southern and central Nova Scotia. Sedimentary Geology 62: 223-240.** Wine Harbour. Glaciotectonically folded Sangamonian lacustrine laminated silts and clays form the core of a drumlin. Deformation structures include drag folds and shear planes which dip at high angles to the west. Structures shown on the figure are cm to 6 m in size. They were tectonized by Wisconsin ice.

NS08 **GOLDTHWAIT, J.W. 1924. Physiography of Nova Scotia. Geological Survey of Canada Memoir 140, 179 p.** Goldthwait reports postglacial faulting as small dislocations in the slate bedrock, with slippage along cleavage planes, 5 km west of Caledonia Corners. This is a 'flight of steps' on grooved outcrop with slippage along the cleavage planes. There are two vertical faults with uplift on the northwest side. Displacements are each 10-18 cm.

NS09 **GOLDTHWAIT, J.W. 1924. Physiography of Nova Scotia. Geological Survey of Canada Memoir 140, 179 p.** Halifax area. Postglacial faulting is seen as small dislocations in the slate bedrock with slippage along cleavage planes, at Point Pleasant Park, Halifax. Glaciated pavements are disrupted by high angle faults. Vertically cleaved slates indicate either elastic recovery or localized isostatic rebound during deglaciation.

NS10 **MORNER, N.A. 1973. A new find of till wedges in Nova Scotia, Canada. Geologisk Foreningens i Stockholm Forhandlingar 94: 581-587.** Milford gypsum quarry near Shubenacadie, NS. Wedges of red clayey till up to 0.5 m long are injected down into yellow sand. The injecting is accredited to the cracking and filling mechanism but could be due to liquifaction caused by post-glacial seismicity.

NS11 **PREST, V.K. Unpublished data from NS.** Gore. Meguma Group slates are offset by two sets of small faults. One set occurs along the northeast trending bedding planes, the other is set at an angle to the first.

NS12 **GRANT, D.R. Unpublished data from southwestern Newfoundland and Nova Scotia** Kentville. A large slab of granite was thrust over an esker in the Late Wisconsinan glaciation.

NS13 **GOLDTHWAIT, J.W. 1924. Physiography of Nova Scotia. Geological Survey of Canada Memoir 140, 179 p.** Lake Kemimkujik. He describes postglacial faulting on glaciated slate bedrock.

NS14 **DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. GRANT, D.R. 1987. Glacial advances and sea-level changes, southwestern Nova Scotia. Geological Society of America, Centennial Field Guide, Northeastern section, p. 421-432.** Yarmouth area. Red Head. An interglacial rock platform is truncated and striated, and the upper 2 m of rock is bent over towards 120-170°, in smooth curves or abrupt kinks. Some folds enclose pods of interglacial beach gravel. Deformation occurred during the Early Wisconsinan glaciation.

NS15 **DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. GRANT, D.R. 1987. Glacial advances and sea-level changes, southwestern Nova Scotia. Geological Society of America, Centennial Field Guide, Northeastern section, p. 421-432.** Yarmouth area. Cranberry Point. Bedrock is folded over old beach gravel and wisps of rock trail off into overlying till. Imbricate low ange thrust faults rise southwards, with amplitude 1-2 m. A freezing-on mechanism is proposed.

NS16 **DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. GRANT, D.R. 1987. Glacial advances and sea-level changes, southwestern Nova Scotia. Geological Society of America, Centennial Field Guide, Northeastern section, p. 421-432.** Cape Cove. Gravel conglomerate is deformed into contorted beds with drag folds and updip overturn folds, 1-2 m in size. Deformation was caused by a glacial readvance depositing the till which overlies the gravels nearby. Deformation occurred before iron-cementation of the gravel. These gravels postdate the Red Head till and were thus deformed by ice during a more recent glacial episode. Also, there are vertically cleaved slates producing high angle faults on striated rock outcrop. Deformation is thought to have occurred during deglaciation during glacial unloading.

NS17 **GRANT, D.R. 1987. Glacial advances and sea-level changes, southwestern Nova Scotia. Geological Society of America, Centennial Field Guide, Northeastern section, p. 421-432.** A displaced block of mud and sand containing interglacial fossils, dragged from the floor of the Bay of Fundy while frozen to the base of the first Wisconsinan glacier, lies along a parting in the till. There are jagged and interpenetrative contacts, and lenses of Red Head till in the sand.

NS18 **DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. GRANT, D.R. 1980. Quaternary stratigraphy of southwestern Nova Scotia: Glacial events and sea level changes. Geological Association of Canada, Guidebook Excursion 9.** Slate outcrop overlain by the lower grey till shows about 20 dislocations across a width of 3 m. The net movement is greater than 1m. Individual striations are traceable across the steps. Displacements are up to the south along vertical cleavage planes that strike N35°E.

PE01 **PREST, V.K. Unpublished data from PEI.** Penn Pt. Shoreline exposures show that platy Permian sandstone and siltstone bedrock underlying till have been deformed into symmetric, asymmetric and overturned folds including till in the nose. The amplitude is 1-2 m. Deformation occurred during the main Wisconsin glaciation of the Island.

NB01 **SEAMAN, A. Unpublished data from Fundy Park, NB.** Faults trending east-west in buried outcrop were seen to displace glacial striae by 5 cm.

NB02 **MATTHEW, G.F. 1894a. Post-glacial faults at St. John, NB. American Journal of Science 48: 501-503. MATTHEW, G.F. 1894b. Movements of the Earth's crust at St. John, NB, in post-glacial times. Bulletin of the Natural History Society of New Brunswick 3: 34-42. BROSTER, B.E. AND BURKE, K.B.S. 1990. Glacigenic postglacial faulting at Saint John, New Brunswick. Atlantic Geology 26: 125-138.** St John. Vertically cleaved strata indicate glacioelastic recovery. Four sites are on glaciated slate bedrock ledges. The faults are reverse. At the hospital Matthew notes 9 faults on a 4 m wide ledge, with downthrows on the north side, each of which are 2-8 cm. Also on Charles St., Rock St., and the Anglican church. On Rock St the ledge is 60 m wide, and has 61 small faults with average throws of 2 cm. Downthrow is on the north side in all cases. Goldthwait notes others on Delhi St. Broster and Burke report offset striae on north facing slopes, and high angle reverse faults several metres in length which are parallel to bedding planes. These are attributed to glacial unloading.

NB03 **FYFFE, L.R. 1983. Joint patterns within the epicentral area of the 1982 Miramichi earthquake. New Brunswick Dept. of Natural Resources Open File 83-13, 19 p.** SW of Indian Lake near the Miramichi earthquake epicenter. Two fractures show evidence of post glacial movement. The first shows a reverse displacement that offsets glacial striations by 2 cm. It can be traced for 5 m. The second fracture shows 4 cm of upthrusting over a length of 3 m. (earthquake generated, or glacial unloading, or both).

NB04 **ADAMS, J. 1981. Postglacial faulting: A literature survey of occurences in eastern Canada and comparable glaciated areas. Atomic Energy Commission of Canada, Report TR-142.** Fredricton N.B. beside the Mactaquac dam. Faults offset glacial striae in greywacke outcrops. The vertical displacement is 2 to 3 cm and is subparallel to the main cleavage. Throws on most offsets are up to the west-northwest, but some are in the opposite direction. The faulting may either by due to frost heaving or to tectonic movement.

NB05 **FYFFE, L. and PRONK, A. 1985. Bedrock and surficial geology: rock and till geochemistry in the Trousers Lake area, Victoria County, New**

Brunswick. New Brunswick Dept. of Natural Resources Report 20: 69-70. Indian Lake, central New Brunswick. The top 1-2 m of weathered granite underlying Wisconsin ablation and basal till has been deformed. Aplite dykes, granite breccia, and joints are curved to the east, implying a shearing force in that direction. There was also injection of bedrock into the till while the till and weathered granite were saturated with water. Striae indicate glacier movement towards 90-100°.

NB06 RAPPOL, M. 1989. Glacial history and stratigraphy of north-western New Brunswick. Géographie physique et Quaternaire 43: 191-206. St-Leonard. He describes deformation of sub-till fine-grained laminated sediments by over-riding of latest late Wisconsinan ice and till. Photos show drag folds and overturned beds about 1 m high indicating movement to the northwest. Also, up-glacier dipping till wedges form the core of a tight recumbent fold. Rappol (unpub.) reports that small scale structures formed as a result of subglacial shearing are observed 'almost everywhere' where there is good exposure. There are also some detatchments of deformed blocks of several cubic metres.

NB07 RAPPOL, M. 1986. Aspects of ice flow pattern, glacial sediments, and stratigraphy in northwest New Brunswick. Geological Survey of Canada Paper 86-lB: 223-23l. Long Lake, Maine. Deformed subtill deltaic gravels reveal a drag structure and recumbent fold with a slightly up-glacier dipping axial surface. The structure is 1-2 m in size. Deformation relates to the Late Wisconsin glaciation.

NB08 DREDGE, L. A. Unpublished data from Edmunston, NB. Small high angle postglacial faults on striated slate surfaces, on numerous outcrops throughout the area. Individual throws are up to 2 cm, and lateral displacement is 0-2 mm.They are thought to be a response to glacial unloading.

NB09 RAPPOL, M. Unpublished data from St-Jacques NB. Offset glacial striae were observed on a flat topped ridge of slate that trends 045°. The fracture displacing the striae strikes nearly parallel to the ridge. Vertical displacement reaches 7 to 8 cm. The slates are well-cleaved, and large blocks of slate are incorporated into the till.

NB10 BROSTER, B.E. and SEAMAN, A.A. 1991. Glacigenic rafting of weathered granite: Charlie Lake, New Brunswick. Canadian Journal Earth of Sciences 28: 649-654. Charlie Lake. Weathered granite was thrust as imbricated rafts under basal till. The rafts vary from 0.3 to 2 m in thickness and are separated by glacigenic fault planes.

NB11 ?

QU01 DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. PARENT, M. Unpublished data from the Magdalen Islands, QU. All the islands have been glacially tectonized. Various materials exhibit ductile and brittle deformation. Grosse Ile. Crumpled 1 m high overturn folds and boudinaged lenses in sandstone regolith, with disconnected blocks of fresh sandstone are less than 2 m in amplitude. Deformation occurred during an early or (less likely) Late Wisconsin glaciation.

QU02 DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. PARENT, M.

Unpublished data from the Magdalen Islands, QU. Grande Entrée. Small blocks of sandstone and regolith about 50 cm thick have been thrust uphill towards the southeast, and incorporated into melanges of rock and till. Deformation is presumed to be Early to Late Wisconsinan.

QU03 DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema,Rotterdam, p. 183-195. PARENT, M. Unpublished data from the Magdalen Islands, QU. Wolf Island. Structures in sandstone include crumpling, flexures, arches and parallel folds, with incorporation of overlying sand and till. Disturbance is less than 1 m deep. The presumed age is Early Wisconsinan, with stress towards the southeast.

QU04 DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. PARENT, M. Unpublished data from the Magdalen Islands, QU. Havre aux Maisons. A sandstone bedrock slab has been detached and thrust over the till.

QU05 DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. PARENT, M. Unpublished data from the Magdalen Islands, QU. Roadway, Havre aux Maisons. Small normal and reverse faults have been generated by brittle deformation in sandstone bedrock directly under diamictons The upper beds are overturned.

QU06 DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. The upper m of sandstone has fracture cleavage and bending of beds towards 120-160° over minute glide planes. Deformation occurred during an Early Wisconsin glaciation.

QU07 DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. PARENT, M. Unpublished data from the Magdalen Islands, QU. Millerand. Till has been injected into underlying interglacial sand beds, and formed clastic dykes less than 1 m in size. The features indicate glacial overriding towards the southeast in Early Wisconsinan time. Sands were probably frozen when deformed.

QU08 DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. Portage du Cap. A large recumbent fold of interglacial gravels underlying diamicton is about 2 m high and 7 m long. Deformation occurred by early Wisconsinan glaciers. The sands were either unfrozen or else ice-rich (ductile).

QU09 DREDGE, L.A. and GRANT, D.R. 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a

regional grounded ice sheet. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 183-195. Des Buttes. The knoll consists of a melange of sandstone, interglacial beds and diamicton. The exposure in about 200 m wide and 2 m high, but the deformed block is thicker. It was probably frozen to the base of an Early Wisconsinan glacier, sheared, transported, and churned. Structures include ptygmatic folds, boudins, till wedges and thrust sandsone sheets. The interglacial sands indicate transport of more than 1 km.

QU10 VEILLETTE, J. J. Unpublished observations from Gaspé and Abitibi areas, QU. Gaspé. Vertically cleaved slates have been bent over in a north northeastern direction by late Wisconsin ice. Bending was observed in the upper 30-60 cm of trenches.

QU11 RAPPOL, M. Unpublished data from Packington QU. Fractured and overturned slate slabs lie at the base of Late Wisconsin till.

QU12 LEE, H.A. 1963. Field trip guide of the Friends of the Pleistocene, Riviere-du-Loup, Québec, Canada. May 25-26, 1963. RAPPOL, M. in press. Glacial history of lower St. Lawrence and western Gaspé, Québec. Geological Survey of Canada Paper. St. Antonin moraine area. The top late Wisconsinan till is heavily jointed along sub-horizontal shear planes which penetrate underlying late-glacial marine sediments. There is also down-glacier dipping normal faults in marine silt and sand. In another pit there are drag folds in late glacial marine silt and sand deformed by overriding late Wisconsinan ice in a style typical of subglacial shearing. Ice movement was to the northwest.

QU13 LEE, H.A. 1963. Field trip guide of the Friends of the Pleistocene, Riviere-du-Loup, Quebec, Canada. May 25-26, 1963. RAPPOL, M. in press. Glacial history of lower St. Lawrence and western Gaspe, Quebec. Geological Survey of Canada Paper. 5 km north of St-Modeste. Delta gravels show deformation structures, some of which are due to shearing during overriding of glaciers and till deposition. Dionne also noted deformation structures in marine prodeltaic sand and clay where deltas were overridden. Ice flow was eastward.

QU14 LEE, H.A. 1963. Field trip guide of the Friends of the Pleistocene, Rivière-du-Loup, Quebec, Canada. May 25-26, 1963. RAPPOL, M. in press. Glacial history of lower St. Lawrence and western Gaspé, Québec. Geological Survey of Canada Paper. St-Arsène. Lee noted anticlinal fault blocks in marine sediments and attributed them to glaciotectonic overriding.

QU15 LEE, H.A. 1963. Field trip guide of the Friends of the Pleistocene, Riviere-du-Loup, Quebec, Canada. May 25-26, 1963. RAPPOL, M. in press. Glacial history of lower St. Lawrence and western Gaspé, Québec. Geological Survey of Canada Paper. At St-Antonin there are striations on slickensided shear planes within till, oriented east-west. Shear planes dip west.

QU16 SCHROEDER, J., BEAUPRÉ, M. and CLOUTIER, M. 1990. Substrat glaciotectonisé et till syngénétique à Pont-Rouge, Québec. Géographie physique et Quaternaire 44: 33-42. Pont-Rouge (Donnacona). Ice push forms were observed in highly deformed limestone beds, including dislocated and rotated joints with injected till, and folded bedrock with till cores in the nose (about 5 m wave amplitude). The deformation is Late Wisconsinan in age.

QU17 CHALMERS, R. 1897. Report on the surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report X, part J, 160 p. Cambro-Silurian slates have small reverse faults. Striae can be traced across the faults. At Ste-Marguerite (east of Jersey Mills), glacially striated slates 2-3 m thick have been dislocated 1.3 m. Downthrow is on the north. Other minor dislocations of 8 to 10 cm also occur.

QU18 **CHALMERS, R. 1897. Report on the surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report X, part J, 160 p.** Cambro-Silurian slates have small reverse faults. Striae can be traced across the faults. Near the mouth of the Gilbert River. Bedrock has been dislocated from 30 to 40 cm, with downthrow to the north.

QU19 **CHALMERS, R. 1897. Report on the surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report X, part J, 160 p.** Cambro-Silurian slates have small reverse faults. Striae can be traced across the faults. East of Jersey Mills faults in slate have a downthrow of 8 cm on the southeast.

QU20 **CHALMERS, R. 1897. Report on the surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report X, part J, 160 p.** Cambro-Silurian slates have small reverse faults. Striae can be traced across the faults. International boundary on old Kennebec road. Striated Cambrian slates are dislocated from 8-16 cm or more in a number of places. Downthrown is on the north side (surfaces are heavily weathered).

QU21 **OLIVER, J., JOHNSON, T. and DORMAN, J. 1970. Postglacial faulting and seismicity in New York and Quebec. Canadian Journal of Earth Sciences 7: 579-590.** All faults occur in slates and throws are 5 cm or less. The authors attribute the faulting to glacial unloading and consequent expansion of the slates. St-Benoit. Faulted outcrop is located on the right about 15 m near a new (1970) cut in the road from St-Honoré to St-Benoit about 8 km from St-Benoit. The fault strike is 70° and is raised 5 cm on the south side. Strike of rock cleavage is 70°. Striae trend 302°.

QU22 **CHALMERS, R. 1897. Report on the surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report X, part J, 160 p.** Cambro-Silurian slates have small reverse faults. Striae can be traced across the faults. At St Evariste de Forsyth, Beauce County, the fault showed displacements since the glacial period, and consists of a band of slate 200 m long thrust upward 2 m. above the general rock surface level. Pressure seems to have been from the south. Fault dips are 30° S. The edges of all the slate bands are striated by ice which moved S 56° E. Measurements: Fault strike = 62°, Raised side = S, Amount = 2 cm. Fault: strike = 62°, Dip = SSE 73°, Striae = 298°.

QU23 **OLIVER, J., JOHNSON, T. and DORMAN, J. 1970. Postglacial faulting and seismicity in New York and Quebec. Canadian Journal of Earth Sciences 7: 579-590.** St-Romain. Postglacial faults are located 1.6 km east of St-Romain on the east side of Route 28. Fault: strike = 24°, raised side = S, amount = 2 cm. Cleavage: strike = 24°. Striae = 307º. Surface dip = NE and gentle.

QU24 **CHALMERS, R. 1897. Report on the surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report X, part J, 160 p.** Cambro-Silurian slates have small reverse faults. Striae can be traced across the faults. MacLeod crossing, CPR, East of Scotstown: glaciated surfaces (slate) have been dislocated 8 or more cm with downthrow to the north.

QU25 **OLIVER, J., JOHNSON, T. and DORMAN, J. 1970. Postglacial faulting and seismicity in New York and Quebec. Canadian Journal of Earth Sciences 7: 579-590.** Scotstown, located 50 m N of McLeod crossing along the railroad tracks. Fault:Strike = 45°, raised side = N, amount = 0.5 cm. Cleavage: strike = 45°, dip = 67°. Surface dip = W and gentle. Striae = 290°.

QU26 **CHALMERS, R. 1897. Report on the surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report X, part J, 160 p.** Cambro-Silurian slates have small reverse faults. Striae can be traced across the faults. On the road leading from Sherbrooke to Stoke Centre 8 to 9 km from St Francois River. Dislocations from 5 to 15 cm occur in slate.

QU27 **CHALMERS, R. 1897. Report on the surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report X, part J, 160 p.** Cambro-Silurian slates have small reverse faults. Striae can be traced across the faults. West of Richmond Junction, Grand Trunk Railway. Glaciated slates are dislocated 8 cm.

QU28 **OLIVER, J., JOHNSON, T. and DORMAN, J. 1970. Postglacial faulting and seismicity in New York and Quebec. Canadian Journal of Earth Sciences 7**: 579-590. St Denis de Brompton. Located east of St. Denis where a power line crosses the road which is sunk in a cut for a short distance is a possible fault with 15 cm offset and south side raised. No continuous offset striations were observed but the outcrop surface on both sides of the fault is polished and striated, and there is a small zone of crushed slate at the foot of the large offset. Fault: strike = 48°, amount = 0.5 cm, raised side = N.

QU29 **CHALMERS, R. 1897. Report on the surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report X, part J, 160 p.** West side of Orford Mountain. Cambro-Silurian slates have small reverse faults. Striae can be traced across the faults. Glaciated rock is dislocated 10 to 12 cm and downthrown to the north towards the mountain.

QU30 **OCCHIETTI, S. 1977. Stratigraphie du Wisconsinien de la région de Trois-Rivières-Shawinigan, Québec. Géographie physique et Quaternaire 31: 307-322.** St Narcisse moraine near Trois-Rivieres, PQ. Much of the ridge is formed by thrusting and compression because of the 'structures en écailles' found throughout the length of the moraine. This follows Lavrushin's (1971) interpretations. These thrusts are dm to m thick and dip up-glacier. St-Etienne-des-Gres: till has been thrust over glaciofluvial material, and capped by ablation till.

QU31 **OCCHIETTI, S. 1977. Stratigraphie du Wisconsinien de la région de Trois-Rivières-Shawinigan, Québec. Géographie physique et Quaternaire 31: 307-322.** St Casimir. Shear moraine reported.

QU32 **OCCHIETTI, S. 1977. Stratigraphie du Wisconsinien de la région de Trois-Rivières-Shawinigan, Québec. Géographie physique et Quaternaire 31: 307-322.** Small step fractures in sands under till are exposed along the Yamachiche River.

QU33 **PARENT, M. and OCCHIETTI, S. 1988. Late Wisconsinan deglaciation and Champlain Sea invasion in the St. Lawrence valley, Quebec. Géographie physique et Quaternaire 42: 215-246.** Trois Rivières area. St-Louis-de-France moraine is a ridge 24 m wide and 5 m high composed of imbricated, north-dipping thrust slices. Shear structures indicate the ridge formed at the margin of grounded ice undergoing compressive flow.

QU34 **BALLIVY, G., LOISELLE, A., DURAND, M. and POIRIER, M. 1977. Caracteristiques géotectoniques du secteur du Parc Olympique, Montréal. Canadian Geotechnical Journal 14: 193-205. GRICE, H. 1972. Engineering**

geology of Montreal. 24th International Geological Congress, Guidebook B-18, p.11. DURAND, M. and BALLIVY, G. 1974. Particularités rencontrées dans la région de Montréal resultant de l'arrachement d'écailles de roc par la déglaciation. Canadian Geotechnical Journal 11: 302-306. PRICHONNET, G., DURAND, M., ELSON, J. GAGNON, P., SCHROEDER, J. and VEILLETTE, J. 1987. Wisconsinan glaciations and deglaciations in southern Quebec. XII Inqua Congress Field Excursion Guide Book A-7/C-7, p.13-16 and 41-44. Montreal Island. Deformation of Ordovician limestone occurs over a thickness of about 25 m. Reverse faults, open joints, and medium compression folds are the result of tearing out of bedrock slices up to 1 square km in area. Décollements are related to low dip of the limestone, a weak layer at depth and horizontal forces exerted by glaciers. At Saguenay St., Ville St-Leonard, four galleries, roughly 3 m wide and 2 m high, totalling a length of 418 m, have been created in horizontally bedded limestone and shale. Galleries are 2-6 m below the surface. Their roofs follow the lower surface of a limestone bed. Opposite sides dovetail, as do roofs with floors; thus a mechanical, rather than karstic origin is proposed. They are interpreted as energy transfer and tractive shear forces by late Wisconsin ice creating slippage along less competent beds and then opening subvertical tension joints between the slippage planes. Galleries are controlled by pre-existant joint systems with strike slip faults. Ice thrust was from the northwest and north. There are postglacial marine clays and till in some cavities. *urban development hazard.

QU35 BALLIVY, G., LOISELLE, A., DURAND, M. and POIRIER, M. 1977. Caracteristiques géotectoniques du secteur du Parc Olympique, Montréal. Canadian Geotechnical Journal 14: 193-205. GRICE, H. 1972. Engineering geology of Montreal. 24th International Geological Congress, Guidebook B-18, p11. DURAND, M. and BALLIVY, G. 1974. Particularités rencontrées dans la région de Montréal resultant de L'arrachement d'écailles de roc par la déglaciation. Canadian Geotechnical Journal 11: 302-306. PRICHONNET, G., DURAND, M., ELSON, J. GAGNON, P., SCHROEDER, J. and VEILLETTE, J. 1987. Wisconsinan glaciations and deglaciations in southern Quebec. XII Inqua Congress Field Excursion Guide Book A-7l/C-7, p.13-16 and 41-44. Rocks beneath the Olympic velodrome foundation between Pie IX and Viau St. Rock is dislocated, displaced and stretched (open fractures) over a length of about 60 m. Displacement is to the south-southwest. There is about 1 square km of displaced rock, and transport was several dozen metres, based on disrupted dykes. Associated with the dislocation are fractured and folded rock, and voids are partly infilled with till and marine clay. One displaced block is about 6 m thick; the decollement was along a 5 cm layer of plastic clayey shale which was saturated.

QU36 BALLIVY, G., LOISELLE, A., DURAND, M. and POIRIER, M. 1977. Caracteristiques géotectoniques du secteur du Parc Olympique, Montréal. Canadian Geotechnical Journal 14: 193-205. GRICE, H. 1972. Engineering geology of Montreal. 24th International Geological Congress, Guidebook B-18, 11 p. DURAND, M. and BAILLIVY, G. 1974. Particularités rencontrées dans la région de Montréal resultant de L'arrachement d'écailles de roc par la déglaciation. Canadian Geotechnical Journal 11: 302-306. PRICHONNET, G., DURAND, M., ELSON, J. GAGNON, P., SCHROEDER, J. and VEILLETTE, J. 1987. Wisconsinan glaciations and

deglaciations in southern Quebec. XII Inqua Congress Field Excursion Guide Book A-7/C-7, p.13-16 and 41-44. Pointe Claire. A Trenton limestone slab is thrust over the base of a till in a section exposed along the Metropolitan between des Sources and St Jean. Diagram in Grice, 1972, p11.

QU37 **SCHROEDER, J., BEAUPRÉ, M. and CLOUTIER, M. 1986. Ice-push caves in platform limestones of the Montreal area. Canadian Journal of Earth Sciences 23: 1842-1851.** Montreal area. Cave systems hundreds of metres long were created by tension and shearing of thinly interbedded limestone and shale. The uppermost 10 m of the limestone was broken up in mid-Wisconsinan time, and sliding occurred in late Wisconsinan. There is no surface expression except for occasional collapse features. The galleries in the caves are thought to be glaciotectonic because the sides fit together. Some of these are reported by Durand.

QU38 **SCHROEDER, J., BEAUPRÉ, M. and CLOUTIER, M. 1986. Ice-push caves in platform limestones of the Montreal area. Canadian Journal of Earth Sciences 23: 1842-1851. STANSFIELD, J. Unpublished data from Montréal area.** Cave systems hundreds of metres long have been created by tension and shearing of thinly interbedded limestone and shale. The uppermost 10 m of the limestone was broken up in mid-Wisconsinan time, and sliding occurred in late Wisconsinan . There is no surface expression except for occasional collapse features. The galleries in the caves are thought to be glaciotectonic because the sides fit together. Some of these are reported by Durand. On Beaudry St. between Craig and Notre Dame Streets consolidated till has been folded into anticlinal and synclinal structures, possibly due to readvance of an ice sheet.

QU39 **SCHROEDER, J., BEAUPRÉ, M. and CLOUTIER, M. 1986. Ice-push caves in platform limestones of the Montreal area. Canadian Journal of Earth Sciences 23: 1842-1851.** Cave systems hundreds of metres long have been created by tension and shearing of thinly interbedded limestone and shale. The uppermost 10 m of the limestone was broken up in mid-Wisconsinan time, and sliding occurred in late Wisconsinan . The features have no surface expression except for occasional collapse structures. The galleries in the caves are thought to be glaciotectonic because the sides fit together. Some of these are also reported by Durand.

QU40 **VEILLETTE, J. J. Unpublished observations from Abitibi area.** All features are Holocene, probably 8-9 ka. and lie north of the Cochrane ice limit. Iceberg furrows of various sizes up to 10 km long and 200 m wide are found where Labradorean and Hudsonian ice calved off into Glacial Lake Ojibway during the Cochrane readvances. Small overturns and gouge structures in furrows and berms are incised into the Cochrane till. Small deformation folds and drag structures in Lake Ojibway varves were observed where Cochrane ice scraped across lake sediment and eskers.

QU41 **MORNER, N.A. Unpublished observations from Poste-de-la-Baleine.** Striated and grooved bedrock surfaces are fractured, often with one side uplifted relative to the main surface. There are numerous examples, some with hundreds of mm of vertical offset. Morner hypothesizes that these features are glaciotectonic structures rather than frost heave forms.

MA01 **DREDGE, L.A. and NIXON, F.M. 1992. Glacial and environmental geology of northeastern Manitoba. Geological Survey of Canada Memoir 432, 80p.** Folds and contortions in the upper 3 m of Lake Agassiz varved clays are exposed in sections along the North Knife River. The deformation occurred near the

Hudsonian ice margin, where the margin surged into Lake Agassiz. The deformed lake clays are commonly overlain by, and reformed into, a clay till.

MA02 **WOODWORTH-LYNAS, C. and GUIGNE, J. 1990. Iceberg scours in the geological record: examples from glacial Lake Agassiz. Geological Society of America Special Publication 53: 217-223.** Deformation structures in glacial lake clays near Winnipeg relate to the surging of glaciers and claving of icebergs from the ice margin. Shallow-angle faults and sub-horizontal thrust faults are developed below the scour troughs. Disturbance layers are up to 3 m thick. The faults formed by vertical and horizontal loading of the glacial lake bed by moving iceberg keels.

MA03 **DREDGE, L.A. and COWAN, W.R. 1989. Quaternary geology of the southwestern Canadian Shield. In Chapter 3 of "Quaternary Geology of Canada and Greenland," R.J. Fulton (ed.). Geological Society of America, The Geology of North America K-1: 214-235.** Northern Ontario. Folds and contortions are found in the upper 3 m of Lake Agassiz varved clays near the Hudsonian ice margin, where the margin surged into Lake Agassiz. The deformed lake clays are commonly overlain by, and reformed into, a clay till. In some places these deformation zones are associated with parallel, long, narrow flutes ending in iceberg scour marks. Iceberg gouges with surrounding furrows, some several km long, straight or arced, formed where late glacial ice (Holocene) surged into Glacial Lake Agassiz and Lake Ojibway.

ON01 **OLIVER, J., JOHNSON, T. and DORMAN, J. 1970. Postglacial faulting and seismicity in New York and Quebec. Canadian Journal of Earth Sciences 7: 579-590.** Flanders, Ont. Outcrop on the right of the road going west, located 200 m east of Flanders Road on Route 11. Faults occur in slates and throws are less than 25mm. The authors attribute the faulting to glacial unloading and consequent expansion of the slates.

ON02 **LAWSON, A.C. 1911. On some postglacial faults near Banning, Ontario. Seismological Society of America Bulletin 1: 159-166.** Along the line of the Canadian Northern Railway 8 km west of Banning (22 telegraph poles west of mile post 164 on the south side of the track). Glacially striated rocks are dark gray, phyllitic slates, distinctly bedded and evenly fissile in planes parallel to the bedding. The strike of the rocks is N81°E and dip is to the north at 65°. The basement faults are reverse and have their north sides upthrown. There are no slickensides on the fault planes and no horizontal component to the movement (by observing the displacement of the striae). Across 20 m there were 24 faults with an average height of 25 mm and a maximum height of 10 cm. The faults can be traced for 5 to 20 m along the strike.

ON03 **LEGGETT, R.F. and BARTLEY, M.W. 1953. An engineering study of glacial deposits at Steep Rock Lake, Ontario. Economic Geology 48: 513-540.** North of Steep Rock Lake. Apparent faulting is revealed in the face of a gravel pit cut into a kame deposit. Sharp shear failure planes are considered not to be a result of melting of buried ice blocks, but to recent crustal movement. This site is near areas where slates are faulted.

ON04 **OLIVER, J., JOHNSON, T. and DORMAN, J. 1970. Postglacial faulting and seismicity in New York and Quebec. Canadian Journal of Earth Sciences7: 579-590.** Shebandowen. Faults in slates are due to glacial unloading. They are located 150 m west of the first railroad crossing on Route 11 after routes 11 & 17 split. Several offset outcrops occur in this area.

ON05 **OLIVER, J., JOHNSON, T. and DORMAN, J. 1970. Postglacial faulting and seismicity in New York and Quebec. Canadian Journal of Earth Sciences7: 579-590.** Beardmore.Several faulted reddish outcrops are located on the hillside to the left going east on Route 11 between Beardmore and Jackpine. Faults occur in slates and throws are less than 25 mm. The authors attribute the faulting to glacial unloading and consequent expansion of the slates.

ON06 **HICOCK, S.R. 1987. Genesis of carbonate till in the lee sides of Precambrian Shield uplands, Hemlo area, Ontario. Canadian Journal of Earth Sciences 24: 2004-2015.** Geraldton. Hickock reports numerous small-scale glaciotectonic structures in till sections. All structures listed are Late Wisconsinan in age; none have surface expressions. In most cases low sediment pore water pressure, rather than permafrost, was a factor in tectonization. Features at Geraldton include mud and sand-filled extension fractures 0.2m long, shear planes in till, and displaced bedrock slabs separated from in situ rock by till.

ON07 **OLIVER, J., JOHNSON, T. and DORMAN, J. 1970. Postglacial faulting and seismicity in New York and Quebec. Canadian Journal of Earth Sciences7: 579-590.** Longlac. Faulted outcrop on the north side of Route 11 about 16km west of Longlac, 91 m before shaft #1 of a gold mine. Faults occur in slates and throws are less than 25 mm. The authors attribute the faulting to glacial unloading and consequent expansion of the slates.

ON08 **HICOCK, S.R. 1987. Genesis of carbonate till in the lee sides of Precambrian Shield uplands, Hemlo area, Ontario. Canadian Journal of Earth Sciences 24: 2004-2015.** Hickock reports numerous small-scale glaciotectonic structures in till sections. All structures listed are Late Wisconsinan in age; none have surface expressions. In most cases low sediment pore water pressure, rather than permafrost, was a factor. Features include till wedges up to 1 m long extending into underlying sand, sand filled extension fractures 10 m long, small sigmoidal sand-filled tension gashes, subparallel shear surfaces, some sand-filled, up to 5 m long, and a faulted boulder within till.

ON09 **LIBERTY, B.A. 1969. Paleozoic geology of the Lake Simcoe area, Ontario. Geological Survey of Canada Memoir 355, 201 p.** 11 km NE of Kirkfield, Ont. Normal faults with small displacements occur in the Bobcaygeon Fm. Linears have a relief from a few mm to 2 m and a lateral extent of 0.4 to 0.8 km. Slabs on the flanks of the linears appear to dip in opposite directions. They are thought to be post-glacial because the linears have not been eroded away by glacial ice movement, and to be the result of a vertical stress release mechanism.

ON10 **CUSHING, H.P., FAIRCHILD, H.L., RUEDEMANN, R. and SMYTH, C.H. 1910. Geology of the Thousand Islands region. New York State Museum Bulletin 145, 182 p.** At least 6 examples of low folds, pop-ups or buckles of the surface rocks are exposed. The author attributed deformation to postglacial warping indicating compression from the NE. 3 sites are in limestones and at least one occurs in Potsdam sandstone. These features could relate to regional continental tectonics, or to glacial unloading. A fold in Potsdam sandstone 3.2 km south of Chippewa Bay is 40 m long and trends N28°W. It rises sharply from the surface of an extensive plain. The structure is underlain by nearly horizontal sandstone. The feature is buckled to a height of 4 m, and striations show that buckling occured since glaciation. A single set of prominent joints appears at right angles to the axis of the fold. A fold in Lowville Limestone covered with soil is the same length as the previous fold and buckled up the same amount. The axis trends to the NW.

ON11 **DREIMANIS, A. Unpublished data for Lake Erie area. DREIMANIS, A. 1958. Wisconsin stratigraphy at Port Talbot on the north shore of Lake Erie, Ontario. Ohio Journal of Science 58: 65-84. DREIMANIS, A. 1982. Two origins of the stratified Catfish Creek Till at Plum Point, Ontario. Boreas 11: 173-180. DREIMANIS, A. 1987. The Port Talbot interstadial site, southwestern Ontario. In Roy, C.D. (ed.), Geological Society America, Centennial Field Guide, Northeastern Section, p. 345-348. DREIMANIS, A., HAMILTON, J.P. and KELLY, P.E. 1987. Complex subglacial sedimentation of Catfish Creek Till at Bradtville, Ontario, Canada. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p.73-86. DREIMANIS, A. and KARROW, P. 1965. Southern Ontario. In Goldthwait, R. (ed.), Guidebook for Field Conference G, Great Lakes-Ohio River valley, International Union of Quaternary Research, VII Congress, p. 90-110. DREIMANIS, A. and PACKER, R. 1959. Field trip guide, Friends of the Pleistocene, eastern section, London, Canada, p. 1-23. HICOCK, S.R. and DREIMANIS, A. 1985. Glaciotectonic structures as useful ice-movement indicators in glacial deposits: four Canadian case studies. Canadian Journal of Earth Sciences 22: 339-346. MORNER, N. and DREIMANIS, A. 1973. The Erie interstade. Geological Society of America Memoir 136: 107-134.** Many small scale features in S. Ontario are less than 0.5 m high, and include shear planes, recumbent folds, sets of crevasses, wedges and dykes. They are exposed in sections with subglacial sediments. Along the L. Erie bluffs between Tyrconnell and Pt Talbot between Waite's gully and the second gully northeast of Bradtville are deformations in the mid-Wisconsinan Tyrconnell Fm and overlying late Wisconsinan Catfish Creek till, created during the late Wisconsin advance depositing the Catfish Creek Till. Folds, tension fractures and overthrusts in the Tyrconnell silt, sand and gyttja are several m high. One till wedge is more than 10 m long. Deformations in the basal part of the Catfish Ck drift are syngenetic shear planes, recumbent folds and hook-folds, all 0.3-2 m high, and are probably formed by subsole drag. Multiple, thin, sand coated shear planes, each traceable for more than 8 m, were observed in the basal part of the Port Stanley till 1.5 km SW of Port Talbot. The sands are sheared laminae from the Late Wisconsin Erie Interstade deposits and were emplaced during the Late Wisconsinan event depositing the Port Stanley Till.

ON12 **DREIMANIS, A. Unpublished data for Lake Erie area. DREIMANIS, A. and KARROW, P. 1965. Southern Ontario. In Goldthwait, R. (ed.), Guidebook for Field Conference G, Great Lakes-Ohio River valley, International Union of Quaternary Research, VII Congress, p. 90-110.** Oldham gravel pit in St. Thomas moraine, 3 km NNE of Iona Station. Port Stanley till diapirs up to 3 m high are injected upwards into the overlying crevasse fillings of sand and gravel.

ON13 **DREIMANIS, A. Unpublished data for Lake Erie area.** Port Stanley: Lake Erie bluffs on both sides of a creek gully 2-3.5 km west of the mouth of Kettle Ck. Small scale (<1 m) near vertical diapirs and tight folds of an intertill silt and sand layer and underlying till are exposed along 400 m of the bluff at the base of the cliff. The intertill layer is between the 2nd and 3rd Port Stanley till (Late Wisconsinan), counting from the top. Up to 10 m high, near-vertical diapirs of glaciolacustrine silt and clay, have been injected upwards into lacustrine sand, and are exposed for about 1.2 km west of the gully. The tops of the highest diapirs are truncated by the overlying (uppermost Port Stanley) till.

ON14 **DREIMANIS, A. Unpublished data for Lake Erie area. DREIMANIS, A. and KARROW, P. 1965. Southern Ontario. In Goldthwait, R. (ed.), Guidebook for Field Conference G, Great Lakes-Ohio River valley, International Union of Quaternary Research, VII Congress, p. 90-110. DREIMANIS, A. and PACKER, R. 1959. Field trip guide, Friends of the Pleistocene, eastern section, London, Canada, p. 1-23.** Core of Mitchell moraine south of Elginfield. Late Wisconsinan deformation includes gently folded sand and gravel covered by 3-5 m of till.

ON15 **DREIMANIS, A. Unpublished data for Lake Erie area. DREIMANIS, A. and PACKER, R. 1959. Field trip guide, Friends of the Pleistocene, eastern section, London, Canada, p. 1-23.** Arva moraine, exposed in cuts along Hwy 4. Gently folded glaciolacustrine silt and sand are covered by 2-3 m of till.

ON16 **DREIMANIS, A. Unpublished data for Lake Erie area. DREIMANIS, A. and PACKER, R. 1959. Field trip guide, Friends of the Pleistocene, eastern section, London, Canada, p. 1-23.** University of Western Ontario, London. Excavations reveal folded glaciolacustrine sand covered by till, and till wedges injected into the sand.

ON17 **LAVRUSHIN, Y. 1976. Structure and development of grounded moraines of continental glaciations. Nauka, Moscow.** Springbank Park dam, London. Thames R. exposure about 0.1 km upstream of the dam. Dykes (diapirs?) and shears in sandy drift are related to Late Wisconsinan deformation.

ON18 **DREIMANIS, A. Unpublished data for Lake Erie area. DREIMANIS, A. and PACKER, R. 1959. Field trip guide, Friends of the Pleistocene, eastern section, London, Canada, p. 1-23.** London. Crest of the Arva moraine where it truncates the Ingersoll moraine at North St and Byron. Eastward overturn folds of silt and sand are covered by a thin layer of Huron lobe till.

ON19 **DREIMANIS, A. Unpublished data for Lake Erie area.** Jaffa. Exposures in sand and gravel pits at Bradley Creek sawmill 1.5 km NW of Jaffa reveal strongly folded sand, with folds several metres high, underneath Huron Lobe Catfish Creek till. Late Wisconsinan deformation.

ON20 **DREIMANIS, A. Unpublished data for Lake Erie area. DREIMANIS, A. 1958. Wisconsin stratigraphy at Port Talbot on the north shore of Lake Erie, Ontario. Ohio Journal of Science 58: 65-84. DREIMANIS, A. 1987. The Port Talbot interstadial site, southwestern Ontario. In Roy, C.D. (ed.), Geological Society America, Centennial Field Guide, Northeastern Section, p. 345-348. DREIMANIS, A. 1982. Two origins of the stratified Catfish Creek Till at Plum Point, Ontario. Boreas 11: 113-180. DREIMANIS, A., HAMILTON, J.P. and KELLY, P.E. 1987. Complex subglacial sedimentation of Catfish Creek Till at Bradtville, Ontario, Canada. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 13-81. DREIMANIS, A. and KARROW, P. 1965. Southern Ontario. In Goldthwait, R. (ed.), Guidebook for Field Conference G, Great Lakes-Ohio River valley, International Union of Quaternary Research, VII Congress, p. 90-110. DREIMANIS, A. and PACKER, R. 1959. Field trip guide, Friends of the Pleistocene, eastern section, London, Canada, p. 1-23.** Aylmer. Sections at Catfish Ck reveal minor overturned folds at the base of and underneath the Port Stanley till. Late Wisconsinan deformation.

ON21 **DREIMANIS, A. Unpublished data for Lake Erie area. DREIMANIS, A. 1958. Wisconsin stratigraphy at Port Talbot on the north shore of Lake Erie, Ontario. Ohio Journal of Science 58: 65-84. DREIMANIS, A. 1987. The Port Talbot interstadial site, southwestern Ontario. In Roy, C.D. (ed.), Geological Society America, Centennial Field Guide, Northeastern Section, p. 345-348. DREIMANIS, A. 1982. Two origins of the stratified Catfish Creek Till at Plum Point, Ontario. Boreas 11: 113-180. DREIMANIS, A., HAMILTON, J.P. and KELLY, P.E. 1987. Complex subglacial sedimentation of Catfish Creek Till at Bradtville, Ontario, Canada. In Meer, J.J.M. van der (ed.), Tills and glaciotectonics, A.A. Balkema, Rotterdam, p. 73-86. DREIMANIS, A. and KARROW, P. 1965. Southern Ontario. In Goldthwait, R. (ed.), Guidebook for Field Conference G, Great Lakes-Ohio River valley, International Union of Quaternary Research, VII Congress, p. 90-110. DREIMANIS, A. and PACKER, R. 1959. Field trip guide, Friends of the Pleistocene, eastern section, London, Canada, p. 1-23. HICOCK, S.R. and DREIMANIS, A. 1985. Glaciotectonic structures as useful ice-movement indicators in glacial deposits: four Canadian case studies. Canadian Journal of Earth Sciences 22: 339-346.** Gullies west of Catfish Creek, 2.5 km WSW of Jaffa. Strongly folded and thrusted sand, with near-vertically deformed layers, under Huron lobe Catfish Creek till were deformed by Late Wisconsinan ice.

ON22 **BARNETT, P. and KELLY, R. 1987. Quaternary history of southern Ontario. International Union for Quaternary Research, XII Congress, Guidebook A-11.** East side of Catfish Ck, 3 km SE of New Sarum. Exposures reveal the sheared base of Port Stanley till and a downward injection dyke in the upper part of the Catfish Creek Till. Late Wisconsinan deformation.

ON23 **DREIMANIS, A. Unpublished data for Lake Erie area.** Lake Erie Bluffs on the south side of the Ridgetown moraine. Folded sand, silt ,and till, with some folds recumbent, others gently folded underlie Port Stanley till. Some folds are up to 5 m high.

ON24 **DREIMANIS, A. Unpublished data for Lake Erie area.** Lake Erie bluffs 3 km south of Eagle. About 6 m of sheared and folded silt and clay underlie 6 m of the uppermost Port Stanley till, which has some silt-coated shear planes in its basal part.

ON25 **DREIMANIS, A. Unpublished data for Lake Erie area.** Duttona Beach, Lake Erie bluffs. Sheared and reworked Catfish Ck till is incorporated into the lowest part of Port Stanley drift, under 3-5 m of typical clayey Port Stanley till. Structures are visible at lake level.

ON26 **WILSON, A. 1902. Some recent folds in the Lorraine Shales. Canadian Record of Science 8: 523-531.** North shore of Lake Ontario at Lorne Park, 22 km west of Toronto. Anticlinal folds of till and Lorraine shale are exposed in the 3-5 m high cliff along the lake. One of the folds strikes N10°W.

ON27 **KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Dept. of Mines, Geological Report 16, 68 p. KARROW, P.F. 1987. Quaternary geology of the Hamilton-Cambridge area, southern Ontario. Ontario Geological Survey Report 255, 94 p.** Toronto Township, Lot 34, Concession 4 S.D.S. Lake Ontario shore, 0.5 km east of Town Line. Contortions, folds and faults were noted in Ordovician shales, at several places, and disturbances decrease with depth, suggesting overriding ice. An alternative explanation is that they are stress-release phenomena (White et al., 1974). Some of these features were reported by Caley (1940).

ON28 **KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Dept. of Mines, Geological Report 16, 68 p. KARROW, P.F. 1987. Quaternary geology of the Hamilton-Cambridge area, southern Ontario. Ontario Geological Survey Report 255, 94 p.** Oakville, Lot 6, Concession 1, S.D.S. 0.8 km west of Queen Elizabeth Way on the east bank of small creek. Contortions, folds and faults were noted in Ordovician shales, and disturbances decrease with depth, suggesting overriding ice.

ON29 **KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Dept. of Mines, Geological Report 16, 68 p. KARROW, P.F. 1987. Quaternary geology of the Hamilton-Cambridge area, southern Ontario. Ontario Geological Survey Report 255, 94 p.** Oakville, Lot 20, concession 3 S.D.S., 0.8 km NW of Highway #2. Contortions, folds and faults were noted in Ordovician shales, at several places and disturbances decrease with depth, suggesting overriding ice.

ON30 **KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Dept. of Mines, Geological Report 16, 68 p. KARROW, P.F. 1987. Quaternary geology of the Hamilton-Cambridge area, southern Ontario. Ontario Geological Survey Report 255, 94 p.** Oakville, Lot 20, Concession 3 S.D.S., North side of Highway #2. Contortions, folds and faults were noted in Ordovician shales at several places, and disturbances decrease with depth, suggesting overriding ice.

ON31 **KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Dept. of Mines, Geological Report 16, 68 p. KARROW, P.F. 1987. Quaternary geology of the Hamilton-Cambridge area, southern Ontario. Ontario Geological Survey Report 255, 94 p.** Oakville, Lot 22, Concession B.F., Lake Ontario shore 3.2 km west of Oakville Creek (16 Mile Creek). Contortions, folds and faults were noted in Ordovician shales and disturbances decrease with depth, suggesting overriding ice.

ON32 **KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Dept. of Mines, Geological Report 16, 68 p. KARROW, P.F. 1987. Quaternary geology of the Hamilton-Cambridge area, southern Ontario. Ontario Geological Survey Report 255, 94 p.** Oakville, Lot 31, Concession 3 S.D.S., South side of QEW, top of east bank of Bronte Creek. Contortions, folds and faults were noted in Ordovician shales, and disturbances decrease with depth, suggesting overriding ice.

ON33 **KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Dept. of Mines, Geological Report 16, 68 p. KARROW, P.F. 1987. Quaternary geology of the Hamilton-Cambridge area, southern Ontario. Ontario Geological Survey Report 255, 94 p.** Burlington, Lot 5, Concession 3 S.D.S., Hendershot Paper Products railway cut. A fold, evident on ground surface as a 0,8 km long ridge of shale <1 m high trends nearly east-west. Other similiar ridges are present, all located on the Lake Iroquois plain. An alternative explanation is that they are stress-release phenomena (White et al., 1974).

ON34 **KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Dept. of Mines, Geological Report 16, 68 p. KARROW, P.F. 1987.**

Quaternary geology of the Hamilton-Cambridge area, southern Ontario. Ontario Geological Survey Report 255, 94 p. Burlington, Lot 3, Concession 2 N.D.S. 1.6 km west of Ash Station, south side of creek. There is a thrust fault in Ordovician shale with a vertical displacement of about 50 cm. It strikes north and dips about 30°E. An alternative explanation to glaciotectonism is that they are stress-release phenomena (White et al., 1974).

ON35 **DREIMANIS, A. Unpublished data for Lake Erie area. HICOCK, S. and DREIMANIS, A. 1992. Sunnybrook drift in the Toronto area Canada: reinvestigation and reinterpretation. Geological Society of America Special Paper 270: 139-161.** Gravel pit about 1 km west of Kleinburg in Humber River Valley. Strongly folded clay and sand, with folds several metres high, underlie Halton (Late Wisconsinan) till.

ON36 **DREIMANIS, A. Unpublished data for Lake Erie area. HICOCK, S. and DREIMANIS, A. 1992. Sunnybrook drift in the Toronto area Canada: reinvestigation and reinterpretation. Geological Society of America Special Paper 270: 139-161.** Humber River at Boyd Conservation Area. Strongly folded and overthrusted lacustrine silt and sand, with near-vertical thrust planes adjoin a Halton (Late Wisconsinan) till sheet.

ON37 **HICOCK, S.R. and DREIMANIS, A. 1985. Glaciotectonic structures as useful ice-movement indicators in glacial deposits: four Canadian case studies. Canadian Journal of Earth Sciences 22: 339-346.** Humber River, 0.5 km below Clairville dam. Small folds in clay till and along the contact with underlying sand were produced by syngenetic deformation during the Early Wisconsin by ice flowing SW. During Late Wisconsinan glaciation with NW ice flow the till was epigenetically deformed, producing tight folds and tensile fractures. Also, the underlying sands were liquefied under high pore pressure and were injected into the clay till along fracture planes; then both the clay till and the injections were sheared by glacier drag. Mylonitization of Dundas shale along a horizontal bedding plane was observed nearby.

ON38 **HICOCK, S.R. and DREIMANIS, A. 1989. Sunnybrook drift indicates a grounded early Wisconsin glacier in the Lake Ontario basin. Geology 17: 169-172. HICKOCK, S. and DREIMANIS, A. 1992. Sunnybrook drift in the Toronto area Canada: reinvestigation and reinterpretation. Geological Society of America Special Paper 270: 139-161.** Scarborough bluffs, Toronto. Small scale glaciotectonic deformations, including sandy shear planes and tension fractures at the base of the Sunnybrook till and into underlying sand of the Scarbough Fm, were produced by basal drag by early Wisconsinan ice.

ON39 **DREIMANIS, A. Unpublished data from Lake Erie.** Fairport Beach south of Dunbarton on the Lake Ontario shore. Silt-coated sub-horizontal shears in till and near-vertical folded varved clay are truncated by the overlying till; in another section, there are recumbent folds in till.

ON40 **KARROW, P.F. 1967. Pleistocene geology of the Scarborough area. Ontario Dept. of Mines Geology Report 46, 106 p. MOHAJER, A., EYLES, N. and ROGOJINA, C., 1992. Neotectonic faulting in Metropolitan Toronto. Geology 20: 1003-1006.** Rouge River, Scarborough. A series of folds several metres high are found within interbedded till, sand, and gravel overlain by till. Materials are mid to Late Wisconsinan age. Section is probably F246 and F113 of Karrow, 1967.

ON41 **KARROW, P.F. 1967. Pleistocene geology of the Scarborough area. Ontario Dept. of Mines Geology Report 46, 106 p.** Beachgrove Dr., Scarborough bluffs. Page 63 contains a photo of contorted stratification in Leaside till (Late Wisconsinan). Section A 1028-1029. " A complex of substratified stony till and kamey sand and gravel, all much contorted into striking folds, constitutes the entire height of the cliffs. All these materials seem related to the Leaside till. Much of this material resembles flow till. (reported as glaciotectonic on forms). Also reported are " countless numbers of small faults and folds at the base of till layers indicating drag". At Scarborough, there is a long sequence of large folds in the sections.

ON42 **KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Dept. of Mines, Geological Report 16, 68 p. KARROW, P.F. 1987. Quaternary geology of the Hamilton-Cambridge area, southern Ontario. Ontario Geological Survey Report 255, 94p.** Between Toronto and Burlington. Contortions, folds and faults were noted in Ordovician shales, and disturbances decrease with depth, suggesting overriding ice. Dip is generally westward.

ON43 **DREDGE, L.A. and COWAN, W.R. 1989. Quaternary geology of the southwestern Canadian Shield. In Chapter 3 of "Quaternary Geology of Canada and Greenland," R.J. Fulton (ed.). Geological Society of America, The Geology of North America K-1: 214-235.** Northen Ontario. In places there are folds and contortions in the upper 3 m of Lake Agassiz varved clays. The deformation occurred near the Hudsonian ice margin, where the margin surged into Lake Agassiz. The deformed lake clays are commonly overlain by, and reformed into, a clay till. Surface expression is parallel, long narrow flutes ending in iceberg scour marks, which have been plotted on regional maps. Gouges with surrounding furrows, some several km long, straight or arced, formed where late glacial ice (Holocene) surged into Glacial Lake Agassiz and Lake Ojibway and broke up. Deformed material is mainly glaciolacustrine silt and clay.

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