THE LABRADORIAN OROGENY: GEOCHRONOLOGICAL DATABASE[1]

by

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ABSTRACT

The Labradorian Orogeny is defined as the deformation and metamorphism of Aphebian sedimentary rocks and the associated emplacement of a granitoid batholith and other plutonic suites that occurred in southern Labrador between 1700 and 1600 Ma. The orogeny is documented here from south-central and southwestern Labrador but its effects may also extend eastwards to the coast of Labrador. Prebatholith (early Labradorian) metamorphism ranged in grade from upper amphibolite to granulite facies and locally resulted in development of the assemblage hypersthene + sillimanite + quartz ± sapphirine ± cordierite. Geochronological data constrains the prebatholith dynamothermal events between 1680 and 1650 Ma. The regional metamorphism was followed by the emplacement of the Trans-Labrador batholith at circa 1655-1650 Ma. The batholith joins together crustal areas in the south, that were affected by the early Labradorian events, to crust in the north that was apparently stabilized during the Hudsonian Orogeny (circa 1800 Ma) and which is not yet known to have been affected by the early Labradorian deformations. A charnockite-gabbronorite association that is present within granulite facies terranes is considered to be the deep crustal equivalents of the batholith. Further high-grade events followed the plutonism in the south, and greenschist facies foliations were imposed on the batholith in the north. The postbatholith events range from late Labradorian (1650-1600 Ma) to Grenvillian (circa 1000 Ma) in age. The area has been variably reworked during the Grenvillian Orogeny and now lies within the northern part of the Grenville Province.

INTRODUCTION

1:100,000 scale mapping (Figure 2), undertaken by the Newfoundland Department of Mines and Energy and the Geological Survey of Canada since 1977, has allowed a new geological compilation of central and western Labrador (Figure 1). A recent geochronological program, within the same region, has revealed the existence of extensive areas that are underlain by pre-Grenvillian gneisses and a granitoid batholith, both of which are 1700-1600 Ma in age. Throughout the area, the late Lower Proterozoic spatial relationships have been modified or obscured by tectonic events of Grenvillian age, during which the rocks were stacked into a series of thrust-separated blocks. The tectonic zonation of the northern part of the Grenville Province that is related to this thrusting is shown in Figure 2.

LABRADORIAN OROGENY[3]

The geochronological program has given numerous dates in the range from 1685 Ma to 1600 Ma.The methods used include U-Pb concordia and discordia dates on zircon, sphene, apatite and monazite, Rb-Sr whole rock isochrons and errochrons, and Ar-Ar hornblende plateau ages. These dates all occur within the northern part of the Grenville Province and come mostly from foliated to gneissic granitoid rocks and high-grade paragneisses. The abundance of 1700-1600 Ma dates and the variety of methods involved suggest that they represent a significant geological event. This has been termed the Labradorian Orogeny (Nunn, Noel and Culshaw, 1984) and the affected area the Labrador Orogen (Thomas, Nunn and Wardle, in press). The orogeny is defined largely on geochronological grounds and a precise separation of the associated structural and metamorphic features from those of earlier or later events is not yet possible.

The orogen is characterized by paragneiss and granitoid plutonic rocks. The paragneiss underwent major high-grade dynamothermal metamorphism in the late lower Proterozoic (Figure 3). Kyanite-

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[1] Adapted from Nunn, G.A.G. and Thomas, A., "The Labradorian Orogeny". Poster Session displayed at Canadian Tectonic Studies Group AGM, Maniwaki, Quebec (Oct. 27, 1984) and Newfoundland Department of Mines and Energy, Open House, St. John's, Newfoundland (Nov. 1-3, 1984).

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[3] More complete discussions of the structure, metamorphism and petrology associated with the Labradorian Orogeny will be found in Thomas, Nunn and Wardle (in press) and Thomas, Nunn and Krogh (in prep.).

LEGEND

Younger Cover

22 *Seal Lake Group; fluviatile and shallow marine sediments with basic volcanic rocks.*

21 *Letitia Lake Group; peralkaline volcanic rocks.*

20 *Blueberry Lake Group; felsic volcanic rocks.*

19 *Sims Formation; fluviatile sediments.*

Younger Plutons

18 *Other late granitoid rocks of unknown age.*

17 *Peralkaline intrusions.*

16 *Shabogamo Intrusive Suite; gabbroid rocks.*

15 *Elsonian granitoid rocks.*

14 *Elsonian anorthositic to noritic intrusions.*

Plutonic Interval

13 *Mackenzie Lake group; fluviatile sediments and acid-intermediate volcanic rock, coeval cover to TLB.*

12 *Trans-Labrador batholith (TLB); calc-alkaline quartz diorite to granite, predominantly granodiorite and quartz monzonite.*

11 *Gabbro, gabbronorite, layered gabbro-peridotite, hydrous gabbro and diorite (may include parts of Unit 16); associated with Unit 12.*

10 *Charnockitic granitoid rocks.*

9 *Norite-gabbronorite (may include parts of Units 14 and 16); associated with Unit 10.*

8 *Lac Fournier anorthosite.*

Ungava Batholith

7 *Massive to foliated granitoid rocks.*

Hudsonian Orthogneisses

6 *Amphibolite facies gneisses and foliated granitoid rocks.*

Aphebian Sedimentary Rocks

Labrador Orogen; semipelitic to pelitic paragneiss, probably derived from graywackes.

5 *Granulite facies gneisses.*

4 *Amphibolite and/or granulite facies gneisses.*

Hudson Orogen (north of Grenville Front) and/or Grenville Orogen (south of Grenville Front); shelf and slope sediments with basic volcanic rocks.

3 *Amphibolite facies metasediments and gneisses.*

2 *Greenschist facies metasediments.*

Archean Gneisses

1 *Granitoid gneisses with massive posttectonic granitic and alkaline plutons.*

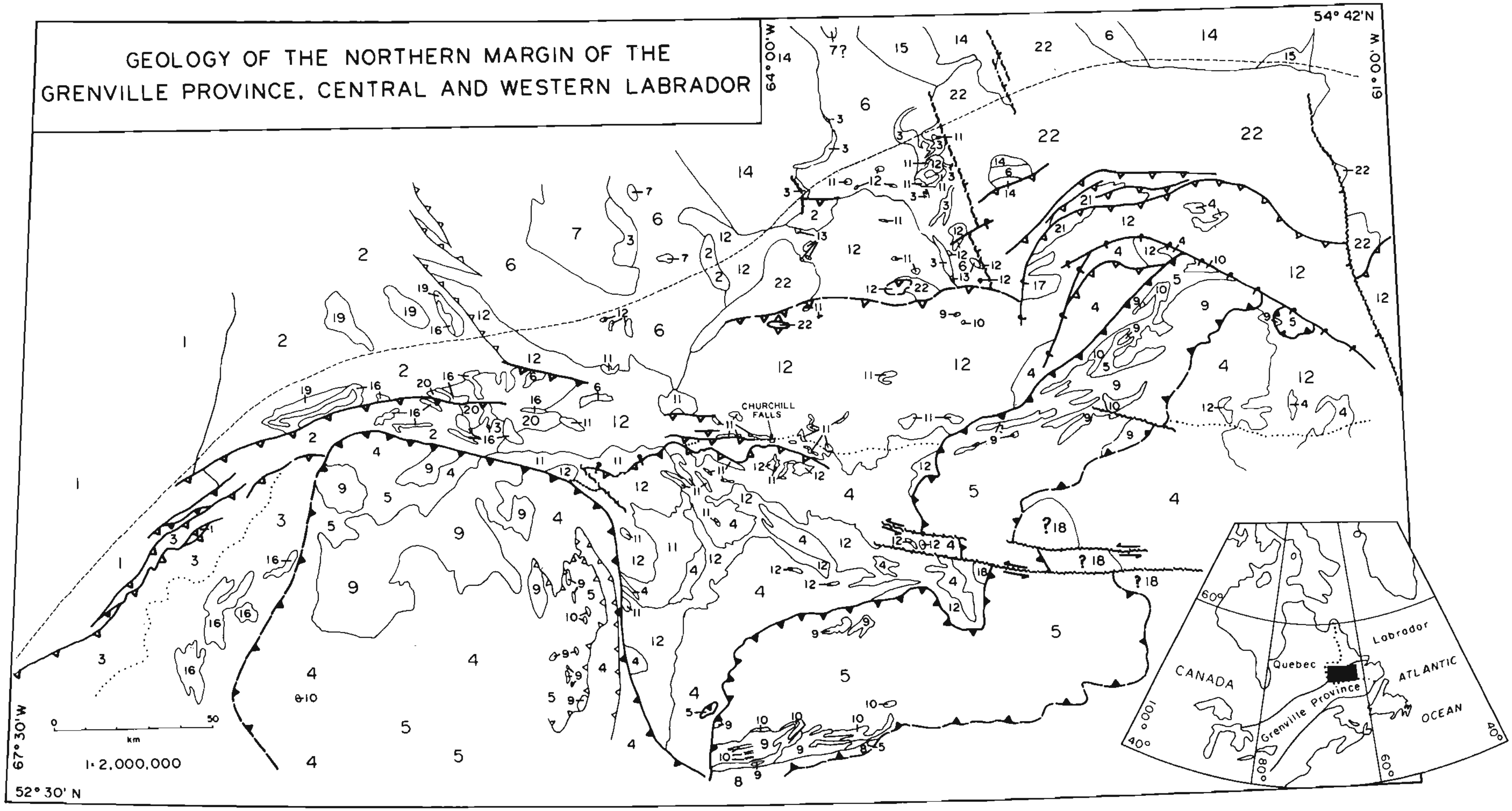


Figure 1: *Geology of the northern margin of the Grenville Province, central and western Labrador: preliminary compilation. Map compiled by Wardle, Nunn and Thomas. Adapted from earlier compilations at 1:1,000,000 scale by Wardle (1983) based on 1:100,000 scale mapping by (approximately W to E) Rivers, Ware, Wardle, Noel, Nunn, Culshaw, Thomas, Emslie and Ryan; and Greene (1972) based on Geological Survey of Canada, 1:250,000 scale mapping by Wynn-Edwards, Emslie, Stevenson, Eade, Roscoe and Fahrig. Most geological and structural boundaries inferred at 1:100,000 scale of mapping.*

SYMBOLS, FIGURES 1–7

Post-Grenville faults - normal.

- strike-slip.

Late Grenville reverse faults.

Post-metamorphic Grenville thrusts.

Syn-metamorphic Grenville thrusts.

Grenville migmatite isograd.

Grenville Front, approximate northern limit of ductile and major brittle to semi-brittle deformation of Grenvillian age.

Labradorian thrusts, in Lac Joseph allochthon.

Hudsonian thrusts, north of the Grenville Front.

LEGEND TO GEOCHRONOLOGY, FIGURES 3–7

U	Uranium-Lead
R	Rubidium-Strontium
S	Samarium-Neodymium
K	Potassium-Argon
A	Argon-Argon
i	Isochron
e	Errorchron
c	Combined isochron/discordia
p	Plateau age

z	Zircon
s	sphene
m	Monazite
a	Apatite
h	Hornblende
b	Biotite
mu	Muscovite
x	Eudialyte, Arfvedsonite, Micas, Nepheline, Pyroxene
wr	Whole rock

<u>3500</u> upper intercept
1676 lower intercept

Numbers in parentheses following each date on the diagrams and in the paragraph below refer to the list of geochronological sources.

U-Pb data give concordia and discordia dates ranging from 3500 Ma to 638 Ma. The data from age determinations on all sphene samples were combined to produce a single discordia plot which yielded an upper intercept of 1654 Ma and a lower intercept of 993 Ma (Figures 4 and 6). The precision of 206Pb/238U versus 207Pb/235U ratios is 2σ for all U-Pb dates except the 1738/638 Ma discordia. This last date was compiled and its precision is not known. Rb-Sr determinations give dates ranging from 1715 Ma to 900 Ma. The 1666 ± 14 Ma dates in these blocks represent a composite isochron, and include both amphibolite-grade paragneiss of the parautochthon and granulite-grade paragneiss of the Wilson Lake allochthon. In addition, the 1666 ± 18 Ma date, from an amphibolite facies paragneiss raft within the parautochthon granitoid rocks was also combined into this isochron (11). Precision of 87Sr/86Sr versus 87Rb/86Sr ratios is 1σ (11), (2) or 2σ(1). 40Ar-39Ar dates range from 1806 Ma to 905 Ma with a reported precision of 2 .

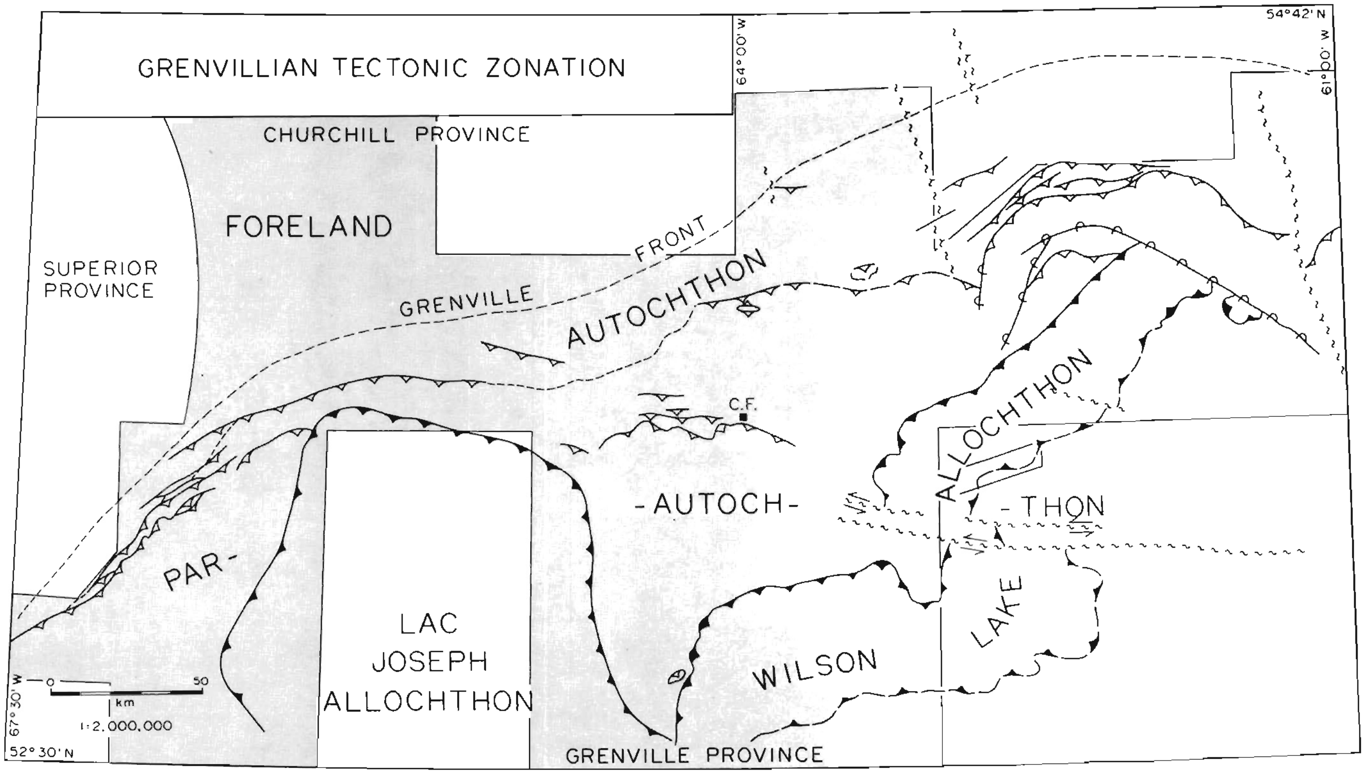


Figure 2: *Tectonic zonation of the northern part of the Grenville Province in central and western Labrador, and the distribution of areas mapped at 1:100,000 scale since 1977. Structural symbols for this and the following diagrams as for Figure 1, western part after Rivers and Nunn (in press). Allochthons = major aeromagnetic, gravimetric and topographic features with structural, metamorphic and geochronological discordance to the parautochthon.*

and/or sillimanite-bearing mineralogies occur throughout and assemblages including hypersthene + sillimanite ± quartz ± sapphirine ± cordierite are common in the Wilson Lake allochthon (Figure 2). The latter indicates PT conditions possibly in excess of 800°C and 10 Kb.

The paragneiss was intruded by voluminous granitoid and gabbroid plutonic suites. In the north these rocks form a linear, predominantly granitoid batholith of calc-alkaline affinity (Thomas, 1981, in preparation) that was emplaced about 1654 Ma and is known as the Trans-Labrador batholith (Wardle and staff, 1982; Figures 1 and 4). In the allochthons gabbronorite and minor charnockitic granitoid rocks may be temporal or earlier (diachronous?) equivalents of the batholith.

Deformation followed the intrusion of the plutonic rocks, at high-grade in the allochthons and at greenschist facies in the batholith (Figure 5).

GEOCHRONOLOGY

The Labradorian deformation and temporally and spatially related plutonism have been divided into a three-stage cycle (Thomas, Nunn and Wardle, in press). These consist of (1) preplutonic deformation and metamorphism (early Labradorian, Figure 3), (2) emplacement of a predominantly calc-alkaline granitoid suite in the north and norite-gabbronorite-charnockite suites in the allochthons during a plutonic interval (the Trans-Labrador batholith, Figure 4), and (3) postplutonic deformation and metamorphism (late Labradorian, Figure 5). We also consider that there may be a causal link between the three stages. However, there is still considerable uncertainty as to how many of the prebatholith structures are Labradorian or older (Hudsonian) and similarly how many of the postbatholith structures are Labradorian or younger (Grenvillian or other).

Stage 1: early Labradorian.

Except in the Churchill and Superior Provinces, where the gneisses are presumed to be, respectively, Hudsonian (circa 1800 Ma) and Kenoran (circa 2600 Ma), the age of the earliest gneissosity in the paragneiss is unknown. It could be coeval with some of the high-grade, metamorphic fabrics in the area (early Labradorian) or be older, perhaps Hudsonian (Figure 3).

In the parautochthon, adjacent to the Wilson Lake allochthon, paragneiss occurs as rafts (up to 8 km across) in the Trans-Labrador batholith which is only locally

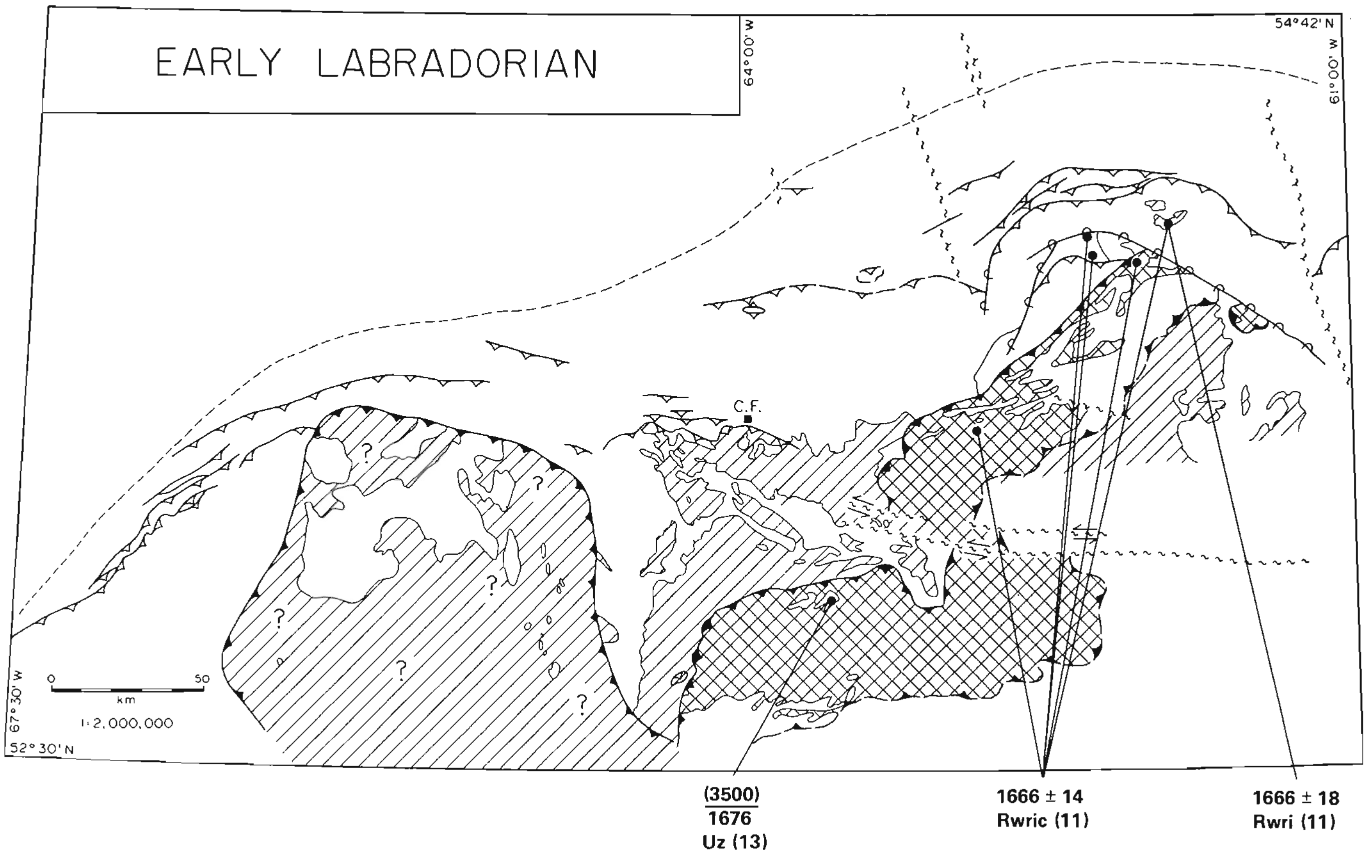
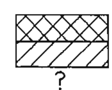


Figure 3: *Stage 1: early Labradorian dates, 1700-1650 Ma.*
Early Labradorian folding of preplutonic gneissosity and axial fabric development:—
Granulite facies
Amphibolite and/or granulite facies
Uncertain



Preplutonic gneissosity in all these areas may be Hudsonian and/or early Labradorian.

deformed at greenschist grade. The greenschist facies event is known to be Grenvillian since it affects both the batholith and its late Middle Proterozoic cover (the Seal Lake Group, Figure 1). The 1666 Ma combined isochron, therefore, relates to the high-grade events in the paragneiss and gives an age for the early Labradorian in the parautochthon (Figure 3). The authors feel that the 1676 to 1666 Ma dates from the Wilson Lake allochthon itself probably date the same high-grade, early Labradorian event. The overlap in dates between the metamorphic event in the paragneiss and the presumed emplacement age of the charnockitic suite (1675-1650 Ma, personal communication R.F. Emslie, 1980), however, could allow for these dates to record a post plutonic, stage-three, thermal or deformation event in the Wilson Lake allochthon.

Stage 2: the plutonic interval.

A minimum age for the early Labradorian events is given by the plutonic suites which crosscut the high-grade, metamorphic fabrics in the paragneiss. These consist of the emplacement of the Trans-Labradorian batholith in the parautochthon (1655-1650 Ma), the emplacement of the charnockitic suite in the Wilson Lake allochthon (1675-1650 Ma) and by a granitoid pluton (? circa 1672 Ma) that crosscuts the paragneiss gneissosity in the Lac Joseph allochthon. The timing of emplacement of the plutonic suites comprises the plutonic interval (Figure 4). Evidence for the age of much of the main component of the plutonic interval, the Trans-Labrador batholith, at 1655-1650 Ma now seems overwhelming. A date of 1619 Ma, from the Lac Joseph allochthon, and two dates of circa 1576 Ma, from northeast of Chruchill Falls, (Figure 4) indicate that there are younger plutons or phases present. Though included on Figure 4 the pluton dated at 1619 Ma appears to be posttectonic to the late Labradorian (personal communication T. Rivers, 1984) and is not strictly a part of stage 2.

Just northeast of the area individual plutons included within the batholith may range down to circa 1500 Ma in age (Ryan, in press). Plutonic rocks within the allochthons, though similar in age to those in the autochthonous zones, have not been

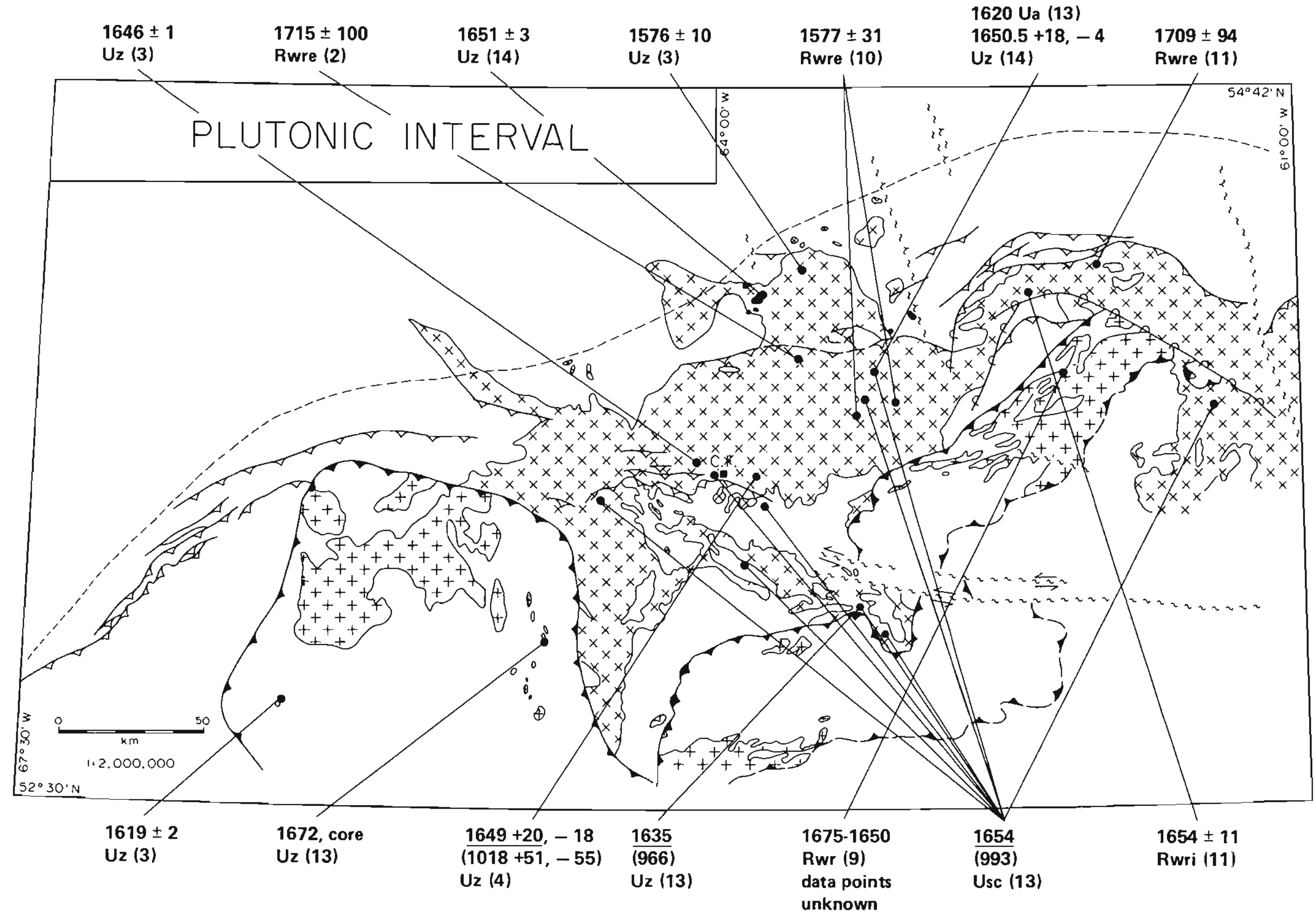


Figure 4: *Stage 2: the plutonic interval, 1675-1650 Ma.*
Trans-Labrador batholith (TLB) and spatially associated gabbroid suites × × ×
Norite-gabbronorite-charnockite: coeval or earlier than TLB but including some spatially associated younger gabbros + + +
Mackenzie Lake group: coeval cover to TLB

included in the Trans-Labrador batholith because they have been transported to the north-northwest during the Grenvillian Orogeny and initially may have been separated from the batholith by many tens of kilometers.

Stage 3: late Labradorian.

In the Lac Joseph allochthon fresh, clear zircons, from a granite pluton containing paragneiss xenoliths, have yielded concordia dates of 1645 and 1647 Ma (Krogh, 1983). A zircon core from the same pluton yielded a date of 1672 Ma. The pluton contains a weak linear fabric that in other, similar plutons ranges from a weakly to a strongly developed fabric with a granulite facies mineralogy and which coincides in orientation with a penetrative mineral recyrstallization at sillimanite grade in the paragneisses. This deformation was regionally pervasive and ranged from amphibolite to granulite facies. We interpret these data to indicate that the Lac Joseph allochthon underwent gneiss-forming deformation in the paragneisses at Hudsonian or early Labradorian time, granitoid emplacement circa 1672 Ma, and pervasive high-grade metamorphism and deformation during the late Labradorian (circa 1646 Ma).

Although the analyzed zircons appear to represent new metamorphic grains and overgrowths, and to date the pervasive upper amphibolite to granulite facies metamorphic fabrics in the allochthon, it is possible that they are relict igneous grains in which the U-Pb systematics survived a pervasive Grenvillian recrystallization. The recrystallization may have occurred at PT conditions rather less than those normally associated with the granulite facies, due to the anhydrous nature of the rocks.

Whereas the Lac Joseph allochthon was pervasively deformed during the late Labradorian the Wilson Lake allochthon was only selectively reworked following the emplacement of the norite-gabbronorite-charnockite plutonic suites. In the Wilson Lake alloch-

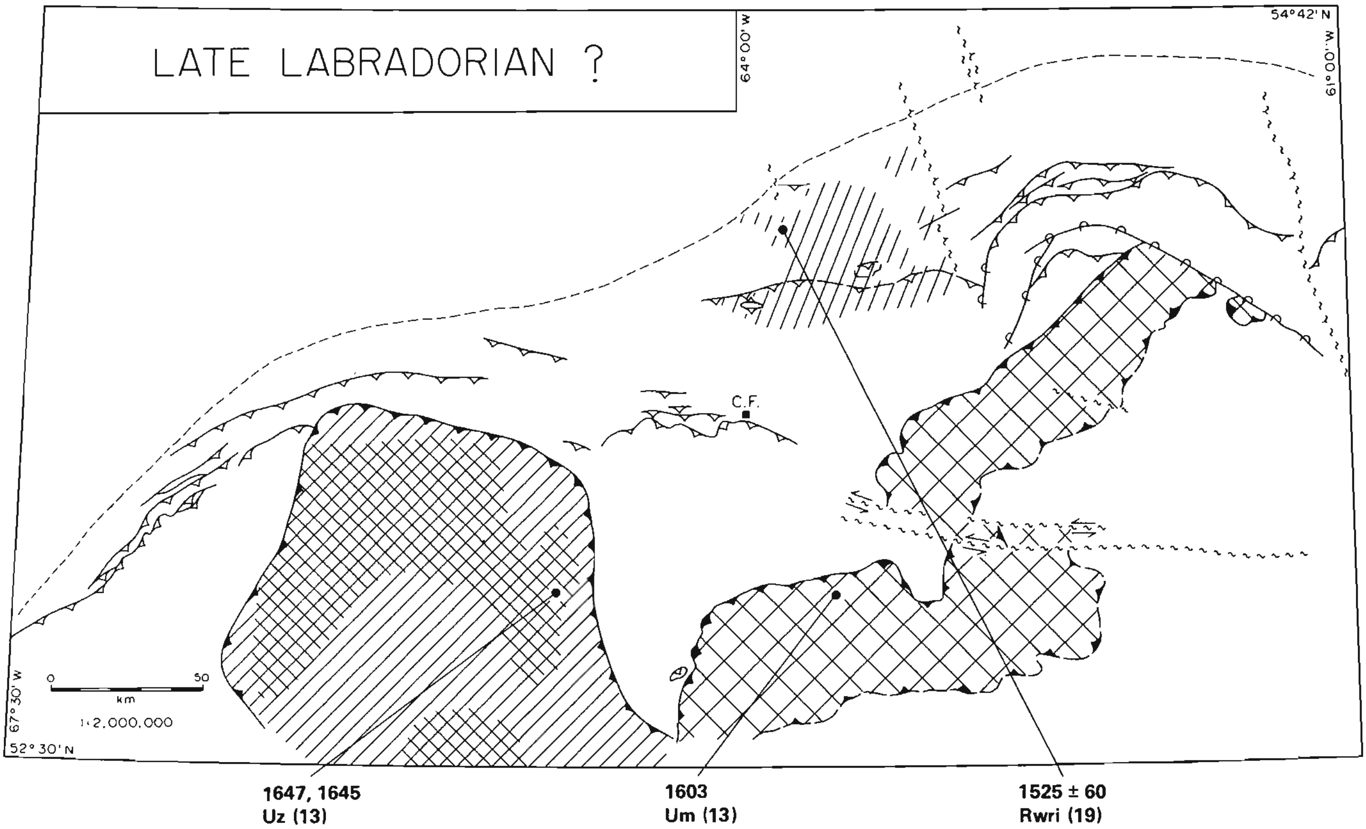


Figure 5: *Stage 3: late Labradorian?, 1670-1600 Ma.*
Late Labradorian or younger deformation:—
Selective, commonly in shear zones - *Granulite facies*
- *Greenschist facies*
Penetrative - *Granulite facies*
- *Amphibolite and/or granulite facies*

thon the deformation occurs in wide shear zones which contain granulite facies mineralogies and commonly have very strong south-southwest plunging lineations. This lineation is coincident in orientation and intensity with that associated with the Grenvillian Orogeny and widely recognized throughout the Grenville Province, particularly along its northern margin (Wynne-Edwards, 1972). The shear zones themselves are undated. Postplutonic deformation in the Wilson Lake allochthon could, therefore, range from late Labradorian to Grenvillian in age. If the 1676 and 1666 Ma dates on the paragneiss in the Wilson Lake allochthon do indeed represent a post plutonic event (instead of stage 1) the three-stage, deformation - plutonism - deformation cycle in this allochthon is an earlier (but perhaps diachronously related) cycle than that seen to the north involving the Trans-Labrador batholith.

Low-grade deformation followed the emplacement of the Trans-Labrador batholith throughout its northern parts sometime within the interval 1650 Ma to 1330 Ma (deposition of late Middle Proterozoic cover) and most probably prior to circa 1480 Ma (age of Michikamau anorthositic Intrusion). The steeply-dipping, north-northeast-striking fabric is only locally developed and is only known from the granitoid rocks of the batholith and the coeval cover sequence. It is most commonly represented by a weak phenocryst and xenolith alignment in an apparently undeformed igneous groundmass but ranges in intensity to narrow zones of mylonite. These relationships suggest a syn- to post plutonic, protoclastic style of deformation related to regional tectonism during emplacement of the batholith (1655-1600 Ma). The 1525 Ma date (Figure 5) is a Rb-Sr isochron from coeval, acid volcanic cover rocks which contain greenschist facies assemblages (Emslie in Wanless and Loveridge, 1978) and provides an alternative guestimate for the age of this fabric. This deformation may have been more extensive but has only been preserved in the northern margin of the Grenville Province in strain augen that remained undeformed during the Grenvillian Orogeny (Nunn and Noel, 1982). The deformation, if present throughout the batholith, was unlikely to have exceeded low-grade since all the sphene samples from the batholith show only one generation of lead loss (normal blocking temperature for lead in sphene

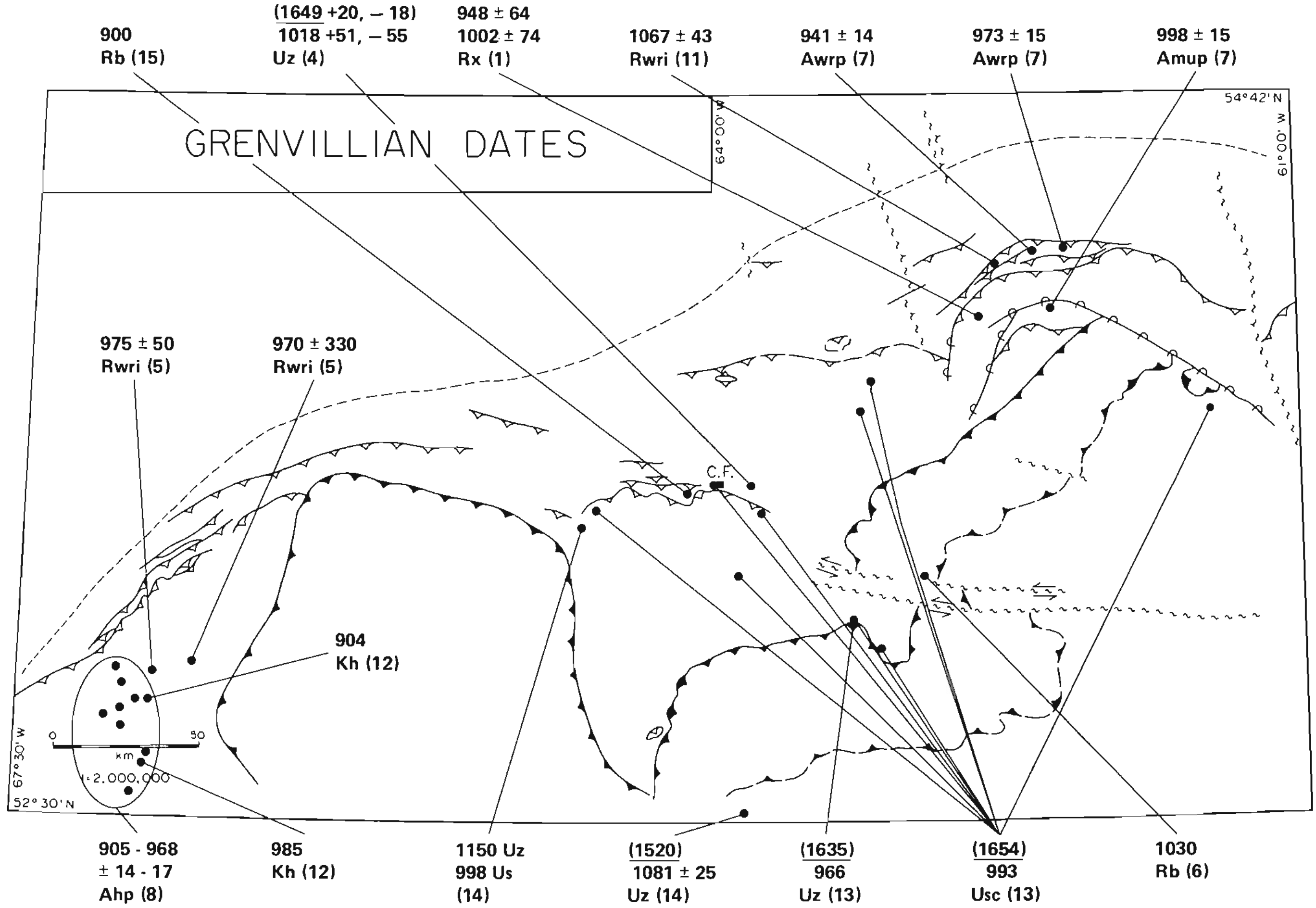


Figure 6: *Grenvillian dates, 1200-900 Ma.*
Grenvillian K-Ar cooling ages in the region range down to circa 800 Ma.

500-550°C) and this was the result of a Grenvillian event (Figure 6).

If the later phases or plutons in the Trans-Labrador batholith do indeed range down to 1570 Ma or younger the 1525 Ma guestimate for the age of the north-northeast striking fabric may be more reliable than the 1655-1600 Ma possibilitiy and the late Labradorian may be confined to the allochthons.

GRENVILLIAN OROGENY

Superimposed Grenvillian dynamothermal metamorphism (Figure 6) ranges from lower greenschist facies in the north of the area to granulite facies in the south of the area and varies in effect from partial or complete resetting of low temperature geochronological systems to new mineral growth of zircon.

A number of other, and commonly enigmatic, dates have been obtained from the area (Figure 7). Some possible explanations are given with the diagram.

Many K-Ar and Ar-Ar dates on biotite, muscovite and whole rock samples, which range from 850 to 2000 Ma, have been omitted from Figures 6 and 7 because of potential problems of excess argon in phyllosilicates in a zone along the northern margin of the Grenville Province. Many of these dates, however, do relate to cooling following the Grenville Orogeny. This phenomenon is discussed with reference to biotite by Dallmeyer and Rivers (1983). Only the most extreme examples of excess argon contamination (dates 2000 Ma) have been included in Figure 7.

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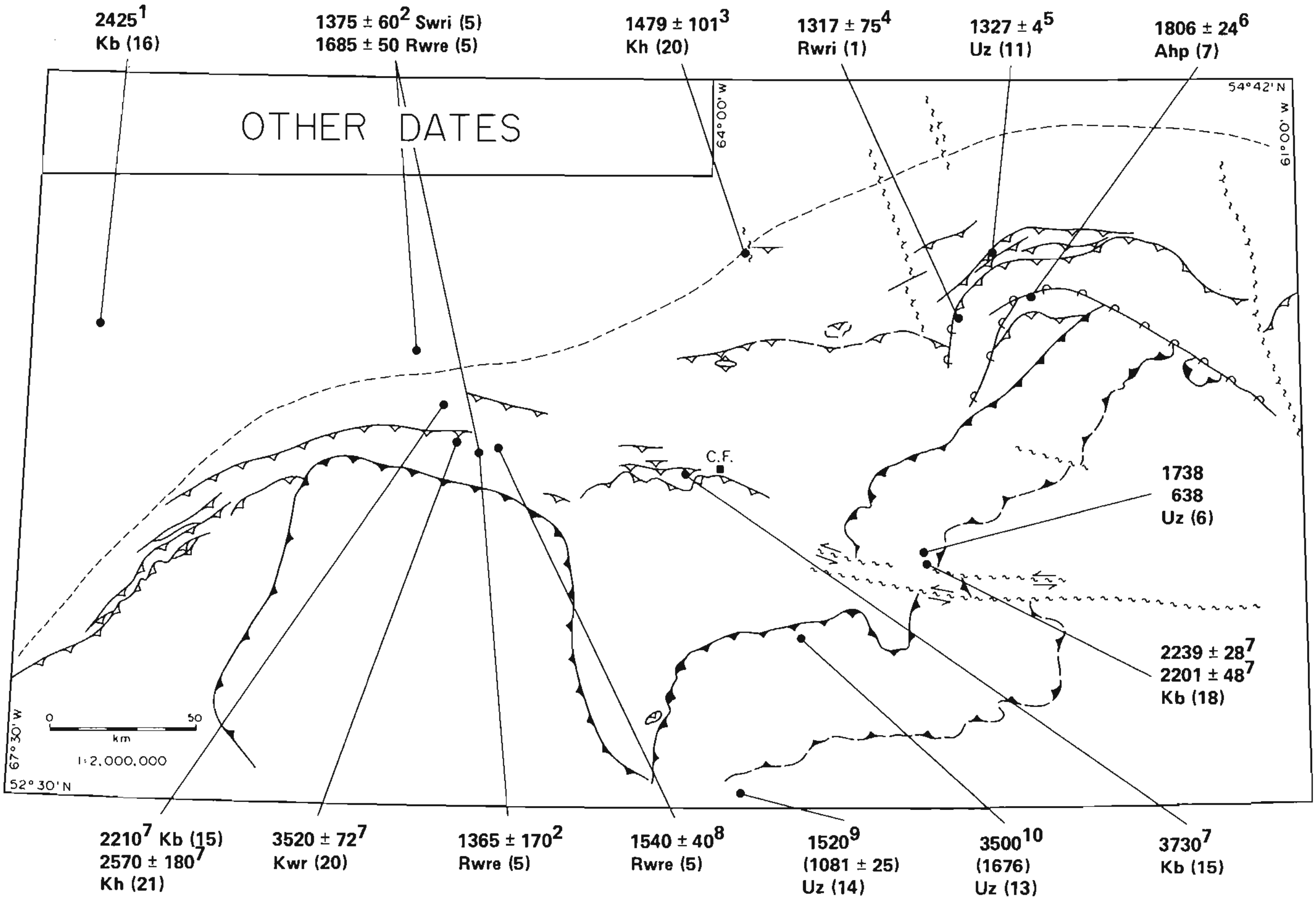

Figure 7: *Other dates.*
Subscripts:
1 *Kenoran cooling age (Unit 1, Figure 1).*
2 *Age of Shabogamo Intrusive Suite (Unit 16, Figure 1).*
3 *Age of Michikamau anorthositic Intrusion (Unit 14, Figure 1).*
4 *Age of peralkaline intrusive complex (Unit 17, Figure 1).*
5 *Age of Letitia Lake Group (Unit 21, Figure 1).*
6 *?tectonic inclusion from Churchill Province basement to thrust sheets.*
7 *Excess argon.*
8 *Age of Blueberry Lake group (Unit 20, Figure 1).*
9 *Poorly constrained upper intercept.*
10 *?Archean source, core detrital in Aphebian sediment.*

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