The Danish Lithosphere Centre in 1995

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The Danish Lithosphere Centre (DLC) is funded by the Danish National Research Foundation and was established in 1994 (Larsen, 1995). In 1995 DLC undertook major field geological investigations in both West and East Greenland, and within the Ocean Drilling Program (ODP) drilling on the continental shelf offshore East Greenland. More than 50 national and international researchers were involved in DLC field geological programmes, and 25 researchers from ODP member countries took part in the offshore drilling operations. The general aims and scope of these activities as well as the continued development of the Centre are summarised below. Preliminary results of the 1995 work programmes are given by van Gool *et al.*, Larsen *et al.* and Brooks *et al.* (all this report).

The centre

The Danish Lithosphere Centre is established as an independent research unit hosted by the Geological Survey of Greenland (GGU) and the Geological Institute of the University of Copenhagen (GIKU). GGU was amalgamated with the Geological Survey of Denmark in 1995 to form the new Geological Survey of Denmark and Greenland (GEUS), and GEUS will thus replace GGU as one of the two host institutions. DLC will remain at its present premises at the Geological Institute.

In 1995 DLC expanded its staff with two guest researchers, two PhD students and a curator/geochemist. At present the centre employs 13 geologists and geophysicists, three PhD students and an administrative department leader. In addition to the DLC staff 12 Research Fellows from GIKU and GEUS are associated with the centre, and an additional 30 international partners from the USA, Canada, Australia, Norway, UK, Germany and The Netherlands are active in DLC work.

The additional funding in support of the centre's research plan obtained in 1994 (Larsen, 1995) has been further expanded in 1995 with support from the US National Science Foundation (NSF; two projects) and the Danish Natural Research Council (one post-doctorate scholarship).

The work of DLC in 1995 has been dominated by the planning and execution of the major data acquisition programmes. Preliminary results of the initial 1994 work have been presented at international meetings or submitted for publication.

Research plan and field operations in 1995

The DLC research plan builds on the application of multidisciplinary studies on selected geological problems of plate tectonic scale and significance. Two major topics have been selected for the first five years period: (A) Early Proterozoic amalgamation of Archaean continents into the North Atlantic craton as illustrated by the Nagssugtoqidian orogen in West Greenland; and (B) formation of the Tertiary volcanic rifted margin in East Greenland during the continental break-up of the northern North Atlantic (see also Larsen, 1995). Investigations in both of these study areas were initiated in 1994 (offshore investigations already in 1993; Larsen *et al.*, 1994, 1995 and Marker *et al.*, 1995) and these were continued in 1995 (Fig. 1). The first theme mainly involves geological studies, whereas the second theme is truly multidisciplinary involving marine geophysics, drilling (Ocean Drilling Program, ODP) and field geology.

Nagssugtoqidian orogen

Studies on the Nagssugtoqidian orogen in central West Greenland (Fig. 1) were carried out by a group of 20 geologists during July – August (van Gool *et al.*, this report).

The Nagssugtoqidian orogen in central West Greenland is part of a major trans-North Atlantic zone of Early Proterozoic (2500–1700 Ma) orogenesis by which older continental blocks were amalgamated into a large craton around 1900–1800 Ma ago (Bridgwater *et al.*, 1991). This presumably involved plate tectonic processes, i.e. ocean basin formation, build up of island arc complexes and closure of ocean basin, followed by continental collision and related mountain belt formation.

The Nagssugtoqidian orogen provides an excellently exposed deep crustal cross-section of the suture zone between suggested southern and northern Archaean continents. Investigations include the southern Nagssugtoqidian foreland, which in the Nuuk area further south contains some of the oldest known continental rocks (*c.* 3900 Ma;

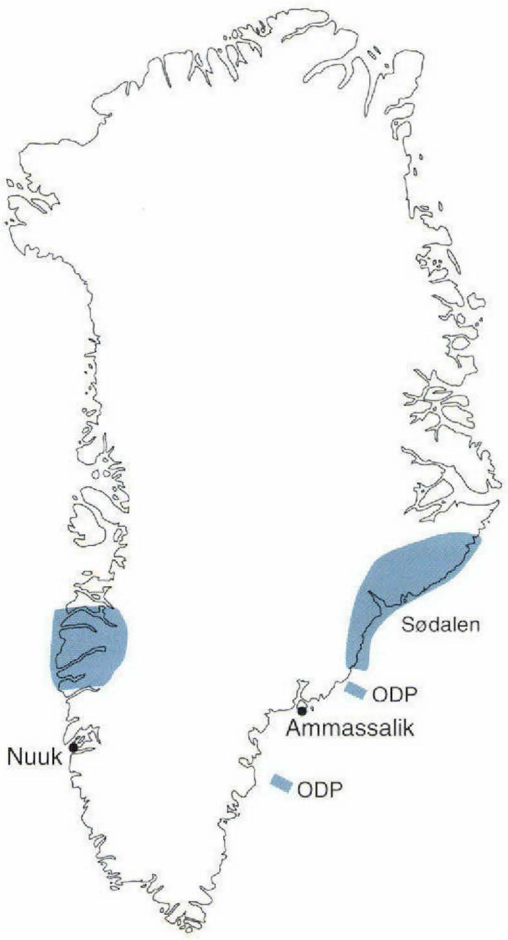

Fig. 1. Areas of DLC investigations in 1995.

e. g. Nutman *et al.*, 1993; Rosing *et al.*, 1996), and an area of *c.* 3500 Ma old gneisses identified close to the southern Nagssugtoqidian front (unpublished data, M. Rosing, 1996). A major, basaltic dyke swarm (Bridgwater *et al.*, 1995), possibly representing a rifting event, intruded the southern foreland at approximately 2050 Ma (A. P. Nutman, unpublished DLC data, 1994). Additional magmatism within the orogen is indicated by similar metasediment provenance (zircon) ages. The dyke swarm and the Archaean basement were subsequently involved in the Nagssugtoqidian deformation to the north of the foreland. The orogen comprises supracrustal sequences of Early Proterozoic age which may represent both continental margin and basin floor sediments (including possible basin floor igneous material). In addition, plutonic rocks representing juvenile island arc material (Kalsbeek *et al.*, 1987) and continental margin magmatism have been identified and dated to about 1930–1920 Ma (F. Kalsbeek and A. P. Nutman, unpublished data, 1996). During the Nagssugtoqidian deformation these key units were dismembered, stacked during thrust movement and interleaved with the Archaean gneisses. Late orogenic, in part strike-slip deformation partly transposed existing structures into steeply dipping to subvertical positions. The DLC investigations in 1995 addressed all these main elements of Nagssugtoqidian orogenesis (see van Gool *et al.*, this report).

East Greenland volcanic rifted margin

Studies on the early Tertiary continental break-up and associated magmatism in East Greenland were carried out by a group of 34 geologists and geophysicists from mid-July to early September (Brooks *et al.*, this report). This work was continuously supported by two helicopters in order to reach some of the most inaccessible areas in Greenland.

The voluminous plateau basalts of 55–60 Ma age along the East Greenland margin are the most extensive exposures of the massive volcanism related to the early Tertiary continental break-up and North Atlantic ocean basin formation. The products of this volcanic event, also manifested by offshore, seaward dipping reflector sequences (targeted in ODP Legs 152 and 163; Larsen *et al.*, 1994, this report), are estimated to have a total volume of several million cubic kilometres throughout the North Atlantic region (Eldholm & Grue, 1994) and to be related to the presence of unusually hot mantle below the region during break-up.

The thick basalt sequences represented onshore as well as offshore show chemical variations reflecting subtle chemical changes in the mantle source regions, which are thought to represent a mantle plume (Iceland mantle plume) ascending from great depths, perhaps from near the core–mantle boundary of the Earth (see White & McKenzie, 1995 for recent review). Intense dyke swarms in a coast-parallel belt record magmatism in a similar way to the basalts, and may preserve information on lava sequences which have since been lost by erosion. The dykes (and lavas, where preserved) also record the structural events associated with continental break-up. Finally, vertical movements of the Earth's crust (i.e. basin formation and uplift and erosion) are important, as they represent significant changes in the temperature and stress regime of the region. All these aspects (plateau lavas, dyke swarms and basin formation and uplift) have been at the forefront of DLC's work in East Greenland in 1995 (Brooks *et al.*, Larsen *et al.*, both this report).

ODP Leg 163 was planned to follow up on the successful Leg 152 to the South-East Greenland margin. The main objectives of these two legs were roughly similar to that of the onshore plateau basalt sampling programme (i.e. the volcanic development with time), but with the additional goals of examining in detail the continent–ocean transition, and to recover samples representing early pristine oceanic volcanism (Larsen *et al.*, this report). The cruise started

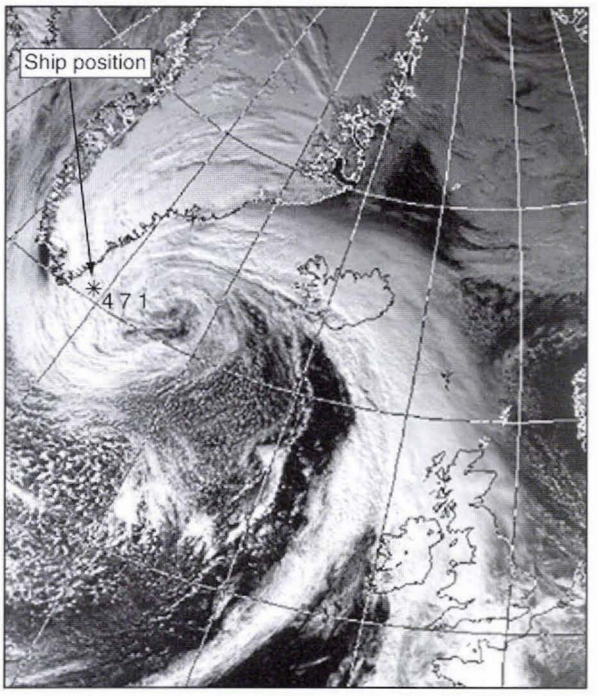

Fig. 2. Satellite image of the storm centre which developed over South-East Greenland 29 September. Wind forces of more than 100 knots (extra-tropical hurricane, force 2) and steep, frequent waves, exceeding 20 m in height were recorded on the ODP drill ship *JOIDES Resolution*, which was in a survival mode from the early morning of 30 September to about noon, 1 October.

from Reykjavik, Iceland on 7 September but soon after returned to Reykjavik for repairs following initial drilling problems and related damage to the equipment. Drilling was resumed on 16 September and continued until 29 September when a storm centre rising to strong hurricane disrupted activities (Fig. 2). During this fierce storm the ODP drilling ship *JOIDES Resolution* suffered severe damage, which excluded further drilling on Leg 163. Only three out of the six planned drill sites were drilled, and only one of these to the planned depth. This was an exceptional event never before experienced in 27 years of scientific ocean drilling.

Future work

Completion of the 1995 field programme in many ways secured the data background necessary to fulfil the research goals of the original DLC research plan for the period 1994–1998. However, within the present research plan and budget, one further major data acquisition programme is planned, a deep crustal seismic study (SIGMA; see also Larsen, 1995), which is scheduled for August – September 1996. SIGMA is a collaborative effort between DLC and Woods Hole Oceanographic Institution, USA. In addition, supplementary field geological work within the Nagssugtoqidian orogen may take place in 1997.

Clearly, the suspension of drilling on Leg 163 constitutes a significant deficiency in the total data set planned for the DLC rifted margin study. Thus, investigations of alternative (to ODP) drilling platforms capable of drilling to a few hundred metres depth on the East Greenland shelf have been initiated. It is hoped that most of the critical data gaps resulting from the early termination of Leg 163 can be filled through this type of supplementary drilling in 1997 or 1998. A preliminary proposal for drilling has been submitted to the Danish National Research Foundation.

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