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Late Archean geologic history of the Nain Province, North River-Nutak map area, Labrador, and its tectonic significance

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Résumé de l'article

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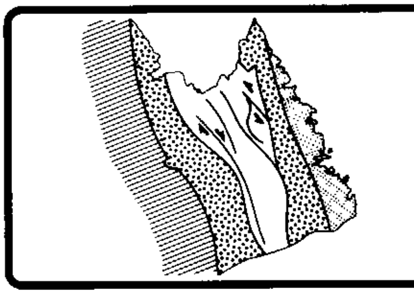

Late Archean geologic history of the Nain Province, North River–Nutak map area, Labrador, and its tectonic significance

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Summary

The high-grade gneisses of the Archean Nain Province were formed through Early and Late Archean orogenic cycles. Late Archean structural development consisted of pre-thermal-peak isoclinal folding and thrusting in allochthonous Upernavik supracrustal rocks, followed by regional, recumbent, isoclinal folding and upright refolding of the Upernavik suite and reworked Early Archean gneisses under amphibolite- to granulite-facies conditions. Style and sequence of the Late Archean structures closely resemble those described by previous workers from the Early Archean gneiss complex of the North Atlantic craton, from Precambrian greenstone belts, and from Phanerozoic orogenic belts, suggesting that no principal differences exist in the structural evolution of these types of terrain.

Introduction

The Archean Nain Province of the Laurentian Shield is a typical high-grade gneiss terrane that consists of 70–80% tonalitic orthogneiss and migmatite and up to 30% tectonic remnants of supracrustal rocks. The province has a complicated geologic history that involved both Early and Late Archean orogenic cycles, separated by the emplacement of the Saglek mafic dykes *ca.* 3.4–3.2 Ga (Bridgwater and Collerson, 1976; Collerson *et al.*, 1981).

The purpose of this paper is to describe the Late Archean structural and metamorphic evolution of the Nain Province in the North River–Nutak map area of northern Labrador (NTS maps 14E and 14F), located south of the Saglek–Hebron area described by Collerson *et al.* (1981).

Early Archean development

Early Archean rocks of the Nain Province are represented by *ca.* 3.8 Ga supracrustal rocks of dominantly basaltic composition (Nulliak assemblage) that were intruded by Uivak I calc-alkaline tonalites at 3.73 Ga (Bridgwater and Collerson, 1976; Schiøtte *et al.*, 1989). Xenocrystic zircons in Uivak I gneisses suggest the presence of even older crust (3.9–3.85 Ga) that may have formed the basement to some of the Nulliak assemblage (*e.g.*, Schiøtte *et al.*, 1989). All of these rock types were tectonically interleaved during high-grade metamorphism at 3.62 Ga (Shiøtte *et al.*, 1989) and intruded by syn-kinematic granitoid sheets (Uivak II gneisses: Bridgwater and Collerson, 1976).

Structures formed during the Early Archean cycle are not well preserved in the study area, but have been documented by previous workers in adjacent areas of northern Labrador that were little affected by Late Archean strain (*e.g.*, Collerson and Bridgwater, 1979). There, and in the well-preserved, contemporaneous, Isukasia region of West Greenland (Nutman, 1986), structural analyses indicate a history of thrusting and recumbent isoclinal folding (Fn) under high metamorphic grade, and the development of a regional gneissosity (Sn)(Table 1).

Late Archean development

In the Late Archean, supracrustal rocks of the Upernavik suite (age uncertain, but >2.7 Ga) were deformed and tectonically interleaved with the Early Archean gneiss complex *ca.* 2.8–2.7 Ga, during granulite- to amphibolite-facies metamorphism (Schiøtte *et al.*, 1989). Syn-kinematic intrusion of tonalitic sheets and migmatization of all rock types occurred at this time, together with the development of a strong gneissosity (S_{n+1}; Table 1). Rocks of Late Archean age can be distinguished from Early Archean gneisses because they do not contain Saglek dykes (*cf.* Bridgwater and Collerson, 1976) and because the structures they contain are also observed in the Saglek dykes and older rocks (Figure 1a).

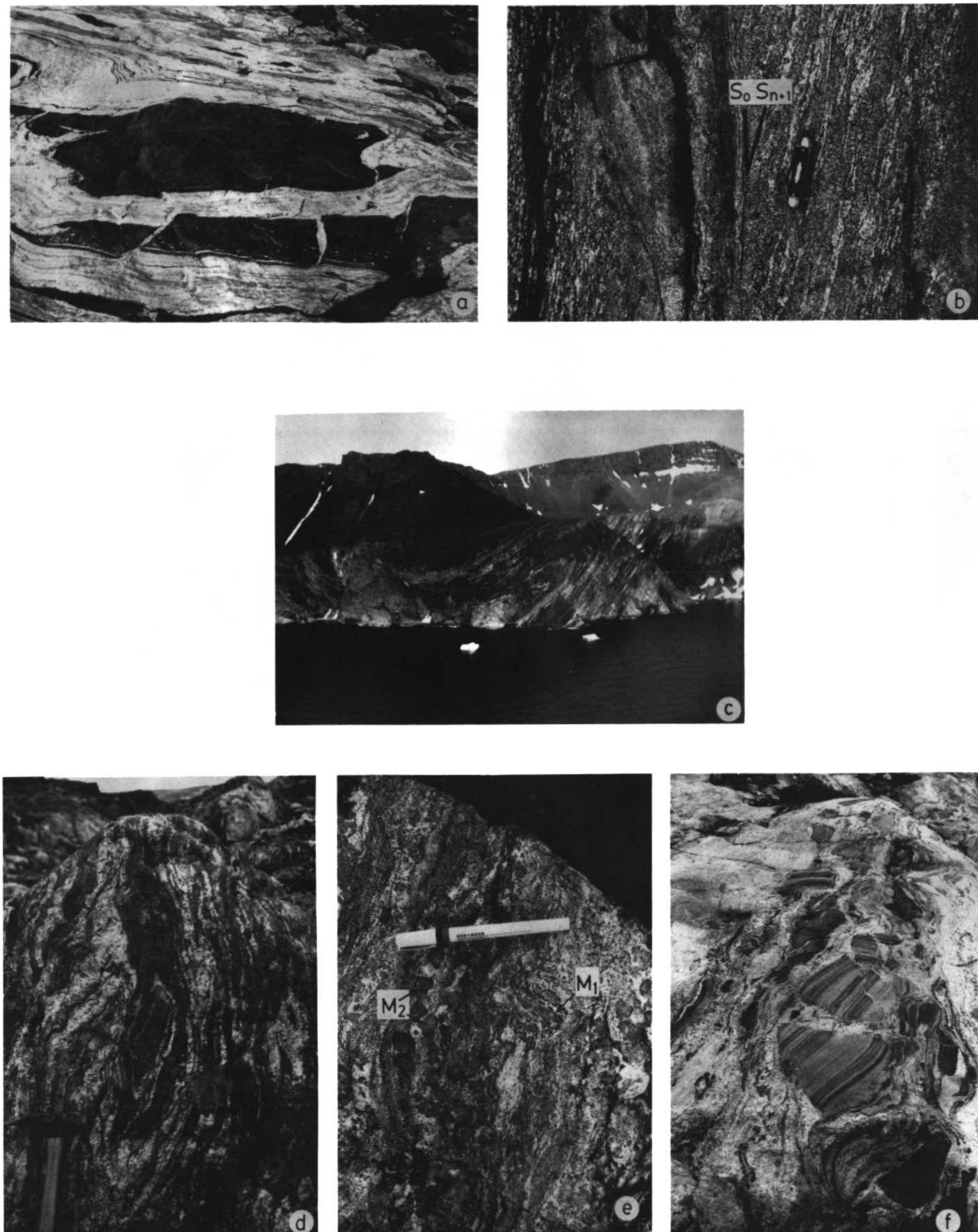
Rocks of the Upernavik suite are well preserved in the North River–Nutak map area as narrow slivers (1 to 10s of metres wide by 100s to 1000s of metres long), or within large fold interference structures such as that located south of Pistolet Bay (Figure 2). Three different lithologic assemblages can be distinguished. First, and most common, is an assemblage comprising structurally lowermost layered mafic and ultramafic rocks, metasedimentary rocks of predominantly pelitic to quartzofeldspathic composition with layers of iron formation and impure marble, and sills of plagioclase-megacrystic metagabbro. A second assemblage contains layered ultramafic-gabbro-anorthosite complexes interleaved with amphibolites and metasedimentary gneiss that, together with some thick sections of ultramafic rocks, may represent slivers of oceanic lithosphere (*cf.* Wiener, 1981). A third type that comprises quartzite, marble, iron formation and mafic gneisses is interpreted to represent fragments of a dismembered shelf sequence.

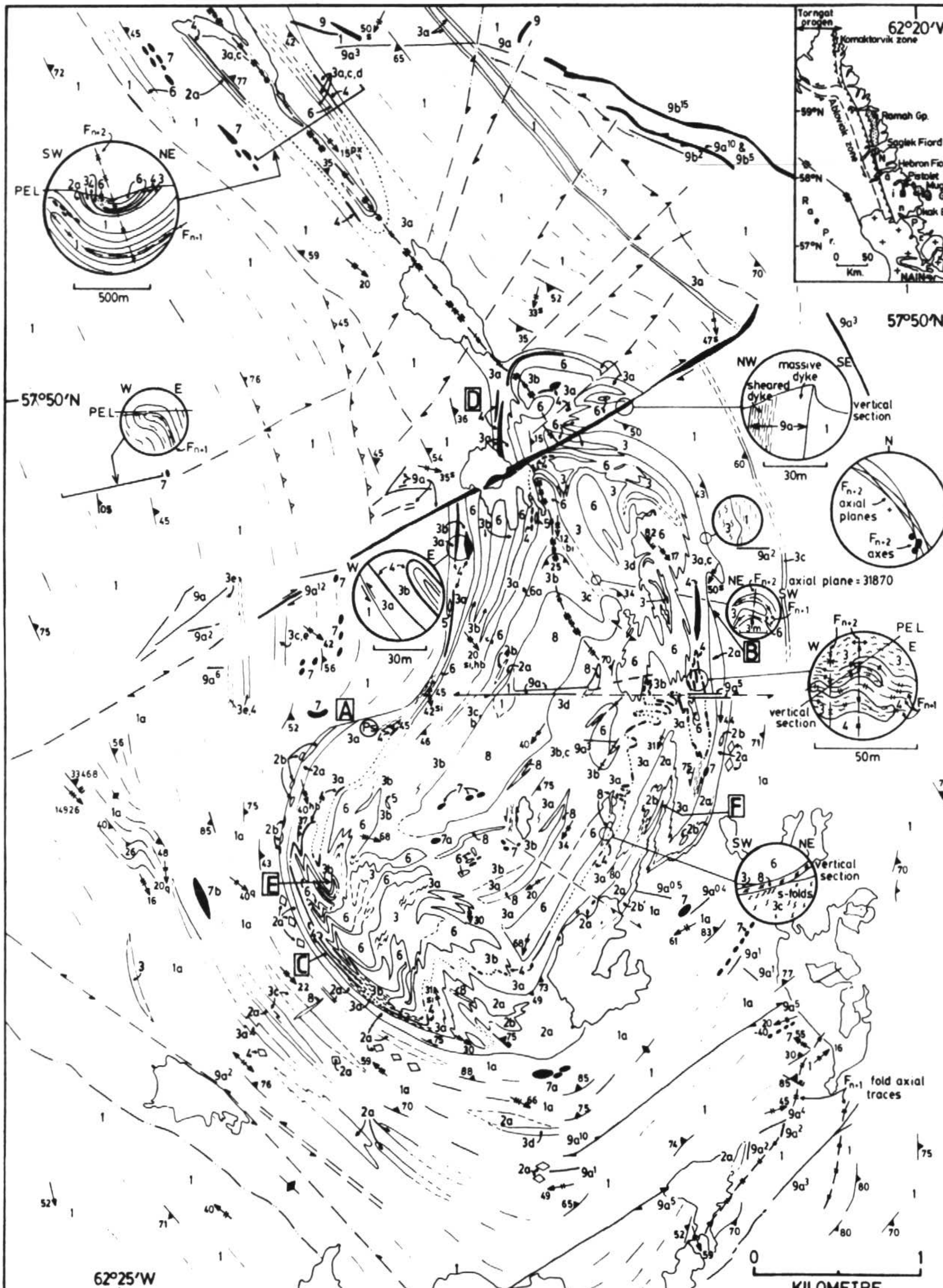
The Upernavik rocks of the Pistolet Bay fold structure are in contact with the Early Archean gneiss complex across a sharp boundary that locally truncates basal Upernavik units (localities A and B in Figure 2). These contacts, and the local repetition of units (*e.g.*, the layer of iron formation at localities C and D in Figure 2), are attributed to thrusting. Thrusts are folded by subsequent regional deformation and are therefore interpreted to be the first set of Late Archean structures (see Table 1). Isolated fold closures (Fo in Table 1; *e.g.*, locality E of Figure 2) that are overprinted by the regional metamorphic foliation (S_{n+1})(Figure 1b) and refolded by later folds are interpreted to be associated with this thrusting. The lack of depositional contacts between the Upernavik rocks and the basement gneisses and the presence of thrust faults along their contacts suggest that the Upernavik rocks are allochthonous, as suggested by Bridgwater

Figure 1 ***(opposite page)***
(**a**) *Mafic Saglek dyke remnant in Uivak I orthogneiss, folded and boudinaged during Late Archean tectonism.*
(**b**) *Relict sedimentary bedding (S_O) in Upernavik meta-sandstone from the Pistolet Bay fold structure, preserved at an angle to S_{n+1} on the limb of an early fold.*
(**c**) *Late Archean recumbent isoclinal fold (F_{n+1}), and open, upright F_{n+2} refold in Nain gneisses unconformably overlain by lower Proterozoic Mugford supracrustal rocks. Cliff face is several hundreds of metres high. Photograph by I. Ermanovics.*
(**d**) *F_{n+1} sheath fold in Uivak I gneiss at locality F in Figure 2.*
(**e**) *Snowball-textured M_1 garnet and post-tectonic M_2 euhedral garnets in leucosome veins in pelite from the Pistolet Bay fold structure.*
(**f**) *Disrupted blocks of Uivak gneiss with Late Archean regional structures in polyphase sheets of ca. 2.56 Ga granitoid gneiss. Amphibolite-facies shear zone, Labrador Sea coast.*

Table 1 Sequence of structures and metamorphism in the North River–Nutak map area, Nain Province, Labrador.

Age	Planar Str.	Folds	Lineation	Metamorphic Assemblage
Early Archean	Sn	Fn	?Ln?	?Mn? (granulite?)
Late Archean	So, thrusts	Fo	(in Upernavik suite rocks, only)	
ca. 2.8-2.7 Ga	S_{n+1}	F_{n+1} recumbent	L_{n+1}	M_1 granulite, high P
	S_{n+2}	F_{n+2} upright	L_{n+2}	M_2 granulite, low P
(coastal shear) *ca.* 2.56 Ga	S_{n+3}	F_{n+3}	L_{n+3}	M_3 amphibolite


a
So Sn+1
b
c
d
M2
M1
e
f


62°20'W
Torngat orogen
Komaktorvik zone
Ramah Gp.
Saglek Fiord
Hebron Fiord
Pistolet Bay
Mugford Gp.
Okak Bay
NAIN
59°N
58°N
57°N
0 50 Km.
57°50'N
57°50'N
500m
SW
NE
PEL
F_{n+2}
F_{n+1}
W
E
NW
SE
massive dyke
sheared dyke
vertical section
30m
N
F_{n+2} axial planes
F_{n+2} axes
axial plane = 31870
A
B
C
D
E
F
50m
s-folds
F_{n+1} fold axial traces
62°25'W
0
1
KILOMETRE

and Collerson (1976) and Collerson *et al.* (1981) in the adjacent Saglek–Hebron area (inset Figure 2).

Thrusting was followed by recumbent, westward to southerly verging, isoclinal nappe folding (F_{n+1}) and coeval development of a syn-metamorphic (M_1), axial planar foliation (S_{n+1} on Figure 2). These folds are visible at all scales (Figures 1c and 2) and may be markedly non-cylindrical (Figure 1d). Nappe fold limbs are zones of relative high strain, suggesting significant translation. Preliminary thermobarometric work on M_1 assemblages of ortho- and clinopyroxene-garnet-plagioclase-quartz in metabasites and garnet-plagioclase-sillimanite-quartz-biotite in pelites suggest peak metamorphic conditions of P≈8.5 kbars and T≈900°C.

Nappes are refolded by upright, open to tight folds (F_{n+2}) with NNW-trending axial surfaces and moderately plunging axes (Figure 2). This deformation produced the regional tectonic grain in the Nain Province, characterized by large-scale antiformal culminations cored by straight-layered basement orthogneiss and Late Archean migmatite veins, and synforms in which most of the Upernavik rocks are preserved. This large-scale pattern suggests density-amplified folding similar to that proposed for the formation of greenstone "keels" in many high-level granite-greenstone terranes (Dixon and Summers, 1983). Granulite-facies metamorphism outlasted the F_{n+2} deformation as shown by post-tectonic assemblages (M_2) that have overgrown the M_1 assemblages (Figure 1e). Symplectites of plagioclase-orthopyroxene around garnet in metabasites and quartzo-feldspathic metasediments, and of cordierite around garnet in pelites indicate significant decompression during M_2 growth. Preliminary thermobarometry on these assemblages indicates that metamorphism occurred at P≈4.8 kbars and continued high temperatures.

Syn-kinematic sheets of leucocratic tonalite gneiss were emplaced along F_{n+1} axial planes, slightly discordant to S_{n+1}. Post-kinematic veins with orthopyroxene±hornblende±clinopyroxene caused bleaching and hydration of adjacent host rocks and were probably responsible for the continued elevated temperatures during M_2.

Along the Labrador coast, an amphibolite-facies shear zone that is hundreds of metres wide cuts across the regional F_{n+2} tectonic grain and re-orients earlier structures (Figure 1f). It is characterized by extensive retrogression of M_1 and M_2 mineral assemblages and contains polyphase, grey to white sheets of biotite-bearing granitoid rocks that have yielded U-Pb dates of 2560±10 Ma (J.C. Roddick, personal communication, 1990). Islands to the east of this zone contain different supracrustal assemblages than those to the west and at least some granitoid gneisses that are of different age (L. Schiøtte and J.C. Roddick, personal communication,

Figure 2 ***(opposite page, legend below)*** *Geology of the Pistolet Bay fold structure. Late Archean Upernavik supracrustal rocks (map units 2 to 6) are juxtaposed against Early Archean Uivak I gneisses (map unit 1) across a basal thrust fault, and deformed by three sets of Late Archean folds (see text for explanation). Localities A-E are discussed in the text: Locality F shown in Figure 1d. Figure locality is shown by black box in inset diagram.*

1 Leucocratic tonalitic orthogneiss and migmatite (Uivak gneiss).
1a as above, with 25-50% supracrustal inclusions.

Upernavik assemblage
2a cm-layered, 2 px-hb-plag amphibolite gneiss.
2b Massive, 2px-hb-ol-sp meta-ultramafic; locally with pseudospinifex texture (2b').
3 Unsubdivided paragneiss.
3a si-rich, gt-bi meta-pelite.
3b gt-opx-bi semi-pelite.
3c gt-bi paragneiss.
3d cd-gt-si-bi meta-pelite.
3e opx-bi psammite: quartzite.
4 Iron formation; known, extrapolated.
5 Impure marble.
6 Plagioclase-phenocrystic meta-gabbro.
6a as above, with relict igneous layering.

7 Tan coloured serpentinite pods, locally with relict olivine and phlogopite.
7a as above, with relict igneous layering.
7b Serpentinite breccia (≤2m diametre blocks) in a biotitic matrix.
8 Late Archean, syn-kinematic sheets of gt-bi±opx bearing, foliated tonalitic gneiss.
9 Early Proterozoic mafic dykes, showing shear sense (if present), and dyke thickness (in metres).
9a² Napaktok diabase meta-dykes.
9b Mafic breccia meta-dykes, younger than 9a, with ≤70% inclusions of country rock fragments in a fine-grained, green biotite matrix.

Lithologic contact; defined, inferred.
Tectonic inclusion in unit 1, 1a.
Trace of gneissic layering: strike and dip; orientation, with shear sense.
Orientation of late Archean F_{n+1} mineral lineation within gneissic layering (see below for mineral abbreviations).
Axial trace and plunge of F_{n+1} folds of lithologic layering in Upernavik rocks and of gneissic layering in Uivak gneisses, to which S_{n+1} metamorphic foliation is axial planar.
Ductile mylonite zone, with schistosity and sense of shear: (unknown, strike slip, oblique normal, reverse).
F_{n+2} axial planes and/or spaced cleavage.
F_{n+2} mineral extension lineation.
Axial trace and plunge of F_{n+2} microcrenulations and folds of gneissic layering: synform; antiform.
Hudsonian fault: strike-slip, reverse.

a = quartzofeldspathic aggregate: bi = biotite: cd = cordierite: gt = garnet: hb = hornblende: ol = olivine: opx = orthopyroxene: P.E.L. = present erosion level: Ps = pseudotachylyte: px = pyroxene: q = quartz: s = undefined stretching lineation: si = sillimanite: sp = spinel.

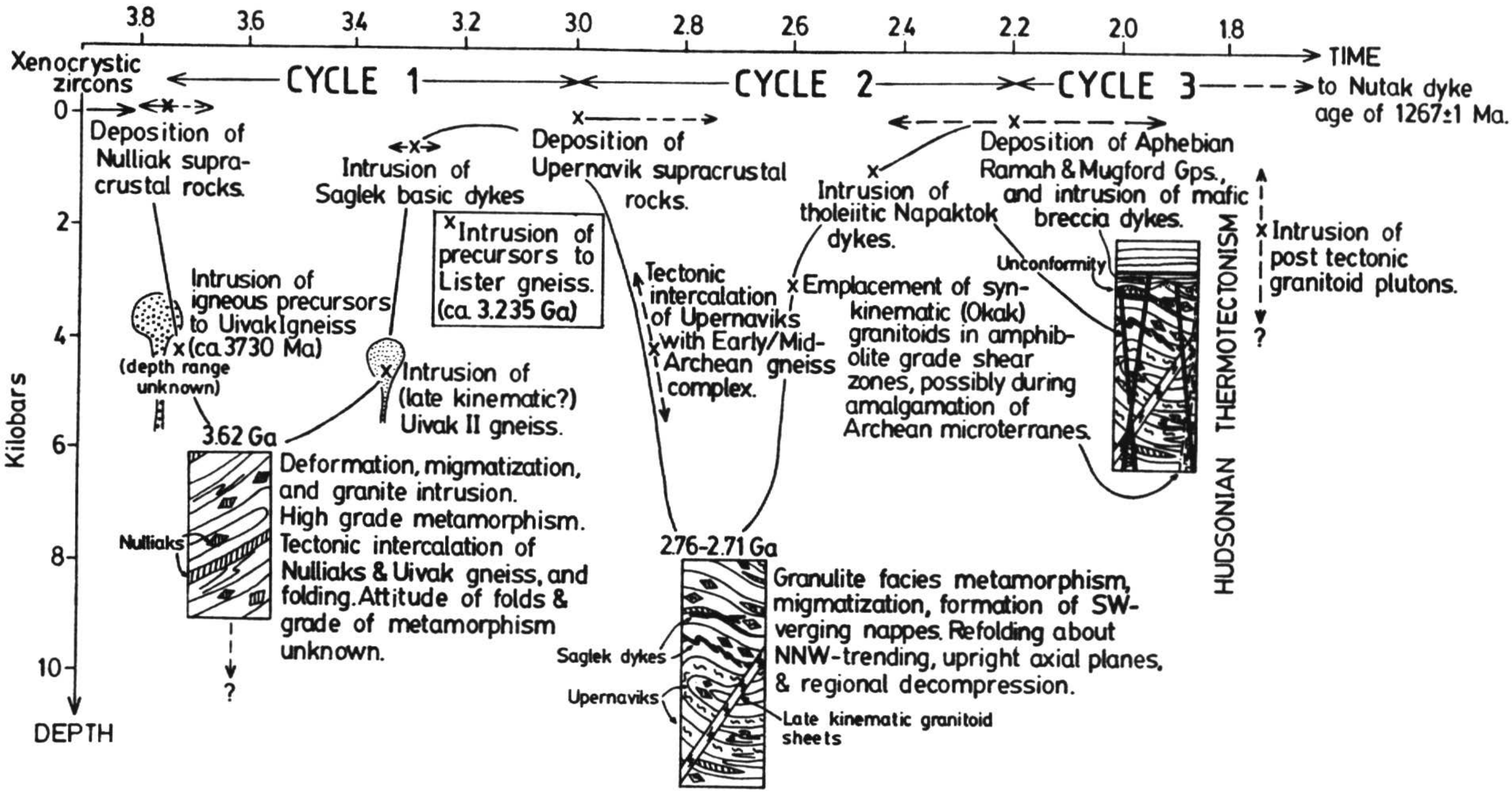


Figure 3 *Time-depth diagram of Nain Province evolution through four cycles of crust formation and deformation. Note that this paper deals only with Archean events; for details of Proterozoic evolution, see Van Kranendonk and Ermanovics (1990).*

1990: *e.g.*, Lister gneiss in Figure 3). These different regions could represent terranes that were juxtaposed along the shear zone prior to the emplacement of post-tectonic granites.

Summary and discussion

The Nain Province evolved through Early and Late Archean orogenic cycles (Figure 3) and was affected by a younger orogenic cycle along its western margin within the Hudsonian Torngat Orogen (see Van Kranendonk and Ermanovics, 1990). There is also evidence of an older cycle, suggested by the xenocrystic zircons in Uivak gneiss (Schiøtte *et al.*, 1989). In the Late Archean cycle, imbrication of allochthonous Upernavik rocks with Early Archean gneisses and recumbent folding under high-grade metamorphic conditions suggest an underthrusting (A-type subduction) regime (*cf.* Bridgwater *et al.*, 1974). A similar set of structures is found in regions underlain by Early Archean gneisses not affected by Late Archean strain, which suggests a similar tectonic history for the two orogenic cycles.

Principal differences between the Early and Late Archean cycles include the relative timing, volume, and composition of granitoid rocks. The Early Archean cycle is interpreted to represent essentially new crust formation through generation of the Nulliak assemblage and voluminous calc-alkaline intrusions (Uivak I gneisses). After recumbent folding under high-grade metamorphic conditions, these rocks were only locally refolded and intruded by Uivak II gneisses.

The Late Archean cycle, on the other hand, involved extensive reworking of the Early Archean crust and intercalation of allochthonous Upernavik rocks. This deformation was accompanied by only minor syntectonic intrusion of granitoid rocks that were derived from partial melting of the crust (Collerson *et al.*, 1981). Partial melting was probably caused by underplating of magmas derived from slab melting, as suggested by the presence of Late Archean intrusive rocks with juvenile Sr-isotopic characteristics (Collerson *et al.*, 1981). The F_{n+2} phase of upright refolding in the Late Archean cycle is interpreted to be the result of a higher level crustal response to continued conversion and shortening of the Nain crust following F_{n+1} nappe formation and uplift, during possible terrane accretion.

This general cycle of (1) formation of supracrustal rocks; (2) calc-alkaline tonalitic magmatism; (3) tectonic intercalation of supracrustal rocks with orthogneiss, and recumbent nappe folding at peak metamorphic grade in an underthrusting (subduction) regime, accompanied by syn-tectonic intrusion of crust-derived partial melts; (4) upright refolding and possible terrane accretion; and (5) emplacement of post-tectonic granites and mafic dykes, is found in most high-grade gneiss terranes. It is broadly compatible with the three-stage fusion process of continental crust formation outlined by Bickford (1988).

The deformational history of the Upernavik suite is also similar to that of many Precambrian greenstone belts (*e.g.*, the Early Archean Barberton Greenstone belt; de Wit, 1982) and some Phanerozoic orogenic belts (*e.g.*, Norwegian Caledonides; Möller, 1988) in which late kinematic granitoid intrusions have not obliterated all evidence of early thrusting. These similarities in structural style and sequence suggest a common tectonic evolution. The differences in the dominant structural style between Archean high-grade gneiss and low-grade granite-greenstone terranes are interpreted to reflect the varying intensity of deformation (*i.e.*, distance of tectonic transport), metamorphism and intrusion as a function of crustal level, but do not mean that these terranes had fundamentally different histories.

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