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THE MAKING OF THE GEOLOGICAL MAP OF EASTERN LABRADOR

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ABSTRACT

The Geological Survey of Newfoundland and Labrador recently released 25 geological maps collectively covering the whole of eastern Labrador at 1:100 000 scale. These maps are the final product of a long-term geological mapping project that commenced in 1979. This article reviews the history of geological mapping in eastern Labrador prior to 1979; gives details regarding the systematic 1:100 000-scale mapping; reviews the nature of data acquired; and addresses features of the resultant maps.

INTRODUCTION

The Geological Survey of Newfoundland and Labrador recently released 25 geological maps collectively covering eastern Labrador at 1:100 000 scale (Figure 1). These maps cover an area of roughly 80 000 km^2, representing about 20% of the land area of Province of Newfoundland and Labrador. It is equivalent to over 70% of the area of insular Newfoundland, or 0.8% of the area of Canada. The maps are the final cartographic product of a long-term geological 1:100 000-scale mapping project for eastern Labrador that commenced in 1979. This article reviews the history of previous geological mapping in eastern Labrador; gives details regarding the systematic 1:100 000-scale mapping; reviews the nature of data acquired; and addresses features of the resultant maps. The area mapped is shown in Figure 1.

PREVIOUS MAPPING

The accumulation of geological information for any particular area typically results from several information-gathering stages, each one tending to be more detailed than the previous and targeting progressively smaller segments of the area at a time. Eastern Labrador is no exception. Here, earlier mapping is divided into four stages, which are reviewed below (Figure 2).

EXPLORER STAGE (1860–1890)

The first geological map (at 1: 4 000 000) that includes eastern Labrador, of which the author is aware, is that of Lieber (1860). Oscar M. Lieber was State Geologist for South Carolina and visited Labrador in 1860 as part of the first (of four) U.S. Coast Guard Eclipse Expeditions. Lieber died at the age of 32 from wounds received in the retreat from Williamsburg in the American Civil War. He divided Labrador into three geological units, all of eastern Labrador falling into a single gneiss unit, which he termed ‘Domino’ gneiss.

The next geological map of eastern Labrador is a half-page sketch (at roughly 1: 6 000 000) by Packard (1891). Alpheus S. Packard was Professor of Zoology and Geology at Brown University, Rhode Island. Packard’s 513-page book is based on two expeditions to Labrador in 1860 and 1864 that were organized by William Bradford of New York. The preface notes that the book is “mainly based on observations and collections made by the author in his early student days” and that “the scientific results, geological and zoological, are reprinted from the Memoirs of the Boston Society of Natural History for 1867”, so, much of the information substantially predates the book’s 1891 publication year. Packard depicted most of eastern Labrador as being underlain by either ‘Laurentian gneiss’, which he described as typically syenitic and interpreted to be derived from clastic sediments, or ‘Domino gneiss’, which was described as schistose, lighter coloured gneiss with associated trap rocks. Domino gneiss was considered to be the younger of the two. Also shown are: anorthositic rocks, now mapped as the coastal part of the White Bear Arm complex; ‘Cambrian’ sediments in the Strait of Belle Isle area (Bradore and Forteau formations); and basaltic flows at Henley Harbour (Lighthouse Cove Formation).

In 1900, Reginald A. Daly (1902), an instructor in geology at Harvard University at the time, participated in an expedition along the Labrador coast. Daly’s page-sized geological sketch map of the coast of Labrador does not show any information for southern Labrador, but his text makes reference to biotite and hornblende gneiss, biotite schist and amphibolite, numerous mafic dykes, and quartz and pegmatite veins, as well as massive and gneissoid granite and

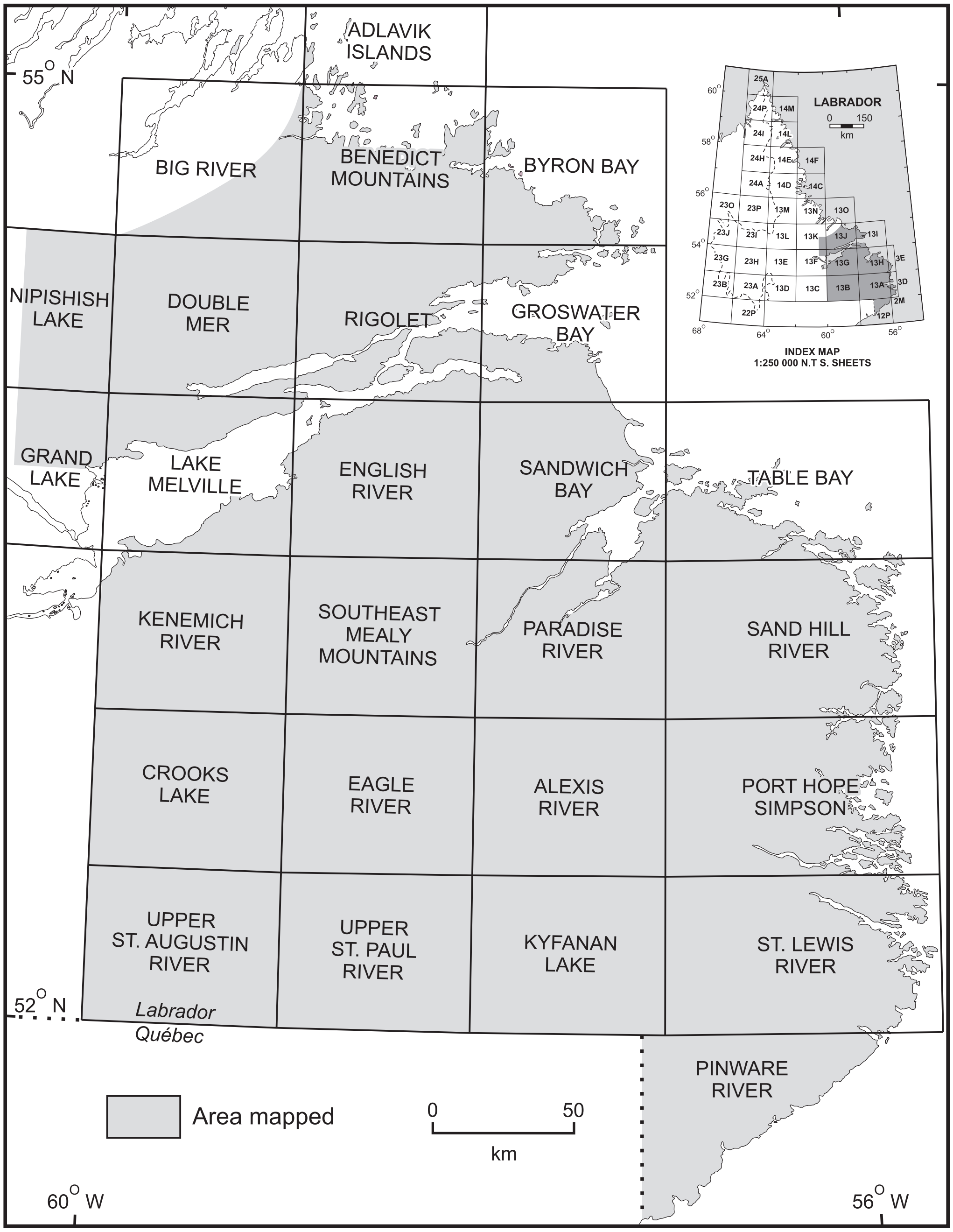

Figure 1. *Names and locations of 1:100 000-scale geological maps for eastern Labrador.*

diorites in the region. Brief discussion is given to interpretation of the Domino gneiss as quartzitic sediments, a thesis apparently shared by Packard (private communication to Daly), although not clearly stated by Packard in his book.

GOVERNMENT SURVEY COASTAL MAPPING STAGE (1895–1960)

By the end of the 'Explorer' stage of mapping, the Geological Survey of Canada was also active (Bell, 1895; Low, 1896). The reports of Bell (*op. cit.*) and Low (*op. cit.*) mention eastern Labrador, but neither is focussed on the region. The first mapping by the Geological Survey of Canada to specifically address eastern Labrador was by Kindle (1924) in the Lake Melville–Groswater Bay region (Figure 2). He included a page-sized fold-out map (1:1 013 760) of this region in his report, showing, in particular, the distribution of the Double Mer Formation, first described by Low (*op. cit.*). Kindle (*op. cit.*) noted anorthosite on the south side of Lake Melville, which constitutes the first recognition of the Mealy Mountains Intrusive suite.

A geological sketch map (at 1:2 534 400) that included parts of eastern Labrador was completed by Kranck (1939), and was the first cartographic product for the region published by the Newfoundland Geological Survey (Figure 2). He carried out his field work in 1937 and 1939 while employed as a lecturer in geology at the University of Helsinki. The most significant, previously unrecognized, feature on his map was the separation of granitoid rocks in the Makkovik Province from gneisses of the Grenville Province. Kranck (*op. cit.*) was also the first to recognize the sedimentary protolith of calc-silicate and quartz-rich clastic rocks on Battle Island and to interpret finely laminated parts of the Domino gneiss as mylonitic. He rejected earlier interpretations claiming age and protolith distinction between Laurentian and Domino gneiss. In fairness to all investigators, although these two gneisses do not correspond consistently with any units on the new 1:100 000-scale maps, this author would argue that elements can be defended from all above-mentioned interpretations regarding the two types. Both the Laurentian and Domino gneisses have igneous and sedimentary protoliths and both are mostly Labradorian or older, but the 'Laurentian' gneiss correlates spatially with those rocks most affected by Grenvillian migmatization and magmatism (Lake Melville and more southerly terranes), whereas the 'Domino' gneiss correlates with areas affected more by Grenvillian dynamic metamorphism (Groswater Bay and Hawke River terranes).

Kranck was appointed a visiting professor at McGill University in Montreal in 1948, and permanently joined the faculty in 1951. He returned to Labrador to carry out field work in 1949 between Domino and Hopedale. The results of this work (Kranck, 1953) (Figure 2) included a geological map (1:760 320) of the coast between Domino and Hopedale, on which, curiously, much of the area that he formerly separated as Makkovik granite is now re-assigned as Domino gneiss. His report gives more detailed descriptions of the various rock types present.

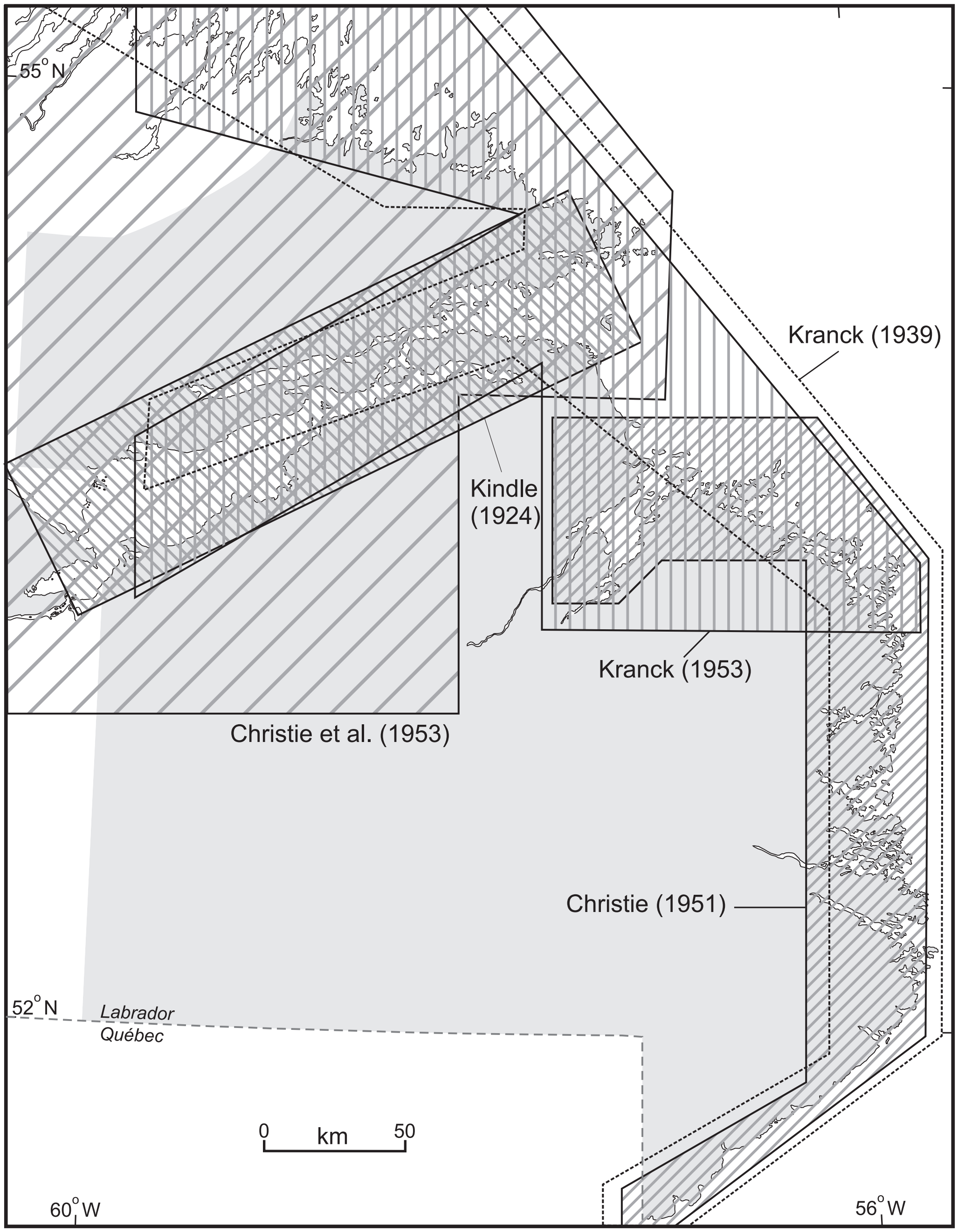

Figure 2. *Areas covered by regional geological maps prior to 1960. Boundaries generalized.*

Other government-funded projects were conducted during the same period. Douglas (1953) visited the coast of Labrador in 1946 and 1947 on behalf of the Government of Newfoundland, and Christie (1951) mapped the coast from Forteau to Cape Porcupine in 1950 for the Geological Survey of Canada. Douglas's objective was to report on economic mineral potential, rather than carry out geological mapping, but he included geological sketch maps of specific localities. Christie (1951) included a geological map at 1:253 440 scale of the coastal areas (Figure 2). The maps of both Kranck (1953; field work 1949) and Christie (1951; field work 1950) were published by the Geological Survey of Canada. They overlap between Domino and Cape Porcupine, but appear to be entirely independent of each other. An interesting detail, shown on both maps, was the discovery of a (now termed) Long Range dyke, 21 km east of Cartwright at Long Island. Both investigators seem to have mapped it independently, but, from the timing of field work and publication, it would seem that Kranck (*op. cit.*) was the first to map the dyke on Long Island but Christie's map (*op. cit.*)

was the first to depict the finding. Credit for first recognition of dyke, however, appears to go to Tanner (1944), who shows an oblique aerial photograph of the dyke in his book. Christie (*op. cit.*) also mapped two other Long Range dykes in the same area. As the location of the Long Island dyke is shown on a map by Taylor (1951), there seems little doubt that Kranck was aware of it before Christie's mapping, because Taylor (1951) accompanied Kranck in the field in 1949, and completed a M.Sc. on mafic rocks from eastern Labrador at McGill University under Kranck's supervision.

The next addition to the geological map of eastern Labrador was by Christie *et al.* (1953). The map (1:506 880) in the report covers much of Labrador, extending from south of Goose Bay in the south, to north of Nain, and from the coast westward to Lake Michikamau (Figure 2). It is a compilation map, rather than the result of additional field work, and the report notes that the eastern part of the map includes information supplied by Dome Exploration Limited, American Metals Exploration Company and Frobisher Exploration Company. The map includes the area covered by Kranck (1953), but there is no indication that Kranck's work was utilized, despite Christie *et al*. (1953) citing Kranck's (1953) report. For the first time, the extent of the anorthositic rocks of the Mealy Mountains Intrusive suite was mapped and the distribution of some distinctive syenitic rocks in the Makkovik Province was shown, some of which were also depicted by Kranck (*op. cit.*).

From 1945 onward, mineral exploration companies were active in the region, especially Brinex, and contributed much to the geological knowledge of eastern Labrador, including the preparation of regional geological maps. A review of the history of exploration activity in eastern Labrador is given by Gower (2010).

SYSTEMATIC GEOLOGICAL SURVEY OF CANADA MAPPING STAGE (1960–1975)

The 1960s heralded a new era in geological mapping in eastern Labrador, facilitated by the use of aircraft, thus removing reliance on water-borne transportation and also enabling previously inaccessible interior areas to be mapped. All the mapping during this stage was conducted by the Geological Survey of Canada (Figure 3).

The first airborne project was carried out in 1961 for NTS map areas 003D, 003E, 013A, 013B, 013G and 013H (Eade, 1962). He gained access to lakes using fixed-winged aircraft. Foot traverses were then made to nearby outcrops (lakeshore outcrop is generally sparse in the region). Mapping coverage was uneven, being controlled by lakes suitable for float-plane landings. Eade's map (1:506 880) was the first to discriminate between metasedimentary gneiss and orthogneiss and to show approximately the distribution of the White Bear Arm complex, and some other mafic intrusive bodies. He made extensive use of reconnaissance geological mapping by Brinex (*cf.* Gower, 2010 for details) and relied on previous work in coastal regions.

Farther north, in 1968, Stevenson mapped NTS map areas 013J and 013I (Stevenson, 1970) at 1:250 000 scale using helicopter access for inland regions and an inflatable boat during coastline mapping. Stevenson's map was the first in eastern Labrador to include geochronological ages (K–Ar). Armed with these ages, and mapping that demonstrated a contrast between granitoid rocks in the Makkovik Province and quartzofeldspathic gneiss in the Grenville Province, he was able to locate the approximate position of the Grenville front in the area (existence of the Grenville Province as a distinct entity within the Canadian Shield was already known). Stevenson also mapped granulite-facies rocks in the Double Mer White Hills (although these had been previously recognized by Halet, 1946), and mapped the inland distribution of various mafic intrusive rocks, including the Michael Gabbro.

In 1969, Bostock (1983) started a mapping project that included both the Labrador and Newfoundland sides of the Strait of Belle Isle. Mapping on the Labrador side (NTS map areas 012P and 002M) was carried out in 1971, using an inflatable boat for coastal work and a helicopter inland. Bostock's map (at 1:125 000 scale) depicts much of the region as being underlain by leucocratic to melanocratic gneiss, but shows remnants of metasedimentary gneiss within it. Metagabbro, mangerite and granite bodies intruding the gneiss also were mapped.

For completeness, three other projects are mentioned, although only small segments are included in the present map (Figure 3), and field data from these projects has not been captured digitally. In 1966, Williams (1970) mapped the eastern half of NTS map area 013K, of which NTS map areas 013K/01 and 013K/08 are included in the present map of eastern Labrador. The project was done by canoe and foot traverses, and serviced by fixed-wing aircraft. Williams only made brief examination of the part that is included in the 1:100 000-scale map of eastern Labrador. Granite gneiss, granite and amphibolite were the main rock types reported. In 1965, Stevenson (1967) carried out a helicopter-assisted mapping project in NTS map area 013F, of which only the northeast corner (013F/16) is included here. Between 1967 and 1971, Taylor carried out Operation Torngat (helicopter- and fixed-wing-assisted), which covered much of the Ungava peninsula. Only NTS map areas 013O/02 and 013O/03 are included in the present map (*cf.* Taylor, 1977).

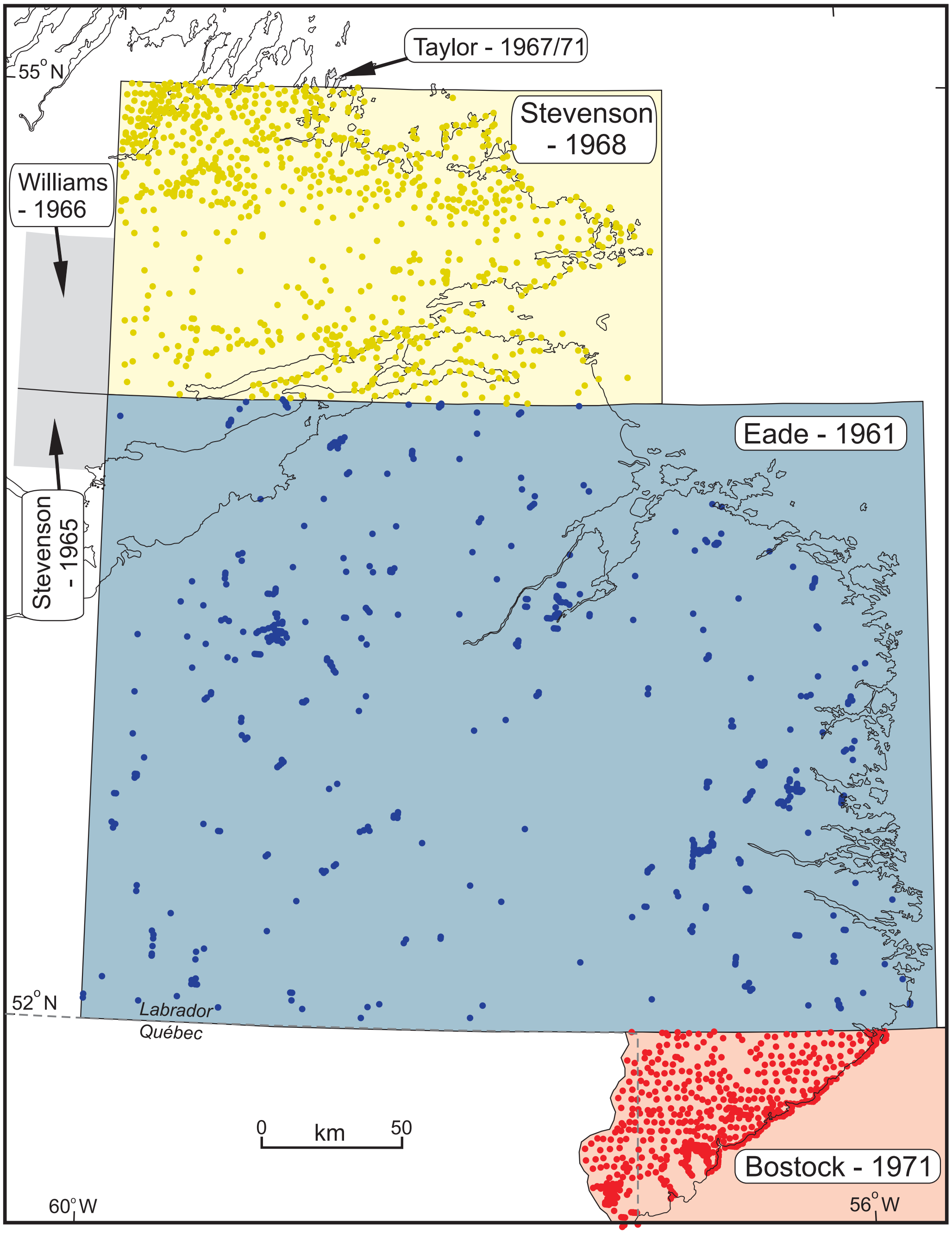

Figure 3. *Areas covered during regional geological mapping by the Geological Survey of Canada between 1960 and 1974. Data captured from projects carried out by Eade (1962), Stevenson (1970) and Bostock (1983) are shown.*

TARGETED GEOLOGICAL MAPPING STAGE (1975–1978)

After the completion of mapping by the Geological Survey of Canada, there was a brief transitional period when specific areas were targeted (Figure 4), before adopting 1:100 000-scale systematic mapping in 1979.

Two of these targeted projects were carried out in 1975. One, by Emslie (1976), targeted the Mealy Mountains Intrusive suite. Emslie distinguished between the leucotroctolitic Kennemich massif in the west and the leucogabbro(noritic) Etagaulet massif in the east, as well as mapping associated monzonitic rocks and the northeast-trending Mealy dyke swarm. Emslie's map (at 1:250 000 scale) was never formally published, although made available to the author and used by Emslie in page-size sketch form in journal publications.

The other project in 1975 was carried out by Wardle (1976, 1977) in the Alexis Bay–Snug Harbour area in southeast Labrador. Wardle (*op. cit.*) mapped migmatitic granitoid rocks and gneisses; mapped and named the White Bear Arm complex; identified and mapped the Gilbert Bay granite; and mapped both metamorphosed and unmetamorphosed mafic dykes, including a Long Range dyke that transects the area. Wardle's (1977) map marked the start of bedrock mapping at 1:100 000 scale in eastern Labrador by the Geological Survey of Newfoundland and Labrador.

The Sandwich Bay area was the next to be targeted in southeast Labrador – in 1977 (Cherry, 1978a, b). Cherry (*op. cit.*) mapped the bedrock as granitoid gneisses of various types, together with anorthositic and gabbroic bodies and mafic dykes, and also recognized a Long Range dyke on Earl Island.

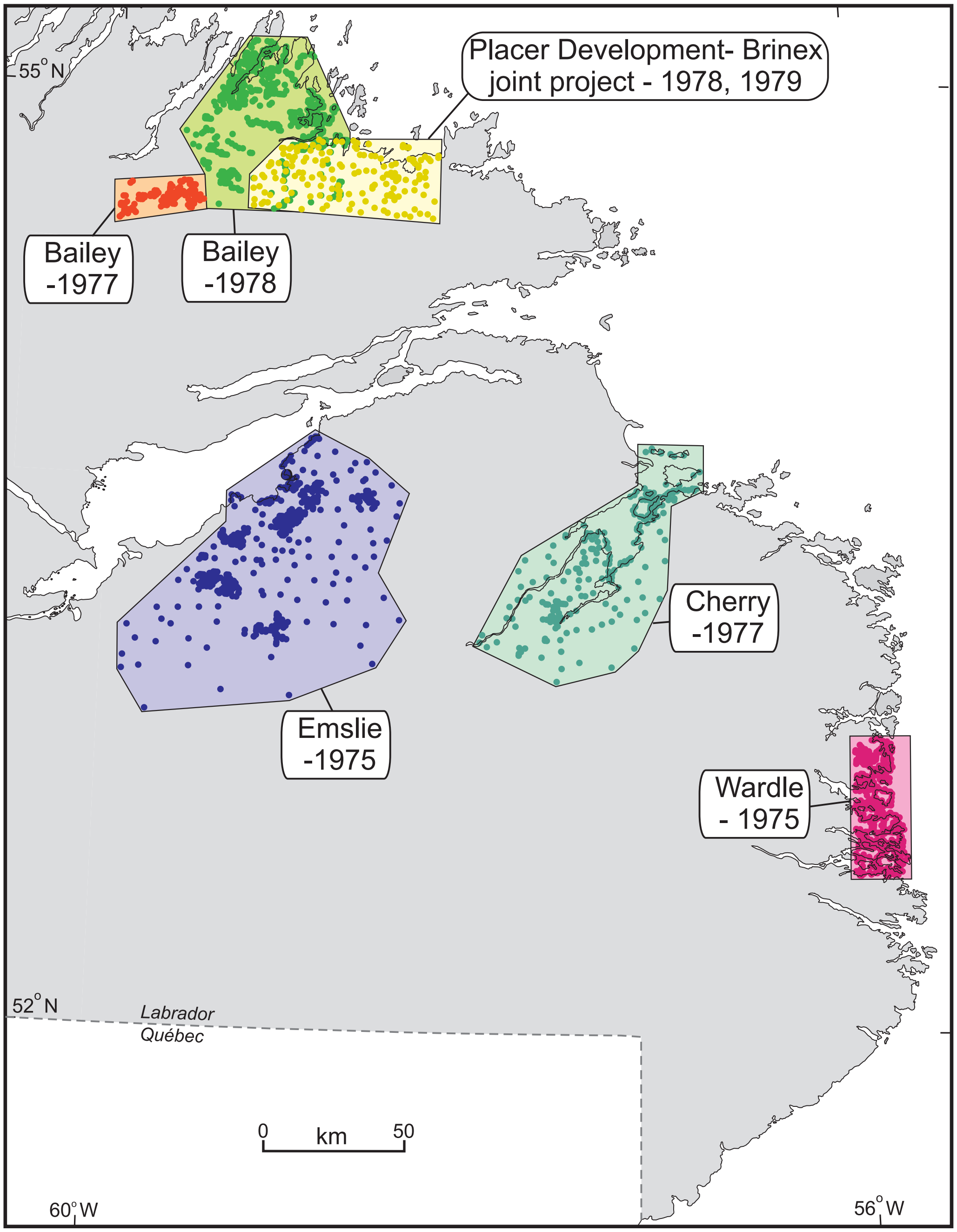

Figure 4. *Areas targeted between 1975 and 1978, also showing distribution of data stations within those areas.*

The final targeted-area projects in eastern Labrador were in the Makkovik Province, by D. Bailey in 1977 and 1978. The areas mapped largely fall outside the limits of the present map, but are mentioned here as they provide continuity to the author's own mapping. In 1977, Bailey (1978) mapped the Walker Lake–MacLean Lake area, which is underlain by felsic volcanic rocks and associated sedimentary rocks of the Aillik Group (adopting the redefined usage of Ketchum *et al.*, 2002) and intruded by 1.85 Ga Makkovikian and 1.65 Ga Labradorian granitoid rocks. This was followed by mapping of similar rocks in the Makkovik area in 1978 by Bailey *et al.* (1979); the project in the Makkovik area was completed by Gower, who produced a report and a 1:100 000-scale map (Gower *et al.*, 1982a).

One other project was carried out as a Placer Development–Brinex joint-venture exploration project (Davidson and Kowalczyk, 1979). The report from this project is an all-too-rare industry example having sufficient geological information for material to be entered into a mapping database.

SYSTEMATIC 1:100 000-SCALE MAPPING OF EASTERN LABRADOR

This stage marked the start of publication of geological maps for eastern Labrador in latitude–longitude-defined blocks, thus avoiding gaps or overlaps in coverage. The start of this period was also the time the author joined the Geological Survey of Newfoundland and Labrador.

The systematic mapping undertaken of eastern Labrador is subdivided into six stages that correlate with funding arrangements (Figures 5 and 6). These were,

i) Canada–Newfoundland Mineral Development Subsidiary Agreement 1977– 1981 (MDA I),
ii) Canada–Newfoundland Cooperative Minerals Program 1982– 1983,
iii) Canada–Newfoundland Subsidiary Agreement on Mineral Development 1984– 1989 (MDA II),

- iv) Canada–Newfoundland Agreement on Mineral Development 1991–1995 (MDA III),
- v) Provincial funding (1996–2000),
- vi) Provincial funding (post-2000). The acronym 'MDA' (Mineral Development Agreement) was the vernacular term applied to the agreements (Figures 5 and 6).

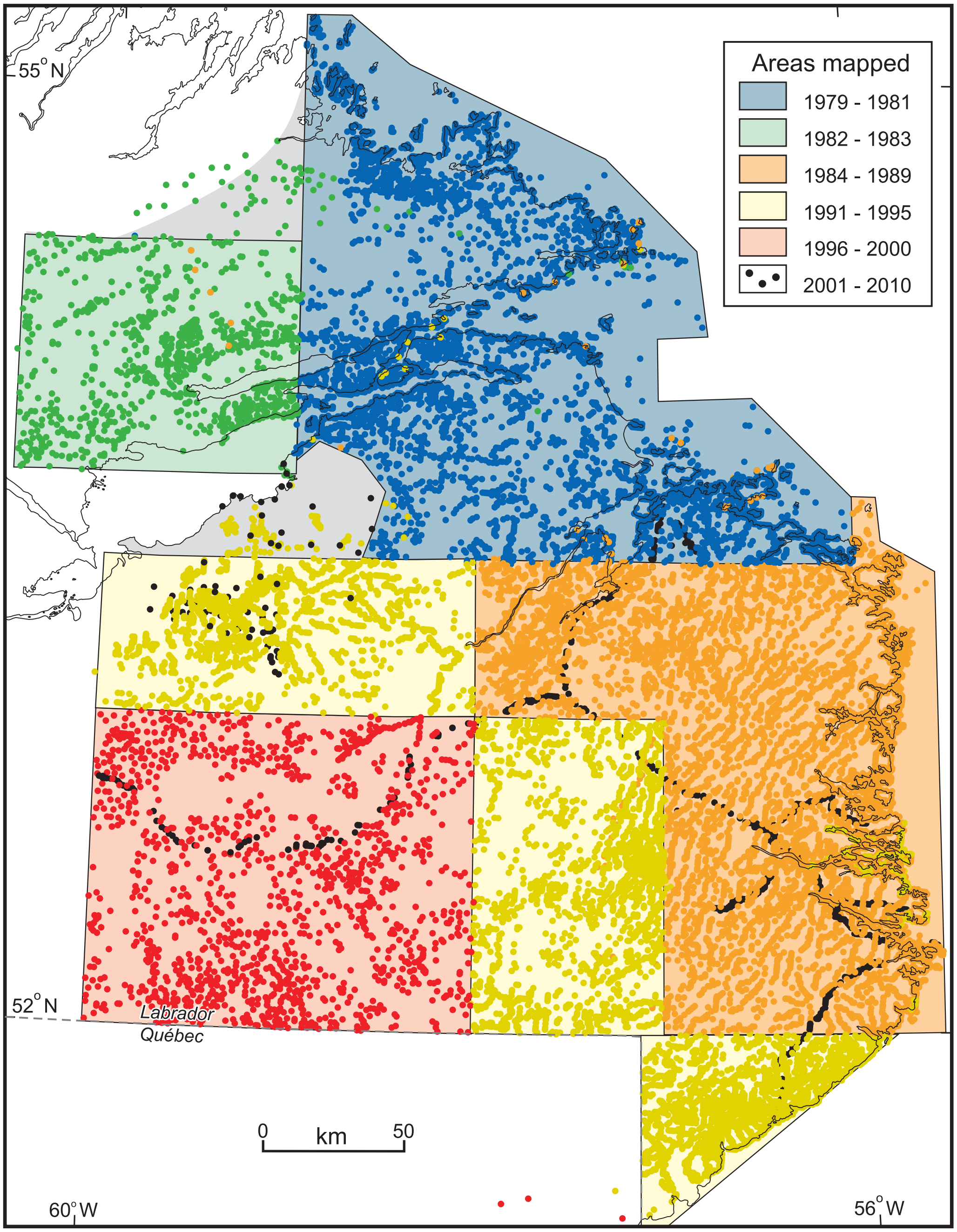

Figure 5. *Distribution of data stations established during 1:100 000-scale geological mapping, colour coded and grouped according to the six time periods outlined in the text. Data captured from other sources during this period are also included. Non-matching dots indicate data collected outside the mapping-project year.*

MDA I (1977–1981)

Between 1979 and 1981 in eastern Labrador during the later part of MDA I, the areas mapped were NTS map areas 013J/east, 013I, 013G/northeast and 013H/north (Gower, 1980, 1981; Gower *et al.*, 1981, 1982b). Mapping was carried out in 1979 using a series of mobile float camps, plus a 10-day period at a cabin on Lake Michael, from which helicopter operations were conducted. Mapping was mostly carried out by a two-person team (the author and his assistant), but for part of the field season, this was augmented by A. Doherty and an assistant, after their completion of mapping in the Adlavik Islands area (Doherty, 1980). D. Bailey (then Senior Geologist for the Labrador Mapping Section), also completed some traverses in the region after finishing a study in the Double Mer area (Bailey, 1980).

In 1980 and 1981, operations, including helicopter-positioned ground traverses, were based in Rigolet and Cartwright, respectively. Float camps and fixed-wing fly camps were used in areas distant from the communities. Operating from a coastal community conferred huge operational benefits, especially in reducing expenditures in positioning helicopter fuel, but also in reducing costs for positioning personnel, equipment and supplies, in providing a main-line power source (enabling daily slabbing and staining of rock samples, for example), shelter to allow efficient use of bad-weather days and also providing a morale-boosting comfort level. The field-party structure, consisting of

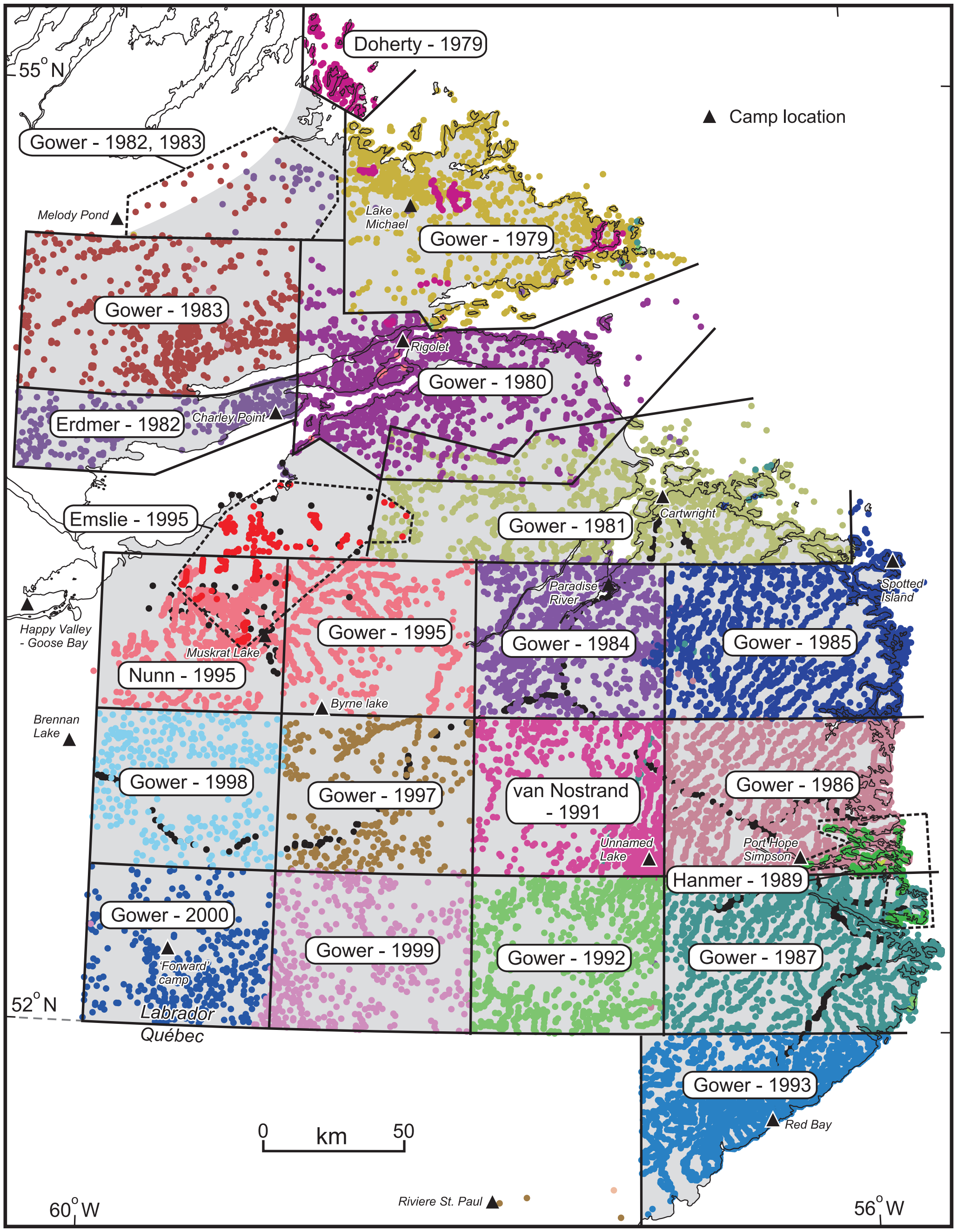

Figure 6. *Data stations colour coded (colours random) according to project year from 1979 onward. Project leaders, year of project and camp locations mentioned in the text are shown. Data captured from Geological Survey of Canada projects carried out by Emslie (1976) and Hanmer (Hanmer and Scott, 1990) are also shown.*

project geologist (the author), two (mapping) senior assistants, four junior assistants, and helicopter personnel, was destined to continue as a preferred mode of operation for several years. The resultant preliminary geological maps during this period were produced as coordinate-bounded blocks, although areas covered each summer were not so regular. This partly reflected incomplete adjustment to the 'quadrant' approach, but was also due to access logistics. Parts of NTS map areas 013G/08 and 13 were compiled from the mapping of R. Emslie, in order to achieve map-boundary regularity.

COOPERATIVE MINERALS PROGRAM 1982–1983

During the Cooperative Minerals Program, two projects were completed in eastern Labrador. The first, in 1982, was carried out in the Double Mer area (NTS map areas 013G/15, 16 and 013F/16) by Erdmer (1983, 1984) leading a five-person party (one senior assistant and three junior assistants) that was based at a tent camp on the shore of Lake Melville near Charley Point. In addition to the three NTS map areas noted above, Erdmer (1984) also compiled NTS map areas 13G/09 and 10 from the mapping of R. Emslie.

The second project, in 1983 (Gower, 1984, 1986), was carried out with two junior assistants, based at Brinex's then-extant exploration camp at Melody Pond. As the area is inland (NTS map areas 013J/03, 04, 05, 06, 013K/01, 08) and very poorly exposed, mapping was done almost entirely by helicopter – except for some ground traverses in the Double Mer White Hills area. During part of the field season, R. Klassen of the Geological Survey of Canada shared the camp and helicopter while conducting surficial-deposit studies in the area (Klassen and Thompson, 1993). The western two NTS map areas (013K01, 08) were included in the project to infill a gap between other eastern Labrador mapping and that completed by Ryan (1984) farther west.

MDA II (1984–1989)

Between 1984 and 1989, major progress was made in 1:100 000-scale mapping of eastern Labrador (Gower *et al.*, 1985, 1986, 1987, 1988). Four projects were completed using a 7-person field-party structure (plus helicopter pilot) and were based successively in Paradise River (1984), Paradise River and Spotted Island (1985), and Port Hope Simpson (1986 and 1987). Areas covered were NTS map areas 013H/south, 013A/east, 003D and 003E. The 1984 project was the last in eastern Labrador to use fixed-wing aircraft to position camps on lake shores, and from which 'rose-petal' traverse loops were conducted. Ground crews in all subsequent projects were dropped off and picked up by helicopter. In 1985, portable radios were used for the first time, enabling oral communication with the helicopter pilot, greatly reducing the time (hence cost) required retrieving field crews on the ground at the end of the day.

MDA III (1991–1995)

No systematic mapping was carried out in 1990, but resumed in 1991. Between August 1990 and July 1991, the author was resident at the University of Gothenburg in Sweden as a Guest Researcher, so the 1991 project (NTS map area 013A/northwest) was led by van Nostrand (van Nostrand, 1992; van Nostrand *et al.*, 1992) as part of a five-person team based at a tent camp in the southeast part of the map region. After the author returned from Sweden, he joined the project during its final weeks.

In 1992, the adjacent area to the south (NTS map area 013A/southwest) was mapped (Gower *et al.*, 1992), using Port Hope Simpson as a base. This was followed, in 1993, by mapping in southeasternmost Labrador (parts of NTS map areas 012P and 002M), based in Red Bay (Gower *et al.*, 1994). No mapping was carried out in eastern Labrador in 1994. It was during this period that GPS devices were introduced, which greatly aided field navigation in wooded areas, although, initially, they were not sufficiently reliable to provide accurate spot locations. It was also at this time that field entry of information into digital databases was started.

During the final year of MDA III, in 1995, two 1:100 000-scale mapping projects were carried out in eastern Labrador in the Mealy Mountains region under the leadership of the author (NTS map area 013G/southeast) and his colleague G. Nunn (NTS map area 013G/southwest). One senior assistant (van Nostrand) was shared between both projects (Gower and van Nostrand, 1996; Nunn and van Nostrand, 1996). The field camp, at cabins on Muskrat Lake in the Mealy Mountains, was also shared by R. Emslie, following up on aspects of his 1975 investigations in the Mealy Mountains.

PROVINCIAL FUNDING (1996–2000)

No systematic mapping was carried out in 1996, partly because of the author's involvement in an international conference held in Goose Bay (29th July – 2nd August: IGCP Project 309 – COPENA), which also featured pre- and post-conference field excursions in various parts of Labrador, including one along the southeast coast.

Mapping resumed in 1997, and was the first of four consecutive projects that completed the mapping of NTS map area 013B (Gower, 1998, 1999, 2000, 2001). This is a very poorly exposed region, so all work was carried out by helicopter spot checks, apart from generally short ground traverses along well-exposed river sections. One exception was mapping along the middle Eagle River in 1997, which was done using an inflatable boat. In 1997, base camp was at a cabin on Byrne Lake; in 1998, during mapping of NTS map area 013B/northwest, camp was at Brennan Lake, south of Goose Bay. The camp and helicopter were shared with colleague D. James, who mapped the adjacent area to the west (NTS map area 013C/northeast). In 1999, during mapping of NTS map area 013B/southeast, camp was based in Rivière St Paul, and in 2000, a base camp was established in Goose Bay and a 'forward' tent camp was set up in the field area, which was then occupied for one or two nights at a time. Although commuting from outside the field area may seem like an expensive luxury, costs were lower than they would have been had a full tent camp been established in the area, and personnel, provisions, equipment and fuel delivered to it.

PROVINCIAL FUNDING (post-2000)

After 2000, mapping contributions to the geological map of eastern Labrador were mainly achieved through examination of roadcuts and quarries created during construction of the Trans-Labrador Highway and its spur roads to various communities. This was done in 2003, 2004, 2005, 2007, 2008, 2009 and 2010, adding over 1000 additional data stations to the database. Some outcrops no longer exist due to subsequent landscaping. Brief helicopter-supported forays were also made in the Mealy Mountains.

DATA ACQUIRED

FIELD DATA STATIONS

The basic building block of a geological map, especially that at reconnaissance scale, is a data station – a site at which the geologist stopped, accurately located his/her position, described the outcrop and collected various types of information (*e.g.*, samples, photographs, structural measurements, geophysical readings). Typically, during reconnais-

Table 1. Summary of number of data stations, area of map and data-station density for each map region in eastern Labrador

Map region		GSNL data stations	GSC data stations	Other Sources	Other source	# data stations	Area (km^2)	Density (stn/10 km^2)
Pinware River	parts of 12P & 2M	2079	588			2667	3135	8.5
Port Hope Simpson	13A/NE	3042	230			3272	5632	5.8
Alexis River	13A/NW	953	7			960	3754	2.6
St. Lewis River	13A/SE	2338	91	4	University	2433	5116	4.8
Kyfanan Lake	13A/SW	979	10			989	3797	2.6
Eagle River	13B/NE	341	14			355	3755	0.9
Crooks Lake	13B/NW	335	27			362	3756	1.0
Upper St. Paul River	13B/SE	378	16			394	3798	1.0
Upper St. Lewis River	13B/SW	383	28			411	3799	1.1
English River	13G/NE	715	189			904	3650	2.5
Lake Melville	13G/NW	212	280			492	3671	1.3
Southeast Mealy Mountains	13G/SE	580	55			635	3712	1.7
Kenemich River	13G/SW	297	342			639	3714	1.7
Table Bay	13H/NE	1211	12			1223	2042	6.0
Sandwich Bay	13H/NW	1056	18			1074	3668	2.9
Sand Hill River	13H/SE	2183	27			2210	5688	3.9
Paradise River	13H/SW	1979	54			2033	3711	5.5
Byron Bay	13I/NW	333	76	57	University	466	1403	3.3
Groswater Bay	13I/SW	641	69	86	University	796	2097	3.8
Benedict Mountains	13J/NE	702	176	676	Exploration	1554	3582	4.3
Big River	13J/NW	142	39	42	Exploration	223	1092	2.0
Rigolet	13J/SE	1176	162			1338	3626	3.7
Double Mer	13J/SW	531	80			611	3627	1.7
Grand/Nipishish lakes	parts of 13K & 13F	251				251	2729	0.9
Adlavik Islands	parts of 13O	126				126	296	4.3
		20884	2002	865		23751	81715	

sance mapping, very few boundaries are actually traced in the field and plotted directly on maps, aerial photographs or other media.

The new 1:100 000-scale geological maps of eastern Labrador include 28 732 data stations. These can be subdivided into three categories, namely those established during 1:100 000-scale mapping, those captured from other mapping projects, and those resulting from other activities (such as sampling for isotopic, paleomagnetic and structural studies). The main sources of data capture were field notes of K. Eade, I.R. Stevenson, H.H. Bostock, R.F. Emslie (field work in 1975 and 1995), S. Hanmer (*cf.* Hanmer and Scott, 1990) and their assistants. The field notes were made available to the author by the Geological Survey of Canada.

Table 1 provides some information regarding the number of data stations, the area mapped and data-station density for each map region. These numbers can be totalled in various ways, so they should only be taken as an approximate guide. The area for individual map regions was calculated by summing the area of geological polygons. In coastal areas, polygons have been extrapolated a short distance offshore, but the additional area included is less than 5% of the total coverage for eastern Labrador. Given that data-station density along the shoreline is much higher than in interior areas, the inclusion of the offshore part of the polygons provides a balancing effect when calculating data density. A noteworthy observation is that the number of data stations is an order of magnitude greater than during earlier Geological Survey of Canada mapping (although taking 18 versus 4 project seasons to do it). The density of data stations ranges from 1 to 8.5 per 10 km^2, including both federal and provincial sources of data. Quality of exposure, quality of access, size of area to be mapped, and size of field party are the principal factors influencing data density.

OTHER FIELD AND RELATED DATA

This category includes samples, field photographs, petrographic thin sections, whole-rock geochemical analyses and XRD investigation of unknown minerals. The database includes records for 18 273 samples, of which 15 502 are housed at the Geological Survey of Newfoundland and

Labrador archives. All the Geological Survey of Newfoundland and Labrador samples have been slabbed, stained (for K-bearing minerals) and scanned. The scanned images are linked to the digital 1:100 000-scale geological maps. The remainder of the samples listed within the database are based on field notes of other projects (especially those of the Geological Survey of Canada); not all those samples necessarily still exist. The author has examined sample collections from eastern Labrador made by K.E. Eade, I.M. Stevenson and H.H. Bostock of the Geological Survey of Canada.

Petrographic descriptions have been completed for all of the 6032 thin sections prepared from samples collected in eastern Labrador, of which about two-thirds have been entered into the database at the time of writing. In general, a thin section was prepared for any sample used in geochemical, isotopic or paleomagnetic studies. The author has also examined thin sections made from samples collected by K.E. Eade, I.M. Stevenson and H.H. Bostock.

Excluding duplicates and controls, whole-rock geochemical analyses were obtained on 1763 samples for major elements and a wide range of trace elements. In many cases, older analytical results have been replaced by more recent data in order to improve consistency of information.

Eighteen samples were investigated by XRD analysis. The results are reported by Gower (2010).

OTHER DATA

Included here are isotopic (U–Pb, Rb–Sr, Nd–Sm, Ar–Ar and K–Ar) data, paleomagnetic data, and mineral occurrence information. Most of the samples for these studies were collected during 1:100 000-scale field work, hence their locations coincide with routine mapping data stations. For some of those that do not, it was possible to obtain precise locations from the original authors, but for others, it was necessary to rely on various other means (*e.g.*, commonly imprecise latitude–longitude information supplied in journal articles). Some sites, especially paleomagnetic sites where a drill was used, were located in the field.

A major policy change was made with respect to geochronological investigations in eastern Labrador in 1984, when reliance shifted from Rb–Sr to U–Pb dating. Most of the U–Pb age determinations were carried out under the leadership T.E. Krogh, at the Jack Satterly laboratory in Toronto. A key feature of the U–Pb geochronological studies (and very successfully applied) was the creation of key geochronological localities. At these sites, which were chosen because they display unequivocal field relationships between several rock units, samples from several units were collected and dated, thus allowing the geochronological data to be rigorously interpreted in the context of known relative ages. The database for eastern Labrador currently contains 355 U–Pb records, 246 Nd–Sm records, 221 Rb–Sr records and 99 K–Ar and Ar–Ar records.

Paleomagnetic studies, carried out by Memorial University of Newfoundland and the Geological Survey of Canada, formed an ongoing part of the mapping project. Many results have been published, but not all. The unpublished data is included in the database, but remains incomplete in some instances. Paleomagnetic sites are shown on the 1:100 000-scale maps, including those of previous studies, the locations of which have been verified from the original data sources. The unpublished data sites are also included on the maps.

All non-confidential mineral occurrences (up to 2009) that are known to the author are included on the 1:100 000-scale maps. Considerable effort was made to verify the sources of information for mineral occurrences, although not possible in every case. The occurrences have been reviewed by Gower (2010).

All the data types mentioned above are included in the digital database for the bedrock geology of eastern Labrador, preparation of which is still in progress. From 1992 onward, field data were entered into the database as collected. Capturing earlier data was a huge task. Data from previous projects are commonly neglected during later work, but the author considers that inclusion of such information was well worth the time and effort to acquire it. Where previous projects extended outside the region covered by the present map (*e.g.*, those of H.H. Bostock and I.M. Stevenson), all that project's field data were included in the database.

FEATURES OF THE MAPS

The Paradise River map region is shown in reduced form as an example of one of the new 1:100 000-scale geological maps in Figure 7, and the whole map for eastern Labrador shown in reduced form in Figure 8. Various features common to all maps are reviewed in the following sections.

NOTES

Rather than provide marginal notes summarizing the geological features of individual maps, the decision was made that this would be done in separate publications and that the notes would be confined to providing specific clarifications regarding data sources and interpretational approach that had been adopted. In the notes, it is empha-

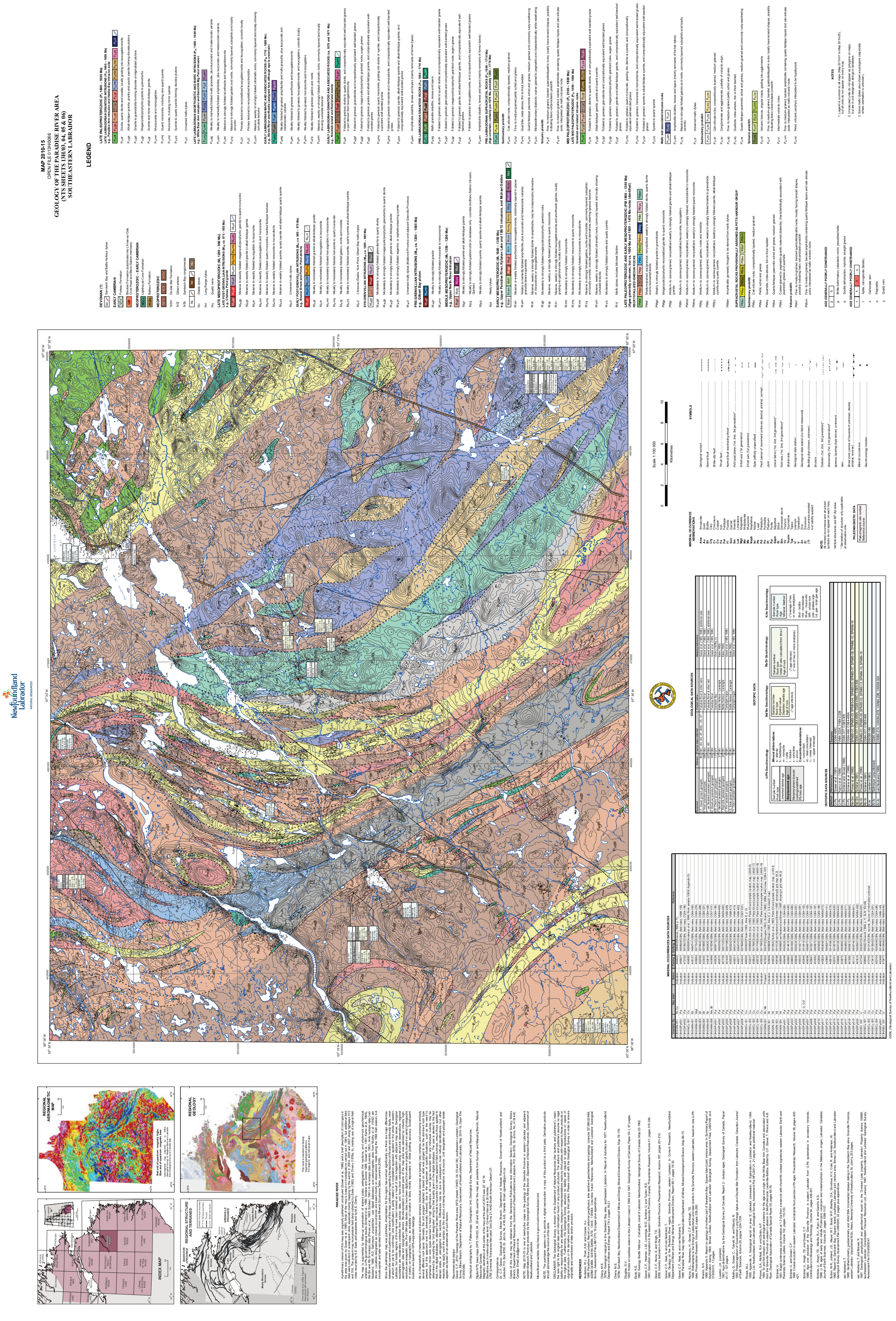

Figure 7. *Reduced version of the Paradise River map region – an example of one of the 1:100 000-scale maps.*

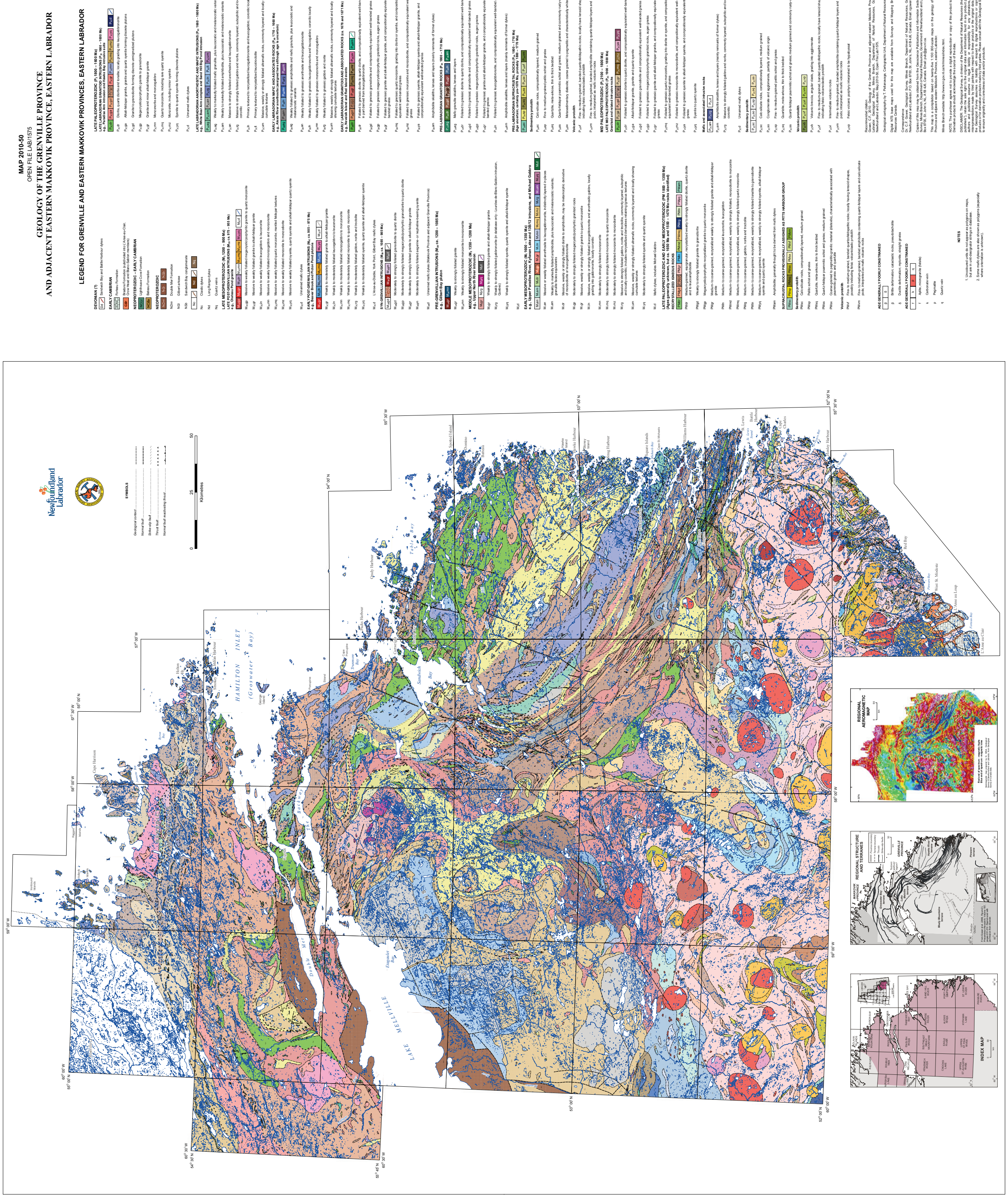

Figure 8. *Reduced version of the new geological map of eastern Labrador.*

sized that these maps are not simply compilation products. Since publication of its preliminary version, every map has;

i) been augmented by follow-up examination of stained slabs,
ii) utilized subsequently obtained petrographic, geochemical, isotopic and geophysical data,
iii) benefited from geological knowledge acquired from adjacent map regions, and
iv) been integrated into a consistent geological model for eastern Labrador.

Also to be kept in mind is that, especially in complex, high-grade metamorphic terrains, such as most of the Grenville Province, any rendering of geological features into a cartographic product is an exercise that involves many simplifications, approximations, compromises and some guesswork. Users should not expect to find features on the ground exactly as depicted on the maps.

LEGEND

A common legend applies to all of the 25 1:100 000-scale maps and to the 1:500 000-scale compilation. Each geological unit is assigned a two-part unit designator, embodying both time and rock type.

The first letter of the time element follows typical time subdivisions for Proterozoic rocks (P – Paleoproterozoic, M – Mesoproterozoic, N – Neoproterozoic), as does the first subscript (*e.g.*, M_1, M_2, M_3 for 1600–1350 Ma, 1350–1200 Ma, 1200–900 Ma, respectively), but the second subscript denotes a local chronology (*e.g.*, M_{3A}, M_{3B}, M_{3C}, M_{3D} for 1200–1085 Ma, 1085–985 Ma, 985–975 Ma, 975– 955 Ma). To maintain consistency with the Geological Map of Labrador (Wardle *et al.,* 1997) 900 Ma (rather than 1000 Ma) is used to define the Mesoproterozoic-Neoproterozoic time boundary. This avoids misleading subdivision of Grenvillian plutonic rocks.

Although having an extensive high-precision geochronological database available made it possible to establish a sequential geological history for the region, given the extrapolations that were required from key geochronological localities, errors in assigning specific time slots to particular rocks inevitably exist.

The second part of the unit-designator label is a two-letter abbreviation of the rock type, intended to be as mnemonic as possible. The 'military' or 'store-keeper' style of abbreviation (*e.g.*, 'mq' for 'monzonite, quartz' rather than 'qm' for 'quartz monzonite') was adopted as it enables greater consistency in unit abbreviations (considerably assisting sorting in the database). The map user might wonder at the abbreviation 'rg' for gabbro. The original idea was also to use 'rn' for norite and 'rt' for troctolite (all three related rock types sharing the letter 'r') but the latter two were later dropped.

Colour coding of polygons follows two principles. The first is that felsic igneous and metamorphic rocks were assigned colours at the red end of the spectrum, whereas mafic and ultramafic rocks are at the blue end of the spectrum. In accordance with normal conventions, older rocks and/or those generally represented by small polygons were assigned darker colour tones.

The maps are designed to be complimented by a digital database. In the digital database, a unit-designator string, which may include several rock types, has been assigned to each outcrop. This allows the user to determine the distribution of a particular rock type across the whole region, even if that rock type is a minor component of a given outcrop and not represented by a polygon (as is commonly the case for pegmatites, mafic dykes and ductile/brittle deformation structures, for example). As a consequence of this approach, not all unit designators appear as units on the maps, remaining as uncoloured boxes in the legend.

STRUCTURAL SYMBOLS

The structural data displayed on the maps are only part of that collected. All the data reside in the digital database and will be accessible to those wanting more detailed information. Priority was assigned on the maps to some types of structural data over others (*e.g.*, mafic dykes were given very high priority). Two clarifications are made. The first is that no distinction is made between types of geological boundaries (*e.g.*, 'assumed', 'inferred' and 'definite'). Such distinctions rely on closeness of geological observations to a contact. In reconnaissance-level maps such as these (lacking field tracing of contacts) that control can be inferred from the distribution of data stations (although augmented by geophysical or topographic clues), so no further information would have been conveyed by such subdivision. It is suspected that many lithological contacts shown are actually shear zones. The second point is that interpretation of various generations of structure applies only to the specific outcrop where they were observed. For example, an F1 fold at one locality might well be synchronous with an F3 fold at another.

MINERAL OCCURRENCE SYMBOLS

Some users of the maps will find it frustrating that the MODS (Mineral Occurrence Data System) mineral inventory label has not been used on the maps. It is possible to cross-reference between the map label and the MODS inventory label using the mineral occurrence table provided with each map, however. The map label has the advantage of allowing several commodities to be listed at any given occurrence, whereas the MODS designation is a unique identifier, based on what is deemed to be the primary commodity for the locality. Note that the mineral occurrence table on the map also provides greater detail than usually supplied regarding the source of information (*e.g.*, page or table number in the referenced report) as it can be difficult to track down such data in the original material.

ISOTOPIC DATA

Isotopic data are subdivided into four types, namely U–Pb, Nd–Sm, Rb–Sr and K–Ar (the latter including Ar–Ar). Boxes are colour coded according to isotopic system, with 'cooler' colours being assigned to isotopic systems characterized by lower closure temperatures. In cases where the same sample has been investigated by several different methods, the rock type is only listed in one isotopic box to save space. Joined boxes indicate analysis of the same sample; a small gap between boxes denotes two samples. In calculating Nd–Sm epsilon and depleted-mantle ages, time 't' (mantle separation age) is based on regional interpretation when the age of emplacement was not known from U–Pb dating of the same rock. For the Rb/Sr initial ratios, rather than using an isochron (or, in practice, more commonly an errorchron) initial-ratio value derived from a regression of several samples, initial ratios have been calculated for individual samples, using a known U–Pb age or an inferred age based on regional interpretation. This approach avoids problems involved in assuming a group of samples to be truly cogenetic, as well as cartographic representation of a single value (namely an initial ratio) that is based on multiple localities.

INSET MAPS

A wide variety of inset maps could have been included. Apart from the index map, the choice was based on those considered by the author to be the most useful in providing the broader regional context, beyond an individual map's borders.

HIDDEN FEATURES

The most important 'hidden' feature for the user to be aware of, is that geological features have been extrapolated under water (lakes and for some distance offshore). From a map-preparation perspective, the main reason for doing this was to help achieve consistency of geological interpretation between areas on either side of bodies of water. It will be possible to view underwater interpretation in the digital versions of maps by 'turning-off' the water-fill layer.

CONCLUDING REMARKS

Although a non-geologist might consider that once an area has been mapped geologically and a factual record has been made of the rocks present, there is no subsequent need to remap the region. Earth scientists, especially those involved in geological mapping, know that this is far from the case. For eastern Labrador, foremost to be kept in mind is that the geological mapping is at reconnaissance level only, and, even if mapped at an order-of-magnitude larger scale, it would still be less detailed than available in some parts of the world. Furthermore, newly evolving concepts and techniques inevitably require rocks to be re-examined in the field to search for features that were previously ignored or had unrecognized significance. One obvious example of the latter in eastern Labrador is kinematic data, which were largely neglected until the mid-1980's, and, even subsequently, collected far more sparsely than now needed.

Geological Survey mapping tends to focus on the questions *what* (a rock is), *where* it is located, and *when* it formed. The questions of *why* and *how* it formed tend to be the realm of university research. The new 1:100 000-scale geological maps for eastern Labrador will provide a basic framework regarding the first three questions and a means by which to address the last two.

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