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Aller au sommaire du numéro

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Résumé de l'article

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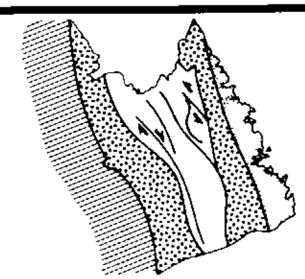

Basement-cover relationships and metamorphic patterns in the foreland of the Torngat Orogen in the Saglek–Hebron area, Labrador

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Summary

The Archean Nain Province of northern Labrador displays a variable imprint of Early Proterozoic thermotectonism several tens of kilometres east of its collisional boundary (Torngat Orogen) with the Archean Rae (eastern Churchill) Province, the latter extensively reworked by Early Proterozoic events. This imprint is discerned by the westward increase in metamorphic grade in the Early Proterozoic Domes diabase dykes and from the degree of retrogression of Archean granulite-facies gneisses. Early Proterozoic tectonic effects also include the translation of Ramah Group cover rocks over their Archean basement, and the subsequent folding of both the basement décollement and the cover. Later steep reverse faults dissect the boundary zone between the Rae (Churchill) Province and the Archean foreland. All these features are believed to be related to Early Proterozoic oblique continental collision between two Archean crustal blocks.

Introduction

The present-day configuration of continents has arisen from the continued fragmentation and amalgamation of long-lived crustal fragments. The assembly of these fragments into larger stable cratonic masses may be accompanied by collisional orogenies. The effects of collision on two colliding fragments are generally difficult to assess without suitable stratigraphic markers that are continuous from the suture zone into the less-affected interior. The Archean Nain Province of northern Labrador is an example of such a stable cratonic fragment that has been sutured against another Archean block, the Rae Province, along an Early Proterozoic (Hudsonian) collisional boundary termed the Torngat Orogen (Hoffman, 1988). Unlike Nain Province, however, Rae Province has been extensively ductilely reworked during the Hudsonian thermotectonism (of which the Torngat Orogen is one expression). The Nain Province in the Saglek–Hebron area constitutes the foreland to the Torngat Orogen, and exhibits variable effects of Hudsonian metamorphism and deformation. Brief descriptions of Hudsonian effects are presented in this contribution. More detailed treatment of this and other aspects of Early Proterozoic thermotectonism in the Saglek–Hebron area will be given elsewhere (Ryan, in preparation).

General geology

Nain Province and Ramah Group. The Archean Nain Province or craton preserves evidence of a complex history extending from *ca.* 3.7 Ga to 2.5 Ga (see summaries and references in Collerson *et al.*, 1976; Bridgwater *et al.*, 1978; Ryan *et al.*, 1983; Ryan *et al.*, 1984). The craton comprises Early Archean polyphase Uivak orthogneisses tectonically intercalated with metasedimentary and metavolcanic supracrustal rocks of probably several generations (Bridgwater *et al.*, 1990; Schiøtte and Bridgwater, 1990). The region was metamorphosed to amphibolite to granulite facies during the Late Archean. In the Saglek area, the granulite-facies rocks occur west of the Proterozoic Handy Fault whilst amphibolite-facies rocks occur east of it (Figure 1). Granulite-facies rocks also occur east of the fault in the Hebron Fiord area. This pattern is apparently due to scissor-like movement along the fault, that has exposed deeper crustal levels southward on the eastern side (Ryan *et al.*, 1984).

A stabilized Nain craton was intruded by a swarm of Early Proterozoic (*ca.* 2.4–2.2 Ga; *cf.* Taylor, 1979) diabase dykes, herein referred to as the Domes dykes (considered to be equivalent to the Napaktok dykes of Ermanovics *et al.* (1989)). The region was subsequently peneplaned and overlain by the Ramah Group, a platformal to basinal sequence comprising primarily siliciclastic rocks (Knight and Morgan, 1981) disposed in a north-south trending synclinorium. Between Saglek and Nachvak fiords (Figure 1b), the eastern margin of the Ramah Group rests with marked unconformity on the Archean complex and the Domes dykes. The western margin is deformed, metamorphosed and overthrust by Nain Province Archean gneisses bearing a Proterozoic overprint (Morgan, 1975; Mengel, 1988). In contrast, the Ramah Group between Saglek Fiord and Okak, 100 km to the south (Ermanovics and Van Kranendonk, 1990), is preserved largely as narrow, highly tectonized, belts within refoliated Archean gneisses (Ryan *et al.*, 1983; Ryan *et al.*, 1984).

Rocks west of the Ramah Group. Archean gneisses that have undergone an Early Proterozoic amphibolite-facies refoliation are in steep reverse-fault contact with the Ramah Group. These pass westward into similar rocks, but at granulite facies. The refoliated Archean gneisses were assigned to the Komaktorvik zone by Korstgård *et al.* (1987). West of the Komaktorvik zone is the Tasiuyak gneiss, a granulite-facies, garnet-rich, leucocratic anatexite and metasedimentary gneiss characterized by an intense mylonitic fabric and subhorizontal quartz-rodding lineation. The contact between the refoliated Archean gneisses and the Tasiuyak gneiss is a zone of tectonic interleaving. Both Komaktorvik zone and Tasiuyak gneisses show penetrative deformation associated with the development of the Abloviak shear zone (Korstgård *et al.*, 1987), a major belt of sinistral transcurrent shear now recognized to affect the Rae Province, the Tasiuyak gneiss and the adjacent Nain craton from Ungava Bay to southern Labrador (*cf.* Hoffman, 1988; Girard, 1990).

The Proterozoic imprint

The Domes dykes. The pre-Ramah Group tholeiitic Domes dyke swarm provides a regional marker that can be used to assess the Early Proterozoic metamorphic overprint on the Archean craton. A marked mineralogical discontinuity, corresponding to the virtual complete metamorphic replacement of igneous clinopyroxene in the dykes by secondary amphibole, occurs in the central part of the Saglek–Hebron region. On the basis of this change, the region is divided into two zones, Zones 1 and 2, the latter being the one in which amphibole dominates (Figure 1c). It should be pointed out here that foliated amphibolite dykes are present across the whole Nain Province foreland and occupy shear or fault zones even in Zone 1. These amphibolites locally exist in close proximity to relatively fresh dykes, and appear to belong to a separate generation, although cross-cutting relationships have not been observed. These anomalous dykes are not included in the descriptions below.

The Domes dykes in easternmost (coastal region) Zone 1 are undeformed and characterized by subophitic augite and plagioclase. Narrow actinolite coronas are developed on pyroxene in some dykes, and plagioclase is clouded by fine oxide dust and saussurite. Chlorite is present as irregular clots between the igneous minerals. In the westernmost part of Zone 1, the primary pyroxene is generally 60–70% replaced by zoned blue-green hornblende, and the saussuritized plagioclase is corroded and replaced along its margins by adjacent amphibole. Red biotite rims on Fe-Ti oxides and intergrowths with the amphibole are also present.

The Domes dykes maintain their straight, undeformed character into Zone 2. In the westernmost part of the zone, however, they change strike from generally east to west and northeast to north-northeast and are locally sheared and foliated. The metamorphic overprint in Zone 2 is such that pyroxene is only rarely preserved; instead, granular, matted and poikilitic hornblende is the chief mafic mineral. Relict igneous textures are recognizable in the dykes because cloudy plagioclase maintains its original tabular form, although in some areas it has broken down to granular albite+epidote+quartz aggregates. Rusty-red biotite is common and, in many rocks, ilmenite has been nearly totally replaced by granular titanite. In the western part of Zone 2, south of Hebron Fiord, some dykes contain small skeletal garnets. In the westernmost part of Zone 2, strongly foliated metadiabase dykes occur within a hundred metres of the eastern boundary of the Ramah Group, and also within the overthrust sheets of reworked Archean gneiss (Figure 1c). These dykes are subparallel to the Proterozoic-re-oriented layering and are hornblende schists, containing dimensionally oriented lozenges of hornblende, clear plagioclase, prismatic epidote, rusty-red biotite, and trains of granular titanite and Fe-Ti oxide.

The Archean quartzofeldspathic gneisses. It was recognized during earlier work in the Saglek area (*cf.* Bridgwater *et al.*, 1975) that the Archean granulite-facies rocks had undergone non-uniform retrogression, and it was proposed that some of this retrogression predated intrusion of the Domes dykes. An attempt has been made to evaluate the retrogression of hypersthene (and other minerals) in the quartzofeldspathic gneisses to determine if there is a relationship between the degree of this retrogression and the prograde metamorphism of the Domes dykes. At least ten different retrograde assemblages of orthopyroxene have been identified, but only a few are mentioned here.

(I) East of the Handy Fault. In the retrogressed granulite-facies gneisses east of the Handy Fault (Figure 1c), orthoamphibole (anthophyllite) pseudomorphs of hypersthene are common. Locally, clots of granoblastic quartz+feldspar (with one or more of green-brown biotite, Fe-Ti oxide, epidote and chlorite) have further replaced the orthoamphibole. Coronas of green biotite overgrow the hypersthene pseudomorphs in many places. Chlorite and epidote are regionally developed and are especially abundant south of Hebron Fiord. Only the green biotite coronas, epidote, and chlorite are considered as Proterozoic, corresponding to the degree of alteration in the Domes dykes; the orthoamphibole pseudomorphs of hypersthene appear to be earlier, and unrelated to dyke alteration.

(II) West of the Handy Fault. Pristine granulite-facies rocks co-exist with retrogressed rocks west of the Handy Fault, and demonstrate the inhomogeneity of retrogression. North of Hebron Fiord, non-retrogressed granulites are restricted to Zone 1, yet south of the fiord, fresh granulites occur well within Zone 2. Orthoamphibole sheaves and quartz+feldspar (± other minerals) clots, similar to those that form pseudomorphs of orthopyroxene in gneisses east of the Handy Fault, also occur west of it. The green biotite coronas are ubiquitous, but disappear in the western part of Zone 2; their disappearance is approximately coincident with the disappearance of the orthoamphibole pseudomorphs after hypersthene and with the growth of new brown biotite in the gneisses (Figure 1c). The former presence of hypersthene in the gneisses in the westernmost

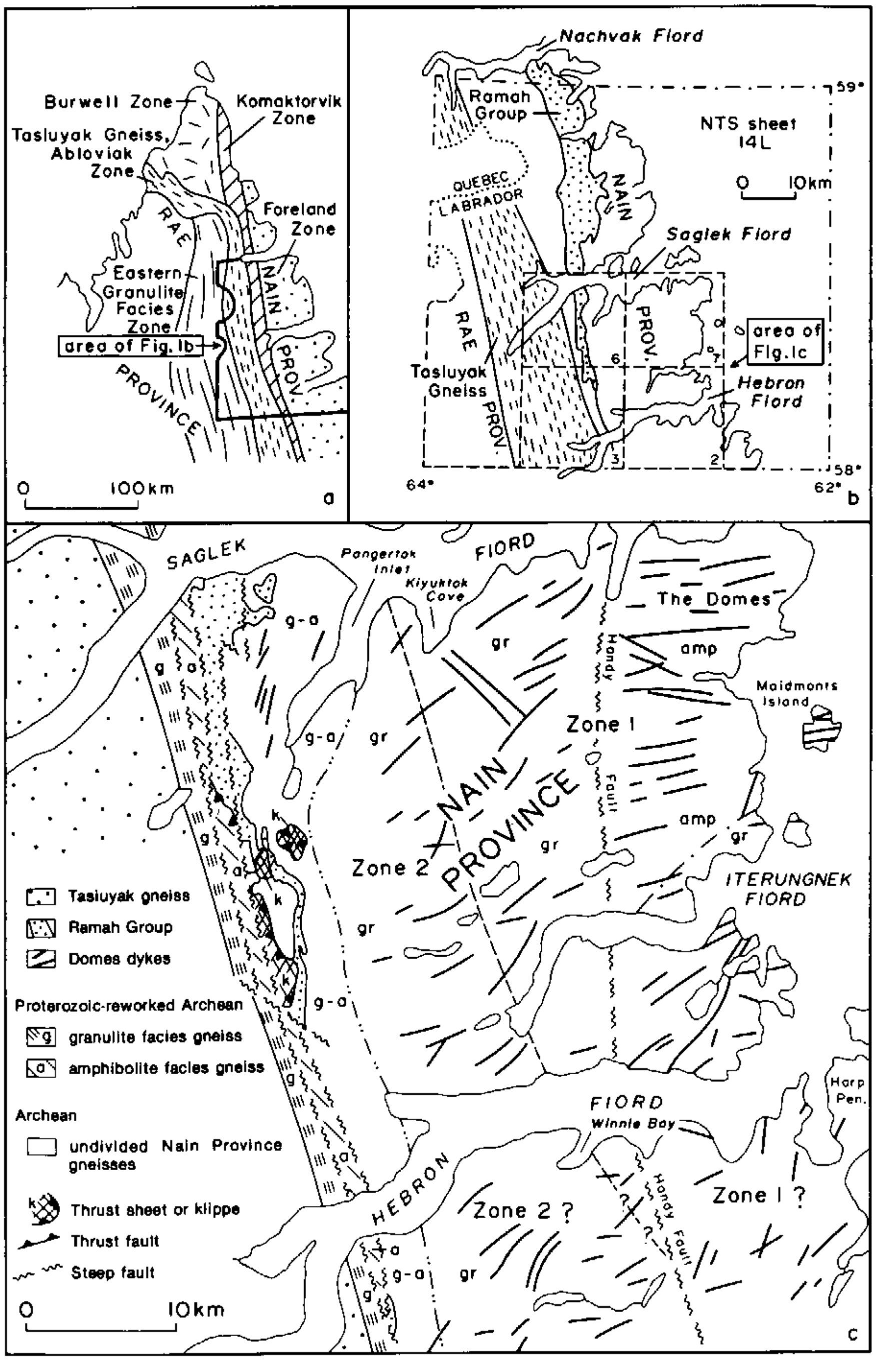

Figure 1 (a) *Major tectonic elements of northern Labrador.* (b) *Regional geological framework of the Nachvak–Hebron area.* (c) *Generalized map of the Saglek–Hebron area illustrating aspects of the geology referred to in the text;* ***amp/gr boundary*** *defines approximate location of Late Archean amphibolite/granulite-facies transition east of the Handy Fault;* ***gr/g-a boundary*** *defines approximate location where all vestiges of granulite-facies mineralogy in quartzofeldspathic rocks are destroyed by the Early Proterozoic greenschist- to amphibolite-facies overprint.*

part of Zone 2 is reflected in granoblastic quartz-feldspar blebs containing disseminated brown biotite, muscovite, epidote, sphene and Fe-Ti oxides. The latter five phases mark the Early Proterozoic middle-greenschist-facies imprint over this part of Zone 2, and reflect the type of alteration seen in the non-schistose Domes dykes. Directly adjacent to the Ramah Group, the Proterozoic retrogression is accompanied by gneiss refoliation, expressed as the development of a mylonitic ribbon-like fabric of biotite+muscovite+epidote that anastomoses around quartzofeldspathic lozenges.

The Ramah Group. The Ramah Group south of Saglek Fiord is variably inclined against the adjacent Archean complex (Figure 1c). Along the southern shoreline of the fiord, open folds of Ramah Group quartzite, marble, pelite and mafic sills are well displayed. The easternmost margin is unexposed, but it appears to be a gently west-dipping, little-modified, folded unconformity. The western margin of the Group is exposed in tectonic contact with the underlying Archean rocks, the junction between them being marked by a 1–2 m thick zone of mylonite. In the contact zone, steeply dipping gneissic layering in the Archean rocks is re-oriented parallel to the basement-cover interface, and a bedding-parallel schistosity is present in the supracrustal rocks.

South of Pangertok Inlet, the Ramah Group occurs as two moderately to steeply dipping belts in tectonic contact with basement; the eastern basement-cover contact is locally overturned toward the west. The interface between the Ramah Group and the adjacent Archean rocks of this area is a shear zone defined by mylonitic tectonic schists (*cf.* Hutton, 1979) in which distinction between basement and cover components becomes difficult. The penetrative planar fabric in this shear zone is similar in attitude and metamorphic grade to the fabric in the adjacent Ramah Group, indicating that they are likely correlative. This basement-cover fabric is, nearly everywhere, subparallel to bedding in the supracrustals. In the quartzofeldspathic schists of the contact zone the foliation is defined by muscovite+biotite+epidote; in Ramah Group quartzite, it is defined by muscovite; and in metapelite, by muscovite-biotite. Other minerals found within Ramah Group metapelites in this area include kyanite, sillimanite, staurolite and garnet; these appear to have a regional distribution pattern that is discordant to the trend of the group. Data are too scarce for delineation of isograds, but indicate that the overall pattern is one of increasing metamorphic grade from north to south and east to west (*cf.* Mengel, 1988).

Upright to westerly overturned, gently to moderately plunging, F_2 folds, which define the present outcrop pattern of the Ramah Group south of Saglek Fiord, have an associated transpositional S_2 axial planar fabric; kyanite and fibrolitic sillimanite are re-oriented into the S_2 fabric in the pelitic rocks.

Interpretation of metamorphic patterns

It is apparent from the assemblages in the Domes dykes and the quartzofeldspathic Archean gneisses that Proterozoic metamorphic effects intensify from the coast westward toward the Ramah Group. The generation of a penetrative foliation in the dykes and in the basement rocks, however, is largely confined to the basement/Ramah Group interface. The formation of this foliation is interpreted to have been synchronous with the regionally developed bedding-subparallel S_1 fabric in the Ramah Group. The following sequence of events is proposed to account for the Early Proterozoic metamorphism and tectonism seen in the Torngat foreland of the Saglek–Hebron area.

Early compressional deformation of the Ramah Group and the Archean gneisses was accommodated in part by ductile translation or tectonic sliding (*cf.* Hutton, 1979) along the basement-cover contact. Thinning of the lowermost formations in the Ramah Group in this area, and the apparent transgressive nature of the contact between basement and individual units within the Ramah Group suggest that parts of the cover succession have been excised along the slide zone. In all likelihood, similar décollement zones in the form of internal thrusts (and nappes?) were generated within the Ramah Group, and account for the formation of the generally bedding-parallel foliations seen within the metasediments of this area. The full geographic extent of this early deformation is not known, but it is suggested that some of the thrusts along the eastern margin of the Ramah Group between Saglek Fiord and Nachvak Fiord (Morgan, 1975) may be of this age. The distribution of aluminosilicate minerals in the Ramah Group and relative timing of their growth suggest that thickening via early thrust-loading was responsible for kyanite formation near Saglek Fiord. A thicker structural succession and elevated geotherms were responsible for growth of fibrolitic sillimanite in the southern part of the area (see also Mengel, 1988).

The most extensive mineral growth in the Archean gneisses below the Ramah Group during this early décollement stage occurred along the slide or shear zone between the two. North of Hebron Fiord, this is expressed in the schistose rocks of the slide zone by a biotite+muscovite+epidote foliation in felsic gneisses and hornblende+plagioclase+epidote foliation in strongly deformed Domes dykes. Structurally below the slide zone, the effects of this thermotectonism are exemplified by the upper-greenschist-facies static replacement of earlier phases in the gneisses and in the Domes dykes. For example, hypersthene in the gneisses is replaced by retrograde assemblages of biotite, muscovite and epidote, and clinopyroxene in the dykes is replaced by amphibole. These effects diminish to a lower-greenschist-facies overprint eastward toward the coast. South of Hebron Fiord the development of the sub-assemblage hornblende+garnet in the Domes dykes points to higher grade conditions, consistent with the assumed greater thickness of the early thrust pile in this area. Similarly, the metamorphic overprint on the Domes dykes is more pervasive in this area than it is to the north of Hebron Fiord, suggesting a more eastward transgression of the Hudsonian front; firm delineation of a Zone 1–Zone 2 boundary cannot be drawn on the basis of present data (Figure 1c).

By analogy with the findings of Ermanovics *et al.* (1989) and Van Kranendonk and Ermanovics (1990), the younger (F_2) folds which affect the Ramah Group and its adjacent basement in the Saglek–Hebron area, and control the present disposition of the Group, developed during the transcurrent shear regime exemplified by the Abloviak shear zone. The mesoscopic folds of the Ramah Group in the study area are generally more steeply plunging than folds and lineations in the Abloviak shear zone, but show the same overall regional reversals in plunge directions that characterize linear elements within the Abloviak shear zone. The Abloviak shearing and concomitant folding appear not to have generated significant new metamorphic mineral growth in the foreland Archean rocks and Ramah Group cover. As a result of this deformation, however, earlier foliations in the décollement zone were folded, the earlier foliation in Ramah Group pelites was folded and transposed, and some new mica growth occurred. The Abloviak event may have also been responsible for the change in the trend of the Domes dykes east of the Ramah Group. It is proposed that the F_2 folding is also responsible for the formation of the regionally doubly plunging synclinorium in which the whole Ramah Group is disposed north of Saglek Fiord (Morgan, 1975). Several younger overthrust blocks of refoliated Archean gneisses sit astride the second generation folds south of Pangertok Inlet (Figure 1c).

Final adjustments to the crust in this region occurred along a series of NNW-trending high-angle reverse faults of probably more than one generation. One such fault is defined by a broad zone of black ultramylonite and pseudotachylyte, with a steep down-dip lineation, developed at epidote-amphibolite facies, which can be traced northward from Hebron Fiord for nearly 30 km. The ultramylonite apparently merges into, or is excised by, sub-parallel faults. All of these steep reverse faults appear to be late in the deformational history, and may be the ramp portions of large thrust faults that mark the final suturing of Rae and Nain provinces.

Conclusions
Archean quartzofeldspathic gneisses and the lower Proterozoic Domes dykes contain mineral assemblages that indicate a widespread greenschist- to lower-amphibolite-facies overprint on the Nain craton resulting from collision with the Rae Province. The distribution of unaltered and altered clinopyroxene in the dykes can be used to define two regional zones, the most westerly one showing the greater degree of Hudsonian overprint. The Ramah Group, which originally rested unconformably on the peneplaned Nain craton and its dyke swarm, is now largely disposed as elongate slivers along the reactivated westernmost margin of the craton. The deformational history of the Ramah Group is considered to record early basement-cover translation (D_1) followed by upright to overturned folding (D_2). Younger overthrusts and steep reverse faults represent events that postdated the above main episodes of Early Proterozoic metamorphism and deformation. All events may be linked to an oblique collision between two Archean continental blocks during Early Proterozoic time (Korstgård *et al.*, 1987).

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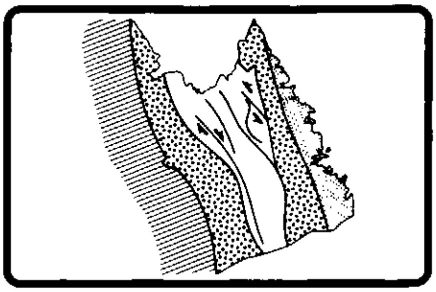

The Torngat Orogen in the North River–Nutak transect area of Nain and Churchill provinces

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Summary
The Archean Nain Province, part of the North Atlantic craton, collided obliquely with the eastern Churchill Province 1900-1800 million years ago. The eastern Churchill Province (Rae Province) and portions of the western Nain Province were deformed by sinistral transcurrent shear at syn- and post-peak granulite- to amphibolite-facies conditions during the collisional phase of the Torngat orogeny. Tectonic remnants of the Early Proterozoic Ramah Group were structurally interleaved with Nain Province rocks in the tectonic foreland during this orogeny. In the Churchill Province, the orogeny deformed felsic and mafic igneous rocks intruded into sediments deposited on a foredeep shelf of inferred metaplutonic rocks of the eastern Churchill Province. The effects of orogeny extend east of the tectonic foreland as waning metamorphic grade across 85 km of the Nain Province.

Introduction
The Proterozoic Torngat Orogen of the eastern Churchill Province extends from the northern tip of the Labrador Peninsula (60°N, Figure 1) 550 km southward in rocks in fault contact with the Archean Nain Province. The orogeny deformed Early Proterozoic and older rocks of the Churchill and Nain provinces during Early Proterozoic (1860-1780 Ma, Bertrand *et al.*, 1990) transcurrent shearing at amphibolite- and granulite-facies conditions (Wardle, 1983; Korstgård *et al.*, 1987; Mengel, 1988). The northern and western limits of the Torngat Orogen remain indeterminate, but, based on criteria in the transect area, the western limit is known to extend at